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

8.3 Star Lake

An Introduction to Star Lake

Star Lake, Vilas County, is a 1,240-acre deep two-story fishery lake with a maximum depth of 68 feet and a mean depth of 23 feet (Star Lake – Map 1). Its watershed encompasses approximately 3,346 acres within the St. Germain River Watershed and is comprised mainly of intact forests and wetlands. Star Lake is fed by upstream Little Star Lake from the north and water leaves Star Lake through Star Creek to the south and flows into Plum Lake. In 2017, 42 native aquatic plant species were located within the lake, of which stoneworts (*Nitella spp.*) was the most common. Two non-native plants, pale yellow iris and purple loosestrife, were found during the surveys.

Lake at a Glance - Star Lake

Morphometry	
Lake Type	Deep Lowland Drainage Lake (Two-Story)
Surface Area (Acres)	1,240
Max Depth (feet)	68
Mean Depth (feet)	23
Perimeter (Miles)	12.1
Shoreline Complexity	6.0
Watershed Area (Acres)	3,346
Watershed to Lake Area Ratio	2:1

Water Quality	
Trophic State	Oligotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (μg/L)	8
Avg Summer Chl-α (μg/L)	2
Avg Summer Secchi Depth (ft)	12.1
Summer pH	7.7
Alkalinity (mg/L as $CaCO_3$)	31.2

Vegetation	
Number of Native Species	42
NHI-Listed Species	-
Exotic Species	Pale yellow iris (*Iris pseudacorus*), Purple loosestrife (*Lythrum salicaria*)
Average Conservatism	6.5
Floristic Quality	31.3
Simpson's Diversity (1-D)	0.9

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

8.3.1 Star Lake Water Quality

Water quality data was collected from Star Lake on six occasions in 2017/2018. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2017/2018 any historical data was researched and are included within this report as available. It should also be noted that while Star Lake is a two-story fishery lake, regional data for two-story lakes are not available so the water quality of Star Lake will be compared to other deep lowland drainage lakes in the state.

Near-surface total phosphorus data from Star Lake are available from 1989 and from 2017 (Figure 8.3.1-1). The weighted summer average total phosphorus concentration is 8 µg/L and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Star Lake's summer average total phosphorus concentrations are over 2.5 times lower than the median values for both deep lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion.

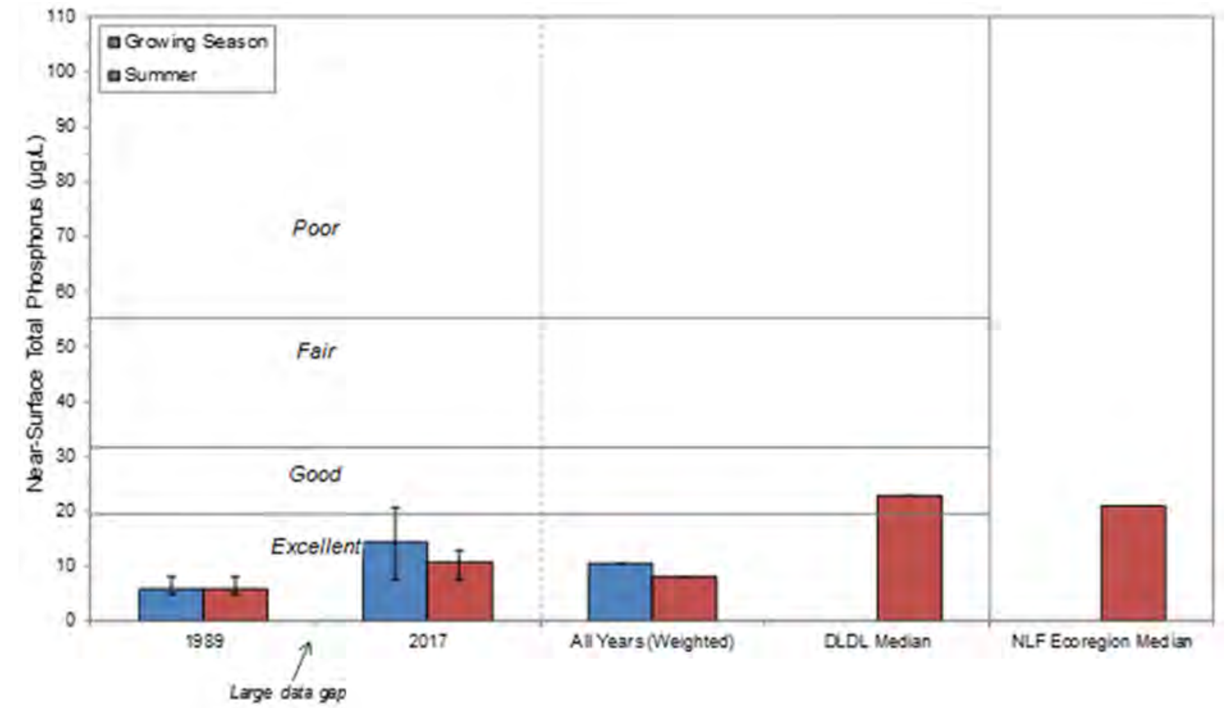


Figure 8.3.1-1. Star Lake, statewide deep lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading is a significant source of phosphorus in Star Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom and near-surface total phosphorus concentrations are displayed in Figure 8.3.1-2. As illustrated, in April of 2017 the near-bottom total phosphorus concentration is similar to the concentration measured near the surface, but in June through October of 2017 the near-bottom concentrations are higher than the near-surface concentrations and continue to grow throughout the summer. The higher concentrations of phosphorus near the bottom occurred when Star Lake was stratified and the bottom layer of water (hypolimnion) was anoxic. The higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia. Overall, while this process may be contributing some phosphorus to Star Lake's water column, the impacts of internal loading are not significant. As previously mentioned, the lake' surface water total phosphorus values are better than the median value for comparable lakes in Wisconsin and all lake types in the NLF ecoregion.

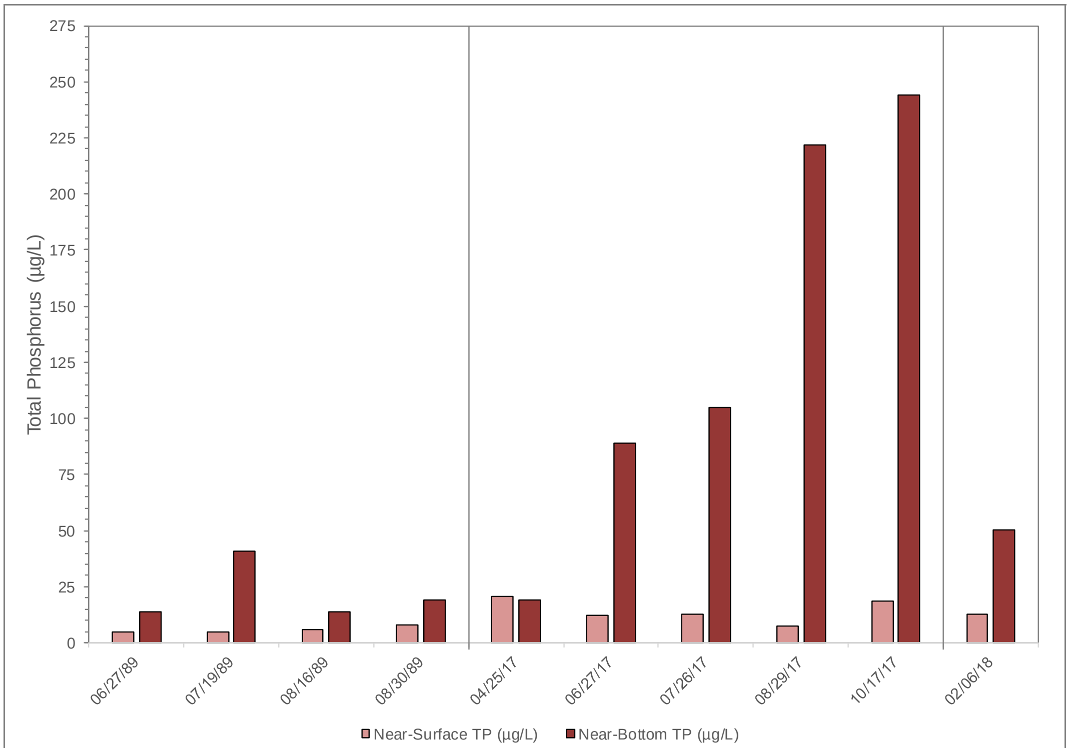


Figure 8.3.1-2. Star Lake near-surface and near-bottom total phosphorus concentrations.

Chlorophyll-*a* data are available from Star Lake from 1979, 1989, and from 2017 (Figure 8.3.1-3). Average summer chlorophyll-*a* concentrations ranged from 1 µg/L in 2017 to almost 3 µg/L in 1989. Star Lake's summer average chlorophyll-*a* concentration is 2 µg/L and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Star Lake's summer average chlorophyll-*a* concentrations are almost 4 times lower than the median value for deep lowland drainage lakes in the state and over 3 times lower than the median value for all lake types in the NLF ecoregion.

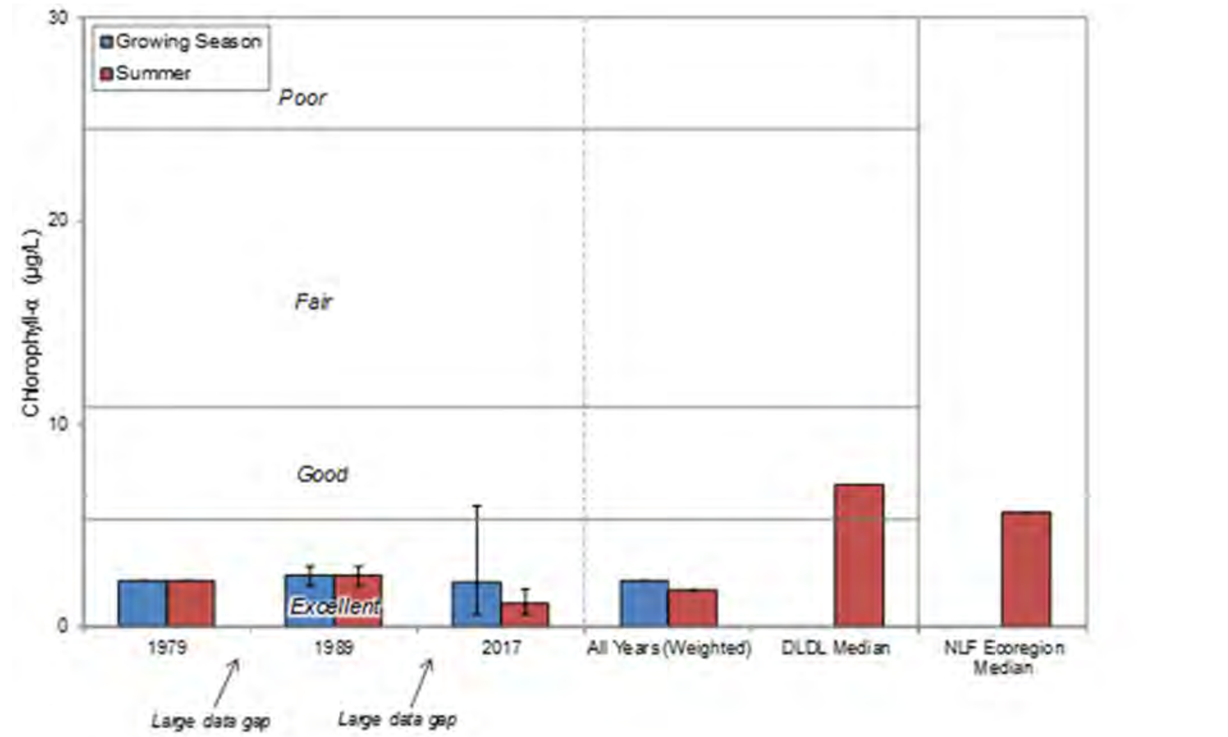


Figure 8.3.1-3. Star Lake, statewide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available from Star Lake from 1979, from 1993 to 2002, and from 2017 (Figure 8.3.1-4). Average summer Secchi disk depths ranged from 9.5 feet in 2002 to 21.7 feet in 2017. The weighted summer average Secchi disk depth is 12.1 feet and falls into the *excellent* category for deep lowland drainage lakes in Wisconsin. Star Lake's weighted summer average Secchi disk depth exceeds the median values for both deep lowland drainage lakes in the state and for all lake types in the NLF ecoregion by approximately 3 feet.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Star Lake in 2017 averaged 12.5 SU (standard units) indicating the lake's water is *slightly colored* and that the lake's water clarity is not influenced by dissolved components in the water. This value indicates that the water clarity in Star lake is mostly influenced by changes in chlorophyll-*a* from year to year.

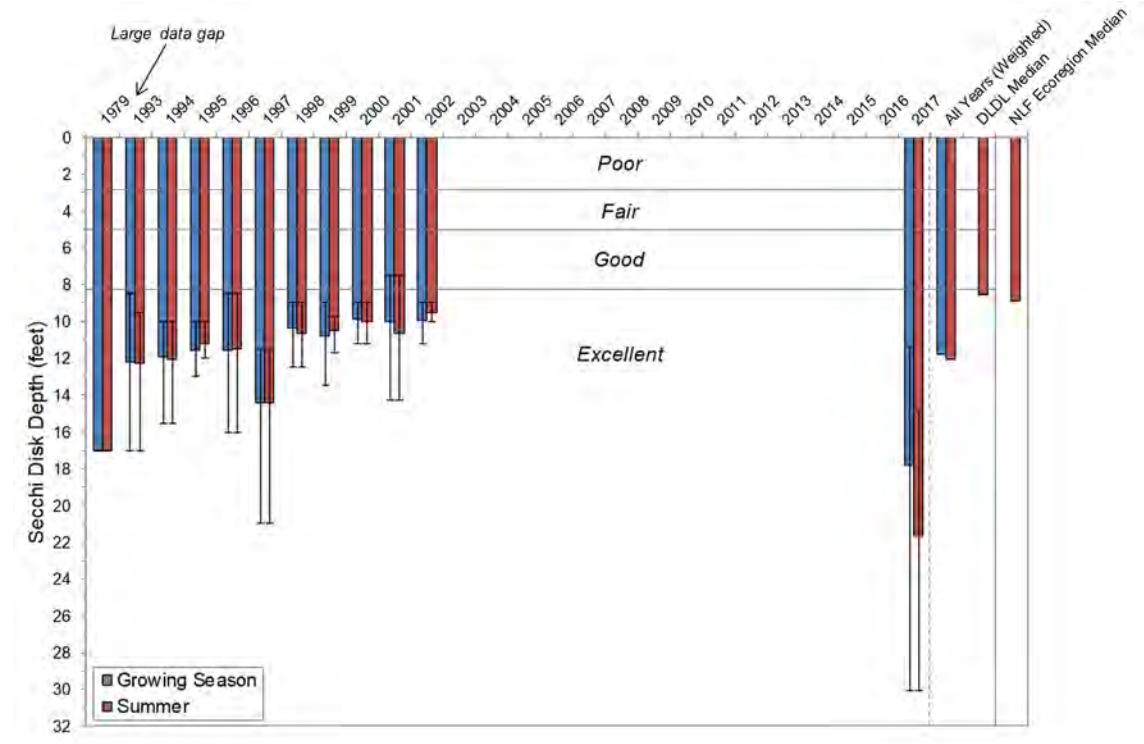


Figure 8.3.1-4. Star Lake, statewide deep lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Star Lake

Using midsummer nitrogen and phosphorus concentrations from Star Lake, a nitrogen:phosphorus ratio of 21:1 was calculated. This finding indicates that Star Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Star Lake Trophic State

Figure 8.3.1-5 contains the Trophic State Index (TSI) values for Star Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer together these three TSI values are indicates a higher degree of correlation between the parameters.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Star Lake indicate the lake is at present in an oligotrophic state. Star Lake's productivity is much lower when compared to both other deep lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

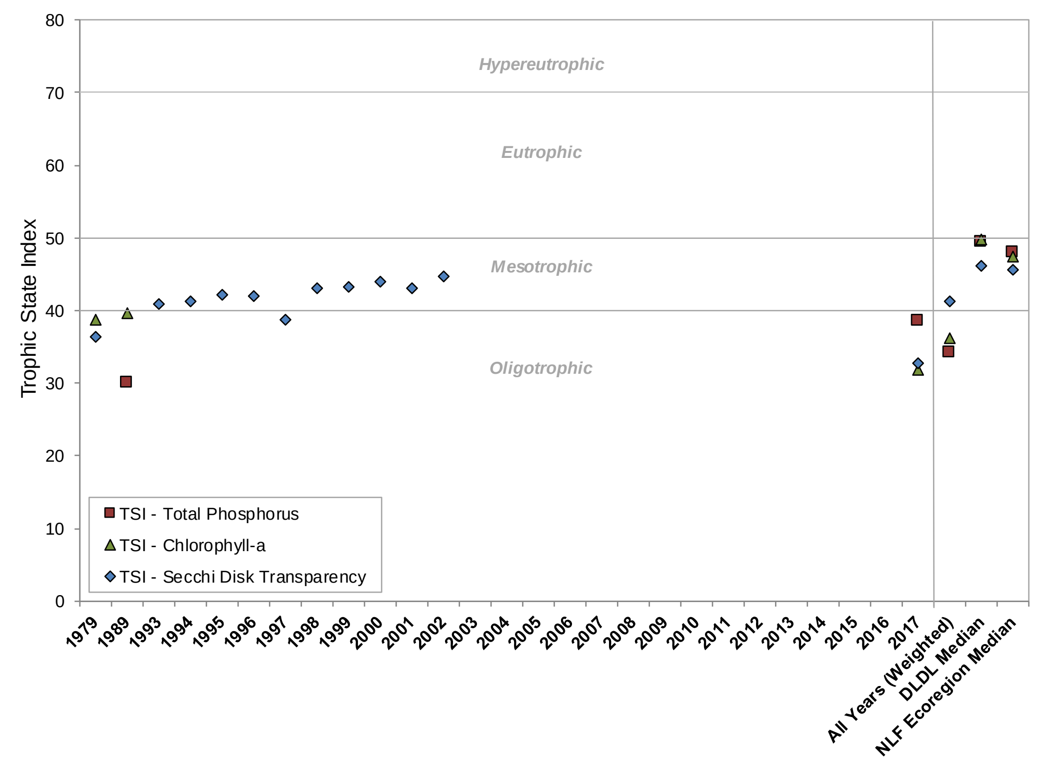


Figure 8.3.1-5. Star Lake, statewide deep lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Star Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Star Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.3.1-6.

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

In fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. In February of 2018, oxygen concentrations remained above 2.0 mg/L throughout the majority of the water column, indicating that fishkills as a result of winter anoxia are likely not a concern in Star Lake.

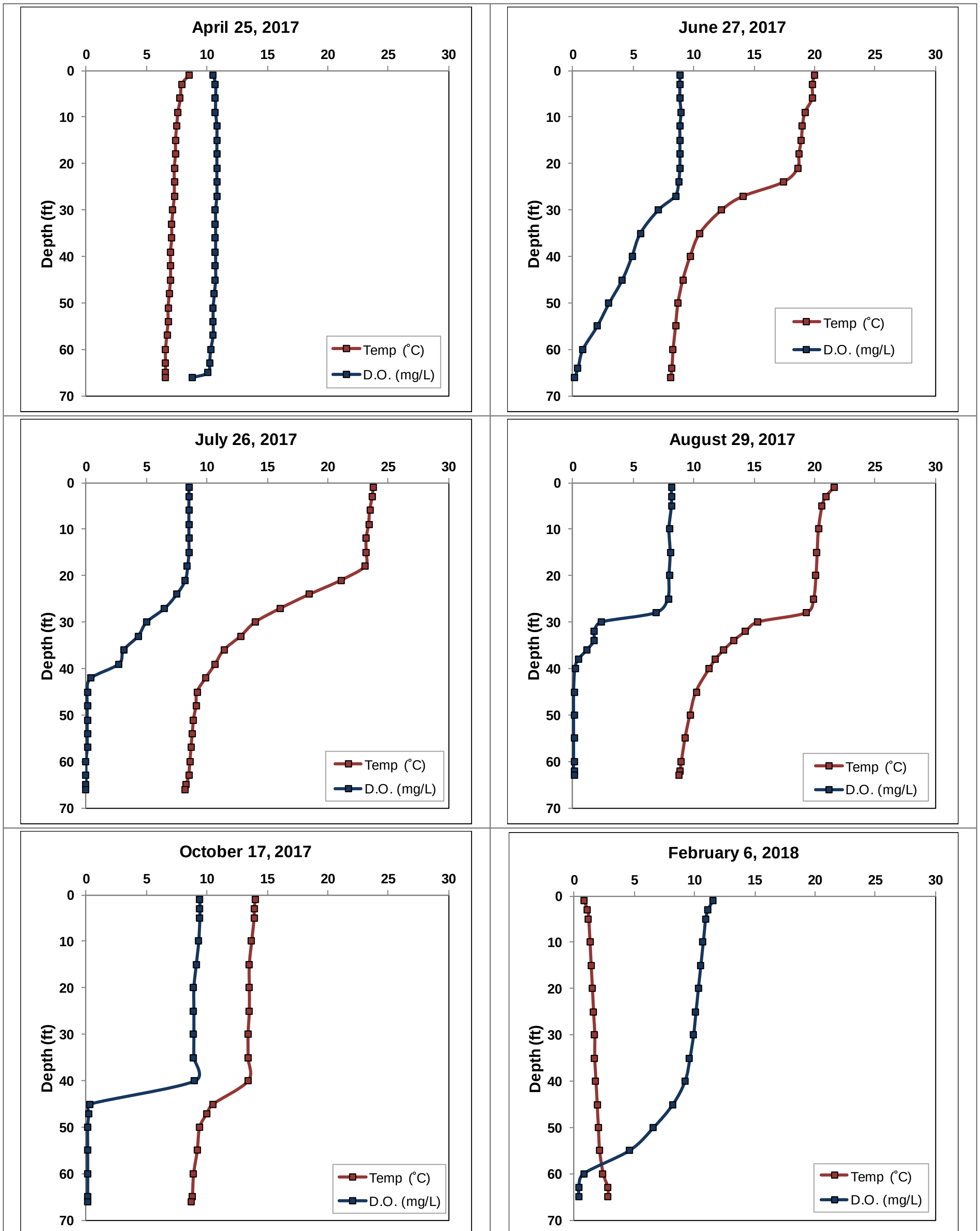


Figure 8.3.1-6. Star Lake 2017 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at 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 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. Star Lake's surface water pH was measured at approximately 7.5 during April 2017 and 7.7 during July 2017. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Star Lake was measured at 31.3 mg/L as $CaCO_3$ in April 2017 and 31.2 in July 2017. This indicates that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Star 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 Star Lake's pH of 7.5 – 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 Star Lake was found to be 8.6 mg/L in April and 8.5 mg/L July, which is below the lower range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2017 and these samples were processed by the WDNR for larval zebra mussels. The results were negative for the presence of zebra mussel veligers.

8.3.2 Star Lake Watershed Assessment

Star Lake's watershed encompasses an area of approximately 3,346 acres, yielding a small watershed to lake area ratio of 2:1 (Figure 8.3.2-1, Star Lake – Map 2). According to WiLMS modeling, the lake's water is completely replaced every 9.5 years (residence time) or approximately 0.1 times per year (flushing rate).

There is one lake within Star Lake's watershed that was treated as a point source: Little Star Lake. For modeling purposes, the lake's watershed was divided into two main subwatersheds: Star Lake's direct watershed and Little Star Lake's subwatershed. Approximately 85% of Star Lake's total watershed is composed of the lake's direct watershed and 15% is composed of Little Star Lake's subwatershed (Figure 8.3.2-1).

Approximately 44% of Star Lake's direct watershed is composed of the lake's surface, 26% of forest, 22% of wetlands, and 8% of pasture/grass. The remaining portions of the watershed are composed of rural residential areas.

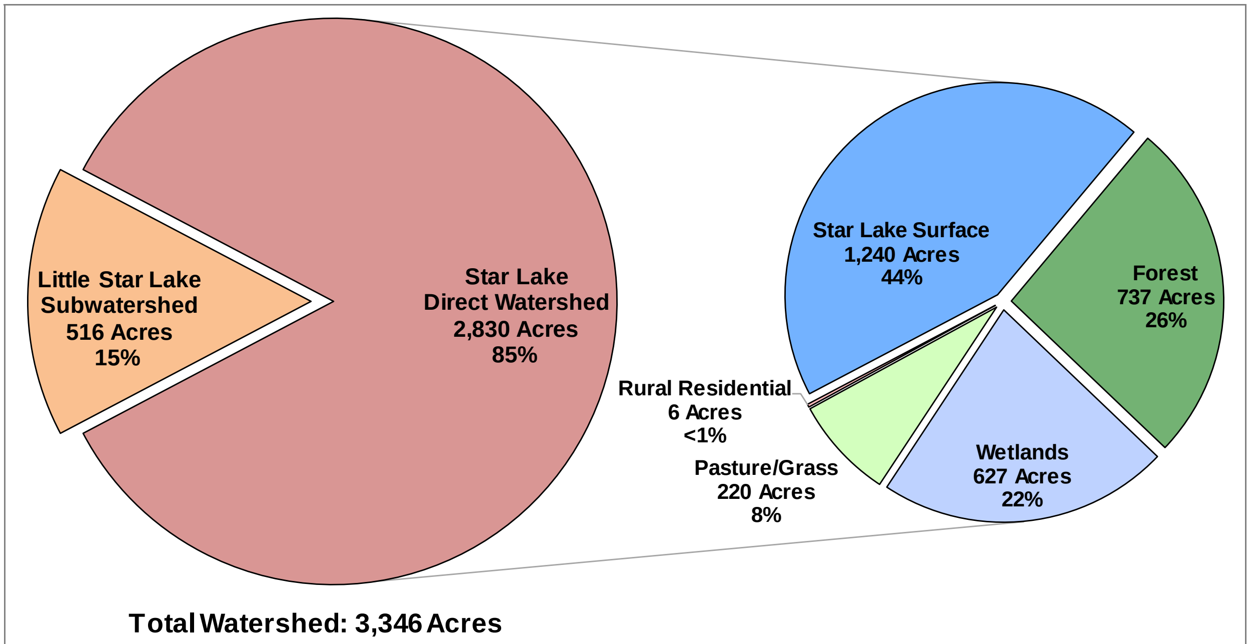


Figure 8.3.2-1. Star Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Star Lake's direct watershed, along with the estimated outflow of phosphorus from the Little Star Lake subwatershed. It was estimated that approximately 581 pounds of phosphorus is delivered to Star Lake from its watershed on an annual basis (Figure 8.3.2-2).

Of the estimated 581 pounds of phosphorus being delivered annually to Star Lake, the majority, 57%, is estimated to originate from direct atmospheric deposition into the lake, 13% from Little Star Lake's subwatershed, 10% from forest, 10% from pasture/grass, and 10% from wetlands (Figure 8.3.2-2). The remaining phosphorus load comes from riparian septic systems.

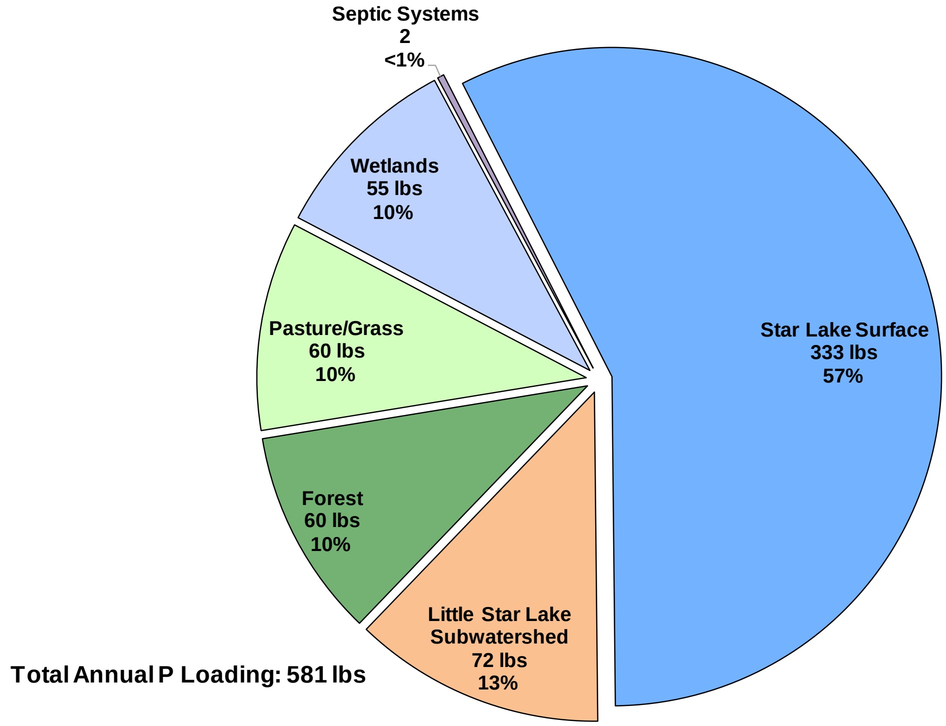


Figure 8.3.2-2. Star Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimated that based on the 581 pounds of phosphorus which are estimated to be loaded to Star Lake annually, the lake should have an in-lake growing season mean (GSM) total phosphorus concentration of approximately 15 µg/L. This predicted GSM total phosphorus concentration is relatively similar to the measured GSM concentration of 10.7 µg/L. This indicates the lake's watershed and phosphorus inputs were modeled fairly accurately and the measured phosphorus concentrations in Star Lake are near expected levels based on the lake's watershed size and land cover composition. There are no indications that significant sources of unaccounted phosphorus are being loaded to the lake.

8.3.3 Star Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Town-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In the fall of 2017, Star Lake's immediate shoreline was assessed in terms of its development. Star Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 10.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.3.3-1). This constitutes about 86% of 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, 0.5 miles of urbanized and developed–unnatural shoreline (4%) was observed. If restoration of the 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. Star Lake - Map 3 displays the location of these shoreline lengths around the entire lake.

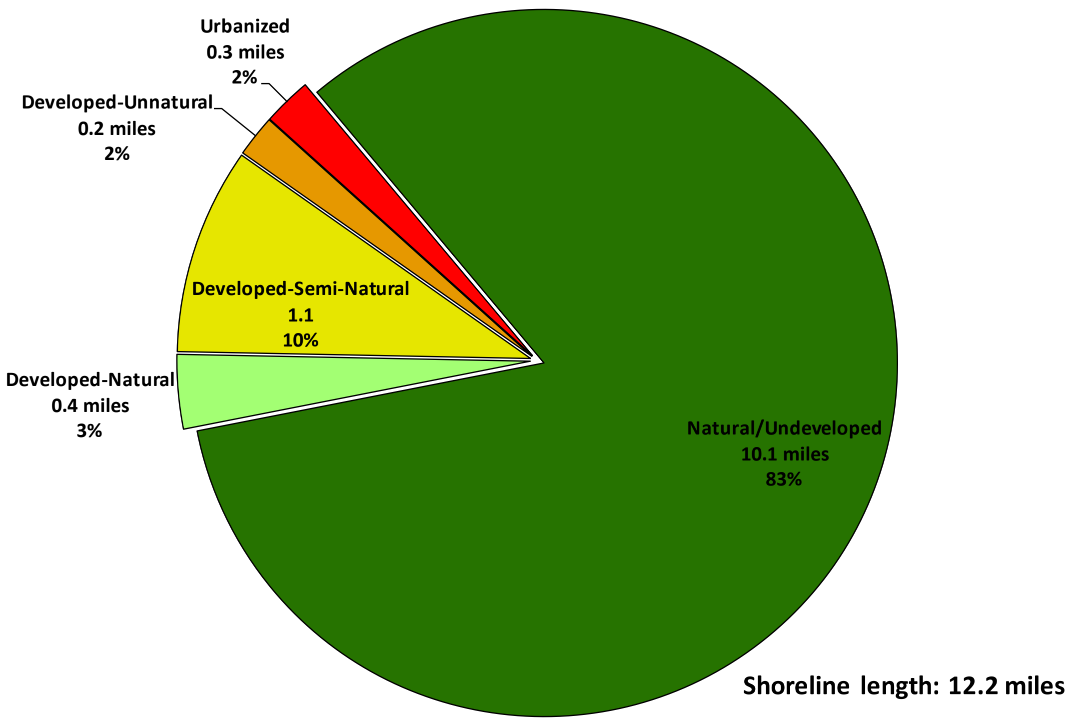


Figure 8.3.3-1. Star Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Star Lake - Map 3.

Coarse Woody Habitat

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

During this survey, 584 total pieces of coarse woody habitat were observed along 12.2 miles of shoreline (Star Lake - Map 4), which gives Star Lake a coarse woody habitat to shoreline mile ratio of 48:1 (Figure 8.3.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 584 total pieces of coarse woody habitat observed during the survey, 468 pieces were 2-8 inches in diameters, 108 were 8 inches in diameter or greater, and 8 clusters of pieces of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on 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 75 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Star Lake fell well above the 75th percentile of these 75 lakes (Figure 8.3.3-2).

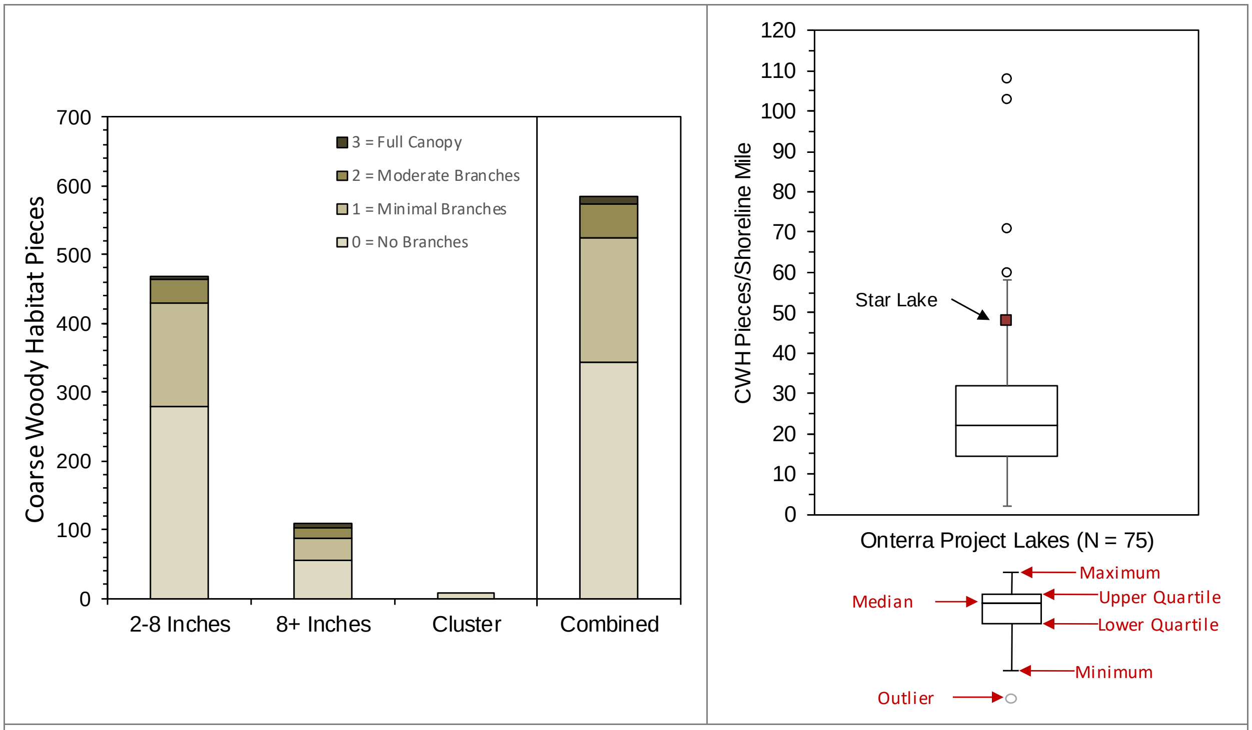


Figure 8.3.3-2. Star Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Star Lake coarse woody habitat can be found on Star Lake - Map 4.

8.3.4 Star Lake Aquatic Vegetation

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

Photograph 8.3.4-1. Star Lake

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Star Lake by Onterra ecologists on July 27, 2017 and August 1-2, 2017. During these surveys, a total of 44 aquatic plant species were located, two of which are considered to be a non-native, invasive species: pale-yellow iris and purple loosestrife (Table 8.3.4-1).

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 45% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 35% contained sand, and 20% contained rock (Figure 8.3.4-1). The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck (Star Lake - Map 5). Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

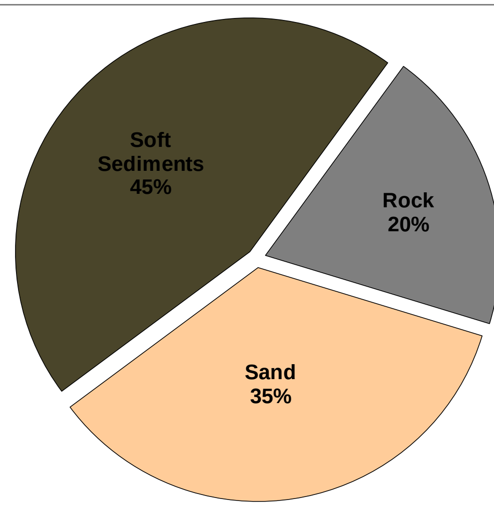


Figure 8.3.4-1. Star Lake 2017 proportion of substrate types. Created from data collected during the 2017 whole-lake point-intercept survey (N = 666).

Table 8.3.4-1. List of aquatic plant species located in Star Lake during Onterra 2017 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Calla palustris*	Water arum	9	I
	Carex comosa	Bristly sedge	5	I
	Carex pseudocyperus	Cypress-like sedge	8	I
	Carex retrorsa	Retrorse sedge	6	I
	Carex sp. 1 (sterile)	Sedge sp. 1 (sterile)	N/A	I
	Carex sp. 2 (sterile)	Sedge sp. 2 (sterile)	N/A	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Iris pseudacorus	Pale yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Juncus canadensis	Canadian rush	9	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Sparganium americanum	American bur-reed	8	I
	Typha spp.	Cattail spp.	1	I
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	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
	Elodea canadensis	Common waterweed	3	X
	Isoetes spp.	Quillwort spp.	8	X
	Lobelia dortmanna	Water lobelia	10	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	I
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton praelongus	White-stem pondweed	8	I
	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
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria cristata	Crested arrowhead	9	X
	Sagittaria graminea	Grass-leaved arrowhead	9	I
FF	*Lemna minor*	Lesser duckweed	5	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

Of the 666 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2017, approximately 27% contained aquatic vegetation. Star Lake – Map 6 displays the point-intercept locations that contained aquatic vegetation in 2017, and the total rake fullness ratings at those locations. Most of the aquatic vegetation in 2017 was located within shallower areas of the lake, mainly near shore and in the northern bay of the lake. Eighteen percent of the point-intercept locations had a total rake fullness (TRF) rating of 1, 5% had a total rake fullness rating of 2, and 4% had the highest total rake fullness rating of 3 (Figure 8.3.4-2). With the majority of the littoral zone (73%) having no vegetation, it can be said that where plants are present within Star Lake, they are sparse.

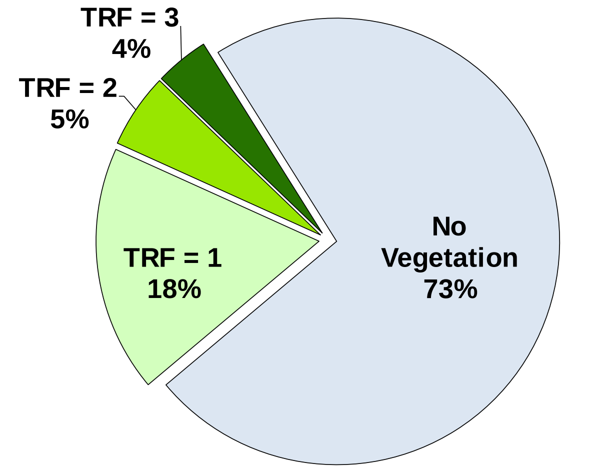


Figure 8.3.4-2. Star Lake 2017 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2017 whole-lake point-intercept survey (N = 666).

Of the 44 native aquatic plant species located in Star Lake in 2017, 23 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.3.4-3). The remaining 21 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 23 species directly sampled with the rake during the point-intercept survey, stoneworts, small pondweed, common waterweed, and muskgrasses were the four-most frequently encountered plants, respectively (Figure 8.3.4-3).

Stoneworts were the most abundant aquatic plant encountered in 2017 in Star Lake, with a littoral occurrence of 11% (Figure 8.3.4-3). 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.

Small pondweed was the second-most abundance aquatic plant encountered in Star Lake in 2017 with a littoral frequency of occurrence of 6% (Figure 8.3.4-3). Small pondweed is a common thin-leaved pondweed found throughout the state of Wisconsin. It can be identified from the other thin-leaved pondweeds by its lack of floating leaves and its winter buds with tight cigar shaped leaves in the middle.

Common waterweed was the third-most abundant aquatic plant encountered in Star Lake in 2017, with a littoral occurrence of approximately 5% (Figure 8.3.4-3). Common waterweed is found throughout lakes in Wisconsin and North America and is often dominant in areas with soft sediments. Its dense foliage provides valuable aquatic habitat while its ability to derive nutrients directly from the water aid in improving water quality.

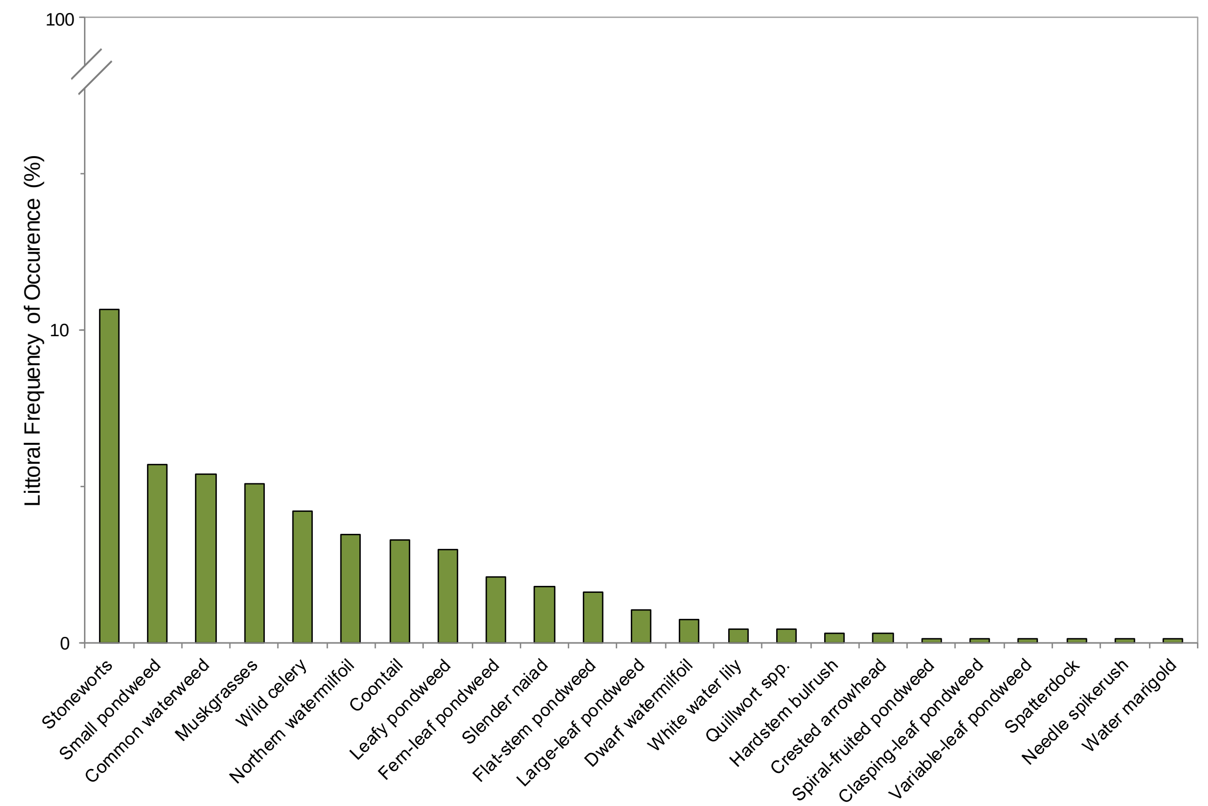


Figure 8.3.4-3. Star Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data from 2017 whole-lake point-intercept survey.

Photograph 8.3.4-2. The aquatic macroalgae muskgrasses (*Chara* spp.) Photo credit Onterra.

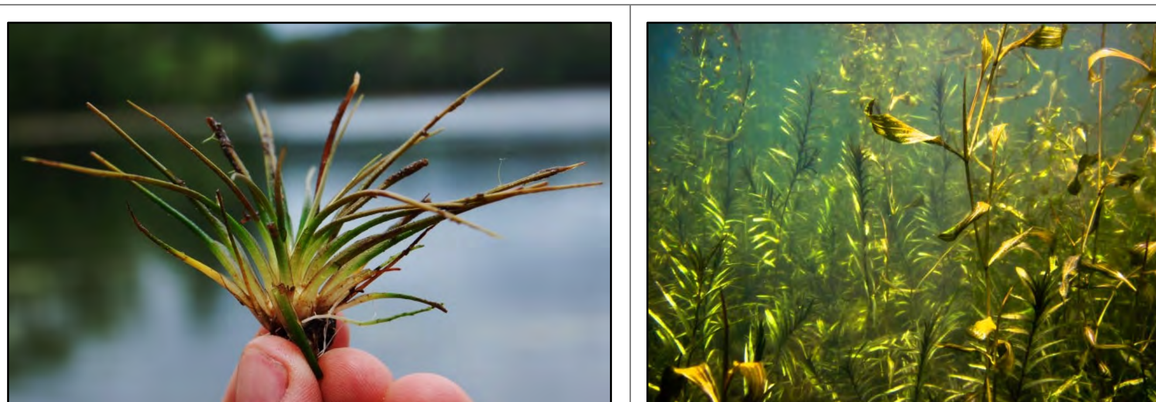
Muskgrasses, like stoneworts, are a genus of macroalgae of which there are seven species in Wisconsin (Photograph 8.3.4-2). In 2017, muskgrasses had a littoral frequency of occurrence of approximately 5% (Figure 8.3.4-3). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes and these macroalgae have been found to be more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photograph 8.3.4-3). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photograph 8.3.4-3). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-watermilfoil (*Myriophyllum tenellum*) found in Star Lake is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern watermilfoil (*Myriophyllum sibiricum*), also found in Star Lake, are classified as elodeids.

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

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Star Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.



Photograph 8.3.4-3. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

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

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

Figure 8.3.4-4 compares 2017 FQI components of Star Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. The number of native aquatic plant species encountered on the rake, or native species richness, was 23 for the 2017 survey. Star Lake's species richness exceeds the median value for lakes within the ecoregion and the state. The lake's excellent water quality and diversity of habitat types result in this high species richness.

Star Lake's average conservatism in 2017 was 6.5 (Figure 8.3.4-4). Star Lake's average conservatism is below the median values for lakes in the ecoregion but exceeds the median for lakes throughout Wisconsin, which indicates Star Lake's aquatic plant community contains a higher number of aquatic plants that are considered to be sensitive to environmental degradation and require high-quality habitats. Given Star Lake's high native species richness and average conservatism values from 2017, Star Lake has a high Floristic Quality Index value of 31.3. This FQI value exceeds the median values for lakes in the ecoregion and the state, and indicates that Star Lake's aquatic plant community is of higher quality than the majority of lakes in the region and throughout Wisconsin.

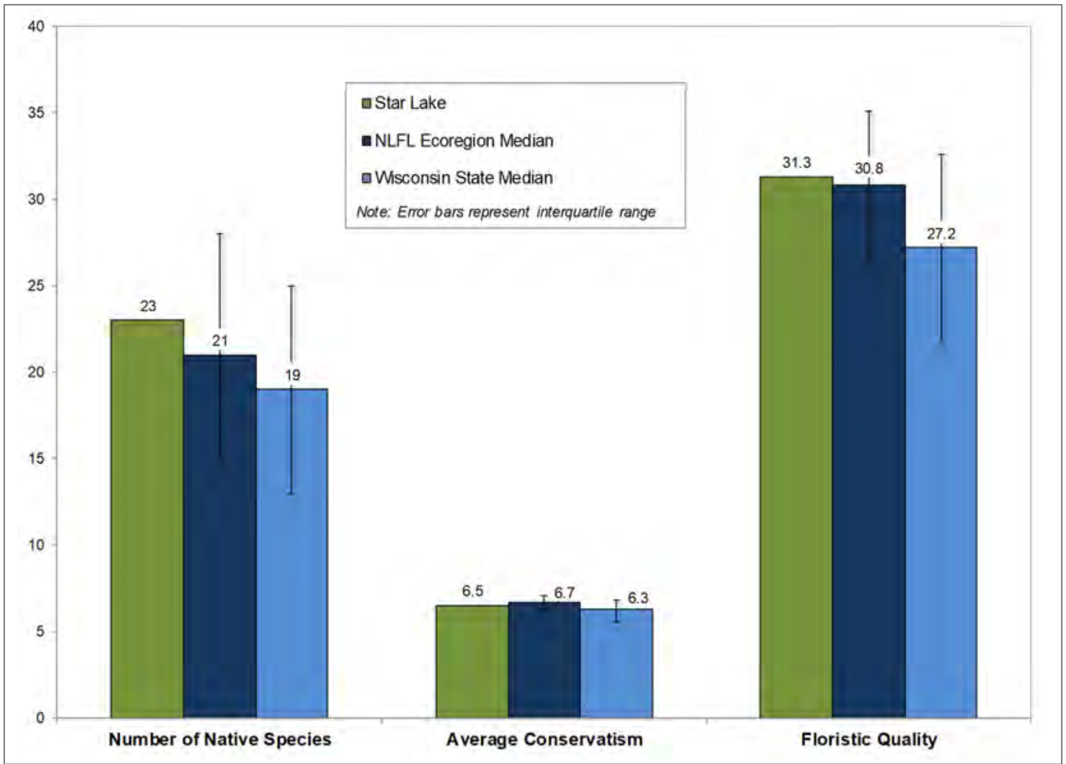


Figure 8.3.4-4. Star Lake Floristic Quality Assessment. Created using data from Onterra 2017 whole-lake point-intercept survey. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Star Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

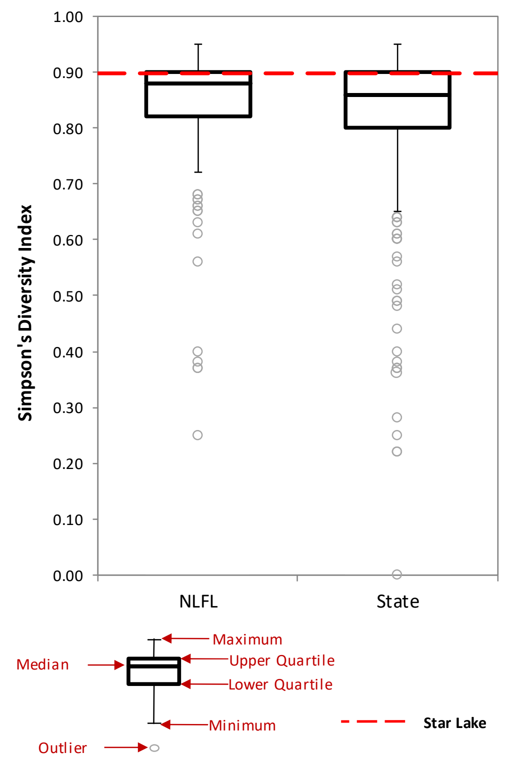


Figure 8.3.4-5. Star Lake species diversity index. Created using data from the Onterra 2017 point-intercept survey.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Star Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 8.3.4-5). Using the data collected from the 2017 point-intercept survey, Star Lake's aquatic plant community is shown to have high species diversity with a Simpson's Diversity Index value of 0.90. In other words, if two individual aquatic plants were randomly sampled from Star Lake in 2017, there would be a 90% probability that they would be different species. This diversity value falls above the median value for lakes in the ecoregion and the state.

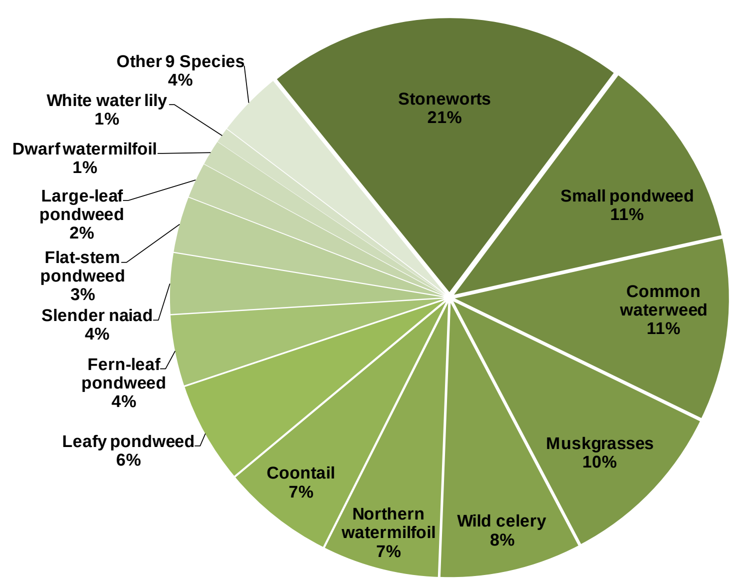


Figure 8.3.4-6. Star Lake 2017 relative frequency of occurrence of aquatic plant species. Created using data from 2017 point-intercept survey.

One way to visualize Star Lake's high species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.3.4-6 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while stoneworts were found at 11% of the littoral sampling locations in Star Lake in 2017, its relative frequency of occurrence is 21%. Explained another way, if 100 plants were randomly sampled from Star Lake in 2017, 21 of them would be stoneworts.

In 2017, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Star Lake. This survey revealed Star Lake contains approximately 13 acres of these communities comprised of 20 different aquatic plant species (Star Lake – Map 7 and Table 8.3.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

Table 8.3.4-2. Star Lake 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2017 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	3.5
Floating-leaf	8.2
Mixed Emergent & Floating-leaf	1.1
Total	**12.9**

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

Non-native Aquatic Plants in 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. Pale-yellow iris was observed growing in shoreline areas of Star Lake in 2017 (Star Lake – Map 7). Control of pale-yellow iris on the Town of Star Lake project lakes will be discussed in the Implementation Plan Section.

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. Populations of purple loosestrife were observed along shoreline areas in Star Lake in 2017 (Star Lake – Map 7). 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. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Control of purple loosestrife on the Town of Plum Lake project lakes will be discussed in the Implementation Plan Section.

8.3.5 Aquatic Invasive Species in Star Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Star Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are six AIS present (Table 8.3.5-1).

Table 8.3.5-1. AIS present within Star Lake

Type	Common name	Scientific name	Location within the report
Plants	Pale-yellow iris	*Iris pseudacorus*	Section 8.3.4 – Star Lake Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 8.3.4 – Star Lake Aquatic Plants
Invertebrates	Chinese mystery snail	*Cipangopaludina chinensis*	Section 8.3.5 – Aquatic Invasive Species in Star Lake
	Banded mystery snail	*Viviparus georgianus*	Section 8.3.5 – Aquatic Invasive Species in Star Lake
	Rusty crayfish	*Orconectes rusticus*	Section 8.3.5 – Aquatic Invasive Species in Star Lake
	Spiny waterflea	*Bythotrephes longimanus*	Section 8.3.5 – Aquatic Invasive Species in Star Lake

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

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

Aquatic Animals

Rusty Crayfish

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

Spiny Water Flea

The spiny water flea (*Bythotrephes longimanus*) first entered the Great Lakes through ship ballast water in the 1980s. They are ¼ to ½ inches in length so individuals are not generally seen with the naked eye, but spiny water fleas will gather in masses on fishing lines or downrigger cables. They eat small, native zooplankton and are direct competitors with juvenile fish. Small fish are unable to eat the spiny water fleas due to their long, spiny tails. At this time, there is no control method to control the spiny water flea. The UW-Center for Limnology has done extensive research on the spiny water flea and its introduction to Lake Mendota. Their findings show that the spiny water flea eats Daphnia, a main consumer of algae, which then causes the lake to become greener due to an absence of algae predator (Hinterthuer 2015). Basically, spiny water fleas can be detrimental to a lake's water quality because they eat the organism that eats the algae causing algae to become more prevalent

Mystery snails

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

8.3.6 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 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 2017 & GLIFWC 2017).

Star Lake Fishery

Energy Flow of a Fishery

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.3.6-1.

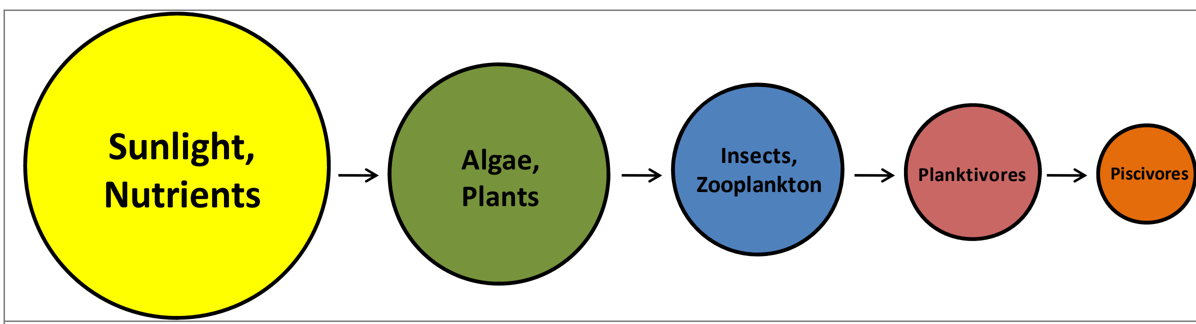


Figure 8.3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Star Lake is oligotrophic, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small. Table 8.3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past surveys of Star Lake include burbot (*Lota lota*), white sucker (*Catostomus commersonii*) and the golden shiner (*Notemigonus crysoleucas*).

Table 8.3.6-1. Gamefish present in Star Lake with corresponding biological information (Becker 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Cisco (*Coregonus artedii*)	22	Late November - Early December	Various shoreline substrates.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates.
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 8.3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electroshocking (Photograph 8.3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

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

Photograph 8.3.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 8.3.6-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Star Lake was stocked from 1973 to 2017 with walleye and muskellunge (Tables 8.3.6-2 and 8.3.6-3). Star Lake is considered a naturally producing walleye lake according to the WDNR.

Photograph 8.3.6-2. Fingerling Muskellunge.

Table. 8.3.6-2. Stocking data available for walleye in Star Lake (1974-1997).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Unspecified	Fingerling	24,100	3
1975	Unspecified	Fingerling	7,000	3
1976	Unspecified	Fingerling	7,000	3
1977	Unspecified	Fingerling	7,000	3
1978	Unspecified	Fingerling	7,000	2
1984	Unspecified	Fingerling	8,645	3
1997	Unspecified	Large Fingerling	28,968	2.1

Table 8.3.6-3. Stocking data available for muskellunge in Star Lake (1973-2017).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1973	Unspecified	Fingerling	1,100	12
1976	Unspecified	Fingerling	1,500	11
1978	Unspecified	Fingerling	1,534	10
1984	Unspecified	Fingerling	1,800	9
1985	Unspecified	Fingerling	1,000	12
1986	Unspecified	Fingerling	508	10
1988	Unspecified	Fingerling	1,150	10
1990	Unspecified	Fingerling	1,150	11
1991	Unspecified	Fingerling	600	11.5
1992	Unspecified	Fingerling	600	11
1993	Unspecified	Fingerling	1,200	10
1993	Unspecified	Fry	29,700	0.4
1994	Unspecified	Fry	25,000	0.4
1997	Unspecified	Large Fingerling	600	10.7
1999	Unspecified	Large Fingerling	585	11.6
2001	Unspecified	Large Fingerling	1,206	10.2
2003	Unspecified	Large Fingerling	1,206	10.5
2005	Unspecified	Large Fingerling	1,206	11.1
2007	Upper Wisconsin River	Large Fingerling	402	12.1
2009	Upper Wisconsin River	Large Fingerling	603	9.9
2011	Upper Wisconsin River	Large Fingerling	603	9.3
2013	Upper Wisconsin River	Large Fingerling	301	9.2
2015	Upper Wisconsin River	Large Fingerling	301	11.8
2017	Upper Wisconsin River	Large Fingerling	193	10.8

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second most important reason for owning property on or near Star Lake (Question #18). Figure 8.3.6-2 displays the fish that Star Lake stakeholders enjoy catching the most, with walleye, smallmouth bass and bluegill/sunfish being the most popular. Approximately 81% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 8.3.6-3). Approximately 81% of respondents who fish Star Lake believe the quality of fishing is somewhat worse or much worse since they started fishing the lake (Figure 8.3.6-4).

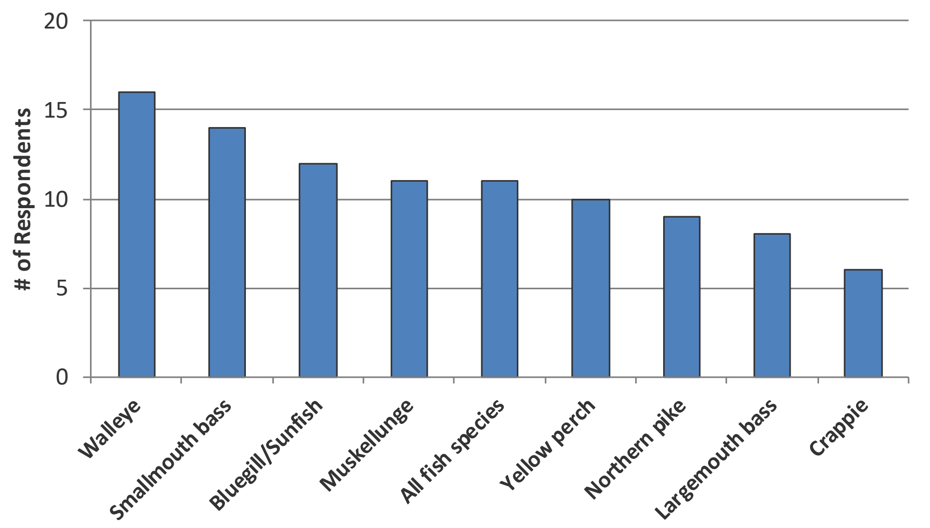


Figure 8.3.6-2. Stakeholder survey response Question #12. What species of fish do you like to catch on Star Lake?

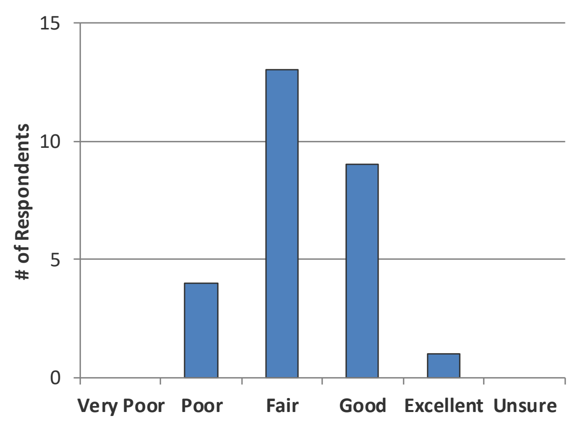


Figure 8.3.6-3. Stakeholder survey response Question #13. How would you describe the current quality of fishing on Star Lake?

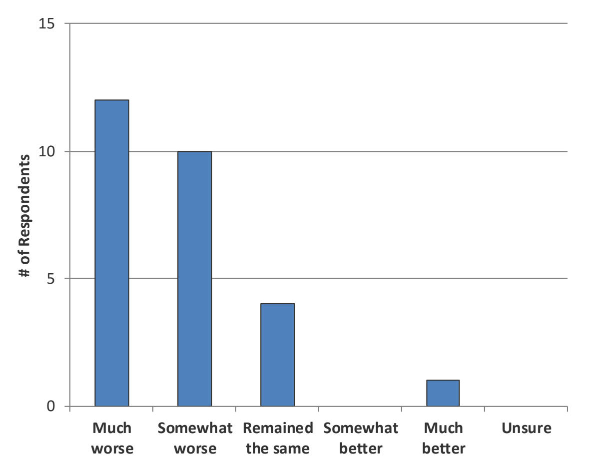


Figure 8.3.6-4. Stakeholder survey response Question #14. How has the quality of fishing changed on Star Lake since you started fishing the lake?

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. A creel survey was completed on Star Lake during the 1993-94, 1997-98 and 2005-06 fishing seasons (Table 8.3.6-4).

Total angler effort was highest during the 1997-98 (22.3 hours/acre) compared to the most recent 2005-06 creel season (12.4 hours/acre). During all creel surveys anglers directed the largest amount of effort towards walleye and muskellunge (Table 8.3.6-4).

Table 8.3.6-4. Creel Survey data fro 1993-1994, 1997-1998, and 2005-2006 fishing seasons (WDNR 2017).

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Largemouth Bass	1997	22.3	0.3	12	0	0	0		
	2005	12.4	0.2	11	0	0			
Muskellunge	1993	16.6	7.3	33	0	2	0	303	5,000.00
	1997	22.3	5.5	89	0.1	0	0	103.1	
	2005	12.4	3.1	67	0.1	2	0	82	2,000.00
Northern Pike	1993	16.6	1.1	757	0.6	196	0.2	15.4	44.1
	1997	22.3	3.7	2337	1.9	540	0.4	5.8	15.1
	2005	12.4	1.2	464	0.4	128	0.1	14.2	21.1
Smallmouth Bass	1993	16.6	0.2	73	0.1	12	0	11.6	70.4
	1997	22.3	1	205	0.2	12	0	13	
	2005	12.4	0.8	516	0.4	22	0	2.6	41.8
Walleye	1993	16.6	8	2873	2.4	604	0.5	3.4	16
	1997	22.3	13.2	5639	4.7	2884	2.4	2.9	5.6
	2005	12.4	7.1	1844	1.5	1019	0.8	4.7	8.4

Fish Populations and Trends

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

The gamefish present on Star Lake represent different population dynamics depending on the species. An overview of the population estimates for walleye are provided in Figure 8.3.6-5. Muskellunge population estimates have only been calculated for 2005 and was estimated to be 118.

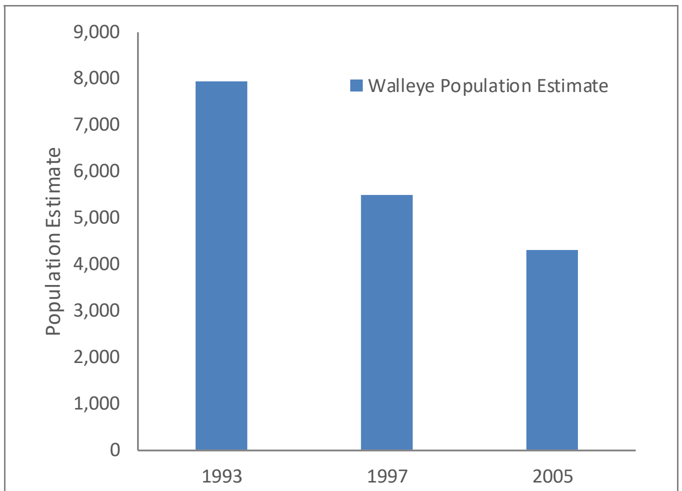


Figure 8.3.6-5. Population estimates for walleye and muskellunge (WDNR 2015)

Star Lake Spear Harvest Records

Figure 8.3.6-6. Location of Star Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.3.6-6). Star Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. By March 15th of each year the relevant Indian communities may declare a proportion of the total Safe Harvest on each lake; this declaration represents the maximum number of fish that can be taken by tribal spearers or netters annually (Spangler, 2009). Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

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

24 inches and one of any size over 20 inches (GLIFWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Walleye open water spear harvest records are provided in Figure 8.3.6-7 from 2001 to 2017. As many as 513 walleye have been harvested from the lake in the past (2016), but the average harvest is roughly 293 fish in a given year. Spear harvesters on average have taken 98% of the declared quota. Additionally, on average 9% of walleye harvested have been female.

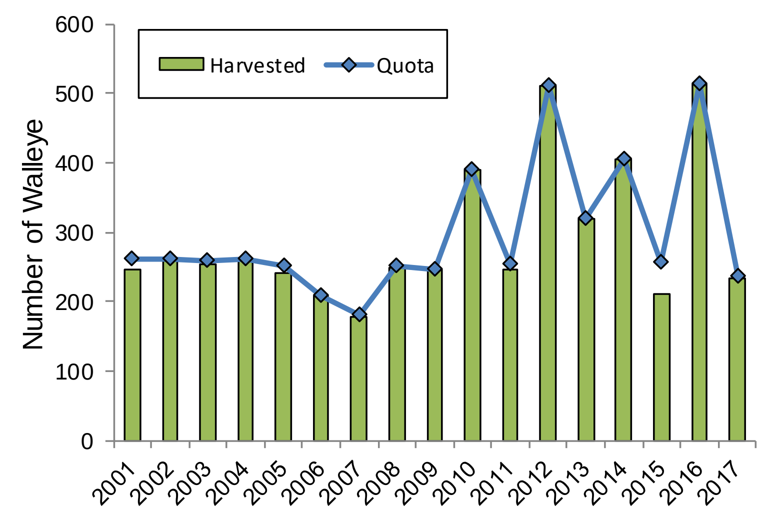


Figure 8.3.6-7. Star Lake walleye spear harvest data. (GLIFWC 2001-2017).

Muskellunge open water spear harvest records are provided in Figure 8.3.6-8 from 2001-2017. As many as 11 muskellunge have been harvested from the lake in the past (2005), however the average harvest is 4 fish in a given year. Spear harvesters on average have taken 34% of the declared quota.

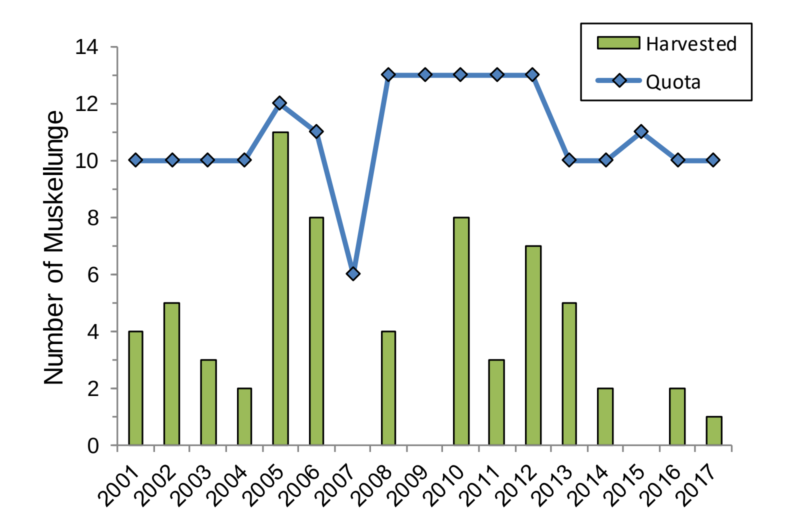


Figure 8.3.6-8. Star Lake muskellunge spear harvest data. (GLIFWC 2001-2017).

Star Lake Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2017, 45% of the substrate sampled in the littoral zone of Star Lake were soft sediments, 35% composed of sand and 20% composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006). A fall 2017 survey documented 584 pieces of coarse woody along the shores of Star Lake, resulting in a ratio of approximately 48 pieces per mile of shoreline.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 8.3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


Photograph 8.3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

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

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 8.3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

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

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

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

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

Regulations

Regulations for Star Lake gamefish species as of April 2018 are displayed in Table 8.3.6-5. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 8.3.6-5. WDNR fishing regulations for Star Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	1	18"	June 16, 2018 to March 3, 2019
Largemouth bass	1	18"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	None but only 1 fish over 14" is allowed	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

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

Mercury Contamination and Fish Consumption Advisories

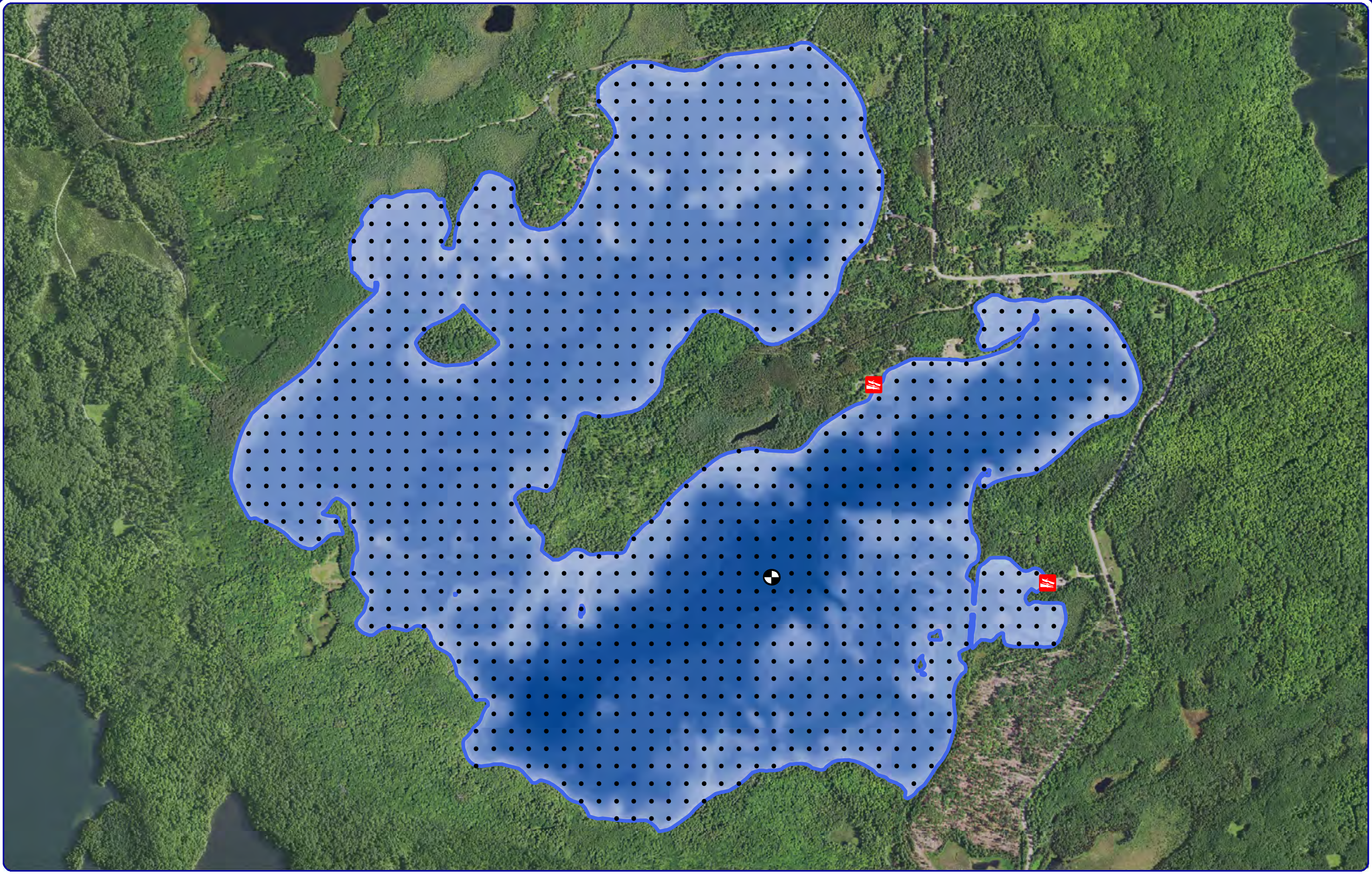
Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated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

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.3.6-9. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

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

Figure 8.3.6-9. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)



N
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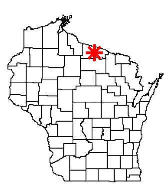
1,500
Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP, 2015
Map Date: April 17, 2018
Filename: *Map1_Star_Location.mxd*



Project Location in Wisconsin

Legend

Star Lake ~1,219 acres
WDNR Definition

Public Access

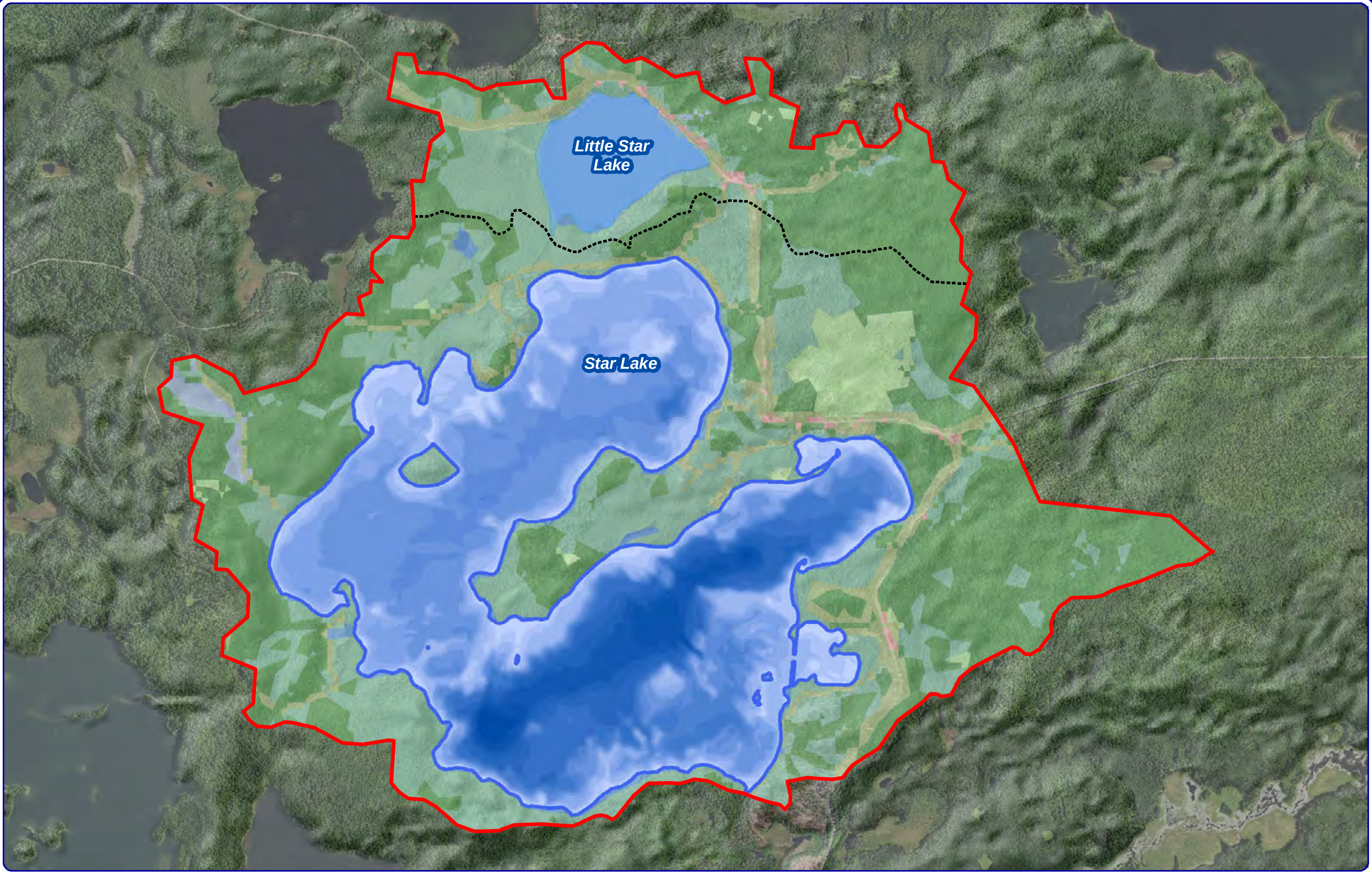
Water Quality
Sampling Location

Point-intercept Sample Location
65 meter points

Star Lake - Map 1

Town of Plum Lake
Vilas County, Wisconsin

Project Location & Lake Boundaries



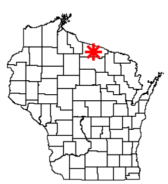
Star Lake - Map 2

Town of Plum Lake

Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types

2,200
Feet



Project Location in Wisconsin

Legend

Land Cover Types

- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Rural Residential
- Star Lake Watershed Boundary
- Subwatershed Boundary
- River/Stream

Sources:
Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP 2015
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017
Map Date: October 31, 2017
Filename: *Map2_Star_WS.mxd*

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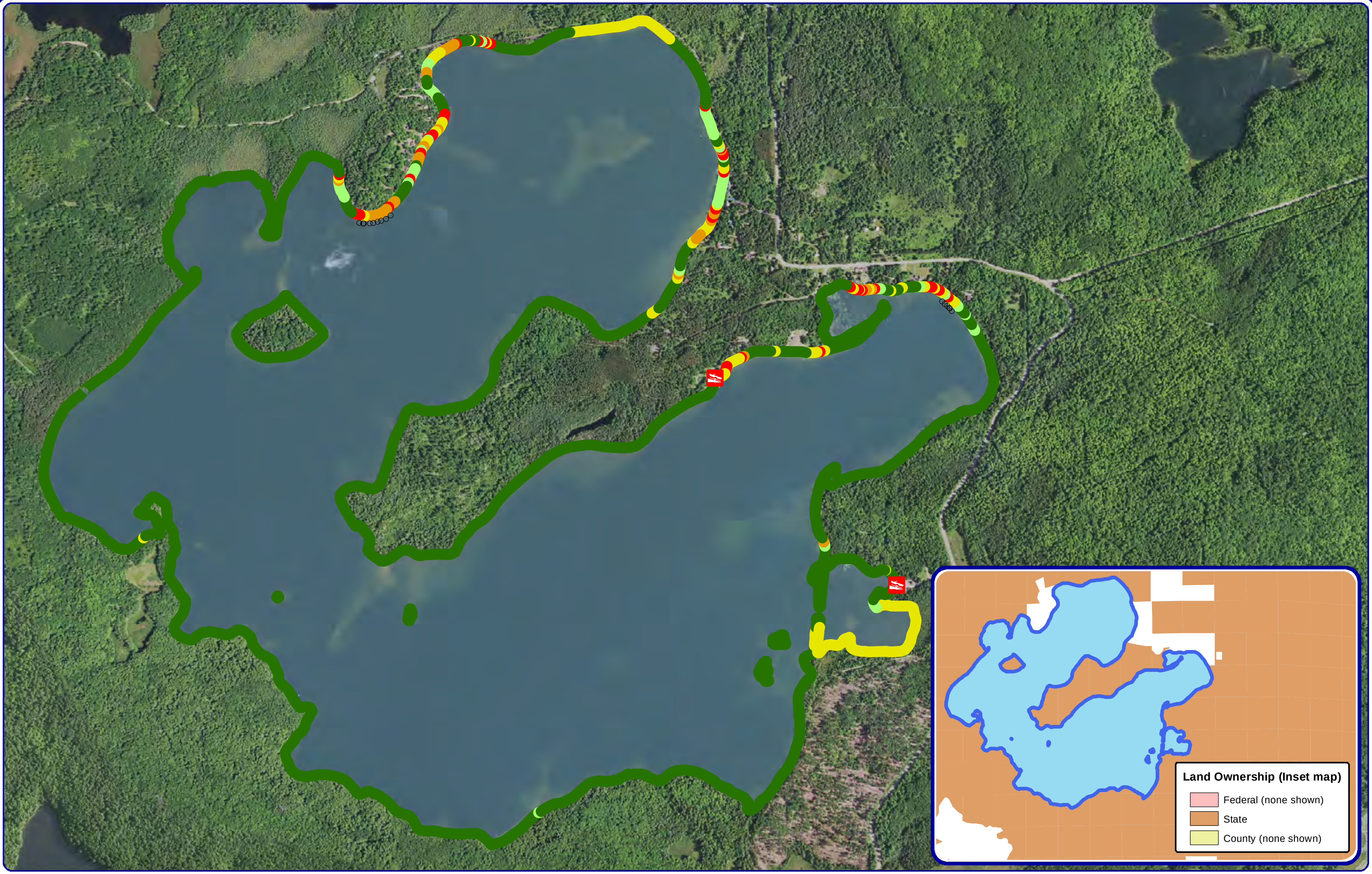

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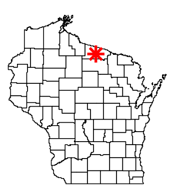
Project Location in Wisconsin

Legend

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

Seawall
Rip-Rap

Star Lake - Map 3

Town of Plum Lake
Vilas County, Wisconsin

2017 Shoreland Condition

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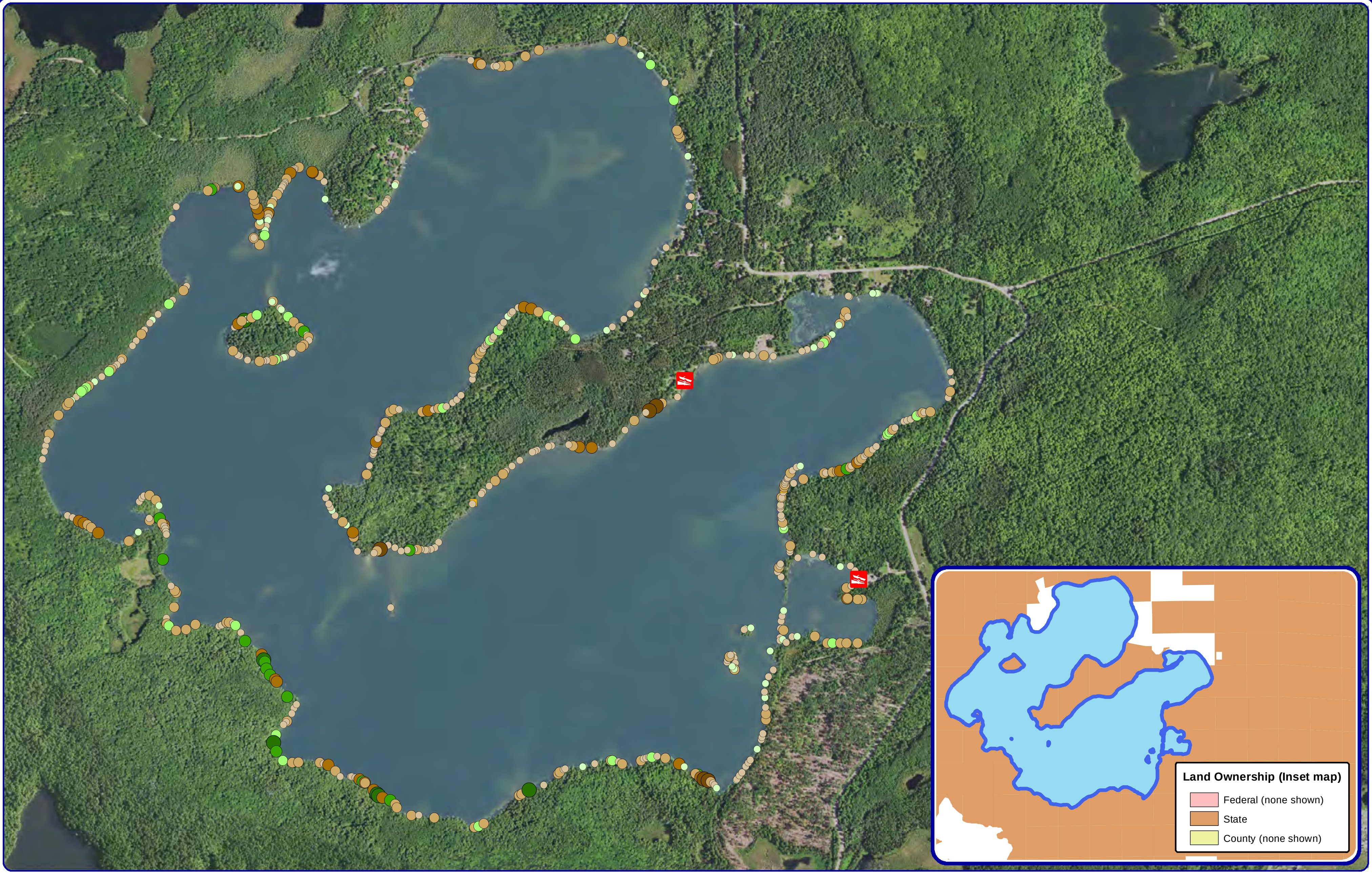
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2017
Map Date: November 1, 2017
Filename: Map3_Star_ShorelandCondition_2017.mxd



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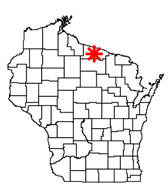

Project Location in Wisconsin

Legend

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

Star Lake - Map 4

Town of Plum Lake

Vilas County, Wisconsin

Coarse Woody Habitat

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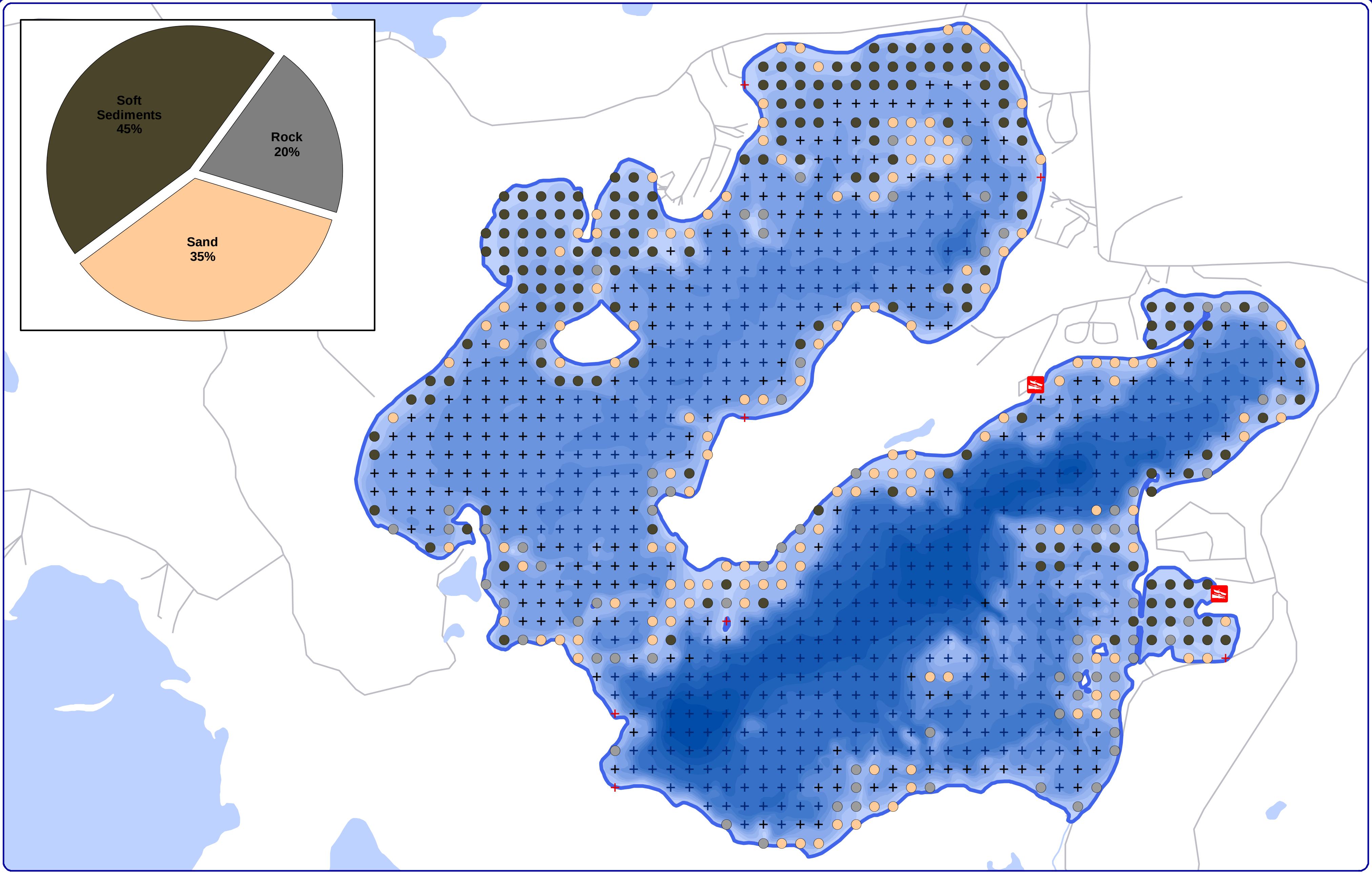
www.onterra-eco.com

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: November 1, 2017
Filename: Map4_Star_CWH_2017.mxd



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1,400
Feet

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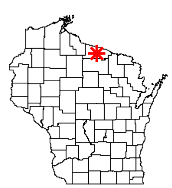
Sources:
Hydro and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: Map5_Star_SubstratePI_2017.mxd



Project Location in Wisconsin

Legend

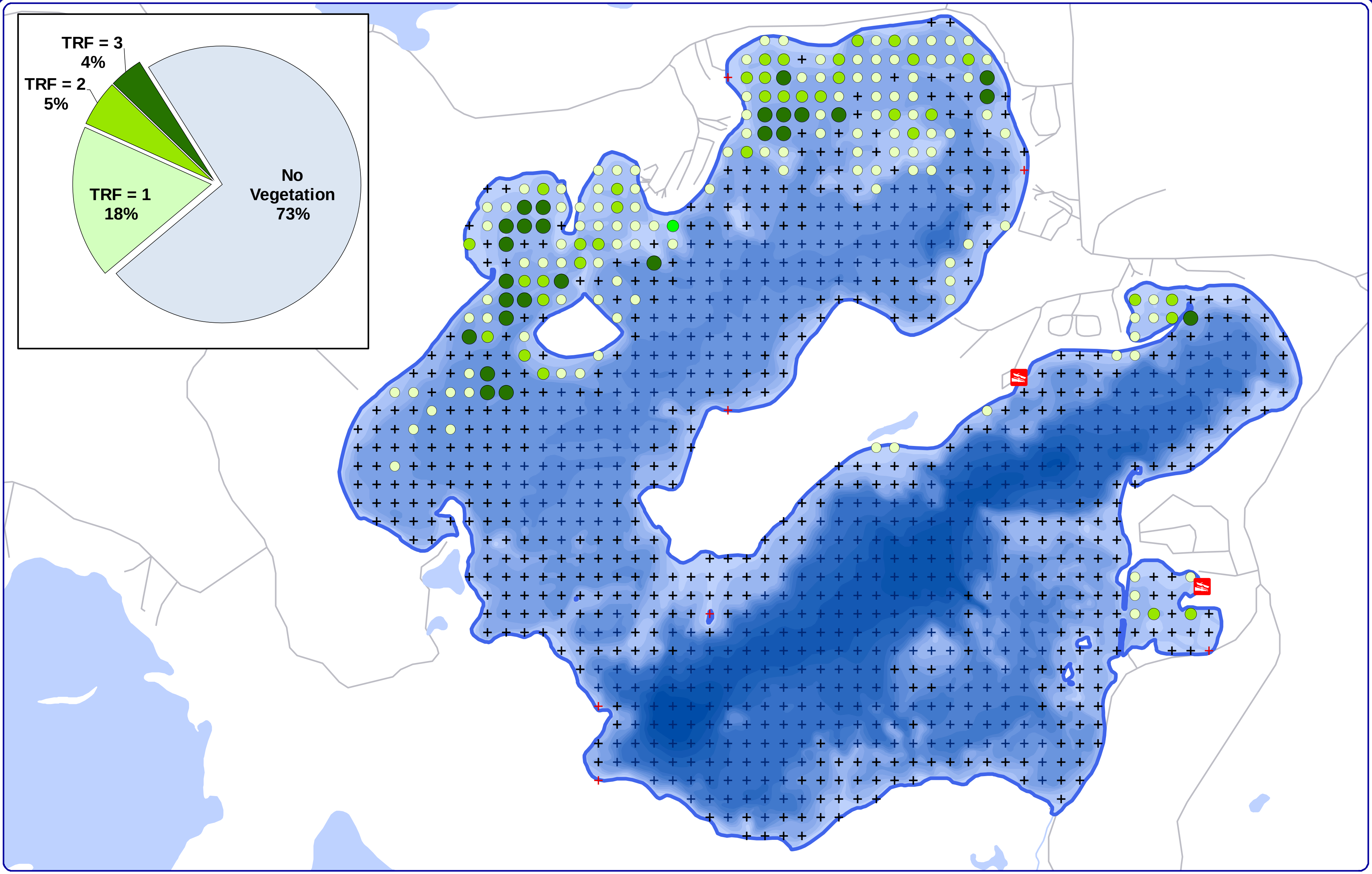
- Soft/Organic Sediments
- Rock
- Sand
- Too Deep
- Non-navigable

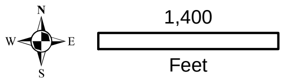
Star Lake - Map 5

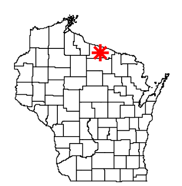
Town of Plum Lake

Vilas County, Wisconsin

2017 PI Survey: Substrate Types







Legend

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

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Sources:
Hydro and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2017
Map Date: November 17, 2017
Filename: Map6_Star_TRFPI_2017.mxd

Star Lake - Map 6

Town of Plum Lake
Vilas County, Wisconsin

2017 PI Survey: Aquatic Vegetation Distribution

N W E S

1,400

Feet

Legend

Large Plant Communities

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

Small Plant Communities

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

Exotic Plant Communities

- Purple Loosestrife
- Pale Yellow Iris

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Sources:
Hydro: WDNR
Orthophotograph: NAIP 2015
Plant Survey: Onterra, 2017
Map Date: August 14, 2017
Filename: *Map7_Star_Comm_2017.mxd*

Star Lake - Map 7

Town of Plum Lake

Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities