# AQUATIC AND SHORE HABITAT OF MILLE LACS LAKE, MINNESOTA

2009 to 2019

**Report by:**

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Acknowledgements: We thank the following reviewers for their careful reading and insightful comments that helped improve this report: Eric Jensen, Gary Montz, and Steve Kloiber. We would also like to thank the numerous surveyors who assisted on this project including Adam Pangrac and Jennifer Hardy (MNDNR Watercraft Inspection Interns) for their field survey assistance in 2009. We remember Dr. David Wright and are grateful that he encouraged us to pursue this project, asked challenging questions and was always interested to learn about our findings.

 

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# EXECUTIVE SUMMARY

This report summarizes shore and aquatic habitat surveys of Mille Lacs conducted between 2009 and 2019. Some assessments were lakewide while others focused on specific bays. We used a tiered survey approach to assess a variety of habitat conditions including remaining shore habitat, nearshore plant stand cover and composition, and submerged plant occurrence, height and diversity.

Mille Lacs Lake supports a healthy aquatic plant community with more than 50 taxa found throughout the lake.

Highlights of our results include:

Shore Habitat (Chapter 2)

- Mille Lacs shore is among the more highly developed of Minnesota lakes with 75% of sites impacted by humans, compared to a statewide average of 58%. Factors that contribute to this high rate include lack of publicly owned shore and the close proximity of most of the shore to roadways.
- The lakewide habitat score (61 out of 100) is lower than the statewide mean of 74 points. This is only partially due to the overall higher development level. When comparing only developed sites, Mille Lacs scores lower (52) than the statewide mean of 61, suggesting greater alteration of the nearshore habitat than typically observed.
- Habitat scores were low to very low in the Shoreland, Shoreline and Aquatic Zone of most developed sites.
- In general, more intensive land use types (condominiums, resorts, boat ramps, and small residential lots) had lower habitat scores but the fact that most land uses had a wide range of scores indicates that people have options on how they can develop various types of sites and that it is feasible to maintain "natural" areas regardless of development type.
- Undeveloped shores are concentrated on the west and south shores and serve as examples to lake residents and managers interested in restoring shore habitat.

Emergent and Floating-leaf Plant Stands (Chapter 3)

- Emergent and floating-leaf plant stands were mapped and classified in Vineland Bay, Cove Bay and Isle Bay. These bays were selected because their shorelines have some protection from the wind and are more likely to support these plant stands.
- A total of 309 acres of plant stands were mapped and this represents about 47% of the total shallow water zone (0-5 ft) in these bays.

- The largest stands occurred adjacent to undeveloped or minimally developed shores.
- Bulrush (*Schoenoplectus* sp.), cattail (*Typha* sp.), white waterlily (*Nymphaea odorata*) and yellow waterlily (*Nuphar variegata*) were the most common plants observed.
- Wild rice was only observed in Isle Bay where approximately 11 acres were delineated.

Submerged Plants – Lakewide (Chapter 4 and 6)

- In 2009, quantitative surveys of lake plants were conducted at Wealthwood, Malmo, Twin Bay, Isle Bay, Wakhon, Cove Bay, Vineland Bay, Shabushkung Bay and Wigwam Bay.
- Shoal substrates were primarily sand with areas of rubble on the north and south shores. Muck and silt were found in the shallow smaller protected bays.
- Submerged aquatic plants were detected to a maximum depth of 20 feet but were most common in the 0 to 15 feet zone where 46% of sites were vegetated.
- Within the 0 to 15 feet zone, plant occurrence was greatest in Cove, Wahkon, Vineland, Shabushkung, and Isle bays where plants were found in at least 40% of sites. In Twin, Wealthwood, and Wigwam bays, plant occurrence ranged from 25% to 31%. Vegetation was sparse in Malmo Bay where plants were detected in only 2% of sites.
- A total of 49 different plant taxa were found and included 28 submerged, three free-floating, six floating-leaf and 12 emergent plants.
- The greatest number of plant taxa was found in water depths from 0-5 feet. The nearshore plots provide detailed data on this zone that are not available from the point-intercept survey alone.
- The most frequently occurring submerged taxa were native species: northern watermilfoil (*Myriophyllum sibiricum*), wild celery (*Vallisneria americana*), coontail (*Ceratophyllum demersum*), white-stem pondweed (*Potamogeton praelongus*) and variable pondweed (*Potamogeton gramineus*), with each found in at least 5% of all sites (0-15 feet depth zone).

Changes in Submerged Plants in Selected Bays (Chapter 5 and 6)

- Aquatic plant species composition and diversity was similar between the three bays.
- Several species varied in abundance between years but for most species, there were no strong patterns of change.
- Non-native submerged plants were a minor part of the plant community, occurring in less than 10% of sites in any bay.

- No significant change in plant occurrence was detected in Isle Bay (2009-2014) or Cove Bay (2009-2019).
- In Vineland Bay, plant occurrence was highest (at least 55% of sites were vegetated) in 2009 and 2010 with the greatest plant occurrence in the 6 to 10 feet depth zone. There was a declining trend in occurrence from 2014 to 2019 (mean of 46% sites were vegetated) and plant occurrence was highest in the 0 to 5 feet zone.
    - water celery (*Vallisneria americana*) frequency fluctuated annually in Vineland Bay and within the nearshore plots of this Bay, it increased from 24% in 2017 to 68% in 2019. Longer term monitoring of this species may help determine if there are consistent patterns in the annual frequency of this species.
    - In Vineland Bay, northern watermilfoil (*Myriophyllum sibiricum*) declined in distribution and frequency through the study period and by 2019 it was detected in only three sites and appeared restricted to only the small isolated bay. This species has declined in other Minnesota lakes, particularly in lakes where water clarity has declined. Longer term monitoring of the Mille Lacs populations will be important.
    - Eurasian watermilfoil is providing the only deep water (>10 feet) aquatic plant habitat within Vineland Bay. Its distribution and occurrence has remained fairly stable over this 10 year study period.

Submerged plant height and biovolume (Chapter 7)

- Plant frequency of occurrence, heights, and biovolume were assessed in Cove Bay, Vineland Bay and Wealthwood in 2014 and 2017.

Zebra mussels (Chapters 4 and 5)

- This survey was not intended to provide lakewide estimates of zebra mussel abundance. Our survey likely underestimated the distribution and abundance of zebra mussels because we did not survey all available habitat and we relied on rake tosses to collect zebra mussels.
- In the bays where zebra mussel detection rate was tracked after several years zebra mussels were detectable through the entire bay and at all depths within the 0 to 15 feet depth zone.
- The results were not sufficient to determine whether zebra mussels preferentially attach to certain types of aquatic plants.

# CHAPTER 1. OVERVIEW AND LAKE DESCRIPTION OF MILLE LACS LAKE

## INTRODUCTION

Mille Lacs Lake is Minnesota's second largest inland lake, with a surface area of about 128,000 acres. It is nationally recognized for its natural resources including premier walleye, smallmouth bass and muskie fisheries. In recent years, lake managers have detected changes in the lake clarity and fish and zooplankton populations along with introductions of non-native aquatic species. There have been perceived, but undocumented, changes in the aquatic plant community and there is concern that such changes in lake habitat may further impact lake quality and the fishery.

This report describes the plant communities of Mille Lacs based on historic surveys and field assessments conducted between 2009 and 2019. For current assessments, we used a tiered survey method approach to assess multiple components of lake and shoreline habitat. In selected bays, we repeated surveys to estimate short term changes in plant growth and diversity. These baseline data may also be used to identify specific lake areas that may warrant additional assessments and monitoring.

## OVERVIEW OF REPORT

This report is divided into chapters that describe the objective and methodology of each survey, the lake areas assessed and the years when each area was assessed by that method (Table 1.1 and Figure 1.1).

## LAKE DESCRIPTION

Mille Lacs is located in east-central Minnesota and occupies portions of Mille Lacs, Aitkin and Crow Wing counties (Figure 1.2). It lies at the top of the Rum River Watershed and serves as the headwaters for the Rum River. All of the land within the watershed drains south through the Rum River, which then flows into the Mississippi River at the city of Anoka. The northern portion of the watershed is primarily forested and land surrounding Mille Lacs Lake includes a mix of agricultural, forested and recreational land. Shoreland ownership includes private lands, Mille Lacs Band of Ojibwe, State of Minnesota, and Mille Lacs County.

Shoreland development includes the cities of Garrison, Isle, and Wahkon, numerous resorts and private residential homes. Paved two and four-lane highways occur around the entire perimeter of the lake and include State Highways 169, 18, 47, and 27. In most areas, these highways are within 500 feet of the lake. Lake access is available through 11 public boat launches and numerous private man-made harbors.

## LAKE PHYSICAL CHARACTERISTICS

Mille Lacs is the second largest lake located entirely within the boundaries of Minnesota. The lake is roughly oval in outline, reaching about 18 miles long from north to south with an average width of 14 miles and a total shoreline perimeter of 105 miles. It is a heavily windswept waterbody with a maximum fetch of 21 miles.

The lake substrates include rock, gravel, and sand in the shallow areas with sedimented deposits (muck or mud flats) in the deeper, northwest center portions (Heiskary 1992, RMB 2008). Large protected bays on the southern half contain areas of soft substrates while the windswept north shore is primarily sandy. Ten islands occur in the south half of the lake and range in size from 0.1 to 37 acres. Malone Island located in Isle Bay is the largest island on the lake and is highly developed with houses. The two smallest boulder islands (Spirit and Hennepin) are a National Wildlife Refuge and are known breeding grounds for Common Terns.

Mille Lacs is a drainage lake and receives inflow from about 12 to 14 perennial streams (Figure 1.3). The Rum River is the only outlet and drains the lake to the south. Water level fluctuates in response to precipitation events but remain fairly stable between years.

The lake is primarily shallow with a mean depth of 28.5 feet and about a fourth of the basin is less than 16 feet in depth (Figure 1.4). The basin slopes gradually to a maximum depth of 42 feet and there are extensive offshore shallow gravel reefs and sand bars. Little thermal stratification occurs due to shallow waters and heavy mixing by wind. Mille Lacs Lake is characterized as a mesotrophic (moderately fertile), hard water lake.

## ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH IN MILLE LACS

### ***Light***

The depth to which macrophytes can grow is greatly influenced by light availability and light quality (Canfield et al. 1985, Spence 1981). Based on water clarity, aquatic plants would be expected to commonly occur to depths of at least 15 feet in Mille Lacs. However, other environmental factors that influence plant growth include water level, water temperature (Dale 1986), substrate type, wind fetch and plant life history (Jonsson and Esseen 1998). The windswept nature of the lake and the predominance of hard substrates limits rooted plant growth in the lake. Shallow protected areas, such as harbors and shallow areas of bays, are more likely to support plant growth than are high energy, windswept shores and offshore reefs of Mille Lacs.

Water clarity data are sparse and disjointed for Mille Lacs. There are indications that clarity has increased since the mid-1980's. Before 1992, average summer Secchi disk readings (June through September) were nine feet. Between 2008 and 2017, average summer Secchi disk readings were 10 feet (MPCA 2014).

Winter light conditions also influence aquatic plant growth. In winters with heavy snow cover, light conditions may not be sufficient to allow plants to continue to grow under the ice. Prolonged ice cover and late, cooler temperatures in the Spring can further limit plant growth. Comparison of annual ice out dates can help discern whether Winter and Spring growth conditions varied greatly between years. On Mille Lacs, for the years the surveys were conducted, ice out dates varied as much as 30 days: 4/24/2009, 4/5/2010, 5/7/2014, 4/25/2017, and 4/28/2019. More specific information on actual snow depth and density and site specific water temperature would be needed to specifically understand how site conditions varied annually.

## NON-NATIVE AQUATIC ANIMAL SPECIES

Several non-native aquatic species occur in Mille Lacs Lake including Common carp, Zebra mussels, Chinese mystery snail, Banded mystery snail, and Spiny waterfleas are also present in Mille Lacs. Species such as carp can directly impact vegetation by uprooting plants, disturbing substrates, and decreasing clarity. Other non-native organisms may indirectly impact plant growth. Management activities to control non-native species may also directly or indirectly impact native plants.

Zebra mussels (*Dreissena polymorpha*) are non-native mussels that were first detected in Minnesota in 1989 and were discovered in 2005 in Mille Lacs. Large numbers of these mussels may lead to decreased phytoplankton and increased water clarity through their filter feeding of fine organic matter. In other lakes where zebra mussel populations increased water clarity, submerged macrophytes have responded by colonizing deeper water and increasing in abundance (Skubinna et al.1995). The trend of increasing water clarity in Mille Lacs may, in part be associated with recent introduction and expansion of zebra mussels.

Spiny waterfleas (*Bythotrephes cederstroemi*) are non-native, fast reproducing predatory zooplankton that can compete with small fish for zooplankton. They were first discovered in Mille Lacs Lake in 2009 and monitoring suggests that the native zooplankton community has been dramatically altered since their discovery in the lake (Hirsch 2006). There are no known direct impacts of this zooplankton to aquatic plants but there may be indirect impacts if it leads to altered zooplankton and phytoplankton communities. For example, heavy predation on cladoceran zooplankton grazers could result in less pressure on the algal community and possibly reduced water clarity.

# AQUATIC VEGETATION OF MILLE LACS

## HISTORICAL PLANT DATA

Because of the size of Mille Lacs, lakewide vegetation surveys have not been attempted but various surveyors have recorded plant information from selected areas of the lake. Most of these assessments were botanical collections and descriptive summaries not quantitative surveys. These surveys did not attempt to assess the plant community on a lake wide basis. Nevertheless, these historical data provide an overall account of the types and amounts of plant life in the lake.

Between 1892 and 2004, various botanists and fishery biologists surveyed selected bays or shorelines of Mille Lacs and made notes and/or collected voucher specimen collections of some of the aquatic plant species they encountered. These surveys varied in the areas searched, the botanical knowledge of the surveyors and the survey goals. Plant species may have been present in the lake, and even encountered by the surveyor, but not recorded.

Early surveys described the value of aquatic plants for waterfowl: "*Several bays of the lake are good areas for ducks. Wigwam Bay is said to be the best. It has little vegetation, but White Fish Lake with good duck food in it is near. Cove and Wahkon are also good duck bays*." (Hotchkiss 1940). Surveyors also commented on the impact of heavy waves on the lake vegetation*: "Submerged plants grew to 15-20 foot depth. Emergent vegetation grew in large beds around the shore but were not dense because of wave action"* (Rasmussen and Melmquist 1954). In recent years, MNDNR fisheries biologists have noted that vegetation is most abundant along the 10 foot contour where wave action has less effect (MNDNR 1996). The most comprehensive assessment of Mille Lacs vegetation was conducted between 1992 and 1996 when MNDNR Fisheries biologists mapped the substrate and aquatic vegetation in the shoal areas (MNDNR Anon. 1996).

The largest group of plants previously reported in Mille Lacs (Table 1.2) are submerged and include 25 different taxa including plants that are commonly found in central Minnesota lakes: pondweeds (*Potamogeton* spp.), northern watermilfoil (*Myriophyllum sibiricum*), coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), and Canada waterweed (*Elodea canadensis*), five free-floating (duckweeds), six floating-leaved plants (including waterlilies), and 22 emergent taxa have also been recorded in the lake or adjacent shoreline.

## NON-NATIVE AQUATIC PLANTS

Two non-native submerged taxa, curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) have been previously documented in the lake. Both are rooted submerged plants with habitat requirements similar to native submerged plants. Their growth is limited to shallow waters where their roots can penetrate the substrate. In Mille Lacs, they have primarily been found in shallow protected areas of harbors and bays.

Curly-leaf pondweed has been present in Minnesota since at least 1900. It was first located in harbors of Mille Lacs Lake in the early 1990's. The plant does not interfere with recreational boating on the lake and no large scale management is conducted.

Eurasian watermilfoil was first found in Mille Lacs in 1998 in several harbors along the western shore. The first documentation of the plant in the main lake was in 2006. In an effort to limit the spread to other lakes, herbicide has been applied to some harbors where Eurasian watermilfoil has been observed. Eurasian watermilfoil and northern watermilfoil (*Myriophyllum sibiricum*) can hybridize and the offspring has features that are intermediate between the two parents (Moody and Les 2002). In 2017 and 2018, Eltawely et al. (2020), collected and analyzed about 100 samples of watermilfoil plants from Mille Lacs and did not detect any hybrid plants. Hybrid watermilfoil can enter Mille Lacs in two ways: 1) because both parents are present in the lake, there is a potential for them to mate and create hybrid offspring and 2) hybrid watermilfoil plants that have been confirmed in other Minnesota lakes could be transported to Mille Lacs on recreational watercraft or by other vectors. Recent studies suggest that hybrid watermilfoil may be resistant to some herbicides and therefore more difficult to kill than Eurasian watermilfoil (LaRue et. al 2013, Thum and McNair 2018).

## RARE PLANTS

Narrow-leaved water plantain (*Alisma graminea*) is a rare species of Special Concern in Minnesota. It is primarily a submerged aquatic plant and may occasionally emerge above the water. The name "graminea" means "grass-like" and refers to the linear leaves that arise from the base of the plant. This is a perennial plant that overwinters by rhizomes. It is a flowering plant and the small purple and white flowers may remain entirely submerged or may occasionally be above water in very shallow water and on mudflats.

The narrow leaves of this plant are well adapted to windswept shores and it has been most often located in shallow (less than 3 feet) waters along sandy shores of larger lakes. It was first documented in Mille Lacs in 1934 and then relocated in 1998. This plant was not observed during the 2009 to 2019 plant surveys but it is likely still present in the lake. Narrow-leaved water plantain is not easily collected on rake samples and is easily overlooked.

The best time to search for this plant is in late summer and on calm days when surveyors can visually search for underwater plants from the lake surface. More information on this plant can be found in MN MNDNR's Rare Species Guide: MNDNR Rare Species Guide.

## TABLE 1.1. INDEX OF SURVEY METHODS USED IN EACH AREA OF MILLE LACS

| Ch. | Objective | Method | Lake Area | Survey Year(s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2009 | 2010 | 2014 | 2016 | 2017 | 2019 |
| 2 | Identify the location and quality of remaining shoreline habitat | Score the Shore | lakewide | | | | X | | |
| 3 | Map and describe the remaining stands of emergent and floating-leaf plant stands | GPS delineation | Cove | X | | | | | |
| | | | Vineland | | | X | | | |
| | | | Isle | | | X | | | |
| 4 | Assess lakewide diversity, distribution and occurrence of lake plants<br>Assess yearly differences in lake plant communities in selected bays<br>Estimate zebra mussel occurrence on plants | Point-intercept | Cove | X | X | X | | X | X |
| | | | Vineland | X | X | X | | X | X |
| | | | Isle | X | X | X | | | |
| | | | Wahkon | X | | | | | |
| | | | Twin Bay | X | | | | | |
| | | | Malmo | X | | | | | |
| | | | Wealthwood | X | | | | | |
| | | | Wigwam Bay | X | | | | | |
| | | | Shabushkung | X | | | | | |
| 5 | Assess nearshore plant diversity | Nearshore plots | Vineland | | | | | X | X |
| | | | Cove | | | | | X | X |
| 6 | Evaluate plant height differences between bays and between survey years | Hydroacoustics | Vineland | | | X | | X | X |
| | | | Wealthwood | | | X | | X | |
| | | | Cove | | | | | | X |

## TABLE 1.2. AQUATIC PLANTS OBSERVED IN MILLE LACS LAKE FROM 1918 TO 2019

### ***Submerged plants***

| Common Name | Scientific Name | 1918-1930 | 1933-1938 | 1954 | 1971 | 1986-1988 | 1996-1998 | 2004 | 2009-2019 | Recent voucher |
|---|---|---|---|---|---|---|---|---|---|---|
| Narrow-leaved water plantain | *Alisma gramineum (SPC)* | | X | | | | X | | | |
| Water marigold | *Bidens beckii* | | | | | | X | | X | |
| Coontail | *Ceratophyllum demersum* | | | | | X | X | | X | x |
| Hornwort | *Ceratophyllum echinatum* | | | | | | | | X | x |
| Muskgrass* | *Chara* sp. | | | | | | X | | X | x |
| Canada waterweed | *Elodea canadensis* | | | | | X | X | X | X | x |
| Water star-grass | *Heteranthera dubia* | | | | | | X | X | X | x |
| Quillwort | *Isoetes* sp. | | | | | | | | X | x |
| Northern watermilfoil | *Myriophyllum sibiricum* | X | X | | | X | X | | X | x |
| Eurasian watermilfoil (I) | *Myriophyllum spicatum* | | | | | | | | X | x |
| Leafless watermilfoil | *Myriophyllum tenellum* | | | | | | | | X | |
| Whorled watermilfoil | *Myriophyllum verticillatum* | | | | | | | | X | |
| Bushy pondweed | *Najas flexilis* | X | | | | X | X | | X | |
| Southern naiad | *Najas guadalupensis* | | | | | | | | X | x |
| Stonewort* | *Nitella* sp. | | | | | | X | | X | x |
| Large-leaf pondweed | *Potamogeton amplifolius* | | | | | | X | | X | x |
| Curly-leaf pondweed (I) | *Potamogeton crispus* | | | | | | X | X | X | x |
| Ribbon-leaf pondweed | *Potamogeton epihydrus* | | | | | X | X | | X | x |
| Narrow-leaf pondweed group | *Potamogeton friesii* | | | | | | | | | |
| | *Potamogeton pusillus* | | X | | | | X | X | X | |
| | *Potamogeton* sp. | | | | | | X | | | |
| Variable pondweed | *Potamogeton gramineus* | | | | | | X | | X | x |
| Illinois pondweed | *Potamogeton illinoensis* | | X | | | | X | | X | x |
| River pondweed | *Potamogeton nodusus* | | | | | | X | | | |
| White-stem pondweed | *Potamogeton praelongus* | | | | | | X | | X | x |
| Clasping leaf pondweed | *Potamogeton richardsonii* | X | X | | | X | X | X | X | x |

## ***Submerged plants (continued)***

| Common Name | Scientific Name | 1918-1930 | 1933-1938 | 1954 | 1971 | 1986-1988 | 1996-1998 | 2004 | 2009-2019 | Recent voucher |
|---|---|---|---|---|---|---|---|---|---|---|
| Robbin's pondweed | *Potamogeton robbinsii* | | | | | | X | | X | x |
| Spiral pondweed | *Potamogeton spirillus* | | | | | | | | X | x |
| Flat-stem pondweed | *Potamogeton zosteriformis* | | | | | X | X | | X | |
| White water buttercup | *Ranunculus aquatilis* | | | | | | X | | X | x |
| Creeping spearwort | *Ranunculus flammula* | X | | | | | X | | X | x |
| Sago pondweed | *Stuckenia pectinata* | | | | | X | X | | X | x |
| Greater bladderwort | *Utricularia vulgaris* | | | | | | X | | X | x |
| Flat-leaved bladderwort | *Utricularia intermedia* | | | | | | | | X | |
| Humped bladderwort | *Utricularia gibba* | | | | | | | | X | |
| Wild celery | *Vallisneria americana* | | | | | X | X | X | X | x |
| Watermoss | *Drepanocladus sp.* | | | | | | X | | X | |
| | **total** | 4 | 4 | 1 | 0 | 9 | 27 | 6 | 35 | |

## ***Free-floating plants***

| Common Name | Scientific Name | 1918-1930 | 1933-1938 | 1954 | 1971 | 1986-1988 | 1996-1998 | 2004 | 2009-2019 | Recent voucher |
|---|---|---|---|---|---|---|---|---|---|---|
| Lesser duckweed | *Lemna* sp.# | | | | | X | X | | X | |
| Star duckweed | *Lemna trisulca* | | | | | | X | | X | |
| Crystalwort | *Riccia fluitans* | | | | | | | | X | |
| Greater duckweed | *Spirodela polyrhiza* | | | | | | X | | X | |
| Watermeal | *Wolffia columbiana* | | | | | | X | | | |
| | **total** | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 4 | |

## ***Floating-leaved plants***

| Common Name | Scientific Name | 1918-1930 | 1933-1938 | 1954 | 1971 | 1986-1988 | 1996-1998 | 2004 | 2009-2019 | Recent voucher |
|---|---|---|---|---|---|---|---|---|---|---|
| Watershield | *Brasenia schreberi* | | | | | | X | | | |
| Floating-leaf smartweed | *Persicaria amphibia* | | | | | X | X | | X | |
| Floating leaf pondweed | *Potamogeton natans* | | | | | | X | | X | |
| White waterlily | *Nymphaea odorata* | | | X | | X | X | | X | |
| Yellow waterlily | *Nuphar variegata* | | | | | X | X | | X | |
| Narrow-leaf burreed | *Sparganium emersum* | | | | | | X | | | |
| Floating-leaf burreed | *Sparganium fluctuans* | | | | | | X | | X | |
| | **total** | 0 | 0 | 1 | 0 | 3 | 7 | 0 | 5 | |

## ***Emergent plants***

<table>
<tr><th>Common Name</th><th>Scientific Name</th><th>1918-1930</th><th>1933-1938</th><th>1954</th><th>1971</th><th>1986-1988</th><th>1996-1998</th><th>2004</th><th>2009-2019</th><th>Recent voucher</th></tr>
<tr><td>River bulrush</td><td>Bolboschoenus fluviatilis</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Needlerush</td><td>Eleocharis acicularis</td><td>X</td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Intermediate spikerush</td><td>Eleocharis intermedia</td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Marsh spikerush</td><td>Eleocharis palustris</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Spikerush</td><td>Eleocharis sp.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td>x</td></tr>
<tr><td>Spikerush</td><td>Eleocharis smallii</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Horsetail</td><td>Equisetum fluviatile</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Giant cane</td><td>Phragmites australis</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Arrowhead</td><td>Sagittaria sp.</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Arrowhead</td><td>Sagittaria cuneata</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>Crested arrowhead</td><td>Sagittaria cristata</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Broad-leaved arrowhead</td><td>Sagittaria latifolia</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Sessile-fruited arrowhead</td><td>Sagittaria rigida</td><td></td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Hardstem bulrush</td><td>Schoenoplectus acutus</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td rowspan="2">*X</td><td></td></tr>
<tr><td>Soft-stem bulrush</td><td>Schoenoplectus tabernaemontani</td><td>X</td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Three-square bulrush</td><td>Schoenoplectus pungens</td><td></td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Blunt-scale bulrush</td><td>Schoenoplectus smithii</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Giant burreed</td><td>Sparganium eurycarpum</td><td></td><td rowspan="2">X</td><td></td><td></td><td></td><td>X</td><td></td><td>*X</td><td></td></tr>
<tr><td>Green-fruited burreed</td><td>Sparganium chlorocarpum</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Broad-leaved cattail</td><td>Typha latifolia</td><td></td><td></td><td rowspan="2">X*</td><td></td><td>X</td><td>X</td><td></td><td rowspan="2">X</td><td></td></tr>
<tr><td>Narrow-leaved cattail</td><td>Typha angustifolia</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Wild rice</td><td>Zizania palustris</td><td></td><td>X</td><td></td><td>X</td><td>X</td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td></td><td>total</td><td>2</td><td>9</td><td>3</td><td>1</td><td>3</td><td>20</td><td>0</td><td>14</td><td></td></tr>
</table>

## ***Wetland emergent plants***

| Common Name | Scientific Name | 1918-1930 | 1933 | 1934 | 1938 | 1954 | 1971 | 1986-1988 | 1996-1998 | 2004 | 2009-2019 | Recent voucher |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sweet flag | *Acorus americanus* | X | | | | | | | | | | |
| Swamp milkweed | *Asclepias incarnata* | | | | | | | | X | | | |
| Nodding bur-marigold | *Bidens cernua* | | | | | | | | X | | | |
| Blue-joint grass | *Calamagrostis canadensis* | | | | | | | | X | | | |
| Water arum | *Calla palustris* | | | | | | | | X | | X | |
| Aquatic sedge | *Carex aquatilis* | | | | | | | | X | | | |
| Bottlebrush sedge | *Carex comosa* | | | | | | | | X | | | |
| Hummock sedge | *Carex stricta* | | | | | | | | X | | | |
| Bulb-bearing water-hemlock | *Cicuta bulbifera* | | | | | | | | X | | | |
| Jewelweed | *Impatiens capensis* | | | | | | | | X | | X | |
| Blue flag | *Iris versicolor* | | | | | | | | X | | | |
| Knotty rush | *Juncus nodosus* | X | | | | | | | | | | |
| Northern bugleweed | *Lycopus uniflorus* | | | | | | | | X | | | |
| Purple loosestrife (I) | *Lythrum salicaria* | | | | | | | | X | | X | |
| Reed canary grass (I) | *Phalaris arundinaceae* | | | | X | | | | X | | X | |
| Pickerelweed | *Pontederia cordata* | | | | | | | | X | | | |
| Icelandic yellow cress | *Rorrippa palustris* | | | X | | | | | | | | |
| Great water dock | *Rumex britannica* | | | | | | | | X | | | |
| Sand-bar willow | *Salix interior* | | | | | | | | X | | | |
| Skullcap | *Scutellaria* sp. | | | | | | | | X | | | |
| | **total** | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 17 | 0 | 4 | |

SPC = rare species of Special Concern
I = introduced
*some plants were identified only to genus level in this year
[X]Several species were collected and sent to an expert for identification. Results are pending. ***Recent Voucher = specimen collected and pressed within last 20 years***

***#Lemna was identified only to species except in 1997 when an expert confirmed the identity of one specimen as Lemna turionifera.***

**Figure 1.1. Vegetation survey areas by year**

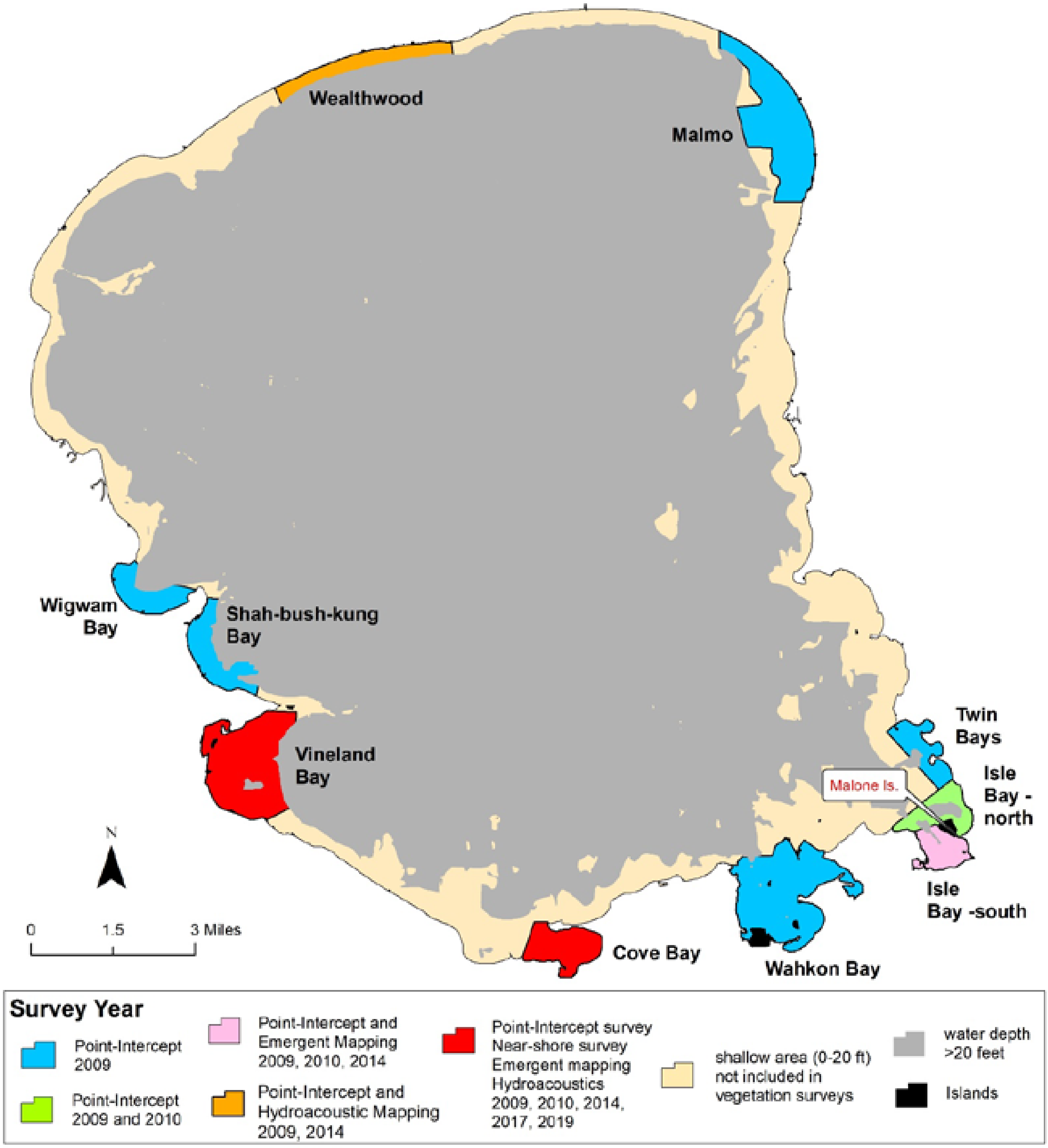


**Figure 1.2. Mille Lacs Lake in Rum River Watershed.**

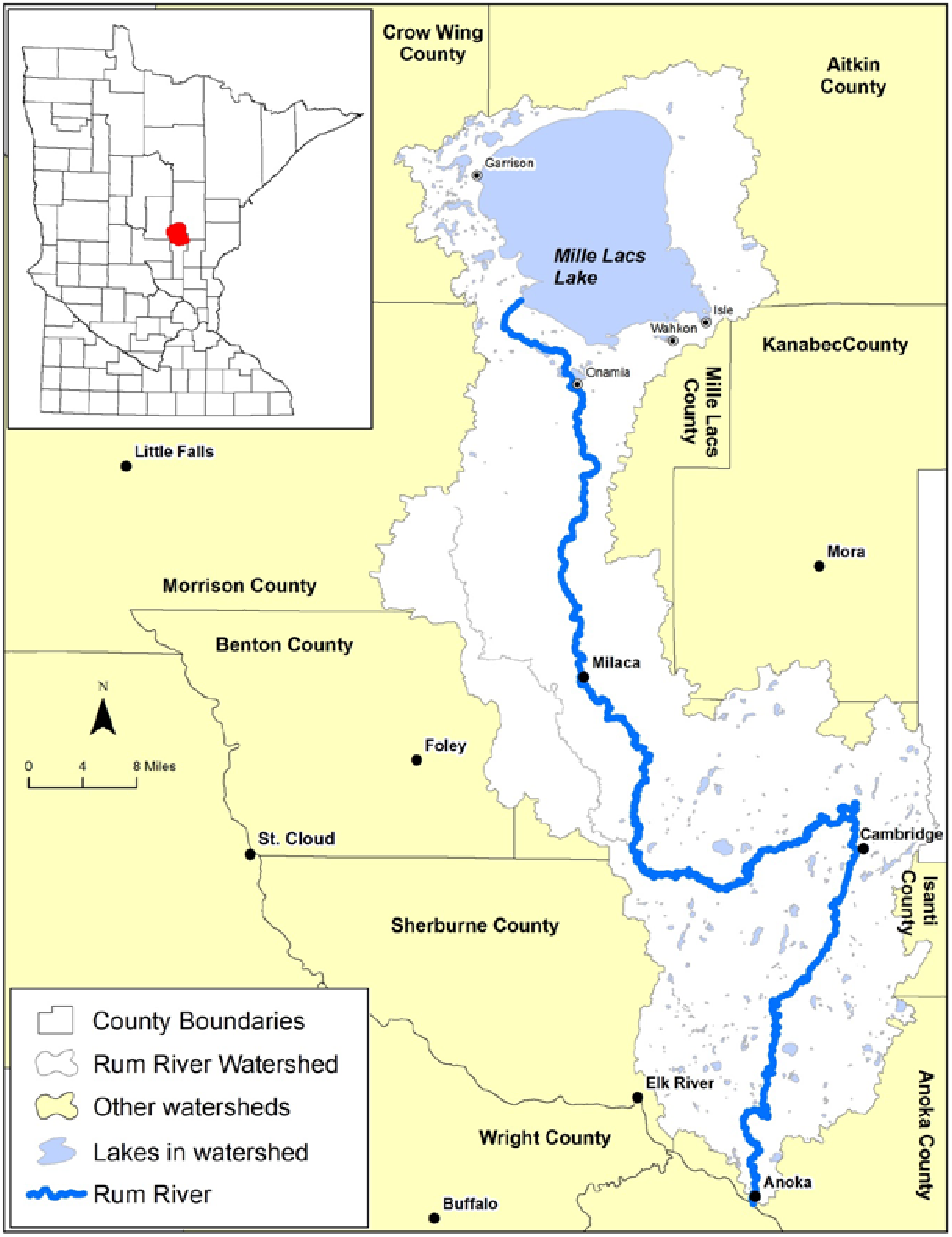


**Figure 1.3. Inlets and outlets of Mille Lacs.**

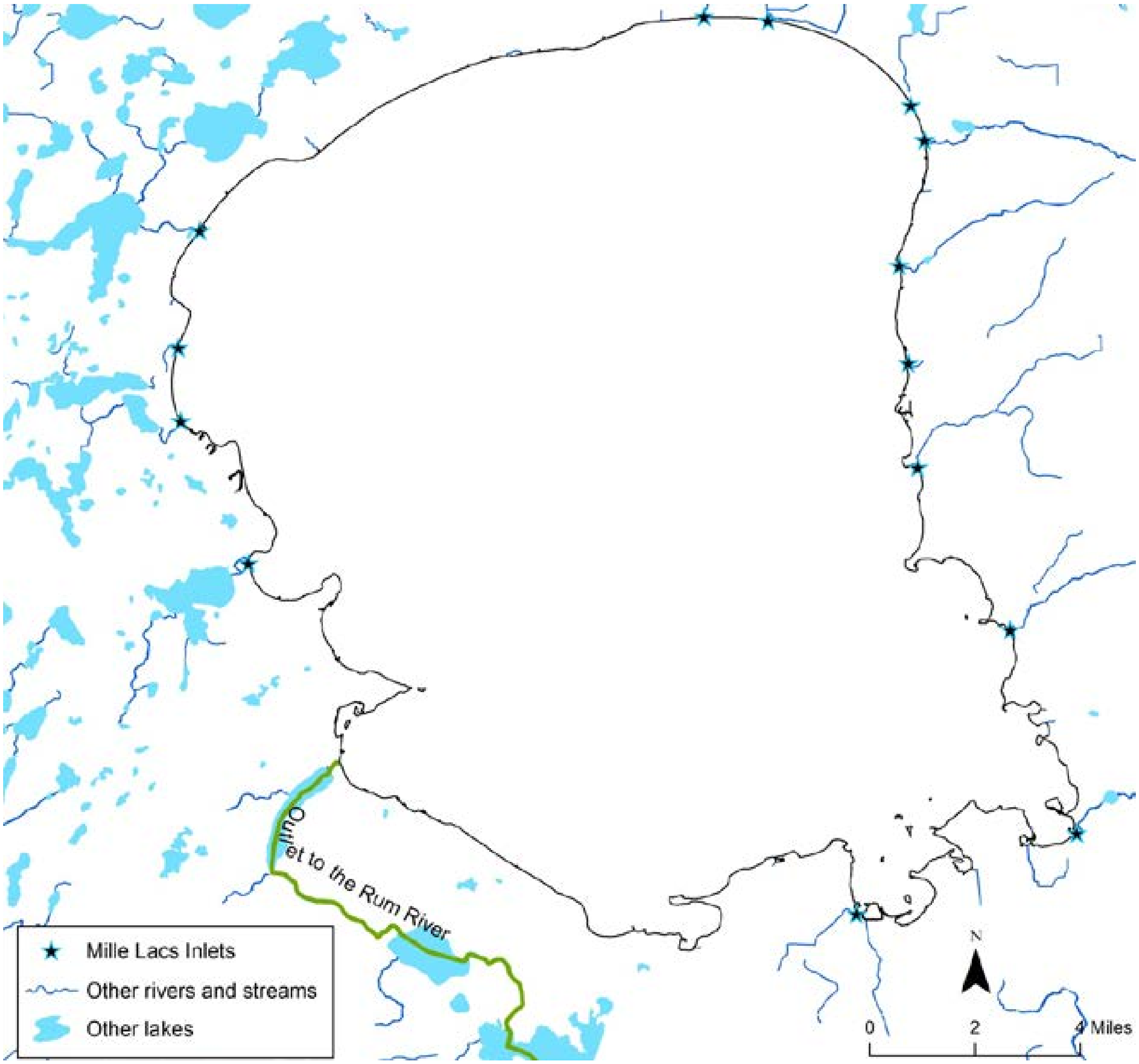
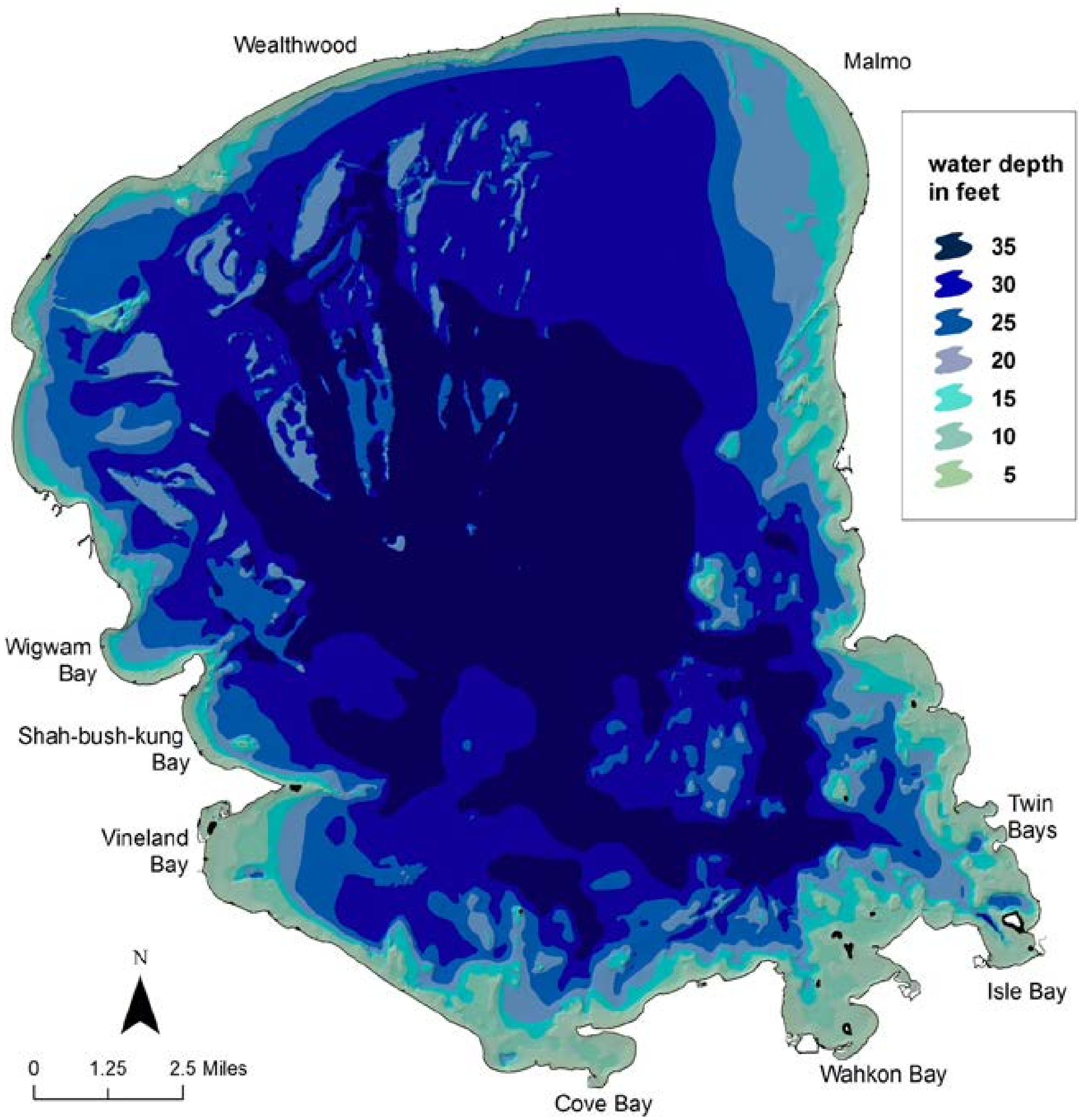


**Figure 1.4. Depth contours of Mille Lacs Lake.**



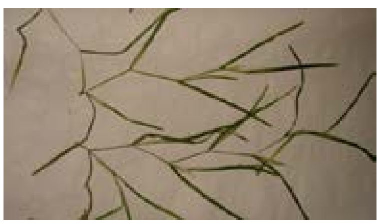
## Figure 1.5. Photos of selected submerged plant species of Mille Lacs vegetation

Northern watermilfoil *(Myriophyllum sibiricum)*

Coontail *(Ceratophyllum demersum)*

Wild celery (*Vallisneria americana*)

Flat-stem pondweed (*Potamogeton zosteriformis*)



Canada waterweed *(Elodea Canadensis)*

Sago pondweed *(Stuckenia pectinata)*

Curly-leaf pondweed *(Potamogeton crispus)*

Large-leaf pondweed *(Potamogeton amplifolius)*

Eurasian watermilfoil *(Myriophyllum spicatum)*

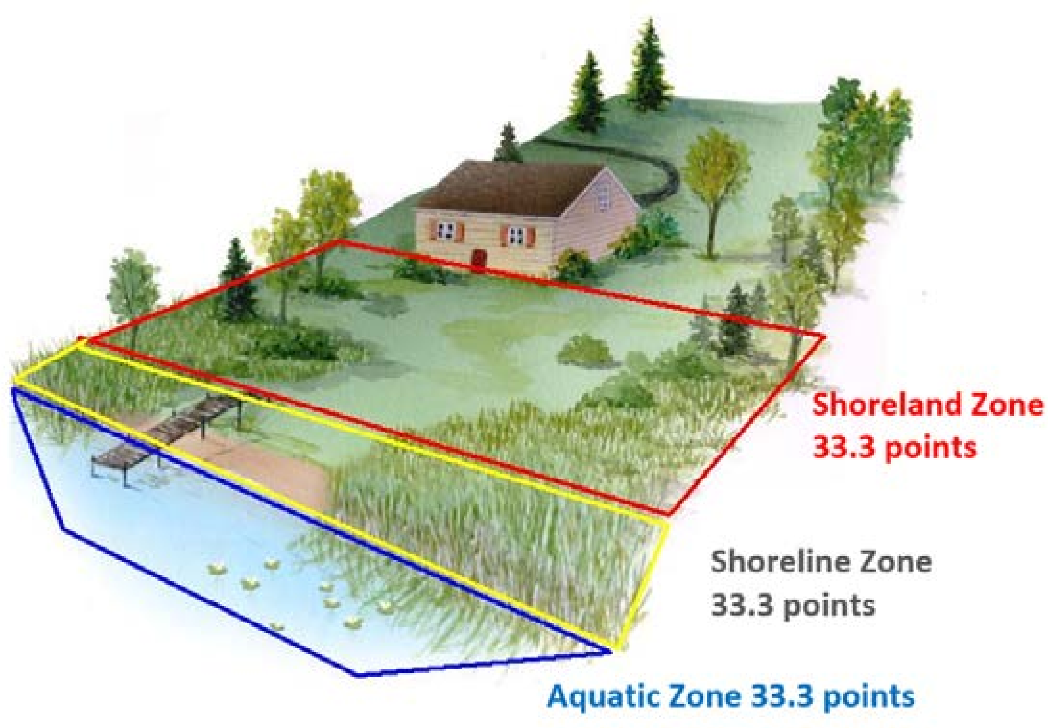
# CHAPTER 2. LAKE SHORE HABITAT (SCORE THE SHORE)

## INTRODUCTION

Shore habitat loss has been identified as the largest problem adversely affecting the health of lakes in the United States (US EPA 2010). Natural lake shores are unique transition zones between the land and water and provide valuable ecological services that benefit wildlife and water quality. Natural shores may include multiple canopies of habitat from the upland into the water: a mix of live and dead trees, shrubs, wildflowers, grasses and rocks, shallow water plants, and submerged woody habitat. Vegetation traps sediments and nutrients, filters water as it flows from the upland into the lake or river, and reduces wave action that can erode shores. Fish and wildlife use this habitat mosaic in a variety of ways: as shade from sunlight, refuge from predators, spawning and nesting sites, and for foraging. As people recreate and build on lakes critical areas for fish and wildlife and important filtering and stabilization effects are lost. Lake shores change from naturally vegetated areas to 'domesticated' sites of turf grass and hard surfaces with sparse or no vegetation.

Lake shores are gradients from upland to water but it is useful to think of them in terms of “zones” that are used differently by both wildlife and humans (Figure 2.1).

**Figure 2.1. Score the Shore habitat zones.**



The Shoreland Zone is the portion of land that is most likely to be developed and approximates the required minimum setback distance for shoreland structures.

The Shoreline Zone is the portion of land between the Shoreland and Aquatic Zones. It begins at the water's edge and extends landward to the bank. This zone may be narrow or broad, depending on the slope.

The Aquatic Zone begins at the land-water interface and extends lakeward 50 feet. It includes shallow water where rooted aquatic plants may grow; this is also the zone of a lake most likely to be utilized and impacted by riparian residents.

## METHODS

In 2016, Mille Lacs shore habitat was assessed by boat using Score the Shore method (Perleberg et al. 2019). The shores of the larger islands were included in the survey.

Objectives are:

1. Describe lake shore development patterns around the lake
2. Estimate the amount of remaining lake shore habitat in each zone

Survey sites were spaced 500 meters apart around the lake perimeter for a total of 332 sites and 13 of those sites occurred on the islands. Each site included 100 meters of shore frontage for a total survey distance of 33,000 meters or about 20.5 shore miles. This represents 19% of the total shore miles of Mille Lacs. At each site, surveyors described the major land use and assessed remaining habitat within each of the three lakeshore zones.

### LAND USE

Surveyors described the major land use of each site using predefined categories (Figure 2.3). If any portion of the site appeared disturbed by humans, the entire site was classified as developed and the major type of disturbance and/or the disturbance that was closest to the lake, was used to classify the entire site. For example, sites with a residential home between the lake and a road were classified as residential home. Land use was determined independent of ownership. For example, sites that occurred with a State Park could be classified as “undeveloped” if surveyors did not detect signs of human disturbance. If no human disturbance was observed at the shore site, the site was defined as undeveloped and then further categorized as undeveloped upland or undeveloped wetland.

### HABITAT FEATURES

Surveyors assessed important habitat features in each zone. A point value from 0 to 33.3, was calculated for each zone based on whether assessed features represent natural conditions (high score) or indicate human disturbance (low score). Higher scores indicate a greater amount of natural habitat. Lower scores indicate a low percent of the zone remains natural and a higher amount has been physically disturbed or altered by humans.

Scores from all three Zones were summed for an overall Site Habitat Score that can range from a low of zero to a high of 100. A lakewide score was calculated by averaging the individual scores from each survey site. Scores were described as High (85 to 100), Moderate (66 to 84), Low (50 to 65) or Very Low (0 to 50) as a simple way to compare with other lakes that have been surveyed in Minnesota.

## RESULTS

### LAND USE

The majority of shore sites (75%) were classified as developed and the main developed land use types were residential homes and roadway (Figure 2.2). Residential homes occurred on 43% of sites; about half of these sites had only one house and other sites had two or more houses within the survey area (this occurs at sites with smaller lake lots). Roadways were the main type of development on 17% of sites; although roads occur around the entire perimeter of the lake, the shore sites where roads were the main development were concentrated on the west and north shores (Figure 2.3). Other types of development included resorts, commercial campgrounds, public parks, boat accesses, campsites (a site where no building is present but human use was detected), other commercial sites, and condominiums.

Undeveloped sites accounted for 25% of the surveyed areas and about 2/3rds of these were undeveloped uplands. Concentrations of undeveloped sites occurred on the west and south shores (Figure 2.3).

**Figure 2.2. Land uses of Mille Lacs shore sites and mean habitat score for each land use classification** (out of 100 maximum points).

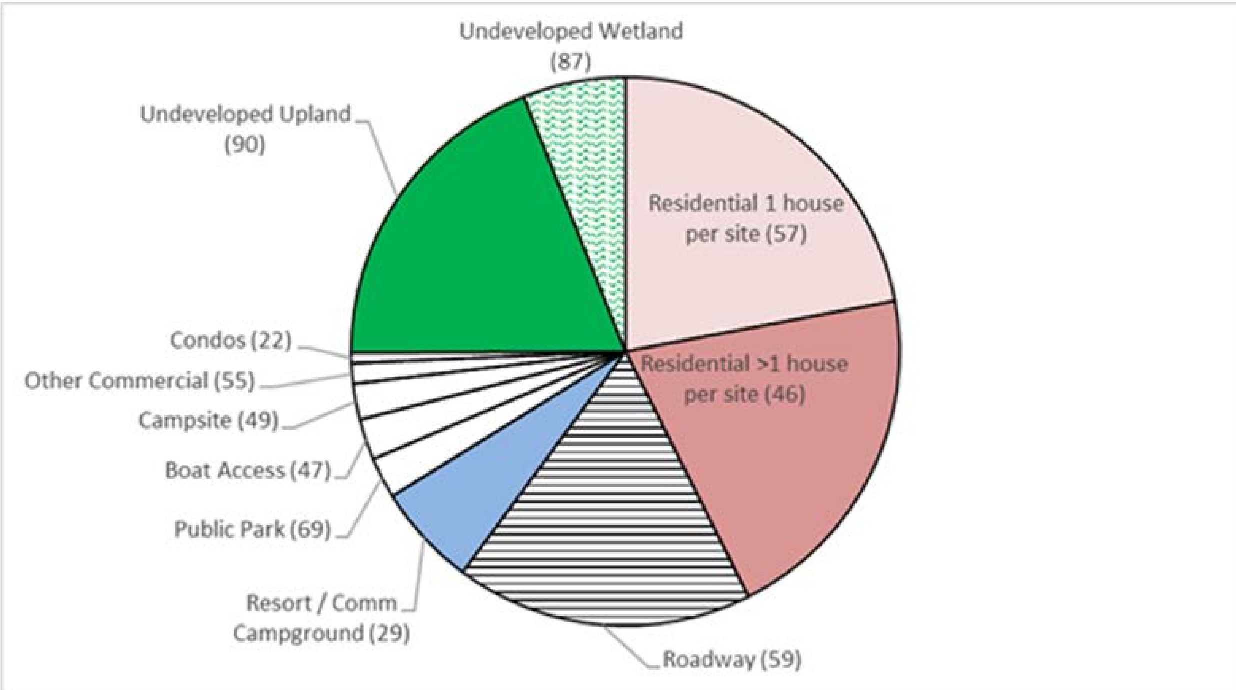
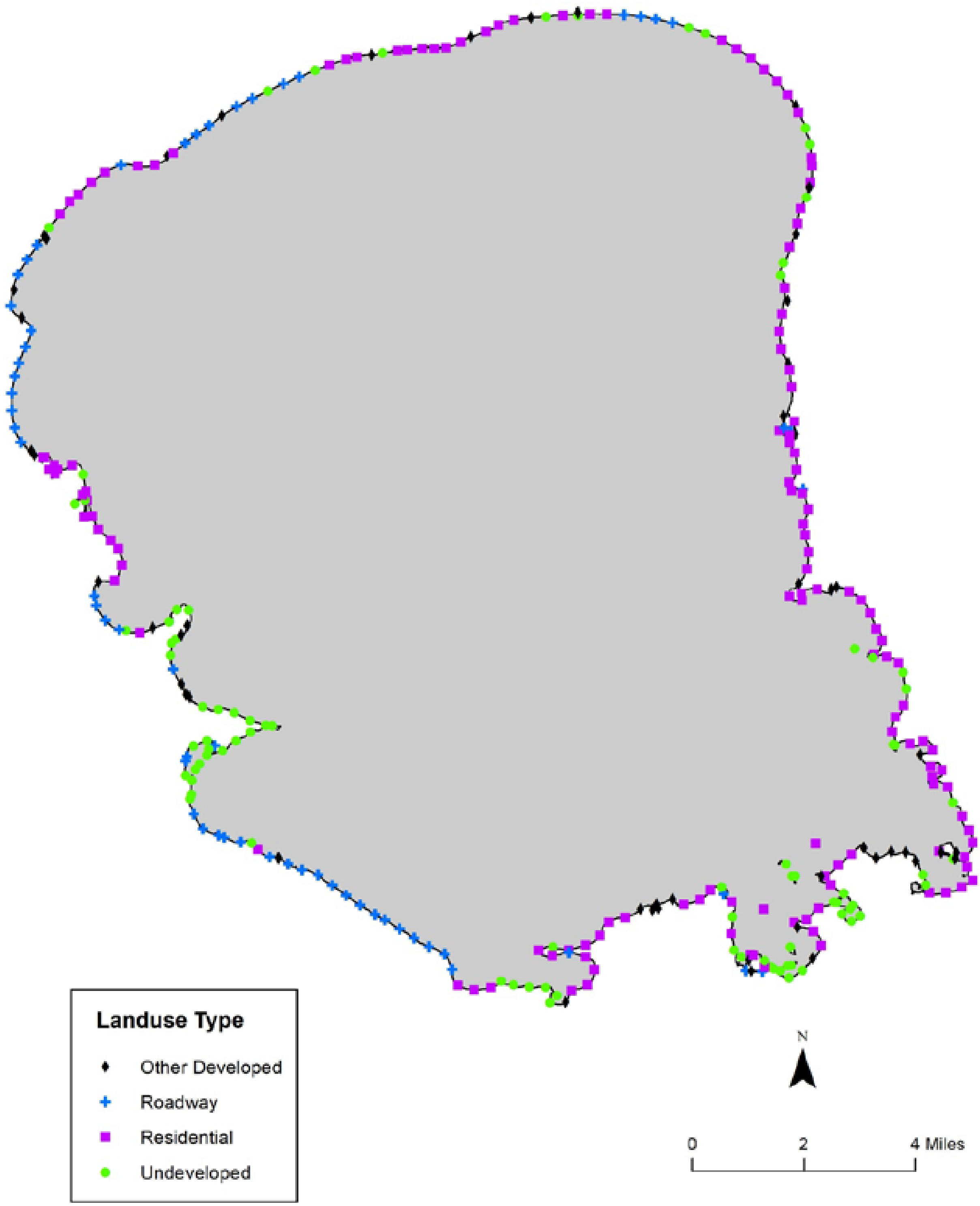


**Figure 2.3. Distribution of developed and undeveloped sites around Mille Lacs.**



## HABITAT SCORES

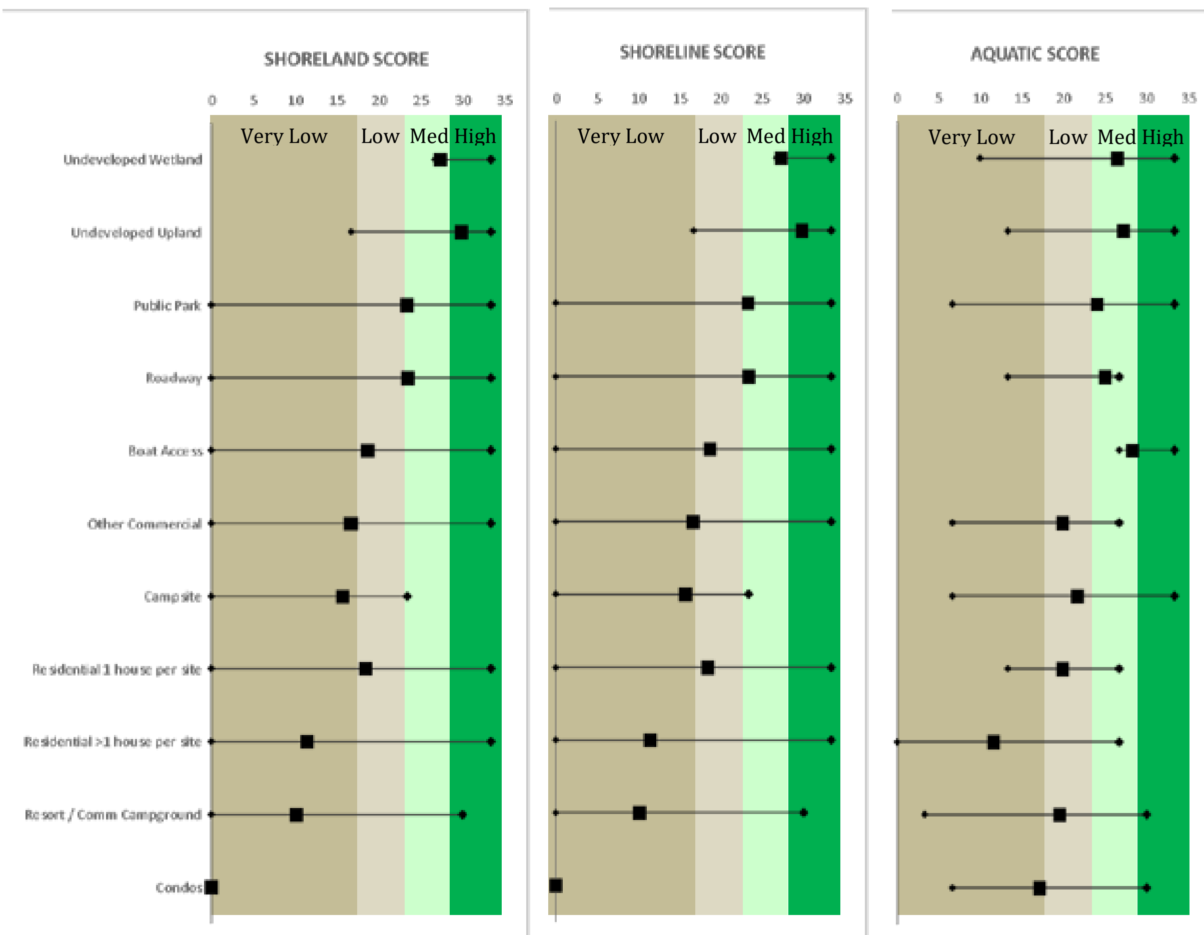
The Lakewide Habitat Score for Mille Lacs was 61, out of a possible total of 100 points. Undeveloped sites scored higher (mean score of 89) than developed sites (mean score of 52). The mean score for each land use type is shown in Figure 2.2. Within the developed categories, public parks had the highest mean score (69), followed by roadways (59), residential developments with one house on site (57), and campgrounds (49). All other developed categories had a mean score of less than 50.

Individual Zone Scores varied by land use type (Figure 2.4). Undeveloped wetland and undeveloped uplands had the highest mean scores in all three zones (Shoreland, Shoreline and Aquatic) with upland sites having higher mean scores than wetland sites. All wetland sites scored in the medium to high range for the Shoreland and Shoreline while upland sites ranged from very low to high. In the Aquatic Zone, both undeveloped wetland and undeveloped upland sites ranged from very low to high with mean scores in the medium range.

For developed sites, individual site scores ranged from high to very low in most categories. Boat accesses were the only category with a mean score in the high range for the Aquatic Zone. Public parks and roadways were the only categories with mean scores in the medium range for all three zones. All other categories had mean scores in the low to very low range for all three habitat zones.

**Figure 2.4. Habitat scores for each Zone by Land Use Type.**

(Minimum, mean and max values shown)



## COMPARISON OF MILLE LACS SHORE HABITAT WITH OTHER MINNESOTA LAKES

Statewide, MNDNR has conducted the Score the Shore survey on 727 lakes. These lakes range in size and development, but it can be useful to compare statewide habitat survey results with Mille Lacs (Table 2.1).

The percent of Mille Lacs sites classified as "developed" was 75, compared to the statewide mean of 58%. Main develop types were residential homes (43%) but this was lower than the statewide mean of 75%. Road development along shores of Mille Lacs was higher (18%) than the statewide mean.

Mille Lacs scored a lower lakewide habitat score (61 out of 100 possible points) than the statewide mean (74) and this was largely due to a lower score at developed sites compared to the statewide mean. Undeveloped sites on Mille Lacs had a mean score similar to the statewide mean.

Table 2.1. Mille Lacs Score the Shore results vs. the statewide mean

| | Mille Lacs | Statewide Mean (N=727) |
|---|---|---|
| Percent of sites classified as "developed" | 75% | 58% |
| development class is "residential home" | 43% | 75% |
| - Single home per 100 feet | 22% | 49% |
| - More than 1 home per 100 feet | 21% | 26% |
| Road present at site | 18% | 11% |
| | | |
| Mean Lakewide Score | 61 | 74 |
| Mean Score of Developed Sites | 52 | 61 |
| Mean Score of Undeveloped Sites | 89 | 92 |

## DISCUSSION

Not all lakes are developed equally. Factors that influence lake development include location, ownership, access, shore condition and lake type. Remote lakes surrounded by public land are generally undeveloped while lakes near population centers and with privately owned shores tend to be heavily developed. Historically, Minnesotan's have populated larger, deep lakes where they can enjoy recreational boating activities. Wetland protection laws and the difficult associated with building in wet areas has lessened development pressures on shallower lakes with wetland margins. Within a lake, not all shore sites are developed equally. In addition to ownership and building site suitability, site preference is influenced by personal preferences such as sandy beaches and scenic vistas of the lake.

Mille Lacs is unique among Minnesota lakes because of its size and shape. Unlike other large lakes, such as Leech, Minnetonka or Gull, it lacks embayments and extensive adjacent wetlands. Mille Lacs is a popular destination lake for fishing, the majority of the lake is privately owned and meets general requirements for most development types; these factors lead to higher development rates than the statewide mean.

Mille Lacs is similar to other heavily developed lakes in that residential homes are the most common type of development. Because of small lot sizes, a high percentage of sites contained more than one home (lower than state mean).

Because of its size and location in the state, state and county roads encircle nearly the entire shore and roads are within 100 feet of the lake in many areas. The percentage of sites adjacent to a road is higher on Mille Lacs (18%) than the statewide mean (11%). One implication of this, is that runoff water from roads that enters Mille Lacs carries added salt and sediment concentrations that can negatively impact fish and wildlife.

Mille Lacs' Lakewide Habitat Score of 61 generally indicates that about 40% of the habitat has been removed from the lake shore zones. This is particularly evident in the Shoreland and Shoreline zones of developed sites where trees, shrubs and natural ground cover have been removed and replaced by homes, yards, and roads. By comparison, most undeveloped sites on the lake are characterized by either upland forest or wetlands with few visual opening to the lake (Figure 2.5). It is important to note that several undeveloped sites did score low in the Shoreland and/or Shoreline Zone. This may occur at sites where natural disturbances such as wind storms create openings in the forest canopy of the Shoreland Zone and/or at heavily windswept sites where wave and wind action limit the amount of vegetation in the Shoreline Zone (Figure 2.6).

**Figure 2.5. Undeveloped Upland site with high amount of habitat remaining in Shoreland and Shoreline Zones.**

**Figure 2.6. Undeveloped site on Mille Lacs where Shoreline Zone is naturally lacking vegetation.**

Similarly, along windswept areas of the north shore of Mille Lacs, strong waves prevent aquatic plant growth in the Aquatic Zone. But, at developed sites, human disturbances such as plant removal and installation of docks and other structures further lowers scores in this zone.

In general, more intensive land use types on Mille Lacs have lower habitat scores but the fact that most land uses had a wide range of scores indicates that people have options on how they can develop various types of sites. For example, on small lake lots, homeowners have limited space for both a dock and a “habitat reserve”. However, if adjacent landowners share a dock, or designate a dock area at their property boundaries, the remaining shore can be less fragmented for fish and wildlife habitat. Resorts, commercial campgrounds and condominiums might be expected to have lower habitat scores because they are providing lake access for multiple users. But the range of scores for these sites on Mille Lacs again indicates the potential exists for these sites to still have wild area. These natural shores are likely to also be popular among the resort visitors who come to Mille Lacs, in large part, to view wildlife and fish (Figure 2.7).

These habitat score data can be used to prioritize lake sites for habitat restoration and to monitor changes in development and shore habitat. We recommend this survey be repeated on a 10 year interval. Individual private riparian landowners are encouraged to evaluate the habitat value of their own property using the "Score Your Shore" assessment method (MNDNR Score Your Shore).

**Figure 2.7. An example of an undeveloped site on Mille Lacs Lake with high habitat value in the Shoreland, Shoreline and Aquatic Zones.**

Information on how to restore shore habitat can be found at MNDNR Restore Your Shore.

# CHAPTER 3. EMERGENT AND FLOATING-LEAF PLANT STANDS

## INTRODUCTION

Emergent and floating-leaf aquatic plants provide important ecological services within the nearshore zone. These plants are anchored in the lake by underground root systems that help stabilize substrates and stop erosion. They are natural wave breaks and help buffer shorelines and nearshore zones from wave activity. These plants provide shade, structure, shelter and food for fish, frogs, and a variety of other wildlife (Killgore et al. 1993; Casselman and Lewis 1996; Valley et al. 2004).

Unfortunately, as shore development increases, humans often remove floating and emergent plant stands and create open sites in front of their property. Research has confirmed that emergent and floating-leaf vegetation cover is lower at developed sites and lakes with greater development density (Jennings et al. 2003, Radomski 2006). By comparing vegetation abundance along undeveloped and developed shorelines for 44 lakes in Minnesota, Radomski and Goeman (2001) estimated that 20 to 28 percent of the nearshore emergent and floating-leaf coverage was lost.

Objectives are:

1) Collect georeferenced baseline data on the type and distribution of emergent and floating-leaf plant stands within selected areas of Mille Lacs
2) Estimate the coverage (acreage) of these plant stands

## METHODS

We did not have the resources to survey the entire lake and concentrated our surveys on the protected vegetated bays because the wide open non-vegetated bays are usually wind-swept sandy bottoms. Surveyors mapped plant stands in Cove Bay in 2009 and in Vineland and Isle bays in 2014. A few bulrush beds were mapped in Twin bays (northeast of Isle bay) when the Isle Bay survey was conducted in 2014.

Surveyors used GPS to delineate all emergent and floating-leaf plant stands greater than 10 square meters. Two different methods were used to delineate stands: In 2009, surveyors used hand-held Garmin GPS units which automatically collected location data. In addition to recording a track line along the lakeward edge of the plant stand, surveyors recorded waypoints at the beginning and the end of each stand and recorded field notes to describe the plant species present in each stand. GPS data were imported into a geographic information system (GIS) for processing. GPS track lines were edited to create polygons. In 2014, surveyors used ArcCollector, an iPad field GIS application coupled with Garmin GLO units. This approach reduces time to process field-collected data for inclusion into GIS databases, as information on the plant class is selected and recorded within a geodatabase at the time of field delineation.

Surveyors navigated around the lakeward edge of the plants and recorded their track with GPS. To minimize damage to plant stands, surveyor used bow-mounted electric trolling motors or waded in shallow water. Plant stands were classified by dominant taxa (Perleberg et al. 2019).

Total area covered (acres) by emergent and floating-leaf plants was estimated for each bay. Estimates of coverage were determined for each individual plant stand and for each plant class. Most emergent and floating-leaf plant stands in Minnesota lakes are restricted to depths of six feet and less. We used depth contour maps to estimate the lake area within this depth zone in each bay and then calculated the percent of that shallow water area occupied by emergent and floating-leaf plants.

## RESULTS

A total of 309 acres of emergent and floating-leaf plant stands were mapped in the three bays. This represents, about 47% of the total shallow water zone (0-5 ft) in these bays. Plant stands covered 134 acres in Isle Bay (68% of shallows) (Figure 3.1), 107 acres in Vineland (40% of shallows) (Figure 3.2) and 56 acres in Cove Bay (34% of shallows) (Figure 3.3). Plant stands ranged in size from 0.004 acres to 41 acres and the mean stand size was 1.29 acres. The largest stands occurred adjacent to undeveloped or minimally developed shores.

Fourteen different plant taxa were reported and plant stands were classified as eight different types (Table 3.1). Photos of some of the commonly observed species are provided in Figure 3.4 Rushes were the most common community class in all three bays and bulrush (*Schoenoplectus* sp.) was the most common rush observed.

In Vineland Bay, a total of 47 acres of rushes ringed the main bay. Cove Bay had 56 acres of rushes that were found scattered around the shoreline with the biggest bed found on the southwest shore. Isle Bay included 88 acres of rushes found around and south of Malone Island with a few scattered beds found on the northeast side of the bay (Table 3.1 & Figures 3.1-3.3).

Cattails (*Typha* sp.) were the second most common emergent plant found; they were found in the protected shallow areas of each bay and a total of 80 acres were mapped. Wild rice (*Zizania palustris*) was only found in Isle Bay with a total of 11 acres mapped. Other emergent plant stands included burreed (*Sparganium* sp.), giant cane (*Phragmites australis*), and arrowhead (*Sagittaria* sp.).

Waterlily stands covered 22 acres within the three bays and included white waterlily (*Nymphaea odorata*) and yellow waterlily (*Nuphar variegata*). Other floating leaf plants that were found mixed with waterlily stands included floating-leaf pondweed (*Potamogeton natans*), and floating-leaf burreed (*Sparganium* sp.). Vineland Bay only had a few waterlily beds located in the smaller bay on the northwest side, Cove Bay had one waterlily stand on the southwest side of the smaller bay, and Isle Bay had a few waterlily beds on the south side of Malone Island and one stand by the stream (Table 3.1).

## DISCUSSION

Within the three bays mapped, floating-leaf and emergent plant stands provide important nearshore habitat and include a diversity of plant species. The locations of each plant community type is influenced by fetch, substrate and shoreline development. Narrow, streamlined rushes are better able to survive in open, windswept sites than are broad, floating-leaf waterlilies. Bulrush, spikerush and giant cane are often associated with sandy or silty shorelines whereas floating-leaf and wild rice plants are often found on marl and muck substrates.

Many bulrush stands in Minnesota lakes established decades ago during low water level years. Seeds from bulrush can grow on mudflats but in deeper water they may be washed away. Once established, bulrush spread by underground rhizomes in shallow water. Many of the smaller plant stands in these bays appear to be remnants of larger, continuous stands that have likely been divided and decreased as shorelines have been developed or in locations where ice scoured the stand at ice-out. These plants are particularly susceptible to destruction by direct cutting by human, motorboat activity and excess herbivory. Restoration of rush stands, especially in deeper water, can be very difficult, making established stands particularly unique and valuable.

We would recommend continuing mapping all floating-leaf and emergent vegetation throughout the lake. We estimate that three weeks with low wind days would be required to complete mapping of the remainder of the lake.

## TABLE 3.1. EMERGENT AND FLOATING-LEAF PLANT STAND ACRES

| Plant Classes | 2014 | | 2009 | Total |
|---|---|---|---|---|
| | Vineland | Isle | Cove | acres |
| Rushes | 47 | 89 | 56 | 193 |
| Wild Rice | 0 | 11 | 0 | 11 |
| Wild Rice and Other | 0 | <1 | 0 | <1 |
| Cattail | 42 | 32 | 7 | 80 |
| Other Emergent | 1.3 | 0.4 | 0 | 2 |
| Waterlilies | 15.4 | 1.4 | 5 | 22 |
| Waterlilies and Other | 1 | 0 | 0 | 1 |
| Other Floating | 0 | <1 | 0 | <1 |
| Total acres of plant stands mapped | 107 | 134 | 68 | 309 |
| Acres of Bay within 0-5 feet zone | 269 | 196 | 199 | 664 |
| Percent of shallow water with emergent and floating plant stands | 40% | 68% | 34% | 47% |

## TABLE 3.2. EMERGENT AND FLOATING-LEAF PLANTS OBSERVED IN EACH BAY

| Plant Class | Common Name | Scientific Name | Vineland | Isle | Cove |
|---|---|---|---|---|---|
| Rushes | River bulrush | *Bolboschoenus fluviatilis* | X | X | |
| | Spikerush | *Eleocharis* sp. | X | X | |
| | Three-square bulrush | *Schoenoplectus pungens* | X | X | |
| | Bulrush | *Schoenoplectus* sp. | X | X | X |
| Other Emergent | Giant cane | *Phragmites australis* | X | | |
| | Arrowhead | *Sagittaria* sp. | X | X | |
| | Burreed | *Sparganium* sp. | X | X | |
| Cattails | Cattail | *Typha* sp. | X | X | X |
| Wild Rice | Wild rice | *Zizania palustris* | | X | |
| Waterlilies | Yellow waterlily | *Nuphar variegata* | X | X | X |
| | White waterlily | *Nymphaea odorata* | X | X | X |
| Other Floating | Floating-leaf pondweed | *Potamogeton natans* | X | X | |
| | Floating-leaf burreed | *Sparganium* sp. | | X | |
| | Water smartweed | *Persicaria amphibia* | X | X | |

**Figure 3.1 Emergent plant stands of Mille Lacs - Vineland bay**

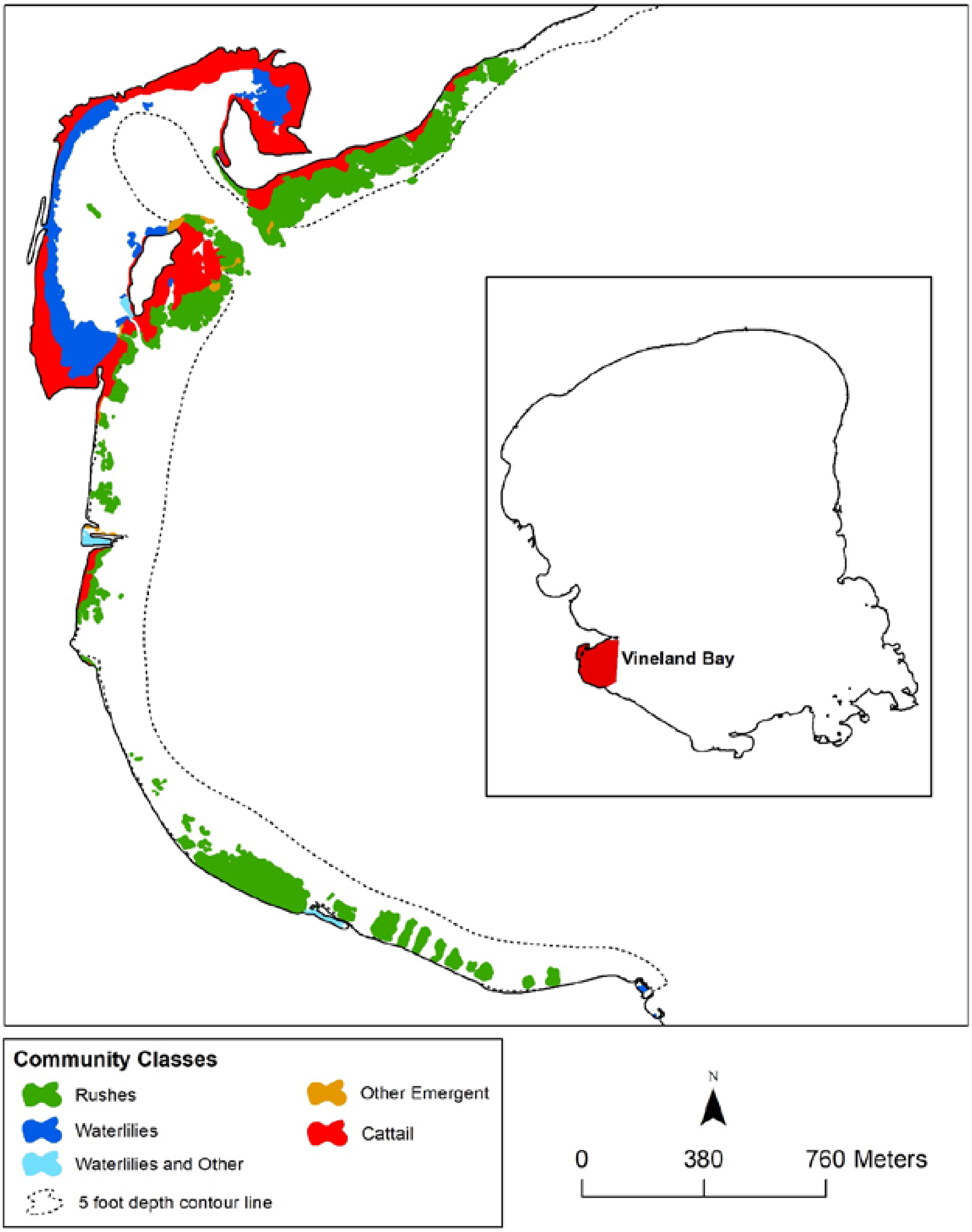


**Figure 3.2 Emergent plant stands of Mille Lacs - Isle bay**

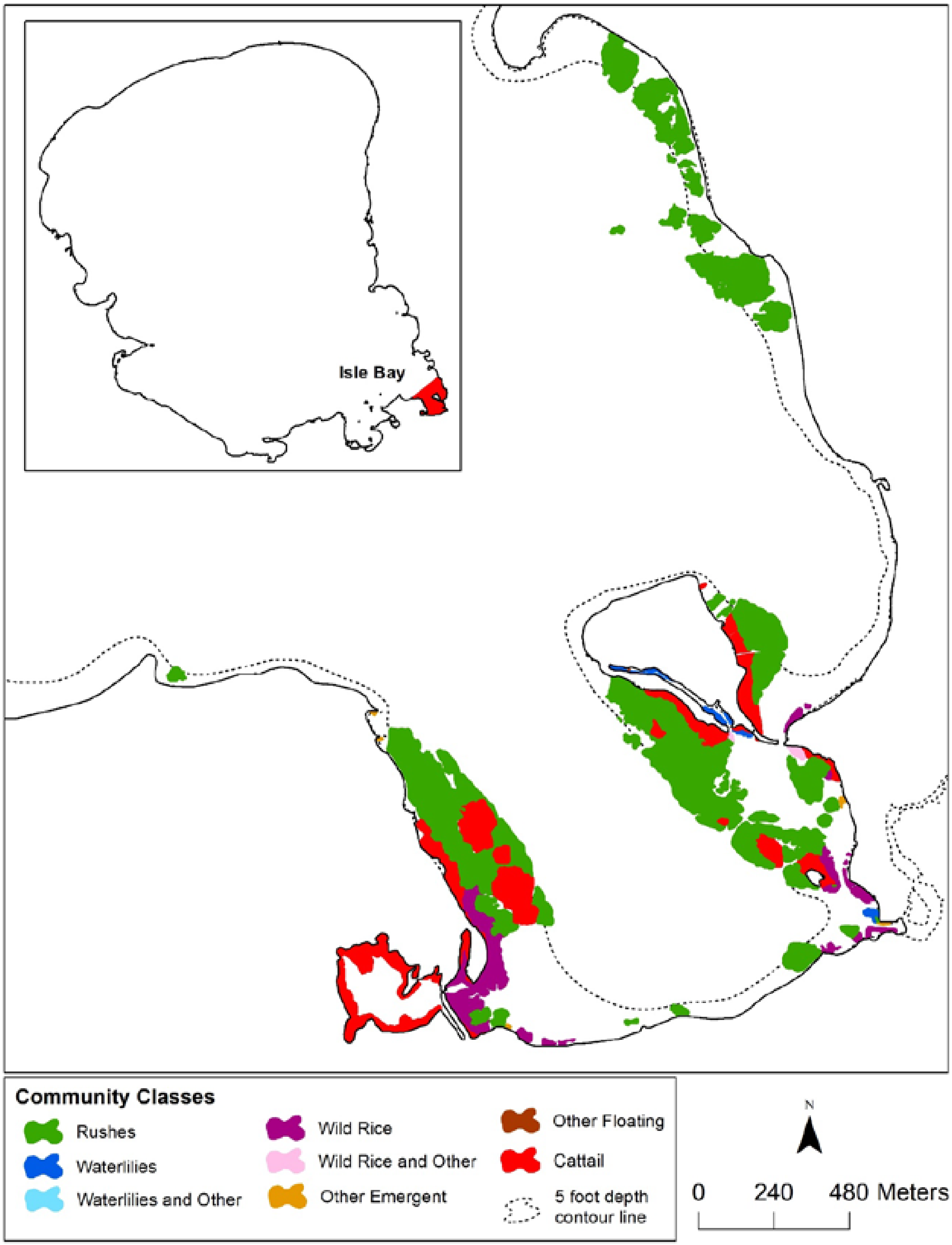


**Figure 3.3 Emergent plant stands of Mille Lacs - Cove bay**

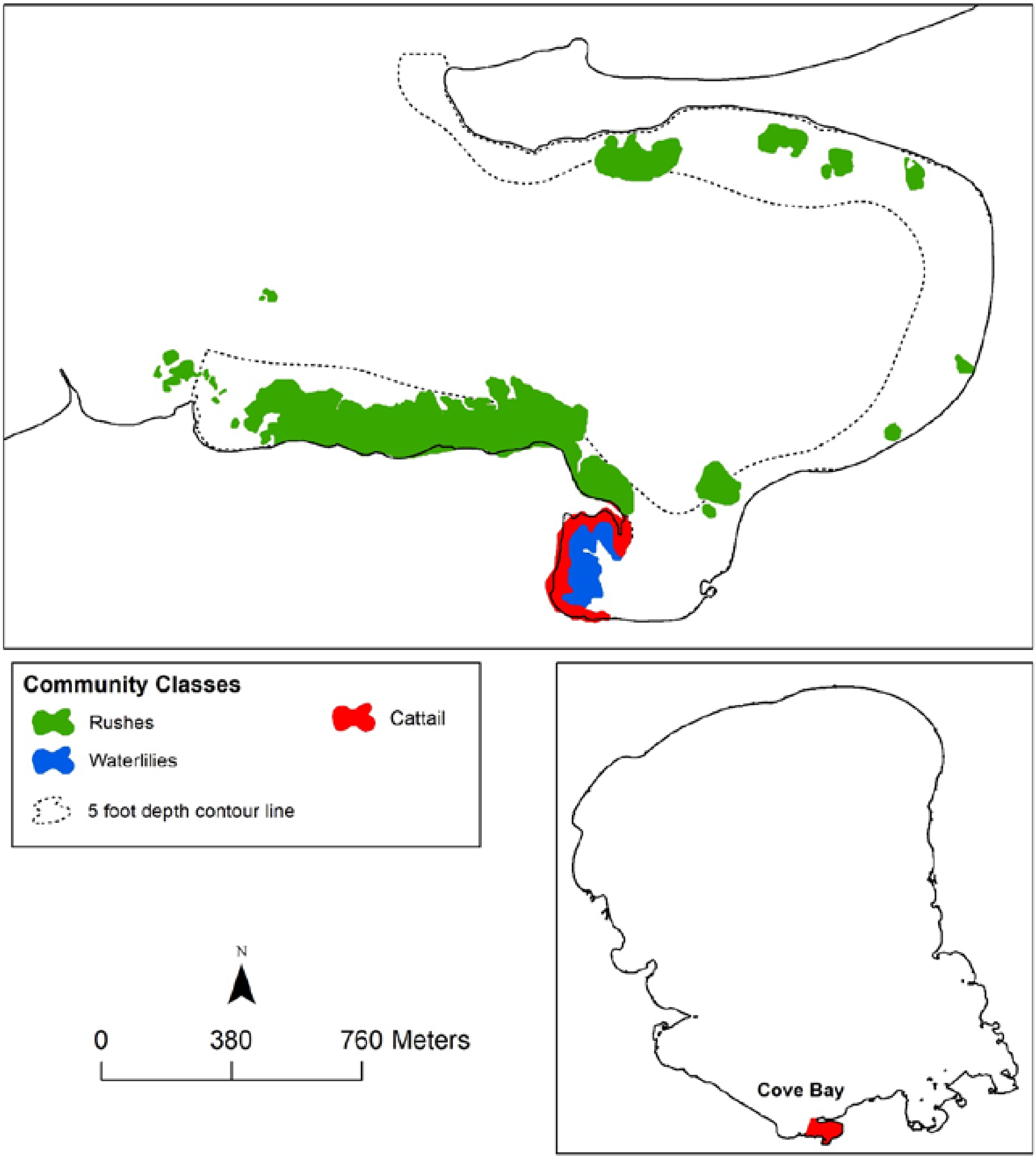
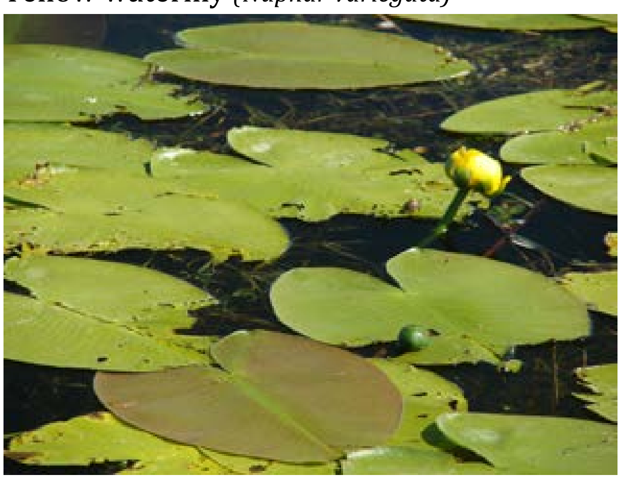


**Figure 3.4. Photos of common emergent and floating-leaf plants in Mille Lacs**

Bulrush (*Schoenoplectus* spp.)

Wild Rice (*Zizania palustris*)

Yellow waterlily *(Nuphar variegata)*



White waterlily (*Nymphaea odorata*)

# CHAPTER 4. SUBMERGED PLANT COMMUNITIES (POINT-INTERCEPT SURVEYS)

## INTRODUCTION

This 2009 study represents the most comprehensive quantitative assessment of Mille Lacs vegetation to date. Although an extensive portion of the lake is shallow, heavy wave activity prevents plant growth in most offshore areas. To maximize the aquatic plant information collected, we focused this survey to selected areas most likely to support plant growth. Objectives include:

1. Describe and contrast plant communities in areas of lake where environmental conditions vary in depth, fetch, substrate, and/or shoreline development.
2. Describe and contrast zebra mussel colonization on vegetation at selected lake areas.
3. Select lake areas that would be appropriate for long term monitoring of plant community.

## METHODS

### MACROPLOT SELECTION

Survey sites were established at nine macroplots located at Wealthwood, Malmo, Twin Bays, Isle Bay, Wahkon Bay, Cove Bay, Vineland Bay, Shah-bush-kung (Roland's) Bay, and Wigwam Bay (Figure 1.5). Macroplots ranged in size from about 400 acres (Twin Bays) to about 1,600 acres (Wahkon Bay). The total area included in the 2009 quantitative surveys was about 7,900 acres, about a fourth of the shallow zone (0-20 feet) of Mille Lacs Lake.

Surveyors subjectively selected macroplot survey areas based on vegetation information provided by MNDNR Fisheries (Aitkin Area) staff and by pre-sampling in early July 2009. An attempt was made to distribute macroplots around the shoreline, rather than clumping them in one portion of the lake. Selected sites included areas known to historically support aquatic plant growth and areas where vegetation growth has been perceived to recently increase. When feasible, natural boundaries such as bays and depth contours were used to delineate macroplots. The shape of each macroplot was determined by the shoreline and extended lakeward to a depth of 20 feet or the lakeward side of a bay, whichever was shorter.

# ESTABLISHMENT OF BASELINE (2009) SAMPLE SITES FOR POINT INTERCEPT SURVEYS

## SAMPLING SITE DENSITY

In 2009, vegetation of each macroplot was surveyed using a modified grid point-intercept method (Madsen 1999, Perleberg et al. 2019). A Geographic Information System (GIS) computer program was used to establish survey points in a grid pattern across each macroplot. A primary objective was to sample a minimum of 100 points per bay. The error associated with frequency data is based on sample number and the reliability of estimates increases with more samples. Original sample sites were established on a 65 meter by 65 meter grid, resulting in about one survey site per acre. Final sampling intensity varied due to time constraints and the relative abundance of vegetation at each site. At Wigwam Bay, Wealthwood, Twin, Malmo, and Wahkon Bay, one sample site was surveyed for every five acres; surveyors sampled every third row of sites within the grid – in effect sampling along a 260 meter by 65 meter grid (Appendix 1). Sampling effort was increased in Shah-bush-kung, Vineland, and Isle bays where surveyors used a 130 meter by 65 meter grid for a sampling density of one point per two acres. In Cove Bay, sites were spaced on a 65 meter by 65 meter grid for a sampling density of one point per acre.

## WATER DEPTHS SAMPLED

Surveyors sampled all depths to 20 feet except at the Malmo macroplot, where vegetation was not found in depths greater than three feet.

Lakewide, within the 0 to 20 feet depth zone, surveyors sampled a total of 2,930 sites. The number of survey points in each macroplot ranged from 109 in Wigwam Bay to 700 in Vineland Bay. The proportion of sites sampled in each water depth varied by macroplot (Figure 4.1). Most sites (90%) occurred in depths less than 16 feet.

Surveys were conducted from July through August. Methods are documented in Perleberg et al. (2019). Surveys were conducted by boat with two or three surveyors per boat. Surveyors used handheld Global Positioning (GPS) units to navigate within at least five meters of the actual sample site location and precision varied due to wind and GPS variability. One side of the boat was pre-selected as the sampling side and at each site, surveyors visually approximated a one meter squared sample area. Water depth and vegetation were sampled at each site and substrate was described at each sample site when water depth was less than eight feet.

To avoid unnecessary damage to vegetation, surveyors did not motor into emergent or floating-leaf plant beds. Survey sites that occurred within these areas were not physically sampled but surveyors made note of the dominant plant type present. These non-surveyed sites were not included in the data analyses.

### Water depth and substrate sampling

Surveyors used an electronic depth finder or measured stick to record water depth in one foot increments. Surveyors evaluated substrate visually and by tapping a pole into the lake bottom; soft substrate could usually be brought to the surface on the pole or sampling rake for evaluation. Surveyors recorded the most common substrate type (Table 4.1) at each site.

### Vegetation sampling

Surveyors used visual observation and a weighted, double-headed rake attached to a rope (Figure 4.2) to sample vegetation. Within the approximate one meter squared sample area, they recorded any plant taxa visible from the boat surface. They tossed the rake once, allowed it to hit the lake bottom and drag about one meter. Surveyors recorded whether or not vegetation was detected and recorded all plant taxa detected within the site. Any additional plant taxa found outside of sample site were recorded as “present” in the lake but these data were not used in frequency of occurrence calculations.

Plant taxa were identified and recorded to the lowest level possible (typically to the species level). Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MnTaxa (2015).

### Zebra mussel assessments

At each of the vegetation sample sites, surveyors recorded if zebra mussels were observed within the approximate one meter square sample area. Adult zebra mussels observed on the rake, the vegetation sample, and/or the substrate were recorded. In water greater than 2 or 3 feet, surveyors relied on rake tosses alone to detect zebra mussels. Surveyors did not attempt to estimate zebra mussel density or size.

## DATA ANALYSIS

Frequency of vegetation occurrence was calculated as the number of sites in which vegetation was detected divided by the total number of sample sites. Frequency of occurrence was also calculated for each individual plant taxon and for zebra mussels. Data were also grouped by 5 feet water depth intervals for analyses. The upper and lower limits of the 95% confidence limits were calculated for frequency estimates of aquatic plants.

**Figure 4.1. Sampling effort by water depth within each macroplot of Mille Lacs, 2009.**

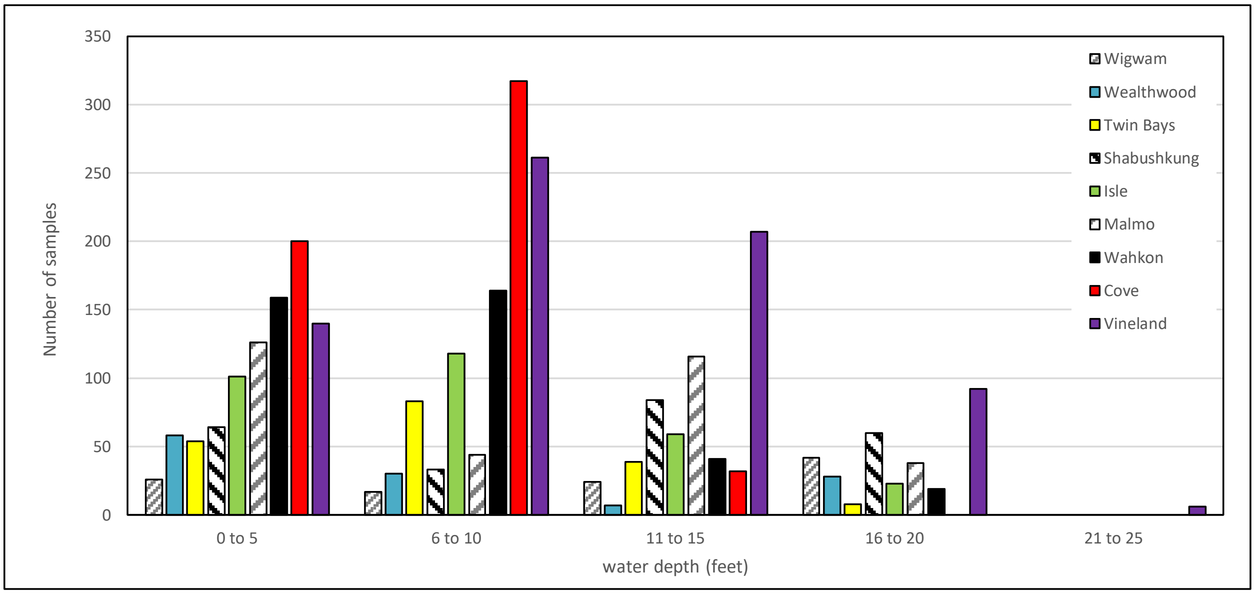



**Figure 4.2. Vegetation sampling rake.**

**Table 4.1 Substrate classes**

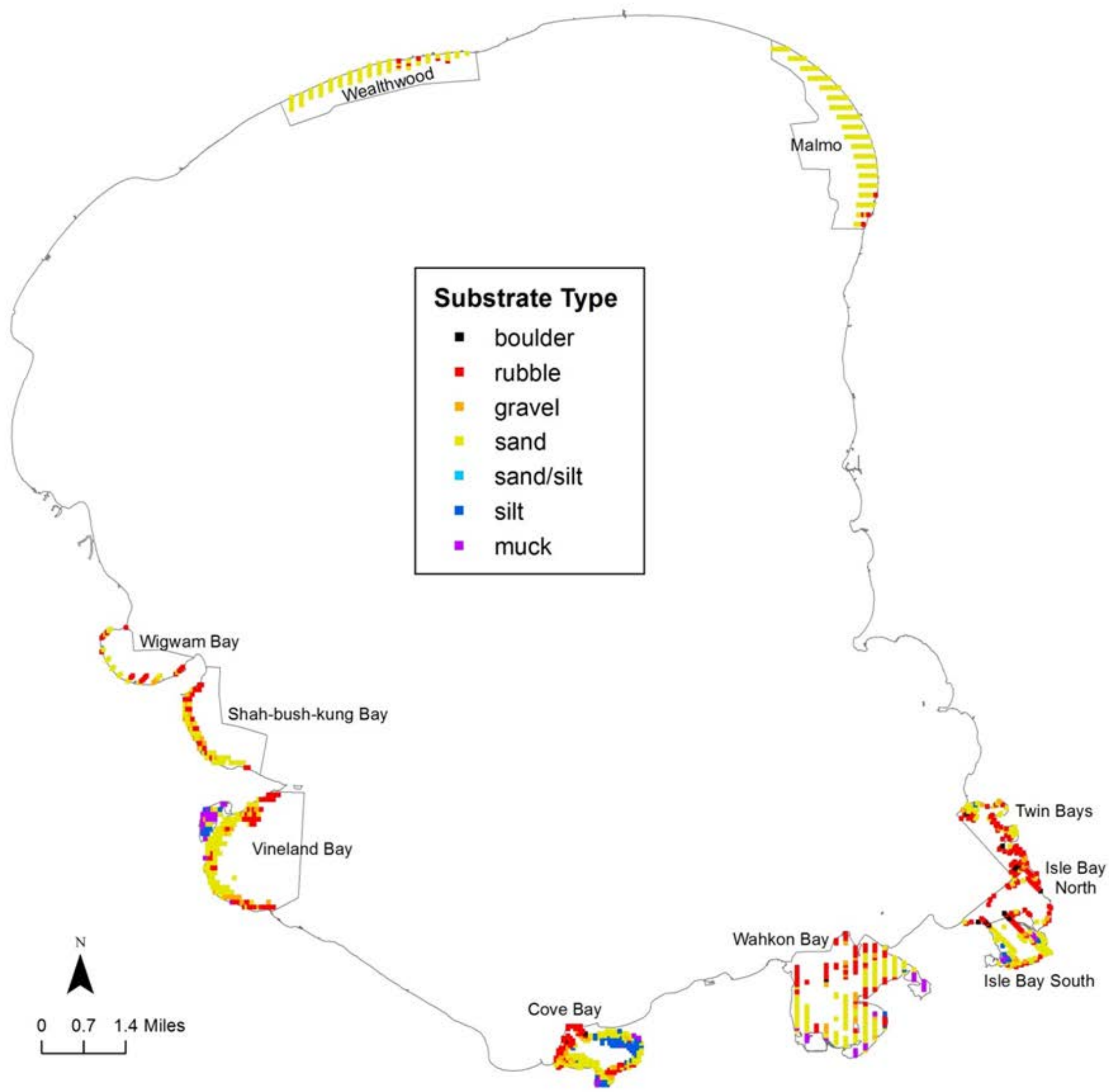
| | | |
|---|---|---|
| Soft | muck | decomposed organic material |
| | marl | calcareous material |
| | silt | fine material with little grittiness |
| Hard | sand | diameter <1/8 inch |
| | gravel | diameter 1/8 – 3 inches |
| | rubble | diameter 3 – 10 inches |
| | boulder | diameter > 10 inches |

# RESULTS – 2009 BASELINE DATA

## NEARSHORE SHALLOW SUBSTRATES

Within the 0 to 7 feet depth zone of macroplots, the most frequent substrate type found was sand, which occurred in 54% of the sites. Rubble was found in scattered locations on the north end of the lake but was more frequent in the southern bays. Muck and silt were found only in the shallow smaller protected bays (Figure 4.3).

**Figure 4.3 Nearshore shallow substrates of selected areas of Mille Lacs Lake, 2009.**

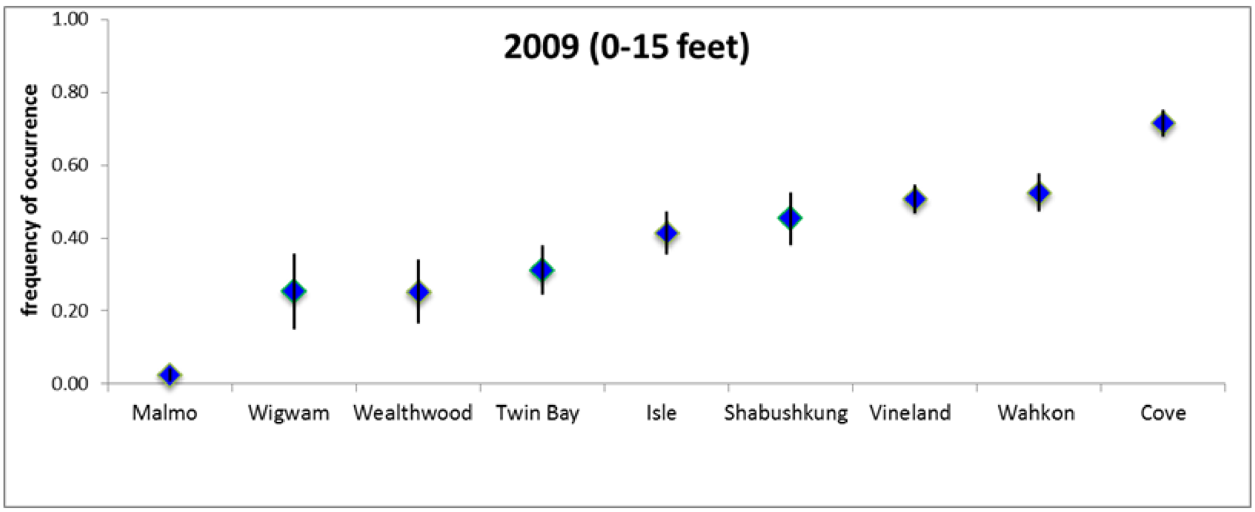


## PLANT COMMUNITIES

### Plant occurrence by water depth

Lakewide, within the 0 to 20 feet zone of the macroplots surveyed, surveyors detected aquatic plants in 41% of all sampled sites. The highest frequency of vegetation occurred in the 0 to 15 feet zone where 46% of sites were vegetated. Within the 0 to 15 feet zone, plant occurrence was greatest in Cove, Wahkon, Vineland, Shabushkung, and Isle bays where plants were found in at least 40% of sites (Figure 4.4). In Twin, Wealthwood, and Wigwam, bays, plant occurrence ranged from 25% to 31%. Vegetation was sparse in Malmo Bay where plants were detected in only 2% of sites.

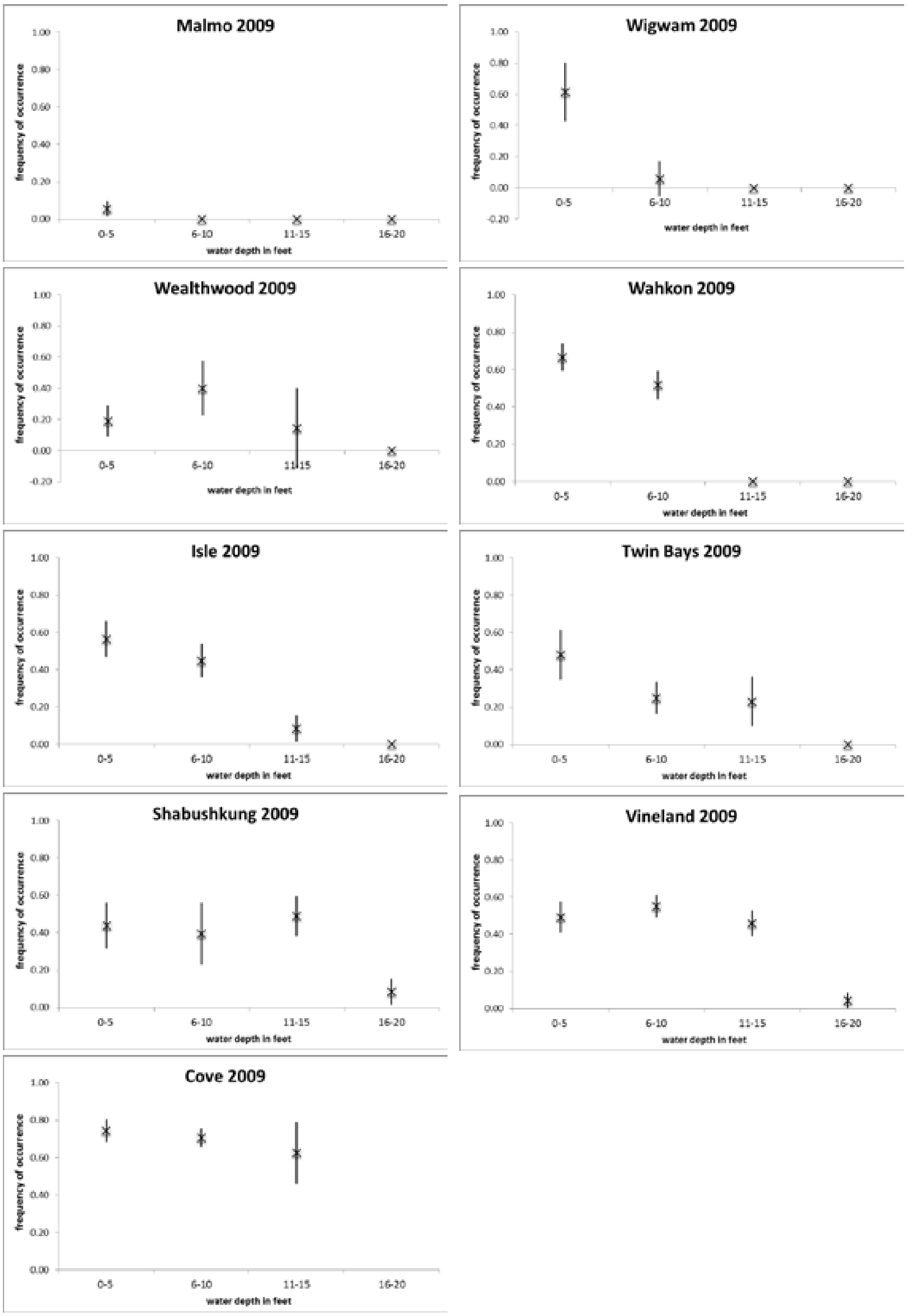
**Figure 4.4 Plant frequency of occurrence in 0-15 feet depth zone in surveyed areas of Mille Lacs, 2009.** (vertical bars represent upper and lower limits of 95% confidence limit)




In each macroplot, plant occurrence was greatest in the 0 to 5 feet depth and generally declined with increasing water depth (Figure 4.5). An exception was Wealthwood, where plant frequency was highest in the 6 to 10 feet zone. The only macroplots where vegetation was detected in depths greater than 15 feet were Shabushkung Bay (18 feet) and Vineland Bay (23 feet). In both of these bays plant occurrence in the 15 to 20 feet zone was sparse (less than 10% frequency).

**Figure 4.5. Frequency of vegetation by water depth in each macroplot**



## Plant taxa observed, lakewide frequency, and distribution by water depth

In 2009, a total of 47 different plant taxa were found and included 27 submerged, three free-floating, six floating-leaf and 11 emergent plants (Table 4.2). The greatest number of plant taxa was found in water depths from 0-5 feet, where all but two taxa were observed (Figure 4.6). Submerged plants were found at all vegetated depths and were the most frequently occurring plant life form in the lake and at each water depth. At least one submerged taxon was detected in 41% of all vegetated sites. Most submerged plants occurred within a broad depth range but the median depth occurrence of most taxa was between 6 and 8 feet (Figure 4.6). Only 8 taxa were detected in depths greater than 15 feet and only 2 taxa (watermoss and Eurasian watermilfoil) had a median depth occurrence greater than 10 feet.

**Table 4.2. Summary vegetation data for 2009 macroplots.**

| **2009 data** | Wealthwood | Malmo | Twin Bays | Isle | Wahkon | Cove | Vineland | Shahbushkung | Wigwam | All sites |
|---|---|---|---|---|---|---|---|---|---|---|
| Total number of samples | 123 | 324 | 184 | 301 | 383 | 549 | 700 | 241 | 109 | 2,914 |
| Frequency of plant occurrence (0 to 15 feet) | 23% | 2% | 34% | 68% | 52% | 74% | 51% | 45% | 25% | 46% |
| Max. rooting depth (ft) | 13 | 3 | 14 | 12 | 10 | 11 | 23 | 18 | 8 | n/a |
| Total # of all plant taxa found | 10 | 5 | 26 | 28 | 37 | 29 | 32 | 23 | 13 | 47 |
| # of submerged | 9 | 4 | 19 | 18 | 22 | 19 | 22 | 17 | 7 | 27 |
| # of free-floating | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 0 | 3 |
| # of floating-leaf | 0 | 0 | 1 | 3 | 4 | 2 | 1 | 0 | 1 | 6 |
| # of emergent | 0 | 0 | 5 | 6 | 9 | 7 | 7 | 6 | 5 | 11 |
| Mean # of plant taxa per sample site (0 to 15 feet) | 0.3 | <0.1 | 1.3 | 1.9 | 1.2 | 2.8 | 1.1 | 0.8 | 0.5 | 1.2 |

The most frequently occurring submerged taxa were native species: northern watermilfoil (*Myriophyllum sibiricum*), wild celery (*Vallisneria americana*), coontail (*Ceratophyllum demersum*), white-stem pondweed (*Potamogeton praelongus*) and variable pondweed (*Potamogeton gramineus*), with each found in at least 5% of all sites (0-15 feet depth zone) and present in 15% of sites in at least one of the nine macroplots (Table 4.3). Non-native submerged plants were a minor part of the plant community. Eurasian watermilfoil (*Myriophyllum spicatum*) was found in one site in Cove Bay and 3% of the sites in Vineland Bay. Curly-leaf pondweed (*Potamogeton crispus*) was detected in 2% of the Cove Bay sites.

Emergent and floating-leaf plants were mostly restricted to water depths less than 6 feet (Figure 4.6). Within the 0 to 5 feet zone, 25% of the sites contained emergent plants and 4% contained floating-leaf plants. Major stands of emergent and floating-leaf plants are described in Chapter 3. Bulrush (*Schoenoplectus* spp.) was the most frequently occurring emergent plant. It occurred to a depth of 6 feet but was most frequent in the 0 to 5 feet depth zone where it was found in 15% of the sites (Table 4.3). Floating-leaved plants included white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), floating-leaf pondweed (*Potamogeton natans*) and floating-leaf burreed (*Sparganium* sp.). They were found in depths less than 6 feet and were present in less than 33% of sites at this depth.

Southern naiad (*Najas guadalupensis*), Eurasian watermilfoil (*Myriophyllum spicatum*), and Fries' pondweed (*Potamogeton friesii*) were found for the first time in 2009. Watershield (*Brasenia schreberi*), small pondweed (*Potamogeton pusillus*), floating-leaf arrowhead (*Sagittaria cuneata*) and river pondweed (*Potamogeton nodosus*) were found during the 1996 survey but was not found during the 2009 survey. Rare species were not found during any of the surveys. Four unique submerged taxa were found and included flat-leaved bladderwort (*Utricularia intermedia*), minor bladderwort (*Utricularia minor*), creeping spearwort (*Ranunculus flammula*) and leaf-less watermilfoil (*Myriophyllum tenellum*).

**Table 4.3. Species percent frequency of occurrence within the 0-15 feet depth zone for each macroplot of Mille Lacs (2009).**

| Life Form | Common Name | Scientific Name | North end | | South end | | | | | | | ALL SITES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wealthwood | Malmo | Twin Bays | Isle | Wahkon | Cove1 | Vineland | Shahbushkung | Wigwam | |
| | **Number of sites** | | 123 | 324 | 184 | 301 | 383 | 549 | 700 | 241 | 109 | 2,914 |
| 1. | Muskgrass | *Chara* sp. | | | 1 | 2 | 3 | 3 | 1 | 2 | 1 | 2 |
| 1. | Stonewort | *Nitella* sp. | | | | 1 | | | <1 | | | <1 |
| 1. | Watermoss | Not identified to genus | | | | | | | 2 | | | 1 |
| 2. Submerged monocots | Bushy pondweed | *Najas flexilis* | | | 3 | 9 | 1 | 1 | 4 | 4 | | 2 |
| 2. Submerged monocots | Southern naiad | *Najas guadalupensis* | | | | | | | | | | |
| 2. Submerged monocots | Large-leaf pondweed | *Potamogeton amplifolius* | | | 1 | 2 | 1 | 2 | 1 | | | 1 |
| 2. Submerged monocots | Variable pondweed | *Potamogeton gramineus* | 9 | 1 | 1 | 4 | 15 | 4 | 9 | 6 | 6 | 6 |
| 2. Submerged monocots | Illinois pondweed | *Potamogeton illinoensis* | 1 | | 2 | 4 | 7 | 4 | 1 | 1 | | 3 |
| 2. Submerged monocots | White-stem pondweed | *Potamogeton praelongus* | 4 | 1 | 2 | 8 | 5 | 17 | 5 | 6 | | 7 |
| 2. Submerged monocots | Clasping-leaf | *Potamogeton richardsonii* | 5 | <1 | 5 | 5 | 7 | 5 | 9 | | 3 | 5 |
| 2. Submerged monocots | Curly-leaf pondweed | *Potamogeton crispus* | | | | | <1 | 1 | 1 | | | 1 |
| 2. Submerged monocots | Fries pondweed | *Potamogeton friesii** | | | 2 | 11 | 1 | 10 | 12 | 7 | | 3 |
| 2. Submerged monocots | Sago pondweed | *Stuckenia pectinata* | 6 | P | 3 | 2 | 3 | 3 | 2 | 1 | P | 2 |
| 2. Submerged monocots | Flat-stem pondweed | *Potamogeton zosteriformis* | | | 11 | 15 | 4 | 22 | 4 | | 1 | 8 |
| 2. Submerged monocots | Robbins pondweed | *Potamogeton robbinsii* | | | | | | 9 | | | | 2 |
| 2. Submerged monocots | Ribbon-leaf pondweed | *Potamogeton epihydrus* | | | | | <1 | | | | | <1 |
| 2. Submerged monocots | Wild celery | *Vallisneria americana* | 1 | | 10 | 15 | 15 | 15 | 9 | 8 | 7 | 10 |
| 2. Submerged monocots | Water stargrass | *Heteranthera dubia* | | | 1 | 2 | 2 | 2 | 3 | 2 | | 2 |
| 2. Submerged monocots | Canada waterweed | *Elodea canadensis* | | | 3 | 7 | 6 | 8 | 6 | 14 | | 5 |
| 3. Submerged dicots | Coontail | *Ceratophyllum demersum* | | | 3 | 11 | 4 | 20 | 4 | 8 | | 7 |
| 3. Submerged dicots | Northern watermilfoil | *Myriophyllum sibiricum* | | | 6 | 19 | 4 | 33 | 11 | 2 | 3 | 12 |
| 3. Submerged dicots | Whorled watermilfoil | *Myriophyllum verticilliatum* | | | | | | | | | | P |
| 3. Submerged dicots | Eurasian watermilfoil | *Myriophyllum spicatum* | | | | | | | 3 | | | 1 |
| 3. Submerged dicots | Water marigold | *Bidens beckii* | | | 1 | 7 | 2 | 8 | <1 | | | 2 |
| 3. Submerged dicots | Water buttercup | *Ranunculus aquatilis* | | | 4 | 12 | 3 | 8 | 6 | 2 | | 5 |
| 3. Submerged dicots | Creeping spearwort | *Ranunculus flammula* | | | | | <1 | | | | | <1 |
| 3. Submerged dicots | Greater bladderwort | *Utricularia vulgaris* | | | | | 1 | | <1 | 1 | 1 | <1 |
| | Total number of taxa | | 6 | 4 | 17 | 18 | 21 | 19 | 24 | 14 | 8 | 27 |
| 4. Free Floating | Star duckweed | *Lemna trisulca* | | | | | | | | | | 11 |
| 4. Free Floating | Lesser duckweed | *Lemna* sp. | | | | | | P | | | | P |
| 4. Free Floating | Greater duckweed | *Spirodella polyrhiza* | | | | <1 | 1 | <1 | | P | P | <1 |
| | Total | | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 3 |

**(For each taxa, the number provided under each Bay is the percent of sites where that taxa was observed. Ex. In Wealthwood Bay, *Potamogeton gramineus* was observed in 9% of the sites)**

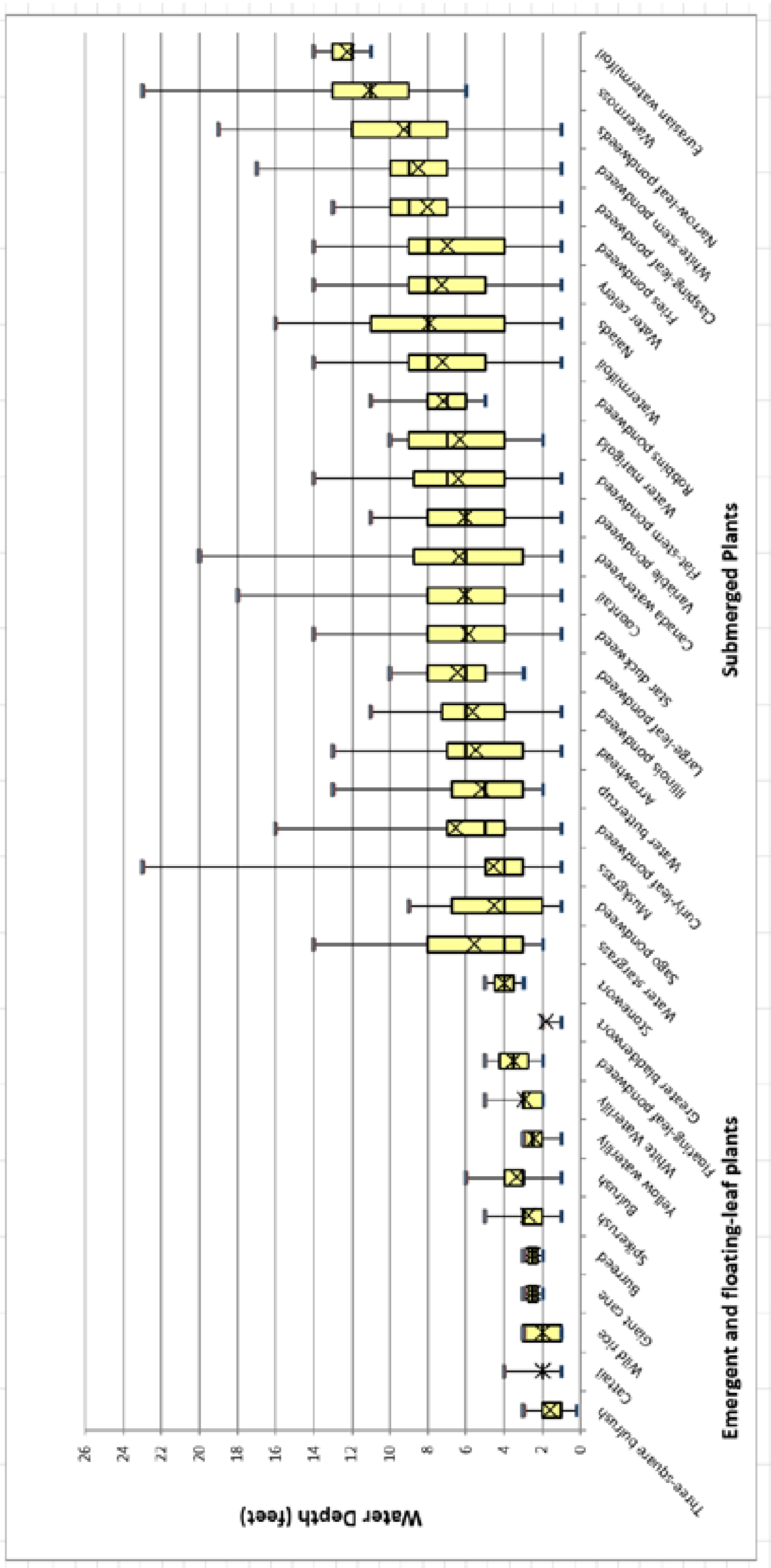
**Table 4.3. contd. Species frequency of occurrence within the 0-15 feet depth zone for each macroplot of Mille Lacs (2009).**

| Life Form | Common Name | Scientific Name | North end | | South end | | | | | | | ALL SITES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wealthwood | Malmo | Twin Bays | Isle | Wahkon | Cove[1] | Vineland | Shahbushkung | Wigwam | |
| | | **Number of sample sites** | 123 | 324 | 184 | 301 | 383 | 549 | 700 | 241 | 109 | 2,914 |
| 5. FLOATING | White waterlily | *Nymphaea odorata* | | | | 2 | 1 | 1 | 1 | | | 2 |
| | Yellow waterlily | *Nuphar variegata* | | | 1 | 4 | 1 | <1 | | | | 1 |
| | Floating-leaf smartweed | *Persicaria amphibia* | | | | | | | P | | | P |
| | Floating-leaf pondweed | *Potamogeton natans* | | | | | 1 | | | | 1 | <1 |
| | Floating-leaf arrowhead | *Sagittaria cuneata* | | | | | | | | | 1 | <1 |
| | Floating-leaf burred | *Sparganium* sp. | | | | 1 | | | | | | <1 |
| | | Total | 0 | 0 | 1 | 3 | 3 | 2 | 1 | 0 | 1 | 5 |
| 6. EMERGENT | River bulrush | *Bolboschoenus fluviatilis* | | | | P | | | P | | | P |
| | Needlerush | *Eleocharis acicularis* | | | 2 | | | 2 | | | | 1 |
| | Spikerush | *Eleocharis* sp. | | | | 5 | 4 | 5 | 2 | 11 | 9 | 3 |
| | Horsetail | *Equisetum fluviatilis* | | | | | | | | | | P |
| | Giant cane | *Phragmites australis* | | | | | <1 | <1 | P | | | <1 |
| | Arrowhead | *Sagittaria latifolia** | 2 | <1 | 2 | 6 | 5 | 2 | 2 | 2 | | 2 |
| | Three-square bulrush | *Schoenoplectus pungens* | | | | 2 | 1 | 1 | <1 | 3 | P | 1 |
| | Round stem bulrush | *Schoenoplectus sp.* | | | 6 | 11 | 8 | 8 | 1 | 4 | 13 | 5 |
| | Giant burred | *Sparganium eurycarpum** | | | 1 | P | <1 | | <1 | | | <1 |
| | Cattail | *Typha* sp. | | | 1 | 1 | 1 | 1 | <1 | | 3 | <1 |
| | Wild rice | *Zizania palustris* | | | | 3 | | | <1 | 1 | | <1 |
| | | Total | 1 | 1 | 5 | 9 | 8 | 7 | 10 | 5 | 6 | 16 |
| | | Grand Total | 7 | 5 | 23 | 31 | 33 | 30 | 35 | 20 | 16 | 51 |

Life Forms: 1. Submerged macroalgae and mosses, 2. Submerged monocots, 3. Submerged dicots, 4. Free-floating, 5. Floating-leaved, 6. Emergent

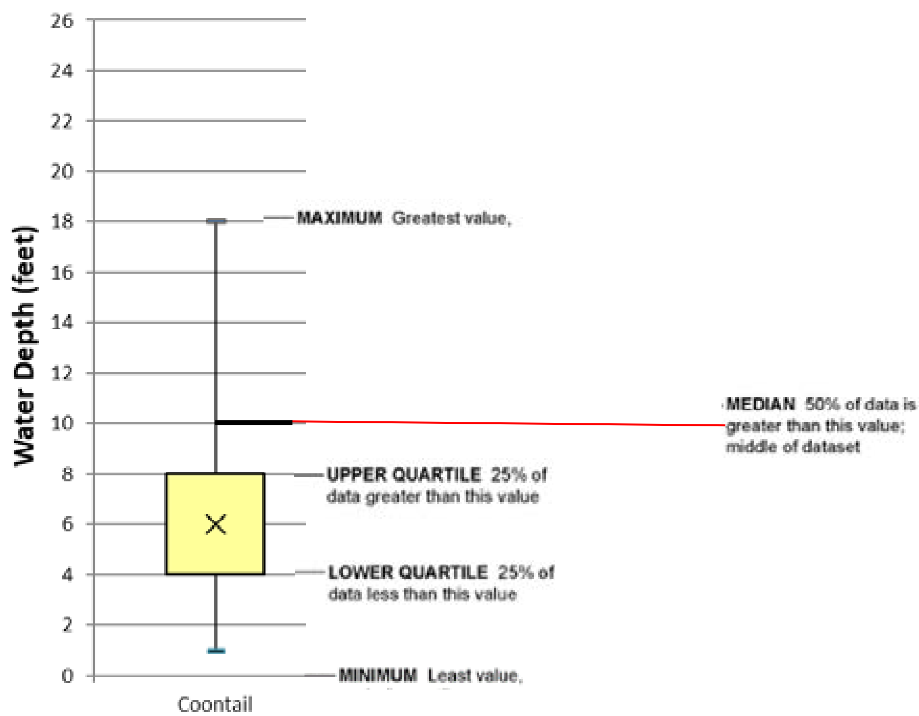
*most plants in this taxa group were not identified to species level and additional look-a-like species may also have been present.

**Figure 4.6 Depth range of plant taxa in Mille Lacs Lake using box plots.**



Interpreting the "box-whisker" plots in Figure 4.6.

- The top "whisker" is the maximum depth at which the taxa was observed
- The lower "whisker" is the mimimum depth at which the taxa was observed
- All of the depth values observed are grouped into four sections:
    - The top 25% of the depth values are shown from the top whisker to the top of the box
    - The next 25% of depth values are shown by the top portion of the box
    - The next 25% of the depth values are shown by the lower portion of the box
    - The last 25% of the depth values are from the bottom of the box to the lower whisker
- "X" marks the median depth (middle value) at which taxa was found




In the above example, Coontail was observed in depths from 1 to 18 feet, with a mean and median depth observation at 6 feet. 25% of the depth observations were in water greater than 8 feet, 25% were in 6 to 8 feet, 25% were in 4 to 6 feet, and 25% were in 1 to 4 feet.

## Plant community differences between macroplots

Taxa richness (the number of taxa) was lowest in macroplots on the north end of the lake, with less than eight taxa observed at Malmo and Wealthwood, and highest in more protected macroplots, with 30 or more taxa found in Cove, Isle, Vineland and Wahkon (Table 4.2). The number of plant taxa found per site ranged from one to twelve (Figures 4.7-4.10). Sites with a high number of plant taxa were usually in shallow water where a mixture of submerged, floating-leaf, and /or emergent plants occurred. Most sample sites that contained plants had only one or two taxa.

**Figure 4.7. Number of taxa per site in Wealthwood and Malmo bays**

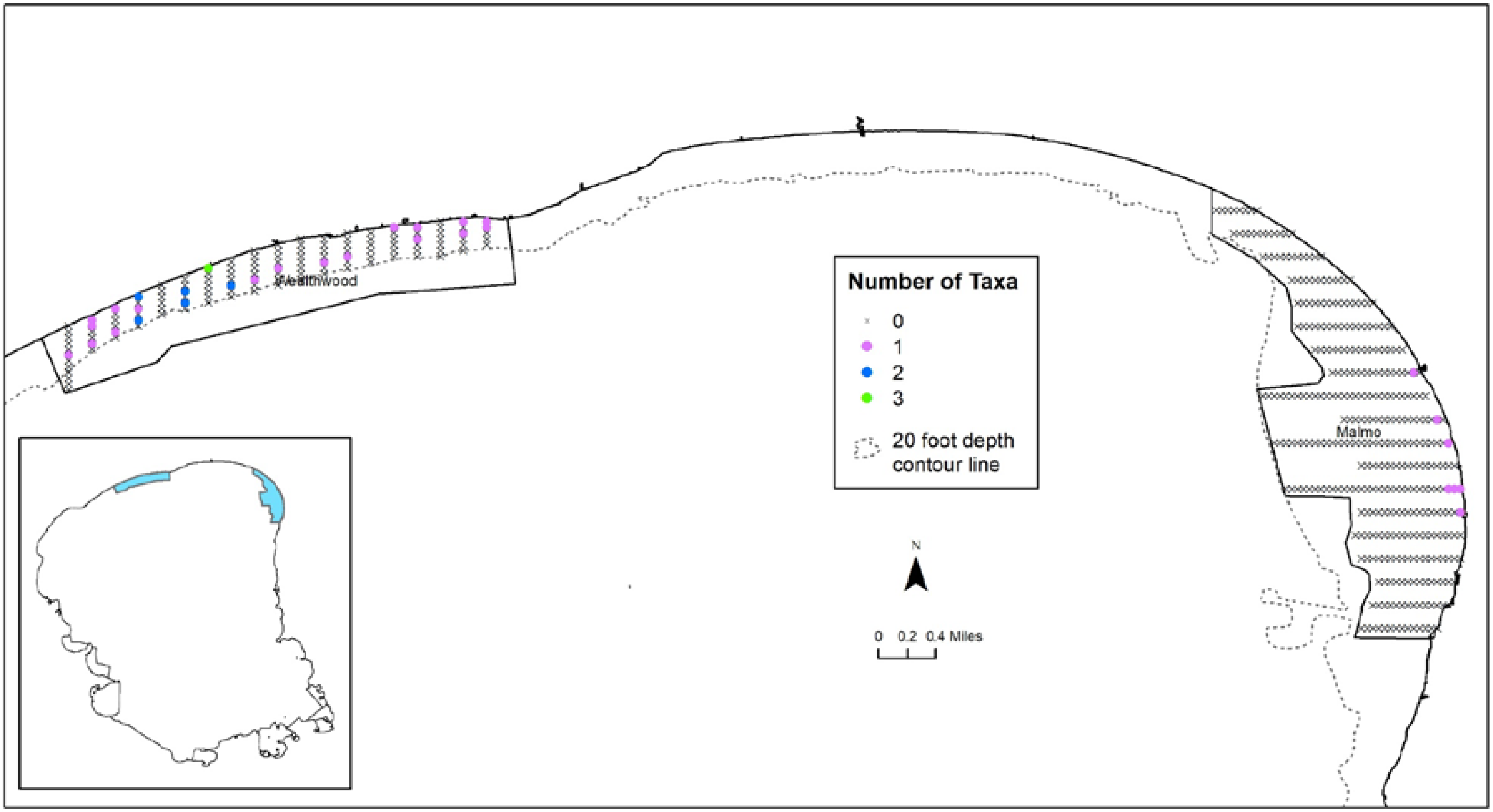


**Figure 4.8. Number of taxa per site in Wahkon and Cove bays**

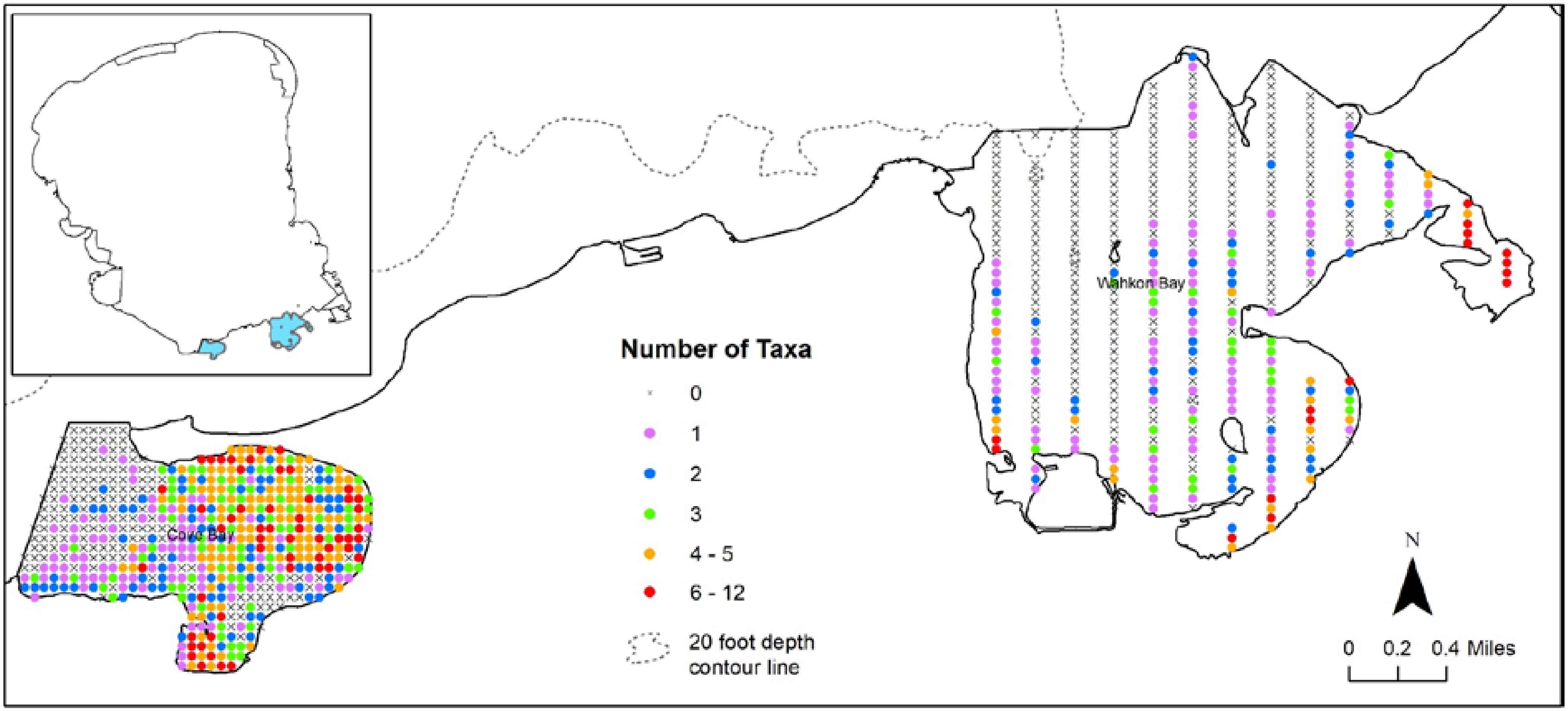


**Figure 4.9. Number of taxa per site in Twin and Isle bays.**

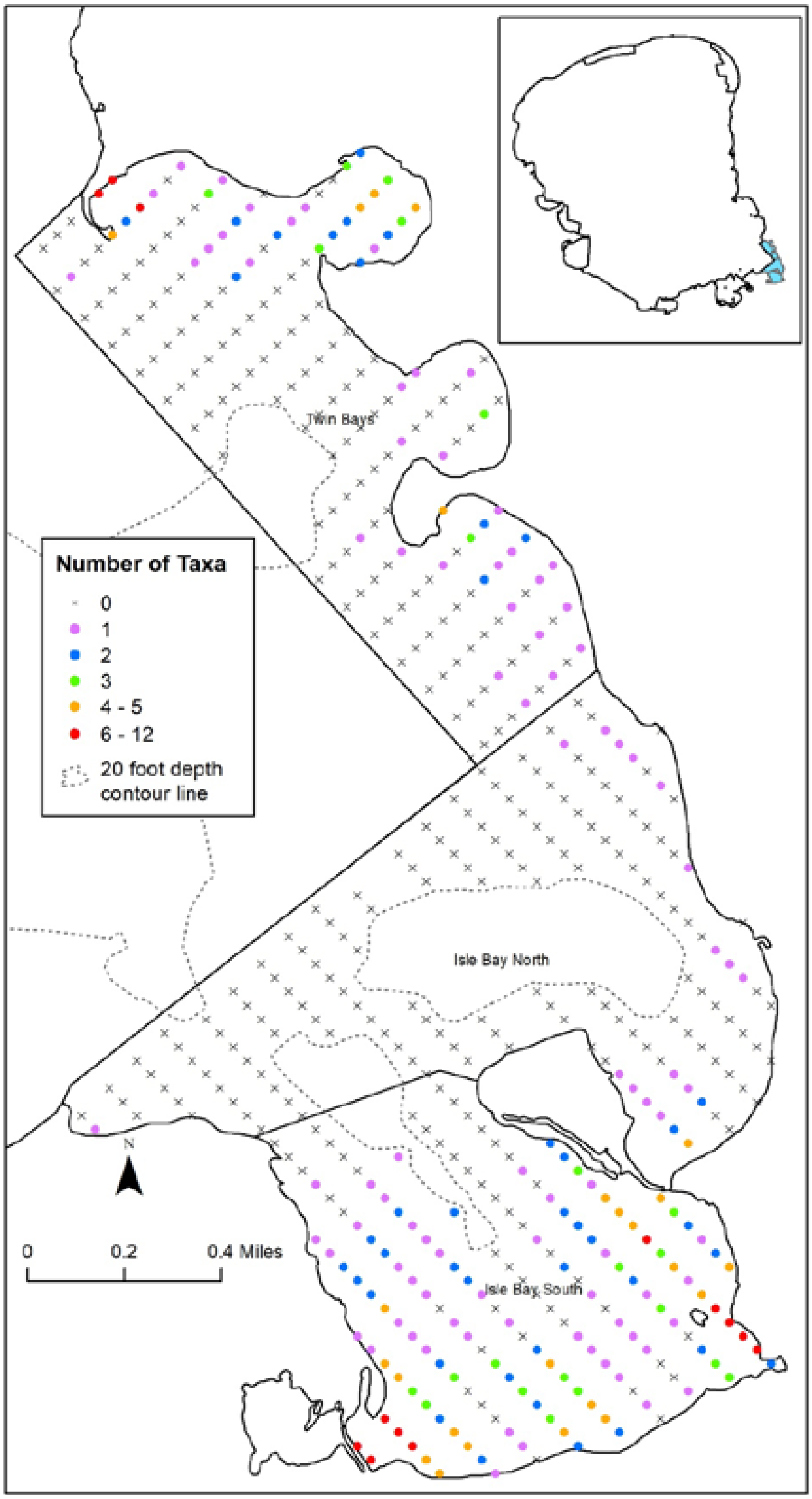
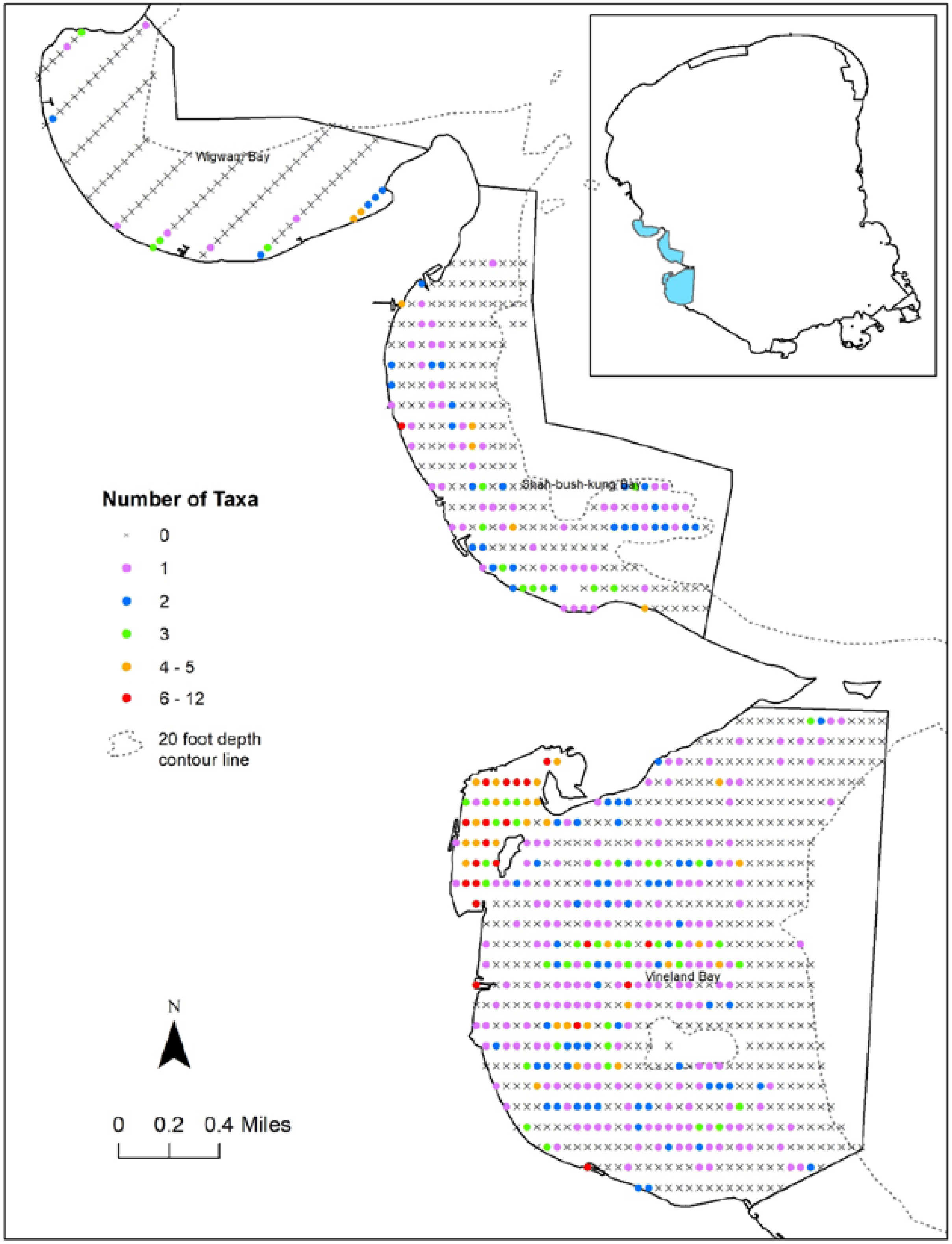


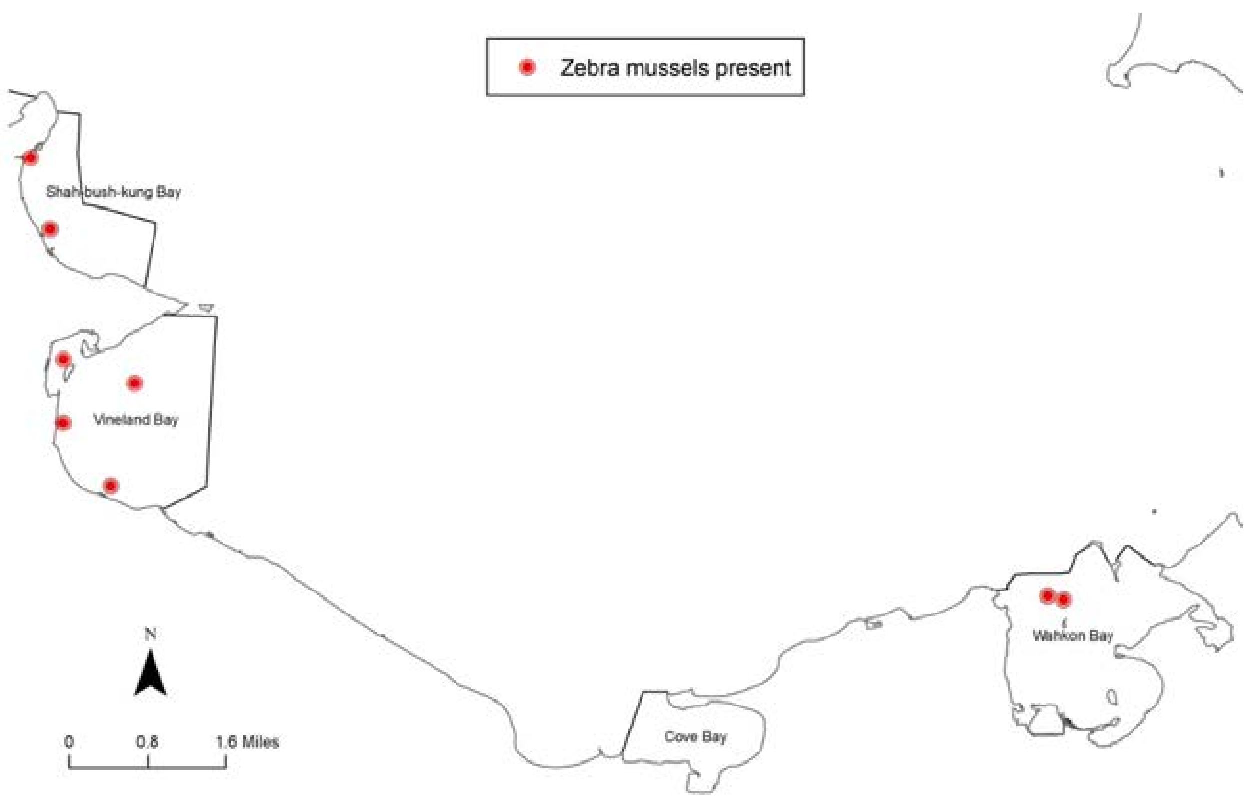
**Figure 4.10. Number of taxa per site in Wigwam, Shahbushkung and Vineland bays.**



## ZEBRA MUSSELS

In 2009, Zebra mussels were found at only 8 of the 1,196 vegetation sample sites (<1%). These sites were in Shah-bush-kung, Vineland and Wahkon bays (Figure 4.11). Depth of sites where zebra mussels were detected range from 1 to 19 feet. At most of the sites where zebra mussels were observed, surveyors did not detect vegetation. At the two vegetated sites where zebra mussels were found, plants present were finely divided species (coontail, northern watermilfoil and water buttercup) and a species with entire leaves (elodea). Substrates at the zebra mussel detection sites were mostly gravel and rubble.

**Figure 4.11. Zebra mussels present in Mille Lacs, 2009.**



## DISCUSSION

Mille Lacs supports a diverse aquatic plant community. The main lake generally does not support abundant or diverse aquatic plant growth but the diversity of habitats in protected lake areas allows a high number of species, some at high abundance, to occur in the lake. The plants found are expected in central Minnesota lakes with moderate to high clarity. The distribution of plants in Mille Lacs is strongly influenced by wave action. Sufficient light reaches the lake bottom in 15 to 25 feet to allow for submerged plant growth but heavy wave action limits the amount of vegetation that can establish and survive at these depths in this large lake. Protected areas of Vineland Bay, Wahkon Bay, Cove Bay and the south end of Isle Bay support the most abundant plant growth while windswept sites on the north shore have limited plant abundance and only a few plant taxa that are adapted to such harsh conditions.

The primary purpose of this survey was to assess vegetation. The zebra mussel data collected in 2009 is not intended to provide estimates of the lakewide zebra mussel population. Our survey likely underestimated that distribution and abundance of zebra mussels because we did not survey all available habitat and we relied on rake tosses to collect zebra mussels. The results of this study are not sufficient to determine whether zebra mussels preferentially attach to certain types of aquatic plants.

The quantitative vegetation data collected in 2009 provide baseline data for future monitoring. We selected three areas for repeated surveys: Vineland Bay, Cove Bay, and the south end of Isle Bay. These repeated surveys are discussed in Chapter 5.

# CHAPTER 5. ANNUAL VARIATION IN SUBMERGED PLANT COMMUNITIES WITHIN THREE BAYS (REPEAT POINT-INTERCEPT SURVEYS)

## INTRODUCTION

This study assessed annual variation in aquatic macrophyte communities of Mille Lacs by comparing the distribution, frequency of occurrence, and species composition between years within selected bays. Vegetation of selected bays was surveyed in 2009 using a point-intercept survey method and surveyors also recorded if zebra mussels were detected at sites during that original survey (Chapter 4).

It was not logistically feasible to repeat the quantitative point-intercept surveys in each of the original nine macroplots. Instead, we selected three sites for resurvey and chose areas that differ in shoreland development, hydrology, physical features, and plant abundance and composition: Isle Bay (area south of Malone Island), Cove Bay and Vineland Bay.

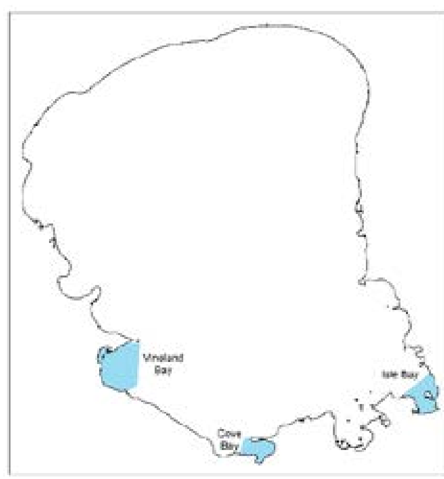
Objectives include:

1. Within each bay, compare plant frequency of occurrence between survey years.
2. Within each bay, compare species frequency of occurrence between survey years.
3. Compare and contrast variations between bays.
4. Evaluate change in zebra mussel detection rates from 2009 to 2019.

### Descriptions of Study Bays

Isle Bay, (Figure 5.1) on the southeast shore of Mille Lacs is about 851 acres in area. It is bordered on the west by Father Hennepin State Park and by private residential homes on the south and east. State Hwy 27 runs along the south end of the bay and merges with State Hwy 47 that continues north along the east shore; as with most areas of Mille Lacs, these highways are as close as 50 meters to the lake in areas. A state administered public access is on the east shore. Unnamed streams enter Isle Bay on the east and southwest shores. Isle Bay is well protected and includes both a deep (15 to 20 feet) littoral area and a shallow littoral zone. Maximum depth in this bay is 30 feet. Substrates in this bay are silt, sand, and muck.

**Figure 5.1. Locations of Study Bays**



Cove Bay, (Figure 5.1) on the south shore of Mille Lacs, is about 586 acres in area. It is mostly bordered by private property with numerous residential homes on the north, east, and south shores and larger undeveloped parcels on the west side. State Hwy 27 runs along the south end of the bay, within about 100 meters of the lake in most areas. A state managed public boat ramp is on south shore. Cove Bay Creek flows into Cove Bay, just north of the public access. Cove Bay is well protected from wind and is entirely shallow with a maximum depth of 14 feet. Substrates are silt and sand.

Vineland Bay, (Figure 5.1) is on the west shore of Mille Lacs. The entire shore of this bay is bordered by State Hwy 169; along many stretches of shore, the highway or a frontage road is less than 50 meters from the lake. At the shoreline center of the bay, the Rum River outlets into Ogechie Lake. The north half of Vineland Bay shore is Mille Lacs Band of Ojibwe property and includes one of the longest stretches of undeveloped shore on the lake including a protected, shallow embayment fringed by wetland. The shoreline on the south end of the lake is just east of Mille Lacs Kathio State Park and includes residential homes between the lake and a frontage road to Hwy 169. There is no public access on Vineland Bay but it is accessible from the public access on Shabushkung Bay to the north or other access points on the lake. The main bay is only moderately protected from the wind and receives the full force of eastern and southeastern winds; the small bay on the northwest side is well protected from wind. Vineland Bay includes a range of water depths less than 25 feet in which plants might potentially grow and substrates are also diverse with sand present in the shallows of the main basin and muck in the northwest bay.

Zebra mussels have been documented in each bay but during the 2009 point-intercept plant surveys (Chapter 4), zebra mussels were not detected at any plant sample sites in Isle Bay or Cove Bay. Zebra mussels were detected at less than one percent of the plant sample sites in 2009.

## METHODS

Plant and zebra mussel detection surveys were repeated in subsequent years using the same sampling grid established in 2009 (see Chapter 4 for survey method details). Isle Bay (the area south of Malone Island) was resurveyed in 2010 and 2014; Vineland and Cove bays were resurveyed in 2010, 2014, 2017 and 2019. Sampling occurred to 14 feet in Cove Bay (the maximum depth of that bay), and to 20 feet in Vineland and Isle bays. Isle Bay was not resurveyed in 2017 and 2019 because of other field work and time constraints.

For each bay, plant distribution, species occurrence, and zebra mussel detection data were compared between survey years. Only sites that were surveyed in all years were included in analyses. Sample number ranged from 131 in Isle Bay (the area south of Malone Island), to 535 in Cove Bay, and 560 in Vineland Bay. Frequency of vegetation occurrence was calculated as the number of sites in which vegetation occurred divided by the total number of sample sites. Frequency of occurrence was also calculated for each 5 foot depth interval and for each individual plant taxon and for zebra mussels. Frequency data are reported with 95% confidence limits for each bay.

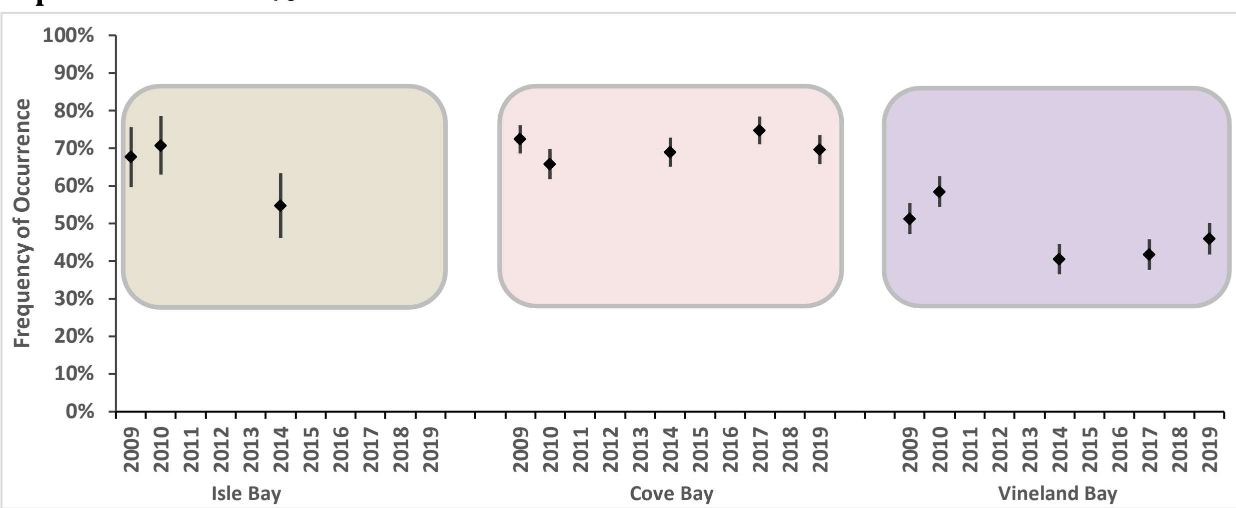
# RESULTS

## ANNUAL VARIATION IN PLANT OCCURRENCE

We compared data within the 0-15 feet depth zone. Deeper water depths were sampled in Isle and Vineland Bays but less than seven percent of those sites were vegetated.

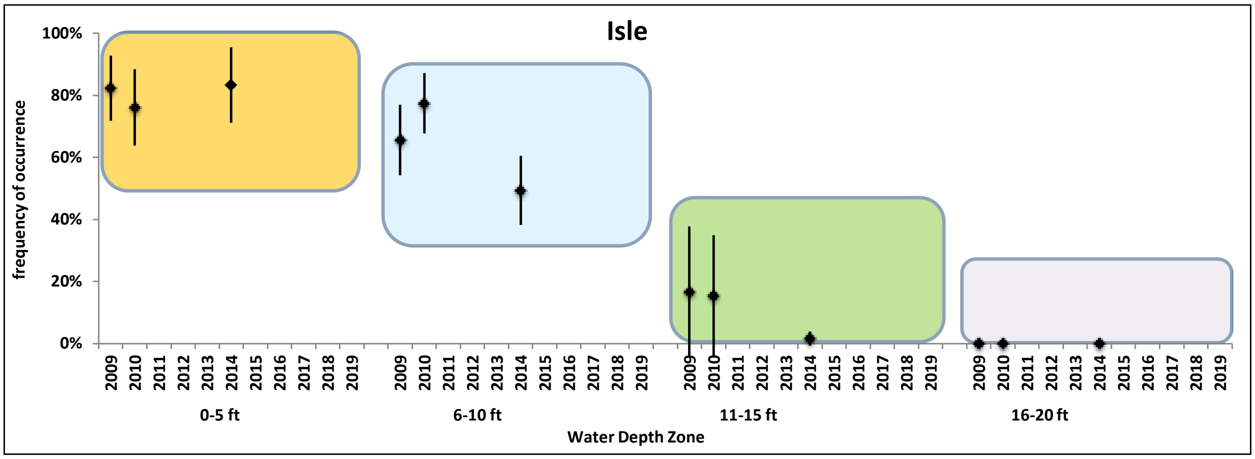
Within the 0-15 feet depth zone, Cove Bay had the highest percent of vegetated sites, followed by Isle and then Vineland (Figure 5.2). In the three seasons of sampling between 2009 and 2014, the mean plant occurrence in Isle Bay was 64% and no significant change was detected. In Cove Bay, mean plant occurrence in the five seasons of sampling between 2009 and 2019 was 70% and no significant change was detected. In Vineland Bay, mean plant occurrence was 48% in the five seasons of sampling between 2009 and 2019; plants occurrence was highest (at least 50%) in 2009 and 2010, but there was a declining trend in occurrence in following survey years.

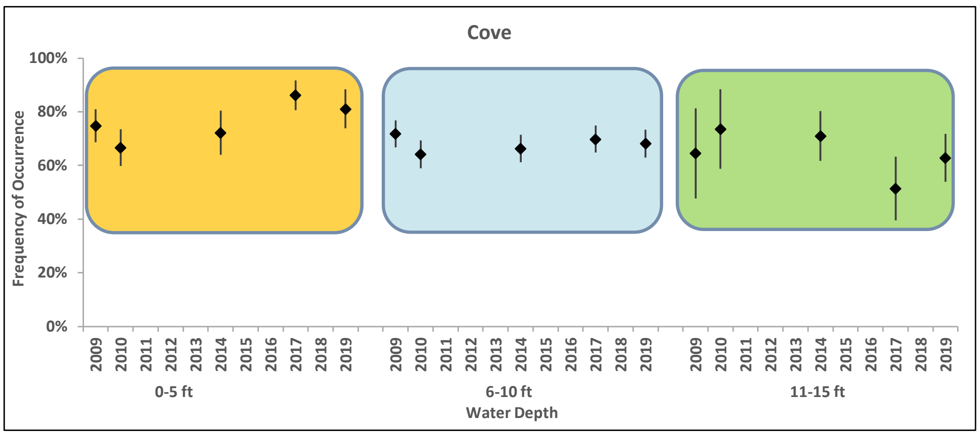
**Figure 5.2. Plant occurrence in 0-15 feet by survey year. The error bars represent the 95% confidence limits.**

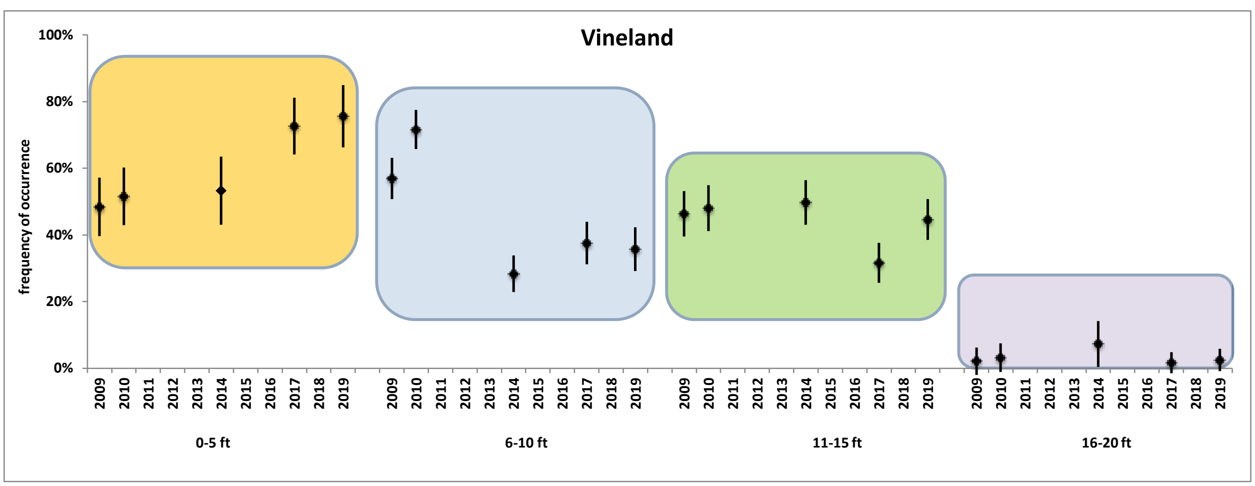



Plant occurrence in Isle declined with increasing depth and few plants were detected in depths greater than 10 feet. Plants were found to a maximum depth of 14 feet in Cove Bay and occurrence was similar (60-80%) at all depths. In Vineland Bay, plants were commonly found to 15 feet with less than 10% occurrence in the 16 to 20 feet zone. Within the 0 to 10 feet zone, plant occurrence changed after 2010. In 2009 and 2010 plant occurrence was highest in 6 to 10 feet depth zone but from 2014 to 2019, peak plant occurrence was in the 0 to 5 feet zone.

**Figure 5.3. Frequency of occurrence per depth zone in Isle, Cove and Vineland Bays from 2009-2019.**



## BETWEEN YEAR VARIATION IN PLANT SPECIES COMPOSITION

Aquatic plant species composition and diversity was similar between the three bays (Table 5.1). Submerged taxa that were detected in at least 15% of the sites in at least one survey of any of the bays include plants with grass-like leaves: wild celery (*Vallisneria americana*), flatstem pondweed (*Potamogeton zosteriformis*), narrow-leaf pondweeds (*Potamogeton* spp.), a broad-leaf pondweed (*Potamogeton praelongus*), and plants with finely divided leaves: coontail (*Ceratopyllum demersum*) and northern watermilfoil (*Myriophyllum sibiricum/verticillatum*). We compare differences in these species across survey years (Figure 5.4).

Eurasian watermilfoil (*Myriophyllum spicatum*) was detected only in Vineland and Cove Bays but we compare differences across years because this is a relatively new species to Mille Lacs and there is interest in tracking how its population may change in the lake.

Robbins pondweed (*Potamogeton robbinsii*) was found only in Cove Bay. Numerous other taxa were detected in low abundance in only one or two bays; these plants may be present in other sites but simply present below detection level.

The submerged plant, bushy pondweed (*Najas flexilis*) is an annual plant and it's look-a-like, southern naiad (*Najas guadalupensis*) can grow as an annual or a perennial. Surveyors did not distinguish these species in the field. *Najas flexilis* does not usually germinate from seed until mid-summer and surveys conducted before mid-July may miss this plant. Therefore, we did not compare data across survey years for these taxa because differences in plant occurrence between years may be due to survey date and not actual differences in plant populations.

The free-floating plant, star duckweed (*Lemna trisculca*) was also commonly found in all survey years. Because this plant is not anchored to the lake bottom, it drifts freely with the current and its location within a bay can vary daily. Therefore, we did not compare differences in this species across years.

### Isle Bay

A total of 32 taxa was recorded from 2009 to 2014 and included 21 submerged, 1 free-floating, 3 floating-leaf and 7 emergent taxa (Table 5.1). Sample number was not large enough to detect changes in most taxa. Two taxa did decrease significantly from 2009-2010 to 2014: northern watermilfoil and narrow-leaf pondweeds (Figure 5.4). Eurasian watermilfoil was not detected in Isle Bay during the 2009, 2010 and 2014 surveys and this bay was not surveyed after 2014.

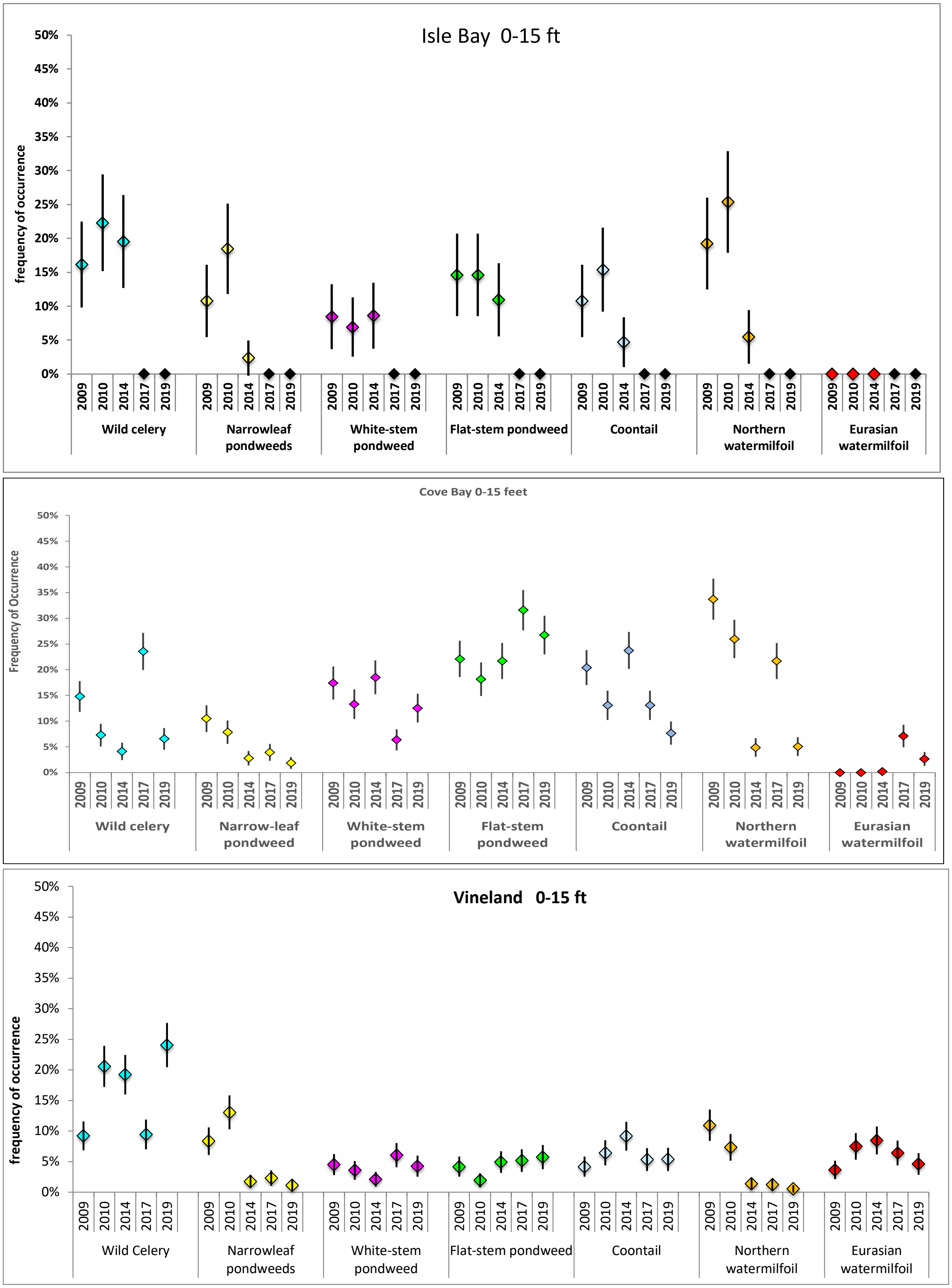
## TABLE 5.1. VEGETATION DATA OF POINT-INTERCEPT SURVEY FOR VINELAND, COVE AND ISLE BAYS OF MILLE LACS (2009, 2010, 2014, 2017, AND 2019).

[1]max depth of Cove Bay is 14 feet

| Life Form | | | Common Name | Scientific Name | Isle | | | Cove[1] | | | | | Vineland | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2009 | 2010 | 2014 | 2009 | 2010 | 2014 | 2017 | 2019 | 2009 | 2010 | 2014 | 2017 | 2019 |
| Large algae, mosses and fern like | | | Muskgrass | *Chara* sp. | 2 | 5 | | 4 | 5 | 3 | 4 | 1 | 1 | 2 | <1 | 2 | 1 |
| | | | Stonewort | *Nitella* sp. | 1 | | | | | <1 | <1 | -- | <1 | | <1 | <1 | |
| | | | Watermoss | Not identified to genus | | | | | 1 | | <1 | <1 | 3 | 3 | | 4 | |
| Monocots (entire leaves) | Annual | Naiads | Bushy pondweed | *Najas flexilis* | 9 | 7 | 1 | 1 | | <1 | 1 | <1 | 4 | 16 | 2 | 2 | 2 |
| | | | Southern naiad | *Najas guadalupensis* | | | | | | | | | | | | | |
| | Pondweeds | Broad-leaf | Large-leaf pondweed | *Potamogeton amplifolius* | 2 | 1 | 2 | 2 | 1 | 2 | 4 | 3 | 1 | 1 | 1 | 2 | 1 |
| | | | Variable pondweed | *P. gramineus* | 4 | 2 | 1 | 4 | 4 | 1 | 2 | 3 | 10 | 8 | 1 | 1 | 1 |
| | | | Illinois pondweed | *P. illinoensis* | 4 | 3 | 6 | 4 | 1 | 1 | 2 | 1 | 2 | 1 | | 2 | <1 |
| | | | White-stem pondweed | *P. praelongus* | **8** | **7** | **9** | **1** | **13** | **19** | **6** | **1** | **5** | **4** | **2** | **6** | **4** |
| | | | Clasping-leaf pondweed | *P. richardsonii* | 5 | 2 | 1 | 6 | 2 | 1 | 8 | 5 | 9 | 9 | 1 | 1 | <1 |
| | | | Curly-leaf pondweed | *P. crispus* | | 3 | 2 | 1 | 1 | 1 | <1 | 1 | 1 | | <1 | 1 | |
| | | Narrow-leaf | Narrow-leaf pondweed | *Potamogeton* sp. | 11 | 18 | 2 | 10 | 8 | 3 | 4 | 2 | 8 | 13 | 2 | 2 | 1 |
| | | | Fries pondweed | *P. friesii* | | | | | | | | | | | | | |
| | | Grass-leaf | Flat-stem pondweed | *P. zosteriformis* | 15 | 15 | 11 | **2** | **18** | **22** | **3** | **2** | 4 | 2 | 5 | 5 | 6 |
| | | | Robbins pondweed | *P. robbinsii* | | | | 10 | 5 | 13 | 10 | 17 | | | | | |
| | | | Wild celery | *Vallisneria americana* | 16 | 22 | 20 | **1** | **7** | **4** | **2** | **7** | 9 | 21 | 19 | 9 | 24 |
| | | | Water stargrass | *Heteranthera dubia* | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | <1 | <1 | |
| | | | Sago pondweed | *Stuckenia pectinata* | 2 | 3 | | 3 | 3 | 1 | 1 | <1 | 2 | 4 | <1 | <1 | <1 |
| | Whorled leaf | | Canada waterweed | *Elodea canadensis* | 7 | 6 | 5 | 8 | 13 | 5 | 6 | 5 | 6 | 4 | 3 | 4 | 3 |
| Dicots | Submerged | | Coontail | *Ceratophyllum demersum* | **11** | **1** | **5** | **2** | **13** | **24** | **1** | **8** | 4 | 6 | 9 | 5 | 5 |
| | | | Native Watermilfoils | *Myriophyllum sibiricum/verticillatum* | **19** | **2** | **5** | **3** | **26** | **5** | **2** | **5** | 11 | 7 | 1 | 1 | 1 |
| | | | Eurasian watermilfoil | *Myriophyllum spicatum* | | | | | | <1 | 7 | 3 | 4 | 8 | 8 | 6 | 5 |
| | | | Leafless watermilfoil | *Myriophyllum tenellum* | | | | | <1 | | | | | | <1 | <1 | |

| Life Form | | Common Name | Scientific Name | Isle | | | Cove[1] | | | | | Vineland | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2009 | 2010 | 2014 | 2009 | 2010 | 2014 | 2017 | 2019 | 2009 | 2010 | 2014 | 2017 | 2019 |
| Dicots | Submerged | Water marigold | *Bidens beckii* | 7 | 15 | 2 | 8 | 7 | 3 | 7 | 1 | <1 | 1 | 1 | 1 | 1 |
| | | Water buttercup | *Ranunculus aquatilis* | 12 | 7 | 2 | 9 | 4 | 2 | 10 | 2 | 6 | 1 | 1 | 4 | |
| | Free-drifting | Greater bladderwort | *Utricularia vulgaris* | | | 2 | | <1 | <1 | <1 | | | | <1 | | <1 |
| | | Flat-leaved bladderwort | *Utricularia intermedia* | | 1 | | | | | | | | | | | |
| | | Humped bladderwort | *Utricularia gibba* | | | | | <1 | | | | | | | | |
| | Free-floating | Star duckweed | *Lemna trisulca* | 17 | 25 | 9 | 37 | 37 | 56 | 46 | 48 | 4 | 4 | 6 | 6 | 2 |
| | | Lesser duckweed | *Lemna* sp. | | | | | | | <1 | <1 | P | | | <1 | |
| | | Greater duckweed | *Spirodella polyrhiza* | | | | | <1 | | <1 | | <1 | | | <1 | |
| | | | Total | 19 | 20 | 18 | 20 | 24 | 23 | 27 | 23 | 24 | 20 | 22 | 26 | 18 |
| Floating-leaf | | White waterlily | *Nymphaea odorata* | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 | 1 | 1 |
| | | Yellow waterlily | *Nuphar variegata* | 4 | 2 | 1 | <1 | <1 | <1 | <1 | 1 | | | | <1 | |
| | | Floating-leaf pondweed | *Potamogeton natans* | | | | | | | | | | | | | <1 |
| | | Floating-leaf burred | *Sparganium* sp. | 1 | | 1 | | P | | | | | | | | |
| | | | Total | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 |
| Emergent | | Needlerush | *Eleocharis acicularis* | | | | 2 | 1 | 3 | 1 | | | | <1 | 1 | |
| | | Spikerush | *Eleocharis* sp. | 5 | 5 | 5 | 5 | 4 | 3 | 5 | 6 | 1 | 2 | 2 | 2 | 2 |
| | | Giant cane | *Phragmites australis* | | | | <1 | <1 | <1 | | | P | | | | |
| | | Arrowhead | *Sagittaria* sp. | 6 | 4 | 3 | 2 | 1 | 1 | 2 | | 2 | 2 | | 1 | 1 |
| | | Three-square bulrush | *Schoenoplectus pungens* | 2 | 1 | 2 | | <1 | | | | <1 | 1 | <1 | 1 | <1 |
| | | Bulrush | *Schoenoplectus acutus* | 11 | 8 | 11 | 8 | 6 | 7 | 6 | 9 | 1 | 1 | 1 | 1 | 1 |
| | | Giant burreed | *Sparganium eurycarpum* | | | | | | | | | <1 | | | | |
| | | Burreed | *Sparganium* sp. | | | 1 | | | | | | | | | | |
| | | Cattail | *Typha* sp. | 1 | 2 | 1 | 1 | 1 | <1 | | <1 | <1 | <1 | <1 | <1 | <1 |
| | | Wild rice | *Zizania palustris* | 3 | 1 | 4 | | P | | | | | | | | |
| | | | Total | 6 | 6 | 7 | 6 | 8 | 6 | 4 | 3 | 7 | 6 | 5 | 6 | 5 |

**Figure 5.4. Common plants in Isle Bay 2009, 2010, and 2014; Cove, and Vineland Bays from 2009, 2010, 2014, 2017, 2019.**



**Cove Bay**
A total of 40 taxa were found from 2009 to 2019 and included 26 submerged, 3 free-floating, 3 floating-leaf and 8 emergent taxa. Several species, including Northern watermilfoil and narrow-leaf pondweeds varied in abundance from 2009 to 2019 (Figure 5.4). Eurasian watermilfoil was observed in 2014, 2017 and 2019 and in all years occurred in less than 10% of the survey site.

**Vineland Bay**

Forty taxa were found in Vineland Bay from 2009 to 2019 and included 24 submerged, 3 free-floating, 3 floating-leaf and 8 emergent taxa (Table 5.1).

Northern watermilfoil declined in distribution and frequency through the study period. In 2009 it was found in 63 sites and was distributed throughout the bay. By 2019 it was detected in only three sites and was confined to the shallow mucky bay on the northwest side of Vineland Bay (Figure 5.4).

Eurasian watermilfoil was detected in all five survey years at a frequency of less than 10%. It was one of only a few plant species observed in water depths greater than 10 feet and formed a stand that covered about 70 acres in the center of the bay (Figure 5.5).

**Figure 5.5. Northern watermilfoil vs Eurasian watermilfoil in Vineland Bay 2009-2019.**

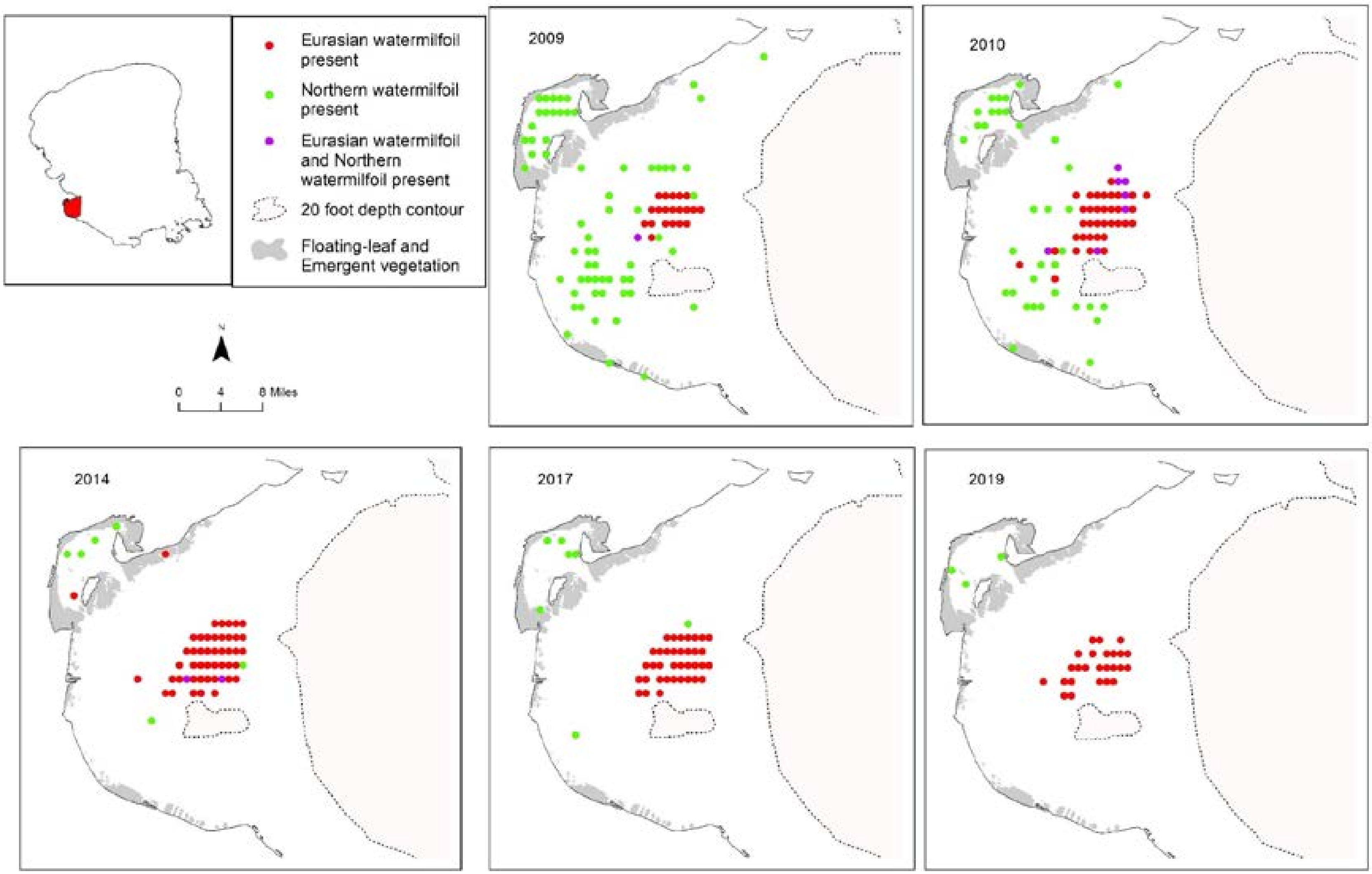
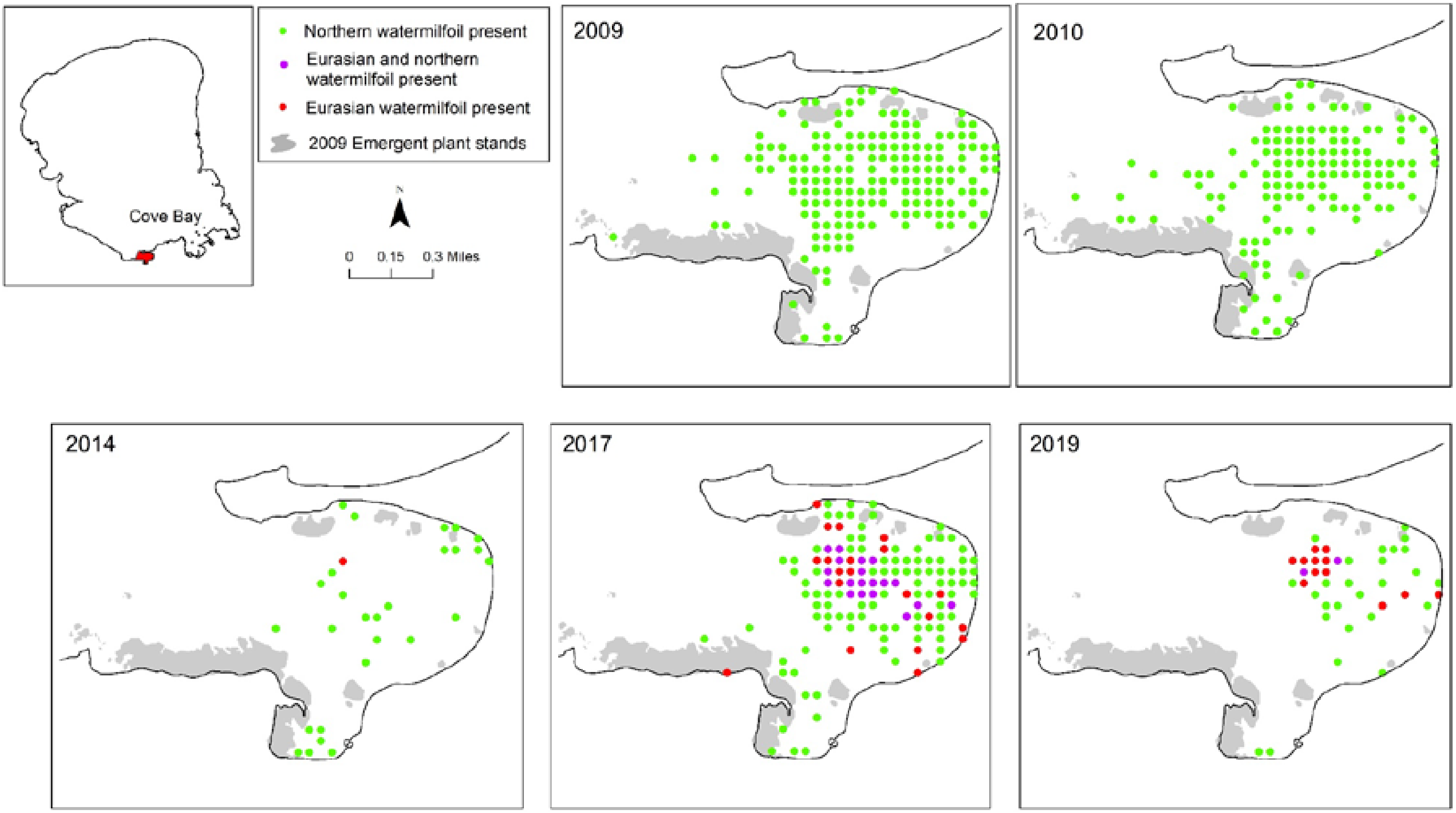


**Figure 5.6. Northern watermilfoil vs Eurasian watermilfoil in Cove Bay 2009-2019.**



## ANNUAL VARIATION IN ZEBRA MUSSEL DETECTION

In 2009, Zebra mussels were found at eight (<1%) of the 1,196 vegetation sample sites (Chapter 4). They were found in 4 sites of Vineland Bay and were not observed in Cove or Isle Bay.

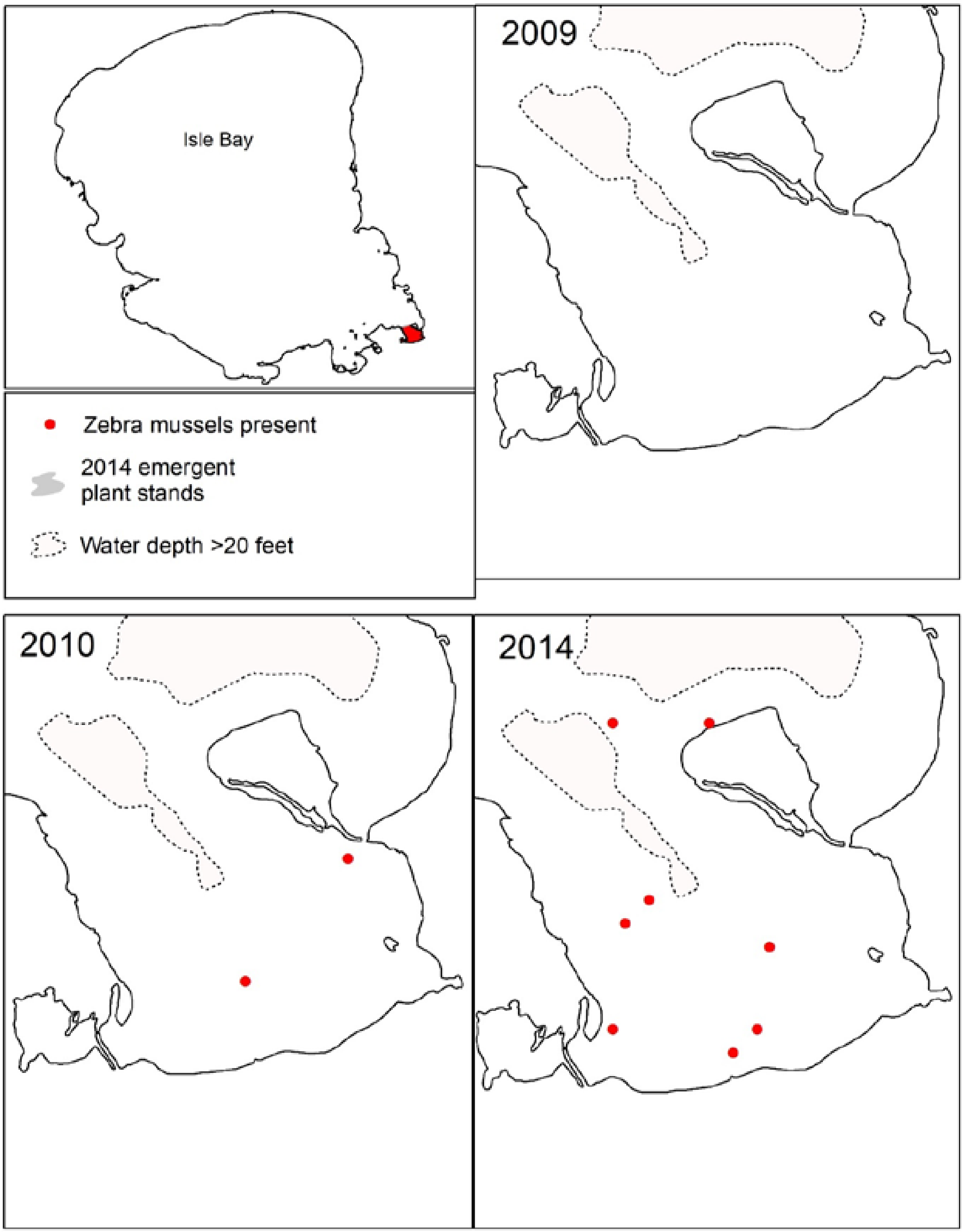
In Isle Bay, zebra mussels were detected in 2014; surveys were not conducted in later years. In Cove Bay, zebra mussels were detected in 2014 and 2017 and occurred throughout the bay at all depths sampled. The survey was not repeated in 2019. In Vineland Bay, zebra mussels were detected in all survey years and by 2010 they were found throughout the bay to a depth of 15 feet. Within the 0-15 feet depth zone, zebra mussel detection rate varied annually (Figure 5.7 and 5.8).

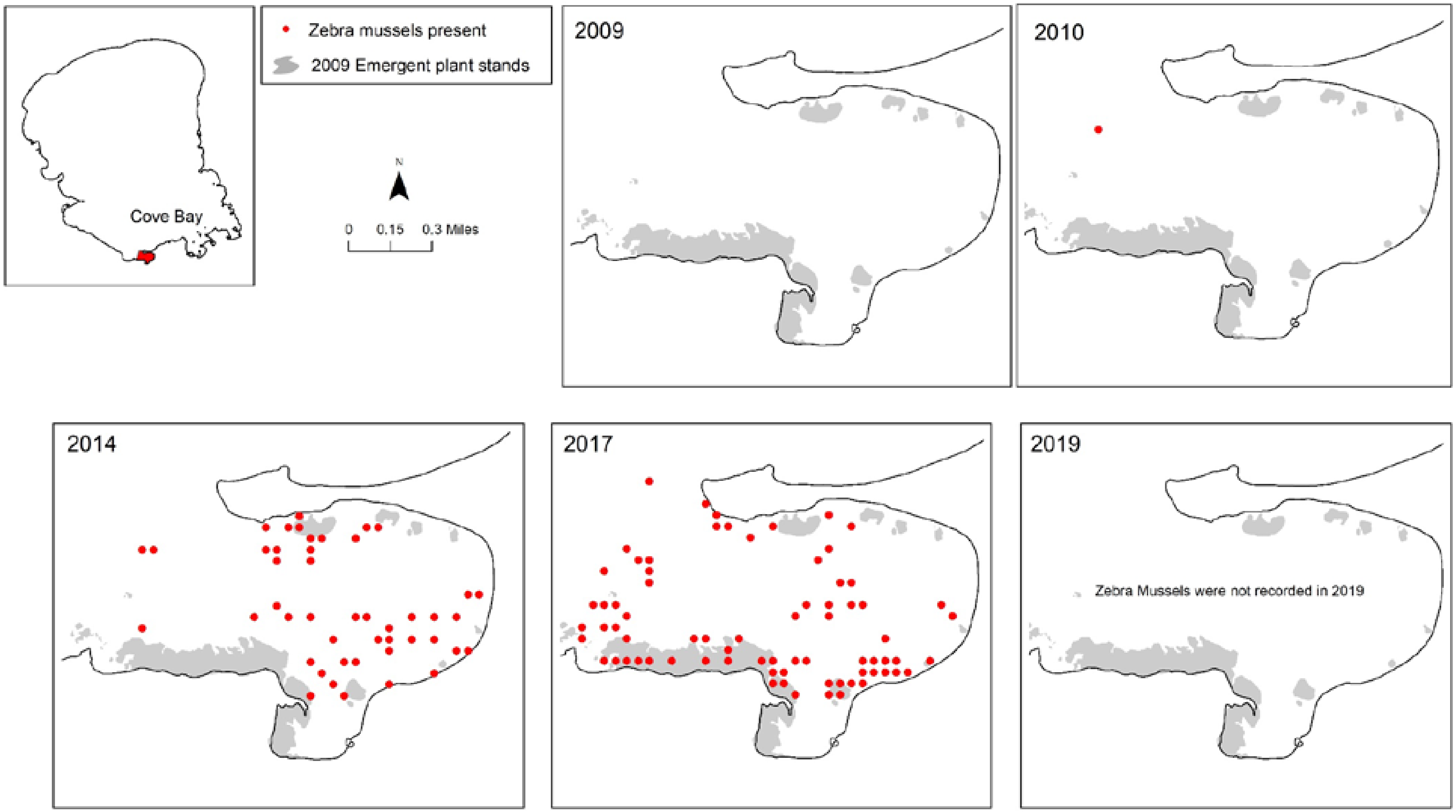
Zebra mussels were observed on a variety of submerged plant types including species with finely divided leaves such as coontail, northern watermilfoil, and Eurasian watermilfoil and plants with entire or grass-like leaves such as wild celery.

## DISCUSSION

These repeated quantitative surveys did not detect dramatic changes in plant distribution, cover or composition. There were annual changes in individual species occurrences but most species did not show a consistent trending pattern (increase or decrease) and patterns were not repeatedly seen in each bay. These datasets provide useful baseline data when surveys are repeated in future years (see recommendations in executive summary).

**Figure 5.7. Zebra mussels in vegetation samples in three selected bays in Mille Lacs, 2009-2019.**




Cove Bay
Zebra mussels present
2009 Emergent plant stands
N
0 0.15 0.3 Miles
2009
2010
2014
2017
2019
Zebra Mussels were not recorded in 2019

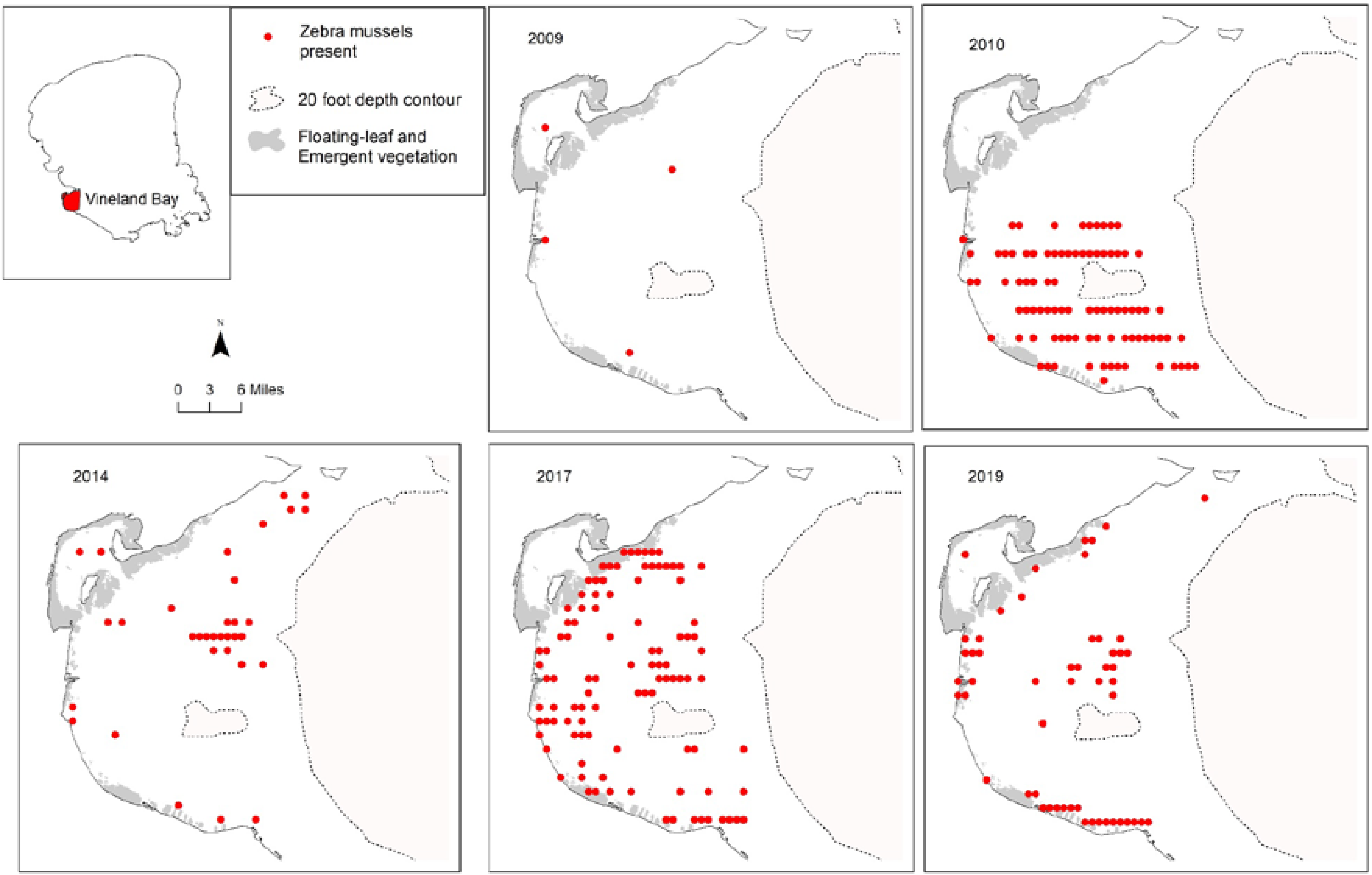
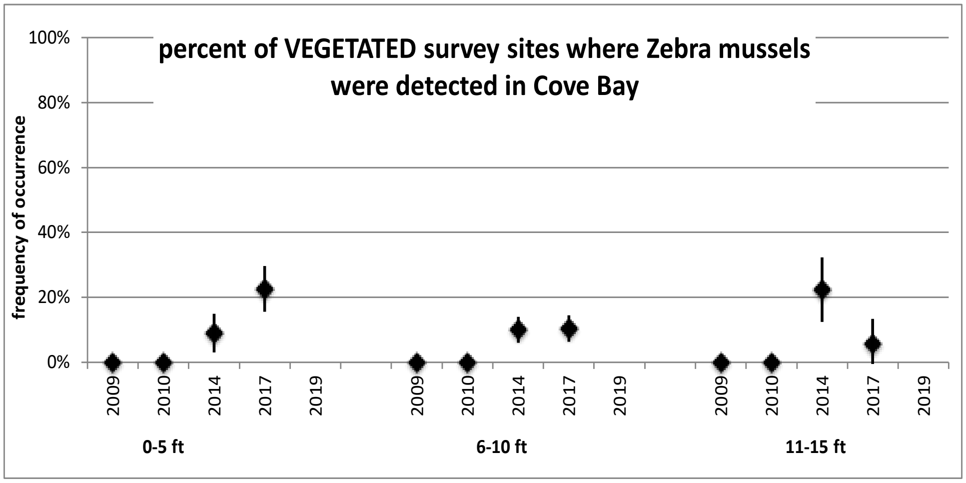
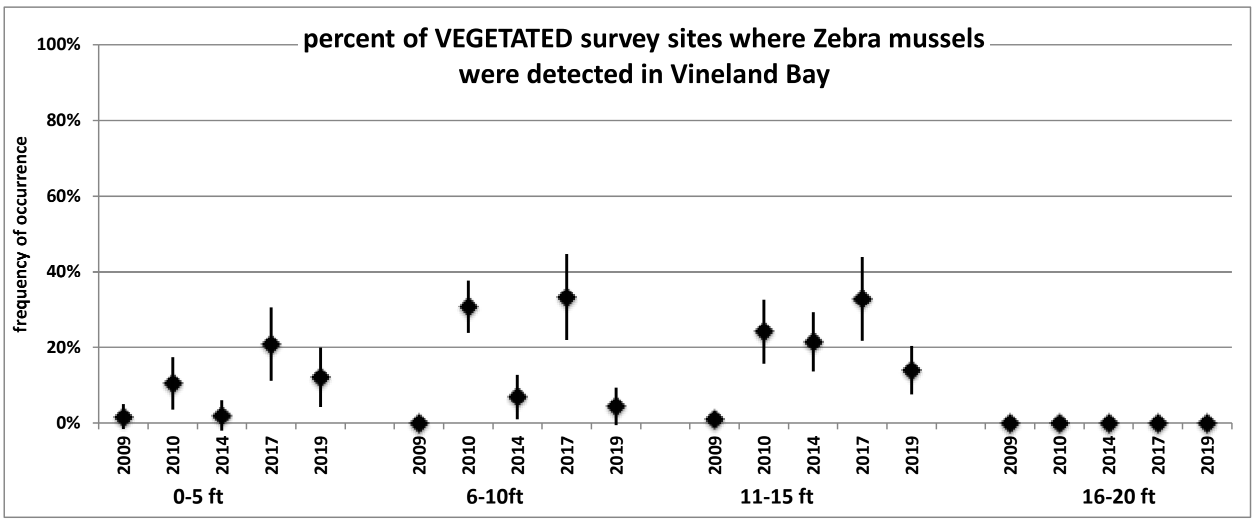

Vineland Bay
Zebra mussels present
20 foot depth contour
Floating-leaf and Emergent vegetation
N
0 3 6 Miles
2009
2010
2014
2017
2019

**Figure 5.8. Percent of vegetated survey sites where zebra mussels were detected.**



# CHAPTER 6. NEARSHORE SURVEYS

## INTRODUCTION

The nearshore zone is often the area of highest plant species richness because it is the area of highest light and a variety of plant life forms (emergent, floating, submerged and free-floating) co-exist in shallow water. This is often a narrow zone, particularly on lakes or bays where water levels increase sharply from the shore. The Point-Intercept Survey (Chapters 4 and 5) may not adequately capture the plant diversity of this nearshore zone because the survey grid has relatively few points in this zone. To account for this, we supplemented the Point-Intercept Survey of Mille Lacs with nearshore plots.

The Objectives of this survey were to search for plant species, particularly those that may have been missed or under-represented in the Point-Intercept Survey and to estimate how frequently they occur within the narrow nearshore zone.

## METHODS

Nearshore vegetation survey plots were established in Cove and Vineland Bay using methodology described in Perleberg et al. (2019). Plots were spaced 500 meters apart along the shore-water interface. Each plot was approximately 5m x 5m in area. At each plot, surveyors recorded the water depth at the center of the plot and all plants observed. In 2017, surveyors also noted if they detected zebra mussels within the plots. Zebra mussel searches were repeated in 2019 in Vineland Bay but not in Cove Bay.

Thirteen plots were surveyed in Cove Bay. The initial survey was conducted in the middle of July, 2017 and repeated in early July, 2019. Twenty-five plots were surveyed in Vineland Bay. The initial survey was conducted in early July, 2017 and repeated in early August, 2019.

For each bay, frequency of occurrence for each plant taxa was calculated and Chi-square analysis was used to determine if annual differences were statistically significant. In Vineland Bay, we also compared zebra mussel distribution and occurrence between survey years.

## RESULTS

Cove Bay plots ranged in depth from 0.5 to 3 feet and most sites had substrate that was described as rubble and gravel. A total of 33 plant taxa were recorded in Cove Bay with 31 reported in 2017 and 24 in 2019. Plant types included 20 submerged, three free-floating, three floating-leaf and eight emergent (Table 6.1). The total number of plant taxa observed in plots ranged from 0 to 14 (Figure 6.1).

**Table 6.1. Frequency of occurrence in the nearshore surveys in 2017.**

| Life Form | Common Name | Scientific Name | Cove Bay Nearshore N=13 | | Vineland Bay Nearshore N=25 | |
|---|---|---|---|---|---|---|
| | | | 2017 | 2019 | 2017 | 2019 |
| Algae | Muskgrass | *Chara* sp.** | 15 | -- | 4 | 12 |
| | Stonewort | *Nitella* sp.** | -- | -- | -- | 8 |
| | | | | | | |
| Submerged | Coontail | *Ceratophyllum demersum* | 46 | 31 | 40 | 60 |
| | Hornwort | *Ceratophyllum echinatum* | -- | -- | -- | 4 |
| | Canada Waterweed | *Elodea canadensis* | 23 | 8 | 32 | 44 |
| | Water Stargrass | *Heteranthera dubia* | 31 | 15 | 4 | 12 |
| | Water marigold | *Bidens beckii* | -- | -- | -- | 8 |
| | Northern watermilfoil | *Myriophyllum sibiricum* | 31 | 15 | 16 | 32 |
| | Eurasian watermilfoil | *Myriophyllum spicatum* | 15 | -- | -- | 12 |
| | Bushy pondweed | *Najas flexilis* | 31 | -- | 16 | 36 |
| | Large-leaf pondweed | *Potamogeton amplifolius* | -- | 23 | -- | -- |
| | Curly-leaf pondweed | *Potamogeton crispus* | -- | 8 | 8 | 4 |
| | Variable pondweed | *Potamogeton gramineus* | 15 | 23 | -- | 8 |
| | Illinois pondweed | *Potamogeton illinoisensis* | 8 | -- | 4 | -- |
| | Clasping-leaf pondweed | *Potamogeton richardsonii* | 15 | 15 | 4 | 12 |
| | Narrow-leaf pondweed | *Potamogeton* sp. *** | 62 | 54 | 56 | 32 |
| | Sago pondweed | *Stuckenia pectinatus* | 8 | 8 | 8 | -- |
| | Robbin's pondweed | *Potamogeton robbinsii* | 8 | -- | -- | -- |
| | Flat-stem pondweed | *Potamogeton zosteriformis* | 69 | 23 | 36 | 44 |
| | White-water buttercup | *Ranunculus aquatilus* | 31 | 15 | 24 | 4 |
| | Greater bladderwort | *Utricularia vulgaris* | 15 | 15 | 20 | 20 |
| | Water celery | *Vallisneria americana* | 46 | 46 | 24 | *68 |
| | | | | | | |
| Free-floating | Lesser duckweed | *Lemna* spp. | 15 | 15 | 20 | 16 |
| | Star duckweed | *Lemna trisulca* | 100 | 77 | 36 | 36 |
| | Greater duckweed | *Spirodela polyrhiza* | 8 | 8 | 8 | 20 |
| | | | | | | |
| Floating-leaf | White waterlily | *Nymphaea odorata* | 23 | 31 | 44 | 32 |
| | Yellow waterlily | *Nuphar variegata* | 15 | 15 | -- | 4 |
| | Floating-leaf pondweed | *Potamogeton natans* | 8 | -- | 8 | 8 |
| | | | | | | |

| Life Form | Common Name | Scientific Name | Cove Bay Nearshore N=13 | | Vineland Bay Nearshore N=25 | |
|---|---|---|---|---|---|---|
| | | | 2017 | 2019 | 2017 | 2019 |
| Emergent | Water arum | *Calla palustris* | 8 | -- | 4 | -- |
| | Needlerush | *Eleocharis acicularis* | 8 | 23 | 4 | 12 |
| | Spikerush | *Eleocharis palustris* | 8 | 15 | 16 | 8 |
| | Arrowhead | *Sagittaria* sp. | 31 | 15 | 32 | 32 |
| | Three-square bulrush | *Schoenoplectus pungens* | 8 | -- | 4 | 4 |
| | Bulrush | *Schoenoplectus* sp. | 8 | -- | 16 | 4 |
| | Cattail | *Typha* sp. | 38 | 46 | 52 | 48 |
| | Reed Canary Grass | *Phalaris arundinaceum* | 8 | 8 | -- | -- |
| | Giant Cane | *Phragmites australis* | -- | -- | 4 | 8 |
| | | Total | 31 | 24 | 27 | 32 |

*indicates a statistically significant increase from the previous year $\chi^2$ (1, N = 25 for Vineland and N=13 for Cove), $p < 0.01$.

**Three species of stonewort (*Nitella*) and two species of muskgrass (*Chara*) were tentatively identified in Mille Lacs as *Nitella furcata, Nitella acuminata, Nitella flexilis, Chara globularis,* and *Chara braunii. Species identification should be considered tentative pending results from DNA analyses.*

***Narrow-leaf pondweeds were grouped together for analysis. One narrow-leaf taxa was identified as Fries pondweed (*Potamogeton friesii*).

Many of the taxa that were frequently found in the bay-wide point-intercept survey were also commonly found in the nearshore plots including flat-stem pondweed, water celery, narrow leaf pondweeds, and coontail, each present in at least 45% of the plots in one or both years. The free-floating plant, star duckweed, was the most frequently detected plant in both survey years. We detected one emergent taxa that was not previously found during the Point-Intercept Survey of this bay: water arum (*Calla palustris*). Bushy pondweed (*Najas flexilis)* was found in 31% of the Cove Bay plots in 2017 but was not relocated in 2019; this is likely because the 2019 survey was conducted in early July before this annual plant is mature. The number of survey plots in Cove Bay was not sufficient to detect change in most species and if a species was detected in one survey year but not both years, this does not indicate an actual change in the species abundance.

Vineland Bay plots ranged in depth from one feet to four feet and sites included a mix of muck, sand, and rubble. A total of 35 plant taxa were recorded including 27 in 2017 and 32 in 2019. The total number of plant taxa observed in plots ranged from 0 to 14 (Figure 6.1). Plant types found included 21 submerged, three free-floating, three floating-leaf and eight emergent. Species that were common (occurring in 45% or more of the plots in one or both years) included flat-stem pondweed, water celery, Canada waterweed, and coontail. We detected three species that were not previously found during Point-Intercept Surveys: hornwort (*Ceratophyllum echinatum*), water arum (*Calla palustris*) and giant cane (*Phragmites australis*). We detected a statistically significant change in only one species between survey years; water celery increased from 24% in 2017 to 68% in 2019.

Eurasian watermilfoil was detected in two of the Cove Bay plots in 2017 but was not relocated in 2019. In 2017 it was not detected in Vineland Bay plots but was found in three plots in that bay in 2019.

Zebra mussels were found in Vineland Bay, in 9 of the 25 sites in both 2017 and 2019.

## DISCUSSION

The nearshore, shallow zones of Cove and Vineland Bays support the highest numbers of aquatic plant taxa. These nearshore plots provide detailed data on this zone that are not available from the point-intercept survey alone. Three new species were found while conducting the nearshore sites that haven't been found in the lake before. These species are usually found in shallow water protected from wind and boat traffic. While some species, such as water celery, decreased in the shallow zone between two survey years, this trend was not observed in the larger, bay-wide assessments that covered 5 years. Repeated monitoring over several years is required to evaluate whether yearly differences are indicating patterns of change or if some taxa simply fluctuate naturally in distribution and/or abundance between years.

We recommend repeating the nearshore survey when the point-intercept is repeated on each bay.

**Figure 6.1. Number of taxa per site - nearshore plots on Cove Bay**

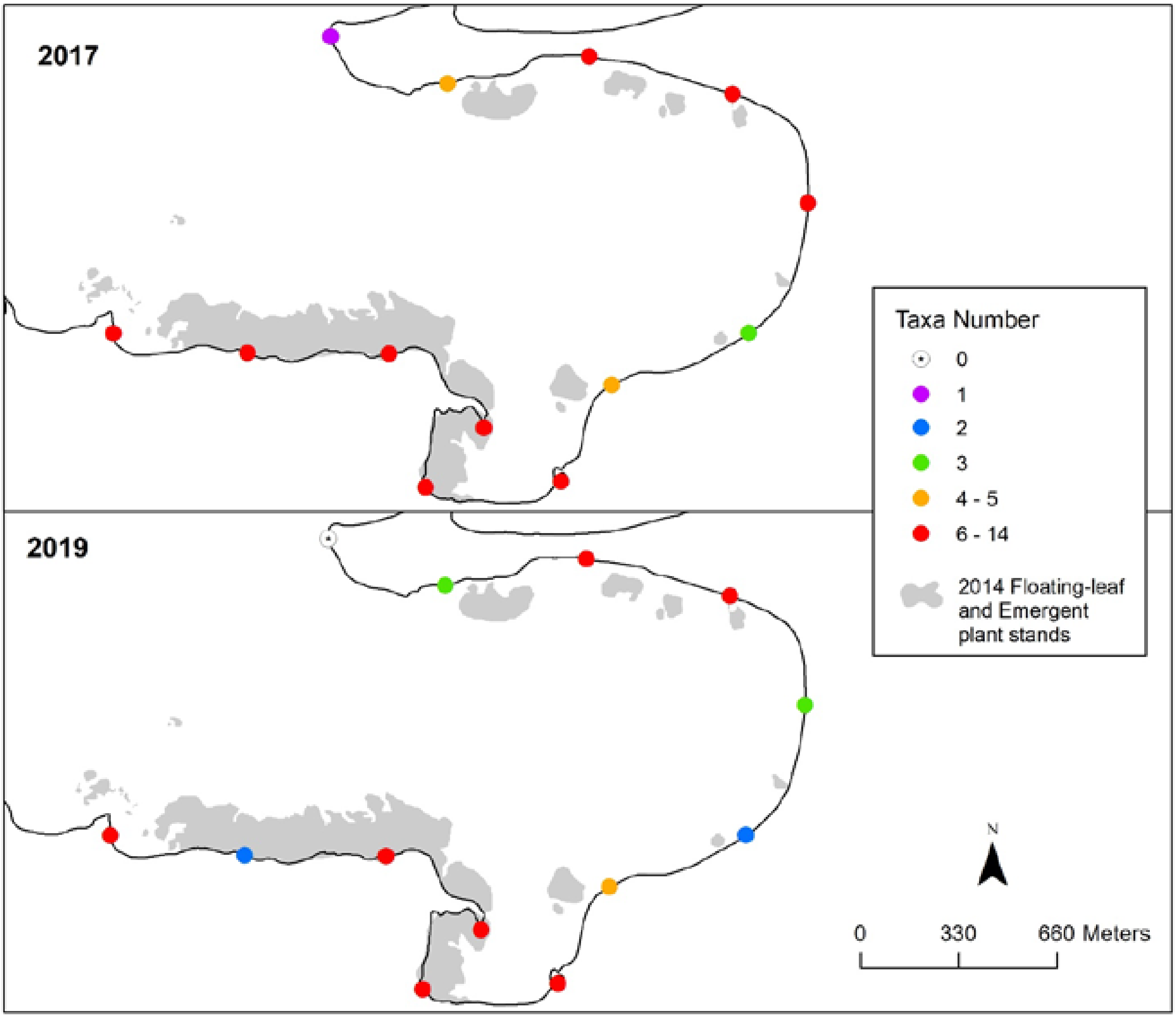
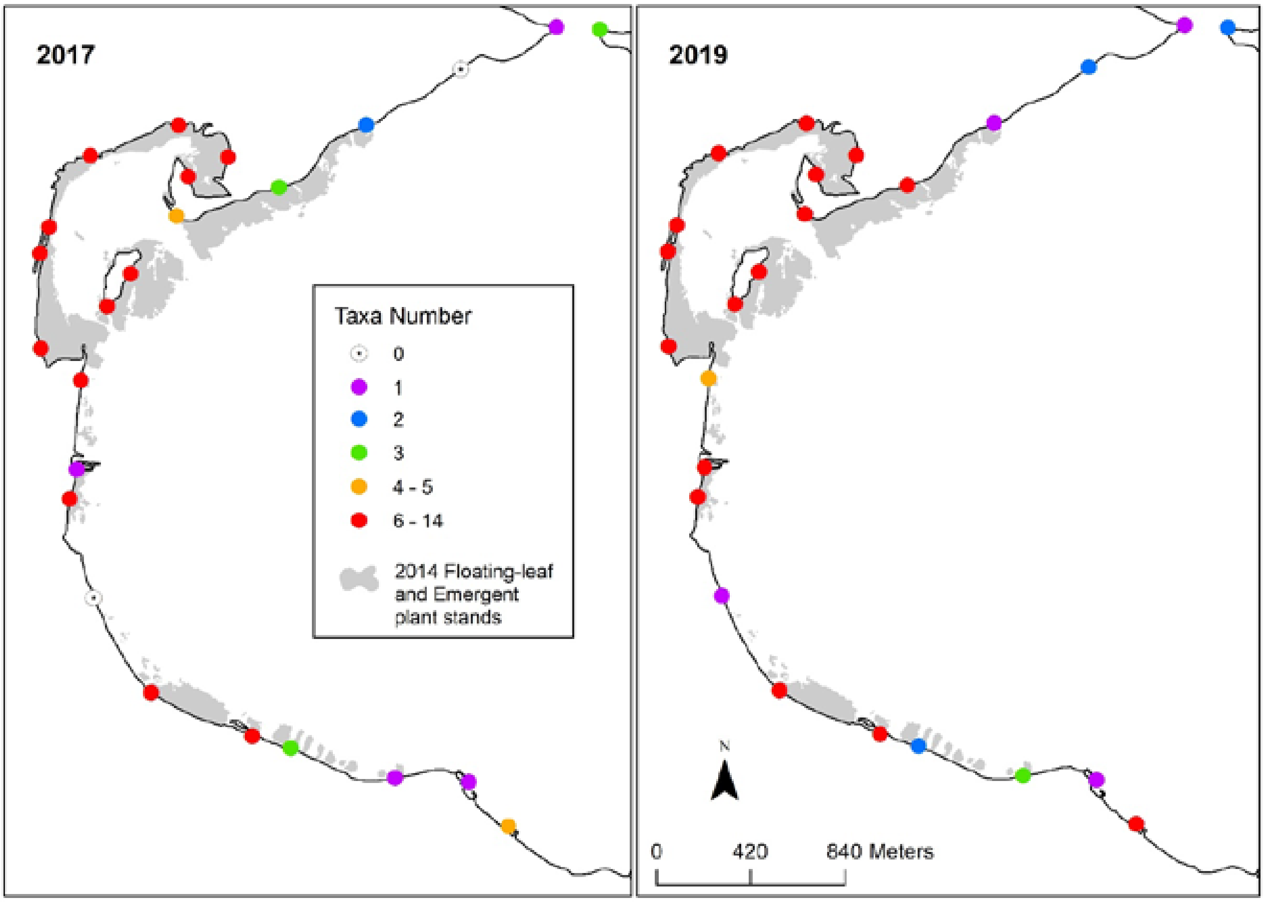


**Figure 6.2. Number of taxa per site - nearshore plots on Vineland bay**



# CHAPTER 7. HYDROACOUSTICS

## INTRODUCTION

Submerged vegetation communities are dynamic, reflecting the varied life histories and environmental preferences of the composed species, e.g., nutrient availability, wind exposure, bottom substrate, water level fluctuations, and water depth (Wetzel 2001). While, quantification of submerged plant abundance is important, abundance estimates are expensive to obtain and are highly variable across littoral areas (Downing and Anderson 1985).

Investigators have used hydroacoustics, or the use of transmitted sound pulses to sample the water column, for aquatic plant surveys for over 30 years (Maceina and Shireman 1980). One of the main advantages of this remote sensing technique is that sound travels quickly in fresh water (~1480 m/s), so that the entire water column can be sampled almost instantaneously using mobile survey techniques. The distance between the transducer and an acoustically reflective target can be calculated based on the time delay between an emitted signal and a return signal using the velocity of sound in water (Simmonds and MacLennan 2005). Sabol et al. (2002) noted that the acoustic reflectivity of submerged macrophytes was likely based on the presence of gases within the leaves and stems of plants so that more buoyant plant species were more acoustically reflective. Thomas et al. (1990) published one of the first studies that determined hydroacoustic techniques yielded substantially greater precision of biovolume estimates and lower data collection costs than SCUBA-based estimates.

If the objective is to identify areas of dense or matted submerged macrophytes for the purposes of aquatic plant management, the use of the BioBase system is reasonable, as it is rapid, efficient, and cost effective (Valley 2012, BioBase 2013). This system quickly creates mats of dense vegetation when surveyors adequately cover an area of interest. Hydroacoustics survey techniques are unique with regards to submerged plant assessment in this approach allows large-scale assessment of submerged plants. However, Radomski and Holbrook (2015) indicate that standardization of data collection equipment and the signal processing approach is necessary prior to using this technology as an assessment tool.

The hydroacoustic survey is designed to assess the distribution of submerged vegetation on a lakewide or bay-wide scale. This survey is designed to, with moderate effort, assess changes in frequency of occurrence and plant height statistics by depth strata. Primary goals include:

1. Describe the geographical distribution of submerged vegetation throughout the littoral zone and within specific depth zone intervals.
2. Estimate the coverage of lake bottom with high biovolume conditions.
3. Estimate the submerged vegetation biovolume across years.

## METHODS

Hydroacoustic data were collected with the Lowrance High Definition System consumer echosounder integrated with wide area augmentation system-corrected GPS and installed as recommended by Navico. A single-beam 200-kHz transducer (20° x 20° half-power beam angle) was oriented vertically and mounted on the boat stern. The Navico BioBase's recommended settings for the Lowrance unit was used (BioBase 2013). Sampling was conducted by traversing transects or tracks using a consistent boat speed of about 2 m/second. Additional details are provided in Perleberg et al. 2019.

Hydroacoustic sampling was conducted in Vineland and Wealthwood in 2014 and Vineland and Cove in 2019 (Figure 7.1). Transects were placed in a zig-zag pattern in Wealthwood, 12 parallel lines at 130 meters apart in Vineland Bay for 2014, 20 parallel lines at 130 meters apart in Vineland Bay for 2019, and 12 parallel lines at 130 meters apart for Cove Bay. Data are analyzed with BioBase software (BioBase 2013).

## RESULTS

The frequency of plant detections was generally highest in Cove Bay (Figure 7.2). Cove Bay is a shallow bay with a maximum depth of about 12.5 feet, and most locations had aquatic plants present (frequency of plants ranged from 60 to 90% for most depths). The Wealthwood section of shore had a low rate of plant detections, with frequency of plants in the shallow water (<5 feet) less than 40%. This shoreline is exposed to more wave action and the shallow water in this area is less likely to be colonized by aquatic plants – it was not until depths of 7.5 to 9 feet did aquatic plants appear more frequent. Vineland Bay's frequency of plant detections generally were modest at shallow depths with maximum frequencies found at 8 to 14 feet of water, and then these frequencies declined to near zero at about 15 feet. In 2019 aquatic plants in Vineland Bay were more frequent in the shallow waters than in 2014, but for deeper water (>10 feet) it was the reverse with aquatic plants more frequent in 2014 than in 2019.

The mean plant height varied by depth strata and location (Figure 7.3). In the Wealthwood section of shore, plants were generally short; whereas, Cove Bay plants were often in excess of 2 feet in height. In Vineland Bay for 2014, aquatic plant heights were tallest in the 10-15 feet water depth stratum, with the mean plant height in this stratum about 4.4 feet. Aquatic plants heights were lower in Vineland Bay in 2019 compared to those in 2014. The mean biovolume was lowest in Wealthwood and for the shallow water stratum mean biovolume was highest in Cove Bay (Figure 7.4). For Vineland Bay, mean biovolume increased by depth strata, peaking at 37% at the 10-15 feet water depth stratum in 2014. In 2019, Vineland Bay mean biovolumes were consistent at about 10% for most depth strata.

## DISCUSSION

Aquatic plant frequency of occurrence, heights, and biovolume varied by location and year. There were distinctive differences in the aquatic plant metrics for the three locations. Continued monitoring of these sites may provide better understanding of the variability of the aquatic plant communities in Mille Lacs.

**Figure 7.1. Hydroacoustic transects**

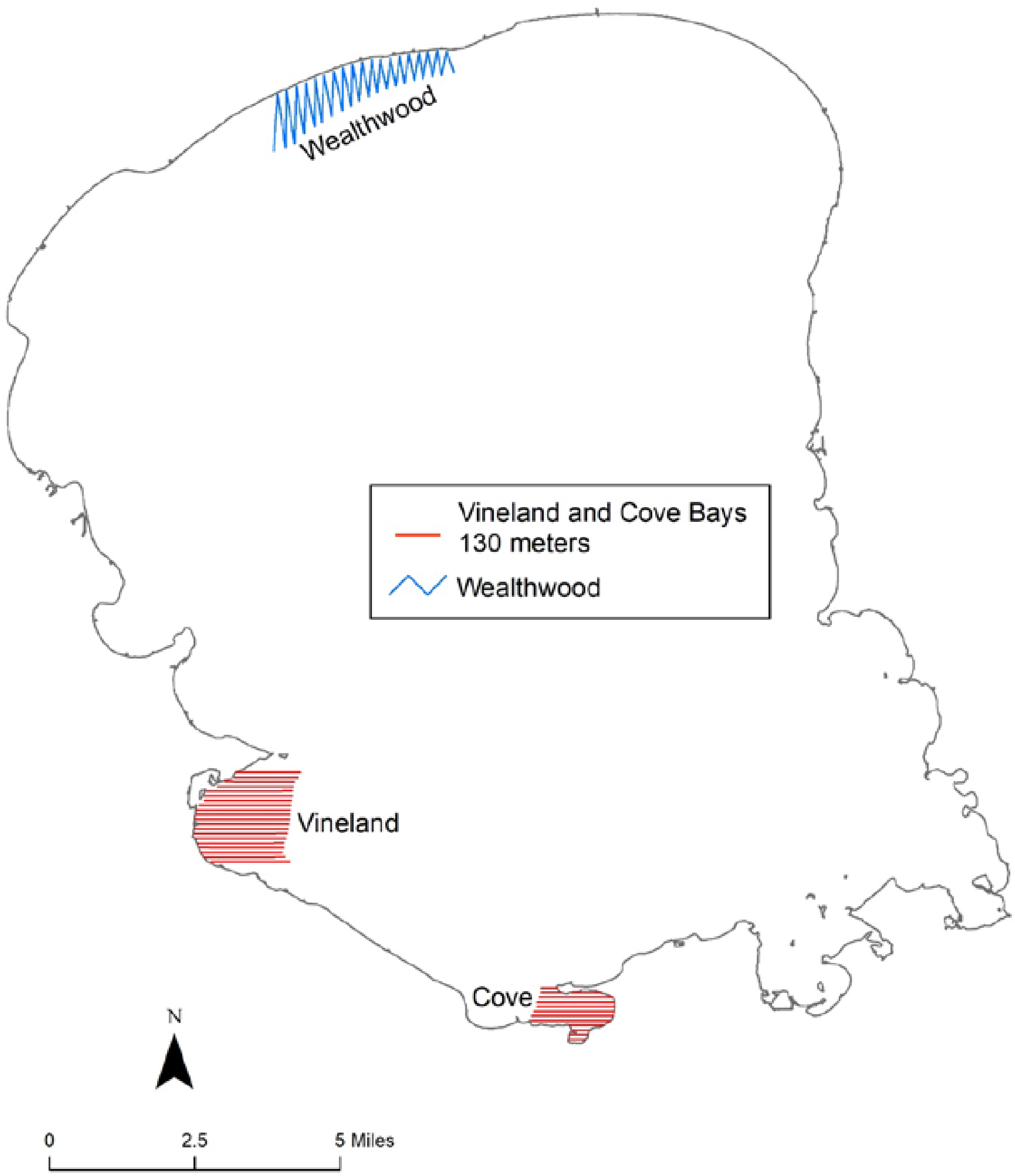


**Figure 7.2. Hydroacoustic data in Mille Lacs**

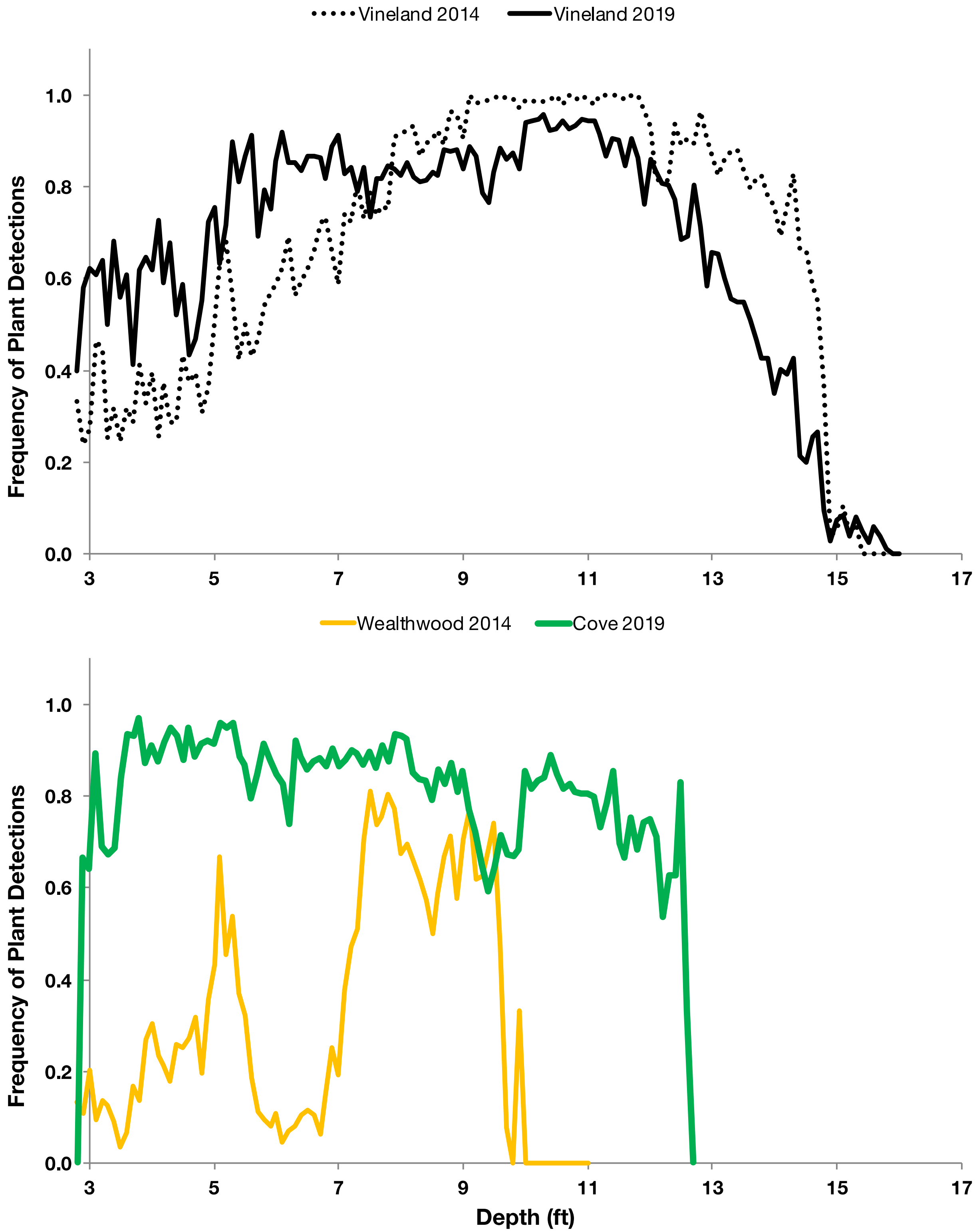


**Figure 7.3. Hydroacoustic Mean Plant Height in Mille Lacs**

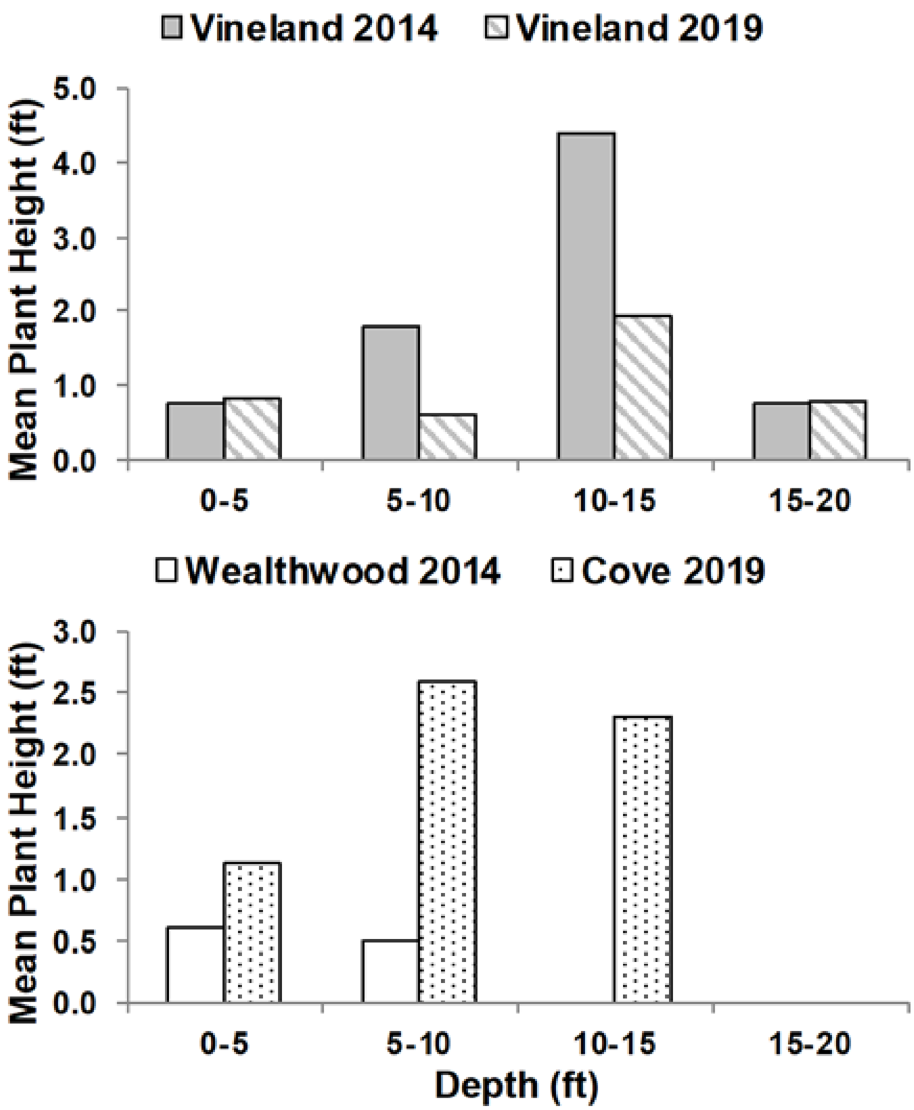
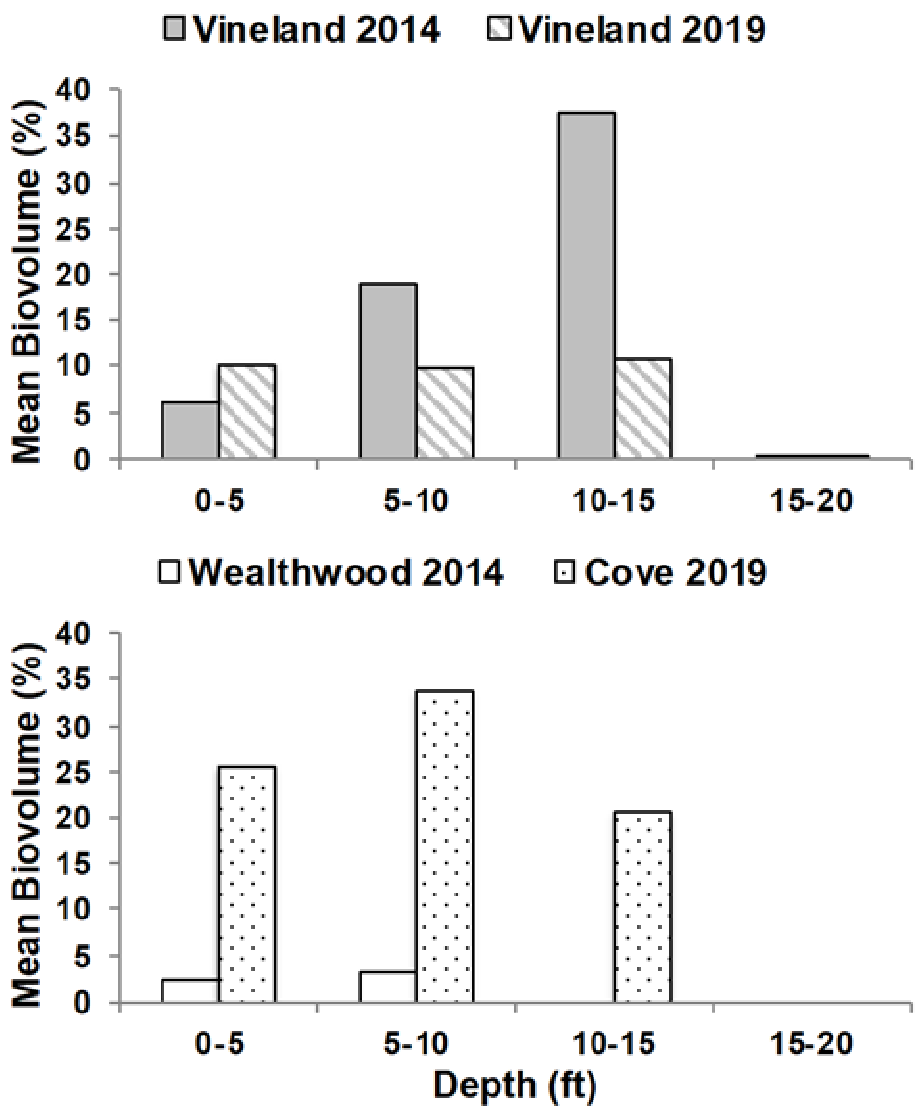


**Figure 7.4. Hydroacoustic mean biovolume in Mille Lacs**



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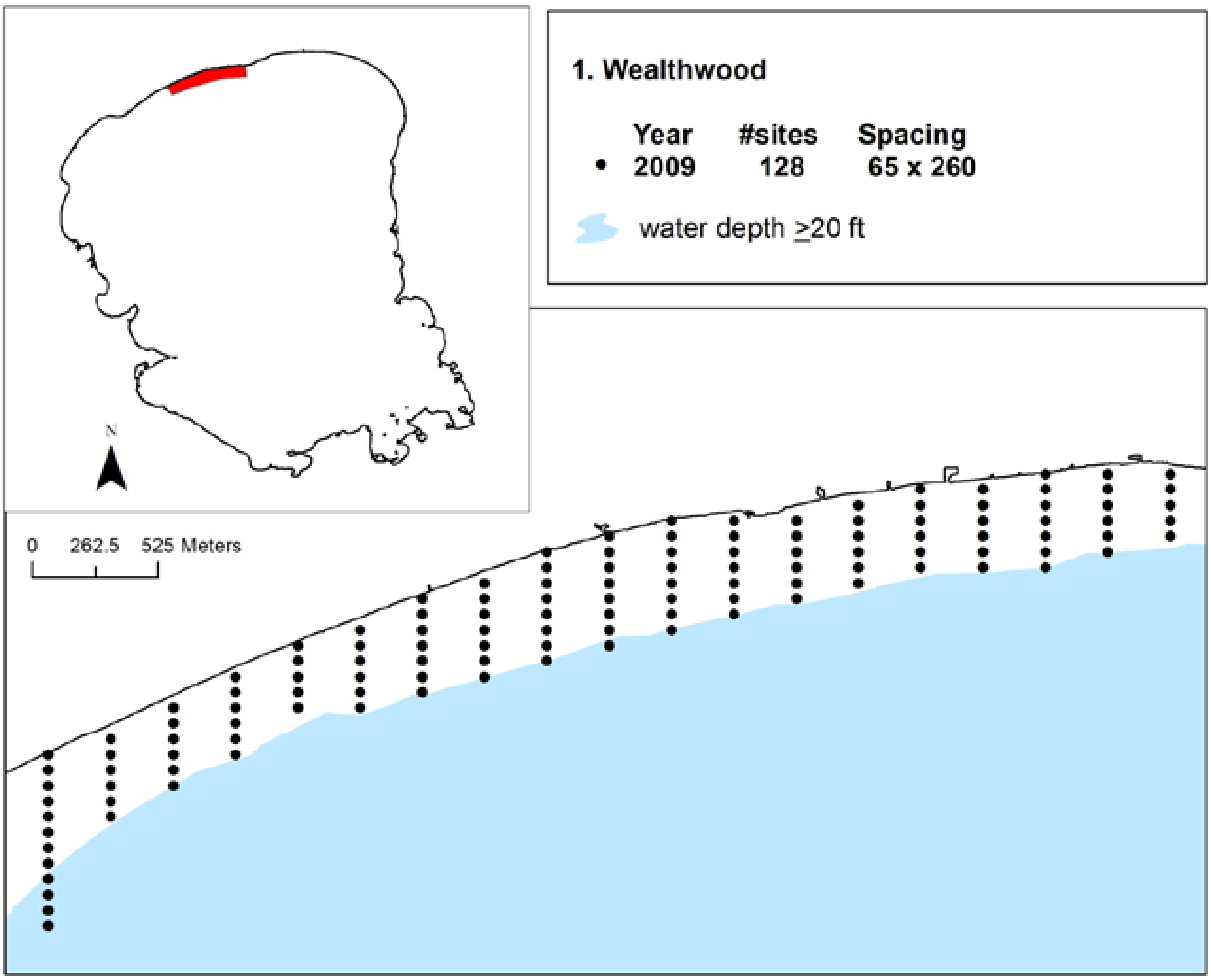
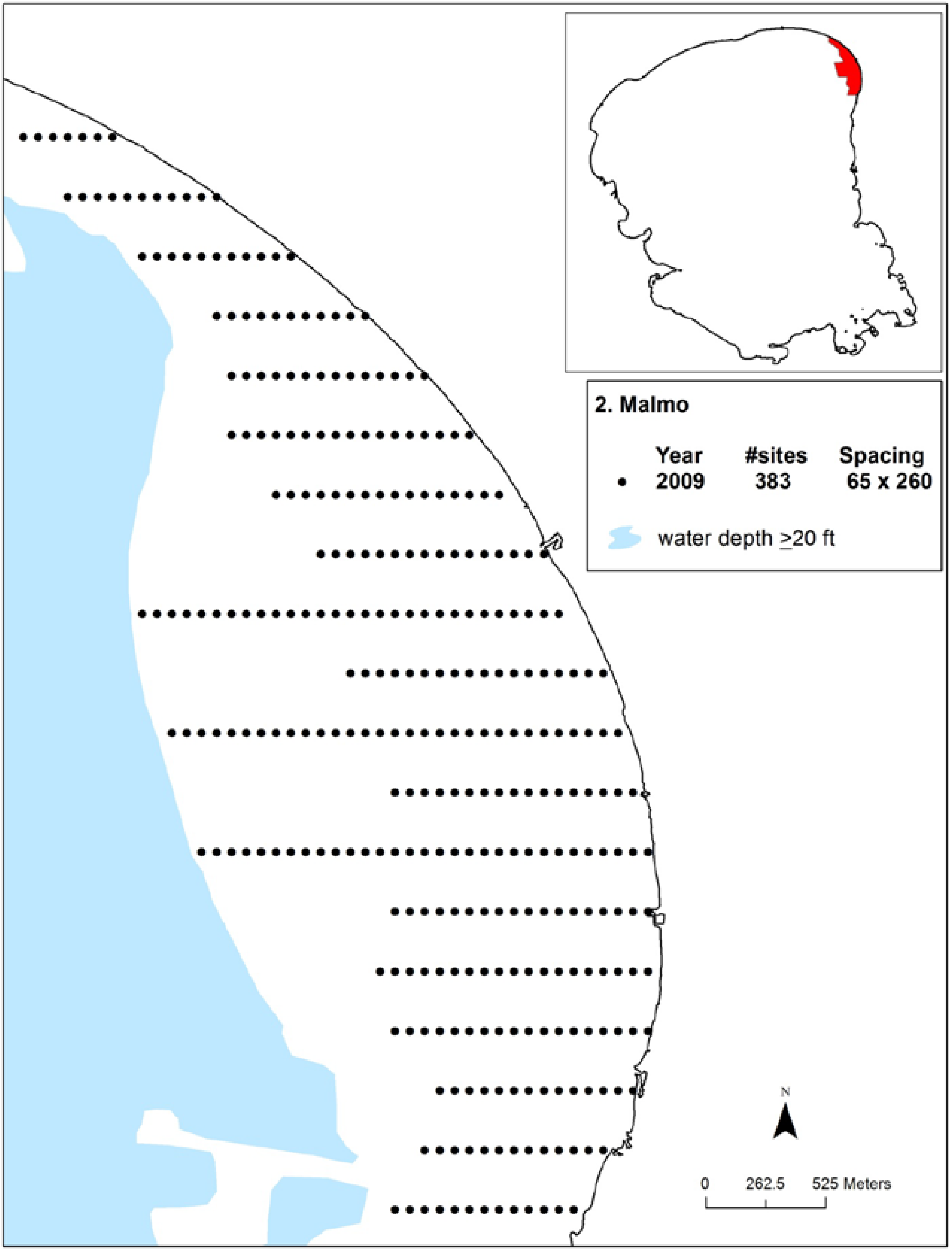
# APPENDIX 1. SURVEY SITE LOCATIONS

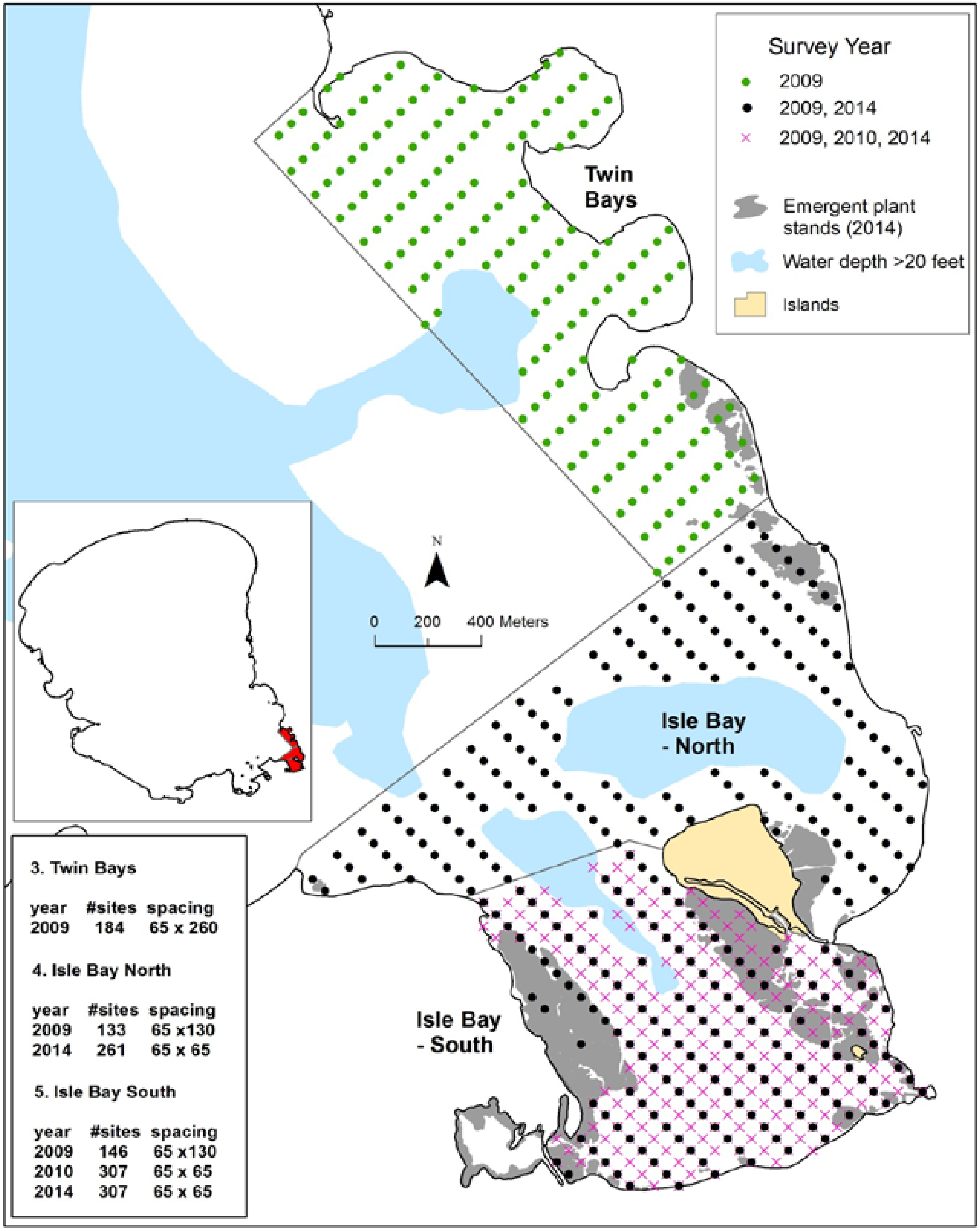
## WEALTHWOOD



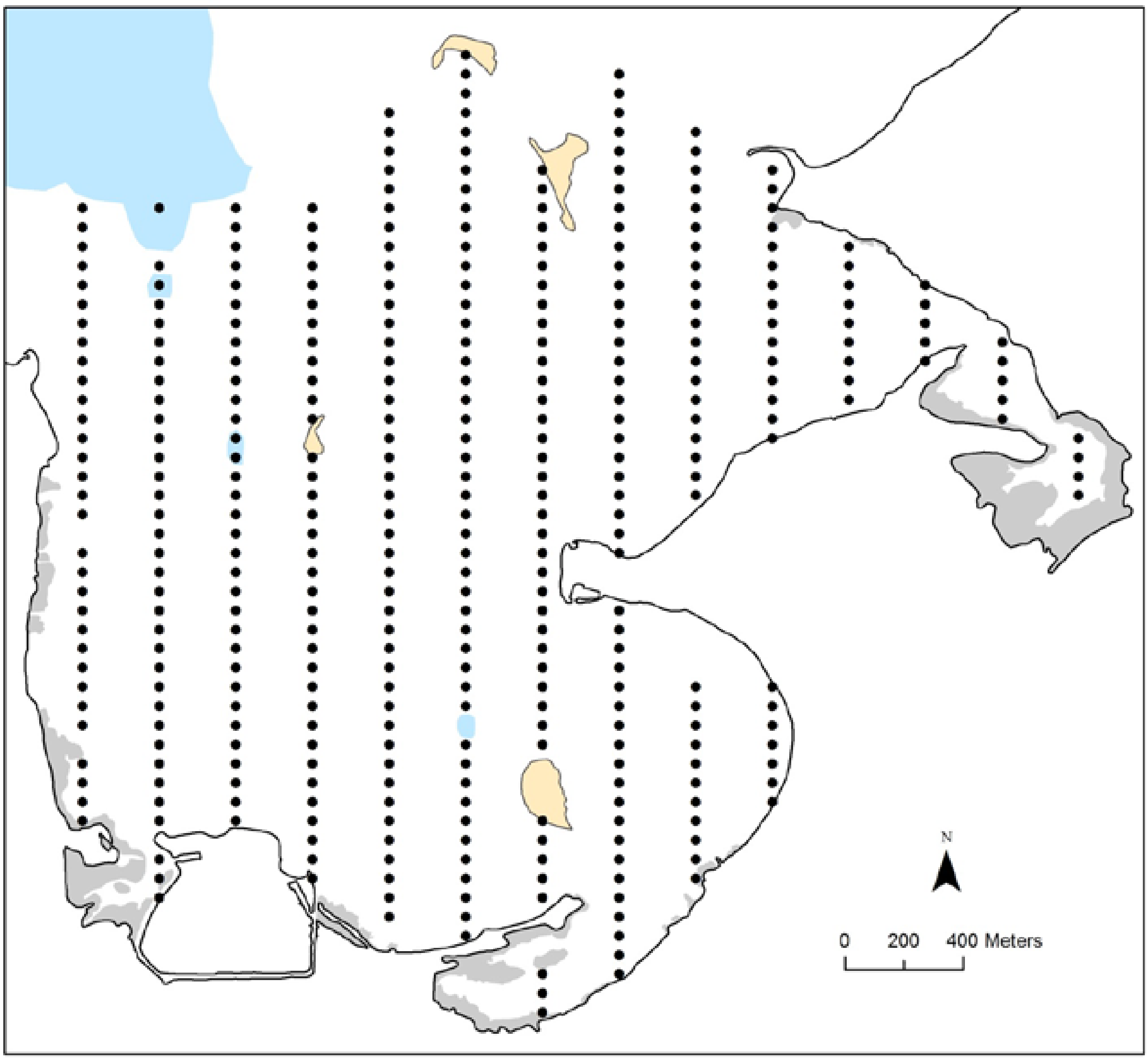
## MALMO


2. Malmo
Year
#sites
Spacing
2009
383
65 x 260
water depth >20 ft
N
0
262.5
525 Meters

## TWIN BAY AND ISLE BAY



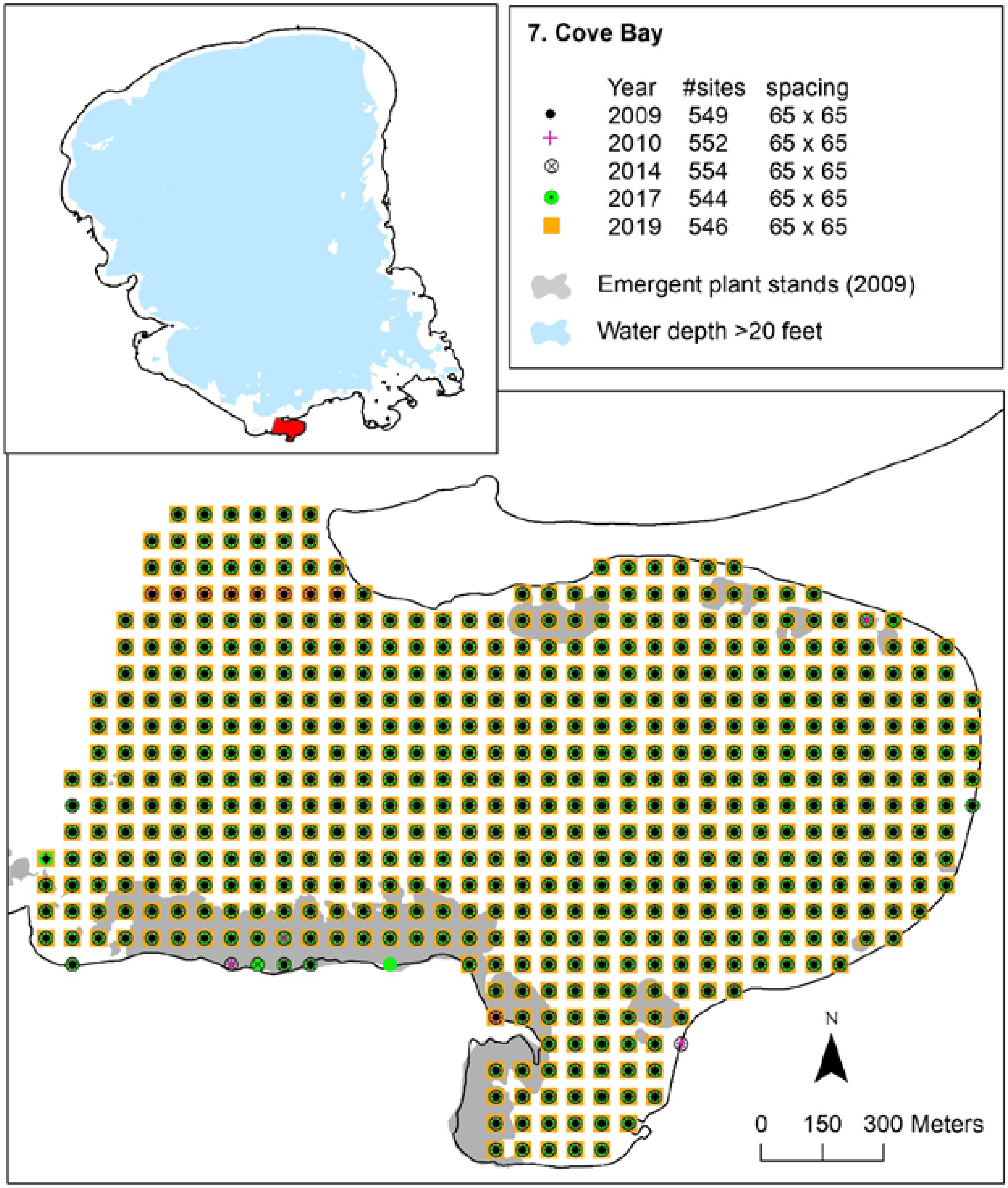
## WAHKON BAY



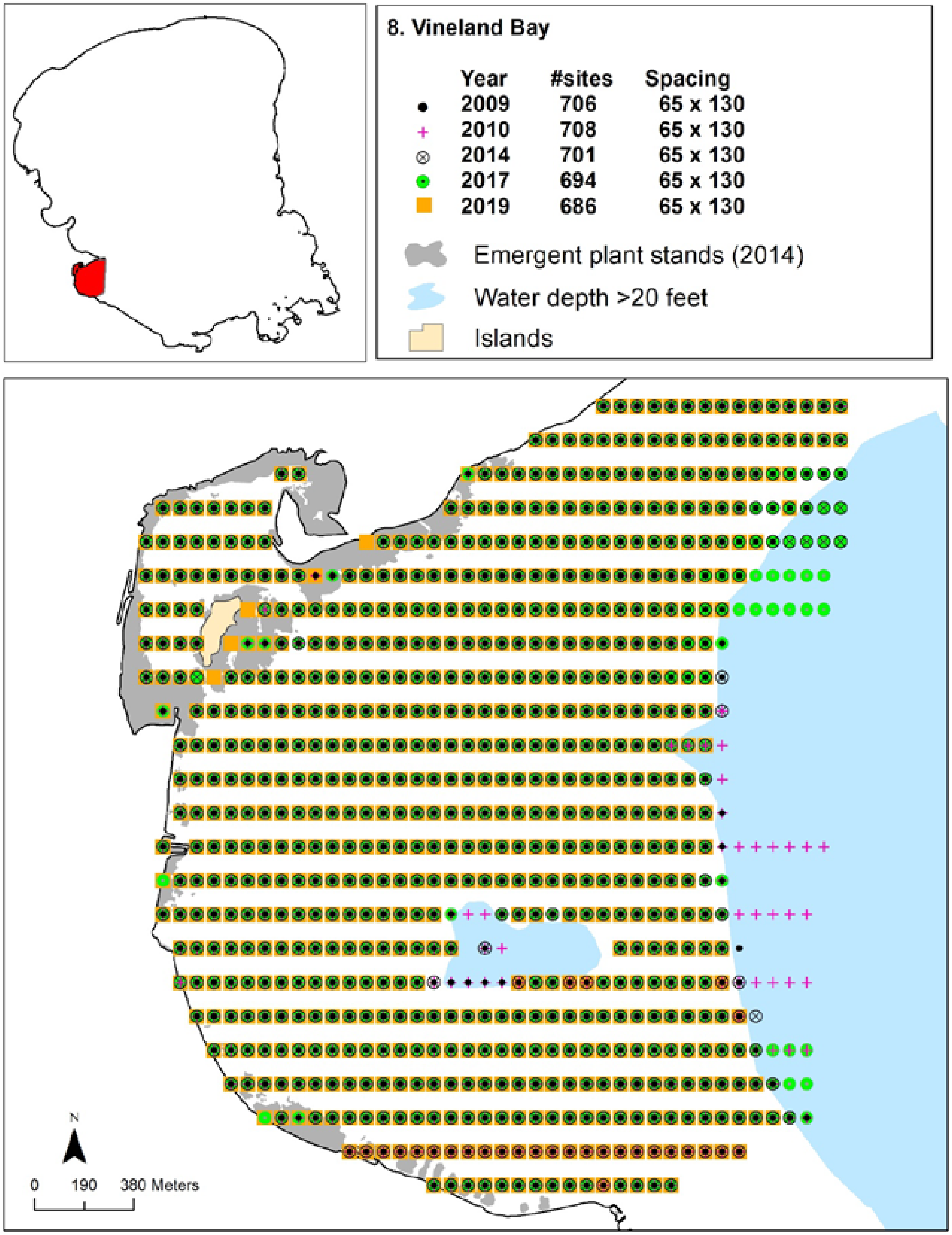
6. Wahkon Bay
Year #sites Spacing
2009 383 65 x 260
Water depth ≥20 ft
Emergent plant stands
Island
N
0 200 400 Meters

## COVE BAY


7. Cove Bay
Year #sites spacing
2009 549 65 x 65
2010 552 65 x 65
2014 554 65 x 65
2017 544 65 x 65
2019 546 65 x 65
Emergent plant stands (2009)
Water depth >20 feet
N
0 150 300 Meters

## VINELAND BAY



## SHAH-BUSH-KUNG BAY AND WIGWAM BAY