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Analysis of the Invasiveness of Cabomba caroliniana A. Gray in Massachusetts and Rhode Island Freshwater Lakes and Assessment of the Impacts of Local Community Action Groups on AIS Management and Intervention Programs

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The Thesis Committee for Nicole Cournoyer

hereby certifies that this is the approved version of the following thesis:

Assessment of Impacts of Local Community Action Groups on Management of Invasive Aquatic Plant Growth in Massachusetts and Rhode Island Freshwater Lakes

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Abstract

Native to parts of South America and southeastern United States, *Cabomba caroliniana* A. Gray is an invasive aquatic pondweed species that has migrated to northern regions of the United States. *C. caroliniana* is known for its rapid growth pattern and its ability to dominate freshwater ecosystems. The overgrowth of this invasive species is difficult to manage, with few effective eradication/control methods available. Dense hairs and crystals found upon the leaf surfaces are believed to enhance the ability of Carolina fanwort to survive in a wide variety of ecosystems. Management of this particular species requires an active approach. This study explored the relative effectiveness of structured lake management groups in controlling and managing *C. caroliniana* populations. Three lakes were studied (one of which is a privately-owned lake while the other two are open to the public). Results show that a well-structured, active citizens' group focusing on a privately managed lake appears to be more effective at controlling *Cabomba caroliniana* than a loosely organized public interest group on a publically managed lake.

Keywords: Carolina Fanwort, *Cabomba caroliniana*, Aquatic Invasive Plants, Pondweed Management, Community Action Groups

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Massachusetts Department of Natural Resources…..……..…….DNR

Massachusetts Department of Environmental Regulation……...…….……DEP

Rhode Island Department of Environmental Management……..……...…….RIDEM

Hickory Hills Lake Management Group……..……..…….…….LMG

Non-Governmental Organization……NGO

Geographic Information System.……GIS

Individual Sewage Treatment System.…….ISDS

Aquatic Invasive Species..……AIS

Diver-Assisted Suction Harvesting……...DASH

Chapter 1 : Introduction and Literature Review

Statement of Importance

The purpose of this study is to examine the effectiveness of mitigation and control efforts for the invasive species *Cabomba caroliniana* A. Gray (Carolina fanwort) in New England ponds and lakes, taking into account the plant's unique biology and the complex ecology of the waterways, including the impacts of adjacent land use and the level of commitment by local citizen action groups.

The range of Carolina fanwort has expanded rapidly in recent years, and its impacts on freshwater lakes and ponds are significant. Since management resources are limited, and causal factors are clearly related to land use and recreational activities, mitigation efforts that involve and engage local residents could be expected to be more successful. Lake management plans that incorporate citizen involvement must be based on accurate biological and ecological data specific to each location. Since these approaches are highly dependent on volunteer action combined with technical knowledge, there must also be a strong education component.

Invasive Species

In general, invasive species are animals or plants that are found in ecosystems outside of their native range (Thorsteinson 2005), although some scholars have emphasized the relative impact of the non-native species on the functioning of native ecosystems, i.e., the degree of invasiveness (Enser 2011), or as those taxa that have been introduced recently and exert substantial negative impact on native biota, economic values, or human health (Lodge et al. 2006; Hellmann et al. 2007). For the purpose of this investigation, we have adopted the definition endorsed by the U.S. National Invasive Species Council, established in 1999 by Executive Order 13112, which defines an invasive species as "a non-native species, the introduction of which causes or will likely cause harm to the economy, environment, or

human health" (USEPA 2007), thus emphasizing taxa that are recent immigrants into ecosystems, and are impacting native species or disrupting ecosystem balance. Overall, invasive species have become an increasing threat in the United States (Lovell 2005). Invasive species can cause harm to native species in an ecosystem, including the loss/decrease of biodiversity, changes to the ecological unit, and have negative impacts on the local economy such as impacts on fisheries, agriculture, and forestry (Lovell 2005), or even wider economic implications if the products are important exports. The economic costs of attempting to control or eradicate invasive species has not been well documented due to the large range of chemicals and treatment methods used (Lovell 2005). Although the exact economic impact has not yet been determined, it would be presumed that costs would rise as invasive species spread.

It has been estimated that the cost for preventing and controlling invasives may range from millions to billions of dollars per year (Lovell 2005). A study in Wisconsin suggested that "a Eurasian milfoil infestation reduced average property values by 8%" and affected land values by as much as 13% (Horsch and Lewis 2009). A New Hampshire study suggested a decline of 21-43% on shoreline property values due to the presence of an aquatic invasive species (Halstead, et al. 2003), and a study in Vermont found property values were diminished by <1%-16% by infestations of the pondweed, Eurasian milfoil, noting that a 20% increase in the infestation can have a 6.4% reduction in property values (Zhang and Boyle, 2010).

Pathways by which invasive species become introduced into new ecosystems include a variety of vectors, including wildlife such as migratory birds or aquatic animals, natural weather patterns, and human actions. Some pathways are intentional while others occur accidentally. Intentional pathways include species being imported for aesthetic and economic purposes and aquarium usage, and unintentional pathways include the accidental transportation of invasive species arriving through livestock and produce products, through the transportation of goods, on equipment, on or in cargo on ships and boats, and packing

materials that are discarded (Lovell 2005). Approximately 81% of invasive pondweeds have entered the United States through the transportation of goods, packing materials, transport vessels, or by overland travel (Lovell 2005). The rise of invasive plants present in the United States has a direct correlation with the increasing number of imported products, as well as the diversity of goods being traded and imported (Lovell 2005).

In a 2011 listing of the biotic communities in Rhode Island, the authors noted that the presence of non-native species (encompassing 400 taxa altogether) to non-native ecosystems can serve as an early warning for potential threats to the ecosystem's natural integrity (Enser et al. 2011). Figure 1-1 shows the extent of distribution of invasive aquatic plants in Rhode Island, and Figure 1-2 illustrates the type of educational materials that the Rhode Island Department of Environmental Management (RIDEM) utilizes to train private boat owners about the dangers of invasive aquatic plants. These figures express the magnitude of the invasive species problem in just one state (the smallest state of the United States). With the effects spreading throughout the States, it is important that accurate educational materials are distributed in order for community members to be informed as well as to gain their cooperation in making strides to combat these infestations.

Attempts to Control Invasive Species in Rhode Island

Figure 1-1 is an excerpt from the GREAT Boater Program packet. This packet was created and is distributed by RIDEM in conjunction with non-governmental organizations (NGOs) such as Save the Lakes. This program is an example of a community action plan combatting invasive species. The program does not focus on a particular species but instead, includes all of the identified species known to Rhode Island waters. By including the map showing the distribution of aquatic invasive species (AIS) throughout the state (Figure 1-1), boaters and other lake users are made aware of the extent of the problem and the importance of vigilant boat cleaning. Volunteers who participate in this program focus on the inspection of boats and boating equipment to prevent the spread of aquatic invasive

species from one lake to another. Volunteers also provide boaters with information about AIS and the importance of inspecting their boats in between usage. This program has been effective in making boaters more aware of what could be on their boats and what they could potentially be transporting between lakes. An informational program such as this one is the first step to curbing the distribution of these species. The entire packet for this program can be accessed on the RIDEM website (RIDEM 2015b).

Although much is known about the negative aspects of invasive species, their presence in New England freshwater communities continues to expand. Understanding the biology and ecology of the invasive species is a crucial component to being able to understand how to control, or at least manage them. The biological information is also important for educating volunteer activists and observers who will assist in the management process.

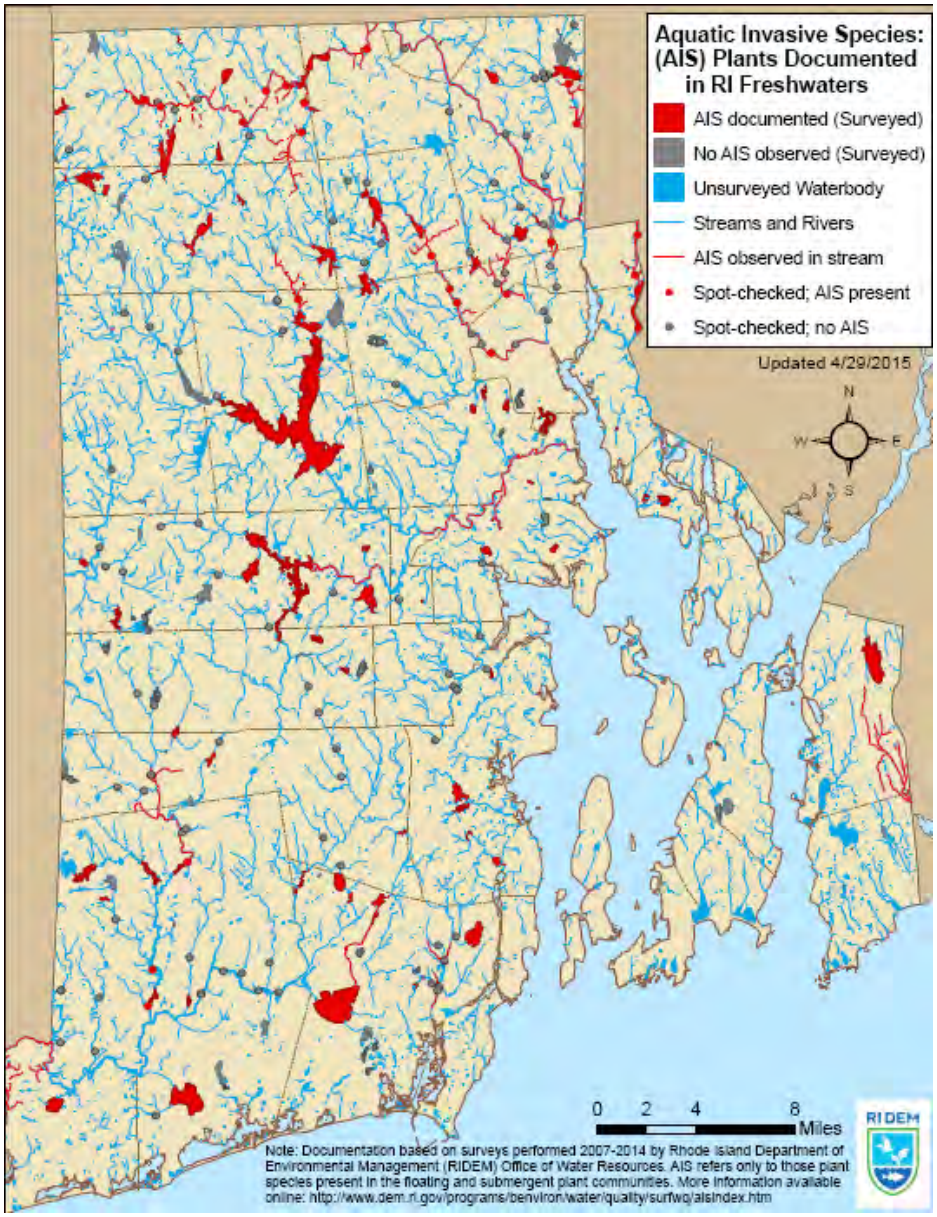


Figure 1-1: A map of the Aquatic Invasive Species (AIS) found in lakes of Rhode Island published by the Rhode Island Department of Environmental Management (RIDEM). The red surveyed areas indicate where AIS were found while the gray areas indicate where no AIS were found. Blue areas were not surveyed and therefore the presence of AIS in these areas could not be determined. This map is inserted in the GREAT Boaters Program packet to visually show how large this invasive problem has become in Rhode Island (RIDEM 2010, 2015a, d).

Figure 1-2: Illustration of a sign utilized in the educational campaign for boaters and fishers of Rhode Island Department of Environmental Management (RIDEM) at the state's boat ramps. This and similar signs serve as a reminder for boaters to inspect and clean their vessels and fishing equipment for potential aquatic invasive species, prior to and after use, which in turn will help prevent the spread of species from one lake to another (RIDEM 2015d).

Biological Characteristics of *Cabomba caroliniana*

Carolina fanwort, an invasive species found extensively in New England freshwater ponds and lakes, illustrates the complex challenges associated with management and control of such species. The rapid expansion of Carolina fanwort within a lake or pond and the common practice among boat owners to trailer their boats from one lake to another,

coupled with the difficulties of the particular species removal and/or management raises a multitude of concerns regarding this invasive aquatic plant.

In order to explore the challenges in managing the overgrowth of Carolina fanwort, it is important to better understand the plant's biological features. Carolina fanwort is a pondweed native to southeastern United States and parts of South America (Fu and Wiersema 2001). The species has spread to the northeastern United States, creating nuisance problems throughout the New England area (DCR 2015). An early report of Carolina fanwort in the New England area occurred in 1930 from Hatfield Massachusetts, and in 1936, the plant was reported in Cranston, RI (DCR 2015). Since the time of these initial reports, Carolina fanwort has become a more controversial problem, specifically in various areas throughout Massachusetts, Rhode Island, Connecticut, New Hampshire and Maine which have been directly affected by the infestations (DCR 2015). According to the Department of Conservation and Recreation of Massachusetts, the states dealing with a non-native Carolina fanwort invasion include Washington, Oregon, Michigan, Ohio, Pennsylvania, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont and Maine (DCR 2015).

There are several hypotheses to explain the saga of Carolina fanwort expansion in New England waterways. Researchers at the University of Maine, along with many other institutions and authors, link the infestation to the number of years of popularity of the pondweed in the aquarium trade (Schneider 1982). As an aquarium plant, Carolina fanwort is favored due to its dense growth pattern which makes for a natural looking background (Schneider 1982).

Some observers have attributed the spread of Carolina fanwort to the process of airborne pollination, while other scientists have emphasized fragmentation of the plant as the main explanation for the rapid spread of this invasive aquatic plant (de Lima 2014). It is also believed that Carolina fanwort is regularly brought to different bodies of water by

boats, boating equipment, trailers, and fishing equipment, which has brought into practice the inspection of boats and trailers (Lovell 2005). If boats, equipment and cargo are not inspected properly, the plant can easily be transported from one area to another (Lovell 2005).

Global climate change may also be playing a role in facilitating the northward expansion of this plant (Hellmann et al. 2007; Rahel & Olden 2008). As a result of its potential effect on fundamental biological processes, it is very likely that climate change will interact with other factors that impose stress, which in turn affects the distribution, spread, abundance, and the impact of invasive species (Gritti et al. 2006). Some invasive species have characteristics that differ from non-invasive species (Hellmann et al. 2007). For example, many invasive terrestrial plants (and a variety of aquatic invasive species such as Carolina fanwort) have been reported to have broad climatic tolerances, as well as broad geographic ranges (Goodwin et al. 1999; Qian & Ricklefs 2006). The wide range of tolerable conditions allows these non-native species to survive and thrive in new locations. This resiliency factor allows for the acceptance of the characteristics that facilitate rapid range shifts (Rejmanek & Richardson 1996), and thereby enable the migrants to more effectively navigate through a set of environmental filters such as geographic barriers, biotic interactions and localized landscape factors (Hellmann et al. 2007; Williamson 2006; Theoharides & Dukes 2007).

Spread of *Cabomba caroliniana* into New England Waterways

As noted earlier, Carolina fanwort was first introduced to New England lakes in the 1930's, originating from southeastern United States and parts of South America (DCR 2015). This invasive plant has the ability to establish itself in a wide variety of aquatic conditions and can tolerate a wide range of temperatures and pH levels. The plant can be found in both low nutrient (oligotrophic) and high nutrient (eutrophic) lakes (DCR 2015). The ideal living conditions for Carolina fanwort are slow moving bodies of waters, such as lentic or still

water bodies. The preferred environments are freshwater lakes and ponds. Despite these favored conditions, there have been recorded instances in which Carolina fanwort has been discovered in faster moving bodies of water, such as rivers (DCR 2015). In rivers this species can most commonly be found growing in shallow water where its short stem grows horizontally and branches extend from this main stem in an irregular pattern (Schneider 1982).

Carolina fanwort has several other unique properties that make the introduction of this species a great threat to New England lakes and ponds. Once introduced, Carolina fanwort aggressively spreads, thus replacing native species (bio.umass.edu). The submerged leaves of this species secrete a sticky mucous which then covers the native foliage (Mackey 1996). Due to the rapid rate of colonization within a new body of water, it is easy for this competitive pondweed to force native aquatic plants out of the area (Wilson 2007).

The plant's highly competitive behaviors described above result in dense infestations, which have a negative impact on native plant species, can alter species relationships, and affect the habitats for fish (UMaine 2015). These dense infestations can also impact recreational activities. This pondweed is rooted in the sediments but can form dense mats at the water's surface. The pondweed's tubular stems attain lengths of up to 10 m (DCR 2015, Wilson 2007) which could impair boating and other recreational activities. In addition, this aquatic weed also has seasonal adaptations that foster its dominance in aquatic ecosystems. In late summer months, the stems of the plant become extremely brittle and tend to break apart (de Lima 2014). Even a small fragment of the stem is enough to create another plant. The fragments have the ability to travel through the waters before becoming rooted and begin the growing process (de Lima 2014). Once this plant has established itself, control and eradication is almost impossible (Taylor 2008). Since Carolina fanwort has the ability to reduce the aquatic plant diversity of an area, the aesthetic aspect

of a location can be negatively impacted. This can result in decreased real estate value for the houses located near or around the lake/pond (DCR 2015). Before discussing further the management programs for this invasive species, it would be beneficial to evaluate the linkages between the morphology and reproduction of Carolina fanwort and its ecological success.

Morphology and Reproduction of *Cabomba caroliniana*

Carolina fanwort is an aquatic flowering plant (angiosperm), belonging to the family Cabombaceae of the order Nymphaeales (USDA 2015). Table 1-1 depicts the taxonomy of the plant.

Although this aquatic species has a competitive and aggressive nature, Carolina fanwort is actually quite delicate structurally. The plant must be handled with extreme caution while they are sampled because the integrity of the leaves can be destroyed very easily. An illustration of the plant is shown in Figures 1-3 to 1-4.

Table 1-1: Taxonomy of *Cabomba caroliniana* (Carolina fanwort). Chart based on information available from Natural Resources Conservation Service (USDA, 2015).

KINGDOM	**Plantae**
SUBKINGDOM	Tracheobionta
SUPERDIVISION	Spermatophyta
DIVISION	Magnoliophyta
CLASS	Magnoliopsida
SUBCLASS	Magnoliidae

ORDER	Nymphaeles
FAMILY	Cabombaceae
GENUS	*Cabomba*
SPECIES	*Cabomba caroliniana* A. Gray

The roots of this plant are slender and develop from the rhizome (Wilson 2007). The roots tend to have an atypical arrangement, or abnormal placement, which begins at lower stem nodes. The portion of the roots that have abnormal arrangements can obtain lengths up to 24 cm long (Wilson 2007). The newly developed roots are initially smooth, unbranched, white in color, and have a yellow tip. As the roots age, branching begins and it becomes dark brown to black in color (Wilson 2007).

Many (3 to 40) stems can arise from the rhizome closely together and start to branch at lower parts to form a dense cluster. It has been noted that young stems, which are pubescent, can have rust-colored hairs as a coating (Wilson 2007). Sometimes the stems, or the entire plant, can have a thin coating of mucous but this is not always the case (Mackey 1996). The stems can obtain lengths up to 10 m but typically are of 1 to 2 m long (Wilson 2007). The stems are green in color and have fine, longitudinal striations (de Lima 2014).

All Carolina fanwort plants have submerged leaves. During flowering season, there will also be floating leaves (Fu and Wiersema 2001). The submerged leaves are petioled and fan-shaped (Schneider 1982). They typically are of a light to dark green color, although sometimes they can be reddish to purplish in color (Wilson 2007). On average, the submerged leaves are 5.08 cm across and they are arranged in pairs on opposite sides of the

tubular stem (Fu and Wiersema 2001). The leaves can arrange themselves around the stem in pairs of three (Mackey 1996). Each submerged leaf has a slender and round petiole which has a typical diameter of 0.2 to 0.4 cm and lengths of 1 to 4 cm (Wilson 2007). Each submerged leaf has a blade of fine segments arranged in a fan-like shape. Lower leaves are smaller and as a result, tend to have a fewer number of segments (3 to 20) than the upper, larger leaves which may have as many as 200 segments (Wilson 2007).

During flowering season, the plant will develop small oval or diamond-shaped floating leaves with long petiole (Fu and Wiersema 2001). These leaves are green to olive green in color, with their undersides being a lighter shade of green (Mackey 1996). The floating leaves are present on the flowering branches (Wilson 2007).

Figure 1-3: Photograph (left) and illustration (right) of typical structures of *Cabomba caroliniana*. Photo: Maine Department of Environmental Protection (Maine DEP 2015); Line drawing illustration (University of Florida/IFAS Center for Aquatic and Invasive Plants 2015).

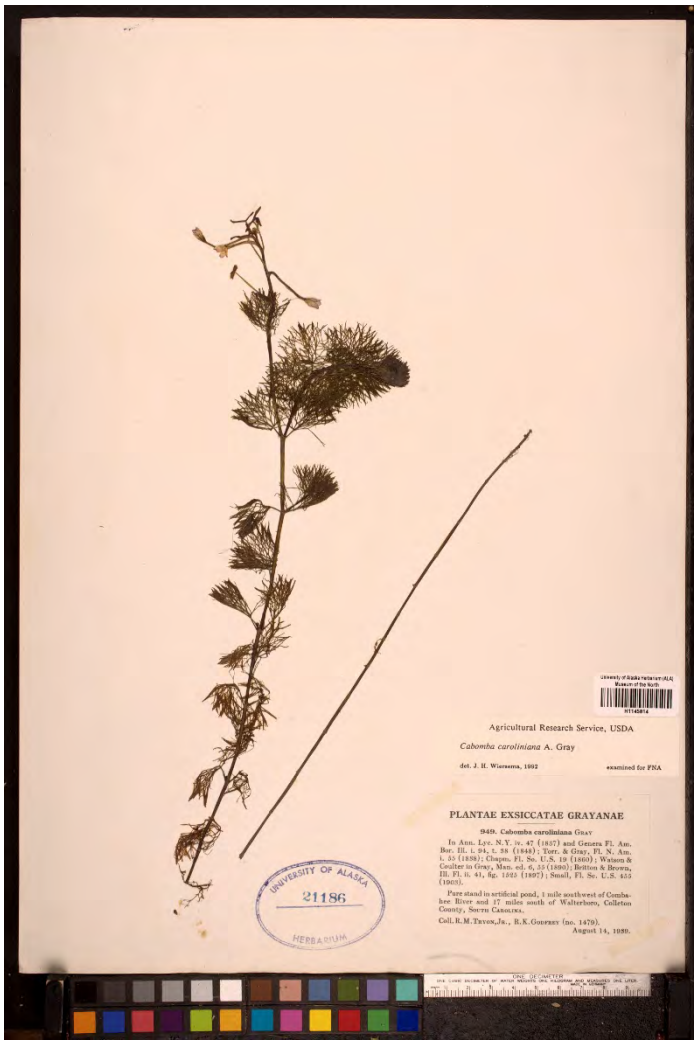


Figure 1-4: Photo of the type specimen of *Cabomba caroliniania* (Created by agent: ALA Imaging Project, cataloged item, UAM: Herb:120551). (ARCTOS 2015). Photo source: Available online at http://web.corral.tacc.utexas.edu/UAF/2008_10_11/jpegs/H1145814.jpg. Accessed 02 August 2015

Between the months of May and September, white/cream colored flowers appear (Fu and Wiersema 2001). These flowers are approximately 1.27 cm wide. Some variation in flower colors (pink or purple) has been noticed (Fu and Wiersema 2001). The flowers are bisexual and protogynous (Schneider 2003). The peduncles of these flowers can range from 3 to 10 cm in length (Wilson 2007). Each flower has three white egg-shaped sepals,

approximately 0.6 cm long and 0.3 cm wide (Ito 1986). There are three petals alternating with the sepals. They have an oblong shape and the main veins of the petals are white (de Lima 2014). Each petal is approximately 0.7 cm in length and 0.35 cm in width (Ito 1986). There are two glands on the upper surface of the petal (Ito 1986). Each flower has 4 or 6 stamens (de Lima 2014), and 1 to 3 free carpels (de Lima 2014). Figure 1-5 shows the structure of the flower of *C. caroliniana*. The most common pollinators of *C. caroliniana* are small flies (Schneider 2003).

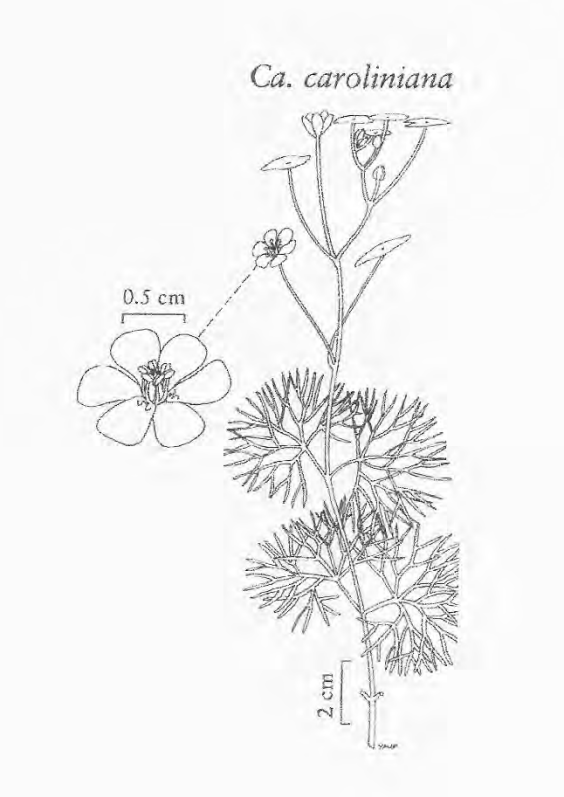


Figure 1-5: Illustration of the plant structure of *Cabomba caroliniana*, noting the stem and leaf arrangements, along with summer flowering structures. Taken from the Flora of North America (FNA) website. Line drawing image: Available online at http://www.efloras.org/object_page.aspx?object_id=41046&flora_id=1. Accessed 2 August 2015.

There are two different ways that this plant reproduces, via a vegetative method and through seed formation (de Lima 2014). The primary way in which this invasive plant

spreads is through the vegetative process known as stem fragmentation (de Lima 2014). Due to their extremely delicate stems that can splinter easily, detached pieces of the stem drift away from the mother plant and can become rerooted as its own individual plant (de Lima 2014). Even small fragments of Carolina fanwort have the ability to survive for weeks free floating, and can then flourish from the fragments (including small fragments) when in a moist environment (Schooler 2009). Once the rooting process has taken place, it can be extremely difficult to eradicate as a result of the rapid clustering of new plants spread (Schooler 2009).

As a flowering plant, this plant is also able to reproduce from seeds. During the fruiting period, the fruits (containing seeds) drift away from the mother plant (de Lima 2014). The seeds have an orbicular shape and have a length of 0.3 cm or less (de Lima 2014). The seeds can remain viable for a minimum of two years (Schooler 2009). When they eventually find their way to lake/pond sediments, they begin germinating (de Lima 2014).

Eradication and Control Methods for *Cabomba caroliniana*

As a result of this plant's morphology and reproductive habits, coupled with its broad tolerance of changing ecological conditions, Carolina fanwort has become well established as an invasive species in southern New England waterways. It has also been proven to be difficult to control and manage. The culmination of these factors makes this aquatic invasive species a complex and enormous threat. There have been a variety of techniques used to control/eradicate Carolina fanwort, most of which are only mildly effective. They are often applied in combination, and in conjunction with specific pond or lake conditions or desired human use. A summary of commonly accepted means of control is provided in Table 1-2.

Table 1-2: Accepted Treatment Methods for Limiting the Growth and Activity of *Cabomba* sp., along with the relative advantages, limitations, and relative costs of each method. See Appendix B for reference details regarding these methods.

Treatment	Mechanism	Advantages	Liabilities	Environmental Costs	Monetary Costs
Grass Carp (*Ctenopharyngodon idella*)	Only known biological control	Known to consume fanwort	Rarely controls the aquatic vegetation within the first year and the fish are illegal in most states	Not a good strategy when maintaining a natural ecosystem is important	Diploid Grass Carp (8-10 in @ $6.00/fish) is more effective than the Triploid Grass Carp
Fertilizers	Chemical control; can result in an algal bloom if the chemicals runoff from land to a lake or pond	Prevents establishment of most lake/pond bottom rooted weeds. Can produce a reliable food chain for lake/pond fish	Can affect pH and oxygen levels in the water; could lead to eu-trophication and algal blooms	Can negatively affect the growth patterns of native vegetation and change the ecosystem	Example: Miracle-Grow 1-lb All Purpose Water-Soluble Granules - $11.48)
Non-toxic dyes or colorants	Chemical control; limits sunlight penetration	Prevents or reduces aquatic plant growth	Could prevent native species from growing	May suppress the natural food chain of the pond	Example: Aquashade (1 gallon - $37.87)
Endothall, dipotassium salt	Contact herbicide; used to control submerged aquatic vegetation and algae	Contact with weeds causes a break down in cell structure; protein inhibition; plant death	May not completely remove the fanwort	Could kill non-targeted plants; also poses health risks	Example: Aquathol K. (1 gallon - $139.00)

Treatment	Mechanism	Advantages	Liabilities	Environmental Costs	Monetary Costs
2,4-d butyl ester	Systemic herbicide; absorbed and moves within the plant	High degree of success	Could be absorbed by other weeds	Could kill any native weeds that absorb the herbicide	Example: Aquacide Pellets. A 10 pound bag (which treats 4,000 sq feet) costs $85.00
Fluridone	Selective translocated aquatic herbicide; susceptible aquatic vascular plants absorb this product through the shoots and roots	Most effective chemical option. Effective when treated at 10-20 ppb	Negative effects to non-target organisms	Could kill native weeds that are affected by the ppb amount	Example: Sonar RTU. A 32 oz bottle sells for $92.68.
Penoxsulam	Systemic herbicide; moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS)	Susceptible plants will stop growing soon after treatment	It takes several weeks to several months for plant death and decomposition to occur	Negative effects on desirable native species can occur	Example: Galleon SC herbicide. A 32 oz bottle sells for $563.88
Flumioxazin	Broad-spectrum contact herbicide; works by interfering with the plant's production of chlorophyll	Plants treated with chemical respond quickly and rapidly decompose	Needs to be applied to young plants early in the spring	Could affects desirable native species	Example: Clipper. For 2 pounds (32oz) the cost is $456.00

Treatment	Mechanism	Advantages	Liabilities	Environmental Costs	Monetary Costs
Diquat	Contact herbicide; works rapidly	Quickly kills the target weed	Kills all foliage it touches	Kills any native species it touches	Example: RedWing. A 32 oz bottle sells for $64.98
Hand pulling	Physical removal; must be done soon after fanwort is present	Works if the fanwort has not become rooted	Unsuccessful if fanwort has become rooted. Low success rate.	Could remove native species in the process	Zero cost
Raking	Physical removal; must be done with extreme caution	Can eliminate the weed	Must collect all seed and plant remnants or else it will come back	Could remove native species in the process	Example: Weed Raker which costs $139.50
Drawdown	Physical removal; entire area of water completely dried/frozen at least 1 month	Fanwort can be killed off	Difficult to obtain optimum condition; need water level control	Other species could die in the process	Permit costs and the construction of a water level control system (or damns). Prices vary by state and size of the body of water
Suction harvesting	Mechanical equipment; requires a lot of equipment	Fanwort can successfully be eliminated	Difficult to do but all seed and plant remnants must be collected	Could remove native species in the process	$163,000: Price obtained from the Save the Lakes President in June of 2015
The Deskuzzer	Mechanical equipment; extra strong seine (1.52 m x 7.32 m pull line)	Collects aquatic debris floating or growing on the water surface	Must collect all seed and plant remnants	Could remove native species in the process	Cost of this piece of equipment is $129.95

Treatment	Mechanism	Advantages	Liabilities	Environmental Costs	Monetary Costs
Dredging	Mechanical equipment; removal of sediments and debris from water bodies	Helps prevent the spread of seeds and sediments	Can negatively impact the natural ecosystem	Can gather native species in the process	Costs for a company using hydraulic dredging, $5 to $15 per cubic yard. Costs for a mechanical dredging, $8 to $30 per cubic yard.
Benthic Barrier	Mechanical equipment; barriers restrict light and upward growth	Prevents plants from growing into and under the barrier	Can have a negative impact on benthic organisms	Can prevent native plants from growing into or beneath the barrier thus resulting in the loss of wanted vegetation	Example: an Aquascreen. A roll of this screen (7' x 100', 35 lbs) costs $425.00.
Lake Bottom Blanket	Mechanical equipment; specializes in killing aquatic weeds, as such it is one of the safest weed control products on the market for aquatic life	Unlike the benthic barrier, the material is lighter and floats thus oxygen depletion doesn't occur	It is not a selective barrier	Native species could be killed off as a result of the nonselective property	Example: the Lake Bottom Blanket. The cost of a blanket (10' x 40') is $249.95
Cutters	Mechanical equipment; device attaches to the bow of a boat in order to cut through the weeds	Clears a wide path through a weed-choked lake	Picks up all weeds in its way and can leave seeds and sediments behind	Could eliminate native plant species	Example: the WeedShear. This cutter costs $134.99

As described earlier, Carolina fanwort is extensively distributed throughout southern New England and has caused significant water quality problems in Rhode Island

and Massachusetts. Figure 1-6 illustrates the distribution pattern for Carolina fanwort in Rhode Island. This study attempts to evaluate the influence of well-organized citizens' groups in helping to implement lake management plans for controlling or mitigating the spread of this invasive species. Before proceeding to discuss the methodology and results found in the study, the three lakes that were studied will be briefly described.

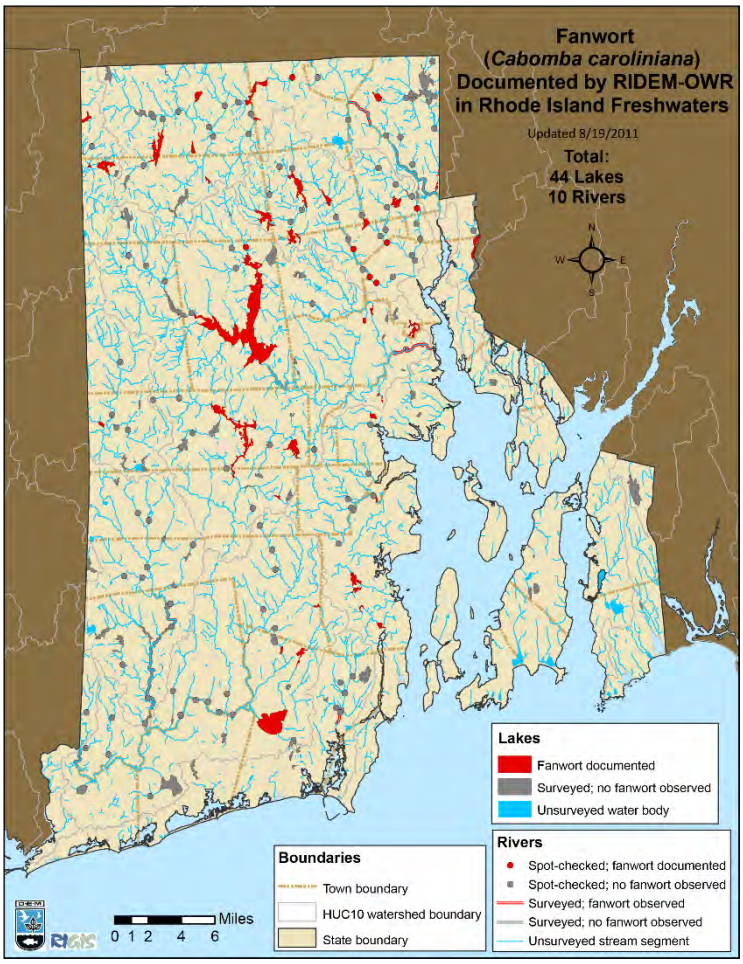


Figure 1-6: Documented ponds and lakes within Rhode Island that contain *Cabomba caroliniana*. The red regions indicate ponds/lakes/rivers which were surveyed and *C. caroliniana* was present. The gray regions represent surveyed water bodies that didn't contain *C. caroliniana*. The blue regions on this map are areas which were not surveyed so it is unknown if the plant species is present (RIDEM 2011).

Lakes/Ponds Selected as Study Sites

In this investigation, three lakes/ponds were used to compare the differences of community input levels and how it relates to the ability to control the Carolina fanwort infestation problem. The first study site is Hickory Hills Lake in Lunenburg, Massachusetts. It is a well-known area that is struggling with increased Carolina fanwort. Residents are highly concerned about the conditions of the lake and the steps being taken to clean the lake and manage water quality. The Carolina fanwort problem has progressively worsened over the past few years, leading residents to become actively involved and work tirelessly to improve the water quality in the lake. Since the lake is privately owned, the citizens are ultimately responsible for maintaining good water quality.

The second lake that was targeted was Spring Lake in Burrillville, Rhode Island. According to the Rhode Island Department of Environmental Management, this lake has had Carolina fanwort present for many years. There is a public beach/swimming area located on Spring Lake, and thus the state is responsible for the water quality. Only one small and loosely organized citizen group is known to exist in the area, resulting in a vastly different profile of community involvement in comparison to the Hickory Hills Lake situation.

The third site chosen was Barber's Pond in South Kingston, Rhode Island. This lake is not chemically treated or managed by the State of Rhode Island, and it contains significantly high amounts of Carolina fanwort, with a long history of infestation. Residents and boaters are aware that there is an increase in the amount of pondweeds but there are no known organized citizen groups working towards cleaning up the pond. The lake is monitored by the Rhode Island Watershed Watch Program located at the University of Rhode Island.

Given the differences in the level of involvement community residents and/or governmental agencies at the three lakes/ponds, this study was designed to determine the

extent to which community involvement is correlated with effective control and management of Carolina fanwort infestations.

Scope of Project

This project set forth to examine the hypothesis that involvement of a well-organized citizens' group will enhance the effectiveness of Carolina fanwort management programs. As noted earlier, the study is focused upon three freshwater ecosystems. These ecosystems include a private lake in Massachusetts (where the Lake Management Group plays a significant role in managing a widespread infestation of Carolina fanwort) and two public water bodies in Rhode Island, neither of which have well-defined citizens' group in place for lake management. In one of the Rhode Island cases, RIDEM provides treatment for aquatic pondweeds at a public beach area, and in the other case, does not provide ongoing treatment, but monitors the levels of invasive aquatic plants and stocks the lake with trout to enhance fishing resources.

In order to confirm the presence or absence of Carolina fanwort in the three lakes, examination of live and preserved samples of plants were made, in order to establish the biological features and confirm the taxonomic identity of the samples. Ecological information and water quality data were recorded at each location when samples were taken or observed, and the microbial Aufwuchs community on the surface of the plant was examined microscopically. The purpose of these observations was to examine the connections among the biologic, chemical, geologic, and ecologic factors affecting the spread of this invasive species.

Chapter 2: Materials and Methods

Description of Study Site 1-Hickory Hills Lake, Lunenburg, MA

Hickory Hills Lake, located in Lunenburg, MA, is a privately-owned, manmade lake constructed in 1925 by Charles P. Dickinson, who cleared the trees and constructed an earthern dike in a wooded swamp near Mulpus Brook. Initially named Dickinson Reservoir, the lake and surrounding property were later sold to the Hickory Hills Lake Corporation. In 1978, a group of residents formed the Hickory Hills Landowners, Inc., and purchased the lake and its surrounding property. This organization now holds management responsibility for the lake and its water quality since the lake is designated as a backup water source for the Town of Lunenburg, MA (Hickory Hills Landowners, Inc. 2015).

Hickory Hills Lake encompasses 319 acres, with an average depth of 3.66 m and a maximum depth of 6.10 m (Freerksen 2012, Scott 2015). A Google Earth image showing the size and configuration of the lake, as well as the surrounding land use, can be seen in Figure2-1. Three community beaches and boat docking areas are provided for the residents of the landowners' association. Along with these recreational features, rules were created for the usage of the beaches as well as the docking areas, including horsepower and speed restrictions for boats and prohibition of some water activities (e.g., jet-skis and water-skis) (Freerksen 2012, ACT 2014).

Along with the associated natural aesthetic beauty of this lake, there is a healthy ecosystem which is characterized by a variety of fish, including largemouth bass, smallmouth bass, chain pickerel, yellow perch, brown bullhead, sunfish, and bluegill (Freerksen 2012).

Monitoring studies in 2014, conducted by Aquatic Control Technology for the Hickory Hills Lake Management Group showed relatively stable levels for pH, alkalinity, turbidity, total phosphorus, as compared with measurements from 2003, 2006, 2008, 2010,

and 2012 (ACT, 2014). Nitrate levels were slightly lower than previous years (<0.05 mg/l in 2014, as compared with 0.1 in 2008, 2010, and 2012), indicating a slight improvement in water quality (AMT 2014). Dissolved oxygen (DO) was 8.16 mg/l at and near the surface, and 7.02 mg/l at 5 m depth (ACT, 2014). Based on the 2014 monitoring report, Bladderwort (*Utricularia* sp.), a native species, was the dominant plant in the lake, with 12.4% coverage (based on sampling locations). Carolina fanwort (a non-native species) was found at some locations outside the designed sample areas during the study (ACT, 2014).

There are 537 properties around the periphery of the lake, within 152.4 m of the water's edge. In 2009, the Lake Management Group (LMG) was formed for the purpose of managing issues that had the potential to affect the quality and health of the water and the lake as a whole, including erosion, dam safety, and invasive plant (fanwort) management. The LMG is composed of a structured set of committees, including the Weed Mitigation Team who organized and implemented the Diver-Assisted Suction Harvesting (DASH) program and spearheaded an array of other mitigation and control techniques for Carolina fanwort management. The Hickory Hills Landowners Association website features a specific web page dedicated to fanwort control (Hickory Hills Lake Management Group, 2015).

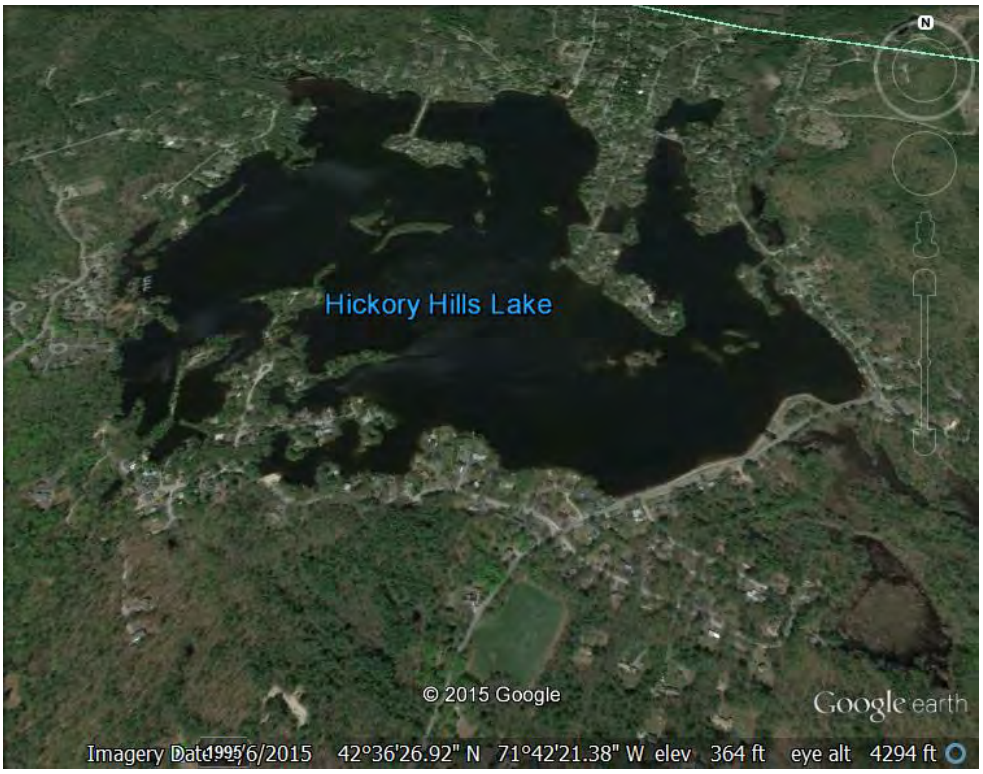


Figure 2-1: Google Earth image of Hickory Hills Lake in Lunenburg, MA, USA, showing the geomorphology of the lake and its surrounding land use patterns and housing density.

Description of Study Site 2-Spring Lake, Burrillville, RI

Spring Lake, formerly called Herring Pond prior to 1900, is a spring-fed lake (1.61 km long, 0.40 km wide). Before industrialization, and construction of factory dams, according to the historical record, alewives and herrings were able to migrate upriver to spawn, thus the original name (Anonymous 2016). Currently, the Town of Burrillville, RI manages a fully developed freshwater public beach. Almost the entire perimeter of the lake is characterized by housing occupancy (Personal Observation July 2015; Zoning Maps, Town of Burrillville, RI, 2015). This lake, designated as oligotrophic or occasionally mesotrophic depending on seasonal changes, shows its greatest depth to be 6.40m, but for most of its coverage the depth is less than 3.05 m during normal rain conditions. During the past few years, the lake has become even shallower as a consequence of the area enduring

drier climate years. Figure 2-2 shows the hydrographic illustration of the depth profile of Herring Pond, as the lake is designated by the Rhode Island Department of Environmental Management (RIDEM 2015c). Both Spring Lake and Herring Pond are names used by regulatory agencies and environmental NGOs in Rhode Island.

Records from the Rhode Island Watershed Watch indicated the lowest dissolved oxygen (DO) levels at 5 m (0 to 1.0 mg/l) in late July for 2010 – 2013, with persistent low levels (around 3.0 to 4.0 mg/l) for several weeks between July and September in 2014. DO levels at 1 m depth ranged from 6.0 – 7.0 mg/l during the same time frame (2010-2014). Chlorophyll levels indicated summer eutrophic conditions at some point during the July-October period across this same time period (URI Watershed Watch 2010b, 2011b, 2012b, 2013b, 2014e). The level of eutrophication is likely heightened by the housing density surrounding the lake, as well as the large number of Individual Sewage Disposal Systems (ISDS) units associated with the homes. A larger pondweed biomass that accumulates in summer months, some of which are invasive species, could also add to the eutrophication process.

Carolina fanwort has been reported by RIDEM in Spring Lake in previous years and the lake has been designated as harboring aquatic invasive species (AIS) (RIDEM 2015a). However, a citizens' group, the Spring Lake Camper's Association, regularly obtains a RIDEM treatment permit that allows for Aquatic Control Technology, located in Spencer, MA, to apply annual chemical treatment for approximately 13 acres of the lake's surface, to improve the clarity of the water for boating, fishing, and other recreational activities. The chemicals Diquat and Clipper have been used, both of which are short-acting compounds with few residuals (Personal Communication, Aquatic Control Technology representative).

According to an active member of the Spring Lake Campers Association, the group deals with water quality monitoring and addresses the concerns of boaters and fishers, as well as representing residents who have expressed other recreational or health issues (Personal Communication, Rick Cayer).

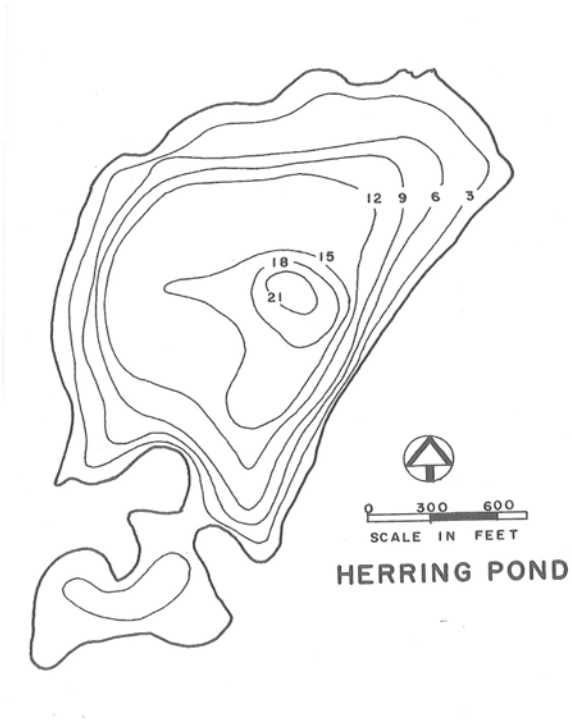


Figure 2-2: Profile of Herring Pond (now called Spring Lake) in Burrillville, RI. Adapted from RIDEM Lake Maps which can be accessed at http://www.dem.ri.gov/maps/mapfile/pondbath.pdf

Description of Study Site 3- Barber Pond, South Kingstown, RI

Barber Pond, also called Barber's Pond, located primarily in South Kingstown, RI, and part of the Wood-Pawcatuck River Watershed, is a relatively long and narrow lake with shallow depths. Most of the lake is characterized by a depth of no more than 3.66 m, as indicated in Figure 2-3. In the state of Rhode Island, there is no definitive difference between the terms, lake and pond, and the RIDEM arbitrarily refers to these freshwater ecosystems as lakes. Most often, the names assigned are rooted in historic precedent, rather than being associated with limnological traits (Personal Communication, Gaytha A. Langlois, Bryant University).

Although Barber Pond is considered to be a mesotrophic or seasonally eutrophic lake, its housing density is lower and the woodland habitat is more extensive than at Spring Lake (RI) or Hickory Hills Lake (MA). However, there is a RIDEM fishing access site on

Barber Pond, with a public boat ramp restricted to non-motorized boats or electric boats. Since the lake is stocked with trout by RIDEM several times a year, fishing is extensive (RI Blueways Alliance 2010), and transient boat use represents a significant vector for transporting AIS in and out of the lake.

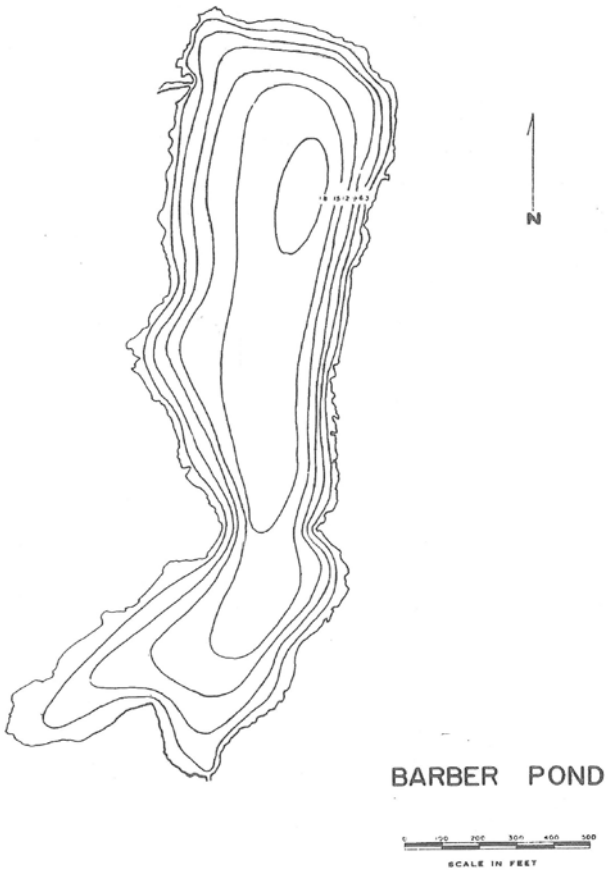


Figure 2-3: Profile of Barber Pond in South Kingstown, RI. Adapted from RIDEM Lake Maps which can be accessed at http://www.dem.ri.gov/maps/mapfile/pondbath.pdf

Data from RI Watershed Watch reports shows dissolved oxygen (DO) readings at 4 m to be near or at 0 mg/l from June to September (2010 – 2015), a condition known as anoxic. At 1 m depth, DO readings for the same 5 years ranged from 6.0 – 7.0 mg/l from June to

September, with slightly better conditions occurring in early June 2012 and 2013 (6.5 – 8.0 mg/l) (URI Watershed Watch, 2010a, 2011a, 2012a, 2013a, 2014a, 2014d). Observations from the Wood-Pawcatuck Watershed Council (WPWC), an environmental NGO in southern Rhode Island, confirmed similar findings for DO measurements for the time period between 2005 to 2013, ranging from 5.5 to 8.0 mg/l at a depth of 1 m (WPWC 2015a), and from a depth ranging from 0 to 5.1 at 4 m in the same 8 year period (WPWC 2015b). It should be noted that only one reading of 5.1 mg/l was recorded in 2008, with the usual pattern from July to September being 0 to 0.3 mg/l (WPWC 2015b). Although low oxygen and even anoxic conditions are not uncommon in summer, overgrowth of aquatic pondweeds could heighten these effects, or extend the conditions for a longer period of time. Mean chlorophyll levels at 1 m showed an average value of 20.8 μg/l in 2014, and the Trophic State Index (TSI) was calculated at 58, which is considered to be a eutrophic lake according to experts (URI Watershed Watch 2014a).

Other data such as Total Phosphorus and Total Nitrogen indicated readily available nutrients in Barber Pond (URI Watershed Watch 2013e, g). This data indicates the eutrophic conditions of Barber Pond, and underlines the importance of the added influence of rapidly growing aquatic invasive plants such as Carolina fanwort, which has been known to be present in 44 Rhode Island lakes and 10 Rhode Island rivers (Coit 2012). According to RI Watershed Watch personnel, Carolina fanwort has been present in Barber Pond for decades (Personal Communication, Elizabeth Herron, Program Coordinator 2015). Overgrowth of pondweeds, especially aquatic invasive plants such as Carolina fanwort, can increase the likelihood of eutrophic conditions and or prolong periods of anoxia in sediments.

There are no known citizens' group associated with Barber Pond, although organized watershed NGO groups such as the WPWA, Save the Lakes and university initiatives such as the URI Watershed Watch, regularly track water quality, fishing and boating access, and wildlife habitat issues.

Sampling Locations

Water samples were collected on 27 July 2015, from Site 1, Hickory Hills Lake in Lunenburg, MA, at 42.61835°N and 71.70370°W, and from Site 3, Barber Pond located in South Kingstown, RI, at 41.50148°N and 71.56367°W. Although in previous years Carolina fanwort was reported as being present in Site 2, Spring Lake in Burrillville, RI (RIDEM 2015a), specimens of Carolina fanwort were not found in the water samples taken from Spring Lake on 27 July 2015, which is most likely a direct result of chemical treatments to the lake in early July (Personal Communication, Rick Cayer, Spring Lake Camper's Association).

Field Sampling and Laboratory Procedures

Several techniques were employed in field sampling and laboratory experiments in order to preserve the integrity of *Cabomba caroliniana* samples and to prepare them for further morphological observations. Procedures were selected from guidelines provided by the Microbial Ecology Laboratory (Personal Communication, Gaytha Langlois 2015), and from the Laboratory for Terrestrial Environments (Personal Communication, Qin Leng 2015). At each location, samples were selected with identical conditions: the plants were approximately of the same size, of almost equal developmental stages, and were collected from approximately the same water depth.

At each location, at least one complete plant with roots, stems, and submerged leaves were obtained for later analysis. Reproductive organs (such as flowers and fruits), and floating leaves were unable to be collected because they were not yet developed during the sampling timeframe. The complete plant samples were gently pulled up from the sediments. Once collected, the samples were placed in a sterile, plastic jar with water from the lake for transportation back to the laboratory in an insulated container. Additional

samples were collected for further ecological analysis of the microbial community around the plant and were also preserved in jars with lake/pond water.

While in the field, photos were taken, latitude and longitude were recorded using a GIS device (Magellan Triton), ecological parameters including temperature, pH, dissolved solids, and conductivity were recorded with a Hanna Multimeter (Model #H1991300). Weather conditions were also noted.

In the laboratory, preservation of the intact plants was conducted by the following procedure: The entire plant was placed on a flat surface and photographed, alongside a scale to show the size of the plant (see Figures 2-4 and 2-5). Each sample was later prepared as a herbarium specimen to enable the plant structures to remain intact and the plants to be preserved for long periods as well as for further research purposes. The plant was dried and pressed in the plant press, frozen at around -80°C for sterilization, and mounted (Personal Communication – Qin Leng 2014).

Figure 2-4: A complete plant of *Cabomba caroliniana* from Barber Pond before being placed into the plant press.

Figure 2-5: A complete *Cabomba caroliniana* plant from Barber Pond (the same plant as shown in Figure 2-4) after being pressed for 25 days. The scale shows both centimeters and inches.

Laboratory Observations and Microscopy

A Zeiss AxioVert, Model 40 CFL, microscope along with a Q-Imaging camera system was used to observe and photograph the leaf structure of the *Cabomba carolinana*, as well to examine the microbial community associated with the leaf surface. Small segments (2-3cm) of fresh leaf samples, which had been preserved in pond water collected from the same sample sites, were placed onto microscope slides for light microscope observation. A Zeiss Discovery V12 dissecting light microscope along with a Q-Imaging camera system was used for documenting SEM preparation (Figure 2-6, b). Photomicrographs were labeled accordingly.

A Scanning Electron Microscope (SEM), JEOL Model JSM-6010LA, was utilized to observe the leaf surface structure of Carolina fanwort. The sample used for this analysis came from Barber Pond after being pressed for 25 days. The entire sample can be seen in figure 2-4 when it was still fresh and in figure 2-5 when it was pressed for 25 days. A small leaf portion was extracted from this completely dried sample. It was then mounted onto the SEM stub with a double sided tape containing carbon for conduction purposes. In order to ensure that both the upper and lower surfaces of the leaf would be analyzed, the leaf segment was folded over on itself so both sides were facing up (see Figure 2-6).

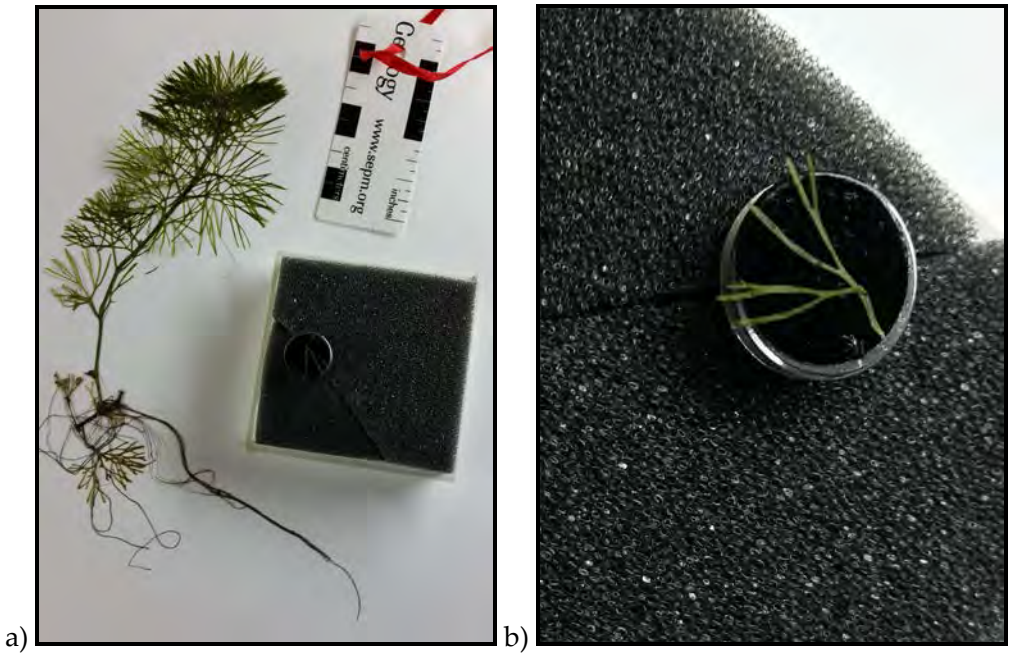


Figure 2-6: Illustration of SEM observation preparation. a) The original *Cabomba caroliniana* sample and a portion of a leaf that has been cut and mounted on a SEM stub for SEM observation. The plant has been pressed for 25 days. b) Close-up of the SEM stub with leaf sample. The folding of the leaf segment can be seen at the base of the sample, a technique to ensure that both leaf surfaces will be observed. The scale shows both centimeters and inches.

Next, the SEM stub containing the sample was coated with a thin film of gold by DESKV Denton Vacuum for 20 seconds at 40m AMPS. The coated sample was then placed into the SEM for observation.

The laboratory observations not only revealed the morphological structures of *Cabomba caroliniana* and the plant's associated Aufwuchs community, but also helped confirm the identification of the species and provided vital information that led to a better understanding of the plant's well-adapted role in the overall ecology of a lake.

Description of Surveys Sent to Hickory Hills Lake and Spring Lake Residents

A survey was created to assess the participants' understanding of the Carolina fanwort invasion in their respective lakes. Two lakes, the Hickory Hills Lake and the Spring Lake, were chosen for specific reasons. Both lakes have experienced Carolina fanwort problems in recent years. As described earlier, Hickory Hills Lake is a privately owned lake while Spring Lake is a publically owned lake. One goal of this study was to determine if there is a difference in the level of awareness and the actions taken to address the problem when comparing the residents near a privately owned lake versus the residents near a publically owned lake. It was hoped that the survey results would also help to (1) determine if the members of the community surrounding each lake have a differentiated understanding of what is occurring in their lake, (2) determine whether or not members of each community are aware of any attempts being made to address the Carolina fanwort problem, and (3) establish if a well-organized citizens' group enhances awareness and helps residents to be better informed about the existing problem and the potential solutions.

An additional difference between the two populations that were sampled is related to the level of residents' responsibility for lake management. Unlike residents surrounding Spring Lake, residents surrounding Hickory Hills Lake are legally responsible for maintaining the water quality in the lake. This responsibility may enhance the level of

knowledge each resident has accumulated, since they have a personal stake in the lake's management.

The surveys varied in minor ways to accommodate the different structures of lake interventions. For example, in the Hickory Hills area, the Lake Management Group maintains a subcommittee called the Weed Mitigation Group, and survey participants were asked if they actively participate in that committee's activities. In comparison, Spring Lake survey participants were asked if they participate in any kind of citizen groups who are working to control invasive pondweeds, and additionally participants were asked if they would be interested in participating in such a group. Aside from those questions, the surveys were similar.

Other questions in the surveys included asking participants how long they have lived in the area, if they have noticed any changes in the nearby lake since they have been living there, if they are aware of the presence of Carolina fanwort in the nearby lake, and what is their level of understanding about the growth pattern of the plant. The surveys asked participants to rate how serious the invasive pondweed problem has become. Other questions explored residents' concerns about the pondweed on the condition of their lake, and if the particular species or any other pondweed has negatively impacted their use of the lake. Next, participants were asked if they knew of any attempts or processes that have been used or are currently being used to address the invasive pondweed problem and if they had any suggestions about how to proceed with the control/eradication of the pondweeds. Finally, both surveys inquired if the respondent knew of any other lakes where residents were dealing with a similar problem and if they felt the homeowners around such lakes should help to assure good water quality.

In many of the questions, there were opportunities for the participant to leave comments or suggestions. With the combination of answers and comments from the respondents, conclusions would ideally be drawn regarding the quality and efficiency of a

well-organized private lake group versus a more random public lake group, and also if a more effective management plan would ensue. Patterns of common answers were evaluated in order to reach these conclusions. Although respondents of both surveys were assured anonymity, a summary of overall results for Hickory Hills Lake and for Spring Lake will be made available to decision makers in each locale. The comments were grouped by content of what factors were being considered by the respondent. The factors to consider were selected based on the content that was seen most frequently as well as by information that was important to this study. The groupings included: AIS management techniques, invasive awareness, lake usage, boating patterns, adjacent land use, water quality, health concerns, property values, stakeholder responsibility and government responsibility. The opportunity to enter personal comments was intended to provide the researchers with deeper insights into residents' knowledge about AIS and their awareness of the lake's water quality, and to ascertain the primary factors of concern.

Description of Interview Questions and Respondents

Interviews were conducted with various members of the community, in order to compare the different viewpoints from invasive species experts, citizens, representatives from state agencies, and members of private organization. Whenever possible, the interviews were conducted by telephone or in person, but some were conducted by email correspondence. The following questions were always used in the interview process, so as to achieve some consistency among the various members of the community who were interviewed.

INTERVIEW QUESTIONS

(1) When did you first become concerned about the problems associated with the overgrowth of pondweeds (especially invasives)?
(2) Do you know if the problem pondweeds in your local pond/lake are native to this area (RI/MA), or are they "invasive species" (area-wide distribution, only the local pond/lake, or new to the area?
(3) What are your concerns for fish and wildlife in these infested ponds/lakes?

(4) What do you believe to be the cause of these new species of aquatic plants? Do you think there is a correlation between the increase of pondweeds and improperly sewered areas?
(5) What do you think is the best approach to get rid of, or at least manage, the pondweeds?
(6) What do you believe to be the best way of informing members of the community about the current pondweed infestations, and what do you believe is the most effective way to get members of the community to take actions (participate in events, programs, and activities)?
(7) What do you see to be the biggest obstacles to implementing management plans?
(8) Do you have any other information regarding invasive aquatic pondweeds?
(9) When did you first become concerned about the problems associated with the overgrowth of pondweeds (especially invasives)?
(10) Do you know if the problem pondweeds in your local pond/lake are native to this area (RI/MA), or are they "invasive species" (area-wide distribution, only the local pond/lake, or new to the area?
(11) What are your concerns for fish and wildlife in these infested ponds/lakes?
(12) What do you believe to be the cause of these new species of aquatic plants? Do you think there is a correlation between the increase of pondweeds and improperly sewered areas?
(13) What do you think is the best approach to get rid of, or at least manage, the pondweeds?
(14) What do you believe to be the best way of informing members of the community about the current pondweed infestations, and what do you believe is the most effective way to get members of the community to take actions (participate in events, programs, and activities)?
(15) What do you see to be the biggest obstacles to implementing management plans?
(16) Do you have any other information regarding invasive aquatic pondweeds?

A slightly different version of these questions was directed to the President of a local NGO, in order to get initial information about Spring Lake in particular, and to assess the appropriateness of the Spring Lake citizen survey. The questions are noted below:

(1) What type of invasive plant species are associated with Spring Lake?
(2) Are all the houses surrounding the lake now sewered (or at least have upgraded to septic systems)? We may have this information already (in association with another project).
(3) What is the type of citizens' group that exists around Spring Lake? Who is a lead person that we could contact?
(4) 4. What actions have been taken already to remedy the aquatic pondweed problems on Spring Lake? Any state programs that apply?
(5) Is there a listing anywhere that includes all the known locations of fanwort in Rhode Island? Where should we be looking for this type of list?
(6) What did you think of the survey and how should design the Spring Lake Survey to be most effective?

The following categories of organizations and interested parties were contacted for phone, in person, or email interviews, although some potential interviewees were not available:

- Directors of NGOs focused on water quality in freshwater lakes and ponds
- Representatives of community action groups associated with a lake or pond
- Program staff at a quasi-governmental watershed group
- Representatives of state agencies overseeing aquatic invasive species in RI
- Academics or other water quality experts
- Residents living near freshwater lakes or ponds
- Other RI governmental agencies

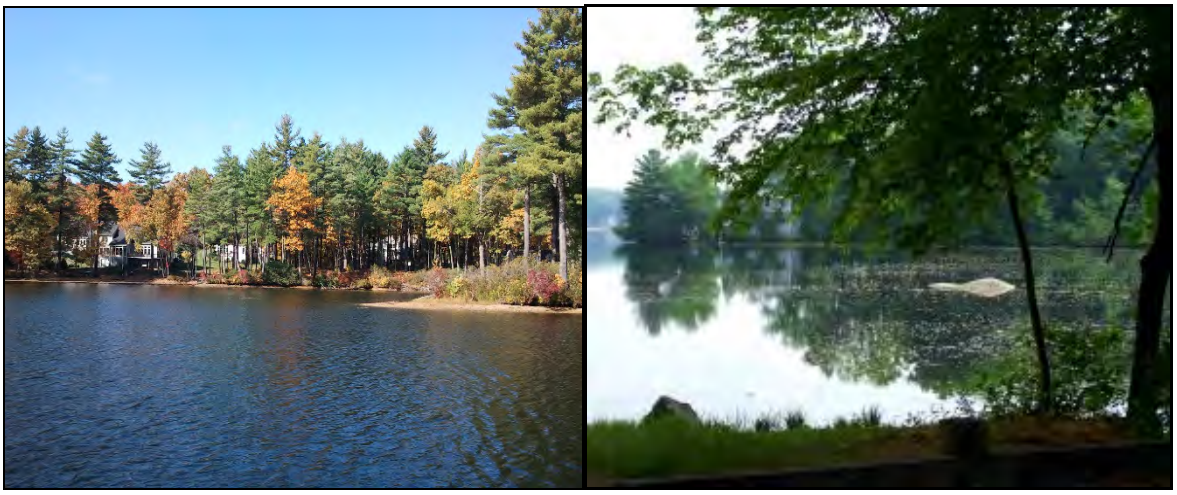
Interview responses were recorded and analyzed for key components regarding awareness of aquatic invasive plant distributions, level of concern, extent of participation, and tools for managing aquatic invasive plants. Each of the interviewees had some connection with, or experience with, managing aquatic invasive plants or in working with citizens' groups, or both.

Chapter 3 : Results

Site Characterization and Plant Ecology

The three sample sites are illustrated in Figure 3-1, characterizing their natural environments.

A. **B.**



C.

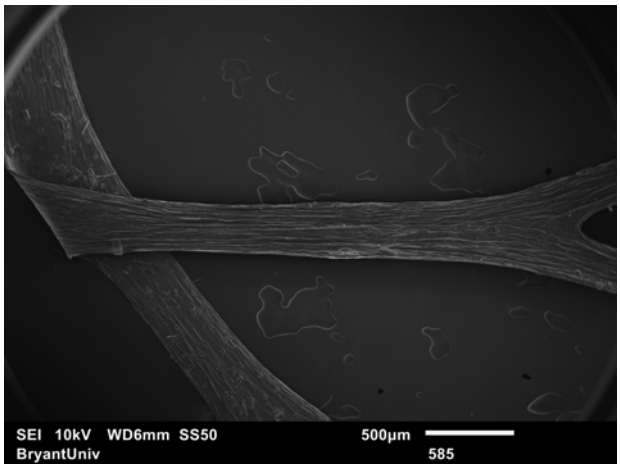
Figure 3-1 A-C: The lakes utilized in this study. **(A).** The photo of Site 1 at Hickory Hills Lake in Lunenburg, MA (42°36′27″N, 71°42′21″W) was taken on 17 October 2014 at 10:30 a.m.**(B).** The photo of Site 2 at Spring Lake in Burrillville, RI (41°58′43.9″N, 71°39′54.4″W) was taken on 09 September 2015 at 6:00 p.m. **(C).** The photo of Site 3 at Barber's Pond, South Kingstown, RI (41.979°N, 71.663°W) was taken on 28 August 2015 at 11:30 a.m.

SEM and Light Microscope Observation of *Cabomba caroliniana* Leaf Surfaces

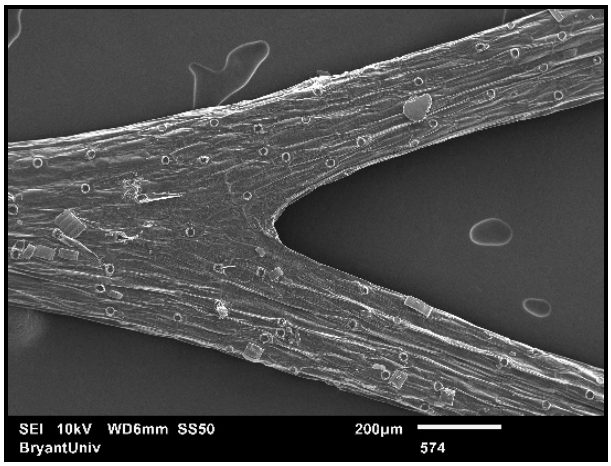
Under SEM, multiple types of diatoms (Figure 3-2, B, C, D, and E) and green algae (Figure 3-2, F) were densely present on the leaf surfaces, showing a rich microbial community in Barber Pond, and depicting the favorability of the Carolina fanwort leaves for supporting epiphytes.

The submerged leaves of Carolina fanwort are highly dissected with fine lobes and dichotomously ramified (Figure 3-2, A, B, G). The leaf's upper surface is covered with dense hairs (Figure 3-2, B-E). Hairs are linear, each with a circular hair base, and are readily shed, with their protruding circular bases remaining on the leaf surface. Some areas of the upper leaf surface are also covered with crystals.

Compared with the upper leaf surface, the lower surface is smooth; neither hairs nor crystals were observed (Figure 3-2, G and H).



A



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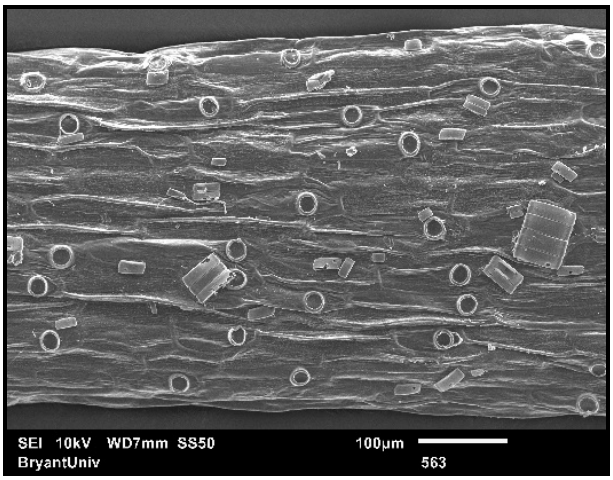
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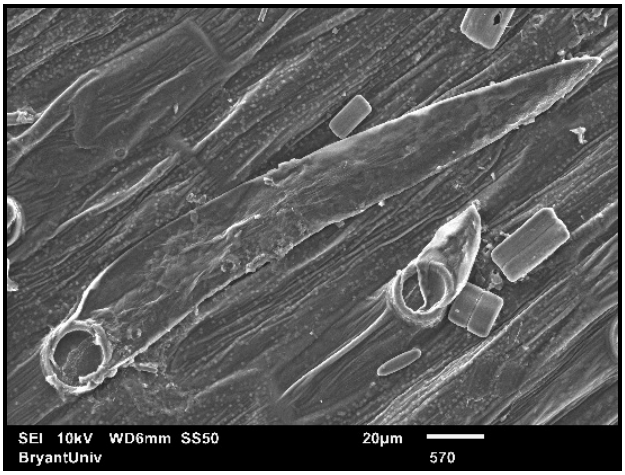
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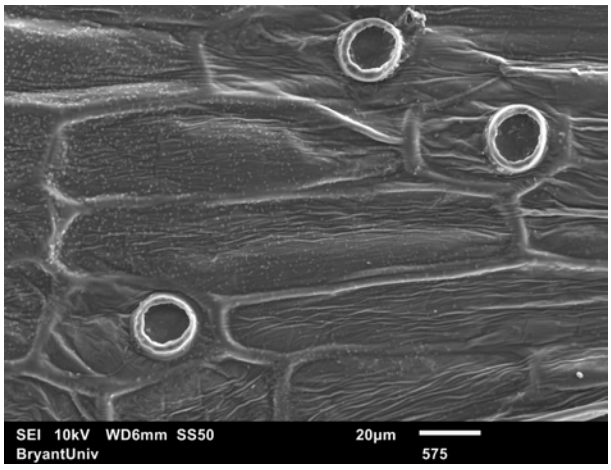
D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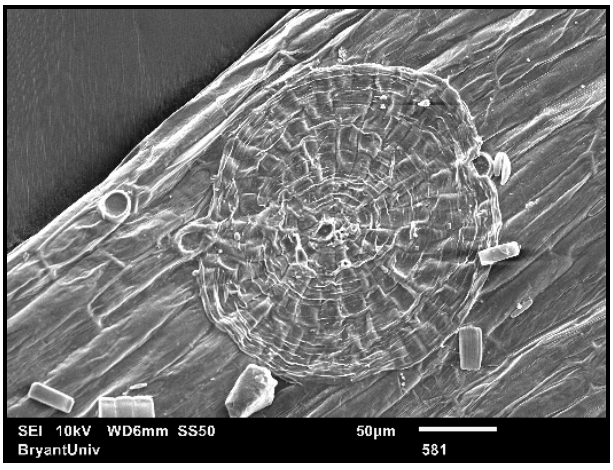
BryantUniv
575

E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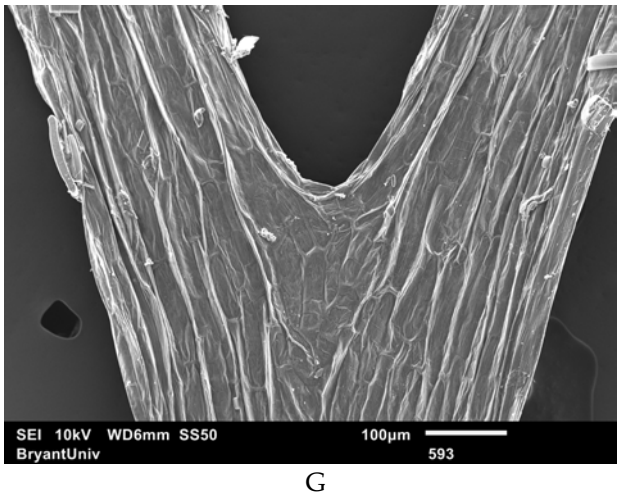
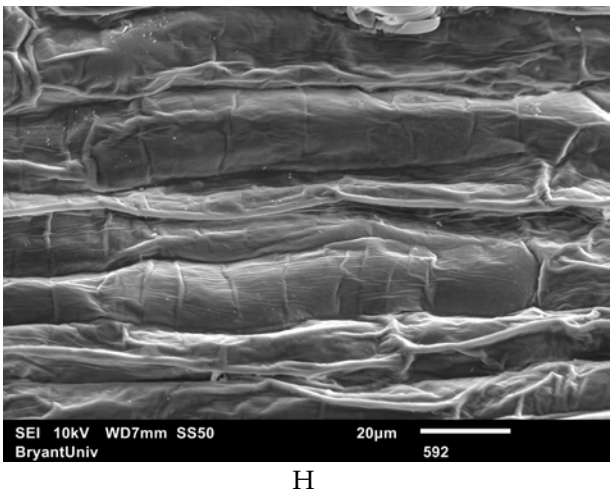
50µm
BryantUniv
581

F


SEI 10kV WD6mm SS50
100µm
BryantUniv
593

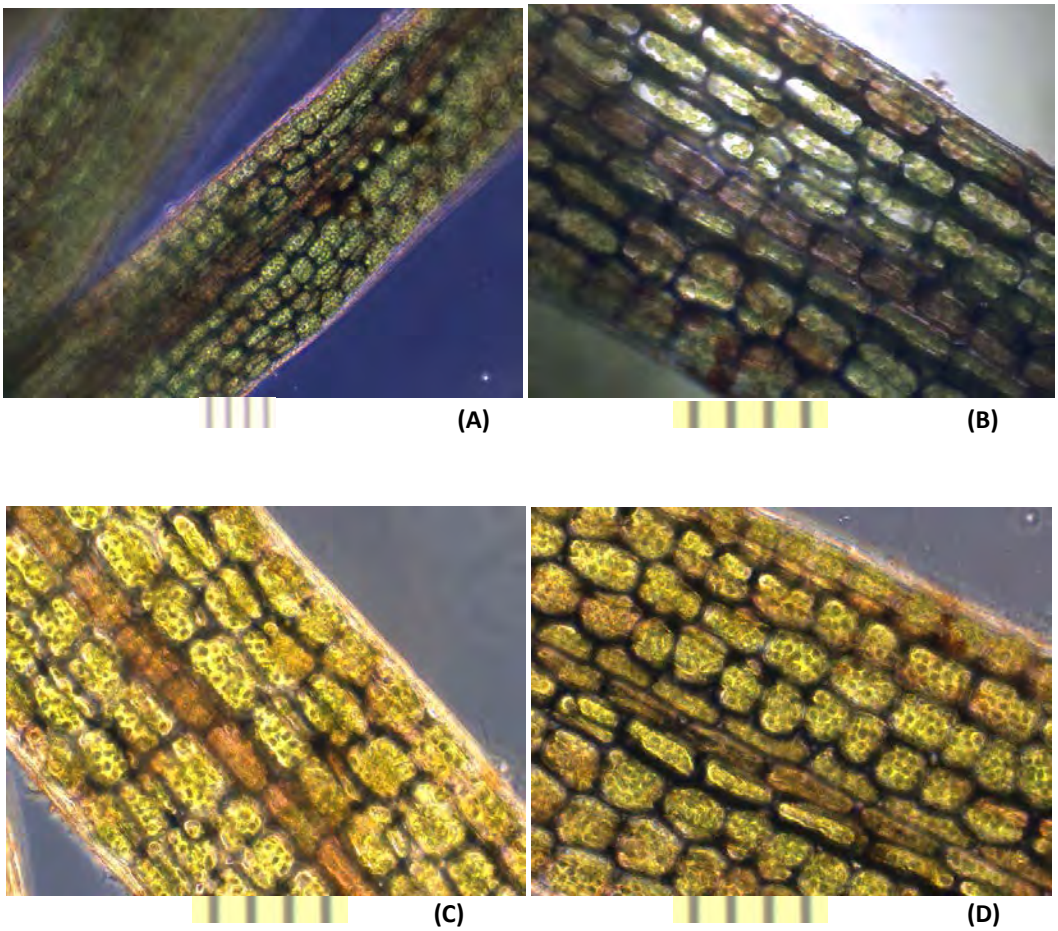
G

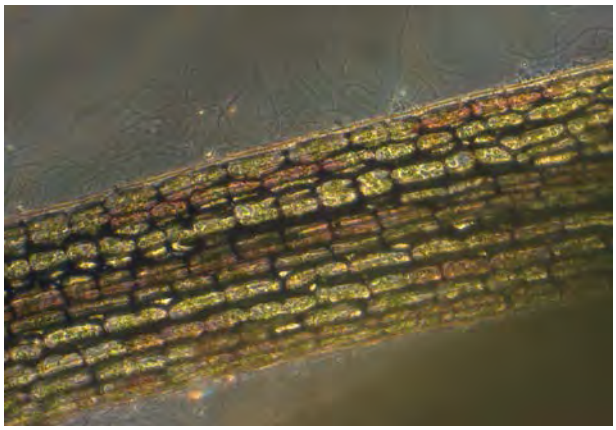

SEI 10kV WD7mm SS50
20µm
BryantUniv
592

H

Figure 3-2: SEM micrographs of a portion of a *Cabomba caroliniana* submerged leaf. A) The portion of the leaf is folded at the base to have both leaf surfaces facing up for observation. B-F show the upper surface and G-H show the lower surface. B) The dichotomously ramifying portion of the leaf segment. C) A portion of the upper leaf surface showing dense hair bases - the circular structures. Various types of diatoms can be seen on leaf surface. D) Two separate hairs of different lengths (stages of development). The circular parts are the hair bases and the portion extending outwards from the circular structures are the hair bodies. The densely distributed small white dots are crystals. Several diatoms are present. E) Three hair bases and densely distributed crystals. F) A green alga and several diatoms are seen on leaf surface. G) The ramifying portion shown on the lower surface. H) The smooth lower surface without hair. "Wrinkles" were due to drying of the leaf.

Figure 3-3 shows the fresh leaf surface structure of Carolina fanwort observed under the light microscope. More or less regularly arranged rectangular epidermal cells are clearly seen. A large number of chloroplasts were also observable within each cell. Some leaves are observed to have dense hairs on their surfaces (figure 3-3,E).





(E)

Figure 3-3: Light micrographs of submerged leaf surface strucuture of fresh *Cabomba caroliniana* from Barber's Pond and Hickory Hills Lake, observed with a Zeiss Axiovert Model 40 CFL microscope and a Q-Imaging camera. Regularly arranged rectangular epidermal cells with a large number of chloroplasts are clearly shown, particularly in C and D. Dense hairs are also observed on some leaves such as the one shown in E. The minimum division of all scales = 0.01mm.

Ecological Data

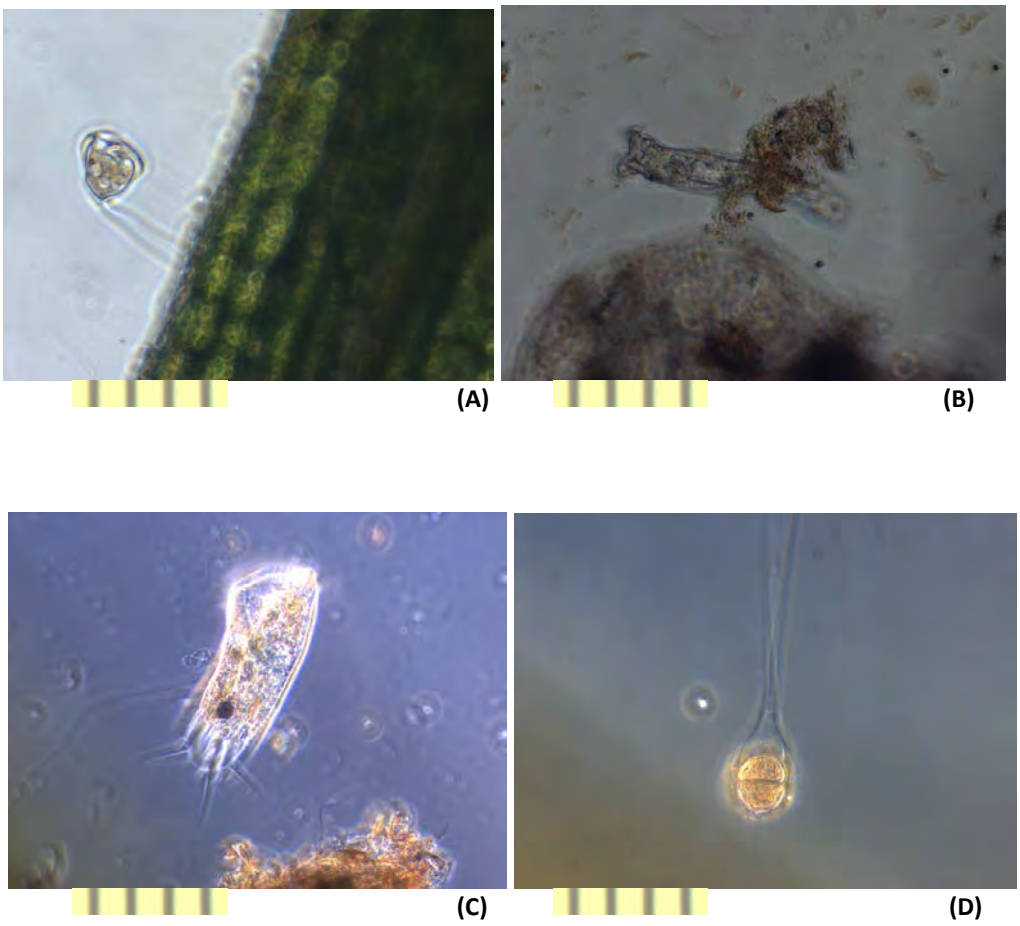
Ecological parameters were assessed at each lake site for basic water quality measurements, hydrologic type, location, and weather conditions, since these factors might affect the presence of the fanwort. The data collected at the three sample sites is compiled in Table 3-1 and shows strong similarities to previously published data pertaining to these lakes and ponds (Aquatic Control Technology 2014, URI Watershed Watch 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2014f).

Table 3-1: Ecological Parameters at Sample Sites

Location	Latitude	Longitude	Air Temperature	Water Temperature	Depth	pH	Conductivity	Elevation
	°N	°W	°C	°C	cm		µS	m
Hickory Hills Lake	42.61835°N	71.70370°W	24.7°C	25.0°C	38.3 cm	7.17	73 µS	125.58m
Spring Lake	41.979°N	71.663°W	25.6°C	24.9 °C	42.2 cm	6.6		32.42m
Barber Pond	41.50148°N	71.56367°W	25.6°C	24.7°C	33.5 cm	6.8	58 µS	48.77m

Assessment of Microbial Community Associated with *Cabomba caroliniana*

Selected results of microscopic observations of fanwort leaves from Hickory Hills Lake (from September 25-October 30, 2014) are shown in Figure 3-4, indicating a diverse microbial community associated with the Carolina fanwort plants.



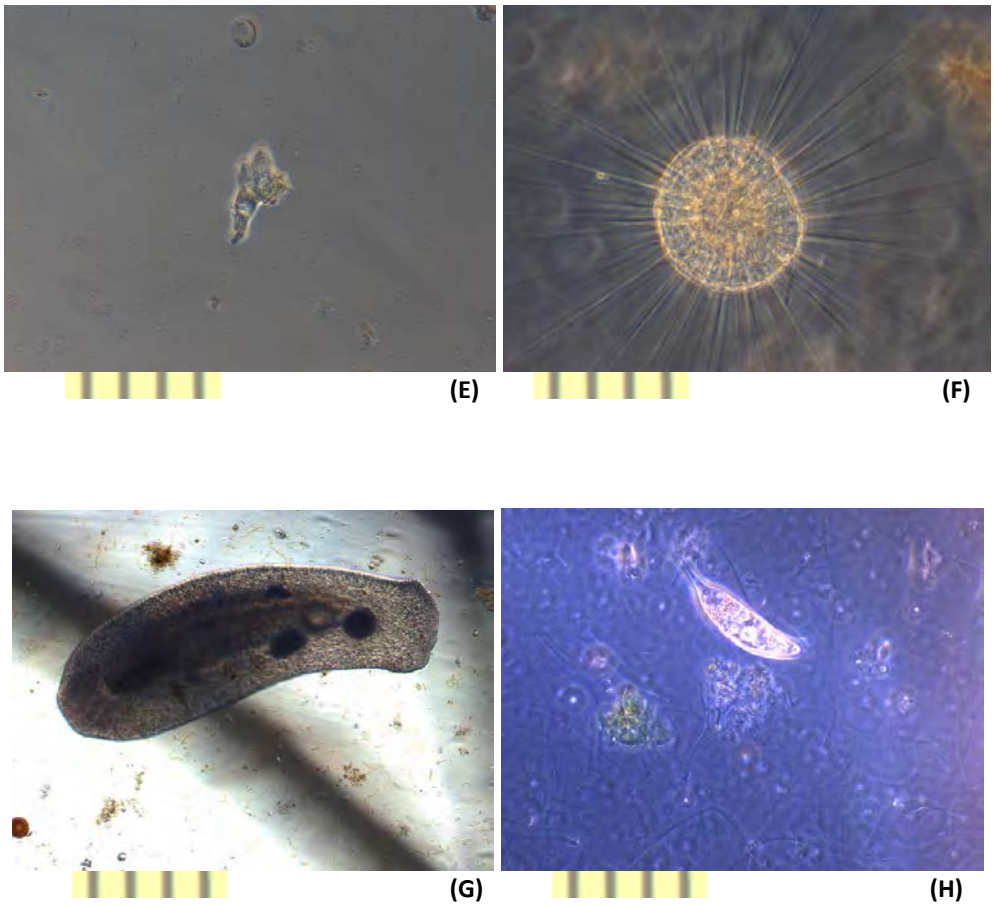


Figure 3-4 A-H: Microbial community associated with *Cabomba carolinana* from Barber Pond and Hickory Hills Lake. A. Peritrich ciliate; B. Small rotifer; C. Large hypotrich ciliate; D. Stalked ciliate dividing; E. Naked amoeba; F. Shelled amoeba; G. Large flatworm; H. Large flagellated protistan. These selected protista and micrometazoa show the biodiversity associated with a Carolina fanwort cluster. Photomicrographs were taken with a Zeiss AxioVert Model 40 CFL microscope and a Q-Imaging camera system. The minimum division of all scales = 0.01mm.

Survey Responses from Hickory Hills Lake Residents

The summary of the responses to the survey is based on an overall response rate of 32.43% for the Hickory Hills Lake survey (215 respondents), with 34.58% for the email responses, and 23.44% for the direct mail responses. It should be noted that the Lake Management Group regularly communicates with their membership using the same mailing lists which may have enhanced the return rate from the residents surrounding Hickory Hills Lake. Table 3-1 summarizes the responses from both the online and mailed in responses. With

the exception of a few minor differences, paper and online survey results were very close, percentage wise, in the answers to each question. Out of all of the participants, approximately 66.51% have lived in the area for 10 years or more, and 62.74% of the participants have noticed a change in the Hickory Hills Lake since they have lived there.

Table 3-1: Survey Results for Hickory Hills Lake Residents.

Hickory Hills Lake Survey - Spring 2015

1. How long have you lived in the Hickory Hills Lake area?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
1 year or less	7.1%	13	0	13	6.0%
2-5 years	19.0%	35	0	35	16.3%
6-10 years	12.0%	22	2	24	11.2%
Over 10 years	62.0%	114	29	143	66.5%
answered question		184	31	215	100.0%
skipped question		1	0		

2. Have you noticed any changes in the nearby lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	63.4%	116	17	133	62.7%
No	36.6%	67	12	79	37.3%
If yes, please describe:		108			
answered question		183	29	212	
skipped question		2	2	4	

3. Are you aware of the presence of fanwort (an invasive pond weed species) in the lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	
Yes	97.8%	181	30	211	97.7%
No	2.2%	4	1	5	2.3%
answered question		185	31	216	
skipped question		0	0	0	

4. What is your understanding of the growth patterns of Fanwort?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Same as other pond weeds	12.8%	19	6	25	14.0%
Noticeable different from other	61.5%	91	11	102	57.0%
Brighter color	42.6%	63	8	71	39.7%
Darker green	5.4%	8	1	9	5.0%
Only found at the bottom	11.5%	17	4	21	11.7%
Only found floating on top of the	4.7%	7	2	9	5.0%
Other (please specify)		65	8	73	40.8%
answered question		148	31	179	
skipped question		37	0	37	

5. How serious do you think the Fanwort problem has become?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Level of Impact	2	17			
Low Impact = 1	1.1%	2	2	4	1.94%
Slight Impact = 2	9.6%	17	4	21	10.19%
Moderate Impact = 3	23.2%	41	8	49	23.79%
Relatively high impact = 4	36.7%	65	3	68	33.01%
High impact = 5	29.4%	52	12	64	31.07%
Rating Average	3.84				100.00%
answered question		177	29	206	
skipped question		8	2	10	

6. What are your concerns about the presence of fanwort?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Cost of removal	57.2%	103	19	122	58.1%
Difficulty of removal	82.8%	149	20	169	80.5%
Negative impact on native	53.9%	97	13	110	52.4%
Affecting lake activities	61.7%	111	15	126	60.0%
Causing unhealthy conditions for	36.1%	65	12	77	36.7%
Other (please specify)		35	5	40	19.0%
answered question		180	30	210	
skipped question		5	1	6	

7. Has the presence of fanwort or any other vegetation hindered your ability to enjoy the lake or affected your lake-related activities (boating , fishing, swimming, etc.)?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	34.3%	62	12	74	34.9%
No	65.7%	119	19	138	65.1%
If Yes, Please describe.		68	12	80	
answered question		181	31	212	100.0%
skipped question		4	0	4	

8. Are you aware of any attempts or processes that have been used or are being used to address the Fanwort issue?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	91.2%	166	27	193	90.6%
No	8.8%	16	4	20	9.4%
If yes, please describe 1 or 2 methods:		129			
answered question		182	31	213	100.0%
skipped question		3	0	3	

9. Do you have any suggestions on how to proceed with the control of the weeds and ultimately their eradication?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
	58%	107	31	138	63.9%
answered question	107		31	138	
skipped question	78		0	78	

10. Do you actively participate in the Weed Mitigation Group?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	30.2%	54	0	54	25.7%
No	69.8%	125	31	156	74.3%
If so, please describe your role.		61			
answered question		179	31	210	100.0%
skipped question		6	0	6	

11. Do you know of any other lakes/ponds in the area that are dealing with a similar fanwort problem?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	32.8%	60	9	69	32.2%
No	67.2%	123	22	145	67.8%
If yes, please describe:		48			
answered question		183	31	214	100.0%
skipped question		2	0	2	

12. Do you think homeowners should help to assure good water quality in Hickory Hills Lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	92.0%	161	26	187	91.2%
No	8.0%	14	4	18	8.8%
Why or why not?		99	20		
answered question		175	30	205	100.0%
skipped question		10	1	11	

Of particular interest to this study, question 5 in the survey asked participants to rate the seriousness of the Carolina fanwort problem on a scale of 1 to 5 (with 1 being low impact and 5 being high impact) and 64.08% of people ranked the seriousness to be a 4 or 5. This shows that more than half of the survey respondents know the severity of the infestation. In question number 6, participants were provided with a list which asked them to indicate their concern(s) about Carolina fanwort being present in their lake. The top answer selected was the difficulty of removing this pondweed. Other primary concerns included the cost of removal and the effect of the pondweed on lake activities. Interestingly enough, when participants were asked in

question 7 if the presence of Carolina fanwort or any other vegetation hindered their ability to enjoy the lake or if it had affected their lake-related activities, 65.09% of people selected a response of "no effect".

Question 11 asked respondents if they were aware of any other lakes/ponds in the area dealing with a similar Carolina fanwort problem. About one-third (32.24%) knew of another lake/pond in the area, while about two-thirds (68.08%) were unaware of any other lake/pond in the area with a similar problem. In question 12, participants were asked if they felt homeowners should help to assure good water quality in the Hickory Hills Lake, and also inquired why they believed homeowners should or should not help. A large majority of respondents (91.22%) believed homeowners should help to assure good water quality, while only 8.78% thought homeowners did not need to help. These findings suggest a strong willingness of residents to be part of the solution to Carolina fanwort related problems.

Survey Responses from Spring Lake Residents

A total of 161 surveys were sent out and only 32 of these surveys were mailed back. This is a response rate of 19.88%, which is lower than the return rate for Hickory Hills Lake respondents. It was not possible to obtain an email list for residents located near Spring Lake. A mailing list was provided by the Spring Lake Camper's Association who maintain a moderate level of communication from time to time (Personal Communication, Rick Cayer). The mailing addresses were for property owners but did not necessarily represent residents in the area. To enhance the number of returned surveys, surveys were distributed in August when the resident population would have been expected to be at its peak, and requests included a stamped and addressed return envelope in which to return the completed survey. A large number of survey mail-outs were returned as "undeliverable" by the U.S. Postage Service. Table 3-2 summarizes the responses of Spring Lake residents/owners who returned their surveys.

Table 3-3: Comparison of Survey Results from Spring Lake Community. All surveys were distributed by direct mailing.

Spring Lake Survey - Spring 2015

1. How long have you lived in the Spring Lake area?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
1 year or less	0.0%	0	1	1	3.1%
2-5 years	0.0%	0	1	1	3.1%
6-10 years	0.0%	0	5	5	15.6%
Over 10 years	0.0%	0	25	25	78.1%
answered question		0	32	32	100.0%
skipped question		0	0	0	

2. Have you noticed any changes in the nearby lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	20	20	62.5%
No	0.0%	0	12	12	37.5%
If yes, please describe:		0			
answered question		0	32	32	100.0%
skipped question		0	2	0	

3. Are you aware of the presence of fanwort (an invasive pond weed species) in the lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	
Yes	0.0%	0	12	12	37.5%
No	0.0%	0	20	20	62.5%
answered question		0	32	32	100.0%
skipped question		0	0	0	

4. What is your understanding of the growth patterns of Fanwort?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Same as other pond weeds	0.0%	0	4	4	10.5%
Noticeable different from other	0.0%	0	4	4	10.5%
Brighter color	0.0%	0	1	1	2.6%
Darker green	0.0%	0	1	1	2.6%
Only found at the bottom	0.0%	0	3	3	7.9%
Only found floating on top of the	0.0%	0	5	5	13.2%
Other (please specify)		0	20	20	52.6%
answered question		0	30	30	100.0%
skipped question		0	2	2	

5. How serious do you think the invasive pond weed problem has become?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Level of Impact					
Low Impact = 1	0.0%	0	4	4	14.29%
Slight Impact = 2	0.0%	0	6	6	21.43%
Moderate Impact = 3	0.0%	0	7	7	25.00%
Relatively high impact = 4	0.0%	0	5	5	17.86%
High impact = 5	0.0%	0	6	6	21.43%
Rating Average					100.00%
answered question		0	29	28	
skipped question		0	2	4	

6. What are your concerns about the presence of invasive pond weeds in Spring Lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Cost of removal	0.0%	0	13	13	43.3%
Difficulty of removal	0.0%	0	18	18	60.0%
Negative impact on native	0.0%	0	14	14	46.7%
Affecting lake activities	0.0%	0	16	16	53.3%
Causing unhealthy conditions for	0.0%	0	20	20	66.7%
Other (please specify)		0	9	9	30.0%
answered question		0	30	30	
skipped question		0	1	2	

7. Has the presence of fanwort or any other vegetation hindered your ability to enjoy the lake or affected your lake-related activities (boating , fishing, swimming, etc.)?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	6	6	19.4%
No	0.0%	0	25	25	80.6%
If Yes, Please describe.		0	6	6	
answered question		0	31	31	100.0%
skipped question		0	1	1	

8. Are you aware of any attempts or processes that have been used or are being used to address the invasive pond weed issue in Spring Lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	18	18	58.1%
No	0.0%	0	13	13	41.9%
If yes, please describe 1 or 2 methods:		0			
answered question		0	31	31	100.0%
skipped question		0	1	1	

9. Do you have any suggestions on how to proceed with the control of the weeds and ultimately their eradication?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
	0%	0	17	17	53.1%
answered question		0	30	30	
skipped question		0	2	2	

10. Do you actively participate in a citizens' group trying to eradicate fanwort and other invasive pond weeds?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	10	10	31.3%
No	0.0%	0	22	22	68.8%
If so, please describe your role.		0			
answered question		0	32	32	100.0%
skipped question		0	0	0	

11. Do you know of any other lakes/ponds in the area that are dealing with a similar fanwort or other invasive pond weed problem?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	7	7	22.6%
No	0.0%	0	24	24	77.4%
If yes, please describe:		0			
answered question		0	31	31	100.0%
skipped question		0	1	1	

12. Do you think homeowners should help to assure good water quality in Spring Lake?

Answer Options	Response Percent	Response Count	MailOut Response	Overall Response	Overall Percent
Yes	0.0%	0	30	30	93.8%
No	0.0%	0	2	2	6.3%
Why or why not?		0	23		
answered question		0	32	32	100.0%
skipped question		0	0	0	

For respondents from Spring Lake, 78.1% have lived in the area for ten or more years and 93.8% of people have lived in the Spring Lake area for six or more years. However, there does not seem to be a corresponding level of awareness regarding Carolina fanwort problems since only 32.5% of respondents noticed any changes in the lake since they have been living there. From specific commentaries written on the returned surveys, the main changes noted included the water being darker, more pondweeds present, and a wider variety of pondweeds.

However, a few respondents noted that the lake was "clearer" and "appeared to be in better condition."

Considering that 37.5% of participants were unaware of fanwort in Spring Lake (question 3), the issue arose to why this might the case. Given the presence of the Town of Burrillville's public beach (with extensive sand deposition that does not foster plant growth), and the yearly chemical biocide treatment by Aquatic Control Technology to kill Carolina fanwort and other nuisance pondweeds that might be present (Personal Communication, Rick Cayer, Spring Lake Camper's Association), perhaps it is not surprising that many of the residents would be unaware of fanwort, especially if they are only summer residents on the lake.

Participants were asked in question 4 to evaluate their understanding of the growth patterns of fanwort. The description that was checked off most frequently described fanwort as only being found floating on top of the water and 62.5% of individuals chose to leave a comment rather than selecting one of the written descriptions found on the survey. The most common comments were that the participants had "never heard of this plant" and had "no understanding of its growth patterns."

Despite the number of people who indicated a change in the number and variety of pondweeds that could be seen at Spring Lake, the severity of the pondweed problem was most commonly checked off as having a moderate severity level (a rating of 3 out of 5). Again, given the State's chemical treatment program, this is not surprising. When asked about what concerns the residents had as a result of invasive pondweeds, the two most common concerns were the pondweeds causing "unhealthy conditions for swimming" and the "difficulty of removal." The Town's public beach is located along one side of Spring Lake, and the area is popular for swimming and other beach activities, thus not surprising that healthy conditions for swimming would be a high concern to surrounding residents.

Only 18.8% of survey respondents indicated that Carolina fanwort or other vegetation was seen as a hindrance to the participant's ability to enjoy the lake or participate in lake-associated activities. One question of high interest for this study was to discover how many

people were aware of the treatments taking place at their lake and the results showed that 56.3% of people knew that there was some level of treatment taking place on the lake but very few individuals knew what products were being used, and how the lake was being treated. Many commented that they knew the lake was treated, and most likely with chemicals, but were "not sure which ones." Some individuals did mention the act of physically removing the plants by hand, and 53.1% of participants offered suggestions on how to control pondweeds. Some comments addressed the need for a boat washing station, using chemicals for treatment, dredging certain areas of the lake, or restricting fertilizers being used on homeowner's lawns. Some participants made comments specifically requesting that the State or a private organization inform the residents about what is really going on in the lake. Concurrently, many comments were made saying "nature needed to take its course" and the pondweeds "should be left alone," while others argued for the state to become more involved in managing the lake. In general, the residents around the lake do not seem to be very well informed about the treatments that the Spring Lake Camper's Association and Aquatic Control Technology have been applying annually in recent years.

Only 31.2% of the residents said they actively participated in a citizen's group that works on dealing with the pondweed infestations. This contradicted some of the findings from previous questions. Many did not seem to think the pondweeds had a significant impact and a number of respondents didn't even know about a problem with these plants. The most mentioned citizens' action group was the Spring Lake Camper's Association, and some respondents thought that this group used some chemicals on the lake. Remarkably, 50% of survey respondents made it clear that they would be interested in participating in a group that addresses the issue of invasive plants. A large percentage did not express knowledge of any other nearby lakes that were dealing with a pondweed infestation problem but two lakes that were specifically named were Johnson's Pond (located in Coventry, RI, approximately 25 miles away from Spring Lake) and Echo Lake (also called Pascoag Reservoir, located in Glocester, RI, which is about 6 miles away). Both of these ponds are listed as good fishing sites in Rhode

Island and are included on the RI Blueways and Greenways website (RI Blueways 2008). This knowledge of other lakes seems to illustrate Rhode Island boaters could be utilizing several ponds and lakes throughout the fishing season.

The survey showed that 93.8% of participants felt the homeowners around and near Spring Lake should help to assure good water quality, and some comments noted a connection between water quality and property values, which might imply that homeowners should help to pay for maintaining water quality. However, other comments indicated that tax rates for waterfront property were already too high. This seems to indicate a clear understanding that the quality of the water affects the property values of their homes, which is of course another important reason to help maintain the lake. Some of the individuals who indicated that they believe homeowners should help to assure good water quality also felt that the taxes for lakefront property in the area are already too high. Thus these respondents do not feel as though they need to help financially in restoring or maintaining water quality. The results from this question had a wide variety of comments, concerns, and belief of who should be the responsible party.

Overall, the number of comments that were made throughout the surveys, from both the Hickory Hills Lake and the Spring Lake resident populations, were extensive, thoughtful, and contained many ideas about the water quality problems in their respective lakes, the actions needed to address these problems, and the relative responsibility of government agencies, NGOs and community action groups, and residents themselves. A factor analysis was performed for three categories of respondents, online and paper survey responses from Hickory Hills Lake residents and the paper survey responses from Spring Lake residents (see Appendix Tables 2a, 2b, and 2c). This factor analysis of hundreds of comments resulted in the following rankings:

(1) Hickory Hills Lake Online Survey – The factors of highest concern were AIS Management Techniques, Invasive Awareness, and Stakeholder Responsibility;

(2) Hickory Hills Lake Paper Survey – The highest areas of concern were ranked as Invasive Awareness, AIS Management Techniques, and Stakeholder Responsibility;
(3) Spring Lake Paper Survey – The concern factors most important to this group were AIS Management Techniques, Stakeholder Responsibility, and Invasive Awareness.

It is interesting to note that all three groups rated the same factors as their highest areas of concern, but in slightly different order. This trend suggests that residents' comments followed the general themes of their question responses, i.e., recognition of significant AIS problems that need to be addressed, along with strong ideas about how this difficult task can be accomplished, accompanied by an apparent willingness to be involved in the process.

Interview Responses

Representatives from the following organizational categories were interviewed using the questions described in the Methodology of this paper.

- Residents living either on or near one of the three lakes being studied
- Other residents living on or near a Rhode Island or Massachusetts lake characterized with aquatic invasive plants (Carolina fanwort or other AIS)
- Representatives from government agencies or quasi-governmental organizations that oversee water quality or track AIS infestations
- Representatives from NGO's associated with aquatic ecology, water quality protection, citizen involvement

The interview questions described in the Methodology section were designed to gather a variety of viewpoints about the extent of AIS problems in Rhode Island and Massachusetts, as well as to seek insights into effective management practices for dealing with the specific challenges surrounding Carolina fanwort. Actual interview notes are included in Appendix B without descriptive information that would reveal the identity of the interviewee, since the

individuals were providing their own viewpoints and not necessarily speaking officially for their agencies or organizations.

Four categories of interviewees were designated, so as to protect individual identities and separate the diverse viewpoints: (1) governmental or quasi-governmental agency representative; (2) leader or manager of an environmental NGO, (3) educators or technical experts; and (4) residents affected by Carolina fanwort infestations. A summary of the trends for each interview question, along with the patterns that emerged following factor analysis of the responses, is shown in Figure 3-5.

Key markers used to analyze the interview comments included the following: AIS management techniques (AMT), stakeholder responsibility (SH), water quality (WQ), governmental responsibility (GR), invasive plant awareness (particularly fanwort) (IA), adjacent land use (ALU), boating patterns and behaviors (BP), lake usage (recreation or water supply) (LU), property value (PV), and health concerns (HC). The level of concern for each factor was noted, with 5 = High concern and 1= Slight concern.

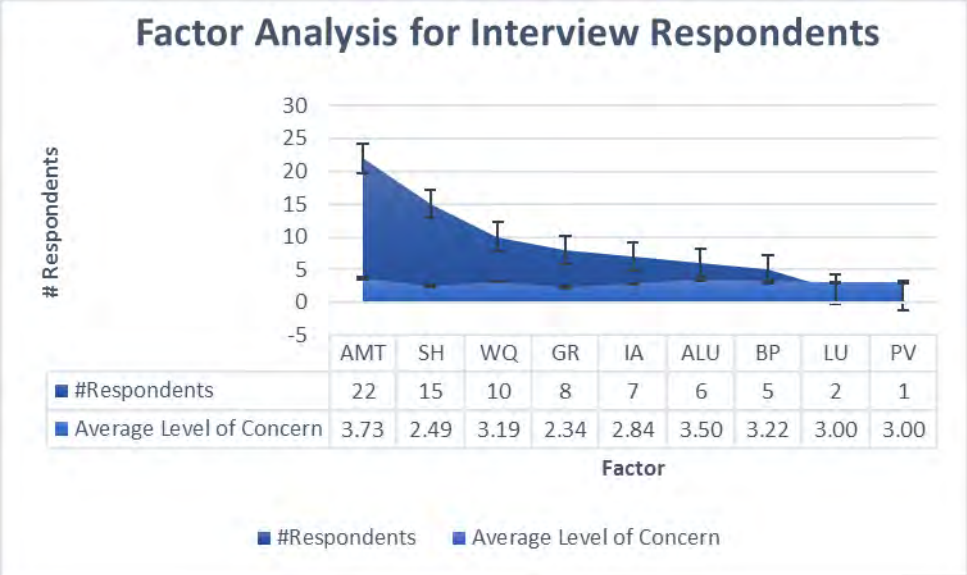


Figure 3-5: Comparison of important factors influencing decisions about assessment of invasive aquatic plant challenges, and for planning community-based mitigation and management strategies, as seen by a variety of stakeholder interviews. Data is arranged by the questions asked of the interviewees. Details of the analysis are included in Appendix A-2.

The interview questions (described earlier in the Methodology) are repeated here, along with a summary of the overall trends that emerged from the various responses. The entire set of responses, coded by interview categories, can be located in Appendix B.

Interview Questions Response Summary:

(1) When did you first become concerned about the problems associated with the overgrowth of pondweeds (especially invasives)?

Summary of Responses: Residents mark the time they began concerning themselves with pondweeds when the lake nearest to them was affected. Experts in the field have noticed it throughout their careers but noted that the problem had worsened over time. Organization members formed the current organizations as a result of the pondweed infestation which began their strides to create programs and outreach programs to attempt to stop the invasive species problem.

(2) Do you know if the problem pondweeds in your local pond/lake are native to this area (RI/MA), or are they "invasive species" (area-wide distribution, only the local pond/lake, or new to the area)?

Summary of Responses: Residents believe that the pondweeds are non-native and widespread in the area. Experts expressed the overwhelming amount of invasive species that have been occurring in the area. Organization members have been focusing their attention on their own lakes and monitoring the presence of new species and determining them to be nonnative and widespread. Some organizations have also noted an increase of native species. Some knew of the map located on the RIDEM website that shows the amount of aquatic invasive species and where they can be found (widespread).

(3A) What are your concerns for fish and wildlife in these infested ponds/lakes?

Summary of Responses: Experts in the field have numerous concerns for the fish and wildlife in these infested ponds and lakes. Among these concerns are anoxia or hypoxia, habitat destruction, and the overall ecosystem of the area. Residents' concern was about fishing which showed a more generalized response.

(3B) What do you believe to be the cause of these new species of aquatic plants? Do you think there is a correlation between the increase of pondweeds and improperly sewered areas?

Summary of Responses: Residents believe the sewage is a major contributor with only one surveyed individual holding the belief that there is no correlation between improperly sewered areas and the presence of AIS. They also attribute the heightened presence of the pondweeds as related to boats not being properly cleaned before being placed in the lakes. Experts and NGO representatives also believe that there is a strong correlation between improperly sewered areas and an increase of pondweeds. A few interviewees questioned whether there is a strong enough correlation between improperly sewered areas and an increase of aquatic invasive species. Overall, there was a mixture of opinions regarding this issue, and although the opinions varied, most interviewees had strong views on the matter.

(4) What do you think is the best approach to get rid of, or at least manage, the pondweeds?

Summary of Responses: Residents believe the best methods of controlling or eradication to be using chemicals and herbicides, dredging, educating the public about cleaning their boats, installing benthic barriers, utilizing suction harvesting, and practicing drawdowns. Experts believe creating a strategic plan is needed before anything is done to the body of water or the plants. It is believed that research about the plant encompassing how it reproduces and how it responds to certain chemicals and herbicides should be examined before any action is taken. The overall quality of the lake water, including nutrient levels, dissolved oxygen, etc. should also be taken into consideration. These factors can affect how a treatment method is going to

work and will help to determine whether the treatment will be helpful or not. Organizations believe a multi-phased technique is needed. This includes hand pulling pondweeds, boat drawn rakes, preventing downstream contamination, and the disposal process of compost on the land surrounding the lakes/ponds. Replanting native species and mapping the plants are believed to be a crucial part. All respondents emphasized advocating for the prevention, rapid response (including eradication if possible), and maintenance of areas to help control the infestations from becoming more serious.

(5) What do you consider to be your best source of information about these pondweeds and their control or eradication? How do you decide which action plan is best for the situation? Summary of Responses: Residents listed RIDEM, Save the Lakes, Aquatic Control Technology, Google, scientific papers, limnologists, and professional lake consultants as sources of information. Residents did not specify how to best decide upon an action plan. Experts viewed lake managers as the best source of information, but noted that stakeholders need to decide on a plan of action. Organizational representatives listed the North American Lake Management Society, academic sources, biological information, RIDEM, and the Office of Water Management as preferred choices for general information, along with consulting with certified lake managers (CLM). To decide which action plan to take. NGO's noted that including the state DEP/DEM environmental organizations and pond associations would be helpful.

(6) What do you believe to be the best way of informing members of the community about the current pondweed infestations and what do you believe is the most effective way to get members of the community to take action (participate in events, programs, and activities)? Summary of Responses: Residents suggested postings on social media websites such as Facebook, posting flyers, and creating an email program. It was suggested that local presentations by RIDEM and or Save the Lakes be set up for community members to ensure the delivery of accurate information as well as informing the constituents of current events and

that status of various programs. Experts recognized the need for more effective community information systems, and noted meetings, flyers, and social media as possibilities, but the main concern was how to get people to want to take the time to attend the meetings or read the flyers and posts on social media. One expert described the challenge as the "million dollar question." Organizations strongly believe that face to face interactions are essential and suggested door to door campaigning, holding training sessions, and conducting workshops.

(7) What do you see to be the biggest obstacles to implementing management plans?

Summary of Responses: The biggest obstacles for implementing management plans were very similar amongst all of the interviewees. Money, awareness, dealing with opposition, negative side effects of the chosen treatment plan, and the amount of work required to work on these plans were common themes expressed.

(8) Do you have any other comments regarding invasive aquatic pondweeds?

Summary of Responses: Residents noted the lack of funding available for treatments, the accumulation of muck at the bottoms of lakes/ponds, and the lack of attention being brought to these issues. The ecosystems of infested bodies of lakes/ponds have changed greatly and the residents noted that there is a great need for creative, yet affordable solutions, while also indicating the importance of gaining permission to take action in order to help to keep the lakes from devolving into peat bogs. Experts noted that the native pondweeds provide many benefits to the ecosystem, such as oxygenation, food and habitats for wildlife and benthic biodiversity. Organizations expressed concern about properly labeling pondweeds as being invasive or native, as well as recognizing the lack of knowledge about invasive pondweeds among the general public and stressed the importance of managing existing AIS infestations and preventing their further expansion before it is too late to take effective action.

Chapter 4: Discussion and Recommendations

Variations among Lake Sites

All three sample sites were considered to be mesotrophic or eutrophic during some portion of the year, usually during late summer or early fall (URI Watershed Watch, 2014a, b; Aquatic Control Technology 2014). By definition, a lake that is characterized as being eutrophic is well nourished, with a moderate to high level of nutrients (Kalff 2002). The level of natural or human-induced eutrophication in a lake or pond is related to the geomorphic features of the lake or pond (depth, hydrologic inputs from steams or springs), the influx of nutrients from nearby land use, and the trophic dynamics within the body of water (URI Watershed Watch, 1996). Carlson's Trophic State Index (TSI) can be used as an indicator of whether a lake is oligotrophic, mesotrophic, or eutrophic (URI Watershed Watch, 1996). The TSI ratings for Barber Pond and Spring Lake across the period of 1992-2014 reflected seasonal variations (URI Watershed Watch 2014d, e, and i).

Historically, Spring Lake usually falls into the category of an oligotrophic or a mesotrophic body of water, and appeared to be in an oligotrophic state at the time of personal observation in late July, 2015. The water was relatively clear and lacking in plant material. This difference can most likely be explained by an early summer application of chemical herbicides by Aquatic Control Technology to clear sections of the lake of pondweed overgrowth, (Personal Communication, Rick Cayer, Spring Lake Camper's Association).

The three sample sites used in this research project are categorized as lentic, or still bodies of water, aside from the waves created by boats and swimmers. This was expected since Carolina fanwort prefers lentic or slow moving bodies of water (DCR 2015). This aquatic invasive species has the ability to thrive in a wide range of temperatures as well as pH levels, so the temperature and pH readings found for our sampling sites was well within the ranges of observations made for ongoing monitoring programs for lakes and ponds in Rhode Island and Massachusetts (DCR 2015; URI Watershed Watch 2014f).

Differences among the sample sites included the size of the water body, the relative presence of Carolina fanwort (as determined from visual observation and photographic analysis), the overall plant biodiversity within the body of water, nearby activities, as well as the surrounding land use. Spring Lake has a relatively large public state beach while Hickory Hills Lake is a privately owned lake with very small beach areas which are only available to residents who are members of the Hickory Hills Lake Association (Hickory Hills 2015a). Spring Lake did not have any Carolina fanwort present at the time of sampling, due to chemical treatments previously described, although the species had been reported in earlier years (see Figure 1-6). Hickory Hills Lake was characterized by an extensive presence of Carolina fanwort (see Figure 4-1), similar to observations at Barber Pond.

Barber Pond is a public pond with no designated public beach, nor is there a strong community action group in place to address AIS problems or to monitor land use impacts (Personal Communication, Elizabeth Herron, URI Watershed Watch, Kingston, RI). However, RIDEM does maintain a fish-stocking program in Barber Pond (Rhode Island Blueways Alliance 2008). Water quality in Barber Pond is monitored by both the URI Watershed Watch Program and the Wood-Pawcatuck Watershed Association (WPWA), and both these organizations post all monitoring information on the Internet for public use (URI Watershed Watch 2016d; WPWA 2015 a, b). Thus, Barber Pond could be seen to represent a relatively unmanaged public pond that is nevertheless open for fishing, swimming, and boating. This raises an interesting possibility that Carolina fanwort populations may stabilize when left alone over longer time frames and allowed to equilibrate with other native species. Going even further, interviewees from some agencies posed the question as to whether Carolina fanwort should now be considered as “native” in Barber Pond. Future analyses may need to define with more clarity the terminology of “invasive” and “native” plants, especially as climate change impacts alter the ranges of additional plant species in temperate regions.

A greater variety of pondweeds were observed in Hickory Hills Lake and Barber Pond compared to Spring Lake, although biological counts were not made for each of the three lakes

when samples were collected for this study. Such monitoring information had been recorded for Hickory Hills Lake in 2014, as part of an ongoing assessment that occurs every 1-2 years, sponsored by the Hickory Hills Lake Management Group (Hickory Hills Association 2015b; Aquatic Control Technology 2014), and aquatic plant species lists are available for both Spring Lake and Barber pond (RIDEM 2015a).

Biological Features of *Cabomba caroliniana* Explain its Success as an Invasive Aquatic Plant

Results from Carolina fanwort leaf surface observations provided botanical details about the samples obtained from Sites 1 and 3 in this investigation, confirming the correct identification of the species to be *Cabomba caroliniana* in both lakes. Such confirmation of the identification of a sample is critical as each species may interact differently with the environment due to its growth patterns, reproductive capacity, and physiology.

In addition, our observations revealed for the first time some special micro-structures on the leaf surface of Carolina fanwort that had not been reported previously, such as the protruding circular hair bases which are persisting on the leaf surface after the hairs are shed (Figure 3-2, B-F). The densely arranged hairs, their protruding and persisting bases, and the crystals on the upper side of the leaves all contribute to the "roughness" of the leaf texture. It is possible to surmise that the roughness makes the plant leaf surfaces “sticky” which may enhance the plant's ability to form dense mats and in addition may help it to attach itself easily onto mobile structures such as boats, equipment, and trailers, thus adding to its competency in “hitch-hiking” from lake to lake (See Figure 4-1).

Furthermore, although Carolina fanwort leaves look delicate, they appear to be the least preferred by aquatic herbivores as food. The URI Watershed Watch laboratories maintain an “invasarium,” which is an aquarium containing a mixture of aquatic invasive plants along with goldfish. Staff members noticed that when the goldfish had choices, they preferentially ate all the other plant species, but avoided Carolina fanwort (Personal Communication, Elizabeth

Herron, URI Watershed Watch). Our new SEM based discovery helps to explain such a phenomenon.

Figure 4-1: Pieces of *Cabomba caroliniana* being transported by trailers, boat motors, and fishing lines. Photo source: (RIDEM 2015e).

There are many other biological characteristics of Carolina fanwort that enhance its survival capability, which explains to some degree its emergence as such a successful invasive species in southern New England waterways. Those characteristics might include the community structure of Carolina fanwort colonies, its rapid reproductive rate, and its capability to support a varied epiphytic microbial biomass on its leaf and stem surface.

During the field sample collections, a trend could be seen in the community structure of Carolina fanwort colonies. The multiple branches on each individual plant were entangled among the branches of other Carolina fanwort plants. The ability of the plants to become intertwined with one another resulted in dense mats, or rafts of plants, which could be seen in Hickory Hills Lake even into September (see Figure 4-2). Once massive networks of long, intertwined segments of Carolina fanwort plants are formed, they can prevent other native pondweed species from obtaining sunlight and key nutrients. This could allow for native aquatic plants to be suppressed as Carolina fanwort thrives. Hence, it appears that the growth pattern of Carolina fanwort enables the plant to dominate its aquatic community, which in turn enhances its competitive advantage and adds to its survivability.

Figure 4-2: Image of a dense mat of *Cabomba caroliniana*. Photograph taken at Hickory Hills Lakes with a Galaxy S5 16MP camera during a boat tour on 03 September 2015.

Another aspect of Carolina fanwort that helps it to survive and thrive is its fast reproductive rate. It can quickly regrow from roots, stems, leaves, seeds and, as previously indicated, is easily transported by boats and fishing gear (Figure 4-1). The reproductive capacity, as well as the ease with which the species can be transported results in infestations that are hard to control. Once established, the plant is quick to create extensive colonies, in the form of tangled mats that continue to extend upward and outward very rapidly. The ability to establish itself in new regions so swiftly and effectively is one of the main threats this species poses. It requires careful examination and surveillance of a lake to find the initial colonizing plants before they become established in the water body. Once the colony or raft is present, the ability to control the infestation becomes problematic to lake managers. Boat inspections, in

which boat owners and volunteers effectively check boats before they enter the water, can help to reduce the movement of Carolina fanwort between lakes.

It is of great importance to recognize that the surface of the plant is associated with many “epiphytes” including a variety of microbes and small metazoans for they could be important to the overall food chain, even though the Carolina fanwort plant itself may not be a preferred food for some herbivores (see Figure 3-6 depicting the overall variety of microbial life on the plant’s surface, i.e., the Aufwuchs community associated with the plant’s surface). The presence of the epiphytes would seem to imply that the surface texture and biochemistry of the Carolina fanwort leaves are amenable for colonization by protists and small metazoans.

In summary, the biological characteristics of Carolina fanwort can help it to migrate easily, reproduce quickly, prevent being consumed by aquatic herbivours, become much more competetive, and survive in a wide range of environmental conditions (temperature, pH levels, elevation, etc). Key points linking its biological characteristics to its ecological succes includes the following:

(1) The rough leaf texture of Carolina fanwort contributed by the protruding and persisting hair bases and crystals prevents the plants from being consumed and facilitates its easy migration through “hitch-hiking.”

(2) The massive network of long and intertwined stems and leaves of Carolina fanwort creating “rafts” of plants which seem to act like one giant entity. This can add to the survivability of the plant when facing seasonal and localized environmental changes, such as freezing/thawing cycles, extensive rainfall/snowfall, and lowered water levels. In addition, the massive network also prevents other aquatic plants to grow.

(3) Carolina fanwort's flexible reproduction methods make it highly competitive. In a favorable environment, the plant can regenerate quickly from fragments of roots, stems, leaves, and seeds which can be easily departed from the "brittle" parts of the mother plant and transported to other locations. Their quick regeneration allows them to form

dominancy in a water body. When the environment becomes unfavorable, such as harsh New England winters, they can also "survive" as seeds which can be dormant for years. (4) Carolina fanwort has a rather long growing season compared with most other competitors. An initial growth spurt commences quite early in spring. For example, some observers have noted its growth under a crust of ice remaining on the pond surface (Personal Communication, Fred Malcomb, Hickory Hills Weed Mitigation Team, March 2015). Samples of Carolina fanwort were also observed within Barber Pond in early March 2016 while no other pond weeds were seen (Personal Communication, Gaytha Langlois, Bryant University).

Ecological Implications of *Cabomba caroliniana*

Although Carolina fanwort is an aquatic invasive species that can negatively impact natural ecosystems, it also supports its own micro-community. The light microscope and SEM observations both revealed that the plant's surface is associated with many epiphytes. Such epiphytic assemblages include a variety of microbes and small metazoans that live on and around this weed, such as diatoms, algae, ciliates, rotifers, amoebae, a flatworm, and protists, etc. Their presence can be important and beneficial to the overall food chain. The epiphyte biodiversity associated with Carolina fanwort raises some interesting questions about the plant's environmental service function. Comments from survey participants in the Hickory Hills Lake group included the observation that the presence of pondweeds improved fishing. At the very least, Carolina fanwort may add to the overall biodiversity of the lake's ecosystem, although some native plants may be out-competed. In the future, it would be helpful to conduct a more thorough analysis on both Hickory Hills Lake and Barber Pond to ascertain the extent of native plant species that are actually present when the Carolina fanwort dominates the ecosystem.

It would appear that the Carolina fanwort is well-adapted to southern New England lakes, although it is still designated as an invasive species by most ecologists. It has been

suggested that the success rate of this plant to thrive in a variety of environments is an example of an expanded range for the plant. The surveys and interviews associated with this study do show a concern about mitigating factors that might be heightening the expansive growth of Carolina fanwort in Rhode Island and Massachusetts in particular, such as surface runoff carrying fertilizers, or nutrients leaching into the groundwater from septic systems. Human-induced eutrophication of freshwater habitats carries many concerns (Tweed, 2009), but one of the side effects could be nutrient additions that not only cause algal blooms on the surface of ponds and lakes, but also enhance the rapid growth of rooted vegetation such as Carolina fanwort.

Connections among Land Use Factors That Influence Water Quality

Although dense housing, along with intense lakeside land use patterns may lead to human-induced eutrophication (commonly associated with inadequate sewage treatment and overuse of lawn and garden fertilizers), the topic remains somewhat controversial among researchers, lake managers, and community members. In general, it is understood by most invasive aquatic plant managers that there are positive correlations between higher nutrient levels and the heightened presence of invasive aquatic plants. Lake managers and plant ecologists have suggested that the influx of nutrients that enter the lake as a result of adjacent land uses can lead to higher levels of aquatic plant growth. In many suburban areas, people near ponds/lakes do not have access to centralized sewage systems, and thus have Individual Sewage Disposal Systems (ISDS). Often, these ponds have a notably higher amount of aquatic invasive plant species (AIS). The problem can be enhanced due to aging or leaking ISDS units. A greater density of residents around the lake or pond can further magnify the impact. The challenge for lake managers or dedicated NGOs lies in how persuasive they can be in encouraging lake shore residents to upgrade their systems in order to enhance the water quality of the lake/pond. Ideally, lake management plans should include education programs for

residents, enlisting the aid of community action groups and NGOs, but backed up by clear guidelines and regulations issued by municipal and state government oversight programs.

A septic system that is not working to its fullest potential can secrete harmful pollutants into nearby water sources, for example, phosphorous, nitrogen, and chlorides. Nutrients that are secreted can lead to an increased growth of algae and pondweeds, which in turn can deplete water bodies of oxygen (Tweed 2009). Dense mats of Carolina fanwort can also block sunlight from reaching deeper regions and potentially result in lowered oxygen in deeper waters. Data described earlier in this paper showed all three ponds in this study having lowered levels of dissolved oxygen (DO) in late summer and early fall months. Future studies of Carolina fanwort should further explore the links between nitrate and phosphate levels in specific locations that are experiencing heightened levels of this and other invasive plants, and compare this data to the type of sewage treatment present in that location.

An example of a Rhode Island partnership attempting to address the problems of aging ISDS units (i.e., cesspools that do not meet current water quality standards) was initiated in 2015, when RIDEM began working in conjunction with the Audubon Society of Rhode Island (ASRI). This collaboration continues to actively assess the impact of ISDS units on a watershed in northern Rhode Island. The goal of this project is to have the local town governments become more actively involved in eliminating cesspools (early versions of ISDS units that provide little sewage treatment and no longer meet state requirements). Residents would be required to upgrade their sewage disposal systems or connect to sewer lines where available. Meetings of interested experts and NGO representatives examined the following types of data: when the houses were built, the type of septic system being used, as well as identifying areas of main importance (e.g., suburban and rural areas with high amounts of ISDS units located near a watershed). Data retrieved from state, local, and NGO sources was then transferred to GIS mapping systems in order to move forward with an action plan. State funding can be accessed by towns that have an action plan. As part of this present study, the author participated in the early stages of GIS data transfer. Missions such as this are very important for watersheds

because of the strong correlation between the treatment of sewage and nutrients in nearby water bodies.

Other sources that affect native and non-native aquatic species are fertilizers and pesticides used for lawn care or recreational fields. Fertilizers are used to enhance lawns and pesticides are used to discourage insects or weeds. Although these two products may have on-land benefits, these products can lead to extremely harmful impacts on lakes and ponds. The fertilizers can move into lakes and ponds from surface runoff or underground leaching when soils are saturated, thus elevating the levels of phosphates, nitrates, and other chemicals which can change the natural water chemistry of the lake or pond (Ongley 1996). The added nutrients, such as phosphates and nitrates, are an additional causative factor of human-induced eutrophication, with consequent algal blooms and falling oxygen levels (Ongley, 1996). Native fish can be killed which reduces the chance of these fish consuming the native and non-native plants in the ecosystem. Ongoing management programs for invasive aquatic plants in the three lakes in this study should include a more thorough assessment of the usage of fertilizers by property owners and residents surrounding the lakes, as well as agricultural activities within the lakes' watersheds.

Eutrophication has additional impacts on an ecosystem, aside from algal blooms. Eutrophication is linked to an increase in primary production by plants, as well as an increase in the biomass of phytoplankton and macrophytes (Ongley 1996). There can be major shifts in the trophic dynamics of the natural aquatic habitat, as a result of the change in the assemblage and organization of aquatic plants (Ongley 1996). Desirable fish can become replaced by less desirable species if the fish die as a direct result of eutrophication and certain algae also can produce a variety of toxins (Ongley 1996).

Land runoff or direct application of pesticides into lakes/ponds can lead to the contamination of surface water as well as organisms that are found near the water's surface (Ongley 1996). This is detrimental to the entire ecosystem as the water chemistry is altered and organisms are killed by these chemicals (Ongley 1996). This was demonstrated in the Spring

Lake case study, where the application of specific herbicides by the Rhode Island DEM in fact reduced the presence of Carolina fanwort in the lake. However, such treatments can also compromise water quality, specifically if a lake is to be used as a source for drinking water. Herbicides recommended by RIDEM for control of Carolina fanwort include forms of 2, 4-D, forms of Diquat, Glyphosate, and Fluridone (Coit 2012). Fluridone and Flumioxazin (Clipper) are two approved herbicides to control expansion of Carolina fanwort in Massachusetts (Massachusetts DCR 2002; Wisconsin DNR 2012). However, pesticide use is strictly controlled in Hickory Hills Lake because the lake is part of the emergency water supply for the Town of Lunenburg, MA (Hickory Hills Lake 2015a).

Future studies on Carolina fanwort distribution should include analysis of nutrient levels, especially as they vary seasonally and locally, along with the other ecological parameters that are measured (temperature, pH, D.O., and chlorophyll), especially in transitional seasons. Ideally, management of lakes suffering from large quantities of pondweeds should also include periodic assessments of sewage treatment around the lake's periphery. Such efforts would probably necessitate a cooperative program between residents and municipal governments.

Invasive Species and Community Ecology:

As invasive aquatic species continue to infiltrate New England waterways, at what juncture should lake managers shift their attention from a focus on the non-native designation to the functional "invasiveness" of a species like Carolina fanwort? In other words, it might be more effective to focus on managing all the aquatic invasive plants by desirable land use and water quality practices rather than trying to tackle a specific plant like Carolina fanwort. The focus would be on ecosystem management, as opposed to species eradication. Deeper consideration should be given to this complex question.

Responses from Community Surveys at Hickory Hills Lake

As noted earlier, for the Hickory Hills Lake survey, a total of 216 people participated, with 185 respondents completing the survey online and 31 people completing paper surveys (see Table 3-1). Since most of the respondents from Hickory Hills residents have lived there ten years or more (66.7%), it is not surprising to find a corresponding percentage who have noted changes in the lake over time (62.7%). Of all the participating members living in the Hickory Hills Lake area, 97.69% of participants were aware of the Carolina fanwort invasion, suggesting that the individuals who participated in the survey are attentive to the condition of the lake, and may be more willing to participate in its management. This also implies that the Lake Management Group has been very efficient in informing members of the community about the infestation. Only 2.31% of the population was unaware that Carolina fanwort was growing in the lake. It is likely that the Carolina fanwort markers in the water are a visual reminder to make residents aware of an invasive plant that is growing in their lake, and to acquaint them with the efforts to curtail the growth of the plant.

Of all of the questions in the survey, the question that had the highest percentage of participants who did not respond was question four, where participants were asked to check off the description that best matched their understanding of the growth patterns of Carolina fanwort. A total of 18.52% of individuals didn't answer this question which suggests that although most respondents are aware of the presence of Carolina fanwort in their lake, they may not be knowledgeable about the specific characteristics that makes this pondweed species and its growth patterns so different from the other pondweeds in the lake. In some cases, their unwillingness to select characteristics may have reflected uncertainty about the plant's description. Of the people that did select characteristics from the list provided, the most frequent answer was that the growth pattern of Carolina fanwort was noticeably different from other pond vegetation. The other most common description was that the Carolina fanwort was a brighter color than other pondweeds. Many people also chose to write their own description in addition to the choices offered.

For question 8, when participants were asked if they knew of any attempts or processes that have been used or are being used to address the Carolina fanwort issue, 90.61% of people were aware of some attempt or process that has occurred or is occurring. This high percentage seems to indicate that the Lake Management Group has been proactive enough to make residents aware of the presence of Carolina fanwort and the efforts being taken to manage and control the pondweed invasion.

An interesting contrast emerges from responses to survey questions 6 and 7. Question 6 inquired what the respondent's highest concern was regarding the presence of the weed. The response that was selected as the second highest concern was the effect on lake activities. Question 7 asked respondents if the pondweed had hindered their ability to enjoy the lake at all. In comparison to the level of potential concern the pondweeds could have on lake activities, most respondents indicate that the presence of the pondweed had not "hindered their ability to enjoy the lake" or affected their "lake-related activities of boating, fishing and swimming." Although it could be reasoned that respondents were more concerned about other residents not being able to carry out their desired activities, or that they were thinking of other activities that those listed (boating, fishing, and swimming), it does seem as if this lack of consistency should be discussed further by Lake Management Group leaders so as to determine the relative merit of the various concerns of residents.

Although it is clear that the presence and problem of Carolina fanwort is well known throughout the community, only 25.71% of survey participants reported being an active participant in the Weed Mitigation Group in question 10. These results were surprising since so many people knew about the existing problem. This question provided the biggest difference between online and paper survey responses. Of the online participants, there were 54 people who actively participated in the Weed Mitigation Group (a subcommittee of the Lake Management Group), while for the paper survey participants, there was not one who actively participated in the activities of the Weed Mitigation Group, although many of them may be involved in other activities sponsored by the larger Lake Management Group. It is possible that

a higher proportion of the direct mailing group are only part-year residents or absentee landlords, but this was not elucidated in the present survey data.

Overall, a few conclusions can be made about the survey of residents living in the Hickory Hills Lake area. Most of whom have lived there for many years, and most are aware of the Carolina fanwort problem, and are acquainted with the attempts being made to manage the problem. Almost everyone believes the homeowners should help to assure good water quality but very few people actively participate in the Weed Mitigation Group.

It also appears to be evident that the Lake Management Group is doing a good job with making residents aware of the problem with Carolina fanwort. Although only a few respondents indicated that they work directly with the Weed Management Group, more of the respondents seem to know of the work that is underway to reduce the impacts of the Carolina fanwort infestation. Carolina fanwort markers (floating markers that designate the presence of the plants in the lake so that they can be removed) have served to make people more aware of the management efforts, and it has made the intervention efforts easier to visualize. The Weed Mitigation Group has had a huge influence on the community and is an effective group.

Responses from Community Surveys from Spring Lake

As noted in Table 3-2, a total of 32 people participated in the Spring Lake survey, where all respondents completed paper surveys, representing a completion/return rate of 19.9% of the 161 surveys mailed to recipients, which is much lower than the response rate from the Hickory Hills Lake Survey. The percentage could imply that the interest in water quality among Spring Lake residents may be less intense, and reflects the reality that the citizens are not as actively engaged in the protection of the lake's quality. However, as noted in the Results, the survey mailing list encompassed the property owners, who may have had a different preferred mailing address, or who may be absentee landlords of summer rental properties. Hence, the survey may have reached key residents who would have expressed a higher interest, or been more responsive. For example, if the "addressee not known" surveys were eliminated, then the

response percentage would have been higher. Future surveys of Spring Lake residents should be distributed in a different manner, working with local NGOs and existing community action groups, even if those groups are not extremely active in their efforts to maintain lake quality. Our conclusions would also suggest that online surveys should be utilized whenever possible.

Although 78% of the respondents have lived in the Spring Lake area for 10 or more years, and 93.8% have resided there for more than 6 years (Table 3-2, Question 2), as noted before, it was interesting that only 62.5% have "noticed any changes" in the lake. Additionally, a much smaller proportion (37.5%) were "aware of the presence" of Carolina fanwort in the lake, and this was no doubt influenced by the herbicide treatments applied in recent summers in order to reduce the impacts of aquatic plants in shallow segments of the lake.

Question 12 addressed a key question for this study (i.e., a query regarding the role of citizens in maintaining lake water quality). Based upon the comments for this question, it was clear that the residents enjoy the lake, and want to preserve its natural beauty for future generations, and they also believe they need to be a part of the preservation process.

One of the most interesting findings from the Spring Lake survey was the number of residents who did not seem to be very well informed about treatments to the lake done by the state. Despite residents knowing the lake has infestation problems, they seemed to be poorly informed about the ecology and water quality of the lake. One resident even commented that they were "unaware of any treatments ever being done to the lake, and if anything had been done, they would like to be informed." Indeed, chemical treatments to the lake could include herbicides that could be harmful if ingested and could affect the ecosystem of the lake in a variety of ways.

The results of this survey strongly suggest that part of the State's lake management plan for Spring Lake should include more effective communication to inform residents of the pondweed problems and any treatment methods that have been, or are going to be utilized, thus assuring residents as well as beach visitors that the intervention methods are safe and based on best practices for public waterways. The residents' usage of the lake should be

ascertained, along with the needs of beach visitors. Local NGOs such as Save the Lakes or the Audubon Society of Rhode Island, or academic institutions such as Bryant University, should become involved in assisting residents to develop a better community action plan. Guidelines for developing effective Lake Management Plans are easily available (Save The Lakes 2016).

Since there appears to be a significant lack of communication between the State and Spring Lake residents, it is not surprising that there is limited communication among Spring Lake residents, or at best that the existing community action groups do not represent a large proportion of residents, nor interact with other interest groups. Without having accurate knowledge about the incidence of Carolina fanwort within the lake, residents are less likely to want to become engaged in meetings. Public awareness is a key factor in combating AIS. If the state had better communication with residents about the true water quality and the treatments being done on the lake, it could result in a larger number of residents being willing to participate in public groups or create new groups.

A very good evaluation of the resident's appreciation of their lake was question 13, where respondents were asked if they "would be interested in participating in a group formed to address invasive plants in Spring Lake," and 50% of the 32 respondents expressed an interest in participating in such a group. Of the 16 individuals who wrote comments to this particular question, 14 submitted either a home address or email address for additional information. Considering the low number of survey respondents to begin with and the number of residents who only use their Spring Lake homes during summer months, 50% was a much higher rate than anticipated. This suggests that if people were better educated about their lake and had opportunities to try to improve matters that there could well be more people willing to help out.

Comparison of the Survey Responses from Residents in RI and MA

Residents from both Hickory Hills Lake and Spring Lake overwhelmingly agree that homeowners of the nearby water bodies should help to assure good water quality. In the Hickory Hills Lake survey, 91.2% of survey participants believe homeowners should help to

assure good water quality and 93.8% of surveyed residents from Spring Lake believe the same. This shows that both communities understand maintaining good water quality is important and actions must be taken to assure the safety of the water. Based upon other questions asked in the surveys, it is believed that homeowners understand that in order to obtain good water quality, actions must be taken to prevent to introduction of or management of non-native aquatic plants.

Aquatic plants affect the entire ecosystem of the water body so ensuring good water quality means being vigilant and proactive when it comes to controlling the spread of any aquatic nuisances/ invasive plants. Surveyed residents from both areas have different levels of understanding regarding the aquatic plant infestation meaning different levels of education was spread throughout the communities. Despite these differences, the high values obtained from question 12 which asks residents about assuring good water quality, it is clear that residents of all ages from different backgrounds agree that it is their responsibility to ensure good water quality and that aquatic invasive species can have a large effect on maintaining a healthy lake ecosystem.

When comparing the knowledge of AIS, as well as AIS treatment methods, between Hickory Hills Lake and Spring Lake residents, there is a clear difference in the level of knowledge. Few members of the Spring Lake community have a good understanding of aquatic invasives and the treatment methods used to treat infested water bodies. More members of the Spring Lake community mentioned that it should be the government's responsibility to deal with the AIS infestations. This shows that unlike the Hickory Hills community, they do not appear to be as likely to step up and work on solving the problem themselves.

There were fewer responses received from the Spring Lake community because email addresses for the surrounding citizens were not available. At Hickory Hills Lake, the Lake Management Group maintains updated contact information for all surrounding residents. This is not the case in Burrillville for lakefront residents at Spring Lake. Broader survey participation might have provided additional clues regarding the feasibility of expanding citizen participation in ongoing lake management activities at Spring Lake, or could have elucidated

more accurate information about historical patterns of Carolina fanwort in the lake. As noted in the Results, a comparison of residents' comments from both locations shows a high degree of similarity, i.e., residents share key concerns. See Appendix Table A-2 (a-c) for details of these comparisons.

Responses from Interviews with Lake Management Decision Makers

The interview questions previously described were designed to gather a variety of viewpoints about the extent of the aquatic invasive plant problems in Rhode Island and Massachusetts, as well as to seek out insights into effective management practices for dealing with the specific challenges surrounding Carolina fanwort. Actual interview notes are included in Appendix C (without descriptive information that would reveal the identity of the interviewee). As noted earlier, there were four categories of individuals selected for interviews: (1) governmental or quasi-governmental agency representative; (2) leader or manager of an environmental NGO, (3) educators or technical experts; and (4) citizens affected by Carolina fanwort infestations. These groups were selected because they all play some role in decision making about techniques for tracking, monitoring, and managing invasive aquatic plants. It was interesting to see some apparent biases emerge. For example, many citizens and environmental groups viewed that it should primarily be a public (governmental) responsibility to manage this type of problem, whereas experts and government regulators were more likely to say that citizens bear some responsibility as well.

Significant concepts and generalizations that emerged from the interview comments were identified based on the key issues described in the Results section. Of particular interest was the observation that as a result of the long-standing presence of Carolina fanwort in southern New England waterways, perhaps it is time for everyone to accept the plant as no longer being "non-native" and we should reframe our management strategies to limit its spread to new waterways and try to reduce its impacts on existing waterways, as part of an overall ecosystem planning approach, e.g., the development of Lake Management Plans.

Effectiveness of Fanwort Management Approaches

Carolina fanwort was not found in Spring Lake at the time of sampling. This was a clear indication that the chemicals used by Aquatic Control Technology (Diquat and Clipper – see Table 1-2) were effective in killing off the Carolina fanwort that had existed prior to the treatment of the lake. Surprisingly, most residents who participated in the survey were unaware of the presence of Carolina fanwort and other invasive pondweeds, and apparently were not officially notified of the chemical treatments being done on the lake. Moreover, representatives from the Town of Burrillville also did not seem to have a clear understanding of exactly what treatment had taken place, or who was responsible for administering the chemicals. Given that many of the Spring Lake survey respondents expressed an interest and willingness to participate in a community action group, and indicated that they wanted to be informed and be able to make a positive impact on their lake, we might conclude that there is an apparent lack of communication among local residents, and town and state officials about chemical treatments for Carolina fanwort and other aquatic vegetation. Although the invasive pondweed problem may have been addressed, in that there were no aquatic plants present at the time of our sampling in July 2016, the citizens did not appear to be well informed about the seriousness of the AIS problems, nor were they apparently taking a direct part in solving the problem. One result of this approach is the failure of the residents to take "ownership" of the lake's overall water quality, which might aid them in carrying out their residential responsibility for the lake.

By comparison, Hickory Hills Lake has an extremely well organized lake management association. Most of the residents who took part in the survey were well aware of the presence of Carolina fanwort and were well informed of all treatment measures being used on the lake. The problem here is that the Carolina fanwort still exists despite their great efforts, and they do not have the option for widespread chemical treatment because of the lake being designated as a backup drinking water supply. There are many individuals involved in the decision making

as part of the Lake Management Plan, which allows for community interaction and engagement, but is unlikely to result in eradication of the invasive plant in Hickory Hills Lake.

Barber Pond, the third sample site, has an ongoing and extensive infestation of Carolina fanwort every year. Unlike Spring Lake, the water quality of the pond is essentially unmanaged, either by the residents or the State of Rhode Island. Since it is the duty of each property owner or pond user, this sample site is different from Hickory Hills Lake and Spring Lake. From our visual observations, Barber Pond appeared to have a denser infestation of Carolina fanwort than was observed in Hickory Hills Lake (except for one shallow cove at Hickory Hills Lake, which is also designated as a boat launching area), as determined by visual observation. However, Barber Pond does not have an active citizens' group such as that found at Hickory Hills Lake to combat the Carolina fanwort problem. Active citizen groups and the effective management of Carolina fanwort in a body of water appear to be related. The more educated and dedicated a residential community is about water quality matters, the more effective the AIS management and control will be.

In conjunction with this study the author participated in a program sponsored by RIDEM, which addressed impacts for boating behaviors, i.e., fishing in many different Rhode Island ponds and lakes. The GREAT Boater Program is a local program that gets local citizens to volunteer their time to inspect boats in order to help prevent the spread of aquatic invasive species. At these events, the crews of volunteers show an excitement and strong commitment to making a difference (Personal Observation). There was a sense of pride in their mission and a great relief when a specimen was removed from the boat prior to the entry of the lake. At the events, there was a core group of members, some of whom attended multiple events.

Commitment seemed to be the greatest challenge of the programs. This was also seen when Bryant University, Save the Lakes, and RIDEM co-sponsored a meeting for the general public about the GREAT Boater Program. Flyers were created and distributed, online social media, emails, and phone calls were all tools that were utilized to inform the public about the meeting. Those who attended the meeting expressed great interest in the content of the

presentation and were eager to become part of the volunteer team, but attendance was meager, so future events will require greater effort to make the public more aware of the GREAT Program. A crucial part to success in managing these difficult aquatic plants is informing the public. If the public is not adequately informed of events that are taking place, they are not likely to become engaged in community efforts to combat the current issues.

Another community outreach event involved a presentation about the GREAT Boater program to a group of students at Bryant University who were visiting from China. All of the students expressed great interest in the program. They were surprised to learn how one fragment of a plant could lead to an entire infestation of a lake/pond, and were very interested in community residents playing a part in improving environmental quality. This event should remind readers of the global nature of AIS management.

Both community outreach events were marked by high levels of interest in the presented material. However, for future events the turnout rates need to be improved, using more effective marketing techniques, including social media and other electronic means of communication. Once the public becomes engaged in the learning process, there is much interest and concern for the environment. The challenge of educating citizens about water quality issues is getting the public interested enough to want to be educated. There is a gap in knowledge and this is something that needs to be addressed in future efforts for AIS management.

In summary, on the basis of the observations that have been made in this study, our initial hypothesis should be accepted, that is, well-structured and efficiently organized citizens' groups can enhance the overall effectiveness of Carolina fanwort management programs.

Summary of Findings

This research project allowed us to understand the biological and ecological features of the aquatic invasive pondweed, *Cabomba Caroliniana*, some of which are new discoveries, such as a dense mat of surface hairs with protruding and persisting circular bases as well as leaf

surface crystals. These biological and ecological features help the plant to migrate easily, reproduce quickly, prevent its being consumed by aquatic herbivours, become more competetive in occupying space and receiving sunlight and nutrients, and survive in a wide range of environmental conditions (temperature, pH levels, elevation, etc), all of which help to explain why this plant has been so successful as an invasive plant within a variety of ecosystems. The extreme success of Carolina fanwort necessitates a well-structured and consistently active approach for controlling/eradicating the plant as soon as it is first noted. It is beneficial for all members of the lakefront resident community to have a large and well-organized community action group. This enhances the level of understanding of AIS impacts, as well increasing the level of participation in regards to AIS management in general.

Recommendations

After various aspects of this thesis have been examined, a number of recommendations can be presented. Education and awareness of the aquatic invasive species infestation is crucial in preventing further spread of these species within a body of water, especially for boating enthusiasts who utilize multiple lake sites. Active citizen/resident involvement is needed in order to set up guidelines and protocols on how to handle new infestations and control existing infestations. There needs to be better communication among residents and NGOs, along with town and state government personnel. A potential recommendation is also for homeowners to begin thinking about placing native vegetation buffers at the edges of their properties to prevent runoff from going into the lake/pond. Fertilizer usage should be limited, and finally, testing needs to be conducted frequently to ensure septic systems are working properly. Biologic and ecologic studies should continue in order to better understand the dynamics of the rapid colonization shown by Carolina fanwort.

Future Studies

Future studies should continue to assess the amount of Carolina fanwort found to be associated with the three sample sites in this study. Monitoring for this aquatic invasive species should include tracking the extent AIS infestations, the regions in which the plant has been identified (the spread of the species throughout the water body and how quickly the plant travels to new areas), as well as the growth rate of the plants. Other notable observations might include any mutations or adaptations the plant seems to be showing. It would also be useful to evaluate and quantify the impacts of Carolina fanwort overgrowth on the number and kinds of native aquatic plants in a given water body, as well as to conduct investigations into which herbivores actually consume this species. Treatments being done on each body of water should be analyzed in order to assess the effectiveness of various treatments. This would help to create a more detailed inventory of the effectiveness of treatments and ascertain the specifics for each different type of water body being treated. Community involvement should be observed and encouraged, thus expanding the sense of ownership and stewardship felt by lakefront residents, providing volunteers for various intervention activities, and educating everyone about preventive measures each property owner or resident can utilize. These efforts will help in assessing which are the most effective treatment methods, in measuring the distribution of the Carolina fanwort in the area, and in establishing the best communication practices within the residential communities.

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Appendix A:

Survey and Interview Commentaries for Residents from Hickory Hills Lake (Lunenburg, MA) and Spring Lake, Burrillville, RI

Table A-1: Summary of Interviewee Responses Showing the Number of Responses and the Relative Level of Concern Expressed for Key Factors (5 = High Concern; 1 = Low Concern). Key factors were coded from the survey data.

Factors to Consider	Question 1		Question 2		Question 3		Question 3B		Question 4		Question 5		Question 6		Question 7		Question 8		Total	Overall
	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	# Indiv.	AveScore	Indiv.	Average
AIS Management Techniques AMT									10	4.40	8	3.50			2	5.00	2	2.00	22	3.73
Stakeholder Responsibility SH											2	3.00	7	2.47	4	1.50	2	3.00	15	2.49
Water Quality WQ	4	1.75			3	3.00	2	3.00									1	5.00	10	3.19
Government Responsibility GR											3	2.34	1	1	2	3.00	2	3.00	8	2.34
Invasive Awareness IA			6	2.67													1	3.00	7	2.84
Adjacent Land Use ALU	1	5.00			4	2.50									1	3.00			6	3.50
Boating Patterns BP					3	3.67							1	3	1	3.00			5	3.22
Lake Usage LU	1	3.00															1	3.00	2	3.00
Property Value PV																	1	3.00	1	3.00
Health Concerns HC																			0	0.00

Tables A-2 a-c: Participants were given the opportunity to make comments in the Hickory Hills Lake survey (online and paper surveys) and in the Spring Lake paper surveys. The comments provided by the respondents were categorized by key factor, and the number of responses by category are summarized in Tables A-2(a) to A-2(c):

Table A-2 (a): Content Analysis of comments made in the Hickory Hills Lake online surveys, showing the relative number of respondents selecting each key factor, listed by survey question. Major concerns for this set of respondents included AIS Management Techniques, Invasive Awareness, and Stakeholder Responsibility.

Factors to Consider	Q 1 #Indiv.	Q 2 #Indiv.	Q 3 #Indiv.	Q 4 #Indiv.	Q 5 #Indiv.	Q 6 #Indiv.	Q 7 #Indiv.	Q 8 #Indiv.	Q 9 #Indiv.	Q 10 #Indiv.	Q 11 #Indiv.	Q 12 #Indiv.
AIS Management Techniques (AMT)	0	4	0	9	0	9	13	128	81	48	2	10
Invasive Awareness (IA)	0	26	0	58	0	19	20	0	0	41	48	3
Lake Usage (LU)	0	12	0	1	0	7	38	8	2	0	0	16
Boating Patterns (BP)	0	6	0	1	0	4	28	11	6	1	1	8
Adjacent Land Use (ALU)	0	7	0	1	0	1	0	0	3	0	0	10
Water Quality (WQ)	0	69	0	4	0	11	2	0	1	0	0	29
Health Concerns (HC)	0	1	0	0	0	1	0	0	1	0	0	7
Property Values (PV)	0	0	0	0	0	4	1	0	0	0	0	15
Stakeholder Responsibility (SH)	0	2	0	0	0	4	0	0	0	54	0	96
Government Responsibility (GR)	0	0	0	0	0	0	0	0	1	0	0	1

Table A-2 (b): Content Analysis of comments made in the Hickory Hills Lake paper surveys, showing the relative number of respondents selecting each key factor, listed by survey question. Major concerns for this set of respondents included Invasive Awareness, AIS Management Techniques, and Stakeholder Responsibility.

Factors to Consider	Q 1 #Indiv.	Q 2 #Indiv.	Q 3 #Indiv.	Q 4 #Indiv.	Q 5 #Indiv.	Q 6 #Indiv.	Q 7 #Indiv.	Q 8 #Indiv.	Q 9 #Indiv.	Q 10 #Indiv.	Q 11 #Indiv.	Q 12 #Indiv.
AIS Management Techniques (AMT)	0	0	0	2	0	0	0	13	10	0	0	0
Invasive Awareness (IA)	0	2	0	5	0	1	5	5	1	0	8	1
Lake Usage (LU)	0	4	0	0	0	1	10	2	0	0	0	0
Boating Patterns (BP)	0	0	0	0	0	1	4	2	0	0	0	2
Adjacent Land Use (ALU)	0	2	0	1	0	1	0	0	0	0	0	0
Water Quality (WQ)	0	9	0	0	0	1	0	0	1	0	0	2
Health Concerns (HC)	0	1	0	0	0	0	0	0	0	0	0	1
Property Values (PV)	0	0	0	0	0	1	0	0	0	0	0	4
Stakeholder Responsibility (SH)	0	2	0	0	0	1	1	2	3	0	0	10
Government Responsibility (GR)	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2 (c): Content Analysis of comments made in the Spring Lake online surveys, showing the relative number of respondents selecting each key factor, listed by survey question. Major concerns for this set of respondents included AIS Management Techniques, Stakeholder Responsibility, and Invasive Awareness.

Factors to Consider	Q 1 #Indiv.	Q 2 #Indiv.	Q 3 #Indiv.	Q 4 #Indiv.	Q 5 #Indiv.	Q 6 #Indiv.	Q 7 #Indiv.	Q 8 #Indiv.	Q 9 #Indiv.	Q 10 #Indiv.	Q 11 #Indiv.	Q 12 #Indiv.
AIS Management Techniques (AMT)	0	12	0	1	0	1	1	11	5	0	0	0
Invasive Awareness (IA)	0	2	2	4	0	2	1	1	1	0	0	0
Lake Usage (LU)	0	0	0	0	0	3	2	1	0	0	1	0
Boating Patterns (BP)	0	0	0	0	0	0	0	0	1	0	1	0
Adjacent Land Use (ALU)	0	0	0	0	0	0	0	0	1	0	0	0
Water Quality (WQ)	0	0	0	0	0	0	3	0	2	1	0	0
Health Concerns (HC)	0	0	0	0	0	0	0	0	0	0	0	0
Property Values (PV)	0	0	0	0	0	1	0	0	0	0	0	0
Stakeholder Responsibility (SH)	0	0	0	0	0	0	0	0	0	6	0	10
Government Responsibility (GR)	0	0	0	0	0	1	0	0	6	1	0	0

APPENDIX B:

Interview Questions and Responses*

Questions:

1. ***When did you first become concerned about the problems associated with the overgrowth of pondweeds (especially invasives)?***
   - Approximately 15 years ago (Resident)
   - In 2002 lived on a pond (Hawkins Pond) and began to see changes in the lake and this is when she first came to be concerned with aquatic invasive species. (Resident)
   - When I noticed a heavier growth of plants in the pond on our property after the neighbors cleared a large area that drains to it and started storing the manure piles from their horse farm at the head of the pond. (Resident)
   - Not applicable (Governmental)
   - 1970s…when I moved to RI in 1972, someone invited me to a picnic/ swimming at Echo Lake, Burrillville. The weeds made swimming impossible. Having grown up in Florida in the 40s and 50s I was aware of nutrient enrichment of waters. (NGO)
   - I first became concerned about invasive aquatics in Smith and Sayles Pond during the summer of 2007. (NGO)
   - I have been involved with an NGO for 8 years… 10 years ago the overgrowth of pondweeds in the body of water near my home became very apparent. (NGO)
   - ~15-20 years ago (Governmental)
   - We created an advanced training program for our volunteers in 1993, and that was when I first recognized what a problem some of these plants could be…our website http://www.uri.edu/ce/wq/ww/Plants/Invasives.html. (Governmental)

   **Overall: Citizens mark the time they noticed pondweeds when the lake nearest to them was affected. Experts in the field have noticed it throughout their careers but noticed it worsening over the time in the field. Organization members formed the current organizations as a result of the pondweed infestation and this began their strides to create programs and outreach programs to attempt to stop the invasive species problem
2. ***Do you know if the problem weeds in your local pond/lake are native to this area (RI/MA), or are they "invasive species" (area-wide distribution, only the local pond/lake, or new to the area)?***
   - I believe that they are non-native but widespread in our area. (Resident)
   - I can't think of any in particular but says the lake behind country kitchen looks to be in bad shape. If someone thinks invasive aquatic growth is a problem, she

suggests they go to look at this lake/pond. She feels as though this example should be enough to get someone involved. (Resident)

- I don't actually know what this vegetation is or whether it is invasive. We have both water lilies – which have remained fairly constant in abundance and this plant which has large multiple blade-like leaves. (Curly-leaved pondweed, *Potamogeton crispus*?) (Resident)
- Not applicable (Government)
- I do not know whether vegetation in Wilson Reservoir are native. I pull them up when I weigh anchor from water quality sampling. (NGO)
- Bladderwort is considered native to our lake and area. It has been, though, a nuisance since my earliest memories in the early 60's. There are references to Bladderwort in SDRA minutes from the 50s. The real bugaboo for SDRA now, however, is variable leaf milfoil. Our efforts to curtail milfoil have had the happy result of reducing Bladderwort densities. (NGO)
- I live near Smith and Sayles Pond… In this body of water, the weeds are invasive… The weeds are all over but there is a significant increase in the number of weeds in the cove… this could be a result of so many people living around this area and other lakes drain into this cove. (NGO)
- In Yawgoo Pond, West Kingston, aggressive native Brassenia (Water shield) arrived ~5 years ago…in Glen Rock Reservoir in Usquepaugh, Milfoil arrived after the floods of 2010. If you go to the DEM website, there are maps of invasive in RI, they were last surveyed 3-4 years ago. Check out the pdf in the right side bar http://www.dem.ri.gov/programs/benviron/water/quality/surfwq/aisindex.htm (Government)
- As the volunteer from Johnson's Pond (Flat River Reservoir) the problem plants tend to be non-natives (*Cabomba*, *M. heterophyllum*, and *U. inflata* primarily). Program wide (we have about 80 lakes in the program from year to year) *Cabomba* and *M. heterophyllum* are the dominant nuisance species, but we are seeing more issues with *U. inflata*, and *M. spicatum*, in many locations, along with a smattering of problem plants (*Trapa natans*, *Egeria densa*, *Potomogeton crispus*, *Najas minor* and *Glossostigma cleistanthum*) at other locations. Occasionally we hear complaints regarding native species such as Typha or various water lilies. (Government)
- **Overall: Citizens believe they are non-native and widespread in the area. Experts expressed the overwhelming amount of invasive species that have been occurring in the area. Organization members have been focusing their attention on their own lake and monitoring the presence of new species and determining them to be nonnative and widespread. Some organizations also noted an increase of native species. Some knew of the map located on the RIDEM website that shows the amount of aquatic invasive species and where they can be found (widespread).

3-A. What are your concerns for fish and wildlife in these infested ponds/lakes?

- Invasives do not usually affect fish or wildlife. However anoxia or hypoxia when plants die certainly can (Government)
- My concerns are habitat destruction - both through physical alteration of the habitat through the creation of dense monocultures of non-natives, but also chemical changes through the uptake of nutrients, decomposition of biomass, etc., and overall out competition of native species altering ecosystems. There are also significant impacts to swimming and boating - with power boats helping to spread invasives through chopping up plants. These all combine to effect both animal and plant systems, changing what can live where. (Government)
- **Overall: Experts in the field have numerous concerns for the fish and wildlife in these infested ponds and lakes. Among these concerns are anoxia or hypoxia, habitat destruction, and the overall ecosystem of the area.

3. ***What do you believe to be the cause of these new species of aquatic plants? Do you think there is a correlation between the increase of weeds and improperly sewered areas?***
   - Probably the major contributor to the weed being in our lake is the transport of same on watercraft being launched at the state launching area. These boats are not properly cleaned and the weeds are then transferred into our water body. Our properties have had sewers for about twenty years and the contamination has continued to increase. (Residents)
   - Yes (Residents)
   - See answer to 1 above. Sewers aren't an issue here and there are only three houses all of which have septic systems over 200 feet away in accordance with town ordinance. In this case I suspect the manure piles. (Residents)
   - New aquatic plants, depending on size and seed structure can be transported by boat or waterfowl. By improper sewering do you include improperly maintained septic systems and now "phased-out" cesspools? This does not only apply to introduced species but to native plants being exposed to increased phosphorus and nitrogen. (NGOs)
   - Human activity is the reason there are invasive aquatics in Smith and Sayles. Human Activity, 100%. There is significant research to suggest that nutrients from failed ISDSs feeds vegetation, including algae blooms and native aquatics. Fertilizer runoff is also a contributor to the growth of native and invasive plants. (NGOs)
   - AIS have nothing to do with sewers. They come in from waterfowl, from residents emptying aquaria into the pond, and from people having water gardens filled with

invasives. If you are trying to make the connection between nutrients and plants, it really has nothing to do with needing sewers, successfully functioning and maintained septic systems do just as well. However, stormwater runoff is a huge problem with bringing all sorts of nutrients into ponds (Government)

- Movement of plants via boats is a significant vector - from powerboats to even canoes and kayaks that have not been properly cleaned. I'm not convinced that there a strong correlation between the increase of weeds and improperly sewered areas. While the increased nutrients would certainly support more plants, if the plants hadn't been moved there from elsewhere, they wouldn't be a problem. The more significant issue is the unknowing movement of plants from place to place. (Government)
- **Overall: Citizens believe the sewers are a major contributor with only one surveyed individual holding the belief that there is little correlation between improperly sewered areas and aquatic invasive species. Experts and organizations also agree that there is a strong correlation, although one of the organizational representatives doesn't believe there to be a strong enough correlation between improperly sewered areas and an increase of aquatic invasive species. Overall, there seem to be strong opinions of agreeing or disagreeing with the statements.

4. ***What do you think is the best approach to get rid of, or at least manage, the weeds?***
   - Chemical weed control application. Dredging. Educational postings about the proper cleaning of boats prior to launch. These should be at the boat launch area. Also, a cleaning station area, with running water, should be provided at that location. (Residents)
   - If cost was not an issue, my preference would be dredging or the freezing method. Dredging is something I wish they could do on our lake but there is the issue of money, as well as where the material would go after the dredging took place. The freezing method involves dropping the water level down in the fall and having a freeze, thus allowing all of the build-up on the bottom to become visible. (This does not work well when the lake has running water. In this case there is a valve to stop the water from flowing, but the valve is on someone's private property, and the owner doesn't wish to turn the valve because they are afraid the valve will break and they will be responsible for the cost of repairing as well as managing to increase the water level). Since money is an issue, non-chemical treatments (e.g., herbicides) have been used on the lake. Sonar and Reward (examples of herbicides) have been used as treatments to kill fanwort and milfoil. These two treatments do work if they are applied to the pond every 3 years and problem areas are retreated on the off years. The downfall to these methods is that they leave a lot of debris (thick layer of almost sludge-like buildup). (Residents)

- First remove the manure piles – this has actually been done, and I'm not sure, but I think maybe there were fewer weeds this past summer. Of course the fact that the pond dried up last fall, was covered with ice until late March or April, and has now dried up again may also have played a role. (Resident)
- The best approach to weed management is to create a strategic plan that has identified the species of plant that is of issue, which takes into account how it reproduces, and therefore determines what the best strategies are for the pondweed's management, e.g., Will pulling help or worsen the problem? Does it respond to target-specific herbicides? Which herbicides have the best success? The plan must also take into account the condition of the lake – is it shallow or deep? What is the water retention time/flushing rate? Does it have a dam at the outlet? Is the water quality good? Are there issues with low dissolved oxygen? Are there high nutrients entering in the water, or are their large amounts of in-lake phosphorus? The conditions that the plant needs to grow are very important and help a lake manager to evaluate how well plant control techniques might work, or if they are appropriate at all. Then, a manager can come up with an integrated pest management (IPM) strategy that uses all of the tools and techniques available to devise the best plan (on a longer term basis – say five year projection) highlighting the best options for management. (Government)
- Some ponds can be mesotrophic; fish and other organisms benefit from some vegetation; one needs to distinguish between types of vegetation. When we refer to submerged vegetation, there are complexities. A multiphased approach would be to reduce input of P and N; before flowering and seeding time volunteers can hand pull weeds (on small ponds), use boat drawn rakes (larger bodies of water), prevent downstream contamination, and dispose/ compost on land. (NGOs)
- No single method for invasive aquatics abatement exists. Every lake is different with unique bathymetries, uses, watersheds, governing bodies, and more. For Smith and Sayles, our blended approach has included herbicides - a highly contentious remedy among association members - harvesting, benthic barriers, and an annual drawdown. The annual drawdown has been our most cost effective tool for maintaining the milfoil problem. (NGOs)
- A multi-task approach is the best way of managing the weeds… Education is key… Boat inspection (looking for any weed contaminants) is important… Drawdowns work… In my lake, there was a drawdown over the winter and then that water froze. There was then a rain storm which created a layer of water on top of the ice that then froze. (a freeze with another freeze on top) We can see weeds being pulled out of the initial freeze into the second – we hope this is going to be an effective way of weed management… I am not a fan of herbicides and believes this is not a sustainable management tool. In my area, $52,000 was spent on herbicides. (NGOs)

- It all depends on what your goal is. First you need to map the plants, determine your management goals and consider options from hand pulling, to suction harvesting, bottom barriers, herbicide applications, shoreline stabilization, replanting with natives. (Government)
- The correct tools depend on the exact site, species and current level of infestation. As a member of the North American Lake Management Society (BTW our annual symposium is coming to NY this November - see http://www.nalms.org/home/conferences-and-events/nalms-upcoming-symposium/nalms-symposium.cmsx for info, our regional chapter may have limited funding to help students attend...) we advocate for prevention, rapid response and eradication if possible, but maintenance as necessary. So the use of plant patrols to prevent new infestations is the first step. Hand removal or barriers for small, early infestations and then the full tool box of herbicides, mechanical removal, drawn down, dredging or suction harvesting, etc. once it has gotten too large for those early measures. Please see http://www.nalms.org/home/policy/lake-management-policy/aquatic-invasive-species/aquatic-invasive-species.cmsx for more. (Government)
- **Overall: Citizens believe the best methods of controlling or eradication to be chemicals, dredging, education the public about cleaning their boats, herbicides, benthic barriers, suction harvesting and drawdowns. Experts believe creating a strategic plan is needed before anything is done to the body of water or plants. It is believed that research about the plant, how it reproduces, how it responds to certain chemicals and herbicides before taking action. The overall quality of the lake water, including nutrient levels, dissolved oxygen, etc, must be taken into consideration. Organizations believe a multi-phased technique is needed. This includes hand pulling of weeds, boat drawn rakes, preventing downstream contamination and the disposal process of compost on the land surrounding the lakes/ponds. Replanting native species and mapping the plants are believed to be a crucial part. They believe in advocating for the prevention, rapid response (including eradication if possible), and maintenance of areas to help control the infestation from growing.

5. ***What do you consider to be your best source of information about these weeds and their control or eradication? How do you decide which action plan is best for the situation?***
   - Information sources are the DEM, R.I. Save the Lakes, and Aquatic Control Technology, our provider of the chemical applications. Our plans of action are annual chemical application and some degree for home owner awareness regarding best practices for waterfront property (e.g. do not apply lawn fertilizer). (Resident)

- Usually just goes under Google search…previously had subscribed to Lake Line magazine. Back in 2002, she also did research and tracked down people who had PhDs and had written papers/articles about aquatic invasive species. She has a booklet from the US army core that has a lot of information on the topic and she finds this to be a valuable source. (Resident)
- There is quite a lot of information on line including guides from RIDEM. I'm planning to let nature take its course unless the weeds start to overgrow the pond completely. At that point I might do some research or contact RIDEM for information. Or you? (Resident)
- All stakeholders should be involved in deciding the best action or control strategy (after those options have been evaluated by a professional-some options found online by a resident may not be applicable/helpful). A lake manager can explain the plant control options, but the stakeholders who are responsible for cost and implementation need to be informed of the options, pros/cons, and costs associated with a control strategy. The manager can provide the control options in written format of a plan, and/or do an oral presentation summing up the options, but the final draft of the plan, and the options decided on should be finalized by group consensus/democratic process that takes into consideration up-front and long-term costs and benefits. (Government)
- North American Lakes Management Society; academic sources; biological information. Action plan should include state DEP/ DEM, environmental organizations, and pond associations. (NGOs)
- SDRA is a uniquely awesome, educated group with a number of Ph.Ds, other educators, and hard working professionals. We have conducted years of research, met dozens upon dozens of times as boards and committees, visited numerous lakes, observed multiple harvesting tools, met with RIDEM Division of Wetlands countless times, held dozens of meetings for the SDRA membership, rebuilt low water outlets, measured, sampled, tinkered and publicly documented the heck out of our efforts. We are pursuing the most effective, legal means in our tool box, and continue to agitate on behalf of our lake's health. (NGOs)
- DEM and Office of water management (NGOs)
- Limnologists and professional lake consultants, also North American Lake Management Society, NE Aquatic Pest Management Society, etc. (Government)
- I recommend consulting certified lake managers (CLM) for assistance with invasive species management (see http://www.nalms.org/home/programs/professional-certification/professional-certification.cmsx). These professionals understand not only limnology, but socioeconomic issues such as how lake resident communities function, as well as regulations for the communities in which they operate. They are also usually the people who have the skills and licenses to apply chemicals such as herbicides -

something that unlicensed people should NEVER do. A full lake assessment and development of a lake management plan should be part of an overall AIS management plan. We work with our local lakes to provide data for those but have limited ability (i.e. time and funding) to help local lake groups to develop their own. Again, we would recommend working with a CLM. (Government)
- **Overall: Citizens list RIDEM, Save the Lakes, Aquatic Control Technology, Google, scientific papers, limnologists, and professional lake consultants as sources of information. Citizens did not specify how to decide which action plan to take. Experts say a lake manager is the best source of information but the stakeholders are the ones who need to be the ones to decide what action plan to take. Organizations list the North American Lake Management Society, academic sources, biological information, DEM and the office of water management should be used for general information. Consulting certified lake managers (CLM) is also another suggestion provided by an organization. To decide which action plan to take, they believe in incorporating the state DEP/DEM, environmental organizations and pond associations.

6. ***What do you believe to be the best way of informing members of the community about the current weed infestations and what do you believe is the most effective way to get members of the community to take action (participate in events, programs, and activities)?***
   - That is a tough one… I would think that an ongoing e-mail information program might be most effective. Also, local presentations by Save the Lakes and DEM would also have benefit. Finally large, clearly visible awareness posters at the ramp should be installed or the ramp should be closed altogether…..very selfish I know! (Resident)
   - Creation of a website and Facebook page. I also believe meetings are an effective way to get people involved as well as passing out flyers. (Resident)
   - I think you need to have a way that they can participate that will have some measureable effect before it makes sense to try to get community buy in. Otherwise you just get a lot of people wound up with nothing they can do. They will lose interest in the problem really fast. If you have a concrete plan that they can participate in – like a weed pulling day maybe you could get some involvement. Otherwise I would stick with education – like being sure to clean kayaks and fishing boats after visiting other ponds to minimize spreading of weeds. (Resident)
   - This is a million dollar question! If only I knew the answer to this….everyone is sure to have their own opinion, and it really depends on your audience demographic. Some folks would say, have a meeting and presentation (but how do you get people there??), but other folks would say advertise on social media, or in

a bait shop, or staff folks at a boat ramp…but maybe there isn't a boat ramp?....This is not an easy question to answer. (Government)
- Door to door campaign around pond/lake/reservoir. (NGOs)
- Meetings, face to face conversation, newsletters, web site, and word of mouth. (NGOs)
- Hold training sessions/workshops about AIS and teach folks to id and map their plants, then discuss at workshops (Government)
- The $84K question! Always take advantage of a crisis! If there is a particularly bad year (Utricularia tends to have bloom years) get out as much information as you can through as many media as you can. Boat patrol events are great, as are other community events. Websites and brochures can be effective with some audiences, but... Our usual approach is a shot gun blast of ideas and hope something works. Sorry I can't be more helpful with this one - I wish I had a good answer. (Government)
- **Overall: Participants in this interview were then asked what they believed to be the most effective way to inform members of the community of the current weed infestation and engage them enough to want to take action. Members of the community suggest postings on social media websites such as Facebook, posting flyers, creating an email program. Finally, it is suggested that local presentations by the Department of Environmental management and or Save the Lakes be given to community members. This would ensure the delivery of accurate information as well as informing the constituents of current events and programs going on. Experts whom were asked could not establish a concrete answer. Meetings, flyers, and social media were mentioned but the main concern was how to get people to want to take the time to attend the meetings or read the flyers and posts on social media. It is said that this is the "million dollar question". Organizations strongly believe that a face to face interaction is the most effective way to accomplish this task. Suggestions made by organizations included door to door campaigning, holding training sessions, and conducting workshops.

7. ***What do you see to be the biggest obstacles to implementing management plans?***
   - Money and awareness. (Resident)
   - She sees two factors as being the biggest obstacles. These obstacles are money and dealing with the opposition from people who believe the water should be left alone for nature to take its course. (Resident)
   - Management plans have to work to have anyone interested in participating. They also can't be too costly. Nor can they have negative side effects – like using herbicides that might also kill or harm native plants or wildlife. (Resident)
   - Generally high costs and/or large amount of effort required overshadows a long-term vision – people generally want to fix a problem quickly, and don't realize that there are many factors that contribute to it that all need to be addressed, OR don't

want to pay the money to fix it. A small infestation that could be eradicated quickly once discovered may require $4,000 for a divers to suction out, and is a relatively small price to pay in the scheme of things, but could get rid of the problem completely, but folks don't always have the money for that put aside, so they don't take care of it right away and soon it becomes a much bigger problem that can't be eradicated, and must be managed. A management plan is usually devised for a specific plant, but should also have a budget for prevention of new introductions, and/or early detection and rapid responses to new populations to have the best long-term effect on the entire lake ecosystem. (Government)

- Lack of coordination between state agency and pond associations and a strategic and comprehensive plan. (NGOs)
- Chemical treatments are cost prohibitive. Short of a much larger association with more dues-paying members - grants are required to cover the cost of treatments. Also, chemical treatments can divide and destroy the cohesiveness of a group, effectively destroying the group. Another limiting factor is Smith and Sayles' bathymetry. Milfoil typically cannot grow in water deeper than 15 feet. So, if you have a milfoil problem in a lake that is 30 feet deep, a moderate drawdown with associated freezing and desiccation eliminates the problem. But, if your lake is only ten feet deep like Smith and Sayles, a drawdown to eliminate milfoil would likely also eliminate a lot of the native ecosystem; fish, clams, turtles, bugs, and more. So we are limited to a partial drawdown that helps us maintain a cleaner circumference, but that also leaves a pile of milfoil in the majority of the lake where we can not legally expose the lakebed for freeze drying. (NGOs)
- Educating the land owners, especially those on waterfront property… Some people won't listen and that will be the most difficult challenge. (NGOs)
- Money, inertia, and people's not understanding that what they do on shore has a major effect on water quality and AIS (Government)
- Funding - most management plans will require some installation of hard scape to redirect or filter runoff or to setup boat washing stations. Enforcement of vegetative buffers - which requires strong DEM enforcement at a time where the DEM budgets have been cut and there are few compliance officers. Funding to help residents install rain gardens and other BMPS, and likely funding to allow the development and implementation of a lake management plan itself (hard to do with all volunteers). Also funding at the municipal levels - local roadways are often a source of contamination, but there may be little incentive or ability for a town to invest in protecting a resource that often directly benefits a small number of residents. (Government)
- **Overall: The biggest obstacle to implementing management plans were very similar amongst all of the interviewees. Money, awareness, dealing with

opposition, negative side effects of the chosen treatment plan, and the amount of work required to work on these plans were common themes expressed.

8. ***Do you have any other comments regarding invasive aquatic pondweeds?***
   - Our state has no effective program for lake dredging or a method to clean the buildup on the lake floor. Our particular lake, over the years, has accumulated a buildup of muck (not the scientific term I am sure!) which I feel fosters the growth of both invasive and non-invasive weeds. Hope that the above is of some benefit to you. Hopefully your efforts will have a small part in making our lakes better for future generations. (Resident)
   - I'm surprised that this topic hasn't gotten more attention due to how prominent the problem is…As part of the Hawkins Pond Association I used to be a part of the Watershed Watch through URI… Starting in 2002, I was very proactive but now someone else is the President of the Association and she feels as a result of her efforts, things are now on autopilot… Due to the cost of the treatments for their lake, the Hawkins Pond Association has managed to get funding through nearby towns. Since the pond isn't owned by a town or the state, it is difficult for them to get funding. They have to present a case which demonstrates funding is needed because if the weeds take over the lake, the property values will go down for the houses surrounding the lake. This then lowers the taxes for the town. With this fact, Smithfield and Johnston contributed funding. The treatment costs approximately $19,000… It's probable that Hawkins Pond flows into Factory Pond, so probably Factory Pond is a beneficiary from their treatments. The Association considered asking residents of Factory Pond to help pay for the treatments since their lake would benefit from the treatment but they never did. (Resident)
   - I think I would select one of the most invasive weeds and create a focused plan to address that weed. Start a program to eradicate this weed and see how effective you are in one or two growing seasons. If you have some success expand the program to other weeds… Looks like RIDEM has done quite a lot of work in this area. Perhaps more streams near headwaters could be surveyed to see if the problem starts upstream and migrates downstream or doesn't really become a problem until the stream passes through more populated areas. (Resident)
   - I generally hate to use the word weeds, as it has a negative connotation, and lumps all plants together as weeds, when really, it's just an invasive plant problem. Native aquatic plants are very important parts of a pond/lake ecosystem, providing oxygen, food and habitat for fish, wildlife and benthos. (Government)
   - Freshwater resources are neglected in northwestern RI to the extent that people mostly use them for a view. I did surveys last year in public areas (market parking lots; post office sidewalks, Farmers' Market) of the Branch River watershed,

focusing on how people use the rivers and ponds, and was surprised that few (if any) swim and only a few boat or fish. (NGOs)

- The invasive aquatics are here. They have already changed the lake's ecosystem. We're not going to eliminate them. Barring some incredible, affordable breakthrough, we will spend lots of money and time postponing their likely, eventual takeover. Associations like ours desperately need free thinking, permissive actions from regulating bodies. It is certainly understood and agreed upon that we want to protect the native eco system. But, people, authorities included, need to realize that the 'native' ecosystem pre-2007 no longer exists. It has been fundamentally changed. We need creative, affordable solutions and permissions to help us keep our lakes from quickly devolving to peat bogs… Hope my dronings have been helpful. If you have additional questions, please holler. (NGOs)
- It can be difficult but it is very important that weeds are classified well and accurately as invasive or native… Remembers from her experience as a teacher that fanwort used to come in different science project kits. (NGOs)
- Aquatic invasive plants suck! They are a big challenge to deal with once they have infested a location - we simply do not have the tools or resources to deal with them effectively, so we need to focus on preventing the spread and manage as best we can where it's too late. (Government)

**Overall: Finally, participants were asked if they had any other comments regarding aquatic invasive pondweeds. Citizens commented about the lack of funding available for treatments, accumulation of muck at the bottoms of lakes/ponds, and the lack of attention being brought to this topic. The ecosystems of infested bodies of lakes/ponds have changed and it is believe that there is a great need for creative, affordable solutions and permission granted to take action in order to help to keep the lakes from devolving into peat bogs. Experts noted that the native pondweeds provide many benefits to the ecosystem. They provide oxygen, food and habitats for marine life, wildlife and benthos. Organizations express the concern with properly labeling pondweeds as being invasive or native as well as the lack of knowledge throughout the general public regarding the invasive pondweed. There is the strong belief among organizations that the main focus should be placed on preventing the spread and managing the present invasives to the best of our abilities in order to stop the problem from growing before it is too late.

➔ ***I have learned a bit about your work with invasive plants kept in aquariums in your lab. Is it true that goldfish did not eat Cabomba at all? Are there other plants that the fish left alone? Do you have any comments or further observations regarding your with Cabomba?***

- Our "invasarium" is a strictly educational tool (an aquarium filled with non-native species) so we have not conducted any experiments. But I have noted several times that our goldfish love to eat the *M. heterophyllum* but tend to leave the *Cabomba* alone (of

course today they began eating the *Cabomba*...). They have also been fed *Utricularia*, but we weren't sure if it was native or non-native *Utricularia*. (Government)

**Overall: Interesting…the goldfish avoided eating the *Cabomba* at first, but apparently will consume it when no other food is present. Texture, taste, energy content?

Appendix C:

Specific References for Eradication Methods (Table I-2, Page 18-21)

General:

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