8.9 Big Muskellunge Lake

An Introduction to Big Muskellunge Lake

Big Muskellunge Lake, Vilas County, is a 900-acre deep headwater, oligotrophic drainage lake with a maximum depth of 70 feet and a mean depth of 25 feet (Big Muskellunge Lake – Map 1). Its watershed encompasses approximately 2,213 acres within the Manitowish River Watershed and is comprised mainly of intact forests and wetlands. Water leaves Big Muskellunge Lake to the north through an unnamed spring and flows into Allequash Creek, then Allequash Lake. In 2019, 45 native aquatic plant species were located within the lake, of which stoneworts (*Nitella* spp.) and slender naiad (*Najas flexilis*) were the most common.

Lake at a Glance - Big Muskellunge Lake

Morphometry	
Lake Type	Deep Headwater Drainage Lake
Surface Area (Acres)	900
Max Depth (feet)	70
Mean Depth (feet)	25
Perimeter (Miles)	10.4
Shoreline Complexity	6.1
Watershed Area (Acres)	2,213
Watershed to Lake Area Ratio	1:1

Water Quality	
Trophic State	Oligotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (μg/L)	6.7
Avg Summer Chl-α (μg/L)	2
Avg Summer Secchi Depth (ft)	21.1
Summer pH	8.0
Alkalinity (mg/L as $CaCO_3$)	24.9

Vegetation	
Number of Native Species	45
NHI-Listed Species	
Exotic Species	Purple loosestrife, Narrow-leaved cattail
Average Conservatism	6.7
Floristic Quality	44.7
Simpson's Diversity (1-D)	0.90

8.9.1 Big Muskellunge Lake Water Quality

Big Muskellunge Lake is a lake within the Long-Term Ecological Research (LTER) Network and all water quality data from this lake was collected by the UW-Trout Lake Station. Water quality data was collected from Big Muskellunge Lake on five occasions in 2019, including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only near-surface samples. In addition to sampling efforts completed in 2018-2019, any historical data were researched and are included within this report as available.

Near-surface total phosphorus data from Big Muskellunge Lake are available from 1981 and 1986-2019 (Figure 8.9.1-1). The weighted summer average total phosphorus concentration is 6.7 μg/L and falls into the *excellent* category for deep headwater drainage lakes in Wisconsin. Big Muskellunge Lake's summer average total phosphorus concentrations are much lower than the median value for deep headwater drainage lakes in the state (17.0 μg/L) and the median value for all lake types in the Northern Lakes and Forests (NLF) ecoregion (21.0 μg/L). The data record of nearly 35 years does not show any trend of increasing or decreasing.

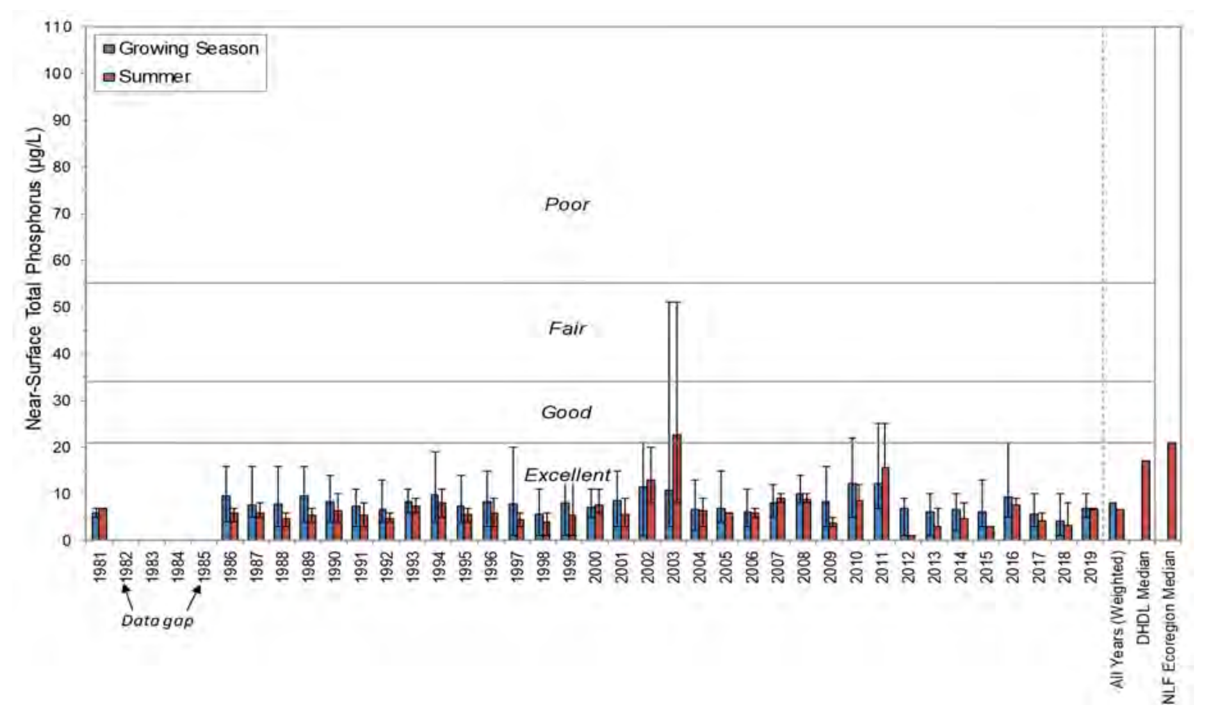


Figure 8.9.1-1. Big Muskellunge Lake, statewide deep headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading is a significant source of phosphorus in Big Muskellunge Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Concentrations near the bottom during stratification were only slightly higher than the surface values. This indicates that internal loading from the deep sediments is not occurring in this lake.

Chlorophyll-*a* data are available from Big Muskellunge Lake from 1981 through 2019 (Figure 8.9.1-2). Big Muskellunge Lake's weighted summer average chlorophyll-*a* concentration is 2.0 µg/L and falls into the *excellent* category for deep headwater drainage lakes in Wisconsin. Big Muskellunge Lake's weighted summer average chlorophyll-*a* concentration is much lower than the median value for deep headwater drainage lakes in the state (5.0 µg/L) and the median value of 5.6 µg/L for all lake types in the NLF ecoregion.

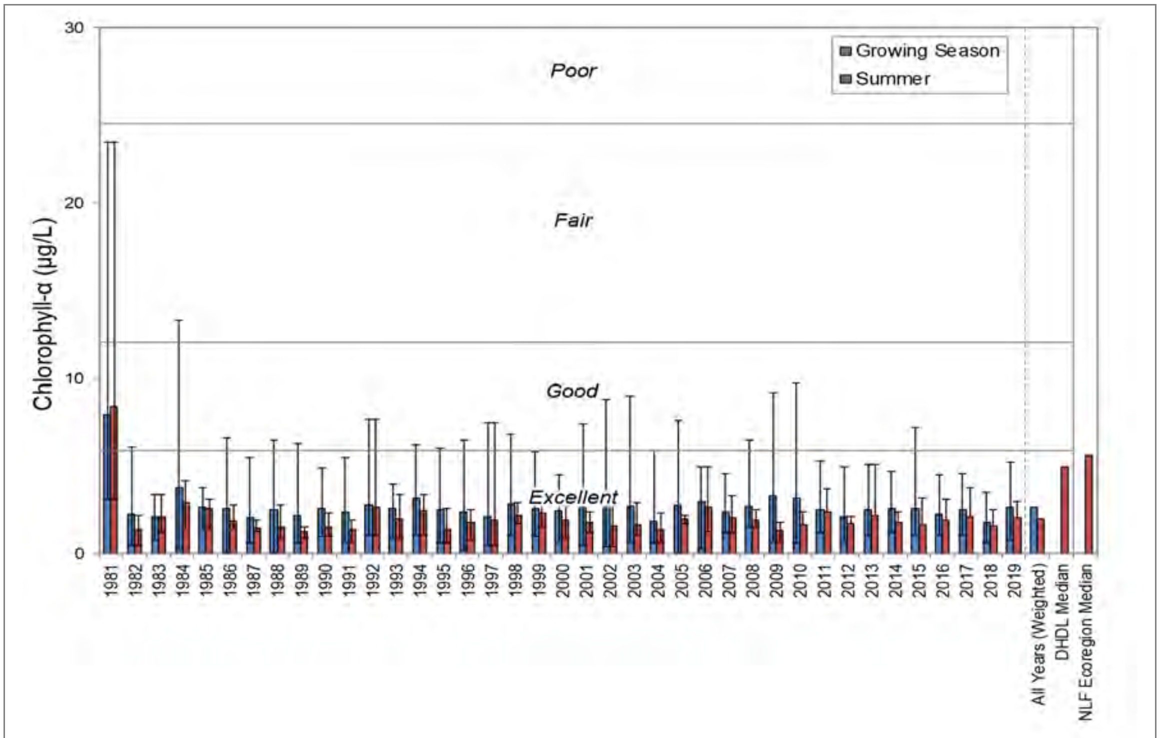


Figure 8.9.1-2. Big Muskellunge Lake, statewide deep headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available from Big Muskellunge Lake from 1973-74 and 1982-2019 (Figure 8.9.1-3). The weighted summer average Secchi disk depth is 21.1 feet and falls into the *excellent* category for deep headwater drainage lakes in Wisconsin. Big Muskellunge Lake's weighted summer average Secchi disk depth is much deeper than the median value of 10.8 feet for deep headwater drainage lakes in the state and the median value of 8.9 feet for all lake types in the NLF ecoregion.

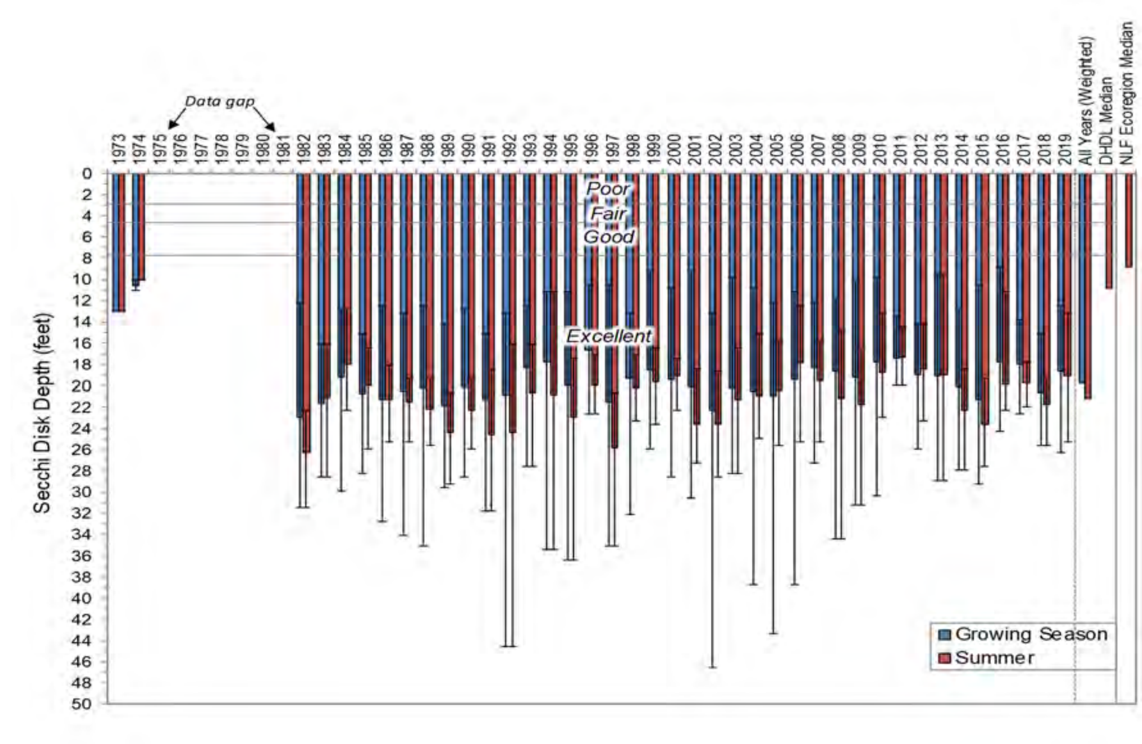


Figure 8.9.1-3. Big Muskellunge Lake, statewide deep headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Big Muskellunge Lake

Using midsummer nitrogen and phosphorus concentrations from Big Muskellunge Lake, a nitrogen:phosphorus ratio of 36:1 was calculated. This finding indicates that Big Muskellunge Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Big Muskellunge Lake Trophic State

Figure 8.9.1-4 contains the Trophic State Index (TSI) values for Big Muskellunge Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk transparency) in Big Muskellunge Lake indicate the lake is at present in an oligotrophic state. Big Muskellunge Lake's productivity is lower when compared to other deep headwater drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

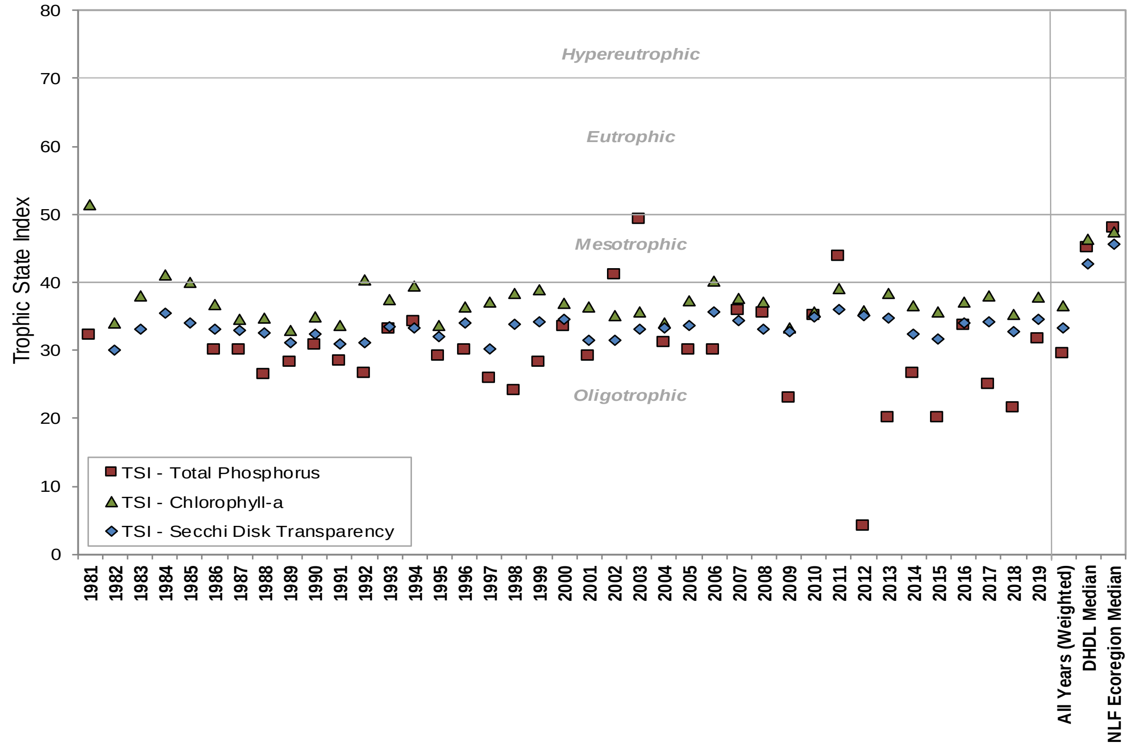


Figure 8.9.1-4. Big Muskellunge Lake, statewide deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Muskellunge Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Big Muskellunge Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.9.1-5.

Big Muskellunge is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Big Muskellunge Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organ matter within this layer depletes available oxygen.

In fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. In February of 2020, oxygen concentrations remained above 2.0 mg/L throughout the majority of the water column, indicating that fishkills as a result of winter anoxia are likely not a concern in Big Muskellunge Lake.

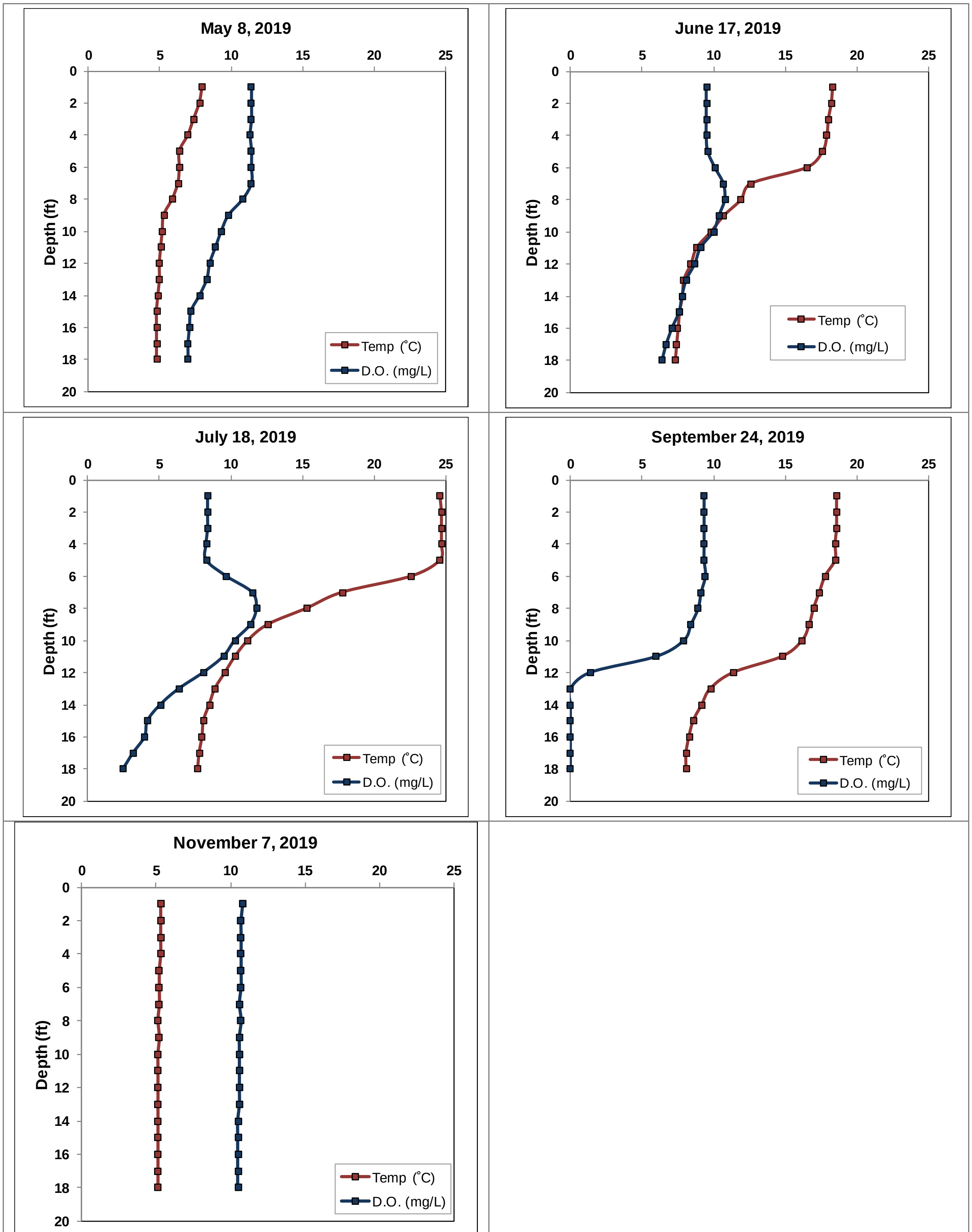


Figure 8.9.1-5. Big Muskellunge Lake 2019-2020 dissolved oxygen and temperature profiles.

8.9.2 Big Muskellunge Lake Watershed Assessment

Big Muskellunge Lake's watershed encompasses an area of approximately 2,213 acres, yielding a very small watershed to lake area ratio of 2:1 (Figure 8.9.2-1 – Big Muskellunge Map 2). According to WiLMS modeling, the lake's water residence time is 11.7 years, meaning the lake water is replaced approximately 0.09 times per year (flushing rate).

Approximately 42% of Big Muskellunge Lake's watershed is composed of forest lands, 41% of the lake itself, 11% of wetlands, 6% of pasture/grass, and <1% of rural residential areas (Figure 8.9.2-1).

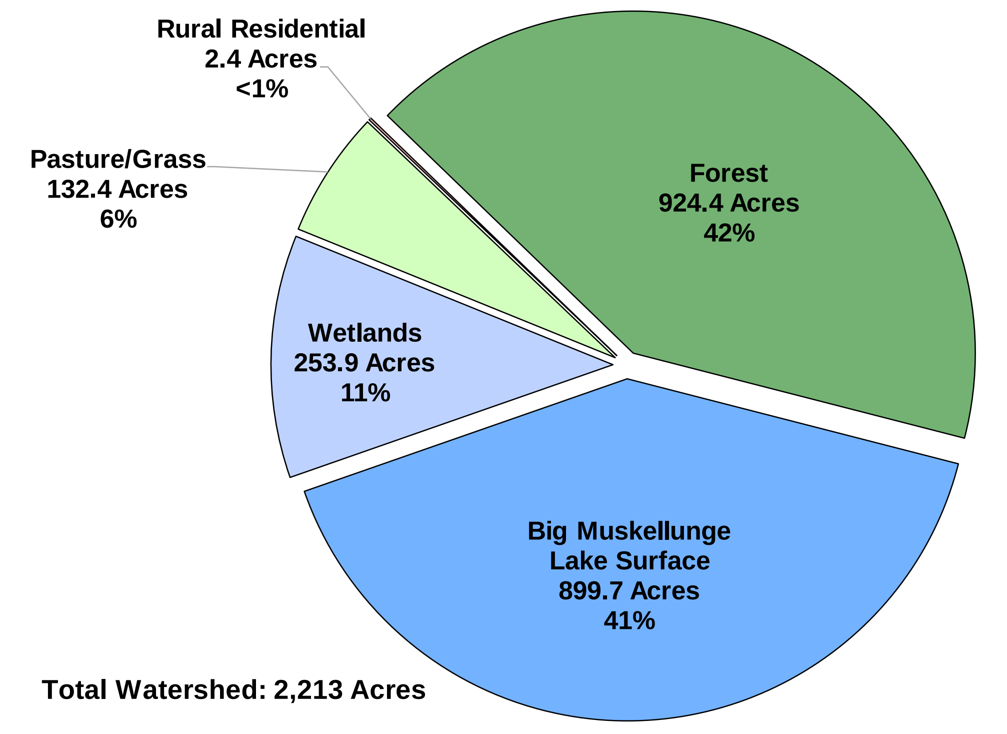


Figure 8.9.2-1. Big Muskellunge Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2016).

Using the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Big Muskellunge Lake's watershed. In addition, the number of homes around the lake was also used to estimate the potential phosphorus loading to the lake from riparian septic systems. The amount of phosphorus delivered to the lake from the atmosphere was determined using information in Robertson et al. 2009. This study measured the amount of phosphorus in wetfall and dryfall at Whitefish Lake, Douglas County, WI. It was estimated that approximately 274 pounds of phosphorus is delivered to Big Muskellunge Lake from its watershed on an annual basis (Figure 8.9.2-2).

Of the estimated 274 pounds of phosphorus being delivered annually to Big Muskellunge Lake, 140 pounds (51%) is estimated to originate from direct atmospheric deposition into the lake, 75 pounds (27%) from forest lands, 35 pounds (13%) from pasture/grass, and 22 pounds (8%) from wetlands, and 1 pounds (<1%) from septic systems (Figure 8.9.2-2).

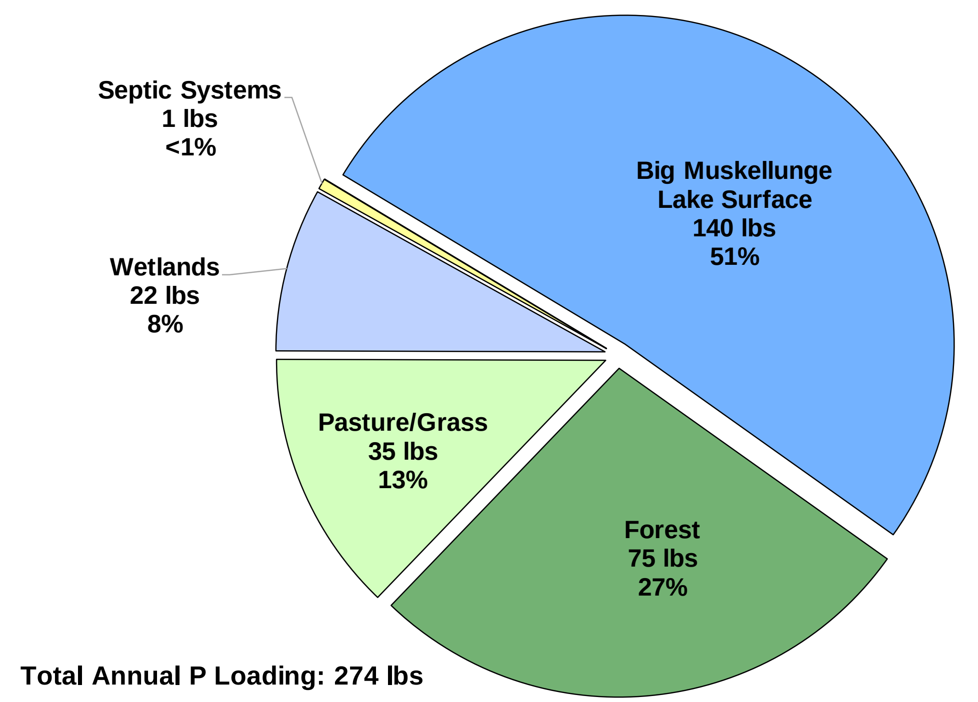


Figure 8.9.2-2. Big Muskellunge Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimated that based on the 274 pounds of phosphorus which are loaded to Big Muskellunge Lake annually, the lake should have an in-lake growing season mean (GSM) total phosphorus concentration of approximately 10.9 µg/L. This predicted GSM total phosphorus concentration is slightly higher than the measured GSM concentration of 8.1 µg/L. The discrepancy between predicted and measured total phosphorus concentrations likely means that either less phosphorus is entering the lake than estimated or that some of the phosphorus is being incorporated into the macrophytes.

8.9.3 Big Muskellunge Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Town-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In the fall of 2019, Big Muskellunge Lake's immediate shoreline was assessed in terms of its development. Big Muskellunge Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 9.6 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.9.3-1). This constitutes about 92% of Big Muskellunge Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if possible. During the survey, less than 1 mile of urbanized, developed-semi-natural, and developed–unnatural shoreline was observed. If restoration of the Big Muskellunge Lake shoreline were to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Big Muskellunge Lake - Map 3 displays the location of these shoreline lengths around the entire lake.

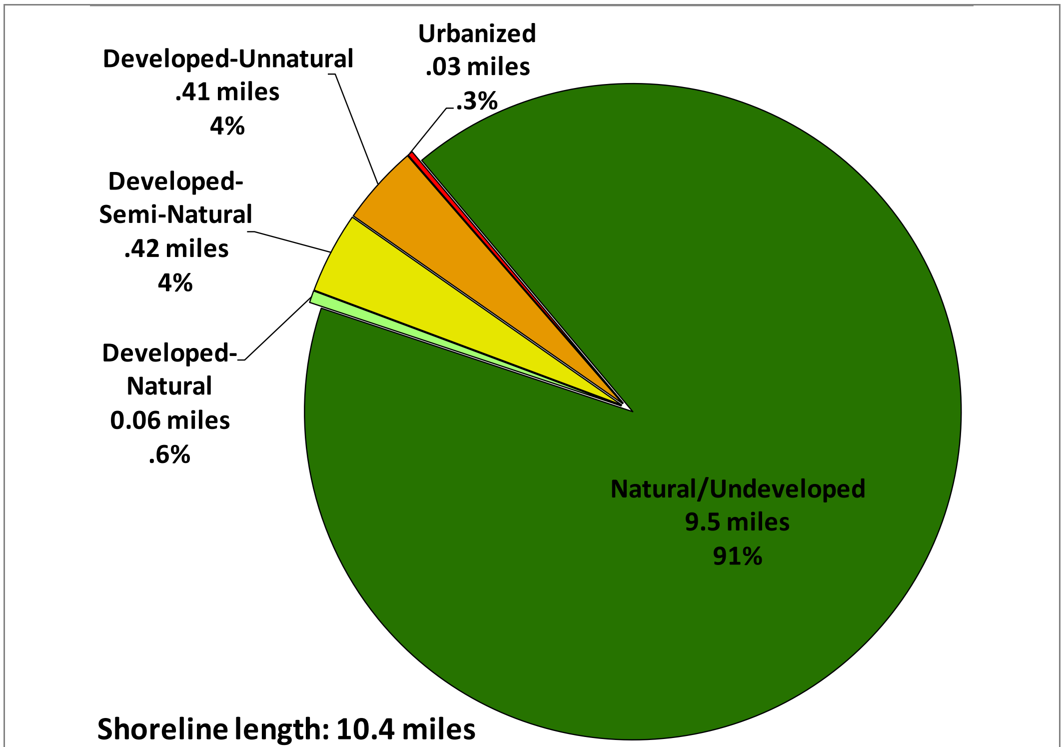


Figure 8.9.3-1. Big Muskellunge Lake shoreland categories and total lengths. Based upon a fall 2019 survey. Locations of these categorized shorelands can be found on Big Muskellunge Lake - Map 3.

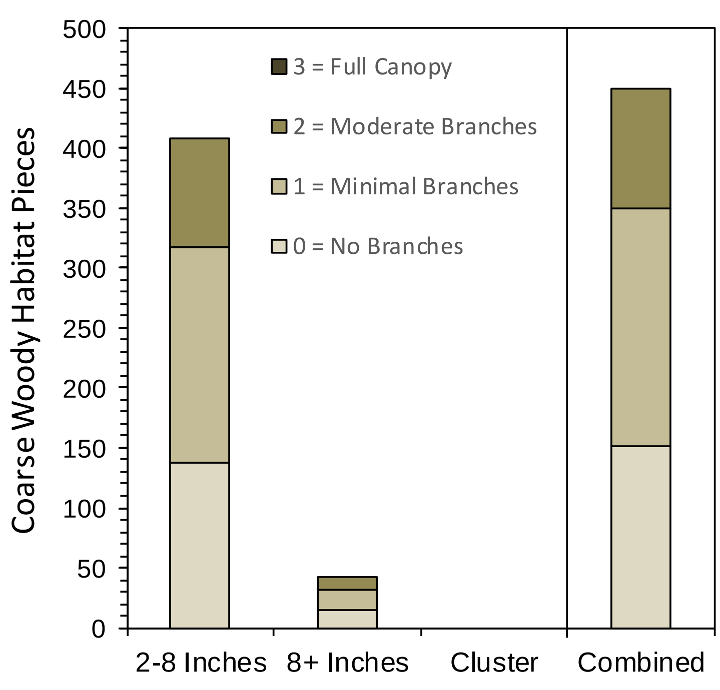
Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, >8 inches in diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 450 total pieces of coarse woody habitat were observed along 10.4 miles of shoreline (Big Muskellunge Lake - Map 4), which gives Big Muskellunge Lake a coarse woody habitat to shoreline mile ratio of 43:1 (Figure 8.9.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 450 total pieces of coarse woody habitat observed during the survey, 408 pieces were 2-8 inches in diameters, 42 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Big Muskellunge Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Big Muskellunge Lake fell just above the 80th percentile of these 111 lakes (Figure 8.9.3-2).



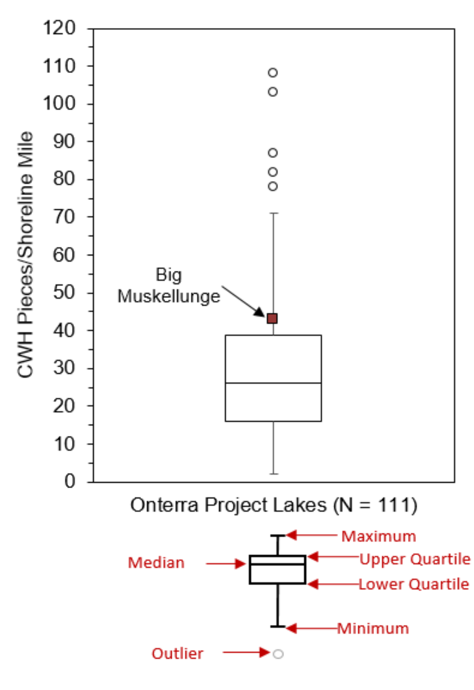


Figure 8.9.3-2. Big Muskellunge Lake coarse woody habitat survey results. Based upon a fall 2019 survey. Locations of Big Muskellunge Lake coarse woody habitat can be found on Big Muskellunge Lake - Map 4.

8.9.4 Big Muskellunge Lake Aquatic Vegetation

The first survey completed on Big Muskellunge Lake was an early-season aquatic invasive species (ESAIS) survey completed on June 26, 2019. The goal of this survey was to identify and assess any new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists did not observe any occurrences of curly-leaf pondweed or pale-yellow iris. Additionally, no Eurasian watermilfoil was located during this early summer survey.

The 2019 whole-lake point-intercept survey on Big Muskellunge Lake was completed by Onterra on July 30-31, 2019. The emergent and floating-leaf community mapping survey was completed by Onterra on July 31, 2019. During the 2019 surveys, a total of 47 aquatic plant species were located in Big Muskellunge Lake, two of which are considered to be non-native, invasive species: purple loosestrife and narrow-leaved cattail (Table 8.9.4-1). These non-native plants are discussed in the Non-Native Aquatic Plants Section. Table 8.9.4-1 also contains the list of the 15 aquatic plant species that were recorded during the 2010 point-intercept survey completed by the WDNR.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the 2019 point-intercept survey on Big Muskellunge Lake, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 44% of the point-intercept locations in 15 feet of water or less contained soft organic sediments, 39% contained sand, and 17% contained rock (Figure 8.9-4-1 and Big Muskellunge Lake – Map 5). Sampling locations with sand and/or rock were primarily located in near-shore areas of the lake, while soft organic sediments were found shallower areas within the southern third of the lake. The combination of both soft and hard substrates in Big Muskellunge Lake creates habitat types which support different aquatic plant community assemblages.

The maximum depth of aquatic plant growth in Big Muskellunge Lake in 2019 was 32 feet, comparable to the maximum depth of plants recorded in 2010 of 29 feet. The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. There has been a slight increasing trend in water clarity in Big Muskellunge Lake between 2010 and 2019, and may explain why aquatic plants were found growing slightly deeper in 2019.

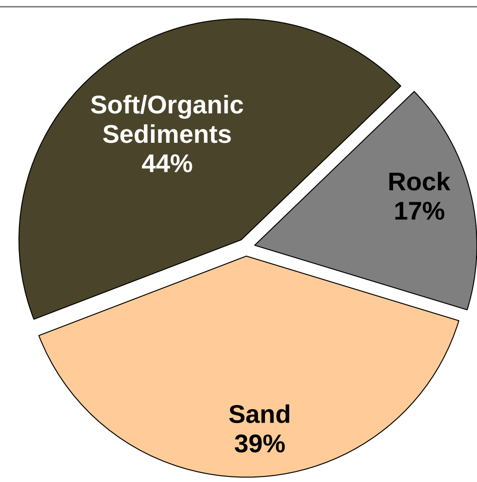


Figure 8.9.4-1. Big Muskellunge Lake 2019 proportion of substrate types in water less than 15 feet deep.

Table 8.9.4-1. Aquatic plant species located in Big Muskellunge Lake during the 2010 and 2019 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010 (WDNR)	2019 (Onterra)
Emergent	*Calamagrostis canadensis*	Bluejoint grass	Native	5		I
	Carex lasiocarpa	Narrow-leaved woolly sedge	Native	9		I
	Carex utriculata	Common yellow lake sedge	Native	7		I
	Dulichium arundinaceum	Three-way sedge	Native	9		I
	Eleocharis palustris	Creeping spikerush	Native	6	X	X
	Juncus effusus	Soft rush	Native	4		I
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A		I
	Phragmites australis subsp. *americanus*	Common reed	Native	5		I
	Sagittaria latifolia	Common arrowhead	Native	3		I
	Schoenoplectus acutus	Hardstem bulrush	Native	5		X
	Scirpus cyperinus	Wool grass	Native	4		I
	Sparganium americanum	American bur-reed	Native	8		I
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A		I
	Typha latifolia	Broad-leaved cattail	Native	1		I
FL	*Brasenia schreberi*	Watershield	Native	7		I
	Nuphar variegata	Spatterdock	Native	6		I
	Nymphaea odorata	White water lily	Native	6	X	X
	Persicaria amphibia	Water smartweed	Native	5		X
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9		I
Submergent	*Bidens beckii*	Water marigold	Native	8	X	X
	Chara spp.	Muskgrasses	Native	7	X	X
	Elatine minima	Waterwort	Native	9		X
	Elodea canadensis	Common waterweed	Native	3	X	X
	Eriocaulon aquaticum	Pipewort	Native	9		X
	Isoetes spp.	Quillwort spp.	Native	8		X
	Lobelia dortmanna	Water lobelia	Native	10	X	I
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X
	Najas flexilis	Slender naiad	Native	6	X	X
	Nitella spp.	Stoneworts	Native	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8		X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X
	Potamogeton natans	Floating-leaf pondweed	Native	5		X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8		I
	Ranunculus flammula	Creeping spearwort	Native	9		X
	Utricularia intermedia	Flat-leaf bladderwort	Native	9		I
	Utricularia vulgaris	Common bladderwort	Native	7		X
	Vallisneria americana	Wild celery	Native	6	X	X
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	X	X
	Juncus pelocarpus	Brown-fruited rush	Native	8	X	X
	Sagittaria graminea	Grass-leaved arrowhead	Native	9		X
FF	*Lemna turionifera*	Turion duckweed	Native	2		X
	Riccia fluitans	Slender riccia	Native	7		X
	Ricciocarpos natans	Purple-fringed riccia	Native	N/A		I
	Spirodela polyrhiza	Greater duckweed	Native	5		I

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; SE = Submergent or Emergent; FF = Free-floating

In 2010, 14% of the point-intercept survey sampling locations that fell within the littoral zone contained aquatic vegetation (Figure 8.9.4-2). In 2019, this percentage increased to 27%, indicating that the littoral frequency of occurrence of aquatic plants in Big Muskellunge Lake had increased by 93%. The total rake fullness (TRF) ratings remained relatively low in 2019, indicating that while the overall occurrence of plants increased, plant biomass in Big Muskellunge Lake is relatively low.

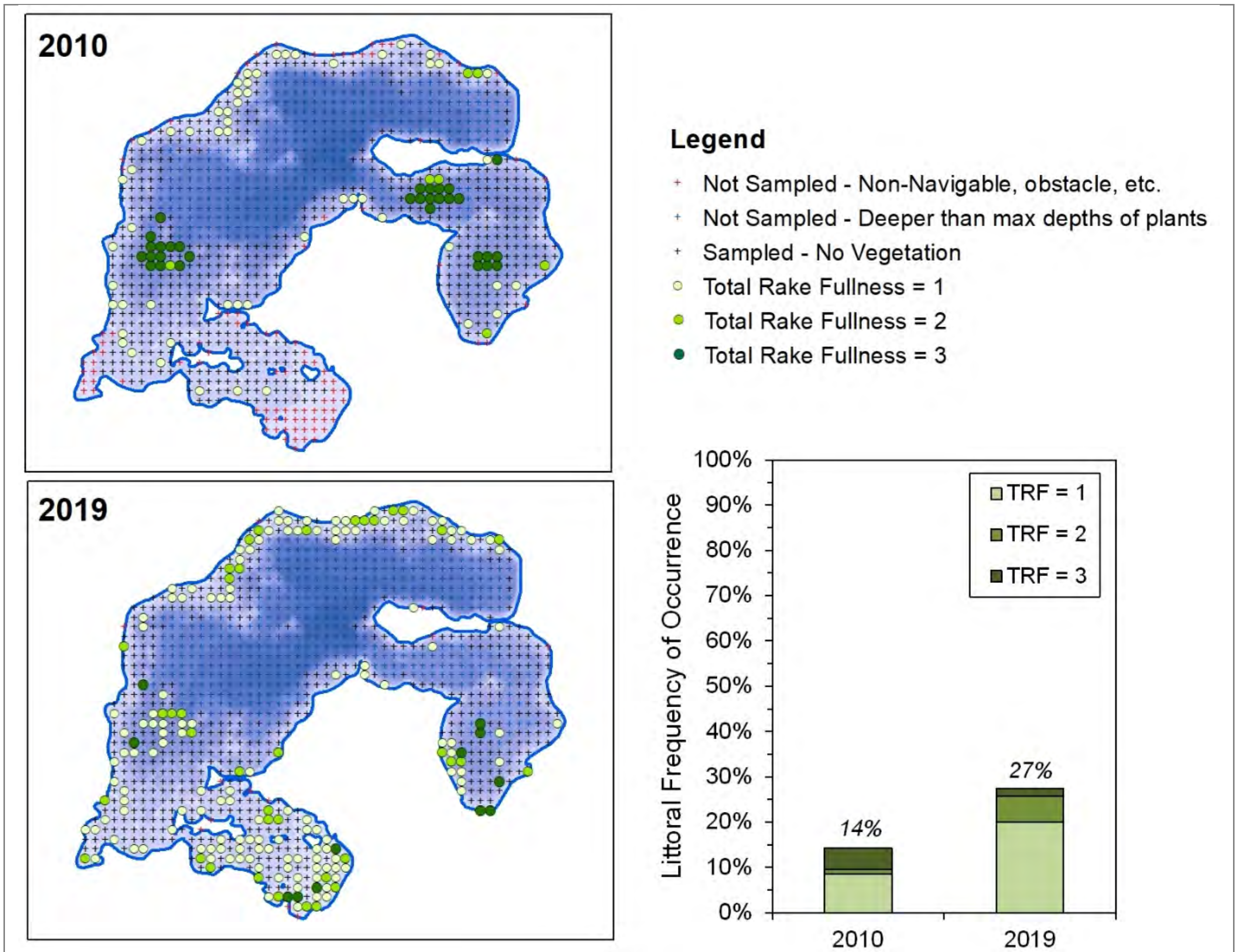


Figure 8.9.4-2. Big Muskellunge Lake littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings from 2010 and 2019.

The point-intercept survey data indicate that water levels were approximately 3.6 feet lower in 2010 compared to 2019. The higher water levels in 2019 allowed for Onterra crews to access the shallower bay on the lake's southeast side which was inaccessible in 2010. In areas sampled in 2010 and 2019 within the southeast bay saw an increase in vegetation in 2019. Similarly, the occurrence of vegetation increased in areas on the northern shore, many areas of which were likely exposed in 2010.

The data collected in the 2010 and 2019 point-intercept surveys can also be used to compare how the occurrence of individual species have changed between these two years. Eleven species exhibited statistically valid increases in their littoral occurrence between these two surveys, while the occurrences of the remaining species were not statistically different (Figure 8.9.4-3). No species were found to have exhibited statistically valid declines in their occurrence between 2010 and 2019.

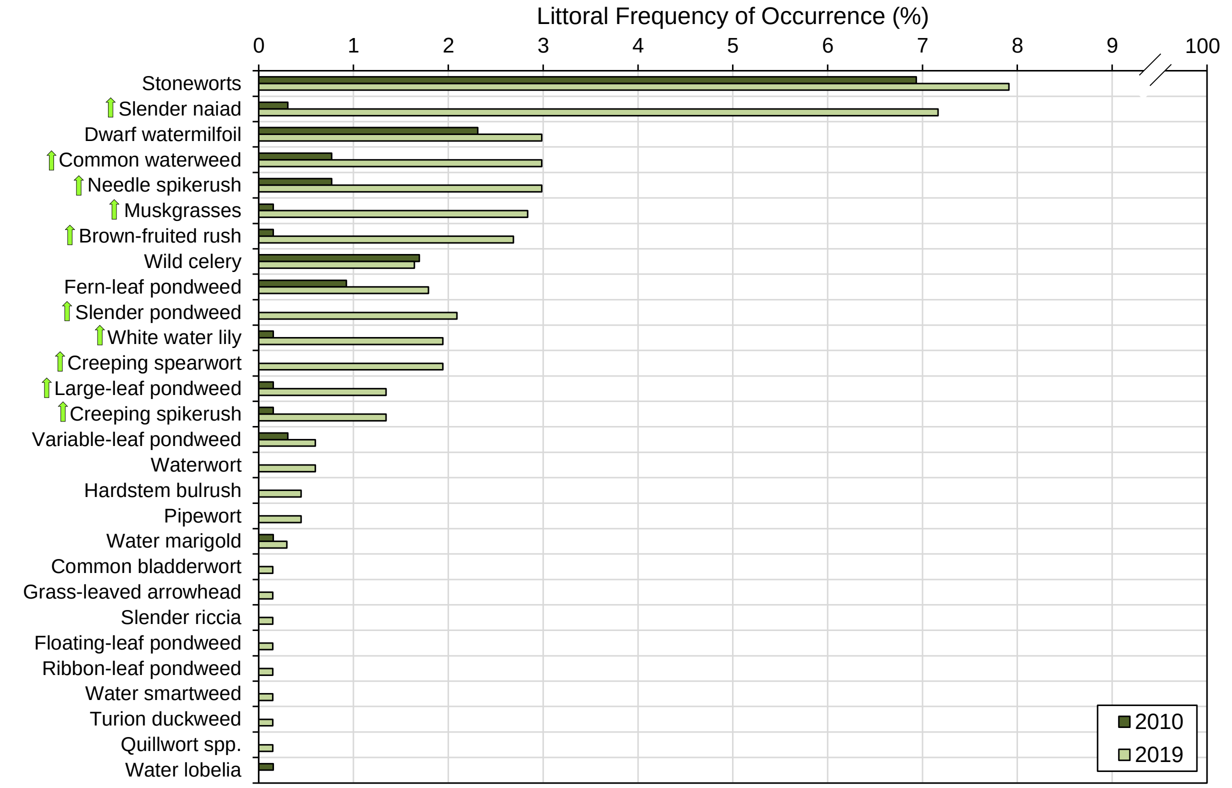


Figure 8.9.4-3. Littoral frequency of occurrence of aquatic plant species in the 2010 and 2019 surveys of Big Muskellunge Lake. Green arrow indicates statistically valid increase in occurrence. No arrow indicates occurrence is not statistically different. Chi-square analysis (α = 0.05) used to determine statistical validity. Created using data from WDNR 2010 (N = 649) and Onterra 2019 (N = 670) whole-lake point-intercept surveys.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Seasonal and longer-term water level fluctuations are natural in Wisconsin's lakes and play an essential ecological role (e.g., maintaining emergent plant communities). Water level fluctuations are most pronounced in seepage lakes like Big Muskellunge Lake where water levels are largely determined by precipitation and groundwater.

Lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. One may assume that because a lake has a high number of aquatic plant species that it also has high species diversity. However, species diversity is influenced by both the number of species and how evenly they are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Big Muskellunge Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion. The Simpson's Diversity Index values were calculated for Big Muskellunge Lake using the 2010 and 2019 point-intercept survey data. Big Muskellunge Lake's species diversity has increased from a value of 0.74 in 2010 to 0.91 in 2019 (Figure 8.9.4-4).

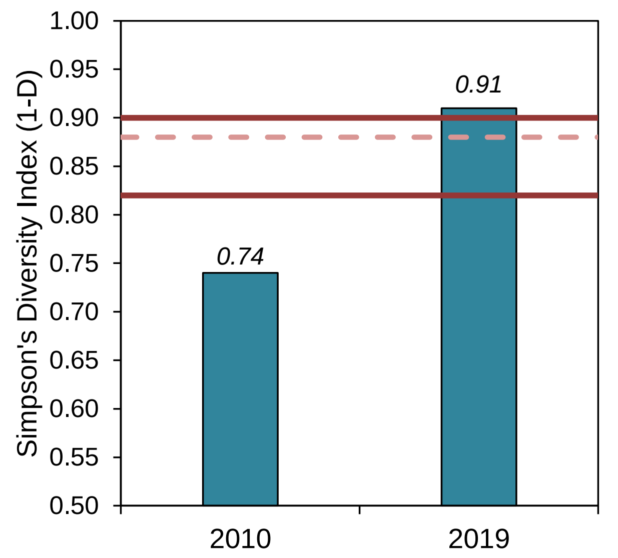


Figure 8.9.4-4. Big Muskellunge Lake Simpson's Diversity Index. Red solid lines represent NLFL upper and lower quartiles; light red dashed line represents NLFL median. Regional and state values calculated with Onterra & WDNR data.

In other words, if plants were randomly sampled from two locations in Big Muskellunge Lake in 2010, there would have been an 74% probability that the plants would be two different species. In 2019, this probability increased to 91%. One way to visualize the diversity of Big Muskellunge Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species. Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while stoneworts were found at 8% of the littoral sampling locations in 2019 (littoral occurrence), their relative frequency of occurrence was 18% (Figure 8.9.4-5).

Explained another way, if 100 plants were randomly sampled from Big Muskellunge Lake in 2019, 18 of them would have been stoneworts, 16 slender naiad, etc. In 2010, 70% of Alma Lake's plant community was comprised of just five species. This dominance of the plant community by a few number of species resulted in lower species diversity. In 2019, nine species comprised 70% of the plant community, indicating a more even distribution in abundance of species and higher species diversity.

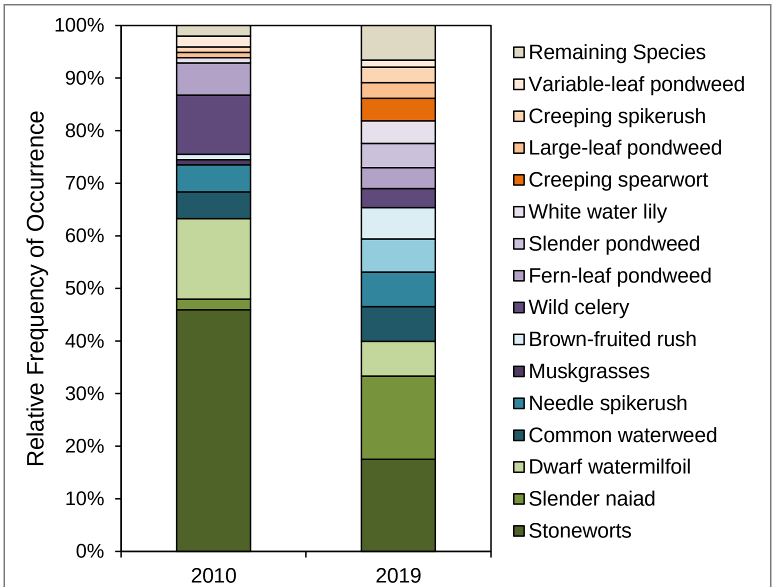


Figure 8.9.4-5. Relative frequency of occurrence of aquatic vegetation in Big Muskellunge Lake. Created using data from 2010 and 2019 point-intercept surveys.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Figure 8.9.4-6). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987) (Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Figure 8.9.4-6). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf watermilfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern watermilfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Figure 8.9.4-6. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and large-leaf pondweed (*Potamogeton amplifolius*) of the elodeid growth form (right). Photo credit: Onterra.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes like Big Muskellunge Lake that have lower alkalinity where they can avoid competition from elodeids.

In lakes which have more moderate alkalinity levels, isoetids are generally restricted to shallower, wave-swept areas where elodeids are unable to grow, or scattered amongst less dense elodeid communities where light can penetrate to the bottom. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders, Lucassen and Roelofs 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

Using the aquatic plant species recorded on the rake during the point-intercept surveys completed on Big Muskellunge Lake, the Floristic Quality Index (FQI) was also calculated for each survey (Figure 8.9.4-7). Native plant species richness, or the number of native species recorded on the rake increased from 15 in 2010 to 27 in 2019. Average species conservatism was similar at 6.9 in 2010 and 6.8 in 2019, while the FQI increased from 26.9 in 2010 to 35.4 in 2019. Big Muskellunge Lake's 2019 species richness is near the 75th percentile for lakes in the ecoregion and above the 75th percentile for lakes throughout Wisconsin. Big Muskellunge Lake's average conservatism values are higher than the median values for both the ecoregion and the state, indicating the lake supports a higher number of environmentally-sensitive species. And the lake's FQI values also exceed both the median values for ecoregion lakes and the state Overall, this analysis shows that Big Muskellunge Lake's aquatic plant community is of higher quality when compared to the majority of lakes in the ecoregion and the state.

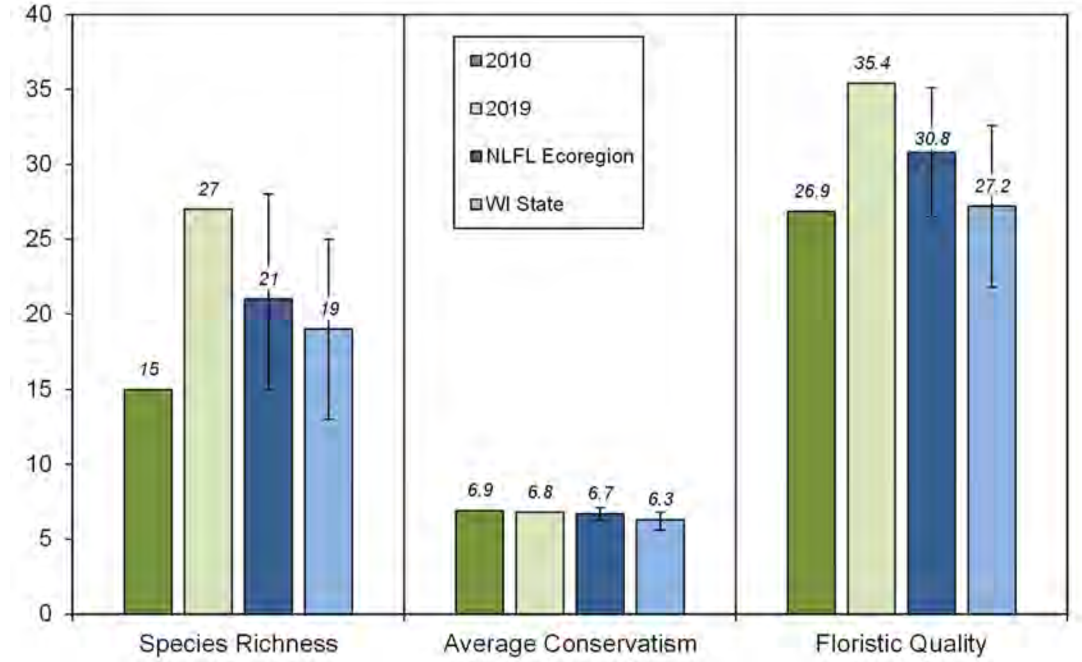


Figure 8.9.4-7. Floristic Quality Assessment (FQA) of Big Muskellunge Lake. Includes survey data from 2009 and 2019 point-intercept surveys by Onterra. Analysis follows Nichols (1999).

In 2019, Onterra ecologists also mapped emergent and floating-leaf aquatic plant communities in Big Muskellunge Lake (Big Muskellunge Lake – Map 7). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plant communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosions control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

In 2019, 70.5 acres of these communities were mapped in Big Muskellunge Lake (Figure 8.9.4-8 and Big Muskellunge Lake - Map 7). The southern third of the lake supported larger emergent, floating-leaf, and mixed emergent and floating-leaf plant communities, while the northern two-thirds of the lake mainly supported emergent communities in near-shore areas. In total, 19 plant species were documented in these communities (Table 8.9.4-1).

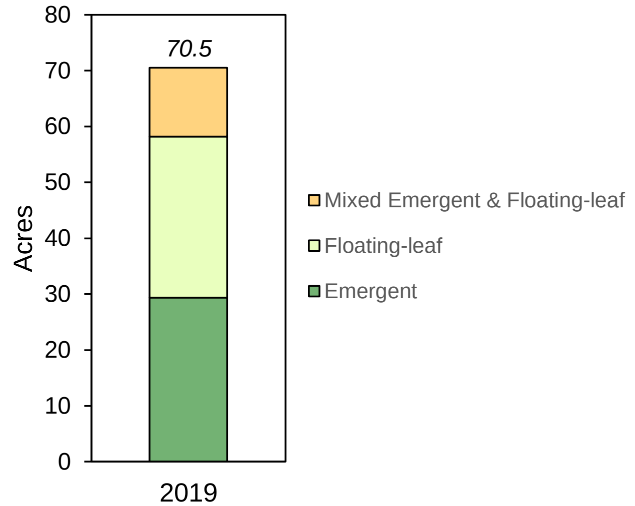


Figure 8.9.4-8. 2019 acreage of emergent and floating-leaf plant communities in Big Muskellunge Lake. Locations of these communities can be found on Big Muskellunge Lake – Map 7.

These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

8.9.5 Aquatic Invasive Species in Big Muskellunge Lake

The WDNR lists one invasive species as *observed* within Big Muskellunge Lake (Table 8.9.5-1). The *observed* status means that the species has either not been verified by a taxonomic expert, or the species does not have an established population. Due to the small number of dwellings around Big Muskellunge Lake, no stakeholder survey was distributed for Phase III of this project, so no stakeholder perceptions of AIS will be included in this section as they were in previous phases.

Table 8.9.5-1. AIS present within Big Muskellunge Lake

Type	Common name	Scientific name	Location within the report
Plants	Giant reed	*Phragmites australis* subsp. *australis*	Section 8.9.5 - Below
	Purple loosestrife	*Lythrum salicaria*	Section 8.9.5 - Below
	Narrow-leaved cattail	*Typha angustifolia*	Section 8.9.5 - Below
Invertebrates	Rusty crayfish	*Orconectes rusticus*	Section 8.9.5 - Below

More information on these invasive species or any other AIS can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

Giant Reed (aka Phragmites)

Giant reed (*Phragmites australis* subsp. *australis*) is a tall, perennial grass that was introduced to the United States from Europe. Giant reed forms towering, dense colonies that overtake native vegetation and replace it with a monoculture that provides inadequate sources of food and habitat for wildlife. A native strain (*P. australis* subsp. *americanus*) of this species also exists in Wisconsin. Giant reed was discovered in one area of Big Muskellunge Lake in 2021.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe that was likely brought over to North America as a garden ornamental (Photo 8.9.5-1). This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. During the 2019 community-mapping survey, Onterra mapped purple loosestrife in many shallow, near-shore areas around Big Muskellunge Lake.

Photograph 8.9.5-1 Purple loosestrife in Big Muskellunge Lake. Photo credit Onterra.

Narrow-leaved cattail

Narrow-leaved cattail (*Typha angustifolia*) is a perennial wetland plant that is found throughout Wisconsin, and is listed by the WDNR as restricted. It can grow very aggressively and outcompete and displace native plants, decreasing biodiversity. The easiest way to tell this species apart from the native variety (broad-leaved cattail) is the space between the male and female portions of the flowers which is not usually visible on the native cattail. The best method of control for invasive narrow-leaved cattail is manual removal. It was only found in one small patch in Big Muskellunge Lake among other native emergents.

Aquatic Animals

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell. They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

8.9.6 Big Muskellunge Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Big Muskellunge Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Eric Weigleitner (WDNR 2020 & GLIFWC 2018).

Big Muskellunge Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Big Muskellunge Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.9.6-1.

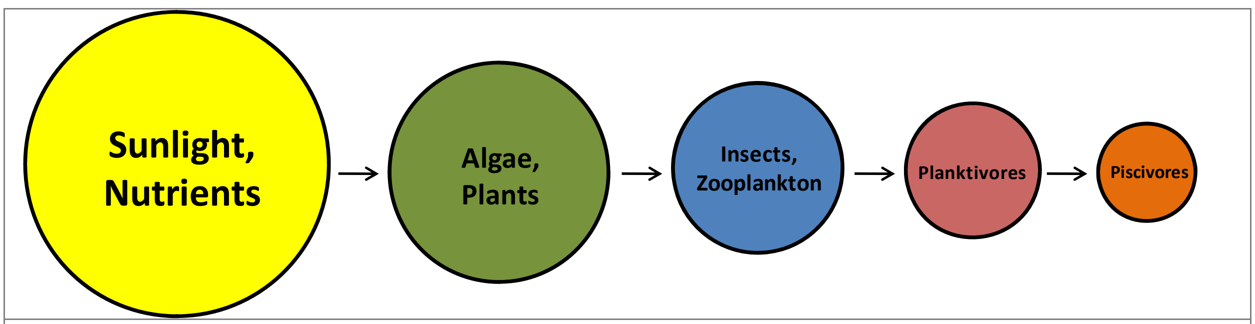


Figure 8.9.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Big Muskellunge Lake is oligotrophic, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small. Table 8.9.6-1 shows the popular game fish present in the system. Big Muskellunge Lake is classified as two-story fishery, as cisco are present within the lake. Cisco are a vital forage species for various gamefish species.

Table 8.9.6-1. Gamefish present in Big Muskellunge Lake with corresponding biological informa (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 8.9.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 8.9.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 8.9.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

Photograph 8.9.6-2. Fingerling Muskellunge.

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 8.9.6-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Big Muskellunge Lake has been stocked from 1972-2019 with muskellunge (Table 8.9.6-2). According to Vilas County fish biologist Eric Weigleitner, Big Muskellunge Lake is on an odd year cycle for muskellunge stocking. Most recently, 255 large fingerlings were stocked at a density of approximately 0.25 fish/acre. Because of this, Big Muskellunge Lake is listed under Category 2 for muskellunge reproduction. This means while some reproduction occurs, it is supplemented with stocking as well.

There was one stocking event of walleye in 1981 where 62,750 fingerlings were stocked. Big Muskellunge Lake is now listed a naturally reproducing walleye lake and no stocking is currently taking place.

Table 8.9.6-2. Stocking data available for Big Muskellunge Lake (1972-2019).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Muskellunge	Unspecified	Fingerling	635	13
1972	Muskellunge	Unspecified	Fry	136,612	1
1973	Muskellunge	Unspecified	Fingerling	1,000	9
1974	Muskellunge	Unspecified	Fingerling	1,200	9
1975	Muskellunge	Unspecified	Fingerling	1,006	10.33
1976	Muskellunge	Unspecified	Fingerling	500	11
1977	Muskellunge	Unspecified	Fingerling	1,500	9
1979	Muskellunge	Unspecified	Fingerling	1,000	11
1980	Muskellunge	Unspecified	Fingerling	1,000	8
1981	Muskellunge	Unspecified	Fingerling	281	12
1982	Muskellunge	Unspecified	Fingerling	1,800	11
1983	Muskellunge	Unspecified	Fry	27,000	1
1986	Muskellunge	Unspecified	Fingerling	1,800	11.67
1986	Muskellunge	Unspecified	Fry	67,500	1
1987	Muskellunge	Unspecified	Fry	48,600	2
1988	Muskellunge	Unspecified	Fingerling	1,800	10.5
1990	Muskellunge	Unspecified	Fingerling	1,800	11
1991	Muskellunge	Unspecified	Fingerling	900	12
1992	Muskellunge	Unspecified	Fingerling	900	10
1993	Muskellunge	Unspecified	Fingerling	1,800	11
1997	Muskellunge	Unspecified	Large Fingerling	900	10.7
1999	Muskellunge	Unspecified	Large Fingerling	900	11.6
2001	Muskellunge	Unspecified	Large Fingerling	465	10.2
2003	Muskellunge	Unspecified	Large Fingerling	465	9.9
2005	Muskellunge	Unspecified	Large Fingerling	465	10.9
2007	Muskellunge	Upper Wisconsin River	Large Fingerling	310	12.1
2009	Muskellunge	Upper Wisconsin River	Large Fingerling	455	10.5
2011	Muskellunge	Upper Wisconsin River	Large Fingerling	465	9.3
2013	Muskellunge	Upper Wisconsin River	Large Fingerling	233	9.2
2015	Muskellunge	Upper Wisconsin River	Large Fingerling	232	11.7
2017	Muskellunge	Upper Wisconsin River	Large Fingerling	146	10.8
2019	Muskellunge	Upper Wisconsin River	Large Fingerling	255	NA

Fishing Activity

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. A creel survey was completed on Big Muskellunge Lake during both the 1996-1997 and 2016-2017 fishing seasons (Table 8.9.6-3). Angling pressure for species such as walleye and smallmouth bass increased between 1997 and 2017. Walleye, yellow perch, and northern pike all saw substantial increases in the number of fish harvested in 2017 compared to 1997.

Table 8.9.6-3. Creel Survey Data from 1996-1997 and 2016-2017 Fishing Seasons

Species	Year	Directed Effort (Hours)	Percent of Total	Total Catch	Specific catch rate (Hours/Fish)*	Total Harvest	Specific harvest Rate (Hours/Fish)*	Mean length of harvested fish
Walleye	1996-97	9,733	40.8	2,490	4	912	10.9	14.8
	2016-17	10,197	52.8	4,563	2.2	2,283	4.5	14.2
Muskellunge	1996-97	2,764	11.6	71	49.8	0	0	-
	2016-17	1,047	5.4	18	58.8	0	-	-
Northern Pike	1996-97	1,540	6.5	382	6.6	53	40	22.1
	2016-17	1,890	9.8	874	8.9	256	15.6	23.3
Smallmouth Bass	1996-97	1,673	7	235	13	22	76.3	12.3
	2016-17	2,002	10.4	1,510	1.4	12	217.4	20.6
Largemouth Bass	1996-97	1,704	7.1	77	31.9	11	263	15.6
	2016-17	235	1.2	28	15.2	0	-	-
Yellow Perch	1996-97	3,988	16.7	6,384	0.7	2,905	1.4	8.1
	2016-17	3,535	18.3	13,150	0.3	2,779	1.4	8.7

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Walleye population estimates have been conducted in three instances on Big Muskellunge Lake, occurring in 1991, 1996, and 2016 (Table 8.9.6-4). When comparing the three years, the population estimates show a slight decrease in the number of walleye present.

Table 8.9.6-4. Adult Muskellunge Population Estimate from 1991, 1996, and 2016 for Big Muskellunge Lake.

Year	Primary Recruitment Source	Population Estimate	Lower 95 C.I.	Number / Acre	# Adults <12 Inches / Acre	# Adults 12-15 Inches / Acre	# Adults 15-20 Inches / Acre	# Adults >20 Inches / Acre
1991	Natural	8,014	6,740	9	3.2	4.5	0.9	0.1
1996	Natural	4,631	4,103	5	0.5	3.7	0.8	0
2016	Natural	3,634	3,056	3.9	0.4	2.3	1.1	0.1

Big Muskellunge Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.9.6.6-2). Big Muskellunge Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

Figure 8.9.6-2. Location of Big Muskellunge Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and

24 inches and one of any size over 20 inches (GLIFWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.6-6 from 2000-2019. As many as 906 walleye have been harvested from Big Muskellunge Lake in the past (2012), but the average harvest is roughly 329 fish in a given year. Spear harvesters, on average, harvest about 100% of the determined quota.

Muskellunge open water spear harvest records are provided in Figure 8.9.6-3 from 2000-2019. As many as 8 muskellunge have been harvested in a year (2019), but the average harvest is roughly 3 fish in a given year. Spear harvesters, on average, harvest about 37% of the determined quota.

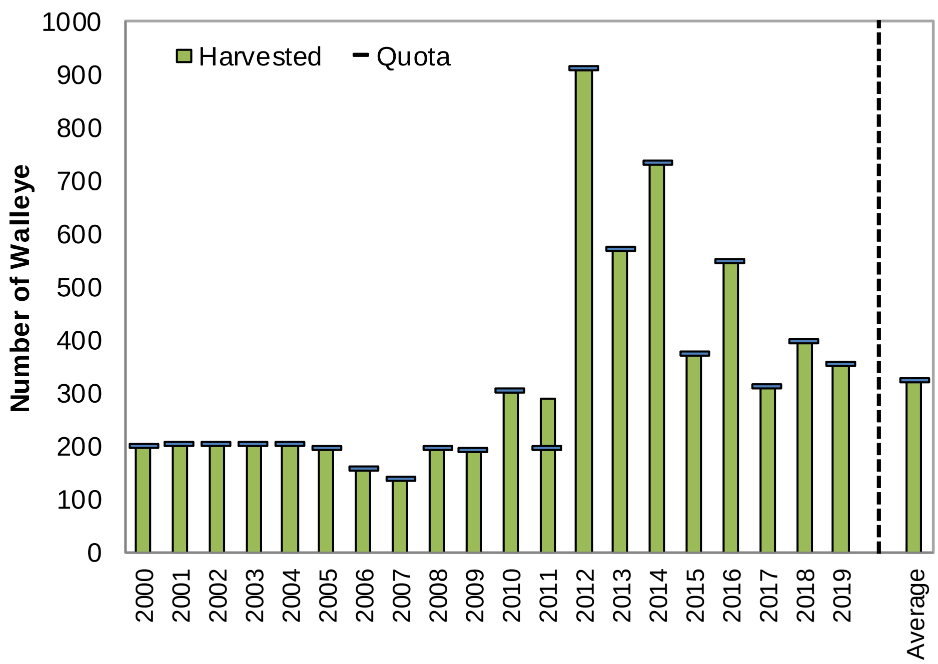


Figure 8.9.6-3. Big Muskellunge Lake walleye spear harvest data. (GLIFWC 2000-2019).

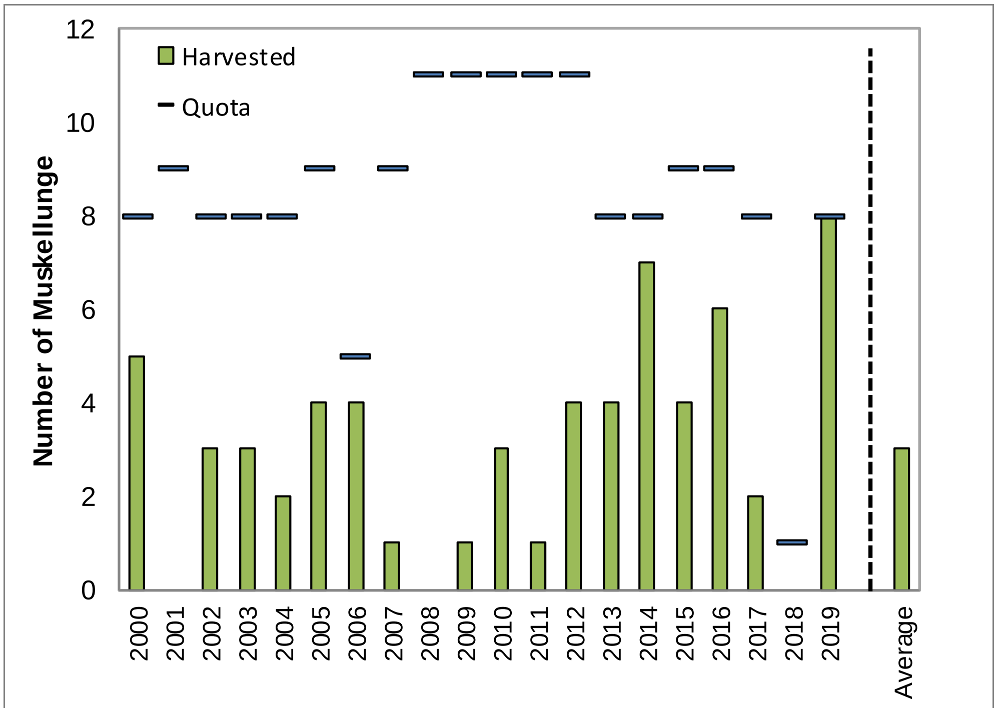


Figure 8.9.6-4. Big Muskellunge Lake muskellunge spear harvest data. (GLIFWC 2000-2019).

Big Muskellunge Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Lakes with primarily a silty/soft substrate, many aquatic plants, and coarse woody debris may produce a completely different fishery than lakes that are largely sandy/rocky, and contain few aquatic plant species or coarse woody habitat.

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2019, 44% of the substrate sampled in the littoral zone of Big Muskellunge Lake were soft sediments, 39% composed of sand sediments, and 17% composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009). A fall 2019 survey documented 450 pieces of coarse woody along the shores of Big Muskellunge Lake, resulting in a ratio of approximately 43 pieces per mile of shoreline.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 8.9.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


Photograph 8.9.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a fish habitat structure that is placed on the lakebed. Installing fish cribs may be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 8.9.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structure in a lake does not require a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested. The TPL may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Big Muskellunge Lake.

Regulations

Regulations for Big Muskellunge Lake gamefish species as of March 2020 are displayed in Table 8.9.6-5. Big Muskellunge Lake has a couple of unique regulations that are not commonly found throughout the rest of the state. There is no minimum length for walleyes, but only one fish over 14 inches may be kept. Largemouth bass and smallmouth bass must be at least 18 inches to be kept, and the daily bag limit is one. This is to protect younger fish and to produce more trophy-sized bass. New to 2020, the open season on muskellunge now extends through December 31, however all muskellunge fishing must be done through open water. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 8.9.6-5. WDNR fishing regulations for Big Muskellunge Lake (As of March 2020).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	1	18"	June 20, 2020 to March 7, 2021
Smallmouth bass	1	18"	June 20, 2020 to March 7, 2021
Largemouth bass	1	18"	May 2, 2020 to March 7, 2021
Muskellunge and hybrids	1	40"	May 23, 2020 to December 31, 2020
Northern pike	5	None	May 2, 2020 to March 7, 2021
Walleye, sauger, and hybrids	3	No minumum length, but only one fish over 14" may be kept	May 2, 2020 to March 7, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks,

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

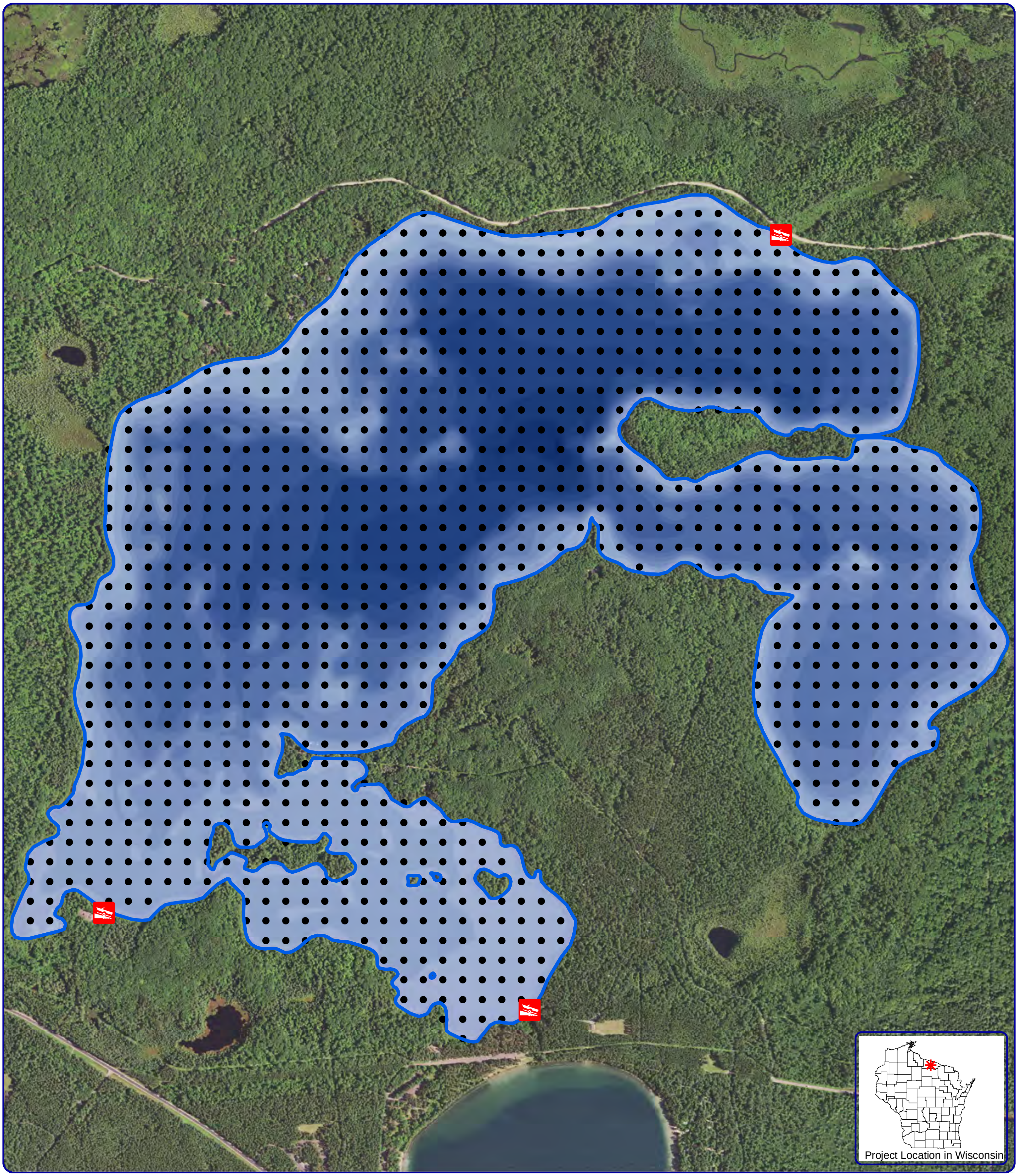
General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.9.6-5. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways

	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 8.9.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)



N
W E
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1,250

Feet

Legend

Big Muskellunge ~ 897 acres
WDNR definition

Point-intercept Sample Location
57-meter spacing, 1109 points

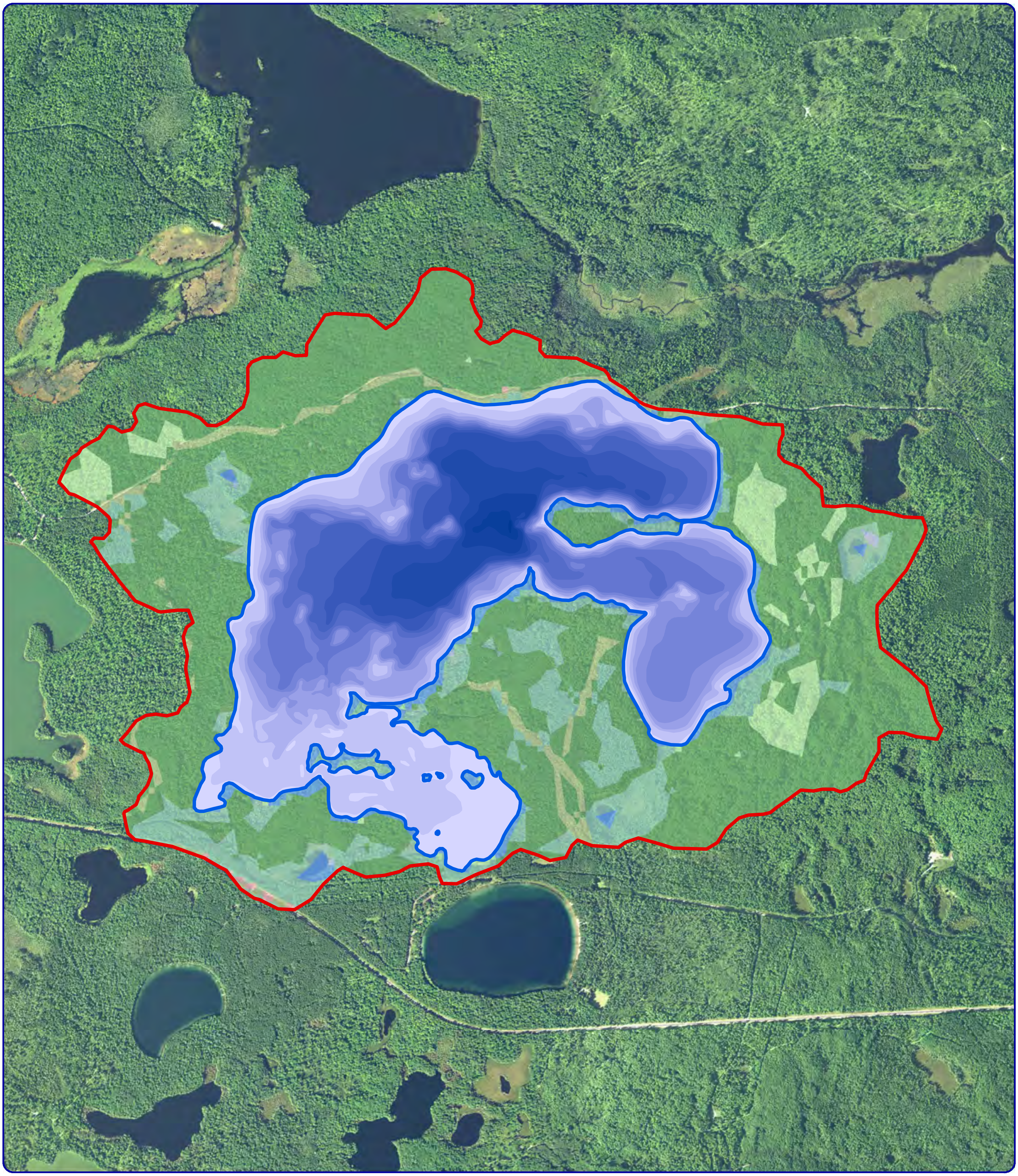
Public Access

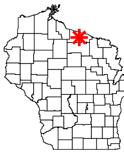
Big Muskellunge Lake
Map 1
Vilas County, Wisconsin

Project Location & Lake Boundaries

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Roads and Hydro: WDNR
Map Date: February 18, 2020 HAL
Filename: *Map1_Big Muskellunge_Location.mxd*





Extent of large map shown in red.

Legend

- Forest
- Forested Wetlands
- Pasture/Grass
- Open Water
- Wetland
- Row Crop Agriculture
- Rural Open Space
- Rural Residential
- Urban - High Density
- Urban - Medium Density
- Big Muskellunge Lake Watershed Boundary

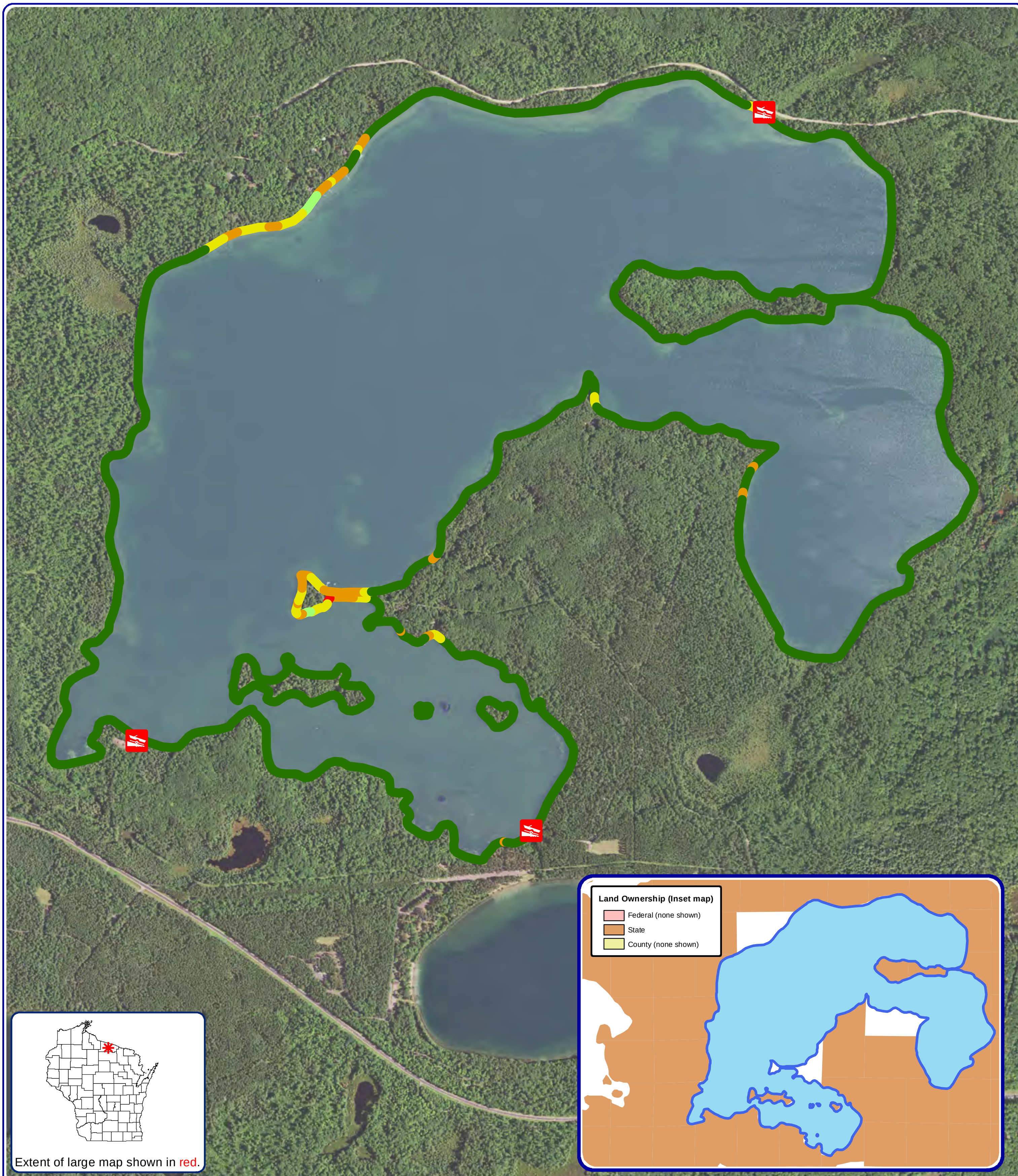
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Orthophotography: NAIP 2017
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2019
Map Date: December 30, 2019 JMB
File Name: Map2_BigMuskellunge_Watershed.mxd

Big Muskellunge Lake - Map 2

Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types



1,150

Feet

Legend

Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized

Seawall Modifier

Masonary/Wood Seawall
Rip-Rap

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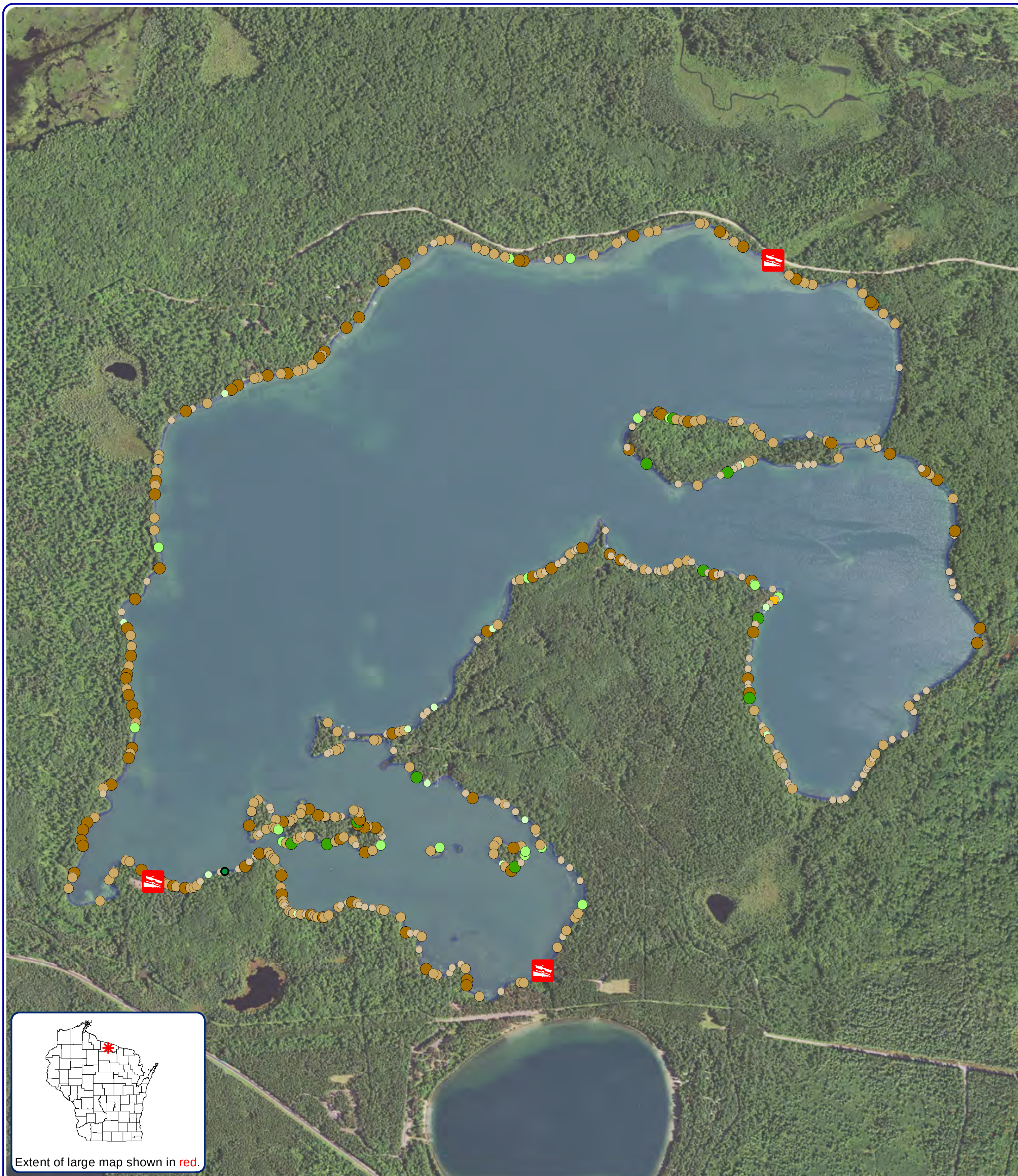
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: November 20, 2019 AMS
Filename: BigMuskellunge_SA_2019.mxd

Big Muskellunge Lake - Map 3

Vilas County, Wisconsin

Shoreland Condition Assessment



N
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S

1,150

Feet

Onterra LLC
Lake Management Planning

815 Prosper Rd
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920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: November 20, 2019 AMS
Filename: BigMuskellunge_CWH_2019.mxd

Legend

2-8 Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

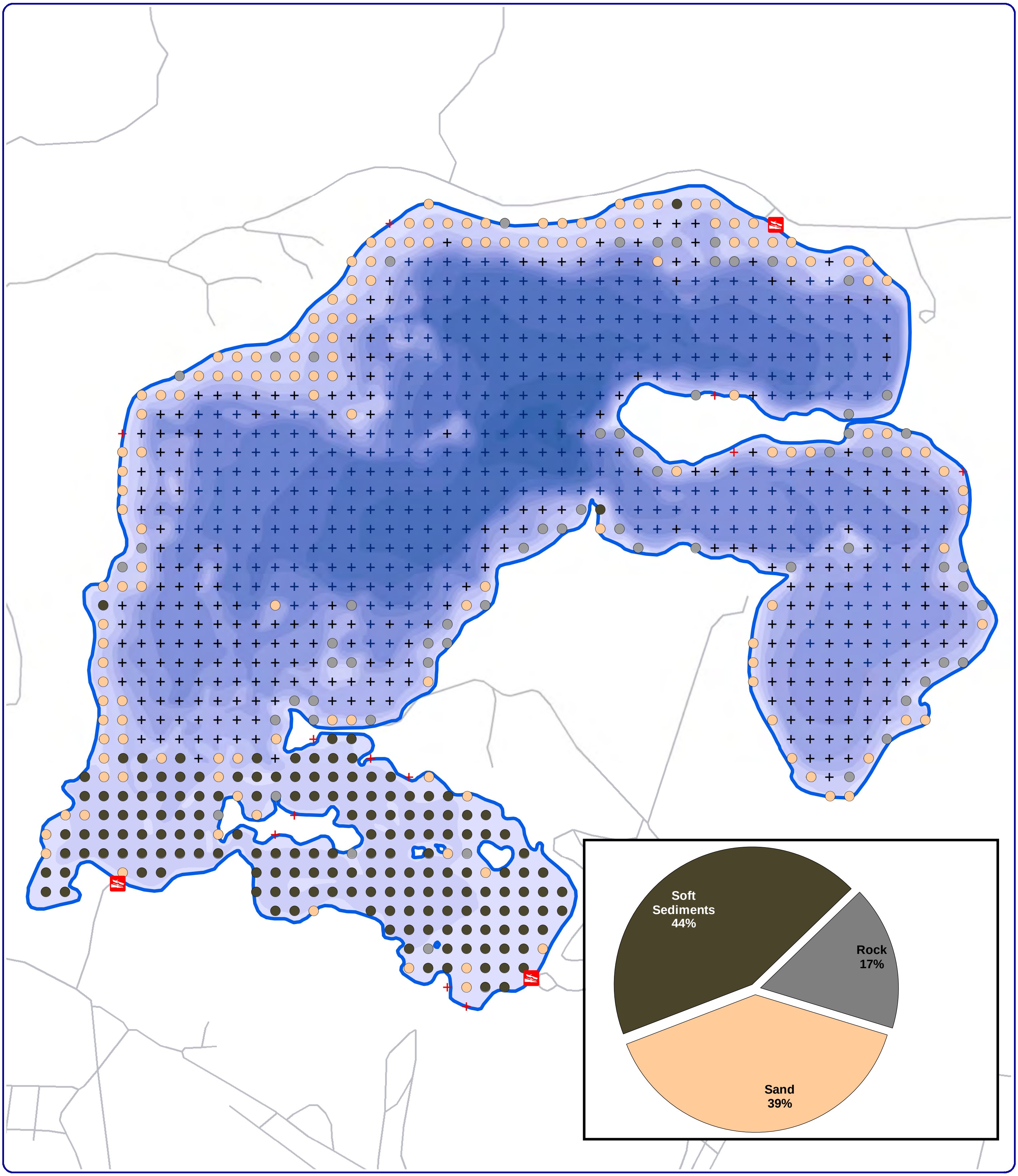
8+ Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

Cluster of Pieces
- Minimal Branches
- Moderate Branches
- Full Canopy

Big Muskellunge Lake - Map 4

Vilas County, Wisconsin

Coarse Woody Habitat



N
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1,200
Feet

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815 Prosper Rd
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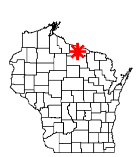
www.onterra-eco.com

Sources
Hydro: WDNR
Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: February 17, 2020 AMS
Filename: MapX_BigMuskellunge_SedimentPI_2019.mxd



Project Location in Wisconsin

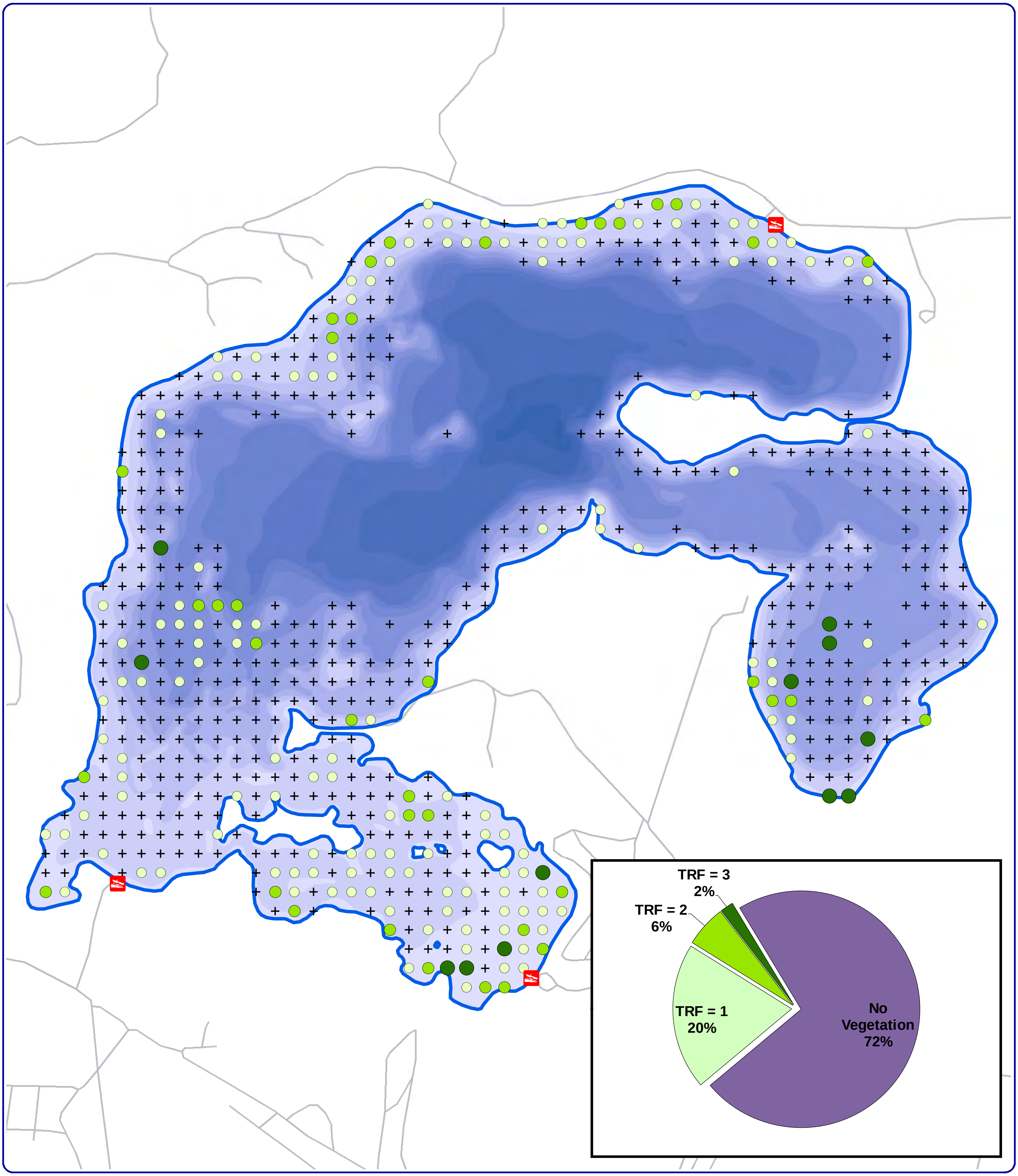
Legend

- Soft/Organic Sediments
- Rock
- Sand
- + Sampled
- + Non-navigable

Big Muskellunge Lake - Map 5

Vilas County, Wisconsin

2019 PI Survey: Substrate Types



1,200
Feet

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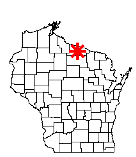
www.onterra-eco.com

Sources
Hydro: WDNR
Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: February 17, 2020 AMS
Filename: MapX_BigMuskellunge_TRFPI_2019.mxd



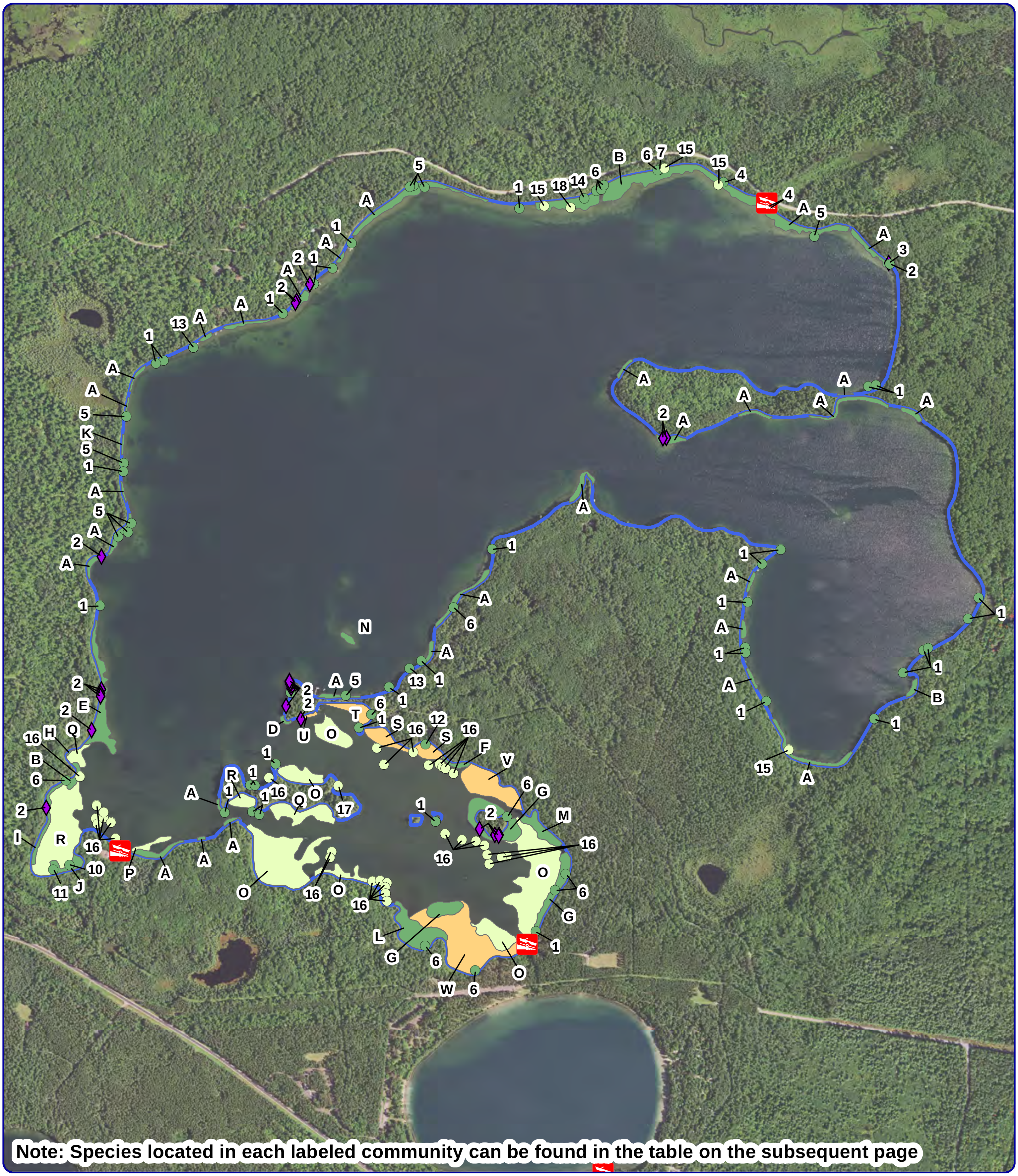
Project Location in Wisconsin

Legend

- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- \+ No Vegetation
- \+ Non-Navigable

Big Muskellunge Lake - Map 6
Vilas County, Wisconsin

2019 PI Survey: Aquatic Vegetation Distribution



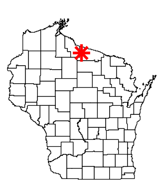
N
W E
S

1,250

Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 10, 2019 AMS
Filename: BigMuskellunge_Comm_2019.mxd



Project Location in Wisconsin

Legend

Small Plant Communities	Large Plant Communities
Emergent	Emergent
Floating-leaf	Floating-leaf
Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent
Purple Loosestrife	

Big Muskellunge Lake - Map 7

Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Big Muskellunge 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Big Muskellunge - Map 7

Large Plant Community (Polygons)									
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
A	Creeping Spikerush								10.70
B	Creeping spikerush	Hardstem bulrush							5.84
C	Creeping spikerush	Hardstem bulrush							0.51
D	Creeping spikerush	Three-way sedge							0.11
E	Creeping spikerush	Hardstem bulrush	Three-way sedge	Water smartweed	Common yellow lake sedge	American bur-reed	Narrow-leaved woolly sedge		3.21
F	Hardstem bulrush								0.25
G	Hardstem bulrush	Creeping spikerush							4.56
H	American bur-reed	Creeping spikerush	Hardstem bulrush	Common arrowhead					0.03
I	American bur-reed	Creeping spikerush	Common arrowhead						0.64
J	American bur-reed	Misc. Wetland Species							0.62
K	Creeping spikerush	Three-way sedge	Hardstem bulrush						0.09
L	Hardstem bulrush	Creeping spikerush	Misc. Wetland Species						2.40
M	Hardstem bulrush	Creeping spikerush	Three-way sedge	Common yellow lake sed	Bur-Reed sp. (sterile)				1.01
N	Narrow-leaved cattail	Creeping spikerush	Hardstem bulrush						0.22
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
O	White water lily								11.15
P	White water lily	Water Smartweed							0.43
Q	White water lily	Spatterdock							2.45
R	White water lily	Spatterdock	Water Smartweed						6.91
Floating-leaf/ Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
S	White water lily	Creeping spikerush							1.85
T	White water lily	Creeping spikerush	Water smartweed						0.94
U	White water lily	Creeping spikerush	Common arrowhead	Bluejoint grass					0.14
V	White water lily	Hardstem bulrush	Creeping spikerush						2.95
W	White water lily	Creeping spikerush	Spatterdock	Water smartweed	Hardstem bulrush				6.44

Small Plant Community (Points)								
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	Creeping spikerush							
2	Purple loosestrife							
3	Bur-reed sp. (sterile)	Common arrowhead	Grass sp. (sterile)					
4	Common Reed							
5	Hardstem bulrush							
6	American bur-reed							
7	Grass sp. (sterile)							
8	Water smartweed							
9	Creeping spikerush	Water smartweed						
10	Cattail sp.							
11	American bur-reed	Three-way sedge	Common arrowhead					
12	Bluejoint grass	Common yellow lake se	Wool grass	Soft rush				
13	Creeping spikerush	Water smartweed						
14	Bur-reed (sterile)							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
15	Water smartweed							
16	White water lily							
17	White water lily	Spatterdock						
18	Narrow-leaf bur reed							

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 8.9.4-1