Northern Champlain Aquatic Invasives Early Detection and Control Project

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Abstract

A collaborative partnership between the Lake Champlain Committee and Arrowwood Environmental was formed in 2011 to conduct an inventory of Aquatic Invasive Species (AIS) and native aquatic vegetation in the Vermont portion of Missisquoi Bay of Lake Champlain. The Northern Champlain Early Detection and Control Project was undertaken with the following goals for Missisquoi Bay: 1) Documenting and mapping the abundance and distribution of aquatic invasive species; 2) Initiating immediate control measures on any small invasive populations; 3) Developing a standard aquatic community classification for native vegetation in the bay; 4) Identifying and mapping native aquatic vegetation; and 5) Developing a Priority Action Plan to deal with AIS in the bay.

Three AIS were discovered during this inventory. The Eurasian water milfoil was the most widespread AIS but was largely interspersed within the native aquatic communities and did not choke out native vegetation. European frog-bit was discovered in three separate areas, each within a Water Lily Aquatic Community, but it never occupied more than 1% of the area. Variable-leaved milfoil was found in one area where it has become well-established, comprising 20-90% of the plant cover while being mixed within a Water Lily and an Eelgrass-Water Stargrass Aquatic Community.

The Priority Action Plan developed for this project details steps that should be taken to control AIS populations in the bay. Controlling the Variable-leaved milfoil is a high priority because this population is one of only two in the state, it has become well established and it threatens native communities. Ensuring that European frog-bit does not become well-established is also a high priority. While this species was found at low densities, eradication in the early stages of establishment is vital.

Thirty-eight different occurrences of eight different natural communities were characterized, mapped and assessed in the study area. Of these, three were aquatic communities that are not currently recognized in the state. In an effort to standardize the aquatic community classification, two of these natural communities have been proposed for adoption in the state.

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Introduction

Missisquoi Bay of Lake Champlain is the northernmost bay of the lake in the United States. The shallow, nutrient-rich waters are interspersed with a wide variety of wetlands. This aquatic and terrestrial wetland mosaic provides habitat for a diverse array of fish and wildlife species. Some of these plant communities, however, have been invaded by aquatic invasive species (AIS). The negative effects of AIS infestations on recreational use, native vegetation and aquatic wildlife habitat have been well documented in the scientific literature. In recent years, Missisquoi Bay has been the site of a number of new invasions. In 2005 water chestnut (*Trapa natans)* was found in the Missisquoi National Wildlife Refuge. In 2009 variable-leaved milfoil (*Myriophyllum heterophyllum*) was discovered in the bay. The extent and abundance of these species and their impact on the native aquatic communities, however, was unknown.

It is also clear in the scientific literature that intact aquatic communities are vital to the functioning of lake ecosystems. These "weed beds" provide nursery areas for young fish, help control algae blooms by promoting the growth of algae-eating plankton, and reduce shoreline erosion by dulling the force of waves before they hit shore. Because of their high biological activity and diversity, these areas are considered the "life blood" of the lake. Despite their importance to the lake ecosystem, there is currently no geo-referenced map or standard classification of aquatic vegetation for Lake Champlain. Consequently, there is no means for monitoring how communities change over time in response to nutrient loads, sedimentation, climate change, or other perturbations.

A collaborative partnership between the Lake Champlain Committee and Arrowwood Environmental was formed in 2011 to address these issues. The Northern Champlain Early Detection and Control Project was undertaken with the following goals for Missisquoi Bay: 1) Documenting and mapping the abundance and distribution of aquatic invasive species; 2) Initiating immediate control measures on any small invasive populations; 3) Developing a standard aquatic community classification for native vegetation in the bay; 4) Identifying and mapping native aquatic vegetation; and 5) Developing a Priority Action Plan to deal with AIS in the bay. The following report details the methodology and results of this study.

1: Methods

1a: Study Area

The study was conducted in Missisquoi Bay on Lake Champlain in Vermont; U.S.A. Missisquoi Bay is a shallow arm in the northeastern portion of Lake Champlain. The bay covers 77.5 km^2 of surface area with a maximum depth of 5m. Over one half (58%) of the bay is in Vermont while the remainder is in the Canadian province of Quebec. Three significant tributaries discharge into the bay: the Missisquoi, Pike, and Rock Rivers. The borders of the study area were taken from the Vermont Hydrography Dataset (VHDCARTO) obtained from Vermont Center for Geographic Information and are shown in Figure 1.

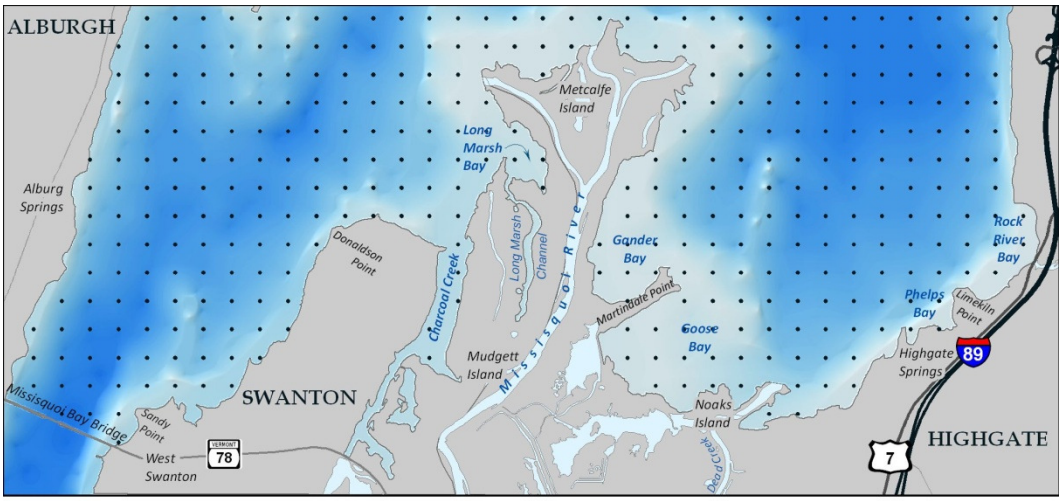

Figure 1. Map of the study area and grid point sampling matrix.

Prior to conducting field work, existing information about vegetation in Missisquoi Bay was compiled. Data from VT Water Quality was obtained, including the variable leaf milfoil populations in Missisquoi Bay (A. Bove, personal communication). Farrell (2006) conducted a survey of invasive plant species within the Missisquoi National Wildlife portion of Missisquoi Bay. While most of his work focused on the terrestrial portions of the refuge he did survey deep broadleaf marshes and shallow waters near shore. He found European frog-bit abundant in deep water marshes and creeks separate from the

main flow of the Missisquoi River; water chestnut in Cranberry Pool, significant infestations of Eurasian milfoil in many places, and less abundant populations of curly pondweed

1b: Sampling Methodology

The primary vegetation sampling was conducted via the point-intercept method (Madson, 1999; Hauxwell et al., 2010) utilizing a grid matrix covering the entire U.S. portion of Missisquoi Bay. The grid matrix allowed for systematic and reproducible sampling of vegetation in the bay. Grid points were spaced 300m apart and are shown in Figure 1. Each grid point was navigated to in a motor boat equipped with a Trimble GeoXH GPS unit. All GPS hardware and software performed to expected standards during the course of the project and no GPS equipment maintenance was required.

At each grid point the following data were recorded: water depth, substrate, plant species, and percent cover of vegetation (when visible). All data were collected by Michael Lew-Smith (Arrowwood) or Mike Winslow (LCC). The plant species data were obtained using the "rake toss" method. For water depths less than 12 feet deep, a rake on the end of poles was used to collect vegetation samples. For water greater than 12 feet deep, a rake attached to the end of a rope was thrown into the water and dragged along the bottom to attain vegetation samples. Waters greater than 12 feet deep typically yielded few plants. Three rake samples were taken at each grid point location.

The actual sampling point locations differed from the grid point locations by a range of 0.58 meter to 57.2 meters. The mean distance from the grid points was 9.92 meters with a standard deviation of 7.07 meters. The varying distances from the Grid Points can be accounted for by two factors. First, maintaining a steady fixed position on the open water was difficult during windy conditions. An anchor was used in some circumstances, but lacking any structure to anchor to, was sometimes ineffective. Secondly, there were 6 Grid points that were located in terrestrial wetlands that could not be accessed by boat. Data were collected nearby each of these 6 points in areas of aquatic vegetation that could be accessed by boat, resulting in a locational inaccuracy.

In addition to the 366 grid sampling points, an additional 199 points were taken. Eighty-one of these points documented the presence and abundance of AIS. The remaining 118 points documented the nature and extent of native aquatic communities.

Water depth was measured using a graduated fiberglass rod. Substrate composition was determined by a combination of visual observation and fiberglass probes. Substrate was categorized as muck (organic), clay, silt, sand, cobble (rock under 4" diameter) or boulder.

In addition to the grid point sampling, field data were taken on boundaries and composition of aquatic natural communities. Vegetation data were taken in a field notebook and linked to specific GPS point location data. This methodology is very similar to the methods described in Vermont's Water Quality Division Field Methods Manual (2006), but incorporates GPS technology.

The initial methodology outlined shoreline sampling areas to be conducted if time allowed, based on the VT Water Quality Methodology. These sampling areas did not get sampled during this inventory due to lack of time.

Species lists were taken from all of the grid point data as well as incidental species noted while mapping AIS and aquatic natural communities. The nomenclature used for species is based on Crow and Hellquist (2000). Four specimens were sent to Art Gilman (author of Flora of Vermont) for verification. As mentioned in Appendix 2, the flooding during 2011 created unusual growth forms of many plants, making identification of some species difficult. In particular, based on leaf morphology alone, some individuals of Water Naiad (Najas spp.) may be the rare southern naiad (*Najas guadalupensis*). These plants were interspersed with the common naiad (*Najas flexilis*). However, plants with flowers or fruit were never found. Since a conclusive determination between these two species cannot be made in the absence of flowers or fruiting structures, it is unknown if the individuals collected were the rare or common species. Aside from the potential southern naiad, no rare, threatened or endangered species were documented during this inventory.

Figure 2. Quantifying vegetation using the rake-toss and point intercept method.

Aquatic Invasive Species populations were discovered using the point intercept method as well as incidentally while mapping native vegetation. Upon finding any AIS, a GPS location was taken and notes on the species abundance and distribution were entered into the GPS data attribute file. Extent of the population was determined by scanning the area visually or with rake samples if water visibility was low. A series of point locations of AIS were used to determine extent of infestation and converted to polygon shapefiles when data were compiled. When harvesting AIS individuals, plants were brought into the boat by hand, placed in a black plastic garbage bag and composted on dry land. No harvested plants were allowed back into the water. This method of disposal was efficient and effective. The weather during the field season of 2011 was notably atypical. In May the level of Lake Champlain reached 103.27 feet; the highest level recorded since the beginning of record keeping in the early 1800s. The lake remained above flood stage (100 feet) until mid-June and remained high through much of July. Then on August 28th, Tropical Storm Irene struck the region and three to six inches of rain fell throughout the Missisquoi Bay watershed. These unusually high water levels, as well as the massive amounts of sediment, nutrients and pollutants that entered the lake from these flooding events may have impacted the distribution and abundance of aquatic plant growth. Since this was a one-year study, the nature and extent of these impacts is unknown.

2: Aquatic Invasive Species (AIS)

During the vegetation survey of Missisquoi Bay three non-native invasive species were found: European frog-bit (*Hydrocharis morus-ranae*), Eurasian water-milfoil (*Myriophyllum spicatum*), and variable-leaved milfoil (*Myriophyllum heterophyllum*). Water chestnut (*Trapa natans*), while known from the area around the bay (outside the study area), was not encountered in our surveys. Each of these four species is described below.

2a: *Hydrocharis morus-ranae* (European frog-bit)

Background

H. morsus-ranae is a free-floating, stoloniferous aquatic plant that can grow to form dense floating mats of interlocking plants. Reproduction is primarily vegetative by means of stolons and turions. A single plant can form approximately 100 to 150 turions. *H. morus-ranae* is extremely difficult to control, and its ability to form new plants vegetatively has allowed it to spread and proliferate quickly (Nault and Mikulyk 2009). In Vermont, turion formation begins in late July (Engelhard 2011).

Figure 3. European frog-bit in flower

H. morsus-ranae first appeared in North American as a horticultural specimen at the Arboretum of the Central Experimental Farm in Ottawa, Canada in 1932. By 1939 it had escaped from cultivation and spread. It was first discovered in Vermont during 1993 at the northern portion of Lake Champlain near the town of Grand Isle. By 1999-2000 it had spread to the southern portion of the lake near Benson, Orwell, and West Haven, Vermont, as well as Mill Bay in eastern New York (Nault and Mikulyuk 2009). Other observations of the plant around Lake Champlain include McUen Slang in Addison, Little Otter Creek Slang in Ferrisburgh, Black Creek in Swanton, and Point Au Roche State Park in Beekmantown, NY (personal observations).

Around the region, *H. morus-ranae* management has been attempted on the Grasse River in New York and in Town Farm Bay on Lake Champlain. On the Grasse River, the Adirondack Invasive Plant Program (APIPP) carried out hand-pulling of *H. morsus-ranae* between 2007 and 2011. The initial infestation was less than one quarter acre in size. Thirty-six five-gallon buckets of plant material were harvested in 2007; seven buckets were harvested in 2008; and fewer than two buckets were harvested in 2009. In 2010, fewer than 1.5 buckets of plant material were harvested. In 2011, just over one bucket of plant material was harvested in a few hours. APIPP intends to continue surveying the site until no new plants are seen for three consecutive years (Smith et al., 2011). On Town Farm Bay *H. morus-ranae* was first discovered in 2007. Volunteer hand-pulling efforts occurred in 2007 and 2008, but were deemed insufficient. In 2009 field crews were hired and seven tons of plant material were harvested. The next year 28 tons were removed followed by another 7.5 tons in 2011. Percent cover of *H. morus-ranae* was reduced from 45% in 2009 to less than 6% in 2011 (Engelhard, 2011). Persistent harvesting of *H. morus-ranae* populations over time can, therefore, substantially reduce the plants population.

Extent in Missisquoi Bay

During our surveys of Missisquoi Bay *Hydrocharis morus-ranae* was found at three locations, as shown in Figure 4. These were the northwest side of Metcalfe Island, in Long Marsh Bay, and in a bay to the east of Dead Creek. At all locations, *H. morus-ranae* accounted for less than 1% cover.

The Metcalfe Island population was discovered on 9/24/11 within a Water Lily Aquatic Community on the edge of a Deep Broadleaf Marsh. Only two individuals were found in the 0.65 acre area inventoried at this location, and both were collected. It is possible that more plants exist in this area and a source population may be present in Eel Creek or in the open water areas of Metcalfe Island. These areas sit directly south of this *H. morus-ranae* population within the Missisquoi National Wildlife Refuge but are outside of the study area and were not inventoried during this study. Given the low number of plants found at this location, European frog-bit is not an immediate threat to the State Significant Water Lily Aquatic Community (see Subsection (3f) for discussion of this community). However, Metcalfe Island and Eel Creek should be inventoried for the presence of a source population.

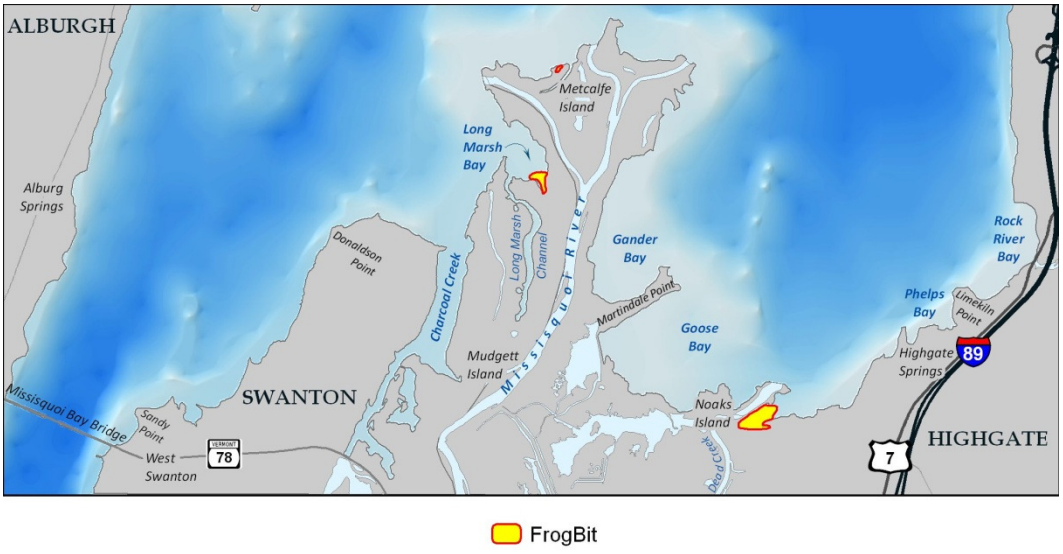

Figure 4. Map of the distribution and extent of European frog-bit in Missisquoi Bay.

The Long Marsh Bay population was discovered on 9/23/11 within a Water Lily Aquatic Community. Forty-five plants were identified and removed from a 4.6 acre area. These were all small, recently germinated plants. It is unknown if there is a source population for these plants outside of the study area within the Wildlife Refuge. The Water Lily Aquatic Community at this site is a State Significant Natural Community (see Subsection (3f) for discussion of this community).

The Dead Creek population was first discovered on 8/12/11 when 12 plants were found and harvested. During a subsequent visit on 8/26/11, sixty-five plants were discovered and harvested during three hours of searching over a 15 acre area. The plants were found mixed among floating aquatic vegetation of a State Significant Water Lily Aquatic Community. Given the dense colonization of floating vegetation and the diminutive nature of the European frog-bit plants, complete eradication was difficult; a final visit to this site on 9/27/11 revealed a few more individuals. Since the history of this population is not known, it is difficult to determine the trajectory of the European frog-bit population at this site.

Management Recommendations

All three of the European frog-bit populations discovered within the study area occur within State Significant Water Lily Aquatic Communities. As described above, none of these populations are extensive. It is likely, therefore, that the threat to these native communities can be addressed with pro-active management requiring relatively little time investment compared to well-established populations. We recommend two steps to controlling European frog-bit in the bay: 1) Investigate possible source populations within the Refuge; and 2) Yearly monitoring and harvesting of European frog-bit at these three sites. Sustained attention to these populations can likely prevent *H. morus-ranae* from becoming established in Missisquoi Bay. We anticipate personnel hours of not more than one day per site per year over three to five years would be sufficient.

2b: *Myriophyllum spicatum* (Eurasian water milfoil)

Background

M. spicatum is a submersed, rooted, perennial herb. It can have green, reddish-brown or whitish pink stems 1.8-6 m (6-20 ft.) long. The leaves are olive green in color, and less than 5 cm (2 in.) long. They are soft and feather-like in texture, and each mature submerged leaf has a central midrib with 12-20 filiform segments on each side. There are both male and female flowers on the same inflorescence. The female flowers are

basal while the male flowers are located distally. The female flowers have a four-lobed pistil and lack sepals and petals. The male flowers have four pink petals and eight stamens. The globular fruit are indehiscent, 2-3 mm (0.08-0.11 in.) long and contain four seeds (University of Connecticut 2009). *M. spicatum* was first documented in a Washington, D.C. pond in 1942. Since then it has spread throughout 45 states and three Canadian provinces. Fragments of stem can give rise to new populations while local populations spread via stolons (Jacono and Richerson 2003).

M. spicatum is found in all neighboring states. The plant is found in 63 Vermont lakes, most concentrated in the western drainages, where it covers thousands of aquatic acres, including large bays in Lake Champlain (VTDEC 2011). Populations appear to be expanding through northeastern New York, particularly into the Upper Hudson River-Albany region and into lakes in the foothills and mountains of the Adirondacks (Jacono and Richerson 2003). It is known from three sites in New Hampshire: Mountain Pond in Brookfield, the Connecticut River south of Hanover, and Mascoma Lake in Enfield (NHDES 2010a). *M. spicatum* is locally abundant and aggressive in Massachusetts and Connecticut.

Various means have been used to control *M. spicatum* including herbicides, bottom barriers, rotovation, hand-pulling, biological controls and harvesting. Because the plant can spread via small fragments, mechanical harvesting can increase the rate of colonization. Management efforts need to be targeted to the conditions of the particular waterbody.

Extent in Missisquoi Bay

Eurasian water-milfoil (*Myriophyllum spicatum*) was the most widespread and abundant aquatic invasive species documented in the study area. The distribution of this species is shown in Figure 5. The total area that contains this species is 1210 acres. In most cases, this species is found at low percent cover, typically less than 5% cover. In these cases, it is often interspersed with native vegetation and appears to have become "integrated" into the native communities (as opposed to overtaking the native communities).

In two areas, one in Goose Bay and one in Gander Bay, this species has become abundant. The population in Gander Bay is the most well established population of this species in the study area and comprises approximately 76 acres. Percent cover of Eurasian water milfoil here ranges from 5-50% and it is one of the dominant plants. It does not, however, occur to the exclusion of native species such as common naiad (*Najas flexilis*), perfoliate pondweed (*Potamogeton perfoliatus*), common coontail (*Ceratophyllum demersum*), and white waterlily (*Nymphaea odorata*), among others. The Eurasian water milfoil infestation occurs across the boundaries of three different native aquatic communities: Water Lily, Waterweed-Water Naiad and Eelgrass-Water Stargrass Aquatic Communities.

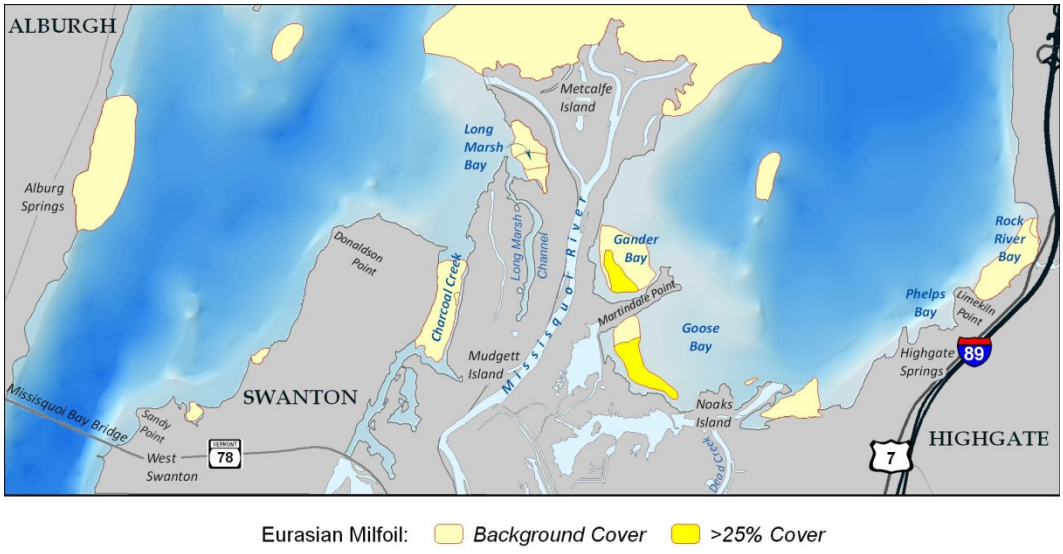

Figure 5. Map of the distribution and extent of Eurasian water milfoil in the bay.

The occurrence of Eurasian water milfoil in Goose Bay also appears to be a well established population and comprises 50 acres. Percent cover varies substantially, ranging from around 10% in the northern part of this area to 60% in the southern part of the polygon. In some places, however, overall vegetation is rather sparse and Eurasian water milfoil is the most common plant. As with the Gander Bay population, this species does not occur to the exclusion of native species. Robbins' pondweed (*Potamogeton robbinsii*), eel grass (*Vallisneria americana*), common naiad (*Najas flexilis*), and common coontail (*Ceratophyllum demersum*) are all found in this area. This population

occurs within two native aquatic communities: Water Lily and Eelgrass-Water Stargrass Aquatic Communities.

Management Recommendations

As mentioned above Eurasian water milfoil (*Myriophyllum spicatum*) is found over a large area in the bay. With the exception of the two areas in Goose and Gander bays, the species is found at fairly low abundance. While there is always a threat that any of these areas could become heavily infested, it does not appear to be an imminent threat to these natural communities. While Goose and Gander bays are more heavily infested, this species does not occur to the exclusion of native species. In addition, any eradication effort would also significantly impact the co-occurring native plants. For these reasons, we recommend that these sites be monitored but no immediate control measures be taken.

2c: *Myriophyllum heterophyllum* (Variable leaved milfoil)

Background

M. heterophyllum is a perennial, aquatic herb that has leaves of two noticeably different forms. The submerged leaves are finely dissected, whorled, reddish/greenish-brown, and 1.3-6.4 cm (½-2 ½ in.) long. The emergent leaves are small, oval, bright green, whorled and up to ¼ in. (0.6 cm) wide. Emergent leaves stand 15.2-20.3 cm (6-8 in.) out of the water and may not be apparent until late summer. Flowers are emergent on 5.1-30.5 cm (2-12 in.), green to reddish stalks. Petals are less than 3 mm (0.1 in.) in length and are subtended by downward curved bracts. Fruits are small, nearly round and have a rough surface (Invasive.org 2010).

M. heterophyllum is an unusual species in Vermont. In Missisquoi Bay it was first reported in 2009. This represented only the second occurrence of the species in the state. The first report occurred one year earlier from Halls Lake in the eastern portion of the state. *M. heterophyllum* is native to the United States, but is listed as an invasive exotic in New England states.

To the east and west of Vermont *M. heterophyllum* is more common. The species was first found in New Hampshire in the late 1960s and has currently been reported from 64 waterbodies. The New Hampshire Department of Environmental Services (2010) speculated that *M. heterophyllum* is more of a nuisance in New Hampshire than *M. spicatum* because *M. spicatum* was found in waters with higher pH ranges than were typical of New Hampshire. Nearly 20 lakes in the Adirondacks have expansive *M. heterophyllum* populations including Lake Flower and Oseetah lakes, Raquette Lake through to Piercefield Flow, the Fulton Chain, Cranberry Lake and the Oswegatchie, among others (Smith et al. 2009). *M. heterophyllum* has also been found in southern Lake Champlain in South Bay on the New York side of the lake.

New Hampshire utilizes an integrated plant management (IPM) approach for control of *M. heterophyllum*. Following assessment, a long-term management plan is prepared for each infestation. Management plans guide control activities for a number of years. Waterbody specific goals range from reduction of the infestation, to control, to possible eradication depending on the status of the infestation and characteristics of the waterbody. All available control options are considered, and actions are chosen that best suit the size, density, and character of the infestation. Hand-pulling, diver assisted suction harvesting, benthic barrier placement, herbicide treatment, and other strategies are evaluated for each infestation, including a review of a 'no control' option, and often a combination of approaches is recommended. (NHDES 2010a).

In the event of new infestations of Massachusetts ponds by *M. heterophyllum*, ENSR (2005) recommended quarantine followed by one of five options for early eradication. The five eradication options were hand-pulling, suction harvesting, benthic barriers, water level drawdowns, and herbicide application. Bottom barriers and hand-pulling were the preferred options with suction harvesting recommended where growth was too extensive for the other two methods. Benthic barriers were not recommended in areas where significant and sensitive protected or desirable species occurred.

Extent in Missisquoi Bay

M. heterophyllum was found in only one location in the study area, as shown in Figure 6. In this 6.2 acre area, it comprises 20-90% of the plant cover. The infestation occurs

within two native communities: Water Lily and Eelgrass-Water Stargrass Aquatic Communities. Throughout most of the infestation, *M. heterophyllum* is clearly the

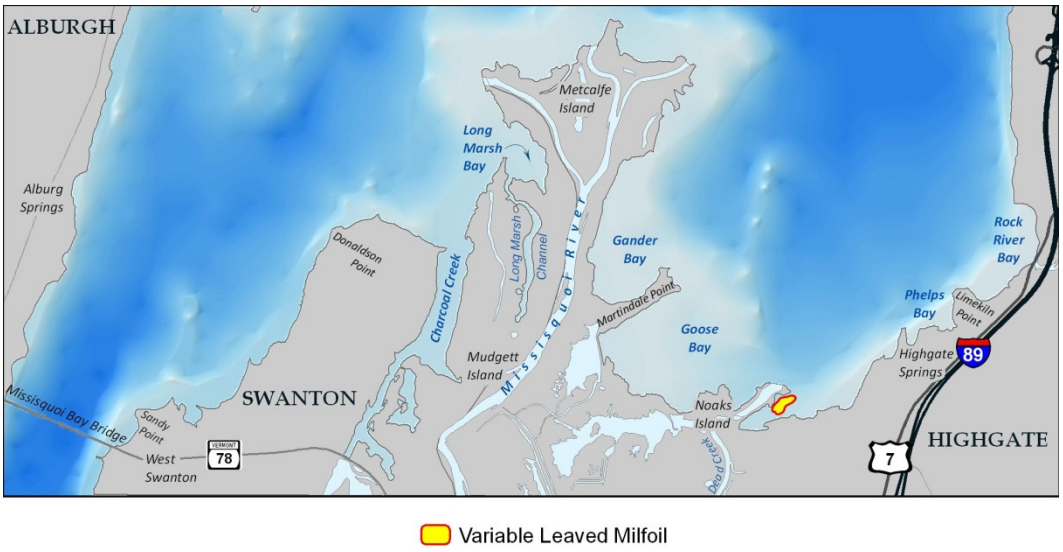

Figure 6. Map of the distribution and extent of variable leaved milfoil in the bay.

dominant plant. Where this species is most abundant near the center of the area shown, it does appear to be choking out native vegetation, forming a thick mat up to the surface of the water (Figure 7). Around the margins of this area, the cover is less and native vegetation is also present. The southwestern corner of this bay was not inventoried due to the presence of a thick mat of floating (native) vegetation which made access difficult.

Management Recommendations

Figure 7. Infestation of variable leaved milfoil in Goose Bay.

The infestation of variable leaved milfoil is the densest AIS found within the study area, and the only one that appears to be choking out native vegetation. This infestation does pose a threat to the two native and State Significant aquatic communities present. For these reasons, we recommend immediate

control measures for this species.

In Missisquoi Bay, water drawdown is not an option and the volume of the bay makes herbicide application less feasible. Benthic barriers are not ideal for two reasons: first, they would be very costly given the extent of this population and; second, they would choke out native vegetation as well. Hand harvesting or diver-assisted suction harvesting are therefore the two methods recommended to control this species.

2d: *Trapa natans* (Water chestnut)

Background

T. natans grows in freshwater lakes and ponds and slow moving streams and rivers. It prefers calm, shallow, nutrient-rich waters. It is an annual aquatic plant, with both surfacing and submersed leaves. Surfacing leaves are triangular with toothed edges and an inflated petiole and form a rosette on the water surface. Submersed leaves are feather-like with each leaf divided into whorled segments around the leaf stem. White flowers form in the axils of the surfacing leaves in July. Fruit are nut-like and "woody" with typically four sharp, barbed spines. Fruits ripen approximately one month after flowering occurs and seeds germinate in the spring. Seeds may be viable for up to five years (Methe et al. 1993).

While *T. natans* was not found during our survey it has been previously reported in the state. *T. natans* is known from 13 sites in Vermont plus southern Lake Champlain, associated tributaries, and Big Marsh Slough in the Missisquoi National Wildlife Refuge (VTDEC 2011). To the north, it has been found in the South River, a tributary of the Richelieu River located within ten km of the northern portion of Missisquoi Bay. It is known from seven out of eight management regions (PRISMS) in New York (Clemants 2009). In New Hampshire it is known from the Nashua River where it was first found in 1998, but it does not appear to have spread from there (NHDES 2010b). Additional *T. natans* populations have been found in Connecticut, Maryland, Massachusetts, Pennsylvania, and Virginia. *T. natans* was first introduced to North America in the 1870s

as an herbarium specimen at Harvard University. By 1879 it had escaped cultivation into the Charles River (Ling 2011).

Figure 8. Water chestnut

There is a long history of management of the Lake Champlain *T. natans* population. Since the 1960s, the plants local range has fluctuated in correspondence with management funding levels. At its greatest extent, *T. natans* could be found throughout the south lake as far north as Little Otter Creek in Ferrisburgh. Following an aggressive management program that began in 1998 with an average annual budget of $500,000 mechanical harvesting is now needed only as far north as Benson, VT. Remaining areas are managed by hand pulling (VTDEC). Meanwhile, the Missisquoi Wildlife Refuge population has largely been controlled with hand harvesting; 219 rosettes were hand harvested in 2011 (LCBP 2011). Hand-harvesting is also used to contain the Quebec population.

Extent in Missisquoi Bay

This species was not documented within the study area.

Management Recommendations

While this species was not found within the study area, it is known from the immediate vicinity. *T. natans* has clearly demonstrated in southern Lake Champlain its propensity for aggressive colonization. Therefore, periodic searches of the area should be conducted to ensure satellite populations do not become established in Missisquoi Bay. *T. natans* is an annual plant, so rapid response against new populations has a high probability of achieving eradication.

2e: Prioritization Plan

The AIS management prioritization summary data are shown in Table 1. A prioritization plan should analyze both the feasibility of controlling the population and the ecological impact of a potential infestation from lack of control. Top priority is given to species or populations that meet two criteria: 1) they threaten significant native aquatic vegetation communities and 2) control is feasible. In all cases, newly established populations are the most easily controlled. Management at this time can also have the greatest ecological impact because the AIS populations are controlled before they degrade the native aquatic communities.

Variable-leaved milfoil in Missisquoi Bay has been flagged as a High Priority for control because it meets both criteria. Though wide-spread in the Adirondacks, this species is only known from two locations in Vermont, one of them being Lake Champlain. Efforts to prevent this species from expanding in the state are therefore warranted. In addition, since this was the only species in the study area which was choking out native vegetation, eradication or control of this species will prevent the native natural community from being further degraded. However, we recognize that it may be difficult to completely remove all individuals in three years given how well this species has become established. Finally, to ensure that this species does not spread beyond its

current location, we recommend yearly monitoring of the vicinity for satellite populations.

European frog-bit in Missisquoi Bay met one of the two criteria. Unlike variable-leaved milfoil, the frog-bit populations in the study area were fairly sparse and did not yet threaten native communities. Despite meeting only one criterion, these sites were flagged as High Priority for control measures for two reasons. First, this species has the potential to choke out native vegetation if not controlled, including three state significant Water Lily Aquatic Communities. Second, since these are small populations, control of this species is feasible.

While water chestnut was not discovered within the study area, it was included in the Prioritization Plan because the potential for establishment is high. As mentioned above, it has been found in northern Missisquoi Bay in Quebec and in the Missisquoi National Wildlife Refuge. Yearly monitoring for this species, especially in areas near source populations such as Big Marsh Slough, is recommended to prevent establishment in the bay.

We do not recommend any management for the control of Eurasian water milfoil (*Myriophyllum spicatum*) in Missisquoi Bay for two reasons. First, the species is well established and widely distributed throughout the bay. Second, despite its presence in the bay for a long period of time, the species does not occur to the exclusion of native species. Given the finite resources available for AIS control, these two factors make management of this species unfeasible and of lesser priority.

In all cases, the combination of low densities of invasive plants and the large size of Missisquoi Bay lead to a recommendation of hand harvesting or suction harvesting as the most viable management tools for all of the invasive species found. The low densities of plants mean harvesting could be successful, and mobilization of mechanical harvesters would not be justified. The large volume of water combined with scattered populations does not lend itself to a recommendation of herbicide applications. Benthic barriers are not recommended because healthy native populations co-occur with the invasive populations and would also be impacted.

Table 1. Summary Prioritization Plan for Four Species of AIS in Missisquoi Bay

Species	Priority Level	Objectives of Management	Action	Timeline
European Frog-bit (*Hydrocharis morus-ranae)*	High	Eradicate populations and prevent further establishment	Monitor three locations, remove all individuals	Yearly for 3 years (or longer depending on establishment)
Eurasian Water Milfoil (*Myriophyllum spicatum)*	None	No management recommended	NA	NA
Variable Leaved Milfoil (*Myriophyllum heterophyllum)*	High	Contain Population	Harvest plants with hand or suction harvesting; monitor in late summer	Yearly for 3-5 years, depending upon success
	Moderate	Prevent population from spreading	Monitor immediate surrounding areas for signs of infestation spread	Yearly for 3 years
Water Chestnut *(Trapa natans)*	Moderate	Prevent species from becoming established	Monitor potential infestations based on source populations	Yearly for 3 years (or longer depending on establishment)

3: Native Aquatic Natural Communities

A natural community is defined as an interacting assemblage of organisms, their physical environment and the ecological factors that affect them. The natural community classification used in Vermont is based on the classification presented in Thompson and Sorenson (2000). This classification includes upland and wetland natural communities, but does not include any aquatic classification. One of the objectives of this project was to classify and map the aquatic natural communities that occur in Lake Champlain's Missisquoi Bay. As a result of this inventory, two new aquatic communities are being proposed for the state, the Eelgrass-Water Stargrass Aquatic Community and the

Water Lily Aquatic Community. Being recognized "natural communities" in Vermont increases our understanding of these vitally important areas, allows for ranking and assessment on a state-wide scale and, in some cases, affords regulatory protection. It is likely that other aquatic communities occur elsewhere in Lake Champlain, but have yet to be described.

Lake shorelines are places where the line between a terrestrial wetland and an aquatic wetland becomes blurred. Yearly and seasonal lake fluctuations change the conditions of much of the lake shore, such that cattails and bulrush colonize open water and submersed aquatic plants are found in Cattail Marshes. In order to have a complete map, therefore, some communities not normally considered "aquatic" types need to be included. Ultimately, the mapping of the communities was restricted by the study area boundary.

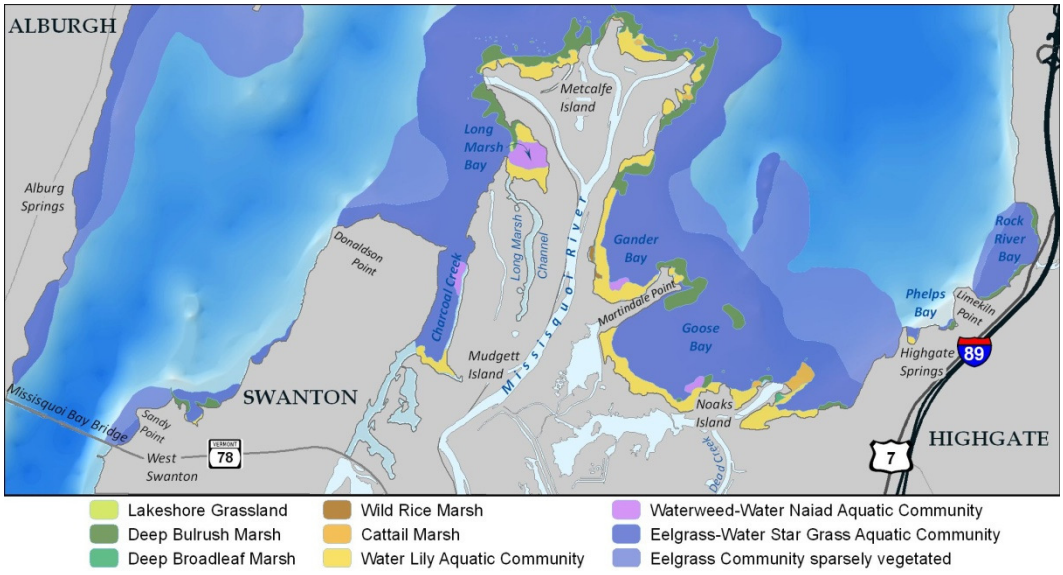

Figure 9. Map of distribution and extent of native aquatic natural communities in the bay.

The descriptions of the new communities that follow are based on field work from the current study and, to a lesser degree, on previous macrophyte inventories of the bay. The classification process also involved researching how other states and provinces in the region have addressed these issues. Community classifications from Maine (Gawler and Cutko, 2010), New Hampshire (Sperduto and Nichols 2004), New York (Edinger et.al. 2002) and Michigan (Minc, 1998) were all consulted. In addition published accounts of aquatic macrophyte assemblages from around the region and the world

were examined, including those from Nature Serve, which hosts data on the International Vegetation Classification (Nature Serve, 2011). We base the classifications proposed herein on the vegetation found in Missisquoi Bay; however there is support in the scientific literature for these (or similar) types.

Table 2. Summary Data on the Native Aquatic Communities in Missisquoi Bay

Natural Community	# of occurrences	Average Acreage	Total Acreage
Cattail Marsh	5	3.0	26.9
Deep Broadleaf Marsh	3	2.1	15.0
Deep Bulrush Marsh	8	8.2	196.2
Eelgrass-Water Star Grass Aquatic Community	3	198.6	3177.6
Lakeshore Grassland	3	0.5	1.6
Water Lily Aquatic Community	10	14.6	263.6
Waterweed-Water Naiad Aquatic Community	4	10.0	39.9
Wild Rice Marsh	2	7.5	22.4

As can be seen from Table 2, 38 different occurrences of eight different natural communities were characterized, mapped and assessed in Missisquoi Bay. Each natural community is described in detail below, including information on the natural community classification and ranking. The Vermont Nongame and Natural Heritage Project protocol was employed to rank each site based on the size, condition and landscape quality of the community. This rank is termed the Element Occurrence (EO) rank and gives a state-wide perspective on each of the communities assessed. Full ranking protocol and methodology are included in Appendix 3 along with a large format Natural Community Map in Appendix 5.

3a: Cattail Marsh

Natural Community Description

The Cattail Marsh is a wetland natural community typically found in more terrestrial settings rather than aquatic environments. However, the wide ecological amplitude of

cattail (*Typha sp.*) plants allows them to become established in deeper water than most terrestrial plants. The occurrences of this community mapped in the study area are on the more "aquatic" end of this type. As the name implies, these sites are dominated by broad-leaved cattail (*Typha latifolia*). Other emergent species such as hard-stem bulrush (*Scirpus acutus*) or freshwater cordgrass (*Spartina pectinata*) are also present in some areas. Aquatic plants such as white waterlily (*Nymphaea odorata*) and eel grass (*Vallisneria americana*) are also common. The bottom sediment is typically characterized by fine organic material. These sites cannot tolerate intense wave action and are therefore found in more sheltered situations.

Natural Community Classification

This community type is currently recognized in the state of Vermont.

Natural Community Ranking

A total of six different occurrences of Cattail Marshes were mapped within the study area. Like the Deep Broadleaf Marshes, much of the acreage of this community may occur outside of the study area, where conditions are more suitable. Only areas within the study area were mapped and are included in the table below.

Table 3. Summary Data on the Cattail Marsh Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
East Branch	8.6	B	NA
Goose Bay	15.1	B	NA
Kingfisher Bay	0.2	C	NA
Shad Island	2.7	C	NA
West Branch	0.35	C	NA

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

In some areas of the state, it is common to see stands of cattails hundreds of acres in size. As shown in Table 3, most of the Cattail Marshes in the study area are relatively small. They do not therefore reach the size required for state or local significance designation.

3b: Deep Broadleaf Marsh

Natural Community Description

The Deep Broadleaf Marsh is a fairly broadly defined marsh that typically occurs along lake shores, river shores and margins of deep water wetlands in the state. This community usually occurs on fine, organic sediments in sheltered bays. Large clones of a single species are common in this community, where vast areas of pickerel weed (*Pontederia cordata*), giant bur-reed (*Sparganium eurycarpum*), or broad-leaved arrowhead (*Sagittaria latifolia*) can be found. Other emergent species such as broad-leaved cattail (*Typha latifolia*) or river horsetail (*Equisetum fluviatile*) can also be found. Since this community occurs in standing water, there is also typically an aquatic component to the vegetation as well. Floating-leaved species such as white waterlily (*Nymphaea odorata*), water smartweed (*Polygonum amphibium*) and yellow waterlily (*Nuphar lutea*) are common. Submerged species such as common coontail (*Ceratophyllum demersum*) and common bladderwort (*Utricularia vulgaris*) can also be found.

Figure 10. A Deep Broadleaf Marsh near Metcalfe Island.

The current study was intended to document and assess aquatic communities in Missisquoi Bay. The Deep Broadleaf Marsh type is transitional between aquatic and terrestrial communities. As such, most of the acreage of this community in the Missisquoi Bay area may occur outside of the study area. Only those sites that occurred within the Missisquoi Bay study area were mapped and assessed for this project.

Natural Community Classification

This community type is currently recognized in the state of Vermont.

Natural Community Ranking

Three different occurrences of the Deep Broadleaf Marsh Community were mapped within the study area. Table 4 lists these occurrences with size, rank and significance assessment.

Table 4. Summary Data on the Deep Broadleaf Marsh Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Metcalfe Island	10.3	B	State Significant
Goose Bay	2.6	B	NA
East Branch	2.1	B	NA

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

3c: Deep Bulrush Marsh

Natural Community Description

Figure 11. The Missisquoi Bay Delta occurrence of the Deep Bulrush Marsh community.

As the name implies, this community occurs in "deep" water. In this context, "deep" is used in comparison to other more terrestrial wetland communities. The Deep Bulrush Marsh community occurs as a transitional community between the aquatic types and the more terrestrial marshes. The two species which dominate this type, hard-stem bulrush (*Scirpus acutus*) and soft-stem bulrush (*Scirpus validus*), can withstand substantial wave action. These communities are `therefore found in more exposed sites. The substrate tends to be sandy or coarser mineral sediments. While this type can occur in more sheltered locations, in these areas it is frequently out-competed and rarely forms extensive stands.

The occurrences documented in Missisquoi Bay are dominated by hard-stem bulrush (*Scirpus acutus*). Percent cover of these plants is actually quite low, around 20% when viewed from above. This, however, is typical for this community when it occurs in open water situations like those found in the bay. In many cases, the sandy sediments do not harbor any other submerged vegetation. In some situations, scattered eel grass (*Vallisneria americana*) plants are found beneath the bulrush plants, with a cover ranging from 5% to 75%.

Natural Community Classification

This community type is currently recognized in the state of Vermont.

Natural Community Ranking

As can be seen from Table 5, there are eight different occurrences of this community in Missisquoi Bay. The Missisquoi Bay Delta occurrence is one of the largest in the state.

Table 5. Summary Data on the Deep Bulrush Marsh Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Charcoal Creek	0.4	C	NA
Gander Bay	0.7	C	NA
Goose Bay	8.7	B	Locally Significant
Martindale Point	37.1	A	State Significant
Missisquoi Bay Delta	131.2	A	State Significant
Phelps Bay	1.3	C	NA
Rock River Bay	9.5	B	Locally Significant
Sandy Point	7.2	B	Locally Significant

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

The Missisquoi Bay Delta occurrence of this community which occurs near the mouth of the Missisquoi consists of a large area along the shore as well as a series of small bulrush "islands" within an Eelgrass-Water Stargrass Aquatic Community.

3d: Eelgrass-Water Stargrass Aquatic Community

Natural Community Description

The Eelgrass-Water Stargrass Aquatic Community is the most widespread and abundant community type mapped in Missisquoi Bay. It occurs as a background or matrix community in the bay in a wide range of conditions. It can be found in deeper waters of sheltered bays as well as more exposed open waters. Substrate is variable depending on location but can range from sands to finer silts. Given its abundance, the vegetation which comprises this community is relatively uniform. Eel grass (*Vallisneria americana*) is overwhelmingly the most dominant plant in this community. In some areas, especially at the mouth of the Missisquoi River, it can form large areas of near monocultures. In other areas, species such as water stargrass (*Heteranthera dubia*) and perfoliate pondweed (*Potamogeton perfoliatus*) are also present. Water Stargrass is more common in deeper water and can be co-dominant in these areas. In many areas, these three species are the only ones that comprise this community. Some sheltered bays, however, may also contain common naiad (*Najas flexilis*), common waterweed (*Elodea canadensis*), flat-stemmed pondweed (*Potamogeton zosteriformis*), and small pondweed (*Potamogeton pusillus*).

Figure 12. Eelgrass-Water Stargrass Aquatic Community

Percent cover of this community is highly variable. In a dense stand, total percent cover of vegetation is 90-95% and distributed as follows: 80% eelgrass; 5% water stargrass; 5% perfoliate pondweed; 0-5% other species. As the water depths increase towards the center of the bay, total percent cover decreases. While a typical occurrence may have 90% cover, the same community in deeper water may only have 5% cover. These areas are very different in terms of plant diversity, biomass, and fish and invertebrate habitat. For this reason, the sparsely vegetated examples of this community were identified as sparsely vegetated variants on the attached map.

Natural Community Classification

This is an aquatic community and is therefore not currently recognized in Vermont. The International Vegetation Classification (IVC), however, has documented a very similar community entitled the "American Eelgrass-Clasping Pondweed" community (CEGL006196). This IVC type is dominated by eelgrass and perfoliate pondweed but also includes ribbonleaf pondweed (*Potamogeton epihydrus*), water-milfoil (*Myriophyllum sp.*), common waterweed (*Elodea canadensis*) and, most notably, water stargrass (*Heteranthera dubia*). The distribution of this proposed community is throughout the northeastern United States including Vermont. Given the documentation of this association on the national level, and its well-documented presence in Missisquoi Bay, this appears to be a valid community type in Vermont. Further work is needed to determine the nature and extent of this community in the rest of Lake Champlain and the state.

Natural Community Ranking

As mentioned above, this community occurs throughout the study area as a background or matrix community type. All of the examples of this community in the study area appear to be in good condition despite the presence of sparse Eurasian water milfoil (*Myriophyllum spicatum*). Table 6 lists the community occurrences with their sizes and ranks.

Table 6. Summary Data on the Eelgrass-Water Stargrass Aquatic Community Occurrences.

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Main Bay	2437	A	State and Regionally Significant
Rock River Bay	103.6	B	State Significant
Sandy Point	76.7	B	State Significant
Western Bay	560.3	A	State and Regionally Significant

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

Since little is currently known about the distribution, abundance and size classes of this community in the state, it is difficult to assign a state-wide rank to these sites. However, given the size of the Main Bay and Western Bay occurrences, it is likely that these are the largest occurrences of this community in the state, and perhaps in New England. In the Biological Survey of the Champlain Watershed from 1930, this community in Missisquoi Bay was deemed "the most extensive and luxuriant weed bed observed in Lake Champlain" (NY Conservation Dept, 1930). Given this, assigning a preliminary A-rank to these sites and labeling them "State Significant" seems justified. Indeed, though there is currently no protocol for such a determination, a "Regionally Significant" designation may also be appropriate.

3e: Lakeshore Grassland

Natural Community Description

The Lakeshore Grassland community is an herbaceous community that is found along the shores of Lake Champlain and Lake Memphremagog in Vermont. Typically, it occurs along shorelines consisting of shale, cobble or coarse gravel and includes (in addition to grasses) upland species and shrubs. The occurrences documented in the study area, on the other hand, were situated in an "aquatic" setting, occurring adjacent to Deep Broadleaf Marshes and Bulrush Marshes. These sites are dominated by freshwater cordgrass (*Spartina pectinata*). In some cases, this is the only emergent species present. Other areas also contain scattered individuals of three-square bulrush (Scirpus

americanus) and pickerel weed (*Pontederia cordata*). The substrate in the study area is characterized by sand and water depth greater than 12".

Natural Community Classification

This community type is currently recognized in the state of Vermont. The occurrences mapped in Missisquoi Bay, however, may be different than those previously documented in the state. Further work on this community type is required to determine the similarities and differences between these sites.

Figure 13. Cordgrass dominates the Lakeshore Grassland community.

Natural Community Ranking

Three small occurrences of this community were mapped within the study area. Table 7 lists these sites with their size, ranks and significance determination.

Table 7. Summary Data on the Lakeshore Grassland Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Long Marsh Bay	0.8	B	State Significant
Metcalfe Island	0.7	B	State Significant
Shad Island	0.15	B	State Significant

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

As mentioned above, typically the examples of this community occur on cobble and shale shorelines. The acreage occupied by most of the examples, therefore, are fairly small. As can be seen in Table 7, the sites documented in Missisquoi Bay are no

exception. Though small, this community type is considered very rare in the state (S2 ranked) and even small sites, if in good condition, are considered state significant.

3f: Water Lily Aquatic Community

Natural Community Description

The Water Lily Aquatic Community is the only community documented that is dominated by floating-leaved aquatic plants. These sites typically occupy the more sheltered bays and coves of Missisquoi Bay and occur on fine organic substrates. Floating-leaved species such as white waterlily (*Nymphaea odorata*) and yellow waterlily (*Nuphar lutea*) dominate this community. Other floating-leaved species such as water shield (*Brasenia schreberi*) and water smartweed (*Polygonum amphibium*) were also found but were not dominant. Overall percent cover of the floating leaved species ranges from 25-90%. A wide variety of submerged aquatic plants are always found beneath the floating leaved-species. These include: common coontail (*Ceratophyllum demersum*), perfoliate pondweed (*Potamogeton perfoliatus*), common waterweed (*Elodea canadensis*), common naiad (*Najas flexilis*), flat-stemmed pondweed (*Potamogeton zosteriformis*), small pondweed (*Potamogeton pusillus*), water-marigold (*Megladonta beckii*) and common bladderwort (*Utricularia vulgaris*), among others. Percent cover of the submerged layer is typically high, ranging from 60-95% cover. In some areas, there are also scattered emergent plants such as hard-stem bulrush (*Scirpus acutus*), pickerel weed (*Pontederia cordata*), or broad-leaved arrowhead (*Sagittaria latifolia*). These are areas where the Water Lily Aquatic Community can grade into other community types such

Figure 14. The Water Lily Aquatic Community is dominated by floating leaved aquatics.

as the Deep Broadleaf Marsh or the Bulrush Marsh. Where cover of the floating-leaved species becomes sparser, the community grades into the Waterweed-Water Stargrass Aquatic Community.

Natural Community Classification

This is an aquatic community and is therefore not currently recognized in Vermont. This type is, however, recognized in Maine as the Waterlily-Macrophyte Aquatic Bed (Gawler and Cutko, 2010). It is also recognized by the International Vegetation Classification as the Waterlily Aquatic Wetland (CEGL002386). Given the documentation of this association on the national level, nearby in Maine and its well-documented presence in Missisquoi Bay, this appears to be a valid community type in Vermont. Further work is needed to determine the nature and extent of this community in the rest of Lake Champlain and in the state.

Natural Community Ranking

Ten different occurrences of this community were mapped within the study area and are listed in Table 8. The condition of all of these sites is slightly downgraded due to the presence of Eurasian water milfoil (*Myriophyllum spicatum*). While present, this species doesn't appear to be choking out native vegetation.

Table 8. Summary Data on the Water Lily Aquatic Community Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Charcoal Creek	12	B	Locally Significant
East Branch	11.5	B	Locally Significant
Gander Bay	59.2	A	State Significant
Goose Bay	92.4	A	State Significant
Kingfisher Bay	1.7	C	NA
Long Marsh Bay	27.4	A	State Significant
Metcalfe Island	31.8	A	State Significant
Phelps Bay	0.13	C	NA

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

Since so little is currently known about the distribution, abundance and size classes of this community in the state, it is difficult to assign a state-wide rank to these sites. However, based on current knowledge, five of these sites should be considered state significant natural communities and two should be considered locally significant. As more becomes known about this community type a more accurate ranking may become possible.

3g: Waterweed-Water Naiad Aquatic Community

Natural Community Description

As the name implies, this community is dominated by Waterweed (*Elodea canadensis*) or Water Naiad (*Najas flexilis*). Unlike the Eelgrass-Water Stargrass Aquatic Community, this type has a much more limited distribution and is found in smaller patches. It was documented in four locations scattered throughout the study area (see attached map). All of these sites occur in relatively sheltered locations in depths less than eight feet and typically with clay or fine organic substrates. The vegetation is overwhelmingly dominated by either waterweed or water naiad. These species can form very dense mats and vegetation cover is typically 85-100% and distributed as follows: 70-80% Common Waterweed (*Elodea canadensis*); 10-15% Common Naiad (*Najas flexilis*); 10-20% Common Coontail (*Ceratophyllum demersum*); 5% Flat-stemmed pondweed (*Potamogeton zosteriformis*); and 5% Eelgrass (*Vallisneria americana*). In occurrences where Water Naiad is dominant, it is found at 70-80% cover and the Waterweed is reduced to 10-15% cover. In the Long Marsh Bay occurrence, Eurasian Water milfoil (*Myriophyllum spicatum*) is also present, though at low abundance (5% cover).

Natural Community Classification

This is an aquatic community and is therefore not currently recognized in Vermont. The International Vegetation Classification recognizes a community from the Great Lakes that may be similar to this type. This is the "Southern Great Lakes Submergent Marsh" (CEGL005152) which is dominated by Flat-stemmed pondweed (*Potamogeton zosteriformis*), Common Coontail (*Ceratophyllum demersum*) and Common Waterweed

(*Elodea canadensis*). It appears to be a much more diverse aquatic community than the Waterweed-Water Naiad type and may represent a more diverse assemblage.

There does, however, appear to be support for this community more locally. A study of the aquatic plants in Lake George, NY, documented an association dominated by waterweed and water naiad in areas with high siltation rates. Furthermore, discussions with Vermont State Lakes and Ponds ecologist confirmed that this association occurs elsewhere in the state, typically in areas with higher nutrients (Susan Warren, VTDEC, personal communication 2/12/2012). However, not enough is currently known about this potential type to propose state-wide recognition as a natural community type at this time. Further work documenting and mapping this community in Lake Champlain and elsewhere in the state is needed to fully understand this assemblage.

Natural Community Ranking

As mentioned above, most of the sites are fairly small, occurring as patches surrounded by other matrix communities. As can be seen in Table 9, The Long Marsh occurrence is the largest mapped in the study area. The condition of this community, however, is slightly downgraded due to the presence of Eurasian water milfoil (*Myriophyllum spicatum*).

Table 9. Summary Data on the Waterweed-Water Naiad Aquatic Community Occurrences.

Site Name	Size	EO-Rank[1]	Significance[1]
Charcoal Creek	7.7	B	NA
Long Marsh Bay	23.7	B	NA
Gander Bay	3.9	B	NA
Goose Bay	4.5	B	NA

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

Since so little is currently known about the distribution, abundance and size classes of this community in the state, it is difficult to assign a state-wide rank to these sites. In addition, since not enough is yet known about this community for official recognition, ranking these sites would be premature. As more becomes known about this type, a more accurate ranking may become possible.

3h: Wild Rice Marsh

Natural Community Description

The Wild Rice Marsh community occupies areas that are relatively protected from wave action and occur in fine organic or mineral substrates. Like the other marshes described here, this community occurs at the ecotone of terrestrial and aquatic systems and is adapted to fluctuating water levels. The emergent vegetation is overwhelmingly dominated by wild rice (*Zizania aquatica*). On the open water edges of this community, floating leaved aquatics such as variable bur-reed (*Sparganium fluctuans*) and white waterlily (*Nymphaea odorata*) are also common. These deeper water areas also can have

Figure 15. Most of the Wild Rice occurrences in the Bay occupy a narrow zone between the lake and the upland shores.

some submerged aquatic species such as common naiad (*Najas flexilis*) and common coontail (*Ceratophyllum demersum*) among others. In some areas, where pickerel weed (*Pontederia cordata*), broad-leaved arrowhead (*Sagittaria latifolia*) or giant bur-reed

(*Sparganium eurycarpum*) are present, the Wild Rice Marsh can be interspersed with and grade into the Deep Broadleaf Marsh community.

Natural Community Classification

This community type is currently recognized in the state of Vermont.

Natural Community Ranking

There are some very large Wild Rice Marshes in the Missisquoi National Wildlife Refuge, but most of these are outside of the study area. The two occurrences within the study area are relatively small and occur as narrow bands in between the terrestrial and aquatic communities. These two sites are shown in Table 10.

Table 10. Summary Data on the Wild Rice Marsh Occurrences

Site Name	Size (acres)	EO-Rank[1]	Significance[1]
Gander Bay	8.7	C	NA
Goose Bay	13.7	C	NA

[1] Preliminary ranks and significance determinations based on draft ranking methodology.

Since both of these sites are fairly small compared to other sites in the state, they are not considered significant communities.

4: Conclusions

Missisquoi Bay hosts a diverse array of native aquatic communities. During the course of this study, 38 occurrences of eight different natural communities were documented, described and mapped. In addition, community classification work has resulted in the proposal for adopting two new aquatic communities in the state. The most widespread native aquatic community in Missisquoi Bay is an Eelgrass-Water Star Grass Aquatic Community covering over 2,400 acres. This is likely one of the largest aquatic communities in the state and habitat for a wide variety of fish and wildlife species.

Three Aquatic Invasive Species were discovered during this inventory. The Eurasian water milfoil was the most widespread AIS but was largely interspersed within the native aquatic communities and did not choke out native vegetation. European frog-bit was discovered in three separate areas, each within a Water Lily Aquatic Community, but it never occupied more than 1% of the area. Most of the individuals of this species were removed. Variable-leaved milfoil was found in one area where it has become well-established, comprising 20-90% of the plant cover while being mixed within a Water Lily and an Eelgrass-Water Stargrass Aquatic Community. Water chestnut was not found during the survey.

The Priority Action Plan developed for this project details steps that should be taken to control AIS populations in the bay. Controlling the variable-leaved milfoil is a high priority because this population is one of only two in the state, it has become well established and it threatens native communities. Ensuring that European frog-bit does not become well-established is also a high priority. While this species was found at low densities, eradication in the early stages of establishment is vital.

The North Champlain Aquatic Invasives Early Detection and Control Project is an important component in the effort to understand native aquatic vegetation and protect these communities from invasion by AIS. Further work is needed in the rest of the lake to better understand the composition and distribution of native aquatic communities and the extent to which these sites are being impacted by AIS. These studies coupled with AIS control efforts will help to ensure functioning aquatic ecosystems in the lake.

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APPENDIX 2: SPECIES LIST

Table 11 shows the plant species recorded in Missisquoi Bay during the 2011 field season. These species were recorded during the point intercept surveys as well as incidentally while mapping aquatic vegetation.

Record flooding in the spring of 2011 followed by flooding from Tropical Storm Irene produced unusual conditions in the lake during the field season. High water in the spring tended to delay growth, as well as create unusual growth forms in many of the aquatic plants. In addition, many of these aquatics did not flower or set seed as they normally would, further complicating identification of some species. Overall, it appears that the high water levels resulted in fewer species being recorded than expected.

Table A1. List of Species of Macrophytes Recorded within the Study Area

Scientific Name	Common Name	Plant Family
Sagittaria latifolia	Broad-leaved Arrowhead	Alismataceae
Megalodonta beckii	Water Beggarticks	Asteraceae
Brasenia schreberi	Water Shield	Cabombaceae
Ceratophyllum demersum	Common Coontail	Ceratophyllaceae
Chara sp.	Muskgrass	Characeae
Nitella sp.	Stonewort	Characeae
Scirpus acutus	Hard-stem Bulrush	Cyperaceae
Scirpus validus	Soft-stem Bulrush	Cyperaceae
Myriophyllum heterophyllum	Variable-leaf milfoil	Haloragaceae
Myriophyllum sibiricum	Northern milfoil	Haloragaceae
Myriophyllum spicatum	Eurasian water-milfoil	Haloragaceae
Elodea canadensis	Common Waterweed	Hydrocharitaceae
Hydrocharis morsus-ranae	European Frog-bit	Hydrocharitaceae
Vallisneria americana	Eel grass	Hydrocharitaceae
Utricularia vulgaris	Common Bladderwort	Lentibulariaceae
Najas cf guadalupensis	Southern Naiad	Najadaceae
Najas flexilis	Common Naiad	Najadaceae
Nuphar lutea	Yellow Waterlily	Nymphaeaceae
Nymphaea odorata	White Waterlily	Nymphaeaceae
Spartina pectinata	Freshwater Cordgrass	Poaceae
Zizania aquatica	Wild Rice	Poaceae
Polygonum amphibium	Water Smartweed	Polygonaceae
Pontederia cordata	Pickerel Weed	Pontederiaceae
Zosterella dubia	Water Star-grass	Pontederiaceae
Potamogeton amplifolius	Largeleaved Pondweed	Potamogetonaceae
Potamogeton crispus	Curly Pondweed	Potamogetonaceae
Potamogeton epihydrus	Ribbonleaf Pondweed	Potamogetonaceae
Potamogeton foliosus	Leafy Pondweed	Potamogetonaceae
Potamogeton natans	Floating Pondweed	Potamogetonaceae
Potamogeton perfoliatus	Perfoliate Pondweed	Potamogetonaceae

Scientific Name	Common Name	Plant Family
Potamogeton pusillus	Small Pondweed	Potamogetonaceae
Potamogeton richardsonii	Richardson's Pondweed	Potamogetonaceae
Potamogeton robbinsii	Robbins' Pondweed	Potamogetonaceae
Potamogeton sp.	Pondweed Species	Potamogetonaceae
Potamogeton spirillus	Northern Snailseed Pondweed	Potamogetonaceae
Potamogeton zosteriformis	Flat-stemmed Pondweed	Potamogetonaceae
Cephalanthus occidentalis	Buttonbush	Rubiaceae
Sparganium eurycarpum	Giant Bur-reed	Sparganiaceae
Sparganium fluctuans	Variable Bur-reed	Sparganiaceae
Typha angustifolia	Narrow-leaved Cattail	Typhaceae
Typha latifolia	Broad-leaved Cattail	Typhaceae

APPENDIX 3: NATURAL COMMUNITY RANKING GUIDELINES FROM Vt. NNHP

Nongame and Natural Heritage Program (NNHP)
Vermont Fish and Wildlife Department
November 5, 1996 (revised 3/2001 and 10/25/2004)

GUIDELINES FOR STATE-SIGNIFICANCE

The following guidelines are for determining whether a particular site will be included in an inventory report and entered into the NNHP database as a species or natural community of statewide conservation significance. The document is primarily intended for NNHP staff and contractors and others performing work for NNHP. Although these are intended as guidelines only, they are meant to represent the default position. Any deviation from them would need to be justified. Meeting any of the following criteria would constitute state-significance of sites for the purposes of NNHP inventories and for mapping and entering into the NNHP database.

SPECIES

- the presence of any state listed (T & E) species, regardless of rank;
- the presence of any S1 or S2 species regardless of rank.
- the presence of an G3/S3 species with an EO rank of A or B.
- the presence of breeding/wintering habitat for S3 species of Special Concern

Note that split rank species default to the lower ranking, e.g. an S2/S3 species is treated as an S2 and mapped regardless of its EO rank. S3 and S3S4 species are recorded in log books.

COMMUNITIES

- the presence of any S1 or S2 communities with an EO rank of A, B, or C;
- the presence of an S3 or S4 community with an EO rank of A or B;
- the presence of an S5 community with an EO rank of A.

Note that C-ranked S3 and S4 communities and B-ranked S5 communities are tracked, and may be considered state-significant, only if their EO rank has been downgraded due to a temporary lowering of condition for which recovery is expected.

HABITATS

- the presence of communal breeding/hibernating areas such as heron rookeries, or bat cave/mine, or vernal pool/amphibian breeding area with significant usage.

Note that there are presently no ranking specs for these habitats, and that the above criteria do not distinguish between natural and artificial examples.

SITE

Some allowances should be made for a cluster of somewhat significant natural communities occurring at a site provided there is some connection between them. Such sites would require at least two communities within one level of significance and a strong justification for a connection between them. Such a connection could be hydrologic as for a small fen within a large marsh or colluvial processes as for a rich woods below a talus slope.

APPENDIX 4: POINT INTERCEPT DATA

Point intercept data in tabular format are available as an electronic file intended to be distributed with this report.

Alternate data access is available through download at: http://www.arrowwoodvt.com/LCinvasives.html, or by contacting Arrowwood Environmental.

APPENDIX 5: AQUATIC NATURAL COMMUNITY MAP