Aquatic Plant Community

Lake Noquebay supports an abundant and diverse aquatic plant community dominated by muskgrass (*Chara sp.*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*) and bushy pondweed (*Najas flexilis*), each found at more than 40% of sample sites. Other abundant plants including flat-stem pondweed (*Potamogeton zosteriformis*), variable-leaf pondweed (Potamogeton graminaeus), Illinois pondweed (*Potamogeton illinoensis*), coontail (*Ceratophyllum demersum*), and large-leaf pondweed (*Potamogeton amplifolius*) were found at more than 18% of sample points. Twenty-seven other species were identified during the 2007 aquatic plant survey for a total of 32 species.

During the summer of 2007 nearly 80% of the lake supported submersed aquatic plant growth. This includes all areas less than 15 feet in depth. Plant growth was most dense in water between 3 and 12 feet deep. Floating leaf plants, such as water lilies, are abundant locally but have a limited distribution in the lake. Emergent vegetation is more widespread, covering nearly 160 acres of the lake.

Exotic Species

No exotic plant species are known to exist in Lake Noquebay. While the exotic Eurasian watermilfoil (*Myriophyllum spicatum*) has been reported growing in Lake Noquebay in the past, its presence in the lake has never been verified and reports have been attributed to misidentification of variable-leaf watermilfoil (VWM), which is abundant in Noquebay and looks similar.

Zebra mussels (*Dreissena polymorpha*), an exotic invasive mussel from Eurasia, were found attached to clam shells and the stems of variable-leaf milfoil throughout the lake. Banded mystery snails (*Viviparus georgianus*) , a species native to the southern U.S. are also found in abundance in shallow water areas where they feed on attached algae and detritus in the sediment.

History of APM Efforts

The LNRD, DNR, and Marinette County Land & Water Conservation Division (LWCD) have been studying and managing aquatic plants on Lake Noquebay for more than 40 years. Early attempts were aimed at reducing aquatic plants and the incidence of swimmers itch. Copper sulfate was used on a limited basis in the 1950's and 1960's but was judged unsuccessful.

In the early 1970's, a three-phase interdisciplinary study was conducted to study the proliferation of variable-leaf watermilfoil and recommend management alternatives. Following this study, lake residents, town and county officials formed a "weed committee" to study the harvesting alternative. This committee was disbanded and the Lake Noquebay Rehabilitation District was formed in 1975. A management plan consisting of intensive harvesting, winter drawdown to dislodge plants in shallow water and spring harvesting of dislodged plant material was adopted to restore beneficial uses to the lake.

In 1978 an EPA clean lakes grant was received to help implement the harvesting plan. The five-year grant allowed for the purchase of two aquatic plant harvesters, one with a ten-foot cutting path and a smaller one with a five-foot cut. A second 10-foot harvester was purchased two years later by the LNRD. Since the mid 80's the LNRD has been operating two aquatic plant harvesters with a third dedicated to removing plant fragments that wash up on the shoreline.

Aquatic Plant Survey

Thanks to the efforts of the LNRD and state resource agencies several aquatic plant surveys have been conducted on Lake Noquebay. The most recent survey conducted in 2007 was by far the most comprehensive and provides a wealth of data from which future aquatic plant management decisions can be made.

Survey Methodology

Marinette County LWCD staff conducted the aquatic plant survey during the first week of August using the most recent Wisconsin DNR point/intercept sampling protocol. A point spacing interval of approximately 112 meters (137 feet) was used, yielding 822 individual sample locations. 773 points (94%) were actually surveyed, the balance were on land or located within a large emergent marsh in the northwest corner of the lake that was not navigable.

Coordinates for each sample points were loaded onto a Garmin Vista handheld GPS unit for navigation in the field. At each sample location a special double-headed garden rake on an extendable aluminum pole was used to determine the water depth and sediment type and to sample aquatic plants. Plants were collected for identification by dragging the rake across the bottom for approximately 0.75 meters and bringing it to the surface. Each species was noted and the overall abundance was estimated by assigning a score of 1 (sparse) to 4 (overflowing) based on the amount of vegetation on the rake.

The field survey was completed using a team of two individuals, a "driver/data recorder" and the "sampler". The driver navigated to each sample point using the GPS receiver. When the sample point was reached the "sampler" would probe for depth and sediment type then pull the plant sample. Typically the sampler could sort and call out the vegetation data before the next sample point was reached. Sample points that were clearly in excess of the maximum depth of colonization (15 ft) were not sampled but depth was recorded based on depth finder readings.

Data was entered and analysis was completed in Microsoft Excel and is reported in full in Appendix D. All sample location and associated data were mapped in the Marinette County Geographic Information Systems (GIS) database. Plant distribution maps for each species can also be found in Appendix D.

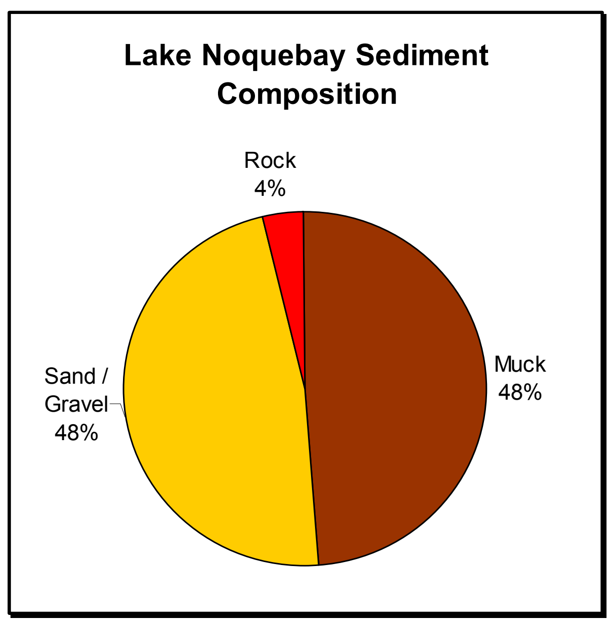


Figure 8. Lake Noquebay sediment composition.

Sediment Type

As part of the aquatic plant survey sediment type was determined for each sample location shallower than the maximum depth of plant growth. Sediment type was determined by "feel" using the metal rake head attached to an aluminum pole. Data was recorded as muck, sand & gravel, or rock. Soft unconsolidated sediment was recorded as muck. Rock included everything from cobble size rock (2-3 inches) to boulders. Sand and gravel are often mixed and difficult to distinguish by feel so they were grouped together.

Analysis of the data shows a nearly equal division between sand & gravel (49%) and muck (47%) with lesser amounts of rock (4%). A map of Lake Noquebay sediments (figure 8) shows that sand is the dominant sediment type in the eastern half of the lake and in water less than 5 feet deep while muck is more prevalent in deep water and in the western half of the lake.
Sediment type is important because aquatic plants have differing sediment preferences. Muck generally supports the greatest diversity of aquatic plants and often more dense plant growth as well.

Aquatic Plant Community Structure

Lake Noquebay supports an abundant and diverse aquatic plant population with 32 native species identified during the survey. While variable-leaf milfoil is one of the dominant plants, under the current management strategy it cannot be said to dominate the population.

A cursory review of the data shows that three plants were found at nearly half of the sample locations (Figure 9). Five plants were found at nearly 20% of sample locations and three additional plants were found at 10% or more sample locations. Together these plants account for more than 85% of the plant population.

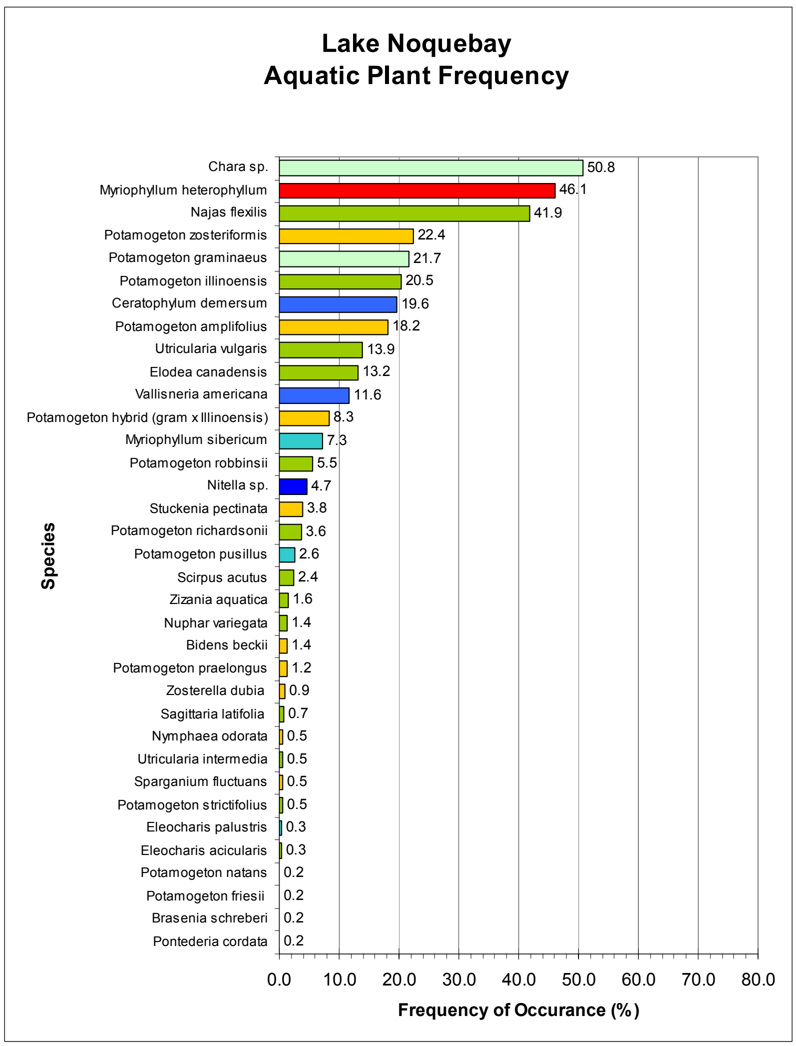


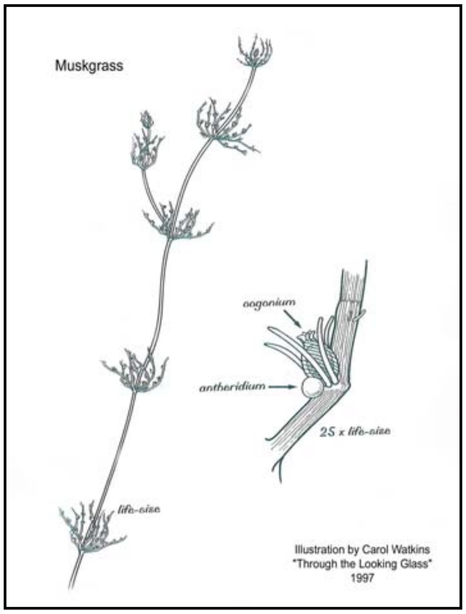
Figure 9. Dominant plants in Lake Noquebay.

Common Aquatic Plants

The following descriptions are taken from *Through the Looking Glass, a Field Guide to Aquatic Plants* (Boreman 1997), a publication of the Wisconsin Lakes Partnership. Distribution maps for each species can be found in Appendix D.

Muskgrass
Muskgrass (*Chara sp.*) is the most widely distributed aquatic plant in Lake Noquebay. It was found growing at 51% of vegetated sites.

While outwardly appearing like many other aquatic plants, muskgrass is actually a type of colonial algae. Each "stem" and "leaf segment" is actually a separate algae cell. Muskgrass has branching slender "stems" with whorls of "leaves" at each joint. The main branches have ridges and the entire plant is often encrusted with calcium



carbonate giving the plant a gritty or crusty feel. Muskgrass can be easily identified by its smell. When crushed the plant smells like skunk!

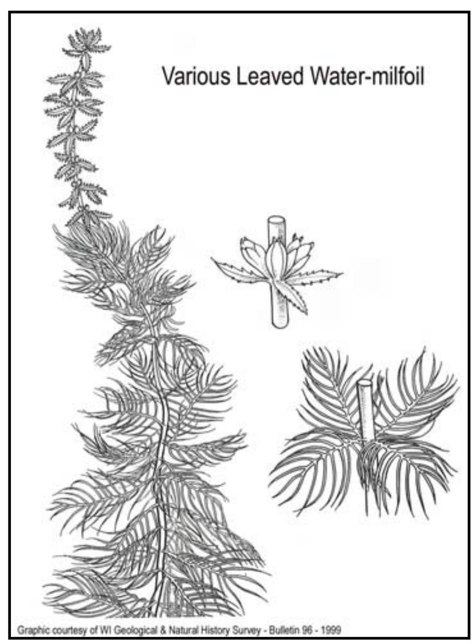
Muskgrass is found in hard water lakes and prefers firm sediment. In Lake Noquebay muskgrass shows a strong preference for sand and rock (91% of sites) over muck (9% of sites). Muskgrass also prefers shallow water. In Lake Noquebay it is found most often in water less than five feet deep and most abundant in 2 to 4 feet of water. Muskgrass tends to hug the bottom and rarely grows more than two feet tall. Due to its short stature muskgrass is seldom viewed as a nuisance species.

Muskgrass is a favorite food of waterfowl and provides excellent fish habitat. In very shallow sandy areas used by newly hatched fry (juvenile fish), muskgrass is often the dominant plant.

Variable-leaf watermilfoil (VWM)
Variable-leaf watermilfoil (*Myriophyllum heterophyllum*) is the species that causes the most concern in the lake and is the primary target of the harvesters. It was found at 46% of sample sites and would surely be the most abundant plant in Lake Noquebay by mass.

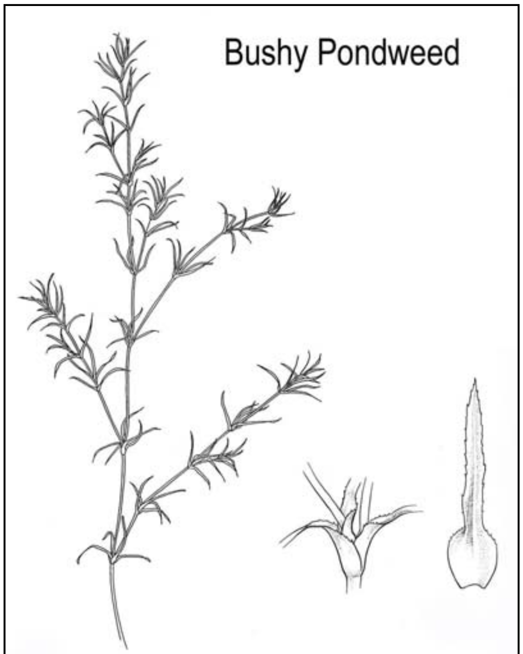
Like most milfoils this species VWM has soft feather like leaves arranged in whorls of four along a long thin stem. Each leaf is divided into 7-10 pairs of thread-like leaflets. The whorls in variable-leaf milfoil are very closely spaced (1/8"-1/4") along the stem giving the plant the appearance of a thick rope. Various-leaf milfoil gets it name from the toothed bracts "leaves" that form on the plants seed head when it emerges from the water. This typically only happens in calm shallow water where plant growth is very dense.

VWM overwinters by hardy rootstocks, rhizomes, and older stems that can survive the winter. Like its exotic cousin Eurasian watermilfoil (*Myriophyllum spicatum*) it spreads primarily by fragmentation, a process where even small fragments of the plant separated by boats or wave action drift to a new place and take root. The rapid growth, ease of spread, and its canopy forming habit, allows VWM to out compete many of the slower growing native plants.



In Lake Noquebay VWM shows a distinct preference for muck (57%) over sand (11%). While it was found growing as deep as 14 feet, variable-leaf milfoil is most common in water between 5 and 9 feet deep.

While native to the United States, it is thought that variable-leaf milfoil may not be native to Lake Noquebay. This plant is more common in the Tennessee Valley area and other southern states. The latest research also points out that there are at least three distinct genotypes of VWM in the US including a very aggressive form common in New Hampshire that has been causing problems in southern lakes where it is out-competing the native strain (Netherland, 2009). It would be interesting to see which strain in present in Lake Noquebay. While it can be a nuisance, the milfoil provides important deep-water habitat in the lake, especially early in the season since it begins growing earlier than many of the pondweeds.



Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

Bushy Pondweed (Slender Naiad)

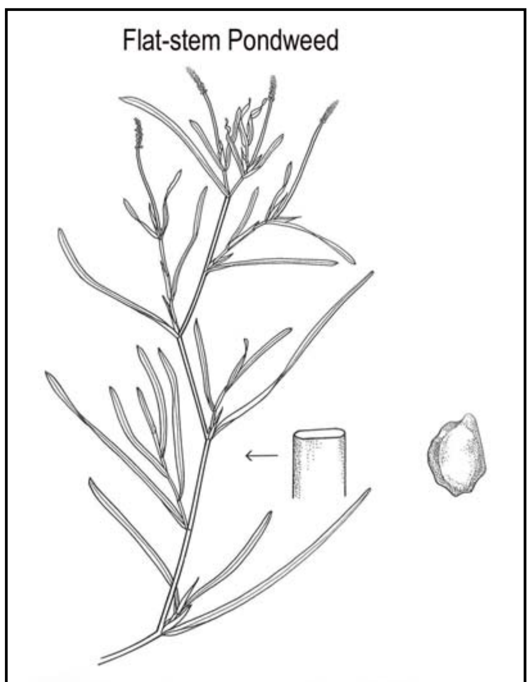
Bushy pondweed (*Najas flexilis*) was found at 42% of vegetated sites in Lake Noquebay. This plant varies greatly in growth form, compact and bushy in shallow water, long and wiry with widely scattered leaves in deep water. The leaves are very narrow (1/16th inch wide) with a broad base where they attach to the stem. Plants generally grow no more than 2 feet tall and prefer a firm substrate.

Bushy pondweed is rather unique in that it's one of the few annual aquatic plants. It dies each winter and depends on seed to grow new plants each year. The plants and the seeds, which are produced in great number each year, are important food for waterfowl.

In Lake Noquebay bushy pondweed is a true generalist. It shows a slight preference for muck sediment (48%) but grows nearly as well in sand (33%). It is also nearly as abundant in 14 feet of water as it is in 3 feet, showing only a slight preference for water between 7 and 10 feet deep.

Due to its short stature bushy pondweed is seldom reported as a nuisance plant and the harvester rarely picks it up. Aquatic plant trend data indicates that the harvesting program may be benefiting the bushy pondweed as will be discussed later in the report.

Bushy pondweed is one of the most important aquatic plants for waterfowl as both the vegetation and seeds are eaten by a wide variety of ducks. It also provides shelter for fish, particularly in very shallow sandy areas where bushy pondweed is often the only cover available.



Graphy courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

Flat-stem Pondweed

Flat-stem pondweed (*Potamogeton zosteriformis*) is identified, as the name implies, by its strongly flattened stems. The leaves are long (4"-8"), narrow (1/8"-1/4") and very stiff. The plant produces no floating leaves.

Flat-stem pondweed is a perennial that rarely reproduces by seed. Typically the entire plant dies back each year and re-grows from the root system. Like many of the pondweeds, flat-stem pondweed spreads by producing winter buds, specialized leaves packed in a tight cluster that form at the end of the season on some side branches. When the plant dies back the winter buds detach and fall to the sediment where they take root.

In Lake Noquebay flat-stem pondweed was found at nearly a quarter of the sample locations (22%). It shows a strong affinity for muck sediment (81%) and water between 8 and 12 feet deep. It was the most abundant plant in water over 9 feet deep.

Because of its affinity for deep water, flat-stem pondweed provides important foraging habitat for panfish and edge cover for gamefish. It also serves as a food source for waterfowl that graze on its leaves and eat the seeds.

Variable pondweed

Variable pondweed (*Potamogeton gramineus*) was also found at found at 22% of vegetated sites on the lake. As the name implies it varies greatly in growth form even within the same lake depending on depth and sediment type where it is found. Typically the plant has lance shaped leaves 1-3 inches long and 1/16" – 1/8" wide. The plant branches repeatedly and the side braches are very bushy. In Lake Noquebay variable-leaf pondweed growing in deep water tends toward the upper end of the size range and the entire plant may be several feet tall. In shallow sandy areas the plant is typically short and very bushy with small narrow leaves. Identification is complicated by the fact that variable-leaf pondweed often crosses with the larger Illinois pondweed which is also common in Lake Noquebay.

Like all of the true pondweeds (Potamogeton sp.), variable-leaf is a perennial that dies back in the fall. It spreads by seeds that are produced on stalks held above the water surface. When flowering it forms small floating leaves that are wider and more ellipse shaped than the submerged leaves.

In Lake Noquebay variable-leaf pondweed shows a distinct preference for sand (50%) and rock (35%) substrate. It is most common in water between 2 and 5 feet deep.

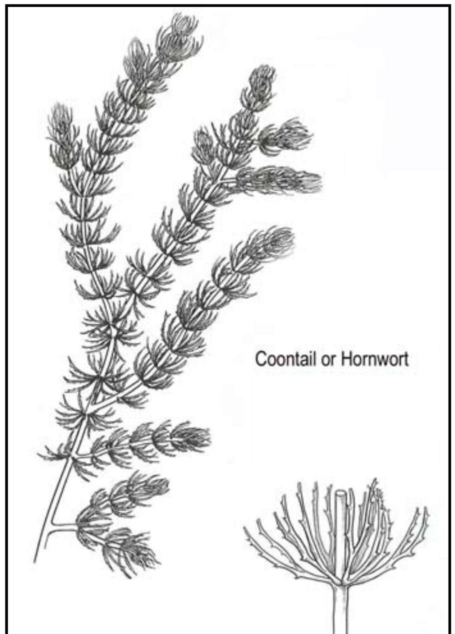
Illinois pondweed

Illinois pondweed (*Potamogeton illinoensis*), found at more than 20% of sample sites, looks very much like a larger version of variable-leaf pondweed, with which it often crosses. In Noquebay its lance shaped leaves are typically ½" to 1" wide and 3 to 8 inches long with pointed tips. When flowering it can produce large ellipse-shaped floating leaves. Fruit are produced on a thick stalk held above the waters surface. Illinois pondweed is a perennial with winter-hardy rhizomes but it can occasionally overwinter green.

Illinois pondweed is much larger in stature than variable-leaf pondweed and is typically found growing in deeper water (6-8 feet). Illinois pondweed shows a strong preference for muck sediment (68%). Fishermen often refer to Illinois pondweed, along with its cousin large-leaf pondweed, as "cabbage". It provides important deep-water fish habitat and is often found growing on the edge of drop-offs.

Coontail

Coontail (*Ceratophyllum demersum*) may be the most common aquatic plant in Wisconsin. In Noquebay it was found at 20% of vegetated sites. Like milfoil, coontail has long trailing stems with leaves arranged in whorls around the stem. Unlike milfoil the leaves of coontail are very stiff with teeth along the margins. The leaf whorls tend to be dense near the ends of the stem, giving them the appearance of a bushy raccoon tail. The plant often forms dense mats on the bottom and can be a nuisance in shallow water areas.



Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

Coontail has no true roots but anchors to the sediment by modified stems wherever it touches the bottom. It rarely produces seed and spreads primarily by fragmentation. Due to its poor "rooting" ability, coontail shows a strong preference for muck (86%). It also shows an affinity for deep water, being found most often at a depth of 8-12 feet.

Coontail is important for fish habitat since it is slow to decompose and often stays alive under the ice. This habit makes it excellent winter habitat, attracting aquatic insects and the fish that feed on them.

Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

Large-leaf pondweed

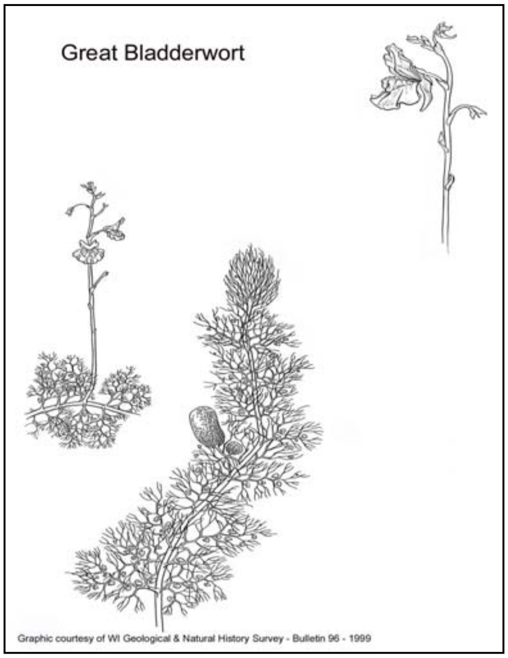
Large-leaf pondweed (*Potamogeton amplifolius)* is the largest of the pondweeds in Lake Noquebay where it was found growing at 18% of the sample sites. It can be identified by its wide (1-2 in) arching leaves and by its thick seed stalk that is held above the surface.

In Lake Noquebay large-leaf pondweed can be found throughout the lake in two to eight feet of water where it provides excellent fish habitat. No sediment preference was found although it is known to prefer firm sediment.

Like many of the pondweeds, large-leaf pondweed has the same habitat preference as VWM and is often displaced by the exotic species. Several other large pondweeds were also found in the lake at lower frequency.

Common bladderwort

Common bladderwort (*Utricularia vulgaris*) is the largest and most visible bladderwort. In Noquebay it was found at 14% of the sites.

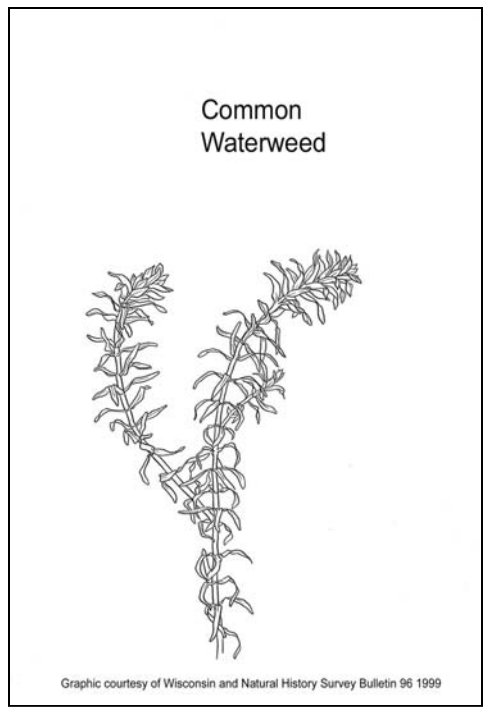


Common bladderwort has long floating stems that are densely covered with fine leaf-like branches, each forked 3-7 times. The branches contain many bladders that are bright green when young and turn purple to black as they age. If you pull a plant from the water you can often hear it snapping like Rice Krispies as the bladders snap open. The bladders are small pouches that trap protozoans and small insect larvae. When set they are sealed shut and spring open when prey brushes against the trigger hairs near the bladder opening. When triggered they suck the prey inside where it is slowly digested.

In late summer common bladderwort forms dense winter buds on the ends of the stem that fall off and lie dormant on the sediment until the following spring.

Common bladderwort is free and prefers sheltered areas and deep water with dense vegetation where it is protected from wave action. For this reason it is most common in areas of muck sediment. It shows no strong depth preference.

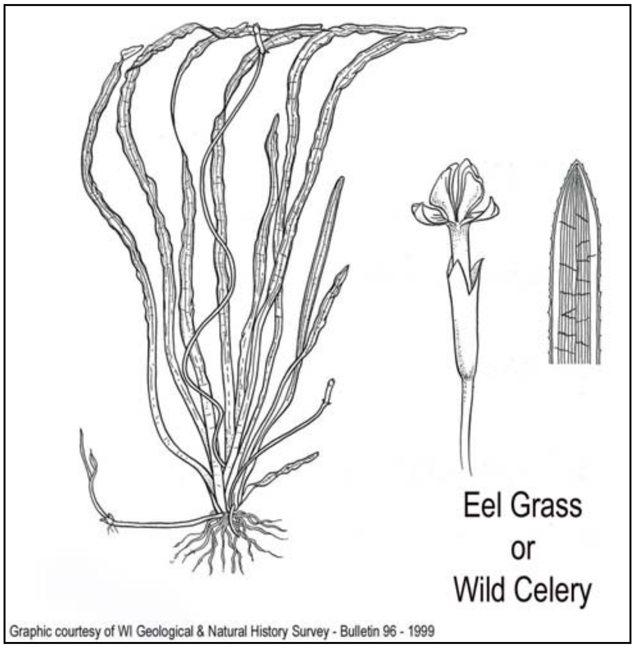
Common waterweed
Common waterweed (*Elodea Canadensis*) has small lance shaped leaves (1/16th to 1/8th inch wide, ¼ to ¾ inches long) attached directly to the stem in whorls of three. The plant branches profusely and often forms tangled mats.



Common waterweed bears male and female flowers on separate plants but seldom produces seed, spreading primarily by fragmentation. In Noquebay it's found almost exclusively in areas of muck sediment (91%). It can be found at almost any depth but prefers water 8 to 10 feet deep.

Common waterweed is important in the lake ecosystem because it overwinters green and continues to produce oxygen under the ice in very low light conditions. Waterfowl eat the plant and it provides good winter habitat for fish and aquatic insects.

Wild Celery
Wild celery (*Vallisneria americana*) is identified by its long ribbon shaped leaves ¼ to ½ inch wide and up to 7 feet long. The leaves have a prominent central stripe and a cellophane-like consistency. The leaves emerge from a central rosette on the bottom. Often the leaf tips grow to the surface where they trail out just under the surface. Late in the summer water celery produces tiny male flowers under water that break free and float up to the surface. The white female flowers are found at the end of a long coiled stalk that extends the flower up to the surface where it is pollinated. After pollination it is withdrawn below the surface and a long narrow seed capsule develops. Water celery prefers a firm substrate and is quite tolerant of turbid water.



Water celery is a perennial plant that spreads primarily by vegetative means, not by seed. Water celery produces abundant tubers just under the sediment surface each summer. These tubers lie dormant during the winter and resume growth in the spring. While waterfowl eat all parts of the plant, these starchy tubers are especially prized. Canvasback ducks are almost completely dependent on the tubers of wild celery during their migration flights. Wild celery also provides important fish habitat.

In Noquebay wild celery was found at 12% of sample sites where it shows a preference for muck bottom (60%). An analysis of its depth preference showed two spikes, one at 5-7 feet and a second at 10-12 feet.

Infrequent Aquatic Plants

The following aquatic plants were found at fewer than 10% of the survey points on Lake Noquebay. This does not necessarily mean they are rare. The survey methodology tends to under sample some plants due to their location or their growth form, especially floating leaf plants and emergent vegetation. Descriptions are taken from *Through the Looking Glass, a Field Guide to Aquatic Plants* (Boreman 1997).

Hybrid (variable-leaf x Illinois) pondweed

Two of the most common pondweeds in lake Noquebay, Illinois pondweed and variable-leaf pondweed, are known to cross freely. The hybrid pondweed (*Potamogeton graminaeus x illinoensis*) is found throughout the lake and complicates identification of the two parent species.

Plants designated as hybrid pondweeds during the survey shared characteristics of both parents. They were typically larger in stature with leaves that were ¼ -½ inches wide and 3-6 inches long although leaves on the same plant varied greatly. Plants were often found superficially resembled Illinois pondweed but had side branches that were strongly branched and had smaller leaves typical of variable pondweed.

In Noquebay the hybrid pondweed was found at 8% of sample points. It was found primarily in water between 5 and 7 feet deep, midway between its parent plants. Like Illinois pondweed it shows a strong preference for muck sediment (60%).

Northern watermilfoil

Northern watermilfoil (*Myriophyllum sibericum*) is probably the most common native milfoil species in Wisconsin. Like the more abundant variable-leaf milfoil, it has feather shaped leaves arranged in whorls of 4 around a central stem. However, leaf spacing along the stem is much greater (1/4 inch or more) and the leaves are stiff and generally hold their shape when out of the water.

Northern watermilfoil is a perennial that overwinters by hardy rootstalks and winter buds. Winter buds are cylindrical growths of small tightly packed leaves that form on the end of some side branches. The buds fall to the sediment when the plant dies back in the fall then sprout to form new plants in the spring.

Northern watermilfoil has a strong preference for muck sediment (98%) and has a fairly broad range of depths at which it can be found (3-8 feet). Northern watermilfoil was found at 7% of sample points, primarily in the northwest corner of the lake near lower middle inlet and in other areas where harvesting is limited. Since it shares similar habitat preferences with variable-leaf milfoil it is likely suppressed by its more aggressive cousin.

Other "Large" pondweeds

Several common large pondweeds were found in Lake Noquebay at low frequency including white-stem pondweed (*P. praelongus*) and clasping-leaf pondweed (*P. richardsonii*). Together with large-leaf and Illinois pondweed fishermen know them as "cabbage" or "musky weed". Also found in the lake were fern pondweed (*P. robbinsii*) and floating-leaf pondweed (*P. natans*). The latter is often viewed as a floating leaf plant since it had no obvious underwater leaves.

Most of the large pondweeds prefer muck sediment and deep water (>5 feet). They are typically the largest submersed plants in a lake and provide excellent fish habitat.

Small pondweeds

Three small narrow-leaved pondweeds were also found in the lake. The most common was small pondweed (*Potamogeton pusillus*) followed by stiff pondweed (*P. strictifolius*) and Fries' pondweed (*P. fresii*). All have fine leaves and prefer moderate depths and muck sediment. The shape of the winter buds, glands, and leaf sheaths differentiate these species.

Sago pondweed (*Stuckenia pectinata*) was also found. Once in the potamogeton family it has been re-classified. Sago is one of the most valuable waterfowl plants in the lake. It grows in shallow water and produces abundant seeds and starchy tubers that most puddle ducks feed on.

Other submersed plants

Several other submersed aquatic plants were also identified in Lake Noquebay. Water marigold (*Bidens beckii*) is often mistaken for a milfoil but can be distinguished by its branching instead of feather-like leaves. Flat-leaf bladderwort (*Utricularia intermedia*) is another "predacious" aquatic plant in the lake.

Water stargrass (*Zosterella dubia*) and floating-leaf bur-reed (*Sparganium fluctuans*) have long grass-like leaves and superficially look very similar. Hairgrass (*Eleocharis acicularis*) is an "emergent" plant that rarely emerges from the water and has very fine hair-like stems when submerged. Also found in the lake is stonewort (*Nitella sp.*), a translucent green algae that looks like a higher plant. Like muskgrass, each "stem segment", "branch", and "leaf" is actually a separate algal cell.

Floating-Leaf Plants

Floating-leaf plants include those with underwater stems and leaves that float on the waters surface. While many pondweeds also produce floating leaves when they flower, their primary leaves are under water. Floating leaf plants found in Lake Noquebay include White pond lily (*Nymphaea odorata*), spatterdock lily (*Nuphar variegata*), and watershield (*Brasenia schreberi*).

None of the floating-leaf plants were found in any significant number during the aquatic plant survey. However, it should be noted that the survey methods do a poor job of sampling the floating leaf community. The point grids tend to under-sample very shallow areas where they grow best and due to their growth form and tough stems the sampling gear often fails to collect the plants. To better describe the community, areas containing floating leaf plants and emergent plants were mapped and described. Figure 10 shows the results of the mapping effort.

The largest concentration of lilies is can be found in the northwest corner where Lower Middle Inlet enters the lake. Here more than 70 acres of dense water lilies can be found mixed with wild rice and other emergent vegetation. The plant density was so great in the area it was impossible to get a boat very far into the plant bed. Smaller areas near the mouth of Middle Inlet and Finnegan's Bay also supported similarly dense water lilies. Elsewhere in the lake floating-leaf vegetation was limited mixed with rushes or found in a narrow band near the shore where it was protected from wave action by dense stands of bulrush.

All of the water lilies are found in relatively shallow water in areas with loose organic sediment. All have large fleshy rhizomes that anchor the plants and store nutrients that allow new plant growth to reach the surface in the spring. In areas with very flocculent muck these rhizomes often break loose and float to the surface where they decay and become rather unsightly.

Emergent Vegetation

Plants such as cattails, bulrushes and others that reach above the surface of the lake are known as emergent vegetation. Many of these plants grow in the lake or in saturated soil on the shoreline. Most are adapted to fluctuating water levels and are unharmed, or actually stimulated, by low water periods. Due to their location on the shoreline emergent plants are greatly under-sampled in grid surveys. For this reason, emergent vegetation on Lake Noquebay was mapped and described (Figure 10).

The most abundant emergent plant in Lake Noquebay is hardstem bulrush (*Scirpus acutus*), which can be identified by its long green leafless stems. Hardstem bulrush is typically found in areas with a hard sand bottom. It forms large stands in shallow water on the north and east sides of the lake. Bulrush stands provide vital habitat functions in the lake. Early in the year northern pike and yellow perch deposit their eggs on the submerged dead stems of last years growth. Later bluegill and bass make their beds in the cover of the bulrush stands. As fish of all species hatch they spend their early weeks and months feeding in the warm shallow water in these same bulrush stands.

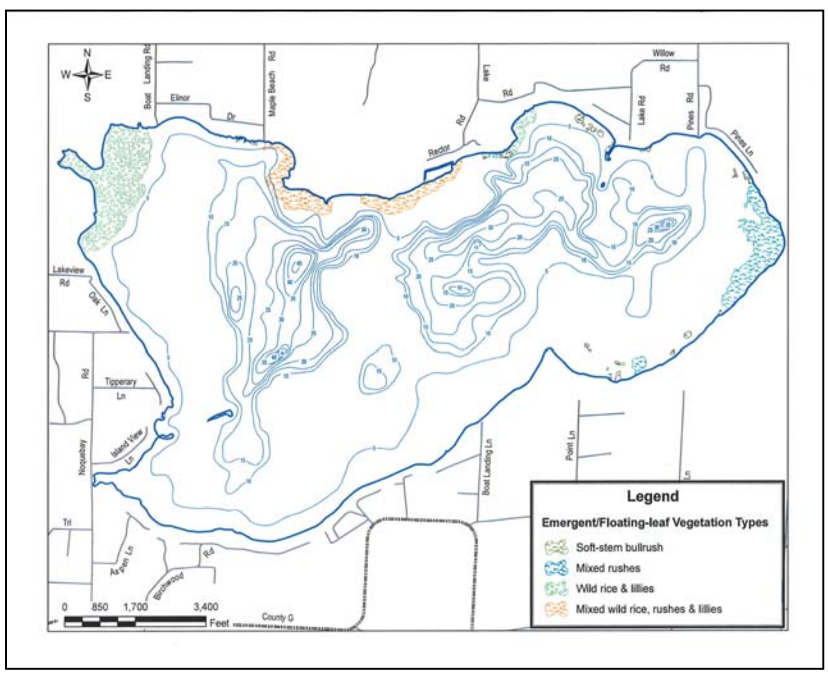


Figure 10. Emergent and floating-leaf vegetation map.

Wild rice (Zizania aquatica) is also found throughout the lake, primarily along the north shore. Wild rice is an annual plant that re-seeds itself every year. Early in the season wild rice has only submerged leaves that float at the surface. As it matures a stem emerges and the seed head develops. Unlike bulrush, wild rice prefers soft organic sediment. State law identifies wild rice as a high value aquatic plant. The plant and its seeds are eaten by a wide variety of waterfowl and muskrats graze the stems. Like all emergent aquatics it provides valuable fish habitat as well.

Other emergent plants identified in the survey include creeping spikerush (*Eleocharis palustris*), common arrowhead (*Sagittaria lattifolia*) and pickerelweed (*Pontederia cordata*). A more intensive survey of shoreline vegetation would certainly show even more species including many types of sedge, rushes and other wetland vegetation.

Floristic Quality Index

One measure of the "health" of a lakes' plant community is the Floristic Quality Index (FQI), which is based on the number of native species and their relative sensitivity to environmental stressors. Each species of plant found in Wisconsin has been assigned a "coefficient of conservatism" which represents how typical the plant is in pristine conditions. The FQI is based solely on the presence of a plant, not its abundance or dominance. Statewide, the average FQI for lakes is 22.2. The FQI for Lake Noquebay was 35.9, indicating a high quality aquatic plant population with good diversity.

Aquatic Plant Distribution

Each species of aquatic plant has habitat preferences that determine where it grows or potentially can grow. These include such factors as depth, light exposure and sediment type. A discussion of these factors and their effect on the plant community of Lake Noquebay follows.

Depth

The area of a lake where aquatic plants can grow is called the littoral zone and is determined by water clarity. Field investigation reveals that the maximum depth of plant colonization in Noquebay is approximately 15 feet. Although beyond the 12-foot depth growth was limited in both variety and density. More than half of the sample points between 13 and 15 feet deep contained no vegetation at all. Approximately 1,925 acres, or 80% of the lake is shallower than 15 feet deep and therefore capable of supporting aquatic vegetation.

The extent of the littoral zone is determined by light penetration (water clarity), which can be effected by suspended sediment, algae, and color. In Lake Noquebay color is primarily responsible for limiting light penetration. The water in Lake Noquebay typically has a light brown color caused by tannins, which are naturally occurring dissolved organic compounds that come from decomposing plants. These compounds are flushed into the lake during spring runoff and large rain events so the amount of staining can very from year-to-year with changing runoff conditions.

Within the littoral zone each species has a depth preference and a maximum depth at which it can grow. In some cases the maximum depth is limited by growth form such as water lilies that have floating leaves attached at the end of long underwater stalks, or emergent plants that must stand above the surface. Submersed plants are limited by the amount of available light, which decreases rapidly as depth increases. Most aquatic plants are perennials that die back to the sediment surface each year. Others sprout anew from specialized plant fragments (winter buds) lying on the lake bottom. These

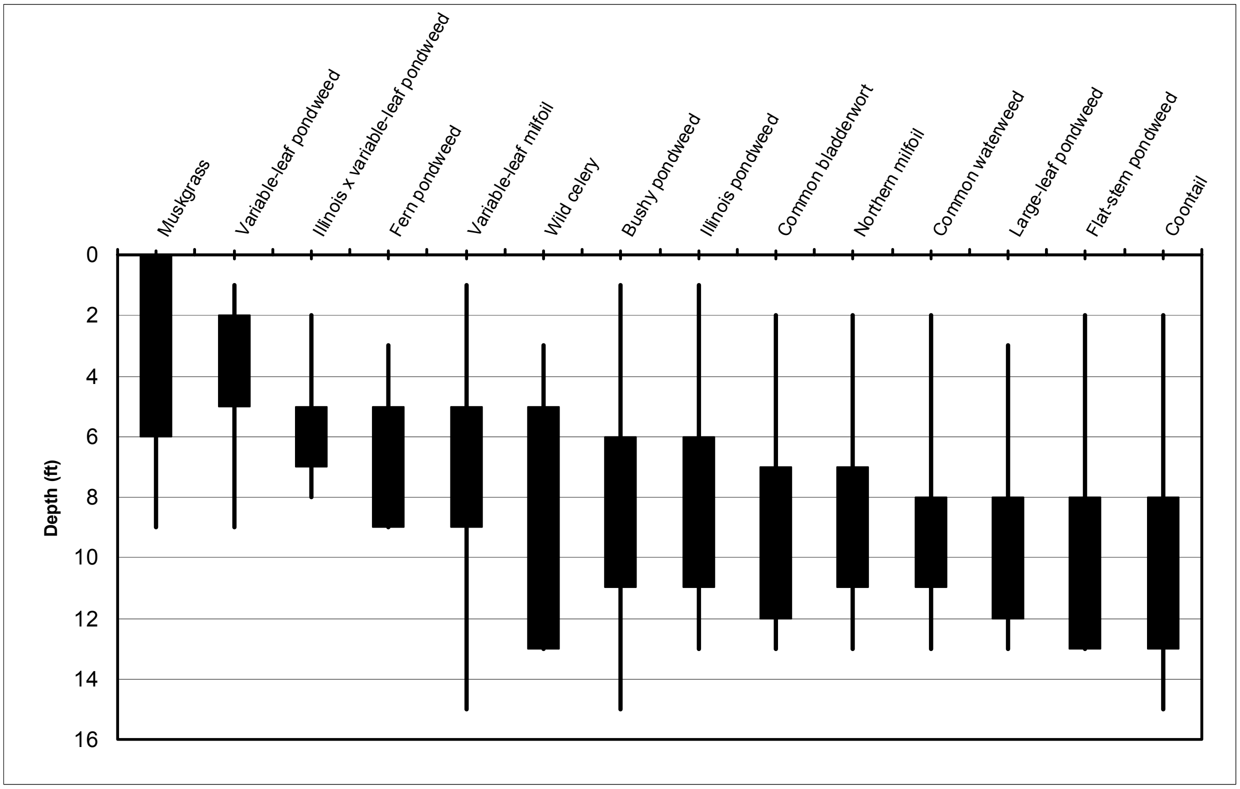


Figure 11. Depth preference of dominant aquatic plants. Solid bar indicates common occurrence while line indicates upper and lower limits of growth.

plants use energy stored in the roots or winter buds to extend upward towards the light each year. They must grow high enough and fast enough to reach the sunlight then grow and export nutrients to the roots to start next year's growth. Different species vary in their ability to grow in low light conditions and fewer species are typically found at greater depth.

Of the dominant species found in Lake Noquebay, muskgrass and variable-leaf pondweed showed the strongest preference for shallow water with most of the plants found in 5 feet of water or less (figure 11). Plants showing the strongest preference for deep water (greater than 10 feet) included large-leaf pondweed, flat-stem pondweed, and coontail. The intermediate depths (5-10 feet) supported the greatest variety of plants and consistently dense plant growth. Variable-leaf milfoil, bushy pondweed, and coontail showed the greatest variability in depth preference.

Sediment

Sediment type also plays a major role in aquatic plant distribution and abundance. Sediment preference can be related to physical properties of the sediment (coarseness, grain size, compaction) or in the chemical properties of the sediment such as pH, or nutrient availability.

Most rooted aquatic plants get their nutrients from the sediment, not the overlying surface water. Because of this, even lakes with low to moderate nutrient levels in the water column can support abundant aquatic plants if sediment nutrient levels and water clarity is sufficient. Sediment that erodes from upland sources is typically high in nutrients. Impounded water such as Noquebay typically has nutrient rich sediment in shallow areas that were historically upland or wetland areas.

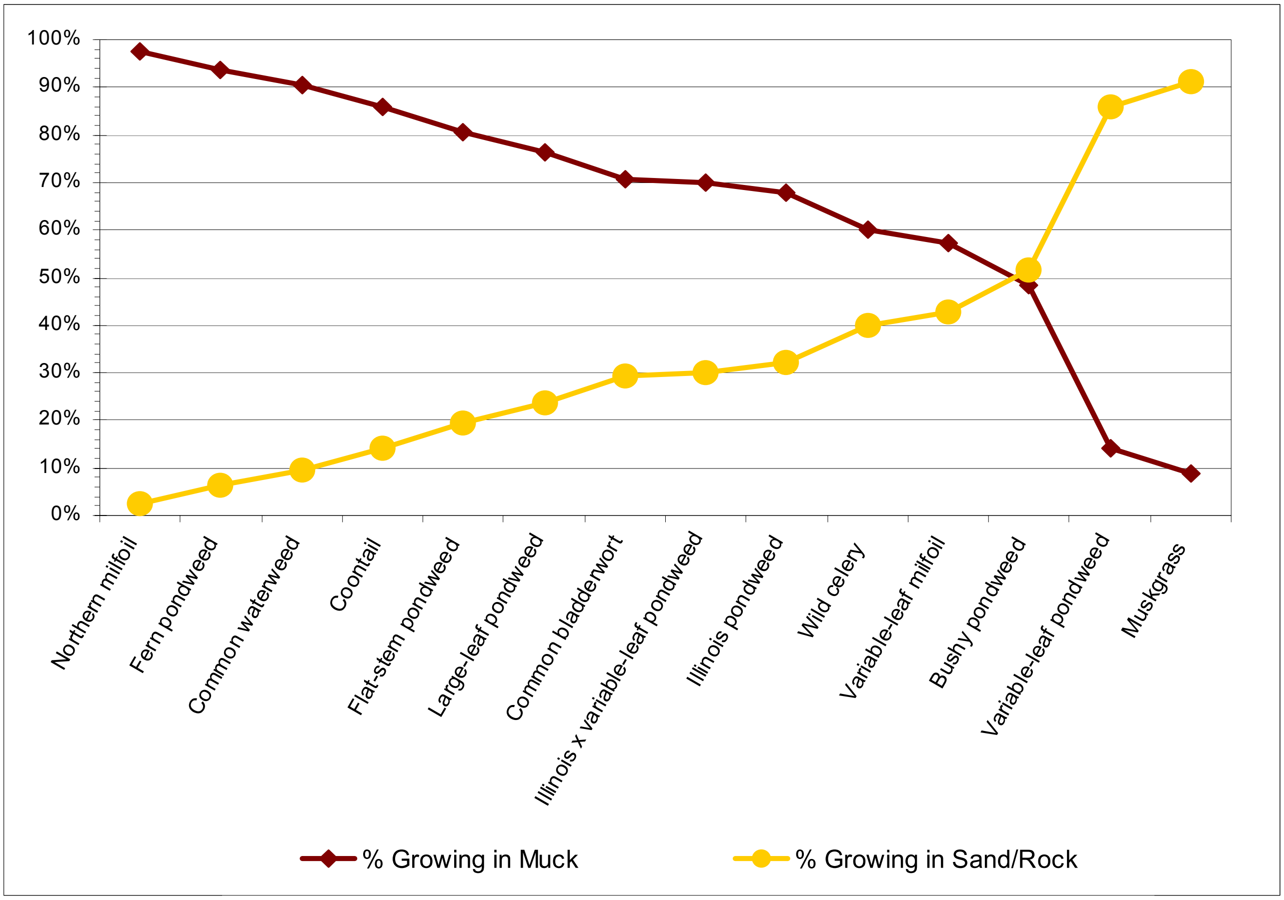


Figure 12. Sediment preference of dominant aquatic plants.

Nutrient availability is closely tied to sediment coarseness. What most people refer to as muck is typically silt with a high percentage of organic particles from decomposing plant material. Organic sediment is typically high in nutrients. Sand, by itself can be very nutrient poor, however there is typically sufficient fine silt and organic matter mixed in to provide good growing medium for plants. Rock by itself will not support plant growth but it is often found mixed with sediment that will. Of the dominant species only musk grass and variable-leaf pondweed showed a strong preference for sandy sediment (figure 12). Many more species show a strong preference for muck including northern milfoil, most of the large pondweeds, bladderworts and coontail. Bushy pondweed was the only common plant that showed no real sediment preference. Wild celery and variable-leaf milfoil had only a weak preference for muck.

Aquatic Plant Abundance

In addition to describing patterns of aquatic plant distribution in Lake Noquebay, the survey was designed to determine total plant abundance. At each sample point a rake "fullness" measure of 1 (sparse) to 4 (abundant) was used to estimate aquatic plant abundance at that site. Overall the data shows abundant plant growth throughout the lake with an average rake fullness of 2.8 at sties shallower than the maximum rooting depth (15 ft). However, abundance did vary considerably by depth and sediment type.

As shown in figure 13, aquatic plants were very abundant in 5-11 feet of water with a rake fullness rating of nearly 4. In 3-4 feet of water the abundance drops to around 3. In water less than 3 feet deep overall plant abundance is moderate or low.

In shallow water most of the difference in abundance can be attributed to sediment type. Most of the points with a sand/gravel or rock substrate were found in shallow water. At these sites abundance was typically low and the dominant plant species are typically small in stature. In deep water muck is the dominant substrate and overall plant abundance is limited by light intensity. The data shows a sharp decline in plant abundance beyond the 12- foot depth. At these depths plants were typically sparse.

Although the abundance of individual species was not estimated, overall abundance is affected by the dominant species at the site. Certain species such as coontail, bushy pondweed, and muskgrass tend to form dense mats and are weakly rooted in areas with a mucky bottom. The sampling gear easily collects plants with this sprawling growth form. Others plants, such as most of the pondweeds have a more upright growth form and are not as easily sampled.

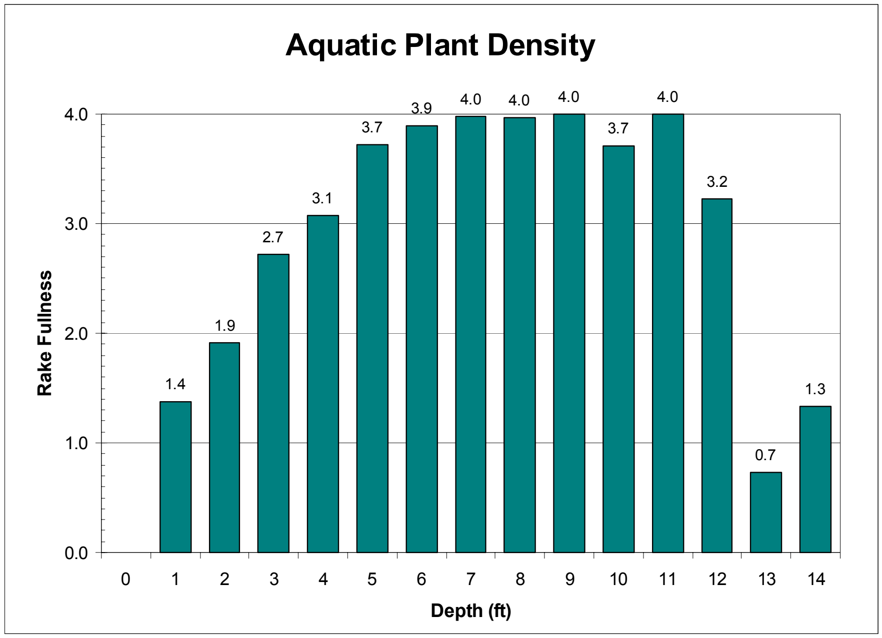


Figure 13. Aquatic plant density as measured by rake fullness.

Changes in the Aquatic Plant Community

Changes in the aquatic plant community of Lake Noquebay have been fairly well documented. Early aquatic plant surveys (1931, 1942, and 1968) provide species lists for the lake with limited information concerning abundance and distribution. Later surveys conducted in 1982, 1992 and 2000 used a modified point intercept method where each sample point was divided into four quadrants in which species presence/absence data was collected. This data was tabulated assuming each quadrant was an individual sample point.

In all four aquatic plant surveys (1982, 1992, 2000, 2007) variable leaf milfoil was found at approximately half of the sample points. Similarly, Illinois pondweed was found at roughly one quarter of the surveyed points. For most other species there are significant differences among the surveys. Many of which can be attributed to variations in sample size.

The surveys conducted in 1982 and 1992 used the same 27 sample locations with four individual survey points at each location for a total of 108 individual data points. Clearly the number and distribution of sample points in these earlier surveys was insufficient to describe the aquatic plant community in any detail. Seventeen species were found in each of the surveys with 15 identified in

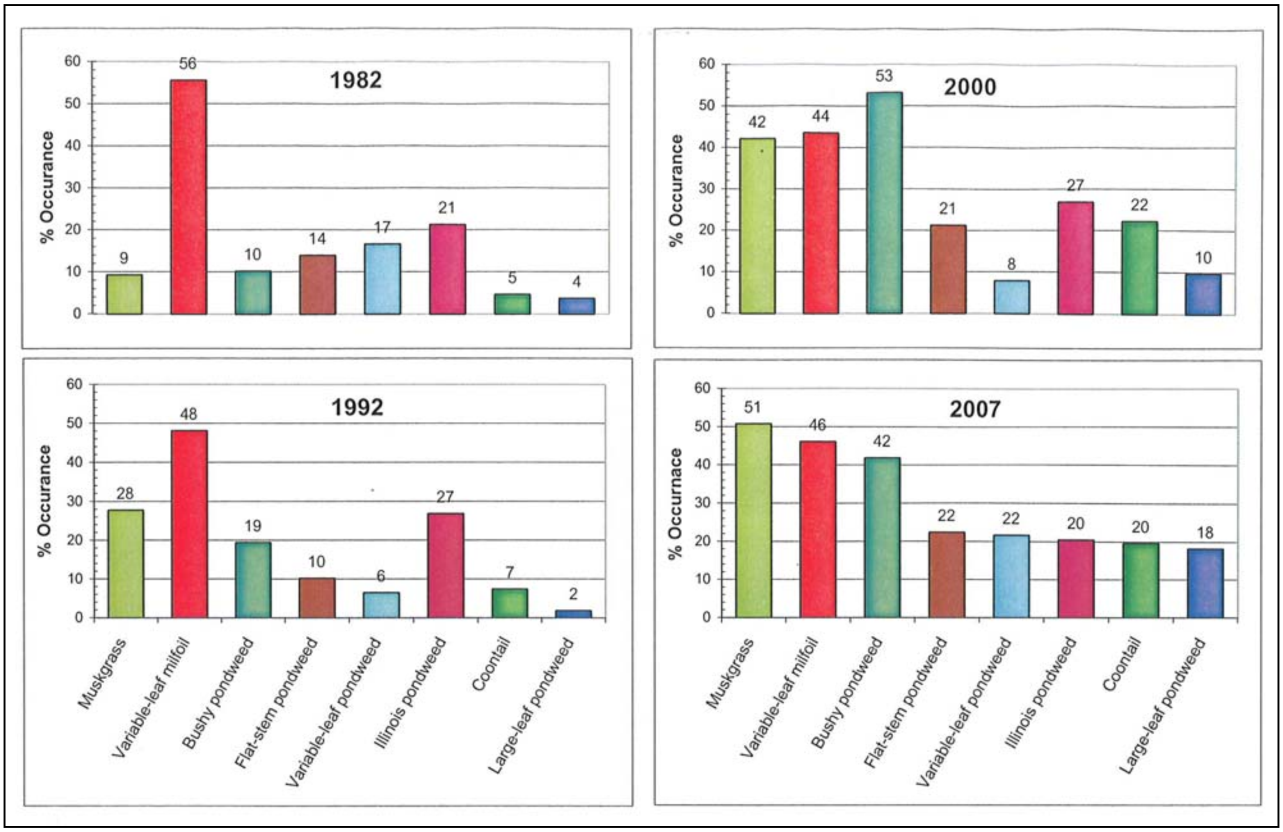


Figure 14. Changes in aquatic plant frequency over a 25-year period.

both. In both surveys variable-leaf milfoil was the most frequent species. Muskgrass, bushy pondweed, flat-stem pondweed, variable-leaf pondweed, and Illinois pondweed were the dominant species in both surveys but their frequency was much lower than in most recent surveys.

The 2000 aquatic plant survey was conducted using the same methodology but the number of sample locations was doubled resulting in 216 individual data points. As a result of the increased sample frequency the number of species identified increased to 25. A broad evaluation of the data shows significant similarities to the 2007 data in both the frequency and distribution of species (figure 14). In 2000 the most abundant plant in Lake Noquebay, measured by frequency of occurrence was bushy pondweed (53%) followed closely by variable-leaf watermilfoil (44%) and muskgrass (42%). Most of the large pondweeds also showed similar frequencies of occurrence. The most notable differences were noted for variable-leaf pondweed, large-leaf pondweed, and common bladderwort which all showed significantly higher frequency of occurrence in 2007. All of the species found in 2007 that were not identified in 2000 were found at fewer than 5% of sample points.

While changes in methodology and sample size make it difficult to directly compare data from the four aquatic plant surveys, there are some broad trends that can be seen over the last 25 years:

- The frequency and distribution of VWM in Lake Noquebay has not changed appreciably.
- The frequency and distribution of muskgrass, bushy pondweed and coontail have increased dramatically.
- The frequency and distribution of large pondweeds has increased.

- Aquatic plant diversity has increased substantially as measured by the number of plants found at 10% of more of the sample points.

Taken together these trends point to a much-improved aquatic plant community in Lake Noquebay. While VWM can still be found throughout the lake, the increase in low-growing species such as muskgrass and bushy pondweed prevent it from dominating the aquatic plant community as it once did. The increase in overall plant diversity is especially promising since it's a good measure of the lakes health.

LNRD Aquatic Plant Harvesting Program

The Lake Noquebay Rehabilitation District has been harvesting aquatic plants on Lake Noquebay for more than 30 years. Harvesting operations began in 1978 with one 10-foot harvester but quickly expanded to include three harvesters.

Since its inception the goal of the LNRD's aquatic plant management operation has been improving navigation in the lake by managing dense beds of variable-leaf milfoil. The primary focus throughout the years has been harvesting VWM in offshore areas, typically in water more than 5 feet deep. Controlling vegetation in and around swim areas and docks has been the responsibility of individual landowners.

A typical harvesting plan includes 15 weeks of harvesting using two harvesters operating 40 hours per week. The third harvester is used for shoreline cleanup three days each week to collect dislodged and cut plants that wash up on the shore. A more intensive 2-3 week shoreline cleanup is also completed each year at the beginning of the harvest season to remove plants accumulated on the shore.

A Harvesting Foreman conducts weekly reconnaissance on the lake to determine where harvesting and shoreline cleanup are needed. Areas in need of harvesting are marked with buoys to guide the harvesters. Most areas are only cut once each year. Shoreline cleanup is directed at the areas of greatest plant accumulation and is determined largely by wind direction. In addition to directing daily harvesting operations the foreman maintains personnel and plant harvesting records.

Analysis of Long-term Harvest Data

During the last 30 years the total number of acres harvested annually has ranged from a low of 120 to more than 500 acres. This variability is due to many factors including weather conditions, mechanical problems with equipment, changes in operating procedures, and more recently the introduction of invasive aquatic species.

Analysis of the available harvest data shows a relatively consistent harvesting effort of 300 to 400 acres annually between 1980 and 1996 (figure 15). However, despite a relatively consistent effort the amount of plant material harvested fell by half from 14 tons/ac to 7 tons/ac. This is consistent with the experience of the harvesting crew who report that in the early 80's in many areas of the lake it was possible to cut a full harvester load (approximately 2.8 tons) in 15 to 20 minutes. By the mid 90's it was taking 45 minutes to one hour to cut a full load.

Between 1996 and 2002 there was a small but steady decline in harvested area followed by a significant (50%) reduction in 2003 and 2004. The drastic reduction in harvest area can be attributed to an unusual rain event in late June 2002 when most of the Lake Noquebay watershed received between 5

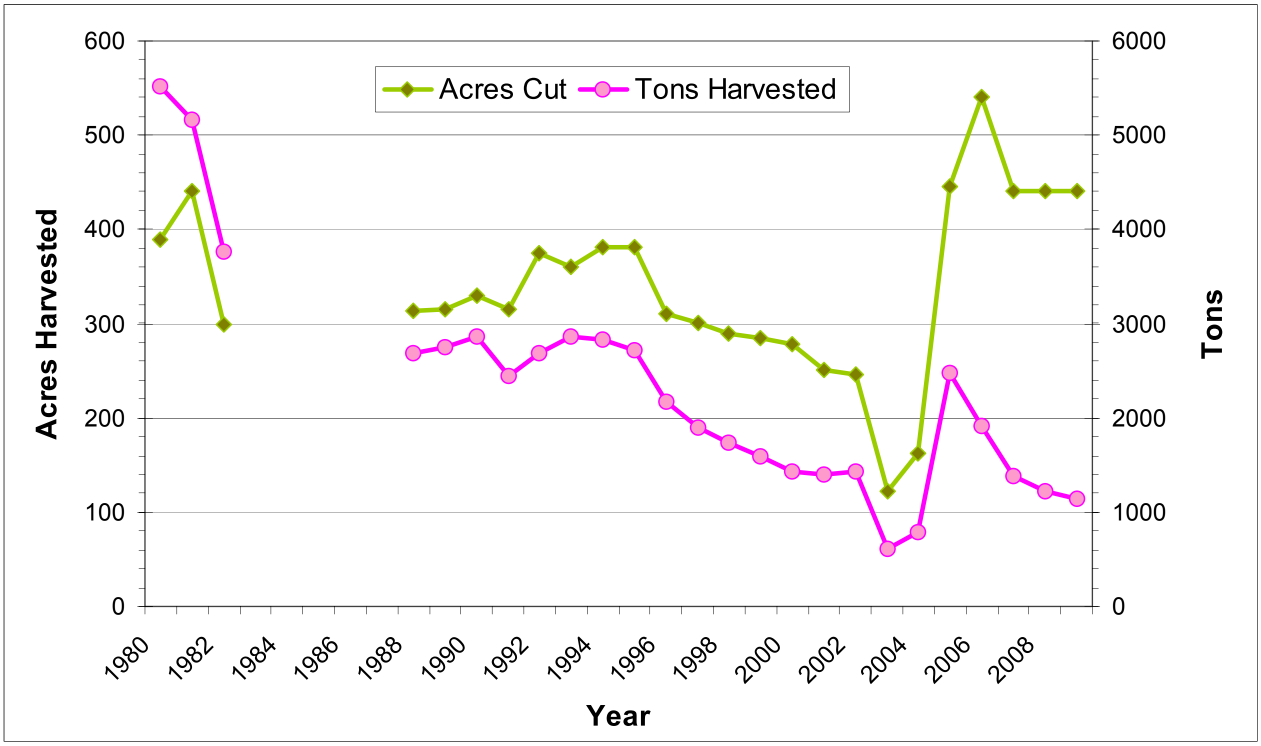


Figure 15. Annual aquatic plant harvesting data for Lake Noquebay.

and 7 inches of rain in a 24-hour period. Sediment and tannins that flushed into the lake reduced Secchi disk visibility from an average of 9.5 feet in 2001 to 3.3 feet in 2002. The reduction in light intensity caused a heavy die-off of bushy pondweed and significantly reduced aquatic plant growth throughout the lake. Although visibility increased the following year, aquatic plant production did not rebound until the summer of 2005.

In 2005 the LNRD adopted several changes in operating procedures that significantly increased the number of acres harvested. Changes included modernizing the harvester fleet, adding a second shoreline conveyor and greatly improving efficiency of the harvesting operation. Despite these changes the harvesting yield has continued to decrease, to a low of 3 tons/ac in 2008.

Zebra mussels (*Drissena polymorpha*) were discovered in Lake Noquebay in the summer of 2006. Since their discovery it has become clear they are having a suppressing effect on VWM in the lake. VWM typically remains standing through the winter and begins growing in early spring, reaching the water surface long before the slower growing pondweeds. During the last few years it appears the overwintering milfoil stems have been dragged to the bottom due to the weight of attached zebra mussels. As a result it takes longer for the VWM to reach a harvestable height.

Role of Aquatic Plant Harvesting in Plant Community Changes

While environmental factors can explain some year-to-year variability in the aquatic plant population, and zebra mussels appear to have had a significant impact since their introduction, neither explains the steady decline in harvest yield observed during the last 30 years. The only consistent stressor acting on the aquatic plant community during the period, and the likely cause of plant community changes, is aquatic plant harvesting.

Typically, aquatic plant harvesting is not viewed as a selective management tool. However, in Lake Noquebay much of the harvesting involves cutting to a depth of 5 feet in 6 to 12 feet of water, effectively topping the larger aquatic plants and opening up the canopy. While the harvesting has not reduced the distribution of VWM in Lake Noquebay, it has lead to a substantial increase in the frequency of muskgrass, bushy pondweed, and coontail.

In the final analysis it appears that sustained aquatic plant harvesting has lead to significant improvements in the plant community of Lake Noquebay as measured by increased plant diversity, a reduction in milfoil dominance, an increase in the frequency of low growing species, and a reduction in the need for harvesting.

Other APM Measures

Water level management
The Lake Noquebay Dam was constructed at its current location in 1929. In 1969 ownership of the dam was received by Marinette County and a permit was issued requiring that the lake level be maintained between 92.00 feet and 92.40 feet measured on the "Railroad Commission Datum" which was established at the time of construction.

In 1972 the DNR authorized an annual lake drawdown of 15 inches (to 90.75 feet) between October 26 and ice out each year to suppress milfoil growth in shallow areas and reduce shoreline damage from ice. In 1993 the drawdown date was moved up to October 15 each year.

Since the drawdown was implemented before any reliable aquatic plant data was available, and due to the fact that recent aquatic plant survey methods do not adequately sample very shallow areas, it's not possible to determine how effective winter drawdown has been as an aquatic plant management tool. However, submersed aquatic plant growth is typically sparse in water less than two feet deep. Also, according to landowners, the drawdown has been very effective at reducing the incidence of shoreline damage from ice heaving.

Aquatic herbicide use
Since its formation the LNRD has not used aquatic herbicide application as a management tool. According to DNR personnel the number of permitted aquatic herbicide treatments on Lake Noquebay is very low, averaging 1-2 per year. However, several instances of illegal herbicide use have been investigated. In most cases of illegal herbicide use the target of control has been emergent vegetation.