



# Final Report

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## Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

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## Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

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## Executive Summary

Arrowwood Environmental, LLC and the Lake Champlain Committee collaborated on a project to conduct an inventory of frog-bit and water chestnut in northern Lake Champlain. The Northern Lake Frog-bit and Water Chestnut Control and Mapping Project was undertaken with the following objectives: 1) remotely identify frog-bit and water chestnut habitat; 2) conduct field inventories in these habitat areas to identify new infestations; 3) initiate control on any new, small infestations; and 4) continue control on known populations in the northern lake.

The study area consisted of the lake and its adjacent marshes from Colchester Point and Ausable Marsh north to the Canadian border. Two types of remotely identified Habitat Areas were identified: Water Lily Habitat Areas and Marsh Habitat Areas. To identify populations of invasive plants, point-intercept and visual survey methods were used in the Water Lily Habitat Areas, and visual surveys in the Marsh Habitat Areas. Though absent in most Water Lily Habitat Areas, frog-bit was found to be widespread and abundant throughout the study area in many Marsh Habitat Areas. Over 100 pounds of frog-bit were harvested from these communities, but it was determined that these populations were too large and dispersed to be effectively controlled. The impact that frog-bit is having on these marsh communities is unknown.

Unlike frog-bit, water chestnut was found to be absent from most of the northern lake. This species has been found only in Missisquoi Bay, in the vicinity of the Missisquoi National Wildlife Refuge (MNWR). There is only one site where it was documented outside of the MNWR borders, where 24 rosettes were pulled by MNWR contractors. Continued monitoring in the northern lake for these two species is recommended.

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## 1 Project Introduction

The Lake Champlain Committee in partnership with Arrowwood Environmental received funding from LCBP to map the extent and controlling small populations of frog-bit and water chestnut in northern Lake Champlain. The project had four main objectives: 1) remotely identify frog-bit and water chestnut habitat; 2) conduct field inventories in these habitat areas to identify new infestations; 3) initiate control on any new, small infestations; and 4) continue control on known populations in the northern lake. The goal of the project was to provide a comprehensive map on the status of frog-bit and water chestnut in the northern lake and coordinate with partner management efforts to initiate control on any nascent populations discovered. The methods, results and priority action plan for this project are presented below.

## 2 Tasks Completed

As outlined in the work plan, the current study focuses on mapping and controlling populations of frog-bit and water chestnut in the northern lake. The results of each of these efforts is described below.

### 2.1 Early Detection Inventory of Study Area

Sampling in the Water Lily Habitat Areas was conducted using the point-intercept method. The grid matrix established 112 sample points within these Habitat Areas, of which, 109 could be accessed and data collected on aquatic vegetation. Only two of these points contained frog-bit plants. The rest of the AIS data in the Water Lily Habitat Areas was collected using the Visual Survey methodology.

In addition to the 109 point-intercept data points, a total of 156 points were taken documenting the presence or absence of frog-bit and water chestnut in the Study Area. Most of these occurred within the Marsh Habitat Areas. Of the 91 different Habitat Areas, the presence of frog-bit was recorded in 38 of them and water chestnut in 4 (data from MNWR). Twenty-six Habitat Areas did not contain frog-bit and the remaining 23 were not visited due to time constraints. All of the Habitat Areas and the 2015 distribution of frog-bit and water chestnut in the northern lake are shown in Figure 1.

# Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

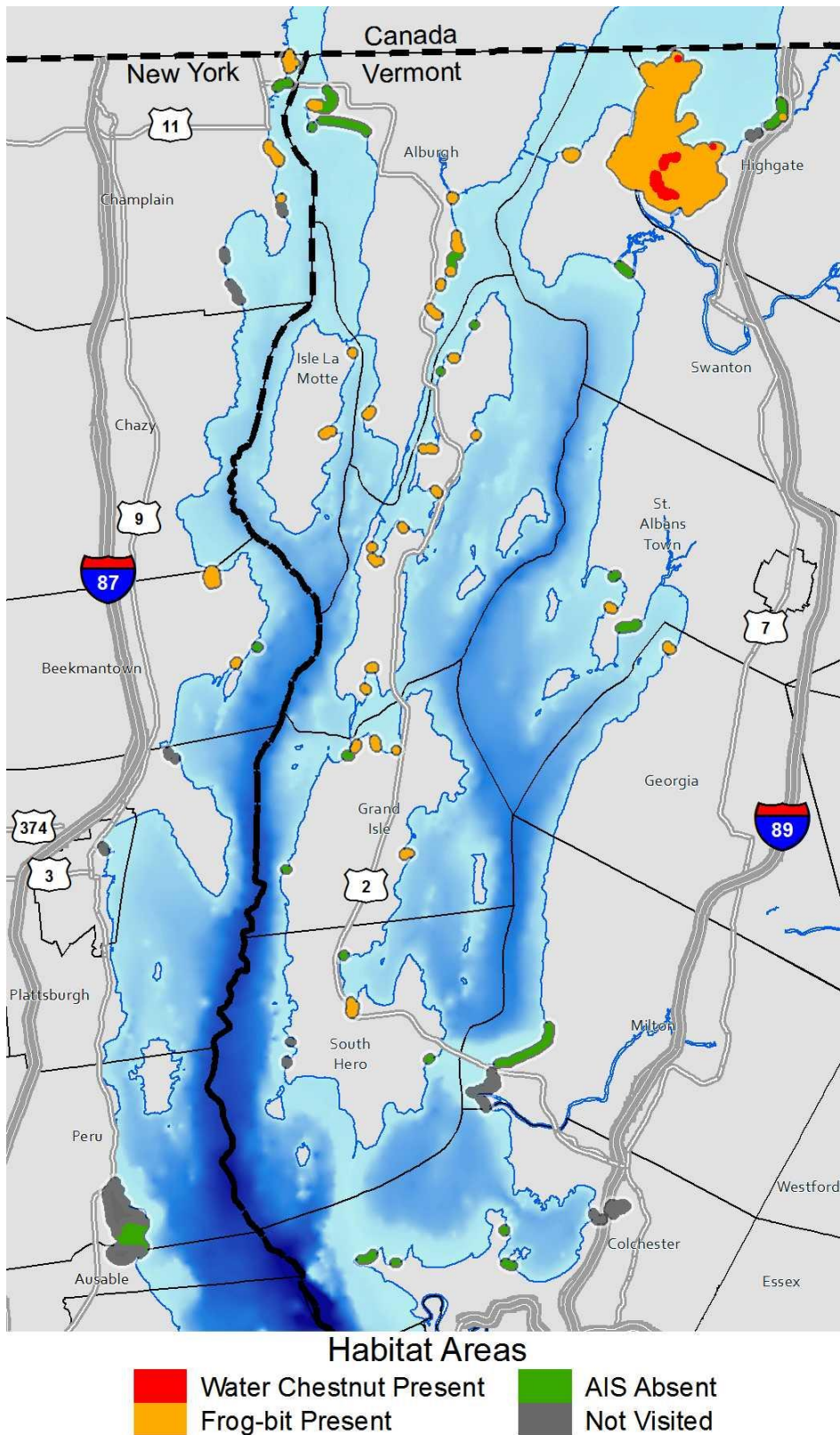


Figure 1. Map of all Habitat Areas with distribution of frog-bit and water chestnut in the northern lake

As can be seen from the map in Figure 1, frog-bit is present throughout the northern lake and the largest population of frog-bit is located within the MNWR. Frog-bit is widespread within the

refuge but refuge managers do not have an active control program for this species. (Ken Sturm, personal communication). This species is likely so abundant in the refuge because the refuge contains the largest amount of habitat for the species in the northern lake. The distribution of frog-bit on the map is representational as being widespread; with the exception of Long Marsh, no surveys for this species were conducted in the refuge.



*Figure 2. Frog-bit growing beneath dense river bulrush*

The sites that contain frog-bit are summarized in Table 1 and the sites that contain water chestnut are summarized in Table 2.

## Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

*Table 1. Sites in the Northern Lake Containing Frog-bit*

Site Name	Abundance	Comments
Carry Bay North	1-5% cover	Sparse in marsh adjacent to open water
Catfish Bay	30-80%	Variably dense under cattails, none noted to west, but difficult to access
Cooper Point	a few plants	Much of marsh inaccessible, may be more frog-bit present
Dead Creek	1-5% cover	Historical population
Deep Bay	25-100% cover	Dense infestation in cattails and along channel
Devil's Pond	5-50% cover	In water lily, marsh and floodplain forest
Dillenbeck Bay	1-5% cover	In marsh
Dillenbeck Bay NW	1-5% cover	In marsh
Fort Montgomery	single plant	Single plant, likely from source population to west
Fort Montgomery Bay	20-100% cover	Areas of very dense cover under cattails and bulrush
Goose Point	1-25% cover	Sparse cover in Cattail Marsh
Graveyard Point	5-50% cover	Abundant in open water areas of marsh
Hibbard Bay	25-50% cover	Dense in cattail marsh
Hibbard Bay SW	1-5% cover	Sparse cover in dense cattails, likely higher cover further SW
Jordan Bay	1-50% cover	Variable cover under dense cattails along inlet
Keeler Bay	1-5% cover	Sparse cover but widespread in marsh and water lily wetlands
Kelly Bay	1-10% cover	Sparse, most present in interior of marsh by beaver activity
King's Bay South	1-25% cover	In water lily wetland
LaMotte Passage	1-5% cover	Sparse in large wetland, separated from lake by cobble beach
Lapans Bay	5-25% cover	In floodplain forest adjacent to lake
Little Bluff	1-25% cover	Variable cover in marsh and edge of water lily wetland
Long Marsh North	5-20% cover	Widespread
Long Marsh South	5-10% cover	Widespread, likely continues into marshes
Macomb Bay	10-30% cover	More abundant in open water areas of marsh, may continue to south
Macomb Bay East	5-30% cover	May continue to east, though difficult to access
Mill River	5-50% cover	Under dense river bulrush and cattail, low cover in water lily
Monty Bay	1-5% cover	Mostly in cattails, some in channel; may be present throughout marsh
Mud Creek Inlet	1-25%	Along channel margins and in cattails
Pearl Bay South	1-5% cover	Sparse cover in marsh and water lily
Pelots Bay NW	1-5% cover	In open marsh adjacent to lake, very low cover
Pelots Bay South	1-25% cover	Widespread in marsh adjacent to open water
Rock River	1-5% cover	On border of channel
Squires Bay	5-25% cover	In Buttonbush Swamp
Stony Point	3 plants	Occasional plants from dense infestation in swamp to south
Stony Point Swamp	25-100% cover	Dense infestation across road from lake
The Gut	5-75% cover	Areas of dense cover in cattail marsh
The Gut SE	5-25% cover	Sparse in water lily wetland
Tromp Point East	1-5% cover	Sparse cover in cattails, though may be more dense deeper in marsh
Tromp Point Inlet	25-50% cover	In cattails and water lily, may continue south
West Swanton	5-25% cover	In marsh on and edge of water lily



## Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

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With the exception of MNWR, most of the occurrences of frog-bit are small, discrete areas where appropriate habitat is present. The appropriate habitat for this species is dense cattail, deep broadleaf marshes or buttonbush swamps on the margins of the lake. In some cases, frog-bit can occupy significant cover beneath these taller herbs and shrubs and may act as source populations for further infestations. Some Habitat Areas contain well established infestation of frog-bit in the marshes, while in adjacent Water Lily Communities little or no frog-bit has become established. This suggests that frog-bit does not compete well in these Water Lily Communities, due to fetch, water depth, substrate, sunlight or a combination of these conditions.

The current study surveyed for frog-bit in Habitat Areas within approximately 50 feet of the lake shoreline. Since only this 50' band around the lake was surveyed, it is unknown how widespread frog-bit is within these marshes. It is also unknown what other marshes in the Lake Champlain watershed (not directly bordering the lake) are infested with frog-bit. Finally, the ecological impact that frog-bit is having on these communities is not understood.

*Table 2. Sites in the Northern Lake Containing Water Chestnut (data from MNWR, 2015)*

Site Name	Abundance	Comments
Big Marsh Slough MNWR	317 rosettes	All rosettes pulled
Cranberry Pool MNWR	688 rosettes	All rosettes pulled
Dead Creek Delta	24 rosettes	All rosettes pulled
Shad Island MNWR	16 rosettes	All rosettes pulled

No new populations of water chestnut were discovered during the early detection work in the Habitat Areas. Four populations of water chestnut were mapped by MNWR in 2015 and are shown in Figure 1 (MNWR, 2015). Only one of these populations, Dead Creek Delta, was located outside of the MNWR boundary. In 2013, a small population was discovered and eradicated from the Rock River Bay area outside of the refuge, but this population was not discovered in 2014 by MNWR or in 2015 by LCC.



*Figure 3. Frog-bit at base of cattails on edge of marsh and open water.*

### 2.2 Control Measures in Study Area

As outlined in work plan, the focus of this project was on mapping and control of frog-bit and water chestnut in the northern lake. The focus of the control efforts were: 1) control small, newly discovered populations of frog-bit and water chestnut and; 2) continue control of known populations in Missisquoi Bay.

#### 2.2.1 Frog-bit

Previous work in the northern lake (LCC & AE, 2012 and 2013) documented frog-bit in numerous locations in the Missisquoi Bay Area. In coordination with MNWR personnel, LCC visited Long Marsh in Missisquoi Bay and some control measures were undertaken. Approximately 100 pounds of frog-bit were harvested from cattail marshes adjacent to the Water Lily Community, primarily on the south side of the bay. During this harvesting process, however, extensive frog-bit infestations were found and the population was determined to be too large to control under the present project. Likewise, when the Dead Creek population was visited, the population had increased substantially from the previous years and was deemed to be too large for effective control under the current project. In addition, with our improved understanding of the appropriate habitats for this species, we expect larger populations can be found in the broadleaf marshes adjacent to the Water Lilly Communities where we have harvested in previous years.

Small amounts of frog-bit (under 20 pounds) were also harvested from the Lapans Bay and Mill Brook Habitat Areas. During this work, however, it was determined that the populations were too large to effectively control. All frog-bit harvested during this project was composted in an upland location.

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As mentioned above, frog-bit was documented at 38 different sites within the study area. At none of these sites was the frog-bit a small or nascent population that could be easily controlled within the parameters of this project. All of the populations appeared to be well established. Even in cases where the percent cover of frog-bit was low, these plants typically occurred over a large area. In addition, access to many of these habitats is difficult. The vegetation is often too dense to allow for penetration of a kayak very far into these communities and deep water and/or mucky substrates typically prevent access by wading. For these reasons, no other control efforts were undertaken on frog-bit during this project. The Lake Champlain Basin Program was notified of this development during the field season. The lack of effective control opportunities, however, allowed for the expansion of the study area as described in Section 3.

### 2.2.2 Water Chestnut

Like frog-bit, water chestnut inventory and control within the MNWR has been under the purview of the refuge managers. Control measures undertaken by MNWR on water chestnut are shown in Table 3. Sites outside of the refuge boundaries are shaded light blue. Outside the MNWR boundaries, it has been documented in the Dead Creek Delta (2015) and in the Rock River Bay (2013). As can be seen from Table 3, only 24 rosettes were pulled from the Dead Creek Delta in 2015 and none were found in the Rock River Bay in 2014 or 2015. Previous control measures appear to be having an impact on these populations.

Table 3. Water Chestnut Control by MNWR 2013-2015 (MNWR, 2015)

Site Name	Abundance 2013 (# rosettes pulled)	Abundance 2014 (# rosettes pulled)	Abundance 2015 (# rosettes pulled)
Big Marsh Slough MNWR	1023	443	317
Cranberry Pool MNWR	3233	413	688
Dead Creek Delta	279	501	24
Rock River Bay	49	0	0
Shad Island MNWR	167	94	16

In the Rock River Bay area, only a 50' margin of the wetlands along the lake shore were inventoried. The extent of water chestnut in the wetland upstream is not known. Outside of Missisquoi Bay, no other water chestnut populations were found within the study area, therefore no other control actions were taken on this species.



Figure 4. Harvesting frog-bit in Long Marsh Bay

## 3 Methodology

### 3.1 Study Area

The initial study area proposed for this inventory consisted of the U.S. portions of Lake Champlain north of and including the Gut in Vermont and north of Pt. Au Roche in New York. After initial work on the project, it was determined the study area could be expanded south. Because of time constraints, however, not all of the habitat areas within this larger study area could be visited. The lake-side borders of the study areas were taken from data obtained from Vermont Center for Geographic Information (VCGI) and based off of the “Water\_LKCH5K\_poly” dataset. This border is referred to as the “lakeshore” and the study area as the “northern lake” in this report.

Prior to commencement of the field season, a meeting was held with staff from VT DEC (Ann Bove) and Missisquoi National Wildlife Refuge managers (Ken Sturm and Judith Sefchick-Edwards). Overall control efforts were discussed and field work between the refuge and LCC was coordinated. It was determined that LCC would inventory the Rock River Bay and Long Marsh areas for AIS and MNWR would inventory the rest of the potential habitat around the refuge.

### 3.2 Remote Habitat Areas

Prior to mapping habitat areas, existing information about vegetation in the Northeast Arm was gathered from Vermont Water Quality Division. Data consisted of species records from previous

inventories in the study area with a focus on historical locations (records from 1982 – 2014) of frog-bit and water chestnut and helped to inform the development of the Habitat Areas.

Both frog-bit and water chestnut are known to occur in slower moving waters colonized by the Water Lily Aquatic Community. Remote mapping of potential habitat areas consisted of identifying areas in the lake dominated by this aquatic community. Aquatic natural community mapping in Missisquoi Bay and the Northeast Arm conducted during previous years served as a baseline for development of the habitat areas. In areas where no natural community map had been previously created, a de novo mapping process was undertaken. This process used information such as lake depth, fetch, exposure, and multiple ortho-images to identify areas where the Water Lily Aquatic Community occurred within the study area. The resultant “Water Lily Habitat Areas” dataset included 26 potential sites.

All remote mapping was conducted in an ArcGIS platform which allowed for transferal of the digital map data to portable GPS units also equipped with ArcGIS software. The potential Water Lily Habitat Area locations were transferred to the portable GPS units and used to focus the field work.

During the initial stage of the field work it was discovered that, while some frog-bit is present in the Water Lily Aquatic Community, it is much more abundant in the dense emergent marshes adjacent to the lake. A different methodology for remotely mapping habitat areas was therefore developed to target densely vegetated emergent marshes and shrub swamps adjacent to the lake.

The mapping of these wetlands, with one exception, was an automated process that incorporated National Wetland Inventory (NWI) wetland data. As an initial step, all NWI wetlands within 50' of the lake boundary were identified. This large dataset was pared down by eliminating all Lacustrine and Riverine wetland types as well as all Palustrine forested wetland types. The Lacustrine and Riverine wetlands were eliminated because they consisted of the open water of the lake and rivers, respectively. The forested wetland types were eliminated because of lack of appropriate habitat. In some cases, manual adjustment of the Habitat Areas was necessary due to inaccuracies in the NWI data or features (such as roads) present in the aerial imagery. This process was conducted for both the initial study area and the expanded study area. In one area of the expanded study area (Valcour Island to the Ausable mouth), the NWI dataset was not available at the time of the analysis. Marsh Habitat Areas in this area were mapped manually by examination of orthophotography. The resultant “Marsh Habitat Areas” dataset included 76 potential sites.

The intention of the field inventory was to conduct inventories in all of the mapped habitat areas, regardless of type. With the expansion of the study area and the addition of the Marsh Habitat Areas, not all sites could be visited due to time constraints. All but 2 of the Water Lily Habitat Areas and 21 of the 76 Marsh Habitat Areas were surveyed (see Section 2.1).

### 3.3 *Field Methodology*

The field methodology consisted of two different approaches to vegetation sampling, the point-intercept and visual survey methodologies. Both methods were employed to sample the Water Lily Habitat Areas, while the visual survey methodology was used for sampling the Marsh Habitat Areas.

The point-intercept methodology used in this study was used in both the Northern Champlain Aquatics Early Detection and Control Project and the Northeast Arm AIS Early Detection and

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Control Project (LCC & AE, 2012 and 2013). This grid matrix allowed for systematic and reproducible sampling of vegetation in pre-determined locations in the Lake. In the 2015 study, the sampling points were established at a grid matrix within the Water Lily Habitat Areas.

A 100m x 100m grid of sampling points was placed over the Water Lily Habitat Areas. Because of the irregular shape of the habitat areas, some areas were underrepresented by point placement. For this reason, points that fell within 25 meters of the Habitat Area boundary line were snapped to the boundary lines and included in the grid sampling points. Only Water Lily Habitat Areas that had not been previously sampled were included in the 2015 inventory. This methodology resulted in the establishment of 112 sampling points.

Each of the 112 sampling points was navigated to in a 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 of the sampling points 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 Environmental) or Mike Winslow (LCC). The plant species data were obtained using the "rake toss" method. A rake on the end of poles was used to collect vegetation samples. Three rake samples were taken at each sampling point location. The nomenclature used for species is based on Crow and Hellquist (2000). No rare, threatened or endangered species were found during the inventory.



*Figure 5. Sampling vegetation with the point-intercept method*

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), boulder or ledge (bedrock).

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As mentioned above, initial field work determined that Frog-bit was often absent in the Water Lily Habitat Areas but present in the adjacent marshes. The point-intercept methodology was not appropriate for sampling in the Marsh Habitat Areas. The point-intercept methodology as outlined above is only for use in aquatic systems and cannot be effectively used in emergent marshes. In addition, while very useful for characterizing aquatic vegetation in general, the point-intercept method was determined to not be an efficient method for detecting frog-bit or water chestnut populations when abundance of these species is very low. The visual survey sampling method was therefore used in all of the Marsh Habitat Areas in the project. This methodology is very similar to the methods described in Vermont's Water Quality Division Field Methods Manual (2006), but incorporates GPS technology for mapping AIS occurrences.

This method consists of navigating to the Marsh Habitat Area with a kayak. No pre-established point locations were employed for this methodology. Rather, each Marsh Habitat Area was sampled at multiple points along its intersection with the open water of the lake. The location of the sampling points was determined in the field based on the habitat characteristics present and the abundance of frog-bit at nearby points. By visiting multiple points in this manner, the extent of the frog-bit population could be determined. At each point, data on AIS was taken including species present, percent cover of the invasive and any comments related to habitat or distribution of the AIS.



*Figure 6. Surveying a Marsh Habitat Area*

Since most of these areas have very shallow water, the kayak was used as the primary sampling boat. In some cases, the investigator left the kayak and waded into the marsh to get samples. In some cases, access into the Marsh Habitat Areas was difficult. Very dense vegetation (typically cattails) often prevented penetration into the Habitat Area with a kayak. In addition, the water level at some sites was too deep for wading. During lower water periods, especially late summer of 2015, access to some sites was also hampered by the presence of exposed mud flats. For these reasons, AIS data in the Marsh Habitat Areas is often limited to the lake-marsh border.

This series of point locations of AIS were used to determine extent of infestation and converted to polygon shapefiles when data were compiled. The habitat areas that contained AIS were therefore re-drawn to reflect the distribution of AIS at that site. Habitat Areas that were not surveyed or did not contain AIS were not re-drawn from the initial, remote mapping. In some cases, a re-drawn AIS site would have multiple, disjunct AIS populations within the same Habitat Area. In other cases, the AIS population occurred across habitat types and the final AIS population boundaries included both Marsh and Water Lily Habitat Areas. This re-drawing process resulted in a total of 91 final sites.

### **4 Quality Assurance Tasks Completed**

There were no significant conditions that would adversely affect the quality and usability of the data collected for this project. Mike Winslow served as the Project Manager and Michael Lew-Smith as the project Quality Assurance Officer. They provided review of all project output, and kept maintenance logs for the GPS units to document any maintenance and service of the units. All use of GPS units followed manufacturer instructions and accepted procedures. Sediment probes and rakes were inspected at the end of each field day; there were no maintenance issues with this equipment. No instruments that would require calibration were used for this project.

To prevent AIS spread, boats and all accessory equipment were inspected prior to leaving the study area and any visible plant material was removed. All frog-bit harvested during this project bagged for transport inside vehicles and was composted in an upland location.

### **5 Deliverables Completed**

According to the Work Plan, a deliverable was listed with each of the tasks to be completed. These deliverables are listed in Table 4 along with comments on the status of the deliverable.



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Table 4. Deliverables from 2015 Work Plan

Task #	Task(s)	Deliverable	Comments
0	Update QAPP	Approved QAPP	Completed May, 2015.
1	Gather existing data, and analyze study area for appropriate frog-bit and water chestnut habitat	Preliminary map	Preliminary map completed in June, 2015 and used to guide field work.
2	Map in the habitat areas using GPS	Data forms and GPS map data	Digital data forms with associated GPS map data submitted to LCBP on February 2, 2016.
3	Remove any newly established small frog-bit or water chestnut populations through hand-pulling	Species and amount of plants harvested dependent upon populations present	Approximately 20 pound of frog-bit harvested from Mill Brook Marsh and Lapans Bay. Populations too large for effective control under this project (see Section 2.2).
4	Re-visit sites identified in 2011-2012 and continue control on frog-bit populations	Amount of plant harvested dependent upon population present	Approximately 100 pounds of frog-bit harvested from Long Marsh. Populations too large for effective control under this project (see Section 2.2).
5	Incorporate field data into digital GIS-based mapping platform	Digitized map of AIS and incorporation into online database	Submitted to LCBP on February 2, 2016.
6	<i>Compile field data, create maps, write quarterly and final reports</i>	<i>Quarterly and final reports</i>	Quarterly report all previously submitted. Final report herein.

Though not mentioned in the Work Plan table, the AIS Prioritization plan is also considered a deliverable of the project. As mentioned in previous reports, an AIS prioritization plan should analyse 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.

Frog-bit was documented throughout the study area in wetlands adjacent to the lake. These areas were inventoried within 50' of the lake boundary, so the full extent and distribution of frog-bit in these wetlands is unknown. In addition, the extent of frog-bit along tributaries and in wetlands in the Lake Champlain watershed is unknown. While frog-bit does not appear to threaten Water Lily Communities in the lake, the impact that this species is having on other wetlands in the watershed is unknown.

Water chestnut is largely restricted to MNWR and a few areas in the vicinity of the refuge. The managers of the refuge have been aggressively undertaking control efforts to keep this species in check. Without continued efforts, this population could act as a source population for more widespread infestations in the northern lake.

The Priority Action Plan outlined in Table 5 addresses these concerns.

## Northern Lake Frog-bit and Water Chestnut Control and Mapping Project

*Table 5. Summary Prioritization Plan for Frog-bit and Water Chestnut in the Northern Lake Outside MNWR*

Species	Population	Priority Level	Action	Objectives of Management
European Frog-bit ( <i>Hydrocharis morus-ranae</i> )	Throughout Northern Lake	Moderate	Continue Mapping Distribution	Understand full extent of species and effect on wetland communities
Water Chestnut ( <i>Trapa natans</i> )	Dead Creek Delta	High	Continue Control	Prevent establishment and development of source population
	Rock River Bay	High	Monitor for re-establishment	Prevent establishment and development of source population

## 6 Conclusions

The Northern Lake, an area from Colchester Point and Ausable Marsh north to the Canadian border, contains many pockets of habitat for frog-bit and water chestnut. Numerous Habitat Areas within the Northern Lake were inventoried for the presence of these aquatic invasive species. Frog-bit was found to be widespread and abundant throughout the study area. Though absent from open water and most Water Lily Aquatic communities, it was abundant in many of the emergent marshes that border the lake. The largest infestation is in the marshes of the Missisquoi National Wildlife Refuge, where extensive habitat is present. The impact that frog-bit is having on these communities is unknown.

Unlike frog-bit, water chestnut is absent from most of the northern lake. Historically, it has been found only in Missisquoi Bay, though control efforts by MNWR have reduced numbers in the bay over the past five years. There are only two sites where it has been documented outside of the MNWR borders, Dead Creek Delta and Rock River Bay. In 2015, water chestnut was harvested from the Dead Creek Delta site and the Rock River Bay site did not contain this species.

A Prioritization Plan for these two species in the northern lake was developed for this study and outlines the most important actions to take based on feasibility of control actions and the significance of the sites that may be threatened.

The Northern Lake Frog-bit and Water Chestnut Control and Mapping Project is an important development in our efforts to understand the distribution, extent and biology of frog-bit and water chestnut in the northern lake. By continuing our inventory and control efforts, we are able to contribute to the maintenance of a healthy Lake Champlain ecosystem.

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## 8 Appendices

**Electronic Data:** Field data in tabular format and ArcGIS compatible shapefiles are available as electronic files intended to be distributed with this report.

### List of Acronyms:

AE – Arrowwood Environmental  
AIS – Aquatic Invasive Species  
GPS – Global Positioning System  
LCBP – Lake Champlain Basin Program  
LCC – Lake Champlain Committee  
MNWR – Missisquoi National Wildlife Refuge  
NWI – National Wetlands Inventory  
QAPP – Quality Assurance Program Plan  
VCGI – Vermont Center for Geographic Information  
VT DEC – Vermont Department of Environmental Conservation