8.4.2 Clear Lake Watershed Assessment

Clear Lake's watershed is 3,046 acres in size. Compared to Clear Lake's size of 568 acres, this makes for a small watershed to lake area ratio of 4:1. The watershed is comprised of land cover types including forest (53%), the lake surface itself (19%), wetlands (16%), pasture/grass/rural open space (12%), rural residential areas (<1%), and urban-medium density (<1%), (Figure 8.4.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Clear Lake's residence time is approximately 2.9 years, or the water within the lake is completely replaced 0.35 times per year.

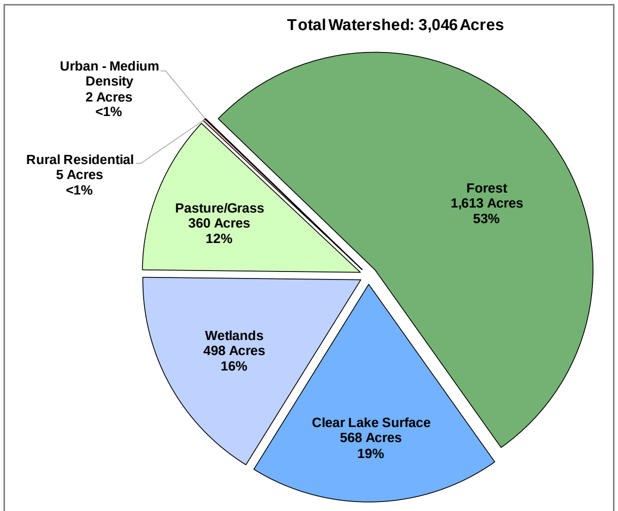


Figure 8.4.2-1. Clear Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 423 pounds of phosphorus being delivered to Clear Lake on an annual basis, approximately 152 pounds (36%) originates through direct atmospheric deposition onto the lake, 130 pounds (31%) from forests, 97 pounds (23%) from areas of pasture/grass/rural open space, and 44 pounds (10%) from wetlands (Figure 8.4.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 18 µg/L, which is essentially the same as the measured growing season average total phosphorus concentration of 20 µg/L. The similarity between the predicted and measured total phosphorus concentrations in Clear Lake is an indication that this is an accurate model of the lake's watershed and that there are no significant, unaccounted sources of phosphorus entering the lake.

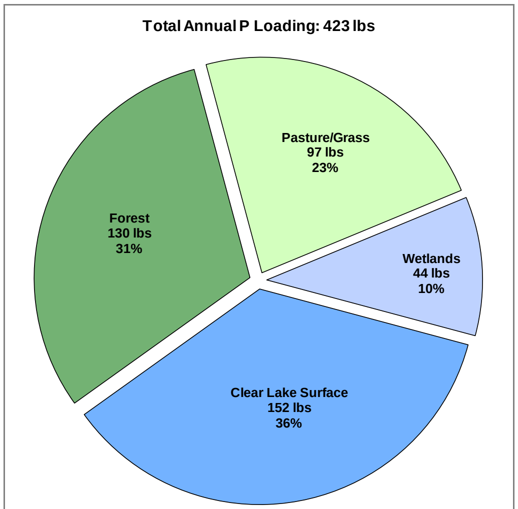


Figure 8.4.2-2. Clear Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the WiLMS model for Clear Lake's watershed, scenarios can be run to determine how Clear Lake's water quality would change given alterations to its watershed. For example, if 25% of the forests within Clear Lake's watershed were converted to row crop agriculture, phosphorus concentrations would be predicted to increase from the current growing season concentration of 18 µg/L to 27 µg/L. This increase in total phosphorus would result in chlorophyll-*a* concentrations increasing from the current growing season average of 6 µg/L to 10 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 9.2 feet to 6.2 feet. This modelling illustrates the importance of the natural land cover types within Clear Lake's watershed in maintaining the lake's excellent water quality.

8.4.3 Clear Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 late summer of 2013, Clear Lake's immediate shoreline was assessed in terms of its development. Clear Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.3 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.4.3-1). This constitutes about 85% of Clear 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, 0.5 miles of urbanized and developed–unnatural shoreline (9%) was observed. If restoration of the Clear 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. Clear Lake Map 1 displays the location of these shoreline lengths around the entire lake.

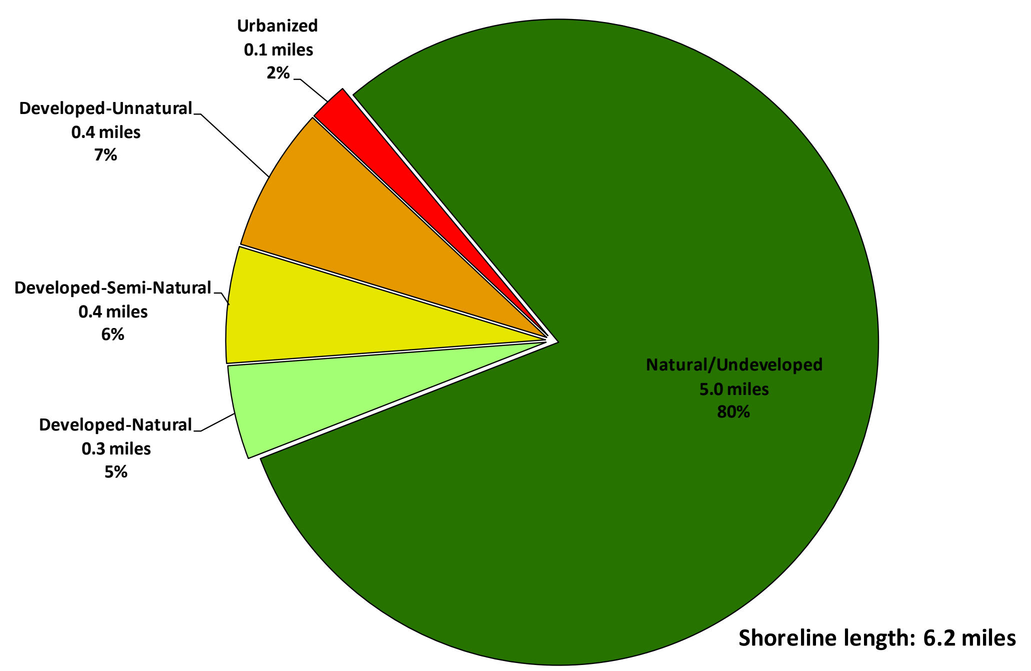


Figure 8.4.3-1. Clear Lake shoreland categories and total lengths. Based upon a late summer 2013 survey. Locations of these categorized shorelands can be found on Clear Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Clear Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 246 total pieces of coarse woody habitat were observed along 6.2 miles of shoreline (Clear Lake Map 2), which gives Clear Lake a coarse woody habitat to shoreline mile ratio of 40:1 (Figure 8.4.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Two hundred and one pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, forty-one pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and four instances of clusters 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 Clear 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 98 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 Clear Lake falls above the 75th percentile of these 98 lakes (Figure 8.4.3-2).

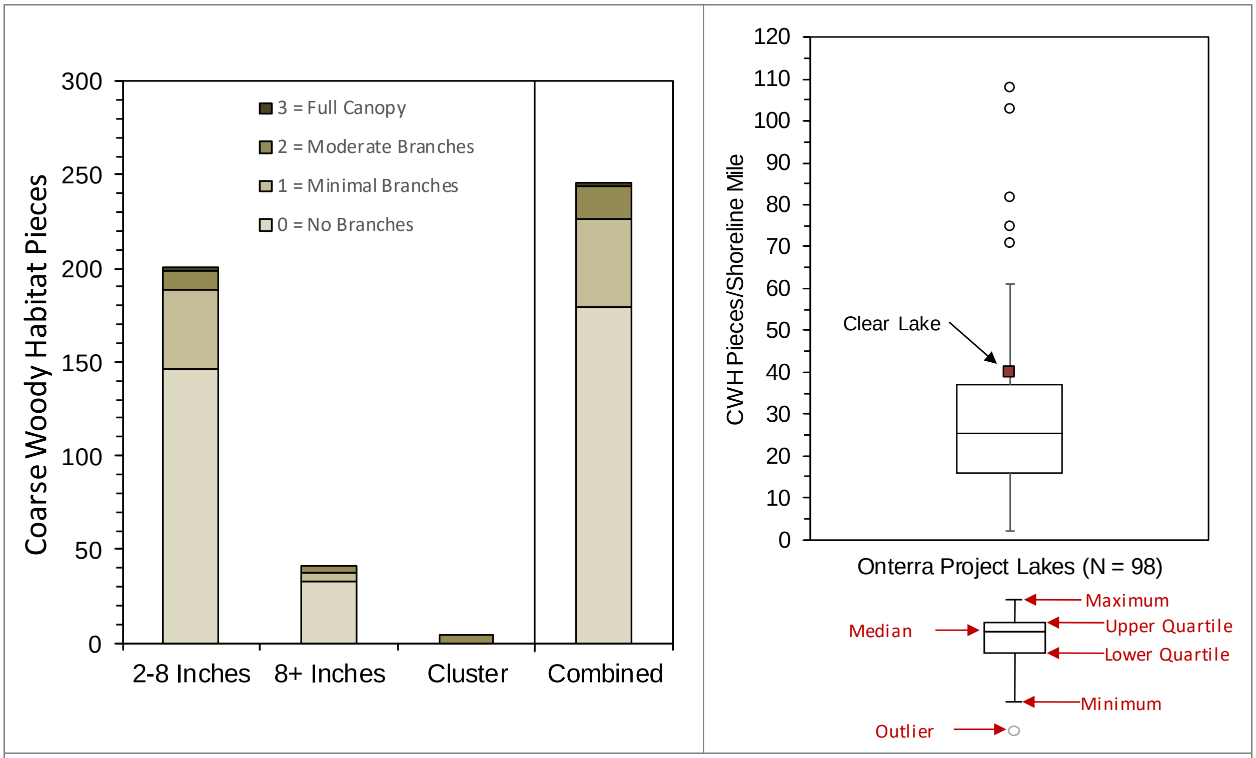


Figure 8.4.3-2. Clear Lake coarse woody habitat survey results. Based upon a late summer 2013 survey. Locations of the Clear Lake coarse woody habitat can be found on Clear Lake Map 2.

8.4.4 Clear Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Clear Lake on June 25, 2013. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Clear Lake on July 31, 2013 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 55 species of native aquatic plants were located in Clear Lake (Table 8.4.4-1). 29 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 26 species were observed incidentally during visits to Clear Lake.

Aquatic plants were found growing to a depth of 21 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 323 point-intercept locations sampled within the littoral zone, roughly 62% contained aquatic vegetation. Clear Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays that are more likely to hold organic substrates. Approximately 34% of the point-intercept sampling locations where sediment data was collected at were sand, 54% consisted of a fine, organic substrate (muck) and 12% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.4.4-1. Aquatic plant species located in Clear Lake during 2013 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2013 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Carex vesicaria	Blister sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis sp.	Spikerush sp.	N/A	I
	Equisetum fluviatile	Water horsetail	7	X
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Schoenoplectus pungens	Three-square rush	5	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Typha spp.	Cattail spp.	1	I
	Zizania sp.	Wild rice Species	8	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	I
	Nymphaea odorata	White water lily	6	X
	Polygonum amphibium	Water smartweed	5	I
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium natans	Little bur-reed	9	I
	Sparganium androcladum	Shining bur-reed	8	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elatine minima	Waterwort	9	I
	Elodea nuttallii	Slender waterweed	7	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes sp.	Quillwort species	N/A	X
	Myriophyllum verticillatum	Whorled watermilfoil	8	I
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	I
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Ranunculus aquatilis	White water-crowfoot	8	I
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia intermedia	Flat-leaf bladderwort	9	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	I
	Sagittaria cuneata	Arum-leaved arrowhead	7	I

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

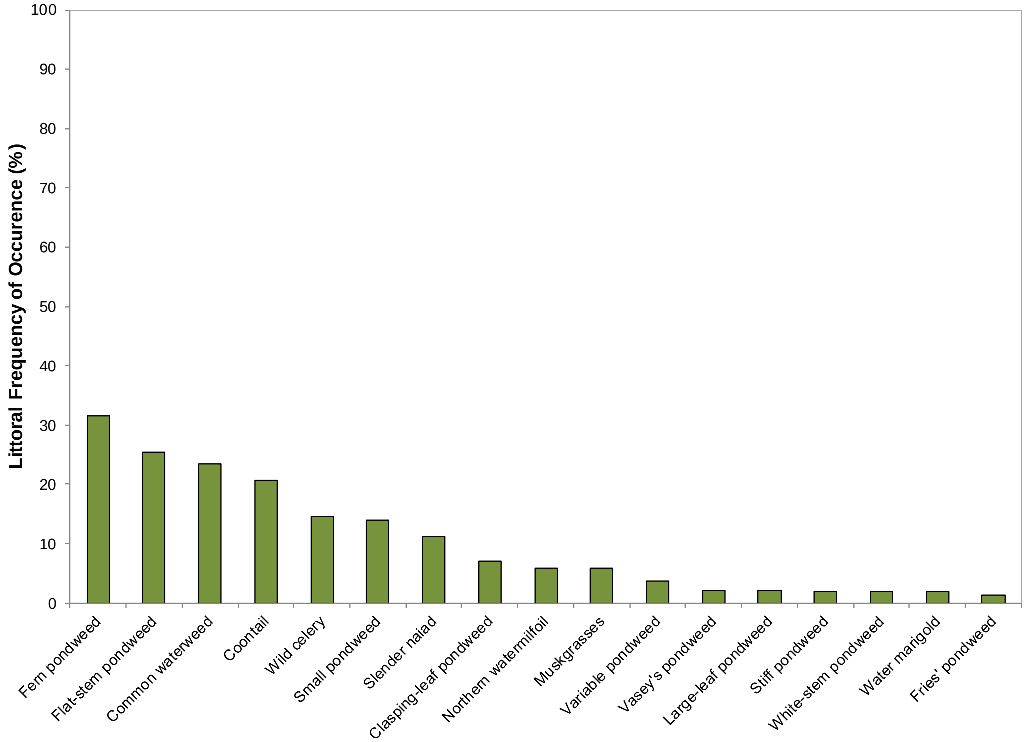


Figure 8.4.4-1. Clear Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2013 point-intercept survey. Please note that only species with a frequency of occurrence greater than 2% are depicted.

Figure 8.4.4-1 (above) shows that fern pondweed, flat-stem pondweed and common waterweed were the most frequently encountered plants within Clear Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms. Common waterweed is an interesting plant in that although it sometimes produces root-like structures that bury themselves into the sediment, it is largely an unrooted plant that can obtain nutrients directly from the water. As a result, this plant's location in a lake can be dependent upon water movement.

One species discovered during 2013 studies, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory as a species of special concern in Wisconsin due to uncertainty regarding its distribution and abundance in Wisconsin. Vasey's pondweed is typically found in bays of large soft-water lakes as well as in rivers and ponds.

During aquatic plant inventories, 55 species of native aquatic plants (including incidentals) were found in Clear Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Clear Lake's plant community (0.90) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 fern pondweed was found at 32% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from Clear Lake, 16 of them would be fern pondweed. This distribution can be observed in Figure 8.4.4-2, where together 11 native species account for 91% of the aquatic plant population within Clear Lake, while the other 18 species account for the remaining 11%. 26 additional native species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.4.4-1 as incidentals.

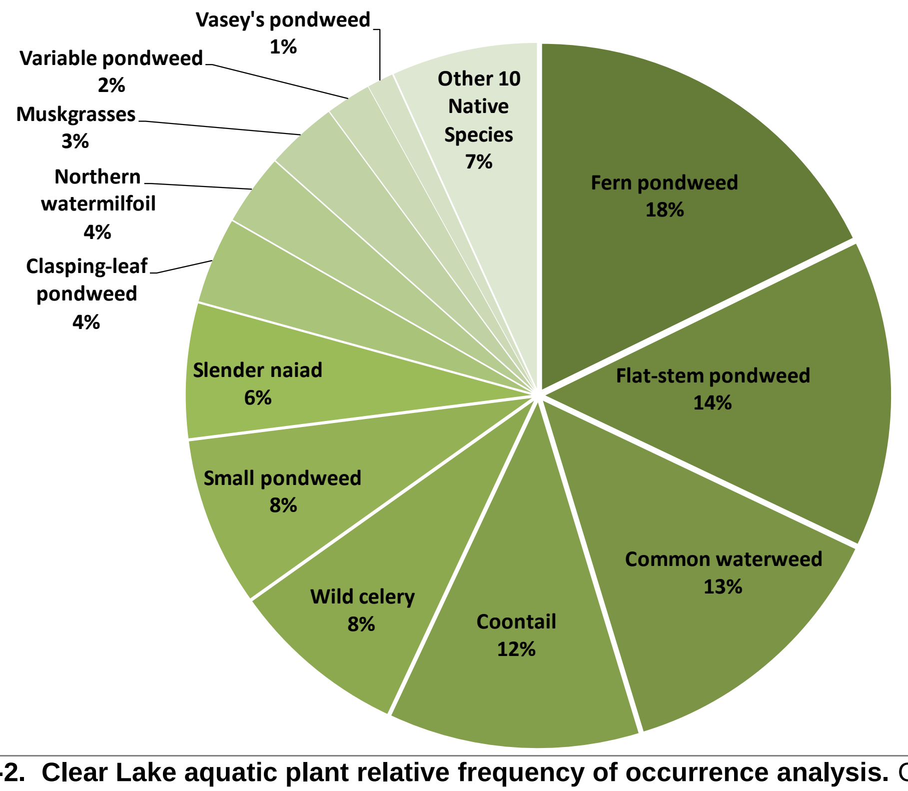


Figure 8.4.4-2. Clear Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2013 point-intercept survey.

Clear Lake's average conservatism value (6.7) is higher than the state (6.0) and equal to the Northern Lakes and Forests ecoregion (6.7) median. This indicates that the plant community of Clear Lake is indicative of a very moderately disturbed system. Combining Clear Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 36.1 which is above the median values of the ecoregion and state.

The quality of Clear Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2013 community map indicates that approximately 62.2 acres of the lake contains these types of plant communities (Clear Lake Map

4, Table 8.4.4-2). 23 floating-leaf and emergent species were located on Clear Lake (Table 8.4.4-1), all of which provide valuable wildlife habitat.

Table 8.4.4-2. Clear Lake acres of emergent and floating-leaf plant communities from the 2013 community mapping survey.

Plant Community	Acres
Emergent	58.1
Floating-leaf	3.6
Mixed Floating-leaf and Emergent	0.5
Total	62.2

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Clear Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

8.4.5 Clear 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 and within each lake's individual report section 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 Clear 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.4.5-1). 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. Clear Lake has been stocked from 1973 to 2016 with muskellunge and walleye (Table 8.4.5-1).

Photograph 8.4.5-1. Fingerling Muskellunge.

Table 8.4.5-1. Stocking data available in Clear Lake (1976-2016).

Lake	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Clear Lake	1976	Walleye	Unspecified	Fingerling	26,000	3
Clear Lake	1973	Muskellunge	Unspecified	Fingerling	2,562	11
Clear Lake	1977	Muskellunge	Unspecified	Fingerling	1,000	7
Clear Lake	1981	Muskellunge	Unspecified	Fingerling	415	12
Clear Lake	1983	Muskellunge	Unspecified	Fingerling	250	11
Clear Lake	1985	Muskellunge	Unspecified	Fingerling	500	11
Clear Lake	1988	Muskellunge	Unspecified	Fingerling	500	11
Clear Lake	1989	Muskellunge	Unspecified	Fingerling	200	9
Clear Lake	1990	Muskellunge	Unspecified	Fingerling	500	9
Clear Lake	1991	Muskellunge	Unspecified	Fingerling	250	11.5
Clear Lake	1992	Muskellunge	Unspecified	Fingerling	250	11
Clear Lake	1993	Muskellunge	Unspecified	Fingerling	500	10
Clear Lake	1997	Muskellunge	Unspecified	Large Fingerling	64	10.5
Clear Lake	1999	Muskellunge	Unspecified	Large Fingerling	250	11.8
Clear Lake	2002	Muskellunge	Unspecified	Large Fingerling	400	10.1
Clear Lake	2004	Muskellunge	Unspecified	Large Fingerling	400	10.5
Clear Lake	2006	Muskellunge	Upper Wisconsin River	Large Fingerling	400	9.9
Clear Lake	2008	Muskellunge	Upper Wisconsin River	Large Fingerling	400	10.1
Clear Lake	2010	Muskellunge	Upper Wisconsin River	Large Fingerling	243	12.5
Clear Lake	2012	Muskellunge	Upper Wisconsin River	Large Fingerling	400	10.2
Clear Lake	2014	Muskellunge	Upper Wisconsin River	Large Fingerling	396	10.4
Clear Lake	2016	Muskellunge	Upper Wisconsin River	Large Fingerling	360	10.9

Clear Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.4.5-1 from 1999 to 2017. As many as 192 walleye have been harvested from the lake in the past (2015), but the average harvest is roughly 116 fish in a given year. Spear harvesters on average have taken 99% of the declared quota. Additionally, on average 6% of walleye harvested have been female.

Muskellunge open water spear harvest records are provided in Figure 8.4.5-2 from 1999 to 2017. As many as 8 muskellunge have been harvested from the lake in the past (2010), however the average harvest is 4 fish in a given year. Spear harvesters on average have taken 53% of the declared quota.

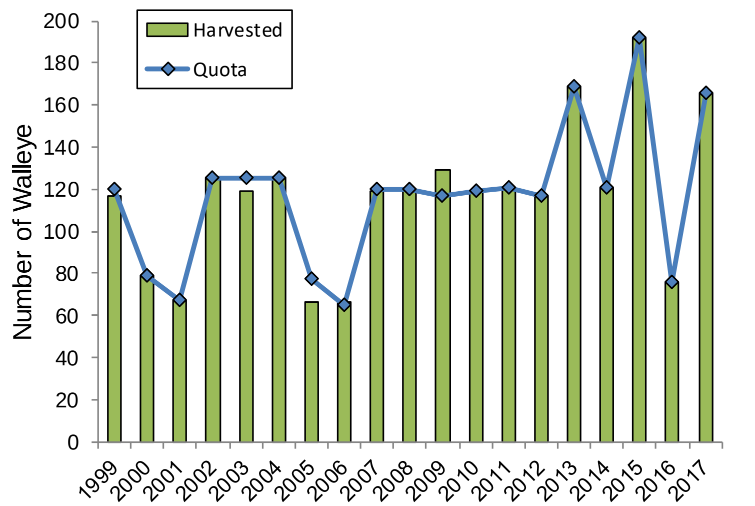


Figure 8.4.5-1. Clear Lake walleye spear harvest data. (GLIFWC 1999-2017).

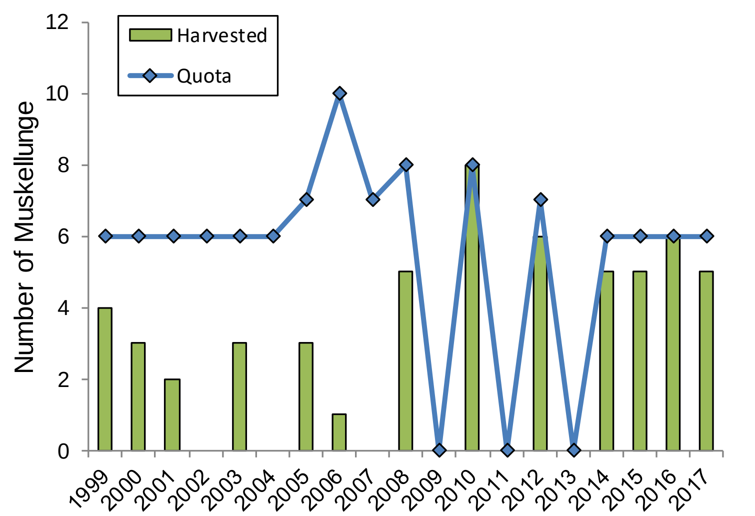
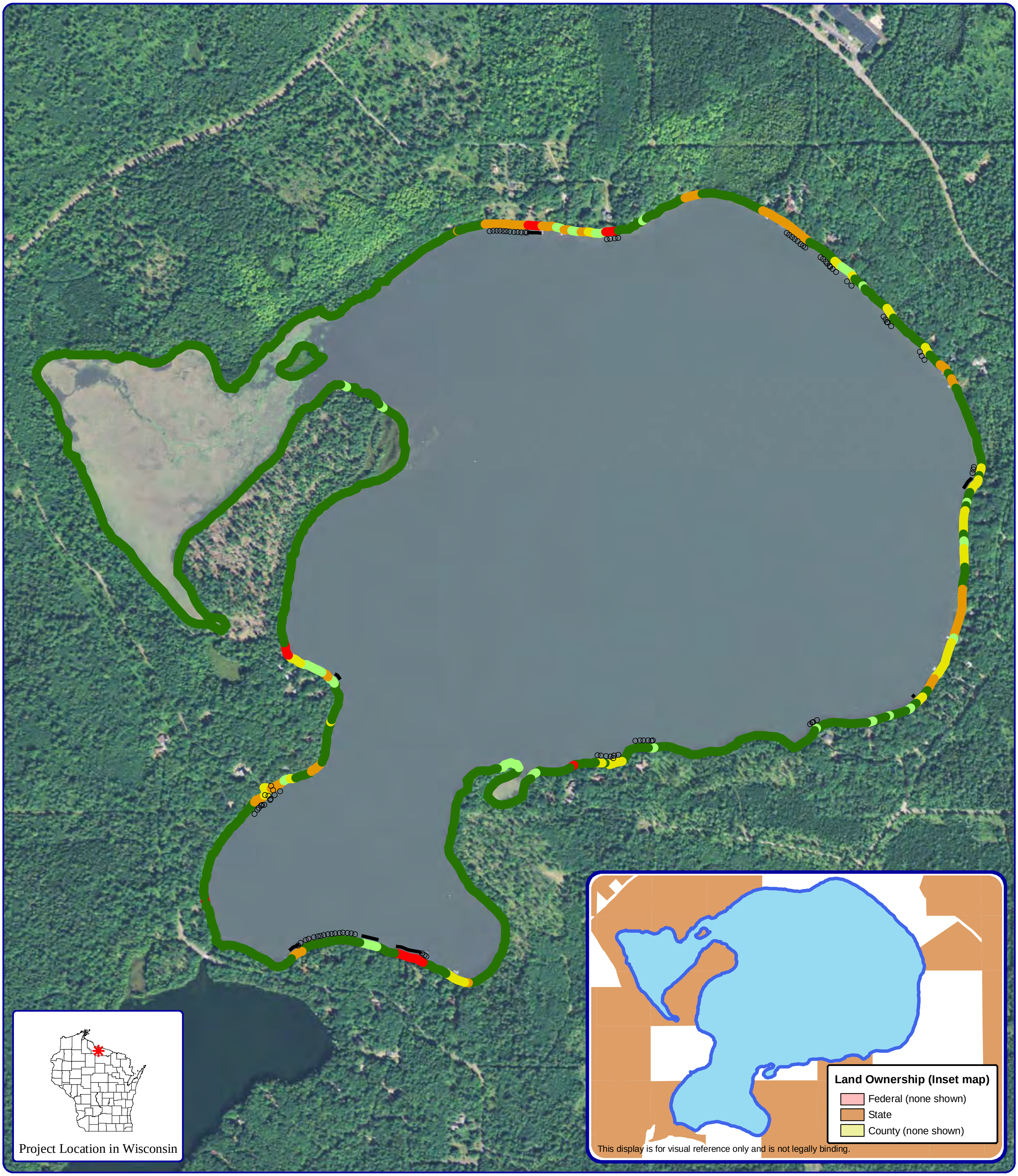


Figure 8.4.5-2. Clear Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



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www.onterra-eco.com

Sources:
Hydro, State Land and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2013
Map date: October 14, 2014
Filename: *Clear_ShorelandCondition_2014.mxd*

Legend

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

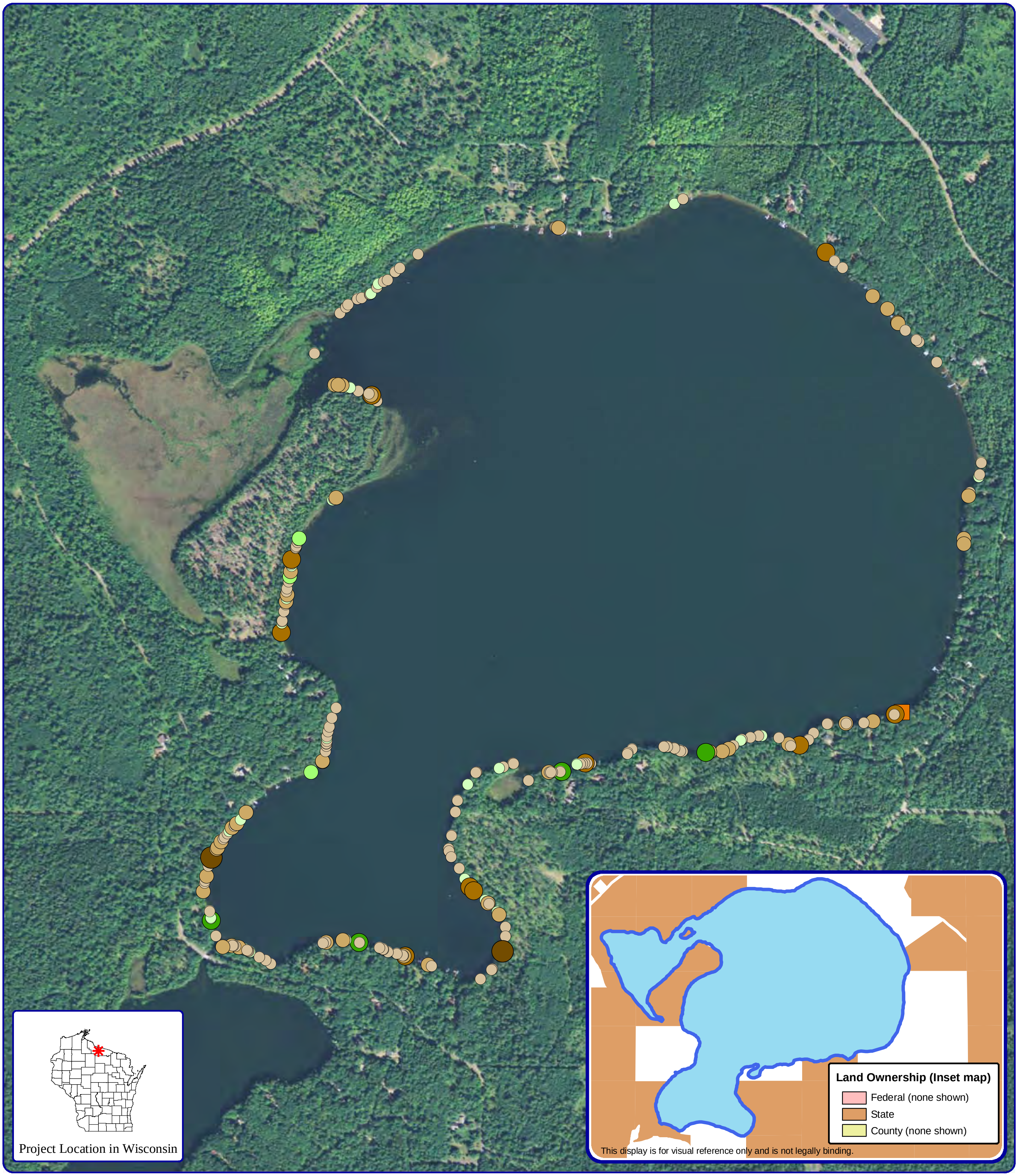
Seawall

- Masonary/Metal/Wood
- Rip-Rap

Clear Lake - Map 1

Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Shoreland Condition



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

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

Cluster of Pieces
- No Branches (none)
- Minimal Branches (none)
- Moderate Branches
- Full Canopy (none)

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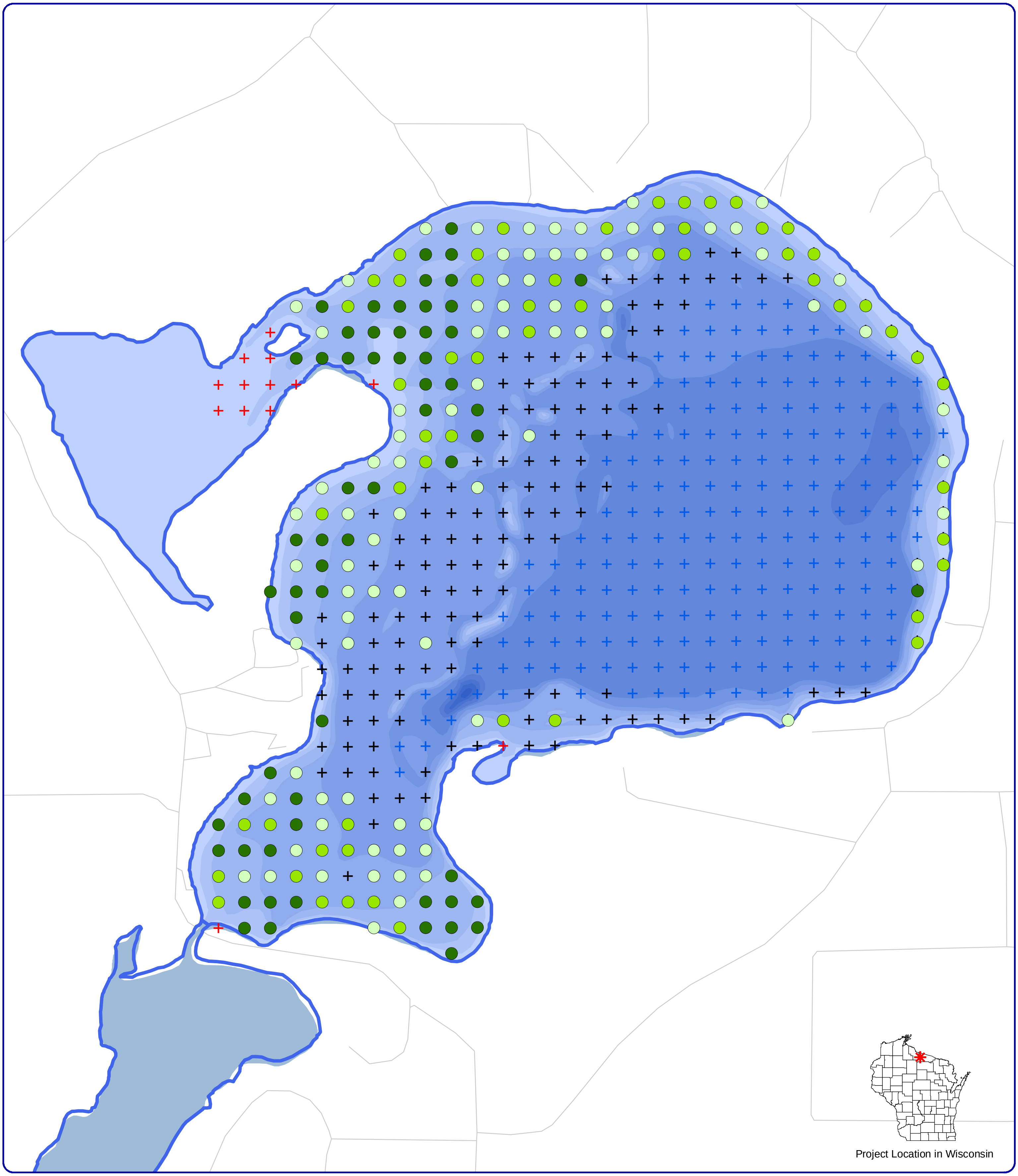
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2013
Map date: October 6, 2014
Filename: *Map2_Clear_CWH_2014.mxd*

Clear Lake - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Coarse Woody Habitat



Legend

2013 Point-intercept Survey

- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- No Vegetation
- Non-navigable
- Deep

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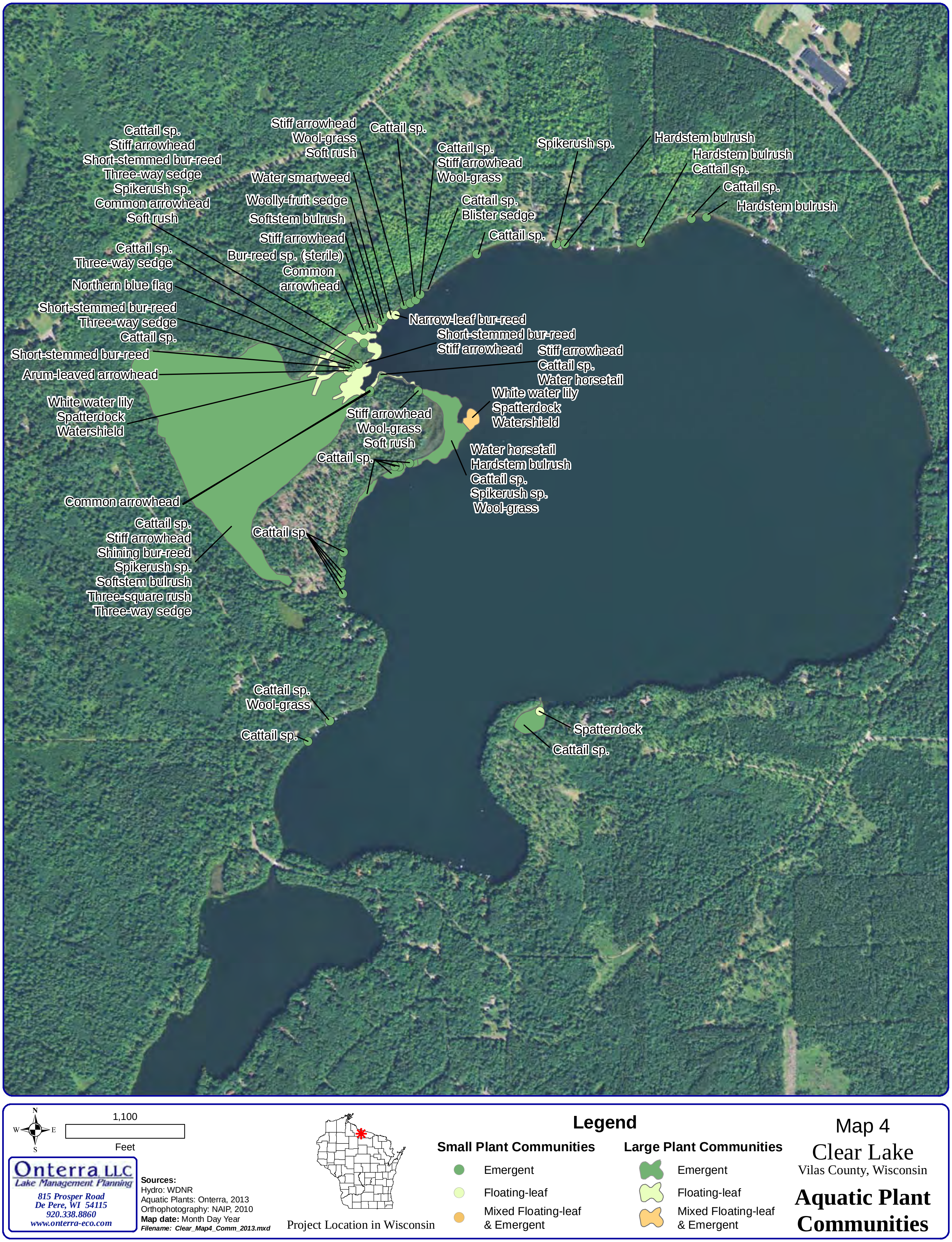
Sources:
Roads and Hydro: WDNR
Map Date: December 16, 2014
Filename: Clear_TRFPI_2013.mxd

Clear Lake - Map 3

Manitowish Waters
Chain of Lakes

Vilas County, Wisconsin

Aquatic Plant Distribution



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Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
Map date: Month Day Year
Filename: *Clear_Map4_Comm_2013.mxd*

Map 4
Clear Lake
Vilas County, Wisconsin
Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Fawn Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.5 Fawn Lake

An Introduction to Fawn Lake

Fawn Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 16 feet, a mean depth of 7 feet, and a surface area of approximately 73 acres. The lake is fed via Clear Lake to the north and empties into Stone Lake to the south. The lake is considered to be mesotrophic and its watershed encompasses approximately 3,440 acres. In 2013, 43 native aquatic plant species were found in the lake, of which fern pondweed (*Potamogeton robbinsii*) was the most common. No aquatic invasive plant species were observed growing in or along the shorelines of Fawn Lake in 2013.

Field Survey Notes

Much aquatic plant growth within lake during summer surveys. Shoreline is largely undeveloped and a fair amount of coarse woody structure observed (see right).

Flow under the bridge that connects Clear Lake to Fawn Lake was able to keep open water during winter sampling visit.

Photo 8.5. Coarse Woody Habitat on Fawn Lake, Vilas County

Lake at a Glance* – Fawn Lake

Morphology	
Acreage	73
Maximum Depth (ft)	16
Mean Depth (ft)	7
Volume (acre-feet)	508
Shoreline Complexity	5.7
Vegetation	
Curly-leaf Survey Date	June 25, 2013
Comprehensive Survey Date	July 31, 2013
Number of Native Species	43
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	-
Simpson's Diversity	0.90
Average Conservatism	6.8
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	46:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.5.1 Fawn Lake Water Quality

Water quality data was collected from Fawn Lake on six occasions in 2013/2014. 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 2013/2014, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2013, average summer phosphorus concentrations (19.2 µg/L) were less than the median value (33.0 µg/L) for other shallow, lowland drainage lakes in the state (Figure 8.5.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Excellent* for a shallow, lowland drainage lake.

Total phosphorus surface values from 2013 are compared with bottom-lake samples collected during this same time frame in Figure 8.5.1-2. As displayed in this figure, on several occasions surface and bottom total phosphorus concentrations were similar. However, on some occasions, namely during August of 2013 and February of 2014, the bottom phosphorus concentrations were much greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.5.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a natural process discussed further in the Manitowish Waters Chain of Lakes-wide document. While this process may be contributing some phosphorus to Fawn Lake's water column, this occurs primarily during the winter months and the impacts of nutrient loading are not apparent in the lake's overall water quality. As previously mentioned, Fawn Lake's surface water total phosphorus values are slightly lower than the median value for comparable lakes in Wisconsin, and rank as *Excellent* overall.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (6.7 µg/L) were slightly lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.5.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2013 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

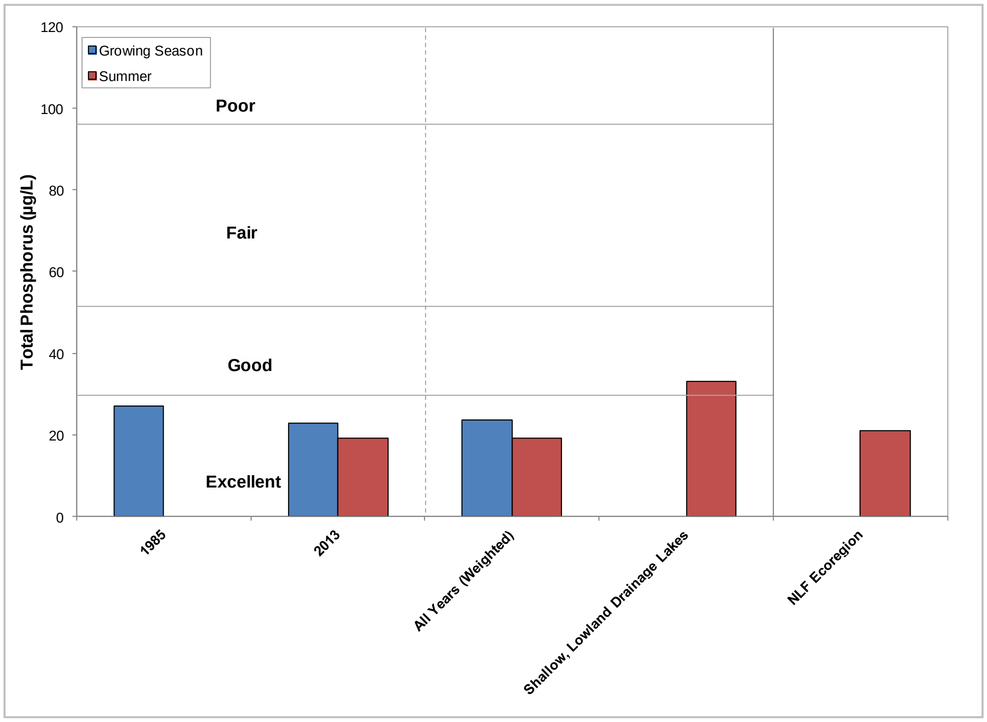


Figure 8.5.1-1. Fawn Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

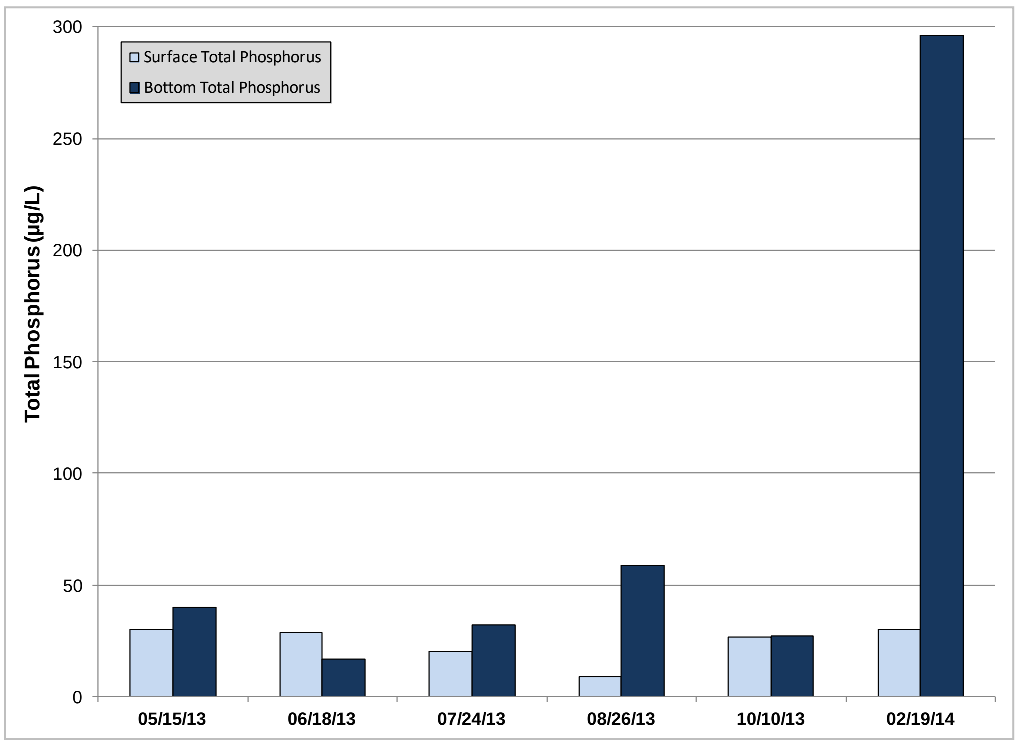


Figure 8.5.1-2. Fawn Lake surface and bottom total phosphorus values, 2013-2014. Anoxia was observed in the hypolimnion of the lake during August and February sampling visits.

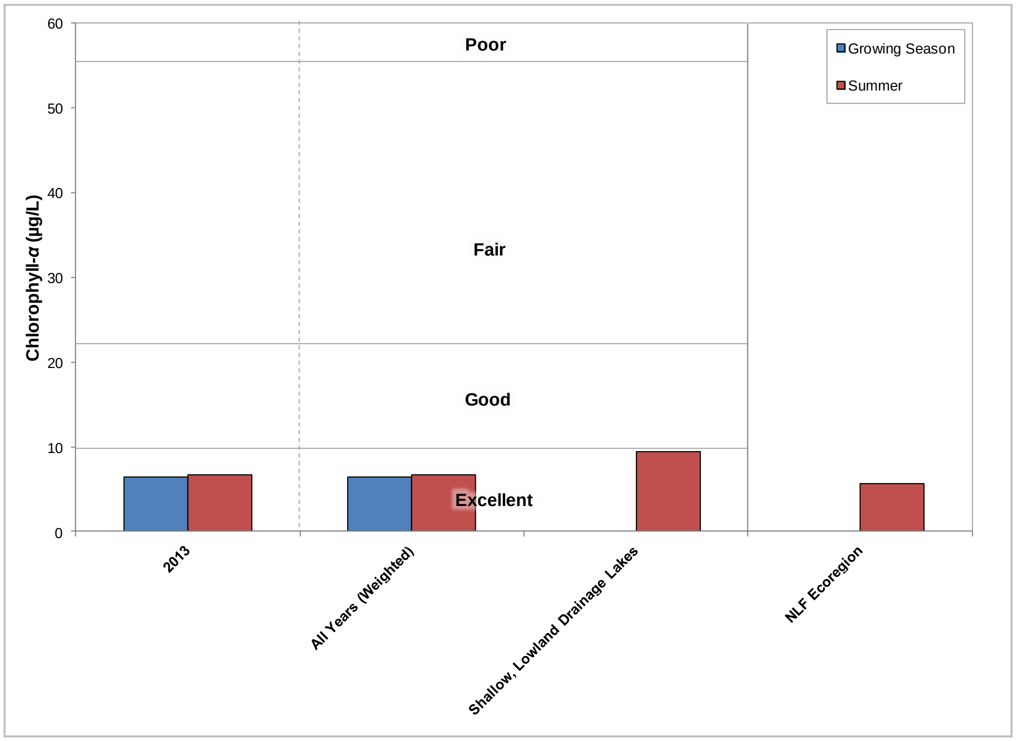


Figure 8.5.1-3. Fawn Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The clarity of Fawn Lake's water can be described as *Excellent* during the summer months in which data has been collected (Figure 8.5.1-4). A weighted average over this timeframe is greater than the median value for other shallow, lowland drainage lakes in the state and is also larger than the regional median. Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Fawn Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Fawn Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake. Because of its smaller watershed relative to the other Manitowish Waters Chain of Lakes, Fawn Lake's water may be less stained.

"True color" measures the dissolved organic materials in water. Water samples collected in May and July of 2015 were measured for this parameter, and were found to be 15 Platinum-cobalt units (Pt-co units, or PCU). Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

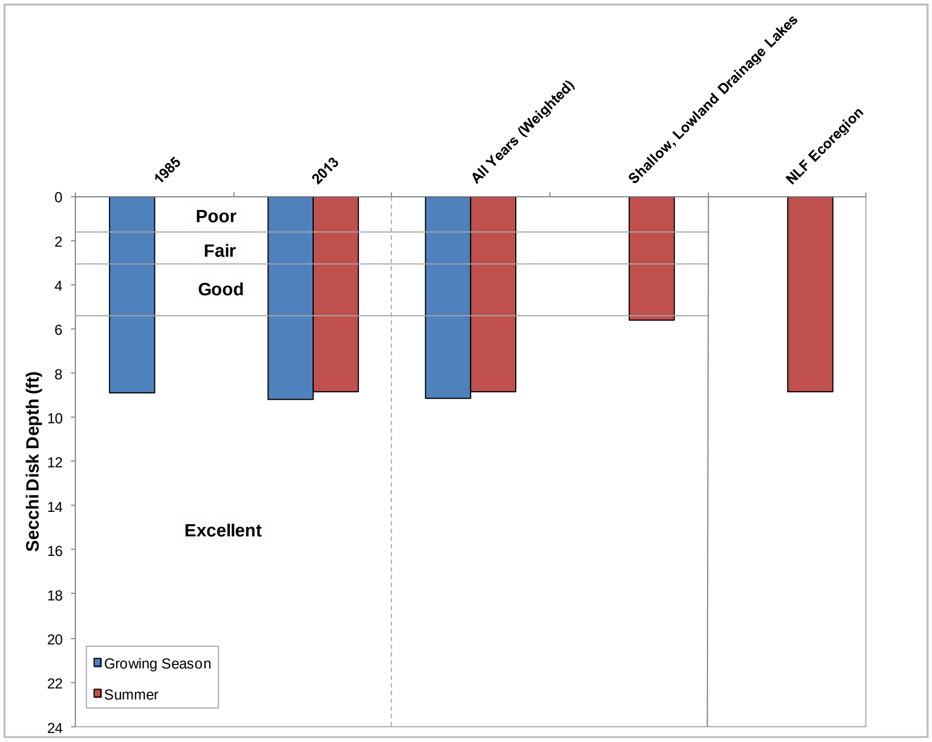


Figure 8.5.1-4. Fawn Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Fawn Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.5.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Fawn Lake is in a mesotrophic state.

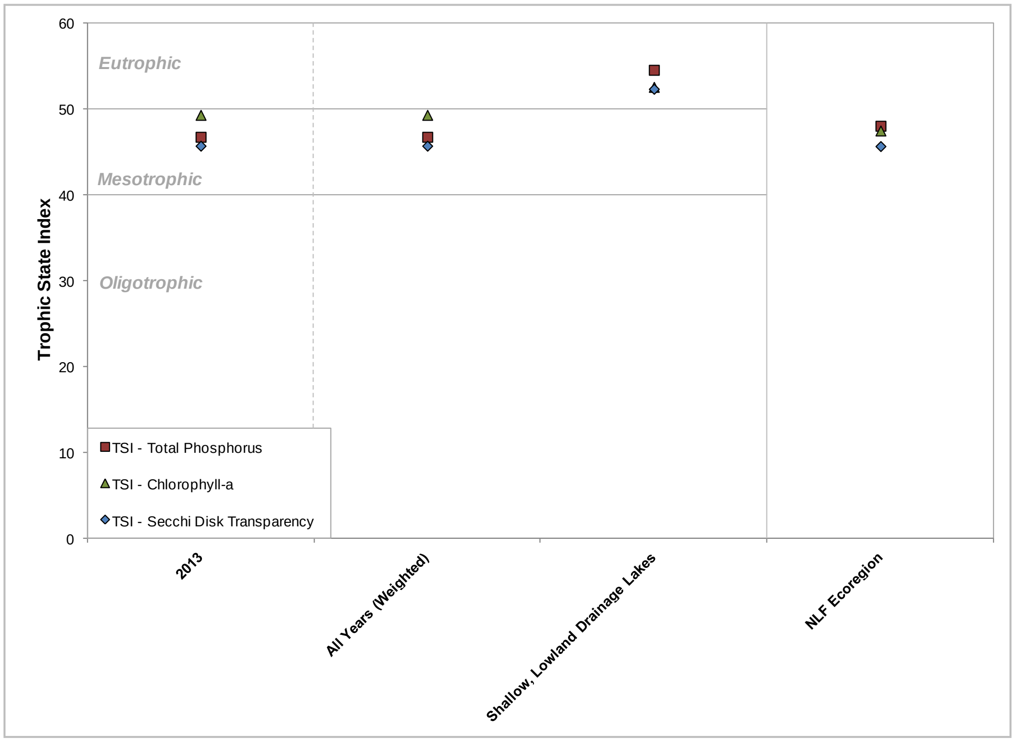


Figure 8.5.1-5. Fawn Lake, state-wide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Fawn Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Fawn Lake by Onterra staff. Graphs of those data are displayed in Figure 8.5.1-6 for all sampling events.

Fawn Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the shallow lake likely mixes often as well. The bottom of the lake was found to become void of oxygen (anoxic) several times during the year. This occurrence is not uncommon in Wisconsin lakes, as bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. If the lake mixes completely, oxygen will be reintroduced to the lower levels of the water column.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

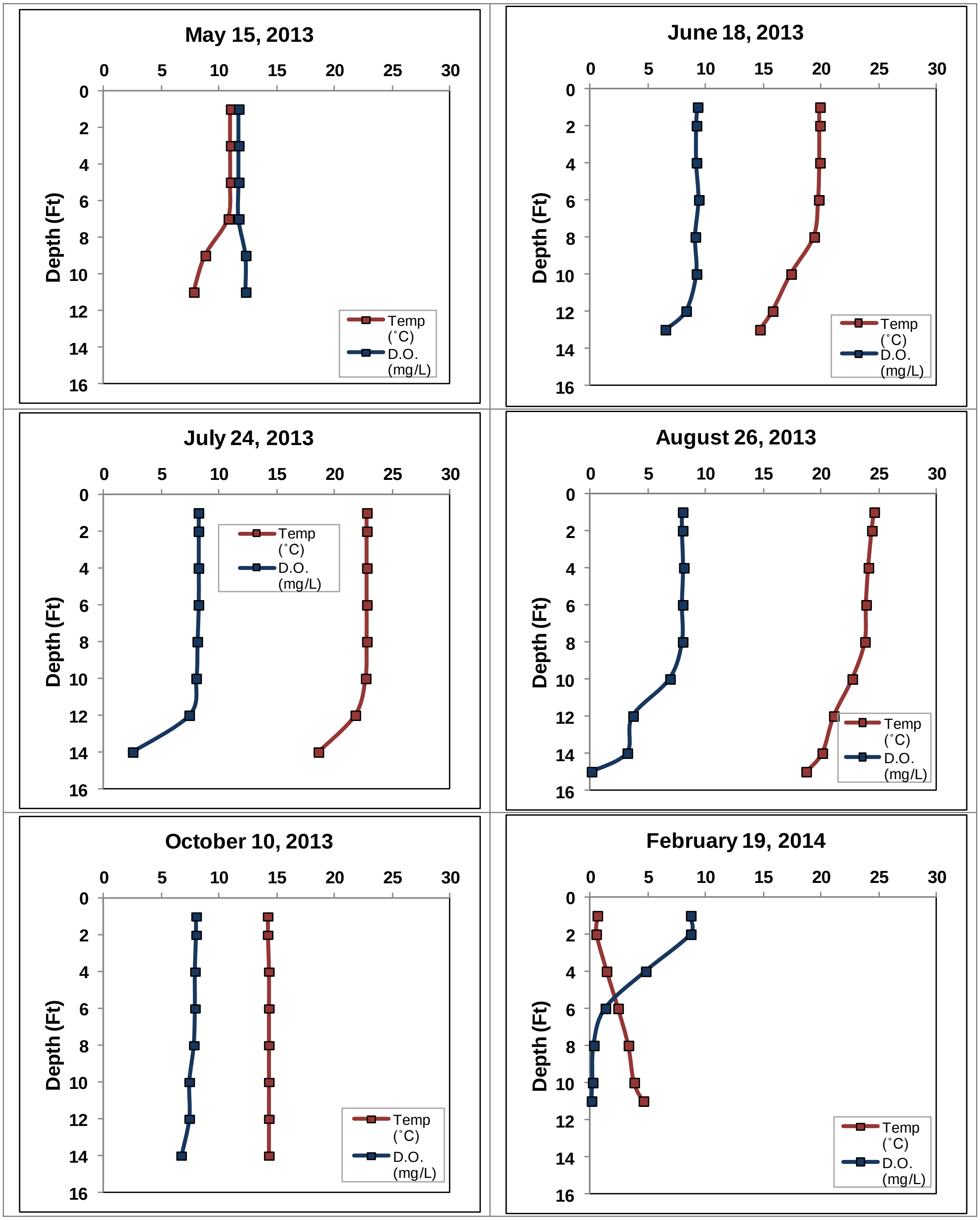


Figure 8.5.1-6. Fawn Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Fawn 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 Fawn 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. Fawn Lake's surface water pH was measured at roughly 7.7 during May and 8.0 during July of 2013. These values are 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 add 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 Fawn Lake was measured at 35.8 and 39.2 mg/L as $CaCO_3$ in May and July of 2013, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Fawn Lake during 2013. 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 Fawn Lake's pH of 7.7 – 8.0 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 Fawn Lake was found to be 11.0 mg/L in July of 2013, which is below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval stage of zebra mussels) were observed within these samples.

8.5.2 Fawn Lake Watershed Assessment

Fawn Lake's watershed is 3,440 acres in size. Compared to Fawn Lake's size of 73 acres, this makes for a large watershed to lake area ratio of 46:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Fawn Lake this means that 3,046 acres (89%) of Fawn Lake's watershed is the Clear Lake subwatershed. The direct watershed of Fawn Lake is a small part of the lake's total watershed (Figure 8.5.2-1). The part of the lake's watershed that is forest is 196 ac (6%) while wetlands comprise 110 acres (3%). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Fawn Lake's residence time is approximately 44 days, or that the water within the lake is completely replaced 8.1 times per year.

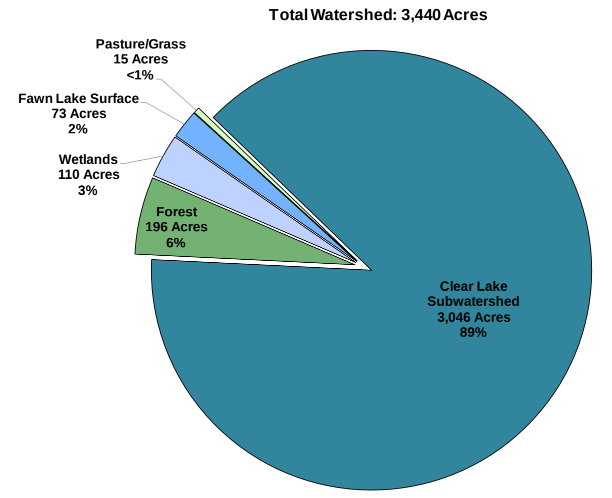


Figure 8.5.2-1. Fawn Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

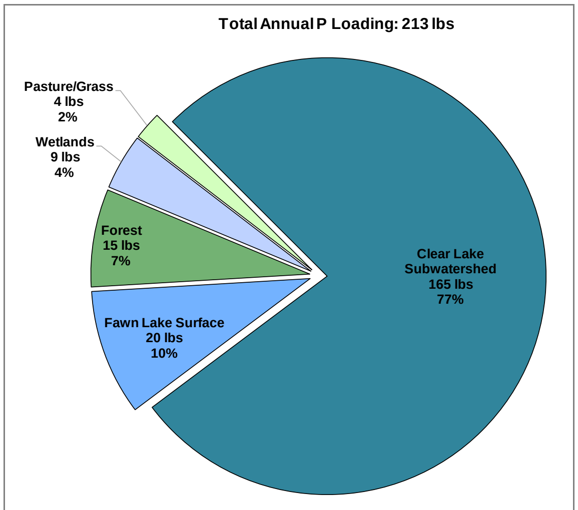


Figure 8.5.2-2. Fawn Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Of the estimated 213 pounds of phosphorus being delivered to Fawn Lake on an annual basis, approximately 168 pounds (77%) originates from Clear Lake which is the lake immediately upstream of Fawn Lake (Figure 8.5.2-2). The remaining phosphorus comes from approximately 20 pounds (10%) through direct atmospheric deposition onto the lake, 15 pounds (7%) from forests, 9 pounds (4%) from wetlands, and 4 pounds (2%) from areas of pasture/grass/rural open space. Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 18 µg/L, which is the slightly less than measured growing season phosphorus concentration of 24 µg/L. This means the model works reasonably well for Fawn Lake.

Because the large majority of the phosphorus that enters Fawn Lake comes from the upstream Clear Lake, efforts to reduce phosphorus levels in Fawn Lake should concentrate on reducing phosphorus inputs to Clear Lake.

8.5.3 Fawn Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 late summer of 2013, Fawn Lake's immediate shoreline was assessed in terms of its development. Fawn Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.6 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.5.3-1). This constitutes about 93% of Fawn 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, 0.2 miles of urbanized and developed–unnatural shoreline (4%) was observed. If restoration of the Fawn 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. Fawn Lake Map 1 displays the location of these shoreline lengths around the entire lake.

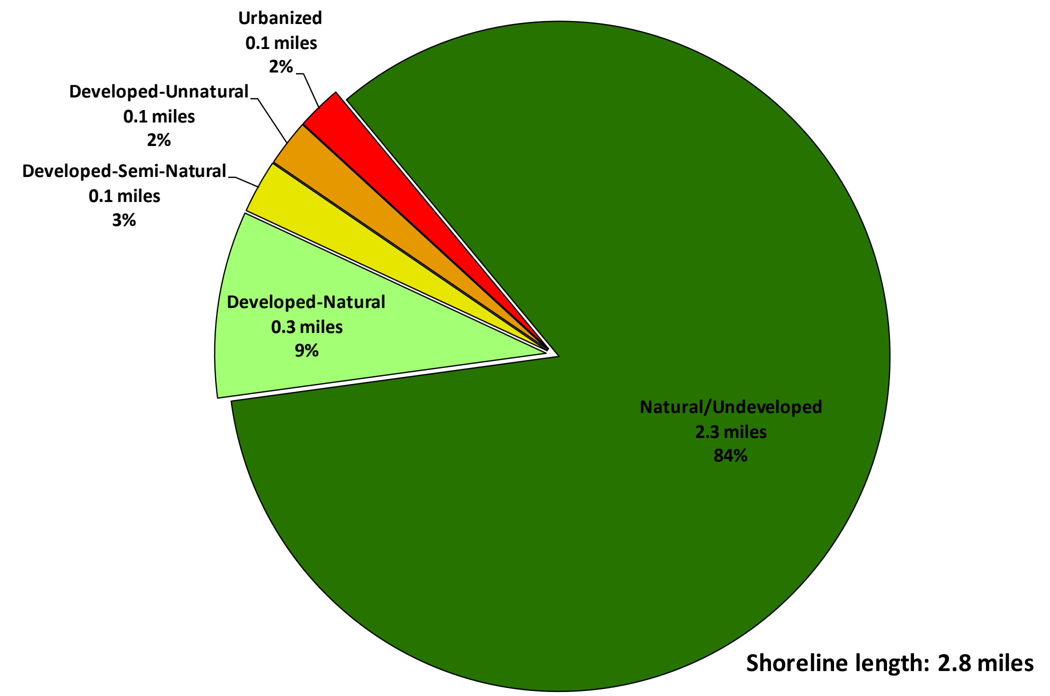


Figure 8.5.3-1. Fawn Lake shoreland categories and total lengths. Based upon a late summer 2013 survey. Locations of these categorized shorelands can be found on Fawn Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Fawn Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 113 total pieces of coarse woody habitat were observed along 2.8 miles of shoreline (Fawn Lake Map 2), which gives Fawn Lake a coarse woody habitat to shoreline mile ratio of 40:1 (Figure 8.5.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Ninety-one pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, fifteen pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and seven instances of clusters 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 Fawn 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 98 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 Fawn Lake falls above the 75th percentile of these 98 lakes (Figure 8.5.3-2).

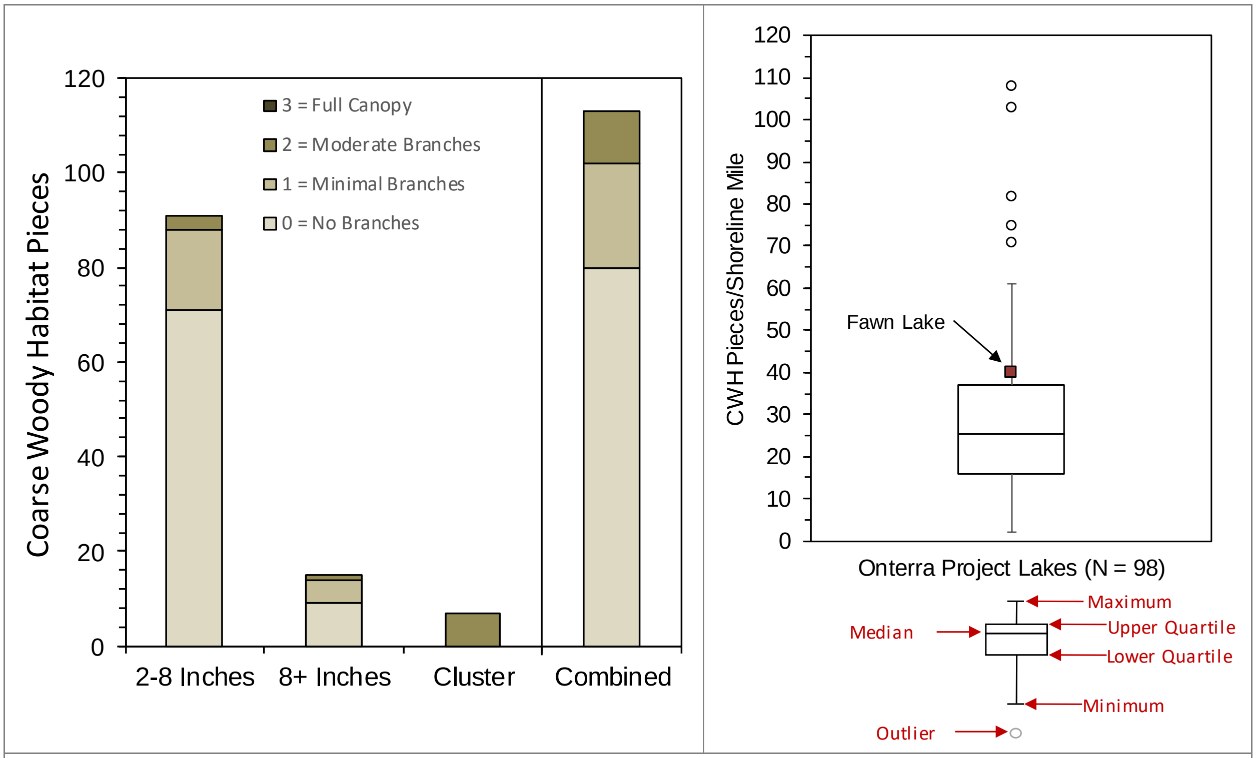


Figure 8.5.3-2. Fawn Lake coarse woody habitat survey results. Based upon a late summer 2013 survey. Locations of the Fawn Lake coarse woody habitat can be found on Fawn Lake Map 2.

8.5.4 Fawn Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Fawn Lake on June 25, 2013. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Fawn Lake on July 31, 2013 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 43 species of native aquatic plants were located in Fawn Lake (Table 8.5.4-1). 32 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 11 species were observed incidentally during visits to Fawn Lake.

Aquatic plants were found growing to a depth of 18 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 200 point-intercept locations sampled within the littoral zone, roughly 98% contained aquatic vegetation. Fawn Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays that are more likely to hold organic substrates. Approximately 13% of the point-intercept sampling locations where sediment data was collected at were sand, 87% consisted of a fine, organic substrate (muck) and 0% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.5.4-1. Aquatic plant species located in Fawn Lake during 2013 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2013 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	*I*
	Carex gynandra	Nodding sedge	6	*I*
	Carex crawfordii	Crawford's sedge	5	*I*
	Carex pseudocyperus	Cypress-like sedge	8	*I*
	Dulichium arundinaceum	Three-way sedge	9	*X*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Schoenoplectus tabernaemontani	Softstem bulrush	4	*I*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Sagittaria rigida	Stiff arrowhead	8	*X*
	Typha spp.	Cattail spp.	1	*X*
	Zizania sp.	Wild rice Species	8	*X*
FL	*Brasenia schreberi*	Watershield	7	*X*
	Nuphar variegata	Spatterdock	6	*X*
	Nymphaea odorata	White water lily	6	*X*
	Polygonum amphibium	Water smartweed	5	*I*
Submergent	*Bidens beckii*	Water marigold	8	*X*
	Callitriche sp.	Starwort sp.	N/A	*I*
	Chara spp.	Muskgrasses	7	*X*
	Ceratophyllum demersum	Coontail	3	*X*
	Elodea canadensis	Common waterweed	3	*X*
	Heteranthera dubia	Water stargrass	6	*X*
	Myriophyllum sibiricum	Northern watermilfoil	7	*X*
	Najas flexilis	Slender naiad	6	*X*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton foliosus	Leafy pondweed	6	*X*
	Potamogeton spirillus	Spiral-fruited pondweed	8	*X*
	Potamogeton vaseyi	Vasey's pondweed	10	*X*
	Potamogeton strictifolius	Stiff pondweed	8	*X*
	Potamogeton friesii	Fries' pondweed	8	*X*
	Potamogeton berchtoldii	Small pondweed	7	*X*
	Potamogeton gramineus	Variable pondweed	7	*X*
	Potamogeton pusillus	Small pondweed	7	*X*
	Potamogeton amplifolius	Large-leaf pondweed	7	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Potamogeton praelongus	White-stem pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	*X*
	Utricularia intermedia	Flat-leaf bladderwort	9	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
	Vallisneria americana	Wild celery	6	*X*

FL = Floating Leaf
X = Located on rake during point-intercept survey; I = Incidental Species

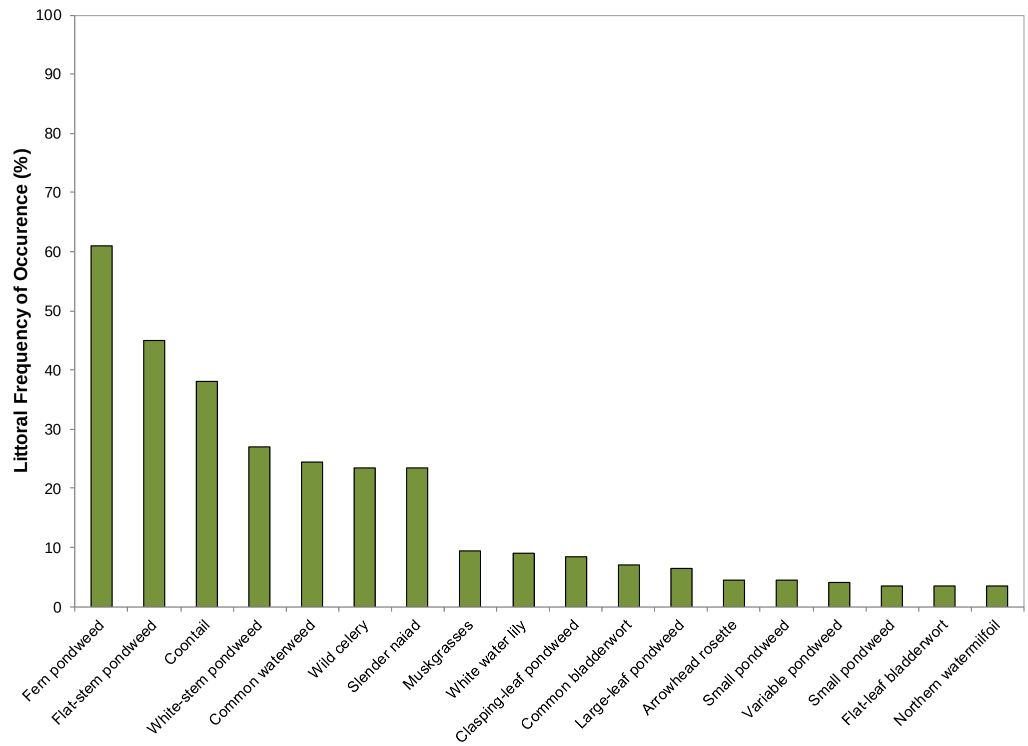


Figure 8.5.4-1. Fawn Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2013 point-intercept survey. Please note that only species with a frequency of occurrence greater than 3% are depicted.

Figure 8.5.4-1 (above) shows that fern pondweed, flat-stem pondweed and coontail were the most frequently encountered plants within Fawn Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms. Coontail is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and its locations can be largely a product of water movement.

One species discovered during 2013 studies, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory as a species of special concern in Wisconsin due to uncertainty regarding its distribution and abundance in Wisconsin. Vasey's pondweed is typically found in bays of large soft-water lakes as well as in rivers and ponds.

During aquatic plant inventories, 43 species of native aquatic plants (including incidentals) were found in Fawn Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Fawn Lake's plant community (0.90) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 fern pondweed was found at 61% of the sampling locations, its relative frequency of occurrence is 19%. Explained another way, if 100 plants were randomly sampled from Fawn Lake, 19 of them would be fern pondweed. This distribution can be observed in Figure 8.5.4-2, where together 7 native (and one non-native) species account for 75% of the aquatic plant population within Fawn Lake, while the other 25 species account for the remaining 25%. 11 additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.5.4-1 as incidentals.

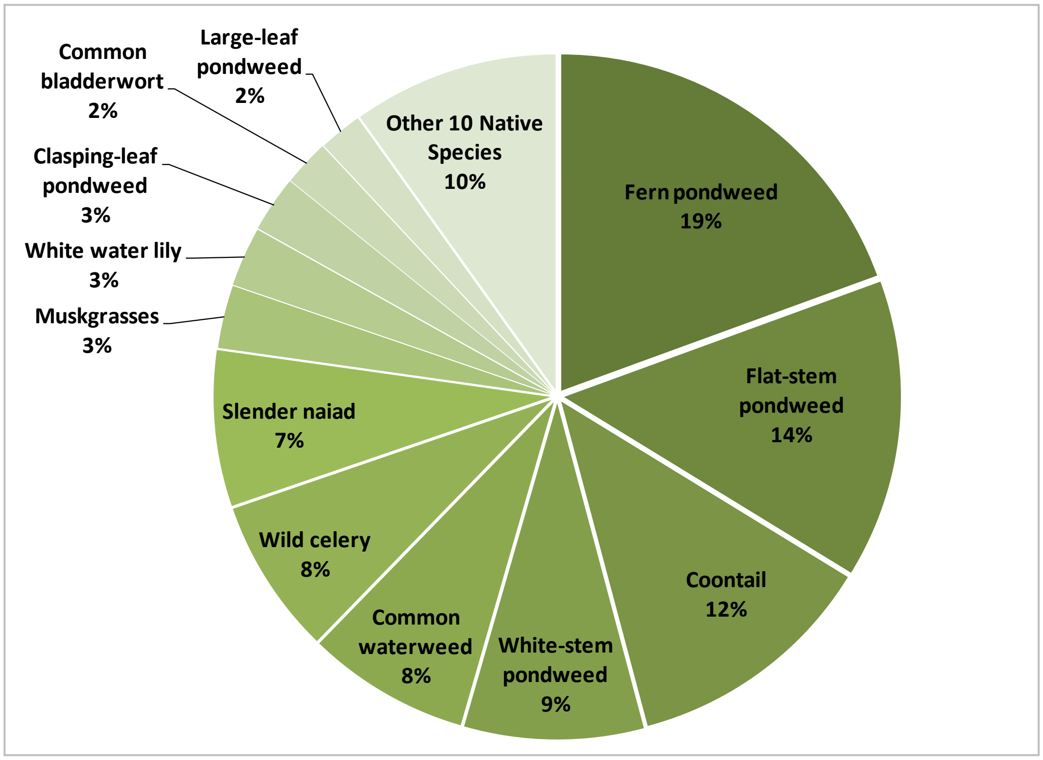


Figure 8.5.4-2. Fawn Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2013 point-intercept survey.

Fawn Lake's average conservatism value (6.8) is higher than the state (6.0) and the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Fawn Lake is indicative of a mostly undisturbed system. Combining Fawn Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 38.3 which is above the median values of the ecoregion and state.

The quality of Fawn Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2013 community map indicates that approximately 13.5 acres of the lake contains these types of plant communities (Fawn Lake Map 4, Table 8.5.4-2). Seventeen floating-leaf and emergent species were located on Fawn Lake (Table 8.5.4-1), all of which provide valuable wildlife habitat.

Table 8.5.4-2. Fawn Lake acres of emergent and floating-leaf plant communities from the 2013 community mapping survey.

Plant Community	Acres
Emergent	2.1
Floating-leaf	11.4
Mixed Floating-leaf and Emergent	-
Total	13.5

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Fawn Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Fawn Lake

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Fawn Lake during 2018. Through 2019, the infrequent occurrences of this exotic were managed through volunteer and professional hand-harvesting. As a part of the Manitowish Waters Comprehensive Management Plan, Fawn Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.5.5 Fawn Lake Fisheries Data Integration

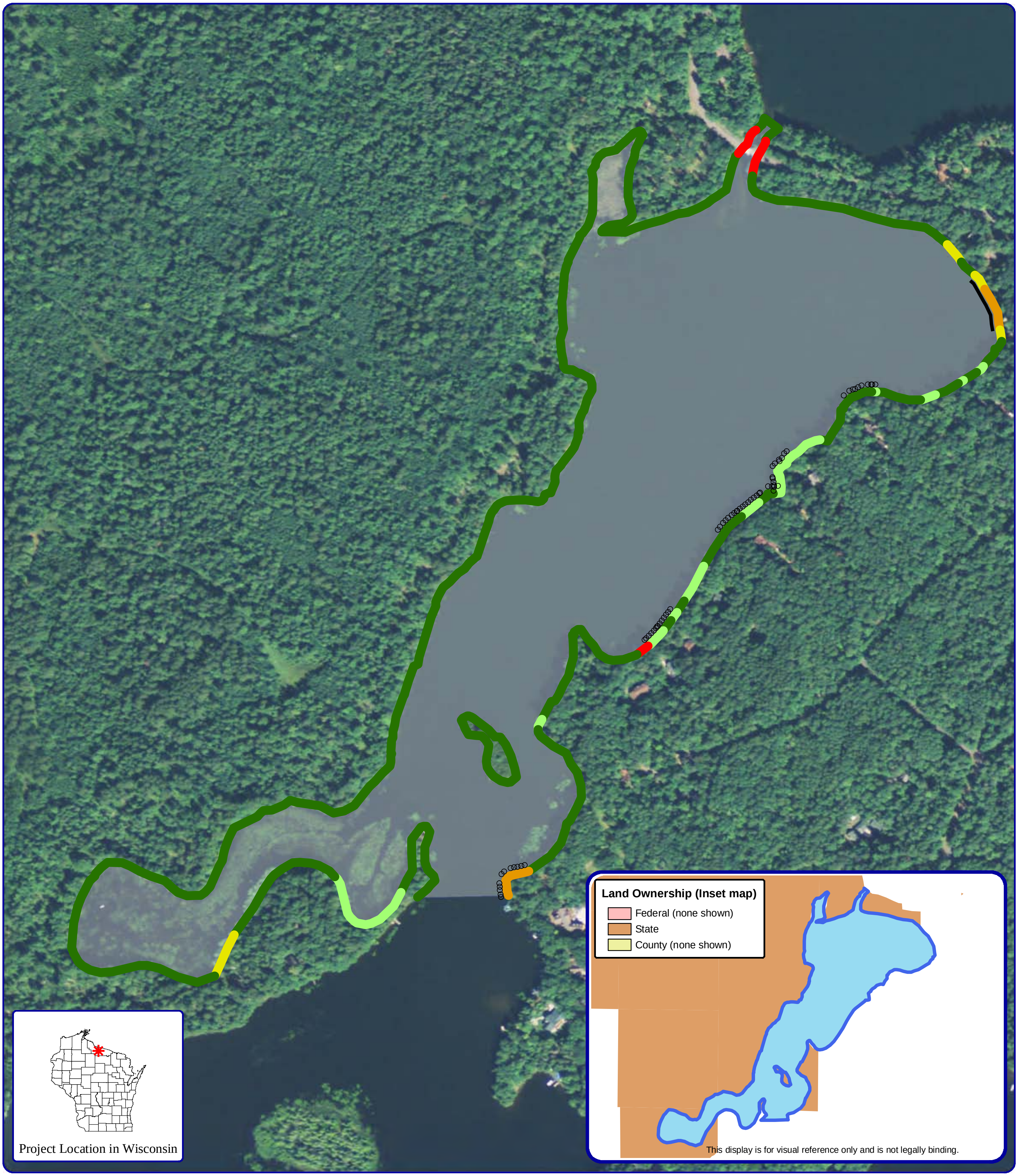
Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here and within the chain wide report section as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Fawn 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries. 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. No known stocking has been conducted on Fawn Lake.

Fawn Lake Spear Harvest Records

Although Fawn Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.



N
W E
S
500
Feet

Legend

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

Seawall
Masonary/Metal/Wood
Rip-Rap

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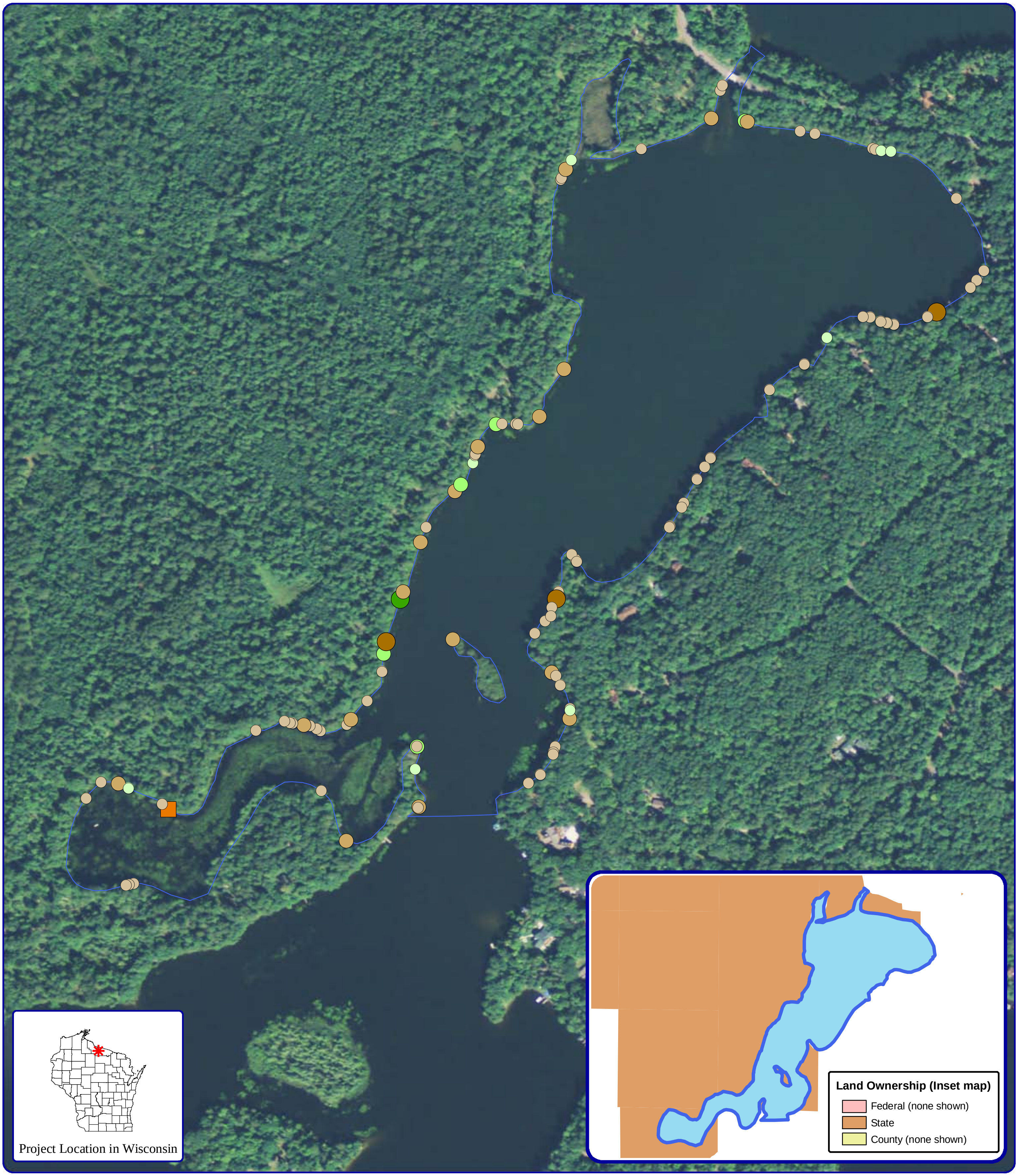
www.onterra-eco.com

Sources:
Hydro, State Land and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2013
Map date: October 14, 2014
Filename: Fawn_ShorelandCondition_2014.mxd

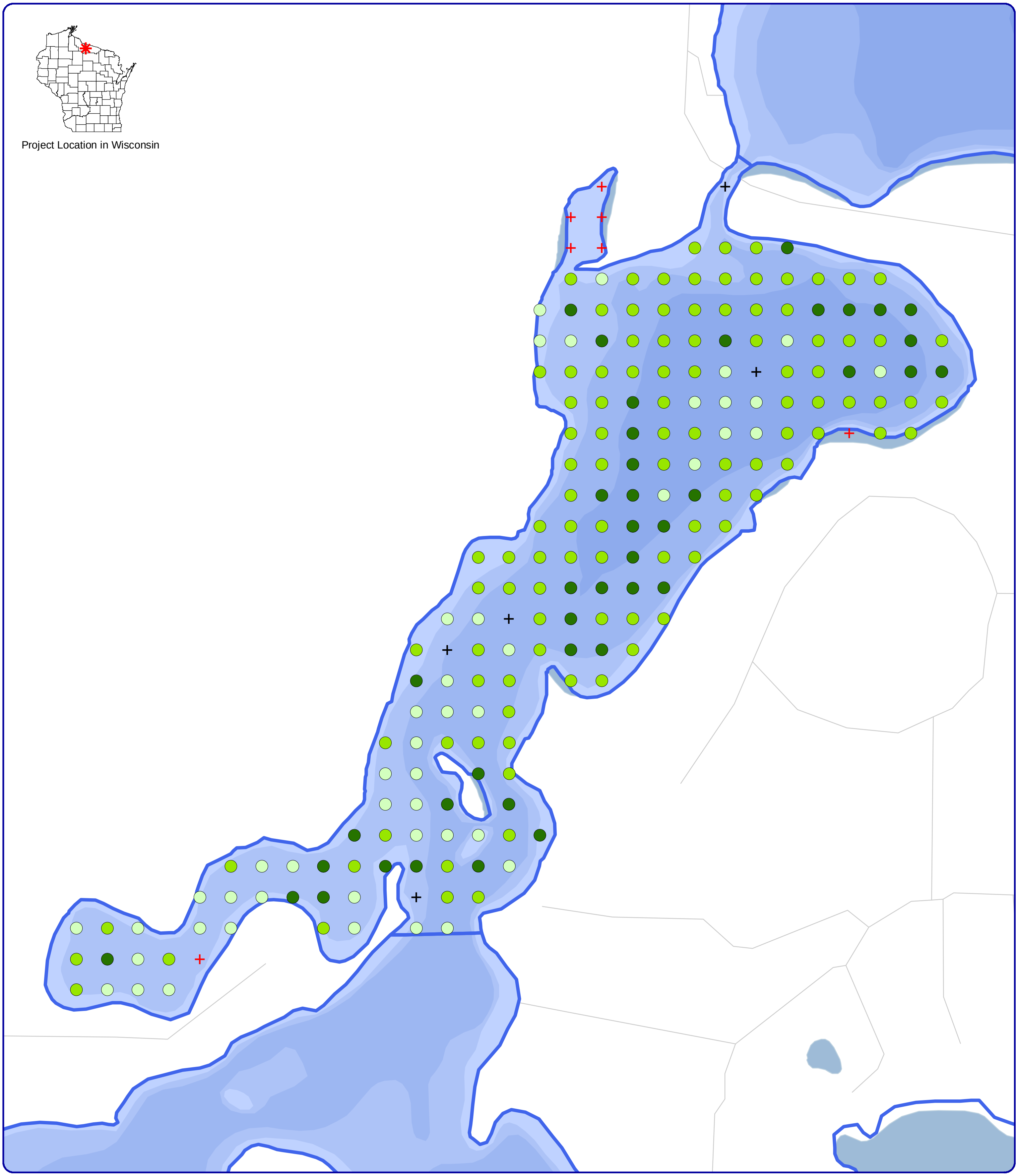
Fawn Lake - Map 1
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Shoreland Condition



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, 2013
Orthophotography: NAIP, 2013
Map date: October 6, 2014
Filename: Fawn_CWH_2014.mxd

Fawn Lake - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Coarse Woody Habitat



N W E S

500

Feet

Onterra LLC

Lake Management Planning

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

Sources:
Roads and Hydro: WDNR
Map Date: December 16, 2014
Filename: Fawn_TRFPI_2013.mxd

Legend

2013 Point-intercept Survey

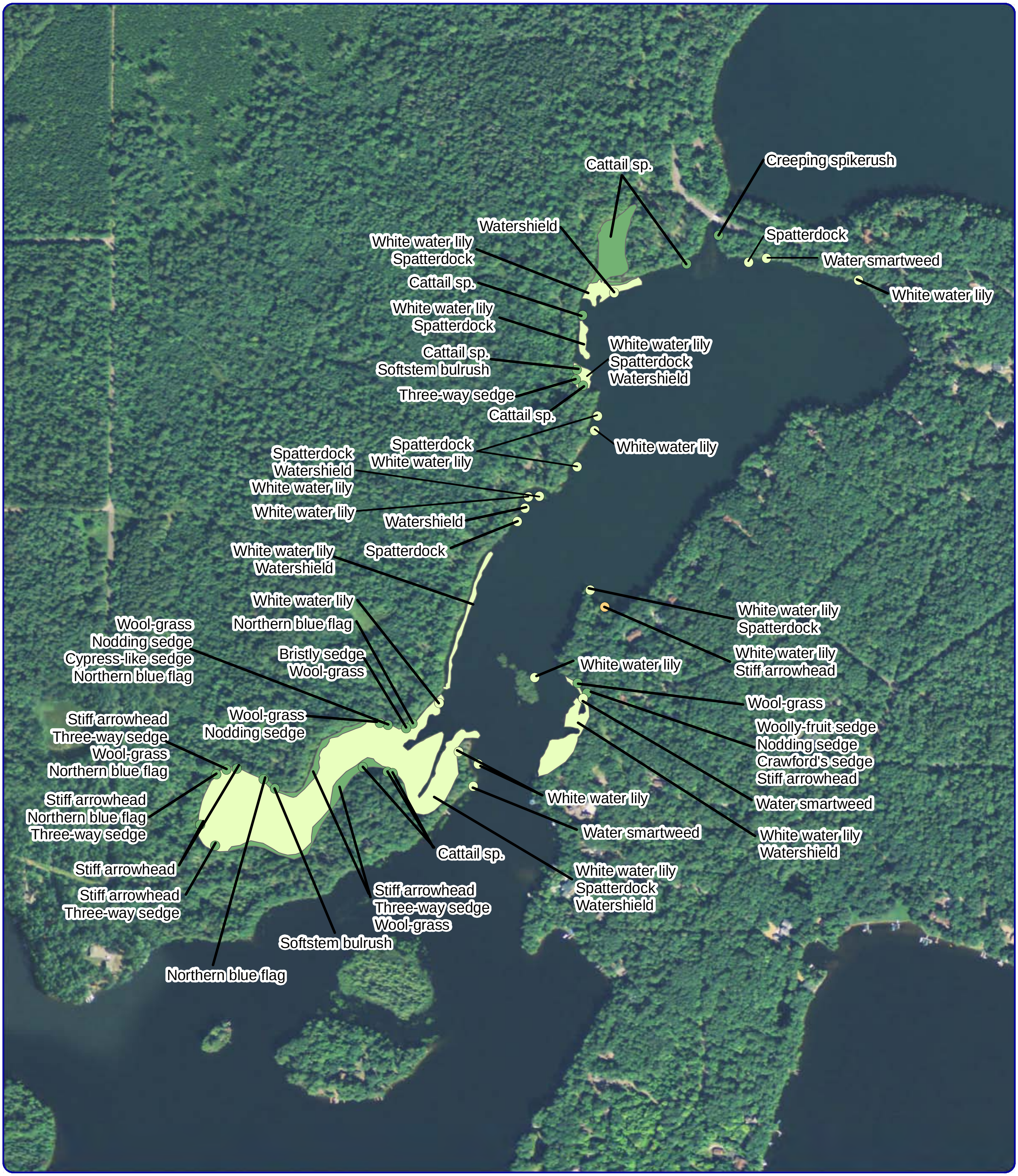
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- No Vegetation
- Non-navigable
- Deep

Fawn Lake - Map 3

Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Aquatic Plant Distribution



N
W E
S

650

Feet

Onterra LLC
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815 Prosper Road
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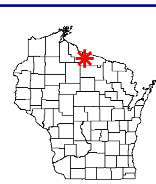
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
Map date: January 29, 2014
Filename: *Fawn_Comm_2013.mxd*



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

Map 4
Fawn Lake
Vilas County, Wisconsin

Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Wild Rice Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.6 Wild Rice Lake

An Introduction to Wild Rice Lake

Wild Rice Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 26 feet, a mean depth of 11.3 feet, and a surface area of approximately 384 acres. The Trout River enters the lake from the southeast, and continues out of the western side of the lake on its way to downstream Alder Lake. Wild Rice Lake is considered to be mesotrophic and its watershed is approximately 47,381 acres. In 2014, 47 native aquatic plant species were found in the lake, of which fern pondweed (*Potamogeton robbinsii*) was the most common. No aquatic invasive plant species were observed growing in or along the shorelines of Wild Rice Lake in 2014.

Field Survey Notes

Stained water and abundant natural shoreline observed during 2014 surveys. Several shoreland birds and bald eagle's nest spotted along western wetland area – great natural habitat!

Photo 8.6. *Nuphar x rubrodisca* (hybrid yellow pond lily) flower, Wild Rice Lake, Vilas County

Lake at a Glance* – Wild Rice Lake

Morphology	
Acreage	384
Maximum Depth (ft)	26.0
Mean Depth (ft)	11.3
Volume (acre-feet)	4,329
Shoreline Complexity	2.4
Vegetation	
Curly-leaf Survey Date	July 2, 2014
Comprehensive Survey Date	July 29, 2014
Number of Native Species	47
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.93
Average Conservatism	6.8
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	46:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.6.1 Wild Rice Lake Water Quality

Water quality data was collected from Wild Rice Lake on six occasions in 2014/2015. 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 2014/2015, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2014, average summer phosphorus concentrations (18.5 µg/L) were less than the median value (33.0 µg/L) for other shallow, lowland drainage lakes in the state (Figure 8.6.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Excellent* for a shallow, lowland drainage lake.

Total phosphorus surface values from 2014-2015 are compared with bottom-lake samples collected during this same time frame in Figure 8.6.1-2. Concentrations from the epilimnion were found to be similar to those in the hypolimnion during these time periods. As explained in the Chainwide Report (Water Quality Section Primer), sediments within a lake often release phosphorus under anoxic conditions. When mixing occurs in the lake, these nutrients may be transported to the upper water column for use by algae or aquatic plants. The data in Figure 8.6.1-2 indicate that a minimal amount of phosphorus release is occurring in Wild Rice Lake.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (6.0 µg/L) were lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.6.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2014 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions. The staining of the lake's water is natural, and described further below.

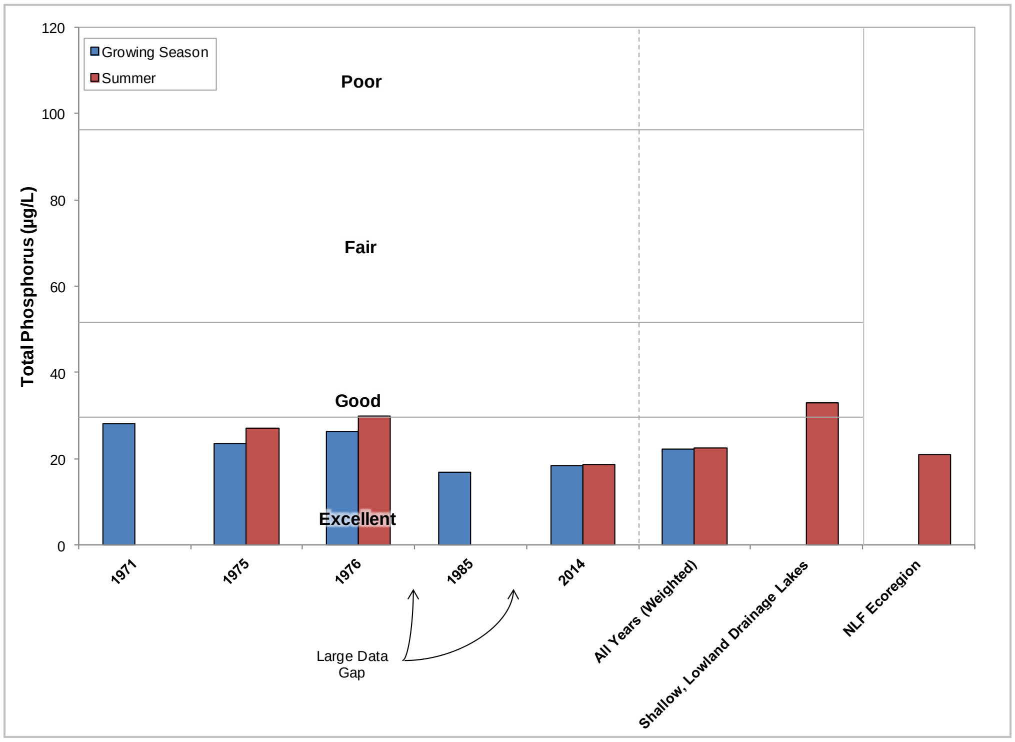


Figure 8.6.1-1. Wild Rice Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

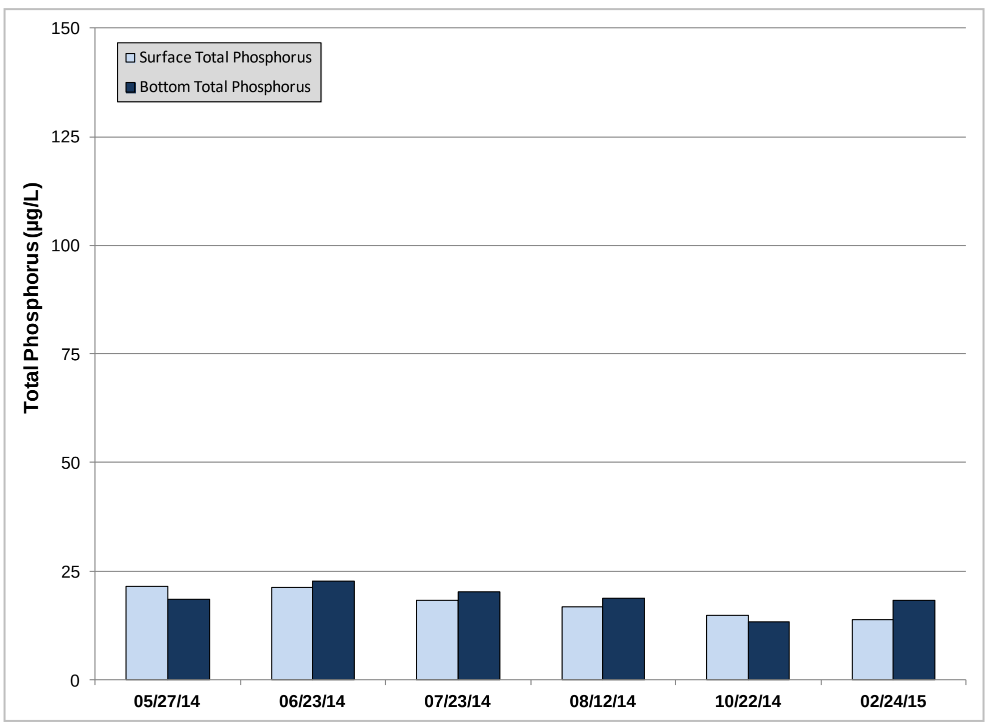


Figure 8.6.1-2. Wild Rice Lake surface and bottom total phosphorus values, 2014-2015. Anoxia was observed in the hypolimnion of the lake during August and February sampling visits.

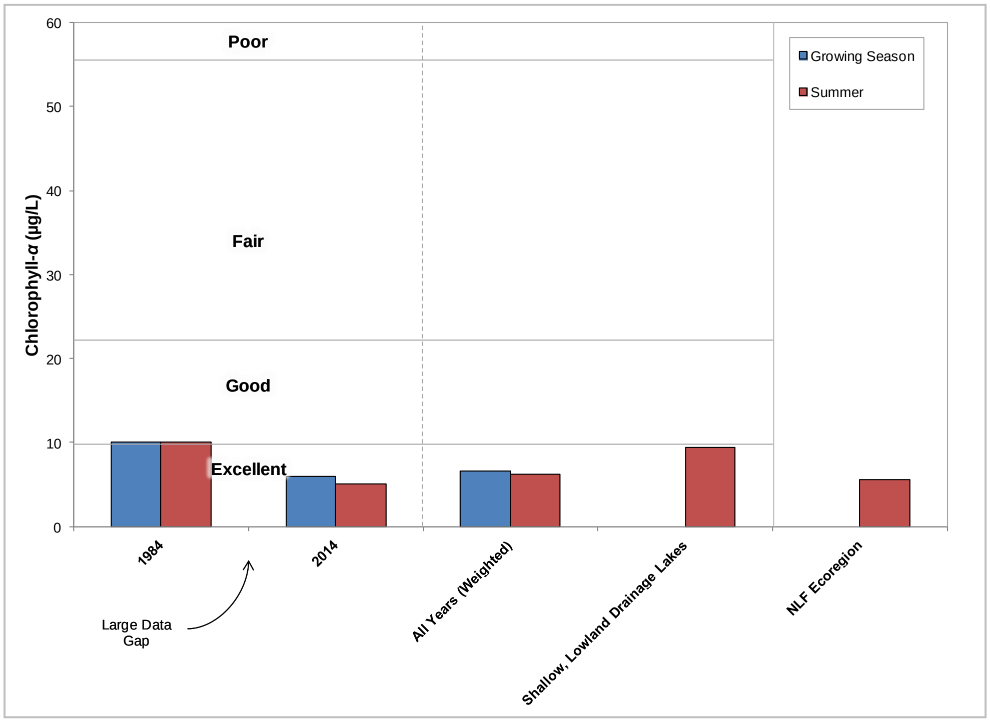


Figure 8.6.1-3. Wild Rice Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The clarity of Wild Rice Lake's water can be described as *Excellent* during the summer months in which data has been collected (Figure 8.6.1-4). A weighted average over this timeframe is greater than the median value for other shallow, lowland drainage lakes in the state but is slightly below the regional median. Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Wild Rice Lake as well as many other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Wild Rice Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in May and July of 2014 were measured for this parameter, and were found to be 40 and 50 Platinum-cobalt units (Pt-co units, or PCU), respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

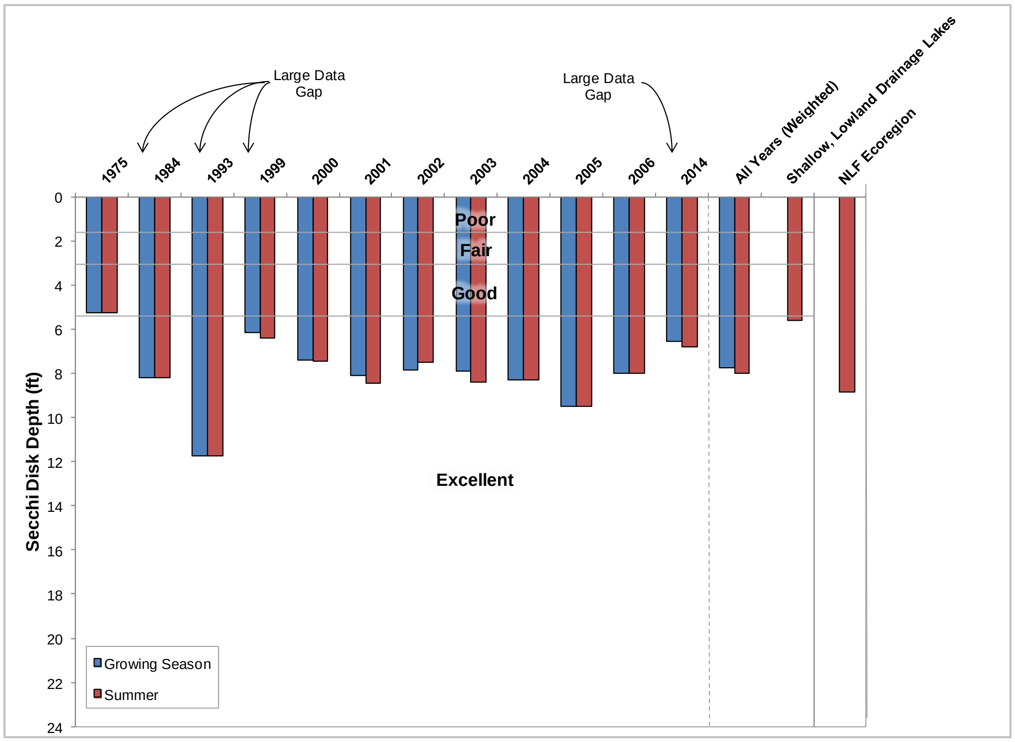


Figure 8.6.1-4. Wild Rice Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Wild Rice Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.6.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Wild Rice Lake is in a mesotrophic state.

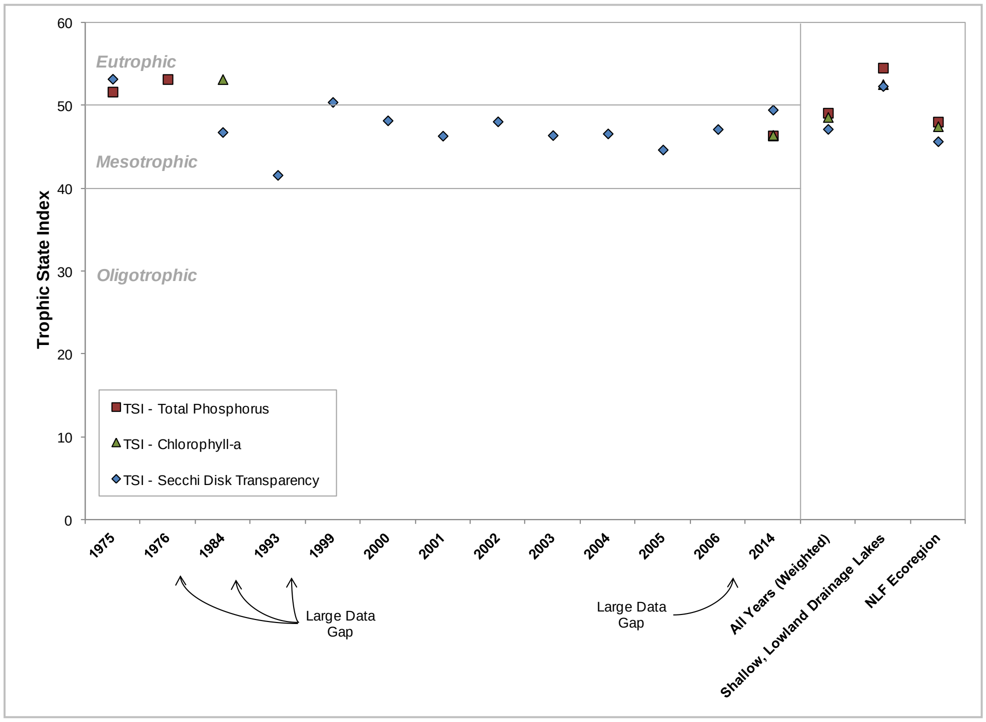


Figure 8.6.1-5. Wild Rice Lake, state-wide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Wild Rice Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Wild Rice Lake by Onterra staff. Graphs of those data are displayed in Figure 8.6.1-6 for all sampling events.

Wild Rice Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the shallow lake likely mixes often as well. The bottom of the lake was found to become void of oxygen (anoxic) several times during the year. This occurrence is not uncommon in Wisconsin lakes, as bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. If the lake mixes completely, oxygen will be reintroduced to the lower levels of the water column.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2014, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

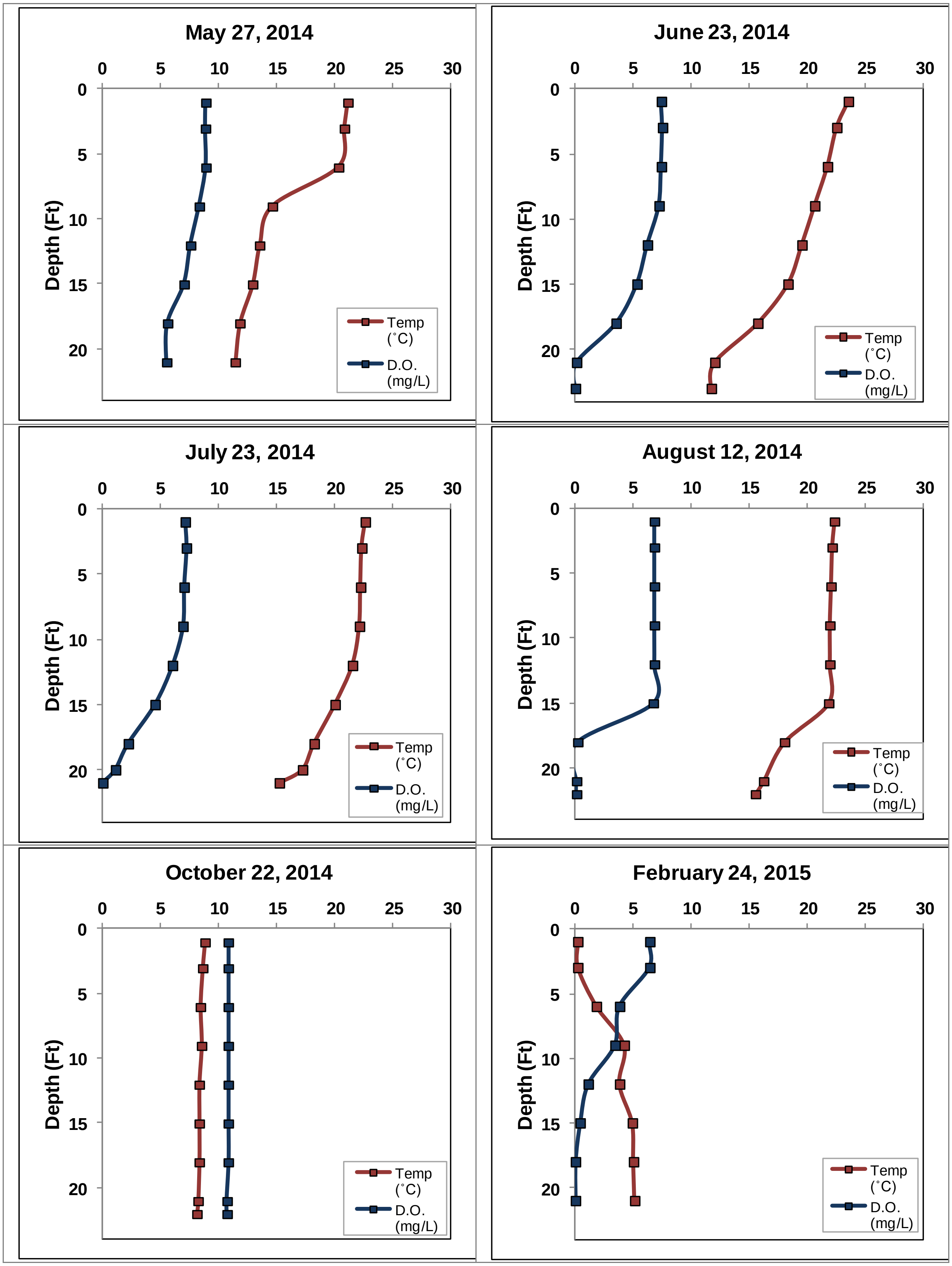


Figure 8.6.1-6. Wild Rice Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Wild Rice 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 Wild Rice 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. Wild Rice Lake's surface water pH was measured at roughly 7.5 during May and 8.6 during July of 2014. These values are 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 add 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 Wild Rice Lake was measured at 36.8 and 43.0 mg/L as $CaCO_3$ in May and July of 2014, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Wild Rice Lake during 2013. 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 Wild Rice Lake's pH of 7.5 – 7.6 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 Wild Rice Lake was found to be 11.5 mg/L in July of 2014, which is below but near the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.6.2 Wild Rice Lake Watershed Assessment

Wild Rice Lake's watershed is 45,068 acres in size. Compared to Wild Rice Lake's size of 396 acres, this makes for a large watershed to lake area ratio of 46:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lakes immediately upstream. For Wild Rice Lake this means that 27,811 acres (62%) of the lake's watershed is the Trout Lake subwatershed while 5,425 acres (12%) is from wetlands, 4,753 (11%) is from forests, 3,460 acres (8%) from the Lower Gresham Lake subwatershed, 1,391 acres (3%) from pasture/grass, 1,031 acres (2%) from West Ellerson Lake subwatershed, and the rest from various landuses and the lake surface (Figure 8.6.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Wild Rice Lake's residence time is approximately 31 days, or the water within the lake is completely replaced 11.6 times per year.

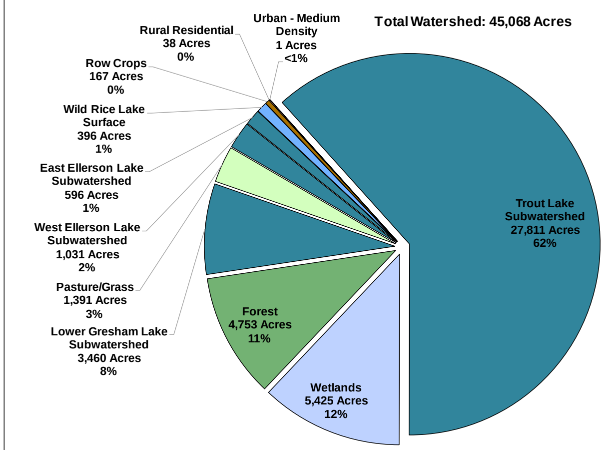


Figure 8.6.2-1. Wild Rice Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 2,456 pounds of phosphorus being delivered to Wild Rice Lake on an annual basis, approximately 658 pounds (27%) originates from the Trout Lake subwatershed, 485 pounds (20%) from wetlands, 381 pounds (16%) from forests, 373 pounds (15%) from pasture and grass, 219 pounds (9%) from the Lower Gresham Lake subwatershed, 150 pounds (6%) from row crops, and the rest from the lake surface itself and East and West Ellerson subwatersheds (Figure 8.6.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 16 µg/L, which is very similar to the measured growing season average total phosphorus concentration of 18 µg/L. This means the model works reasonably well for Wild Rice Lake.

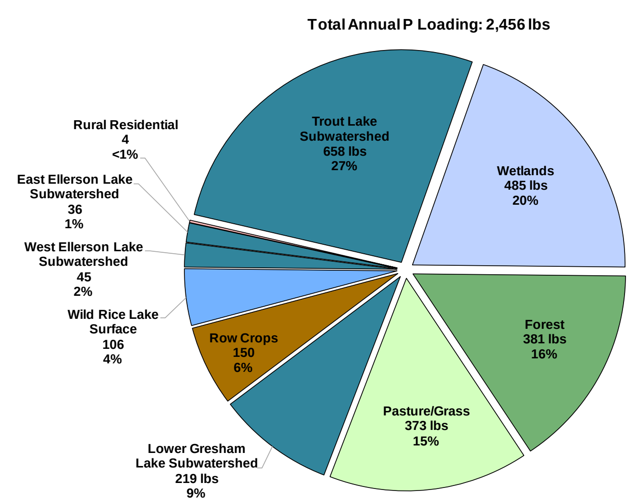


Figure 8.6.2-2. Wild Rice Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the large majority of the phosphorus that enters Wild Rice Lake comes from the upstream lakes, especially Trout Lake, efforts to reduce phosphorus levels in Wild Rice Lake should concentrate on reducing phosphorus inputs to the upstream lakes.

8.6.3 Wild Rice Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 late summer of 2014, Wild Rice Lake's immediate shoreline was assessed in terms of its development. Wild Rice Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.0 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.6.3-1). This constitutes about 74% of Wild Rice 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, 0.5 miles of urbanized and developed–unnatural shoreline (13%) was observed. If restoration of the Wild Rice 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. Wild Rice Lake Map 1 displays the location of these shoreline lengths around the entire lake.

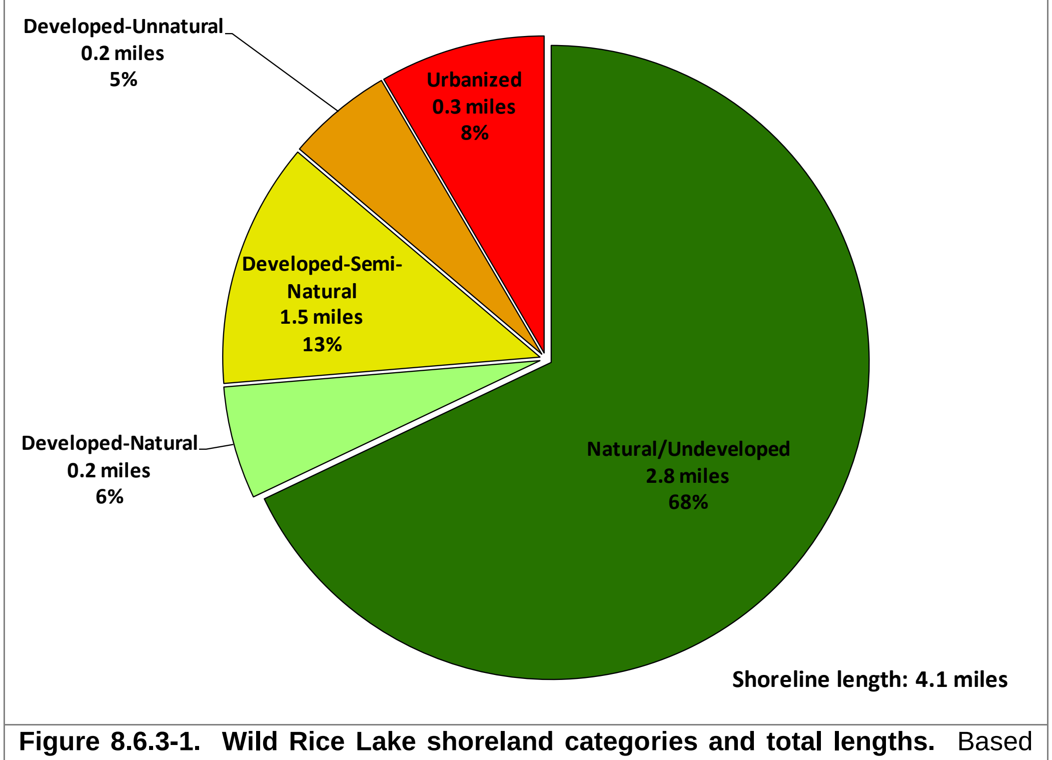


Figure 8.6.3-1. Wild Rice Lake shoreland categories and total lengths. Based upon a late summer 2014 survey. Locations of these categorized shorelands can be found on Wild Rice Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Wild Rice Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 85 total pieces of coarse woody habitat were observed along 4.1 miles of shoreline (Wild Rice Lake Map 2), which gives Wild Rice Lake a coarse woody habitat to shoreline mile ratio of 21:1 (Figure 8.6.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Sixty-four pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, twenty-one pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Wild Rice 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 98 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 Wild Rice Lake falls below the median of these 98 lakes (Figure 8.6.3-2).

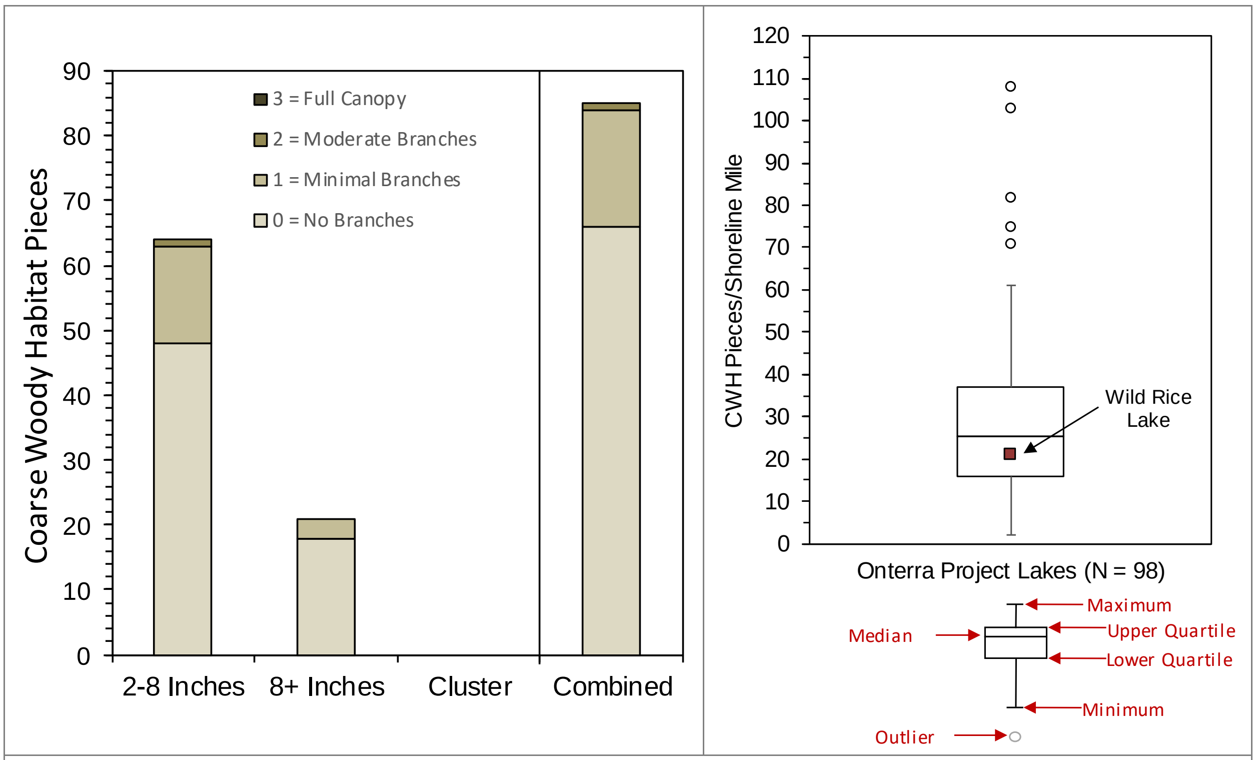


Figure 8.6.3-2. Wild Rice Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of the Wild Rice Lake coarse woody habitat can be found on Wild Rice Lake Map 2.

8.6.4 Wild Rice Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Wild Rice Lake on July 2, 2014. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Wild Rice Lake on July 29, 2014 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 47 species of native aquatic plants were located in Wild Rice Lake (Table 8.6.4-1). 35 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 12 species were observed incidentally during visits to Wild Rice Lake.

Aquatic plants were found growing to a depth of 14 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 222 point-intercept locations sampled within the littoral zone, roughly 77% contained aquatic vegetation. Wild Rice Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays that are more likely to hold organic substrates. Approximately 26% of the point-intercept sampling locations where sediment data was collected at were sand, 65% consisted of a fine, organic substrate (muck) and 10% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.6.4-1. Aquatic plant species located in Wild Rice Lake during 2013 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2014 (Onterra)
Emergent	*Dulichium arundinaceum*	Three-way sedge	9	X
	Eleocharis palustris	Creeping spikerush	6	X
	Glyceria borealis	Northern manna grass	8	I
	Iris versicolor	Northern blue flag	5	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Myrica gale	Sweet gale	9	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X
	Zizania sp.	Wild rice Species	8	X
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	I
	Nuphar x *rubrodisca*	Intermediate pond-lily	9	I
	Nymphaea odorata	White water lily	6	X
	Nuphar microphylla	Yellow water lily	9	I
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Bidens beckii*	Water marigold	8	X
	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort species	N/A	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Nitella spp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia minor	Small bladderwort	10	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria graminea	Grass-leaved arrowhead	9	I
	Sagittaria cristata	Crested arrowhead	9	I
FF	*Spirodela polyrhiza*	Greater duckweed	5	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

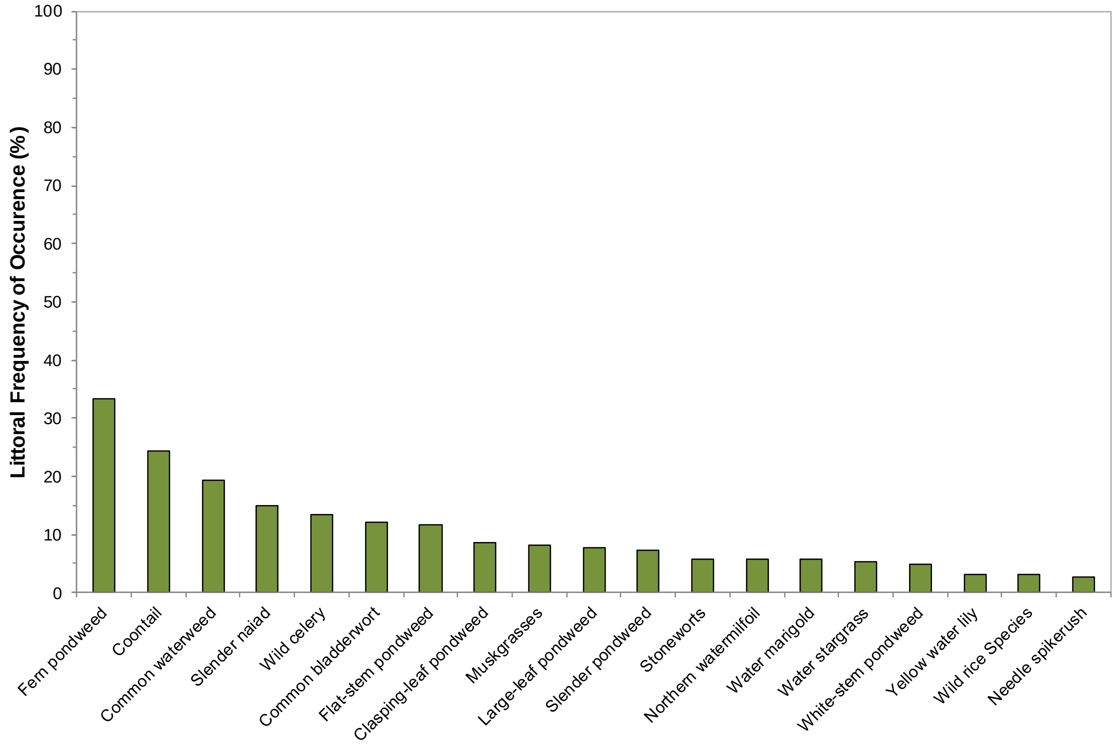


Figure 8.6.4-1. Wild Rice Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2014 point-intercept survey. Please note that only species with a frequency of occurrence greater than 2% are depicted.

Figure 8.6.4-1 (above) shows that fern pondweed, coontail and common waterweed were the most frequently encountered plants within Wild Rice Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Coontail and common waterweed are largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and their locations can be largely a product of water movement.

During aquatic plant inventories, 47 species of native aquatic plants (including incidentals) were found in Wild Rice Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Wild Rice Lake's plant community (0.93) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 fern pondweed was found at 33% of the sampling locations, its relative frequency of occurrence is 16%. Explained another way, if 100 plants were randomly sampled from Wild Rice Lake, 16 of them would be fern pondweed. This distribution can be observed in Figure 8.6.4-2, where together 11 native (and one non-native) species account for 75% of the aquatic plant population within Wild Rice Lake, while the other 26 species account for the remaining 25%. 12 additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.6.4-1 as incidentals.

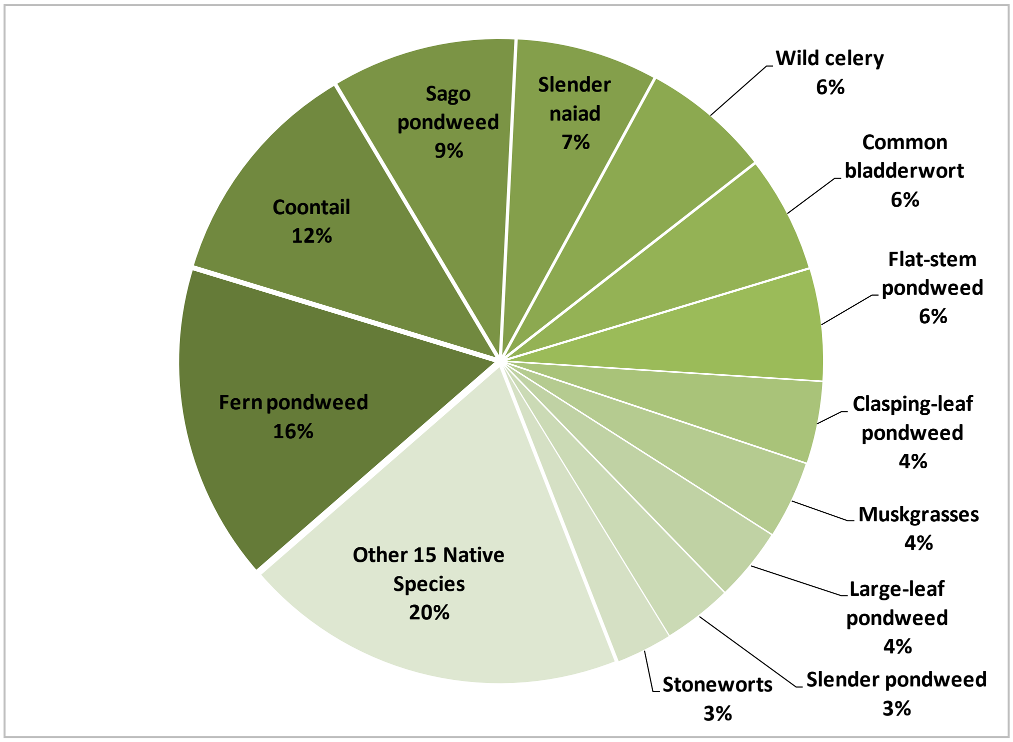


Figure 8.6.4-2. Wild Rice Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2014 point-intercept survey.

Wild Rice Lake's average conservatism value (6.8) is higher than the state (6.0) and the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Wild Rice Lake is indicative of a moderately disturbed system. Combining Wild Rice Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 38.3 which is above the median values of the ecoregion and state.

The quality of Wild Rice Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2014 community map indicates that approximately 27.0 acres of the lake contains these types of plant communities (Wild Rice Lake Map 4, Table 8.6.4-2). Seventeen floating-leaf and emergent species were located on Wild Rice Lake (Table 8.6.4-1), all of which provide valuable wildlife habitat.

Table 8.6.4-2. Wild Rice Lake acres of emergent and floating-leaf plant communities from the 2014 community mapping survey.

Plant Community	Acres
Emergent	8.3
Floating-leaf	4.9
Mixed Floating-leaf and Emergent	13.8
Total	27.0

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Wild Rice Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Wild Rice Lake

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. 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.

In Wild Rice Lake, purple loosestrife was located along the western shoreline of the lake (Wild Rice Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Wild Rice Lake.

8.6.5 Wild Rice 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 and within each lake's individual report section 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 Wild Rice 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.6.5-1). 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. Wild Rice Lake has been stocked from 1974 to 2016 with walleye and muskellunge (Table 8.6.5-1).

Photograph 8.6.5-1. Fingerling Muskellunge.

Table 8.6.5-1. Stocking data available for Wild Rice Lake (1974-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Walleye	Unspecified	Fingerling	14,385	5
1975	Walleye	Unspecified	Fingerling	8,000	3
1975	Muskellunge	Unspecified	Fingerling	400	9
1988	Muskellunge	Unspecified	Fingerling	400	10.5
1990	Muskellunge	Unspecified	Fingerling	400	10
1991	Muskellunge	Unspecified	Fingerling	200	11
1992	Muskellunge	Unspecified	Fingerling	200	10
1993	Muskellunge	Unspecified	Fingerling	200	12
1996	Muskellunge	Unspecified	Fingerling	400	9.8
1998	Muskellunge	Unspecified	Large Fingerling	400	12.2
2000	Muskellunge	Unspecified	Large Fingerling	396	10.3
2002	Muskellunge	Unspecified	Large Fingerling	400	10.1
2004	Muskellunge	Unspecified	Large Fingerling	400	10.5
2006	Muskellunge	Upper Wisconsin River	Large Fingerling	400	10.2
2008	Muskellunge	Upper Wisconsin River	Large Fingerling	400	10.1
2010	Muskellunge	Upper Wisconsin River	Large Fingerling	332	13.1
2012	Muskellunge	Upper Wisconsin River	Large Fingerling	400	10.2
2014	Muskellunge	Upper Wisconsin River	Large Fingerling	398	10.4
2016	Muskellunge	Upper Wisconsin River	Large Fingerling	360	10.9

Wild Rice Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.6.5-1 from 1999 to 2017. As many as 65 walleye have been harvested from the lake in the past (1999), but the average harvest is roughly 16 fish in a given year. Spear harvesters on average have taken 89% of the declared quota. Additionally, on average 29% of walleye harvested have been female.

Muskellunge open water spear harvest records are provided in Figure 8.6.5-2 from 1999 to 2017. As many as four muskellunge have been harvested from the lake in the past (2007), however the average harvest is one fish in a given year. Spear harvesters on average have taken 20% of the declared quota.

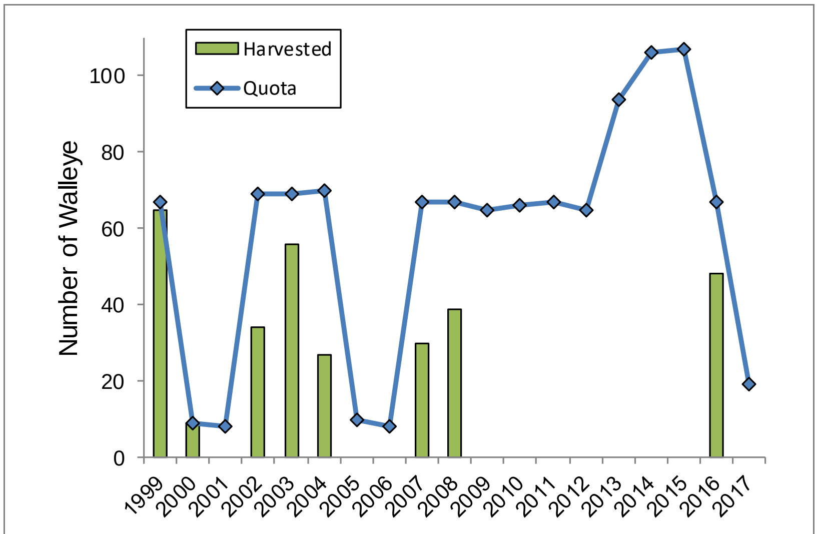


Figure 8.6.5-1. Wild Rice Lake walleye spear harvest data. (GLIFWC 1999-2017).

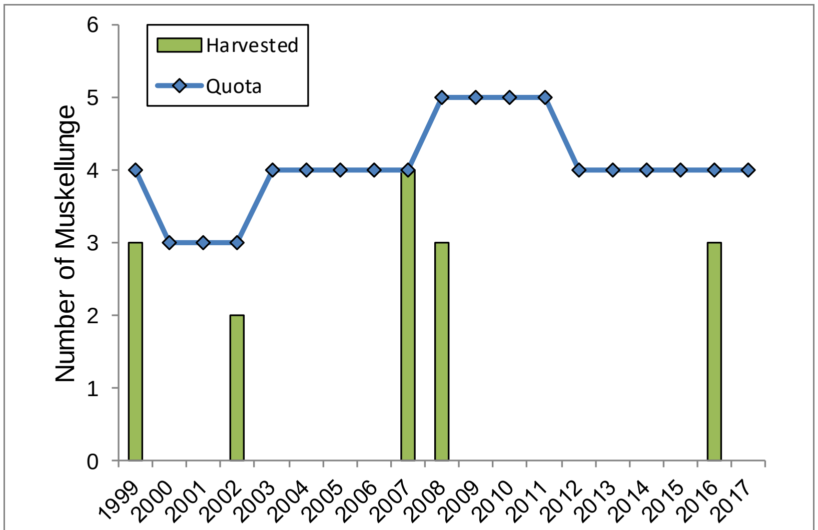
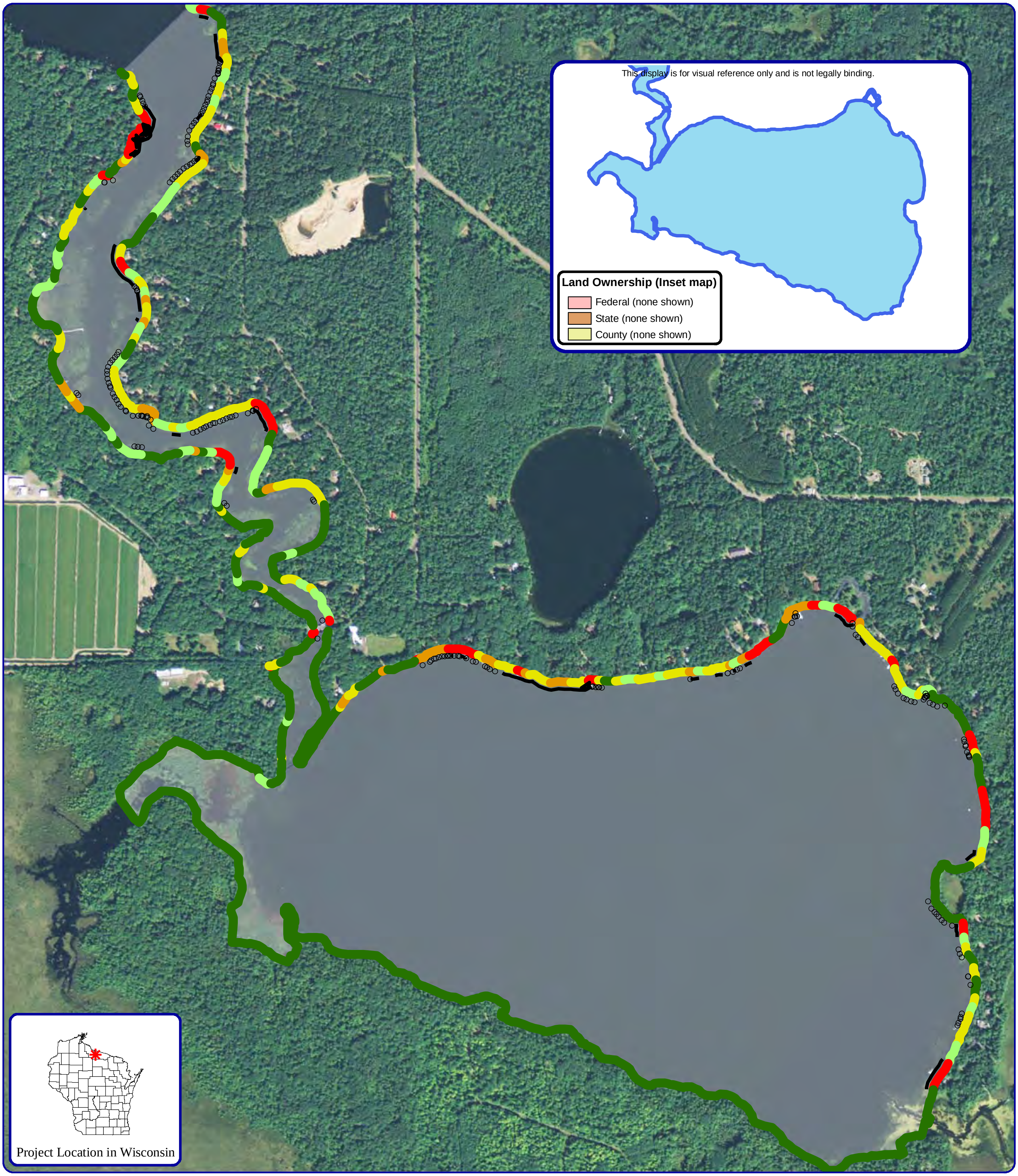


Figure 8.6.5-2. Wild Rice Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



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Feet

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

Seawall
- Masonry/Metal/Wood
- Rip-Rap

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

Sources:
Hydro: WDNR
CWH Survey: Onterra, 2014
Orthophotography: NAIP, 2013
Map date: October 21, 2014
Filename: MapX_WildRice_SCA_2014.mxd

Map 1
Wild Rice Lake
Vilas County, Wisconsin
2014 Shoreland Condition Assessment


This display is for visual reference only and is not legally binding.
Land Ownership (Inset map)
Federal (none shown)
State (none shown)
County (none shown)
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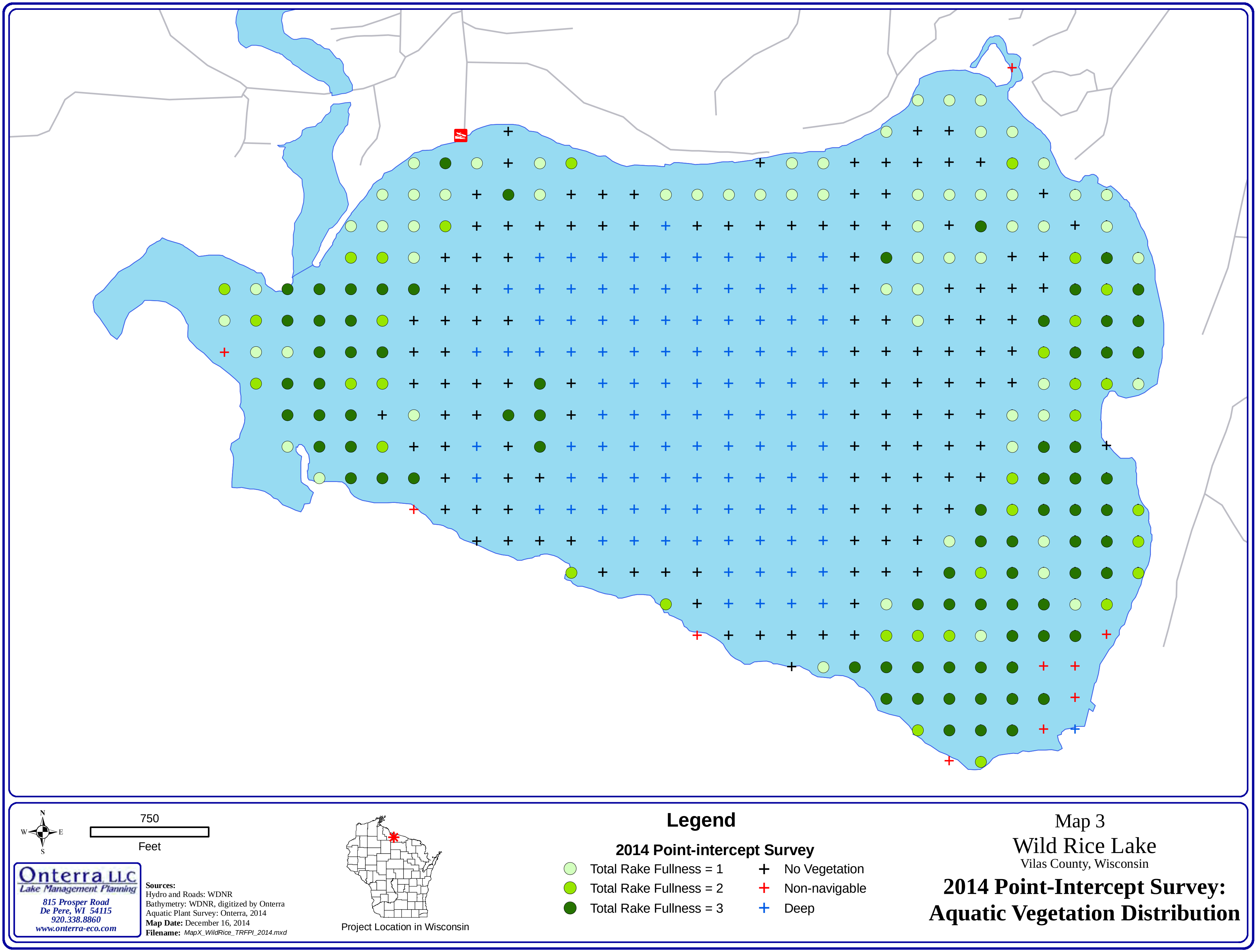
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro: WDNR
CWH Survey: Onterra, 2014
Orthophotography: NAIP, 2013
Map date: October 21, 2014
Filename: MapX_WildRice_CWH_2014.mxd
Project Location in Wisconsin
Legend
2-8 Inch Pieces
No Branches
Minimal Branches
Moderate Branches
Full Canopy
8+ Inch Pieces
No Branches
Minimal Branches
Moderate Branches (none)
Full Canopy (none)
Map 2
Wild Rice Lake
Vilas County, Wisconsin
2014 Coarse
Woody Habitat



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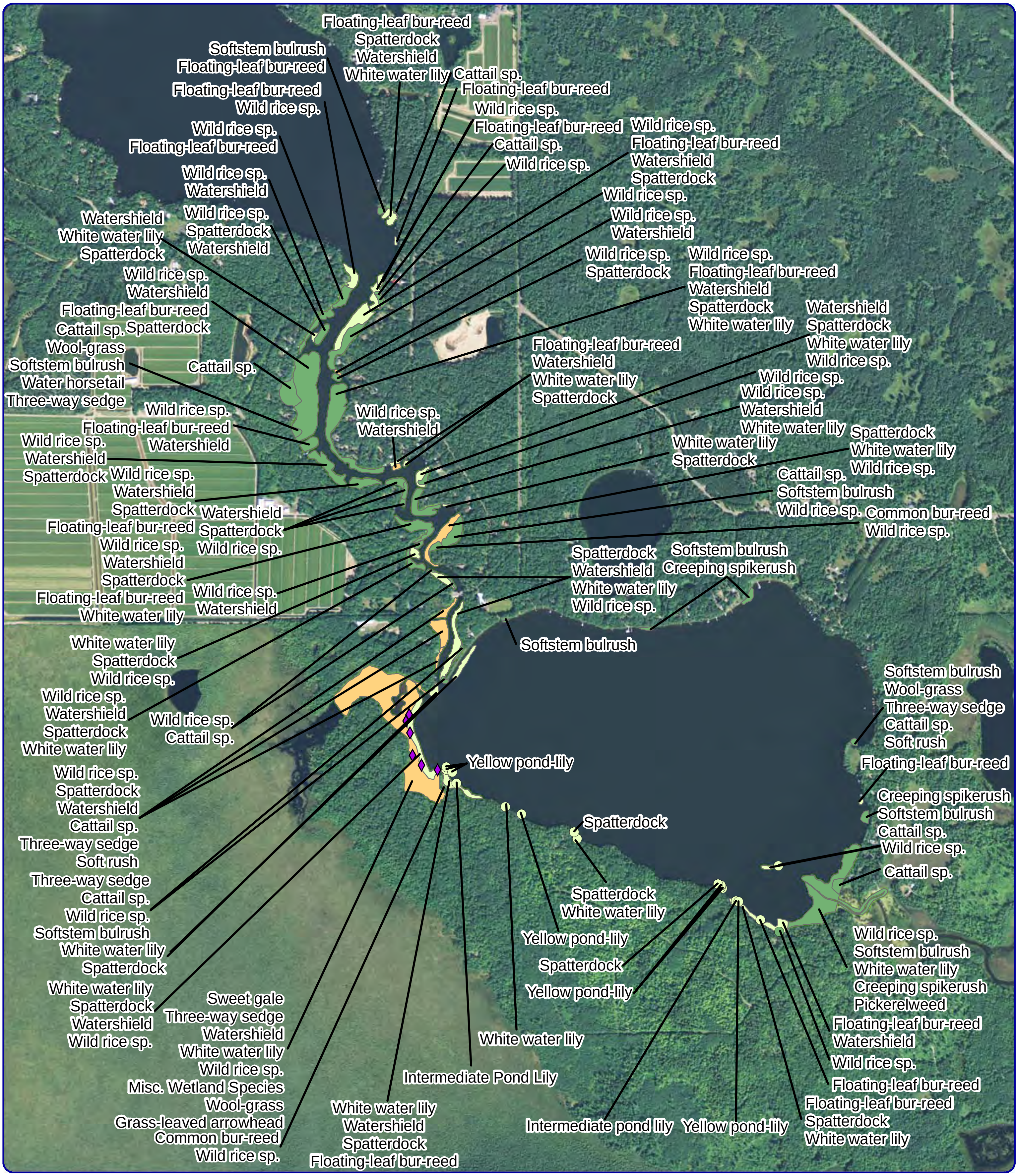
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2014
Map Date: December 16, 2014
Filename: MapX_WildRice_TRFPI_2014.mxd
Project Location in Wisconsin
Legend
2014 Point-intercept Survey
Total Rake Fullness = 1
Total Rake Fullness = 2
Total Rake Fullness = 3
No Vegetation
Non-navigable
Deep
Map 3
Wild Rice Lake
Vilas County, Wisconsin
2014 Point-Intercept Survey:
Aquatic Vegetation Distribution



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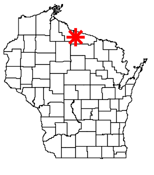
Feet

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, 2014
Orthophotography: NAIP, 2013
Map date: October 14, 2014
***Filename:** MapX_WildRice_Comm_2014.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	

Map 4
Wild Rice Lake
Vilas County, Wisconsin

Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Wild Rice Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.7 Alder Lake

An Introduction to Alder Lake

Alder Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 28 feet, a mean depth of 11.1 feet, and a surface area of approximately 265 acres. The Trout River enters the lake from the south, coming from downstream Wild Rice Lake. It then empties to the north, on its way to Manitowish Lake. Alder Lake is considered to be mesotrophic and its watershed encompasses approximately 50,694 acres. In 2014, 37 native aquatic plant species were found in the lake, of which fern pondweed (*Potamogeton robbinsii*) was the most common. Two non-native shoreland plants, giant reed and reed canary grass, were found during surveys.

Field Survey Notes

Much vegetation observed in the shallower, organic-sediment flats along the southeastern side of the lake. Sparser vegetation along the steeply sloped southern side of lake.

Vasey's pondweed located on a few point-intercept locations.

Shoreline erosion occurring along public access point on northwestern side of lake.

Photo 8.7. Alder Lake, Vilas County

Lake at a Glance* – Alder Lake

Morphology	
Acreage	265
Maximum Depth (ft)	26.0
Mean Depth (ft)	11.1
Volume (acre-feet)	2,935
Shoreline Complexity	1.7
Vegetation	
Curly-leaf Survey Date	July 2, 2014
Comprehensive Survey Date	July 29, 2014
Number of Native Species	37
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	Giant reed, reed canary grass
Simpson's Diversity	0.92
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	46:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.7.1 Alder Lake Water Quality

Water quality data was collected from Alder Lake on six occasions in 2014/2015. 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 2014/2015, any historical data was researched and are included within this report as available.

Some historical data exist for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2014, average summer phosphorus concentrations (20.5 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.7.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Excellent* for a deep, lowland drainage lake.

Total phosphorus surface values from 2014-2015 are compared with bottom-lake samples collected during this same time frame in Figure 8.7.1-2. Concentrations from the epilimnion were found to be similar to those in the hypolimnion during these time periods, with slightly higher concentrations observed in the hypolimnion in August and February. As explained in the Chainwide Report (Water Quality Section Primer), sediments within a lake often release phosphorus under anoxic conditions. When mixing occurs in the lake, these nutrients may be transported to the upper water column for use by algae or aquatic plants. The data in Figure 8.7.1-2 indicate that a minimal amount of phosphorus release is occurring in Alder Lake.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (4.5 µg/L) were slightly lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.7.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2014 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

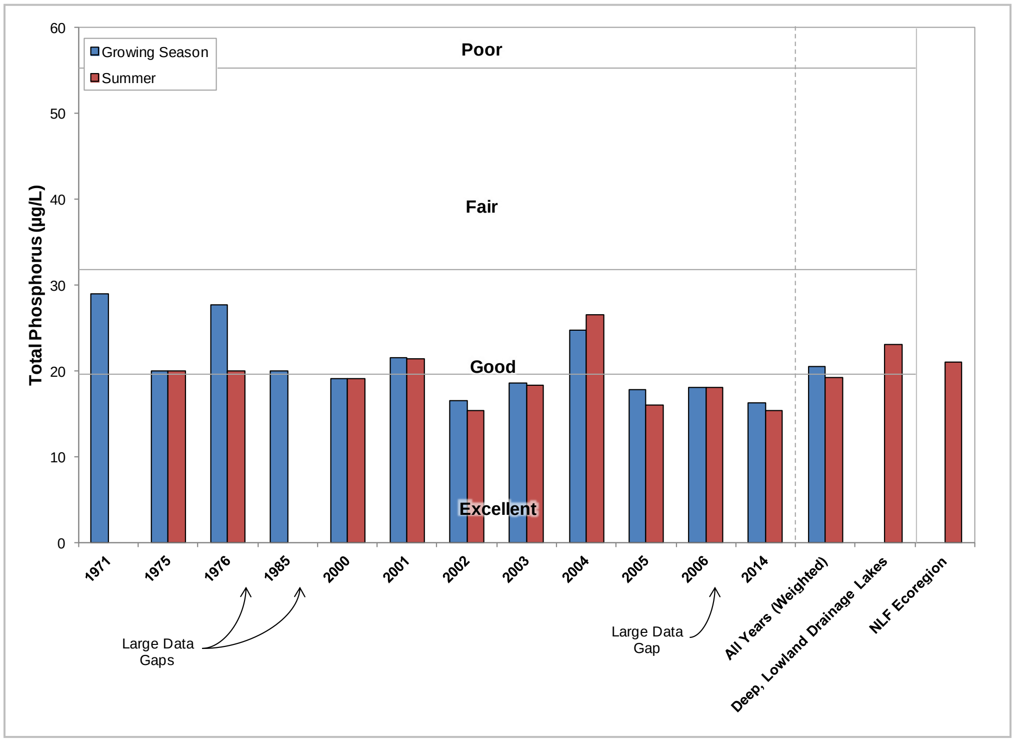


Figure 8.7.1-1. Alder Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

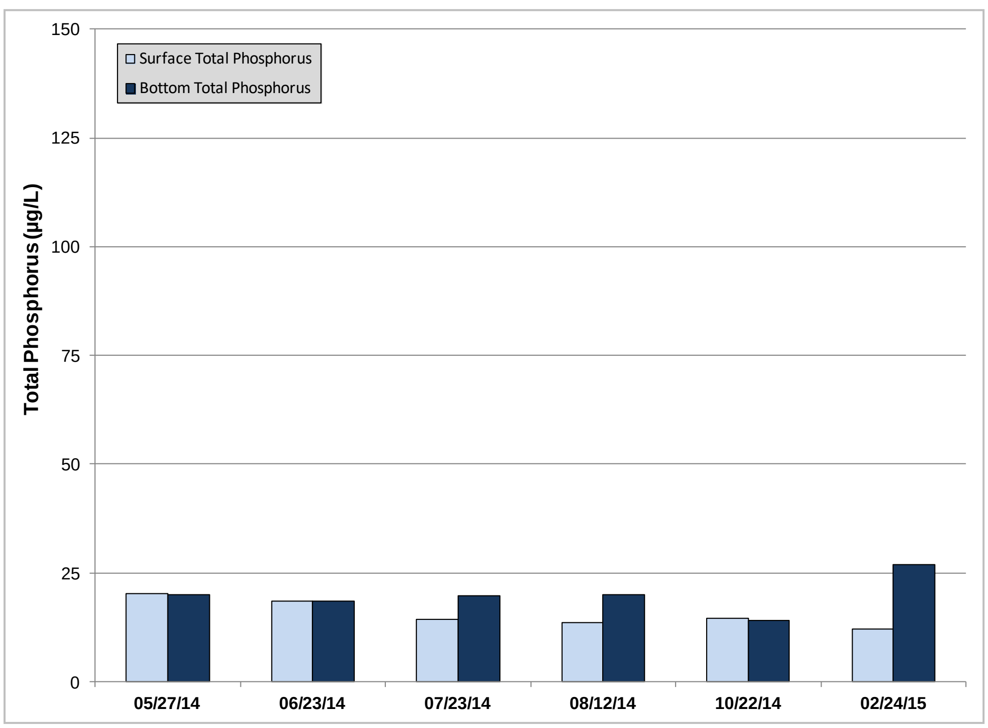


Figure 8.7.1-2. Alder Lake surface and bottom total phosphorus values, 2014-2015.

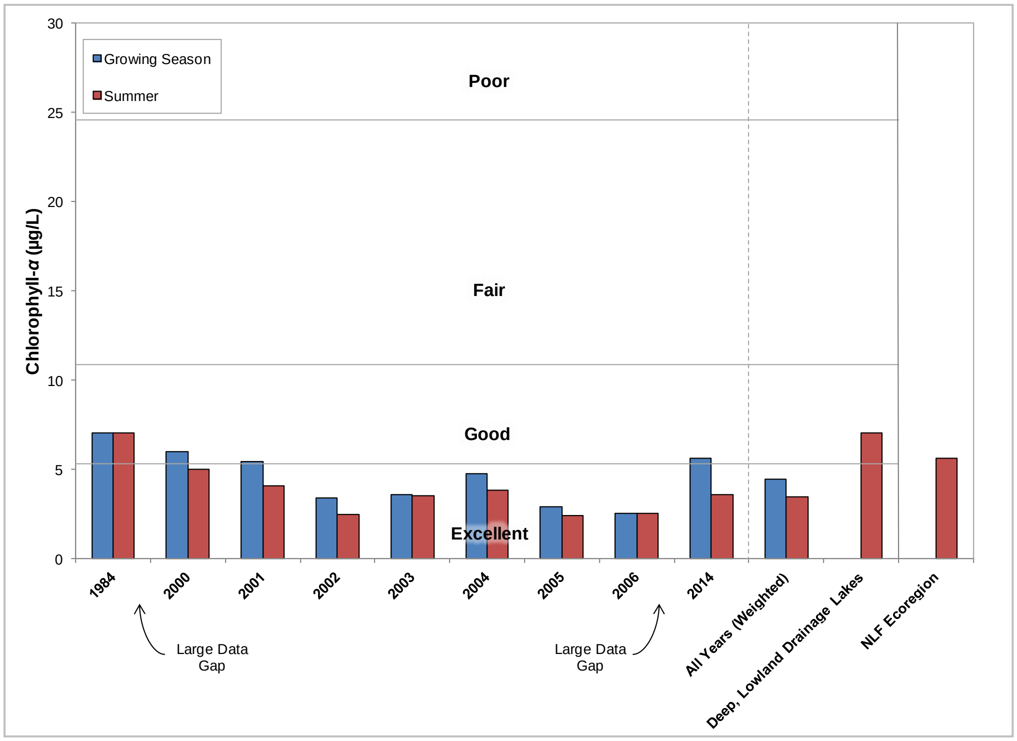


Figure 8.7.1-3. Alder Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The clarity of Alder Lake's water can be described as *Good* to *Excellent* during the summer months in which data has been collected (Figure 8.7.1-4). A weighted average over this timeframe is greater than the median value for other deep, lowland drainage lakes in the state and is also larger than the regional median. Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Alder Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Alder Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in May and July of 2014 were measured for this parameter, and were found to be 40 and 50 Platinum-cobalt units (Pt-co units, or PCU), respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

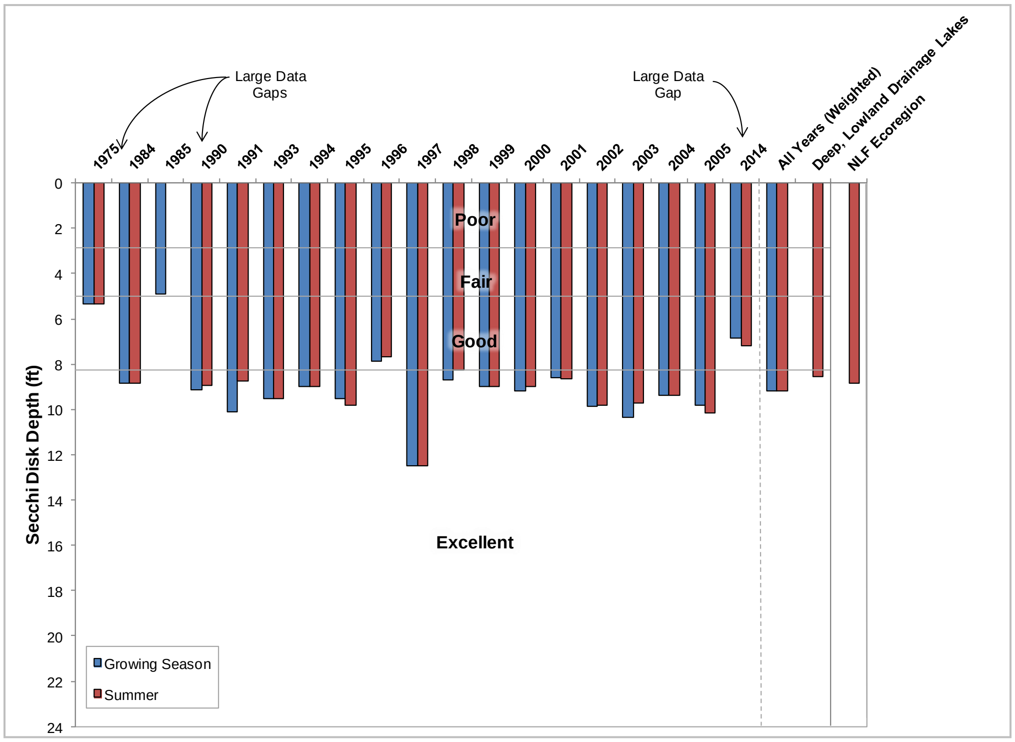


Figure 8.7.1-4. Alder Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Alder Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.7.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Alder Lake is in a mesotrophic state.

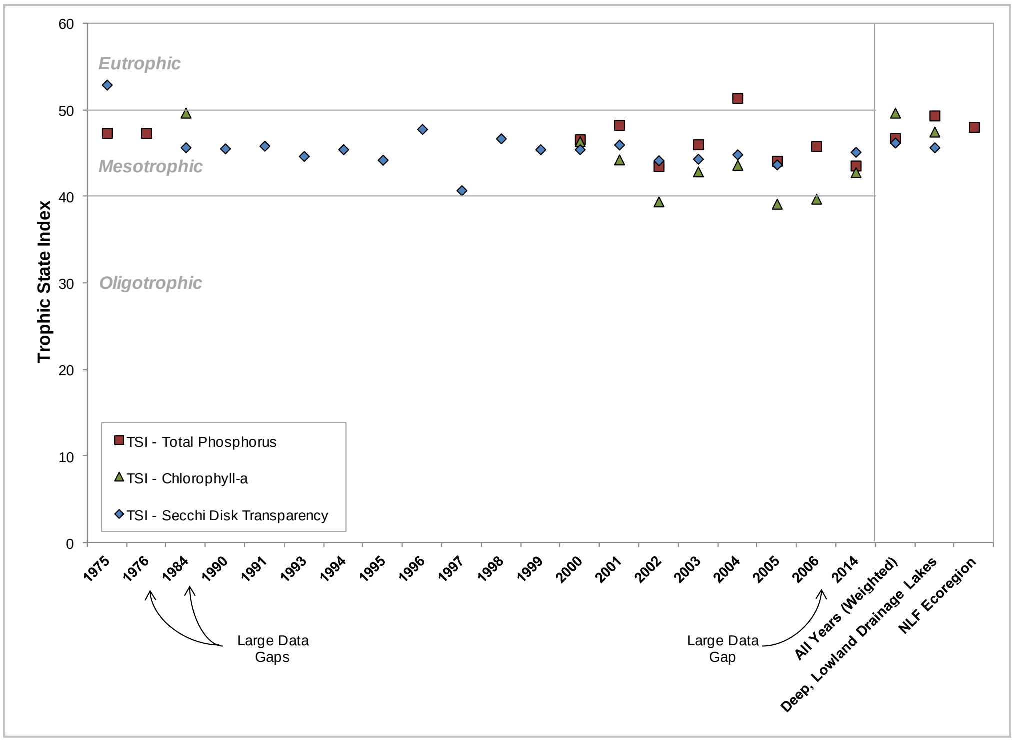


Figure 8.7.1-5. Alder Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Alder Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Alder Lake by Onterra staff. Graphs of those data are displayed in Figure 8.7.1-6 for all sampling events.

Alder Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the lake was not observed to mix completely. The bottom of the lake was found to become void of oxygen (anoxic) several times during the year. This occurrence is not uncommon in Wisconsin lakes, as bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. If the lake mixes completely, oxygen will be reintroduced to the lower levels of the water column.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2015, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

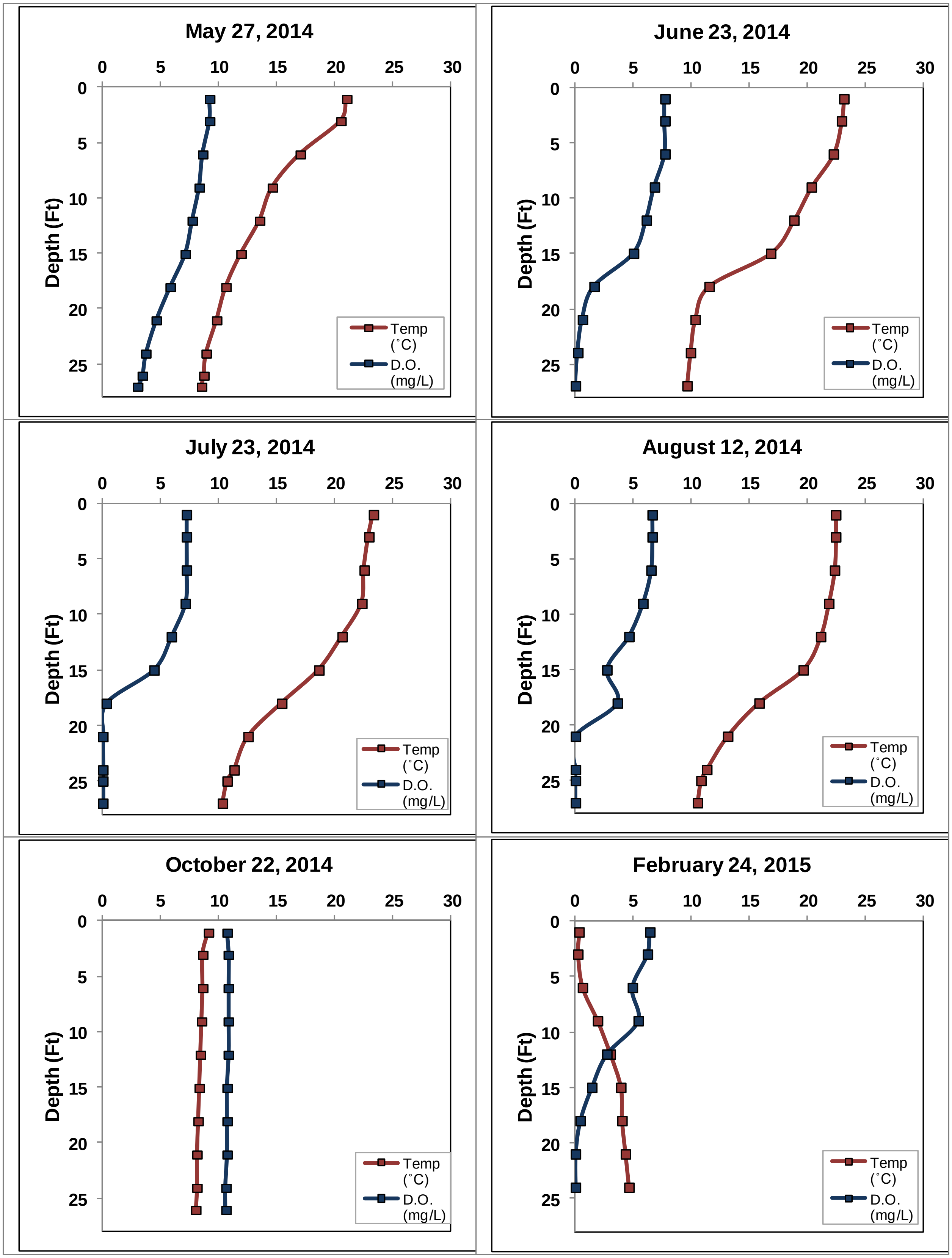


Figure 8.7.1-6. Alder Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Alder 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 Alder 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. Alder Lake's surface water pH was measured at roughly 7.6 during May and July of 2014. These values are slightly above neutral and falls 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 Alder Lake was measured at 33.2 and 40.2 mg/L as $CaCO_3$ in May and July of 2014, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Alder Lake during 2013. 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 Alder Lake's pH of 7.6 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 Alder Lake was found to be 11.0 mg/L in July of 2014, which is below but near the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.7.2 Alder Lake Watershed Assessment

Alder Lake's watershed is 48,381 acres in size. Compared to Alder Lake's size of 265 acres, this makes for an incredibly large watershed to lake area ratio of 182:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Alder Lake this means that 45,068 acres (98%) of Alder Lake's watershed is the Wild Rice Lake subwatershed. The direct watershed of Alder Lake is a very small part of the lake's total watershed (Figure 8.7.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Alder Lake's residence time is approximately 22 days, or that the water within the lake is completely replaced 17.5 times per year.

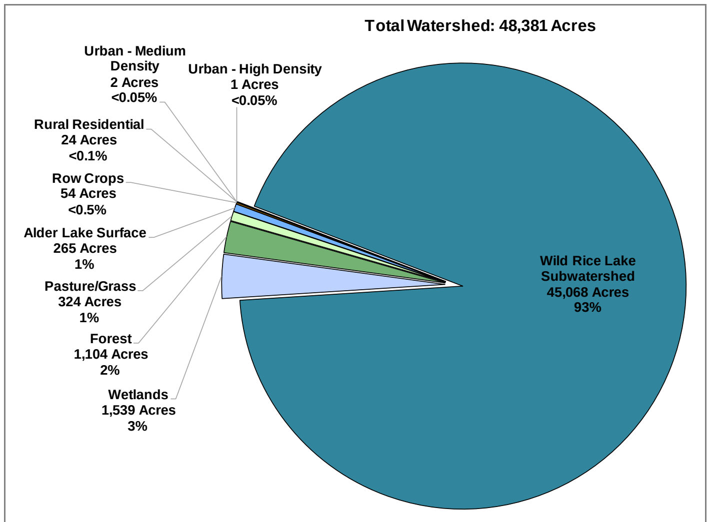


Figure 8.7.2-1. Alder Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

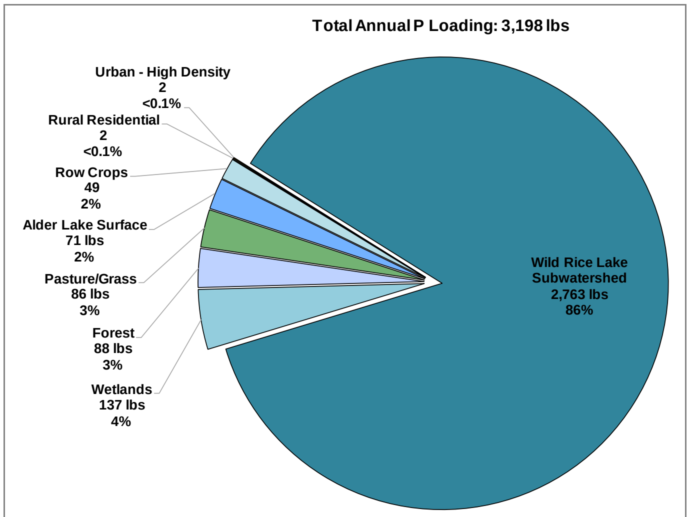


Figure 8.7.2-2. Alder Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Of the estimated 3,198 pounds of phosphorus being delivered to Alder Lake on an annual basis, approximately 2,763 pounds (86%) originates from Wild Rice Lake which is the lake immediately upstream of Alder Lake (Figure 8.7.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 20 µg/L, which is the same as the measured growing season phosphorus concentration of 20 µg/L. This means the model works well for Alder Lake.

Because the large majority of the phosphorus that enters Alder Lake comes from the upstream Wild Rice Lake, efforts to reduce phosphorus levels in Alder Lake should concentrate on reducing phosphorus inputs to Wild Rice Lake.

8.7.3 Alder Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 late summer of 2014, Alder Lake's immediate shoreline was assessed in terms of its development. Alder Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.7.3-1). This constitutes about 54% of Alder 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, 0.5 miles of urbanized and developed–unnatural shoreline (20%) was observed. If restoration of the Alder 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. Alder Lake Map 1 displays the location of these shoreline lengths around the entire lake.

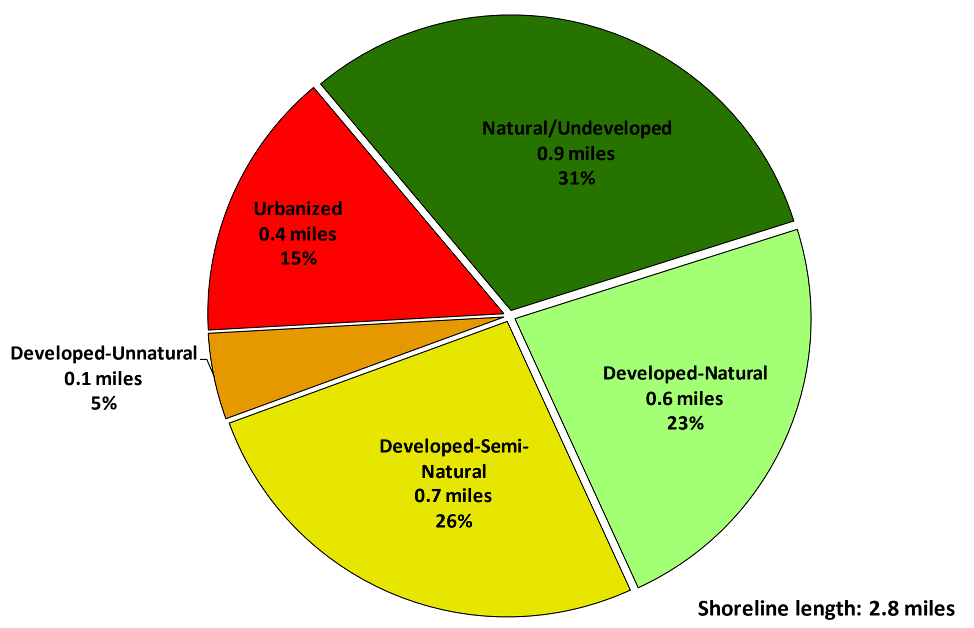


Figure 8.7.3-1. Alder Lake shoreland categories and total lengths. Based upon a late summer 2014 survey. Locations of these categorized shorelands can be found on Alder Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Alder Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 36 total pieces of coarse woody habitat were observed along 2.8 miles of shoreline (Alder Lake Map 2), which gives Alder Lake a coarse woody habitat to shoreline mile ratio of 13:1 (Figure 8.7.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Twenty-five pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, eleven pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Alder 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 98 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 Alder Lake falls below the 25th percentile of these 98 lakes (Figure 8.7.3-2).

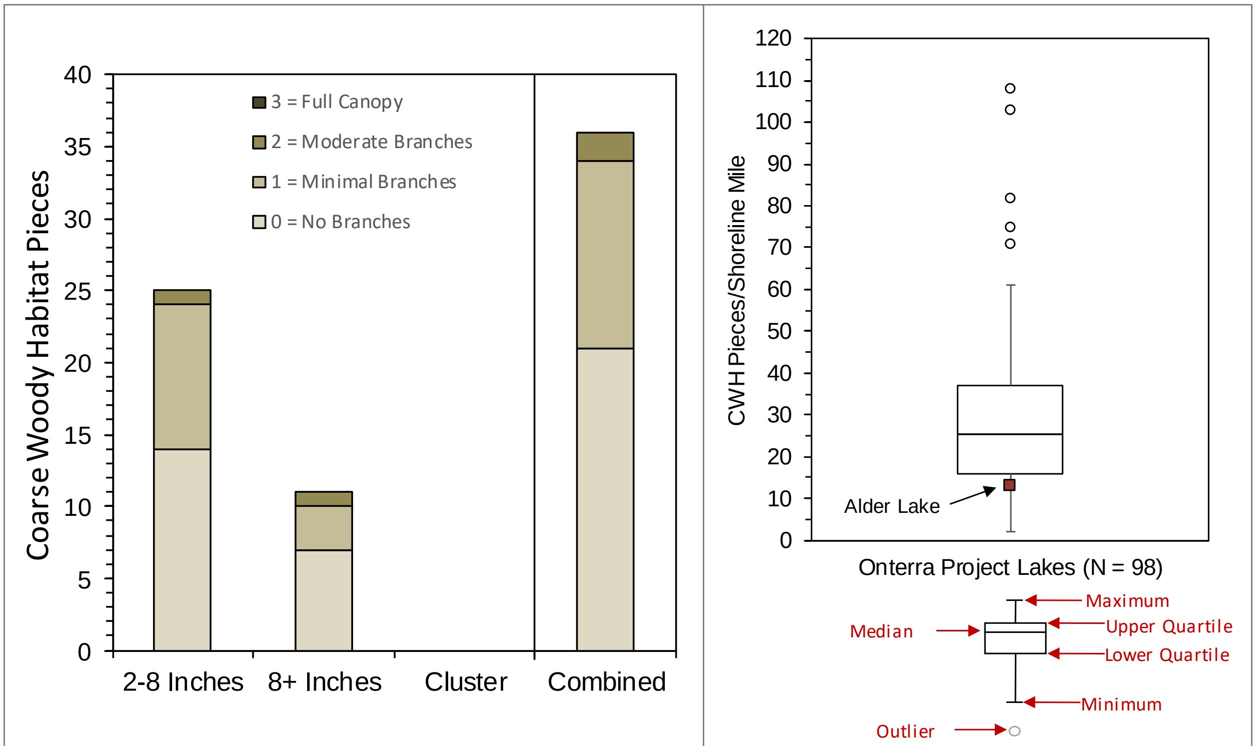


Figure 8.7.3-2. Alder Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of the Alder Lake coarse woody habitat can be found on Alder Lake Map 2.

8.7.4 Alder Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Alder Lake on July 2, 2014. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Alder Lake on July 29, 2014 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 37 species of native aquatic plants were located in Alder Lake (Table 8.7.4-1). Twenty-six of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 11 species were observed incidentally during visits to Alder Lake. Two non-native species, giant reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*) were observed along the Alder Lake shoreline.

Aquatic plants were found growing to a depth of 15 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 149 point-intercept locations sampled within the littoral zone, roughly 74% contained aquatic vegetation. Alder Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays that are more likely to hold organic substrates. Approximately 61% of the point-intercept sampling locations where sediment data was collected at were sand, 31% consisted of a fine, organic substrate (muck) and 8% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.7.4-1. Aquatic plant species located in Alder Lake during 2014 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2014 (Onterra)
Emergent	*Bolboschoenus fluviatilis*	River bulrush	5	I
	Carex lasiocarpa subsp. *americana*	American woolly-fruit sedge	9	I
	Equisetum fluviatile	Water horsetail	7	I
	Eleocharis palustris	Creeping spikerush	6	X
	Juncus effusus	Soft rush	4	I
	Phragmites australis	Giant reed	Exotic	I
	Phalaris arundinacea	Reed canary grass	Exotic	I
	Scirpus cyperinus	Wool grass	4	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elatine minima	Waterwort	9	I
	Elodea nuttallii	Slender waterweed	7	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes spp.	Quillwort species	N/A	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Nitella spp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia minor	Small bladderwort	10	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria sp.	Arrowhead sp.	-	I

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

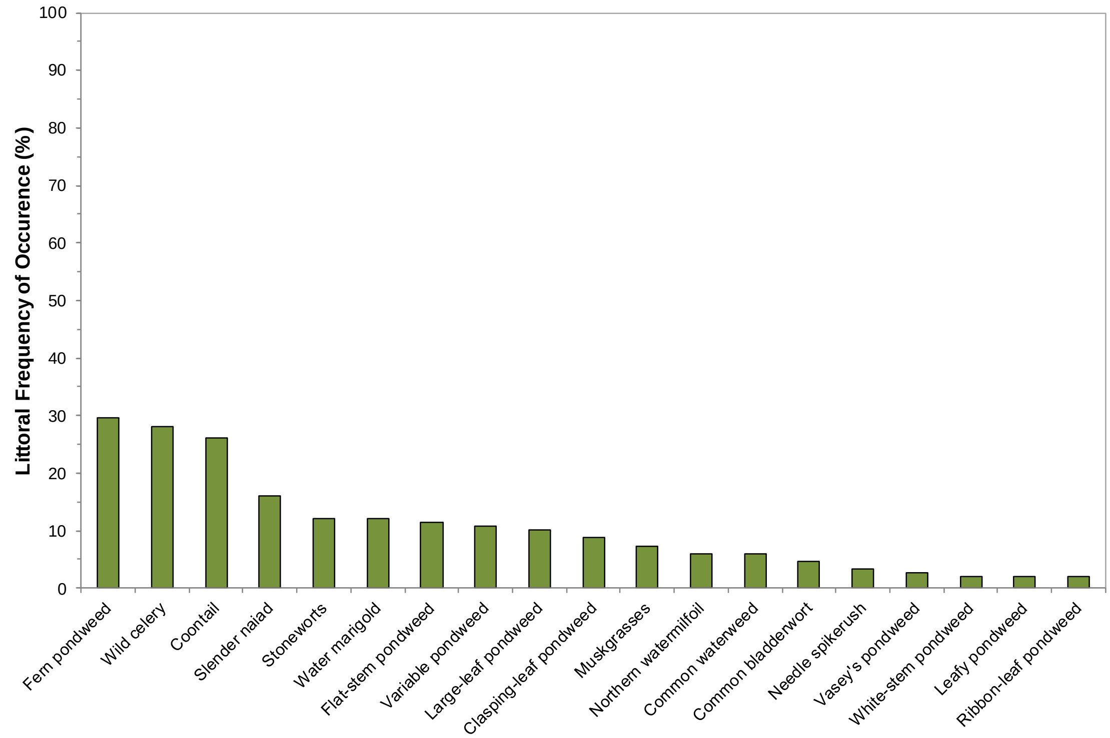


Figure 8.7.4-1. Alder Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2014 point-intercept survey. Please note that only species with a frequency of occurrence greater than 2% are depicted.

Figure 8.7.4-1 (above) shows that fern pondweed, wild celery and coontail were the most frequently encountered plants within Alder Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Coontail is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and its location can be largely a product of water movement.

During aquatic plant inventories, 37 species of native aquatic plants (including incidentals) were found in Alder Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Alder Lake’s plant community (0.92) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 fern pondweed was found at 30% of the sampling locations, its relative frequency of occurrence is 14%.

Explained another way, if 100 plants were randomly sampled from Alder Lake, 14 of them would be fern pondweed. This distribution can be observed in Figure 8.7.4-2, where together 14 native (and one non-native) species account for 90% of the aquatic plant population within Alder Lake, while the other 12 species account for the remaining 10%. Eleven additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.7.4-1 as incidentals.

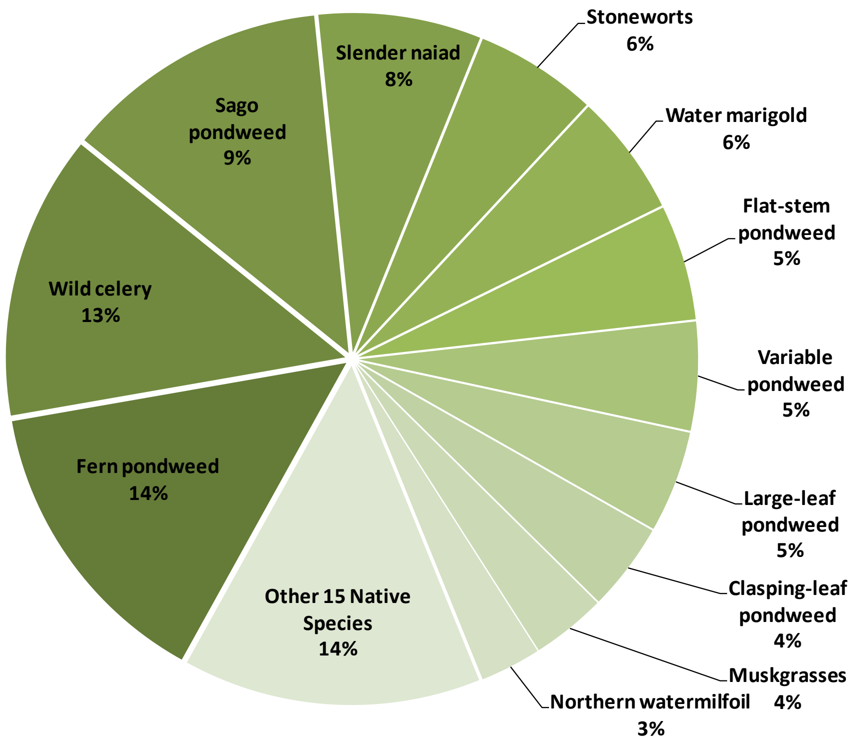


Figure 8.7.4-2. Alder Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2014 point-intercept survey.

Alder Lake's average conservatism value (6.6) is higher than the state median (6.0) but slightly lower than the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Alder Lake is indicative of a moderately disturbed system. Combining Alder Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.9 which is above the median values of the ecoregion and state.

Alder Lake was found to have few emergent and floating-leaf aquatic plant communities. The 2014 community map indicates that approximately 0.7 acres of the lake contains these types of plant communities (Alder Lake Map 4, Table 8.7.4-2). Ten floating-leaf and emergent species were located on Alder Lake (Table 8.7.4-1), all of which provide valuable wildlife habitat.

Table 8.7.4-2. Alder Lake acres of emergent and floating-leaf plant communities from the 2014 community mapping survey.

Plant Community	Acres
Emergent	0.7
Floating-leaf	0.0
Mixed Floating-leaf and Emergent	0.0
Total	0.7

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Alder Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

One species located within an emergent community on Alder Lake is non-native, giant reed (*Phragmites australis*). This species was mixed within a cattail community on the lake's northern shoreline. Further downstream, a colony of giant reed was observed on the north shore of the Trout River (Map 4). There are 27 known genetic strains for giant reed worldwide – 11 of which appear to be native to the United States. The European strain is far more invasive than the native US strains. Vouchers of this plant were collected and sent to the UW-Stevens Point Herbarium for verification. Though difficult to differentiate based upon morphological features along, the samples are believed to be of the non-native, invasive strain.

Further information pertaining to this non-native species may be found in the Chain-wide Aquatic Plant section, non-native plants sub-section. Continued monitoring of this population and nearby shoreline reaches is important to learn impacts of this species on the native shoreline plant community.

Non-Native Aquatic Plants in Alder Lake

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed infrequently along the shore of Alder Lake. Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Giant Reed (aka Phragmites)

Giant reed (*Phragmites australis* subsp. *australis*) is a tall, perennial grass that was introduced to the United States from Europe. While a native strain (*P. australis* subsp. *americanus*) of this species exists in Wisconsin, the plants located along the shorelines and in shallow water in Alder are the non-native, invasive strain. 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.

Giant reed was found growing along the shore on the northeast and northwest sides of the lake (Alder Lake Map 4). Because this species has the capacity to displace the valuable wetland plants along the exposed shorelines, it is recommended that these plants be removed by cutting and bagging the seed heads and applying herbicide to the cut ends. This management strategy is most effective when completed in late summer or early fall when the plant is actively storing sugars and carbohydrates in its root system in preparation for over-wintering. A permit issued by the WDNR will likely be needed to place herbicide on plants that are located within the water.

8.7.5 Alder 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 Alder 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.7.5-1). 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. Alder Lake has been stocked from 1999 to 1973 with muskellunge. Stocking efforts for Alder Lake are displayed in Table 8.7.5-1.

Photograph 8.7.5-1. Fingerling Muskellunge.

Table 8.7.5-1. Stocking data available for <u>muskellunge</u> in Alder Lake (1973-1999).

Lake	Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
Alder Lake	1973	Muskellunge	Fingerling	500	9
Alder Lake	1976	Muskellunge	Fingerling	500	11
Alder Lake	1980	Muskellunge	Fingerling	500	9
Alder Lake	1983	Muskellunge	Fingerling	150	11
Alder Lake	1986	Muskellunge	Fingerling	300	12
Alder Lake	1988	Muskellunge	Fingerling	300	10.5
Alder Lake	1990	Muskellunge	Fingerling	300	9
Alder Lake	1991	Muskellunge	Fingerling	150	11.5
Alder Lake	1992	Muskellunge	Fingerling	150	11
Alder Lake	1993	Muskellunge	Fingerling	300	10
Alder Lake	1999	Muskellunge	Large Fingerling	150	12.1

Alder Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.7.5-1 from 1999 to 2017. As many as 130 walleye have been harvested from the lake in the past (2000), but the average harvest is roughly 42 fish in a given year. Spear harvesters on average have taken 56% of the declared quota. Additionally, on average 8% of walleye harvested have been female.

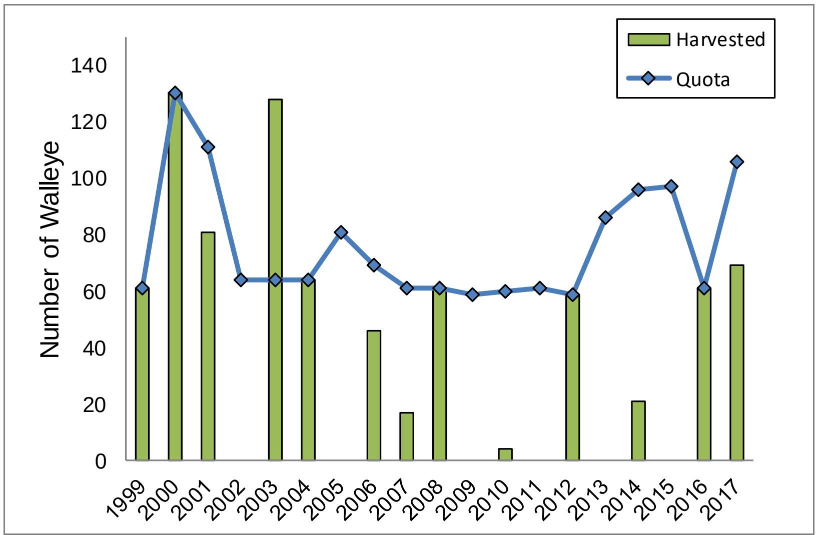
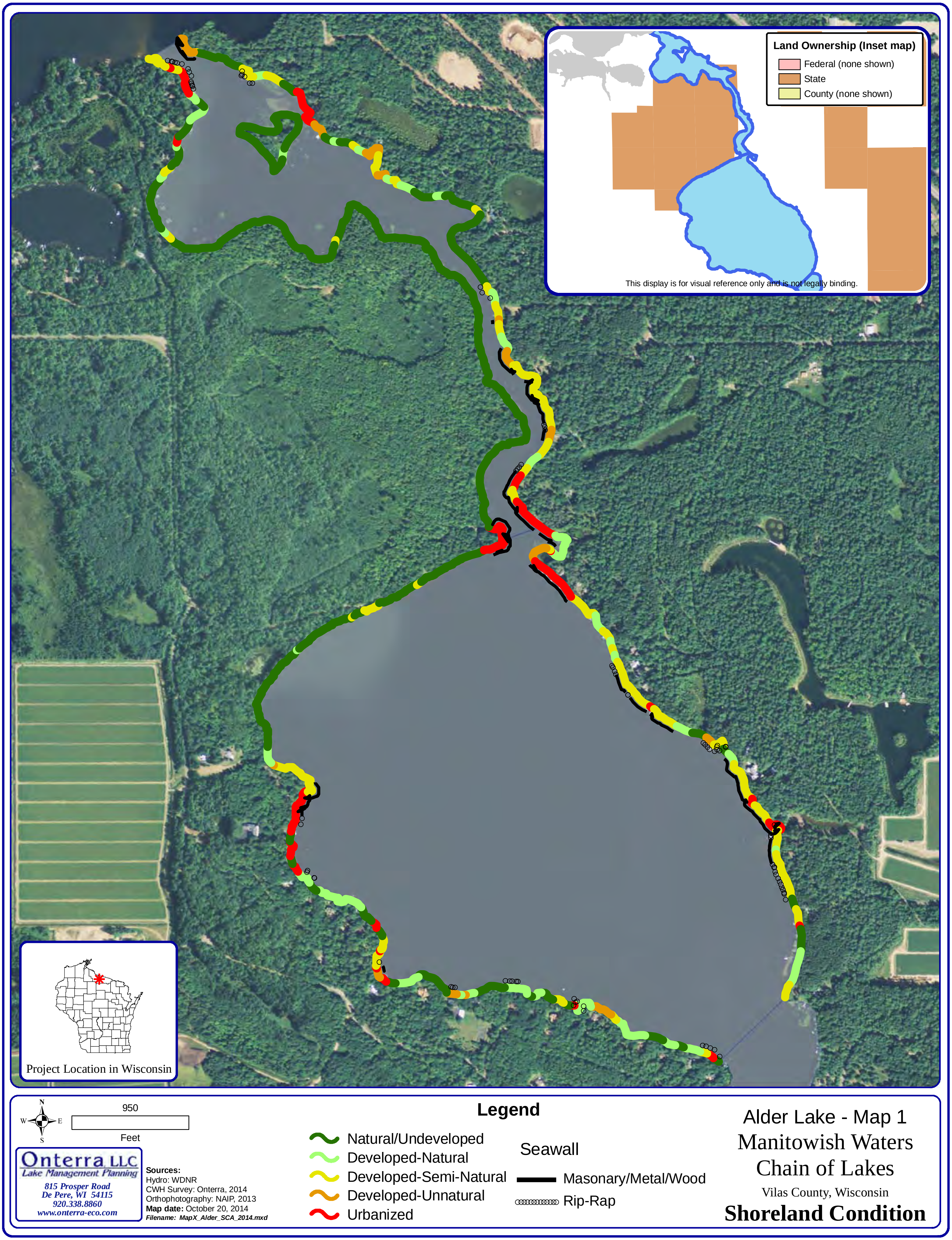
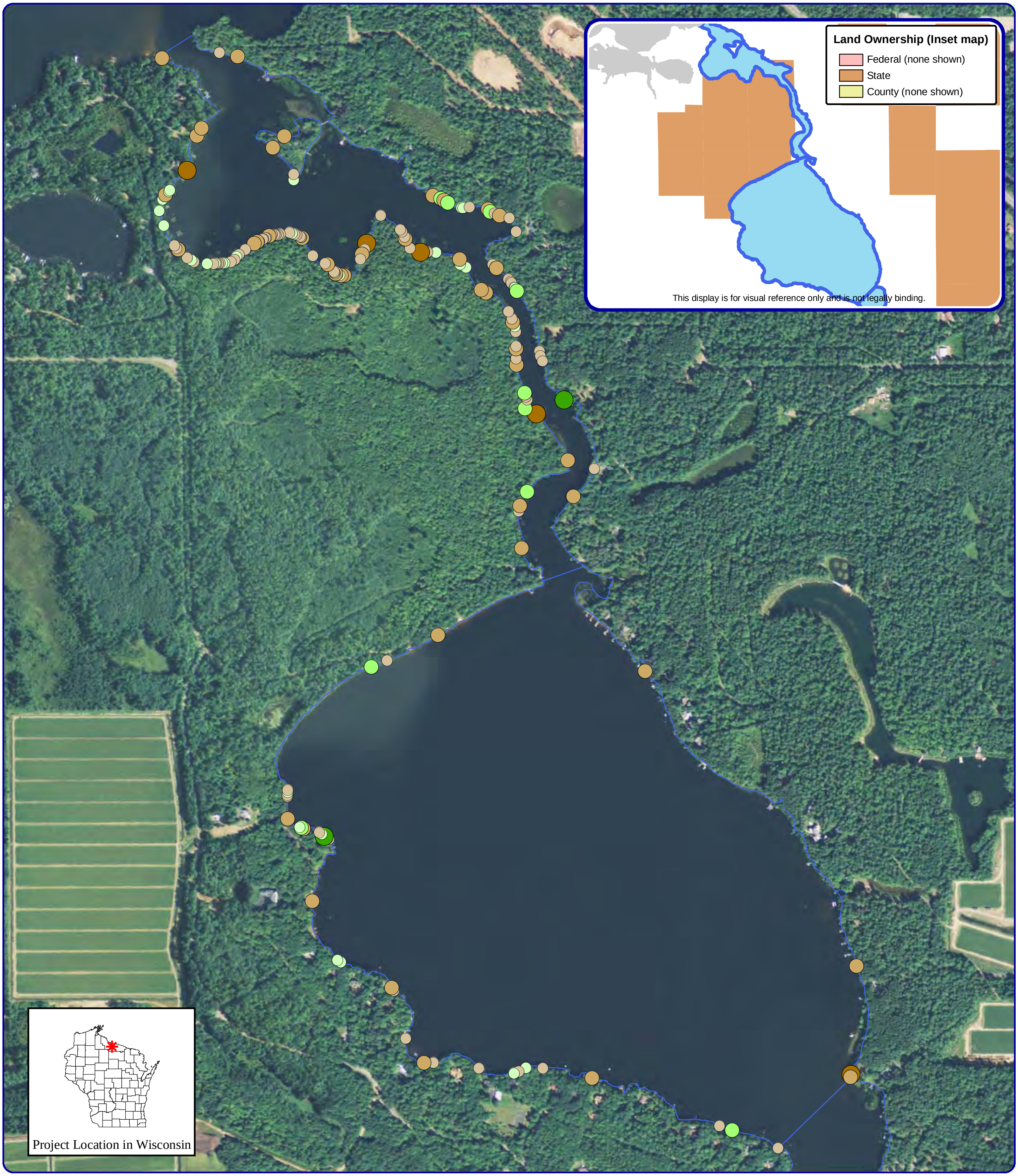


Figure 8.7.5-1. Alder Lake walleye spear harvest data. (GLIFWC 1999-2017).

Although Alder Lake has been declared as a spear harvest lake for muskellunge, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for muskellunge.


Land Ownership (Inset map)
Federal (none shown)
State
County (none shown)
This display is for visual reference only and is not legally binding.
Project Location in Wisconsin
N
W
E
S
950
Feet
Legend
Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized
Seawall
Masonary/Metal/Wood
Rip-Rap
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro: WDNR
CWH Survey: Onterra, 2014
Orthophotography: NAIP, 2013
Map date: October 20, 2014
Filename: MapX_Alder_SCA_2014.mxd
Alder Lake - Map 1
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Shoreland Condition



950
Feet

Legend

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

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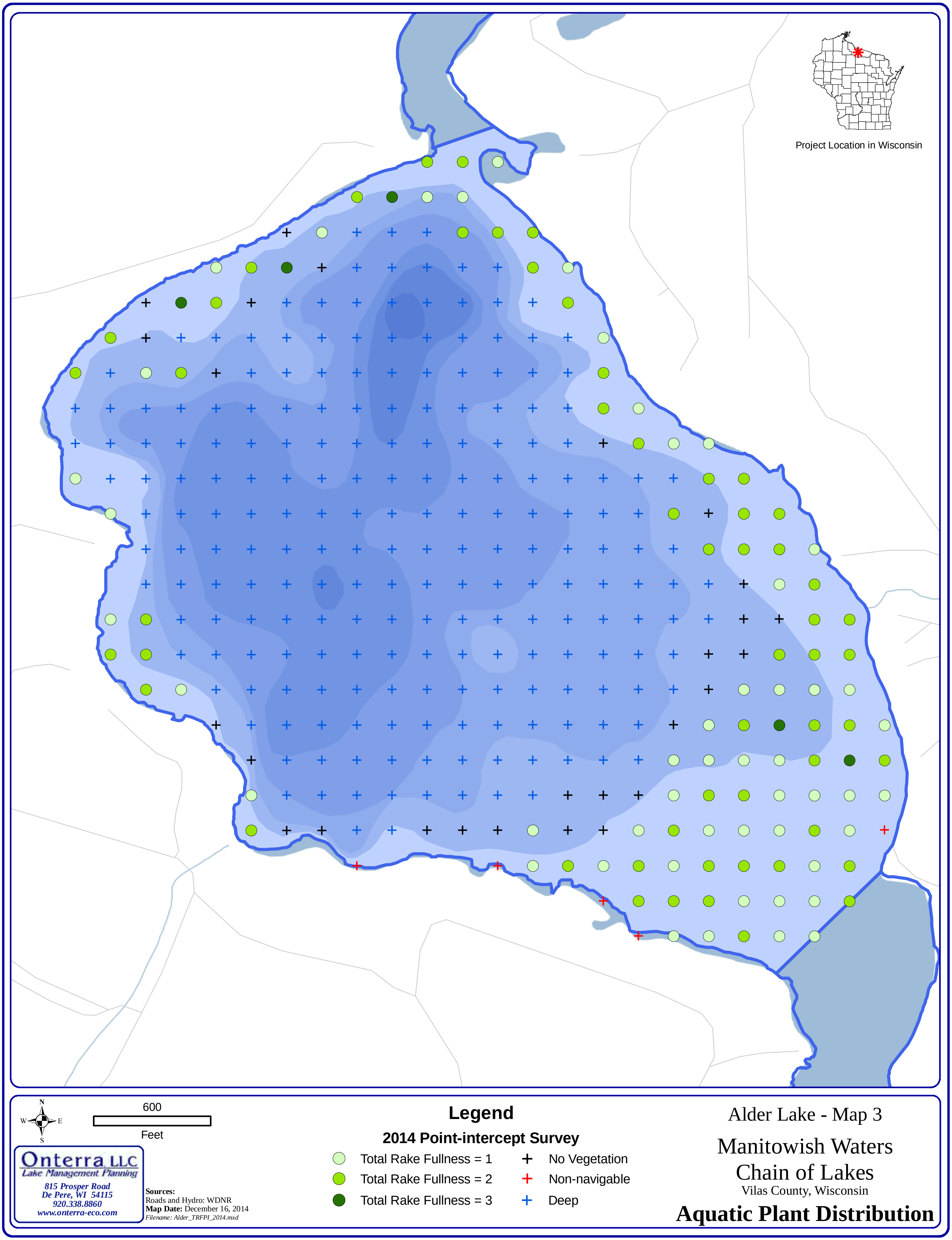
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

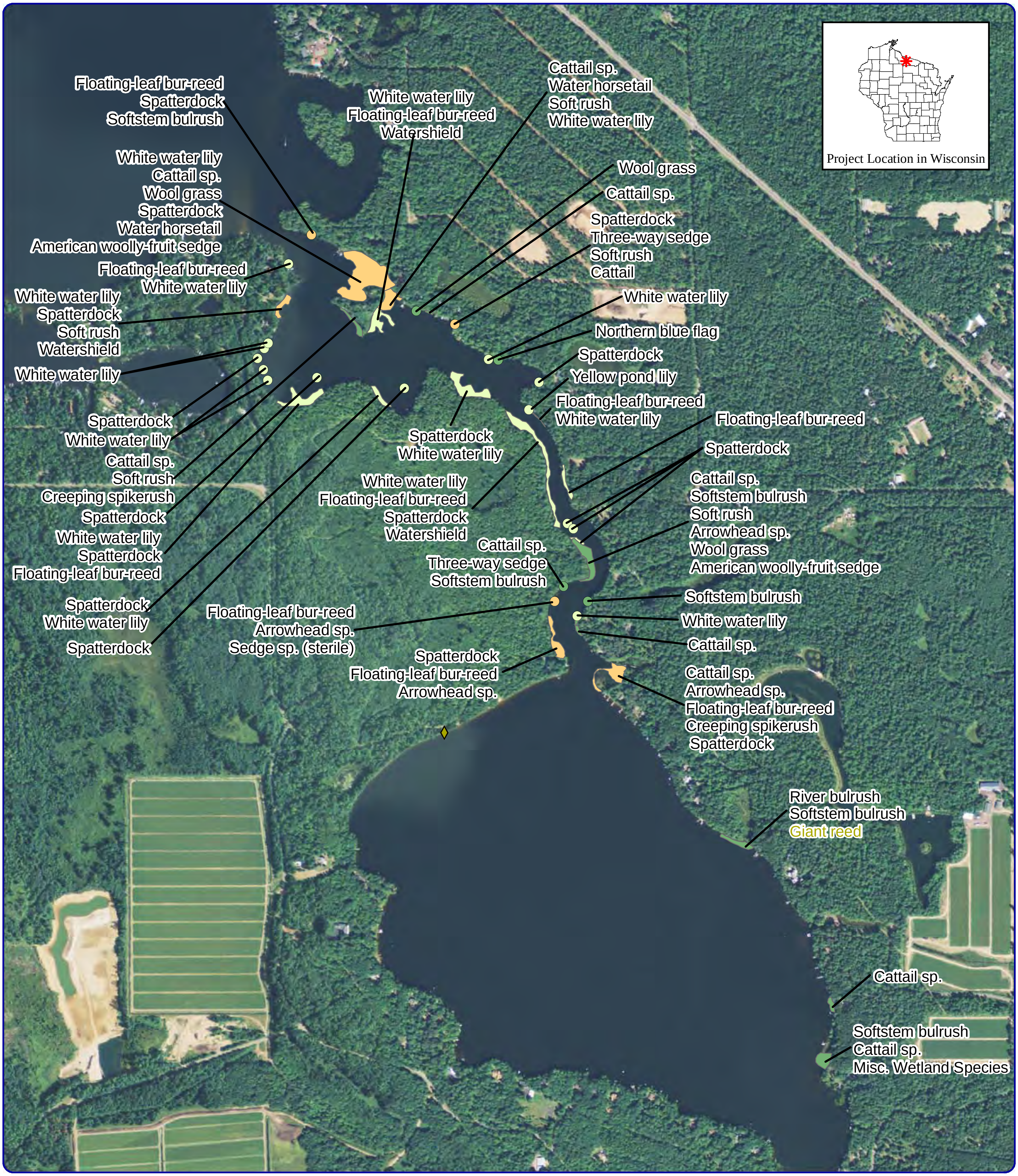
Sources:
Hydro: WDNR
CWH Survey: Onterra, 2014
Orthophotography: NAIP, 2013
Map date: October 20, 2014
Filename: MapX_Alder_CWH_2014.mxd

Alder Lake - Map 2
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin

Coarse Woody Habitat



Project Location in Wisconsin
N
W
E
S
600
Feet
Legend
2014 Point-intercept Survey
Total Rake Fullness = 1
Total Rake Fullness = 2
Total Rake Fullness = 3
No Vegetation
Non-navigable
Deep
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Map Date: December 16, 2014
Filename: Alder_TRFPI_2014.mxd
Alder Lake - Map 3
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Aquatic Plant Distribution



N
W E
S
1,150
Feet

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920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2014
Orthophotography: NAIP, 2013
Map date: October 14, 2014
***Filename:** MapX_Alder_Comm_2014.mxd*

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Giant Reed

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

Alder Lake - Map 4
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-Leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Manitowish Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.8 Manitowish Lake

An Introduction to Manitowish Lake

Manitowish Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 61 feet, a mean depth of 23 feet, and a surface area of approximately 496 acres. Manitowish Lake is considered to be mesotrophic and its watershed encompasses approximately 53,720 acres. In 2016, 55 aquatic plant species were found in the lake, of which wild celery (*Vallisneria americana*) the most common. Two non-native shoreland plants, pale-yellow iris and purple loosestrife, were found during surveys.

Field Survey Notes

Of all the lakes in the Chain, Manitowish Lake was found to have the highest species richness (number of different aquatic plant species). One of the species found was Vasey's pondweed, a state-listed special concern plant, which requires a high-quality environment to live.

Photo 8.8. Manitowish Lake, Vilas County

Lake at a Glance* – Manitowish Lake

Morphology	
Acreage	496
Maximum Depth (ft)	61
Mean Depth (ft)	23
Volume (acre-feet)	11,632
Shoreline Complexity	8.7
Vegetation	
Curly-leaf Survey Date	June 28-29, 2016
Comprehensive Survey Date	July 18-19, 2016
Number of Native Species	53
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	Pale-yellow iris & Purple loosestrife
Simpson's Diversity	0.91
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Oligo-mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	107:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.8.1 Manitowish Lake Water Quality

Water quality data was collected from Manitowish Lake on six occasions in 2016/2017. 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 2016/2017, any historical data was researched and are included within this report as available.

Very little historical data exist for two water quality parameters of interest – total phosphorus and chlorophyll-*a*. In 2016, average summer phosphorus concentrations (14.7 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.8.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted summer value from all available data ranks as *Excellent* for a deep, lowland drainage lake.

Total phosphorus surface values from 2016-2017 are compared with bottom-lake samples collected during this same time frame in Figure 8.8.1-2. Concentrations from the epilimnion were found to be lower to those in the hypolimnion during these time periods. As explained in the Chainwide Report (Water Quality Section Primer), sediments within a lake often release phosphorus under anoxic conditions. When mixing occurs in the lake, these nutrients may be transported to the upper water column for use by algae or aquatic plants. The data in Figure 8.8.1-2 indicate that phosphorus is being released from the sediments in Manitowish Lake; however, the near-bottom phosphorus concentrations are relatively low, and internal phosphorus loading is not a significant source of phosphorus in Manitowish Lake.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (1.4 µg/L) were slightly lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.7.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2016 visits to the lake, Onterra ecologists recorded field notes describing stained water but good conditions overall.

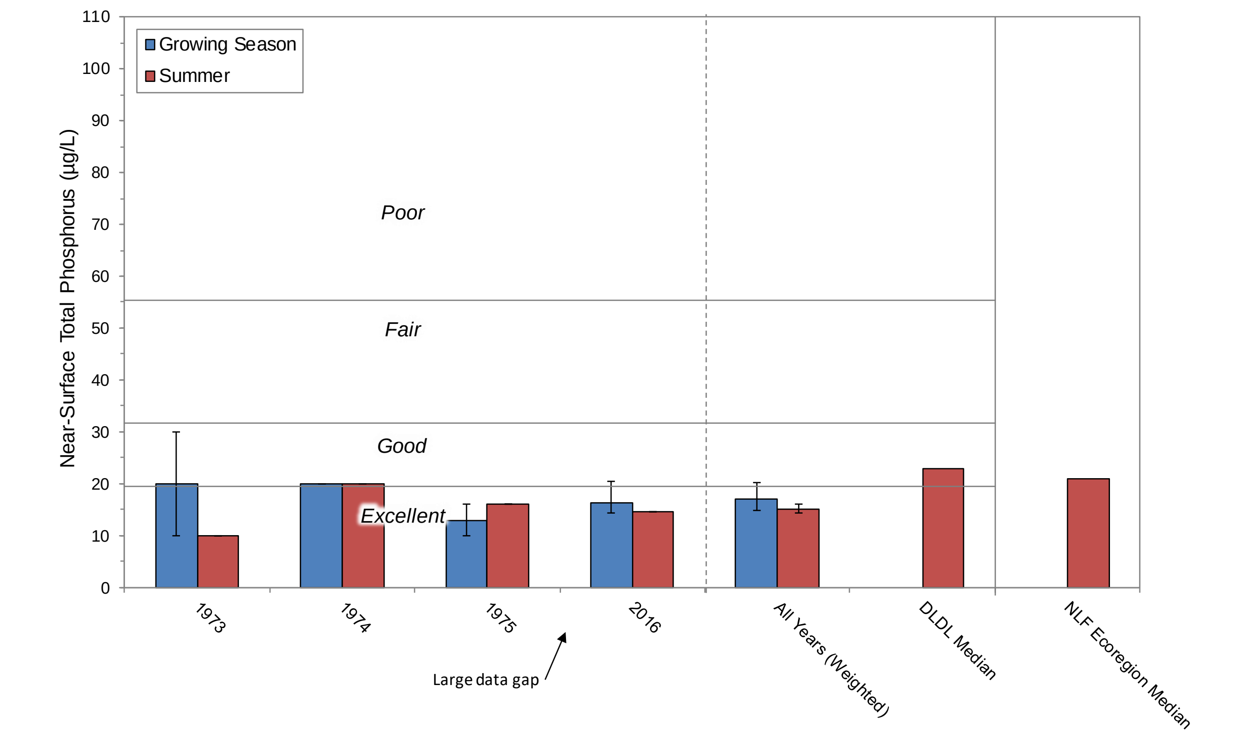


Figure 8.8.1-1. Manitowish Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

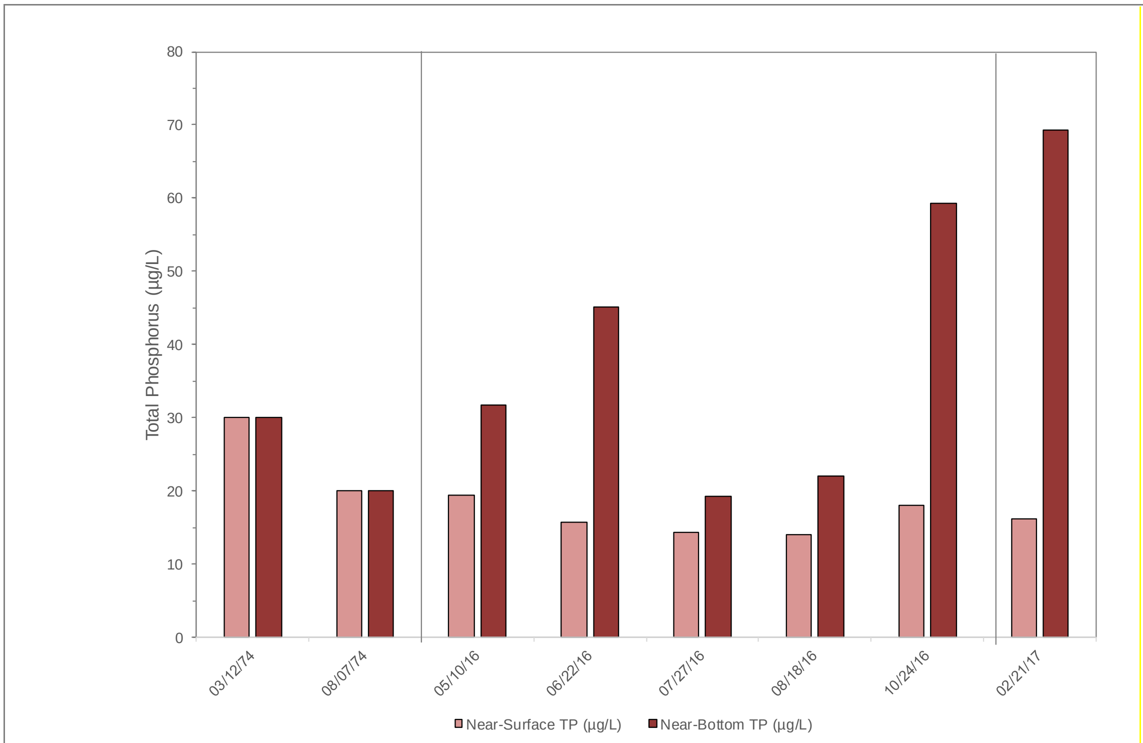


Figure 8.8.1-2. Manitowish Lake surface and bottom total phosphorus values.

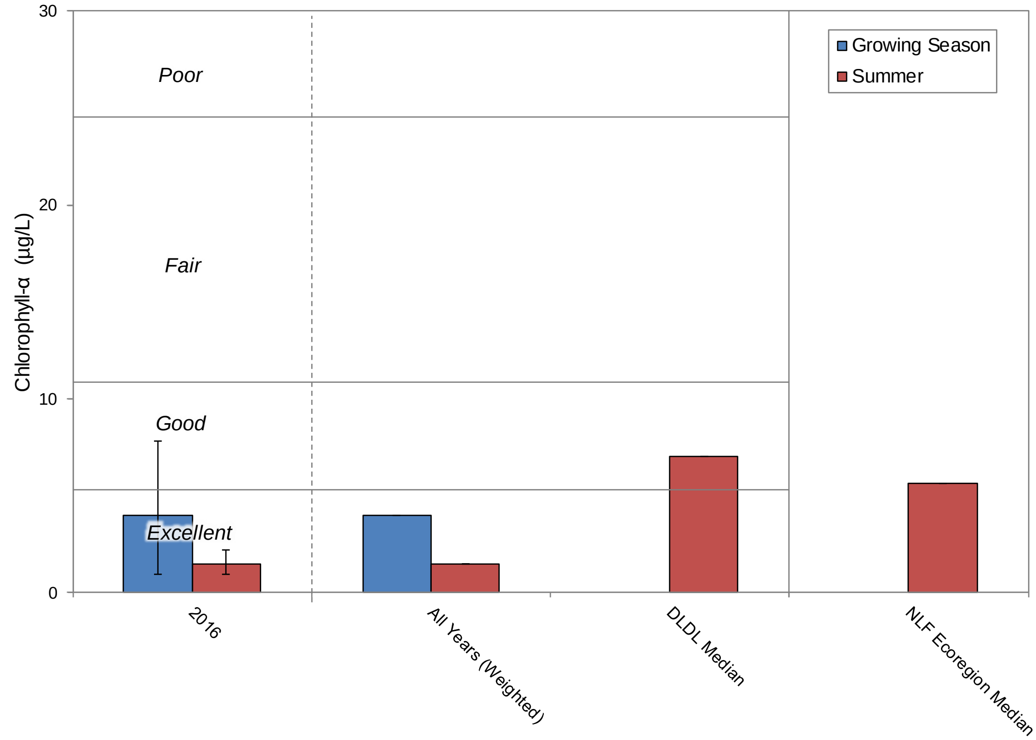


Figure 8.8.1-3. Manitowish Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The clarity of Manitowish Lake's water can be described as *Excellent* during the summer months in which data has been collected (Figure 8.8.1-4). A weighted average over this timeframe is greater than the median value for other deep, lowland drainage lakes in the state and is also larger than the regional median. Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Manitowish Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Manitowish Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

True color measures the dissolved organic materials in water. Water samples collected in May and July of 2016 were measured for this parameter, and were found to be 20 Platinum-cobalt units (Pt-co units, or PCU), for both months. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having low color, 40-100 PCU as medium color, and >100 PCU as high color.

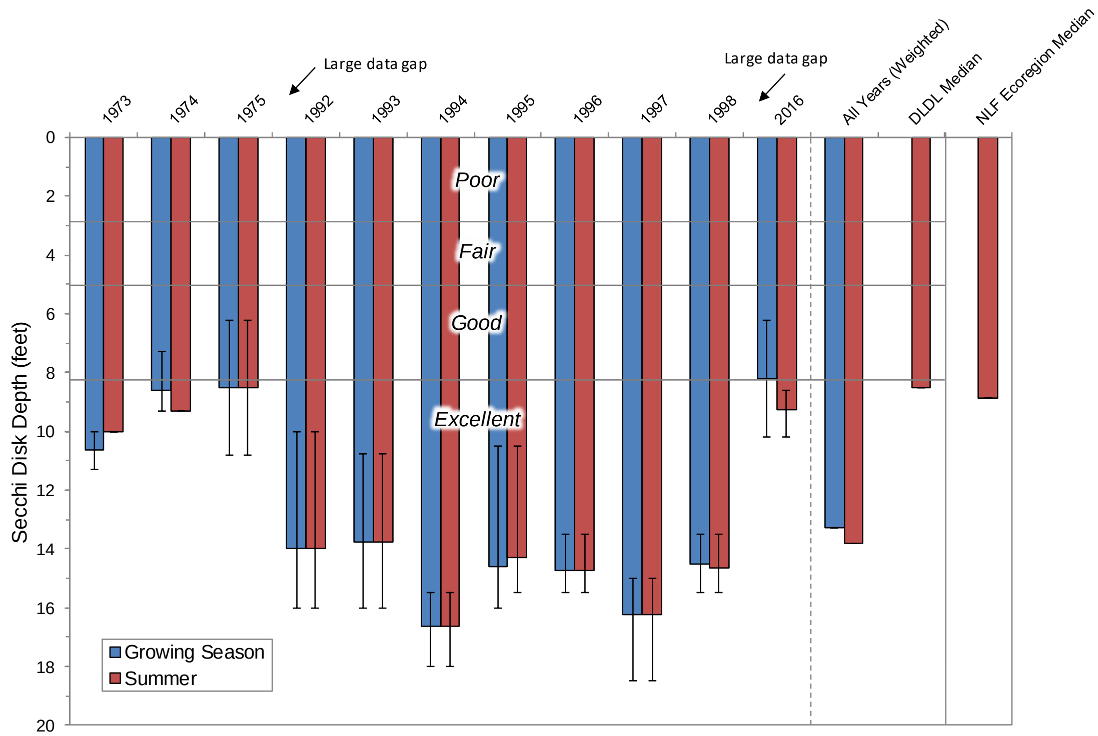


Figure. 8.8.1-4. Manitowish Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Manitowish Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.8.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Manitowish Lake is in an oligo-mesotrophic state.

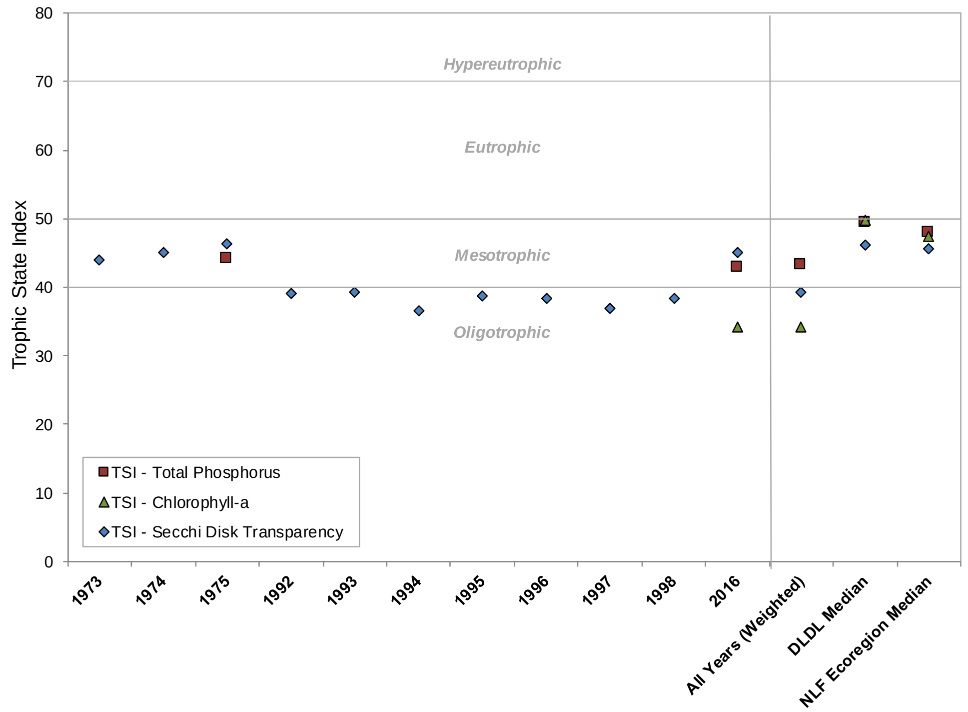


Figure 8.8.1-5. Manitowish Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Manitowish Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Manitowish Lake by Onterra staff. Graphs of those data are displayed in Figure 8.8.1-6 for all sampling events.

Manitowish Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the lake remained thermally stratified, developing an anoxic hypolimnion. This occurrence is not uncommon in Wisconsin lakes, as bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. If the lake mixes completely, oxygen will be reintroduced to the lower levels of the water column.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2017, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

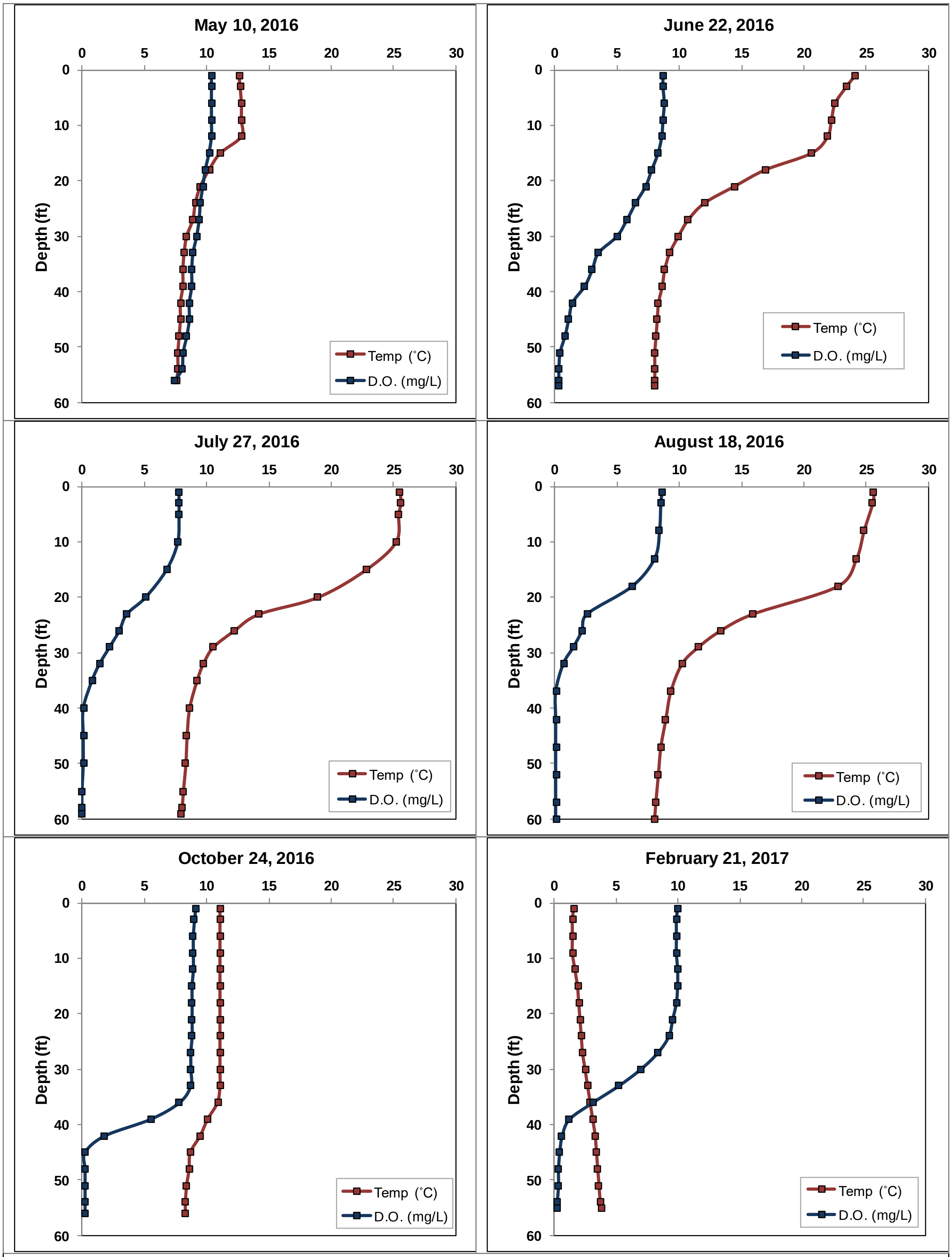


Figure 8.8.1-6. Manitowish Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Manitowish 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 Manitowish 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. Manitowish Lake's surface water pH was measured at roughly 7.9 during May and 7.8 in July of 2016. These values are slightly above neutral and falls 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 Manitowish Lake was measured at 37.8 and 37.0 mg/L as $CaCO_3$ in May and July of 2016, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Manitowish Lake during 2016. 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 Manitowish Lake's pH of 7.85 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 Manitowish Lake was found to be 11.7 mg/L in July of 2016, which is just below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2016 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.8.2 Manitowish Lake Watershed Assessment

Manitowish Lake's watershed is 51,408 acres in size. Compared to Manitowish Lake's size of 500 acres, this makes for a large watershed to lake area ratio of 102:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Manitowish Lake this means that 46,088 acres (94%) of the lake's watershed is the Alder Lake subwatershed, 890 acres (2%) from the Little Star subwatershed, and the rest of the Manitowish Lake's watershed is comprised of land cover types including forest (2%), wetlands (1%), and smaller amounts of other landuses (Figure 8.8.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Manitowish Lake's residence time is approximately 77 days, or the water within the lake is completely replaced 4.7 times per year.

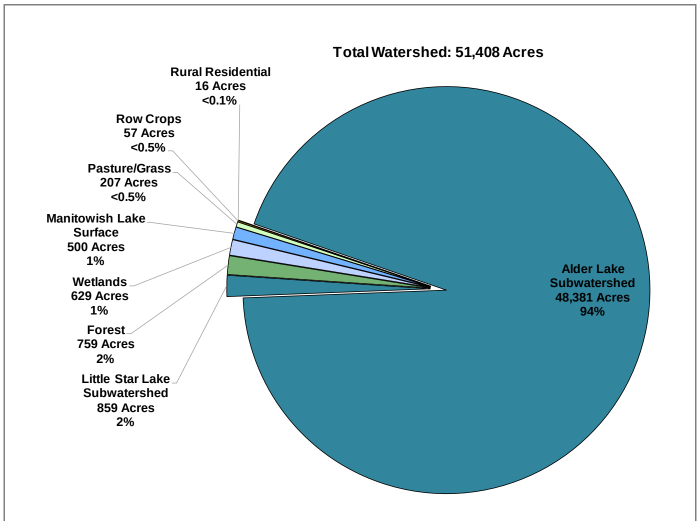


Figure 8.8.2-1. Manitowish Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 3,118 pounds of phosphorus being delivered to Manitowish Lake on an annual basis, approximately 2,735 pounds (88%) originates from the Alder Lake subwatershed, with next largest source being the lake surface itself 134 pounds (4%) and the remainder being from various landuses (Figure 8.8.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 16 µg/L, which is essentially the same as the measured growing season average total phosphorus concentration of 15 µg/L. This means the model works reasonably well for Manitowish Lake.

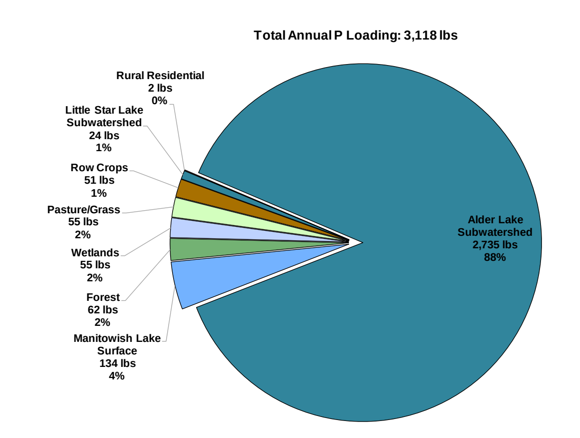


Figure 8.8.2-2. Manitowish Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the large majority of the phosphorus that enters Manitowish Lake comes from the upstream Alder Lake, efforts to reduce phosphorus levels in Manitowish Lake should concentrate on reducing phosphorus inputs to the upstream lake.

8.8.3 Manitowish Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2016, Manitowish Lake's immediate shoreline was assessed in terms of its development. Manitowish Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.1 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.8.3-1). This constitutes about 59% of Manitowish 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, 1.5 miles of urbanized and developed–unnatural shoreline (20%) was observed. If restoration of the Manitowish 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. Due to water levels in Manitowish Lake, at the time of the fall survey, 1.9 miles of shoreline were inaccessible by boat. This shoreline length was not taken into account in Figure 8.8.3-1. Manitowish Lake Map 1 displays the location of these shoreline lengths around the entire lake.

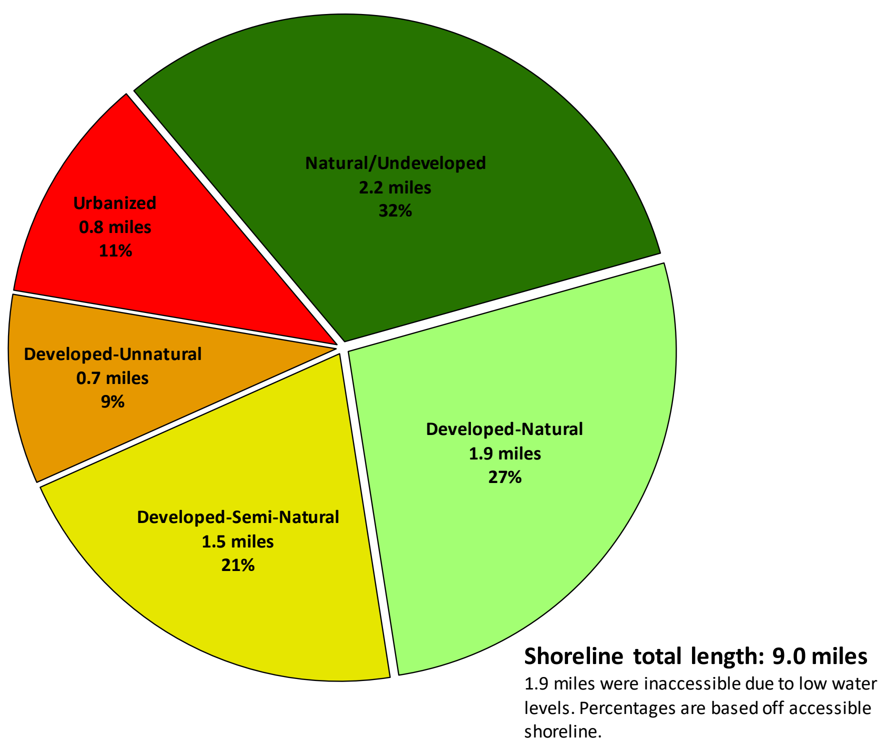


Figure 8.8.3-1. Manitowish Lake shoreland categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Manitowish Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Manitowish Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 175 total pieces of coarse woody habitat were observed along 7.0 miles of shoreline (Manitowish Lake Map 2), which gives Manitowish Lake a coarse woody habitat to shoreline mile ratio of 25:1 (Figure 8.8.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. One hundred and forty-seven pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, nineteen pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and nine instances of clusters 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 Manitowish 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 98 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 Manitowish Lake falls just below the median of these 98 lakes (Figure 8.8.3-2).

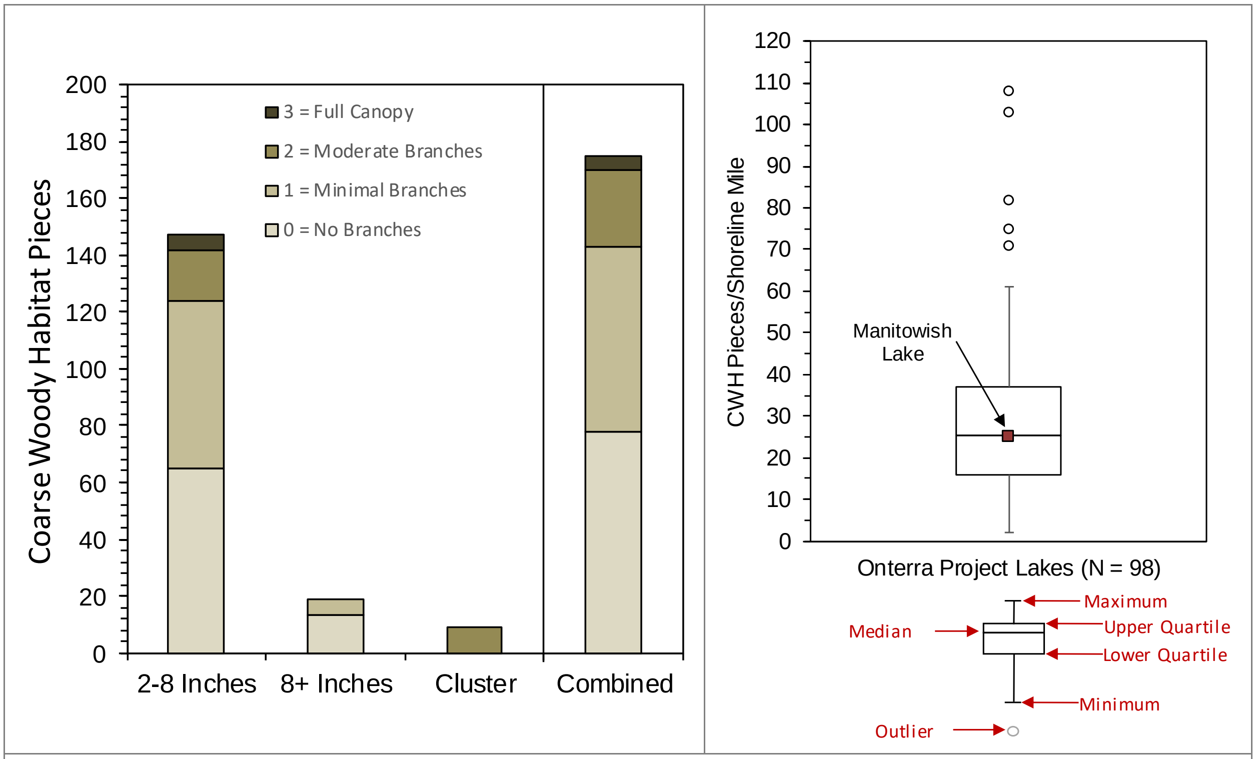


Figure 8.8.3-2. Manitowish coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of the Manitowish Lake coarse woody habitat can be found on Manitowish Lake Map 2.

8.8.4 Manitowish Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Manitowish Lake on June 28 and 29, 2016. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species in Manitowish Lake.

The aquatic plant point-intercept survey was conducted on Manitowish Lake on July 18 and 19, 2016 by Onterra. The floating-leaf and emergent plant community mapping survey was completed at that same trip to map these community types. During all surveys, 55 species of aquatic plants were located in Manitowish Lake (Table 8.8.4-1). Twenty-nine of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 26 species were observed incidentally during visits to Manitowish Lake. Two non-native species, pale-yellow iris (*Iris pseudacorus*) and purple loosestrife (*Lythrum salicaria*) were observed along the Manitowish Lake shoreline.

Aquatic plants were found growing to a depth of 13 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and diverse. Of the 433 point-intercept locations sampled within the littoral zone, roughly 60% contained aquatic vegetation. Manitowish Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays and near shore; areas that have adequate light availability to sustain growth. Approximately 64% of the point-intercept sampling locations where sediment data was collected at were sand, 25% consisted of a fine, organic substrate (muck) and 11% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.8.4-1. Aquatic plant species located in Manitowish Lake during 2016 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Alisma trivale*	Northern waterplantain	4	I
	Calla palustris	Water arum	9	I
	Carex pellita	Broad-leaved woolly sedge	4	I
	Carex pseudocyperus	Cypress-like sedge	8	I
	Carex utriculata	Common yellow lake sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Glyceria borealis	Northern manna grass	8	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris pseudacorus	Pale yellow iris	Exotic	I
	Juncus effusus	Soft rush	4	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Schoenoplectus pungens	Three-square rush	5	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	I
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
FL/E	*Sparganium* sp. (sterile)	Bur-reed sp. (sterile)	N/A	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elatine minima	Waterwort	9	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum farwellii	Farwell's watermilfoil	9	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton alpinus	Apline pondweed	9	I
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	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 spirillus	Spiral-fruited pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia minor	Small bladderwort	10	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

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

Figure 8.8.4-1 shows that wild celery, fern-leaf pondweed and slender naiad were the most frequently encountered plants within Manitowish Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Fern-leaf pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Slender naiad, a common annual species in Wisconsin, is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food. The small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

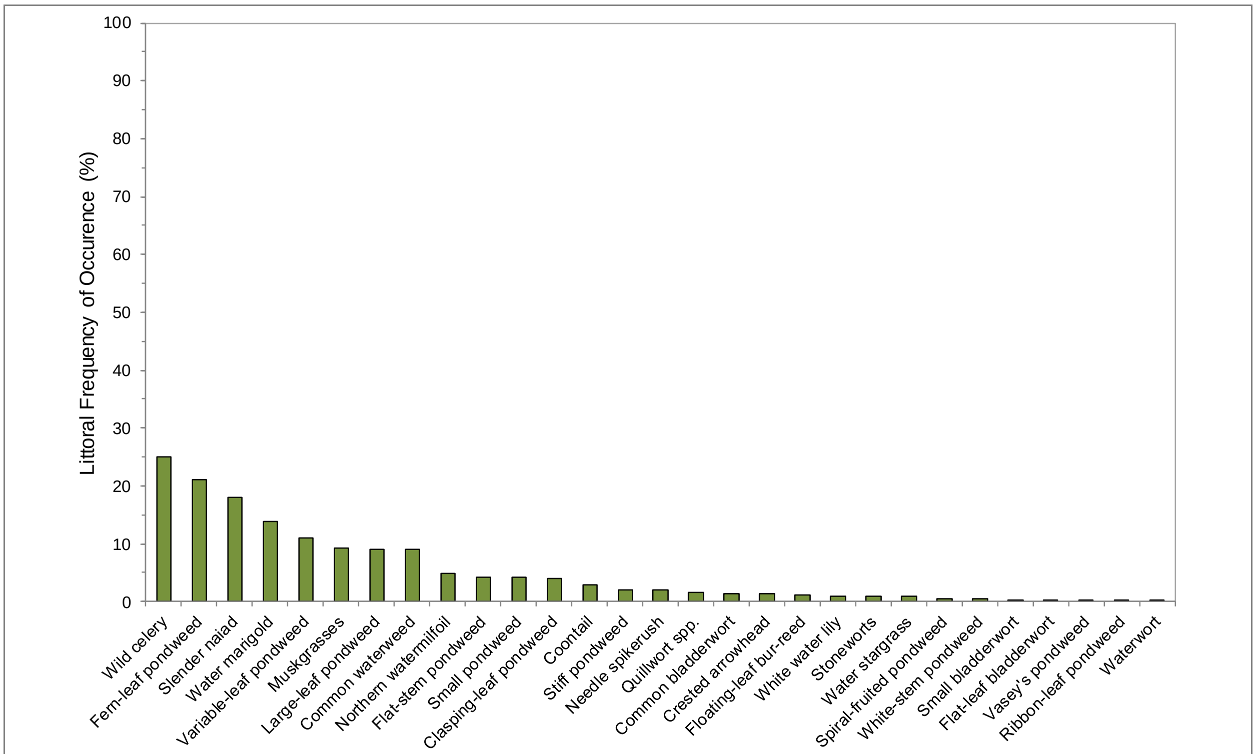


Figure 8.8.4-1. Manitowish Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2016 point-intercept survey. .

During aquatic plant inventories, 53 species of native aquatic plants (including incidentals) were found in Manitowish Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Manitowish Lake's plant community (0.91) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 wild celery was found at 25% of the sampling locations, its relative frequency of occurrence is

17%. Explained another way, if 100 plants were randomly sampled from Manitowish Lake, 17 of them would be wild celery. This distribution can be observed in Figure 8.8.4-2, where together 14 native species account for 92% of the aquatic plant population within Manitowish Lake, while the other 15 species account for the remaining 8%. Twenty-two additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.8.4-1 as incidentals.

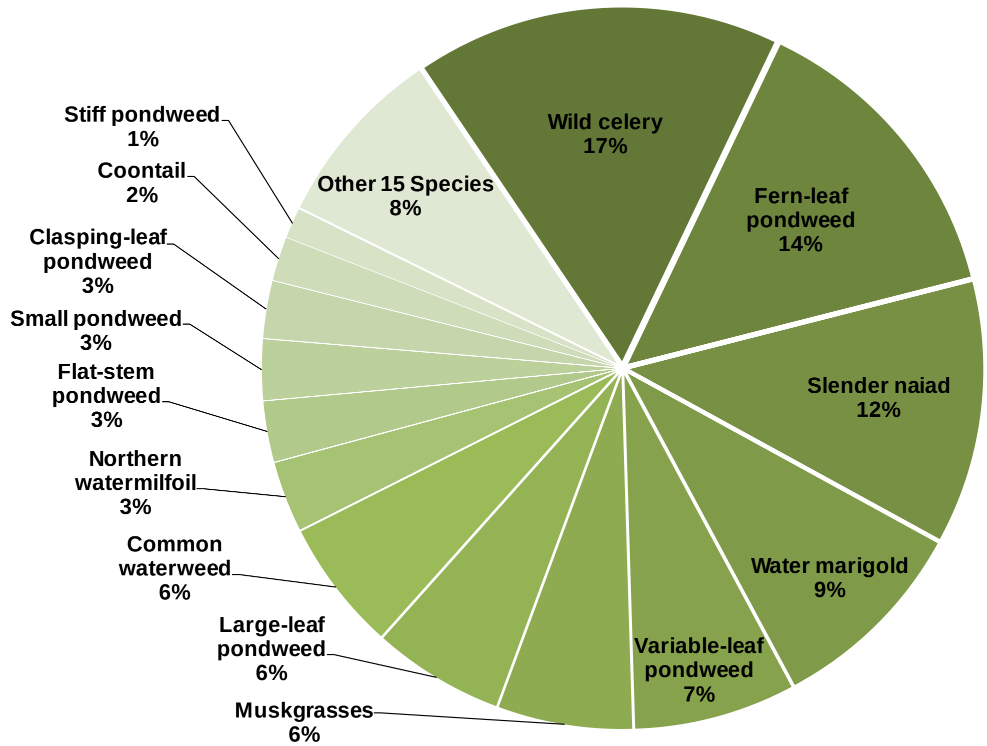


Figure 8.8.4-2. Manitowish Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2016 point-intercept survey.

Manitowish Lake's average conservatism value (6.6) is higher than the state median (6.3) but slightly lower than the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Manitowish Lake is indicative of an average system within Wisconsin. Combining Manitowish Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 47.0 which is above the median values of the ecoregion and state.

The 2016 community map indicates that approximately 18.1 acres of the lake contains these types of plant communities (Manitowish Lake Map 4, Table 8.8.4-2). Twenty-six floating-leaf and emergent species were located on Manitowish Lake (Table 8.8.4-1), all of which provide valuable wildlife habitat. The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Manitowish Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill

(*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Table 8.8.4-2. Manitowish Lake acres of emergent and floating-leaf plant communities from the 2016 community mapping survey.

Plant Community	Acres
Emergent	2.3
Floating-leaf	15.2
Mixed Floating-leaf and Emergent	0.6
Total	18.1

Non-Native Aquatic Plants in Manitowish 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. This species was observed flowering along the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale-yellow iris on Manitowish Lake can be viewed on Manitowish Lake Map 4.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. 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.

In Manitowish Lake, purple loosestrife was located in mostly on an island on the eastern side of the lake (Manitowish Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Manitowish Lake.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Manitowish Lake during 2013. Through 2019, the infrequent occurrence of this exotic was managed through volunteer and professional hand-harvesting. As a part of the Manitowish Waters Comprehensive Management Plan, Manitowish Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.8.5 Manitowish 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 and within each lake's individual report section 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 Manitowish 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.8.5-1). 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. Manitowish Lake has been stocked from 1975 to 2000 with muskellunge and walleye (Table 8.8.5-1).

Photograph 8.8.5-1. Fingerling Muskellunge.

Table 8.8.5-1. Stocking data available for Manitowish Lake (1975-2000).

Lake	Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
Manitowish Lake	1975	Walleye	Fingerling	15,000	3
Manitowish Lake	1973	Muskellunge	Fingerling	2,596	10
Manitowish Lake	1976	Muskellunge	Fingerling	359	11
Manitowish Lake	1983	Muskellunge	Fingerling	250	11
Manitowish Lake	1984	Muskellunge	Fingerling	500	11
Manitowish Lake	1986	Muskellunge	Fingerling	500	11.5
Manitowish Lake	1987	Muskellunge	Fingerling	1,500	12
Manitowish Lake	1988	Muskellunge	Fingerling	500	10
Manitowish Lake	1990	Muskellunge	Fingerling	433	10
Manitowish Lake	1991	Muskellunge	Fingerling	250	11
Manitowish Lake	1996	Muskellunge	Fingerling	225	10.8
Manitowish Lake	1998	Muskellunge	Large Fingerling	450	12.2
Manitowish Lake	2000	Muskellunge	Large Fingerling	450	9.9

Manitowish Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.8.5-1 from 1999 to 2017. As many as 159 walleye have been harvested from the lake in the past (2015), but the average harvest is roughly 84 fish in a given year. Spear harvesters on average have taken 79% of the declared quota. Additionally, on average 14% of walleye harvested have been female.

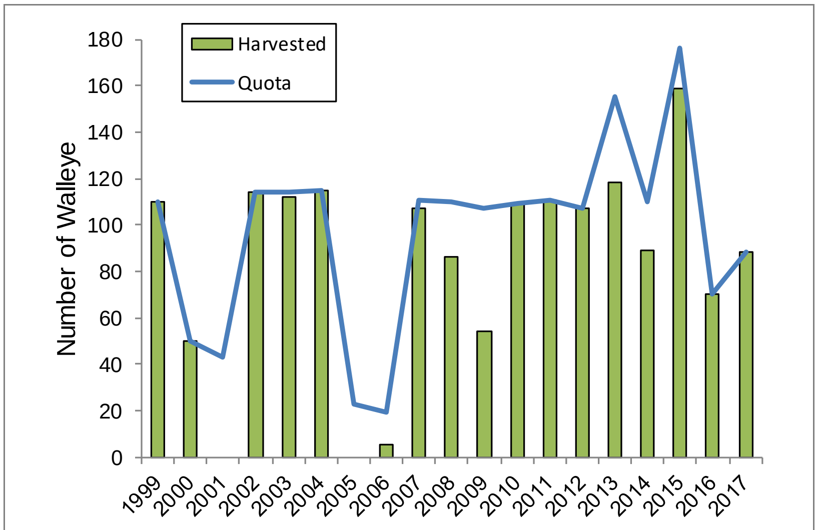


Figure 8.8.5-1. Manitowish Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records are provided in Figure 8.8.5-2 from 1999 to 2017. As many as six muskellunge have been harvested from the lake in the past (2008), however the average harvest is one fish in a given year. Spear harvesters on average have taken 18% of the declared quota.

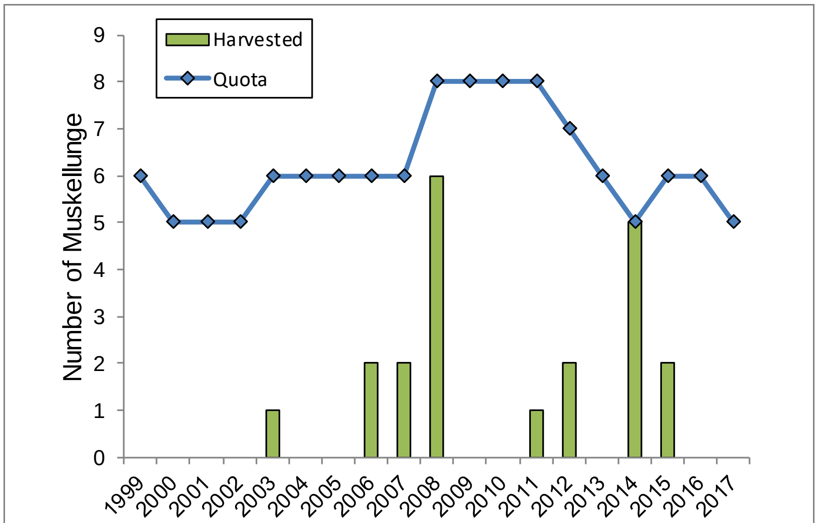
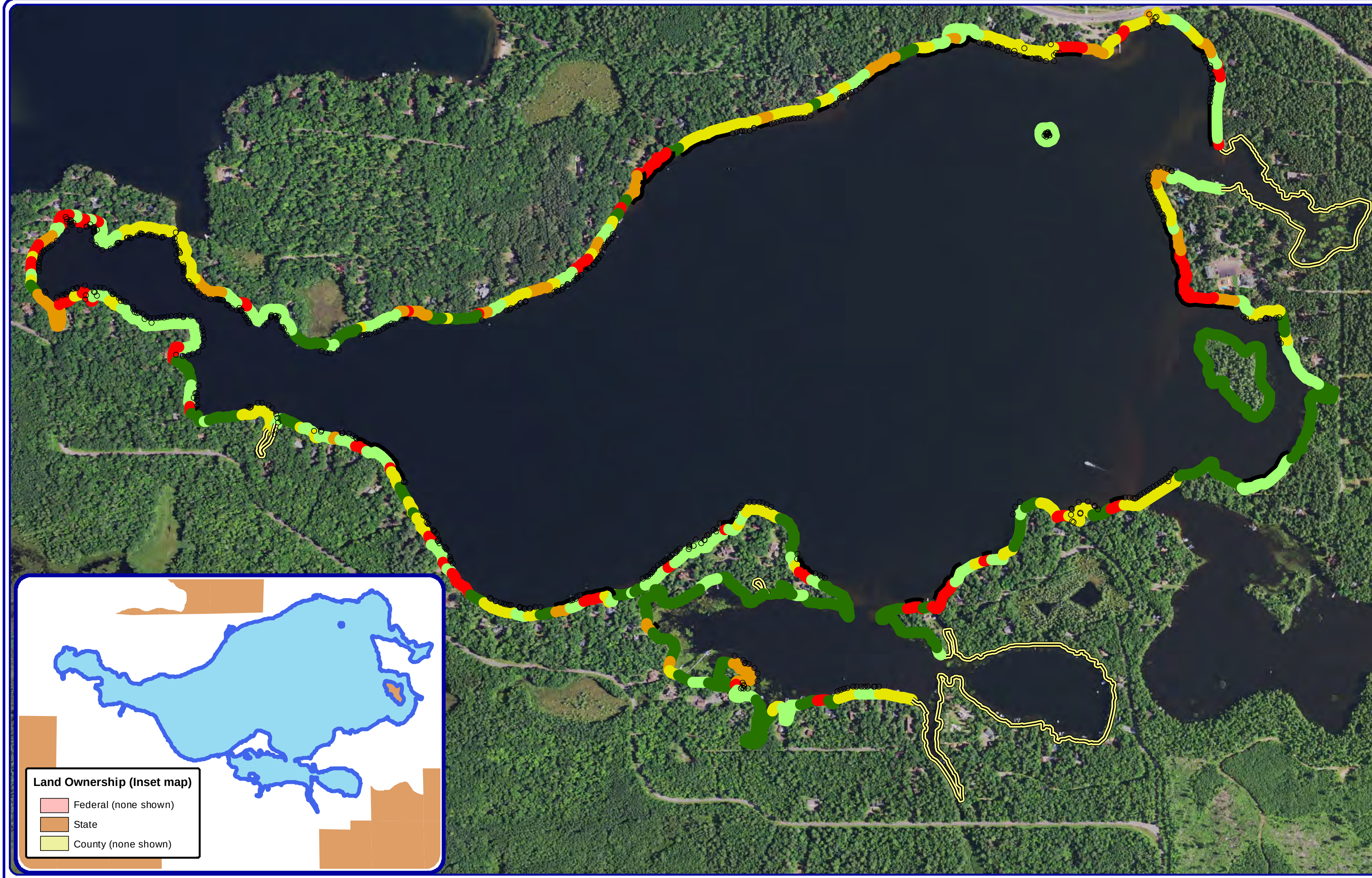


Figure 8.8.5-2. Manitowish Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



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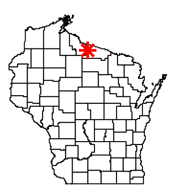
www.onterra-eco.com

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2016
Map Date: December 8, 2016
Filename: Manitowish_Map1_ShorelandCondition_2016.mxd



Project Location in Wisconsin

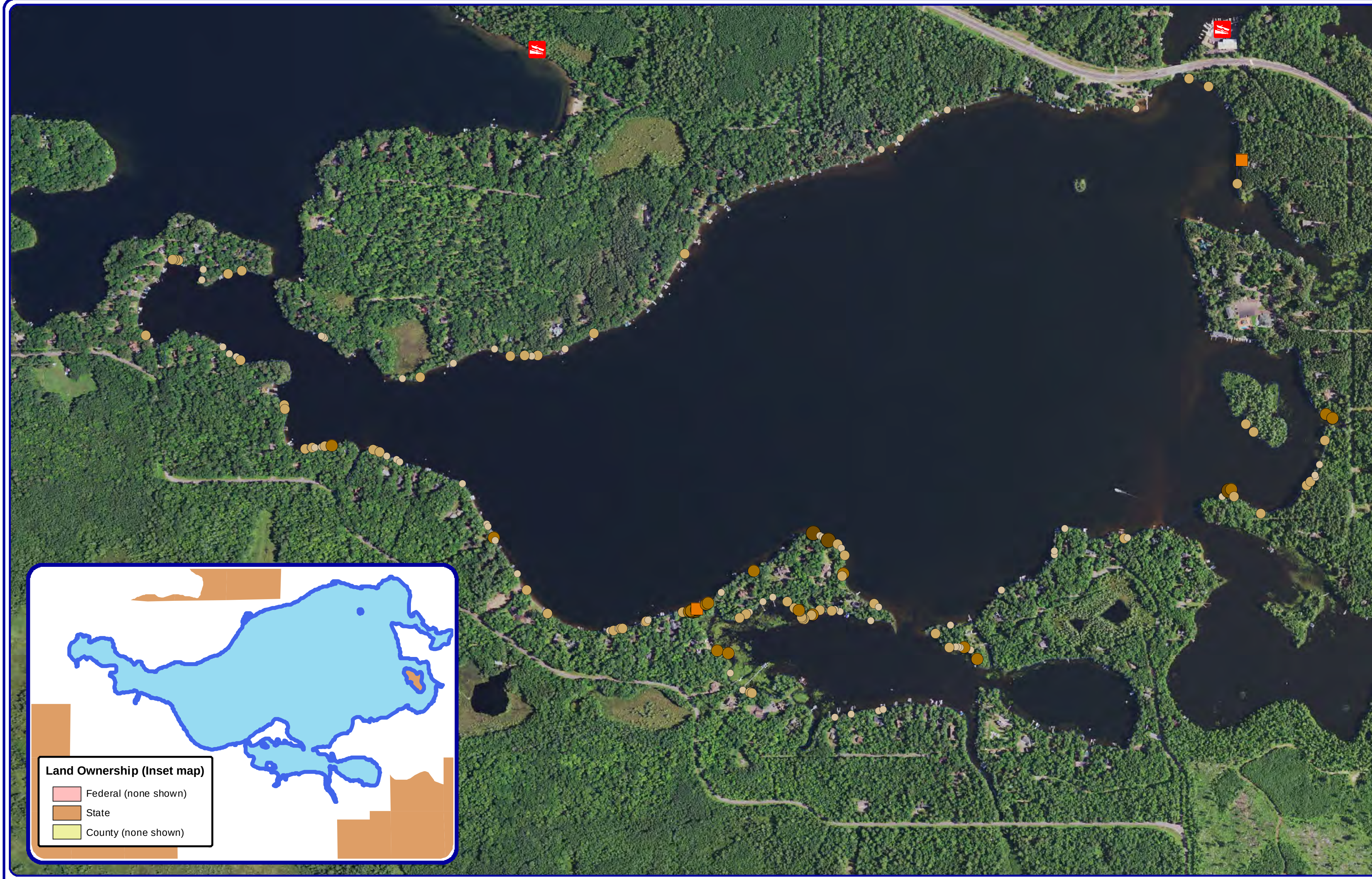
Legend

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

Seawall
Rip-Rap
Wood/Masonary/Metal

Map 1
Manitowish Lake
Vilas County, Wisconsin

2016 Shoreland Condition



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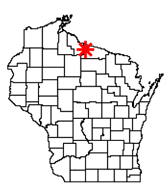
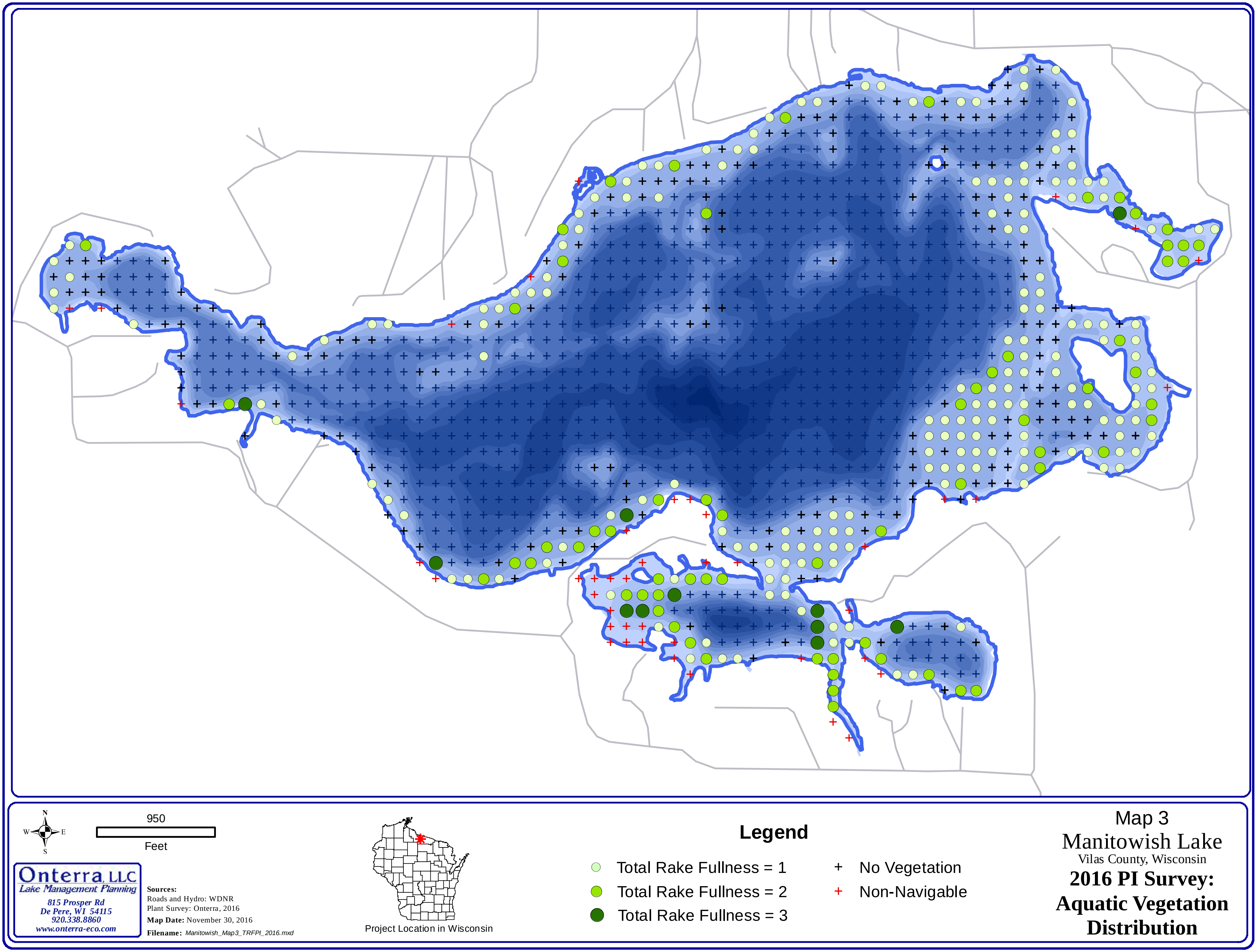
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2016
Map Date: December 9, 2016
Filename: Manitowish_Map2_CWH_2016.mxd


Project Location in Wisconsin

Legend

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

Map 2
Manitowish Lake
Vilas County, Wisconsin
Coarse Woody Habitat



N
W
E
S
950
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
Plant Survey: Onterra, 2016
Map Date: November 30, 2016
Filename: Manitowish_Map3_TRFPI_2016.mxd
Project Location in Wisconsin
Legend
Total Rake Fullness = 1
Total Rake Fullness = 2
Total Rake Fullness = 3
No Vegetation
Non-Navigable
Map 3
Manitowish Lake
Vilas County, Wisconsin
2016 PI Survey:
Aquatic Vegetation
Distribution

Manitowish Lake - Map 4

Manitowish Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

1,000
Feet

Legend

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

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Adjacent Wetland Habitat

Exotic Plant Communities
- Purple loosestrife
- Pale yellow iris

Onterra LLC
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815 Prosper Road
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Sources:
Aquatic Plants: Onterra, 2016
Orthophotography: NAIP, 2015
Map date: October 26, 2016
Filename: Manitowish_Map4_Comm_2016.mxd

Note: Methodology, explanation of analysis and biological background on Little Star Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.9 Little Star Lake

An Introduction to Little Star Lake

Little Star Lake, Vilas County, is a deep, headwater drainage lake with a maximum depth of 67 feet, a mean depth of 31 feet, and a surface area of approximately 260 acres. Little Star Lake is considered to be oligotrophic and its watershed encompasses approximately 859 acres. In 2016, 32 native aquatic plant species were found in the lake, of which slender naiad (*Najas flexilis*) the most common. One non-native shoreland plants, pale-yellow iris, was found during surveys.

Field Survey Notes

Little Star Lake was found to have the lowest Simpson's Diversity Index value of all the Manitowish Chain Lakes, as well as the lowest acreage of emergent and floating-leaf vegetation.

Photo 8.9. Little Star Lake, Vilas County

Lake at a Glance* – Little Star Lake

Morphology	
Acreage	260
Maximum Depth (ft)	67
Mean Depth (ft)	32
Volume (acre-feet)	8,098
Shoreline Complexity	3.5
Vegetation	
Curly-leaf Survey Date	June 29, 2016
Comprehensive Survey Date	July 19, 2016
Number of Native Species	31
Threatened/Special Concern Species	-
Exotic Plant Species	Pale-yellow iris
Simpson's Diversity	0.83
Average Conservatism	6.5
Water Quality	
Wisconsin Lake Classification	Deep, Headwater Drainage
Trophic State	Oligotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	2:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.9.1 Little Star Lake Water Quality

Water quality data was collected from Little Star Lake on six occasions in 2016/2017. 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 2016/2017, any historical data was researched and are included within this report as available.

In 2016, average summer phosphorus concentrations (11.1 µg/L) were less than the median value (17.0 µg/L) for other deep, headwater drainage lakes in the state (Figure 8.9.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted summer value from all available data ranks as *Excellent* for a deep, lowland drainage lake, except for one year, 1997.

Total phosphorus surface values from 2016-2017 are compared with bottom-lake samples collected during this same time frame in Figure 8.9.1-2. Concentrations within the hypolimnion were found to be slightly higher than those measured from the epilimnion during stratification. As explained in the Chainwide Report (Water Quality Section Primer), sediments within a lake often release phosphorus under anoxic conditions. When mixing occurs in the lake, these nutrients may be transported to the upper water column for use by algae or aquatic plants. The near-bottom total phosphorus concentrations indicate that internal nutrient loading occurs to some degree in Little Star Lake, but that it is not a significant source of phosphorus to the lake.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (0.6 µg/L) were lower than the median value (5.0 µg/L) for other lakes of this type (Figure 8.8.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2016 visits to the lake, Onterra ecologists recorded field notes describing stained water but good conditions overall.

The clarity of Little Star Lake's water can be described as *Excellent* during the summer months in which data has been collected, except for in 1979 (Figure 8.9.1-4). A weighted average over this timeframe is greater than the median value for other deep, headwater drainage lakes in the state and is also larger than the regional median. Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. The Manitowish Waters Chain of Lakes displays a natural staining of the water which plays a role in light penetration, and thus water clarity, as well.

True color measures the dissolved organic materials in water. Water samples collected in May and July of 2016 were measured for this parameter, and were found to be 5 Platinum-cobalt units (Pt-co units, or PCU) in May and not detectable in July. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having low color, 40-100 PCU as medium color, and >100 PCU as high color.

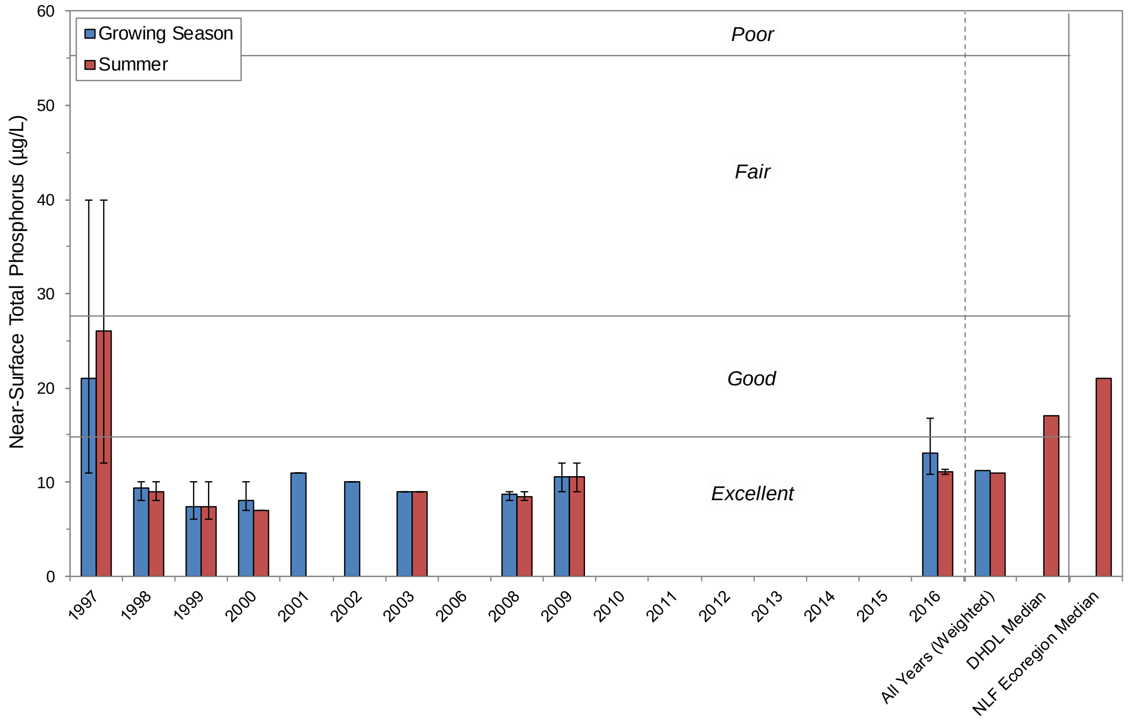


Figure 8.9.1-1. Little Star Lake, state-wide deep, headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

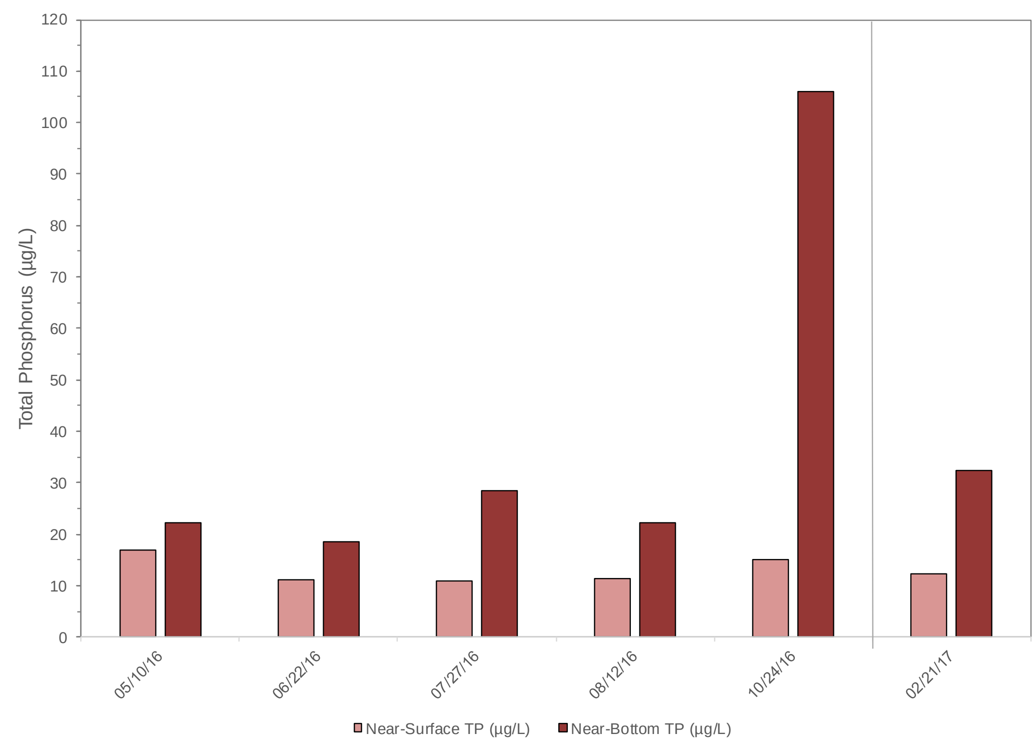


Figure 8.9.1-2. Little Star Lake surface and bottom total phosphorus values, 2016-2017.

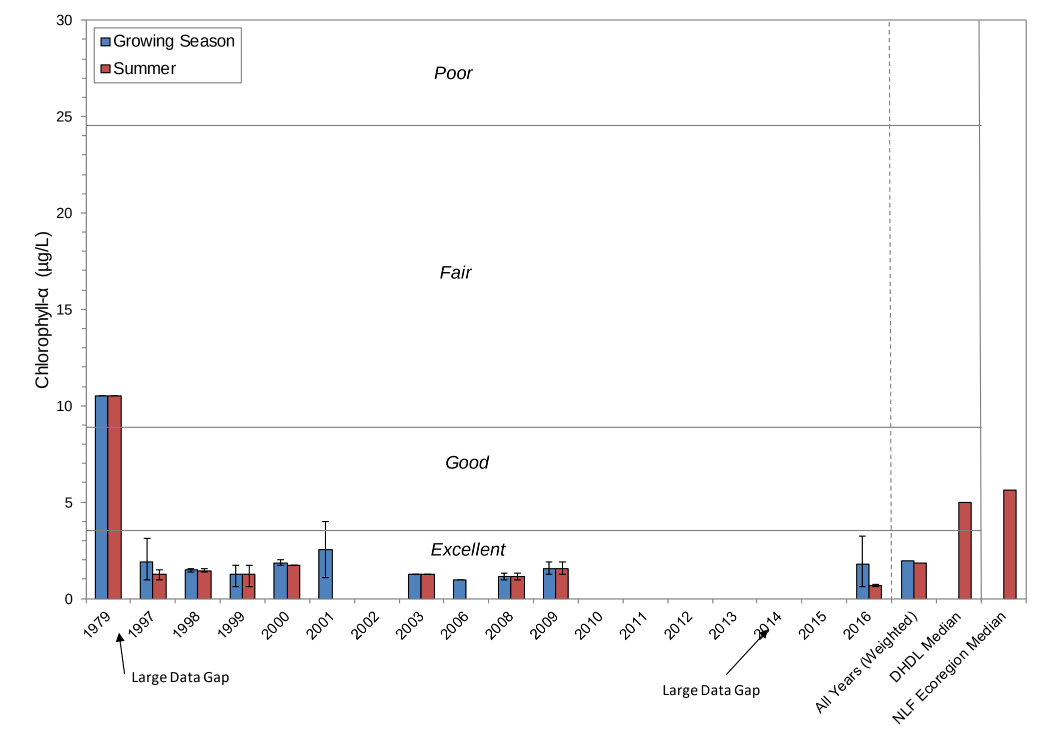


Figure 8.9.1-3. Little Star Lake, state-wide deep, headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

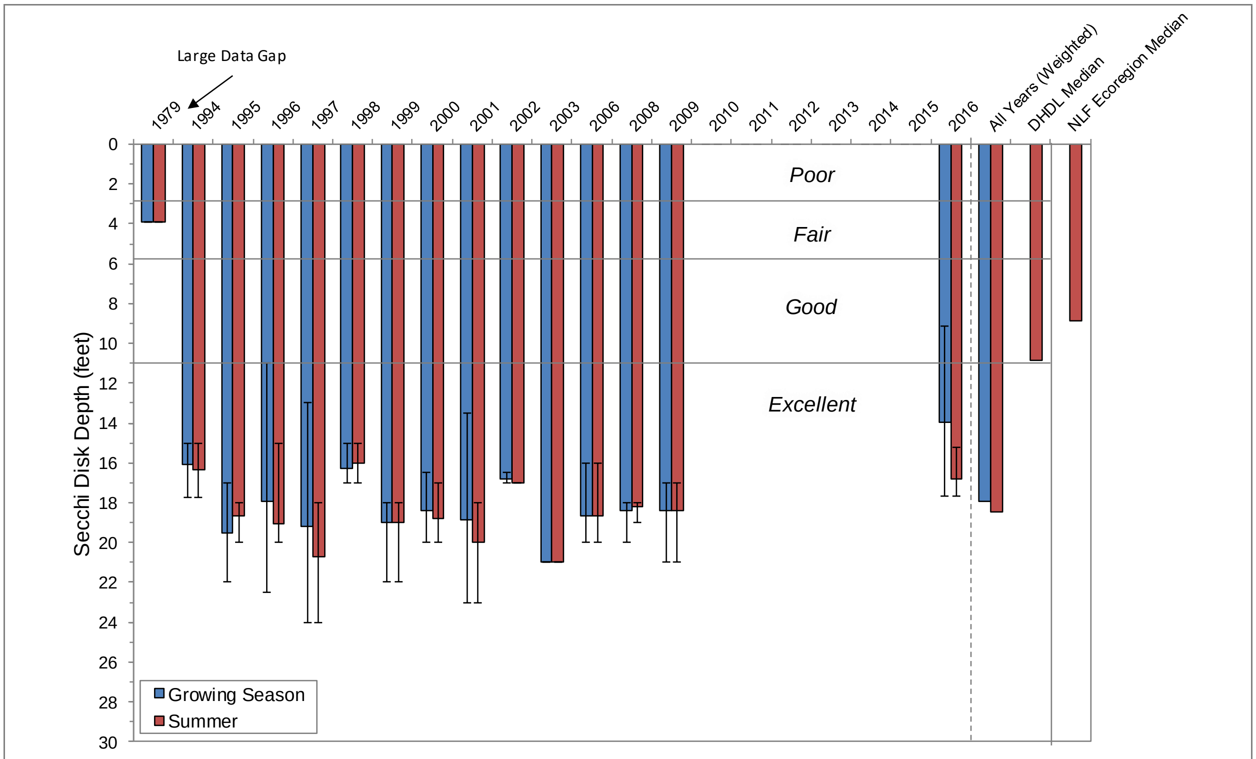


Figure. 8.9.1-4. Little Star Lake, state-wide deep, headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Little Star Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.9.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Little Star Lake is in an oligotrophic state.

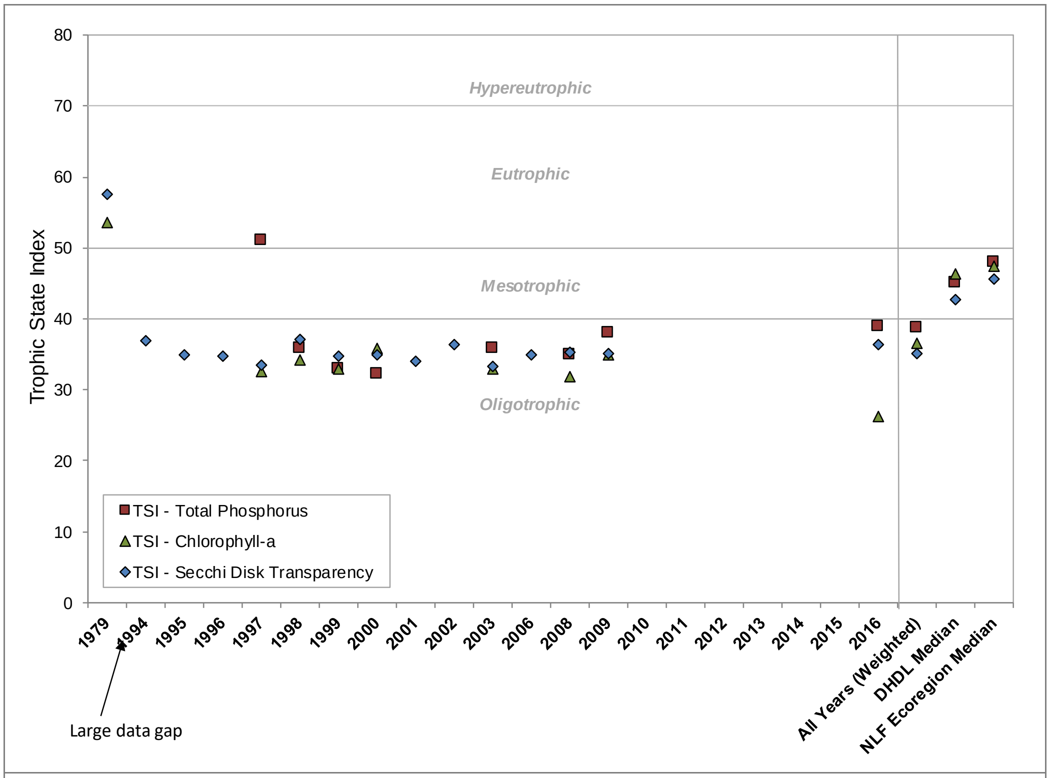


Figure 8.9.1-5. Little Star Lake, state-wide deep, headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Little Star Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Little Star Lake by Onterra staff. Graphs of those data are displayed in Figure 8.9.1-6 for all sampling events.

Little Star Lake mixes thoroughly during the spring, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the lake was not observed to mix completely. The bottom of the lake was found to become void of oxygen (anoxic) only during August and October. This occurrence is slightly uncommon in Wisconsin lakes because usually bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. When oxygen is available deep down in the water column, during the summer, a different phenomenon is occurring.

Little Star Lake is exhibiting metalimnetic oxygen maxima during the summer months. This type of profile occurs because there is a large algal community in the metalimnion. Lakes that exhibit this profile need to have good water clarity in the epilimnion so that sufficient light reaches the metalimnion to support photosynthesis. Algae thrive in this deeper water because there is sufficient light and higher amounts of nutrients, e.g. phosphorus, in these deeper waters. If there is sufficient light reaching the metalimnion, but there is not a large algal community, this indicates that nutrient levels are low in this part of the water column. If lakes have a greater metalimnetic oxygen maxima now compared with earlier years, it is an indication that nutrient levels are higher at the present time in the deeper waters.

During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2017, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

Additional Water Quality Data Collected at Little Star 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 Little Star 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. Little Star Lake's surface water pH was measured at roughly 7.9 during May and 7.8 in July of 2016. These values are slightly above neutral and falls 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 Manitowish Lake was measured at 38.2 and 37.5 mg/L as $CaCO_3$ in May and July of 2016, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Little Star Lake during 2016. 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 Little Star Lake's pH of 7.85 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 Little Star Lake was found to be 11.8 mg/L in July of 2016, which is just below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2016 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

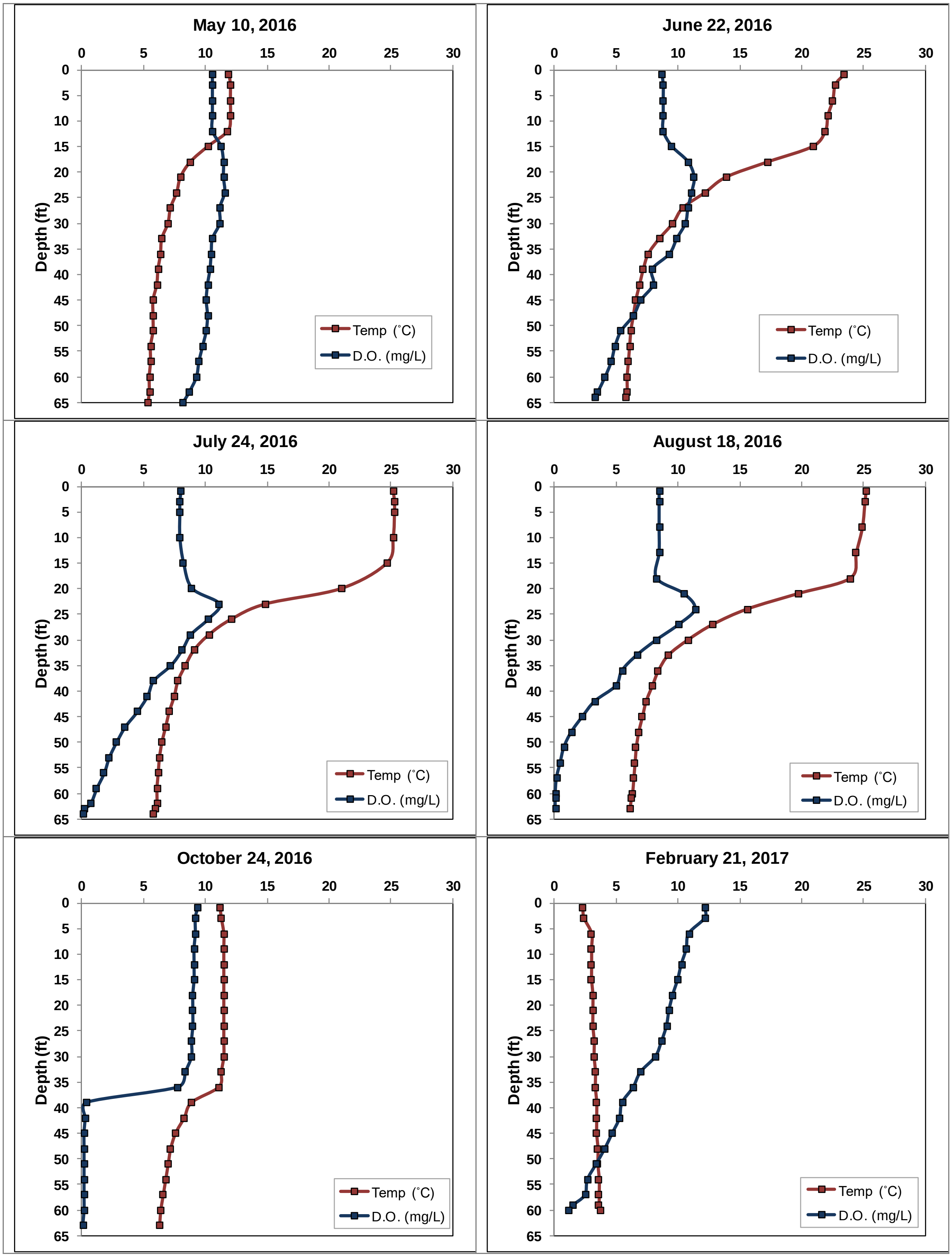


Figure 8.9.1-6. Little Star Lake dissolved oxygen and temperature profiles.

8.9.2 Little Star Lake Watershed Assessment

Little Star Lake's watershed is 859 acres in size. Compared to Little Star Lake's size of 261 acres, this makes for a small watershed to lake area ratio of 2:1. The watershed is comprised of land cover types including forest (53%), the lake surface itself (19%), wetlands (16%), pasture/grass/rural open space (12%), rural residential areas (<1%), and urban-medium density (<1%), (Figure 8.9.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Little Star Lake's residence time is approximately 9.9 years, or the water within the lake is completely replaced 0.1 times per year.

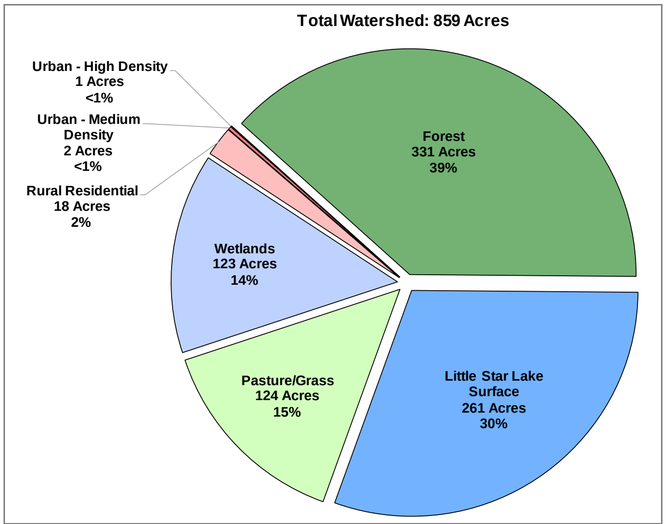


Figure 8.9.2-1. Little Star Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 423 pounds of phosphorus being delivered to Little Star Lake on an annual basis, approximately 152 pounds (36%) originates through direct atmospheric deposition onto the lake, 130 pounds (31%) from forests, 97 pounds (23%) from areas of pasture/grass/rural open space, and 44 pounds (10%) from wetlands (Figure 8.9.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 14 µg/L, which is essentially the same as the measured growing season average total phosphorus concentration of 11 µg/L. This means the model works reasonably well for Little Star Lake and that there are no significant, unaccounted sources of phosphorus entering the lake.

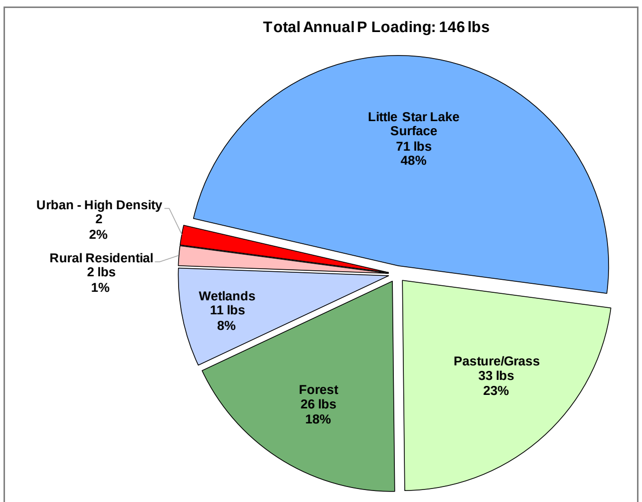


Figure 8.9.2-2. Little Star Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the WiLMS model for Little Star Lake's watershed, scenarios can be run to determine how Little Star Lake's water quality would change given alterations to its watershed. For example, if 25% of the forests within Little Star Lake's watershed were converted to row crop agriculture, phosphorus concentrations would be predicted to increase from the current growing season concentration of 11 µg/L to 14 µg/L. This increase in total phosphorus would result in chlorophyll-*a* concentrations increasing from the current growing season average of 3 µg/L to 4 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 14.8 feet to 11.9 feet. This modelling illustrates the importance of the natural land cover types within Little Star Lake's watershed in maintaining the lake's excellent water quality.

8.9.3 Little Star Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2016, Little Star Lake's immediate shoreline was assessed in terms of its development. Little Star Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.1 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.9.3-1). This constitutes about 50% of Little Star 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, 1.6 miles of urbanized and developed–unnatural shoreline (37%) was observed. If restoration of the Little Star 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. Little Star Lake Map 1 displays the location of these shoreline lengths around the entire lake.

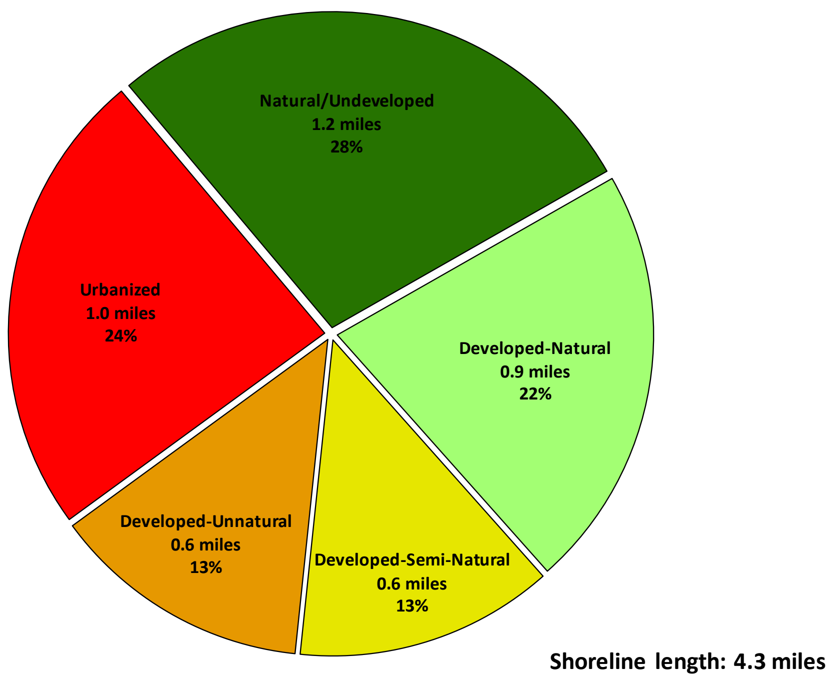


Figure 8.9.3-1. Little Star Lake shoreland categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Little Star Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Little Star Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 110 total pieces of coarse woody habitat were observed along 4.3 miles of shoreline (Little Star Lake Map 2), which gives Little Star Lake a coarse woody habitat to shoreline mile ratio of 26:1 (Figure 8.9.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. One hundred and six pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, four pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Little Star 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 98 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 Little Star Lake falls near the median of these 98 lakes (Figure 8.9.3-2).

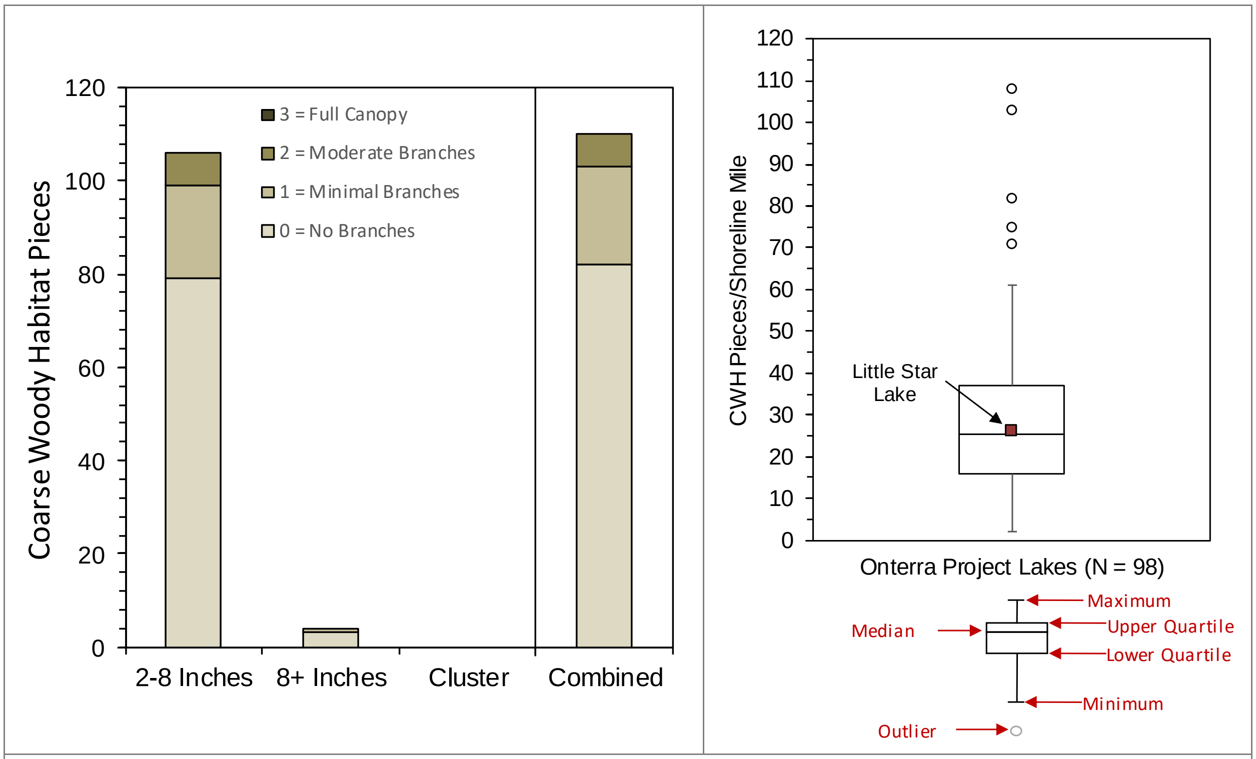


Figure 8.9.3-2. Little Star Lake coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of the Little Star Lake coarse woody habitat can be found on Little Star Lake Map 2.

8.9.4 Little Star Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Little Star Lake on June 29, 2016. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Little Star Lake on July 19, 2016 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 33 species of aquatic plants were located in Little Star Lake (Table 8.9.4-1). Nineteen of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 14 species were observed incidentally during visits to Little Star Lake. One non-native species, pale-yellow iris (*Iris pseudacorus*) was observed along the Little Star Lake shoreline.

Aquatic plants were found growing to a depth of 13 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 189 point-intercept locations sampled within the littoral zone, roughly 54% contained aquatic vegetation. Little Star Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays and near shore; areas that are more likely to hold organic substrates. Approximately 83% of the point-intercept sampling locations where sediment data was collected at were sand, 3% consisted of a fine, organic substrate (muck) and 13% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.9.4-1. Aquatic plant species located in Little Star Lake during 2016 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris pseudacorus	Pale yellow iris	Exotic	I
	Juncus effusus	Soft rush	4	I
	Mimulus ringens	Monkey-flower	6	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Typha spp.	Cattail spp.	1	I
	Zizania spp.	Wild rice sp.	8	I
FL	*Nuphar variegata*	Spatterdock	6	I
	Nymphaea odorata	White water lily	6	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum farwellii	Farwell's watermilfoil	9	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	I
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus flammula	Creeping spearwort	9	I
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	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

Figure 8.9.4-1 shows that slender naiad, muskgrasses and variable-leaf pondweed were the most frequently encountered plants within Little Star Lake. Slender naiad, a common annual species in Wisconsin, is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food. The small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Muskgrasses, a genus of macroalgae, are not true vascular plants, and are often abundant in waterbodies that are clear with higher alkalinity. While several species of muskgrasses occur in Wisconsin, the muskgrasses in Little Star Lake were not identified to the species level. Often growing in dense beds, muskgrasses stabilize bottom sediments, provide excellent structural habitat for aquatic organisms, and are sources of food for fish, waterfowl, and other wildlife (Borman et al. 2007). Variable-leaf pondweed is one of several pondweed species found in Wisconsin. Variable-leaf pondweed produces long, slender stems with alternating lance-shaped leaves. As its name indicates, this plant can look very different from lake to lake, with some populations having larger leaves and others possessing smaller leaves.

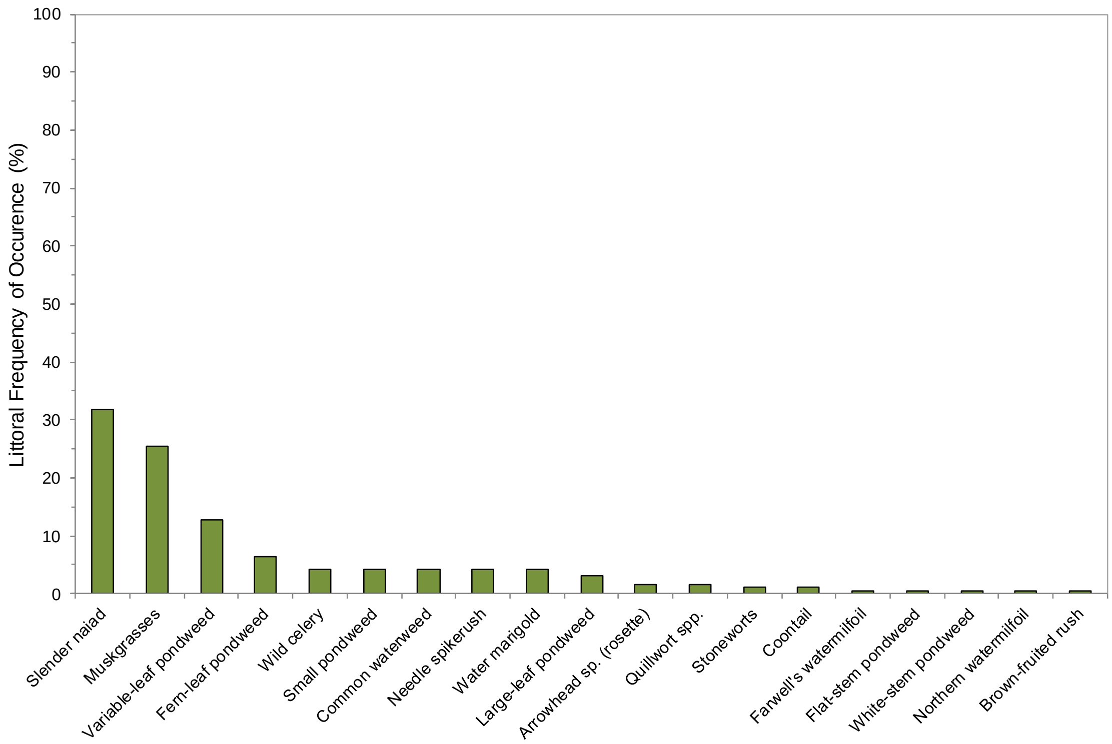


Figure 8.9.4-1. Little Star Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2016 point-intercept survey. .

During aquatic plant inventories, 32 species of native aquatic plants (including incidentals) were found in Little Star Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Little Star Lake's plant community (0.83) lies below the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds diversity similar to the lakes in the same ecoregion.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 slender naiad was found at 32% of the sampling locations, its relative frequency of occurrence is 29%. Explained another way, if 100 plants were randomly sampled from Little Star Lake, 29 of them would be slender naiad. This distribution can be observed in Figure 8.9.4-2, where together 3 native species account for 64% of the aquatic plant population within Little Star Lake, while the other 16 species account for the remaining 36%. Thirteen additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.9.4-1 as incidentals.

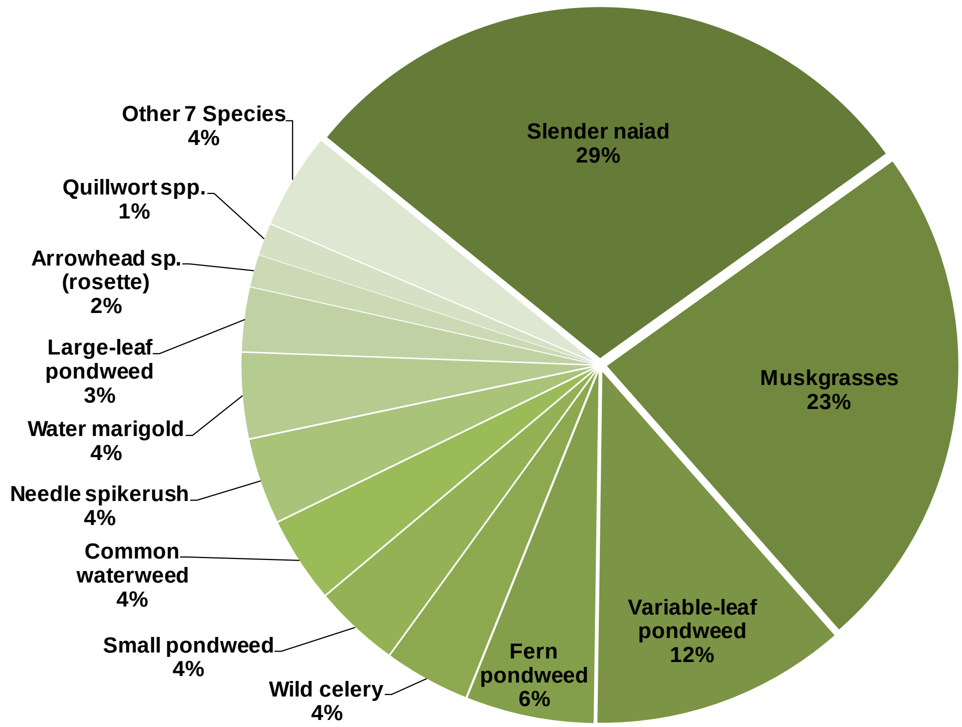


Figure 8.9.4-2. Little Star Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2016 point-intercept survey.

Little Star Lake's average conservatism value (6.6) is higher than the state median (6.3) but slightly lower than the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Little Star Lake is indicative of an average system within Wisconsin. Combining Little Star Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 37.2 which is above the median values of the ecoregion and state.

Little Star Lake was found to have few emergent and floating-leaf aquatic plant communities. The 2016 community map indicates that approximately 0.8 acres of the lake contains these types of plant communities (Little Star Lake Map 4, Table 8.8.4-2). Twelve floating-leaf and emergent species were located on Little Star Lake (Table 8.8.4-1), all of which provide valuable wildlife habitat.

Table 8.9.4-2. Little Star Lake acres of emergent and floating-leaf plant communities from the 2016 community mapping survey.

Plant Community	Acres
Emergent	0.4
Floating-leaf	0.0
Mixed Floating-leaf and Emergent	0.4
Total	0.8

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Little Star Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Little Star 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. This species was observed flowering along the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale-yellow iris on Little Star Lake can be viewed on Little Star Lake Map 4. This exotic plant is typically controlled with hand-removal and in cases of heavy infestations, the use of herbicides.

8.9.5 Little Star 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 Little Star 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.9.5-1). 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. Little Star Lake has been stocked from 1974 to 1989 with muskellunge (Table 8.9.5-1).

Photograph 8.9.5-1. Fingerling Muskellunge.

Table 8.9.5-1. Stocking data available for Muskellunge in Little Star Lake (1974-1989).

Lake	Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Little Star Lake	1974	Unspecified	Fingerling	250	11
Little Star Lake	1974	Unspecified	Fingerling	500	11
Little Star Lake	1976	Unspecified	Fingerling	100	13
Little Star Lake	1976	Unspecified	Fingerling	596	5
Little Star Lake	1989	Unspecified	Fingerling	160	9

Little Star Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.9.5-1 from 1999 to 2017. As many as 114 walleye have been harvested from the lake in the past (2003), but the average harvest is roughly 35 fish in a given year. Spear harvesters on average have taken 67% of the declared quota. Additionally, on average 9% of walleye harvested have been female.

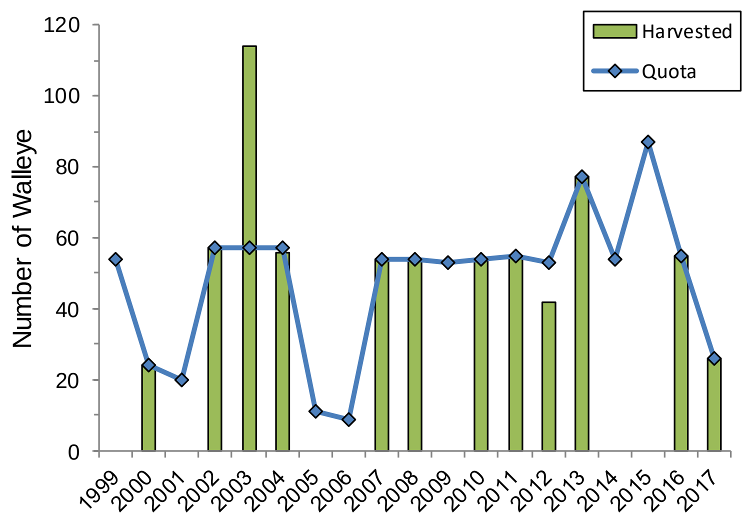


Figure 8.9.5-1. Little Star Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records are provided in 8.9.5-2 from 1999 to 2017. As many as one muskellunge have been harvested from the lake in the past (2013 and 2017), however the average harvest is zero fish in a given year. Spear harvesters on average have taken 3% of the declared quota.

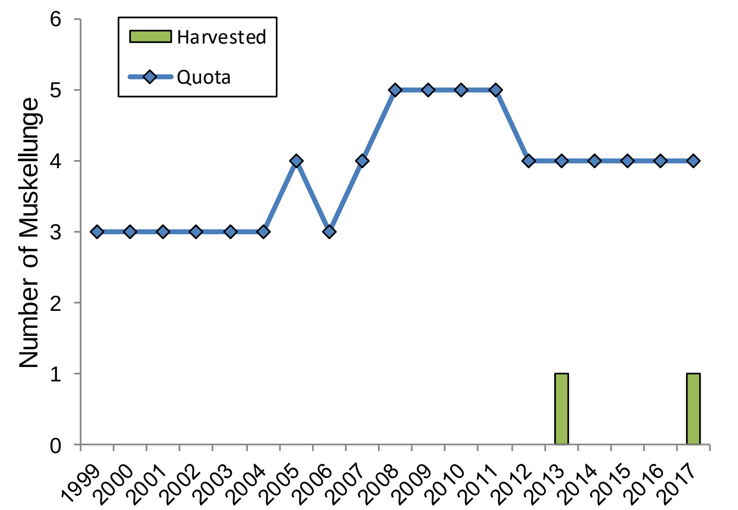
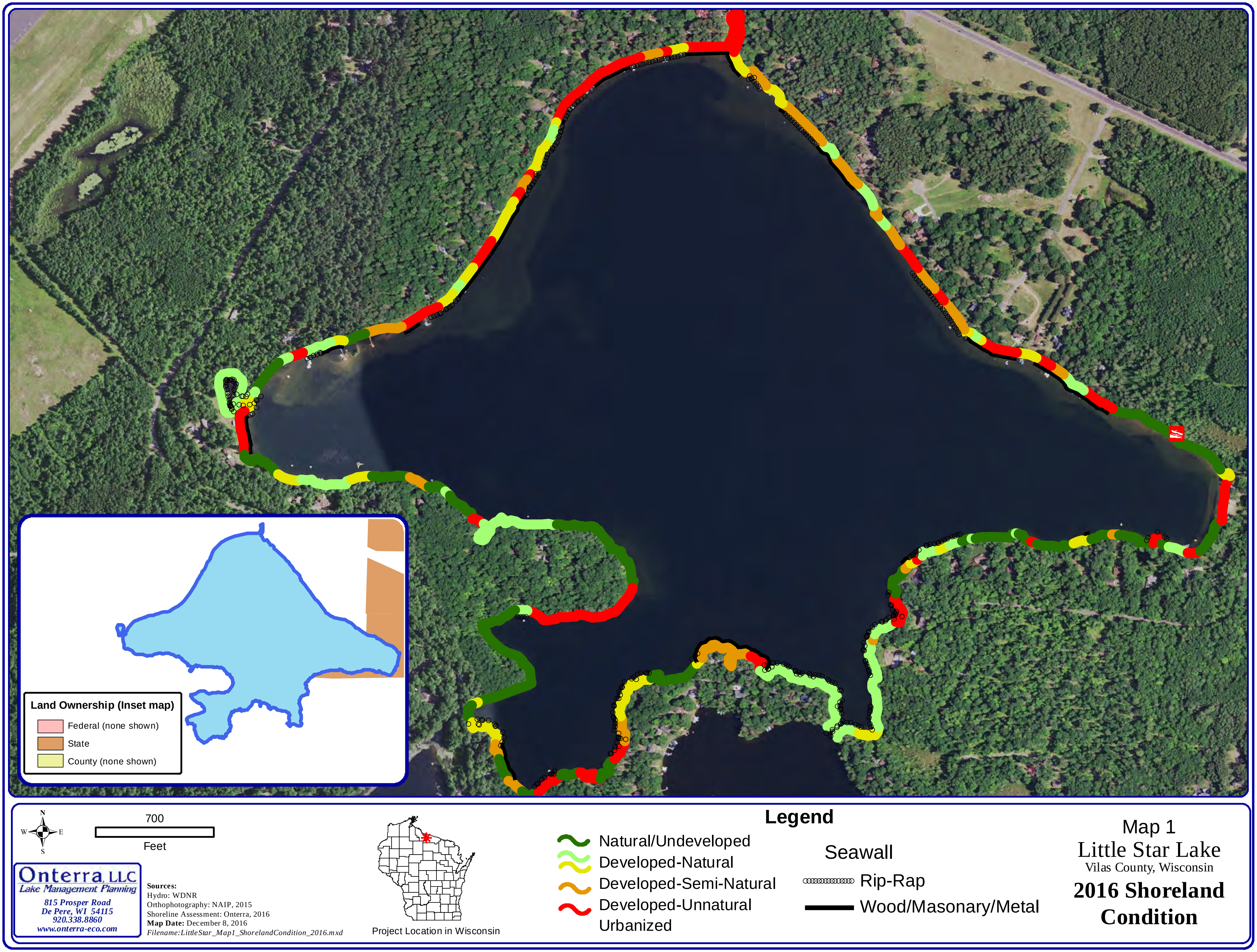
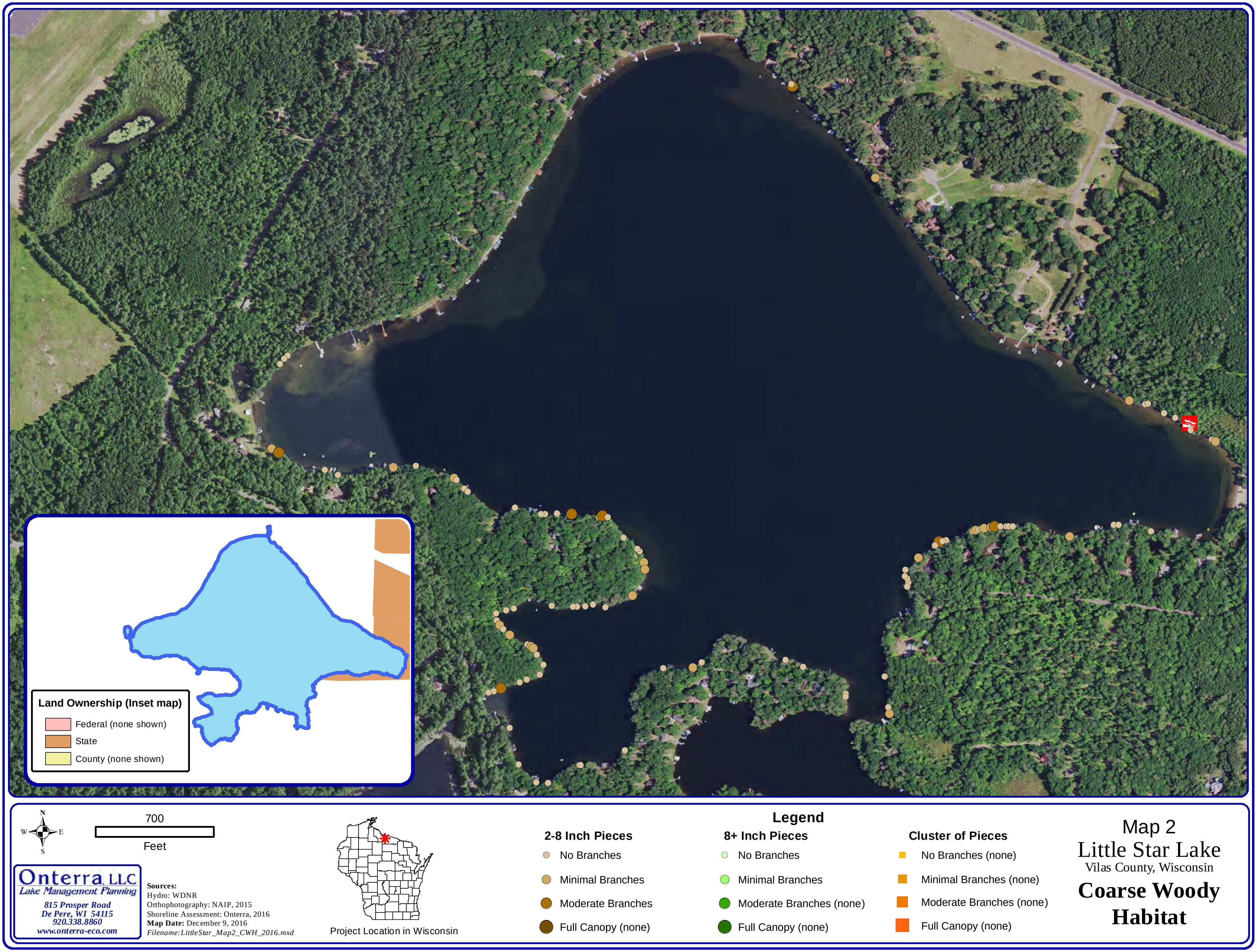
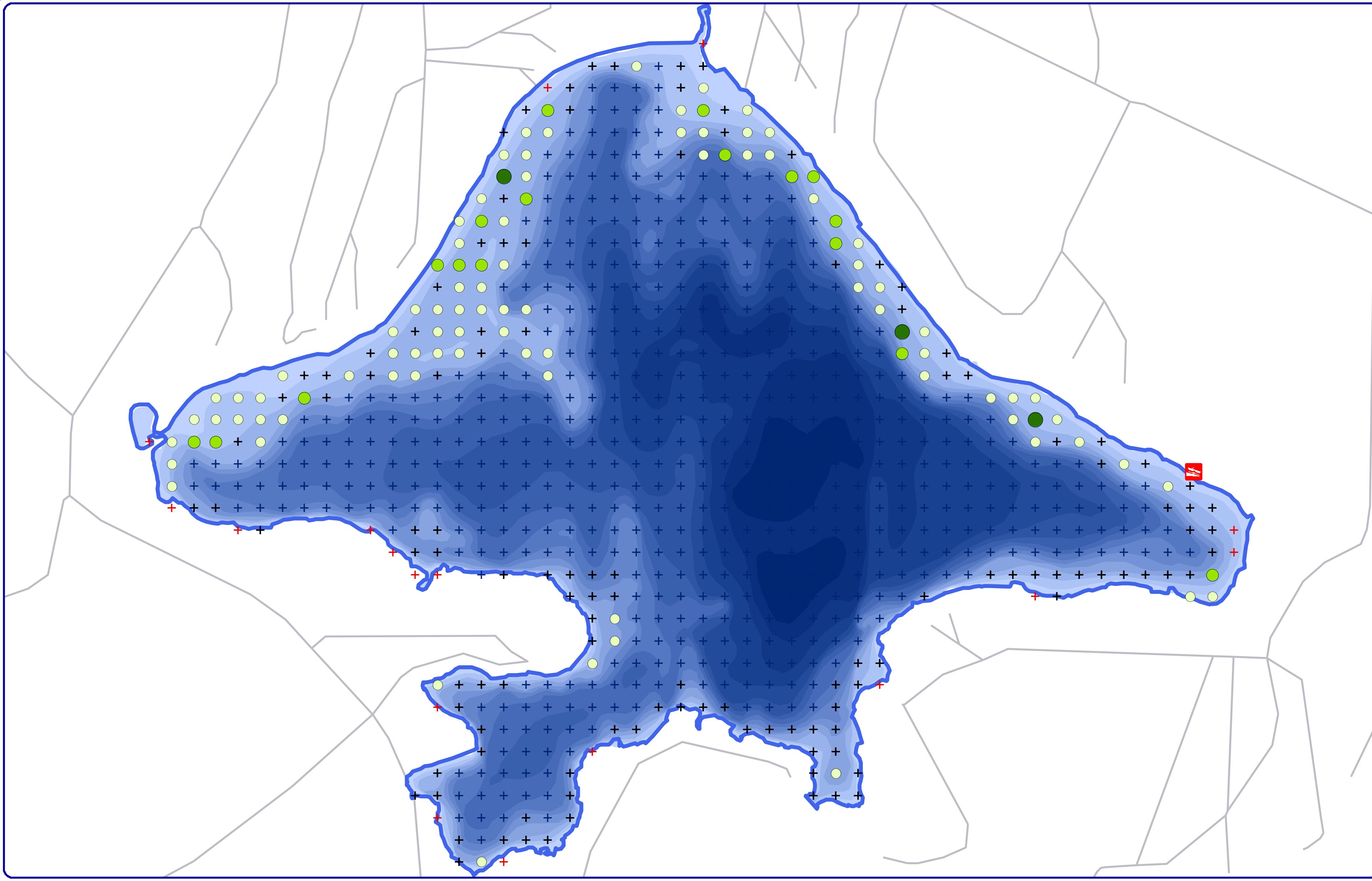


Figure 8.9.5-2. Little Star Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



Land Ownership (Inset map)
Federal (none shown)
State
County (none shown)
N
W
E
S
700
Feet
Onterra, LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2016
Map Date: December 8, 2016
Filename: LittleStar_Map1_ShorelandCondition_2016.mxd
Project Location in Wisconsin
Legend
Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized
Seawall
Rip-Rap
Wood/Masonary/Metal
Map 1
Little Star Lake
Vilas County, Wisconsin
2016 Shoreland Condition


Land Ownership (Inset map)
Federal (none shown)
State
County (none shown)
N
W
E
S
700
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2016
Map Date: December 9, 2016
Filename: LittleStar_Map2_CWH_2016.mxd
Project Location in Wisconsin
Legend
2-8 Inch Pieces
No Branches
Minimal Branches
Moderate Branches
Full Canopy (none)
8+ Inch Pieces
No Branches
Minimal Branches
Moderate Branches (none)
Full Canopy (none)
Cluster of Pieces
No Branches (none)
Minimal Branches (none)
Moderate Branches (none)
Full Canopy (none)
Map 2
Little Star Lake
Vilas County, Wisconsin
Coarse Woody Habitat

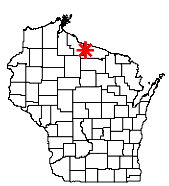


N W E S

700
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
Plant Survey: Onterra, 2016
Map Date: November 30, 2016
Filename: *LittleStar_Map3_TRFPI_2016.mxd*



Project Location in Wisconsin

Legend

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

Map 3
Little Star Lake
Vilas County, Wisconsin
2016 PI Survey: Aquatic Vegetation Distribution

N W E S

700

Feet

Legend

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

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

Exotic Plant Communities
- Pale yellow iris

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920.338.8860
www.onterra-eco.com

Sources:
Aquatic Plants: Onterra, 2016
Orthophotography: NAIP, 2015
Map date: October 27, 2016
Filename: LittleStar_Map4_Comm_2016.mxd

Little Star Lake - Map 4
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Stone Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.10 Stone Lake

An Introduction to Stone Lake

Stone Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 43 feet, a mean depth of 12 feet, and a surface area of approximately 145 acres. Stone Lake is considered to be mesotrophic and its watershed encompasses approximately 137,942 acres. In 2017, 33 native aquatic plant species were found in the lake, of which wild celery (*Vallisneria americana*) is the most common. One non-native plant, curly-leaf pondweed, was found during surveys.

Field Survey Notes

Primarily sandy and rocky substrate observed during the 2017 point-intercept survey. Abundant coarse woody habitat was also observed along the lake's shoreline.

Photo 8.10. Stone Lake, Vilas County

Lake at a Glance* – Stone Lake

Morphology	
Acreage	145
Maximum Depth (ft)	43
Mean Depth (ft)	12
Volume (acre-feet)	1,681
Shoreline Complexity	5.3
Vegetation	
Curly-leaf Survey Date	June 13, 2017
Comprehensive Survey Date	August 9, 2017
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Curly-leaf pondweed
Simpson's Diversity	0.9
Average Conservatism	6.5
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Nitrogen
Watershed to Lake Area Ratio	950:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.10.1 Stone Lake Water Quality

Water quality data was collected from Stone 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.

Very little historical data exist for two water quality parameters of interest – total phosphorus and chlorophyll-*a*. In 2017, average summer phosphorus concentrations (23.0 µg/L) were the same as the median value (23.0 µg/L) for other deep lowland drainage lakes in the state (Figure 8.10.1-1). This value is slightly higher than the median value (21.0 µg/L) for other lakes within the Northern Lakes and Forests ecoregion. The 2017 average summer phosphorus concentration falls in the *good* category for deep lowland drainage lakes in the state.

Total phosphorus surface values from 2017 are compared with bottom-lake samples collected during this same time frame in Figure 8.10.1-2. As displayed in this figure, during the spring turnover in April 2017 (lake vertical mixing) and during July 2017 surface and bottom total phosphorus concentrations were similar. However, during the remaining sampling events, the bottom phosphorus concentrations were greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.10.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain of Lakes-wide document. This is a natural process that most lakes have. While the hypolimnetic concentrations are higher than surface water concentrations, these relatively higher levels are not high enough to negatively impact Stone Lake's surface water quality. Typically, lake managers do not become concerned unless these concentrations near 200 µg/L)

In 2017, the average summer chlorophyll-*a* concentration (6.2 µg/L) was slightly lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.10.1-3). This value is slightly higher than the median value (5.6 µg/L) for other lakes within the Northern Lakes and Forests ecoregion. The weighted average summer chlorophyll-*a* concentration (6.1 µg/L) falls in the *good* category for deep lowland drainage lakes in the state.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *good*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present.

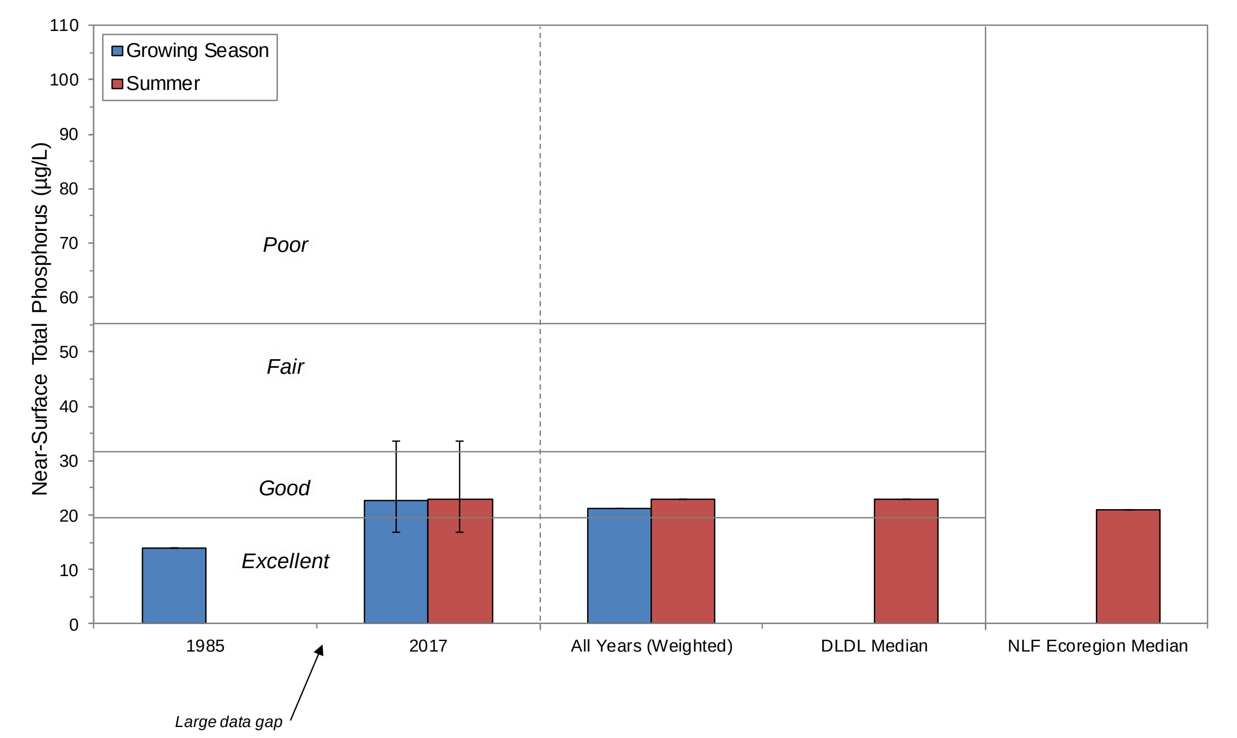


Figure 8.10.1-1. Stone Lake, state-wide deep lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

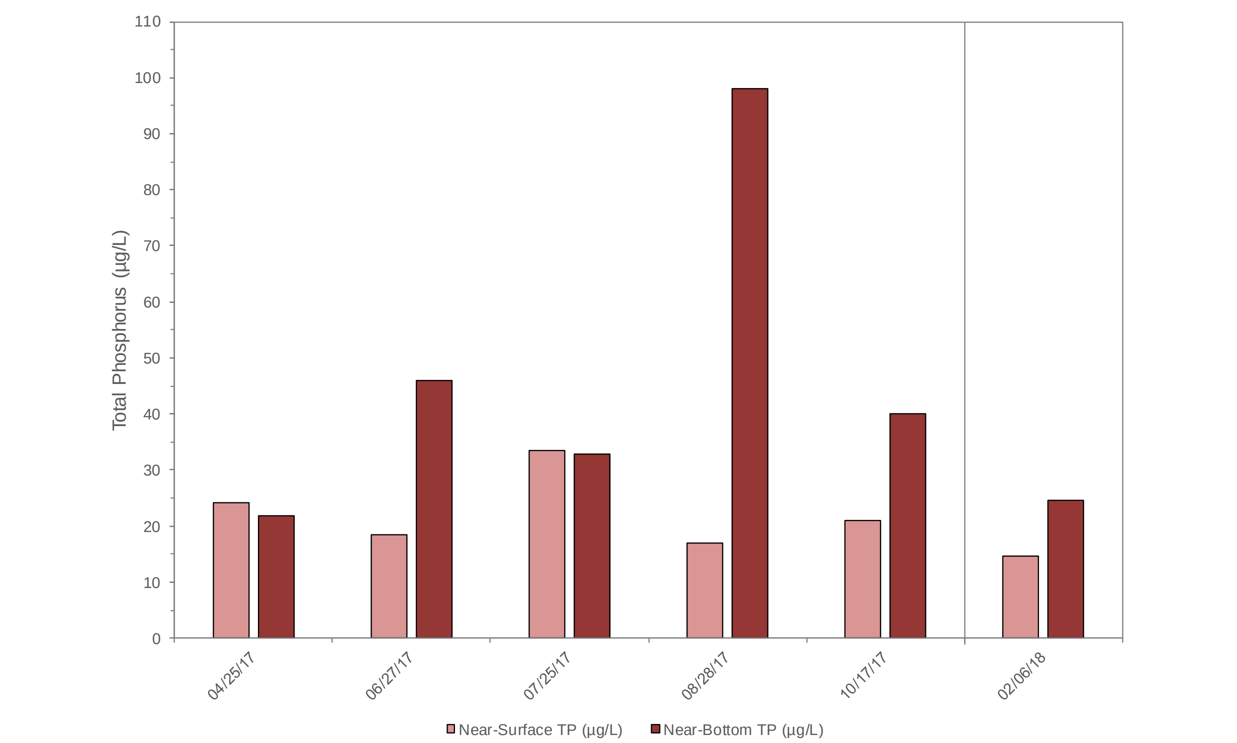


Figure 8.10.1-2. Stone Lake surface and bottom total phosphorus values.

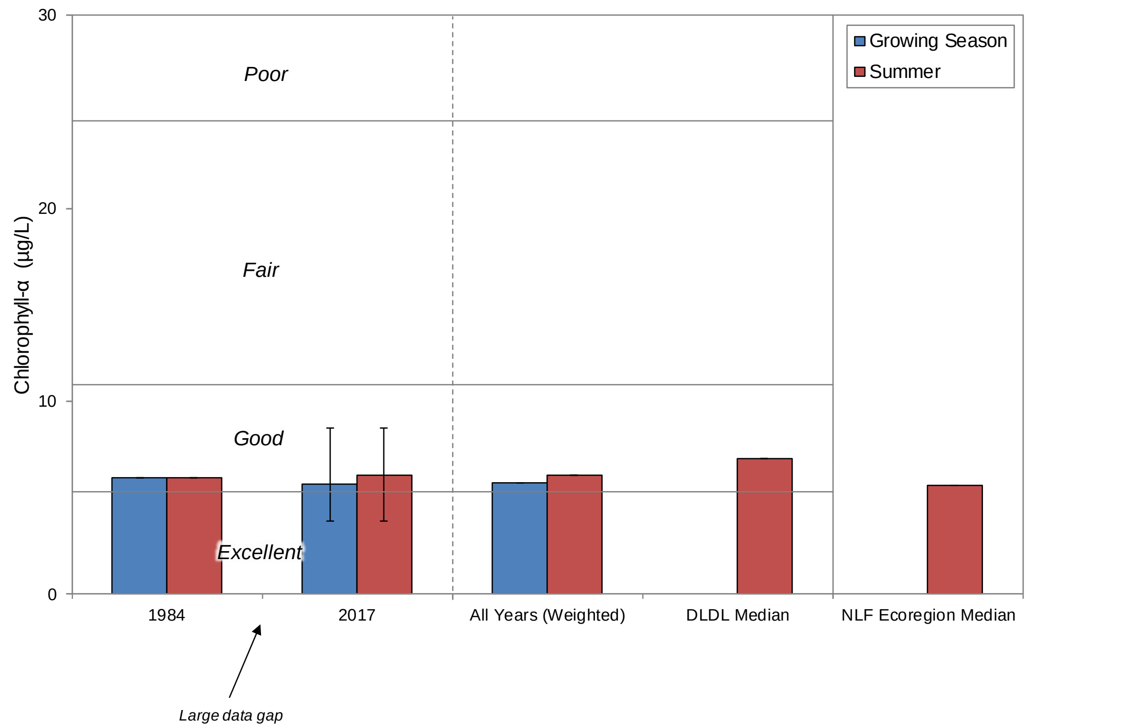


Figure 8.10.1-3. Stone Lake, state-wide deep lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The clarity of Stone Lake's water can be described as *excellent* during the summer months in which data has been collected (Figure 8.10.1-4). A weighted average over this timeframe (8.8 feet) is similar to the median value for other deep lowland drainage lakes in the state (8.5 feet) and the regional median (8.9 feet). Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Stone Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Stone Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

True color measures the dissolved organic materials in water. Water samples collected in April and July of 2017 were measured for this parameter, and were found to be 30 SU (Standard Units), for both months indicating the lake's water is *lightly tea-colored*.

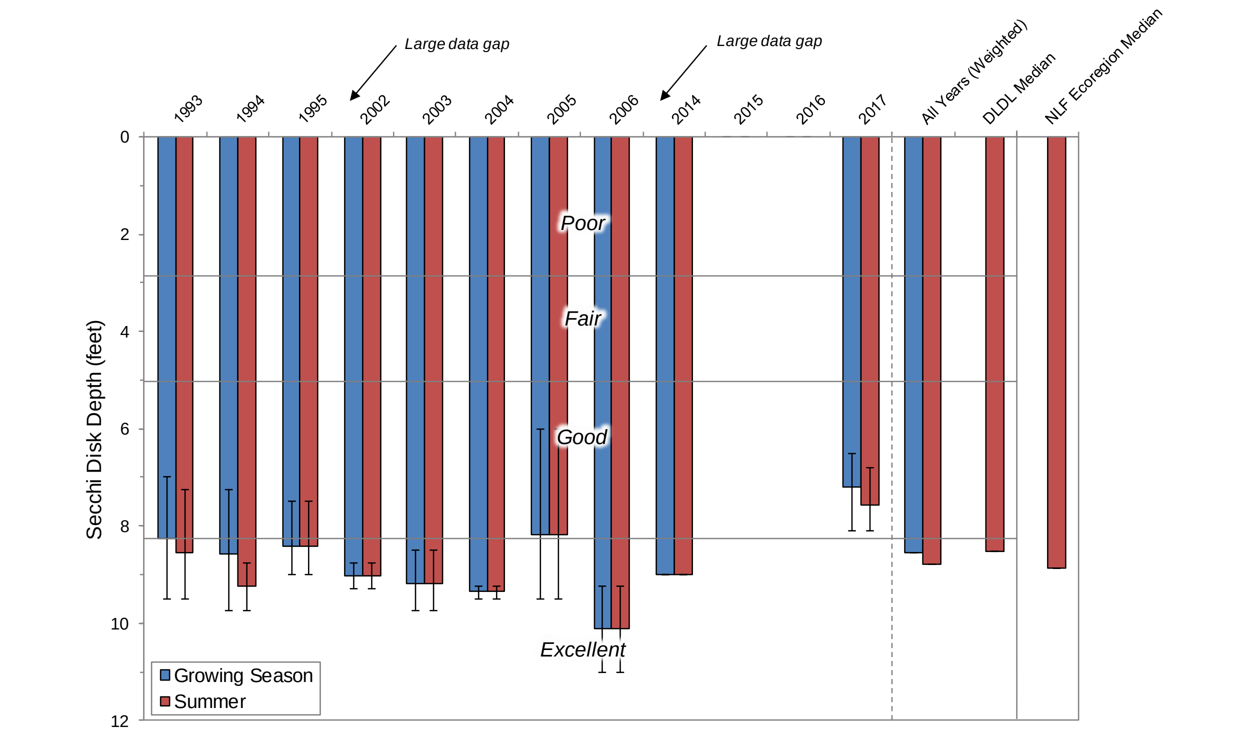


Figure. 8.10.1-4. Stone Lake, state-wide deep lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Stone Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to upper mesotrophic (Figure 8.10.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Stone Lake is in an upper mesotrophic state.

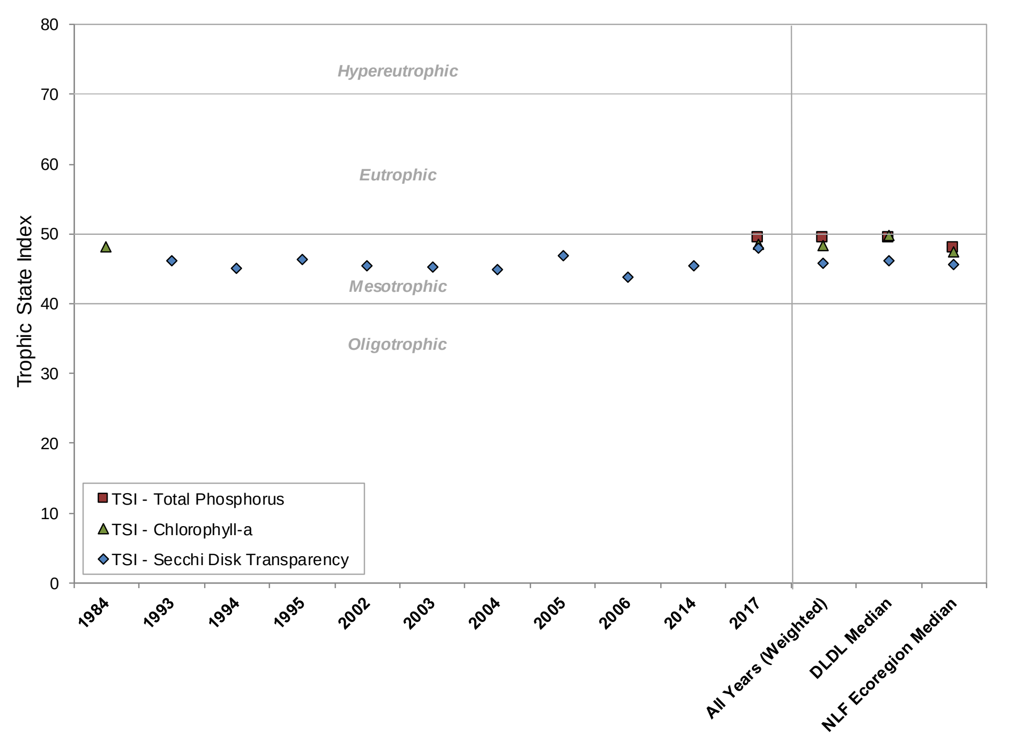


Figure 8.10.1-5. Stone Lake, state-wide deep lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Stone Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Stone Lake by Onterra staff. Graphs of those data are displayed in Figure 8.10.1-6 for all sampling events.

Stone Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the lake remained thermally stratified, developing an anoxic hypolimnion. This occurrence is not uncommon in Wisconsin lakes, as bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen. If the lake mixes completely, oxygen will be reintroduced to the lower levels of the water column.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2018, oxygen levels remained sufficient throughout the water column to support most aquatic life in northern Wisconsin lakes.

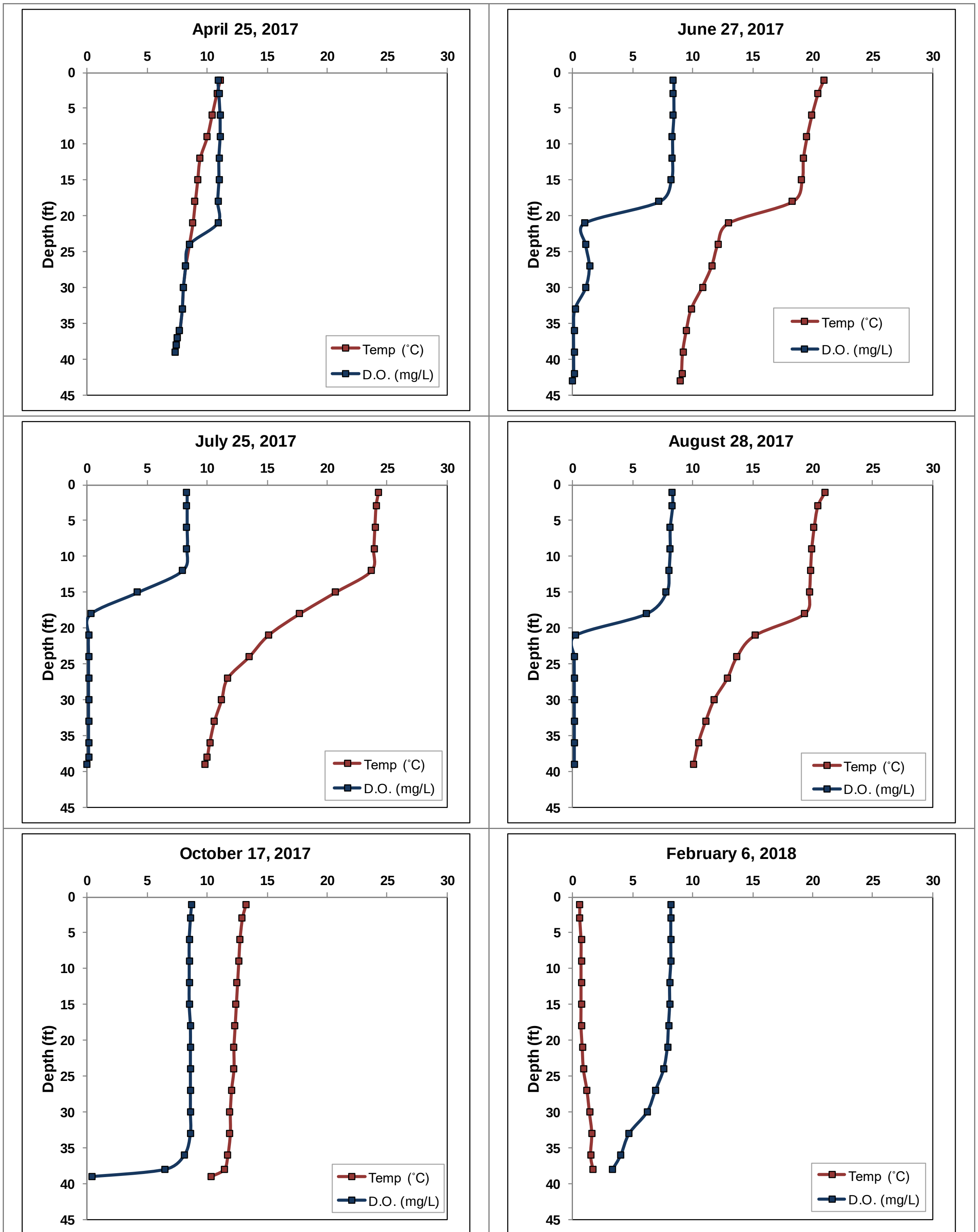


Figure 8.10.1-6. Stone Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Stone 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 Stone 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. Stone Lake's surface water pH was measured at roughly 7.4 during April and 7.7 in July of 2017. These values are 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 Stone Lake was measured at 38.1 and 37.2 mg/L as $CaCO_3$ in April and July of 2017, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Stone 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 Stone Lake's pH of 7.7 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 Stone was found to be 10.5 mg/L in July of 2017, which is below the optimal 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. No veligers (larval zebra mussels) were found within these samples.

8.10.2 Stone Lake Watershed Assessment

Stone Lake's watershed is 137,942 acres in size. Compared to Stone Lake's size of 145 acres, this makes for a very large watershed to lake area ratio of 950:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. This means that 134,041 acres (97%) of Stone Lake's watershed is the Spider Lake subwatershed and 3,440 acres (3%) is the Fawn Lake subwatershed. The direct watershed of Stone Lake is a very small part of the lake's total watershed (Figure 8.10.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Stone Lake's residence time is approximately 4 days, or that the water within the lake is completely replaced 88 times per year.

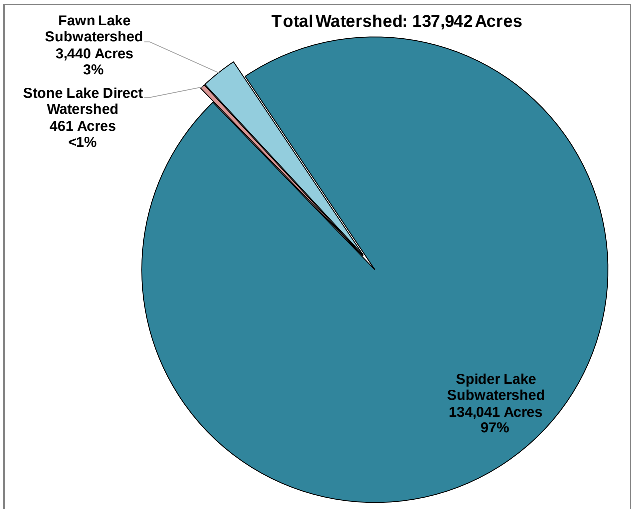


Figure 8.10.2-1. Stone Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 5,998 pounds of phosphorus being delivered to Stone Lake on an annual basis, nearly all of it originates from Spider Lake and Fawn Lake, which are immediately upstream of Stone Lake (Figure 8.10.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 14 µg/L, which is lower than the measured growing season average total phosphorus concentration of 21 µg/L. This means the model underestimates phosphorus loading to Stone Lake.

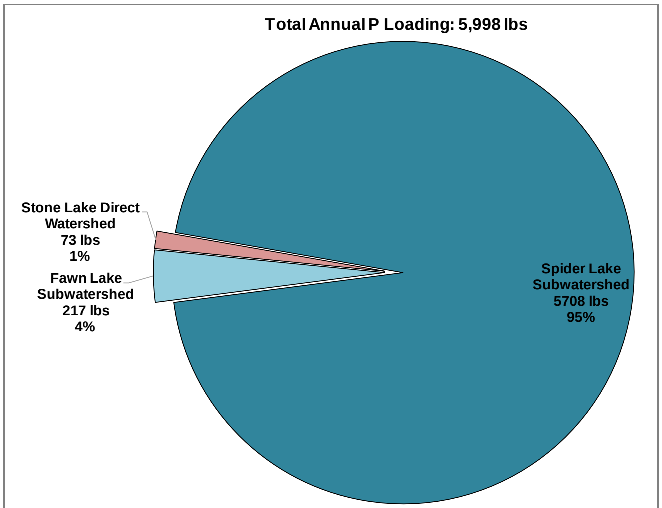


Figure 8.10.2-2. StoneLake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the nearly all of the phosphorus that enters Stone Lake comes from the upstream Spider and Fawn Lakes, efforts to reduce phosphorus levels in Stone Lake should concentrate on reducing phosphorus inputs to Spider and Fawn Lakes.

8.10.3 Stone Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2017, Stone Lake's immediate shoreline was assessed in terms of its development. Stone Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.7 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.10.3-1). This constitutes about 60% of Stone 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, 1.8 miles of urbanized and developed–unnatural shoreline (23%) was observed. If restoration of the Stone 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. Stone Lake Map 1 displays the location of these shoreline lengths around the entire lake.

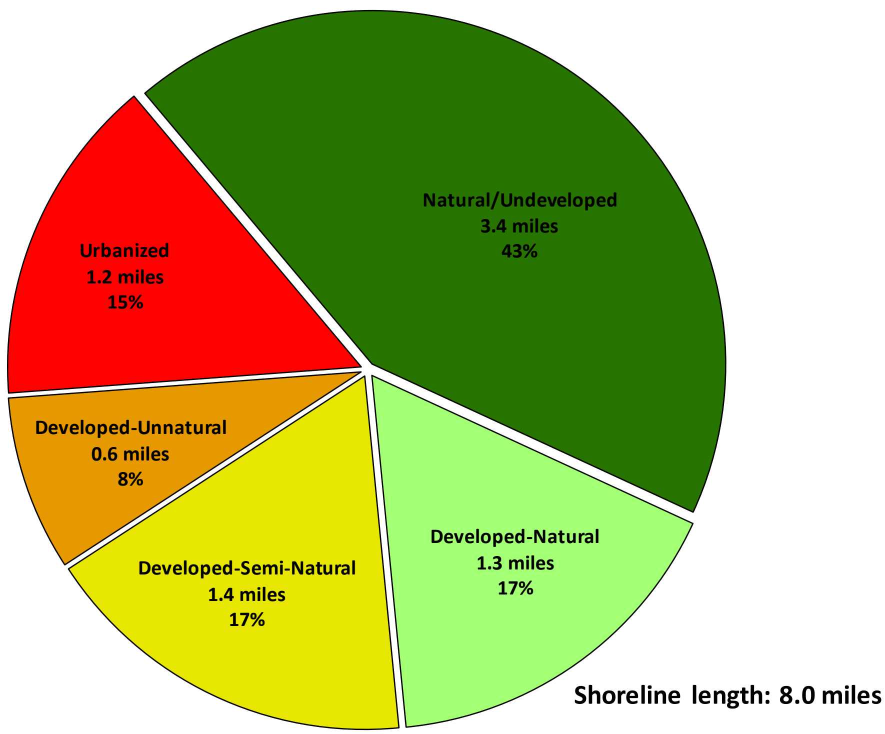


Figure 8.10.3-1. Stone Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Stone Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Stone Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 447 total pieces of coarse woody habitat were observed along 8.0 miles of shoreline (Stone Lake Map 2), which gives Stone Lake a coarse woody habitat to shoreline mile ratio of 56:1 (Figure 8.10.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Two hundred and eight-four pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 163 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Stone 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 98 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 Stone Lake falls well above the 75th percentile of these 98 lakes and had one of the highest coarse woody habitat pieces per shoreline mile recorded since these surveys began in 2012 (Figure 8.10.3-2).

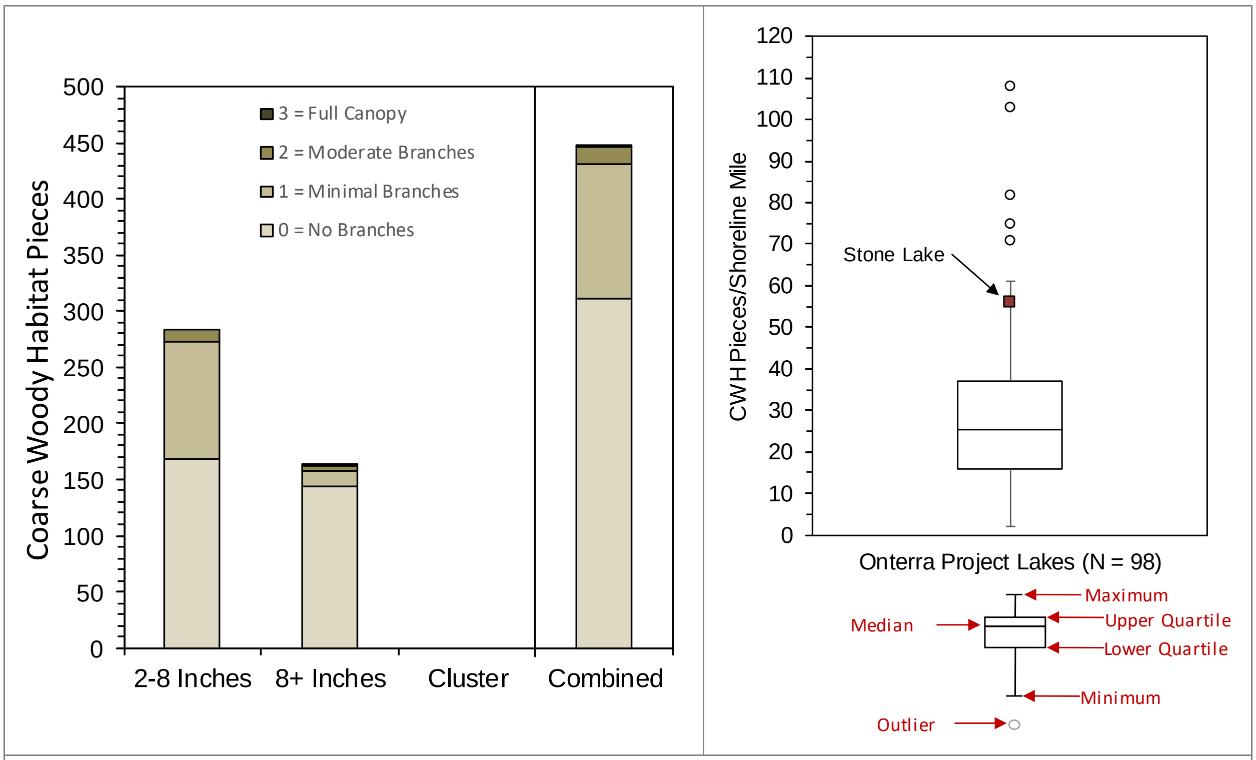


Figure 8.10.3-2. Stone Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of the Stone Lake coarse woody habitat can be found on Stone Lake Map 2.

8.10.4 Stone Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Stone Lake on June 13, 2017. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists located a single plant and a clump of curly-leaf pondweed during the early season survey. Due to the nature of curly-leaf pondweed, it will be discussed in the Non-Native Aquatic Plant Section. Further discussion regarding curly-leaf pondweed and its management can be found in the Manitowish Waters AIS Monitoring & Control Strategy Assessment Reports, which can be found on the MWLA website.

The aquatic plant point-intercept survey and floating-leaf and emergent plant community mapping survey were conducted on Stone Lake on August 9, 2017 by Onterra. During these surveys, 33 species of native aquatic plants were located in Stone Lake (Table 8.10.4-1). Twenty-three of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 10 species were observed incidentally during visits to Stone Lake.

Aquatic plants were found growing to a depth of 13 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 178 point-intercept locations sampled within the littoral zone, roughly 68% contained aquatic vegetation. Stone Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in northern bay that is more likely to hold organic substrates. Approximately 40% of the point-intercept sampling locations where sediment data was collected at were sand, 48% consisted of a fine, organic substrate (muck) and 12% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.10.4-1. Aquatic plant species located in Stone Lake during 2017 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Carex gynandra*	Nodding sedge	6	I
	Iris versicolor	Northern blue flag	5	I
	Scirpus cyperinus	Wool grass	4	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	I
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
FL/E	*Sparganium acaule*	Short-stemmed bur-reed	8	I
	Sparganium sp. (sterile)	Bur-reed sp.	N/A	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
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	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 spirillus	Spiral-fruited pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	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

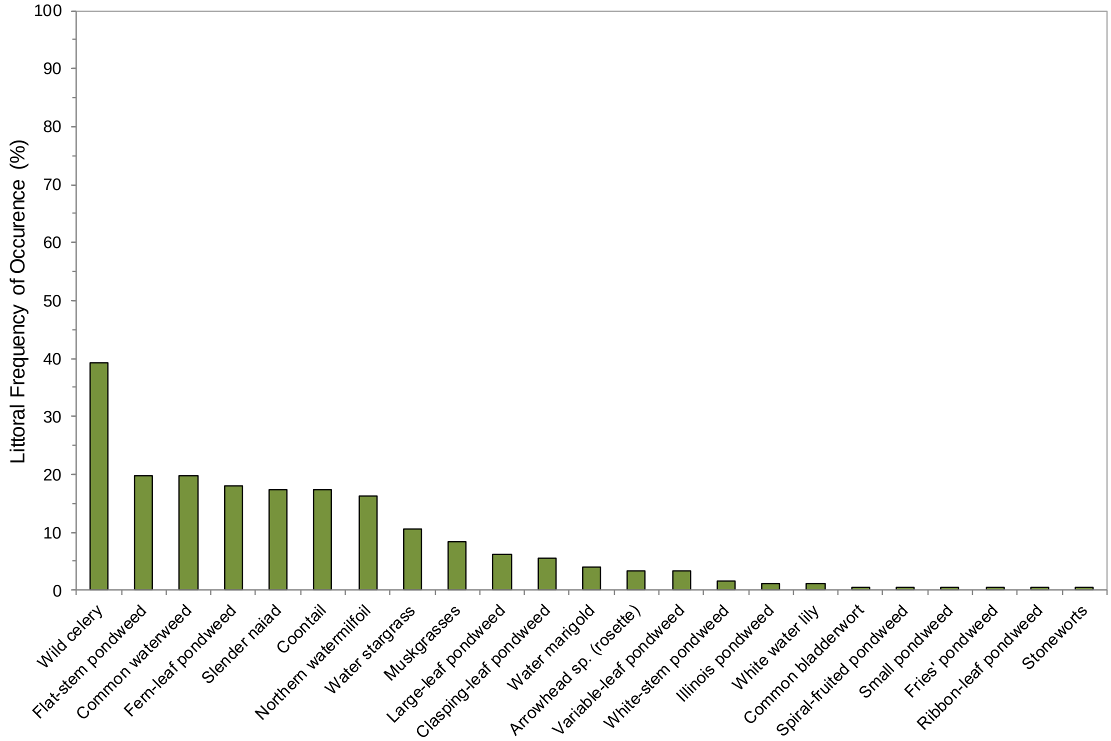


Figure 8.10.4-1. Stone Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2017 point-intercept survey.

Figure 8.10.4-1 shows that wild celery, flat-stem pondweed, common waterweed, and fern-leaf pondweed were the most frequently encountered plants within Stone Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms. Common waterweed is a largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and its locations can be largely a product of water movement. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes.

During aquatic plant inventories, 33 species of native aquatic plants (including incidentals) were found in Stone Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Stone Lake's plant community (0.90) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 wild celery was found at 39% of the sampling locations, its relative frequency of occurrence is 20%. Explained another way, if 100 plants were randomly sampled from Stone Lake, 20 of them would be wild celery. This distribution can be observed in Figure 8.10.4-2, where together five native species account for 58% of the aquatic plant population within Stone Lake, while the other 18 species account for the remaining 42%. Ten additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.10.4-1 as incidentals.

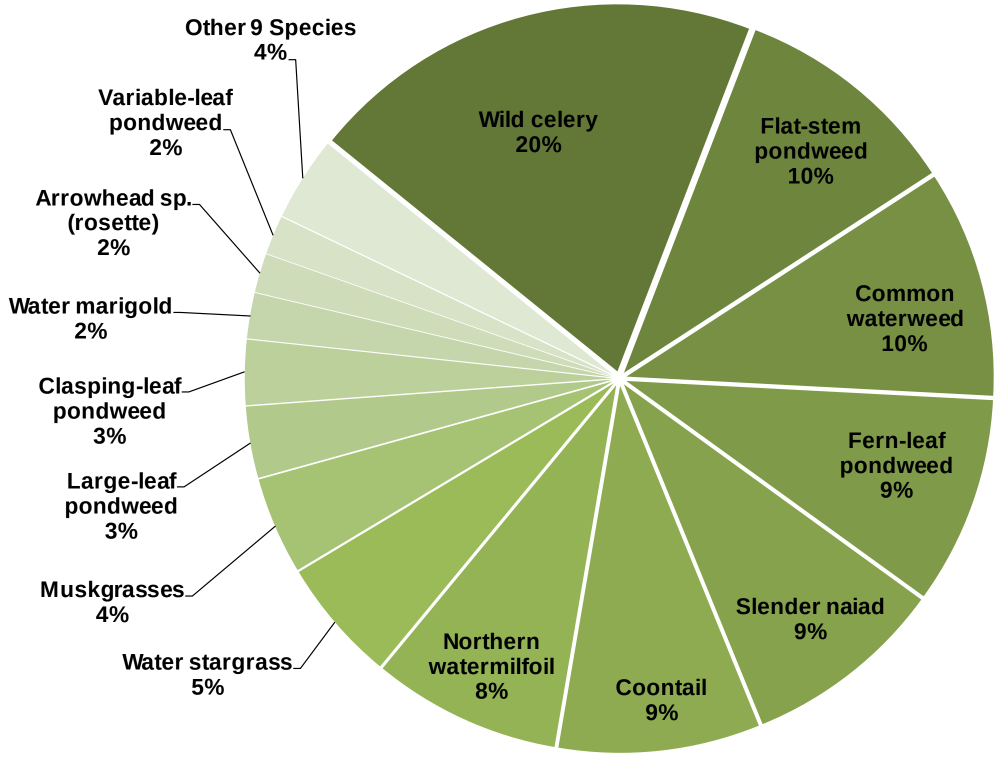


Figure 8.10.4-2. Stone Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2017 point-intercept survey.

Stone Lake's average conservatism value (6.5) is higher than median for the state (6.3) and lower than the median for Northern Lakes and Forests ecoregion (6.7). This indicates that the plant community of Stone Lake is indicative of a moderately disturbed system. Combining Stone Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.4 which is above the median values of the ecoregion and state.

The quality of Stone Lake is also indicated by the incidence of emergent and floating-leaf plant communities that occur in many areas. The 2017 community map indicates that approximately 4.5 acres of the lake contains these types of plant communities (Stone Lake Map 4, Table 8.10.4-2). Ten floating-leaf and emergent species were located on Stone Lake (Table 8.10.4-1), all of which provide valuable wildlife habitat.

Table 8.10.4-2. Stone Lake acres of emergent and floating-leaf plant communities from the 2017 community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-leaf	4.1
Mixed Emergent & Floating-leaf	0.3
Total	**4.5**

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Stone Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Stone Lake

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Stone Lake during 2013. Through 2019, the infrequent occurrences of this exotic were managed through volunteer and professional hand-harvesting. As a part of the Manitowish Waters Comprehensive Management Plan, Stone Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.10.5 Stone 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 and within each lake's individual report section 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 Stone 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.10.5-1). 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. Stone Lake has only been stocked in 1976 with 4,000 fingerling walleye.

Photograph 8.10.5-1. Fingerling Muskellunge.

Stone Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.10.5-1 from 2010 to 2017. As many as 25 walleye have been harvested from the lake in the past (2016), but the average harvest is roughly one fish in a given year. Spear harvesters on average have taken 10% of the declared quota.

Muskellunge open water spear harvest records are provided in Figure 8.10.5-2 from 2010 to 2017. As many as two muskellunge have been harvested from the lake in the past (2016), however the average harvest is zero fish in a given year. Spear harvesters on average have taken 13% of the declared quota.

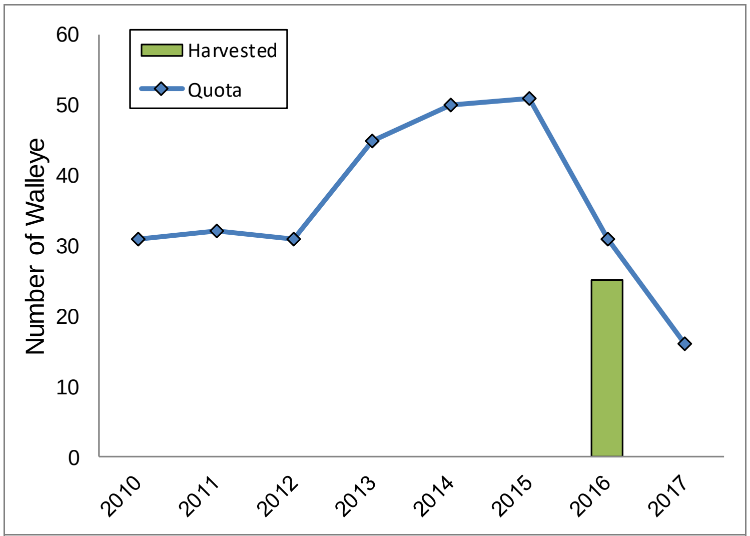


Figure 8.10.5-1. Stone Lake walleye spear harvest data. (GLIFWC 1999-2017).

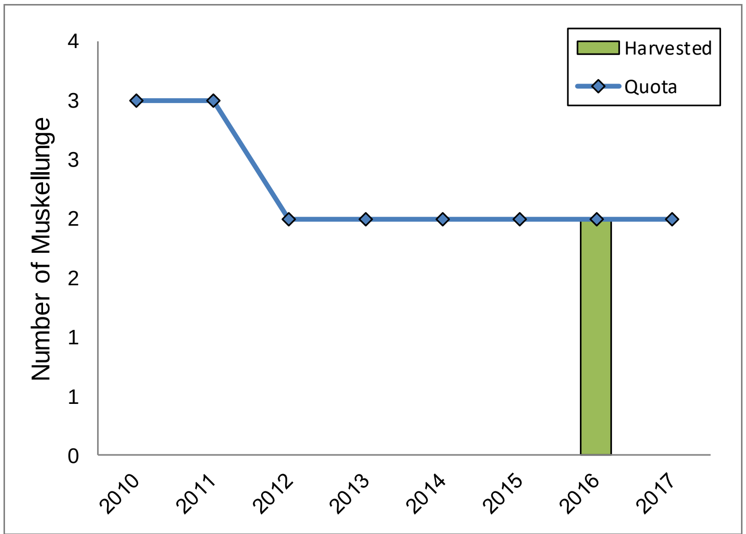
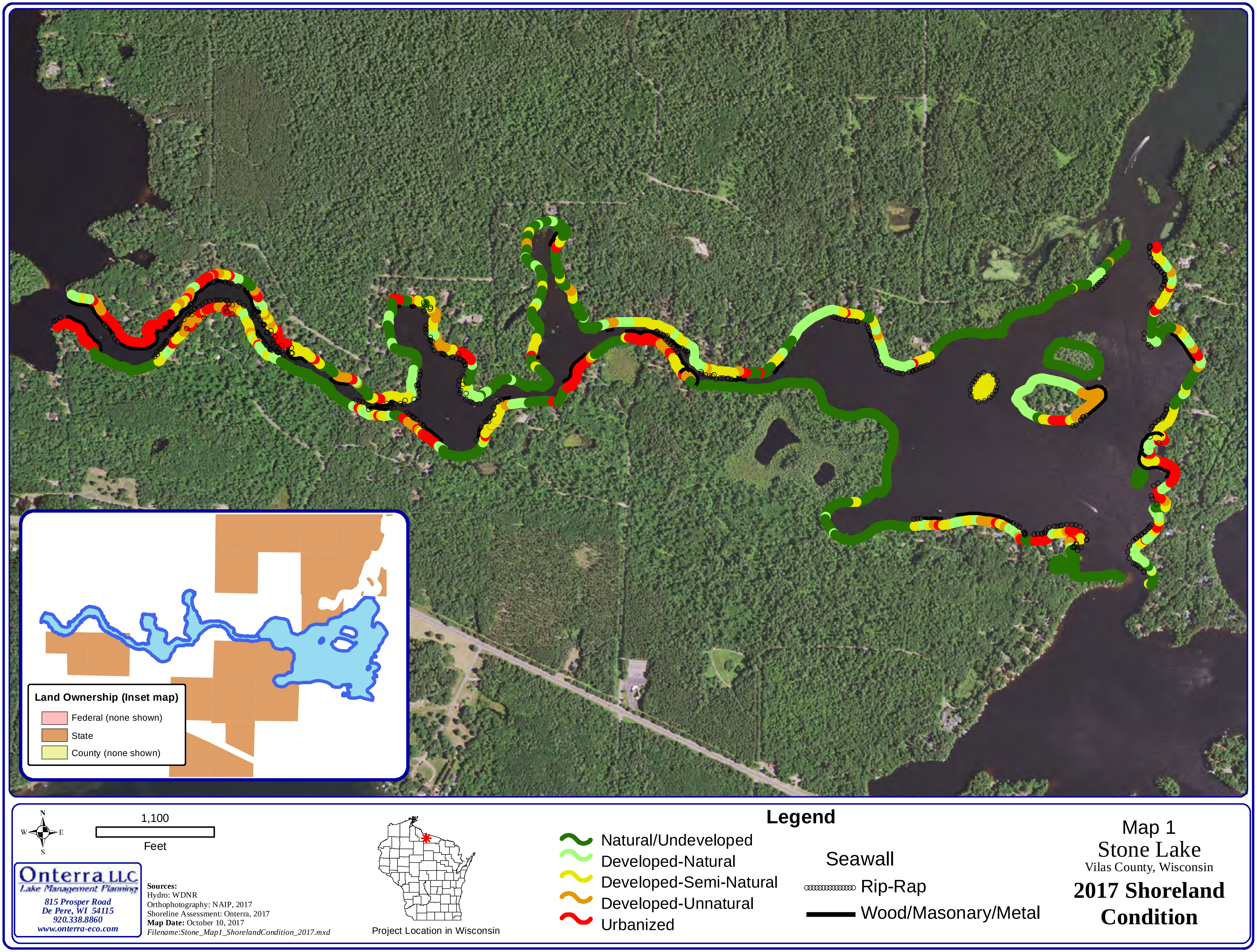
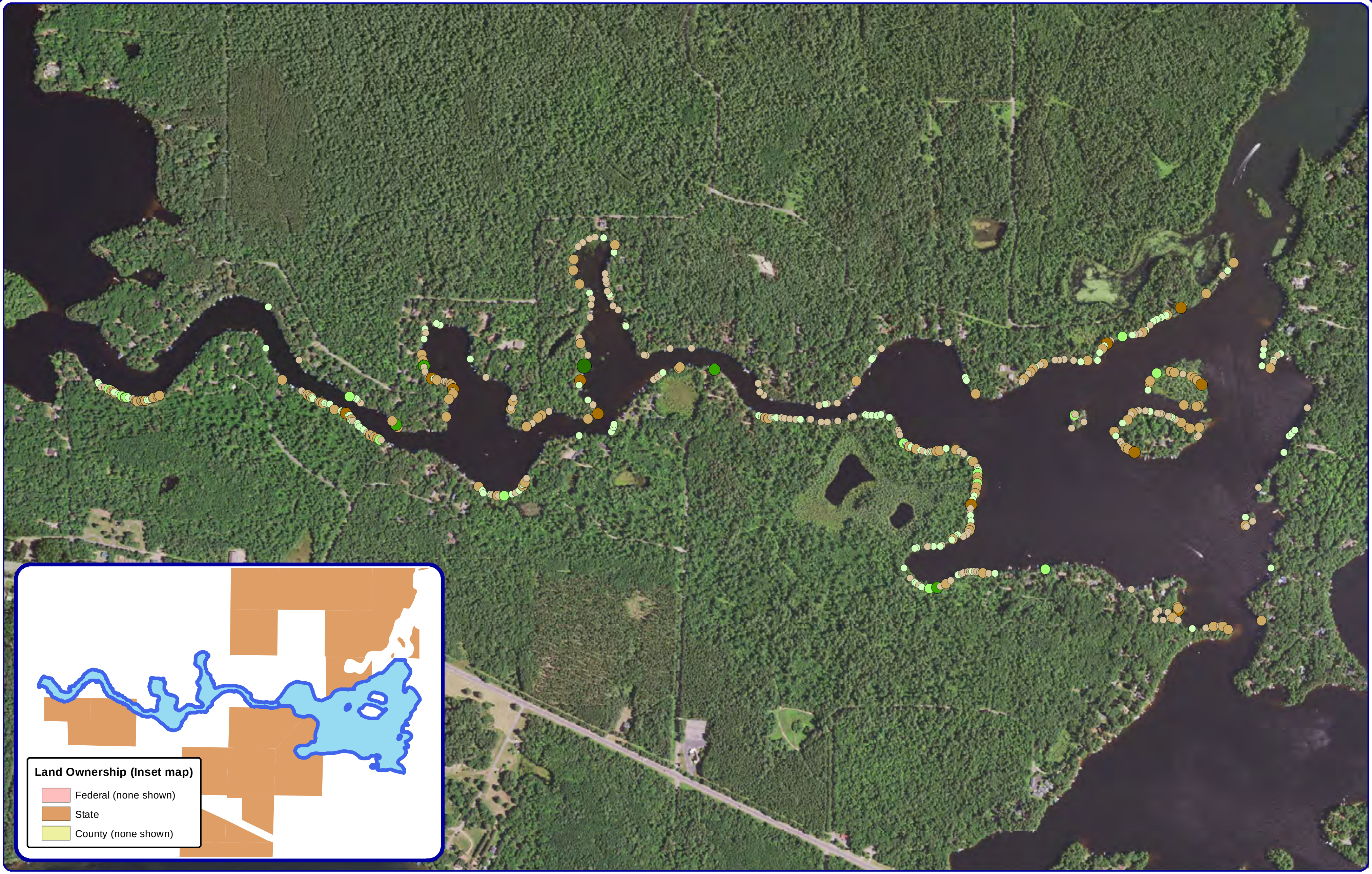


Figure 8.10.5-2. Stone Lake muskellunge spear harvest data. (GLIFWC 1999-2017).


Land Ownership (Inset map)
Federal (none shown)
State
County (none shown)
N
W
E
S
1,100
Feet
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
Shoreline Assessment: Onterra, 2017
Map Date: October 10, 2017
Filename:Stone_Map1_ShorelandCondition_2017.mxd
Project Location in Wisconsin
Legend
Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized
Seawall
Rip-Rap
Wood/Masonary/Metal
Map 1
Stone Lake
Vilas County, Wisconsin
2017 Shoreland Condition



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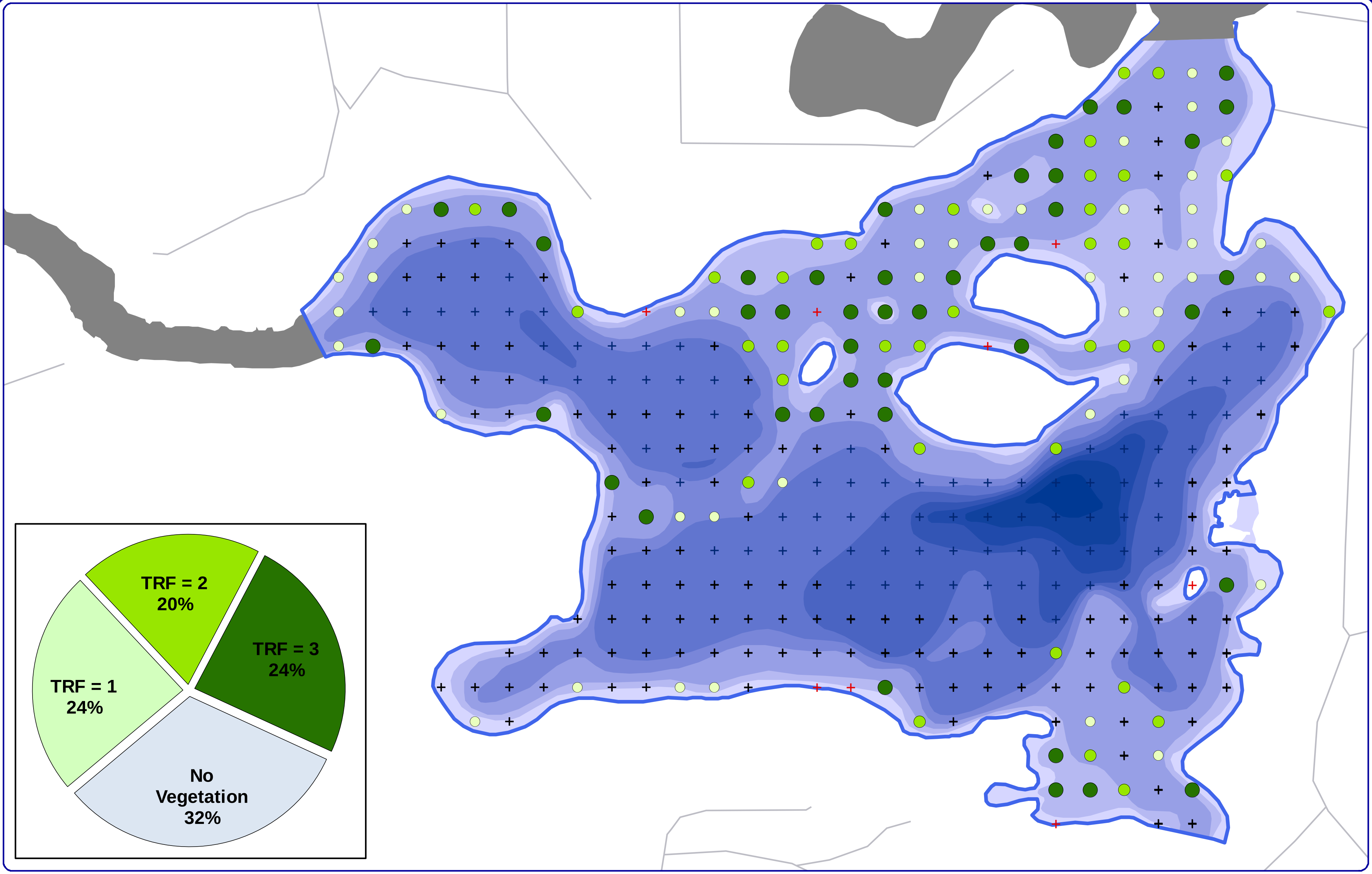
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2017
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: October 10, 2017
Filename:Stone_Map2_CWH_2017.mxd

Map 2
Stone Lake
Vilas County, Wisconsin
Coarse Woody Habitat



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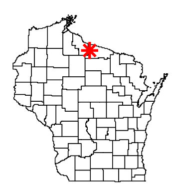
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

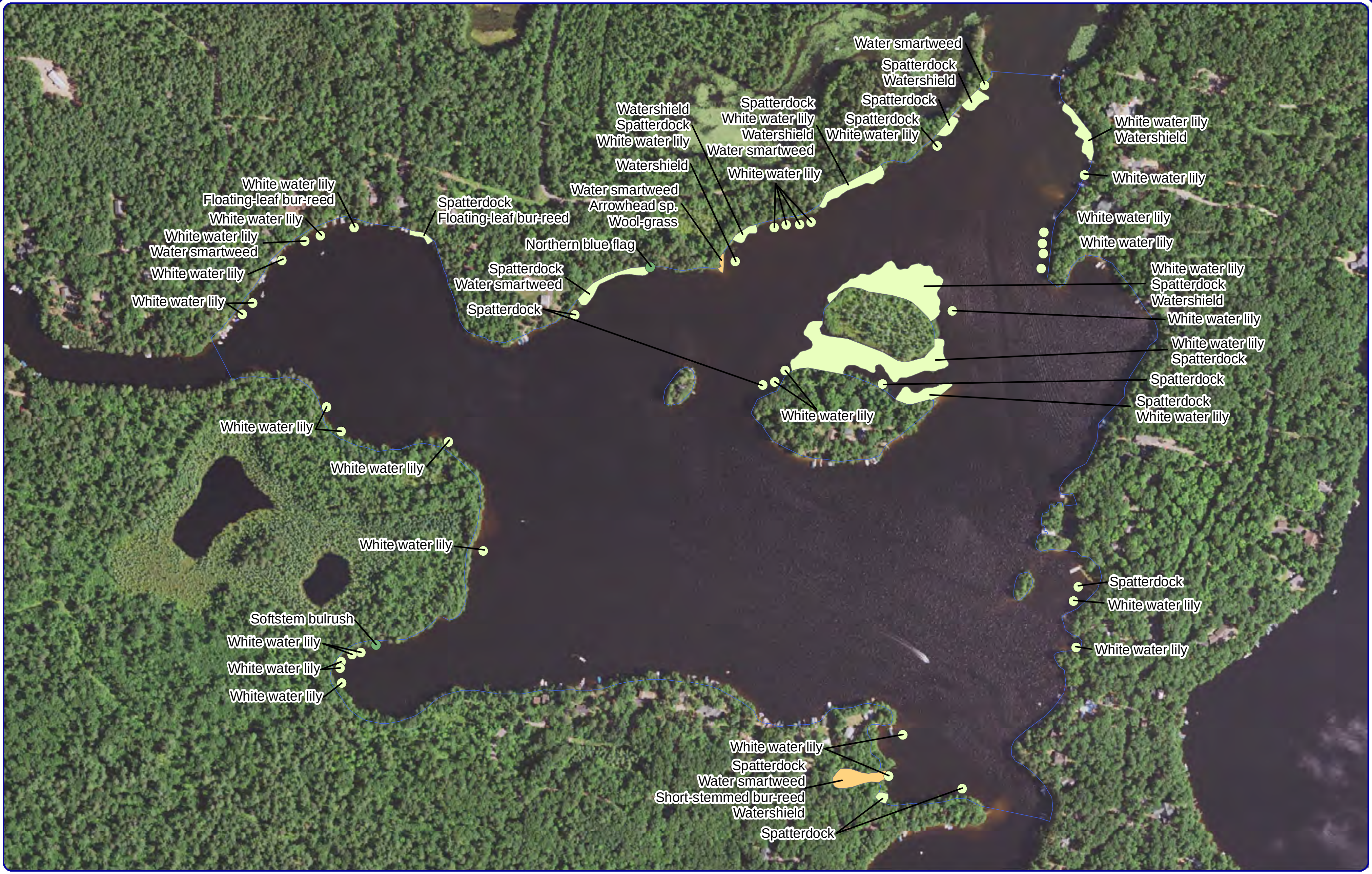
Sources:
Roads and Hydro: WDNR
Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: *MapX_Stone_TRFPI_2017.mxd*


Project Location in Wisconsin

Legend

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

Map 3
Stone Lake
Vilas County, Wisconsin
2017 PI Survey: Aquatic Vegetation Distribution



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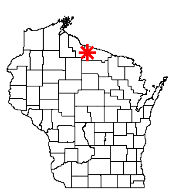
550
Feet

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

Sources:
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2015
Map date: October 20, 2017
Filename: Stone_Comm_2017.mxd


Project Location in Wisconsin

Legend

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

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

Map 4

Stone Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Vance Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.11 Vance Lake

An Introduction to Vance Lake

Vance Lake, Vilas County, is a shallow lowland drainage lake with a maximum depth of 12 feet, a mean depth of 7 feet, and a surface area of approximately 30 acres. Vance Lake is considered to be mesotrophic and its watershed encompasses approximately 146,640 acres. In 2017, 27 native aquatic plant species were found in the lake, of which coontail (*Ceratophyllum demersum*) was the most common. Two non-native plants, purple loosestrife and reed canary grass were observed growing in or along the shorelines of Vance Lake in 2017.

Field Survey Notes

A dam separates Vance Lake from upstream Rest Lake and primarily sandy and rocky substrate was observed during the 2017 point-intercept survey. The shoreline is largely undeveloped and a fair amount of coarse woody structure was observed in 2017.

Photo 8.11. Vance Lake, Vilas County

Lake at a Glance* – Vance Lake

Morphology	
Acreage	30
Maximum Depth (ft)	12
Mean Depth (ft)	7
Volume (acre-feet)	197
Shoreline Complexity	2.5
Vegetation	
Curly-leaf Survey Date	June 28, 2017
Comprehensive Survey Date	August 2, 2017
Number of Native Species	27
Threatened/Special Concern Species	-
Exotic Plant Species	Purple loosestrife, Reed canary grass
Simpson's Diversity	0.91
Average Conservatism	6.0
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	4,946:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.11.1 Vance Lake Water Quality

Water quality data was collected from Vance Lake on three occasions in 2017. 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, any historical data was researched and are included within this report as available.

Vance Lake is located on the Manitowish River downstream of the Rest Lake Dam. As such, it is more like a river than a natural lake. Because of the very short hydrologic residence time, water quality likely reflects concentrations in the river.

No historical data exist for two water quality parameters of interest – total phosphorus and chlorophyll-*a*. In 2017, average summer phosphorus concentrations (17.3 µg/L) were lower than the median value (33.0 µg/L) for other shallow lowland drainage lakes in the state and the median value (21.0 µg/L) for other lakes within the Northern Lakes and Forests ecoregion (Figure 8.11.1-1). The 2017 average summer phosphorus concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

In 2017, the average summer chlorophyll-*a* concentration (5.6 µg/L) was slightly lower than the median value (9.4 µg/L) for other lakes of this type (Figure 8.11.1-2). This value is the same as the median value (5.6 µg/L) for other lakes within the Northern Lakes and Forests ecoregion. The 2017 average summer chlorophyll-*a* concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present.

The clarity of Vance Lake's water can be described as *excellent* during the summer months in which data has been collected (Figure 8.11.1-3). A weighted average over this timeframe (10.9 feet) exceeds the median value for other shallow lowland drainage lakes in the state (5.6 feet) and the regional median (8.9 feet). Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In many lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Vance Lake may contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake. *True color* measures the dissolved organic materials in water; however, true color was not measured in Vance Lake

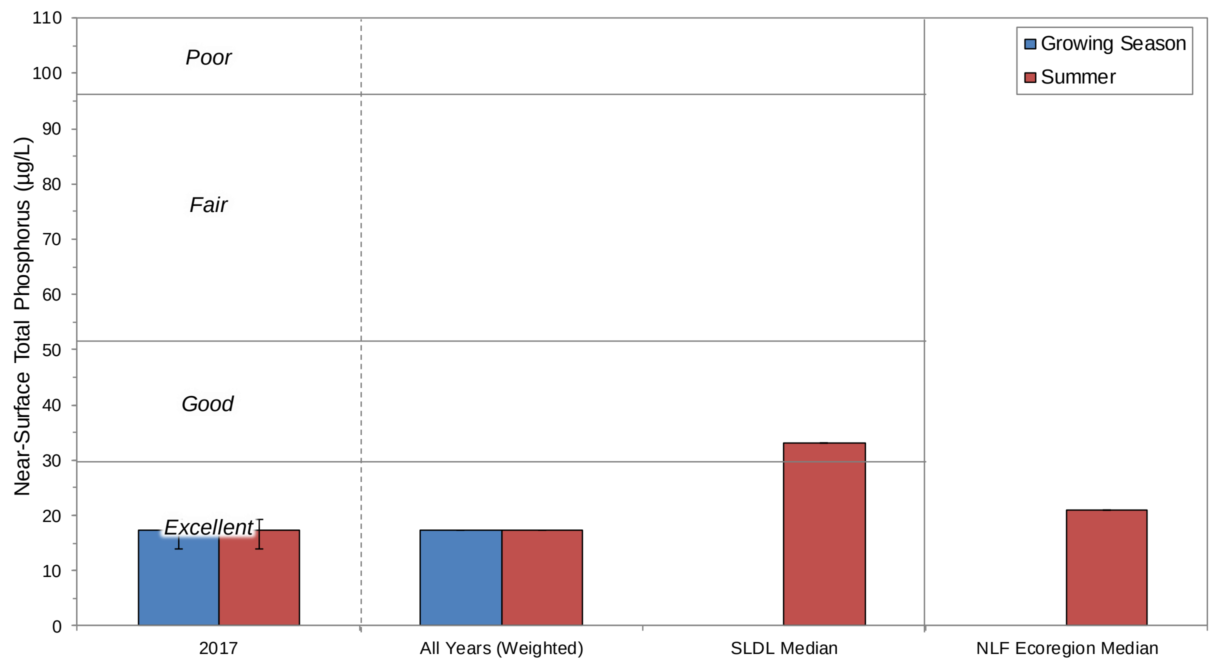


Figure 8.11.1-1. Vance Lake, state-wide shallow lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

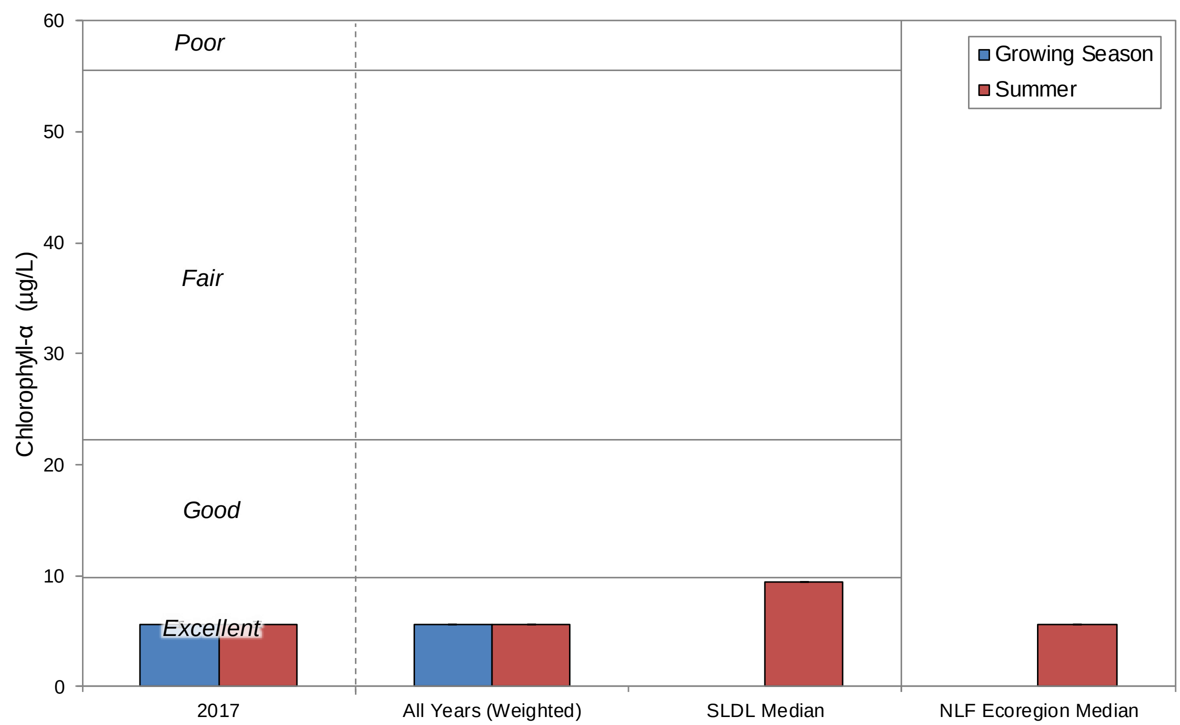


Figure 8.11.1-2. Vance Lake, state-wide shallow lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

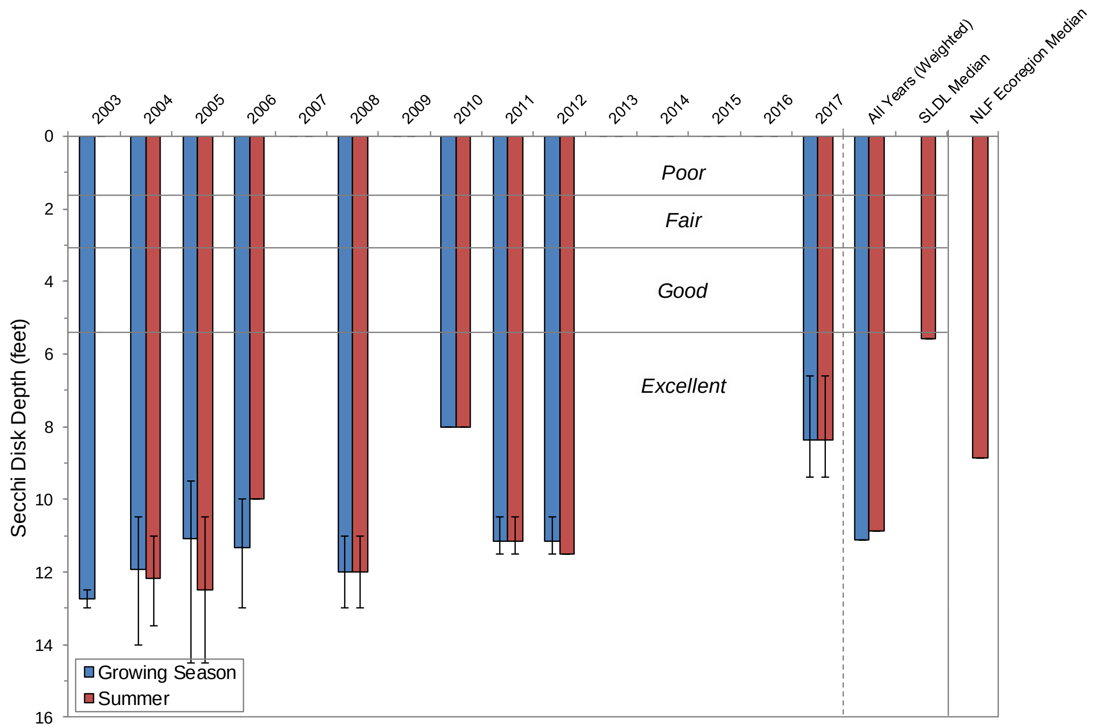


Figure. 8.11.1-3. Vance Lake, state-wide shallow lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Vance Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values are displayed in Figure 8.11.1-4. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Vance Lake is in a mesotrophic state.

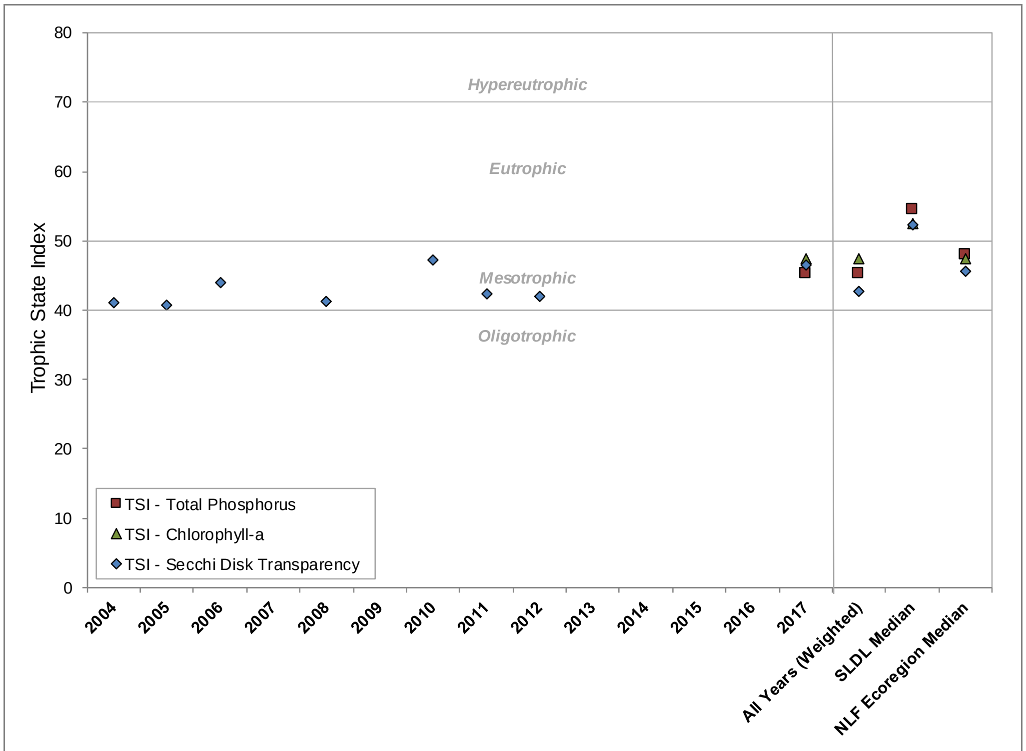


Figure 8.11.1-4. Vance Lake, state-wide shallow lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Vance Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Vance Lake by Onterra staff. Graphs of those data are displayed in Figure 8.11.1-5 for all sampling events.

Vance Lake remained thoroughly mixed throughout the summer months in 2017 (Figure 8.11.1-5). This is not uncommon in lakes that are moderate in size and fairly shallow. Energy from the wind and flow from the Manitowish River is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

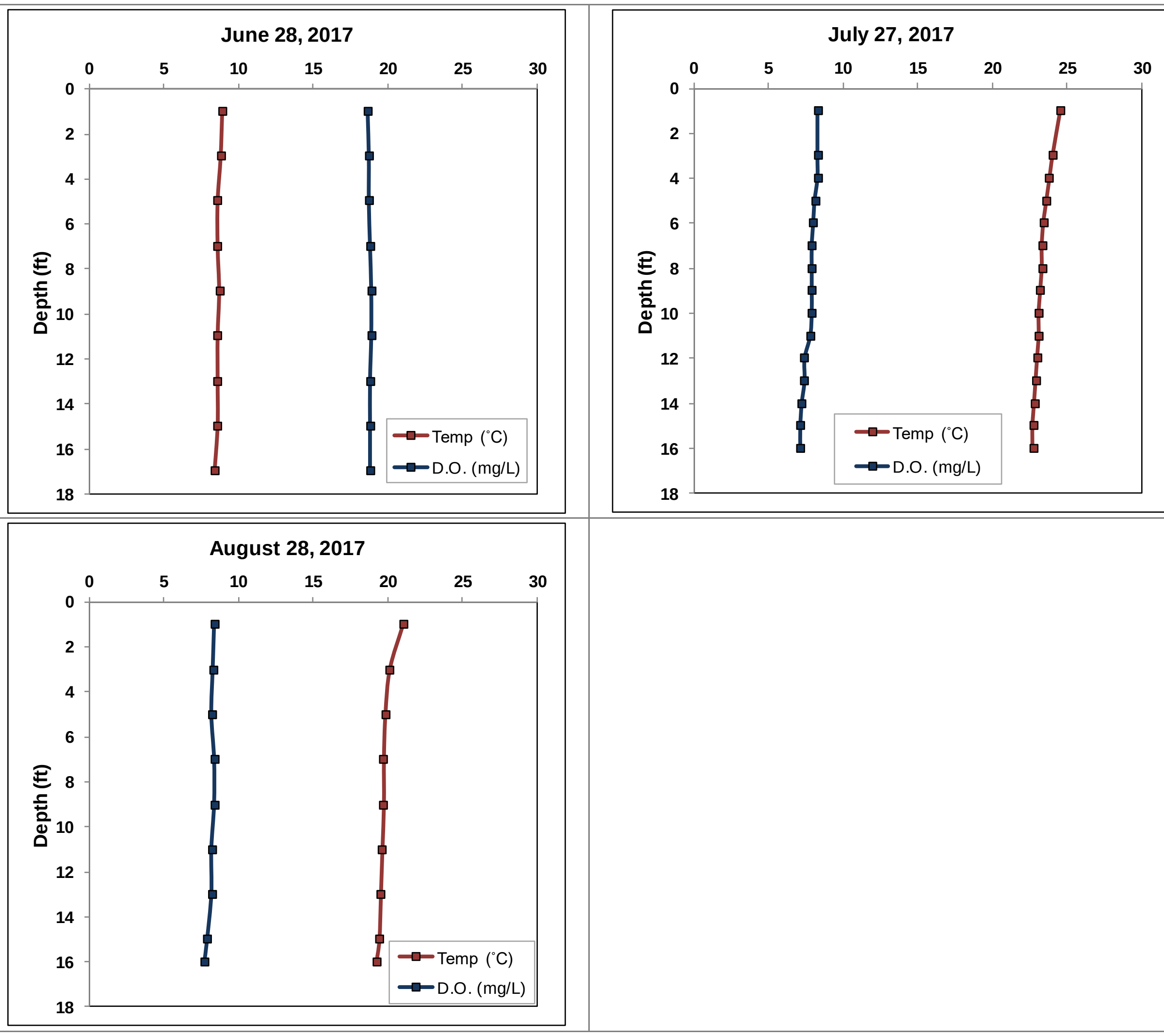


Figure 8.11.1-5. Vance Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Vance 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 Vance 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. Vance Lake's surface water pH was measured at roughly 7.8 July of 2017. This value is slightly above neutral and falls 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 Vance Lake was measured at 38.8 in July of 2017 and indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

While samples of calcium were not collected from Vance Lake in 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 Vance Lake's pH of 7.8 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. Plankton tows were completed by Onterra staff during the summer of 2017 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.11.2 Vance Lake Watershed Assessment

Vance Lake's watershed is 146,640 acres in size. Compared to Vance Lake's size of 30 acres, this makes for an incredibly large watershed to lake area ratio of 4946:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Vance Lake this means that 146,517 acres (100%) of Vance Lake's watershed is the Vance Lake subwatershed. The direct watershed of Vance Lake is a very small part of the lake's total watershed (Figure 8.11.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Vance Lake's residence time is approximately one half of a day, or that the water within the lake is completely replaced 803 times per year.

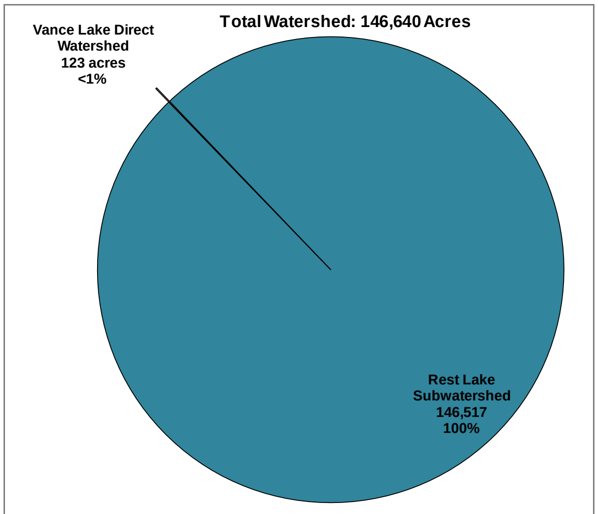


Figure 8.11.2-1. Vance Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 6,278 pounds of phosphorus being delivered to Vance Lake on an annual basis, nearly all of it originates from Rest Lake which is the lake immediately upstream of Vance Lake (Figure 8.11.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 14 µg/L, which is similar to the measured growing season average total phosphorus concentration of 17 µg/L. This means the model works reasonably well for Vance Lake and that there are no significant, unaccounted sources of phosphorus entering the lake.

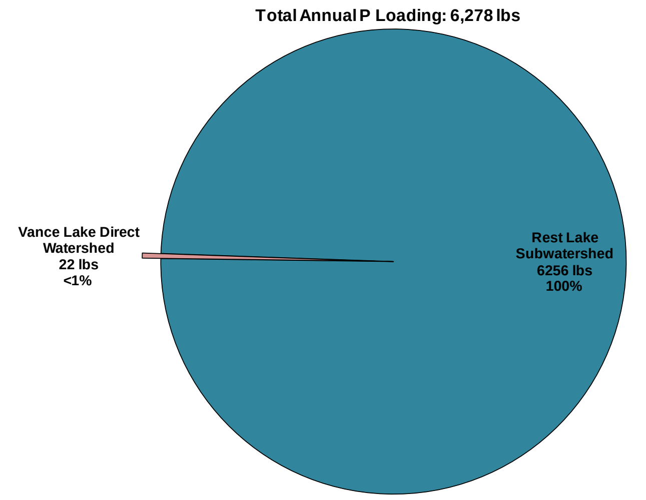


Figure 8.11.2-2. Vance Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the nearly all of the phosphorus that enters Vance Lake comes from the upstream Rest Lake, efforts to reduce phosphorus levels in Vance Lake should concentrate on reducing phosphorus inputs to Rest Lake.

8.11.3 Vance Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2017, Vance Lake's immediate shoreline was assessed in terms of its development. Vance Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.2 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.11.3-1). This constitutes about 92% of Vance 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, less than a tenth of a mile of urbanized and developed–unnatural shoreline (3%) was observed. If restoration of the Vance 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. Vance Lake Map 1 displays the location of these shoreline lengths around the entire lake.

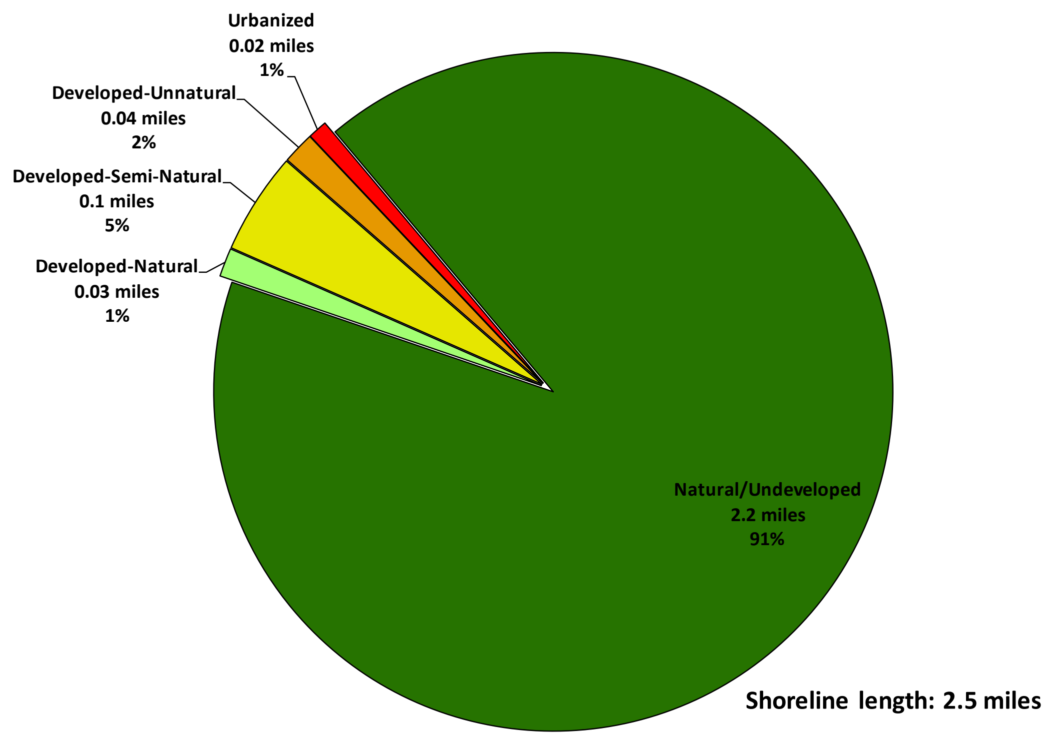


Figure 8.11.3-1. Vance Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Vance Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Vance Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 133 total pieces of coarse woody habitat were observed along 2.5 miles of shoreline (Vance Lake Map 2), which gives Vance Lake a coarse woody habitat to shoreline mile ratio of 46:1 (Figure 8.11.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Eighty-nine pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 19 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and five clusters 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 Vance 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 98 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 Vance Lake falls well above the 75th percentile of these 98 lakes surveyed since 2012 (Figure 8.11.3-2).

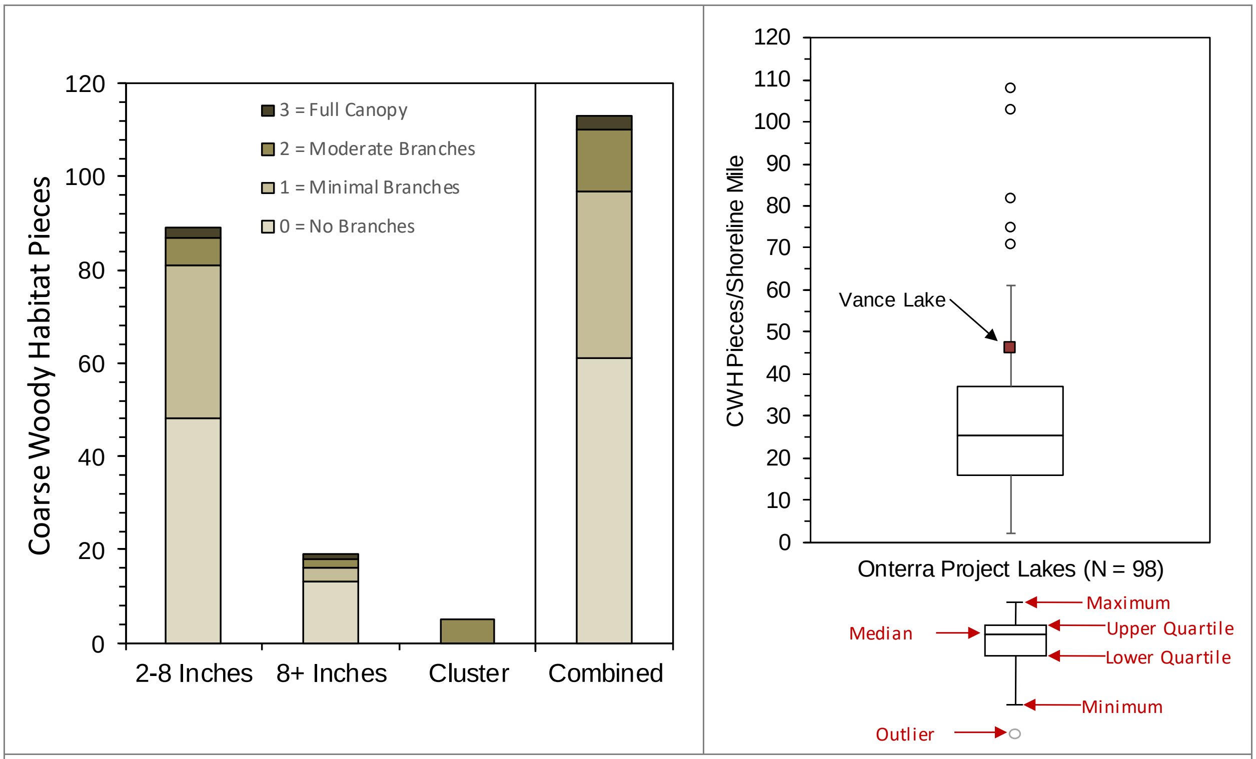


Figure 8.11.3-2. Vance Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of the Vance Lake coarse woody habitat can be found on Vance Lake Map 2.

8.11.4 Vance Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Vance Lake on June 28, 2017. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey and floating-leaf and emergent plant community mapping survey were conducted on Vance Lake on August 2, 2017 by Onterra. During all surveys, 27 species of native aquatic plants were located in Vance Lake (Table 8.11.4-1). Fifteen of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 12 species were observed incidentally during visits to Vance Lake. Two non-native species, purple loosestrife (*Lythrum salicaria*) and reed canary grass (*Phalaris arundinacea*) were observed along the Vance Lake shoreline.

Aquatic plants were found growing to a depth of 12 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 72 point-intercept locations sampled within the littoral zone, roughly 22% contained aquatic vegetation. Vance Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow areas that are more likely to hold organic substrates. Approximately 67% of the point-intercept sampling locations where sediment data was collected at were sand, 6% consisted of a fine, organic substrate (muck) and 26% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.11.4-1. Aquatic plant species located in Vance Lake during 2017 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
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Phalaris arundinacea	Reed canary grass	Exotic	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Sparganium eurycarpum	Common bur-reed	5	I
	Typha spp.	Cattail spp.	1	I
FL	*Nuphar variegata*	Spatterdock	6	I
	Nymphaea odorata	White water lily	6	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton nodosus	Long-leaf pondweed	5	I
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Vallisneria americana	Wild celery	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

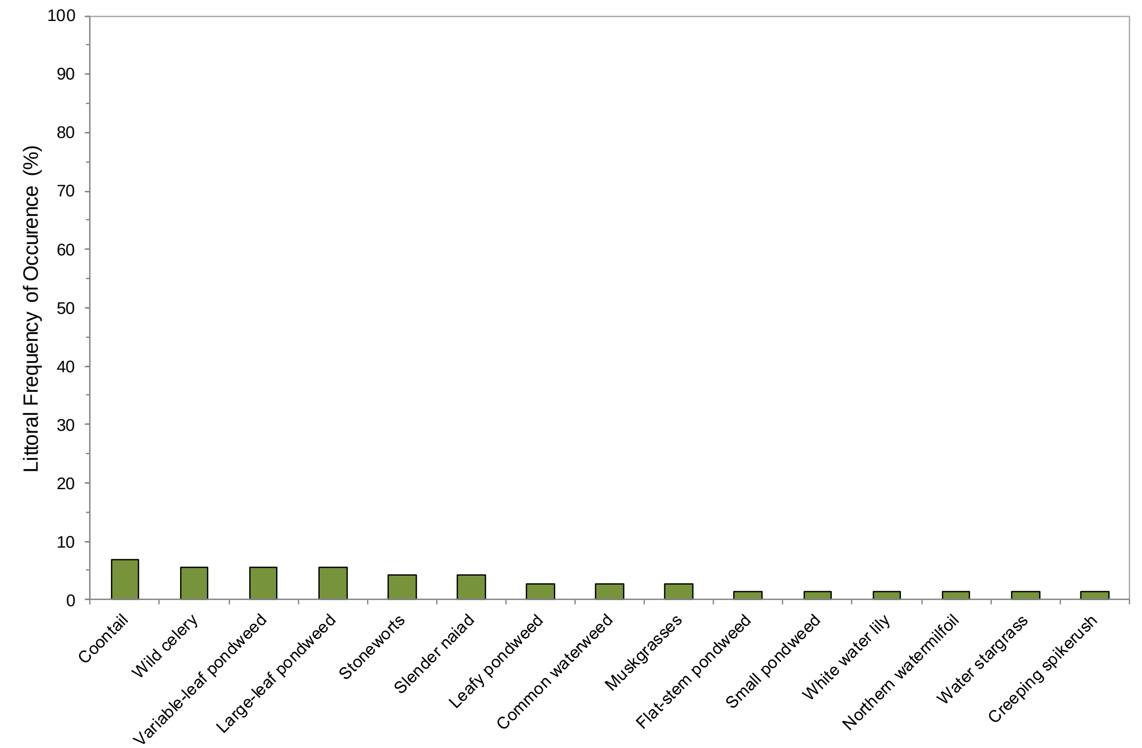


Figure 8.11.4-1. Vance Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2017 point-intercept survey.

Figure 8.11.4-1 shows that coontail, wild celery, variable-leaf pondweed, and large-leaf pondweed were the most frequently encountered plants within Vance Lake. Coontail is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and its location can be largely a product of water movement. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Variable-leaf pondweed is one of several pondweed species found in Wisconsin. Variable-leaf pondweed produces long, slender stems with alternating lance-shaped leaves. As its name indicates, this plant can look very different from lake to lake, with some populations having larger leaves and others possessing smaller leaves. Large-leaf pondweed, often called "cabbage" due to its appearance, has the broadest leaf (3.5-7 cm wide) of any pondweed in the Midwest. The leaves are arched and slightly folded, and though often found in a greenish color can take on a reddish appearance in the late summer.

During aquatic plant inventories, 27 species of native aquatic plants (including incidentals) were found in Vance Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Vance Lake's plant community (0.91) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 37% of the sampling locations, its relative frequency of occurrence is 14%. Explained another way, if 100 plants were randomly sampled from Vance Lake, six of them would be coontail. This distribution can be observed in Figure 8.11.4-2, where together 14 native species account for 65% of the aquatic plant population within Vance Lake, while the other 9 species account for the remaining 35%. Twelve additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.11.4-1 as incidentals.

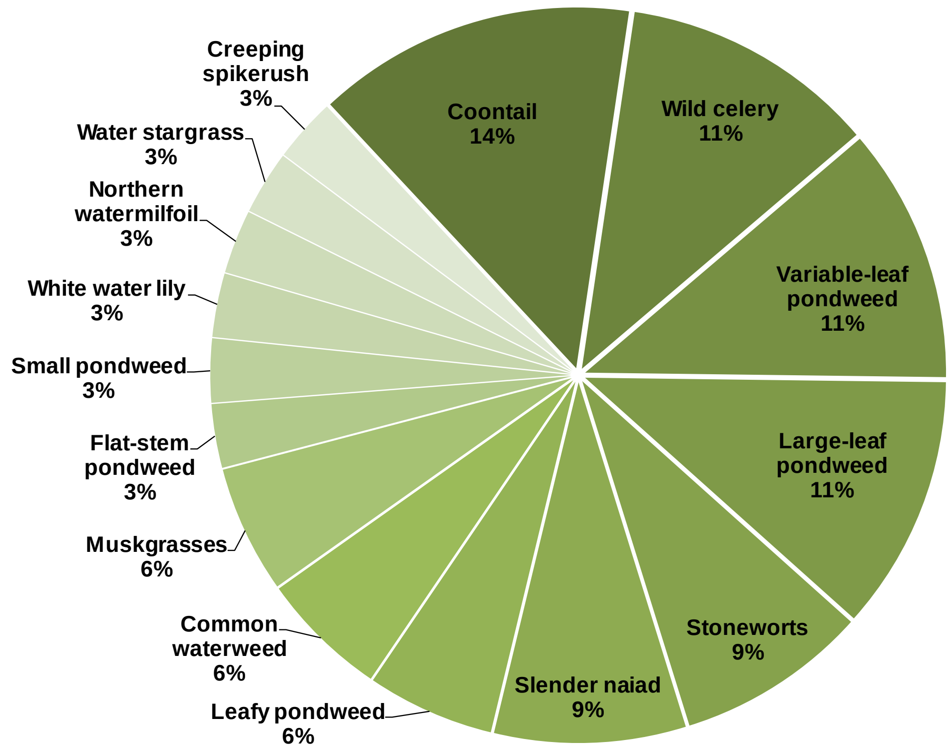


Figure 8.11.4-2. Vance Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2017 point-intercept survey.

Vance Lake's average conservatism value (6.0) is lower than the state median (6.3) and the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Vance Lake is indicative of a moderately disturbed system. Combining Vance Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 23.2 which is below the median values of the ecoregion and state.

Vance Lake was found to have few emergent and floating-leaf aquatic plant communities. The 2017 community map indicates that approximately 3.3 acres of the lake contains these types of plant communities (Vance Lake Map 4, Table 8.11.4-2). Fourteen floating-leaf and emergent species were located on Vance Lake (Table 8.11.4-1), all of which provide valuable wildlife habitat.

Table 8.11.4-2. Vance Lake acres of emergent and floating-leaf plant communities from the 2017 community mapping survey.

Plant Community	Acres
Emergent	0.2
Floating-leaf	0.3
Mixed Emergent & Floating-leaf	2.7
Total	**3.3**

The community map represents a ‘snapshot’ of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Vance Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Vance Lake

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. 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.

In Vance Lake, purple loosestrife was located along the shoreline of the lake (Vance Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Vance Lake.

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed along the northeastern shore of Vance Lake (Vance Lake – Map 4). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

8.11.5 Vance 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 and within the chain wide report section 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 Vance 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 2018 & GLIFWC 2017).

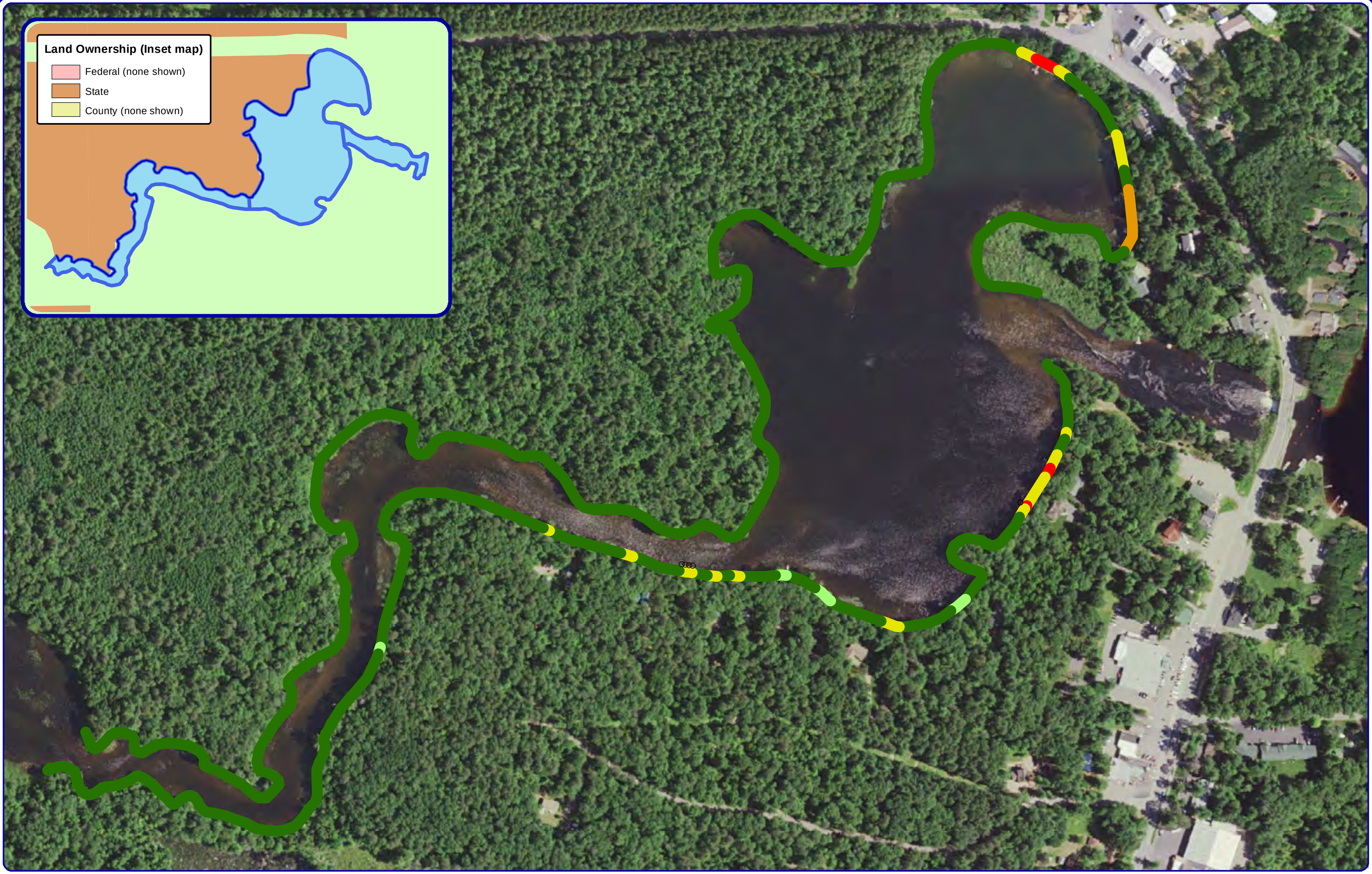
Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.11.5-1). 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. Vance Lake historically has only been seen one stocking event of 100 fingerling muskellunge in 1972.

Photograph 8.11.5-1. Fingerling Muskellunge.

Vance Lake Spear Harvest Records

Although Vance Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.



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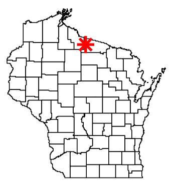
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2017
Shoreline Assessment: Onterra, 2017
Map Date: October 10, 2017
Filename:Vance_Map1_ShorelandCondition_2017.mxd



Project Location in Wisconsin

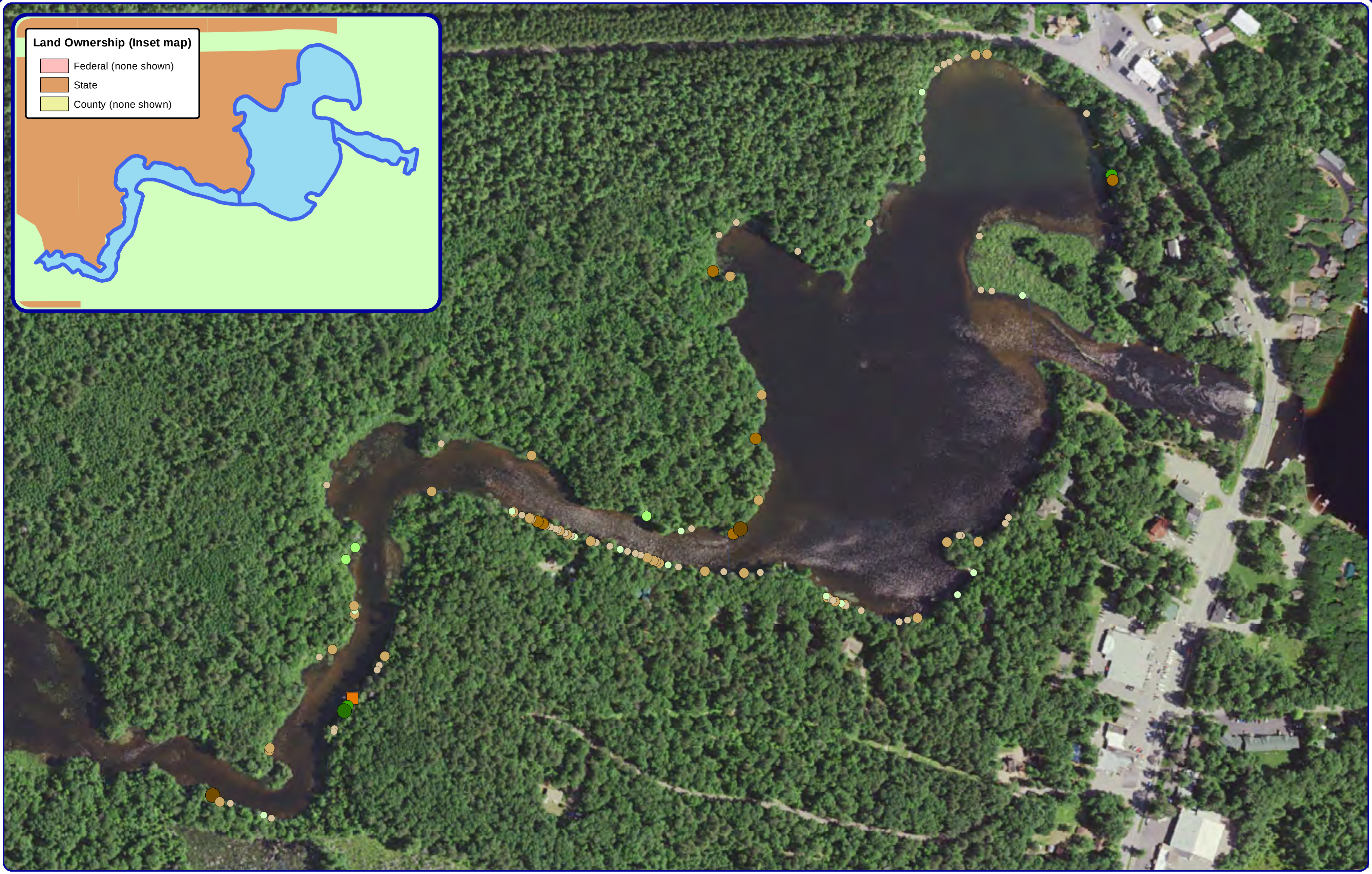
Legend

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

Seawall

- Rip-Rap
- Wood/Masonary/Metal

Map 1
Vance Lake
Vilas County, Wisconsin
2017 Shoreland Condition



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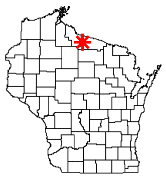
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2017
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: October 10, 2017
Filename:Vance_Map2_CWH_2017.mxd

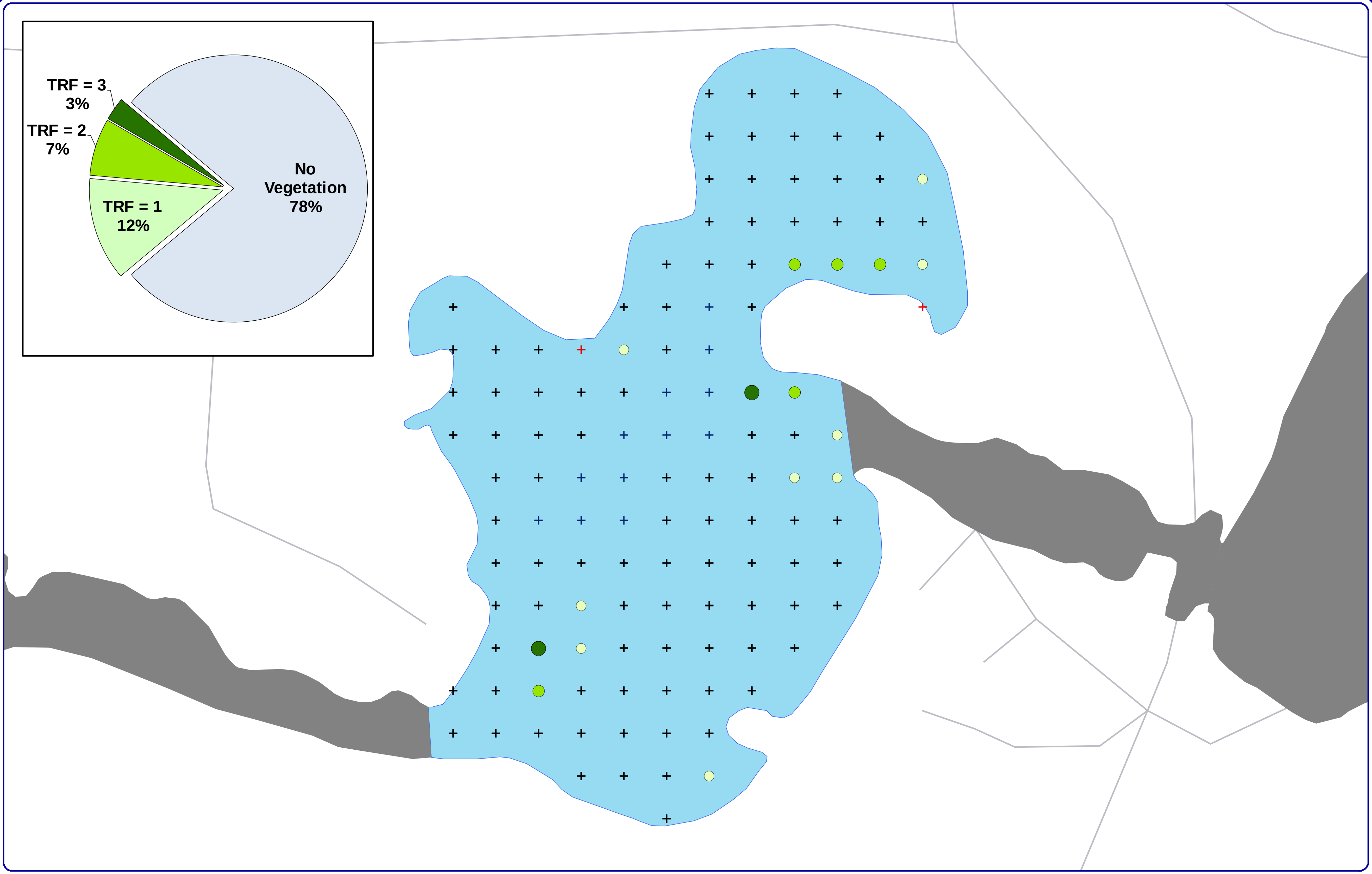

Project Location in Wisconsin

Legend

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

Map 2
Vance Lake
Vilas County, Wisconsin

Coarse Woody Habitat



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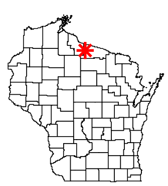
Sources:
Roads and Hydro: WDNR
Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: *MapX_Vance_TRFPI_2017.mxd*

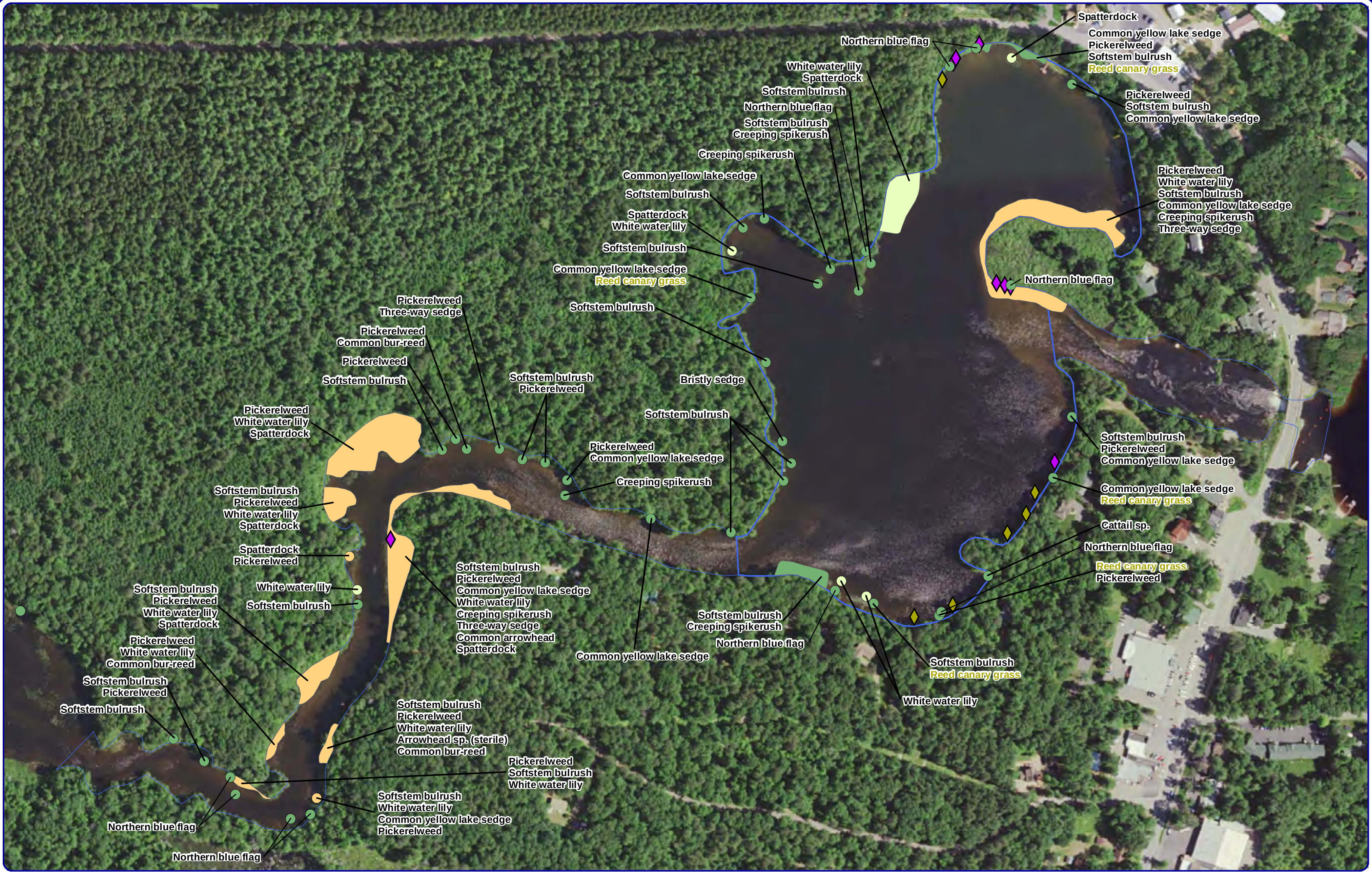


Project Location in Wisconsin

Legend

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

Map 3
Vance Lake
Vilas County, Wisconsin
2017 PI Survey: Aquatic Vegetation Distribution



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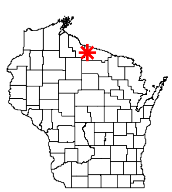
Sources:
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2017
Map date: November 3, 2017
Filename: Vance_Comm_2017.mxd



Project Location in Wisconsin

Legend

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

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

Map 4

Vance Lake

Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Sturgeon Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.12 Sturgeon Lake

An Introduction to Sturgeon Lake

Sturgeon Lake, Vilas County, is a deep lowland drainage lake with a maximum depth of 18 feet, a mean depth of 5 feet, and a surface area of approximately 32 acres. Sturgeon Lake is considered to be mesotrophic and its watershed encompasses approximately 147,704 acres. In 2017, 41 native aquatic plant species were found in the lake, of which slender naiad (*Najas flexilis*) is the most common. No non-native plants were found during surveys.

Field Survey Notes

Abundant natural shoreline primarily sandy and rocky substrate observed during the 2017 surveys. Vasey's pondweed was located on a few point-intercept locations.

Photo 8.12. Sturgeon Lake, Vilas County

Lake at a Glance* – Sturgeon Lake

Morphology	
Acreage	32
Maximum Depth (ft)	18
Mean Depth (ft)	5
Volume (acre-feet)	151
Shoreline Complexity	2.8
Vegetation	
Curly-leaf Survey Date	June 28, 2017
Comprehensive Survey Date	August 1, 2017
Number of Native Species	41
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	-
Simpson's Diversity	0.89
Average Conservatism	6.4
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	4,631:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.12.1 Sturgeon Lake Water Quality

Water quality data was collected from Sturgeon Lake on three occasions in 2017. 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. No historical data exists for total phosphorus, chlorophyll-*a*, or water clarity.

Sturgeon Lake is located on the Manitowish River downstream of the Rest Lake Dam. As such, it is more like a river than a natural lake. Because of the very short hydrologic residence time, water quality likely reflects concentrations in the river.

In 2017, average summer phosphorus concentrations (19.0 µg/L) were lower than the median value (23.0 µg/L) for other deep lowland drainage lakes in the state and the median value (21.0 µg/L) for other lakes within the Northern Lakes and Forests ecoregion (Figure 8.12.1-1). The 2017 average summer phosphorus concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

In 2017, the average summer chlorophyll-*a* concentration (5.1 µg/L) was lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.12.1-2). This value is relatively similar to the median value (5.6 µg/L) for other lakes within the Northern Lakes and Forests ecoregion. The 2017 average summer chlorophyll-*a* concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present.

The clarity of Sturgeon Lake's water can be described as *good* during the summer months in which data has been collected (Figure 8.12.1-3). The 2017 average summer Secchi disk depth (7.8 feet) is slightly lower than the median value for other deep lowland drainage lakes in the state (8.5 feet) and the regional median (8.9 feet). Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In many lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Sturgeon Lake may contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake. *True color* measures the dissolved organic materials in water; however, true color was not measured in Sturgeon Lake and it is unknown if the lake's water clarity is primarily influenced by staining from organic acids.

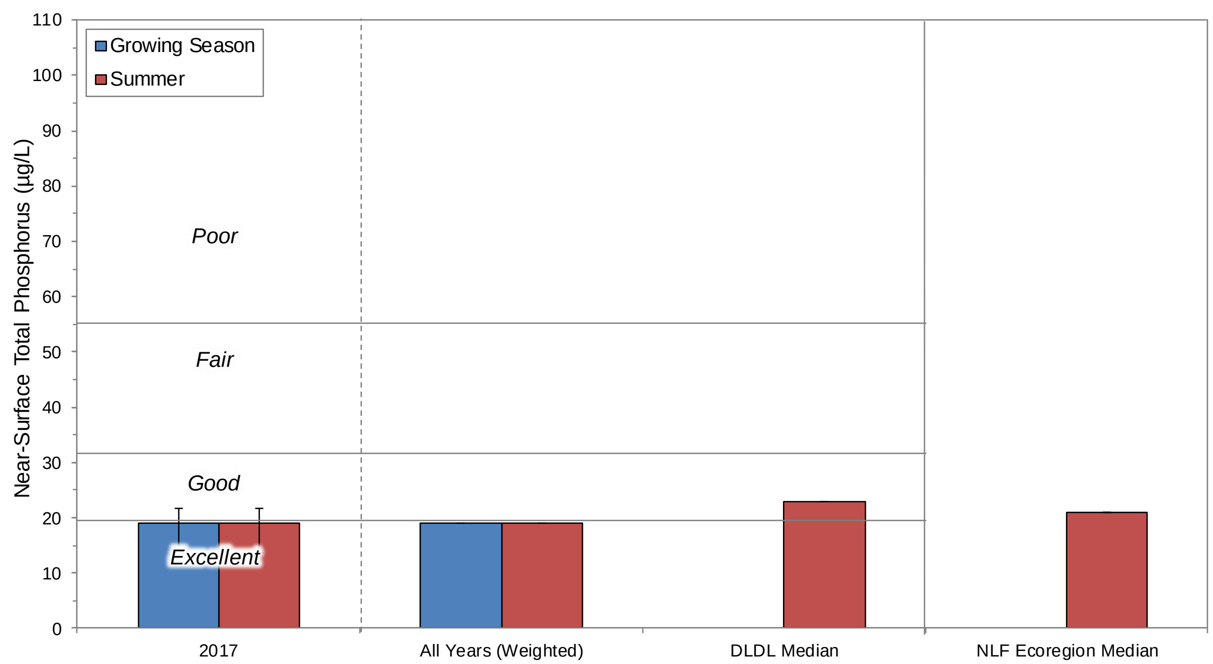


Figure 8.12.1-1. Sturgeon Lake, state-wide deep lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

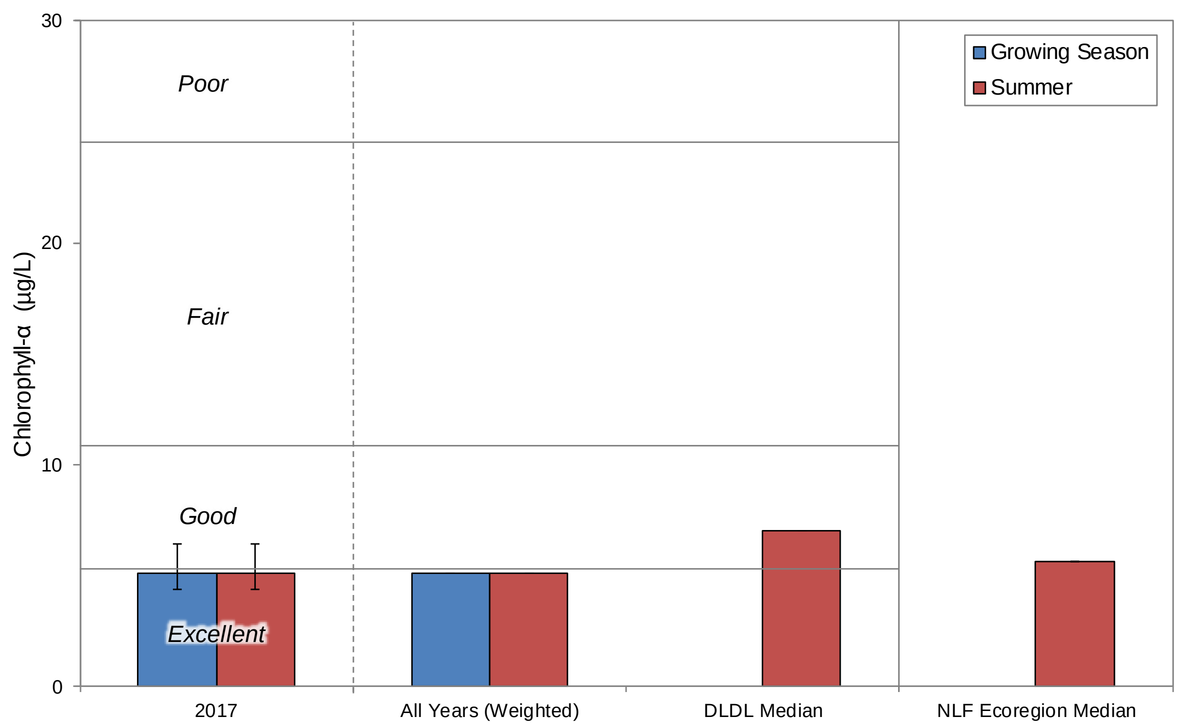


Figure 8.12.1-2. Sturgeon Lake, state-wide deep lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

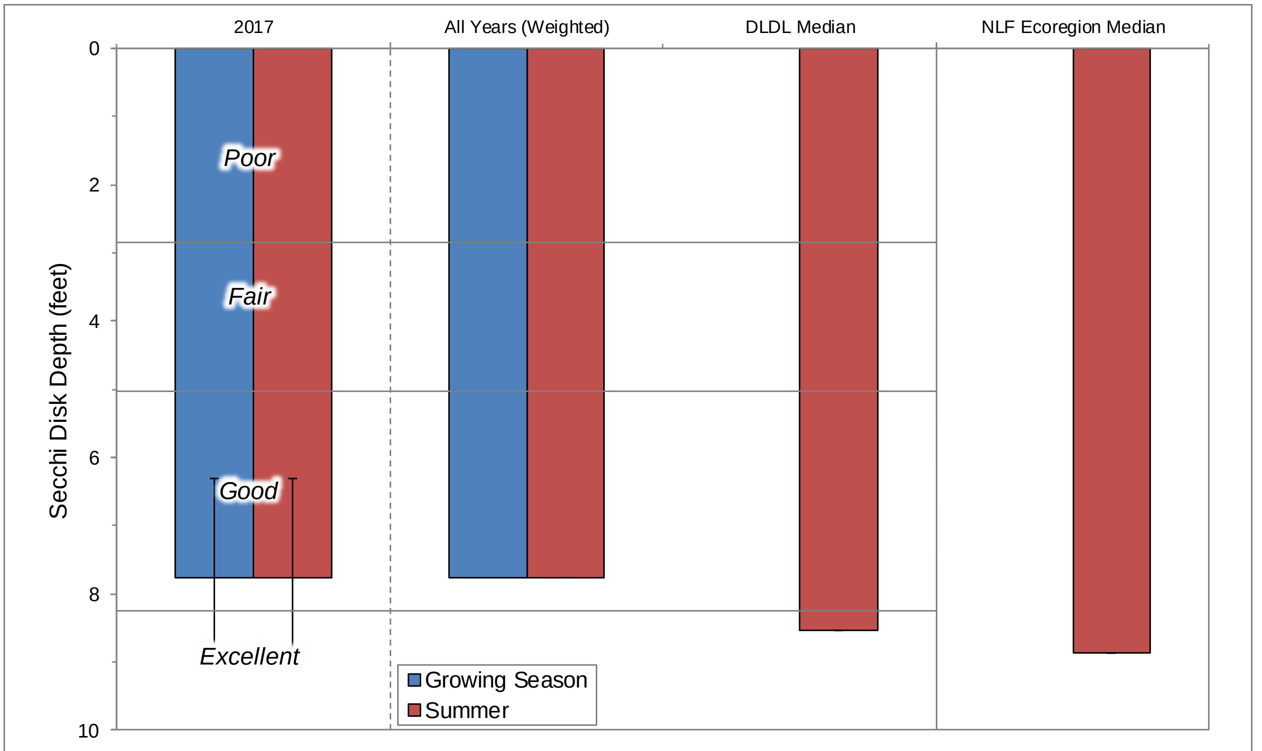


Figure. 8.12.1-3. Sturgeon Lake, state-wide deep lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Sturgeon Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values are displayed in Figure 8.12.1-4. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Sturgeon Lake is in a mesotrophic state.

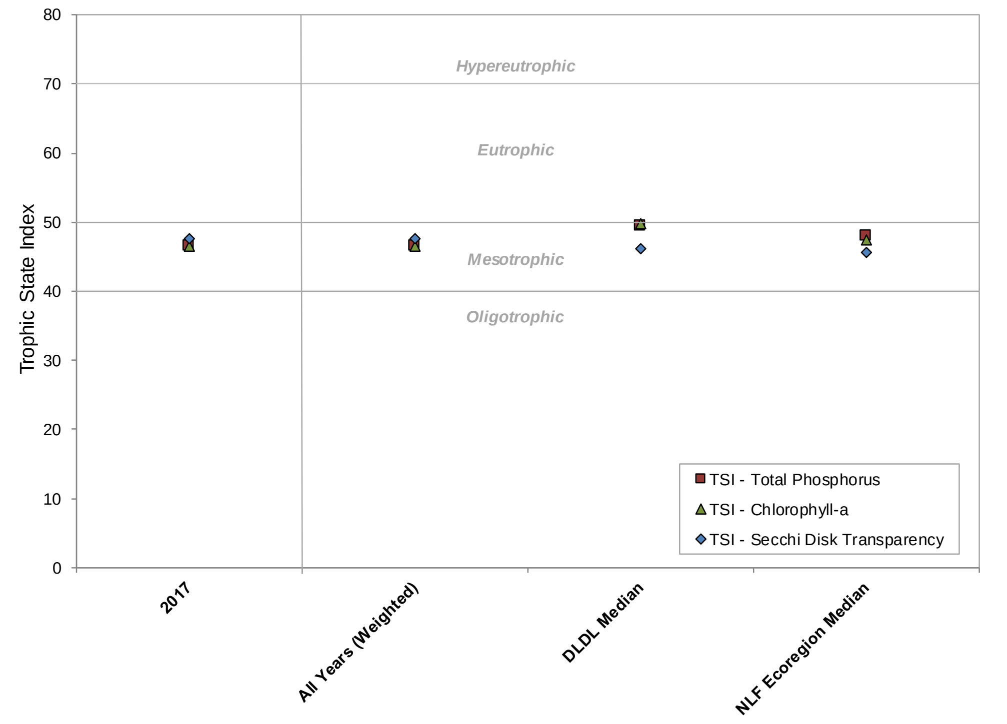


Figure 8.12.1-4. Sturgeon Lake, state-wide deep lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Sturgeon Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Sturgeon Lake by Onterra staff. Graphs of those data are displayed in Figure 8.12.1-5 for all sampling events.

The temperature and dissolved oxygen data collected in 2017 show that Sturgeon Lake's temperature and dissolved oxygen were fairly uniform throughout the water column during every sampling event, an indication that the lake was not thermally stratified (Figure 8.12.1-5). However, it should be noted that Sturgeon Lake was not sampled in the deepest part of the lake, and it is uncertain if the lake stratified during the summer in 2017. Sturgeon Lake is deep with a small surface area, and thus is classified as an intermediate lake based on the Osgood Index. The Osgood Index predicts the probability that a lake will remain stratified during the summer, and uses an equation that relates the lake's mean depth to its surface area (equation below). Lakes with an Osgood Index of less than 4.0 are deemed polymictic, and given Sturgeon Lake's surface area relative to its depth, it has an Osgood Index of 4.4. This Osgood Index value indicates that while Sturgeon Lake may thermally stratify during the summer, it may also mix during the summer.

$$Sturgeon\ Lake\ Osgood\ Index\ (4.4) = \frac{Sturgeon\ Lake\ Mean\ Depth\ (1.5\ m)}{\sqrt{Sturgeon\ Lake\ Area\ (0.12\ km^2)}}$$

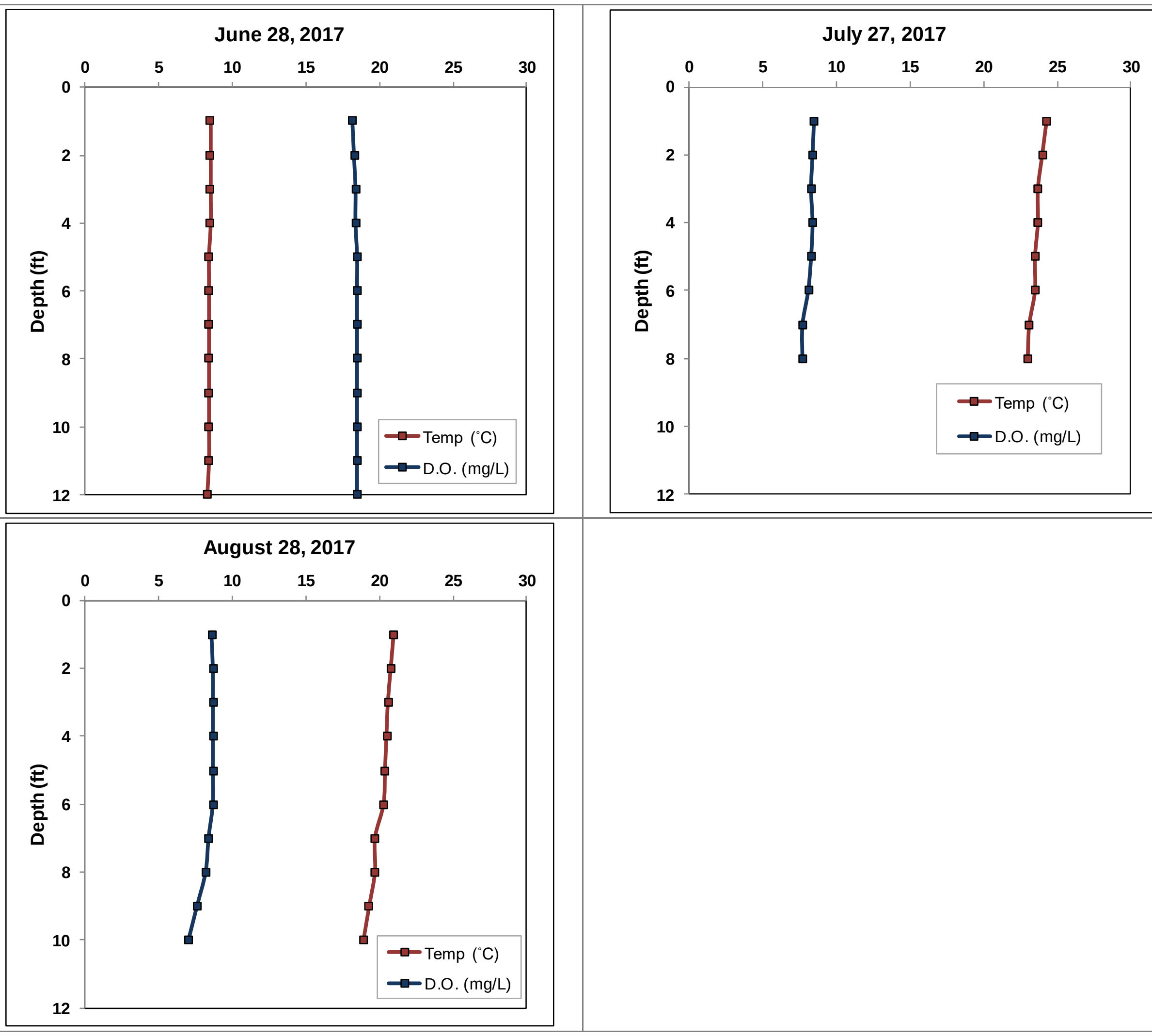


Figure 8.12.1-5. Sturgeon Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Sturgeon 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 Sturgeon 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. Sturgeon Lake's surface water pH was measured at roughly 7.8 July of 2017. This value is slightly above neutral and falls 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 Sturgeon Lake was measured at 38.8 in July of 2017 and indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

While samples of calcium were not collected from Sturgeon Lake in 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 Sturgeon Lake's pH of 7.8 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. Plankton tows were completed by Onterra staff during the summer of 2017 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.12.2 Sturgeon Lake Watershed Assessment

Sturgeon Lake's watershed is 147,704 acres in size. Compared to Sturgeon Lake's size of 32 acres, this makes for an incredibly large watershed to lake area ratio of 4631:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Sturgeon Lake this means that 146,640 acres (98%) of Sturgeon Lake's watershed is the Vance Lake subwatershed. The direct watershed of Sturgeon Lake is a very small part of the lake's total watershed (Figure 8.12.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Sturgeon Lake's residence time is approximately one third of a day, or that the water within the lake is completely replaced 1050 times per year.

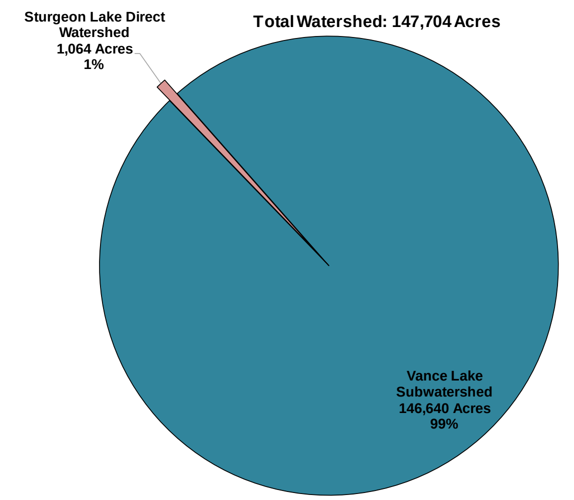


Figure 8.12.2-1. Sturgeon Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 7,201 pounds of phosphorus being delivered to Sturgeon Lake on an annual basis, nearly all of it originates from Sturgeon Lake which is the lake immediately upstream of Sturgeon Lake (Figure 8.12.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 16 µg/L, which is similar to the measured growing season average total phosphorus concentration of 19 µg/L. This means the model works reasonably well for Sturgeon Lake and that there are no significant, unaccounted sources of phosphorus entering the lake.

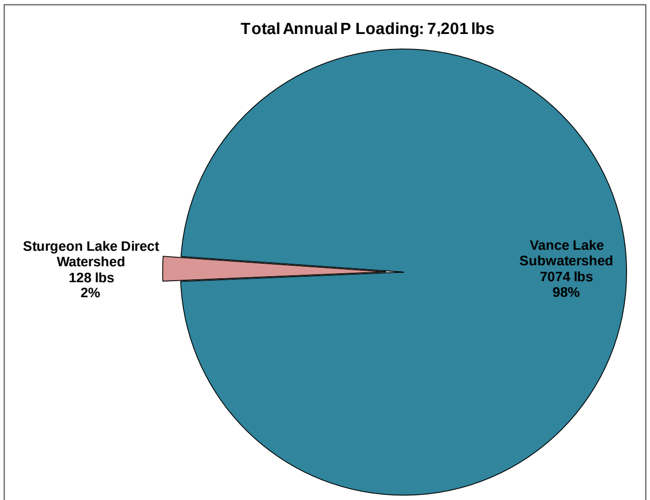


Figure 8.12.2-2. Sturgeon Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the nearly all of the phosphorus that enters Sturgeon Lake comes from the upstream Vance Lake, efforts to reduce phosphorus levels in Sturgeon Lake should concentrate on reducing phosphorus inputs to Vance Lake.

8.12.3 Sturgeon Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2017, Sturgeon Lake's immediate shoreline was assessed in terms of its development. Sturgeon Lake has stretches of shoreland that fit four of the five shoreland assessment categories. In all, 1.2 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.12.3-1). This constitutes about 97.9% of Sturgeon 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, less than one tenth of a mile of developed–unnatural shoreline (0.3%) was observed. If restoration of the Sturgeon 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. Sturgeon Lake Map 1 displays the location of these shoreline lengths around the entire lake.

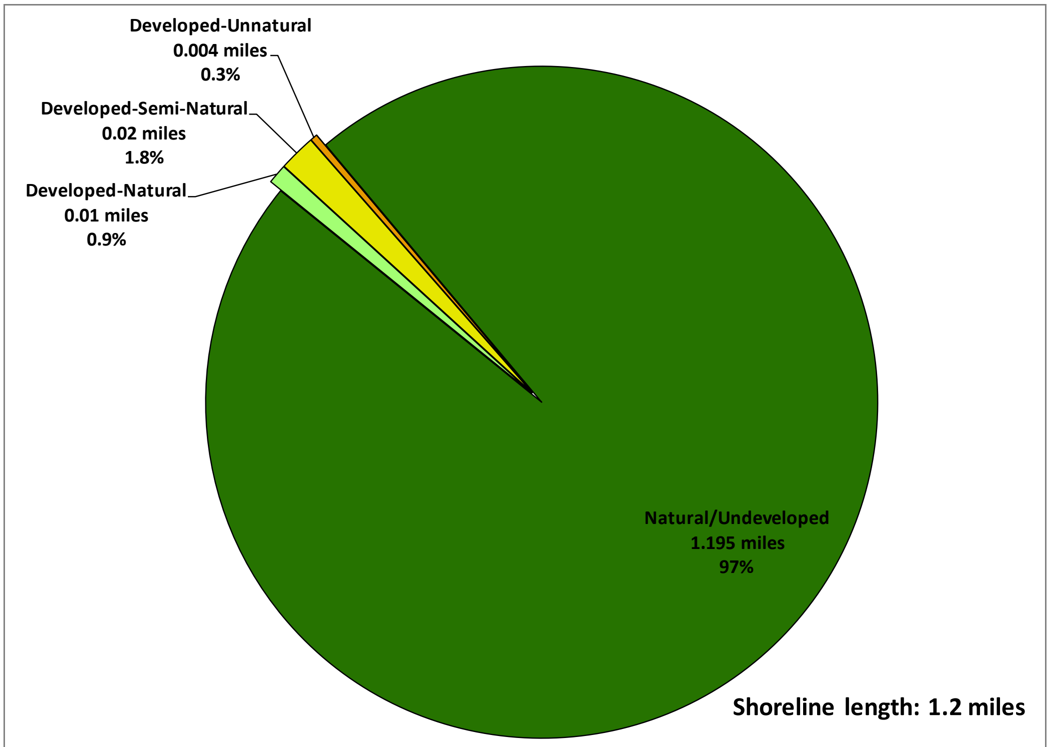


Figure 8.12.3-1. Sturgeon Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Sturgeon Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Sturgeon Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters 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, 34 total pieces of coarse woody habitat were observed along 1.2 miles of shoreline (Sturgeon Lake Map 2), which gives Sturgeon Lake a coarse woody habitat to shoreline mile ratio of 28:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Thirty pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, four pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Sturgeon 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 98 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 Sturgeon Lake falls just above above the median of these 98 lakes (Figure 3.3-3).

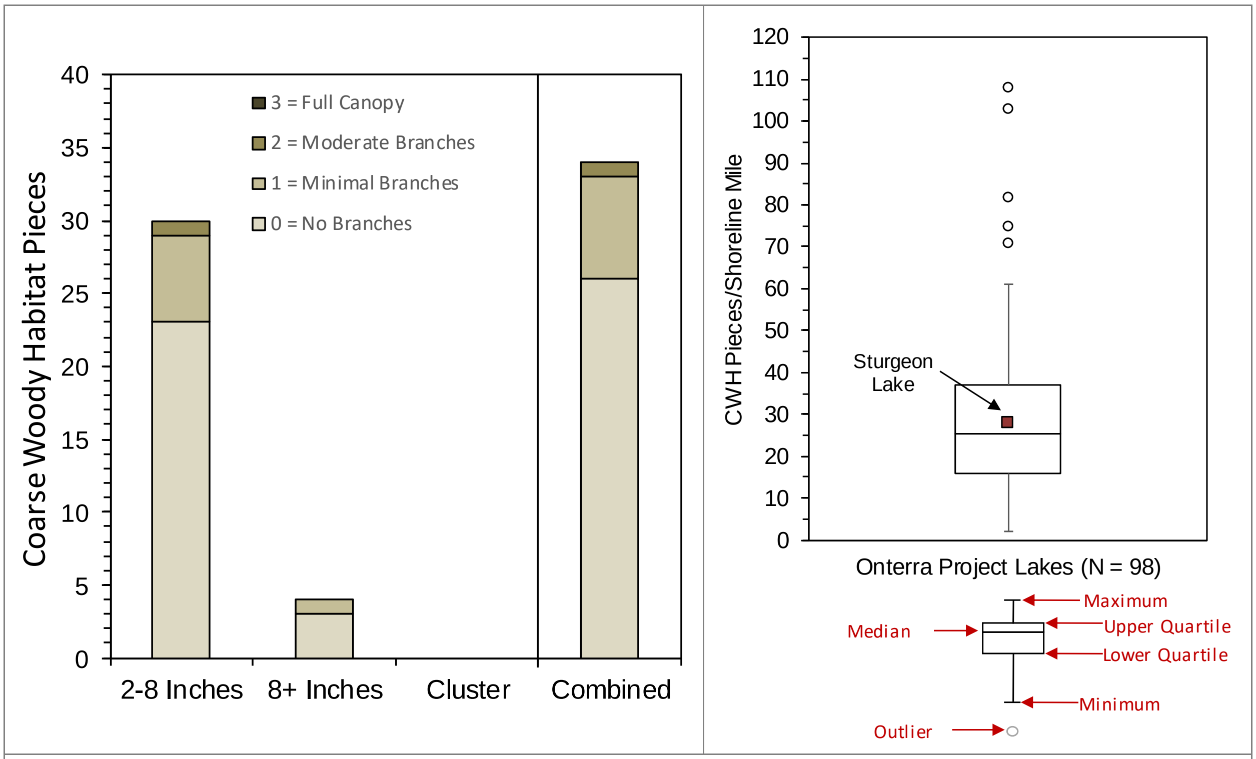


Figure 8.12.3-2. Sturgeon Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of the Sturgeon Lake coarse woody habitat can be found on Sturgeon Lake Map 2.

8.12.4 Sturgeon Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Sturgeon Lake on June 28, 2017. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species in Sturgeon Lake.

The aquatic plant point-intercept survey and floating-leaf and emergent plant community mapping survey were conducted on Sturgeon Lake on August 1, 2017 by Onterra. During all surveys, 41 species of aquatic plants were located in Sturgeon Lake (Table 8.12.4-1). Twenty-five of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 16 species were observed incidentally during visits to Sturgeon Lake.

Aquatic plants were found growing to a depth of 10 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and diverse. Of the 99 point-intercept locations sampled within the littoral zone, roughly 83% contained aquatic vegetation. Sturgeon Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located lake-wide. Approximately 69% of the point-intercept sampling locations where sediment data was collected at were sand, 28% consisted of a fine, organic substrate (muck) and 3% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.12.4-1. Aquatic plant species located in Sturgeon Lake during 2017 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
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Sparganium eurycarpum	Common bur-reed	5	I
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum sibiricum	Northern watermilfoil	7	I
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	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	I
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus aquatilis	White water crowfoot	8	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia geminiscapa	Twin-stemmed bladderwort	9	I
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	I
	Sagittaria cristata	Crested arrowhead	9	I

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*

Figure 8.12.4-1 shows that slender naiad, wild celery, and stoneworts were the most frequently encountered plants within Sturgeon Lake. Slender naiad, a common annual species in Wisconsin, is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food. The small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Stoneworts are a species of macro-algae rather than a vascular plant. Whorls of forked branches are attached to the “stems” of the plant, which are long, slender, smooth-textured algae. Because they lack roots, stoneworts remove nutrients directly from the water.

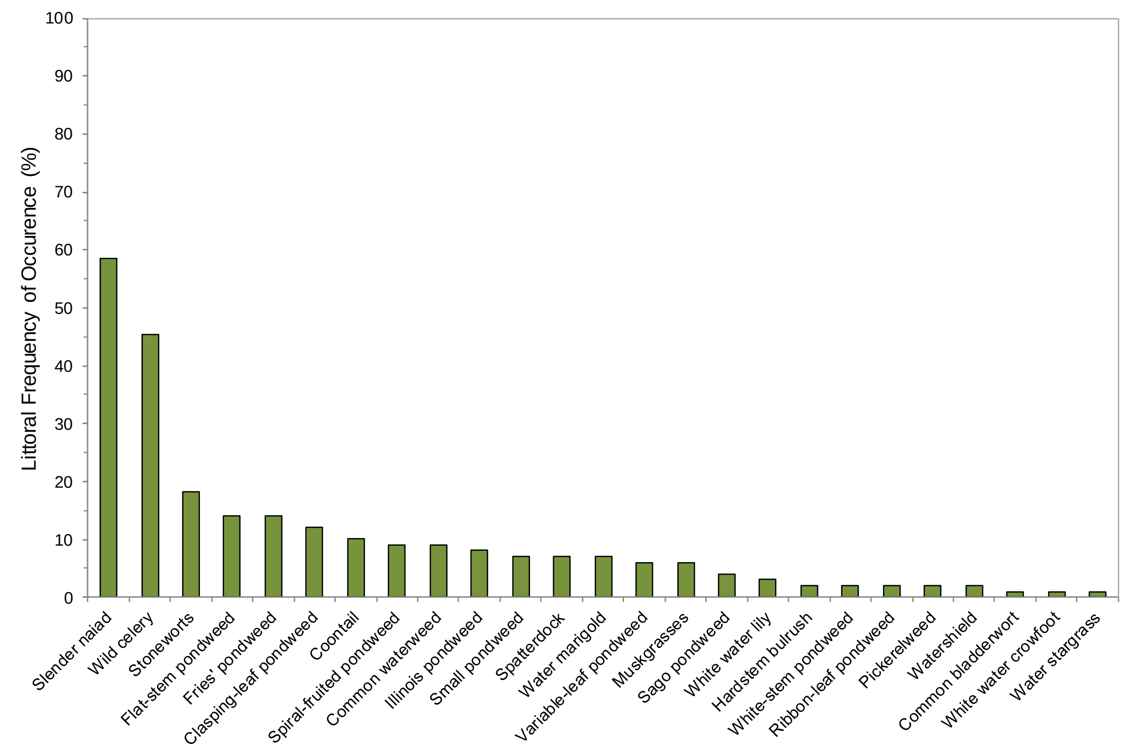


Figure 8.12.4-1. Sturgeon Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2017 point-intercept survey. .

During aquatic plant inventories, 41 species of native aquatic plants (including incidentals) were found in Sturgeon Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Sturgeon Lake’s plant community (0.89) lies above the Northern Lakes and Forest Lakes median ecoregion value (0.88), indicating the lake holds a high diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 slender naiad was found at 59% of the sampling locations, its relative frequency of occurrence is 23%. Explained another way, if 100 plants were randomly sampled from Sturgeon Lake, 23 of them would be wild celery. This distribution can be observed in Figure 8.12.4-2, where together four native species account for 54% of the aquatic plant population within Sturgeon Lake, while the other 21 species account for the remaining 46%. Sixteen additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.12.4-1 as incidentals.

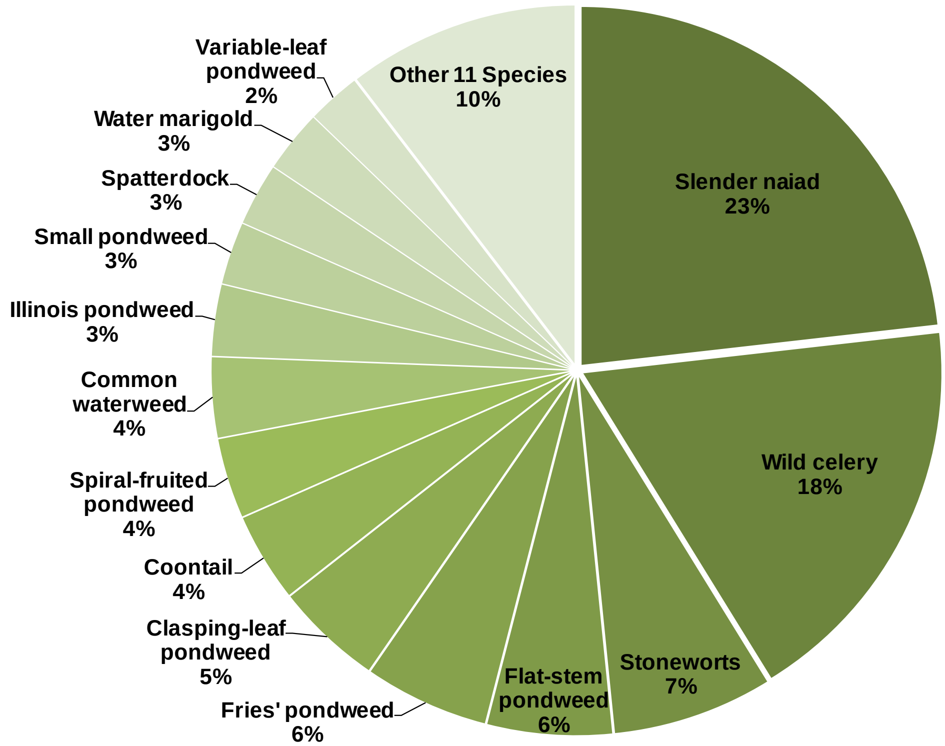


Figure 8.12.4-2. Sturgeon Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2017 point-intercept survey.

Sturgeon Lake's average conservatism value (6.4) is higher than the state median (6.3) but slightly lower than the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Sturgeon Lake is indicative of an average system within Wisconsin. Combining Sturgeon Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 32.0 which is above the median values of the ecoregion and state.

The 2017 community map indicates that approximately 12.6 acres of the lake contains these types of plant communities (Sturgeon Lake Map 4, Table 8.12.4-2). Fourteen floating-leaf and emergent species were located on Sturgeon Lake (Table 8.12.4-1), all of which provide valuable wildlife habitat.

Table 8.12.4-2. Sturgeon Lake acres of emergent and floating-leaf plant communities from the 2017 community mapping survey.

Plant Community	Acres
Emergent	2.9
Floating-leaf	2.7
Mixed Emergent & Floating-leaf	7.0
Total	**12.6**

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Sturgeon Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

8.12.5 Sturgeon 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 and within the chain wide report section 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 Sturgeon 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 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries. 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. Sturgeon Lake has no historical record of stocking.

Sturgeon Lake Spear Harvest Records

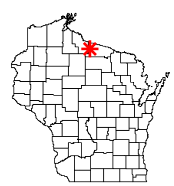
Although Sturgeon Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.

N
W E
S

300
Feet

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
Shoreline Assessment: Onterra, 2017
Map Date: October 10, 2017
Filename:Sturgeon_Map1_ShorelandCondition_2017.mxd


Project Location in Wisconsin

Legend

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

Seawall
Rip-Rap
Wood/Masonary/Metal

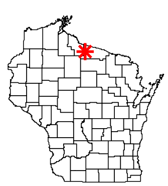
Map 1
Sturgeon Lake
Vilas County, Wisconsin
2017 Shoreland Condition

N
W E
S

300
Feet

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

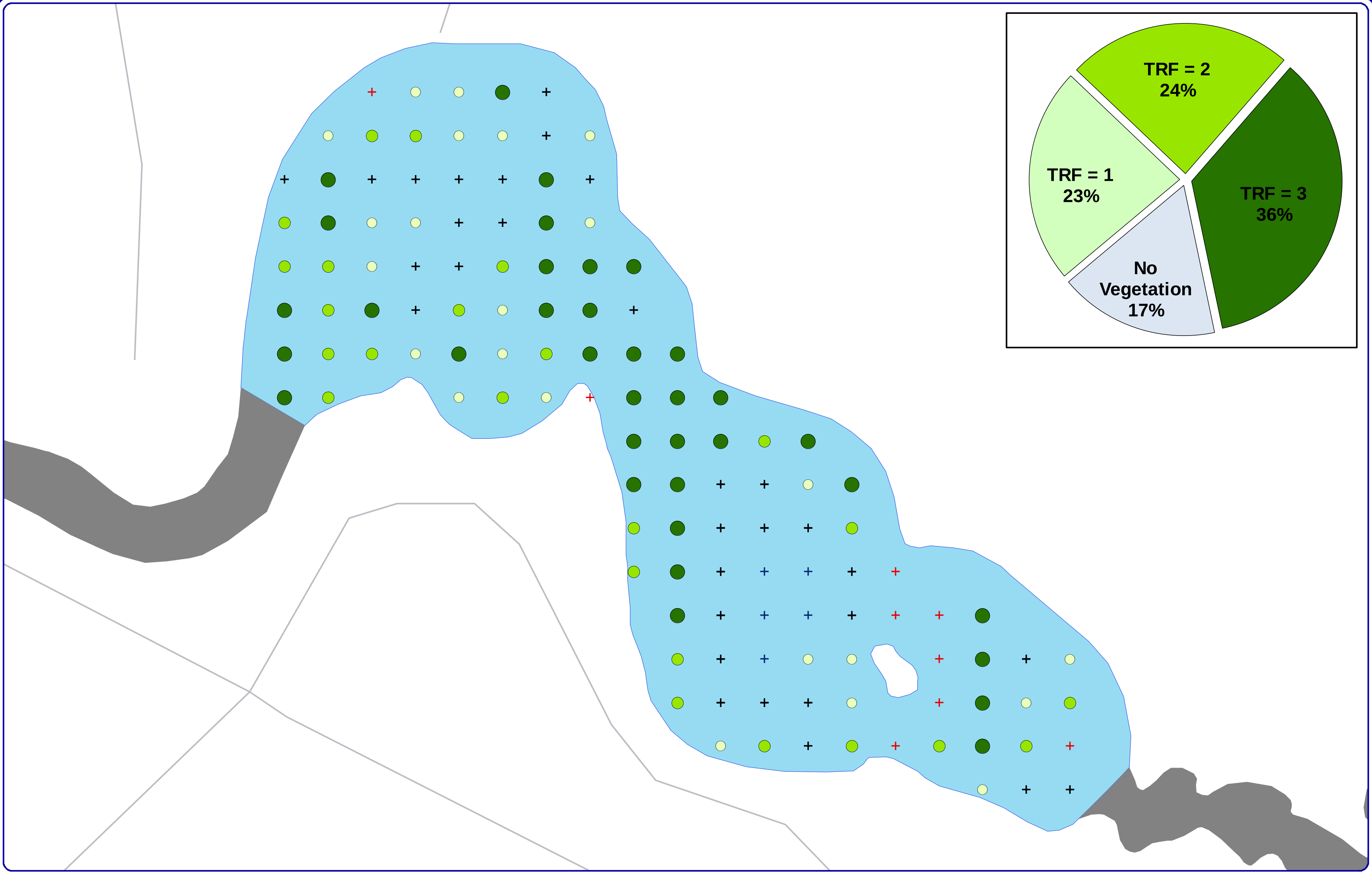
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2017
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: October 10, 2017
Filename:Sturgeon_Map2_CWH_2017.mxd

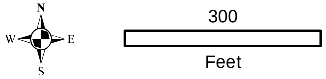

Project Location in Wisconsin

Legend

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

Map 2
Sturgeon Lake
Vilas County, Wisconsin
Coarse Woody Habitat



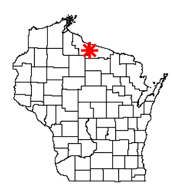


Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Plant Survey: Onterra, 2017

Map Date: November 17, 2017

Filename: *MapX_Sturgeon_TRFPI_2017.mxd*

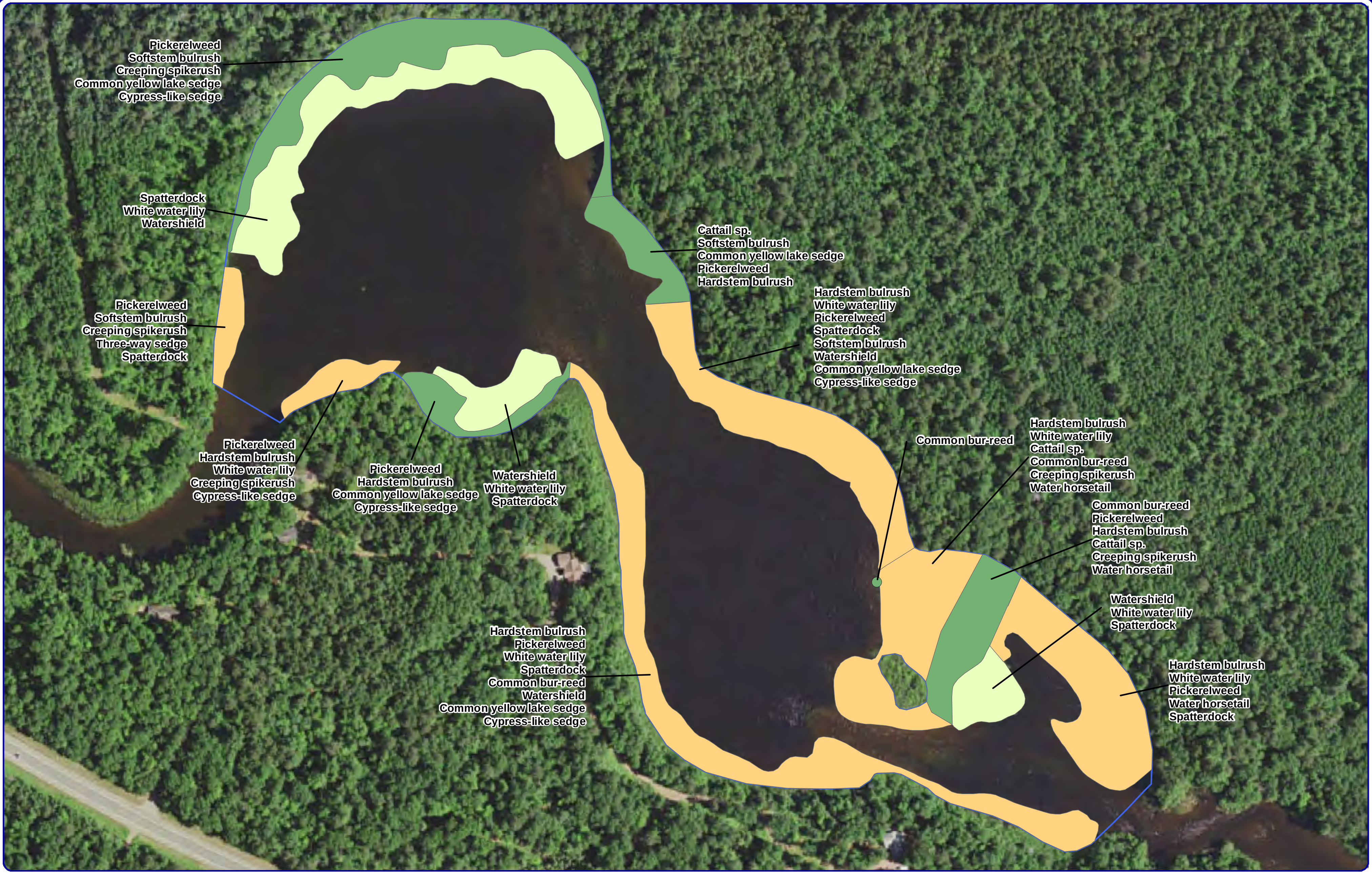


Project Location in Wisconsin

Legend

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

Map 3
Sturgeon Lake
Vilas County, Wisconsin
2017 PI Survey: Aquatic Vegetation Distribution



N S E W

275

Feet

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

Sources:
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2017
Map date: August 16, 2017
Filename: Sturgeon_Comm_2017.mxd

Project Location in Wisconsin

Legend

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

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

Map 4

Sturgeon Lake

Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Benson Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.13 Benson Lake

An Introduction to Benson Lake

Benson Lake, Vilas County, is a shallow lowland drainage lake with a maximum depth of 15 feet, a mean depth of 7 feet, and a surface area of approximately 33 acres. Benson Lake is considered to be mesotrophic and its watershed encompasses approximately 147,950 acres. In 2017, 31 native aquatic plant species were found in the lake, of which wild celery (*Vallisneria americana*) is the most common. One non-native plant, reed canary grass, was found during surveys.

Field Survey Notes

Primarily sandy and rocky substrate observed during the 2017 point-intercept survey. The lake has abundant emergent and floating-leaf communities (Photo 8.13).

Photo 8.13. Benson Lake, Vilas County

Lake at a Glance* – Benson Lake

Morphology	
Acreage	33
Maximum Depth (ft)	15
Mean Depth (ft)	7
Volume (acre-feet)	237
Shoreline Complexity	2.1
Vegetation	
Curly-leaf Survey Date	June 28, 2017
Comprehensive Survey Date	August 2, 2017
Number of Native Species	31
Threatened/Special Concern Species	-
Exotic Plant Species	Reed canary grass
Simpson's Diversity	0.88
Average Conservatism	29.3
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Upper Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	4,513:1

*These parameters/surveys are discussed within the Chain-wide portion of the management plan.

8.13.1 Benson Lake Water Quality

Water quality data was collected from Benson Lake on three occasions in 2017. 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, any historical data was researched and are included within this report as available.

Benson Lake is located on the Manitowish River downstream of the Rest Lake Dam. As such, it is more like a river than a natural lake. Because of the very short hydrologic residence time, water quality likely reflects concentrations in the river.

No historical data exist for two water quality parameters of interest – total phosphorus and chlorophyll-*a*. In 2017, average summer phosphorus concentrations (23.2 µg/L) were similar to the median value (21.0 µg/L) for other shallow lowland drainage lakes in the state and lower than the median value (33.0 µg/L) for other lakes within the Northern Lakes and Forests ecoregion (Figure 8.13.1-1). The 2017 average summer phosphorus concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

In 2017, the average summer chlorophyll-*a* concentration (5.1 µg/L) was slower than the median value (9.4 µg/L) for other lakes of this type (Figure 8.13.1-2). This value is similar to the median value (5.6 µg/L) for other lakes within the Northern Lakes and Forests ecoregion. The 2017 average summer chlorophyll-*a* concentration falls in the *excellent* category for shallow lowland drainage lakes in the state.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present.

The clarity of Benson Lake's water can be described as *excellent* during the summer months in which data has been collected (Figure 8.13.1-3). A weighted average over this timeframe (8.5 feet) exceeds the median value for other shallow lowland drainage lakes in the state (5.6 feet) and is similar to the regional median (8.9 feet). Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In many lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Benson Lake may contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake. *True color* measures the dissolved organic materials in water; however, true color was not measured in Benson Lake and it is unknown if the lake's water clarity is primarily influenced by staining from organic acids.

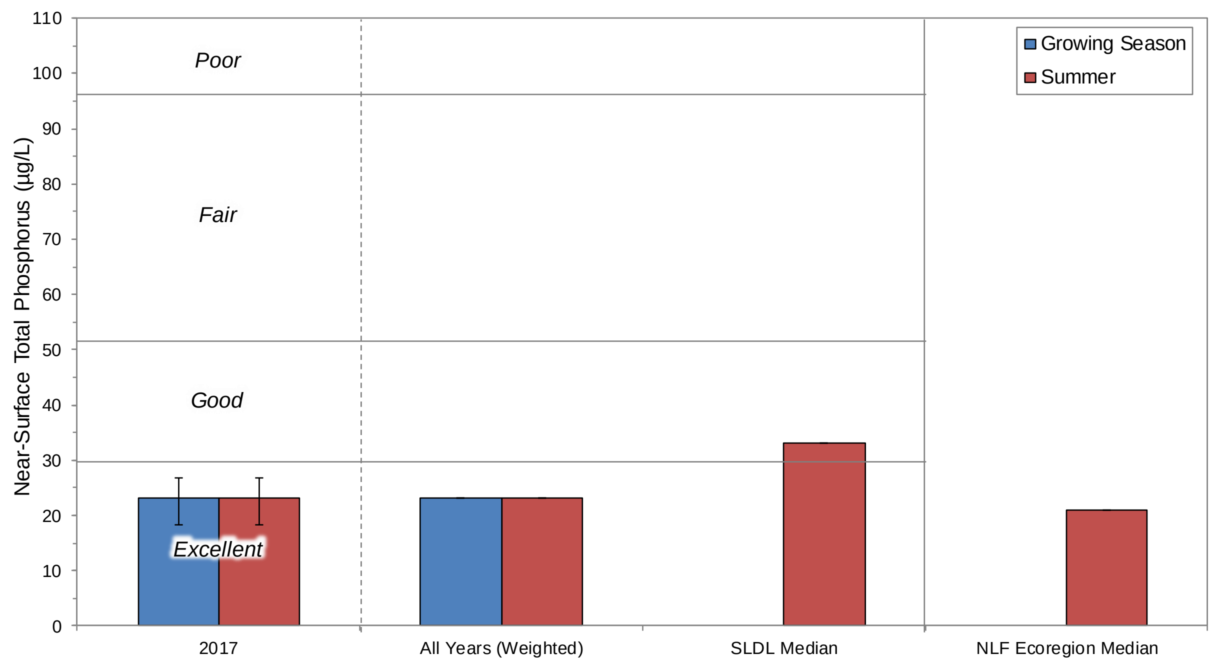


Figure 8.13.1-1. Benson Lake, state-wide shallow lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

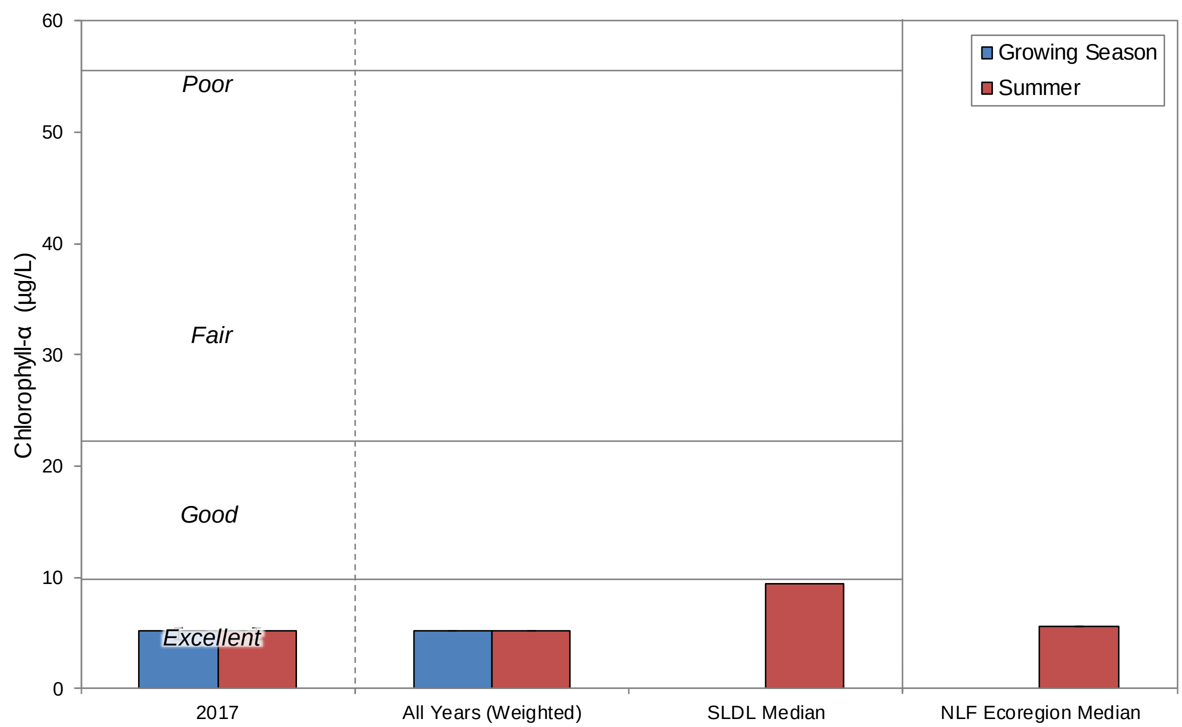


Figure 8.13.1-2. Benson Lake, state-wide shallow lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

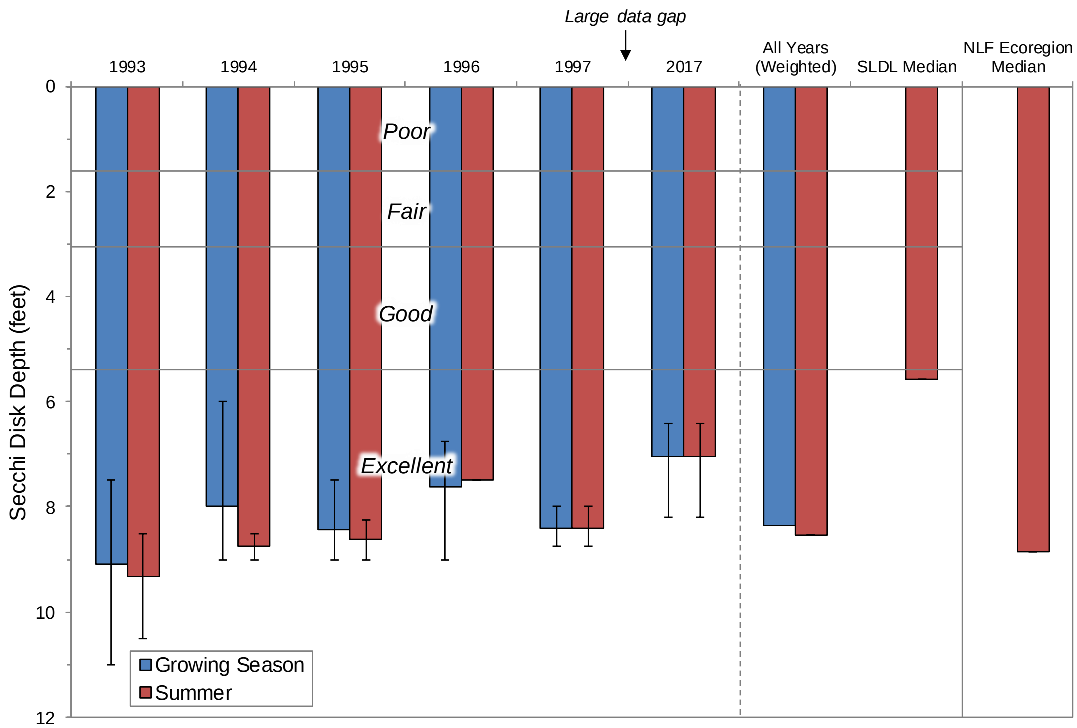


Figure. 8.13.1-3. Benson Lake, state-wide shallow lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Benson Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values are displayed in Figure 8.13.1-4. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Benson Lake is in an upper-mesotrophic state.

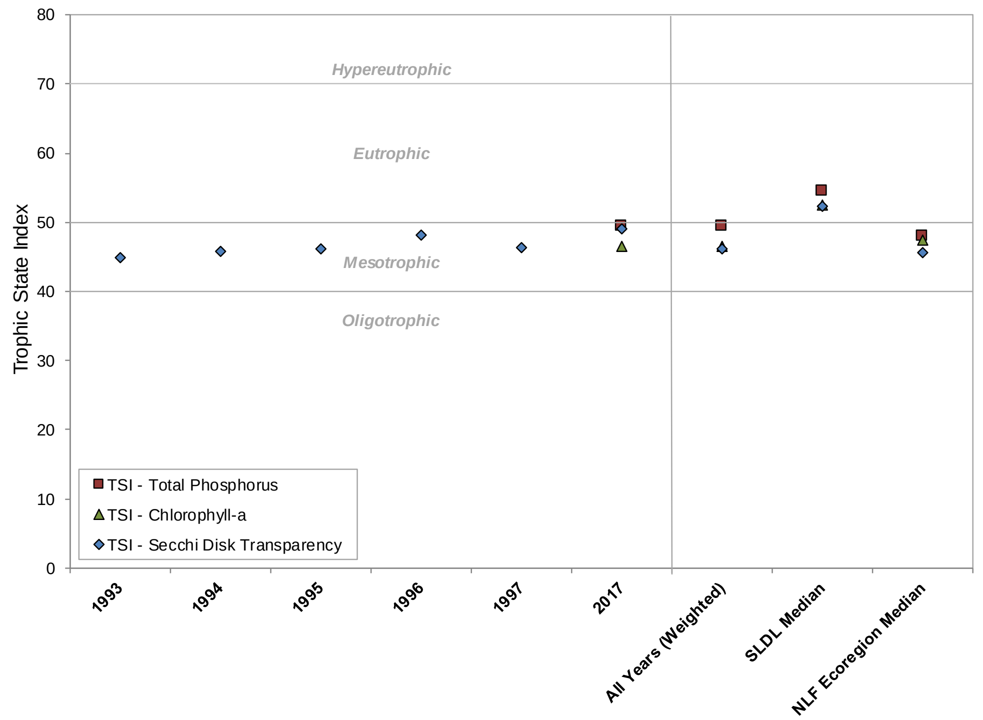


Figure 8.13.1-4. Benson Lake, state-wide shallow lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Benson Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Benson Lake by Onterra staff. Graphs of those data are displayed in Figure 8.13.1-5 for all sampling events.

Benson Lake remained thoroughly mixed throughout the summer months in 2017 (Figure 8.13.1-5). This is not uncommon in lakes that are moderate in size and fairly shallow. Energy from the wind and flow from the Manitowish River is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

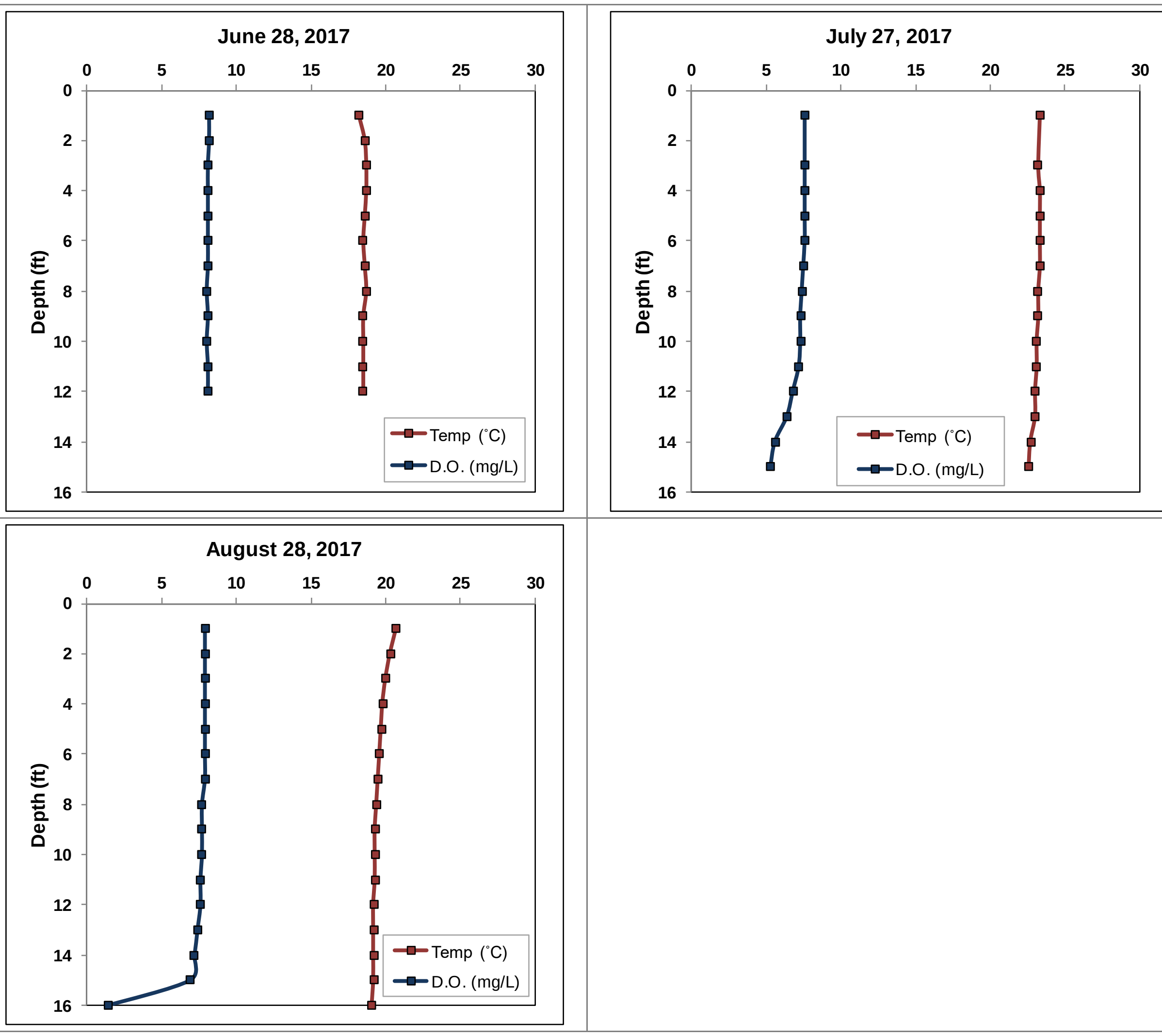


Figure 8.13.1-5. Benson Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Benson 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 Benson 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. Benson Lake's surface water pH was measured at roughly 7.7 July of 2017. This value is slightly above neutral and falls 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 Benson Lake was measured at 39.1 in July of 2017 and indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

While samples of calcium were not collected from Benson Lake in 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 Benson Lake's pH of 7.7 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. Plankton tows were completed by Onterra staff during the summer of 2017 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.13.2 Benson Lake Watershed Assessment

Benson Lake's watershed is 147,950 acres in size. Compared to Benson Lake's size of 33 acres, this makes for an incredibly large watershed to lake area ratio of 4513:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Benson Lake this means that 147,704 acres (>99%) of Benson Lake's watershed is the Sturgeon Lake subwatershed. The direct watershed of Benson Lake is a very small part of the lake's total watershed (Figure 8.13.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Benson Lake's residence time is approximately one-half day, or that the water within the lake is completely replaced 672 times per year.

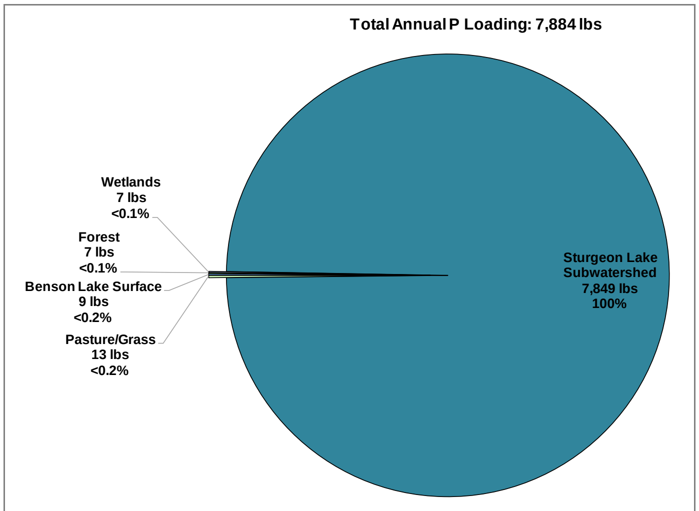


Figure 8.13.2-1. Benson Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 7,884 pounds of phosphorus being delivered to Benson Lake on an annual basis, nearly all of it originates from Sturgeon Lake which is the lake immediately upstream of Benson Lake (Figure 8.13.2-2). Using the estimated annual potential phosphorus load, WiLMS similar to the measured growing season phosphorus concentration of 23 µg/L. This means the model works fairly well for Benson Lake.

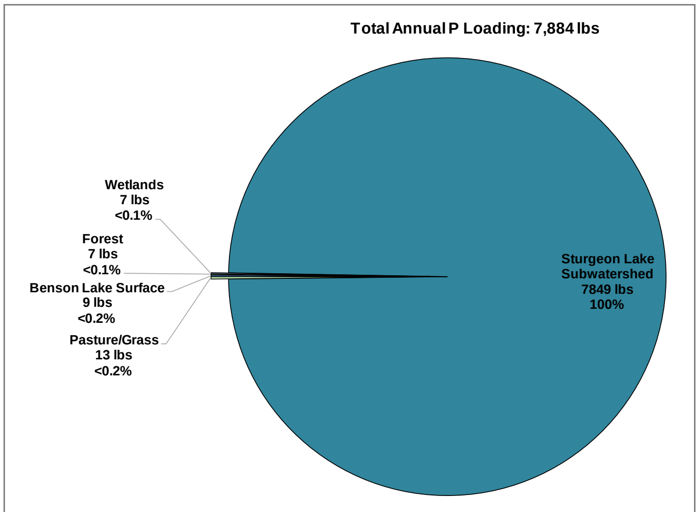


Figure 8.5.2-2. Benson Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Because the nearly all of the phosphorus that enters Benson Lake comes from the upstream Sturgeon Lake, efforts to reduce phosphorus levels in Benson Lake should concentrate on reducing phosphorus inputs to Sturgeon Lake.

8.13.3 Benson Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-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 fall of 2017, Benson Lake's immediate shoreline was assessed in terms of its development. Benson Lake has stretches of shoreland that three of the five shoreland assessment categories. In all, 1.1 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.13.3-1). This constitutes about 93% of Benson Lake's shoreline. This shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, less than one tenth of a mile of developed–unnatural shoreline (1%) was observed. If restoration of the Benson Lake shoreline is to occur, primary focus should be placed on this shoreland area as they currently provide little benefit to, and actually may harm, the lake ecosystem. Benson Lake Map 1 displays the location of these shoreline lengths around the entire lake.

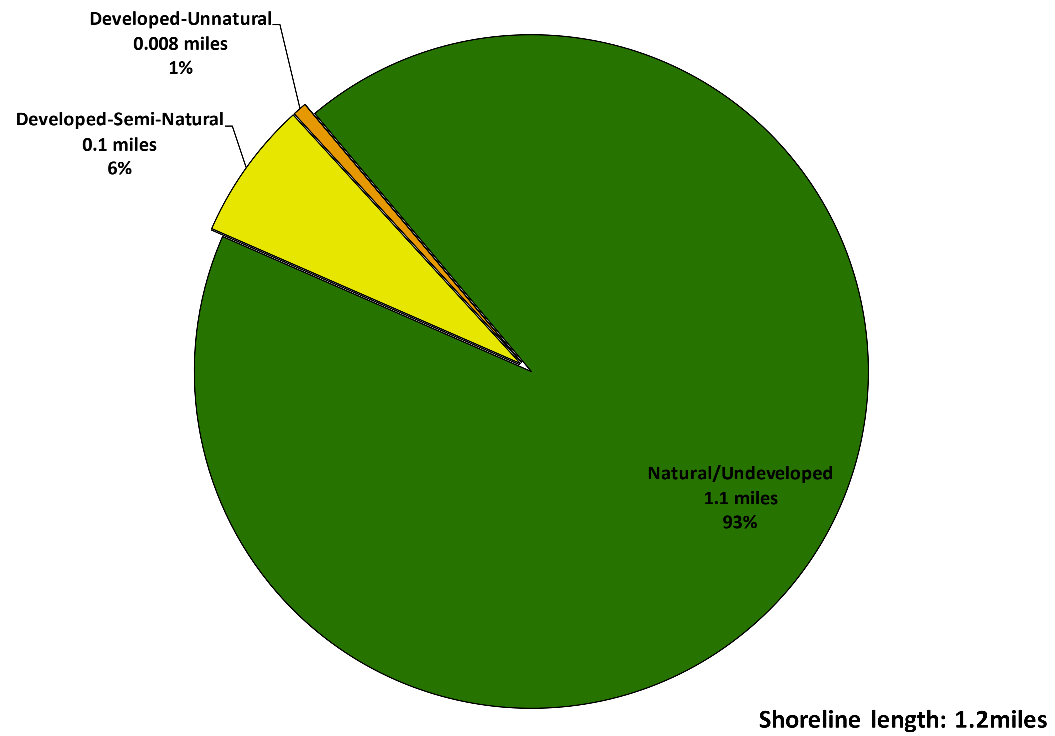


Figure 8.13.3-1. Benson Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Benson Lake Map 1.

Coarse Woody Habitat

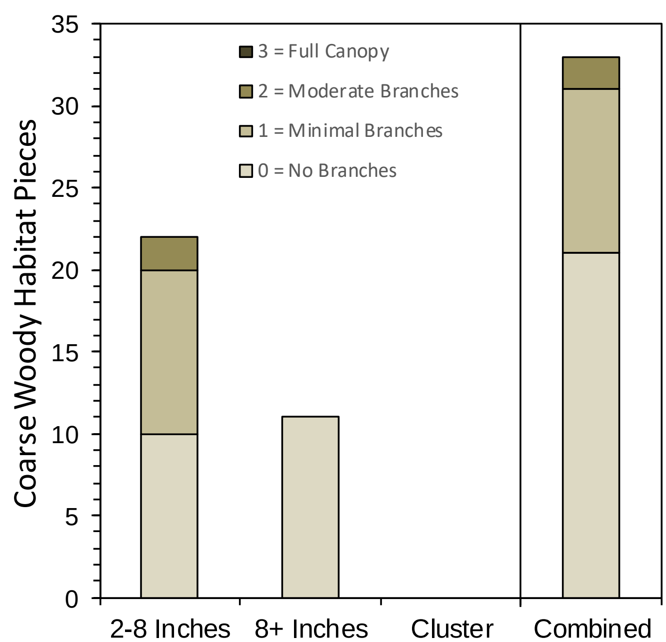
As part of the shoreland condition assessment, Benson Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters of pieces) as well as four branching 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, 33 total pieces of coarse woody habitat were observed along 1.2 miles of shoreline (Benson Lake Map 2), which gives Benson Lake a coarse woody habitat to shoreline mile ratio of 28:1 (Figure 8.13.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Twenty-two pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 11 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Benson 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 98 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 Benson Lake falls just above the median of these 98 lakes (Figure 8.13.3-2).



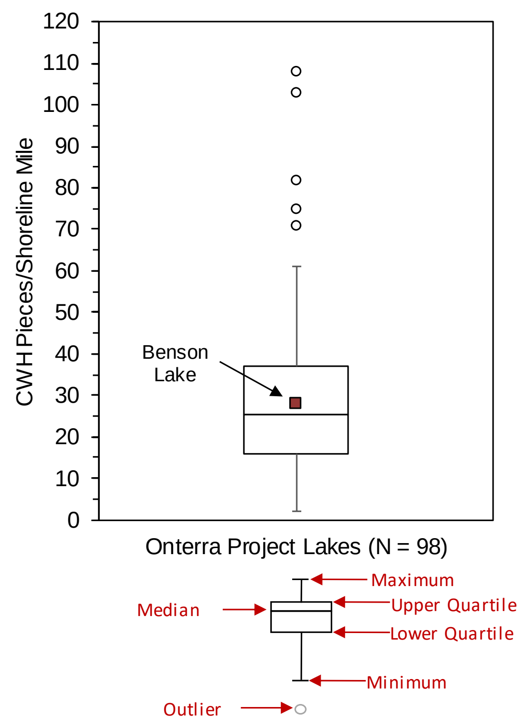


Figure 8.13.3-2. Benson Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of the Benson Lake coarse woody habitat can be found on Benson Lake Map 2.

8.13.4 Benson Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Benson Lake on June 28, 2017. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey and floating-leaf and emergent plant community mapping were conducted on Benson Lake on August 2, 2017 by Onterra. During all surveys, 32 species of aquatic plants were located in Benson Lake (Table 8.13.4-1). Twenty-two of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 10 species were observed incidentally during visits to Benson Lake. One non-native species, red canary grass (*Phalaris arundinacea*) was observed along the Benson Lake shoreline.

Aquatic plants were found growing to a depth of 14 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 106 point-intercept locations sampled within the littoral zone, roughly 29% contained aquatic vegetation. Benson Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in the northern bay of the lake. Approximately 46% of the point-intercept sampling locations where sediment data was collected at were sand, 41% consisted of a fine, organic substrate (muck) and 12% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.13.4-1. Aquatic plant species located in Benson Lake during 2017 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Carex pseudocyperus*	Cypress-like sedge	8	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris versicolor	Northern blue flag	5	I
	Phalaris arundinacea	Reed canary grass	Exotic	I
	Phragmites australis subsp. *americanus*	Common reed	5	I
	Pontederia cordata	Pickerelweed	9	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Sparganium eurycarpum	Common bur-reed	5	X
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Myriophyllum sibiricum	Northern watermilfoil	7	I
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	I
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton nodosus	Long-leaf pondweed	5	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia vulgaris	Common bladderwort	7	I
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X

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

Figure 8.13.4-1 shows that wild celery, slender naiad, coontail, and flat-stem pondweed were the most frequently encountered plants within Benson Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Slender naiad, a common annual species in Wisconsin, is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food. The small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Coontail is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and its location can be largely a product of water movement. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms.

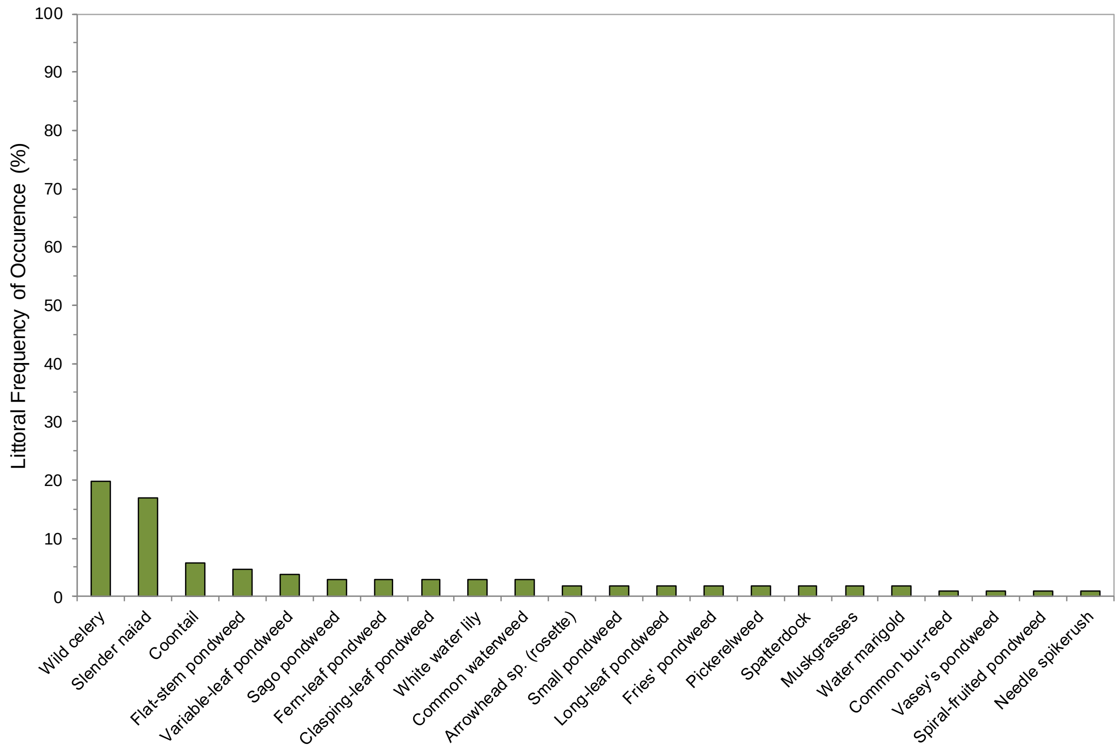


Figure 8.13.4-1. Benson Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2017 point-intercept survey. .

During aquatic plant inventories, 31 species of native aquatic plants (including incidentals) were found in Benson Lake. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Benson Lake's plant community (0.88) lies at the Northern Lakes and Forest Lakes ecoregion value (0.88), indicating the lake holds diversity similar to the lakes in the same ecoregion.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. 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 wild celery was found at 20% of the sampling locations, its relative frequency of occurrence is 24%. Explained another way, if 100 plants were randomly sampled from Benson Lake, 24 of them would be wild celery. This distribution can be observed in Figure 8.13.4-2, where together four native species account for 57% of the aquatic plant population within Benson Lake, while the other 18 species account for the remaining 43%. Nine additional native species were found incidentally from the lake but not from of the point-intercept survey, and are indicated in Table 8.13.4-1 as incidentals.

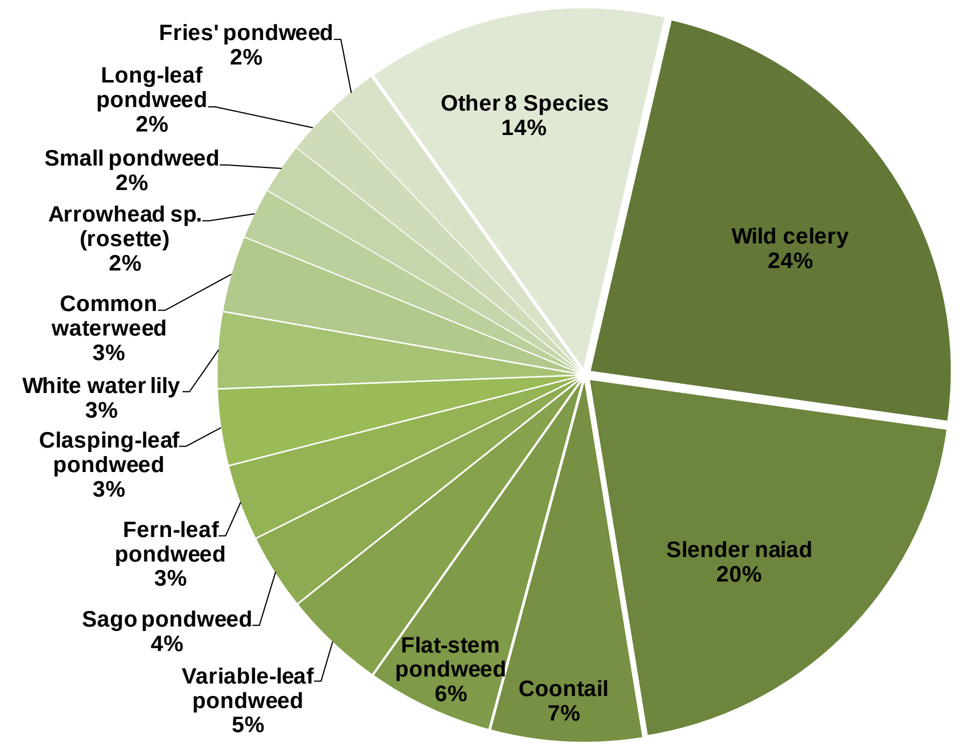


Figure 8.13.4-2. Benson Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2017 point-intercept survey.

Benson Lake's average conservatism value (6.2) is below the state median (6.3) and the Northern Lakes and Forests ecoregion median (6.7). This indicates that the plant community of Benson Lake is indicative of a slightly below average system within Wisconsin. Combining Benson Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 29.3 which is below the median values of the ecoregion (30.8) but above the median for the state (27.2).

The Benson Lake 2017 community map indicates that approximately 5.5 acres of the lake contains these types of plant communities (Benson Lake Map 4, Table 8.8.4-2). Ten floating-leaf and emergent species were located on Benson Lake (Table 8.8.4-1), all of which provide valuable wildlife habitat.

Table 8.13.4-2. Benson Lake acres of emergent and floating-leaf plant communities from the 2017 community mapping survey.

Plant Community	Acres
Emergent	0.5
Floating-leaf	0.9
Mixed Emergent & Floating-leaf	4.2
Total	**5.5**

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Benson Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-Native Aquatic Plants in Benson Lake

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed along the eastern shore of Benson Lake (Benson Lake – Map 4). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

8.13.5 Benson Lake Fisheries Data Integration

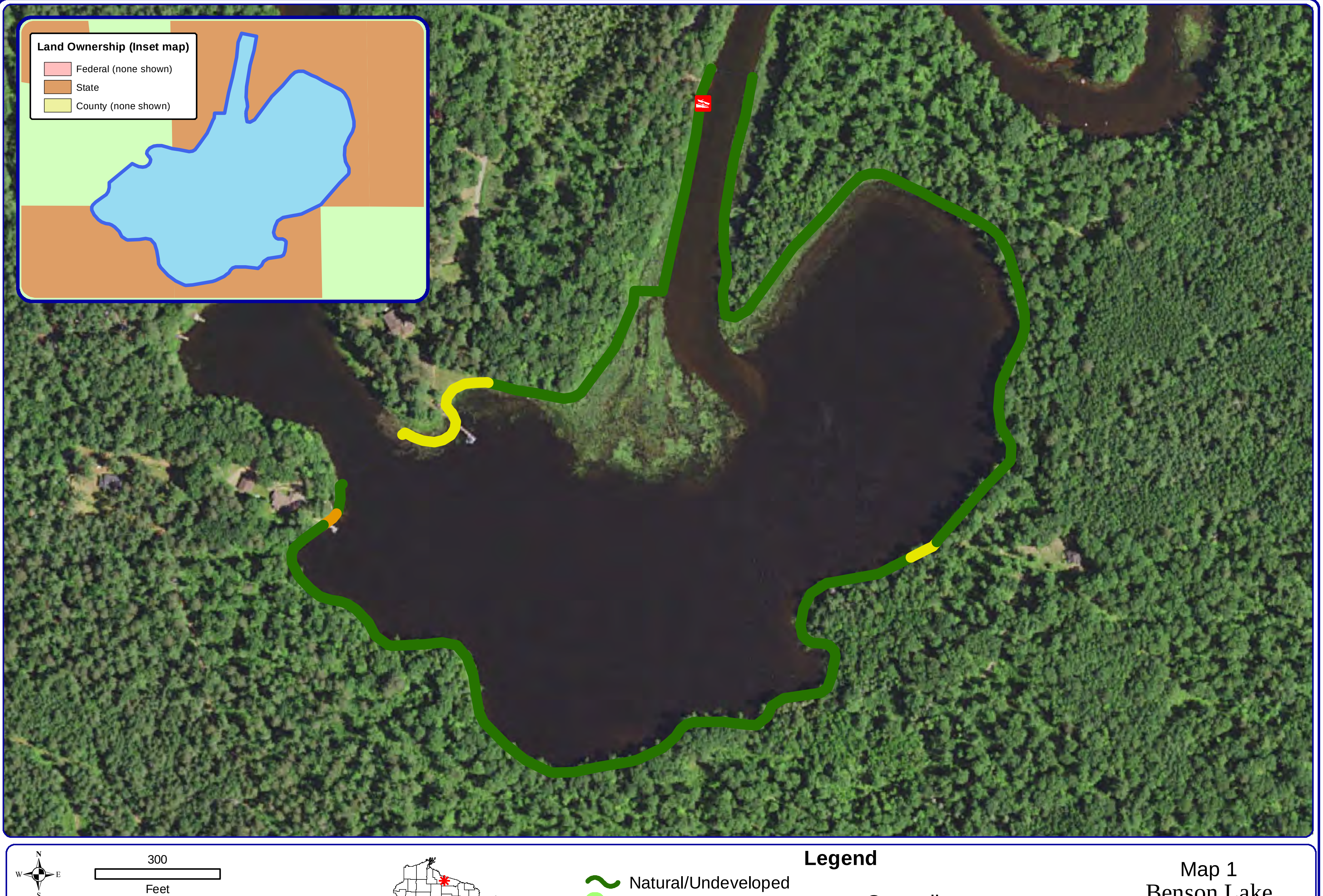
Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here and within the chain wide report section as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Benson 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 2018 & GLIFWC 2017).

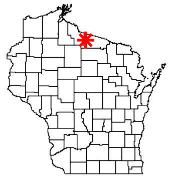
Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries. 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. Benson Lake has no historical stocking records.

Benson Lake Spear Harvest Records

Although Benson Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.





Project Location in Wisconsin

Legend

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

Seawall

- Rip-Rap
- Wood/Masonary/Metal

Map 1
Benson Lake
Vilas County, Wisconsin

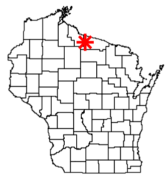
2017 Shoreland Condition

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
Shoreline Assessment: Onterra, 2017
Map Date: October 9, 2017
Filename:Benson_Map1_ShorelandCondition_2017.mxd

N
W E
S

300
Feet



Project Location in Wisconsin

Legend

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

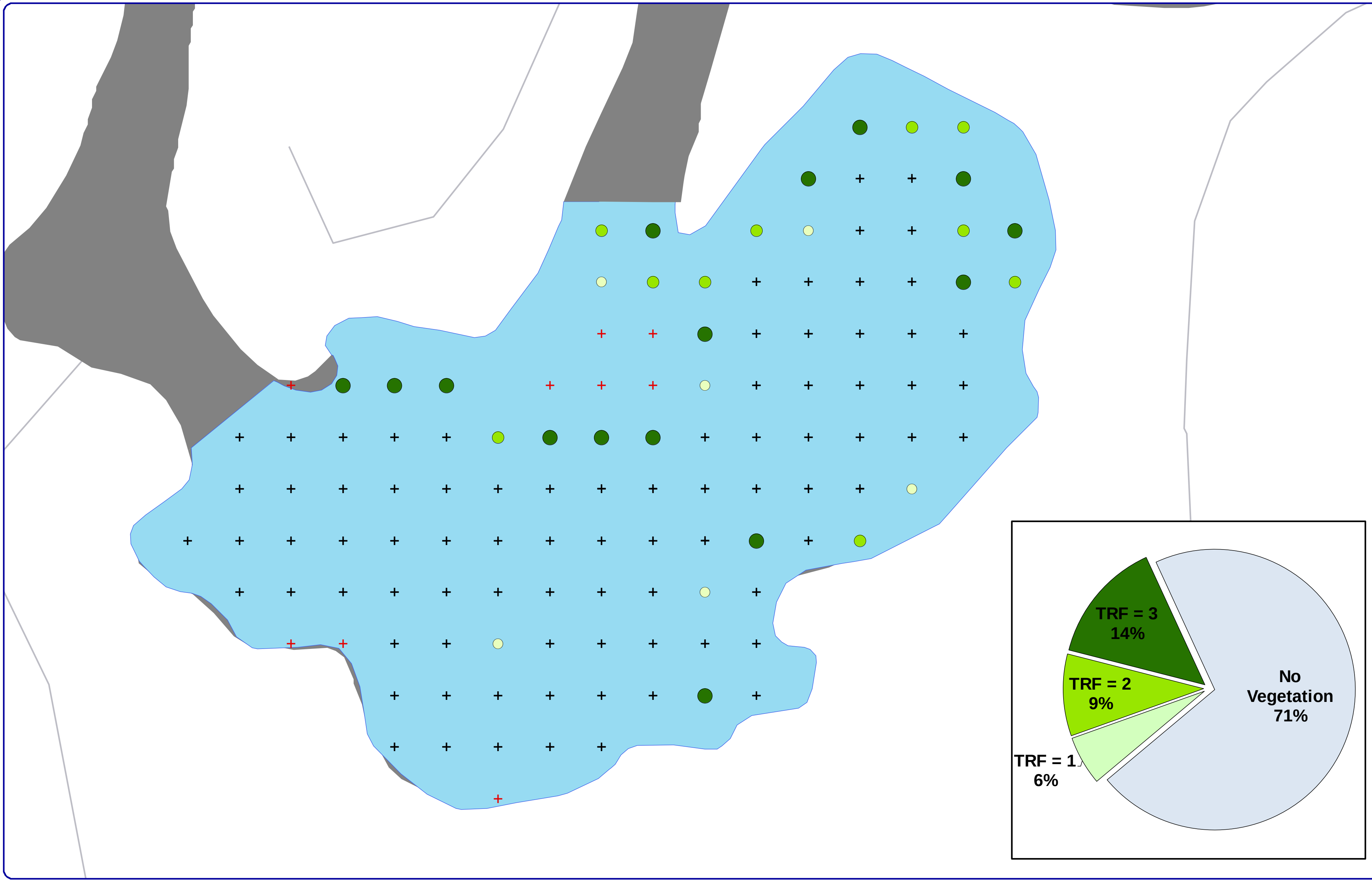
8+ Inch Pieces
- No Branches
- Minimal Branches (none)
- Moderate Branches (none)
- Full Canopy (none)

Cluster of Pieces
- No Branches (none)
- Minimal Branches (none)
- Moderate Branches (none)
- Full Canopy (none)

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
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: October 9, 2017
Filename:Benson_Map2_CWH_2017.mxd

Map 2
Benson Lake
Vilas County, Wisconsin
Coarse Woody Habitat

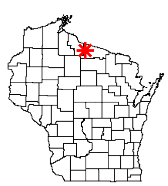


N
W E
S

250
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
Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: *MapX_Benson_TRFPI_2017.mxd*


Project Location in Wisconsin

Legend

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

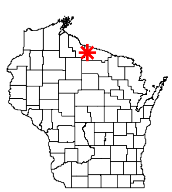
Map 3
Benson Lake
Vilas County, Wisconsin
2017 PI Survey: Aquatic Vegetation Distribution

N
W E
S

250
Feet

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

Sources:
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2017
Map date: November 3, 2017
Filename: Benson_Comm_2017.mxd


Project Location in Wisconsin

Legend

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

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

Map 4

Benson Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities