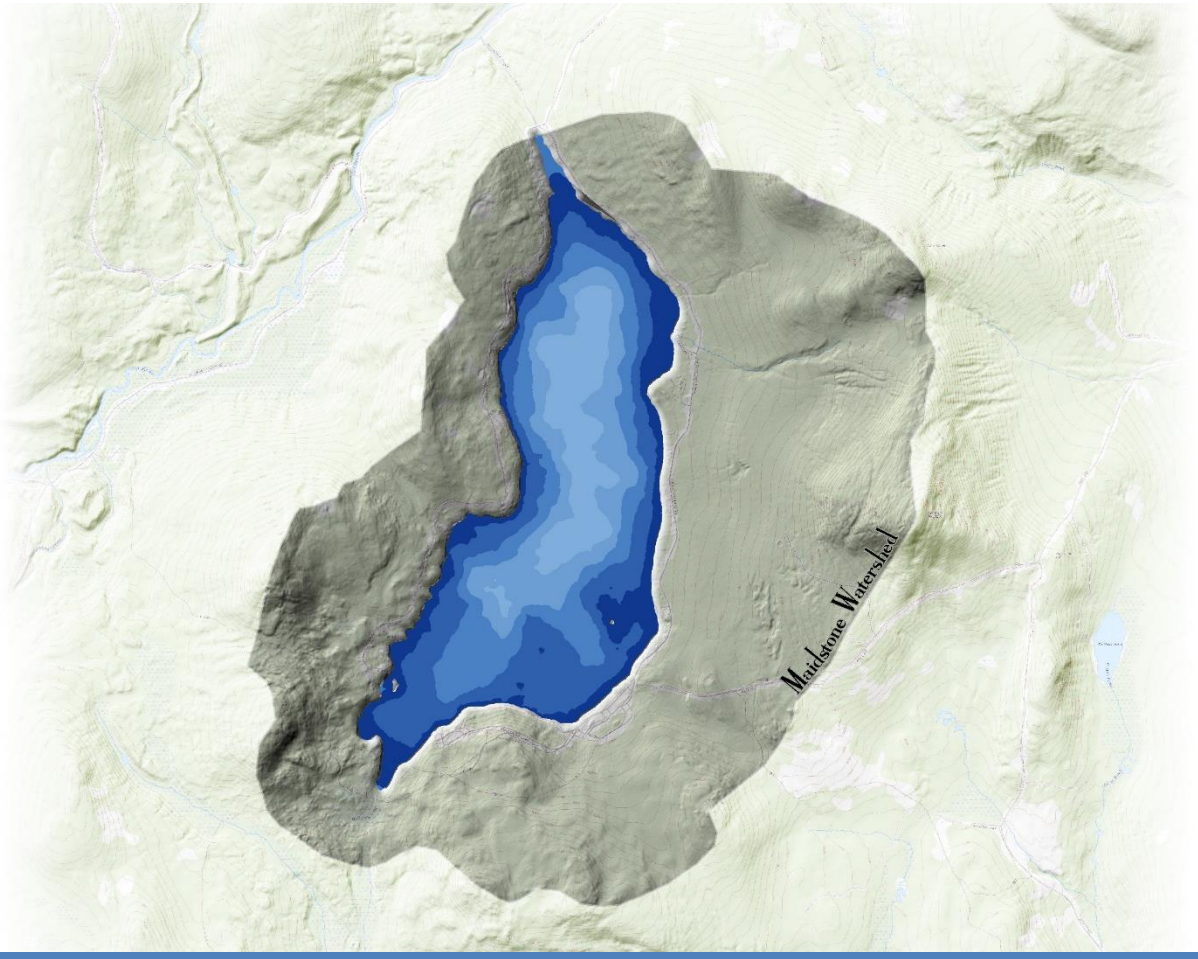

Maidstone Lake Aquatic Plant Inventory

Report Submitted to the Maidstone Lake Association

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1. Introduction

In 2022, Arrowwood Environmental (AE) was retained by the Maidstone Lake Association to conduct an inventory of aquatic macrophytes in Maidstone Lake. The objective of the project was to characterize the aquatic vegetation in the lake and identify and map any non-native invasive species.

Maidstone Lake is a 756 acre lake in the town of Maidstone, Vermont. The lake is quite deep for its size, with a maximum depth of 121 feet. The deepest area is located in the north-central part of the lake. The northern end of the lake is characterized by a shallow bay with a thin muck (organic) sediment layer over sand for substrate. The southern end of the lake has two similar, though smaller shallow bays. The eastern and western shores of the lake consist of a narrow band of shallow water which quickly increases in depth. There are two small islands in the lake with shallower areas around them. The sediments of the lake consist of sandy/gravelly sediments in many of the shallower areas as well as extensive boulder fields which lack these finer sediments. The deeper areas of the lake consist of finer silt and organic sediments over sand. A map of the lake showing bathymetric contours is shown in Figure 1.

Lakes are classified based on physical parameters such as size, depth, trophic status and alkalinity. Trophic status is a way to categorize lakes by the amount of biologically useful nutrients in the water (primarily phosphorus and nitrogen). Oligotrophic lakes have very low nutrient availability for plant (including algae) growth leading to low overall productivity and high water clarity. Mesotrophic lakes have a moderate level of nutrients available for plant growth and eutrophic lakes have high nutrient availability. Water clarity can be low in eutrophic lakes because of the higher degree of algae growth that is possible when nutrients are plentiful. Phosphorus is typically the limiting nutrient for aquatic plant growth, and therefore trophic status is commonly determined by measuring the phosphorus content of the water that is entering the lake during spring runoff and snow melt. Phosphorus measurements indicate that Maidstone is an oligotrophic lake with low nutrient levels. Maidstone is characterized by clear waters with low plant and algae growth. Oligotrophic lakes are relatively rare in Vermont, and many may be transitioning to more

mesotrophic conditions as indicated by long-term monitoring by Vermont Department of Environmental Conservation (Matthews, Merrell, and Thomas 2018).

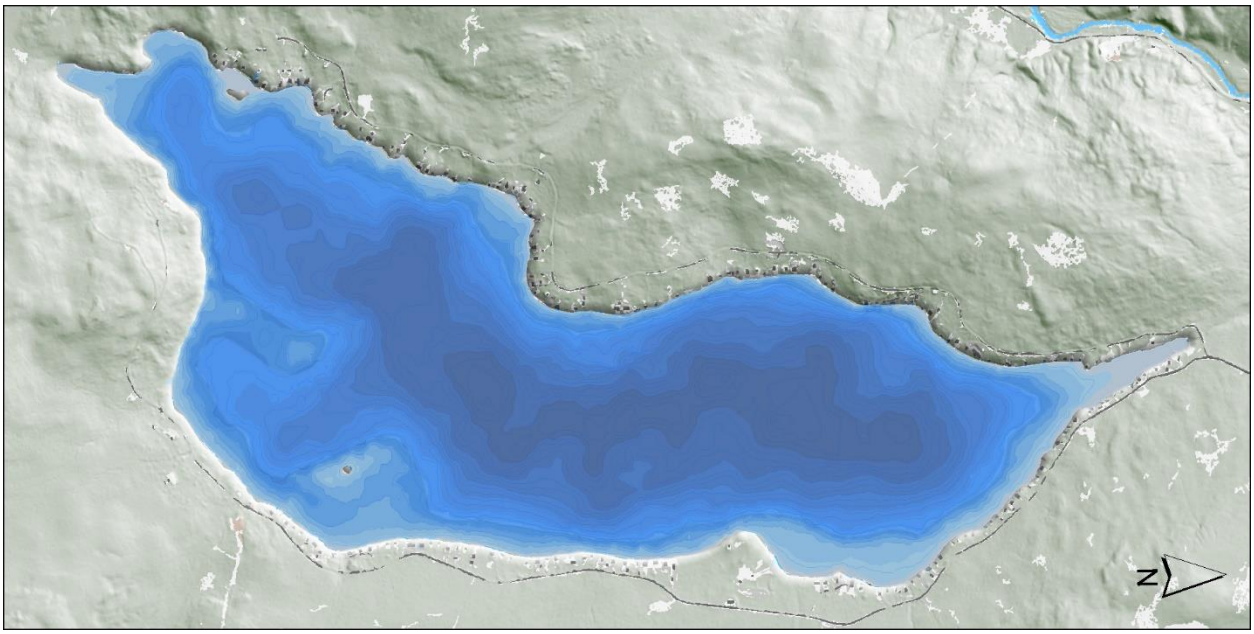


Figure 1. Bathymetric Contours of Maidstone Lake

Maidstone Lake was formed about 12,000 years ago during the last ice age when the glaciers scoured out the basin. The region around Maidstone Lake is underlain by granitic bedrock of the Maidstone Pluton. The underlying bedrock can impact the chemistry of the water, in this case resulting in a low-alkalinity (soft-water) lake. Low-alkalinity, oligotrophic lakes are fairly rare in Vermont, the only others being Little and Great Averill and Sunset Lake (in Marlboro).

Chemistry and nutrient content of the water is also highly influenced by the nature of the surface water inputs. Maidstone Brook enters the lake on the southern end, though the brook at this location is has only intermittent flow. The other surface water input occurs on the northeastern side of the lake from an unnamed tributary. The lake flows out the northern bay as Maidstone Brook which feeds into Paul Stream and eventually the Connecticut River. The land use around both of these surface water inputs is largely forested, though some development occurs along the margins of the lake and the unnamed tributary in the northeast.

Maidstone has a drainage basin area of 3000 acres and a ratio of drainage basin to lake area of 4:1. In general, the larger an area that drains into a lake (or the higher the basin:lake area ratio) the more nutrients that will enter that lake from surface water inputs. The amount of nutrients entering a lake is also impacted by the landuse of the surrounding drainage basin. In the case of Maidstone, a relatively low basin:drainage ratio and a largely forested drainage basin surrounding the lake help to protect its water quality.

2. Methods

The study area for the inventory consisted of the entire waterbody of Maidstone Lake. The shoreline boundary was derived from the Vermont Hydrography Dataset (VHD). Aquatic species and emergent species that typically occur within aquatic plant communities were included in this inventory. Three days of field work were conducted in 2022: on August 10-11 and September 2. During the field work, the lake was circumnavigated with a motorboat or a kayak. The motor boat was used for the majority of the inventory while the kayak was used to inventory shallow areas, especially in the northern and southern bays. The lake boundary was uploaded to an iPhone XR data collector, running ArcGIS Field Maps and Survey123 field data collection applications. Customized digital data forms were used to standardize data collection and link to a GPS, providing specific geographic locations for the survey data. Narrative data was also recorded in a field notebook.

Three different methods were used to inventory aquatic vegetation in Maidstone: 1) Visual Littoral Surveys; 2) Grid Point Sampling, and; 3) Underwater Transects. The methodology used for each of these survey types is outlined below.

a. Visual Littoral Survey

The Visual Littoral Survey methodology is based on methods from the Vermont Agency of Natural Resources Department of Environmental Conservation (2006) field manual. This methodology involves visual inspection of the littoral zone which in the case of Maidstone are areas from zero to 15’ deep. The entire perimeter of the lake was surveyed either by kayak (less than 2' depths) or

by motorboat. Clear water visibility allowed for the consistent survey of areas 12-15' deep and less with this method. During these surveys, the presence of individual species as well as composition and extent of aquatic plant communities were recorded with GPS in the customized data forms.

b. Grid Point Sampling

The Grid Point Sampling method provides a standardized procedure of inventorying deeper areas of the lake that cannot be sampled by the Visual Littoral Survey method. Because the aquatic vegetation in the lake is so sparsely distributed, targeted grid point sampling was used to first identify the presence of deeper aquatic vegetation and then define the boundaries. Since visibility in Maidstone lake was so good, this method was most useful in areas where the vegetation could not be readily distinguished during the littoral survey.

At each grid point sampling location, an aquatic survey rake on a rope was used to take a vegetation sample. Rake fullness was recorded for each sample to obtain information about vegetation density (Hauxwell et al. 2010; Madsen et al. 1996). Each aquatic plant on the rake was identified to species. All data was recorded using a digital data form on the data collection unit.

c. Underwater Transects

The Underwater Transects consisted of snorkeling in shallow areas and deployment of the Remotely Operated Vehicle (ROV) in deeper areas. Snorkeling was primarily used in the northern shallow bay and in the two southern bays. An underwater writing slate was used to take notes and a mesh sampling bag was used to collect plant samples while snorkeling as needed.

A Chasing M2 (ROV) was used to inventory selected deeper areas of the lake. The motorboat was anchored at selected locations and the ROV deployed on a pre-determined compass bearing. Live video feed from the ROV was viewed on the motorboat on a iPad with a 10.5" screen. Selected still photographs were also taken in areas that represented typical conditions.

During all survey methodologies, GPS points were taken for rare species locations and boundaries of aquatic natural communities. Once field work was completed, the data was analyzed on an ArcGIS platform. Data from the survey was used to create the aquatic natural community map.

3. Results

The results of the inventory are presented below in two sections: a) Native Aquatic Vegetation Communities; b) Aquatic Plant Species.

a. Native Aquatic Vegetation Communities

A natural community is an interacting assemblage of organisms, their physical environment, and the natural processes that affect them (Thompson, Sorenson, and Zaino 2019). Most studies conducted by scientists on natural communities have focused on terrestrial systems. Much work remains to be done on classifying groups of aquatic plants into natural communities. The native aquatic vegetation documented in Maidstone has been categorized into two community types: the Pipewort-Water Lobelia Aquatic Community and the Stonewort Aquatic Community. There are instances of Cattail Marsh that occur along the margins of the lake. Most notable of these are the large occurrences in the shallow northern bay and in the southwest lake by the island. Since this community type is a wetland (not aquatic) community type, it was not included in the aquatic community map produced for this report. However, the plant species inventory was conducted within these Cattail Marshes and the species present are included in the species lists provided.

A map of the location and extent of the two aquatic communities present in Maidstone Lake is presented in Figure 2. This map represents the extent of the aquatic vegetation in the lake which is largely restricted to a narrow band along the shore (the Pipewort-Water Lobelia Community) and areas of deeper vegetation scattered around the perimeter of the lake (the Stonewort Community).

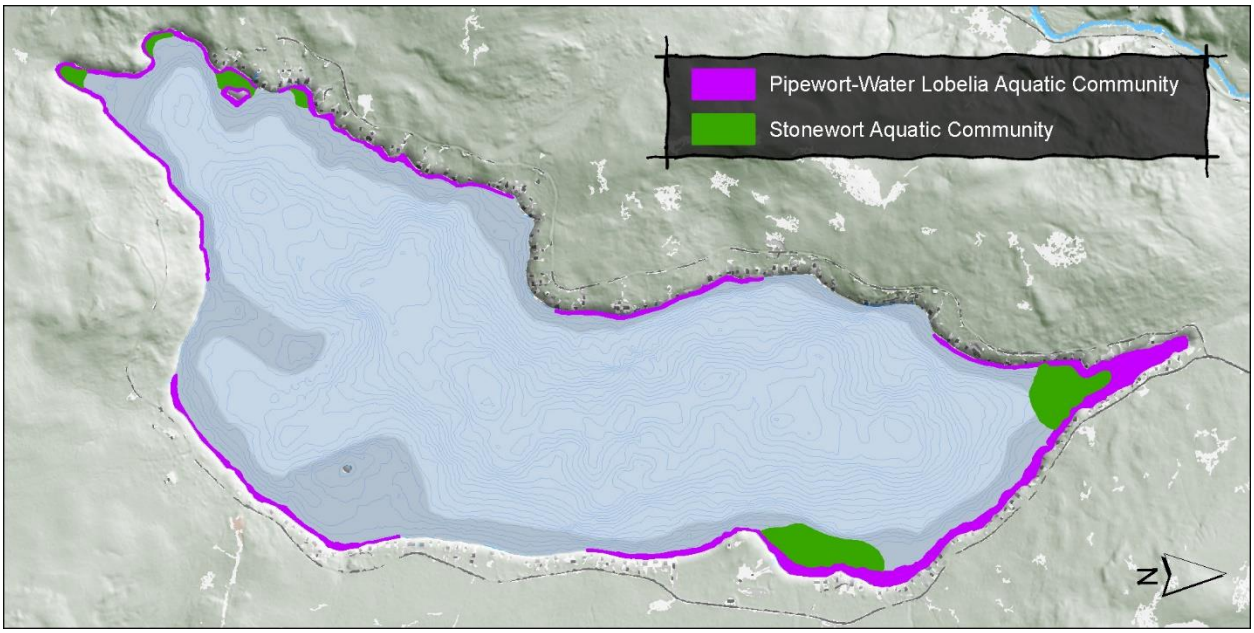


Figure 2. Aquatic Natural Communities of Maidstone Lake

Many lakes in Vermont are characterized by dense growth of aquatic plants. Aquatic vegetation in Maidstone, on the other hand, is quite sparse. Being an oligotrophic lake, the lack of nutrients excludes many aquatic species and creates an inhospitable environment for prolific plant growth. In addition, lack of suitable substrates can also limit aquatic plant growth in Maidstone. The aquatic plants that are present require sand or silt substrates to become rooted, and are unable to become established in areas dominated by boulders.

The areas depicted in the map in Figure 2 show the areas with consistent (if sparse) vegetation. Scattered small patches of stonewort or pipewort may be present outside of the mapped areas. In addition, in some areas, these two community types grade into each other . In these cases, the characteristic vegetation found in each community overlaps.

A description of each of the aquatic communities is presented below.

Pipewort-Water Lobelia Aquatic Community

This community is the dominant aquatic community in Maidstone Lake. Though it is named for the two most dominant plants in this community type, in Maidstone it is overwhelmingly dominated by pipewort. Water lobelia is found sporadically throughout these areas, however, it rarely becomes dominant. Other species include snailseed pondweed, white water lily and grass-leaved arrowhead. The overall abundance of vegetation in this community is relatively low, with percent cover in the 5-25% range.

This community type is relatively uncommon in the state because the requisite habitat is also uncommon. Species in this community require shallow areas with sandy substrate and compete best in nutrient poor, oligotrophic lakes. The community can be found in small patches in more mesotrophic (moderate nutrient) lakes, but often gets out-competed by other aquatic vegetation.

Stonewort Aquatic Community

The Stonewort Aquatic Community is unique in that it is overwhelmingly dominated by a single genus: *Nitella spp.*. Though it looks like an aquatic vascular plant, *Nitella* is a genus of macroalgae which is capable of forming dense mats under very low light and low nutrient conditions. In Maidstone, this community is found in deeper locations than the Pipewort-Water Lobelia Community, generally occupying areas from 3’ to 27’ deep. Vegetation can be quite dense, with stonewort completely covering the lake bottom. In other areas, scattered small patches of this species are present

comprising only 25% cover. Because of this dense growth, this species makes up the most biomass of any aquatic plant in the lake, though because of its depth it remains largely unnoticed by lake users.

This aquatic community is known to occur in a few more mesotrophic waters in deep, low light conditions, but additional study is needed to understand the overall distribution of this community in the state and its role in lake ecology.

b. Aquatic Plant Species

No non-native or invasive aquatic plant species were documented during the inventory. All species found in Maidstone Lake are native species that do not pose a risk to the natural ecology of the lake system. A total of 22 species were documented in the lake during the inventory. Table 1 lists each of these plant species along with an "S-rank" for species that are uncommon or rare in the state, as well as an indication if a species is listed on the Vermont Threatened and Endangered Species List. For clarity, these species are broken up into major plant growth forms: 1) plants which form basal rosettes; 2) creeping plants that grow along the surface of the substrate; 3) submerged aquatic plants; 4) floating-leaved aquatic plants; and 5) emergent plants that have the majority of their leaves and flowers above the surface of the water. The "Emergent" plants grow along the margins of the lake, often associated with the Cattail Marsh Community, while the rest of the species are components of the aquatic natural communities described above.

Brief species profiles of dominant and rare (S1-S3-ranked) aquatic species are presented below along with notes on their distribution and abundance in Maidstone Lake.

Table 1 List of Plant Species Documented in Maidstone Lake

Latin Name	Common Name	State Rank*	State_Status	Growth Form
Sagittaria graminea	grass-leaved arrowhead			Basal Rosette
Nitella spp.	stonewort			Submerged
Carex vesicaria	inflated sedge			Emergent
Dulichium arundinaceum	three-way sedge			Emergent
Equisetum fluviatile	water horsetail			Emergent
Chamaedaphne calyculata	leatherleaf			Emergent
Eriocaulon aquaticum	pipewort			Basal Rosette
Myriophyllum tenellum	leafless water-milfoil			Creeping
Iris versicolor	blue flag			Emergent
Isoetes lacustris	lake quillwort	S1		Basal Rosette
Utricularia resupinata	resupinate bladderwort	S1	Threatened	Creeping
Nymphoides cordata	smaller floating-heart			Floating-leaved
Myrica gale	sweet gale			Emergent
Nymphaea odorata	waterlily			Floating-leaved
Callitriche sp.	water starwort			Submerged
Glyceria canadensis	rattlesnake grass			Emergent
Potamogeton bicupulatus	slender snailseed pondweed	S2		Submerged
Potamogeton epihydrus	ribbon-leaved pondweed			Submerged
Potamogeton natans	floating pondweed			Submerged
Sparganium angustifolium	narrow-leaved bur-reed			Emergent
Typha latifolia	broad-leaved cattail			Emergent
Fontinalis antipyretica	common water moss			Submerged

** State rarity ranks (S-ranks): S1=very rare; S2=rare; S3=uncommon*

Basal Rosettes

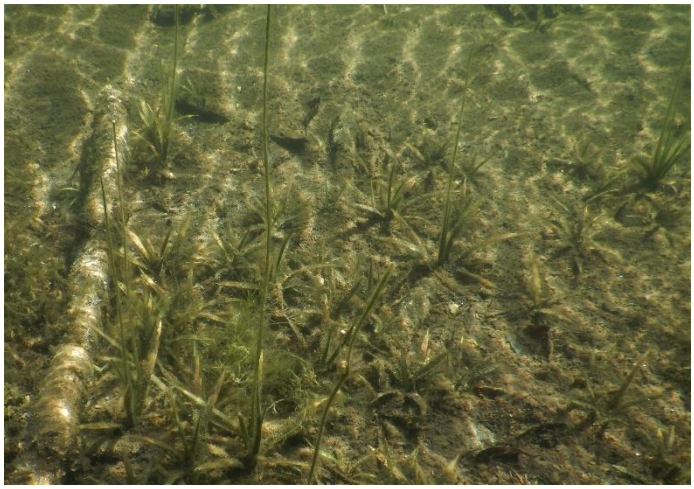
Plants that have a basal rosette growth form typically have short leaves (<3") that all arise from a central point. This growth form is common in oligotrophic lakes because the root:shoot ratios are quite high and the expenditure of resources for production of leaf tissue is low.

Pipewort (*Eriocaulon aquaticum*)

Pipewort is the most common vascular aquatic plant in the lake. Its primary growth form is of a basal rosette but can form dense mats of tightly clustered individuals. These dense mats make up the majority of the plant cover within the Pipewort-Water Lobelia community. It requires mineral soil to establish its root system and prefers sandy substrates but can also grow in finer substrates such as silty sands. The flowering stalk emerges from the center of the basal leaves and reaches to the surface. If the plants are in deep water, the stalk can reach an impressive 8' long. The tip of the flowering stalk forms the distinctive white button, which is a cluster of tiny flowers. Unlike most other aquatic plants which are wind pollinated, pipewort flowers have tiny nectar glands at the tip of each petal and are pollinated by insects such as bees and hummingbird moths.

In Maidstone, pipewort is found throughout the vegetated portions of the lake. It can be found sparsely distributed along the eastern and western shores where boulders make up the dominant substrate. Where sand substrates are common, this plant can form dense mats. Pipewort is quite abundant in the shallow northern and southern bays of the lake.

Grass-leaved Arrowhead (*Sagitaria graminea*)



The arrowhead plants are a familiar group of aquatic plants recognized by their distinctive arrow-shaped leaves. Though still in the "arrowhead" genus, the grass-leaved arrowhead has linear grass-shaped leaves that grow in a basal rosette. It also has emergent leaves that grow on mature plants which are linear or slightly widened, but never arrow-shaped This species can grow in sandy and silty substrates in shallow areas along the shore and in areas away from shore up to 6 feet deep. The flowering stalk arises from the center of the basal rosette and stands well above the water surface with a stalk of white petals. Plants that grow in deeper water rarely flower. It reproduces by rhizomes (underground stems) as well as by nutlets, which drop from the flowering stalk in late summer. A wide variety of wildlife rely on these rhizomes and nutlets for food.

In Maidstone Lake, grass-leaved arrowhead is most abundant in the northern and southern shallow bays. In the southeastern bay, in particular, it forms one of the dominant species. It can also be found in scattered locations along the eastern and western shores, especially in more protected inlets.

Water Lobelia (*Lobelia dortmanna*)

This species also forms a basal rosette of leaves and grows scattered amongst the more common pipewort. This beautiful aquatic plant flowers in early summer with a tall stalk of small, purple and white flowers. Later in the summer, the drooping capsules drop seed to the water surface where they sink, overwinter, and typically sprout the following season. If not for the flowering stalk, this plant would likely go unnoticed by most people. Its growth form is superficially similar to the pipewort, though the leaves are more rounded at the tip.

In Maidstone Lake, Water lobelia is a minor component of the Pipewort-Water Lobelia community and can be found at low abundance throughout this community. It is most abundant in the shallow northern bay of the lake.

Quillwort (*Isoetes lacustris*)

Quillwort is named for the stiff, erect, quill-like leaves that arise from the base of the plant. These leaves are short, only a few inches tall. Like ferns and clubmosses, quillworts do not produce flowers; rather, they reproduce by spores, which can be found at the base of each leaf in the late summer. Lake quillwort, the species found in Maidstone is quite rare in Vermont, known from only 9 other lakes. Lake quillwort also occurs at much deeper depths than other species in this group.

In Maidstone, lake quillwort is found in a few areas within the Pipewort-Water Lobelia community. It is quite rare in the lake, having been noted only in the southwestern corner of the lake by the State Park campground and in the northern end of the lake.

Creeping Plants

The plants in this group are low-growing and spread horizontally across the bottom of the lake via rhizomes (underground stems). They produce only very small leaves and are easily missed by the casual observer.

Resupinate bladderwort (*Utricularia resupinata*)

The bladderworts are a group of aquatic plants that occur in nutrient poor lakes, ponds and bogs throughout the state. The resupinate bladderwort is a state-threatened plant that is known from only 9 other lakes in Vermont and is rare in most other New England states. Its growth form makes it one of the most inconspicuous plants in the lake. The leaves are reduced to thin thread-like structures and most of the plant occurs either at or below the sediment surface. This plant is only conspicuous when it rarely flowers with each plant producing a single, relatively large purple flower. Bladderworts are named for the tiny bladders that are scattered along the leaves. These bladders are traps for zooplankton, which are digested by the plant for their valuable nutrients and allows them to survive in nutrient-poor environments.

In Maidstone Lake, resupinate bladderwort is most common in the northern and southwestern bays. In these shallow bays, this species is somewhat common and forms fairly extensive mats. It can also be found occasionally in small areas along the eastern shore and in between the island and the mainland in the southwestern part of the lake.

Slender water-milfoil (*Myriophyllum tenellum*)

Though this species is in the milfoil genus, it is a native species and looks nothing like any of the other milfoil species. The stems of this plant are typically just a few inches tall and the leaves are entirely absent. This plant spreads by a thin underground stem (rhizome) and puts up short stems which are easily overlooked. It grows in shallow sandy areas of mesotrophic to oligotrophic lakes throughout Vermont.

In Maidstone Lake, slender water-milfoil is found in low abundance throughout the mapped Pipewort-Water Lobelia community occurrences.

Submerged Aquatics

There are only two truly submerged aquatic species dominant in Maidstone Lake, the stoneworts and slender snailseed pondweed. This pondweed could also be considered a floating leaved species because it can (but doesn't always) produce small floating leaves. Two other pondweeds (ribbon-leaved pondweed and floating pondweed) are found in Maidstone, but at low abundance, mostly in the shallow bays in the northern and southern ends of the lake.

Stonewort (*Nitella sp.)*

Despite the large size and growth habit of stonewort, this plant is not a flowering plant, but a macroalgae. The plants anchor themselves to the substrate with "rhizoids" (which are similar to roots in vascular plants) and reproduce by spores. The species found in Maidstone is native and occurs in many freshwater lakes and ponds in the state. There is a recent invasive species, starry stonewort, which is restricted to a few lakes in Vermont with high phosphorus content. Stonewort can form a dense mat in areas of low nutrients and low light conditions. There are many benthic organisms that graze on the stoneworts, which then become food for a wide variety of fish species. In addition, waterfowl are known to eat stonewort.

In Maidstone Lake, stonewort are found in dense concentrations where the Stonewort Aquatic community has been mapped, and form the dominant species in these communities. Scattered smaller patches are also present throughout the lake in areas less than 27 feet deep.

Slender snailseed pondweed (*Potamogeton biculpatus*)

The pondweeds are the largest group of aquatic plants in the region, consisting of approximately 26 species in the state. Slender snailseed pond weed is by far the most common pondweed in Maidstone. While it is common in Maidstone, it is fairly rare in Vermont, being known from only 16 other lakes. The submerged leaves of this species are thread-like

and the floating leaves are small and oblong. It reproduces by small snail-shaped seeds which sink to the bottom of the lake and germinate the following spring. Waterfowl are known to eat the seeds and leaves of pondweeds.

In Maidstone, this species is an integral component of the Pipewort-Water Lobelia Aquatic community. It is most abundant in the shallow northern and southeastern bays, though never gets very dense, and scattered in localized areas along the eastern and western shores. It appears to prefer substrates with mineral soil (avoiding areas that are too rocky) and areas in the lake that are a little sheltered. This species is hand-pulled by landowners and may be otherwise more widespread than reported.

Floating-Leaved Aquatics

Floating-leaved aquatics are distinguished from other aquatics (such as the pondweeds) in that they only produce leaves that float on the surface. The white water lily is the only species in the group that is widespread in Maidstone. The small floating heart (*Nymphoides cordata*) is present, but restricted to the northeastern part of the lake.

White water lily (*Nymphaea odorata*)

This familiar aquatic plant has round leaves with a narrow V-shaped sinus at its base. The leaves float on the surface and are attached to the rest of the plant by a long petiole. Leaves can range in size from a few inches across to over 8 inches wide, though are typically on the smaller side in oligotrophic lakes like Maidstone. The flower is a showy, white and fragrant blossom that emerges in early summer. The thick fleshy rhizome which grows in the sediment is a favorite food for a wide variety of wildlife including beaver, moose, muskrat and wildfowl. White waterlilies thrive in organic substrates and prefer habitats that are nutrient rich and protected from waves.

In Maidstone, white water lilies are found in the shallow northern bay and scattered throughout the margins of the lake in low abundance. This species is hand-pulled by landowners and may be otherwise more widespread than reported. Though it can survive in Maidstone, the nutrient-poor conditions are not ideal for this species and it is not likely to become overly abundant.

4. Conclusions

Maidstone Lake is an oligotrophic, low alkalinity lake surrounded by 3000 acres of forest and is known for its clear waters and pristine setting. Ecologically, Maidstone is exceptional because it is one of the few large, truly oligotrophic lakes in the state. A total of 22 different plant species were documented in the lake, including a macroalgae and an aquatic moss. This includes 3 rare aquatic plant species known from few other Vermont lakes. Two aquatic natural communities were mapped in the lake: the Pipewort-Water Lobelia Aquatic Community and the Stonewort Aquatic Community. These communities provide valuable habitat and food resources for the wide array of invertebrates and fish species in the lake. This unique ecosystem is an important component of the region's biodiversity and its existence is dependent upon preventing nutrient enrichment and invasion of non-native species.

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