Please note that study methods and explanations of analyses for Plum Lake can be found within the Town of Plum Lake Town-wide Management Plan document.

8.1 Plum Lake

An Introduction to Plum Lake

Plum Lake, Vilas County, is a 1,074-acre deep two-story fishery lake with a maximum depth of 57 feet and a mean depth of 22 feet (Plum Lake – Map 1). Its watershed encompasses approximately 11,631 acres within the St. Germain River Watershed and is comprised mainly of intact forests and wetlands. Plum Lake is fed by upstream Star Lake through Star Creek from the north and from West Plum Lake to the west, and water leaves Plum Lake through Plum Creek to the south. In 2017, 44 native aquatic plant species were located within the lake, of which coontail (*Ceratophyllum demersum*) was the most common. One non-native plant, pale yellow iris, was found during the surveys.

Lake at a Glance - Plum Lake

Morphometry	
Lake Type	Deep Lowland Drainage Lake
Surface Area (Acres)	1,074
Max Depth (feet)	57
Mean Depth (feet)	22
Perimeter (Miles)	13.6
Shoreline Complexity	8.8
Watershed Area (Acres)	11,631
Watershed to Lake Area Ratio	10:1

Water Quality	
Trophic State	Oligo-mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (μg/L)	13
Avg Summer Chl-α (μg/L)	3
Avg Summer Secchi Depth (ft)	14.9
Summer pH	7.9
Alkalinity (mg/L as $CaCO_3$)	38

Vegetation	
Number of Native Species	44
NHI-Listed Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Species	Pale yellow iris (*Iris pseudacorus*)
Average Conservatism	6.7
Floristic Quality	34.8
Simpson's Diversity (1-D)	0.9

Descriptions of these parameters can be found within the town-wide portion of the management plan

8.1.1 Plum Lake Water Quality

Water quality data was collected from Plum Lake on six occasions in 2017/2018. Onterra staff sampled the lake for a variety of water quality parameters 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 surface samples. In addition to sampling efforts completed in 2017/2018, any historical data was researched and are included within this report as available. It should also be noted that while Plum Lake is a two-story fishery lake, regional data for two-story lakes are not available so the water quality of Plum Lake will be compared to other deep lowland drainage lakes in the state.

Near-surface total phosphorus data from Plum Lake are available from 1989, 1994, 1996, and intermittently from 2007 to 2017 (Figure 8.1.1-1). Average summer total phosphorus concentrations ranged from 8 µg/L in 1989 to 18 µg/L in 2013. The weighted summer average total phosphorus concentration is 13 µg/L and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Plum Lake's summer average total phosphorus concentrations are lower than the median values for both deep lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion.

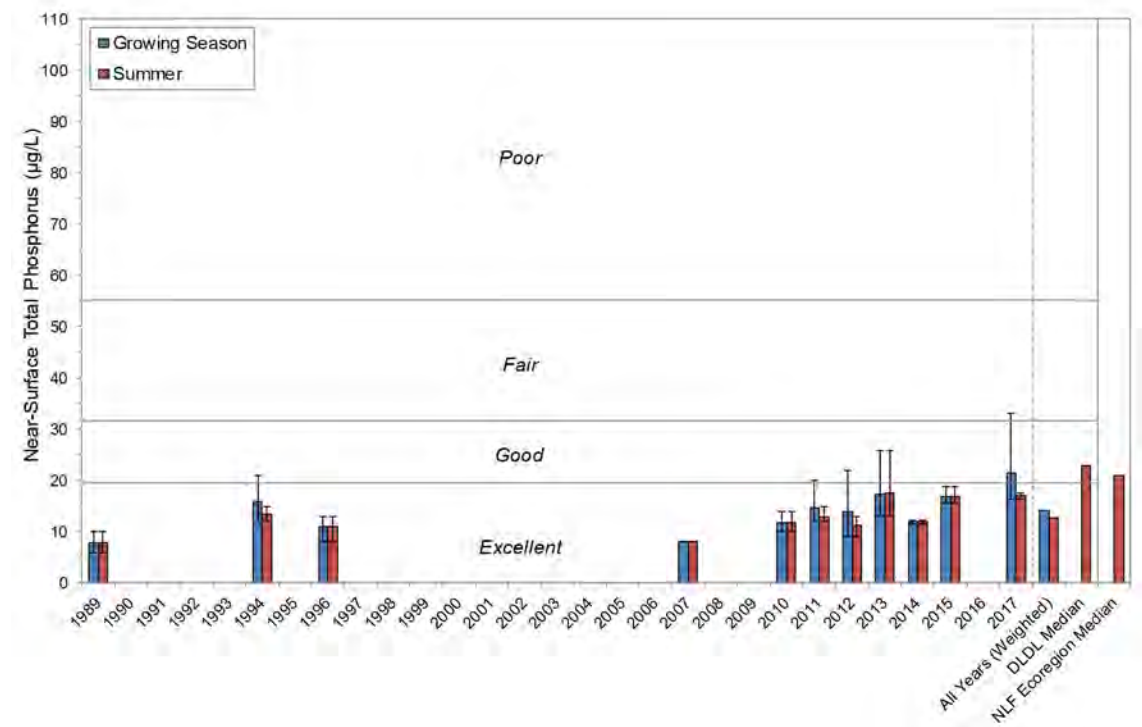


Figure 8.1.1-1. Plum Lake, statewide deep lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* data are available from Plum Lake from 1989, 1994, 1996, and intermittently from 2007 to 2017 (Figure 8.1.1-2). Average summer chlorophyll-*a* concentrations ranged from 2 µg/L in 2007 to 5 µg/L in 2017; however, it should be noted that only one summer chlorophyll-*a* concentration sample was collected in 2007 and may not be representative of the summer average. Plum Lake's summer average chlorophyll-*a* concentration is 3 µg/L and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Work completed Catherine Higley, Lakes Conservation Specialist, Vilas County, found a slight, but statistically valid increase in chlorophyll-*a* values for Plum Lake between 2010 and 2019. Plum Lake's summer average chlorophyll-*a* concentrations are lower than the median values for both deep lowland drainage lakes in the state and all lake types in the NLF ecoregion.

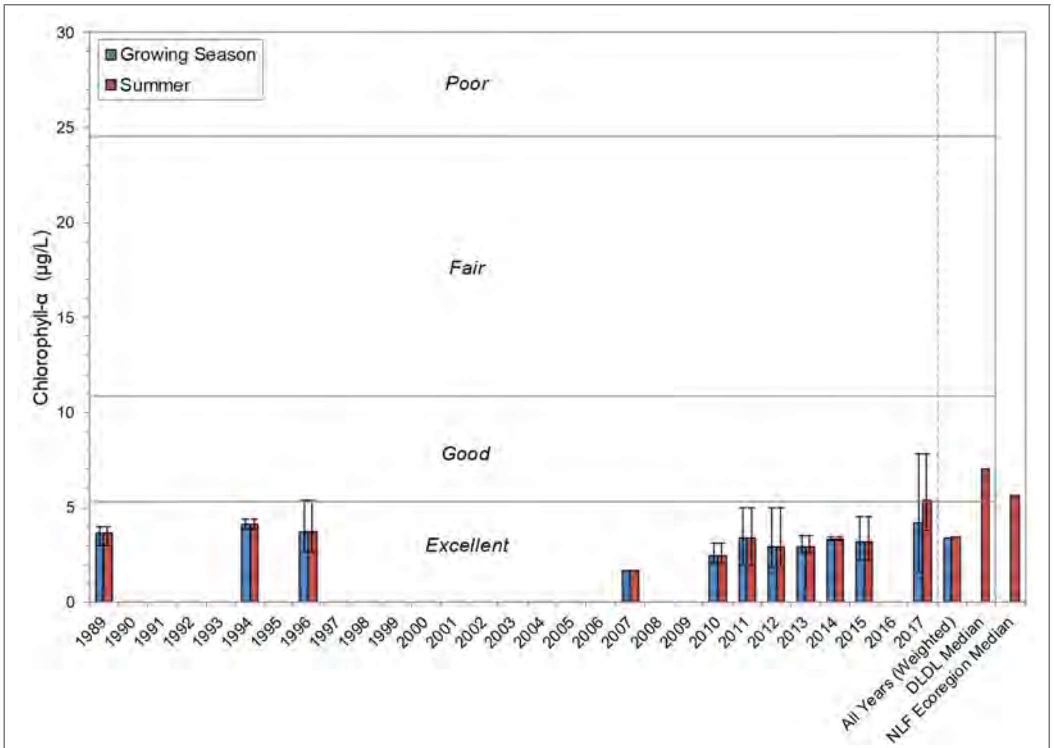


Figure 8.1.1-2. Plum Lake, statewide deep lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available from Plum Lake intermittently from 1989 to 2017 (Figure 8.1.1-3). Average summer Secchi disk depths ranged from 8.2 feet in 1989 to 18.2 feet in 1995; however, it should be noted that only one summer Secchi disk measurement was taken in 1989 and may not be representative of the summer average. The weighted summer average Secchi disk depth is 14.9 feet and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Plum Lake's weighted summer average Secchi disk depth exceeds the median values for both deep lowland drainage lakes in the state and for all lake types in the NLF ecoregion by approximately 6 feet.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color,* and measures how the clarity of the water is influenced by dissolved components. True color values measured from Plum Lake in 2017 averaged 20 SU (standard units) indicating the lake's water is *slightly colored* to *lightly tea-colored* and that the lake's water clarity is slightly influenced by dissolved components in the water. This value indicates that the water clarity in Plum lake is mostly influenced by changes in chlorophyll-*a* from year to year.

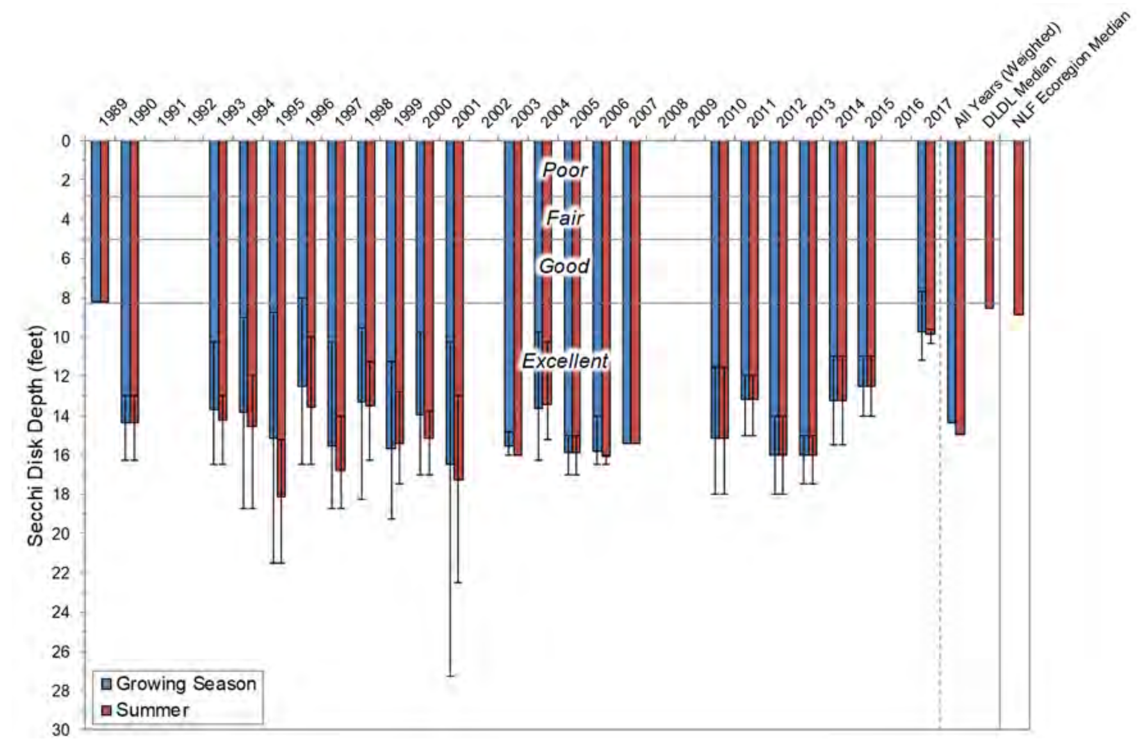


Figure 8.1.1-3. Plum Lake, statewide deep lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Plum Lake

Using midsummer nitrogen and phosphorus concentrations from Plum Lake, a nitrogen:phosphorus ratio of 20:1 was calculated. This finding indicates that Plum 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.

Plum Lake Trophic State

Figure 8.1.1-4 contains the Trophic State Index (TSI) values for Plum 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 for these three parameters are to one another the higher the degree of correlation between the parameters.

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

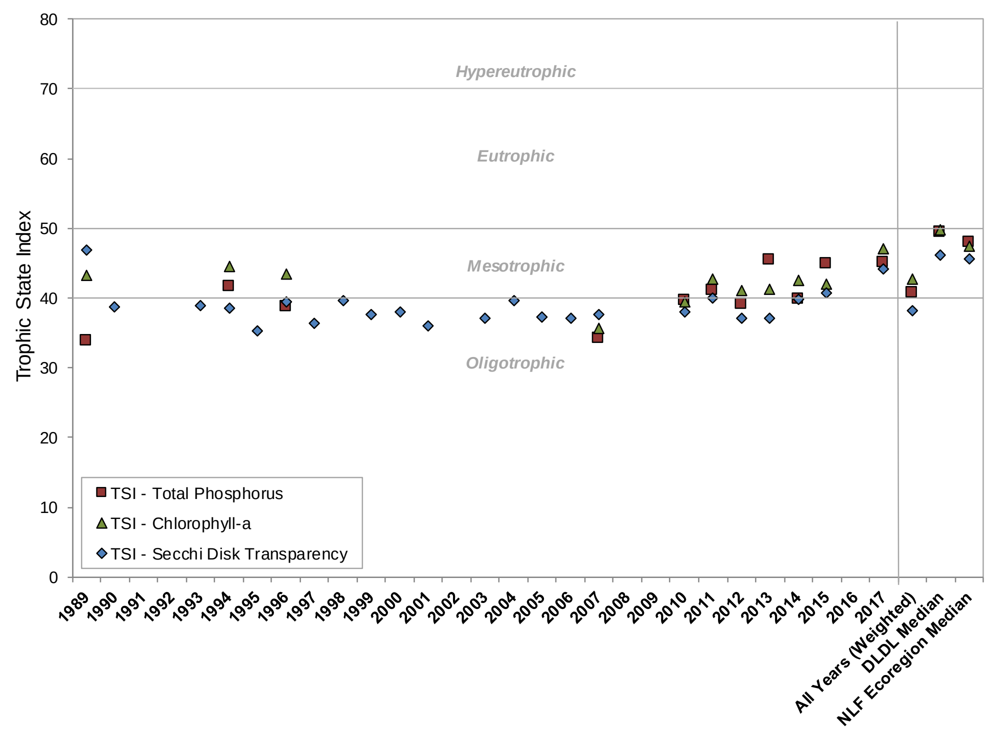


Figure 8.1.1-4. Plum Lake, statewide deep lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Plum Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Plum Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.1.1-5.

Plum Lake 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 Plum 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 (hypolimnion) 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 2018, 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 Plum Lake.

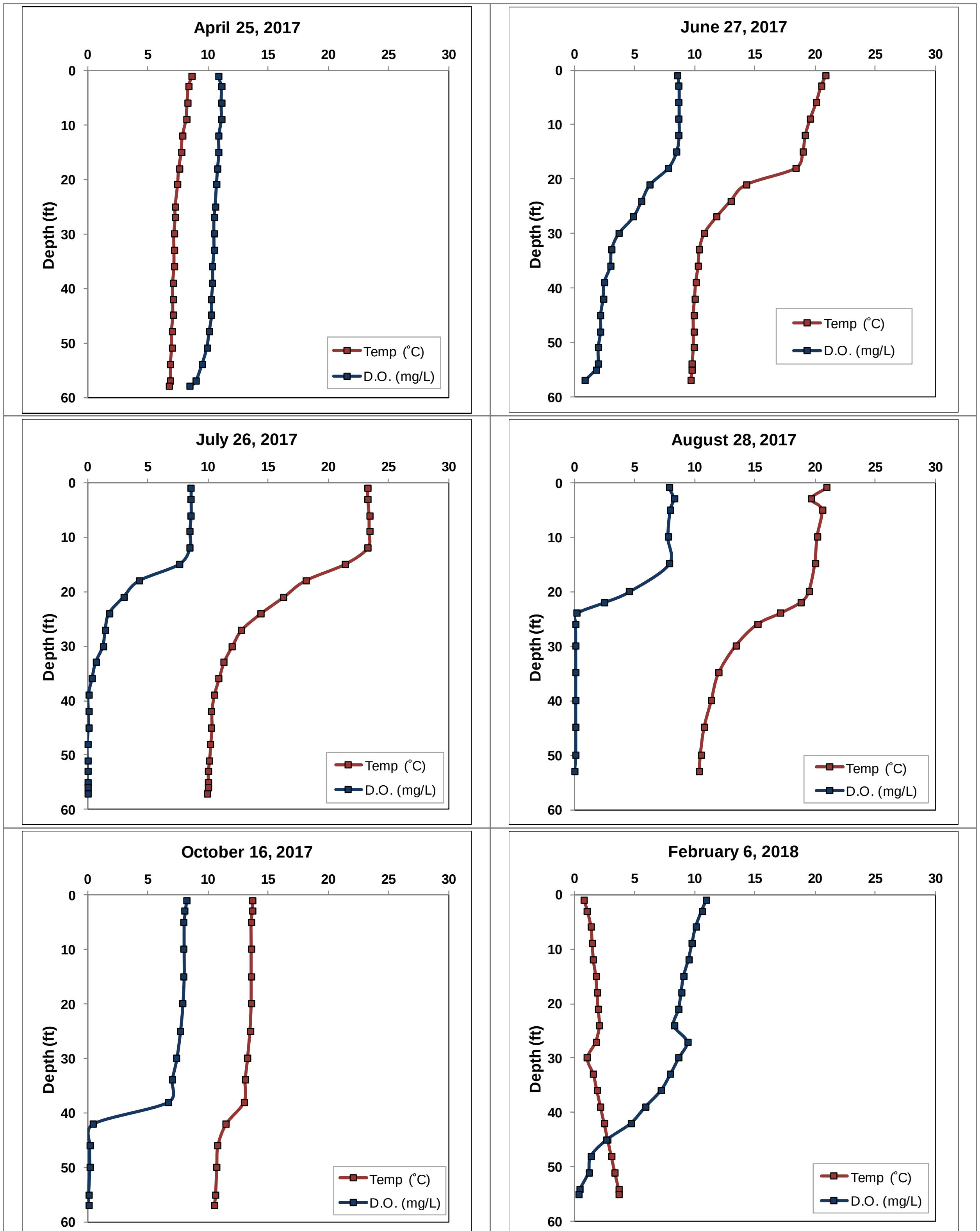


Figure 8.1.1-5. Plum Lake 2017/2018 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Plum Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Plum Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Plum Lake's surface water pH was measured at approximately 7.6 during April 2017 and 7.9 during July 2017. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Plum Lake was measured at 39.6 mg/L as $CaCO_3$ in April 2017 and 38.0 in July 2017. This indicates that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Plum Lake during 2017. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Plum Lake's pH of 7.6 – 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Plum Lake was found to be 11.1 mg/L in both April and July, which is below the lower range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2017 and these samples were processed by the WDNR for larval zebra mussels. The results were negative for the presence of zebra mussel veligers.

8.1.2 Plum Lake Watershed Assessment

Plum Lake's watershed encompasses an area of approximately 11,631 acres, yielding a watershed to lake area ratio of 10:1 (Figure 8.1.2-1, Plum Lake – Map 2). According to WiLMS modeling, the lake's water is completely replaced every 2 years (residence time) or approximately 0.5 times per year (flushing rate).

There are three lakes within Plum Lake's watershed that were treated as point sources: West Plum Lake, Aurora Lake, and Star Lake. For modeling purposes, the lake's watershed was divided into four main subwatersheds: Plum Lake's direct watershed, West Plum Lake's subwatershed, Aurora Lake's subwatershed, and Star Lake's subwatershed. Approximately 41% of Plum Lake's total watershed is composed of the lake's direct watershed, 29% of Star Lake's subwatershed, 23% of Aurora Lake's subwatershed, and 7% of West Plum Lake's subwatershed (Figure 8.1.2-1).

Approximately 36% of Plum Lake's direct watershed is composed of wetlands, 35% of forest, 22% of the lake's surface, and 7% of pasture/grass (Figure 8.1.2-1). The remaining portions of the watershed are composed of rural residential areas, row crop agriculture, and medium density urban areas.

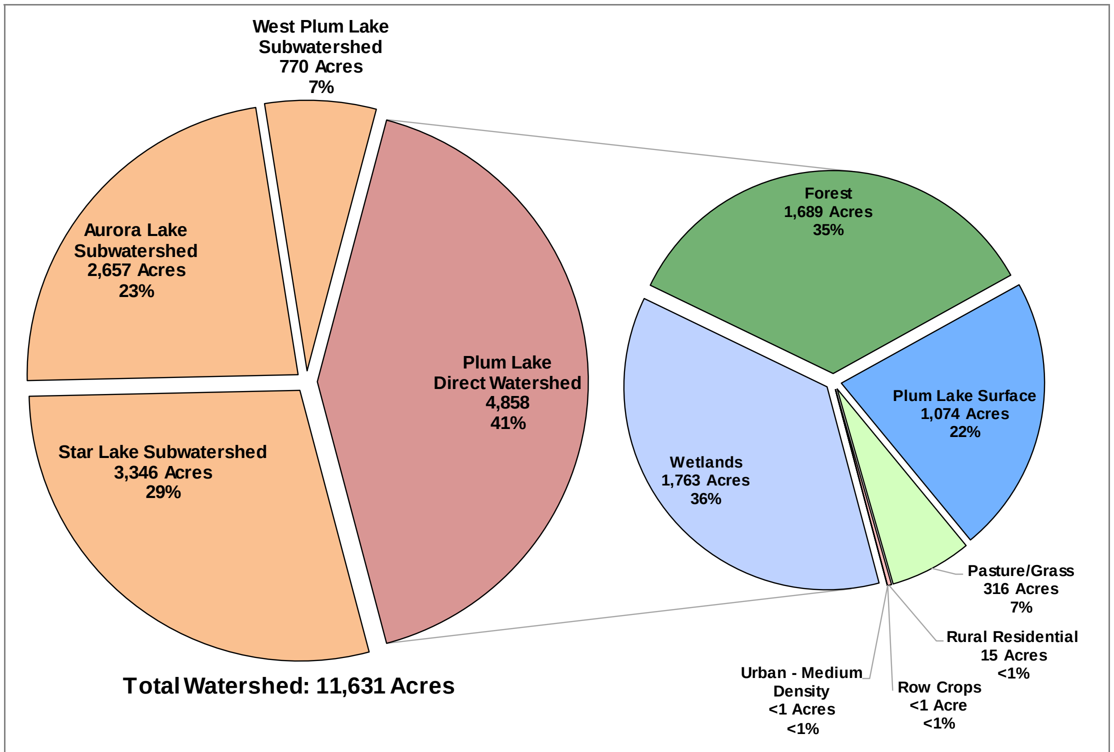


Figure 8.1.2-1. Plum Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Plum Lake's direct watershed, along with the estimated outflow of phosphorus from the three subwatersheds. It was estimated that approximately 984 pounds of phosphorus is delivered to Plum Lake from its watershed on an annual basis (Figure 8.1.2-2).

Of the estimated 984 pounds of phosphorus being delivered annually to Plum Lake, 29% is estimated to originate from direct atmospheric deposition into the lake, 16% from Aurora Lake's subwatershed, 16% from wetlands, 14% from forest, 9% from pasture/grass, 8% from Star Lake's subwatershed, 7% from West Plum Lake's subwatershed, and 1% from riparian septic systems (Figure 8.1.2-2). The remaining phosphorus load comes from rural residential areas.

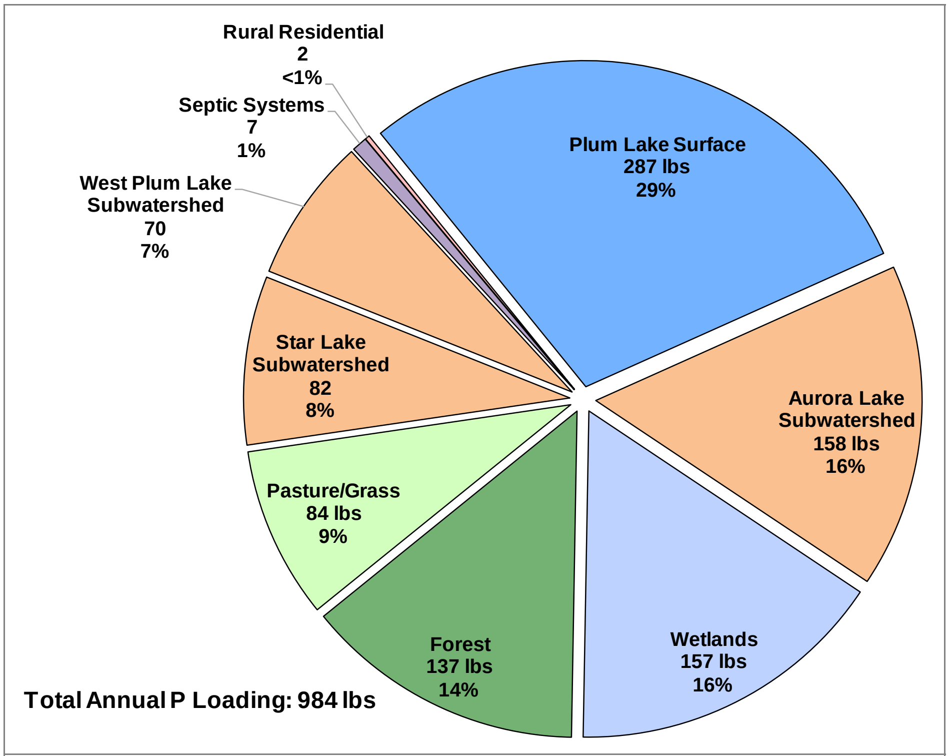


Figure 8.1.2-2. Plum Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimated that based on the 984 pounds of phosphorus which are estimated to be loaded to Plum Lake annually, the lake should have an in-lake growing season mean (GSM) total phosphorus concentration of approximately 14 μg/L. This predicted GSM total phosphorus concentration is the same as the measured GSM concentration of 14.1 μg/L. This indicates the lake's watershed and phosphorus inputs were modeled fairly accurately and the measured phosphorus concentrations in Plum Lake are near expected levels based on the lake's watershed size and land cover composition. There are no indications that significant sources of unaccounted phosphorus are being loaded to the lake.

8.1.3 Plum 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 2017, Plum Lake's immediate shoreline was assessed in terms of its development. Plum Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 11.1 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). This constitutes about 81% of Plum Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.3 miles of urbanized and developed–unnatural shoreline (9%) was observed. If restoration of the Plum Lake shoreline is 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. Plum Lake - Map 3 displays the location of these shoreline lengths around the entire lake.

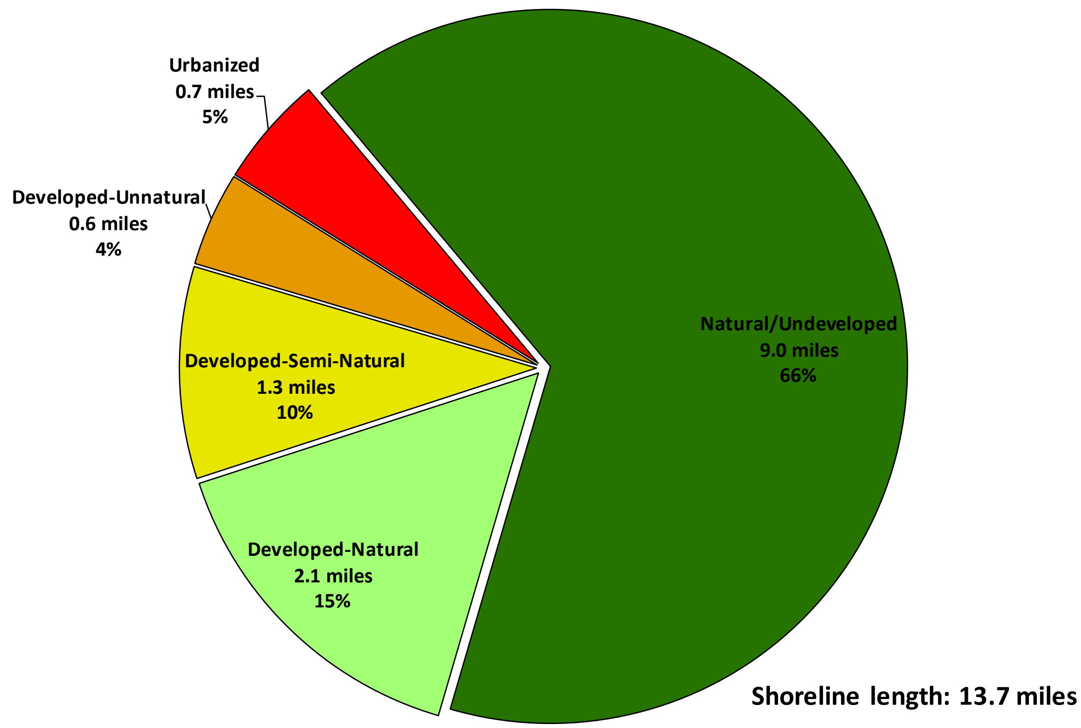


Figure 8.1.3-1. Plum Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Plum Lake - Map 3.

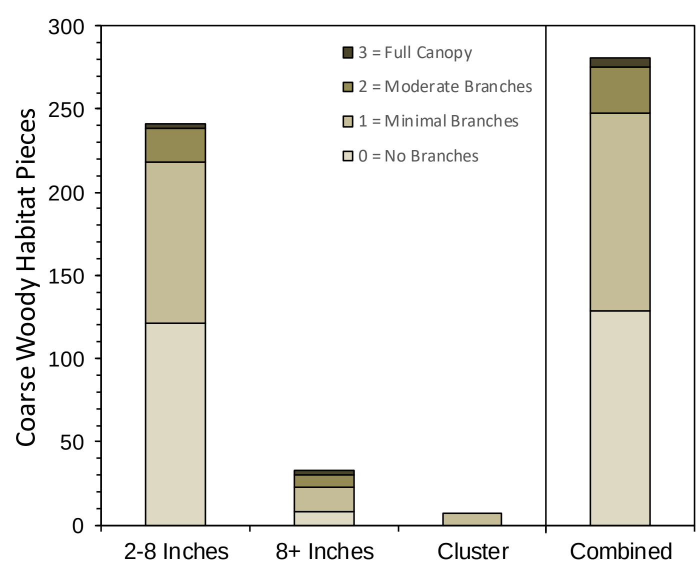
Coarse Woody Habitat

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, 281 total pieces of coarse woody habitat were observed along 13.7 miles of shoreline (Plum Lake - Map 4), which gives Plum Lake a coarse woody habitat to shoreline mile ratio of 21:1 (Figure 8.1.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 281 total pieces of coarse woody habitat observed during the survey, 241 pieces were 2-8 inches in diameters, 33 were 8 inches in diameter or greater, and 7 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 Plum 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 75 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 Plum Lake fell just below the 50th percentile of these 75 lakes (Figure 8.1.3-2).



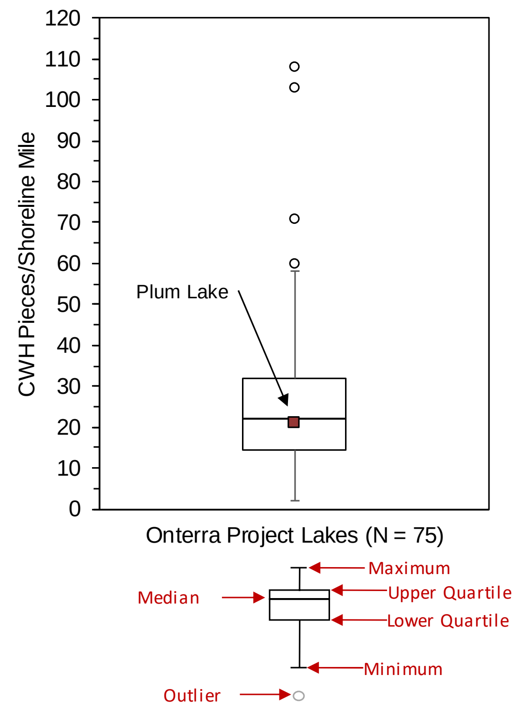


Figure 8.1.3-2. Plum Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Plum Lake coarse woody habitat can be found on Plum Lake - Map 4.

8.1.4 Plum Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Plum Lake on June 29, 2017. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate potential occurrences of the non-native curly-leaf pondweed, which should be at or near its peak growth at this time. No curly-leaf pondweed was located during the survey but pale-yellow iris was located during the survey in 2017.

Photograph 8.1.4-1. Plum Lake

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Plum Lake by Onterra ecologists on July 26-27, 2017. During these surveys, a total of 45 aquatic plant species were located, one of which is considered to be a non-native, invasive species: pale-yellow iris (Table 8.1.4-1). One native aquatic plant species present in Plum Lake, Vasey's pondweed, is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 46% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 33% contained sand, and 20% contained rock (Figure 8.1.4-1). The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck (Plum Lake - Map 5). Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

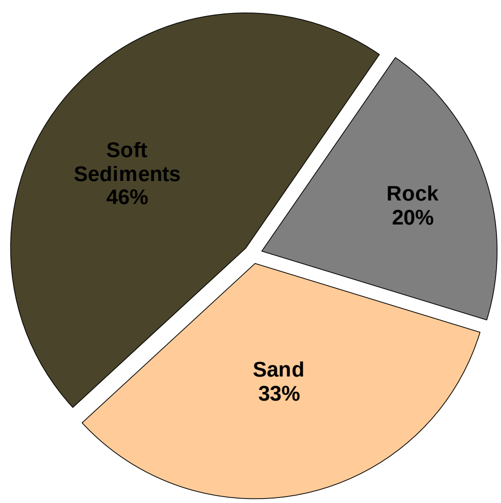


Figure 8.1.4-1. Plum Lake 2017 proportion of substrate types. Created from data collected during the 2017 whole-lake point-intercept survey (N = 410).

Table 8.1.4-1. List of aquatic plant species located in Plum Lake during Onterra 2017 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Carex utriculata	Common yellow lake sedge	7	I
	Decodon verticillatus	Water-willow	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris pseudacorus	Pale yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Pontederia cordata	Pickerelweed	9	X
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Scirpus cyperinus	Wool grass	4	I
	Sparganium americanum	American bur-reed	8	I
	Sparganium eurycarpum	Common bur-reed	5	I
	Typha spp.	Cattail spp.	1	I
	Zizania spp.	Wild rice sp.	8	X
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	8	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elatine minima	Waterwort	9	I
	Elodea canadensis	Common waterweed	3	X
	Eriocaulon aquaticum	Pipewort	9	I
	Heteranthera dubia	Water stargrass	6	X
	Lobelia dortmanna	Water lobelia	10	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria cristata	Crested arrowhead	9	X
FF	*Lemna trisulca*	Forked duckweed	6	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern by WI Natural Heritage Inventory*

Of the 410 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2017, approximately 48% contained aquatic vegetation. Plum Lake – Map 6 displays the point-intercept locations that contained aquatic vegetation in 2017, and the total rake fullness ratings at those locations. Most of the aquatic vegetation in 2017 was located within shallower areas of the lake, mainly near shore and in the eastern and western bays of the lake. Twenty-eight percent of the point-intercept locations had a total rake fullness (TRF) rating of 1, 8% had a total rake fullness rating of 2, and 12% had the highest total rake fullness rating of 3 (Figure 8.1.4-2). With the majority of the littoral zone (80%) made of total rake fullness ratings of 1 or no vegetation, it can be said that where plants are present within Plum Lake, they are sparse.

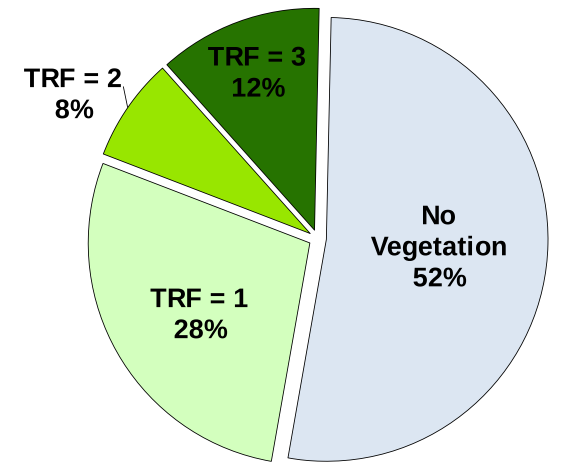


Figure 8.1.4-2. Plum Lake 2017 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2017 whole-lake point-intercept survey (N = 410).

Of the 45 native aquatic plant species located in Plum Lake in 2017, 27 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.1.4-3). The remaining 18 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 27 species directly sampled with the rake during the point-intercept survey, coontail, common waterweed, slender naiad and wild celery were the four-most frequently encountered plants, respectively (Figure 8.1.4-3).

Coontail was the most abundant aquatic plant encountered in 2017, with a littoral occurrence of approximately 18% (Figure 8.1.4-3). Coontail is a free-floating submersed species that obtains the majority of its nutrients directly from the water. It is arguably the most common aquatic plant in Wisconsin, able to grow in a wide variety of conditions. Coontail produces whorls of stiff leaves and has the capacity to grow in very dense colonies. Its leaves and dense network of branches provide excellent structural habitat for aquatic organisms, and the fact it obtains most of its nutrients directly from the water aids in reducing nutrients that would otherwise be available to free-floating algae.

Common waterweed was the second-most abundant aquatic plant encountered in Plum Lake in 2017, with a littoral occurrence of approximately 16% (Figure 8.1.4-3). Common waterweed is found throughout lakes in Wisconsin and North America and is often dominant in areas with soft sediments. Its dense foliage provides valuable aquatic habitat while its ability to derive nutrients directly from the water aid in improving water quality.

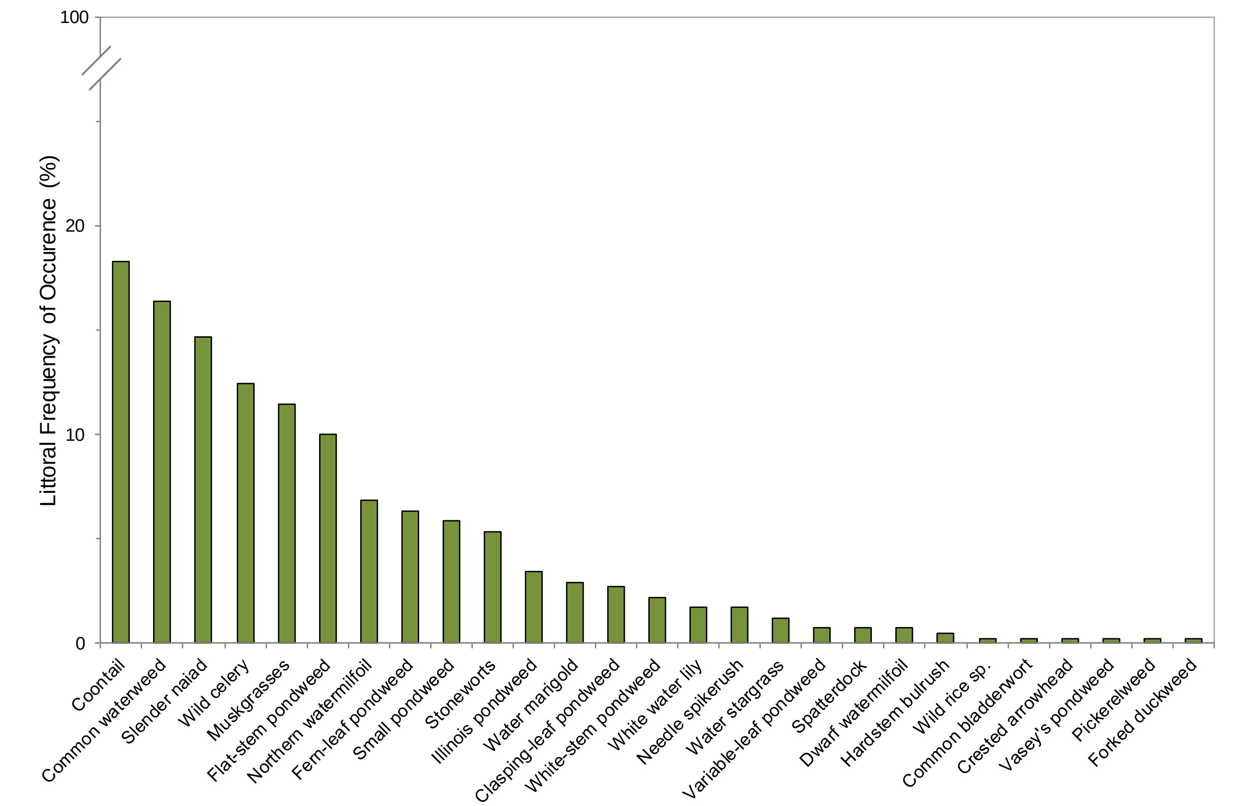


Figure 8.1.4-3. Plum Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data from 2017 whole-lake point-intercept survey.

Slender naiad, the third-most abundant aquatic plant in Plum Lake in 2017 with a littoral occurrence of 15% (Figure 8.1.4-3), is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, the fourth-most abundant aquatic plant in Plum Lake in 2017 with a littoral occurrence of 12% (Figure 8.1.4-3), has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basal rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman, Korth and Temte 1997).

One aquatic plant species located in 2017, Vasey's pondweed (*Potamogeton vaseyi* – Photograph 8.1.4-1), is listed as special concern in Wisconsin by the Natural Heritage Inventory due to uncertainty regarding its population and rarity in the state (WDNR PUBL-ER-001 2014). The locations of Vasey's pondweed are currently being tracked by the Wisconsin Natural Heritage Inventory to determine if it requires further listing as either threatened or endangered. Vasey's pondweed has very fine and slender leaves which alternate on the stem (Photograph 8.1.4-2). Upon

Photograph 8.1.4-2. Flowers and floating-leaves of Vasey's pondweed. Photo credit Onterra.

reaching the surface, the plant produces small oval-shaped floating-leaves which aid in holding the flower stalk above the surface. It prefers water with lower alkalinity and a moderate pH range, and Plum Lake contains optimal conditions for this species (Nichols 1999).

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 (Photograph 8.1.4-3). 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 (Photograph 8.1.4-3). 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*) found in Plum Lake is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern watermilfoil (*Myriophyllum sibiricum*), also found in Plum Lake, are classified as elodeids.

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 et al. 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 with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Plum Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

Photograph 8.1.4-3. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

As discussed in the Town-wide section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during the 2017 point-intercept survey and their conservatism values were used to calculate the FQI of Plum Lake's aquatic plant community (equation shown below).

$$FQI = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

Figure 8.1.4-4 compares 2017 FQI components of Plum Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. The number of native aquatic plant species encountered on the rake, or native species richness, was 27 for the 2017 survey. Plum Lake's species richness exceeds the median value for lakes within the ecoregion and the state. The lake's excellent water quality and diversity of habitat types result in this high species richness.

Plum Lake's average conservatism in 2017 was 6.7 (Figure 8.1.4-4). Plum Lake's average conservatism is the same as the median values for lakes in the ecoregion and exceeds the median for lakes throughout Wisconsin, which indicates Plum Lake's aquatic plant community contains a higher number of aquatic plants that are considered to be sensitive to environmental degradation and require high-quality habitats. Given Plum Lake's high native species richness and average conservatism values from 2017, Plum Lake has a high Floristic Quality Index value of 34.8. This FQI value exceeds the median values for lakes in the ecoregion and the state and indicates that Plum Lake's aquatic plant community is of higher quality than the majority of lakes in the region and throughout Wisconsin.

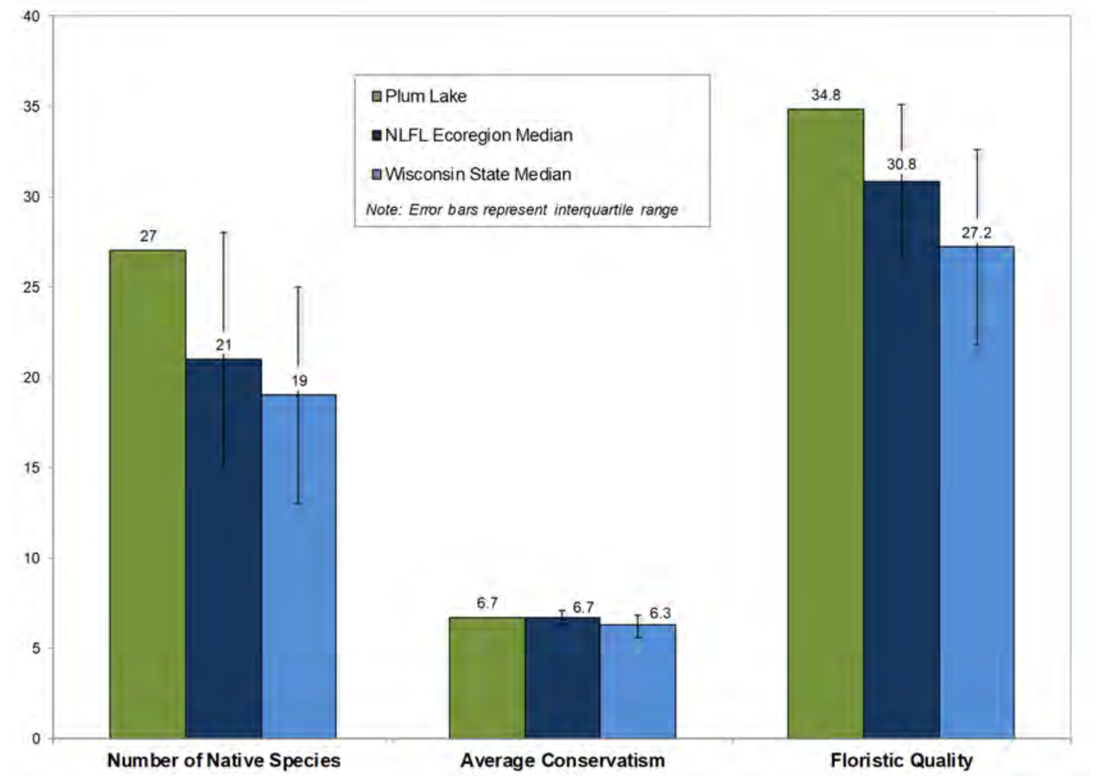


Figure 8.1.4-4. Plum Lake Floristic Quality Assessment. Created using data from Onterra 2017 whole-lake point-intercept survey. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities 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. Because Plum Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species 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 Plum Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 8.1.4-5). Using the data collected from the 2017 point-intercept survey, Plum Lake's aquatic plant community is shown to have high species diversity with a Simpson's Diversity Index value of 0.91. In other words, if two individual aquatic plants were randomly sampled from Plum Lake in 2017, there would be a 91% probability that they would be different species. This diversity value falls above the upper quartile value for lakes in the ecoregion and the state.

One way to visualize Plum Lake's high species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-6 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 18% of the littoral sampling locations in Plum Lake in 2017, its relative frequency of occurrence is 14%. Explained another way, if 100 plants were randomly sampled from Plum Lake in 2017, 14 of them would be coontail.

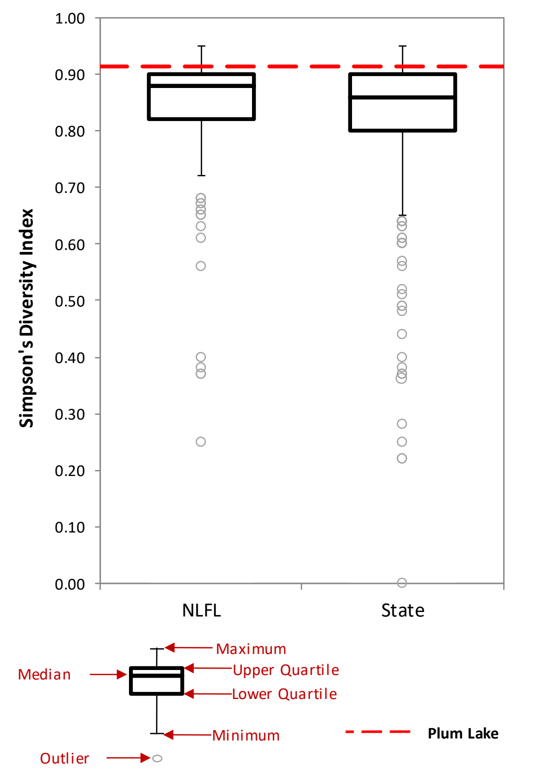


Figure 8.1.4-5. Plum Lake species diversity index. Created using data from the Onterra 2017 point-intercept survey.

In 2017, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Plum Lake. This survey revealed Plum Lake contains approximately 30 acres of these communities comprised of 20 different aquatic plant species (Plum Lake – Maps 7-8 and Table 8.1.4-2). 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.

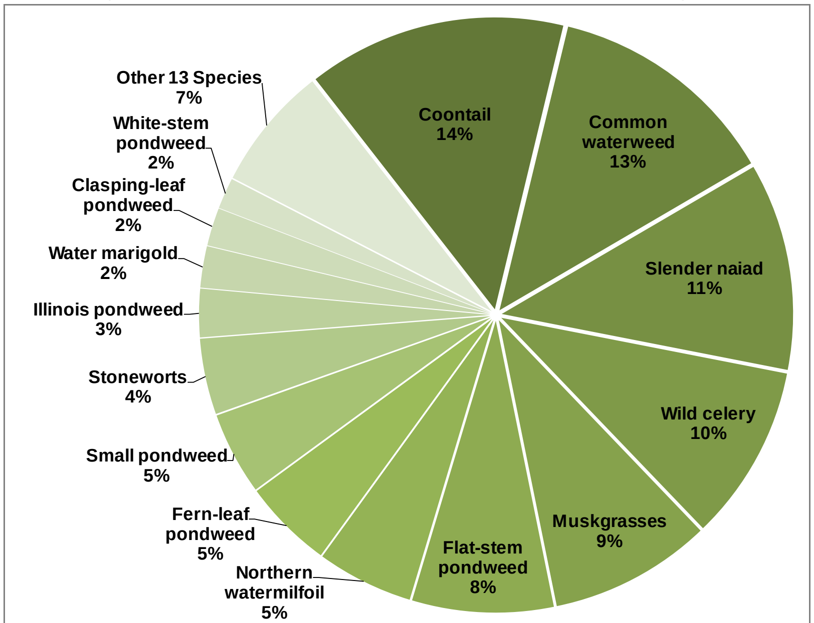


Figure 8.1.4-10. Plum Lake 2017 relative frequency of occurrence of aquatic plant species. Created using data from 2017 point-intercept survey.

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Plum Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.1.4-2. Plum Lake 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2017 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	6.1
Floating-leaf	2.1
Mixed Emergent & Floating-leaf	21.9
Total	**30.1**

Non-native Aquatic Plants in Plum Lake

Pale-yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Pale-yellow iris was observed growing in shoreline areas of Plum Lake in 2017 (Plum Lake – Maps 7-8). Control of pale-yellow iris on the Town of Plum Lake project lakes will be discussed in the Implementation Plan Section.

8.1.5 Aquatic Invasive Species in Plum Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Plum Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are five AIS present (Table 8.1.5-1).

Table 8.1.5-1. AIS present within Plum Lake

Type	Common name	Scientific name	Location within the report
Plants	Pale-yellow iris	*Iris pseudacorus*	Section 8.1.4 – Plum Lake Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 8.1.5 – Aquatic Invasive Species in Plum Lake
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 8.1.5 – Aquatic Invasive Species in Plum Lake
	Freshwater jellyfish	*Craspedacusta sowerbyi*	Section 8.1.5 – Aquatic Invasive Species in Plum Lake
	Rusty crayfish	*Orconectes rusticus*	Section 8.1.5 – Aquatic Invasive Species in Plum Lake

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

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.

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

Freshwater jellyfish

Freshwater jellyfish (*Craspedacusta sowerbyi*) are believed to have been introduced to the Great Lakes region around 1933 with the first Wisconsin sightings dating back to 1969. They are quite small, growing to about one inch in diameter. These jellyfish are ephemeral, living for only six to seven weeks and then disappearing, sometimes forever. While there is not yet a thorough understanding of how freshwater jellyfish affect their ecosystems, it is thought that they may outcompete other native species for zooplankton. Crayfish are a natural predator of freshwater jellyfish.

8.1.6 Plum 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 Plum 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 Hadley Boehm (WDNR 2017 & GLIFWC 2017).

Plum 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 Plum 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 8.1.6-1.

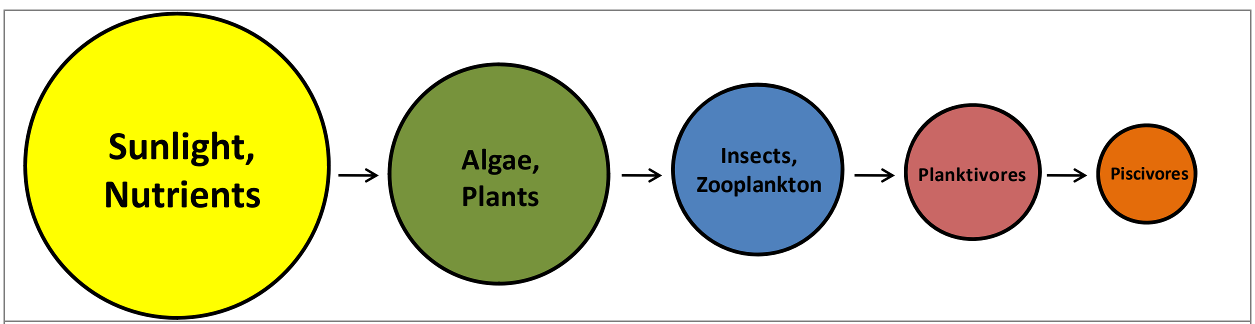


Figure 8.1.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Plum Lake is an oligo-mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Plum Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 8.1.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past surveys of Plum Lake include white sucker (*Catostomus commersonii*), burbot (*Lota lota*), common shiner (*Luxilus cornutus*), mimic shiner (*Notropis volucellus*), bluntnose minnow (*Pimephales notatus*), logperch (*Percina caprodes*), johnny darker (*Etheostoma nigrum*), creek chub (*Semotilus atromaculatus*).

Table 8.1.6-1. Gamefish present in Plum Lake with corresponding biological information. (Becker 1983)

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Cisco (*Coregonus artedii*)	22	Late November - Early December	No clear substrate preference.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates.
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
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
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 Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
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 8.1.6-1). 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 electroshocking (Photograph 8.1.6-1). 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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 8.1.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

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 8.1.6-2). 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. Plum Lake was stocked from 1972 to 2016 with muskellunge, brown trout and walleye (Table 8.1.6-2, Table 8.1.6-3, and Table 8.1.6-4).

Photograph 8.1.6-2. Fingerling Muskellunge.

Table 8.1.6-2. Stocking data available for brown trout in Plum Lake (1979-2001).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1979	Brown Trout	Unspecified	Yearling	2,000	
1987	Brown Trout	Unspecified	Yearling	6,000	8
1999	Brown Trout	St. Croix	Yearling	1,000	8
2000	Brown Trout	St. Croix	Yearling	1,000	8.5
2001	Brown Trout	St. Croix	Yearling	1,000	7.1

Table 8.1.6-3. Stocking data available for muskellunge in Plum Lake (1973-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1973	Muskellunge	Unspecified	Fingerling	1,100	12
1974	Muskellunge	Unspecified	Fingerling	300	13
1977	Muskellunge	Unspecified	Fingerling	2,536	7
1983	Muskellunge	Unspecified	Fingerling	1,800	10
1985	Muskellunge	Unspecified	Fingerling	1,800	10
1986	Muskellunge	Unspecified	Fingerling	508	10
1987	Muskellunge	Unspecified	Fingerling	5,328	11.5
1989	Muskellunge	Unspecified	Fingerling	900	11
1991	Muskellunge	Unspecified	Fingerling	900	11.5
1992	Muskellunge	Unspecified	Fingerling	1,147	11
1999	Muskellunge	Unspecified	Large Fingerling	847	11.1
2010	Muskellunge	Upper Wisconsin River	Large Fingerling	300	12.7
2014	Muskellunge	Upper Wisconsin River	Large Fingerling	278	11.3
2016	Muskellunge	Upper Wisconsin River	Large Fingerling	277	10.8

Table 8.1.6-4. Stocking data available for walleye in Plum Lake (1972-1991).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Walleye	Unspecified	Fingerling	1,728	3
1972	Walleye	Unspecified	Fry	100,000	1
1974	Walleye	Unspecified	Fingerling	30,070	3
1975	Walleye	Unspecified	Fingerling	7,000	3
1976	Walleye	Unspecified	Fingerling	22,000	3
1977	Walleye	Unspecified	Fingerling	7,000	3
1978	Walleye	Unspecified	Fingerling	7,000	2
1983	Walleye	Unspecified	Fingerling	16,732	3
1986	Walleye	Unspecified	Fingerling	38,640	2
1986	Walleye	Unspecified	Fry	4,200	2
1987	Walleye	Unspecified	Fingerling	44,550	2
1988	Walleye	Unspecified	Fingerling	20,000	4
1989	Walleye	Unspecified	Fingerling	25,500	2
1990	Walleye	Unspecified	Fingerling	9,996	4
1991	Walleye	Unspecified	Fingerling	22,050	2.5

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second most important reason for owning property on or near Plum Lake (Question #18). Figure 8.1.6-2 displays the fish that Plum Lake stakeholders enjoy catching the most, with walleye, bluegill/sunfish and smallmouth bass being the most popular. Approximately 50% of these same respondents believed that the quality of fishing on the lake was fair (Figure 8.1.6-3).

Approximately 60% of landowners who fish Plum Lake believe the quality of fishing is somewhat or much worse since they first started fishing the lake (Figure 8.1.6-4).

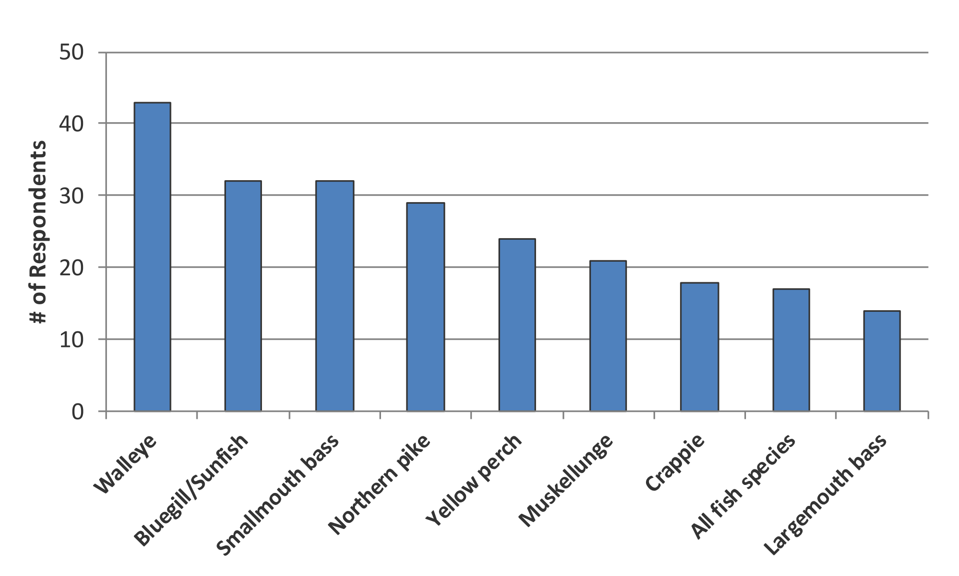


Figure 8.1.6-2. Stakeholder survey response Question #12. What species of fish do you like to catch on Plum Lake?

Figure 8.1.6-3. Stakeholder survey response Question #13. How would you describe the current quality of fishing on Plum Lake?

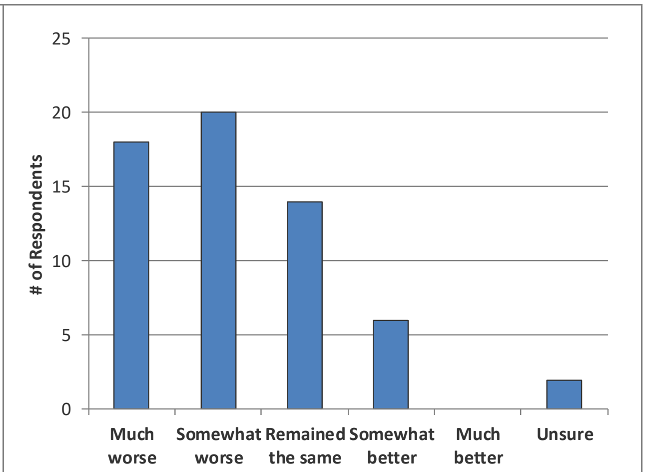


Figure 8.1.6-4. Stakeholder survey response Question #14. How has the quality of fishing changed on Plum Lake since you started fishing the lake?

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 Plum Lake during the 2012-13 and 2015-16 fishing seasons (Table 8.1.6-5). Total angler effort hours/acre was lower in 2015-16 (19.9 hours/acre) compared to the 2012-13 season (28.7 hours/acre). Anglers directed the largest amount of effort towards walleye and smallmouth bass during the 2015-16 season compared to the 2012-13 season that saw the majority of effort directed at northern pike and walleye (Table 8.1.6-5).

Table 8.1.6-5. Creel Survey data for 2012-2013 and 2015-2016 fishing seasons.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Walleye	2012	28.7	13.7	3393	3.3	1022	1	4.2	13.9
	2015	19.9	6.3	755	0.7	232	0.2	9.9	31.3
Muskellunge	2012	28.7	5.8	97	0.1	5	0	72.5	1,250.00
	2015	19.9	3.4	73	0.1	0	0	76.3	
Northern Pike	2012	28.7	7.9	3465	3.4	598	0.6	3.9	14.5
	2015	19.9	4.6	2158	1.9	472	0.4	3.4	12.5
Smallmouth Bass	2012	28.7	6.1	2699	2.6	69	0.1	2.5	104.2
	2015	19.9	6.5	2939	2.7	17	0	2.7	434.8
Largemouth Bass	2012	28.7	1.7	346	0.3	7	0	5.7	232.6
	2015	19.9	2.2	282	0.3	13	0	12.4	285.7

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above 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.

Gamefish

The gamefish present on Plum Lake represent different population dynamics depending on the species. An overview of the population estimates for walleye and muskellunge are provided in Figure 8.1.6-5 and 8.1.6-6.

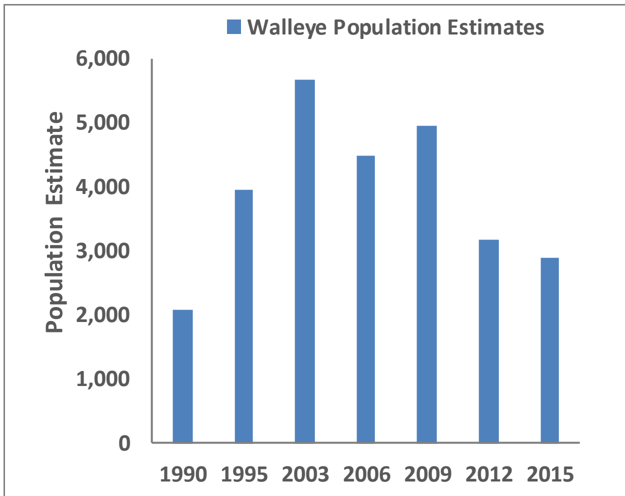


Figure 8.1.6-5. Walleye population estimates by the WDNR (WDNR 2015).

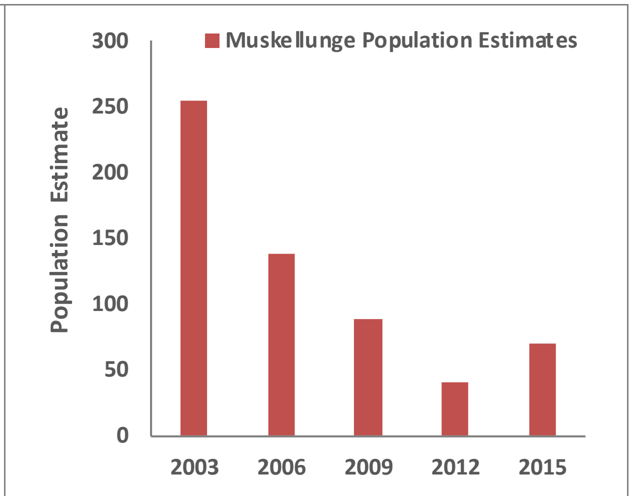


Figure 8.1.6-6. Muskellunge population estimates by the WDNR (WDNR 2015).

Panfish

The panfish present on Plum Lake represent different population dynamics depending on the species. Abundant yellow perch populations were found during the 2015 WDNR fyke net survey along with a sizeable population of bluegill (WDNR 2015).

Plum 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 8.1.6-7). Plum 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, either by spear harvest or angler 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 is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. 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 tribal or recreational harvesting means. By March 15th of each year the relevant Indian communities may declare a proportion of the total Safe Harvest on each lake; this declaration represents the maximum number of fish that can be taken by tribal spearers or netters annually (Spangler 2009). 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).

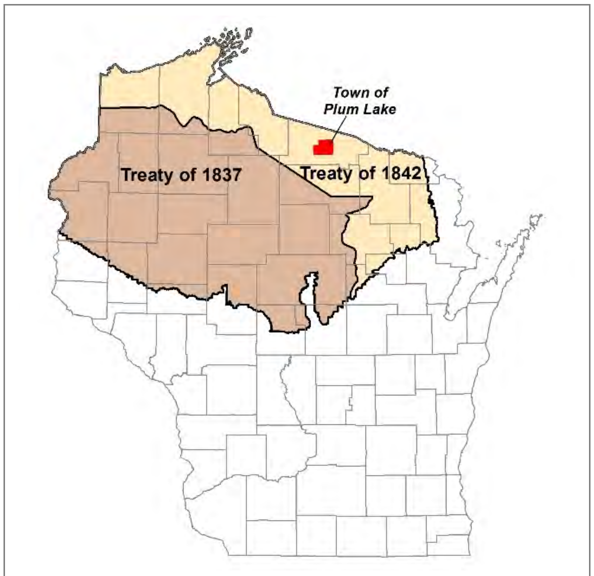


Figure 8.1.6-7. Location of Plum Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Spearers are able to 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. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Walleye open water spear harvest records are provided in Figure 8.1.6-8 from 1999 to 2017. As many as 468 walleye have been harvested from the lake in the past (2010), but the average harvest is roughly 254 fish in a given year. Spear harvesters on average have taken 99% of the declared quota. Additionally, on average 10% of walleye harvested have been female.

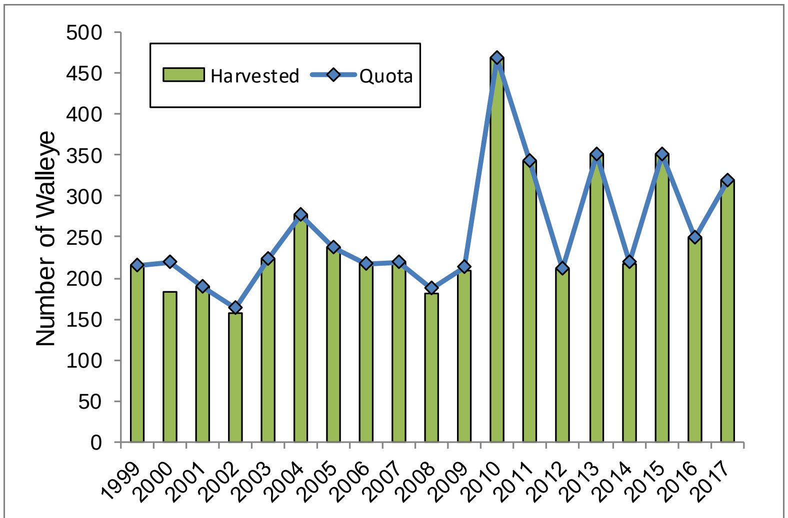


Figure 8.1.6-8. Plum Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records are provided in Figure 8.1.6-9 from 1999 to 2017. As many as 6 muskellunge have been harvested from the lake in the past (2013), however the average harvest is 3 fish in a given year. Spear harvesters on average have taken 30% of the declared quota.

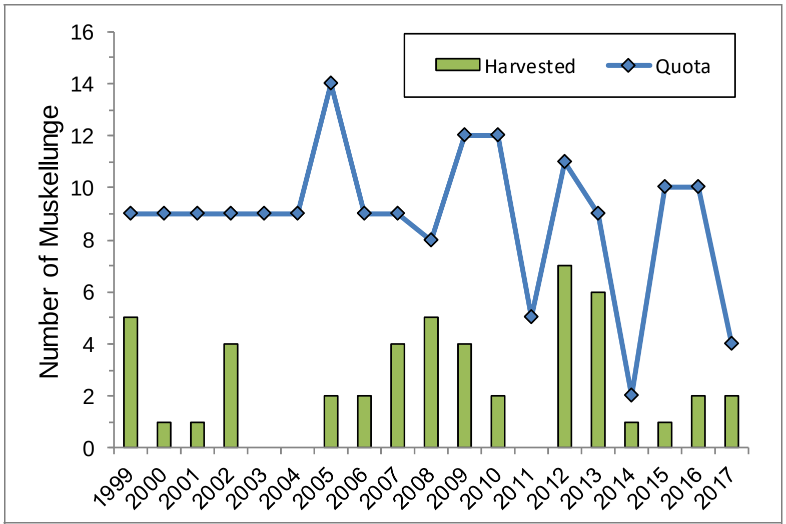


Figure 8.1.6-9. Plum Lake muskellunge spear harvest data. (GLIFWC 1999-2017).

Plum Lake Fish Habitat

Two-Story Fishery

Plum Lake is unique compared to most lakes in Wisconsin in that it is a two-story fishery. A two-story fishery is capable of supporting both a warm-water and cold-water fishery. The top-story supports warmer water species such as bass and pike. The lower-story is colder, deeper, and well oxygenated and supports species such as cisco or trout. A 2014 survey conducted by the WDNR found cisco (*Coregonus* spp.) in Plum Lake in high relative abundance (Lyons et al. 2015).

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 2017, 46% of the substrate sampled in the littoral zone of Plum Lake were soft sediments, 33% composed of sand and 20% 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 2006). A fall 2017 survey documented 281 pieces of coarse woody along the shores of Plum Lake, resulting in a ratio of approximately 21 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 and spawning areas. 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 8.1.6-3). 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 8.1.6-3. 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 8.1.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan and Haynes 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 (Neuswanger and Bozek 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 should 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 Plum Lake.

Regulations

Regulations for Plum Lake gamefish species as of April 2018 are displayed in Table 8.1.6-7. 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 8.1.6-7. WDNR fishing regulations for Plum Lake. (As of April 2018)

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	1	18"	June 16, 2018 to March 3, 2019
Largemouth bass	1	18"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 201
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	No minimum lenth, but walleye, sauger, and hybrids from 14" to 18" may not be kept, and only 1 fish over 18" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	25 pounds plus one more fish of either species in total	None	Open All Year

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

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.

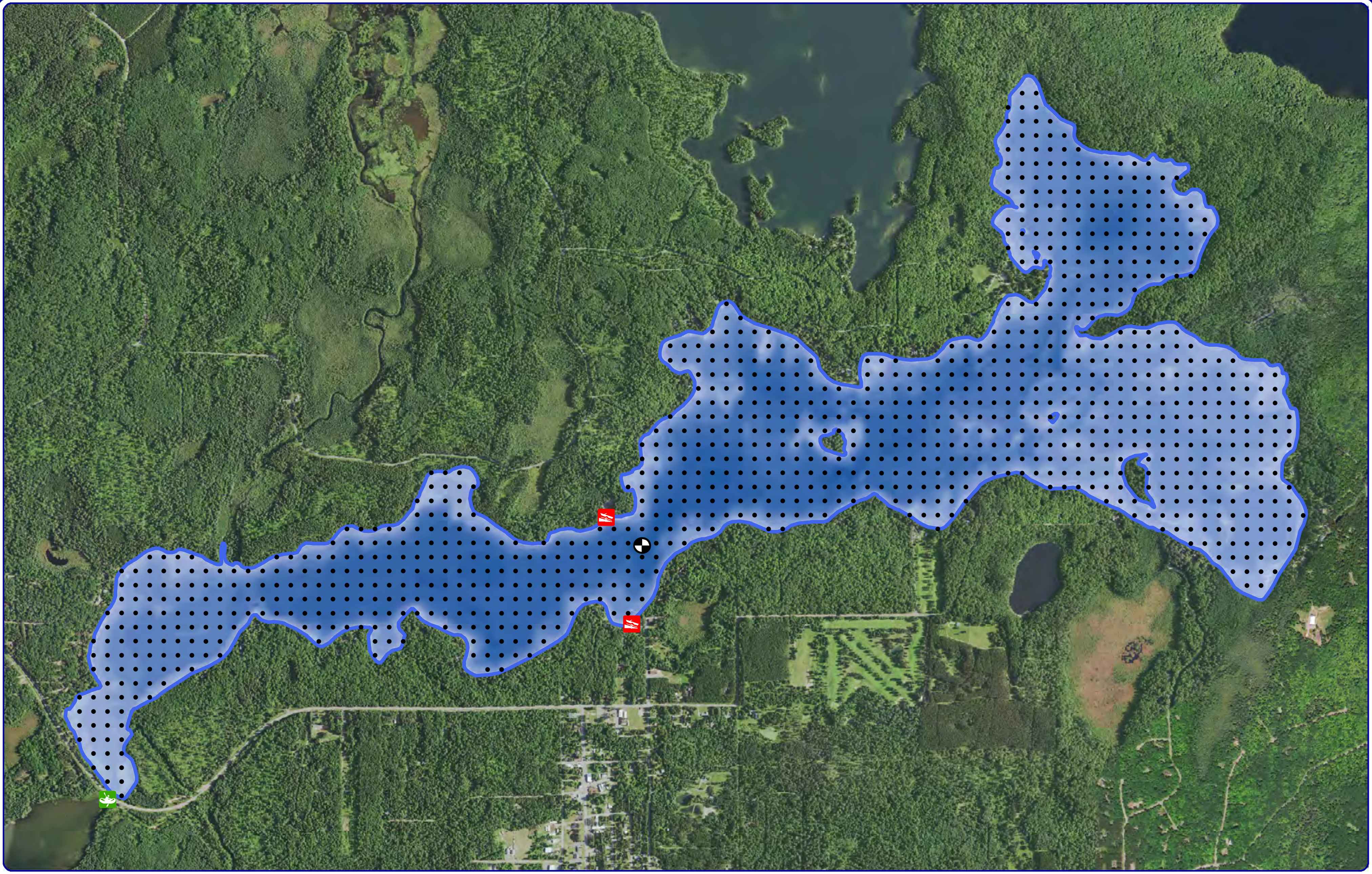
General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.1.6-10. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions 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 8.1.6-10. 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/)

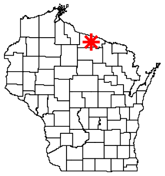


1,800

Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP, 2015
Map Date: April 17, 2018
Filename: *Map1_Plum_Location.mxd*



Project Location in Wisconsin

Legend

Plum Lake ~1,057 acres
WDNR Definition

Public Access

Carry-In Access

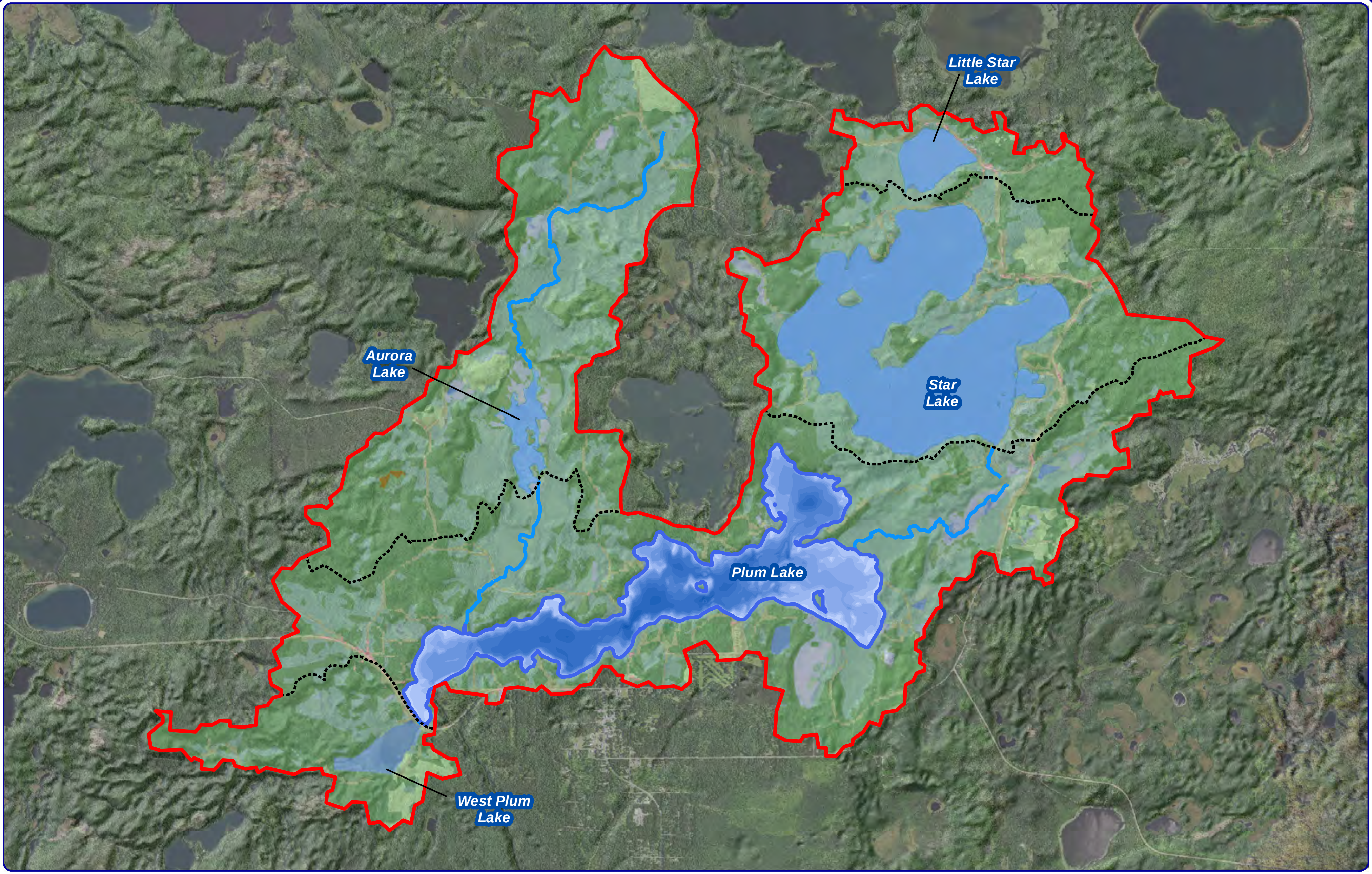
Water Quality
Sampling Location

Point-intercept Sample Location
63 meter points

Plum Lake - Map 1

Town of Plum Lake
Vilas County, Wisconsin

Project Location & Lake Boundaries



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Feet

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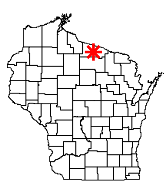
Sources:
Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP 2015
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017
Map Date: October 31, 2017
Filename: *Map2_Plum_WS.mxd*


Project Location in Wisconsin

Legend

Land Cover Types

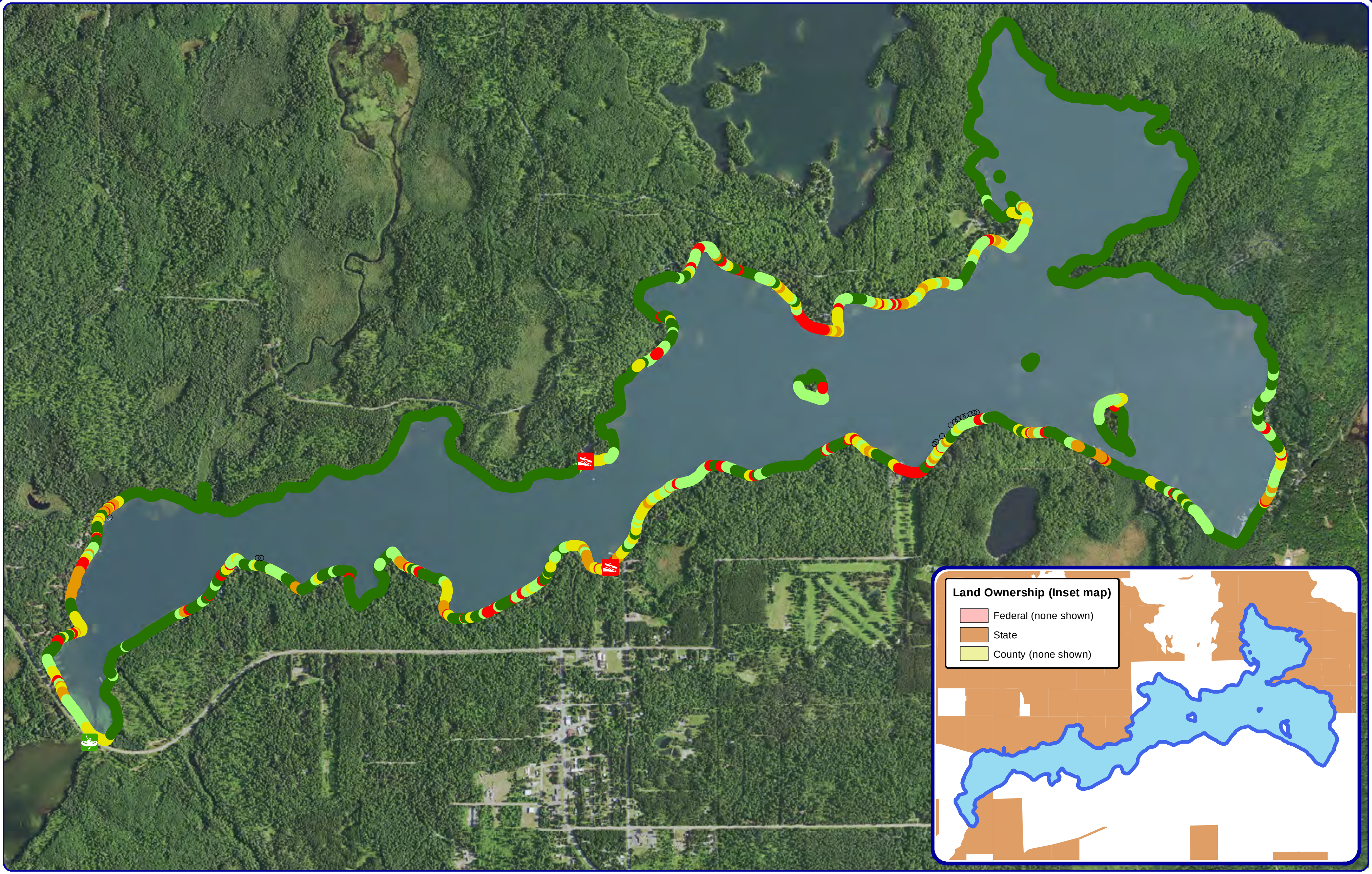
- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Medium Density Urban

- Plum Lake Watershed Boundary
- Subwatershed Boundary
- River/Stream

Plum Lake - Map 2

Town of Plum Lake
Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types



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1,900

Feet

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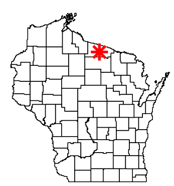
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2017
Map Date: November 2, 2017
Filename: Map3_Plum_ShorelandCondition_2017.mxd



Project Location in Wisconsin

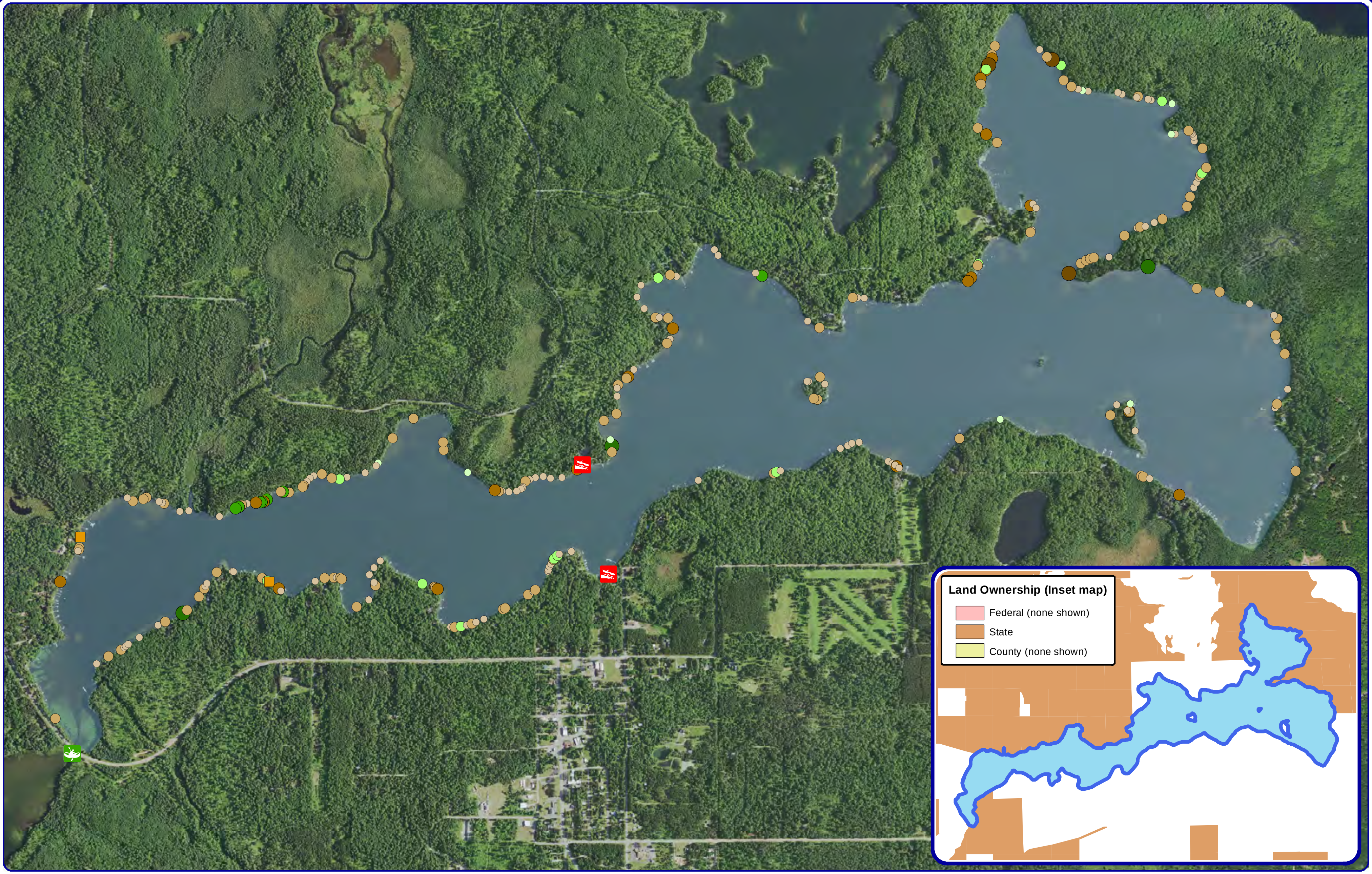
Legend

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

Seawall
Rip-Rap

Plum Lake - Map 3
Town of Plum Lake
Vilas County, Wisconsin

2017 Shoreland Condition



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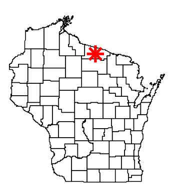
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: November 2, 2017
Filename: Map4_Plum_CWH_2017.mxd



Project Location in Wisconsin

Legend

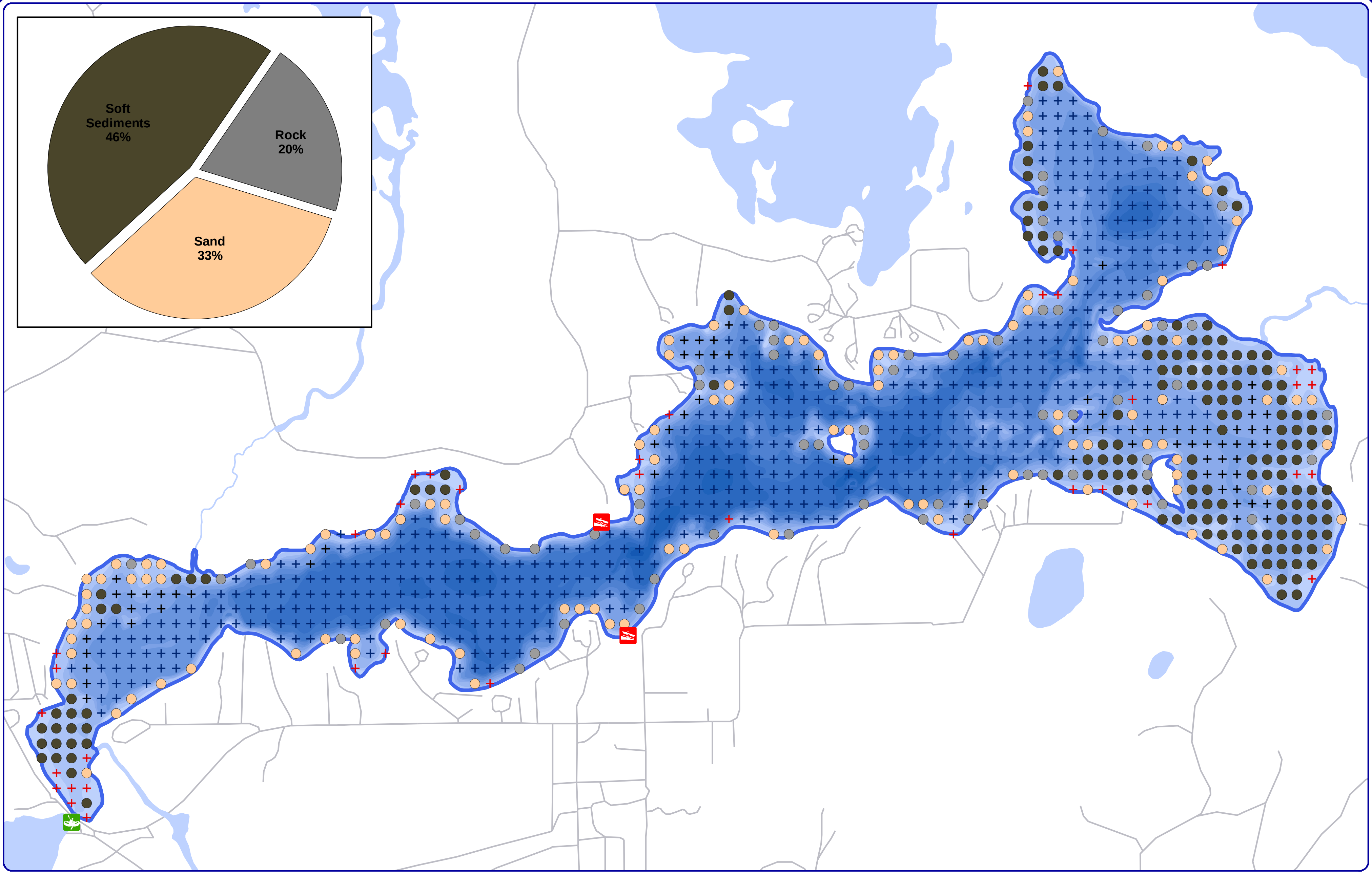
2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches (none)
Moderate Branches	Moderate Branches	Moderate Branches (none)
Full Canopy	Full Canopy	Full Canopy (none)

Plum Lake - Map 4

Town of Plum Lake

Vilas County, Wisconsin

Coarse Woody Habitat



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Feet

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920.338.8860
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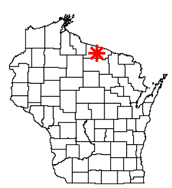
Sources:
Hydro and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: Map5_Plum_SubstratePI_2017.mxd

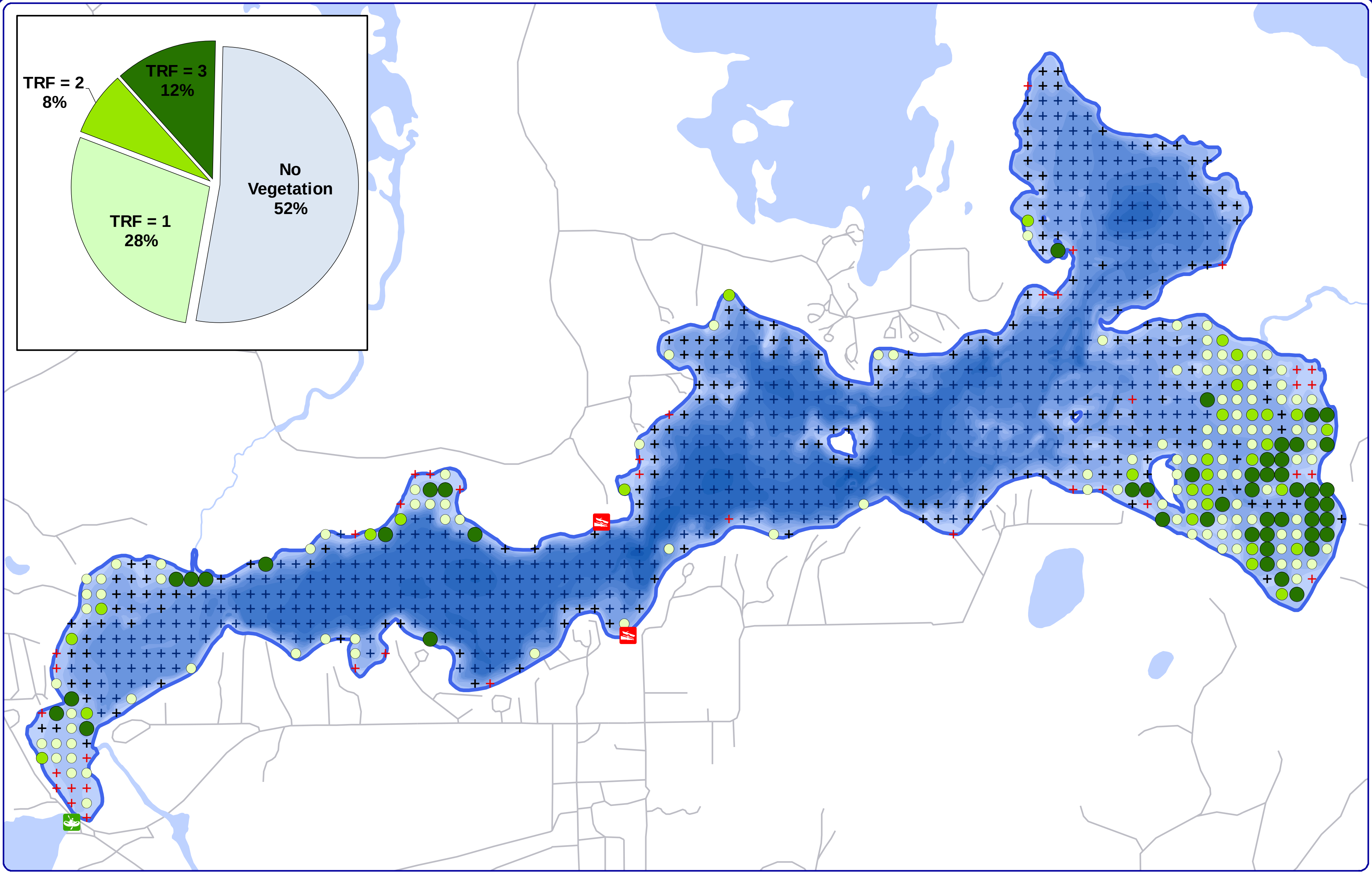

Project Location in Wisconsin

Legend

- Soft/Organic Sediments
- Rock
- Sand
- Too Deep
- Non-navigable

Plum Lake - Map 5
Town of Plum Lake
Vilas County, Wisconsin

2017 PI Survey: Substrate Types



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1,800
Feet

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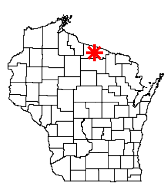
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: *Map6_Plum_TRFPI_2017.mxd*



Project Location in Wisconsin

Legend

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

Plum Lake - Map 6

Town of Plum Lake
Vilas County, Wisconsin

2017 PI Survey: Aquatic Vegetation Distribution

Legend

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Small Plant Communities
- Emergent *(Northern blue-flag unless otherwise noted)*
- Floating-leaf
- Mixed Floating-leaf & Emergent

Exotic Plant Communities
- Pale Yellow Iris

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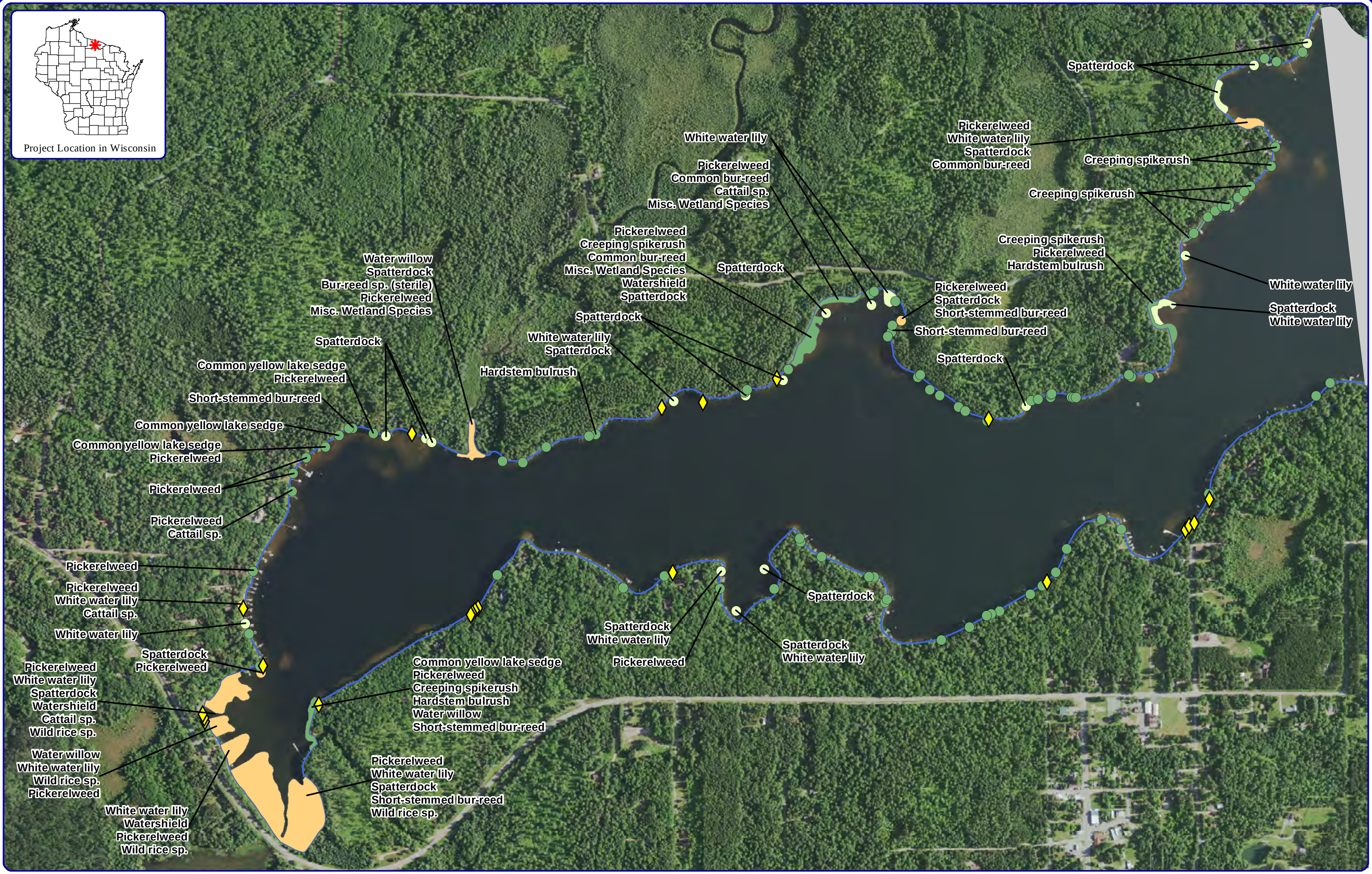
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2015
Map date: August 17, 2017
Filename: Map7_Plum_Comm_2017_East.mxd

Plum Lake - Map 7

Town of Plum Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities



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1,100
Feet

Legend

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Small Plant Communities

- Emergent *(Northern blue-flag unless otherwise noted)*
- Floating-leaf
- Mixed Floating-leaf & Emergent

Exotic Plant Communities

- Pale Yellow Iris

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De Pere, WI 54115
920.338.8860
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Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2015
Map date: August 17, 2017
Filename: Map8_Plum_Comm_2017_West.mxd

Plum Lake - Map 8

Town of Plum Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities