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

8.1 Virgin Lake

An Introduction to Virgin Lake

Virgin Lake, Oneida County, is a drainage lake with a maximum depth of 31 feet and a surface area of 276 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Virgin Lake contains 48 native plant species, of which flat-stem pondweed was the most common plant. One exotic plant, Eurasian water milfoil, was observed in 2010.

Field Survey Notes

Many species observed during aquatic plant surveys. Several bryozoans (aquatic invertebrates consisting of colonies of microscopic organisms called "zooids" – pictured to the right), *some relatively large in size, spotted as well.*

Small colony of Eurasian water milfoil discovered during point-intercept survey, roughly 20 ft. in diameter. Area marked with GPS.

Photo 8.1 Bryozoan from Virgin Lake, Oneida County

Lake at a Glance* – Virgin Lake

Morphology	
Acreage	276
Maximum Depth (ft)	31
Mean Depth (ft)	13
Volume (acre-feet)	3,638
Shoreline Complexity	2.0
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 4 & 5, 2010
Number of Native Species	48
Threatened/Special Concern Species	*Potamogeton vaseyi* (Vasey's pondweed)
Exotic Plant Species	Eurasian water milfoil
Simpson's Diversity	0.94
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	65:1

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

8.1.1 Virgin Lake Water Quality

Water quality data was collected from Virgin Lake on six occasions in 2010/2011. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity for almost two decades (1994-2011). These efforts provide a considerable amount of historical data, which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Virgin Lake.

Unfortunately, very limited data exists for the other two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2010, average summer phosphorus concentrations (14.3 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state. Similarly, summer average chlorophyll-*a* concentrations (4.4 µg/L) were slightly less than the median value (7.0 µg/L) for other lakes of this type. Both of these values 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 2010 visits to the lake, Onterra ecologists recorded field notes describing good water conditions, though slightly stained water. As explained below, the stained water is not due to nutrients or another form of pollution.

From the examination of two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Virgin Lake's water can be described as *Excellent* in most years (Figure 8.1.1-1). A weighted average over this timeframe is above the median value for other deep, headwater lowland lakes in the state. Secondly, with exception to 2011, there is very little variation seen in this data set. In 2011, Onterra ecologists noted exceptionally stained water during visits to monitor a small Eurasian water milfoil infestation (see the Aquatic Plant Section for more details on this). Similar stained water was observed on the other lakes in the Three Lakes Chain of lakes, as well as other lakes within the Northwoods of Wisconsin.

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 Virgin Lake as well as the other lakes in the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Virgin Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

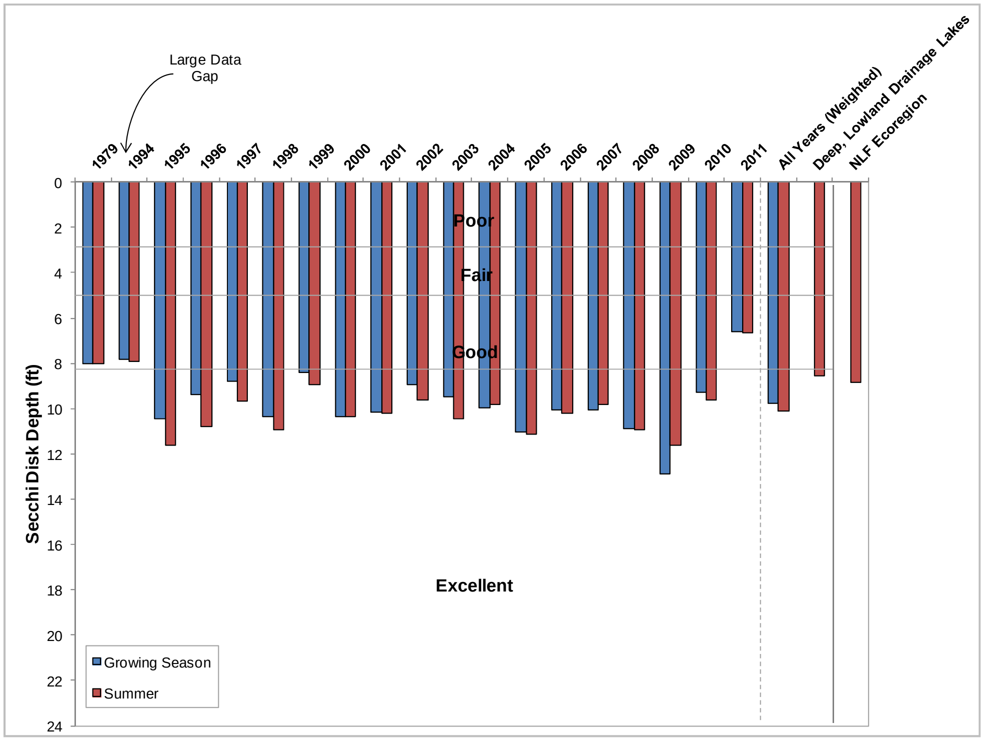


Figure 8.1.1-1. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Virgin 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 8.1.1-2). 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 Virgin Lake is in a mesotrophic state.

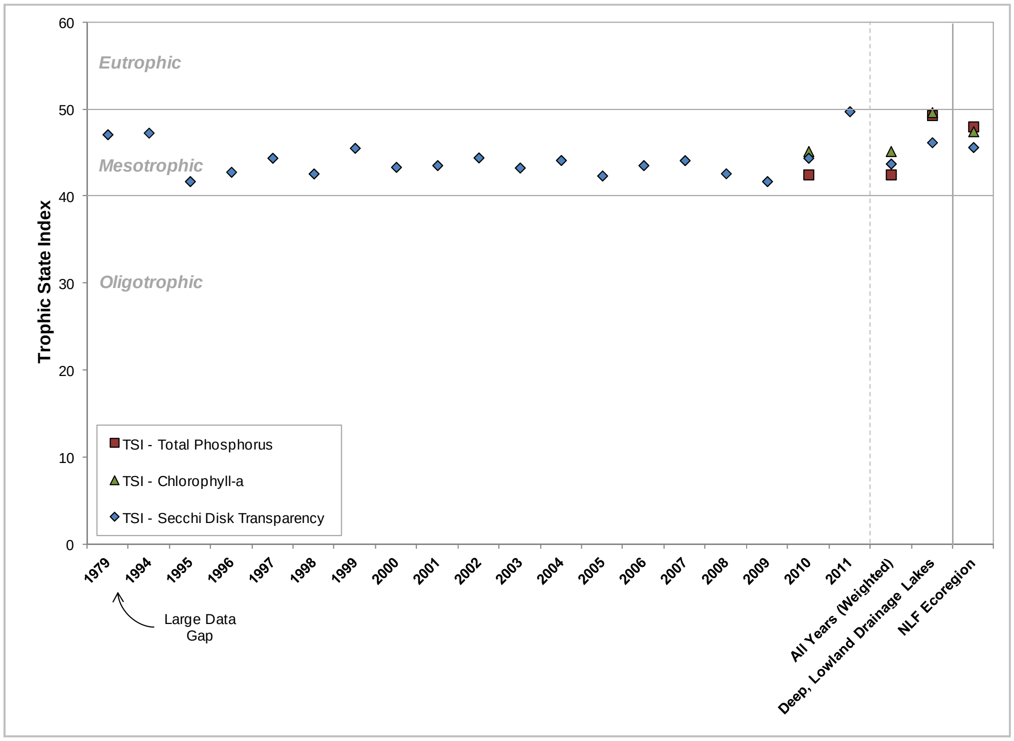


Figure 8.1.1-2. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Virgin Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Virgin Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-3 for all sampling events.

Virgin 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 bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in fairly deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

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 2011, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

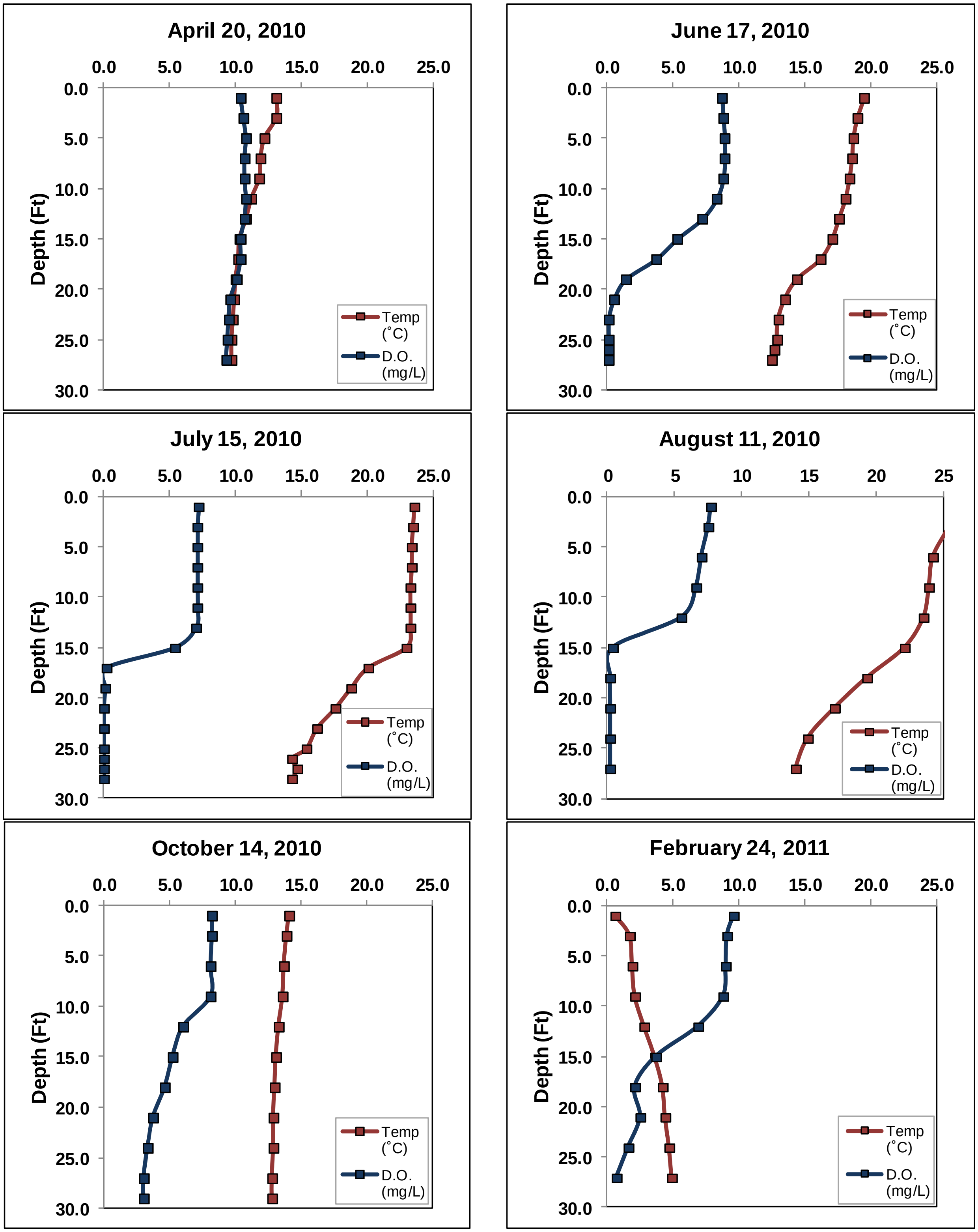


Figure 8.1.1-3. Virgin Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Virgin 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 Virgin 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. Virgin Lake's surface water pH was measured at roughly 7.8 during summer 2010. This value is near neutral and falls within the normal range for Wisconsin lakes.

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 Virgin Lake was measured at 48.2 (mg/L as $CaCO_3$), indicating 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 Virgin Lake during the summer of 2010. 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 Virgin Lake's pH of 7.8 - 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Virgin Lake was found to be 12.0 mg/L, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (zebra mussels in the larval form) were found within these samples.

8.1.2 Virgin Lake Watershed Assessment

Virgin Lake's watershed is 18,268 acres in size. Compared to Virgin Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 65:1.

Exact land cover calculation and modeling of nutrient input to Virgin Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.1.3 Virgin Lake Shoreland Condition

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 2010, Virgin Lake's immediate shoreline was assessed in terms of its development. Virgin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles (25% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). 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, 0.6 miles of urbanized and developed–unnatural shoreline (20% of the total shoreline) was observed. If restoration of the Virgin 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. Virgin Lake Map 1 displays the location of these shoreline lengths around the entire lake.

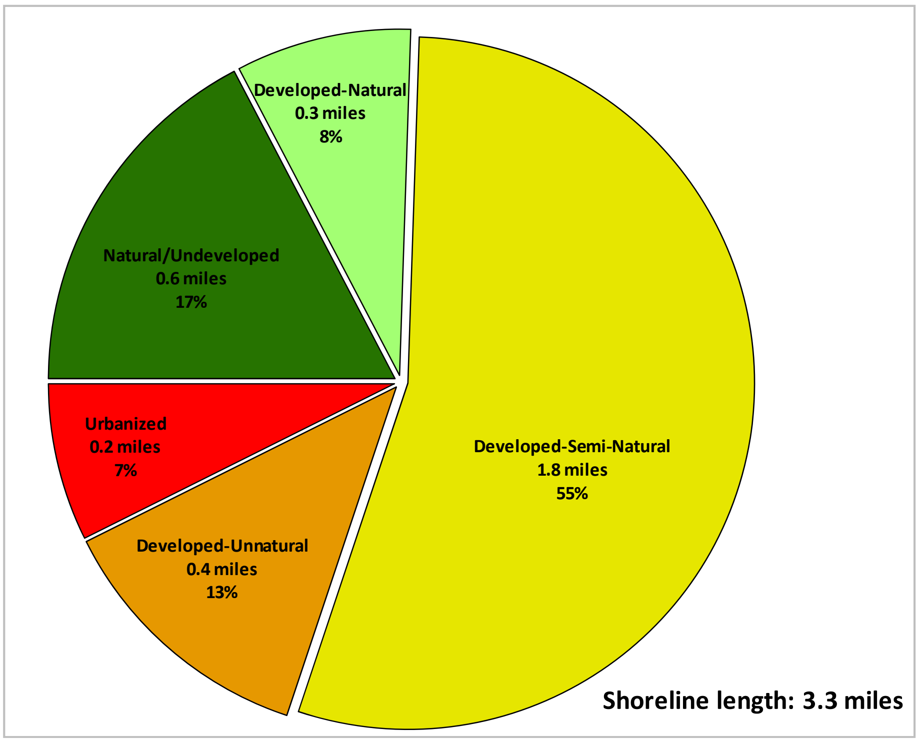


Figure 8.1.3-1. Virgin Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Virgin Lake Map 1.

8.1.4 Virgin Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Virgin Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Virgin Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Virgin Lake on August 4 & 5, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Virgin Lake Map 2) during this time. During all surveys, 48 species of native aquatic plants were located in Virgin Lake (Table 8.1.4-1). 33 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 15 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. 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. One aquatic plant that was found during the 2010 surveys, Vasey's pondweed (*Potamogeton vaseyi*) is listed by the Natural Heritage Inventory (NHI) Program as a species of special concern in Wisconsin.

Of the 181 point-intercept locations sampled within the littoral zone, approximately 62% contained aquatic vegetation. Approximately 51% of the point-intercept sampling locations where sediment data was collected at were sand, 34% consisted of a fine, organic substrate (muck) and 15% were determined to be rocky.

Table 8.1.4-1. Aquatic plant species located in the Virgin Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex lacustris*	Lake sedge	6	I
	Carex lasiocarpa	Wooly-fruit sedge	9	I
	Carex utriculata	Northwest Territory sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus subterminalis	Water bulrush	9	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Zizania palustris	Northern wild rice	8	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
	Polygonum punctatum	Dotted smartweed	5	I
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	I
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Eriocaulon aquaticum	Pipewort	9	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes echinospora	Spiny-spored quilwort	8	I
	Isoetes lacustris	Lake quillwort	8	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus flammula	Creeping spearwort	9	X
	Ranunculus aquatilis	White water-crowfoot	8	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	I

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent;
X = Located on rake during point-intercept survey; I = Incidental Species

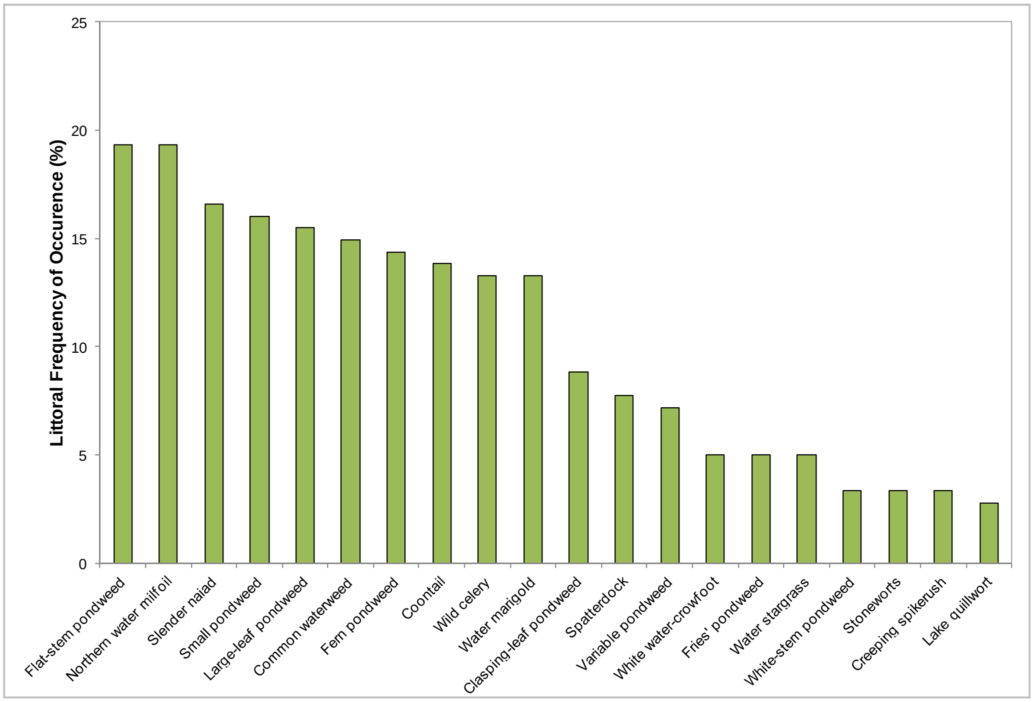


Figure 8.1.4-1 Virgin Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.1.4-1 (above) shows that flat-stem pondweed, northern water milfoil, and slender naiad were the most frequently encountered plants within Virgin Lake. 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.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and Eurasian water milfoil) were located from Virgin Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic. Eurasian water milfoil, an exotic relative of northern water milfoil, was found within Virgin Lake as well. Because of its significance, details of Eurasian water milfoil's presence in Virgin Lake will be discussed towards the end of this section and within the Implementation Plan.

An incredible 48 species of native aquatic plants (including incidentals) were found in Virgin Lake, along with one non-native plant. 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 Virgin Lake's plant community (0.94) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 northern water milfoil was found at 19% of the sampling locations, its relative frequency of occurrence is 9%. Explained another way, if 100 plants were randomly sampled from Virgin Lake, 9 of them would be northern water milfoil. This distribution can be observed in Figure 8.1.4-2, where together 10 species account for 71% of the population of plants within Virgin Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.1.4-1 as incidentals.

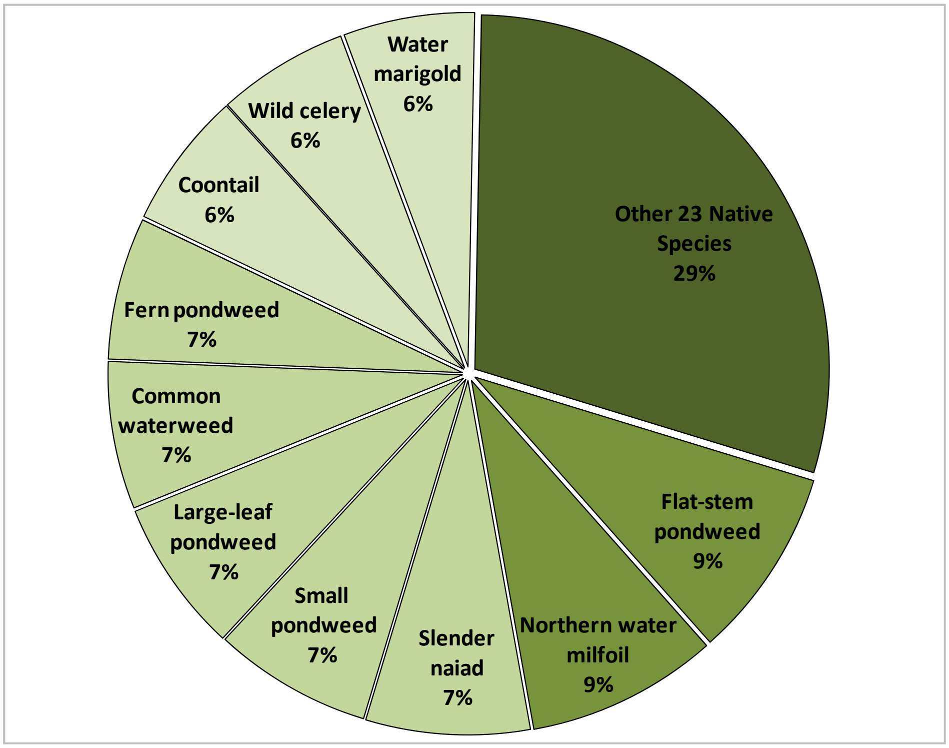


Figure 8.1.4-2 Virgin Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Virgin Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Virgin Lake is indicative of an undisturbed system. This is not surprising considering Virgin Lake's plant community has great diversity and high species richness. Combining Virgin Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 40.8 which is well above the median values of the ecoregion and state.

The quality of Virgin Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.6 acres of the lake contains these types of plant communities (Virgin Lake

Map 2, Table 8.1.4-2). Fifteen floating-leaf and emergent species were located on Virgin Lake (Table 8.1.4-1), all of which provide valuable wildlife habitat.

Table 8.1.4-2. Virgin Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	1.6
Floating-leaf	8.4
Mixed Floating-leaf and Emergent	5.6
Total	15.6

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 Virgin 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.

Aquatic Invasive Species in Virgin Lake

Virgin Lake is currently monitoring a small Eurasian water milfoil population (Virgin Lake Map 3). During the point-intercept survey in August of 2010, Onterra staff located a small plant colony just south-west of the Virgin Lake island. The colony measured approximately 15-feet in diameter, and was located within a depth of about 8 to 9 feet. Although the colony was too large to remove from a boat using a rake, several plants located outside of the main colony were removed. Onterra staff marked the colony with GPS coordinates as well as temporary buoys, and the proper communications ensued with TWLA planning committee members and WDNR personnel. Shortly after that time, TWLA volunteers placed more permanent buoys around the colony to alert boaters to its presence, in hopes of reducing fragmentation of the plants.

On July 8, 2011, Onterra staff visited Virgin Lake to hand harvest Eurasian water milfoil plants located within the colony. Because of the relatively shallow depth, snorkeling gear was utilized. Two staff members repeatedly swam to the lake bottom and removed Eurasian water milfoil by the roots of the plant. Plants were carefully placed into mesh bags following extraction from the sediment. A third staff member remained in the boat, unloading the mesh bags periodically from the snorkelers and grabbing plant fragments from the water with a pool skimmer on an extendable pole. Weather conditions were good, however visibility into the water column and under the water was impaired by the naturally stained water of the lake. One laundry basket (approximately 50-70 plants) was filled following the removal efforts, which lasted a little over an hour, and no plants were observed on post-removal inspection of the area.

Photo 8.1.4-1 a) Virgin Lake Eurasian water milfoil hand harvesting, and **b) Hand harvesting results.** Hand harvesting occurred in July and September of 2011.

Following reports from TLWA members that more Eurasian water milfoil existed within the previously marked colony, Onterra staff members revisited the lake on September 8th to conduct plant removal again. This time, three staff slipped on donned snorkeling gear while a fourth staff member emptied mesh bags and scooped plant fragments from the surface with a pool skimmer on an extendable pole. About 35 plants were pulled during this time, though stained water was again an issue the snorkelers faced and some single plants were likely left behind.

On July 3, 2012, Onterra staff once again visited Virgin Lake to hand remove Eurasian water milfoil plants. Donning SCUBA gear this time, three staff members entered the water hoping to spend more time near the substrate and get a better grasp on the extent of milfoil growth. A fourth staff member stayed aboard a nearby boat, coordinating the three SCUBA divers, emptying mesh harvesting bags and planning to catch stray fragments with a pool skimmer. Soon after the divers entered the water, they observed that the colony had expanded only slightly in size, but increased very much in density. In addition to many "tall" plants, a good number of plants were very short in stature and not visible from the surface. The biomass was too much to hand remove, so their attention turned towards determining the outer extents of the colony and identifying outlier plants by swimming transect lines from the center of the population.

Following this survey, discussions were held between Onterra staff, TLWA board members and WDNR staff. It was decided that an aggressive approach – a mid-summer 2,4-D herbicide application, was necessary in order to bring the rapidly expanding colony under control and reduce plant auto fragmentation. A treatment of 0.9 acres at 4.0 ppm 2,4-D herbicide, which is the maximum label rate, was conducted in mid-July of 2012.

The infestation of Eurasian water milfoil in Virgin Lake is still in its infancy, and has been aggressively attacked and monitored since its discovery. At this point in time, continued monitoring of the entire lake is necessary to identify expansion of the known colony and also identify any additional areas where Eurasian water milfoil may be located. Onterra staff will continue to visit the known Eurasian water milfoil colony and determine the appropriate course of action, be it herbicide application or hand-removal methods.

8.1.5 Virgin Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Virgin Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Virgin Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Virgin Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Virgin Lake's implementation plan is compiled by describing how Virgin Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Virgin Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Virgin Lake as part of this chain-wide management planning project, it is up to Virgin Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Virgin Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Virgin Lake does not contain a public access and because of this, the threat of introduction of aquatic invasive species is reduced from transient boaters. However, in lakes without a single public access, often lake residents (and friends and family) access the lake on their individual properties. This essentially creates the potential to have numerous points on a lake where different boats with different owners may be entering occasionally.

Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Virgin Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Virgin Lake or from Virgin Lake elsewhere. If a Virgin Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Virgin Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Because of the current population of Eurasian water milfoil on the lake, professional surveys are encouraged (see next management action), however having more "eyes on the water" increases the odds of spotting early pioneer colonies of Eurasian water milfoil should they develop.

Management Action: Continue aggressive control strategy for early-stage Eurasian water milfoil population

Description: As a part of Phase I of this project (2010), a small colony of Eurasian water milfoil was discovered within Virgin Lake. Because of its size, it is believed this is a very recent introduction. As outlined within the Aquatic Plant Section, the small colony was first addressed with hand-removal efforts, with several visits by Onterra ecologists in summer of 2011 and again in 2012. In 2012, four Onterra SCUBA certified ecologists visited the lake to hand harvest once again. Unfortunately, underwater observations indicated the biomass of the colony was more substantial than that which was observed the previous summer. The amount of plant encountered was in fact too much for hand removal, and an aggressive strategy was enacted to conduct an herbicide treatment upon the colony. This treatment occurred in July, which is somewhat atypical, but warranted given the rapidly growing/expanding nature of the colony.

The TLWA will continue to have professional monitoring conducted on the Eurasian water milfoil colony, as well as the rest of Virgin Lake. Continuing with an aggressive strategy on this early, relatively small population, the TLWA and Virgin Lake riparian property owners should be prepared to continue herbicide applications on the Eurasian water milfoil colony. Monitoring costs can be supported through a WDNR Aquatic Invasive Species Early Detection and Response grant, which would fund three years (2012, 2013 and 2014) of treatments and professional monitoring. Eurasian water milfoil management in Virgin Lake (monitoring and control) will combine an integrated approach of manual removal by certified SCUBA divers and volunteers as well as herbicide applications, and will be conducted in the following format:

Spring Pretreatment Confirmation & Refinement Surveys (April/May)

In April/May of each year during this project, Onterra ecologists would visit areas marked through the summer 2012 mapping survey to verify the growth of Eurasian water milfoil. A qualitative assessment would be completed at this time (prior to herbicide applications) to verify treatment area extents. This survey would determine if colonial expansion had occurred from the previous year and would be utilized to determine the final treatment areas. An herbicide treatment would occur in late spring/early summer of 2013 upon the colonies observed during this survey. Subsequent spring pretreatment surveys would deliver information about the Eurasian water milfoil colonies and from there, the appropriate strategy (herbicide treatment, hand-removal efforts, etc.) would be determined.

Early-Season Aquatic Invasive Species Surveys (June)

A survey would be conducted in June of each project year to search the entire littoral zone of Virgin Lake for aquatic invasive species. Water clarity is greater at this time of year, and native plants have just begun their growth and thus are lower in the water column than Eurasian water milfoil, which grows rapidly in the spring. Thus, this is an excellent time of year for spotting aquatic invasive species colonies. Locations of Eurasian water milfoil colonies identified during this survey would be marked with GPS technology. If only single plants or small clumps were encountered, hand-removal efforts by Onterra staff would be deployed to remove these plants from the lake. All occurrences would be refined by Onterra staff during the peak-biomass surveys discussed below.

Summer Peak-biomass Mapping Surveys (August-September)
As the name implies, the Eurasian water milfoil peak-biomass survey is completed when the plant is at its peak growth, allowing for a true assessment of the amount of the exotic within the lake. As with the early-season AIS survey, this survey would include a complete meander survey of the lake's littoral zone by professional ecologists. Past findings from professional and volunteer surveys would be used as focus areas.

The re-treatment of previously treated areas is not uncommon in Eurasian water milfoil management as dense areas often require multiple years of treatment to significantly reduce a site's density and/or size. The TLWA and Virgin Lake residents understand that multiple years of herbicide treatment and hand-removal will likely be needed on Virgin Lake. The results of the summer peak-biomass survey will help to shape management strategy for the next spring.

It is the responsibility of the TLWA to contract with a licensed commercial aquatic pesticide to conduct early season treatments of Eurasian water milfoil. The treatments would occur roughly each year before June 1 when water temperatures are between 55-65°F. Onterra would create the treatment areas in the form of polygons within their Geographic Information System (GIS) and then transmit them to the applicator in native shapefile format or similar format recognized by the applicator's GPS technology. The association's applicator would be responsible for completing the necessary permit applications.

Letter Report (Winter)
During the winter following each herbicide treatment, a brief letter report would be provided that would include an assessment of the prior spring's treatment and guidance for the next year's control strategy. A map depicting the peak-biomass survey results and recommended treatment areas would be included within the report. Those remedial actions may include further monitoring, manual harvesting (hand removal), herbicide treatments, or a combination of all three.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Virgin Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Virgin Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Virgin Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Virgin Lake is protected. Volunteers from Virgin Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Virgin Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Virgin Lake shoreline was categorized in terms of its development. According to the results from this survey, only 25% of the shoreline is in a natural or developed-natural state, while over half (55%) of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

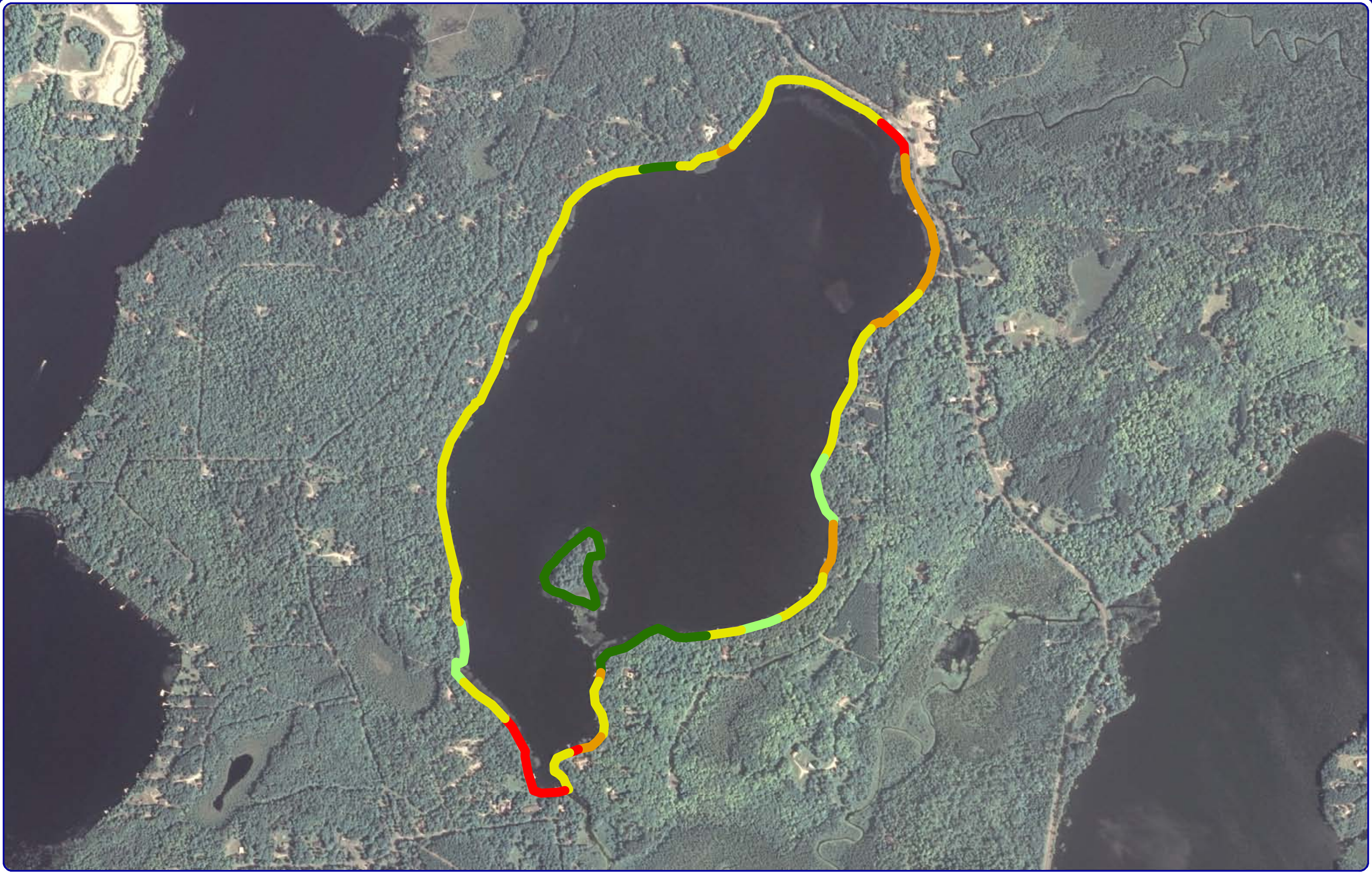
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Virgin Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Virgin Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Virgin Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



Legend

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

Virgin Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreline Condition

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
Map date: March 7, 2012
Filename: Virgin_Map1_SA_2010.mxd

N
W E
S
850
Feet

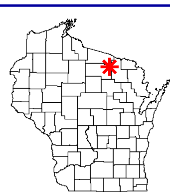
Onterra LLC
Lake Management Planning

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

Sources:
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010

Map Date: March 7, 2012

File Name: Virgin_Comm_2010.mxd



Project Location in Wisconsin

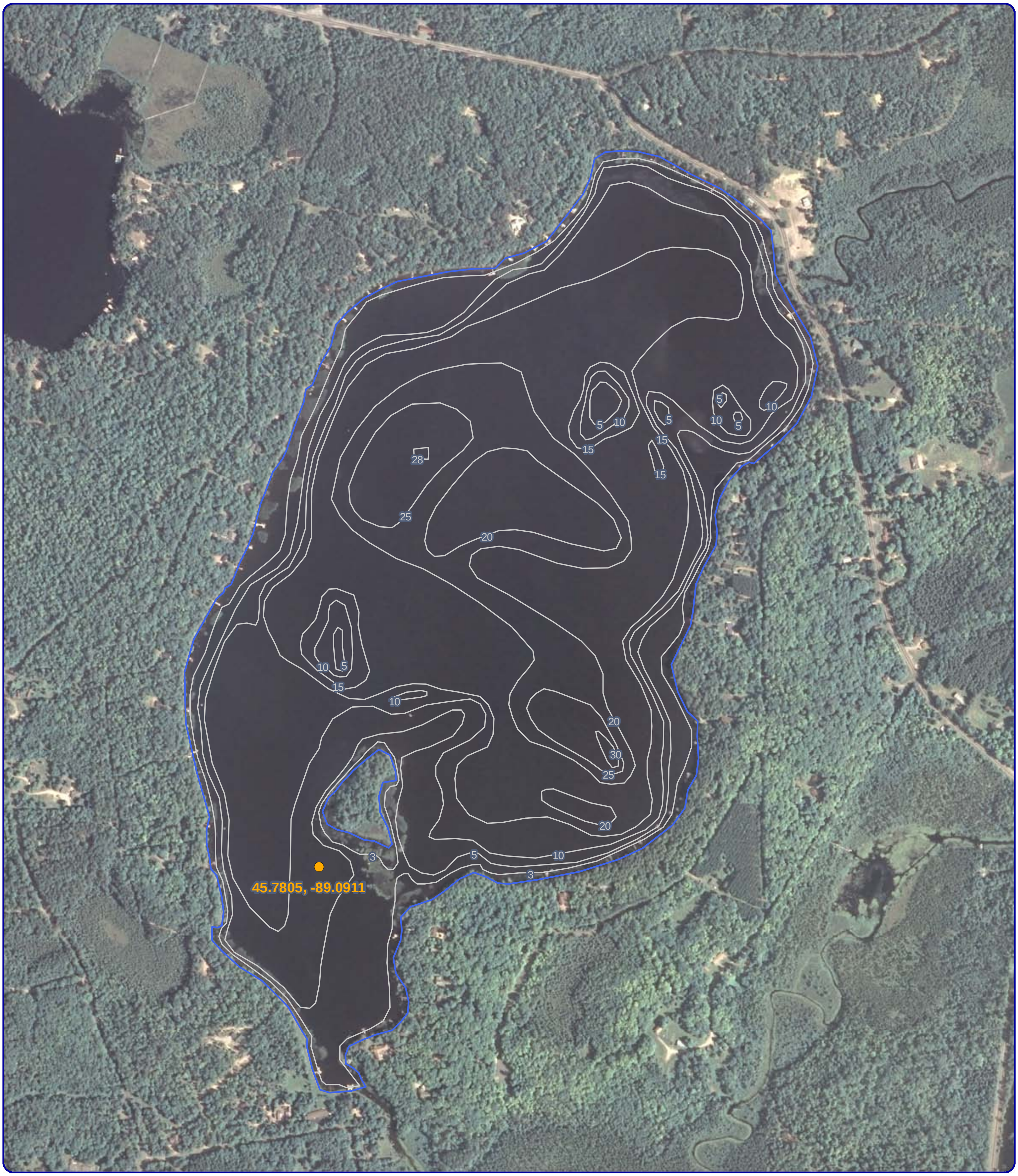
Legend

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

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

Virgin Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

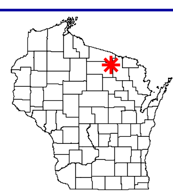
Aquatic Plant Communities



N
W E
S

750

Feet



Project Location in Wisconsin

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

Sources:
Hydrology: WDNR
Ortho: NAIP, 2010
Aquatic Plant Survey - Onterra, 2010 & 2011
Map Date: March 7, 2012
File Name: Virgin_EWM_2011.mxd

Legend

EWM Small Plant Colony
(Found August 2010, density and location confirmed September 2011)

Virgin Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin
Eurasian Water Milfoil Survey Results

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

8.2 Whitefish Lake

An Introduction to Whitefish Lake

Whitefish Lake, Oneida County, is a drainage lake with a maximum depth of 33 feet and a surface area of 205 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Whitefish Lake contains 49 native plant species, of which wild celery is the most common plant. No exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Difficulty accessing lake via Throoughfare in mid-April, due to lower water levels. Access was possible later in the month.

Many (49) aquatic plant species encountered during poin-intercept survey. Very large muskellunge spotted in shallow waters of isolated eastern bay.

Photo 8.2.1 Whitefish Lake, Oneida County

Lake at a Glance* – Whitefish Lake

Morphology	
Acreage	205
Maximum Depth (ft)	33
Mean Depth (ft)	16
Volume (acre-feet)	3,252
Shoreline Complexity	3.1
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 10, 2010
Number of Native Species	49
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.93
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	95:1

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

8.2.1 Whitefish Lake Water Quality

During 2011/2012, water quality data was collected from Whitefish Lake on six occasions. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Whitefish Lake for years to come.

During this time, summer average total phosphorus concentrations have ranged consistently between 14.5 and 19.7 µg/L (Figure 8.2.1-1). Some of these average annual concentrations rank within the TSI category of *Good*, with most ranking as *Excellent*. A weighted value across all years is lower than the median for deep, lowland drainage lakes in the state of Wisconsin. As with the total phosphorus values, average summer chlorophyll-*a* concentrations also rank within categories of *Good* and mostly *Excellent*, and a weighted average is less than the median concentration for similar lakes across the state (Figure 8.2.1-2).

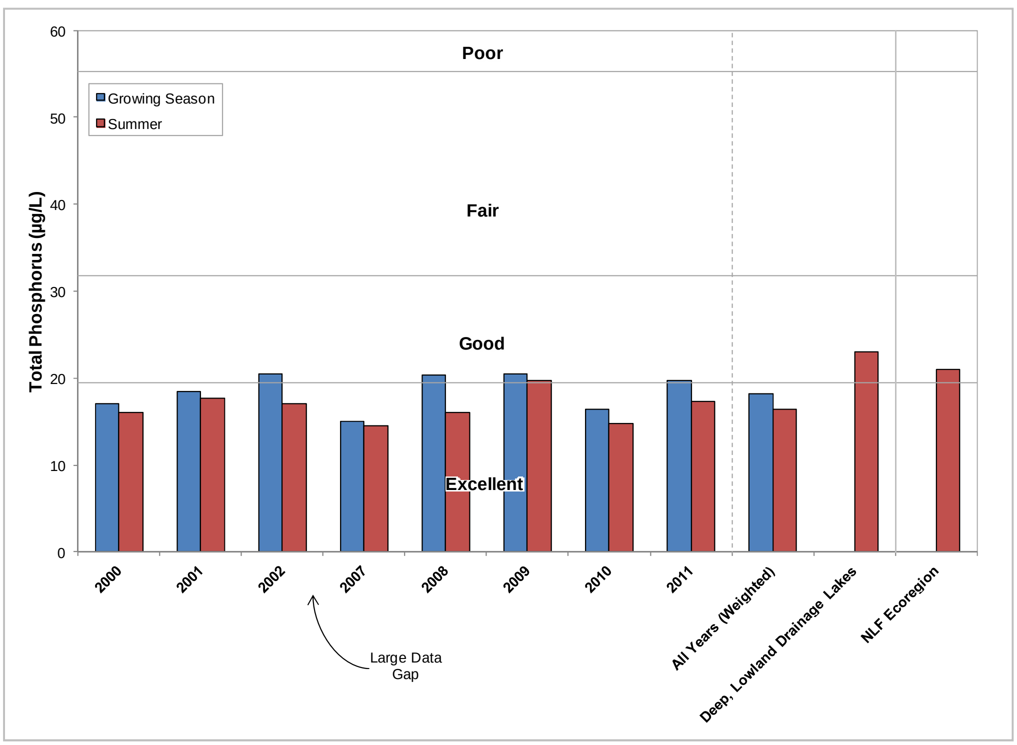


Figure 8.2.1-1. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

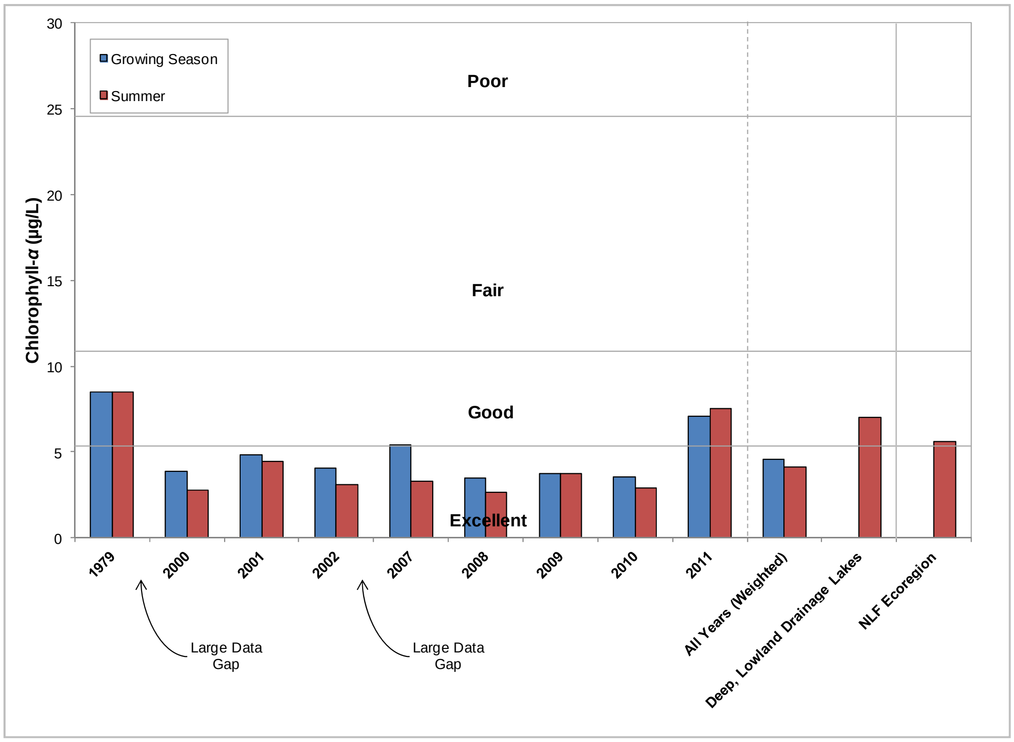


Figure 8.2.1-2. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.2.1-3). Summer averages lie mostly within the *Excellent* category. A weighted average across all years is slightly greater than the average for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. Comparing the chlorophyll-*a* dataset with the Secchi disk clarity dataset, it is apparent that during most years the two parameters do indeed have an inverse relationship. For example, in 2010 chlorophyll-*a* concentrations were relatively low in the lake, and in that same year Secchi disk depth averages are fairly high. On the other hand, in 2011 average chlorophyll-*a* concentrations were particularly high for Whitefish Lake and, as a result, the average Secchi disk depth was fairly low during that time.

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 lakes such as the Three Lakes Chain of lakes, a natural staining of the water also plays a role in light penetration, and thus water clarity, as well. The darker waters of Whitefish Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

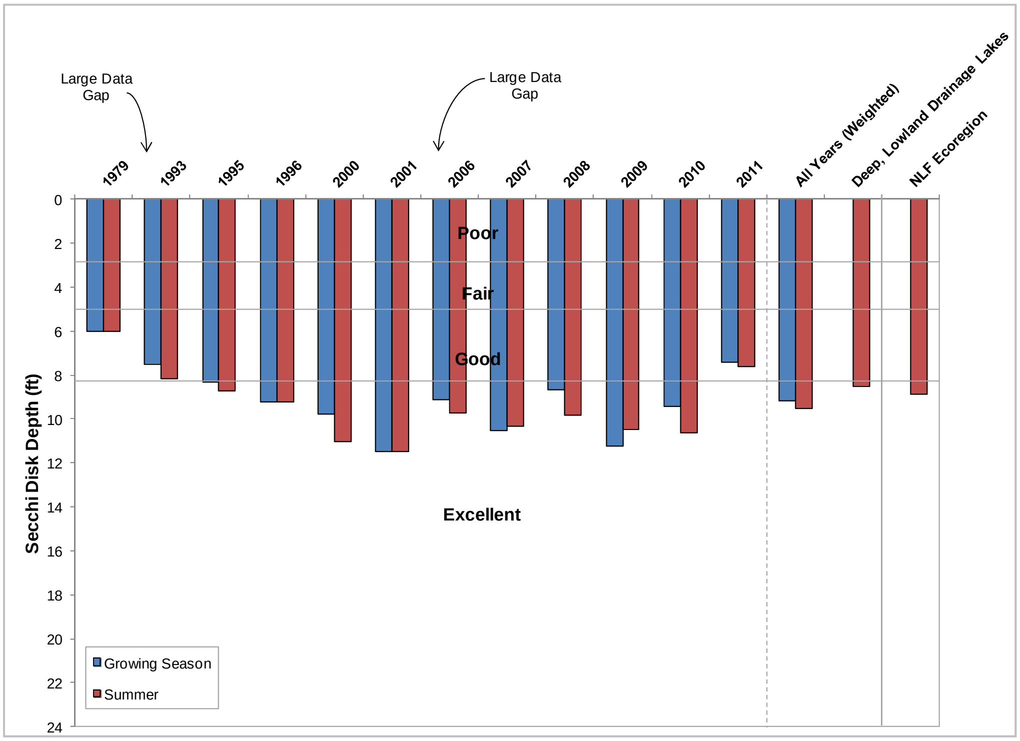


Figure 8.2.1-3. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Whitefish 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 8.2.1-4). 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 Whitefish Lake is in a mesotrophic state.

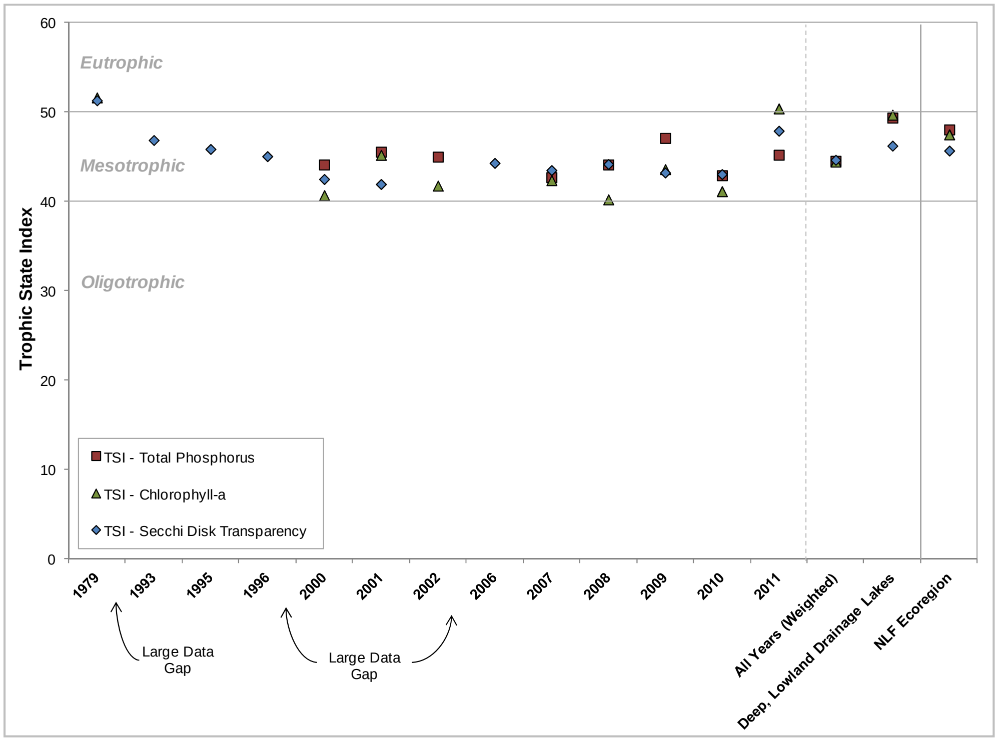


Figure 8.2.1-4. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Whitefish Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Whitefish Lake by Onterra staff. Graphs of those data are displayed in Figure 8.2.1-5 for all sampling events.

Whitefish Lake was found to be thoroughly mixed during the spring, but quickly stratified once the weather warmed the uppermost layers of water in June. Throughout the summer months, the lake remained thermally stratified at about 15 feet. This is not uncommon in lakes that are moderate in size and fairly deep. Energy from the wind is sufficient to mix only the upper layer of water, allowing the cooler, denser water to remain below. Decomposition of organic matter along the lake bottom is the cause of the decrease in dissolved oxygen observed in the summer months. In October, the lake is mixed once again by fall winds and oxygen is restored throughout the water column. During the winter months, dissolved oxygen depletes within the lake because the water is not able to exchange oxygen with the air through the ice. Dissolved oxygen levels remained sufficient in the upper 15 feet of the water column year-round to support most aquatic life found in northern Wisconsin lakes.

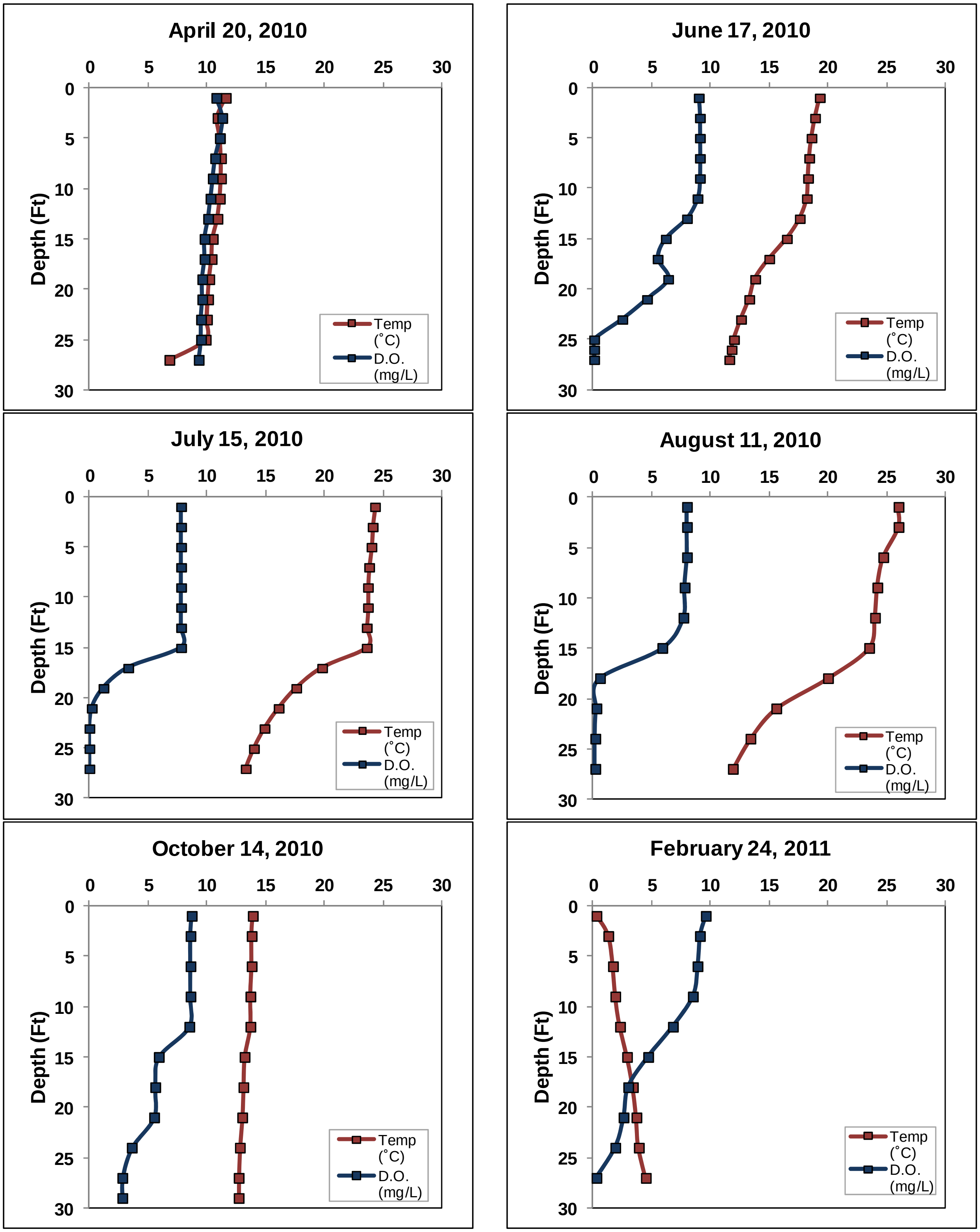


Figure 8.2.1-5. Whitefish Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Whitefish 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 Whitefish 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 Chainwide 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. Whitefish Lake's pH was measured at roughly 7.9 in the summer months of 2010. This value is above neutral and falls within the normal range for Wisconsin lakes.

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 Whitefish Lake was measured at 44.5 (mg/L as $CaCO_3$), indicating 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 Whitefish Lake during the summer of 2010. 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 Whitefish Lake's pH of 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Whitefish Lake was found to be 11.3 mg/L, falling just below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval mussels. No veligers (larval mussels) were found within these samples.

8.2.2 Whitefish Lake Watershed Assessment

Whitefish Lake's watershed is 19,630 acres in size. Compared to Whitefish Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 95:1.

Exact land cover calculation and modeling of nutrient input to Whitefish Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.2.3 Whitefish Lake Shoreland Condition

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 2010, Whitefish Lake's immediate shoreline was assessed in terms of its development. Whitefish Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.1 miles of natural/undeveloped and developed-natural shoreline (33% of the entire shoreline) were observed during the survey (Figure 8.2.3-1). 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, about 0.9 miles of urbanized and developed–unnatural shoreline (27% of the total shoreline) was observed. If restoration of the Whitefish 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. Whitefish Lake Map 1 displays the location of these shoreline lengths around the entire lake.

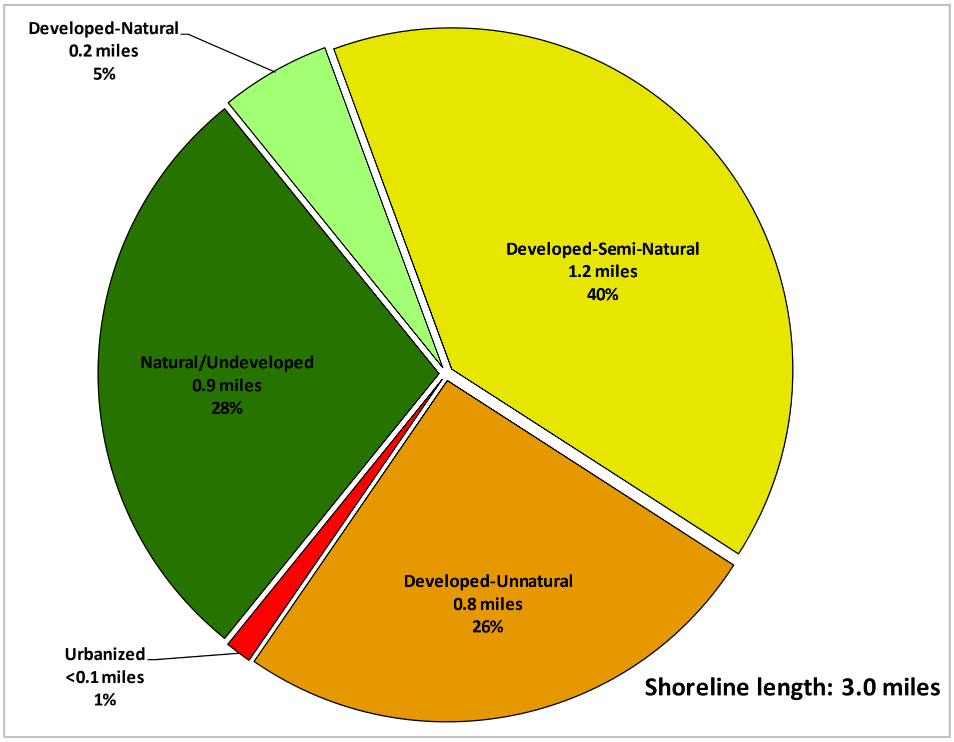


Figure 8.2.3-1. Whitefish Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Whitefish Lake Map 1.

8.2.4 Whitefish Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Whitefish Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Whitefish Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Whitefish Lake on August 10, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Whitefish Lake Community Map). During all surveys, 49 species of native aquatic plants were located in Whitefish Lake (Table 8.2.4-1). 36 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 14 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 86% contained aquatic vegetation. Approximately 74% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and 3% were determined to be rocky.

Table 8.2.4-1. Aquatic plant species located in the Whitefish Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Carex utriculata	Northwest Territory sedge	7	I
	Calla palustris	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Scirpus cyperinus	Wool grass	4	I
	Schoenoplectus subterminalis	Water bulrush	9	X
	Typha spp.	Cattail spp.	1	X
	Zizania palustris	Northern wild rice	8	X
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X
	Sparganium emersum	Short-stemmed bur-reed	8	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes lacustris	Lake quillwort	8	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton strictifolius	Stiff pondweed	8	I
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton pusillus	Small pondweed	7	X
	Ranunculus aquatilis	White water-crowfoot	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
S/E	*Eleocharis acicularis*	Needle spikerush	5	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent;
X = Located on rake during point-intercept survey; I = Incidental Species

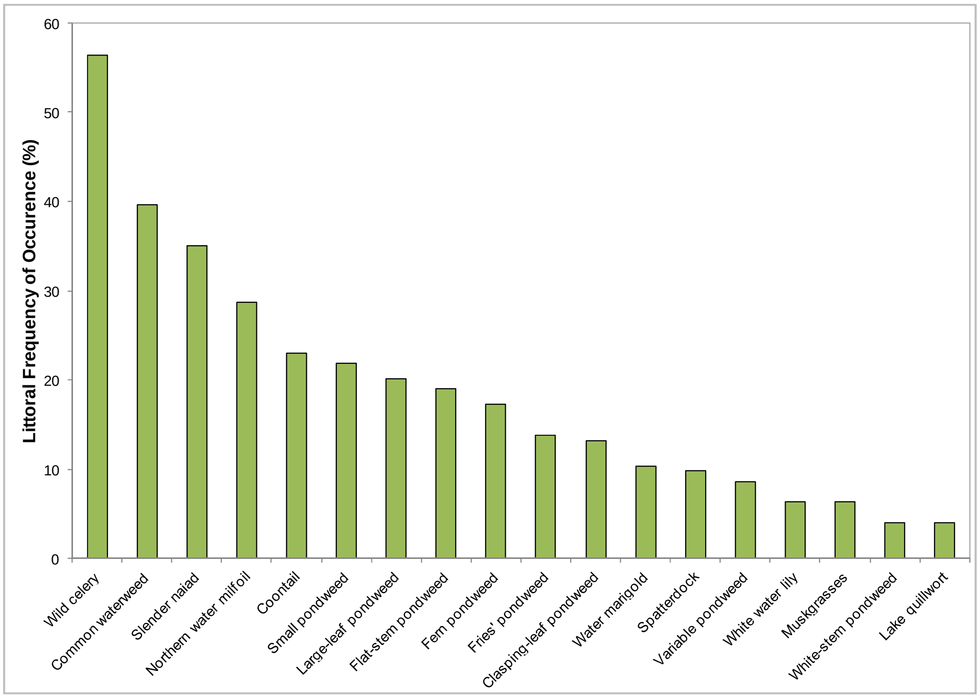


Figure 8.2.4-1 Whitefish Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 3.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.2.4-1 (above) shows that wild celery, common waterweed, and slender naiad were the most frequently encountered plants within Whitefish Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Common waterweed is able to obtain most of its nutrients through the water and thus does not produce extensive root systems. Sometimes, this plant may produce structures similar to roots (rhizoids) or become partially buried in the sediment. Because of this, the plant is susceptible to being easily uprooted and migrated by water-action and movement. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was located from Whitefish Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

An incredible 49 species of aquatic plants (including incidentals) were found in Whitefish Lake and 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 Whitefish Lake's plant community (0.93) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 56% of the sampling locations, its relative frequency of occurrence is 15%. Explained another way, if 100 plants were randomly sampled from Whitefish Lake, 15 of them would be wild celery. This distribution can be observed in Figure 8.2.4-2, where together nine species account for 72% of the population of plants within Whitefish Lake, and the other 27 species account for the remaining 28%. Thirteen additional species were found incidentally within the lake (not from of the point-intercept survey), and are indicated in Table 8.2.4-1 as incidentals.

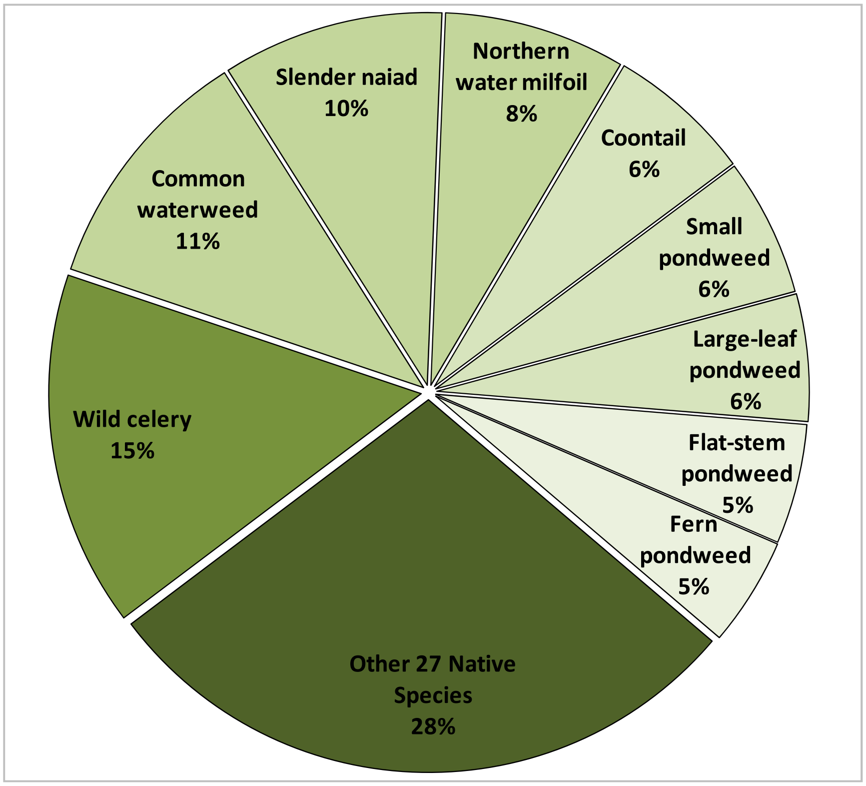


Figure 8.2.4-2 Whitefish Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Whitefish Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Whitefish Lake is indicative of an undisturbed system. This is not surprising considering Whitefish Lake's plant community has great diversity and high species richness. Combining Whitefish Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 42.5 which is well above the median values of the ecoregion and state.

The quality of Whitefish Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.4 acres of the lake contains these types of plant communities (Whitefish Lake Map 2, Table 8.2.4-2). 18 floating-leaf and emergent species were located on Whitefish Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.2.4-2. Whitefish Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	0.1
Floating-leaf	1.2
Mixed Floating-leaf and Emergent	14.1
Total	15.4

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 Whitefish 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.

.

8.2.5 Whitefish Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Whitefish Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Whitefish Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Whitefish Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Whitefish Lake's implementation plan is compiled by describing how Whitefish Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Whitefish Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Whitefish Lake as part of this chain-wide management planning project, it is up to Whitefish Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Whitefish Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Whitefish Lake contains a public carry-in access, and is accessible through the Thoroughfare which contains several public access points. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Whitefish Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Whitefish Lake or from Whitefish Lake elsewhere. If a Whitefish Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Whitefish Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Whitefish Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Whitefish Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Whitefish Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Whitefish Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Whitefish Lake is protected. Volunteers from Whitefish Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Whitefish Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Whitefish Lake shoreline was categorized in terms of its development. According to the results from this survey, 27% of the shoreline is in an urbanized or developed-unnatural state, while 40% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

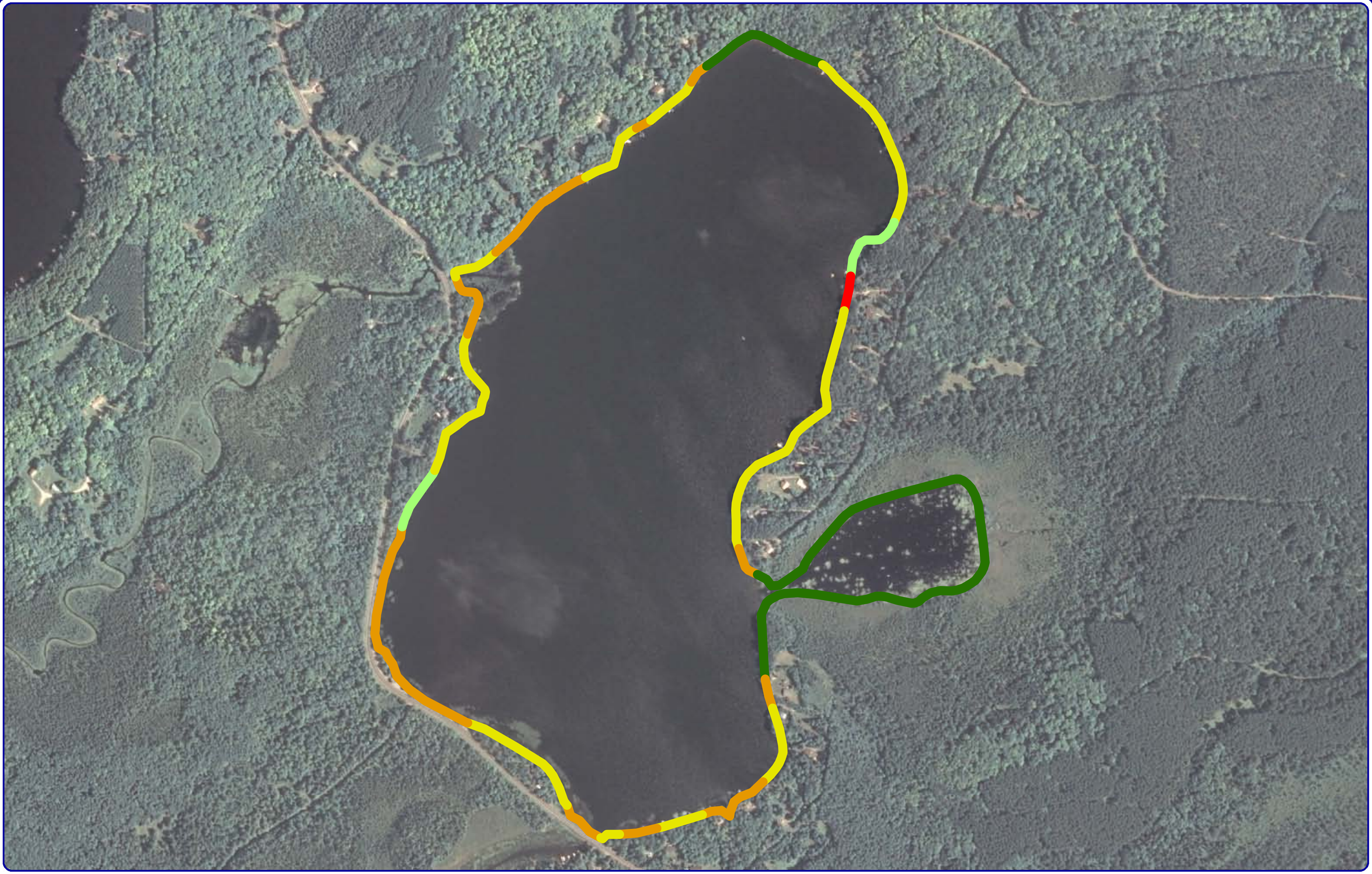
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Whitefish Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Whitefish Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Whitefish Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



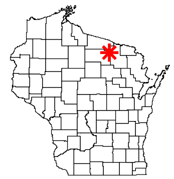
N
W E
S

750

Feet

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
Map date: March 14, 2011
Filename: Whitefish_Map1_SA_2010.mxd



Project Location in Wisconsin

Legend

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

Whitefish Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreline Condition

N
W E
S

1,000

Feet

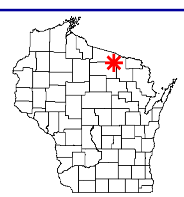
Onterra LLC
Lake Management Planning

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

Sources:
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010

Map Date: March 7, 2012

File Name: Whitefish_Comm_2010.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

Whitefish Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

Aquatic Plant Communities

Note: Methodology, explanation of analysis and scientific background on The Thoroughfare studies are contained within the Three Lakes Chain-wide Management Plan document.

8.3 The Thoroughfare

An Introduction to the Thoroughfare

The Thoroughfare, Oneida County, is a narrow passage-way that connects Big Lake to Whitefish Lake. It has a maximum depth of 12 feet and a surface area of 175 acres. The Thoroughfare contains 35 native plant species, of which coontail was the most common plant as determined through the point-intercept survey. Wild rice, an emergent species, was found in great abundance as well but was not accounted for as often using the point-intercept methodology. No exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Much undeveloped shoreline observed along the Thoroughfare. Fluctuating water levels made access to Whitefish Lake difficult in mid-April.

Numerous emergent and floating-leaf aquatic plants observed during point-intercept survey, including wild rice, sedge species, cattails, white water lilies, spatterdock and watershield.

Photo 8.3.1 The Thoroughfare, Oneida County

Lake at a Glance* – The Thoroughfare

Morphology	
Acreage	175
Maximum Depth (ft)	12
Shoreline Complexity	13.5
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 8 & 9 2010
Number of Native Species	35
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.91
Average Conservatism	6.9

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

8.3.1 The Thoroughfare Water Quality

Water quality studies were not completed on the Thoroughfare as a part of this project.

8.3.2 The Thoroughfare Watershed Assessment

Because the Thoroughfare is more of a passage between lakes than a lake per se, watershed modeling was not conducted as a part of this project. A shoreline assessment, however, was completed as described in the next section.

8.3.3 The Thoroughfare Shoreland Condition

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 2010, the Thoroughfare's immediate shoreline was assessed in terms of its development. The Thoroughfare has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.2 miles of natural/undeveloped and developed-natural shoreline (77% of the entire shoreline) were observed during the survey (Figure 8.3.3-1). 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, 0.4 miles of urbanized and developed–unnatural shoreline (6% of the total shoreline) was observed. If restoration of the Thoroughfare 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. The Thoroughfare Map 1 displays the location of these shoreline lengths around the entire lake.

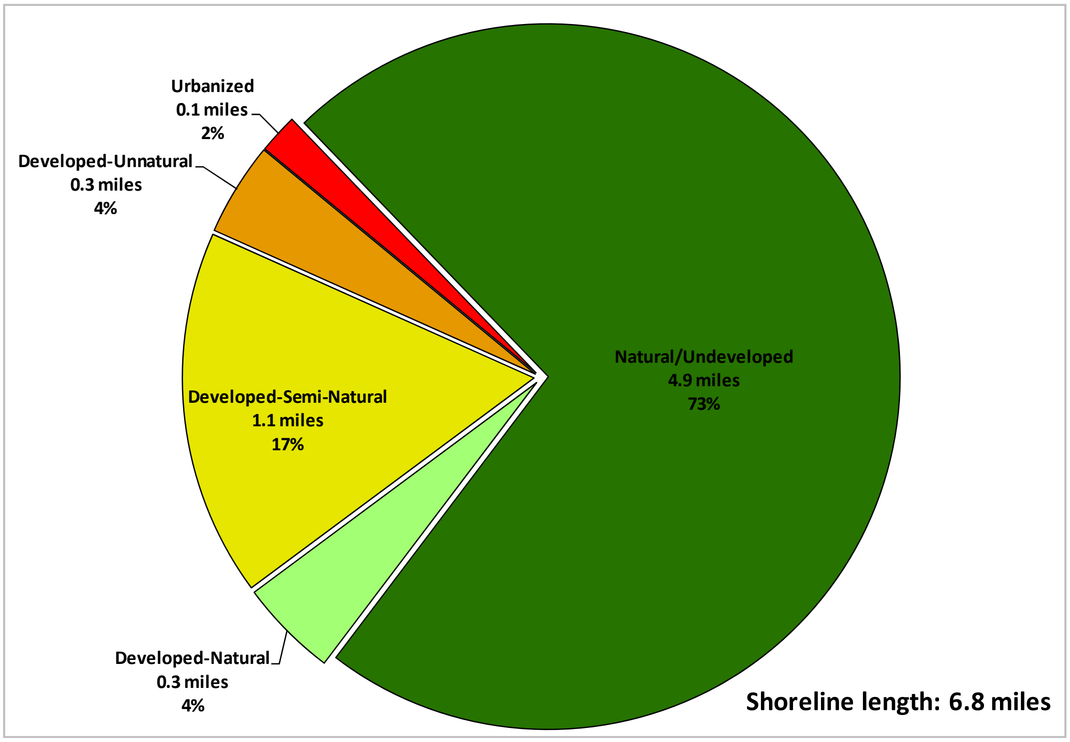


Figure 8.3.3-1. The Thoroughfare shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on the Thoroughfare Shoreline Condition Map.

8.3.4 The Thoroughfare Aquatic Vegetation

The curly-leaf pondweed survey was conducted on the Thoroughfare on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in the Thoroughfare or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on the Thoroughfare on August 8 & 9 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 to create the aquatic plant community map (The Thoroughfare Map 2) during this time. During all surveys, 35 species of native aquatic plants were identified in the Thoroughfare (Table 8.3.4-1). 25 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of nine feet. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 139 point-intercept locations sampled within the littoral zone, approximately 61% contained aquatic vegetation. Approximately 5% of the point-intercept sampling locations where sediment data was collected at were sand and 95% consisted of a fine, organic substrate (muck). No rocky areas where encountered.

Table 8.3.4-1. Aquatic plant species located in the Thoroughfare during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	Onterra 2010
Emergent	*Calla palustris*	Water arum	9	I
	Carex aquatilis	Water sedge	7	I
	Carex utriculata	Northwest Territory sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria rigida	Stiff arrowhead	8	I
	Scirpus cyperinus	Wool grass	4	I
	Sagittaria latifolia	Common arrowhead	3	X
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Sagittaria cuneata*	Arum-leaved arrowhead	7	X
	Sagittaria graminea	Grass-leaved arrowhead	9	X
FF	*Lemna trisulca*	Forked duckweed	6	X
	Lemna turionifera	Turion duckweed	2	X
	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

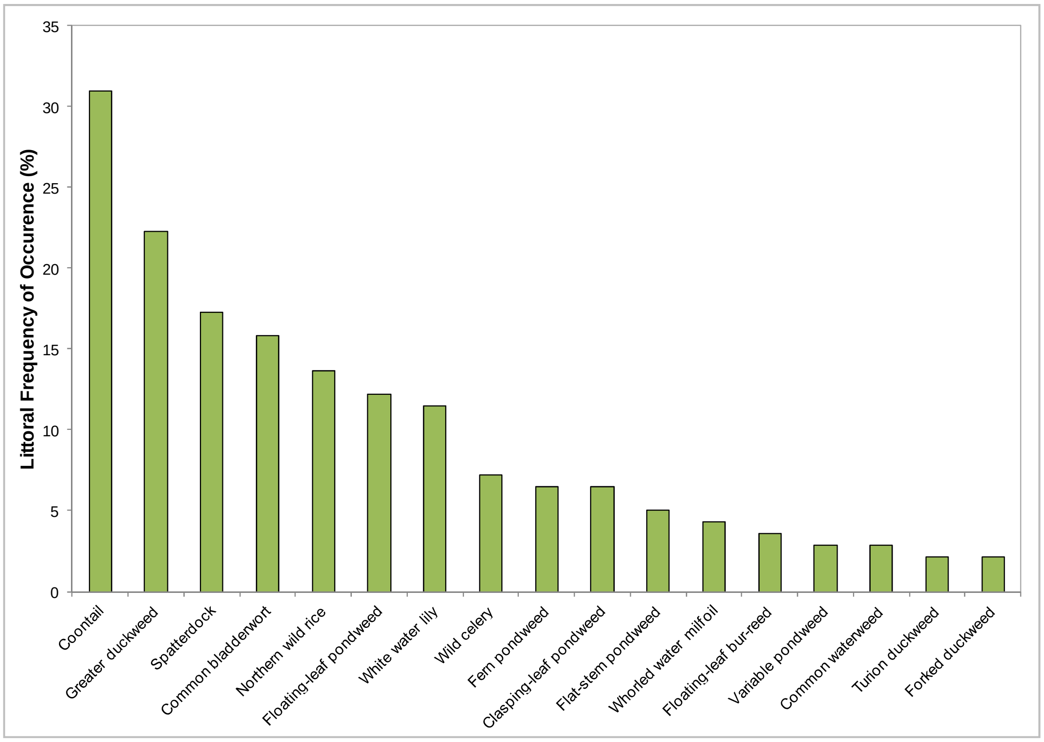


Figure 8.3.4-1 The Thoroughfare aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.3.4-1 (above) shows that coontail, greater duckweed, and spatterdock were the most frequently encountered plants within the Thoroughfare. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making them susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form mats. Greater duckweed has round to oval-shaped leaf bodies called fronds that float individually or in groups on the water surface. This plant can be found worldwide in freshwater habitats that are protected from the wind where wave action in minimal. Interestingly, duckweed is largely made up of metabolically active cells with very little fiber; the tissue contains twice the protein, fat, nitrogen and phosphorus as other vascular plants. This makes the plant very high in nutritional value, and is a preferred food choice by waterfowl. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one was located within the Thoroughfare. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. The leaves have somewhat of a feathery appearance. It is often mistaken for other species of milfoil, such as northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

35 species of aquatic plants (including incidentals) were found in the Thoroughfare and 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 the Thoroughfare's plant community (0.91) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 31% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from the Thoroughfare, 18 of them would be coontail. This distribution can be observed in Figure 8.3.4-2, where together 7 species account for 71% of the population of plants within the Thoroughfare and the other 18 species account for the remaining 29%. Ten additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.3.4-1 as incidentals.

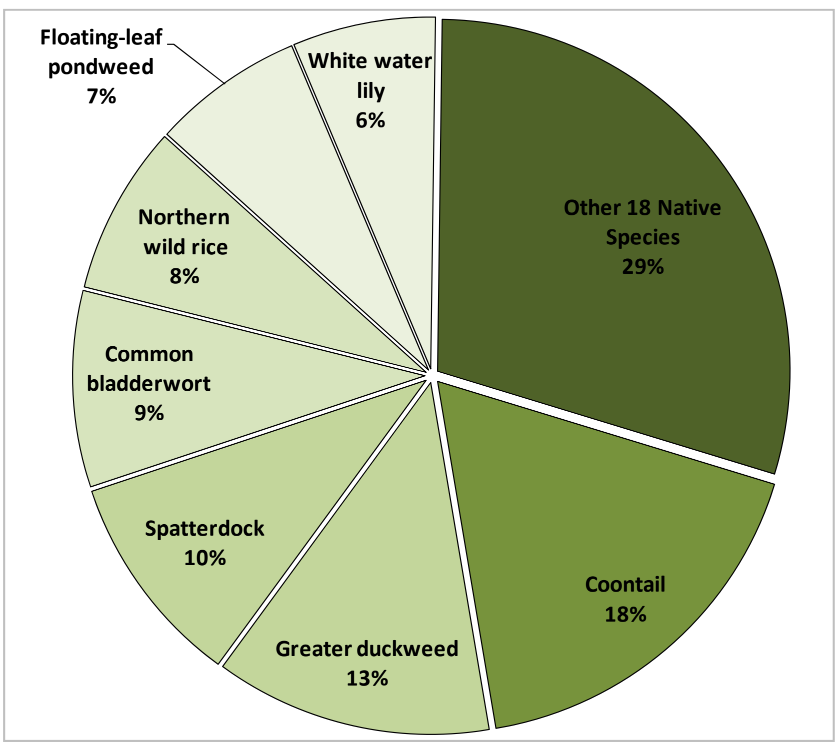


Figure 8.3.4-2 The Thoroughfare aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

The Thoroughfare's average conservatism value (6.9) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of the Thoroughfare is indicative of an undisturbed system. This is not surprising considering the Thoroughfare's plant community has great diversity and high species richness. Combining the Thoroughfare's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 34.6 which is well above the median values of the ecoregion and state.

The quality of the Thoroughfare is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 162.9 acres of the lake contains these types of plant communities (The Thoroughfare Map 2, Table 8.3.4-2). Ten floating-leaf and emergent species were located on the Thoroughfare (Table 8.3.4-1), all of which provide valuable wildlife habitat.

Table 8.3.4-2. The Thoroughfare acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	0
Floating-leaf	0
Mixed Floating-leaf and Emergent	162.9
Total	162.9

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 the Thoroughfare. 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.

.

8.3.5 The Thoroughfare Implementation Plan

The Implementation Plan below is a result of collaborative efforts between the Thoroughfare stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of the Thoroughfare and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including the Thoroughfare's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, the Thoroughfare's implementation plan is compiled by describing how the Thoroughfare stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to the Thoroughfare

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on the Thoroughfare as part of this chain-wide project, it is up to the Thoroughfare stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, the Thoroughfare may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: The Thoroughfare contains several public access points and is accessible from many other Three lakes Chain lakes by only a short boat ride. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On the Thoroughfare, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to the Thoroughfare or from the Thoroughfare elsewhere. If a Thoroughfare property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: The Thoroughfare stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Thoroughfare riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving the Thoroughfare and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, the Thoroughfare property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: This management action is not applicable to the Thoroughfare

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. The Thoroughfare stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Thoroughfare shoreline was categorized in terms of its development. According to the results from this survey, 73% of the Thoroughfare's nearly 7 miles of shoreline is in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Thoroughfare shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

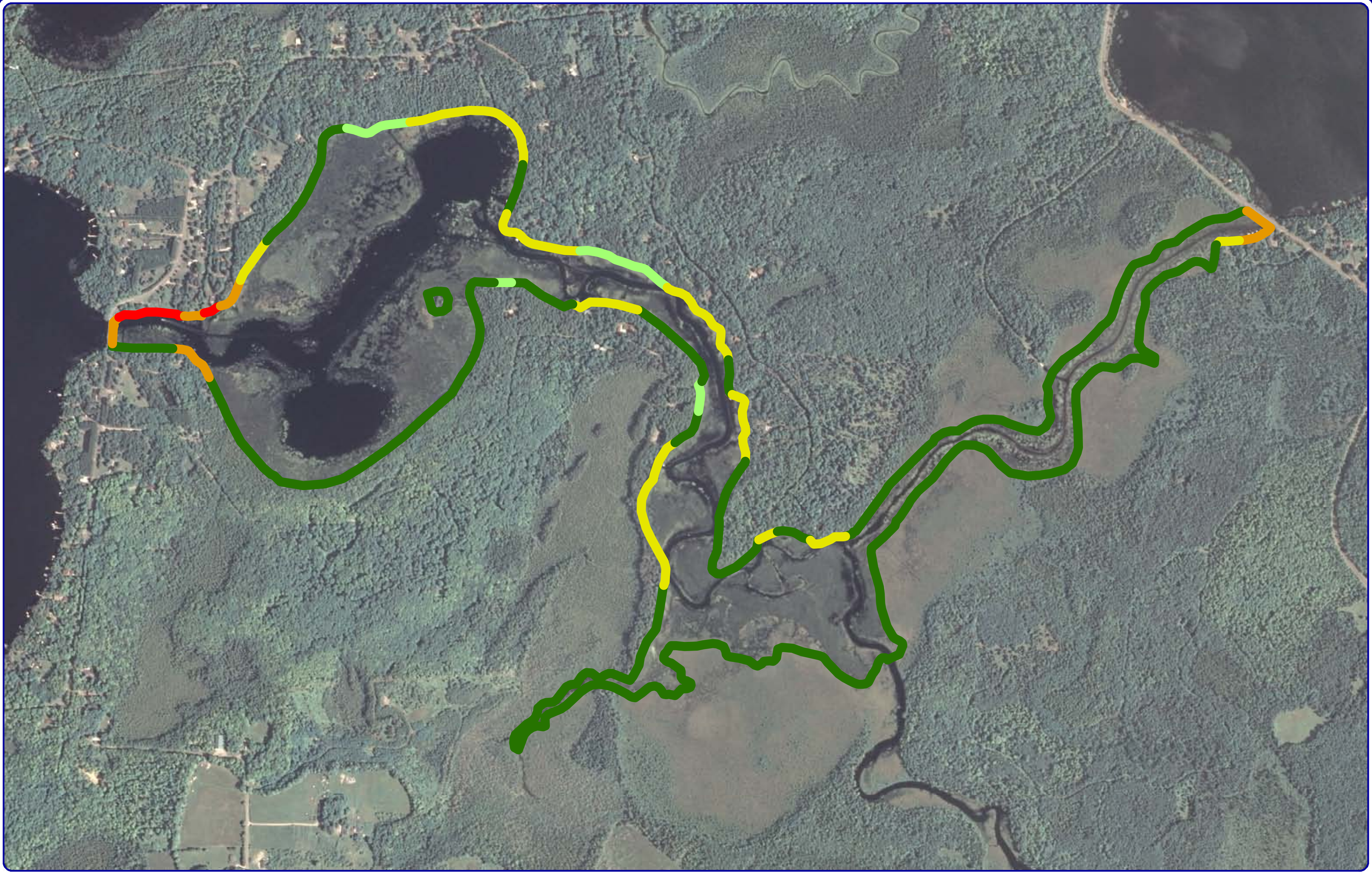
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to the Thoroughfare.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Thoroughfare stakeholders have specific questions/concerns about the walleye population or the overall fishery of the Thoroughfare, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



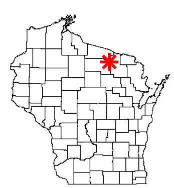
N
W E
S

1,000

Feet

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
Map date: March 7, 2012
Filename: Thoroughfare_Map1_SA_2010.mxd



Project Location in Wisconsin

Legend

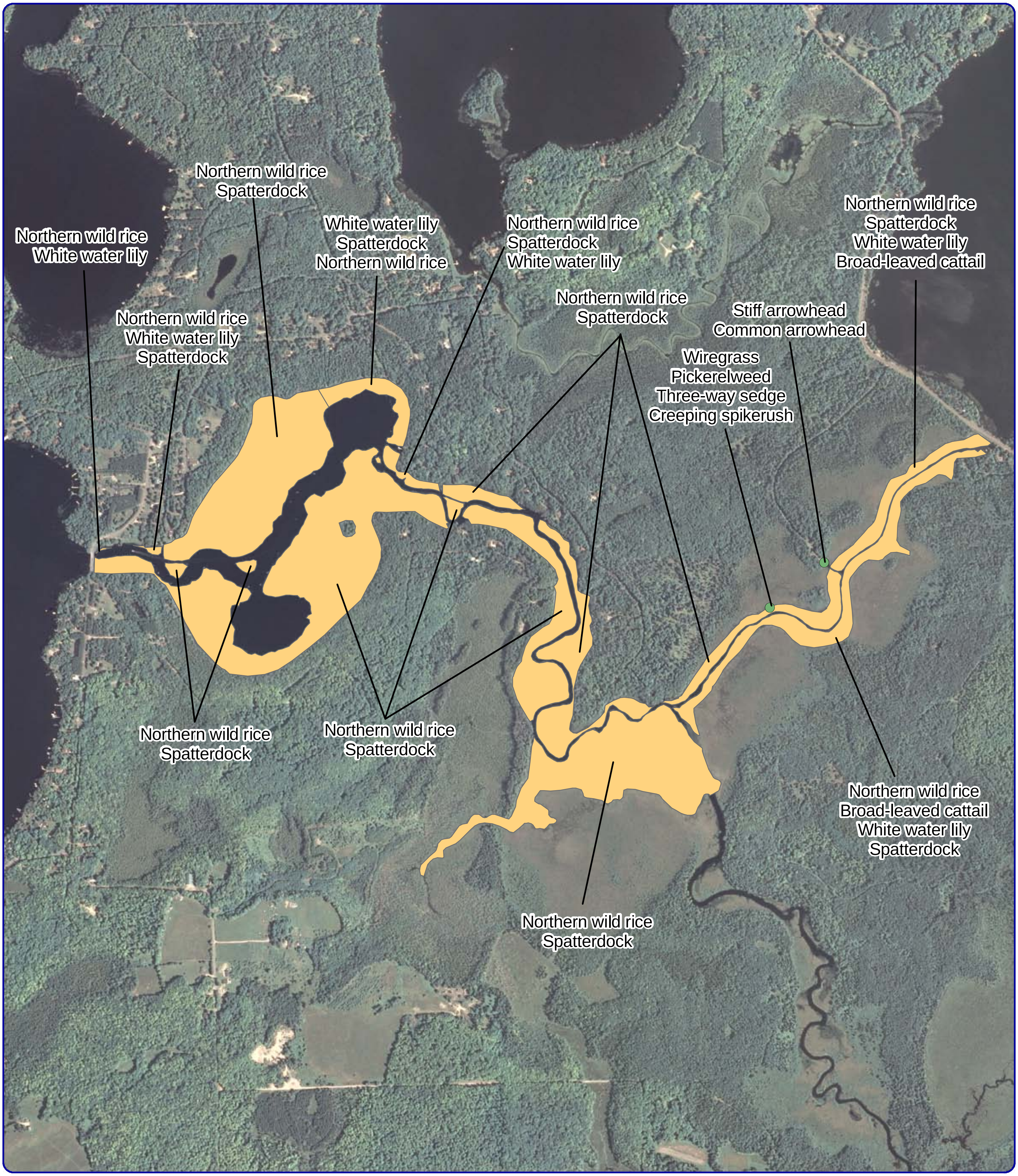
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

The Thoroughfare - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreline Condition



1,250
Feet

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

Sources:
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010
Map Date: March 7, 2012
File Name: Thoroughfare_Comm_2010.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

The Thoroughfare - Map 2
Three Lakes Chain
Oneida County, Wisconsin

Aquatic Plant Communities

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

8.4 Big Lake

An Introduction to Big Lake

Big Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 865 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Big Lake contains 32 native plant species, of which wild celery was the most common plant. Two wetland exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Rough water conditions experienced during survey on August 5th. Several otters spotted near island – very playful critters!

Purple loosestrife plant located along shoreline. Plant was hand-pulled entirely, location marked with GPS coordinates.

Photo 8.4.1 Big Lake, Oneida County

Lake at a Glance* – Big Lake

Morphology	
Acreage	865
Maximum Depth (ft)	27
Mean Depth (ft)	12
Volume (acre-feet)	10,810
Shoreline Complexity	2.6
Vegetation	
Curly-leaf Survey Date	June 18, 2010
Comprehensive Survey Date	August 5 & 9, 2010
Number of Native Species	32
Threatened/Special Concern Species	-
Exotic Plant Species	Amur silver grass & Purple loosestrife
Simpson's Diversity	0.89
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	52:1

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

8.4.1 Big Lake Water Quality

Water quality data was collected from Big Lake on three occasions in summer of 2010. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water quality through an advanced monitoring program since 2006. These efforts provide a considerable amount of data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Big Lake.

During this time, summer average total phosphorus concentrations have fluctuated slightly, ranging between 25.0 and 37.0 μg/L (Figure 8.4.1-1). These average values rank within the TSI categories of *Good* and *Excellent*, and a weighted value across all years is slightly lower than the median value for shallow, lowland drainage lakes in the state of Wisconsin. Average chlorophyll-*a* concentrations have shown some variation within the dataset (Figure 8.4.1-2). Most values fall within the TSI *Excellent* category, though some rank as *Good*. The weighted average across all years is similar to the median for other shallow, lowland drainage lakes statewide.

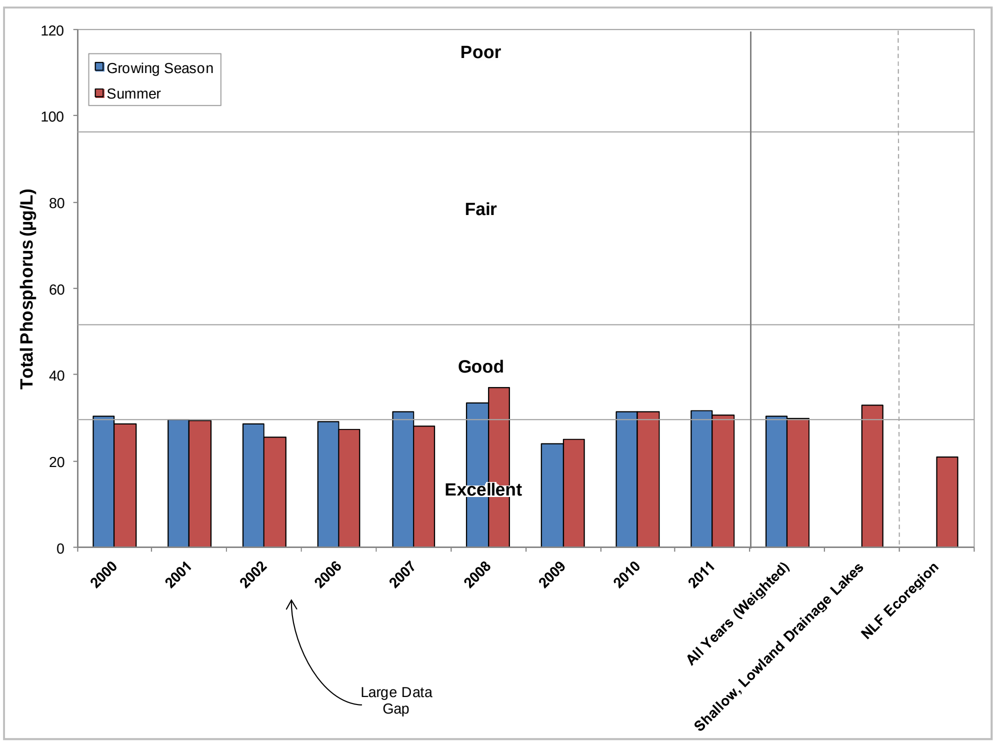


Figure 8.4.1-1. Big Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

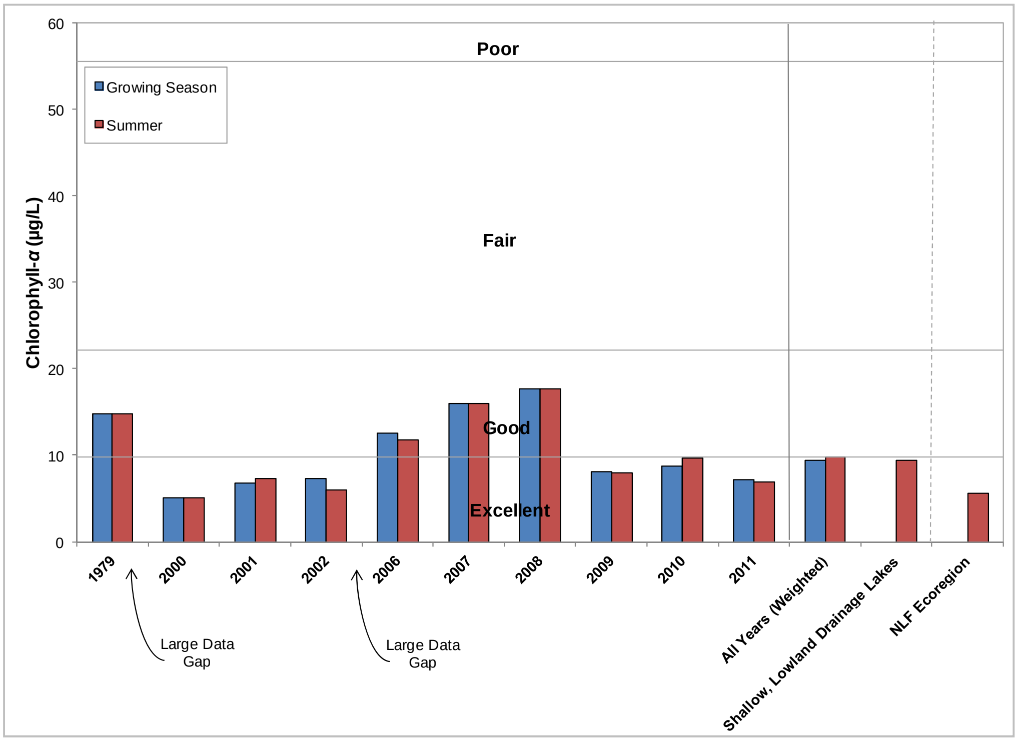


Figure 8.4.1-2. Big Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show little annual variance (Figure 8.4.1-3). All summer averages range between categories of *Fair* and *Good*, and a weighted average across all years is less than the median for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. It is likely, however, that another factor is limiting the water clarity in Big Lake.

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 lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. Indeed, during the point-intercept aquatic vegetation survey that took place on Big Lake in 2010, aquatic plants were found growing to a maximum depth of seven feet.

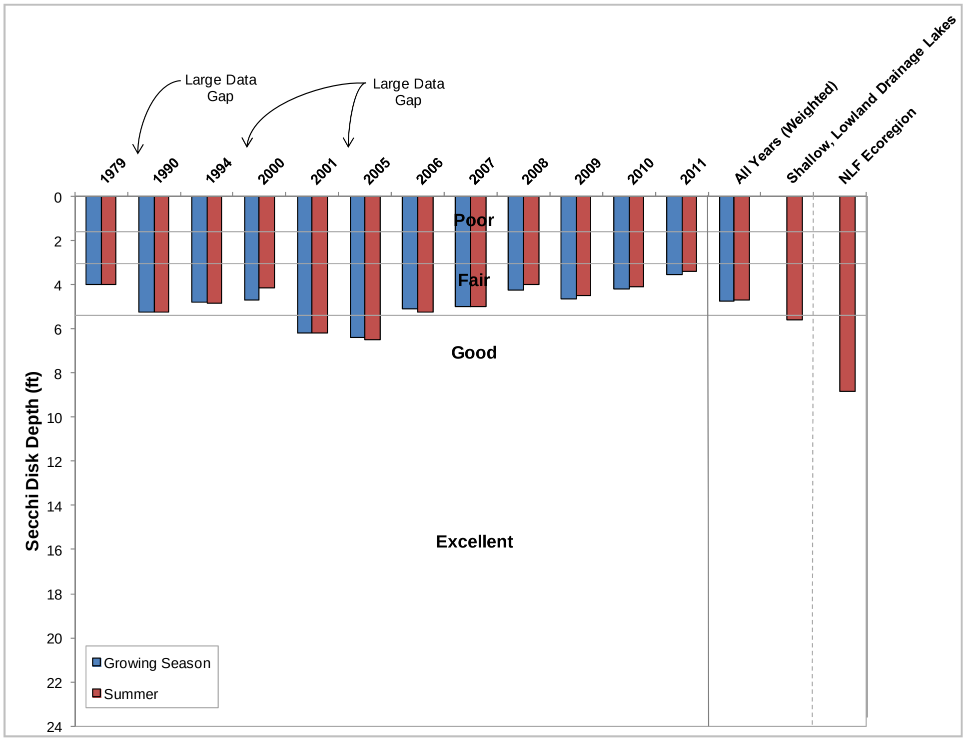


Figure 8.4.1-3. Big Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Big Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.4.1-4). 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 Big Lake is in a eutrophic state.

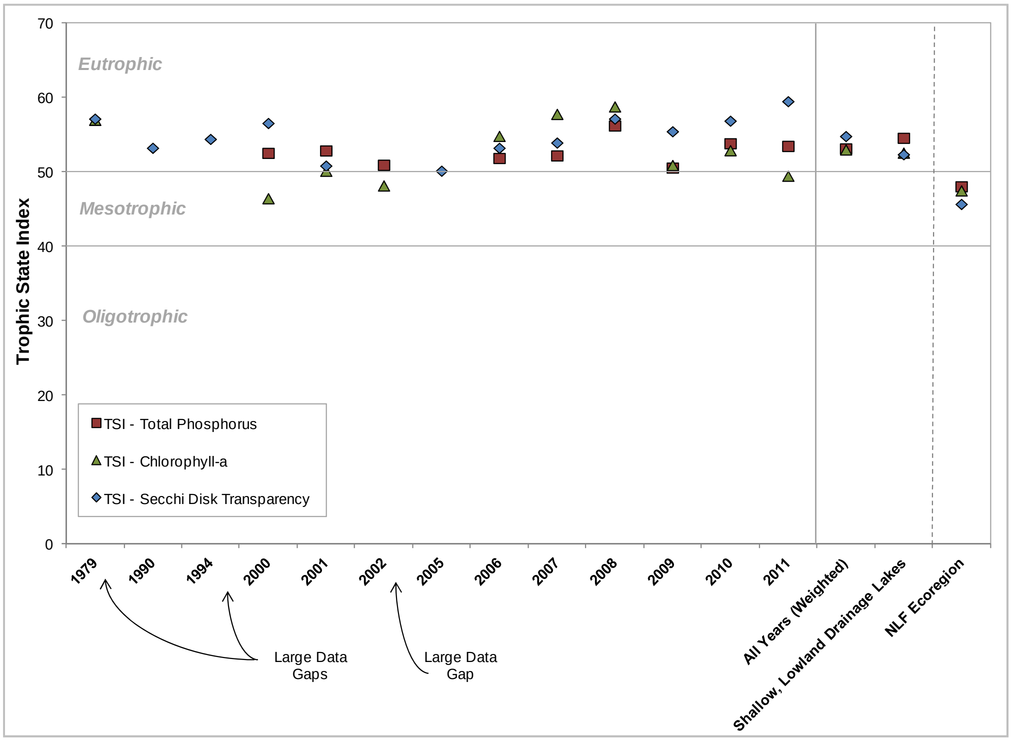


Figure 8.4.1-4. Big Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Big Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Lake by Onterra staff. Graphs of those data are displayed in Figure 8.4.1-5 for all sampling events.

Big Lake remained thoroughly mixed throughout most of the summer months in 2010, though a small amount of stratification likely occurs periodically in the deeper portions of the lake as seen in the August profile. This is not uncommon in lakes that are large in size and moderately deep. Energy from the wind 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.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer and winter months. Despite this decrease in oxygen near the bottom of the lake, levels remained sufficient to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2011, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

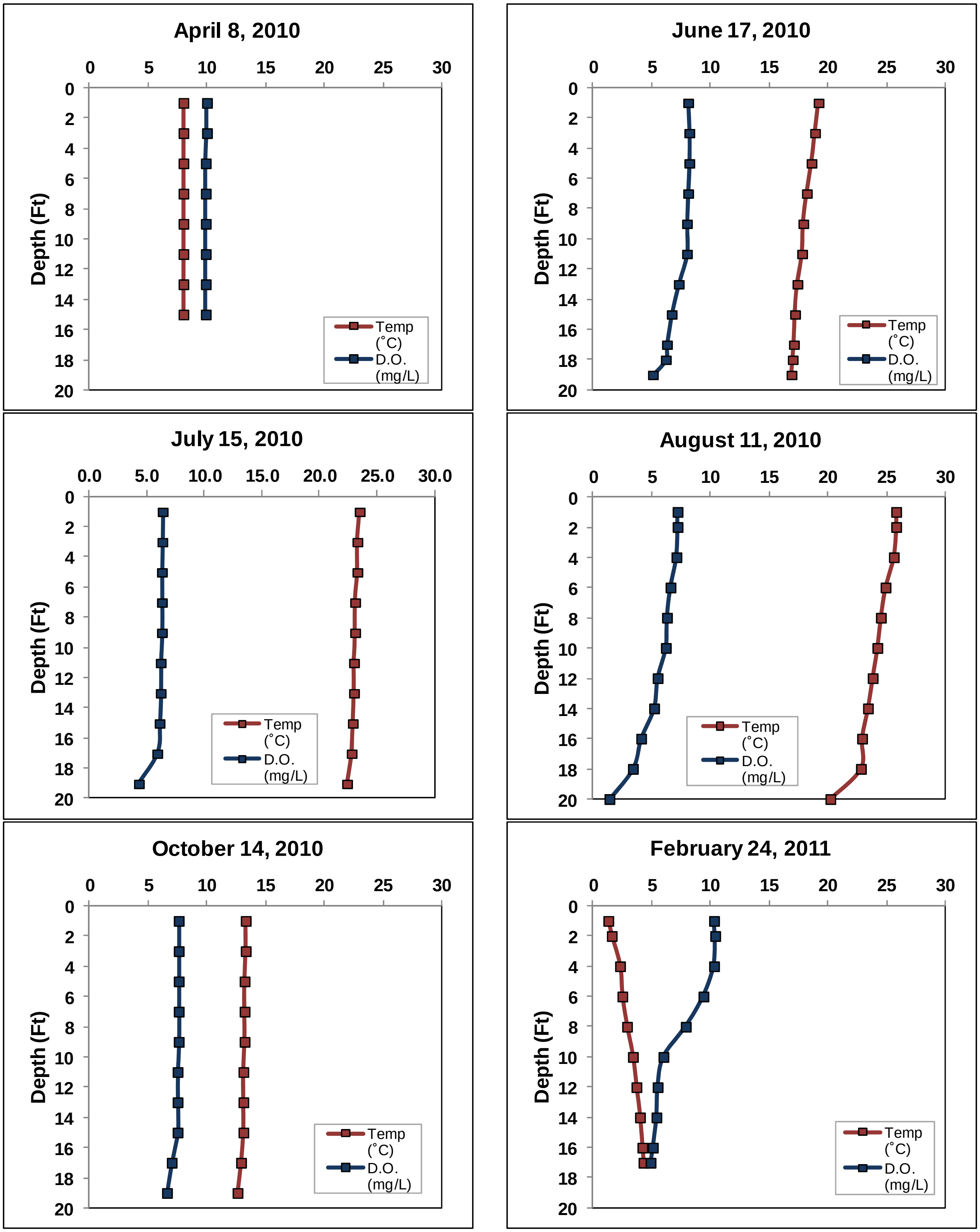


Figure 8.4.1-5. Big Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big 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 Big 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 Chainwide 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. Big Lake's pH was measured at roughly 7.3 in the summer months of 2010. This value is near neutral and fall within the normal range for Wisconsin lakes.

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 Big Lake was measured at 24.0 (mg/L as $CaCO_3$), indicating 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 Big Lake during the summer of 2010. 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 Big Lake's pH of 7.3 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 Big Lake was found to be 8.0 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval mussels) were found within these samples.

8.4.2 Big Lake Watershed Assessment

Big Lake's watershed is 45,504 acres in size. Compared to Big Lake's size of 865 acres, this makes for a large watershed to lake area ratio of 52:1.

Exact land cover calculation and modeling of nutrient input to Big Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.4.3 Big Lake Shoreland Condition

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 2010, Big Lake's immediate shoreline was assessed in terms of its development. Big Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.7 miles of natural/undeveloped and developed-natural shoreline (52% of the shoreline) were observed during the survey (Figure 8.4.3-1). 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, 1.2 miles of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Big 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. Big Lake Map 1 displays the location of these shoreline lengths around the entire lake.

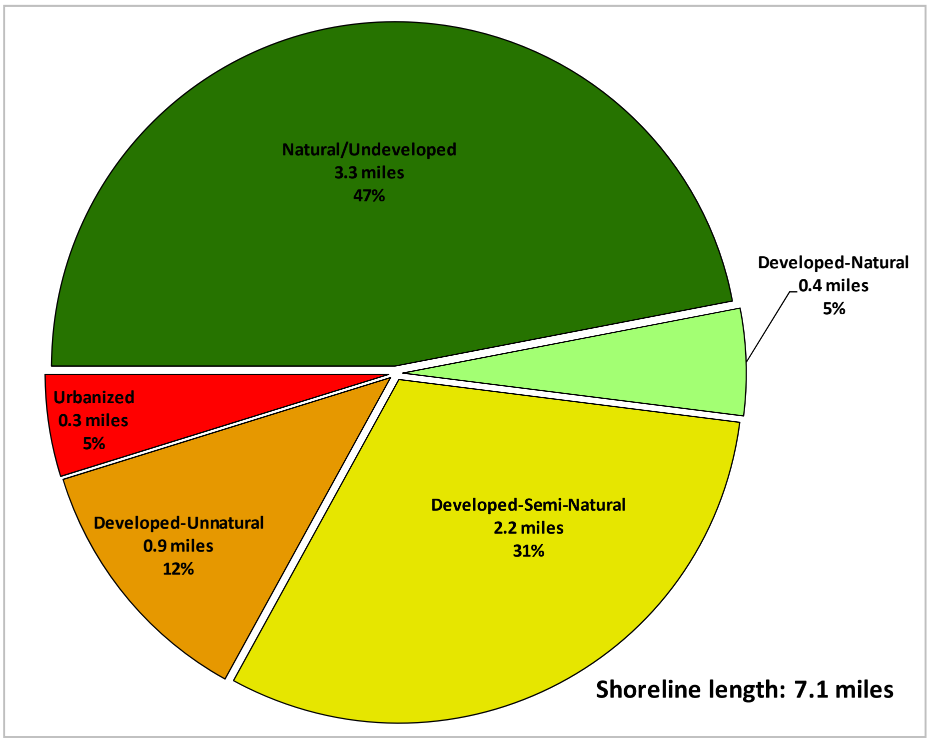


Figure 8.4.3-1. Big Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Big Lake Map 1.

8.4.4 Big Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Lake on June 18, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Big Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Lake on August 5 & 9, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Big Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Big Lake (Table 8.4.4-1). 23 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Additionally, two species of emergent exotic plants were found on the Big Lake shoreline – amur silver grass and purple loosestrife. Submergent aquatic plants were found growing to a depth of seven feet, which is not uncommon for lakes as heavily stained as Big Lake (see the Big Lake Water Quality Section for discussion on Big Lake's water clarity). As discussed later on within this section, many of the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 236 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 59% of the point-intercept sampling locations where sediment data was collected at were sand, 37% consisted of a fine, organic substrate (muck) and 4% were determined to be rocky.

Table 8.4.4-1. Aquatic plant species located in the Big Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex crinita*	Fringed sedge	6	I
	Carex utriculata	Common yellow lake sedge	7	I
	Calla palustris	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Equisetum fluviatile	Water horsetail	7	X
	Eleocharis palustris	Creeping spikerush	6	X
	Glyceria canadensis	Rattlesnake grass	7	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Miscanthus sacchariflorus	Amur silver grass	Exotic	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool-grass	4	I
	Zizania palustris	Northern wild rice	8	X
FL	*Nymphaea odorata*	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes echinospora	Spiny-spored quilwort	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Megalodonta beckii	Water marigold	8	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
FF	*Lemna trisulca*	Forked duckweed	6	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free-Floating
X = Located on rake during point-intercept survey; I = Incidental Species

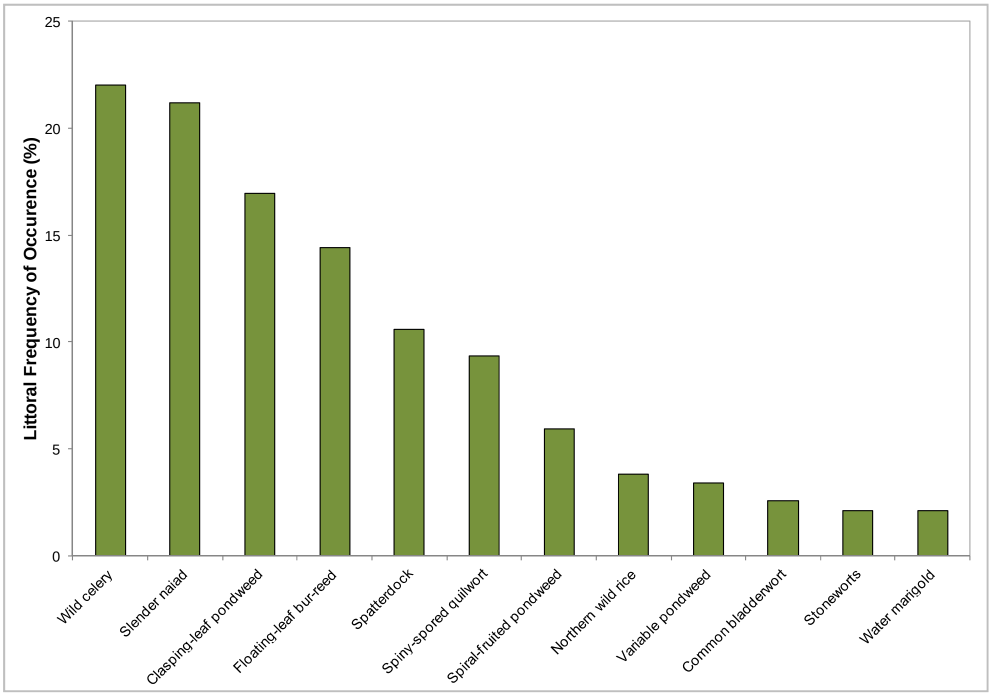


Figure 8.4.4-1 Big Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.4.4-1 (above) shows that wild celery, slender naiad and clasping-leaf pondweed were the most frequently encountered plants within Big Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is also a food source of waterfowl. Clasping-leaf pondweed is a submergent plant that has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Unlike many other pondweeds, this plant does not produce floating leaves.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, one was located within Big Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of native aquatic plants (including incidentals) were found in Big Lake and 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 Big Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds good diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 22% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from Big Lake, 18 of them would be wild celery. This distribution can be observed in Figure 8.4.4-2, where together 10 species account for 88% of the population of plants within Big Lake, while the other 13 species account for the remaining 12%. Eleven additional species (native and non-native) were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.4.4-1 as incidentals.

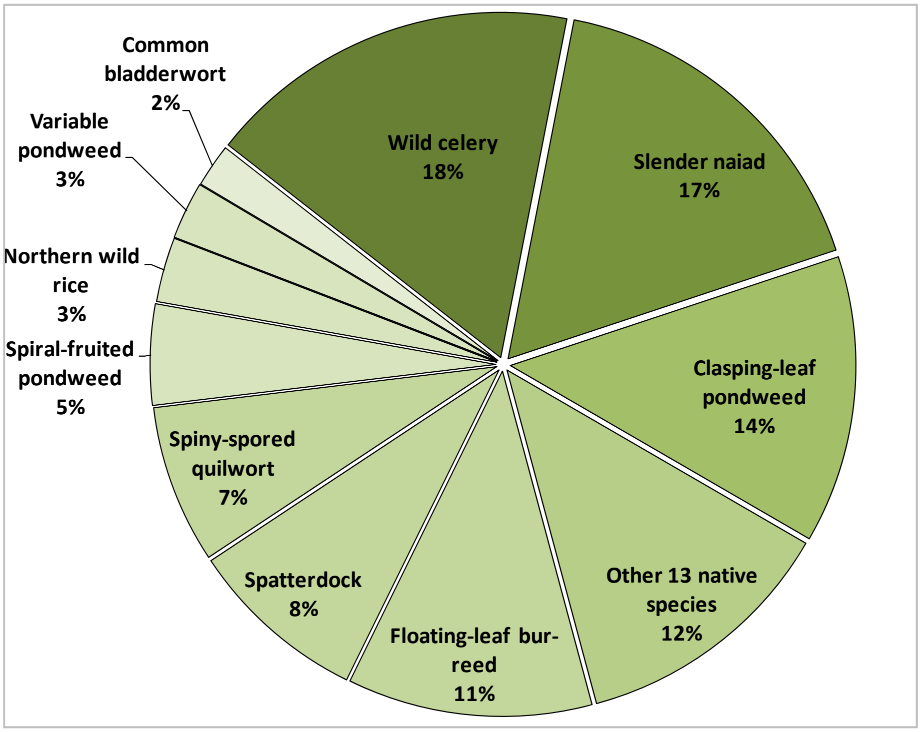


Figure 8.4.4-2 Big Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Big Lake's average conservatism value (6.6) is higher than the state median (6.0) but slightly under the ecoregion median (6.7). This indicates that the plant community of Big Lake is indicative of a moderately disturbed system. This is not surprising considering Big Lake's plant community has good diversity and fairly high species richness. Combining Big Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.5 which is above the median values of the ecoregion and state.

The quality of Big Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.6 acres of the lake contains these types of plant communities (Big Lake Map 2,

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

Table 8.4.4-2. Big Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	4.7
Floating-leaf	5.5
Mixed Floating-leaf and Emergent	114.9
Total	125.1

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 Big 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.

Aquatic Invasive Species in Big Lake

During the 2011 community mapping survey, a single purple loosestrife plant was located on the shoreline of Big Lake (Big Lake Map 2). 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.

The single plant that was found on Big Lake was carefully pulled by Onterra staff. Volunteer monitoring of this location and the Big Lake shoreline in general is recommended to spot any other occurrences of purple loosestrife. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

.

8.4.5 Big Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Lake's implementation plan is compiled by describing how Big Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Big Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Big Lake as part of this chain-wide management planning project, it is up to Big Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Big Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Big Lake contains multiple public access points and is directly connected to the rest of the Three Lakes Chain of Lakes via Dog Lake and is also accessible by Whitefish Lake through the Thoroughfare. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Lake or from Big Lake elsewhere. If a Big Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Big Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Big Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Lake is protected. Volunteers from Big Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Big Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

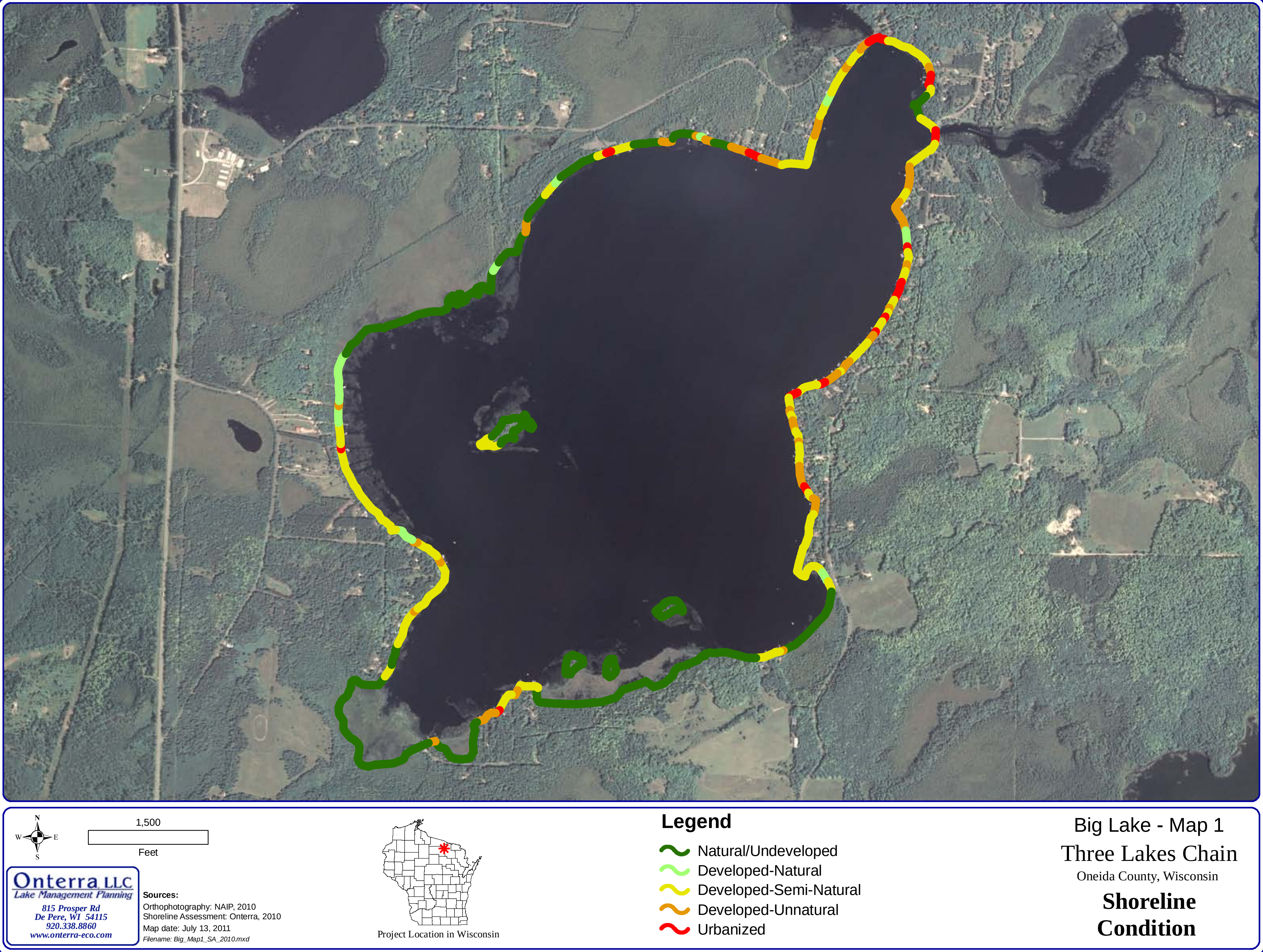
Description: As mentioned within the Chain-wide Implementation Plan, photographic evidence of sporadic blue-green algae blooms in Big Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in production of these algal blooms, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Big Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through tributary streams.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

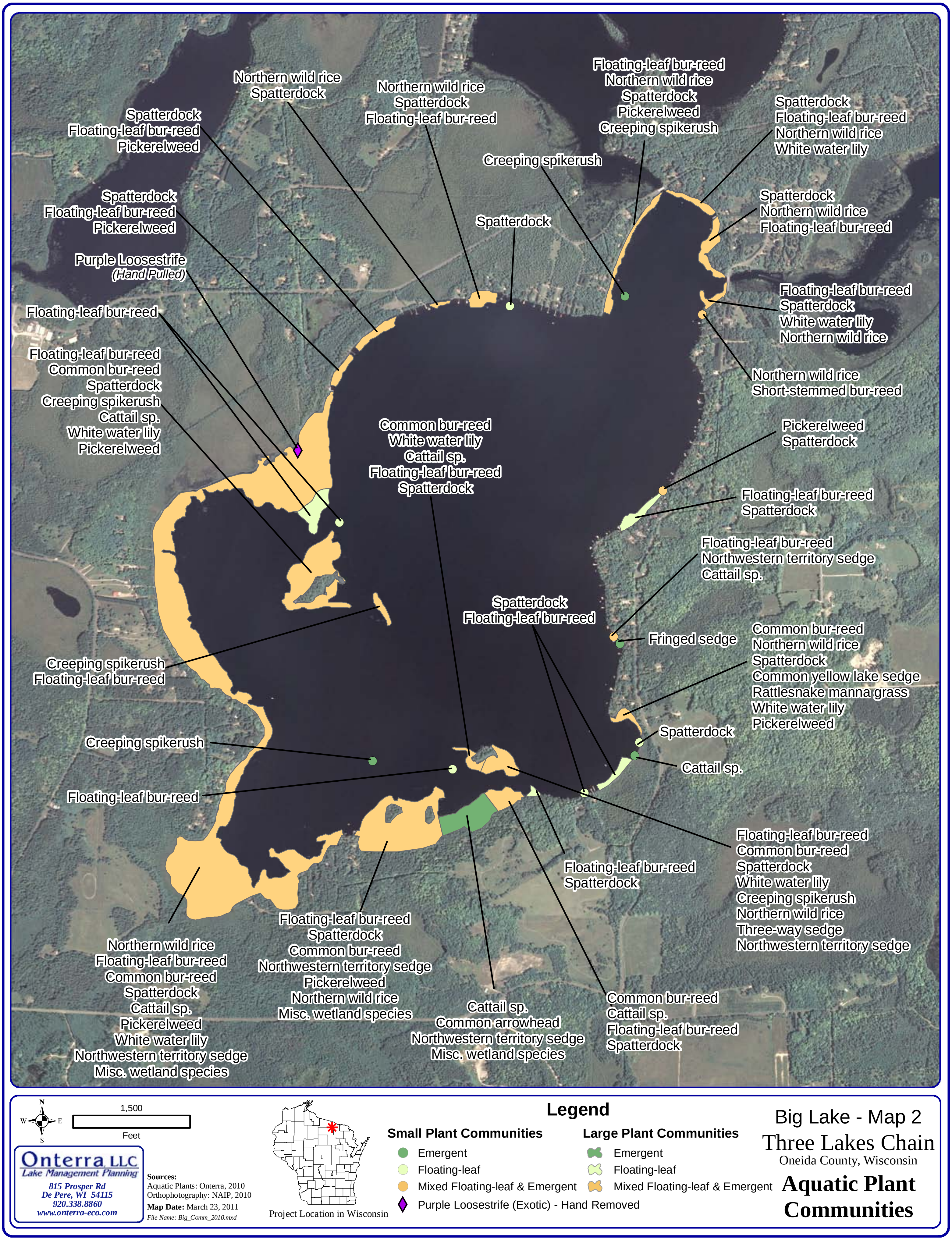


Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
Map date: July 13, 2011
Filename: Big_Map1_SA_2010.mxd

Big Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

Shoreline Condition



Northern wild rice
Spatterdock
Northern wild rice
Spatterdock
Floating-leaf bur-reed
Floating-leaf bur-reed
Northern wild rice
Spatterdock
Pickerelweed
Creeping spikerush
Spatterdock
Floating-leaf bur-reed
Pickerelweed
Spatterdock
Floating-leaf bur-reed
Northern wild rice
White water lily
Creeping spikerush
Spatterdock
Floating-leaf bur-reed
Pickerelweed
Spatterdock
Spatterdock
Northern wild rice
Floating-leaf bur-reed
Purple Loosestrife
(Hand Pulled)
Floating-leaf bur-reed
Spatterdock
White water lily
Northern wild rice
Floating-leaf bur-reed
Floating-leaf bur-reed
Common bur-reed
Spatterdock
Creeping spikerush
Cattail sp.
White water lily
Pickerelweed
Northern wild rice
Short-stemmed bur-reed
Common bur-reed
White water lily
Cattail sp.
Floating-leaf bur-reed
Spatterdock
Pickerelweed
Spatterdock
Floating-leaf bur-reed
Spatterdock
Floating-leaf bur-reed
Northwestern territory sedge
Cattail sp.
Spatterdock
Floating-leaf bur-reed
Fringed sedge
Common bur-reed
Northern wild rice
Spatterdock
Common yellow lake sedge
Rattlesnake manna grass
White water lily
Pickerelweed
Creeping spikerush
Floating-leaf bur-reed
Spatterdock
Creeping spikerush
Cattail sp.
Floating-leaf bur-reed
Floating-leaf bur-reed
Common bur-reed
Spatterdock
White water lily
Creeping spikerush
Northern wild rice
Three-way sedge
Northwestern territory sedge
Floating-leaf bur-reed
Spatterdock
Floating-leaf bur-reed
Spatterdock
Common bur-reed
Northwestern territory sedge
Pickerelweed
Northern wild rice
Misc. wetland species
Northern wild rice
Floating-leaf bur-reed
Common bur-reed
Spatterdock
Cattail sp.
Pickerelweed
White water lily
Northwestern territory sedge
Misc. wetland species
Cattail sp.
Common arrowhead
Northwestern territory sedge
Misc. wetland species
Common bur-reed
Cattail sp.
Floating-leaf bur-reed
Spatterdock
N
W
E
S
1,500
Feet
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010
Map Date: March 23, 2011
File Name: Big_Comm_2010.mxd
Project Location in Wisconsin
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Purple Loosestrife (Exotic) - Hand Removed
Large Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Big Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin
Aquatic Plant Communities

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

8.5 Dog Lake

An Introduction to Dog Lake

Dog Lake, Oneida County, is a lowland drainage lake with a maximum depth of 22 feet and a surface area of 216 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Dog Lake contains 32 native plant species, of which wild celery was the most common plant. No exotic plants were observed during the 2011 lake surveys.

Field Survey Notes

Unusually large community of water horsetail (Equisetum fluviatile) encountered during aquatic plant surveys (pictured at right).

Photo 8.5.1 Dog Lake, Oneida County

Lake at a Glance* – Dog Lake

Morphology	
Acreage	216
Maximum Depth (ft)	22
Mean Depth (ft)	8
Volume (acre-feet)	1,710
Shoreline Complexity	3.2
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 9, 2011
Number of Native Species	32
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.88
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	210:1

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

8.5.1 Dog Lake Water Quality

During 2011/2012, water quality data was collected from Dog Lake on six occasions. 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. Additionally, historical databases were searched for any prior data that may have been collected on Dog Lake. Unfortunately, Secchi disk clarity data had been collected only sporadically on Dog Lake in the past, making a long term trend analysis difficult. However, it is possible to make some comparisons from recent data to that which was collected years ago.

Dog Lake total phosphorus and chlorophyll-*a* values can be found in Table 8.5.1-1. In 2011, summer total phosphorus concentrations averaged 31.7 μg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 μg/L). The 2011 average summer chlorophyll-*a* concentration (8.8 μg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 μg/L). The total phosphorus average ranks as *Good* in the Trophic State Index, while the chlorophyll-*a* average value ranks as *Excellent*.

Table 8.5.1-1. Dog Lake, state-wide shallow, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

	Secchi (feet)				Chlorophyll-*a* (μg/L)				Total Phosphorus (μg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	4.0	1	4.0	1	3.6	1	3.6	1	43.0	1.0	43.0
1990	5	5.2	5	5.2								
1991	6	3.0	6	3.0								
1994	6	4.2	4	4.2								
1995	8	4.6	8	4.6								
1996	11	4.3	8	4.4								
2011	5	2.5	3	2.5	5	8.0	3	8.8	5	34.6	3.0	31.7
All Years (Weighted)		4.0		4.1		7.3		7.5		36.0		34.5
Shallow, Lowland Drainage Lakes				5.6				9.4				33.0
NLF Ecoregion				8.9				5.6				21.0

In addition to data collected during 1979 and the 1990's, measurements of Secchi disk clarity were taken in Dog Lake during 2011 field visits as well. A weighted average across all summers ranks as *Good*, however is slightly below the median value for other shallow, lowland drainage lakes in Wisconsin. During the aquatic plant surveys that took place on Dog Lake in 2011, plants were found growing to a maximum depth of six feet; however, the vast majority of plants grew to only five feet of depth. This is an added testament to the low water clarity in Dog Lake.

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 lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Dog Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

Dog Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.5.1-1). 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 Dog Lake is in a eutrophic state.

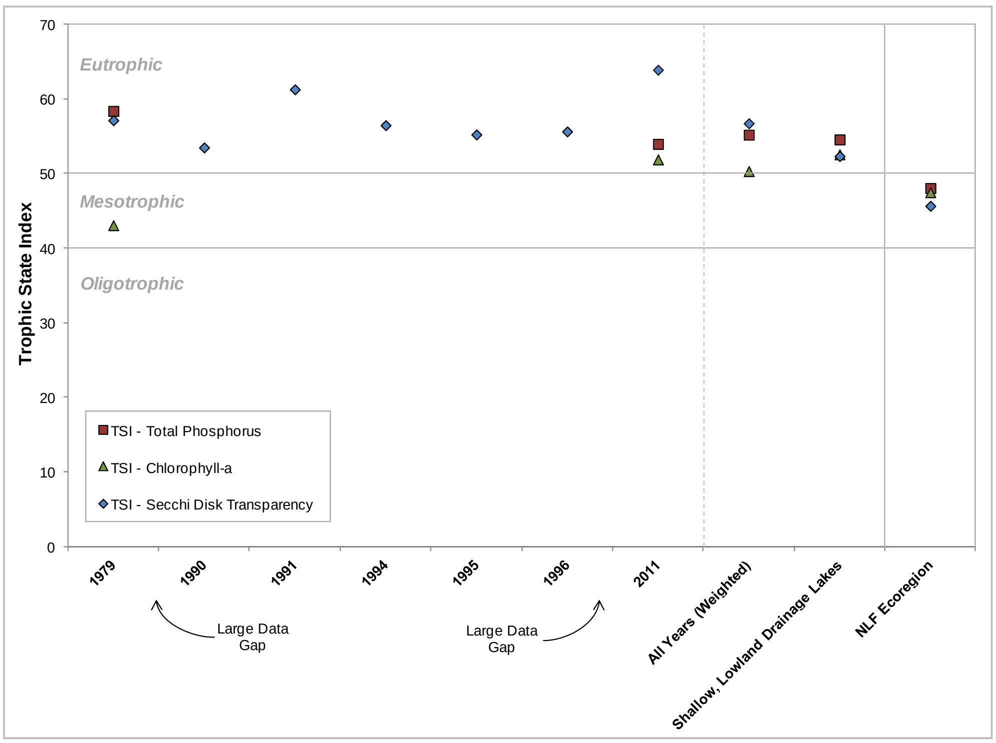


Figure 8.5.1-1. Dog Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Dog Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Dog Lake by Onterra staff. Graphs of those data are displayed in Figure 8.5.1-2 for all sampling events.

Dog Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind 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. Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in July. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~12 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2012, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

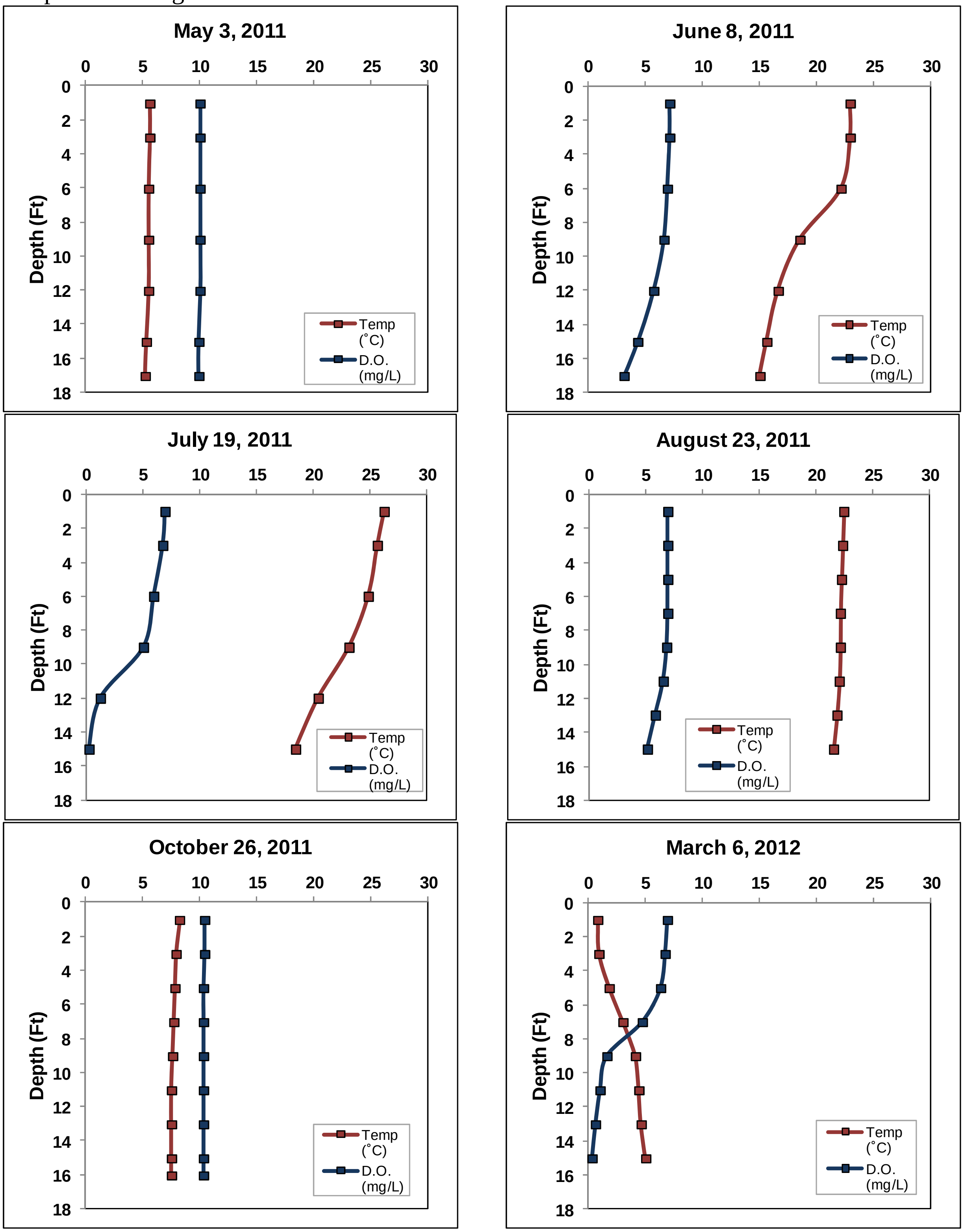


Figure 8.5.1-2. Dog Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Dog 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 Dog 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 Chainwide 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. Dog Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

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 Dog Lake was measured at 17.6 (mg/L as $CaCO_3$), indicating 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 Dog Lake during the summer of 2011. 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 Dog Lake's pH of 7.0 is at the bottom end of 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 Dog Lake was found to be 5.5 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.5.2 Dog Lake Watershed Assessment

Dog Lake's watershed is 45,631 acres in size. Compared to Dog Lake's size of 216 acres, this makes for an incredibly large watershed to lake area ratio of 210:1.

Exact land cover calculation and modeling of nutrient input to Dog Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.5.3 Dog Lake Shoreline Condition

As mentioned previously in the Chain-wide Shoreline 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 2011, Dog Lake's immediate shoreline was assessed in terms of its development. Dog Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.0 miles of natural/undeveloped and developed-natural shoreline (54% of the entire shoreline) were observed during the survey (Figure 8.5.3-1). 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, 1.0 miles of urbanized and developed–unnatural shoreline (26% of the total shoreline) was observed. If restoration of the Dog 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. The Dog Lake Map 1 displays the location of these shoreline lengths around the entire lake.

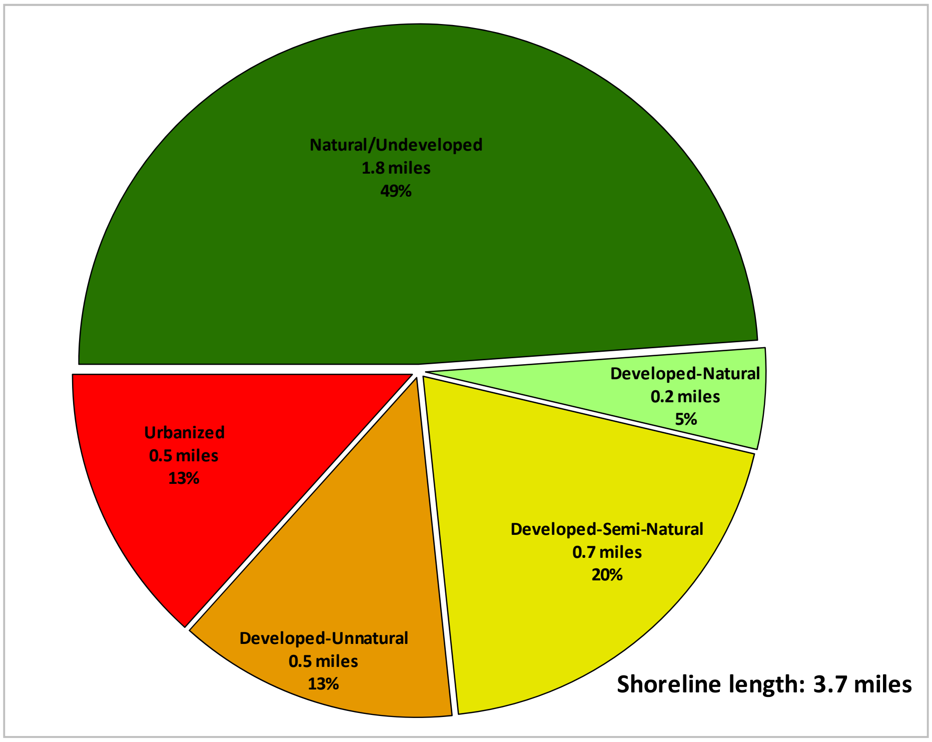


Figure 8.5.3-1. Dog Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Dog Lake Map 1.

8.5.4 Dog Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Dog Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Dog Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Dog Lake on August 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 9 & 10 to create the aquatic plant community map (Dog Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Dog Lake (Table 8.5.4-1). 21 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is common within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 116 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 75% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and no areas of rocky substrate were encountered.

Table 8.5.4-1. Aquatic plant species located in the Dog Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	Acorus calamus	Sweetflag	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Equisetum fluviatile	Water horsetail	7	X
	Eleocharis palustris	Creeping spikerush	6	X
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	Sparganium emersum	Short-stemmed bur-reed	8	I
	Sparganium eurycarpum	Common bur-reed	5	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	Elodea canadensis	Common waterweed	3	X
	Isoetes sp.	Quilwort species	N/A	X
	Myriophyllum sibiricum	Northern water milfoil	7	I
	Najas flexilis	Slender naiad	6	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	Eleocharis acicularis	Needle spikerush	5	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent;
X = Located on rake during point-intercept survey; I = Incidental Species

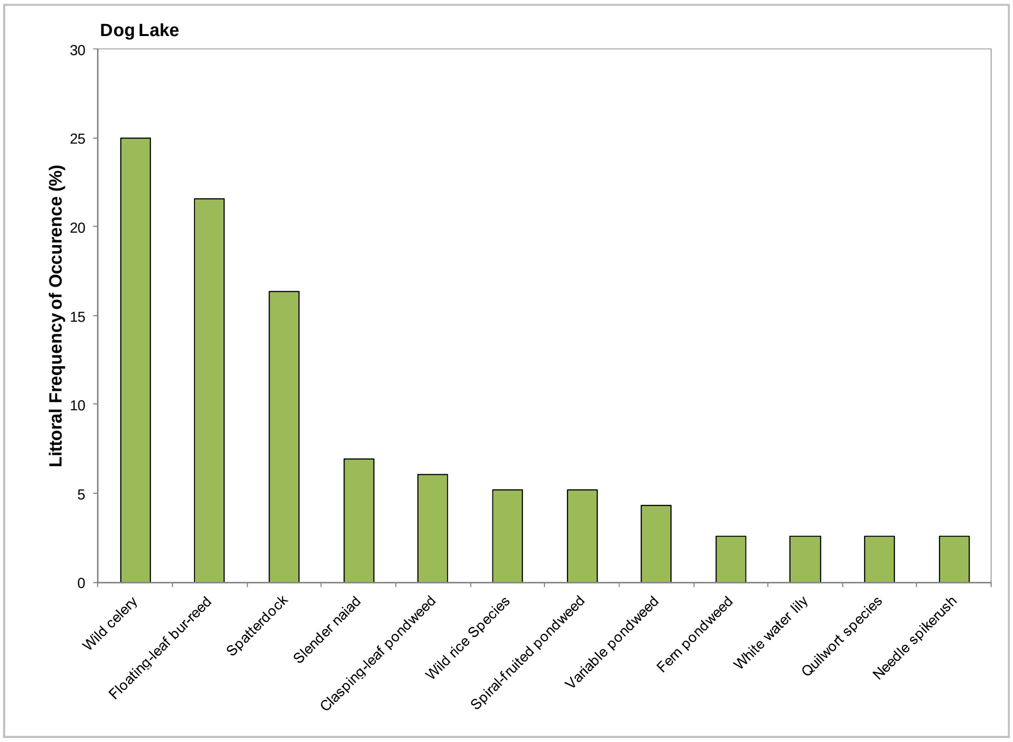


Figure 8.5.4-1 Dog Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2011 point-intercept survey.

Figure 8.5.4-1 (above) shows that wild celery, floating-leaf bur-reed and spatterdock were the most commonly encountered species during the point-intercept survey. 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. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Dog Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of aquatic plants (including incidentals) were found in Dog Lake and 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 Dog Lake's plant community (0.88) lies slightly above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake has good diversity in its plant community.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 23%. Explained another way, if 100 plants were randomly sampled from Dog Lake, 23 of them would be wild celery. This distribution can be observed in Figure 8.5.4-2, where together 10 species account for 71% of the population of plants within Dog Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.5.4-1 as incidentals.

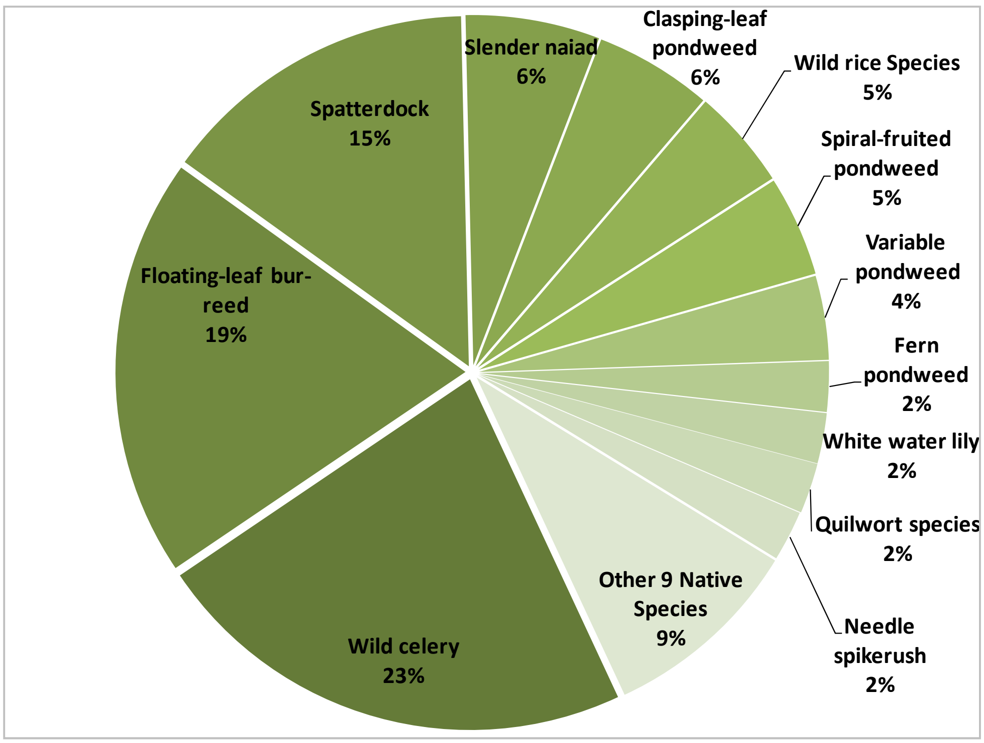


Figure 8.5.4-2 Dog Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Dog Lake's average conservatism value (6.7) is equal to the ecoregion but larger than the state-wide median. This indicates that the plant community of Dog Lake is indicative of a moderately undisturbed system. This is not surprising considering Dog Lake's plant community has good diversity and high species richness. Combining Dog Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 30.5 which is above the median values of the ecoregion and state.

The quality of Dog Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 41.6 acres of the lake contains these types of plant communities (Dog Lake Map 2, Table 8.5.4-2). Seventeen floating-leaf and emergent species were located on Dog Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.5.4-2. Dog Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	6.3
Floating-leaf	15.0
Mixed Floating-leaf and Emergent	20.3
Total	41.6

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 Dog 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.

.

8.5.5 Dog Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Dog Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Dog Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Dog Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Dog Lake's implementation plan is compiled by describing how Dog Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Dog Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Dog Lake as part of this chain-wide management planning project, it is up to Dog Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Dog Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: While Dog Lake does not have a public access point, it is directly connected to the rest of the Three Lakes Chain of Lakes via Big Lake and Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Dog Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Dog Lake or from Dog Lake elsewhere. If a Dog Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Dog Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Dog Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Dog Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Dog Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, no volunteer water quality collection is occurring on Dog Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Dog Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Dog Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Dog Lake shoreline was categorized in terms of its development. According to the results from this survey, 49% of the shoreline is currently in a natural state, while 26% is in an urban or developed-unnatural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

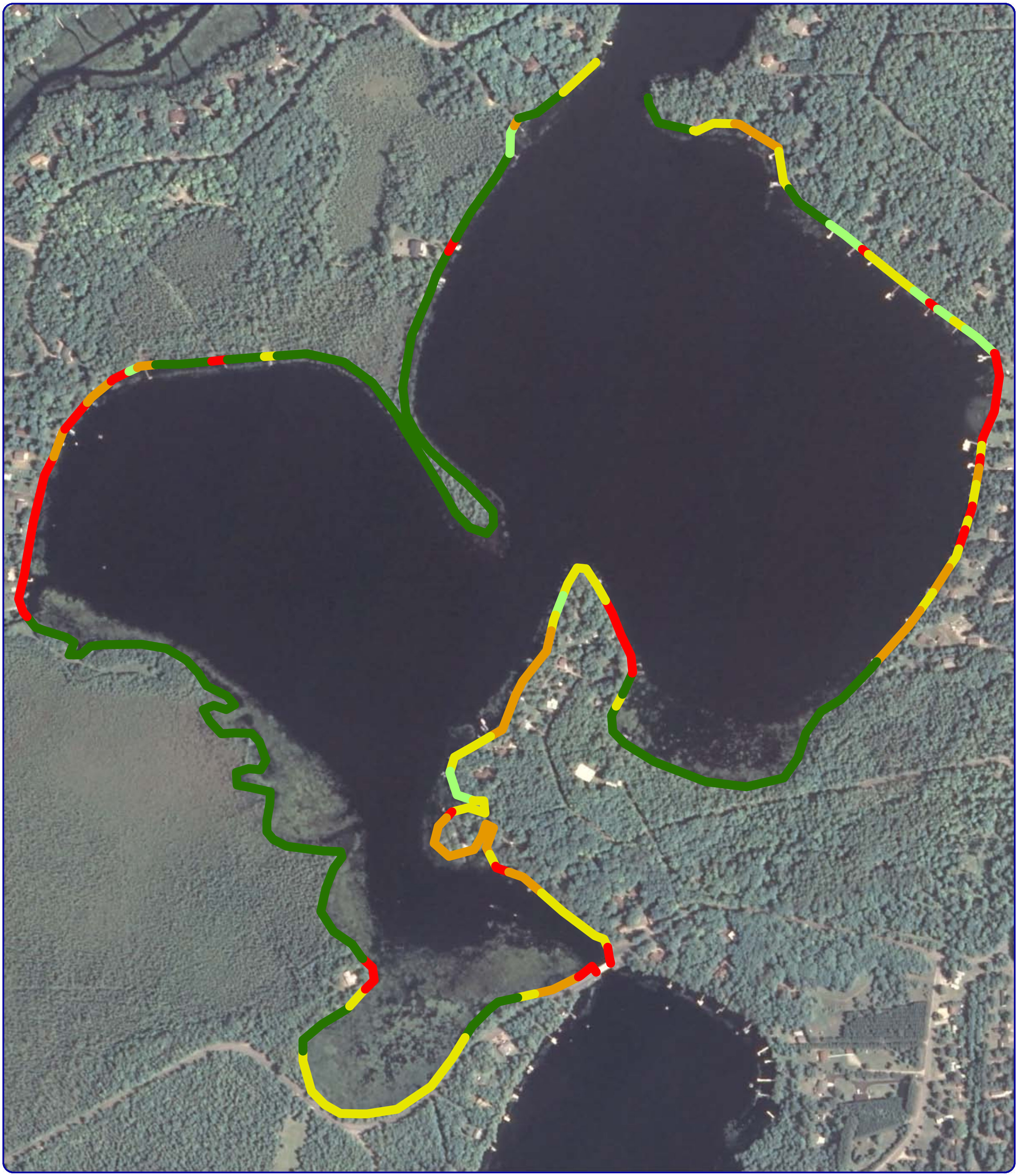
<u>Management Action:</u> Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Dog Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

<u>Management Action:</u> Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Dog Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Dog Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

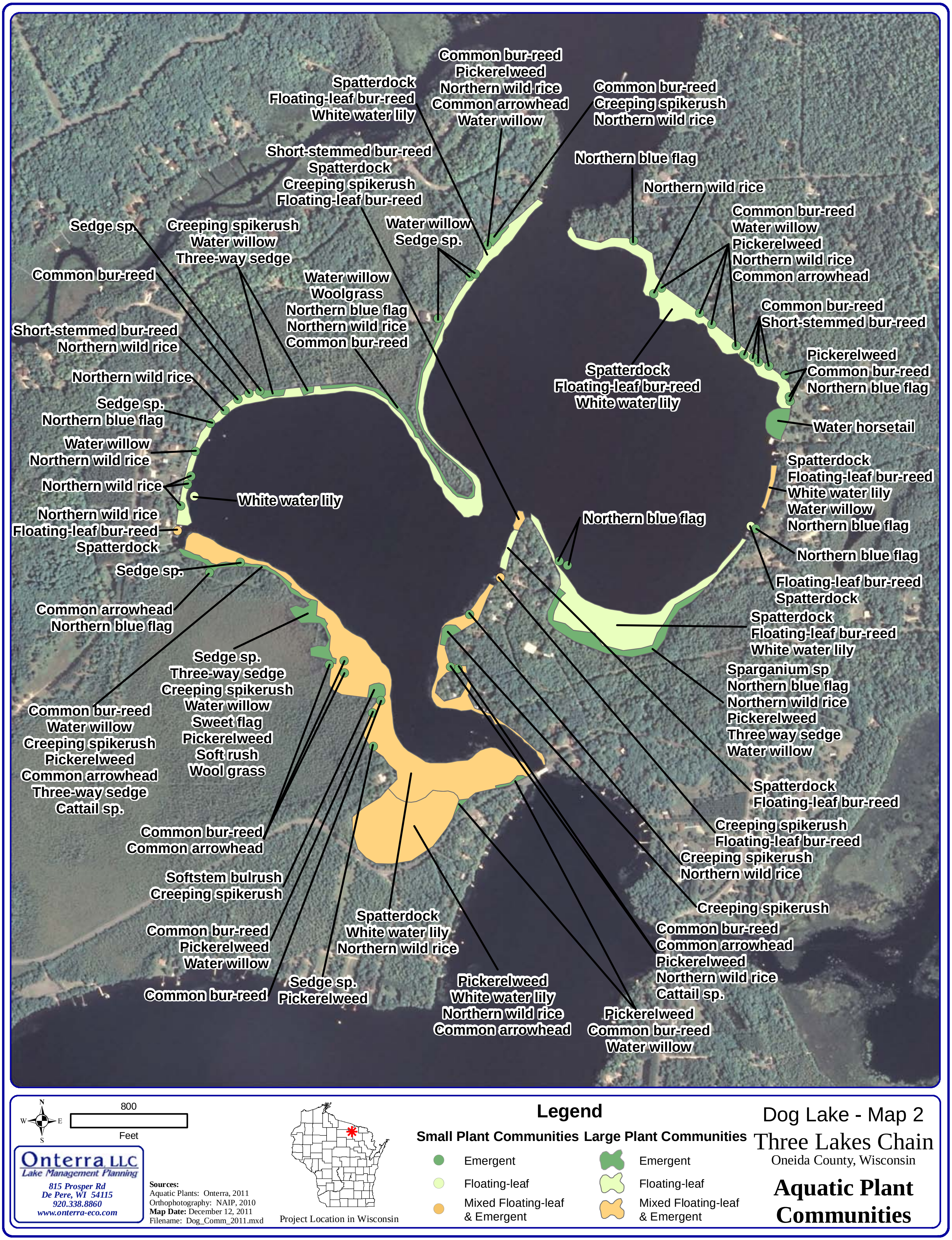


Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
Filename: Dog_SA_2011.mxd

Dog Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

Shoreline Condition


Common bur-reed
Pickerelweed
Northern wild rice
Common arrowhead
Water willow
Spatterdock
Floating-leaf bur-reed
White water lily
Common bur-reed
Creeping spikerush
Northern wild rice
Short-stemmed bur-reed
Spatterdock
Creeping spikerush
Floating-leaf bur-reed
Northern blue flag
Northern wild rice
Common bur-reed
Water willow
Pickerelweed
Northern wild rice
Common arrowhead
Sedge sp.
Creeping spikerush
Water willow
Three-way sedge
Water willow
Sedge sp.
Common bur-reed
Water willow
Woolgrass
Northern blue flag
Northern wild rice
Common bur-reed
Common bur-reed
Short-stemmed bur-reed
Short-stemmed bur-reed
Northern wild rice
Pickerelweed
Common bur-reed
Northern blue flag
Spatterdock
Floating-leaf bur-reed
White water lily
Northern wild rice
Sedge sp.
Northern blue flag
Water horsetail
Water willow
Northern wild rice
Spatterdock
Floating-leaf bur-reed
White water lily
Water willow
Northern blue flag
Northern wild rice
White water lily
Northern blue flag
Northern wild rice
Floating-leaf bur-reed
Spatterdock
Northern blue flag
Sedge sp.
Floating-leaf bur-reed
Spatterdock
Common arrowhead
Northern blue flag
Spatterdock
Floating-leaf bur-reed
White water lily
Sedge sp.
Three-way sedge
Creeping spikerush
Water willow
Sweet flag
Pickerelweed
Soft rush
Wool grass
Sparganium sp
Northern blue flag
Northern wild rice
Pickerelweed
Three way sedge
Water willow
Common bur-reed
Water willow
Creeping spikerush
Pickerelweed
Common arrowhead
Three-way sedge
Cattail sp.
Spatterdock
Floating-leaf bur-reed
Common bur-reed
Common arrowhead
Creeping spikerush
Floating-leaf bur-reed
Softstem bulrush
Creeping spikerush
Creeping spikerush
Northern wild rice
Creeping spikerush
Spatterdock
White water lily
Northern wild rice
Common bur-reed
Pickerelweed
Water willow
Common bur-reed
Common arrowhead
Pickerelweed
Northern wild rice
Cattail sp.
Sedge sp.
Pickerelweed
Common bur-reed
Pickerelweed
White water lily
Northern wild rice
Common arrowhead
Pickerelweed
Common bur-reed
Water willow
N
W
E
S
800
Feet
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map Date: December 12, 2011
Filename: Dog_Comm_2011.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
Dog Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin
Aquatic Plant Communities

Note: Methodology, explanation of analysis and scientific background on Crystal (Mud) Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.6 Crystal (Mud) Lake

An Introduction to Crystal (Mud) Lake

Crystal (Mud) Lake, Oneida County, is a drainage lake with a maximum depth of nine feet and a surface area of 124 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Crystal (Mud) Lake contains 26 native plant species, of which floating-leaf bur-reed was the most common plant. No exotic plants were observed during 2011

Field Survey Notes

A shallow, dark lake consisting primarily of mucky substrate. Few sampling locations held aquatic plants. No exotic aquatic plant species observed during 2011 field work.

Photo 8.6.1 Crystal (Mud) Lake, Oneida County

Lake at a Glance* – Crystal (Mud) Lake

Morphology	
Acreage	124
Maximum Depth (ft)	9
Mean Depth (ft)	5
Volume (acre-feet)	648
Shoreline Complexity	3.0
Vegetation	
Curly-leaf Survey Date	June 22, 2011
Comprehensive Survey Date	August 4 & 5, 2011
Number of Native Species	26
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.80
Average Conservatism	6.4
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	63:1

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

8.6.1 Crystal (Mud) Lake Water Quality

During 2011/2012, water quality data was collected from Crystal (Mud) Lake on six occasions. 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. Additionally, historical databases were searched for any prior data that may have been collected on Crystal (Mud) Lake. Only a single historical record was turned up for each of the three water quality parameters – in 1979. No additional data was discovered, leaving only the 2011/2012 data available for analysis.

Crystal (Mud) Lake total phosphorus and chlorophyll-*a* values can be found in Table 8.6.1-1. In 2011, summer total phosphorus concentrations averaged 72.0 μg/L, which is considerably higher than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 μg/L). The 2011 average summer chlorophyll-*a* concentration (5.9 μg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 μg/L). The total phosphorus average ranks as *Fair* within the WiSCALM narrative, while the chlorophyll-*a* average value ranks as *Excellent*.

Measurements of Secchi disk clarity were taken in Crystal (Mud) Lake during 2011 field visits as well. The summer average was 1.5 feet, ranking as *Poor* within the Trophic State Index and falling below the median for other Wisconsin shallow, lowland drainage lakes (5.6 feet). It is interesting to note that while total phosphorus values are exceptionally high, an elevated abundance of algae was not picked up through chlorophyll-*a* sampling. It is possible that the water clarity of the lake is limiting the algal and plant growth, more so than the abundance of nutrients, which are sufficient for algae and plant growth. During the aquatic plant surveys that took place on Crystal (Mud) Lake in 2011, plants were found growing to a maximum depth of seven feet; however, the vast majority of plants grew to only 4 feet of depth. This is an added testament to the *Poor* water clarity in Crystal (Mud) Lake.

Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Crystal (Mud) Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Crystal (Mud) Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

Table 8.6.1-1. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	1.5	1	1.5	1	5.2	1	5.2	1	13.0	1.0	13.0
2011	5	1.6	3	1.5	5	7.8	3	5.9	5	70.8	3.0	72.0
All Years (Weighted)		1.6		1.5		7.3		5.7		61.2		57.3
Shallow, Lowland Drainage Lakes				5.6				9.4				33.0
NLF Ecoregion				8.9				5.6				21.0

Crystal (Mud) Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall into categories of mesotrophic (chlorophyll-*a*) and eutrophic (phosphorus and Secchi disk clarity). Values above 50 are generally classified as being within the eutrophic category; two of Crystal (Mud) Lake's water quality parameters fall above this benchmark (Table 8.6.1-2). Therefore, it can be concluded that Crystal (Mud) Lake is in a eutrophic state.

Table 8.6.1-2. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Year	TP	Chl-a	Secchi
1979	41.1	46.8	71.3
2011	65.8	48.0	71.3
All Years (Weighted)	62.5	47.7	71.3
Shallow, Lowland Drainage Lakes	54.6	52.6	52.4
NLF Ecoregion	48.1	47.5	45.7

Dissolved Oxygen and Temperature in Crystal (Mud) Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Crystal (Mud) Lake by Onterra staff. Graphs of those data are displayed in Figure 8.6.1-1 for all sampling events.

Crystal (Mud) Lake remained thoroughly mixed throughout the spring, summer and fall months in 2011. This is not uncommon in lakes that are moderate in size and fairly shallow. Energy from the wind 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.

Dissolved oxygen concentrations remained sufficient throughout the open water months for warm water fish species. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Crystal (Mud) Lake, levels remained high enough in the upper half of the water column.

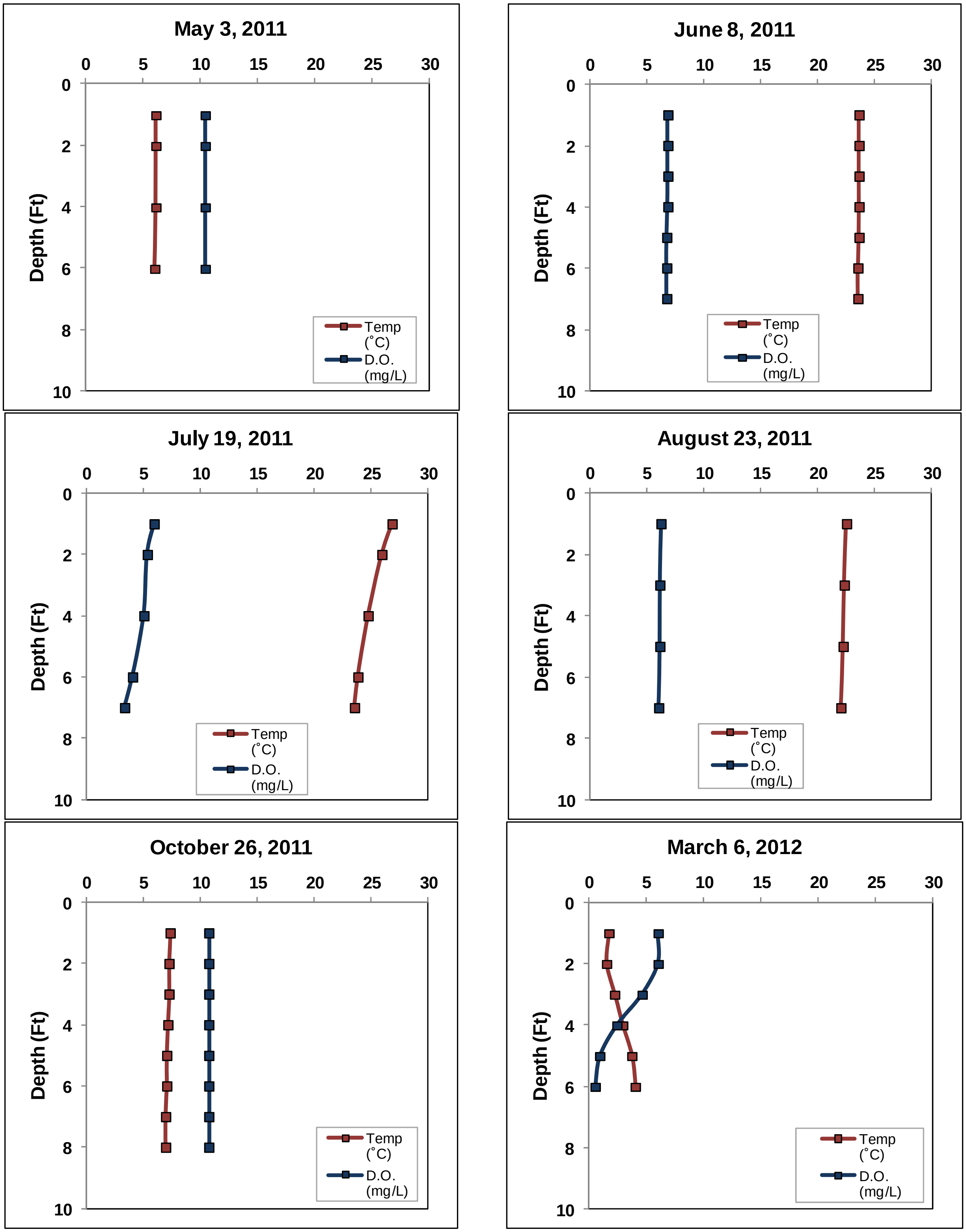


Figure 8.6.1-1. Crystal (Mud) Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Crystal (Mud) 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 Crystal (Mud) 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 Chainwide 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. Crystal (Mud) Lake's pH was measured at 6.8 in the summer months of 2011. This value is near neutral and falls within the normal range for Wisconsin lakes.

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 Crystal (Mud) Lake was measured at 15.9 (mg/L as $CaCO_3$), indicating 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 Crystal (Mud) Lake during the summer of 2011. 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 Crystal (Mud) Lake's pH of 6.8 falls slightly outside of 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 Crystal (Mud) Lake was found to be 4.2 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 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 Crystal (Mud) Lake Watershed Assessment

Crystal (Mud) Lake's watershed is 7,964 acres in size. Compared to Crystal (Mud) Lake's size of 124 acres, this makes for an incredibly large watershed to lake area ratio of 63:1.

Exact land cover calculation and modeling of nutrient input to Crystal (Mud) Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.6.3 Crystal (Mud) Lake Shoreland Condition

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 2011, Crystal (Mud) Lake's immediate shoreline was assessed in terms of its development. Crystal (Mud) Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (66% of the entire shoreline) were observed during the survey (Figure 8.6.3-1). 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, 0.3 miles of urbanized and developed–unnatural shoreline (12% of the total shoreline) was observed. If restoration of the Crystal (Mud) 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. The Crystal (Mud) Lake Map 1 displays the location of these shoreline lengths around the entire lake.

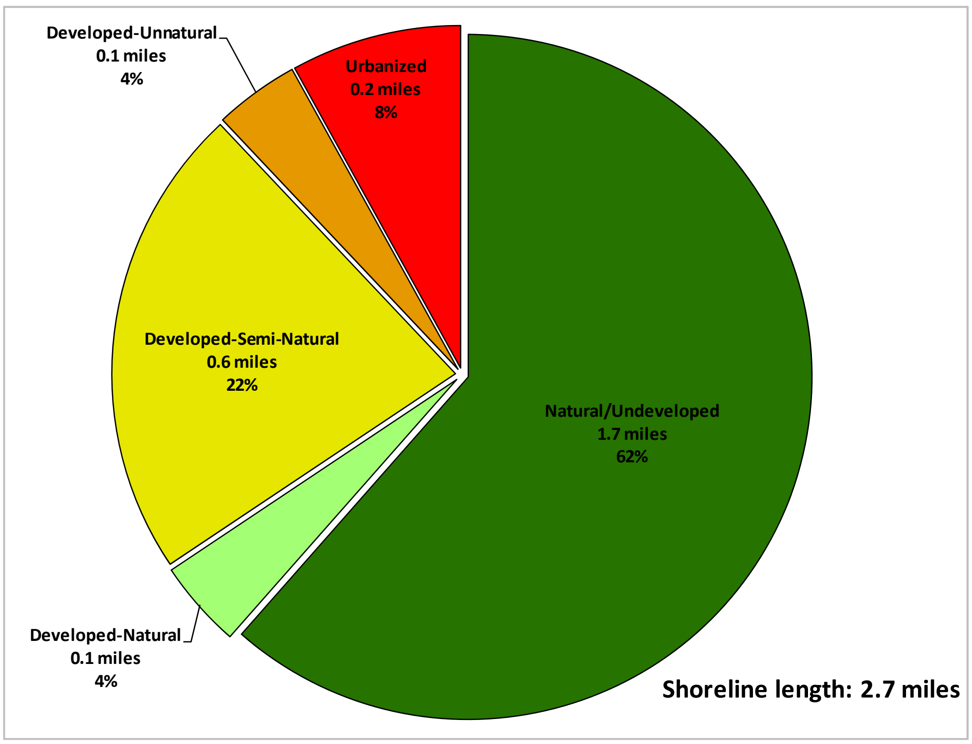


Figure 8.6.3-1. Crystal (Mud) Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Crystal (Mud) Lake Map 1.

8.6.4 Crystal (Mud) Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Crystal (Mud) Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Crystal (Mud) Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Crystal (Mud) Lake on August 4 & 5, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8th to create the aquatic plant community map (Crystal (Mud) Lake Map 2). During all surveys, 26 species of native aquatic plants were located in Crystal (Mud) Lake (Table 8.6.4-1). 12 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and moderately diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 24% contained aquatic vegetation. Approximately 9% of the point-intercept sampling locations where sediment data was collected at were sand, 91% consisted of a fine, organic substrate (muck) while no rocky substrate was encountered.

Table 8.6.4-1. Aquatic plant species located in the Crystal (Mud) Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Dulichium arundinaceum	Three-way sedge	9	*I*
	Decodon verticillatus	Water-willow	7	*I*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Pontederia cordata	Pickerelweed	9	*X*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Schoenoplectus tabernaemontani	Softstem bulrush	4	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Typha spp.	Cattail spp.	1	*I*
	Zizania palustris	Northern wild rice	8	*I*
FL	*Brasenia schreberi*	Watershield	7	*I*
	Nuphar variegata	Spatterdock	6	*X*
	Nymphaea odorata	White water lily	6	*X*
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	*I*
	Sparganium emersum	Short-stemmed bur-reed	8	*I*
	Sparganium fluctuans	Floating-leaf bur-reed	10	*X*
Submergent	*Ceratophyllum demersum*	Coontail	3	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
FF	*Lemna turionifera*	Turion duckweed	2	*X*
	Spirodela polyrhiza	Greater duckweed	5	*I*

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

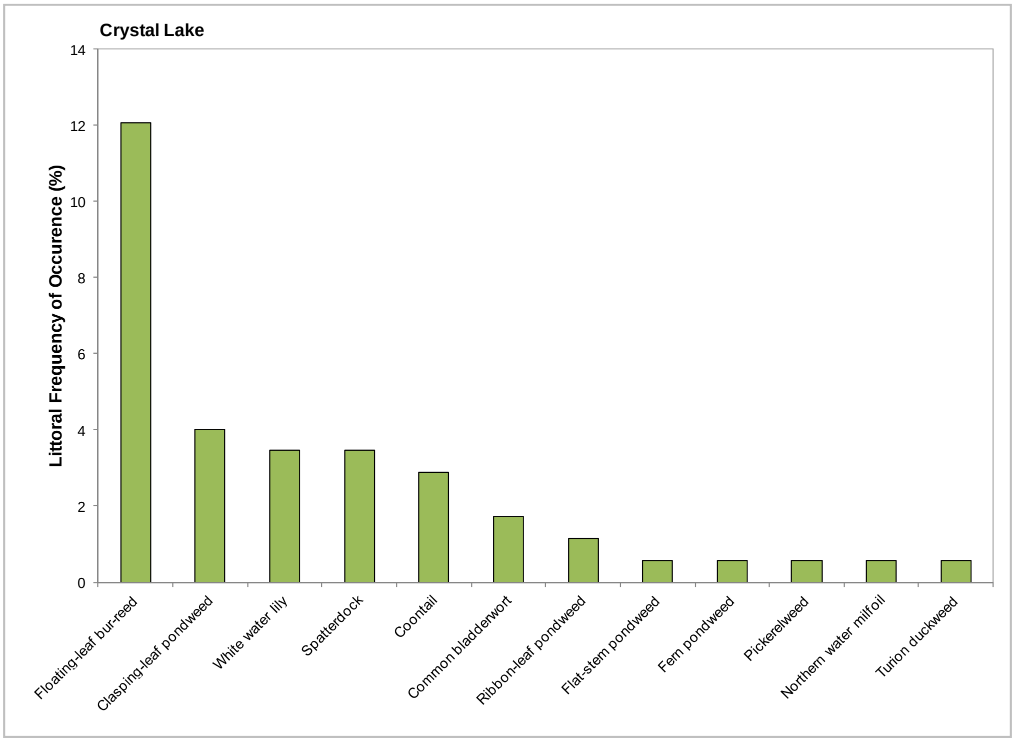


Figure 8.6.4-1 Crystal (Mud) Lake aquatic plant littoral frequency of occurrence analysis. Chart includes all species encountered during the 2011 point-intercept survey.

Figure 8.6.4-1 (above) shows that floating-leaf bur-reed, clasping-leaf pondweed were the two species encountered most within the point-intercept survey. White water lily and spatterdock were encountered often as well. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Clasping-leaf pondweed has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Leaves have 13-21 veins, which is a good characteristic to use in distinguishing this plant from other similar looking plants in the genus *Potamogeton*. White water lily and spatterdock are floating-leaf plants that are commonly found near the shoreline on Wisconsin lakes. White water lilies, as the name implies, are round in shape and produce a white flower. Spatterdock leaves resemble a heart shape and produce yellow roundish flowers in the summer months.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Crystal (Mud) Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

26 species of aquatic plants (including incidentals) were found in Crystal (Mud) Lake and 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 Crystal (Mud) Lake's plant community (0.80) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86).

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 floating-leaf bur-reed was found at 12% of the sampling locations, its relative frequency of occurrence is 38%. Explained another way, if 100 plants were randomly sampled from Crystal (Mud) Lake, 38 of them would be floating-leaf bur-reed. Floating-leaf bur-reed is therefore relatively dominant compared to other species within the lake. This distribution can be observed in Figure 8.6.4-2, where together seven species account for 91% of the population of plants within Crystal (Mud) Lake, while the other five species account for the remaining 9%. Fourteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.6.4-1 as incidentals.

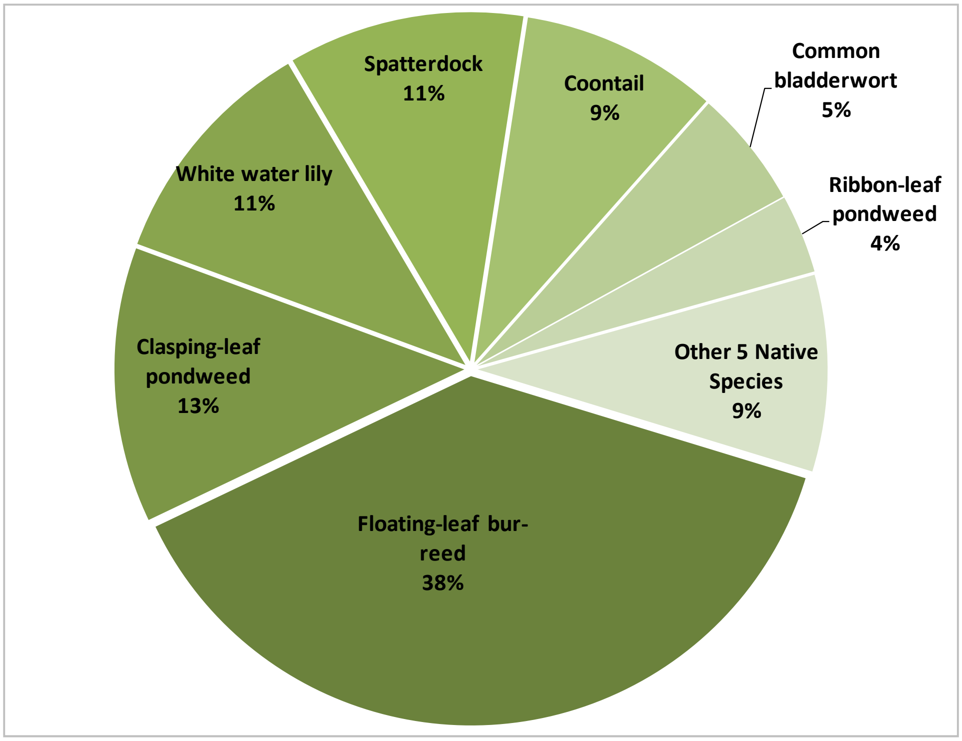


Figure 8.6.4-2 Crystal (Mud) Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Crystal (Mud) Lake's average conservatism value (6.4) is lower than the ecoregion median, but higher than the state median. This indicates that the plant community of Crystal (Mud) Lake is indicative of moderately disturbed system. This is not surprising considering Crystal (Mud) Lake's plant community has moderate diversity and low species richness. Combining Crystal (Mud) Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.2 which is below the median value of the ecoregion and equal to the state median value.

Crystal (Mud) Lake holds numerous areas of emergent and floating-leaf plant communities. The 2011 community map indicates that approximately 19.3 acres of the lake contains these types of plant communities (Crystal (Mud) Lake Map 2, Table 8.6.4-2). Fifteen floating-leaf and emergent species were located on Crystal (Mud) Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.6.4-2. Crystal (Mud) Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	2.6
Floating-leaf	14.7
Mixed Floating-leaf and Emergent	2.0
Total	19.3

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 Crystal (Mud) 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.

.

8.6.5 Crystal (Mud) Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Crystal (Mud) Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Crystal (Mud) Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Crystal (Mud) Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Crystal (Mud) Lake's implementation plan is compiled by describing how Crystal (Mud) Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Crystal (Mud) Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Crystal (Mud) Lake as part of this chain-wide project, it is up to Crystal (Mud) Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Crystal (Mud) Lake Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Crystal (Mud) Lake contains a single public access, and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Crystal (Mud) Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Crystal (Mud) Lake or from Crystal (Mud) Lake elsewhere. If a Crystal (Mud) Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Crystal (Mud) Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Crystal (Mud) Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Crystal (Mud) Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Crystal (Mud) Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, no volunteer water quality collection is occurring on Crystal (Mud) Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Crystal (Mud) Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Crystal (Mud) Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Crystal (Mud) Lake shoreline was categorized in terms of its development. According to the results from this survey, 62% of the shoreline is currently in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Crystal (Mud) Lake shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The

TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

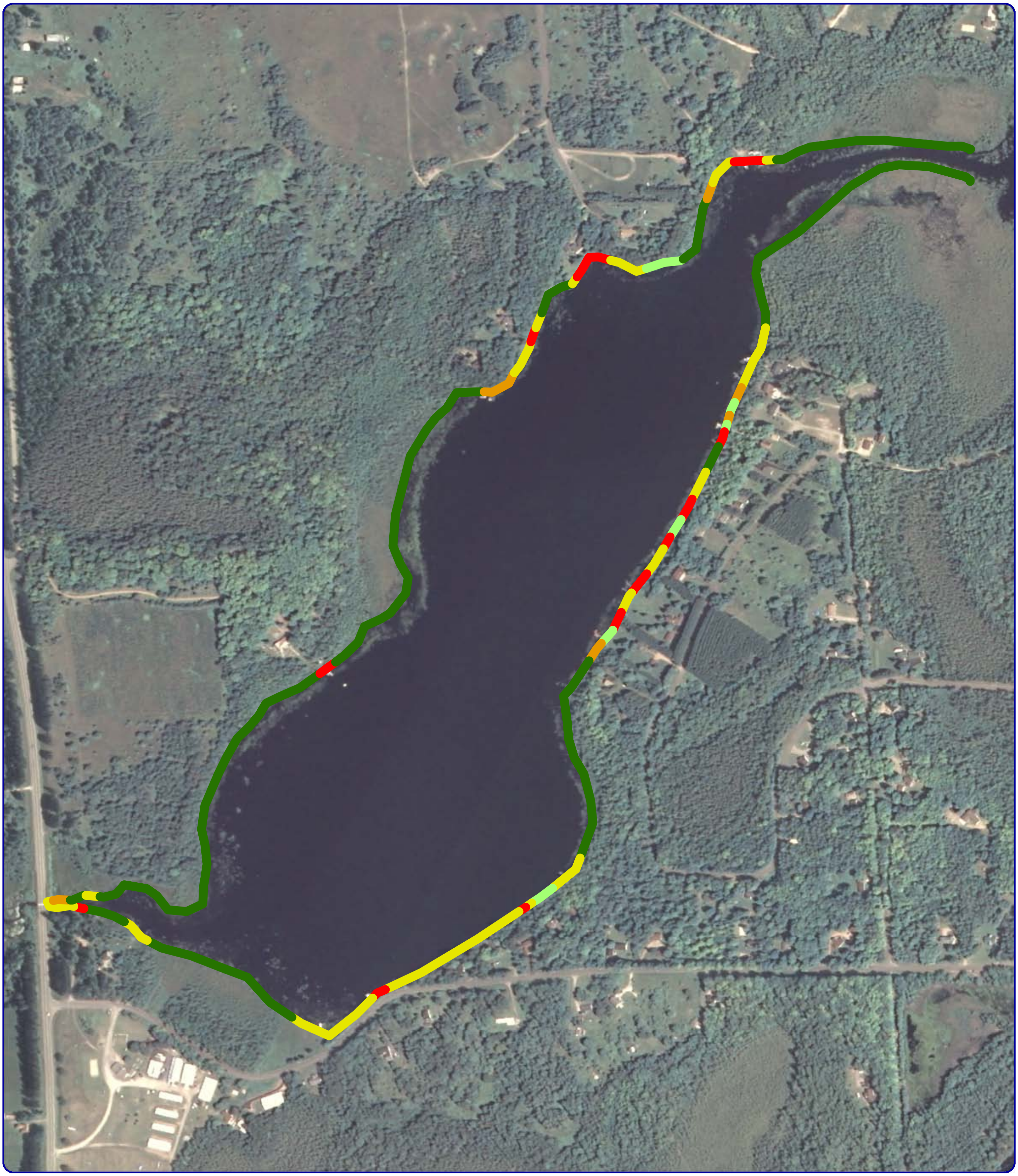
Description: As mentioned within the Chain-wide Implementation Plan, evidence of elevated nutrient levels in Crystal (Mud) Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in producing these high nutrient levels, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Crystal (Mud) Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through its tributary stream.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

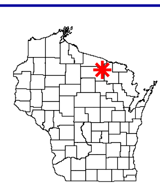
Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Crystal (Mud) Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Crystal (Mud) Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



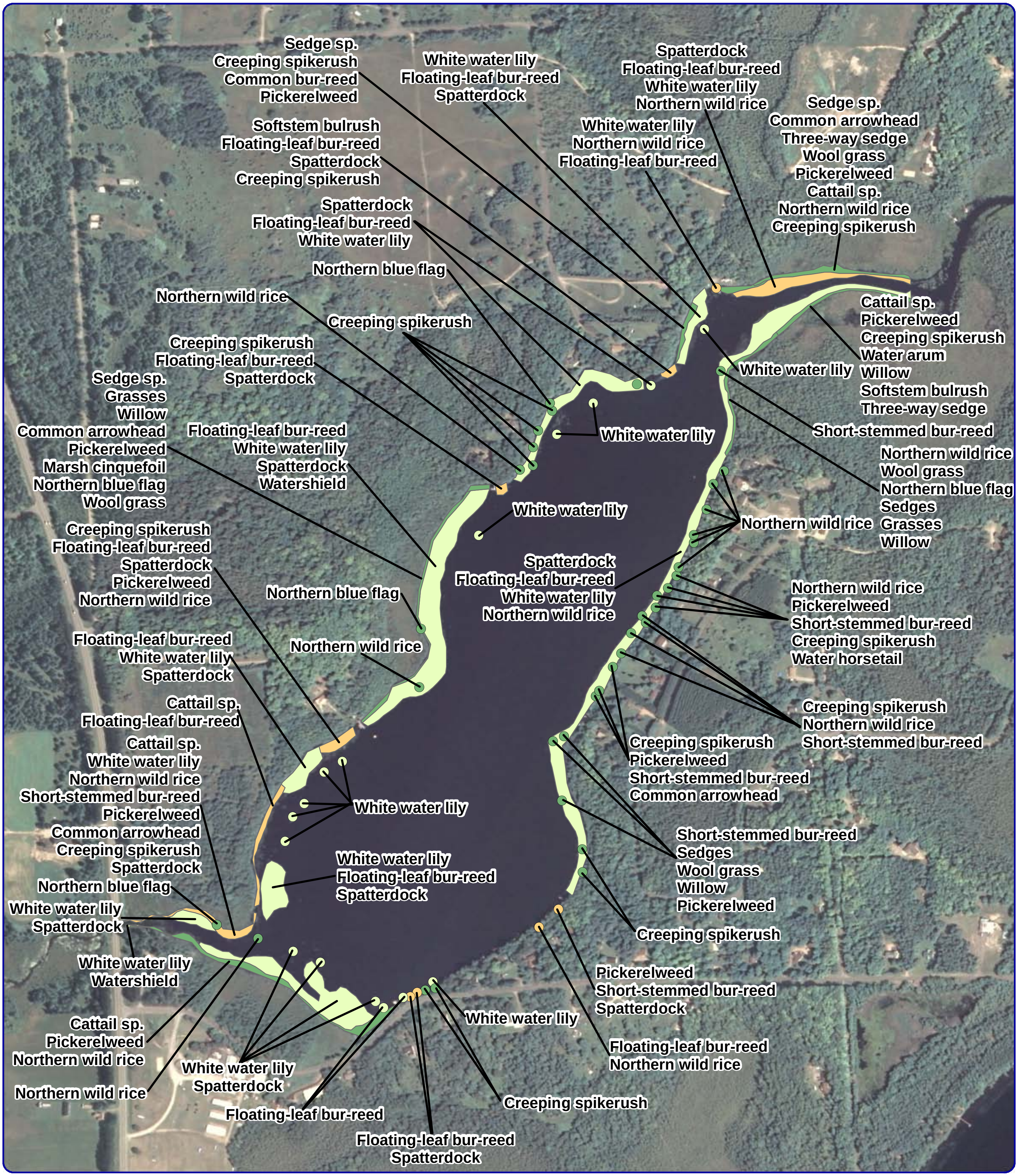
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
Filename: Crystal_SA_2011.mxd



Crystal (Mud) Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

Shoreline Condition

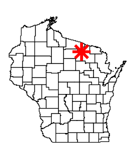


N
W E
S

700
Feet

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

Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 12, 2011
Filename: *Crystal_Comm_2011.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

Crystal (Mud) Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

Aquatic Plant Communities

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

8.7 Deer Lake

An Introduction to Deer Lake

Deer Lake, Oneida County, is a drainage lake with a maximum depth of 20 feet and a surface area of 177 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Deer Lake contains 38 native plant species, of which white water lily was the most common plant. No exotic plants were observed during the 2011 lake surveys.

Field Survey Notes

Navigation tricky on west side of lake, where shallow water and thick floating-leaf aquatic plants were commonly encountered. Dark, stained water observed during surveys.

Photo 8.7.1 Deer Lake, Oneida County

Lake at a Glance* – Deer Lake

Morphology	
Acreage	177
Maximum Depth (ft)	20
Mean Depth (ft)	10
Volume (acre-feet)	1,794
Shoreline Complexity	9.7
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 4 & 9, 2011
Number of Native Species	38
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.89
Average Conservatism	6.3
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	306:1

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

8.7.1 Deer Lake Water Quality

During 2011/2012, water quality data was collected from Deer Lake on six occasions. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006, and various volunteers and agencies have taken Secchi readings on Deer Lake in the late 1980's and mid 1990's also (Figure 8.7.1-1). These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Deer Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding and has not been sampled besides dates in 1979 and 2011.

In 2011, summer total phosphorus concentrations averaged 32.3 μg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 μg/L). 2011 average summer chlorophyll-*a* concentrations (11.0 μg/L) are somewhat higher than the median for other shallow, lowland drainage lakes statewide (9.4 μg/L). Both the total phosphorus and chlorophyll-*a* average concentrations rank as *Good* in the Trophic State Index.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show some variance between years (Figure 8.7.1-1). Summer averages fall mostly within categories of *Fair* and *Good*, and a weighted average across all years is less than the average for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Deer Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Deer Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. In 2011, aquatic plants were found growing to a depth of only six feet within the lake.

Deer Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.7.1-2). 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 Deer Lake is in a eutrophic state.

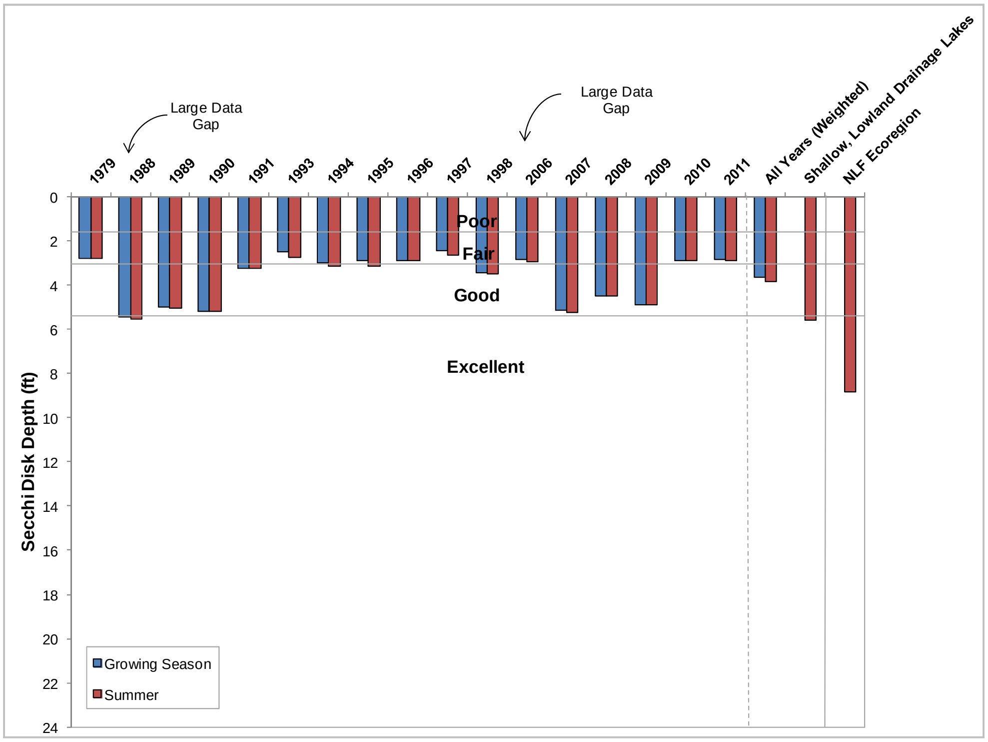


Figure 8.7.1-1. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

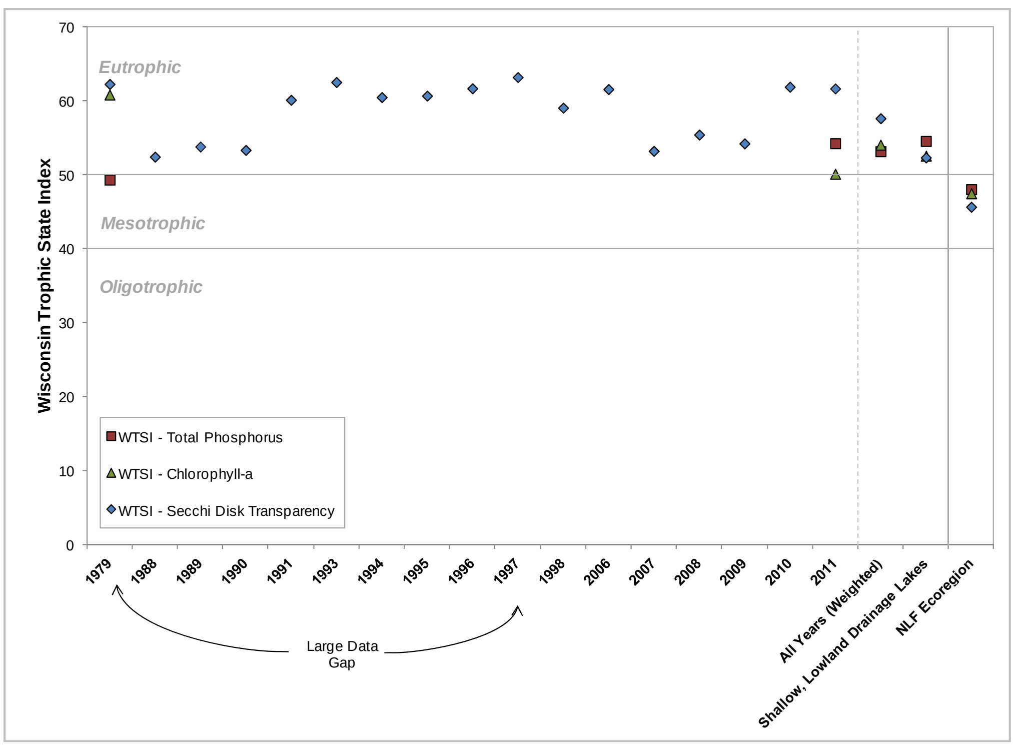


Figure 8.7.1-2. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Deer Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Deer Lake by Onterra staff. Graphs of those data are displayed in Figure 8.7.1-3 for all sampling events.

Deer Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind 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.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer months. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~13 feet of the water column to support most aquatic life found in northern Wisconsin lakes. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Deer Lake, levels remained high enough in the upper half of the water column.

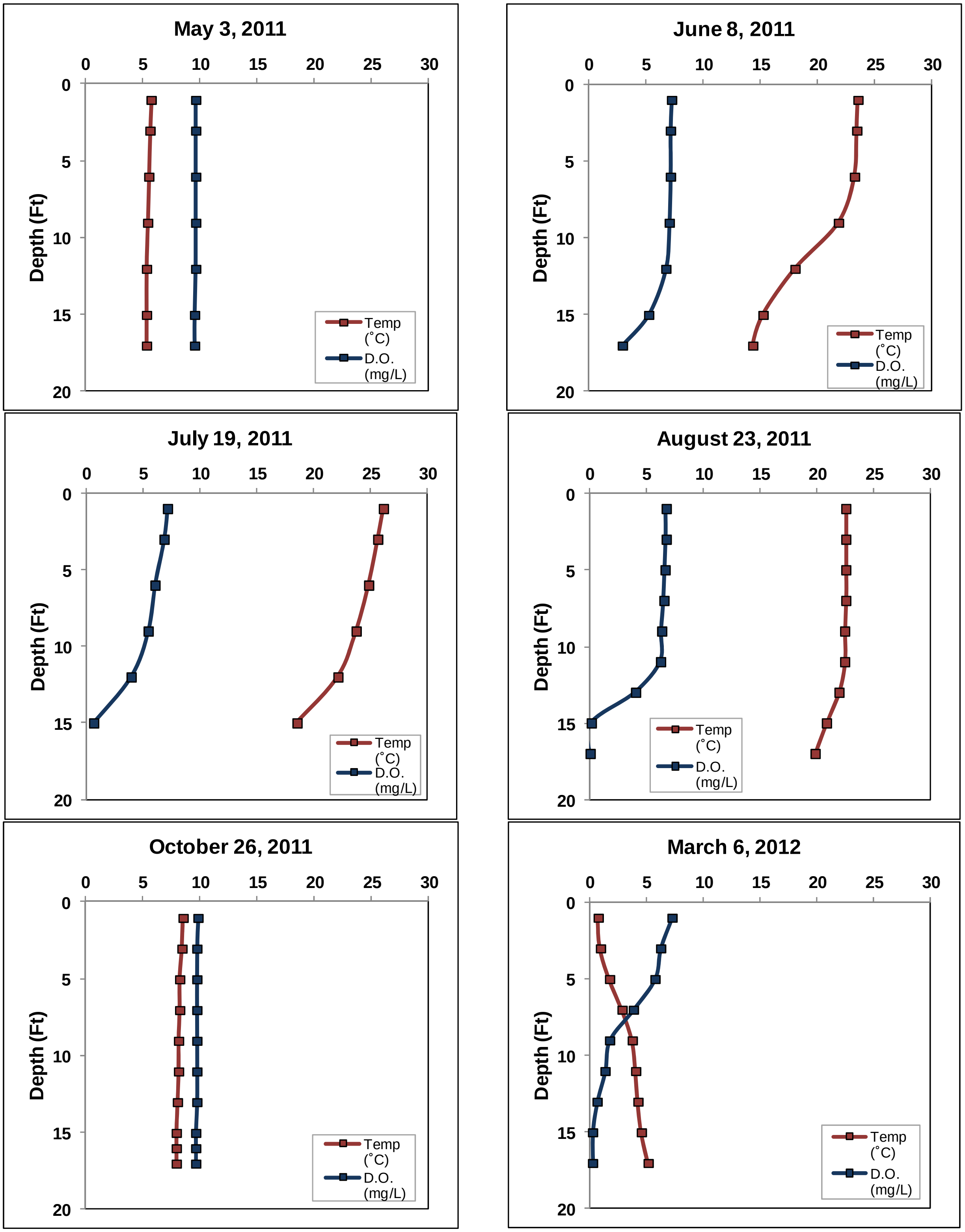


Figure 8.7.1-3. Deer Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Deer 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 Deer 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 Chainwide 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. Deer Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

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 Deer Lake was measured at 18.1 (mg/L as $CaCO_3$), indicating 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 Deer Lake during the summer of 2011. 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 Deer Lake's pH of 7.0 is at the bottom end of 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 Deer Lake was found to be 5.6 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 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 Deer Lake Watershed Assessment

Deer Lake's watershed is 54,378 acres in size. Compared to Deer Lake's size of 177 acres, this makes for an incredibly large watershed to lake area ratio of 306:1.

Exact land cover calculation and modeling of nutrient input to Deer Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.7.3 Deer Lake Shoreland Condition

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 2011, Deer Lake's immediate shoreline was assessed in terms of its development. Deer Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.9 miles of natural/undeveloped and developed-natural shoreline (50% of the entire shoreline) were observed during the survey (Figure 8.7.3-1). 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, 1.0 mile of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Deer 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. Deer Lake Map 1 displays the location of these shoreline lengths around the entire lake.

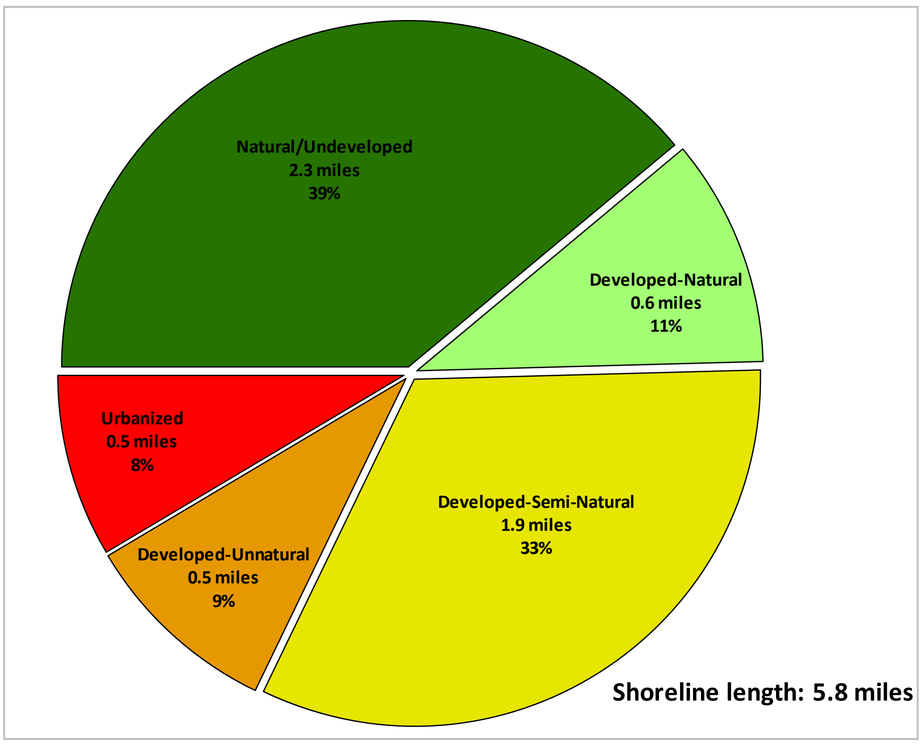


Figure 8.7.3-1. Deer Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Deer Lake Map 1.

8.7.4 Deer Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Deer Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Deer Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Deer Lake on August 4 & 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8 & 9 to create the aquatic plant community map (Deer Lake Map 2). During all surveys, 38 species of native aquatic plants were located in Deer Lake (Table 8.7.4-1). 26 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 149 point-intercept locations sampled within the littoral zone, approximately 64% contained aquatic vegetation. Approximately 39% of the point-intercept sampling locations where sediment data was collected at were sand, 60% consisted of a fine, organic substrate (muck) and only 1% were determined to be rocky.

Table 8.7.4-1. Aquatic plant species located in the Deer Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	X
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	X
	Zizania palustris	Northern wild rice	8	X
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea canadensis	Common waterweed	3	I
	Elodea nuttallii	Slender waterweed	7	X
	Isoetes sp.	Quilwort species	N/A	X
	Myriophyllum sibiricum	Northern water milfoil	7	I
	Myriophyllum verticillatum	Whorled water milfoil	8	I
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
FF	*Lemna turionifera*	Turion duckweed	2	I
	Lemna trisulca	Forked duckweed	6	X
	Spirodela polyrhiza	Greater duckweed	5	I

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floatin
X = Located on rake during point-intercept survey; I = Incidental Species

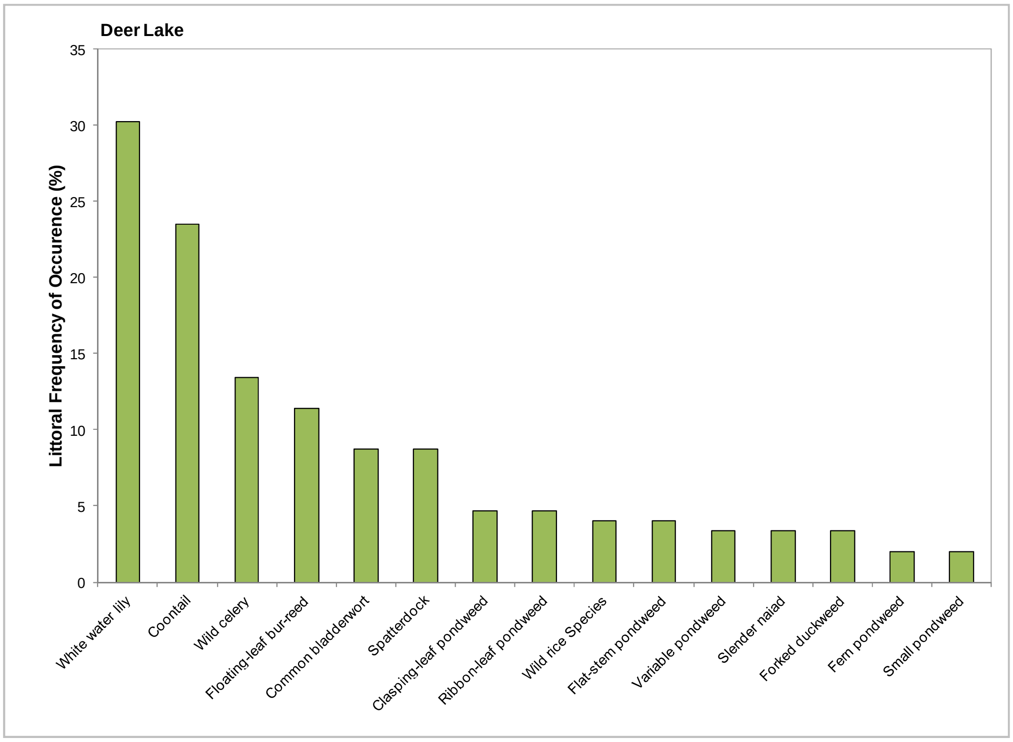


Figure 8.7.4-1 Deer Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.7.4-1 (above) shows that white water lily, coontail and wild celery were the most frequently encountered plants within Deer Lake. White water lily is a floating-leaf species that produces broad, round leaves and a white flower. This plant is common in Wisconsin lakes around the shoreline, and in addition to creating shade for aquatic organisms it also serves as a food source. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making it susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Coontail is tolerant to low-light conditions. 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.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and whorled water milfoil) were located from Deer Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. As with northern water milfoil, the leaves of this plant have somewhat of a feathery appearance. It is often mistaken for northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

38 species of aquatic plants (including incidentals) were found in Deer Lake and 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 Deer Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds great diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 23% of the sampling locations, its relative frequency of occurrence is 17%. Explained another way, if 100 plants were randomly sampled from Deer Lake, 17 of them would be coontail. This distribution can be observed in Figure 8.7.4-2, where together 10 species account for 83% of the population of plants within Deer Lake, while the other 16 species account for the remaining 17%. Twelve additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.7.4-1 as incidentals.

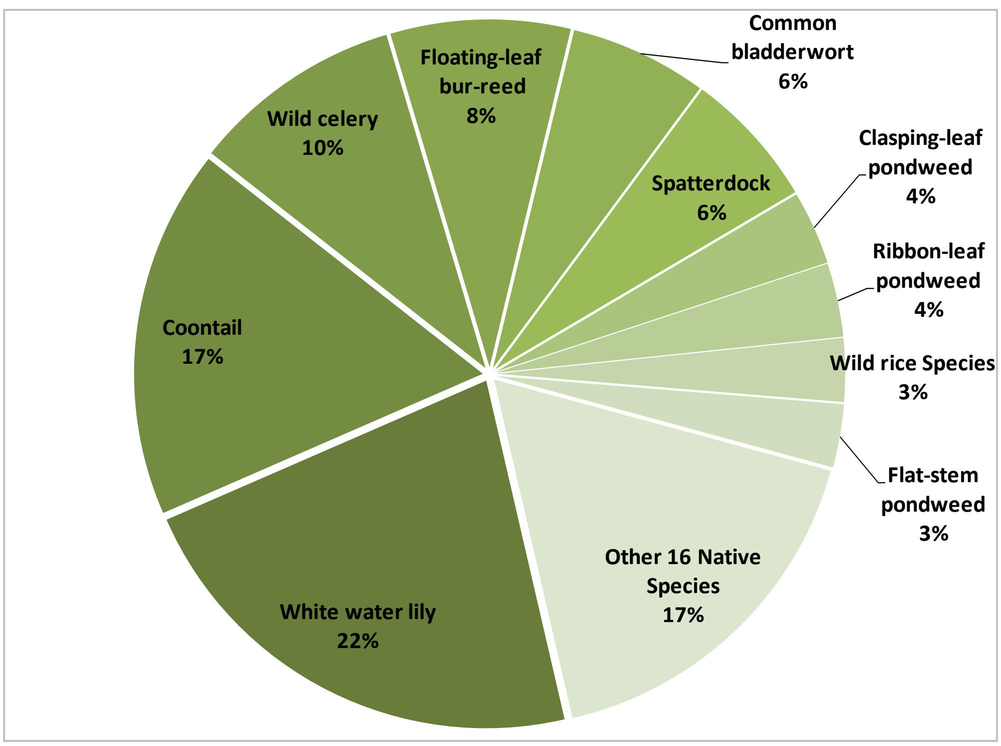


Figure 8.7.4-2 Deer Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Deer Lake's average conservatism value (6.3) is slightly higher than the state median value, but lower than the ecoregion median. This indicates that the plant community of Deer Lake is indicative of a moderately disturbed system. This is not surprising considering Deer Lake's plant community has moderate diversity and species richness. Combining Deer Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in value of 32.2 which is above the median values of the ecoregion and state.

The quality of Deer Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 70.2 acres of the lake contains these types of plant communities (Deer Lake Map 2, Table 8.7.4-2). Fifteen floating-leaf and emergent species were located on Deer Lake (Table 8.7.4-1), all of which provide valuable wildlife habitat.

Table 8.7.4-2. Deer Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	23.2
Floating-leaf	13.9
Mixed Floating-leaf and Emergent	33.1
Total	70.2

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 Deer 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.

.

8.7.5 Deer Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Deer Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Deer Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Deer Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Deer Lake's implementation plan is compiled by describing how Deer Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Deer Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Deer Lake as part of this chain-wide project, it is up to Deer Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Deer Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Deer Lake does not have a public access location, but is directly connected to the rest of the Three Lakes Chain of Lakes via Crystal (Mud), Dog and Big Stone Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Deer Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Deer Lake or from Deer Lake elsewhere. If a Deer Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Deer Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Deer Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Deer Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Deer Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Deer Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Deer Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Deer Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Deer Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Deer Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Deer Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

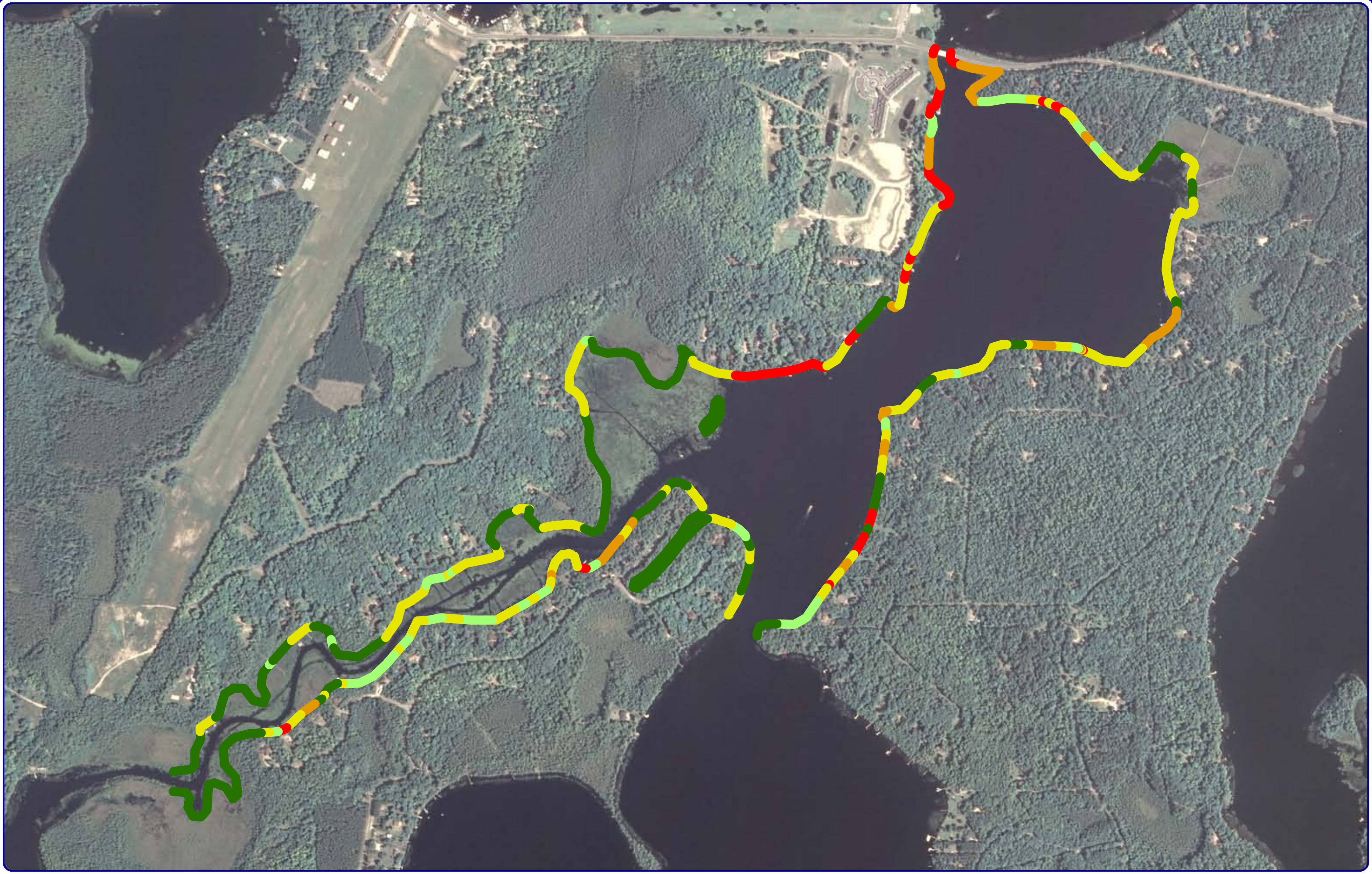
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Deer Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Deer Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Deer Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



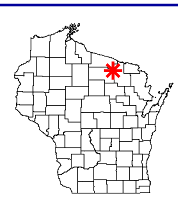
N
W E
S

1,000

Feet

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: July 13, 2011
Filename: Deer_Map1_SA_2011.mxd



Project Location in Wisconsin

Legend

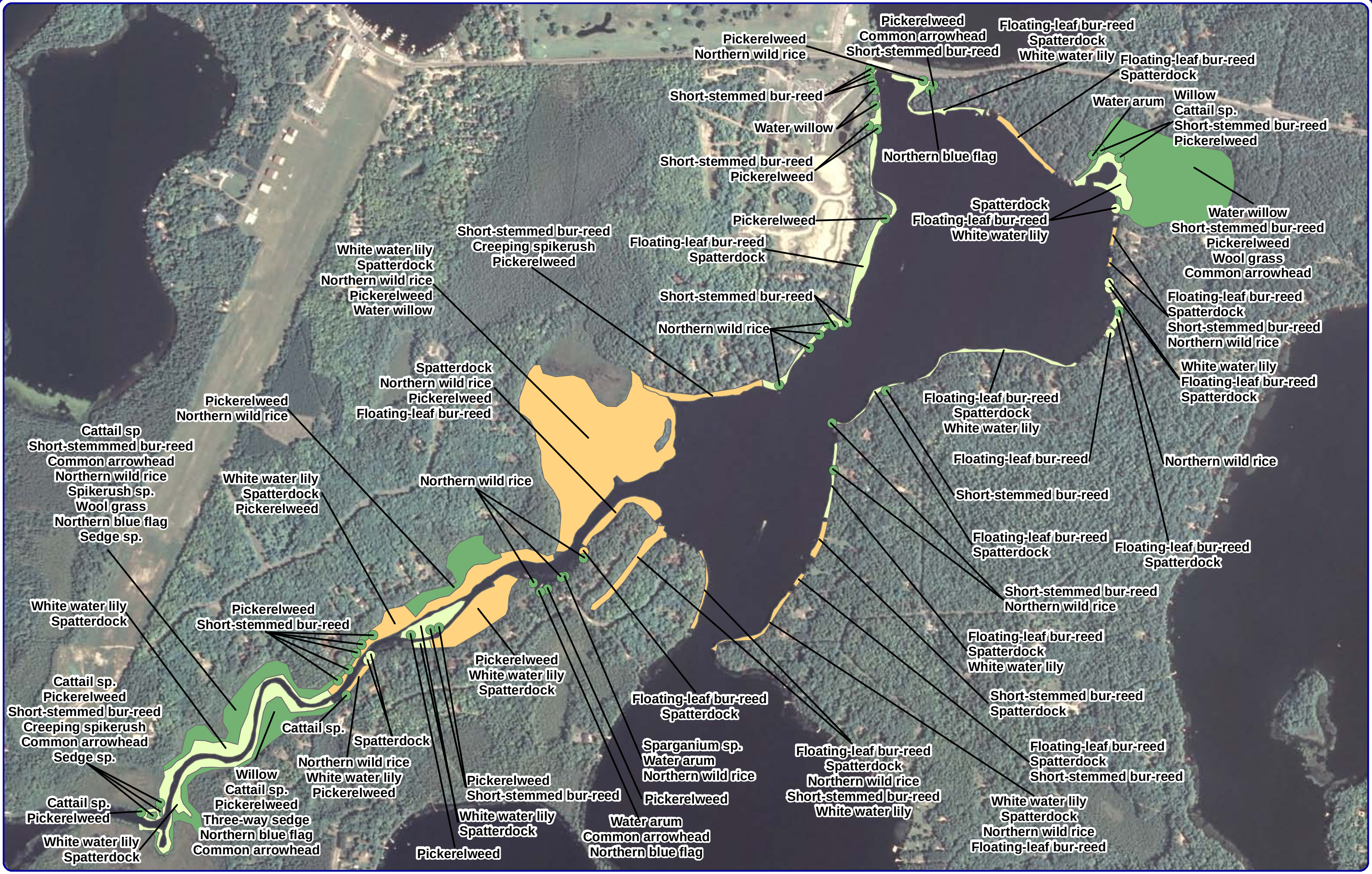
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Deer Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreline Condition



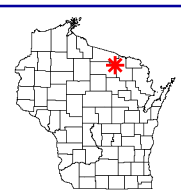
N
W E
S

1,000

Feet

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

Sources:
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 12, 2011
Filename: Deer_Comm_2011.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

Deer Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

Aquatic Plant Communities

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

8.8 Big Stone Lake

An Introduction to Big Stone Lake

Big Stone Lake, Oneida County, is a drainage lake with a maximum depth of 57 feet and a surface area of 548 acres. This lake has a relatively large watershed when compared to the size of the lake. Big Stone Lake contains 33 native plant species, of which wild celery was the most common plant. Purple loosestrife, an invasive wetland plant, was observed during the 2011 lake surveys.

Field Survey Notes

Much purple loosestrife observed in the southeastern wetland area of lake. Another colony spotted near Hwy 32.

Lake is quite deep. The littoral region is dominated by a sandy substrate. Primary plant species appears to be wild celery. Much unnatural shoreline observed during surveys.

Photo 8.8.1 Big Stone Lake, Oneida County

Lake at a Glance* – Big Stone Lake

Morphology	
Acreage	548
Maximum Depth (ft)	57
Mean Depth (ft)	21
Volume (acre-feet)	11,701
Shoreline Complexity	4.4
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 10, 2011
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Purple loosestrife
Simpson's Diversity	0.65
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Eutrophic / mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	99:1

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

8.8.1 Big Stone Lake Water Quality

During 2011/2012, water quality data was collected from Big Stone Lake on six occasions. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Big Stone Lake for years to come.

During this time, summer average total phosphorus concentrations have fluctuated little, ranging between 18.8 and 26.7 µg/L (Figure 8.8.1-1). These average values rank within the TSI category of *Good*. A weighted value across all years is nearly equal to the median for deep, lowland drainage lakes in the state of Wisconsin. As with the total phosphorus values, average chlorophyll-*a* concentrations also rank in the *Good* category, and a weighted average is nearly equal to the median concentration for similar lakes across the state (Figure 8.8.1-2). Very little fluctuation is seen in this small dataset.

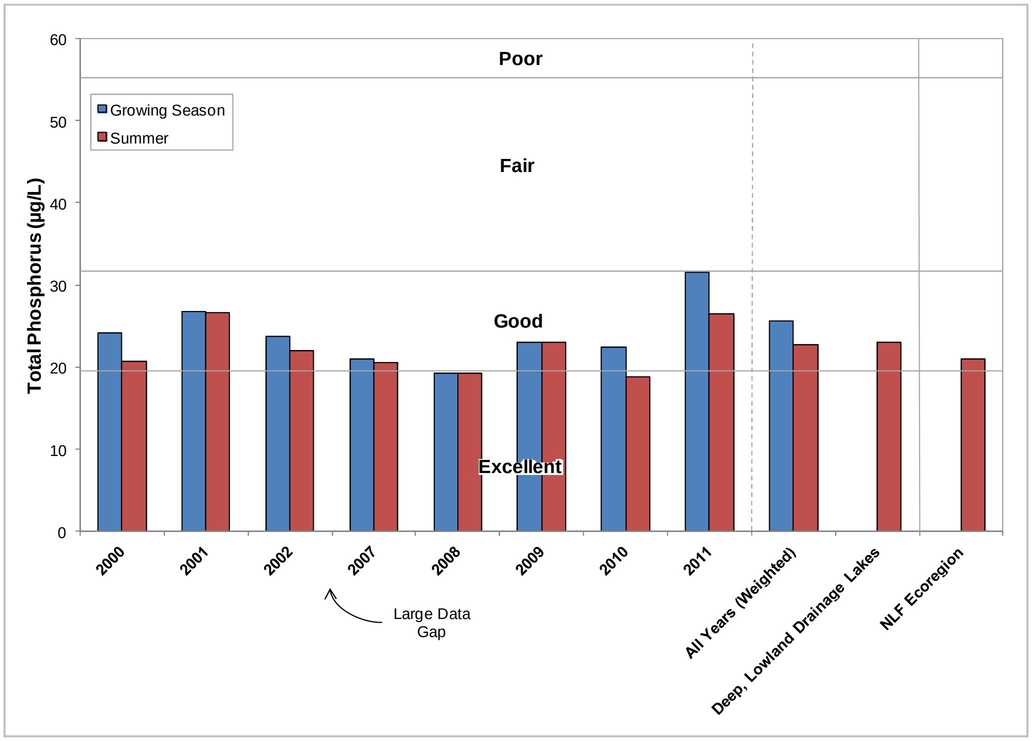


Figure 8.8.1-1. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

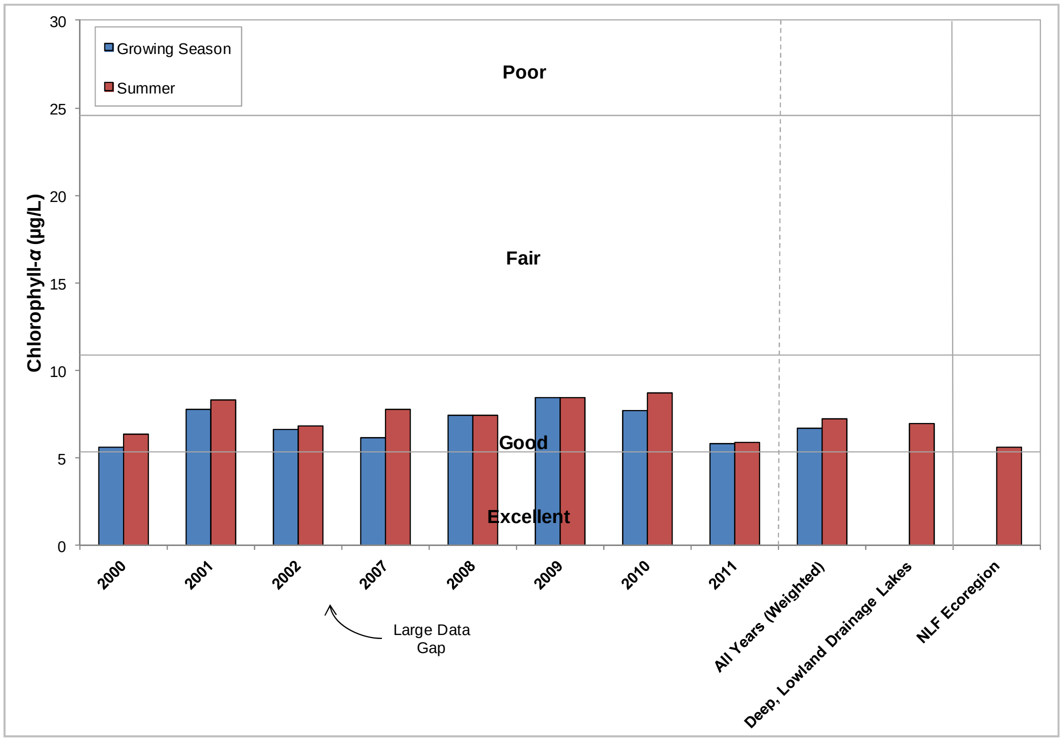


Figure 8.8.1-2. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Measurements of Secchi disk clarity span a similar timeframe as the other two primary water quality parameters, and show a little annual variance as well (Figure 8.8.1-3). All summer averages range between categories of *Fair* and *Good*, though a weighted average across all years is less than the median for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However, other factors may influence the clarity of a lake's water as well. For example, in 2011 Onterra ecologists noted exceptionally dark water – more so than in previous years when studies had been completed on the Three Lakes Chain of lakes. As seen in Figure 8.8.3-1, nutrient levels were slightly higher in 2011, but chlorophyll-*a* concentrations were not elevated; in fact, they were slightly lower than in previous years (Figure 8.8.1-2). In that same year, the Secchi disk depth summer average was roughly 2.5 feet lower than in previous years (Figure 8.8.1-3). Clearly, presence or absence of algae is not the cause of the reduced water clarity in 2011.

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 lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Stone Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. It is possible that wetlands flushed the Three Lakes Chain with these organic acids in 2011. Even with higher-than-normal nutrients in the water column, the natural staining of the water reduced visibility as well as light penetration, which is likely the cause for relatively limited algal production in that year.

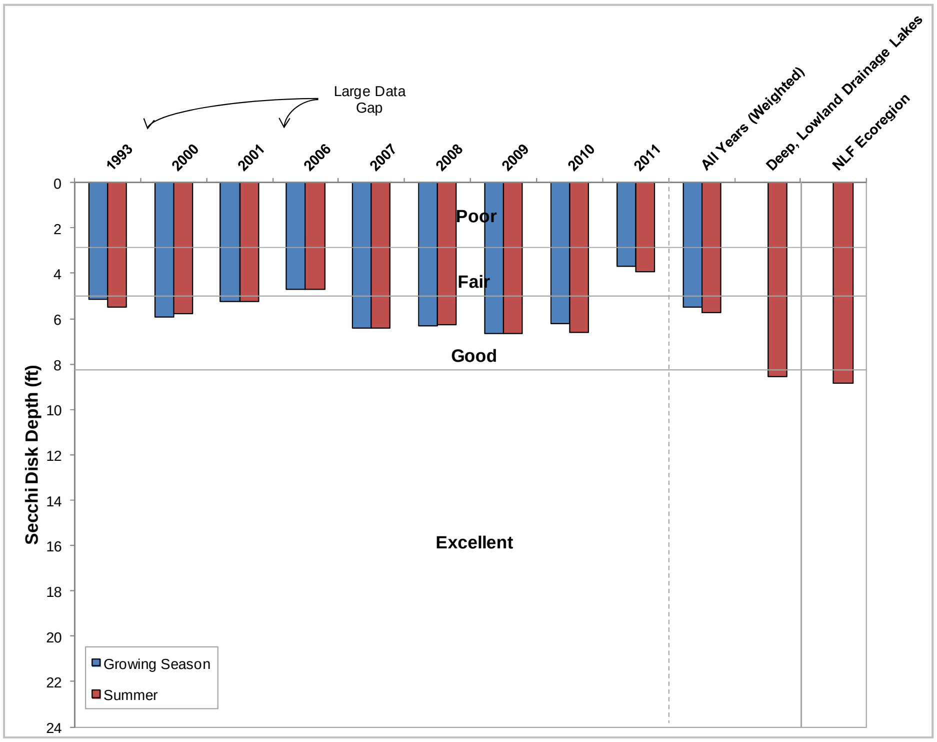


Figure 8.8.1-3. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Big 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 eutrophic (Figure 8.8.1-4). 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 Big Stone Lake is in a borderline eutrophic/mesotrophic state.

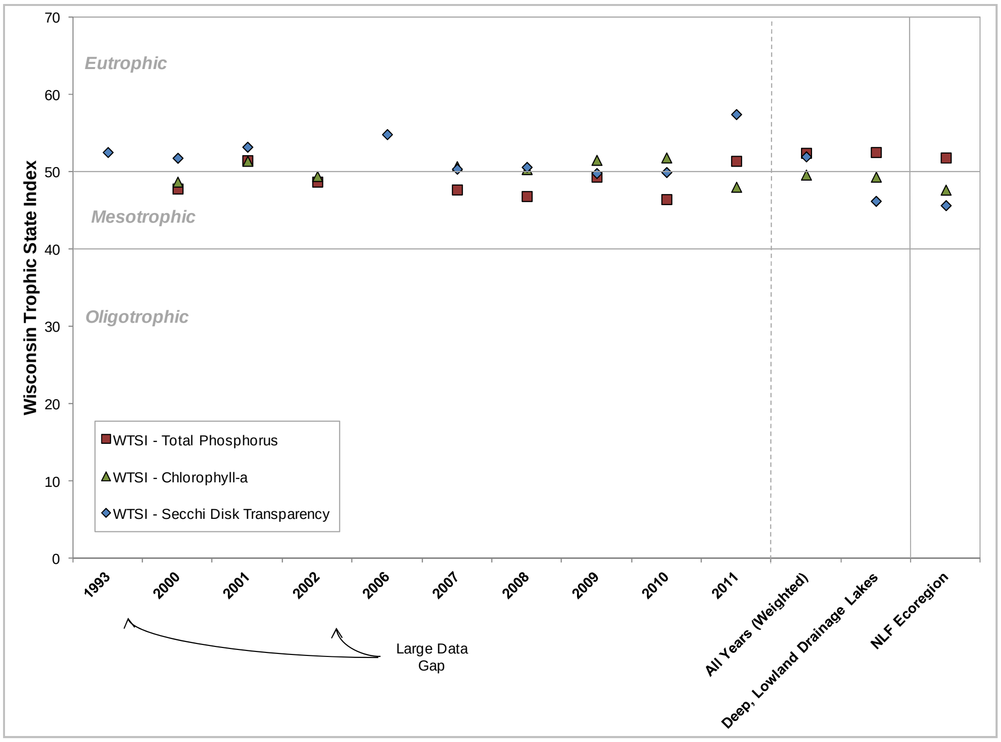


Figure 8.8.1-4. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Big Stone Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Stone Lake by Onterra staff. Graphs of those data are displayed in Figure 8.8.1-5 for all sampling events.

Big Stone Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which becomes stratified by June and continues through August. Once the fall winds begin, the lake mixes completely and oxygen is restored to the bottom of Big Stone Lake. Despite the late summer dip, dissolved oxygen levels remained sufficient in the upper 20 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Ample oxygen concentrations were also present within the winter months of 2012 as well, when dissolved oxygen is of most concern.

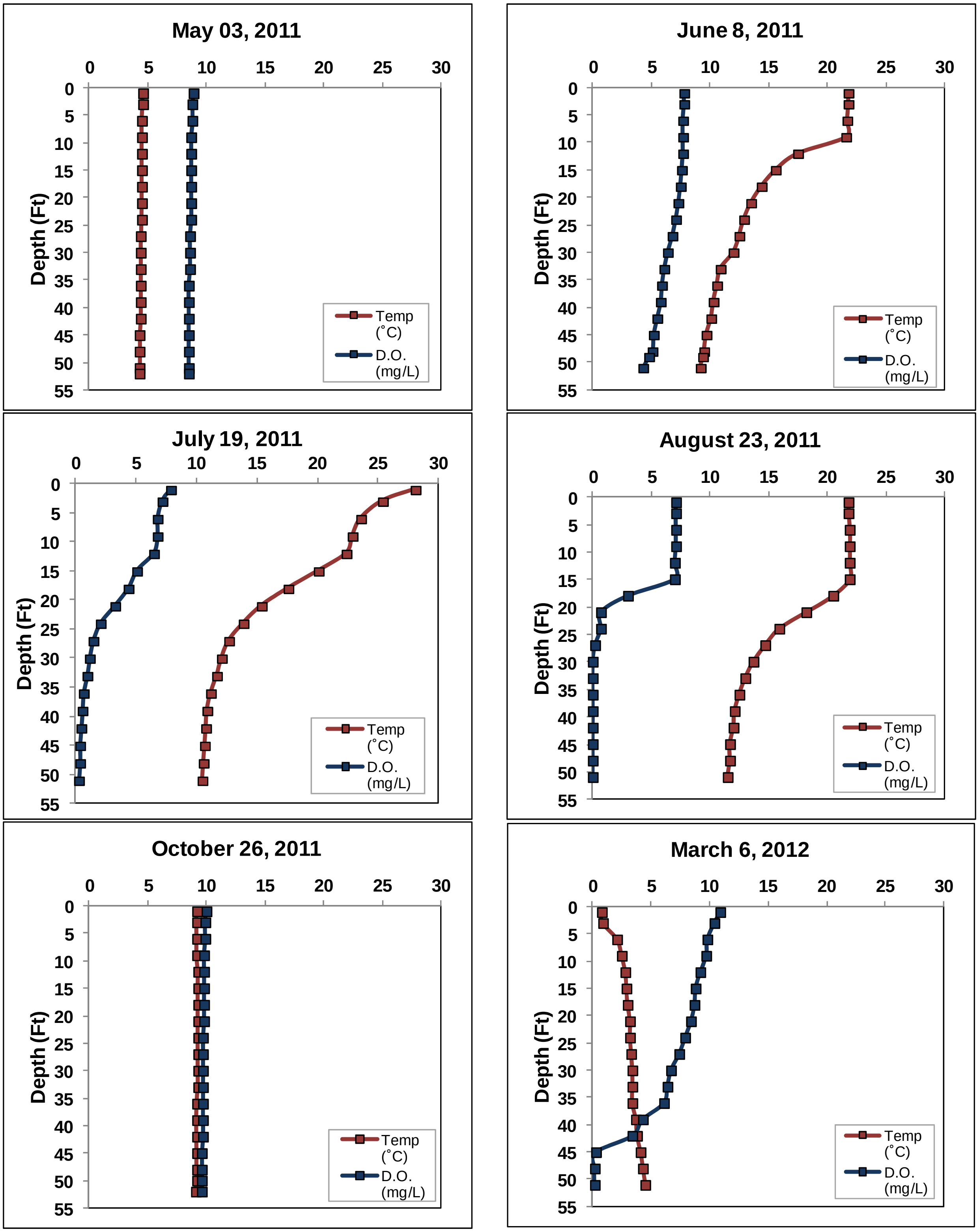


Figure 8.8.1-5. Big Stone Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big 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 Big 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 Chainwide 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. Big Stone Lake's pH was measured at 7.0 during the summer months of 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

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 Big Stone Lake was measured at 21.3 (mg/L as $CaCO_3$), indicating 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 Big Stone Lake during the summer of 2011. 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 Big Stone Lake's pH of 7.0 falls at the lower end of 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 Big Stone Lake was found to be 7.8 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. Results to be included in next draft.

8.8.2 Big Stone Lake Watershed Assessment

Big Stone Lake's watershed is 55,027 acres in size. Compared to Big Stone Lake's size of 548 acres, this makes for an incredibly large watershed to lake area ratio of 99:1.

Exact land cover calculation and modeling of nutrient input to Big Stone Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.8.3 Big Stone Lake Shoreland Condition

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 2011, Big Stone Lake's immediate shoreline was assessed in terms of its development. Big Stone Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (26% of the entire shoreline) were observed during the survey (Figure 8.8.3-1). 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, 2.1 miles of urbanized and developed–unnatural shoreline (30% of the total shoreline) was observed. If restoration of the Big 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. Big Stone Lake Map 1 displays the location of these shoreline lengths around the entire lake.

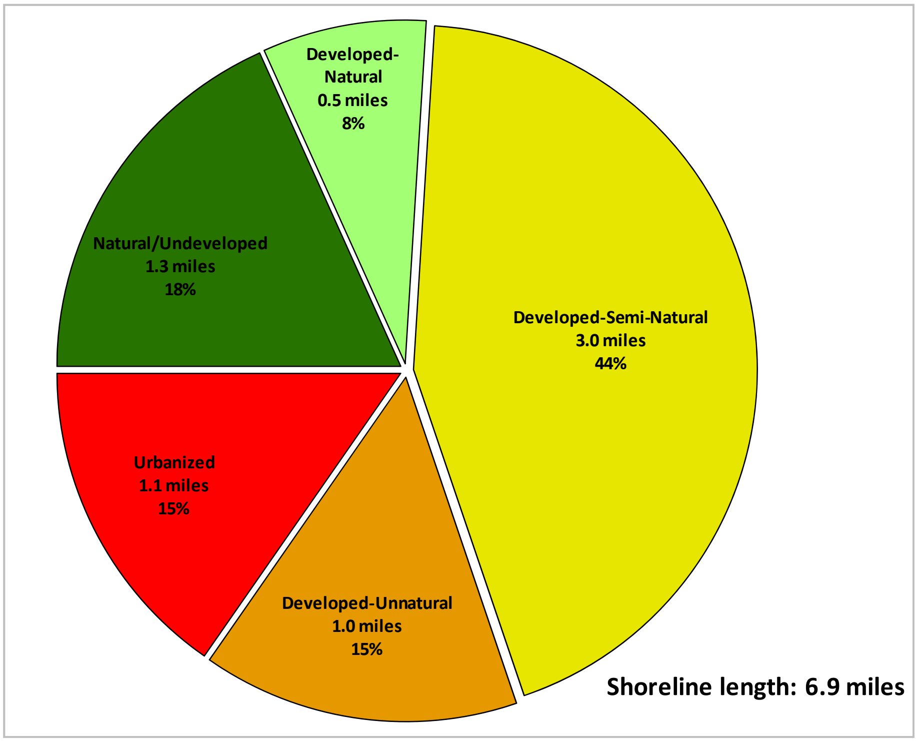


Figure 8.8.3-1. Big Stone Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Big Stone Lake Map 1.

8.8.4 Big Stone Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Stone Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not exist in Big Stone Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Stone Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to create the aquatic plant community map (Big Stone Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Big Stone Lake (Table 8.8.4-1). 22 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the maximum depth of plant growth within the other Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in these surveys indicate that the overall aquatic plant community is healthy and fairly diverse.

Of the 170 point-intercept locations sampled within the littoral zone, approximately 66% contained aquatic vegetation. Approximately 92% of the point-intercept sampling locations where sediment data was collected at were sand, 4% consisted of a fine, organic substrate (muck) and 5% were determined to be rocky.

Table 8.8.4-1. Aquatic plant species located in the Big Stone Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Dulichium arundinaceum	Three-way sedge	9	*I*
	Decodon verticillatus	Water-willow	7	*I*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Lythrum salicaria	Purple loosestrife	Exotic	*I*
	Pontederia cordata	Pickerelweed	9	*X*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Typha spp.	Cattail spp.	1	*I*
	Zizania palustris	Northern wild rice	8	*X*
FL	*Brasenia schreberi*	Watershield	7	*X*
	Nymphaea odorata	White water lily	6	*X*
	Nuphar variegata	Spatterdock	6	*X*
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	*I*
	Sparganium eurycarpum	Common bur-reed	5	*I*
	Sparganium fluctuans	Floating-leaf bur-reed	10	*X*
Submergent	*Callitriche palustris*	Common water starwort	8	*X*
	Ceratophyllum demersum	Coontail	3	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*I*
	Najas flexilis	Slender naiad	6	*X*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	*X*
	Potamogeton amplifolius	Large-leaf pondweed	7	*X*
	Potamogeton pusillus	Small pondweed	7	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton vaseyi	Vasey's pondweed	10	*X*
	Potamogeton spirillus	Spiral-fruited pondweed	8	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Potamogeton gramineus	Variable pondweed	7	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
	Vallisneria americana	Wild celery	6	*X*
SE	*Eleocharis acicularis*	Needle spikerush	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

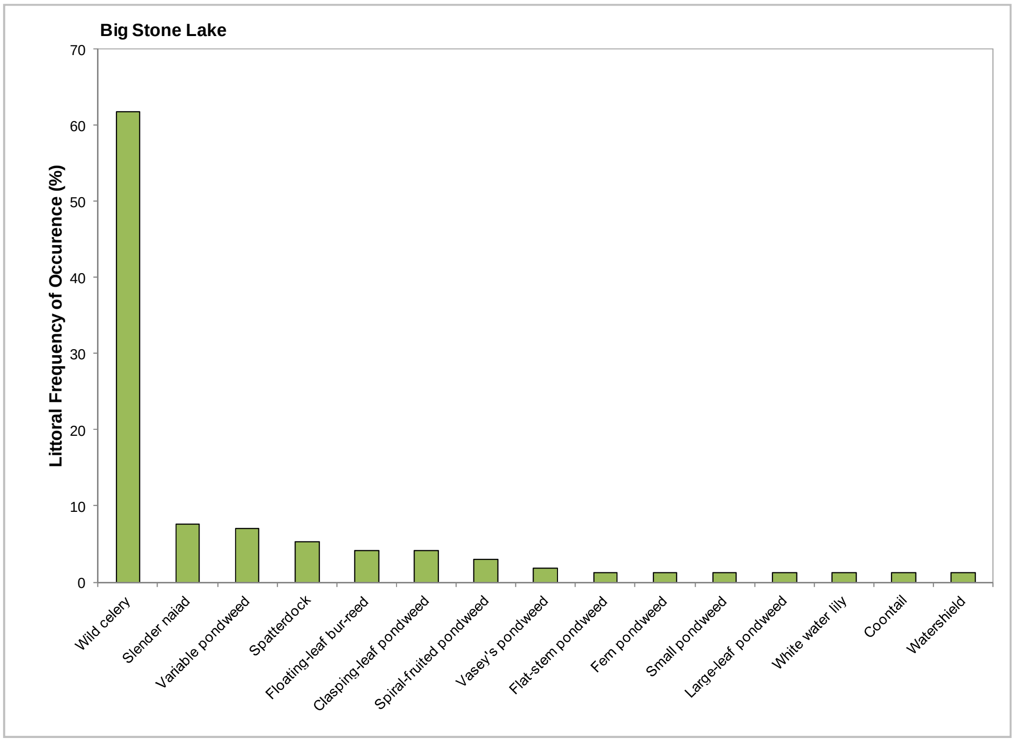


Figure 8.8.4-1 Big Stone Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.8.4-1 (above) shows that wild celery, slender naiad and variable pondweed were the most frequently encountered plants within Big 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. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Variable pondweed, is a submersed plant that produces a thin, cylindrical stem that has numerous branches. These branches produce linear leaves that grow anywhere from four to eleven centimeters long, and may produce three to seven veins per leaf. The floating leaves this plant produces are much more oval in shape, and may have 11 to 19 veins per leaf. This plant also hybridizes easily with other pondweed (*Potamogeton*) species; thus, this plant can appear quite variable in size and shape and is named appropriately.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil were located from Big Stone Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. It was found only incidentally on Big Stone Lake; the presence of much hard substrate may be keeping this plant from establishing itself to a larger level. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Big Stone Lake, which is more than the regional and state median value. 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 Big Stone Lake's plant community (0.65) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86), indicating the lake's plant community holds low diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 62% of the sampling locations, its relative frequency of occurrence is 58%. Explained another way, if 100 plants were randomly sampled from Big Stone Lake, 58 of them would be wild celery. This distribution can be observed in Figure 8.8.4-2, where together seven species account for 87% of the population of plants within Big Stone Lake, while the other 15 species account for the remaining 13%. Wild celery dominates the plan community, with a relative frequency of 58%. Eleven additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.8.4-1 as incidentals.

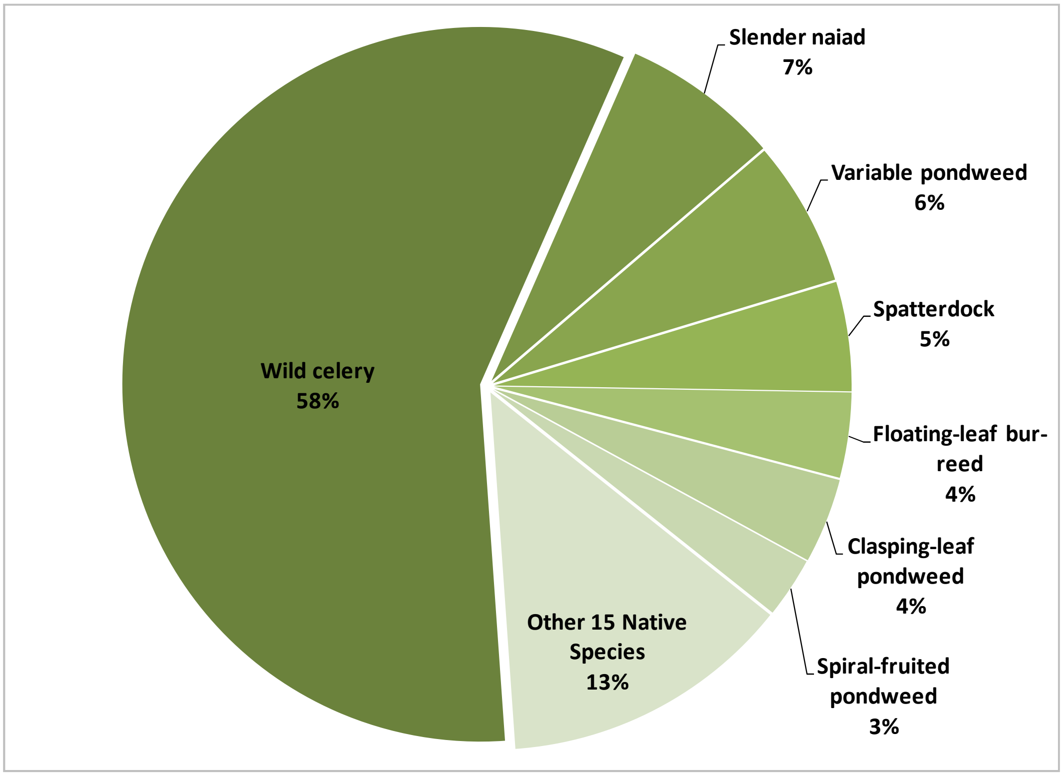


Figure 8.8.4-2 Big Stone Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Big Stone Lake's average conservatism value (7.1) is higher than both the state and ecoregion median. This indicates that the plant community of Big Stone Lake is indicative of an undisturbed system. This is not surprising considering Big Stone Lake's plant community has moderate diversity but high species richness. Combining Big Stone Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.3 which is above the median values of the ecoregion and state.

The quality of Big Stone Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 27.5 acres of the lake contains these types of plant communities (Big Stone Lake Map 2, Table 8.8.4-2). Eleven floating-leaf and emergent species were located on Big Stone Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.8.4-2. Big Stone Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	8.2
Floating-leaf	19.3
Mixed Floating-leaf and Emergent	0.1
Total	27.5

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities. Replications of this survey will provide a valuable understanding of the dynamics of these communities within Big 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 developed shorelines.

Aquatic Invasive Species in Big Stone Lake

During the 2011 community mapping survey, numerous occurrences of purple loosestrife were located along the shorelines of Big Stone Lake and within shallow emergent plant communities (Big Stone Lake Map 2, Table 8.8.4-2). 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.

Purple loosestrife has likely been present in Big Stone Lake for some time. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Big Stone Lake. .

8.8.5 Big Stone Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Stone Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Stone Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Stone Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Stone Lake's implementation plan is compiled by describing how Big Stone Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Big Stone Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Big Stone Lake as part of this chain-wide project, it is up to Big Stone Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Big Stone Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Big Stone Lake contains a public access and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer and Laurel Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Stone Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Stone Lake or from Big Stone Lake elsewhere. If a Big Stone Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Big Stone Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Stone Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Stone Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Stone Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Big Stone Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Stone Lake is protected. Volunteers from Big Stone Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Stone Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Big Stone Lake shoreline was categorized in terms of its development. According to the results from this survey, 30% of the shoreline is in an urbanized or developed-unnatural state, while 44% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

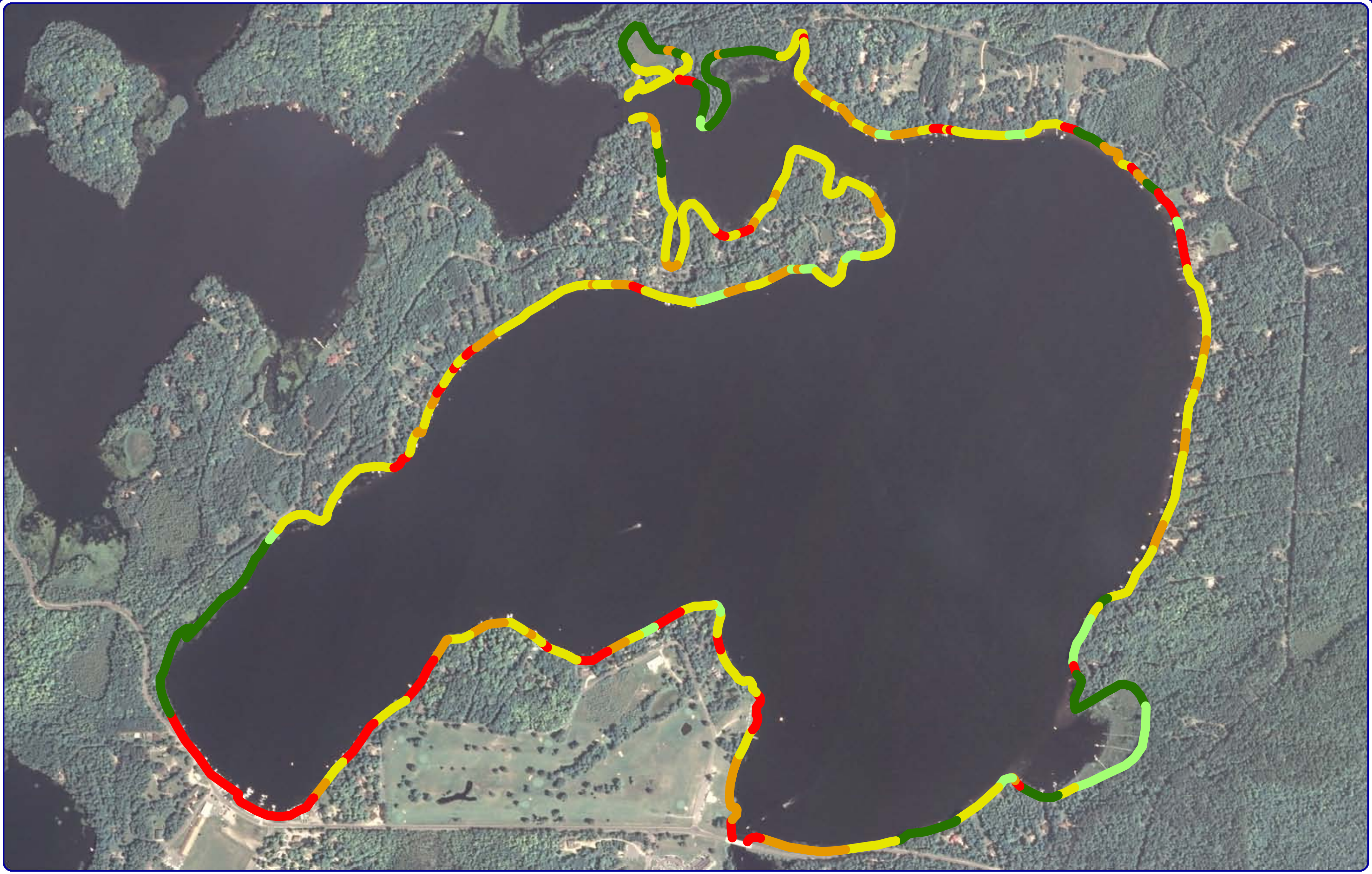
<u>Management Action:</u> Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

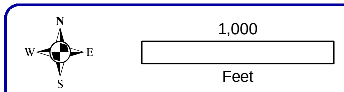
Description: This management action is not applicable to Big Stone Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

<u>Management Action:</u> Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

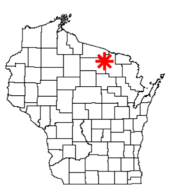
Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Stone Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Stone Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.





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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
Filename: BigStone_Map1_SA_2011.mxd



Project Location in Wisconsin

Legend

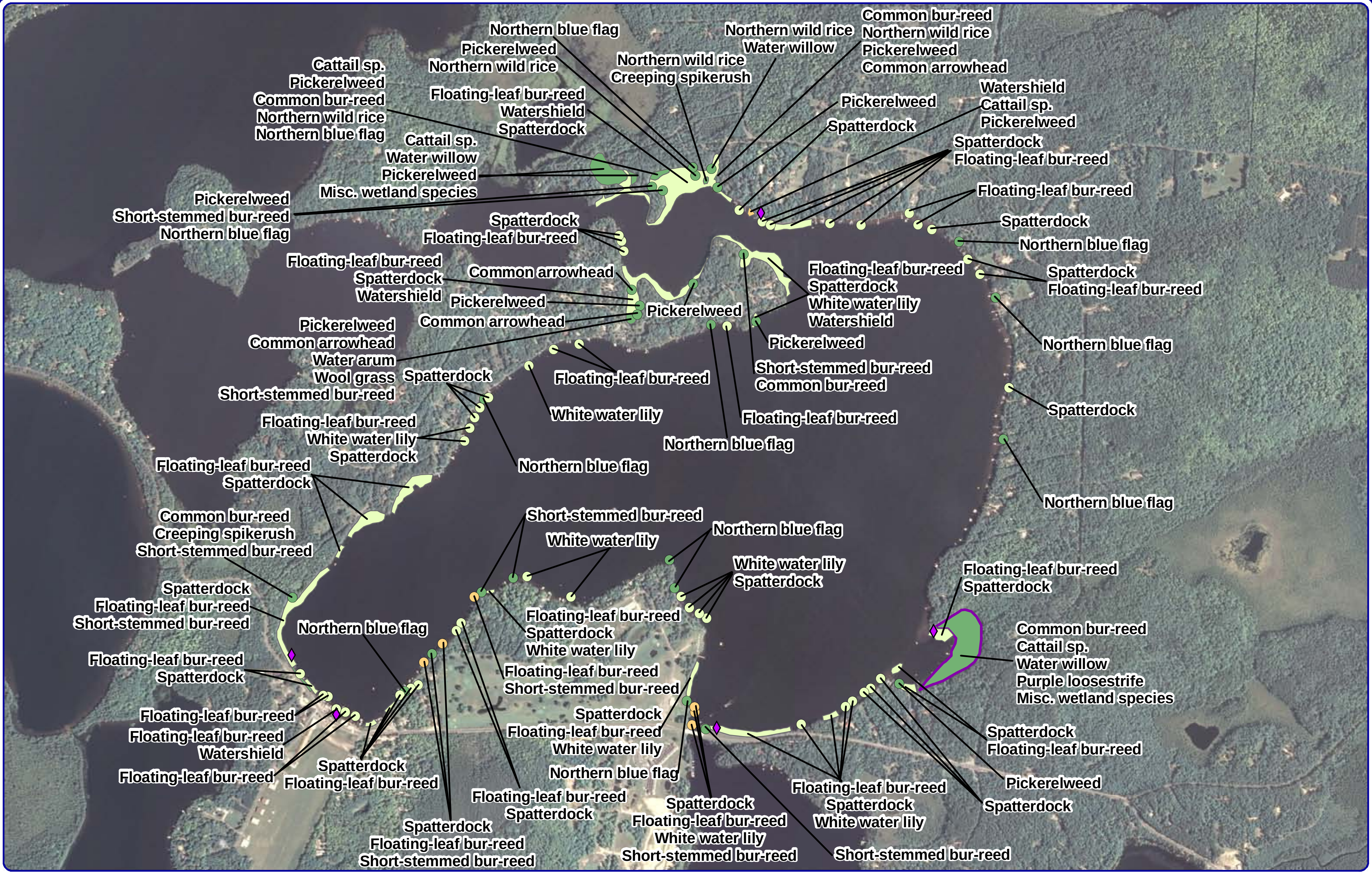
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Big Stone Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreline Condition



N
W E
S

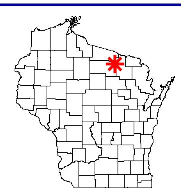
1,400

Feet

Onterra LLC
Lake Management Planning

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

Sources:
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 13, 2011
Filename: BigStone_Comm_2011.mxd



Project Location in Wisconsin

Legend

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

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

Big Stone Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

Aquatic Plant Communities

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

8.9 Laurel Lake

An Introduction to Laurel Lake

Laurel Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 232 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Laurel Lake contains 33 native plant species, of which wild celery was the most common. Purple loosestrife, an exotic emergent wetland plant, was found along Laurel Lake.

Field Survey Notes

Many emergent and floating-leaf plants as well as islands located in north-eastern section of lake – very diverse habitat, great for wildlife!

Photo 8.9.1 Laurel Lake, Oneida County

Lake at a Glance* – Laurel Lake

Morphology	
Acreage	232
Maximum Depth (ft)	27
Mean Depth (ft)	*Not available*
Volume (acre-feet)	*Not available*
Shoreline Complexity	7.4
Vegetation	
Curly-leaf Survey Date	June 22, 2011
Comprehensive Survey Date	August 10, 2011
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Purple loosestrife
Simpson's Diversity	0.77
Average Conservatism	6.9
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage Lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	242:1

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

8.9.1 Laurel Lake Water Quality

During 2011/2012, water quality data was collected from Laurel Lake on six occasions. 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.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006. These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Laurel Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding.

In 2011, summer total phosphorus concentrations averaged 29.3 μg/L, which is higher than the median value for other deep, lowland drainage lakes in the state of Wisconsin (23.0 μg/L). As with the total phosphorus values, 2011 average summer chlorophyll-*a* concentrations are also somewhat higher than the median for other deep, lowland drainage lakes statewide (Table 8.9.1-1). Both the total phosphorus and chlorophyll-*a* values rank as *Good* in the Trophic State Index.

Table 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

	Secchi (feet)				Chlorophyll-*a* (μg/L)				Total Phosphorus (μg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	4.6	1	4.6								
1993	4	3.5	4	3.5								
1994	7	4.4	4	4.6								
2006	6	4.4	4	4.5								
2007	8	6.5	7	6.6								
2008	9	5.4	8	5.3								
2009	7	7.0	7	7.0								
2010	4	6.3	4	6.3								
2011	10	3.4	7	3.6	5	8.6	3	9.6	5	31.0	3.0	29.3
All Years (Weighted)		5.1		5.3		8.6		9.6		31.0		29.3
Deep, Lowland Drainage Lakes				8.5				7.0				23.0
NLF Ecoregion				8.9				5.6				21.0

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.9.1-1). All summer averages range between categories of *Fair* and *Good*; but a weighted average across all years is less than the median for other deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Laurel Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Laurel Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

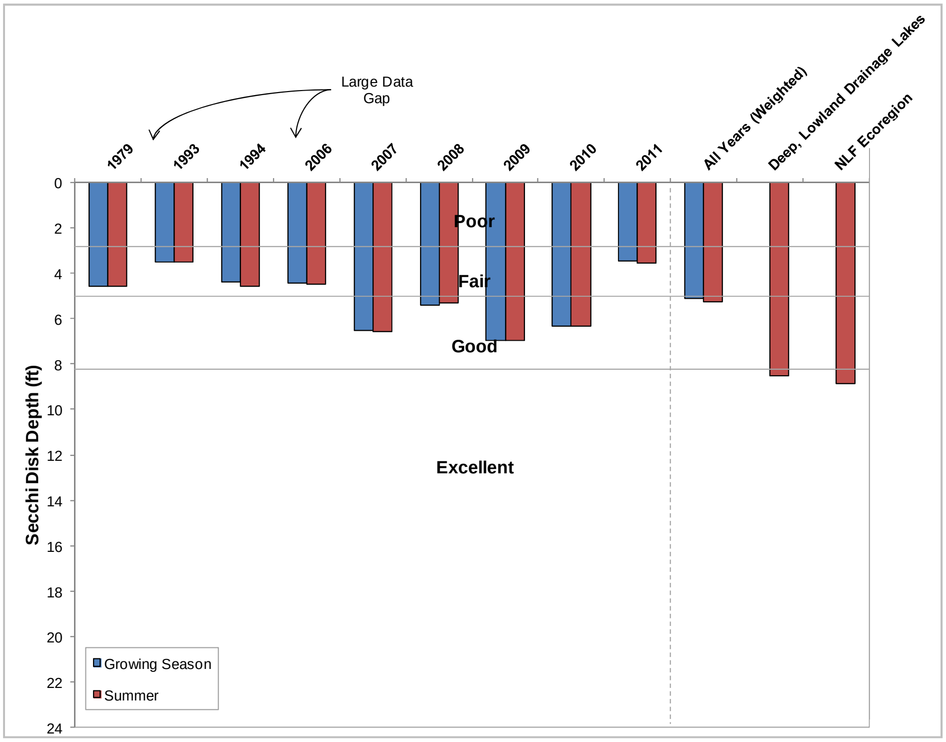


Figure 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Laurel 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 8.9.1-2). 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 Laurel Lake is in a eutrophic state.

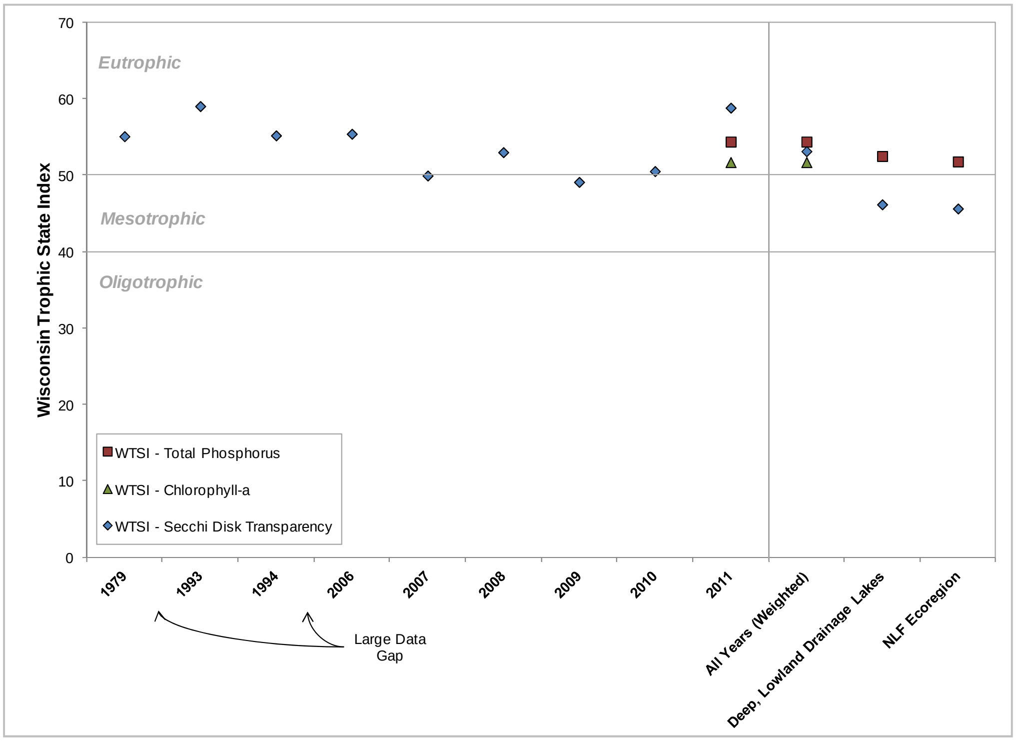


Figure 8.9.1-2. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Laurel Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Laurel Lake by Onterra staff. Graphs of those data are displayed in Figure 8.9.1-3 for all sampling events.

Laurel Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which has been fully stratified by August. Once the October winds begin, the lake mixes completely and oxygen is restored to the bottom of Laurel Lake.

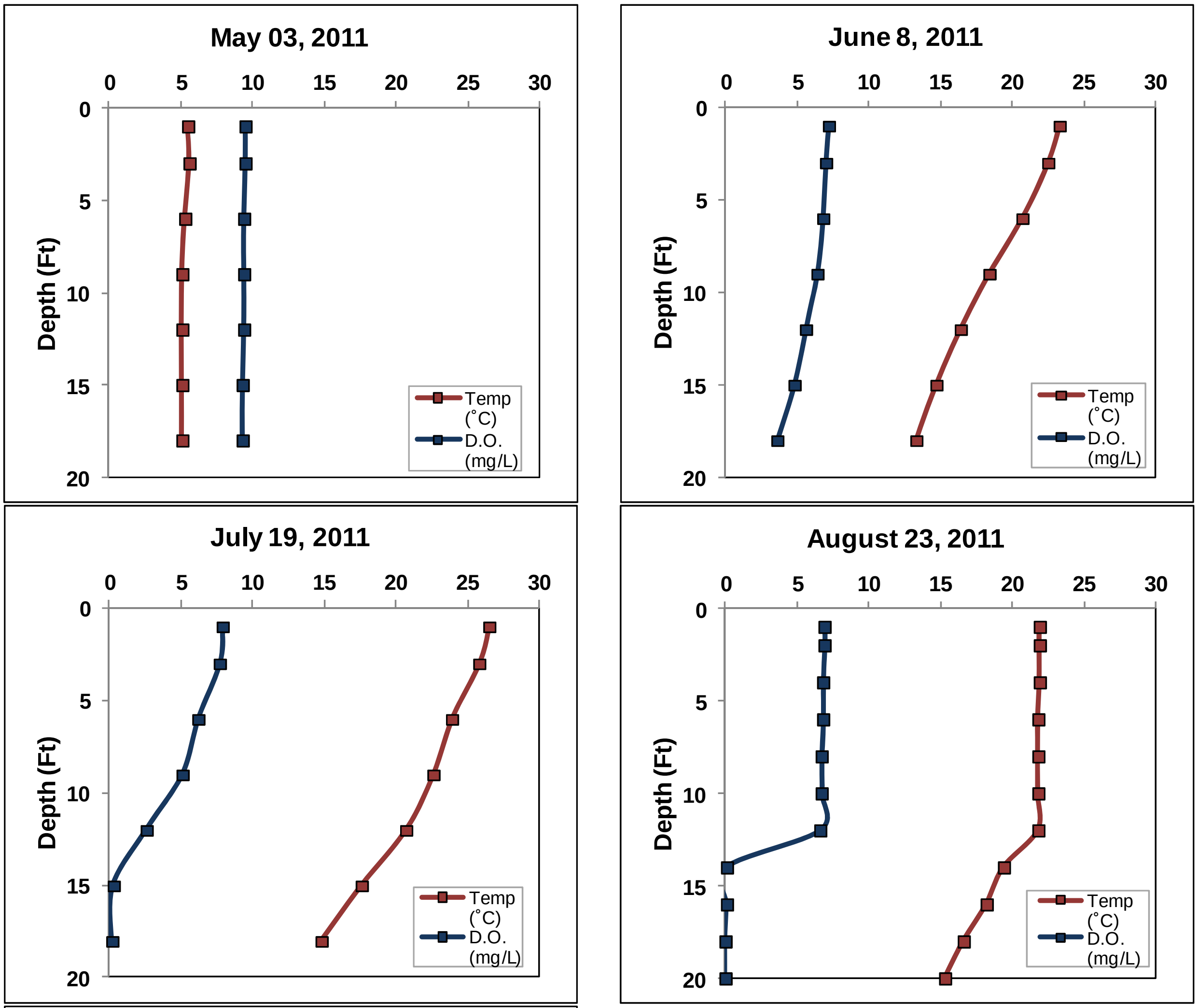
Additional Water Quality Data Collected at Laurel Lake

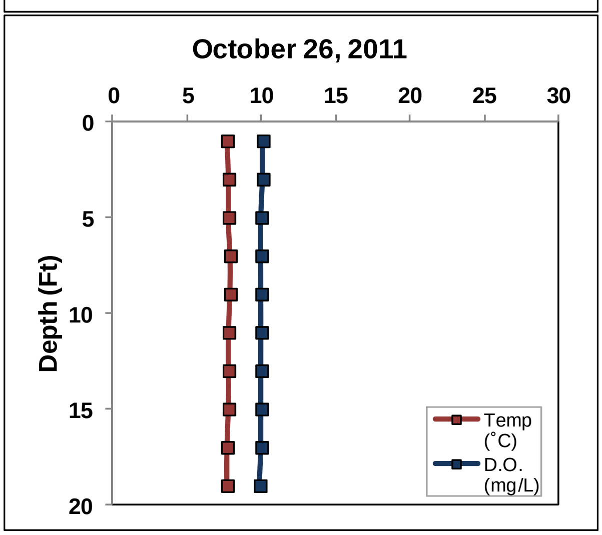
The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Laurel Lake's water quality and are recommended as a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

As the Chainwide 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. Laurel Lake's pH was measured at about 7.3 during summer 2011 surveys. This value is near neutral and falls within the normal range for Wisconsin lakes.

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 Laurel Lake was measured at 22.1 (mg/L as $CaCO_3$), indicating 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 Laurel Lake during the summer of 2011. 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 Laurel Lake's pH of 7.3 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 Laurel Lake was found to be 7.5 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.





No profile was taken during the winter WQ sampling due to equipment failure.

Figure 8.9.1-3. Laurel Lake dissolved oxygen and temperature profiles.

8.9.2 Laurel Lake Watershed Assessment

Laurel Lake's watershed is 56,382 acres in size. Compared to Laurel Lake's size of 232 acres, this makes for an incredibly large watershed to lake area ratio of 242:1.

Exact land cover calculation and modeling of nutrient input to Laurel Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.9.3 Laurel Lake Shoreland Condition

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 2011, Laurel Lake's immediate shoreline was assessed in terms of its development. Laurel Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.2 miles of natural/undeveloped and developed-natural shoreline (55% of the entire shoreline) were observed during the survey (Figure 8.9.3-1). 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, 1.0 mile of urbanized and developed–unnatural shoreline (16% of the total shoreline) was observed. If restoration of the Laurel 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. The Laurel Lake Map 1 displays the location of these shoreline lengths around the entire lake.

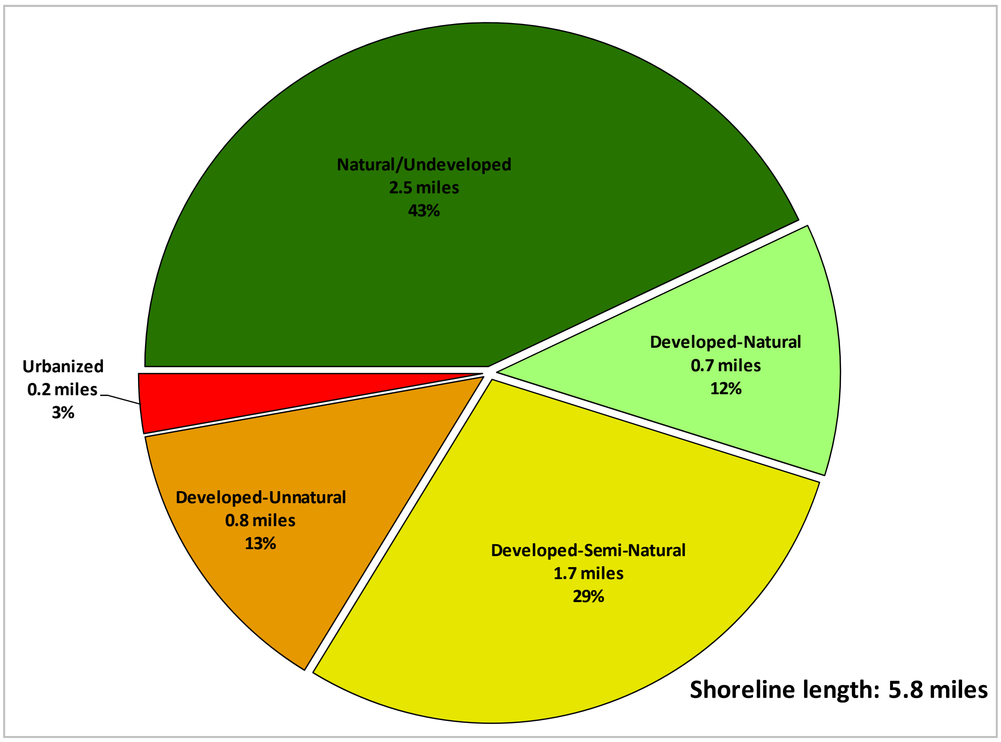


Figure 8.9.3-1. Laurel Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Laurel Lake Map 1.

8.9.4 Laurel Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Laurel Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Laurel Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Laurel Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 & 11 to create the aquatic plant community map (Laurel Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Laurel Lake (Table 8.9.4-1). 24 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. An additional exotic plant, purple loosestrife, was found along the shoreline of Laurel Lake. Submergent aquatic plants were found growing to a depth of eight feet, which is comparable to the maximum depth of plants in the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 158 point-intercept locations sampled within the littoral zone, approximately 71% contained aquatic vegetation. Approximately 36% of the point-intercept sampling locations where sediment data was collected at were sand, 63% consisted of a fine, organic substrate (muck) and 1% were determined to be rocky.

Table 8.9.4-1. Aquatic plant species located in the Laurel Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris versicolor	Northern blue flag	5	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	I
FL	Brasenia schreberi	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	Sparganium eurycarpum	Common bur-reed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea nuttallii	Slender waterweed	7	X
	Isoetes sp.	Quillwort species	N/A	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton gramineus	Variable pondweed	7	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	Eleocharis acicularis	Needle spikerush	5	X
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

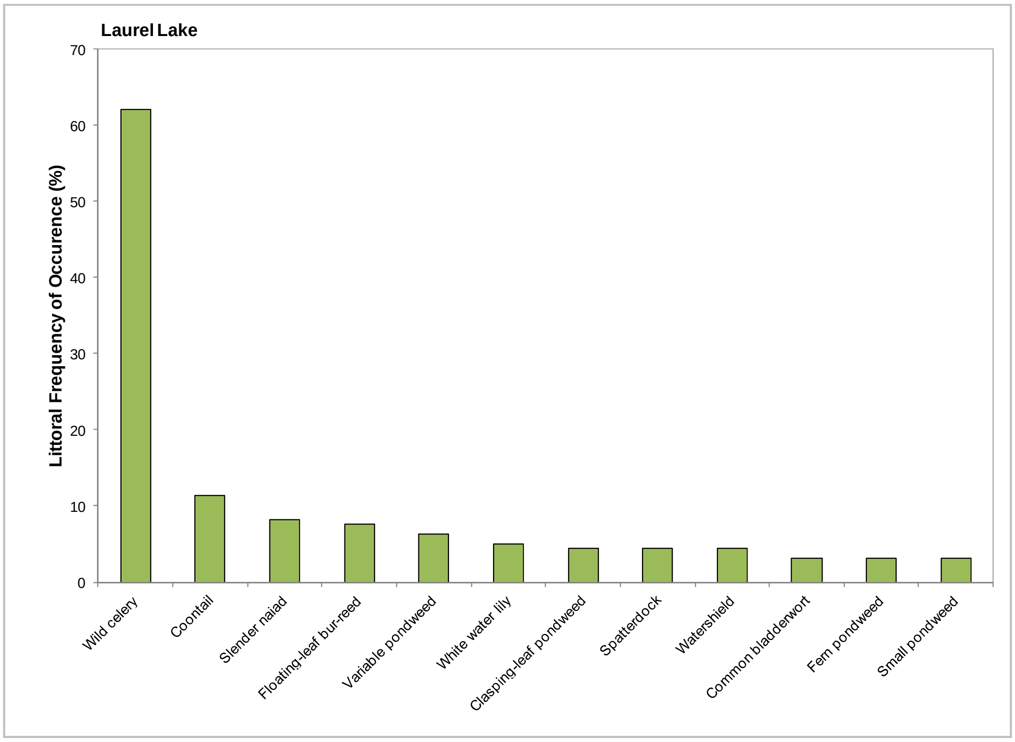


Figure 8.9.4-1 Laurel Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.9.4-1 (above) shows that wild celery, coontail and slender naiad were the most frequently encountered plants within Laurel 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. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making the plant susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Further, coontail is able to tolerate low-light conditions; this in addition to its ability to obtain nutrients directly from the water allow this species to thrive in productive systems. Slender naiad, as its name implies, is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil was located within Laurel Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Laurel Lake and 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 Laurel Lake's plant community (0.77) lies below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake only moderate diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 62% of the sampling locations, its relative frequency of occurrence is 46%. Explained another way, if 100 plants were randomly sampled from Laurel Lake, 46 of them would be wild celery. This distribution can be observed in Figure 8.9.4-2, where together 12 species account for 90% of the population of plants within Laurel Lake, while the other 12 species account for the remaining 20%. However, wild celery clearly dominates the plan community. Nine additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.9.4-1 as incidentals.

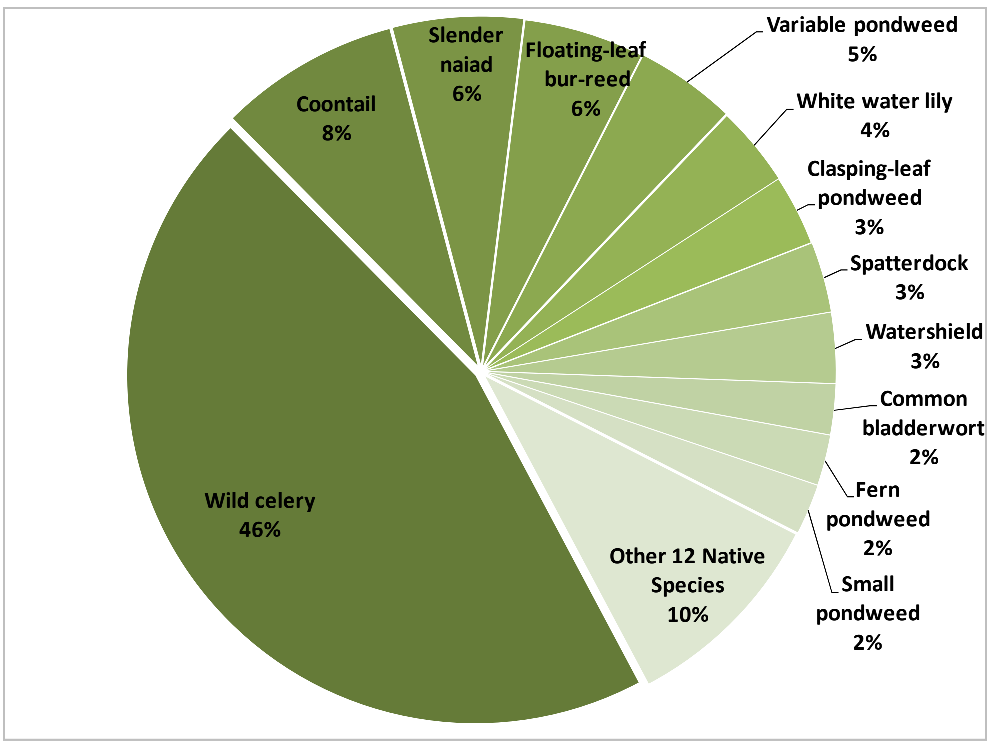


Figure 8.9.4-2 Laurel Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Laurel Lake's average conservatism value (6.9) is higher than both the state and ecoregion median. This indicates that the plant community of Laurel Lake is indicative of a moderately undisturbed system. This is not surprising considering Laurel Lake's plant community has great diversity and high species richness. Combining Laurel Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.7 which is above the median values of the ecoregion and state.

The quality of Laurel Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 79.1 acres of the lake contains these types of plant communities (Laurel Lake Map 2, Table 8.9.4-2). Fourteen floating-leaf and emergent species were located on Laurel Lake (Table 8.9.4-1), all of which provide valuable wildlife habitat.

Table 8.9.4-2. Laurel Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	17.1
Floating-leaf	31.7
Mixed Floating-leaf and Emergent	30.3
Total	79.1

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 Laurel 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 lost a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Aquatic Invasive Species in Laurel Lake

During the 2011 community mapping survey, a single occurrence of purple loosestrife was located along the shorelines of Laurel Lake (Laurel Lake Map 2). 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.

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Laurel Lake. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

.

8.9.5 Laurel Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Laurel Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Laurel Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Laurel Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Laurel Lake's implementation plan is compiled by describing how Laurel Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Laurel Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Laurel Lake as part of this chain-wide project, it is up to Laurel Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Laurel Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: In addition to having a public access location, Laurel Lake is directly connected to the rest of the Three Lakes Chain of Lakes via Laurel and Medicine Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Laurel Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Laurel Lake or from Laurel Lake elsewhere. If a Laurel Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Laurel Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Laurel Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Laurel Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Laurel Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Laurel Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Laurel Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Laurel Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Laurel Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Laurel Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Laurel Lake shoreline was categorized in terms of its development. According to the results from this survey, 16% of the shoreline is in an urbanized or developed-unnatural state, while 29% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Laurel Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Laurel Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Laurel Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

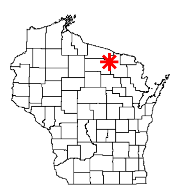
N
W E
S

1,000
Feet

Onterra LLC
Lake Management Planning

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
Filename: Laurel_Map1_SA_2011.mxd



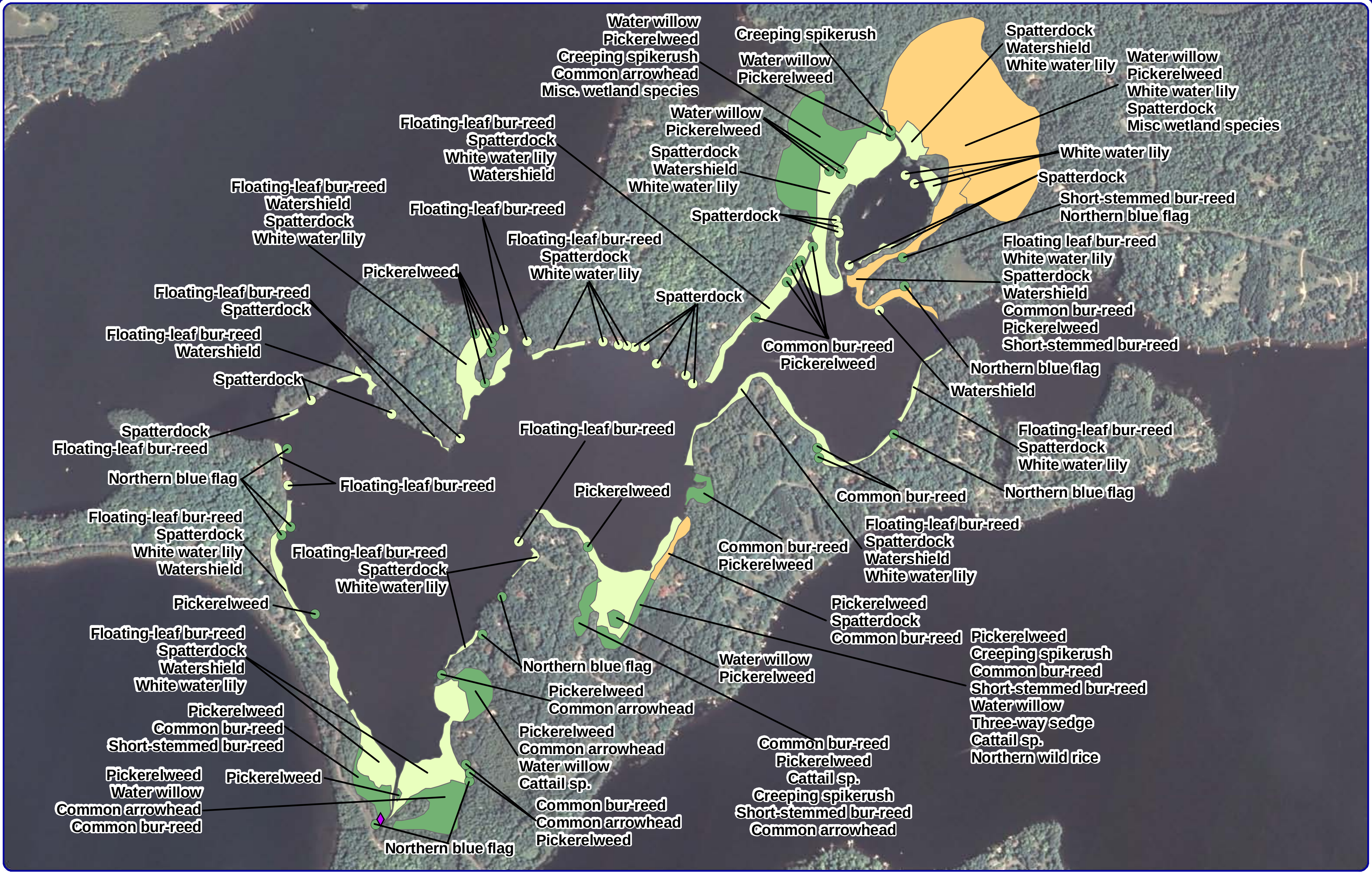
Project Location in Wisconsin

Legend

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

Laurel Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

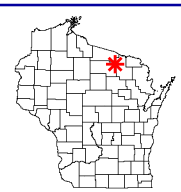
Shoreline Condition



N
W E
S
1,000
Feet

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

Sources:
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 13, 2011
Filename: Laurel_Comm_2011.mxd



Project Location in Wisconsin

Legend

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

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

Laurel Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

Aquatic Plant Communities

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

8.10 Fourmile Lake

An Introduction to Fourmile Lake

Fourmile Lake, Oneida County, is a lowland drainage lake with a maximum depth of 26 feet and a surface area of 210 acres. This eutrophic lake has a large watershed when compared to the size of the lake. Fourmile Lake contains 31 native plant species, of which slender naiad was the most common plant in 2012. One exotic plant, pale yellow iris, is known to be found on the lake.

Field Survey Notes

Abundant wild rice observed during aquatic plant surveys. Lake has much natural shoreline surrounding it – great wildlife habitat! Pale yellow iris spotted several times during the early season AIS survey.

Photo 8.10.1-1 Fourmile Lake, Oneida County

Lake at a Glance* – Fourmile Lake

Morphology	
Acreage	210
Maximum Depth (ft)	26
Mean Depth (ft)	12
Volume (acre-feet)	2,507
Shoreline Complexity	3.9
Vegetation	
Curly-leaf Survey Date	June 5, 2012
Comprehensive Survey Date	July 17, 2012
Number of Native Species	31 (including incidentals)
Threatened/Special Concern Species	n/a
Exotic Plant Species	Pale yellow iris
Simpson's Diversity	0.91
Average Conservatism	6.9
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	68:1

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

8.10.1 Fourmile Lake Watershed Assessment

Fourmile Lake's watershed is 14,558 acres in size. Compared to the lakes size of 210 acres, this makes for an incredibly large watershed to lake area ratio of 68:1.

Exact land cover calculation and modeling of nutrient input to Fourmile Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.10.2 Fourmile Lake Shoreland Condition Assessment

Shoreland Development

As mentioned previously in the Chain-wide Watershed 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 2012, Fourmile Lake's immediate shoreline was assessed in terms of its development. Fourmile Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.2 miles of natural/undeveloped and developed-natural shoreline (78% of the entire shoreline) were observed during the survey (Figure 8.10.2-1). 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, roughly 0.1 miles of urbanized and developed–unnatural shoreline (3% of the total shoreline) was observed. If restoration of the Fourmile 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. The Fourmile Lake Shoreline Condition Map displays the location of these shoreline lengths around the entire lake.

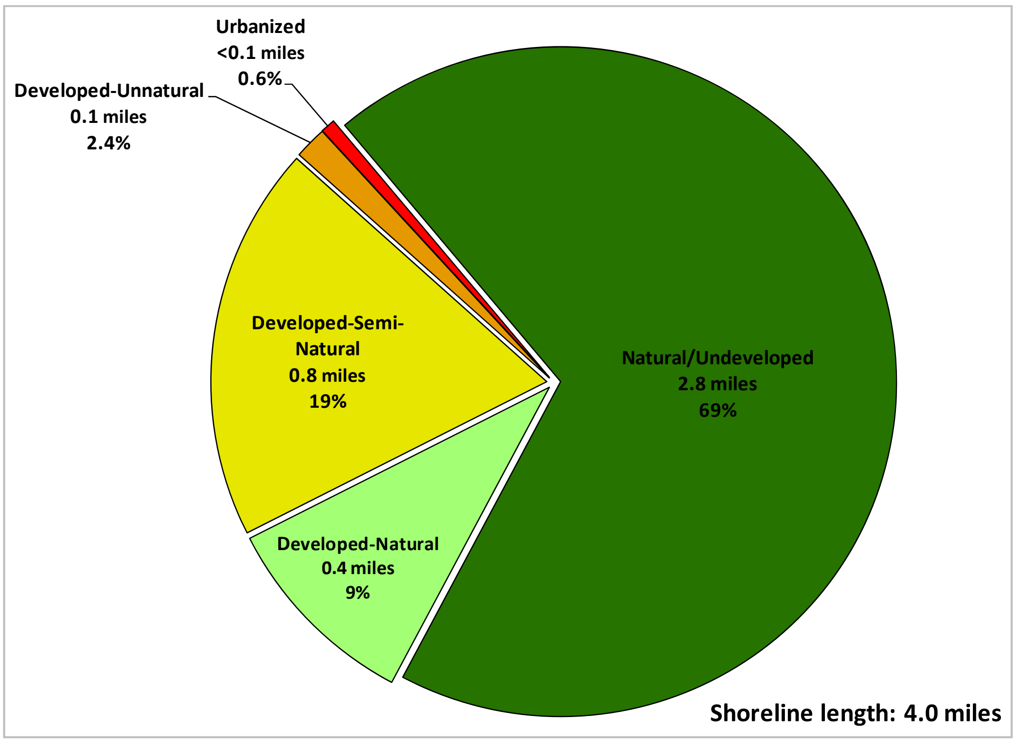


Figure 8.10.2-1. Fourmile Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on the Fourmile Lake Shoreline Condition Map.

8.10.3 Fourmile Lake Water Quality

As a part of this project, water quality data was collected from Fourmile Lake on six occasions. 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. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. As Table 8.10.3-1 indicates, very little historical data exists for these parameters.

During 2012, total phosphorus values collected from the Fourmile Lake surface averaged 27.0 µg/L, which is only slightly higher than the median values for deep, lowland drainage lakes throughout the state and also for all lakes within the Northern Lakes and Forests ecoregion (Table 8.10.3-1). Similarly, chlorophyll-*a* concentrations (10.7 µg/L average during summer 2012) were slightly higher than comparable lakes across the state and all lakes within the ecoregion. Regardless of being slightly higher in value than comparable lakes, the 2012 total phosphorus and chlorophyll-*a* concentrations in Fourmile Lake rank as *Good* within these state-wide and ecoregional datasets.

Table 8.10.3-1. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	4.0	1	4.0	1	11.5	1	11.5				
1993	2	2.3	2	2.3								
1994	4	3.6	4	3.6								
1995	1	4.0	1	4.0								
1996	3	3.6	3	3.6								
2012	5	4.1	3	4.4	5	8.7	3	10.4	5	30.6	3.0	27.0
All Years (Weighted)		3.6		3.6		9.1		10.7		30.6		27.0
Deep, Lowland Drainage Lakes				8.5				7.0				23.0
NLF Ecoregion				8.9				5.6				21.0

Some historical data is available for Fourmile Lake with regards to Secchi disk clarity. Data was collected in 1993-1996 through the Citizens Lake Monitoring Network (CLMN) by a Fourmile Lake volunteer. These data are comparable to what was collected by Onterra ecologists during 2012 (Figure 8.10.3-1). Weighted over the entire time period, an average summer value of roughly 3.6 ft is much lower than 8.5 ft, the median value for similar lakes across the state and 8.9, the median value for lakes within the ecoregion. This value ranks as *Fair* when comparing Fourmile lake to other deep, lowland drainage lakes.

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 lakes such as the Three Lakes Chain, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Fourmile Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

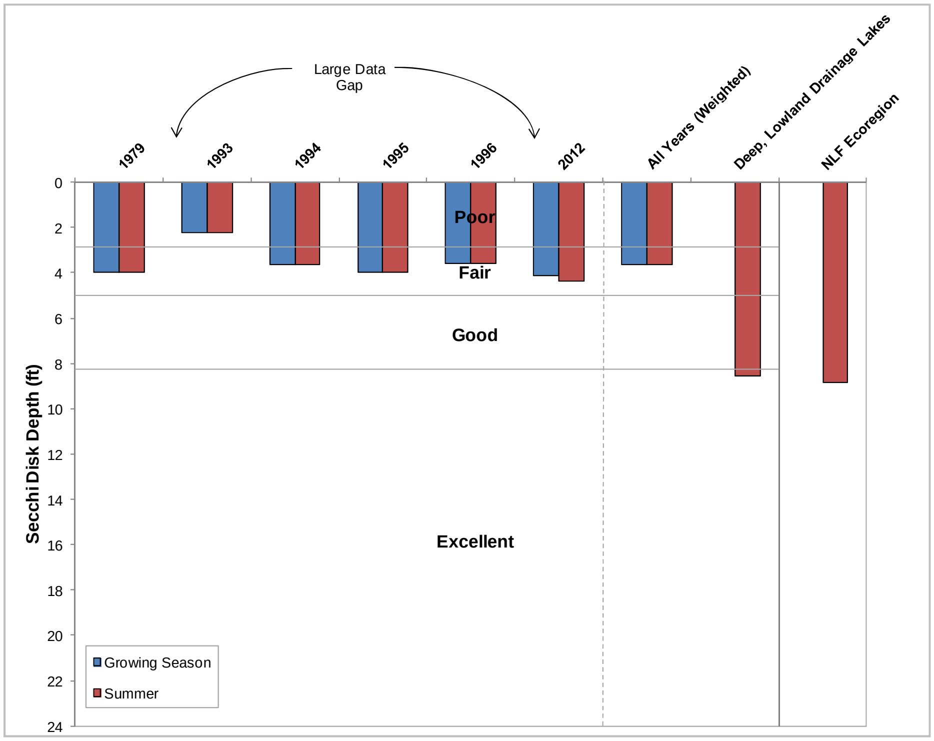


Figure 8.10.3-1. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Fourmile Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall within the eutrophic category (Figure 8.10.3-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; the Secchi disk clarity value can be influenced by the color of the water as described above. Therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Fourmile Lake is in a lower eutrophic state.

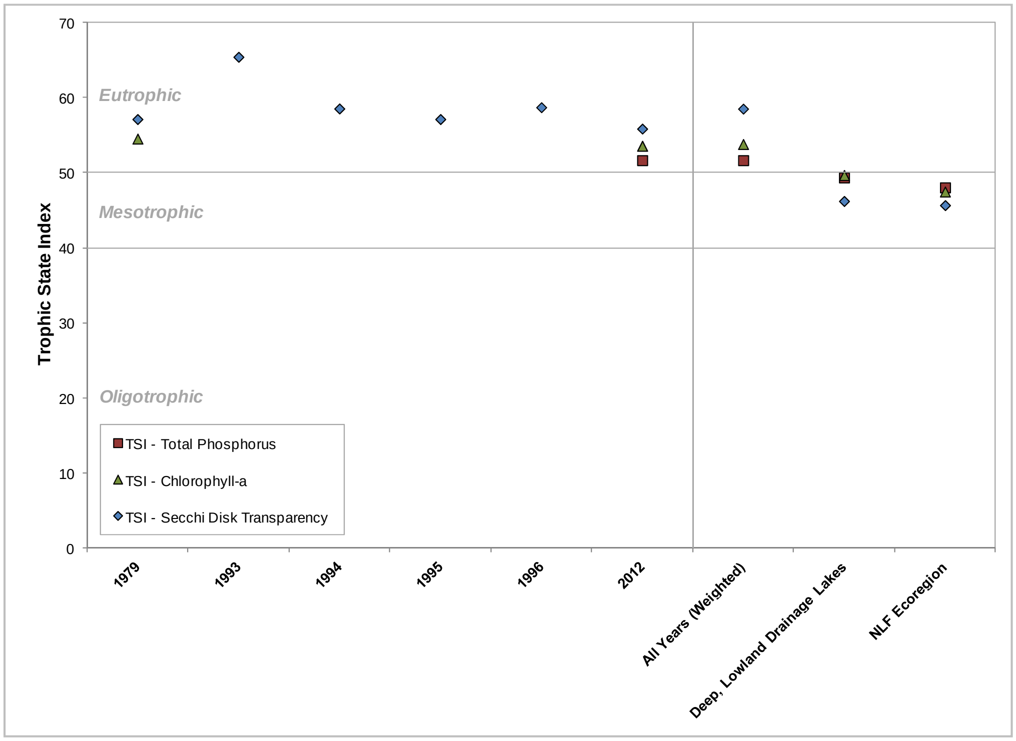


Figure 8.10.3-2. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Fourmile Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Fourmile Lake by Onterra staff. Graphs of those data are displayed in Figure 8.10.3-3 for all three sampling events.

In April and October, the lake was found to be completely mixed, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. During June, these parameters were higher in the epilimnion and dropped with depth. In July and August, Fourmile Lake became stratified, with a distinct warmer epilimnion and cooler hypolimnion. During these summer months, anoxic conditions were observed from 12 to 26 ft in July and 16 to 26 ft in August. Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being found in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Despite the decrease in dissolved oxygen levels during the summer months, oxygen remained sufficient in the upper 12 feet of the water column to support most aquatic life found in northern Wisconsin lakes.

Dissolved oxygen depletion may be of concern during the winter months due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. Fortunately, dissolved oxygen was sufficient within the majority of the water column in February of 2013.

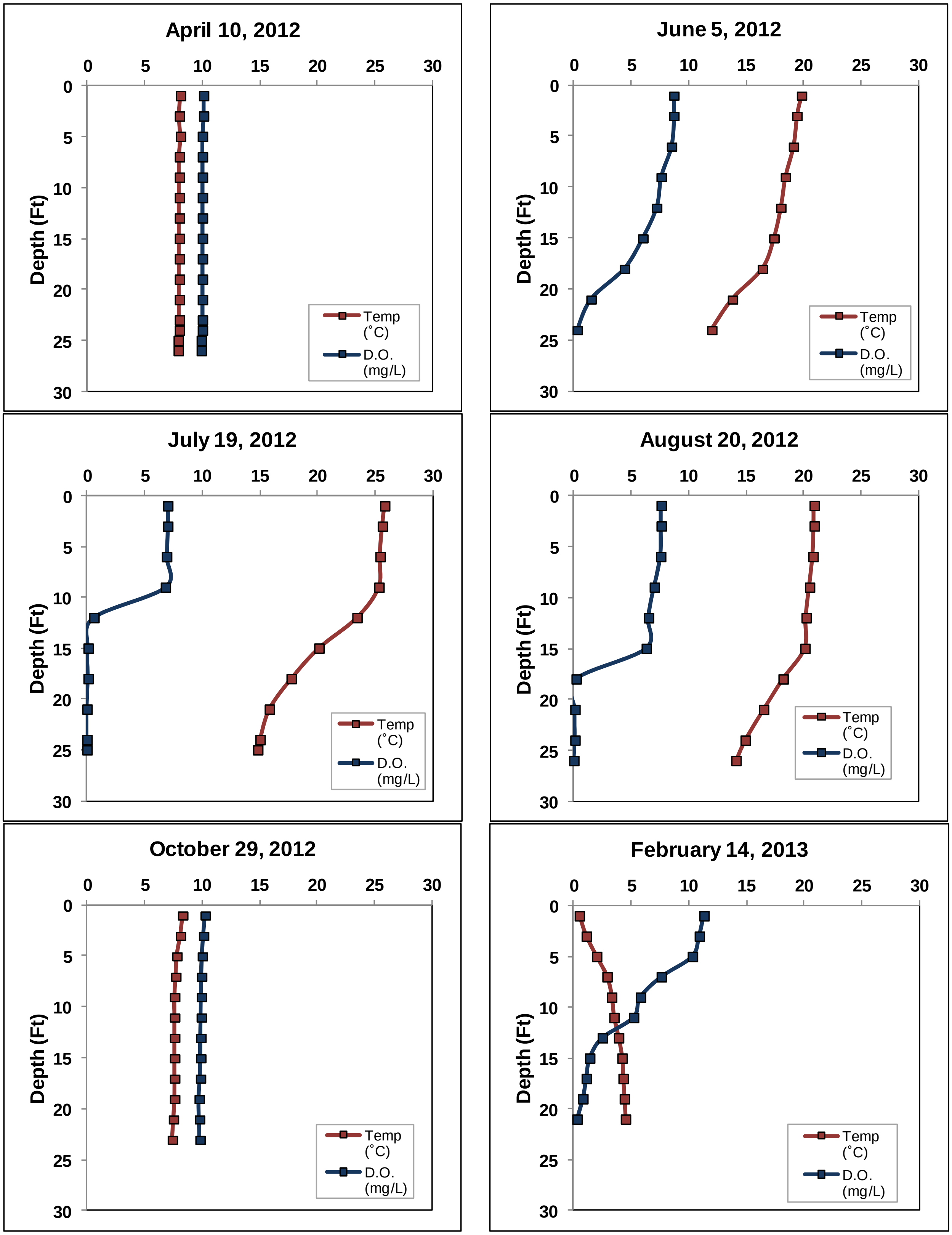


Figure 8.10.3-3. Fourmile Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Fourmile 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 Fourmile 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 Chainwide 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. Fourmile Lake's pH was measured at 7.3 in July 2012. This value is near neutral and falls within the normal range for Wisconsin lakes.

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 Fourmile Lake was measured at 24.0 (mg/L as $CaCO_3$) near the surface, indicating 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 Fourmile Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element to build shells 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 Fourmile Lake's pH of 7.3 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 Fourmile Lake was found to be 6.5 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.10.4 Fourmile Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Fourmile Lake on June 5, 2012. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants. One exotic plant, pale yellow iris, was found along the shorelines of the lake during subsequent surveys. This plant is discussed in detail at the end of this section.

The aquatic plant point-intercept survey was conducted on Fourmile Lake on July 17, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that same day to create the aquatic plant community map (Fourmile Lake Community Map). During these surveys, 31 species of native aquatic plants were located in Fourmile Lake (Table 8.10.4-1). 21 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while 10 species were found incidentally.

Aquatic plants were found growing to a depth of seven feet, which is comparable to the other lakes within the Three Lakes Chain of lakes, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 93 point-intercept locations sampled within the littoral zone, approximately 54% contained aquatic vegetation. Approximately 61% of the point-intercept sampling locations where sediment data was collected at were sand, 40% consisted of a fine, organic substrate (muck) and 13% were determined to be rocky.

Table 8.10.4-1. Aquatic plant species located in the Fourmile Lake during the 2012 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2012 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Pontederia cordata	Pickerelweed	9	*X*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Sagittaria rigida	Stiff arrowhead	8	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Typha spp.	Cattail spp.	1	*I*
	Zizania palustris	Northern wild rice	8	*X*
FL	*Brasenia schreberi*	Watershield	7	*I*
	Nuphar x rubrodisca	Intermediate pond-lily	9	*X*
	Nymphaea odorata	White water lily	6	*X*
	Nuphar variegata	Spatterdock	6	*X*
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	*I*
	Sparganium fluctuans	Floating-leaf bur-reed	10	*X*
Submergent	*Chara spp.*	Muskgrasses	7	*X*
	Ceratophyllum demersum	Coontail	3	*X*
	Heteranthera dubia	Water stargrass	6	*X*
	Nitella spp.	Stoneworts	7	*X*
	Najas flexilis	Slender naiad	6	*X*
	Potamogeton natans	Floating-leaf pondweed	5	*I*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton amplifolius	Large-leaf pondweed	7	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Potamogeton gramineus	Variable pondweed	7	*X*
	Potamogeton spirillus	Spiral-fruited pondweed	8	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
	Vallisneria americana	Wild celery	6	*X*
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

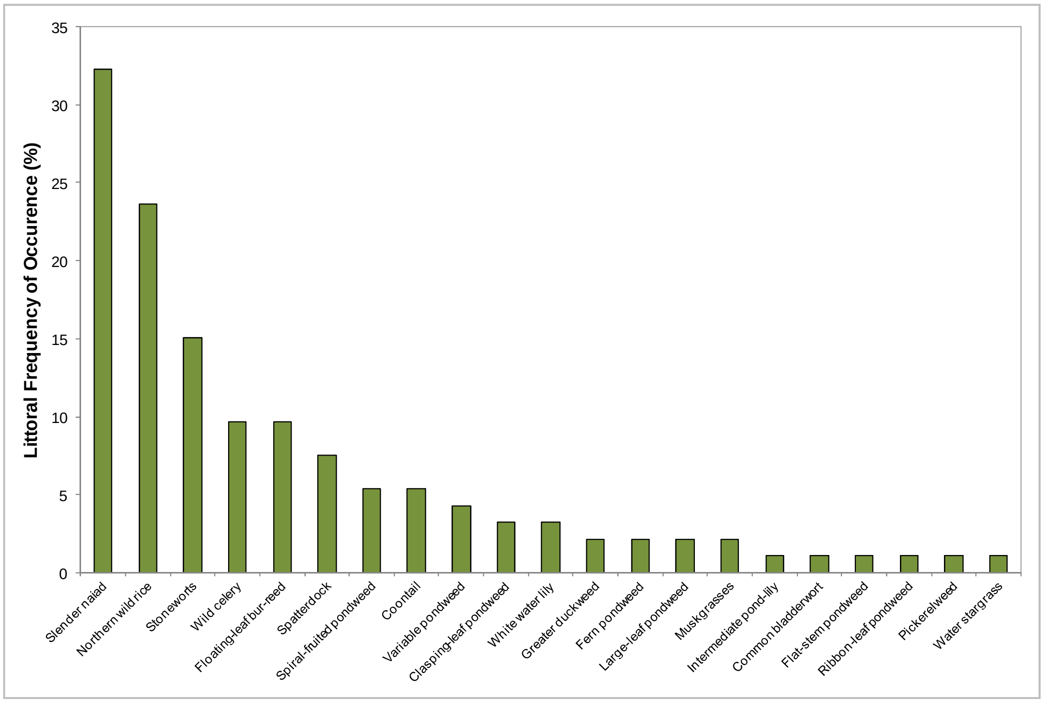


Figure 8.10.4-1 Fourmile Lake aquatic plant littoral frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

Figure 8.10.4-1 (above) shows that slender naiad, northern wild rice and members of the stonewort grouping were the most frequently encountered plants within Fourmile Lake. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Manoomin, as it is referred to by Ojibewa Tribal Communities, has great cultural significance as well as being an important component of Native American diets. Wild rice is also an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish. Perhaps one of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive nutrients, stabilize sediments, and form natural wave-breaks to protect shoreline areas. Nitella species, or stoneworts as they may be called, are actually a type 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.

31 species of aquatic plants (including incidentals) were found in Fourmile Lake and 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 Fourmile Lake's plant community (0.91) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity with respect to its aquatic plant community.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 24%. Explained another way, if 100 plants were randomly sampled from Fourmile Lake, 24 of them would be slender naiad. This distribution can be observed in Figure 8.10.4-2, where together six species account for 73% of the population of plants within Fourmile Lake, while the other 15 species account for the remaining 27%. Ten additional species were located from the lake but not from of the point-intercept survey, as indicated in Figure 8.10.4-1 as incidentals.

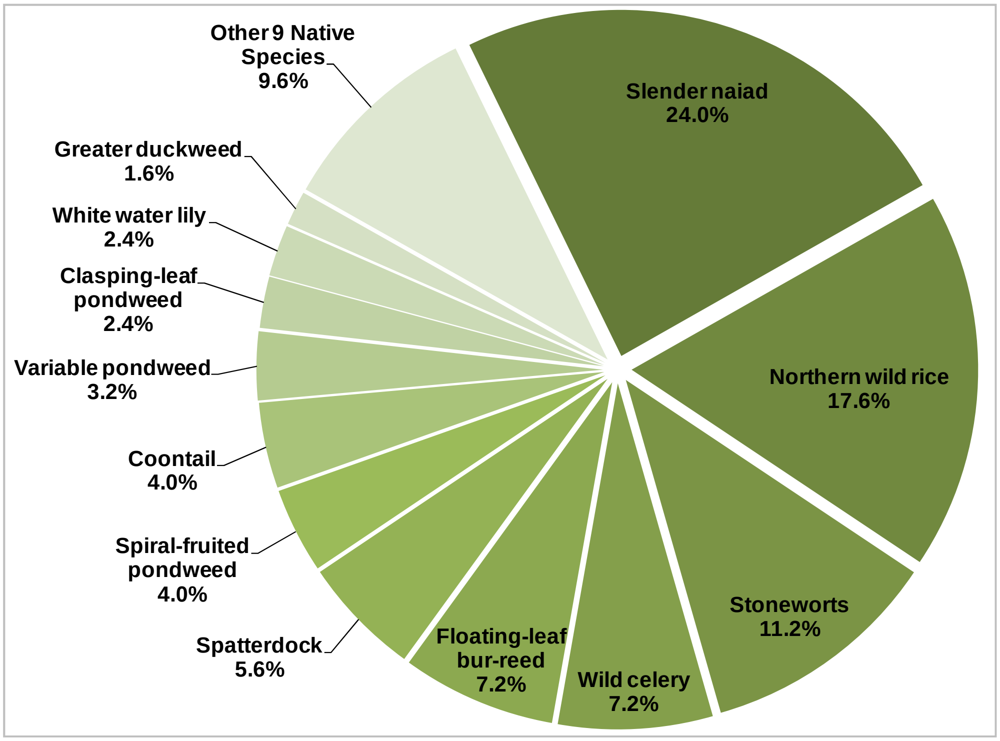


Figure 8.10.4-2 Fourmile Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

Fourmile Lake's average conservatism value (6.9) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Fourmile Lake is indicative of an undisturbed system. This is not surprising considering Fourmile Lake's plant community has high diversity as well as species richness. Combining Fourmile Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.4 which is well above the median values of the ecoregion (24.3) and state (22.2).

The quality of Fourmile Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 45.6 acres of the lake contains these types of plant communities (Fourmile Lake

Map 2, Table 8.10.4-2). Fifteen floating-leaf and emergent species were located on Fourmile Lake (Table 8.10.4-1), all of which provide valuable wildlife habitat.

Table 8.10.4-2. Fourmile Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Acres
Emergent	26.4
Floating-leaf	2.1
Mixed Floating-leaf and Emergent	17.1
Total	45.6

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 Fourmile 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.

Aquatic Invasive Species in Fourmile Lake

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 some of the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Fourmile Lake can be viewed on Fourmile Lake Map 2. At this time, there are a few locations where this plant is located. Visiting these locations in mid-June and hand pulling the plant, using care not to spread the reproductive seeds, is likely the best way to control this species for now. More information on this methodology is discussed within the Implementation Plan.

.

8.10.6 Fourmile Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Fourmile Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Fourmile Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Fourmile Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Fourmile Lake's implementation plan is compiled by describing how Fourmile Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Fourmile Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Fourmile Lake as part of this chain-wide project, it is up to Fourmile Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Fourmile Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: While Fourmile Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Big Fork Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Fourmile Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Fourmile Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Fourmile Lake or from Fourmile Lake elsewhere. If a Fourmile Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Fourmile Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Fourmile Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Fourmile Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Fourmile Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Fourmile Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, no volunteer water quality collection is occurring on Fourmile Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Fourmile Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Fourmile Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Fourmile Lake shoreline was categorized in terms of its development. According to the results from this survey, 3.0% of the shoreline is in an urbanized or developed-unnatural state, while 19.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

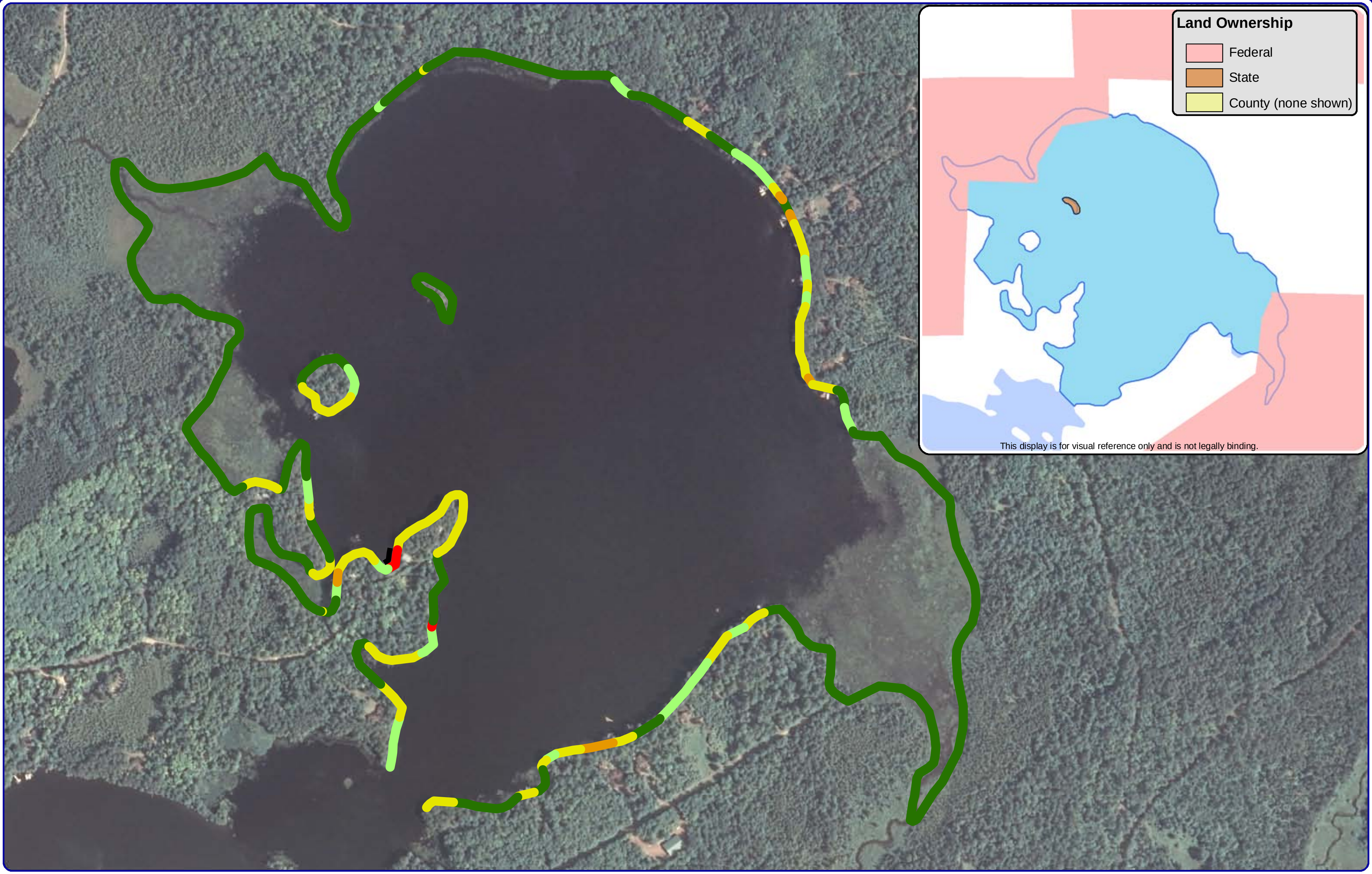
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Fourmile Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Fourmile Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Fourmile Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

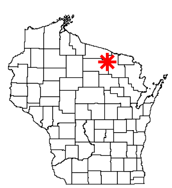


N
W E
S

650
Feet

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2012
Federal Land: USDA Forest Service
State Land: WDNR
Map date: January 3, 2013
Filename: Fourmile_ShorelineCondition_2012.mxd


Project Location in Wisconsin

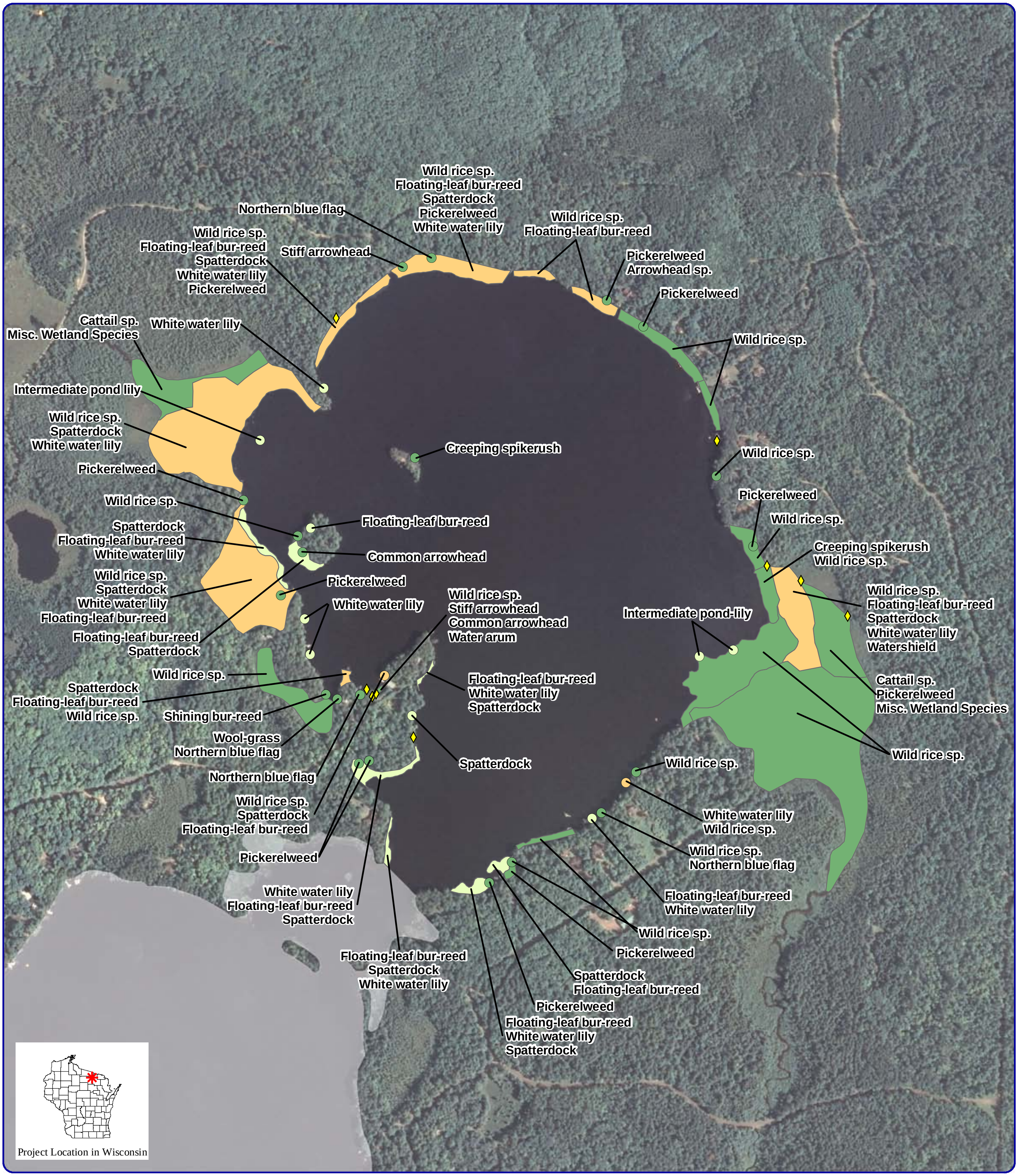
Legend

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

Seawall
Masonary/Metal/Wood

Fourmile Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

Shoreland Condition



N
W E
S
750
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, 2012
Orthophotography: NAIP, 2010
Map date: December 7, 2012
Filename: *Fourmile_Comm_2012.mxd*

Legend

Small Plant Communities	Large Plant Communities	Exotic Plant Communities
Emergent	Emergent	Pale Yellow Iris
Floating-leaf	Floating-leaf	
Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent	

Fourmile Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

Aquatic Plant Communities

Note: Methodology, explanation of analysis and scientific background on Big Fork Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.11 Big Fork Lake

An Introduction to Big Fork Lake

Big Fork Lake, Oneida County, is a lowland drainage lake with a maximum depth of 37 feet and a surface area of 670 acres. This eutrophic lake has a large watershed when compared to the size of the lake. Big Fork Lake contains 38 native plant species, of which wild celery was the most common plant in 2012. One exotic plant, pale yellow iris, is known to be found on the lake.

Field Survey Notes

A fair amount of development observed on the lake. Vasey's pondweed found in two point-intercept locations. Shoreline was dotted with much pale yellow iris during early-season AIS survey.

Photo 8.11.1-1 Big Fork Lake, Oneida County

Lake at a Glance* – Big Fork Lake

Morphology	
Acreage	670
Maximum Depth (ft)	37
Mean Depth (ft)	17.5
Volume (acre-feet)	11,690
Shoreline Complexity	2.5
Vegetation	
Curly-leaf Survey Date	June 5, 2012
Comprehensive Survey Date	July 17, 2012
Number of Native Species	38
Threatened/Special Concern Species	Vasey's pondweed *(Potamogeton vaseyi)*
Exotic Plant Species	Pale-yellow iris *(Iris pseudacorus)*
Simpson's Diversity	0.84
Average Conservatism	7.2
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	21:1

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

8.11.1 Big Fork Lake Watershed Assessment

Big Fork Lake's watershed is 14,833 acres in size. Compared to the lakes size of 670 acres, this makes for a large watershed to lake area ratio of 21:1.

Exact land cover calculation and modeling of nutrient input to Big Fork Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.11.2 Big Fork Lake Shoreland Condition Assessment

Shoreland Development

As mentioned previously in the Chain-wide Watershed 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 2012, Big Fork Lake's immediate shoreline was assessed in terms of its development. Big Fork Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.5 miles of natural/undeveloped and developed-natural shoreline (44% of the entire shoreline) were observed during the survey (Figure 8.11.2-1). 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, roughly 1.1 miles of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Big Fork 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. The Big Fork Lake Shoreline Condition Map displays the location of these shoreline lengths around the entire lake.

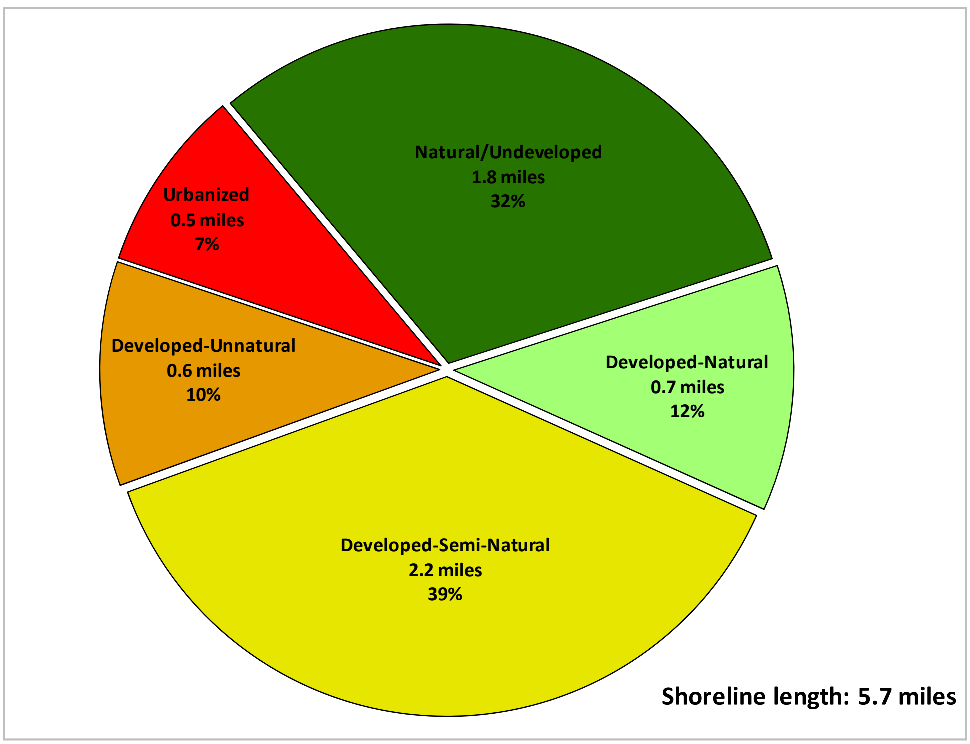


Figure 8.11.2-1. Big Fork Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on the Big Fork Lake Shoreline Condition Map.

8.11.3 Big Fork Lake Water Quality

As a part of this project, water quality data was collected from Big Fork Lake on six occasions. 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. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. As Table 8.11.3-1 indicates, some historical data exists for these parameters. In addition to this project, data has been collected by the WDNR, Wisconsin Valley Improvement Company (WVIC) and Citizens Lake Monitoring Network (CLMN).

During 2012, total phosphorus values collected from the Big Fork Lake surface averaged 23.3 μg/L, which ranks as *Good* when compared to similar deep, lowland drainage lakes within the state and all lakes in the Northern Lakes and Forests ecoregion (Figure 8.11.3-1). A weighted value across all years of data is also only slightly higher than the median values for similar lakes throughout the state and also for all lakes within the ecoregion.

Table 8.11.3-1. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

	Secchi (feet)				Chlorophyll-*a* (μg/L)				Total Phosphorus (μg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1986	3	4.8	3	4.8								
1987	16	4.7	9	5.0								
1993	7	5.2	5	5.3								
1994	6	7.2	6	7.2								
1995	7	6.9	7	6.9								
1996	8	6.1	7	6.0								
1998	9	5.1	8	5.2								
1999	4	5.7	3	5.9								
2000	9	5.9	4	7.2	4	8.5	3	8.0	4	24.0	3.0	21.3
2001	1	7.6	1	7.6	4	12.0	3	10.7	4	29.3	3.0	30.0
2002	1	5.0	0		4	8.7	3	7.5	4	21.8	3.0	20.7
2010	4	9.3	3	9.8	4	8.3	3	6.9	4	21.8	3.0	17.7
2011	4	5.7	3	5.9	4	10.5	3	9.5	2	23.0	2.0	23.0
2012	8	6.0	6	6.2	8	6.8	6	6.8	8	23.5	6.0	23.3
All Years (Weighted)		5.8		6.1		8.8		8.0		23.9		22.8
Deep, Lowland Drainage Lakes				8.5				7.0				23.0
NLF Ecoregion				8.9				5.6				21.0

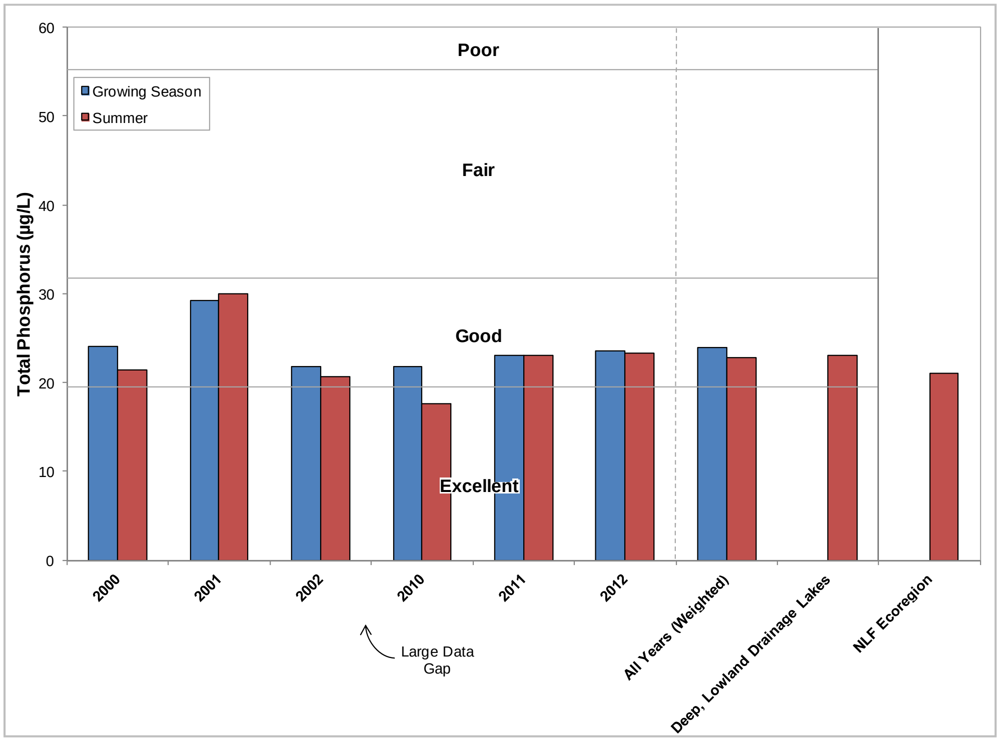


Figure 8.11.3-1. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

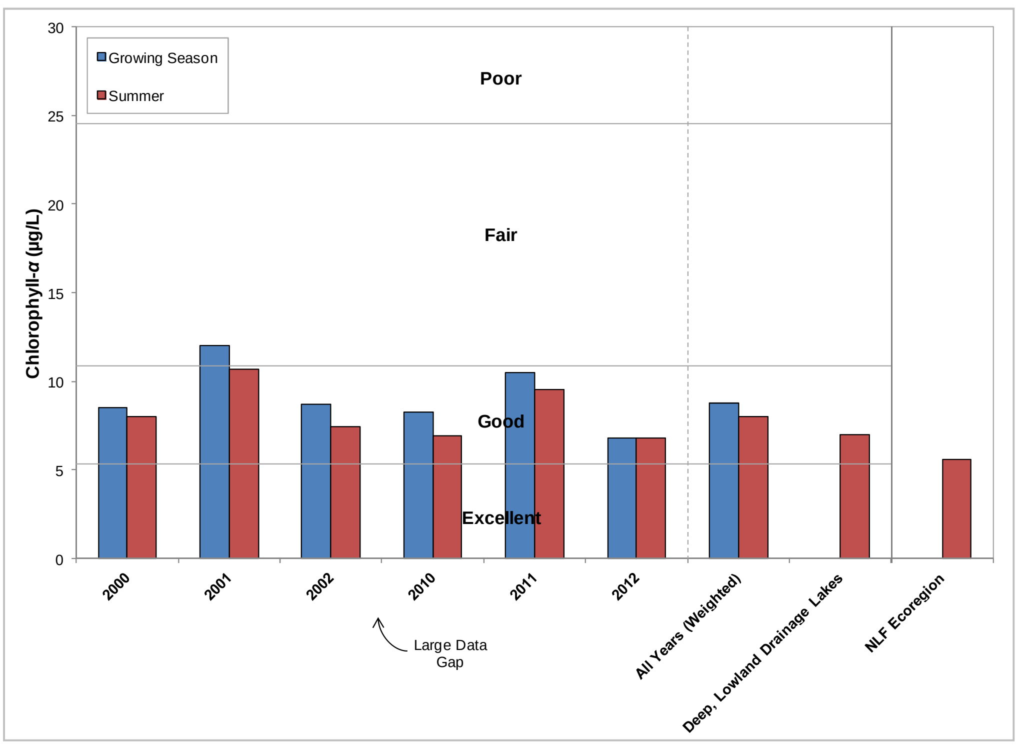


Figure 8.11.3-2. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional cholorphyll-*a* values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Average annual chlorophyll-*a* concentrations vary over the available time period; however, summer values rank as *Good* category for deep, lowland drainage lakes (Figure 8.11.3-2). A weighted average is somewhat higher than comparable lakes across the state within the ecoregion. The data indicates that algae levels within the lake are at a level that is healthy for the ecosystem and not excessive enough to cause ecological issues or recreational problems.

A larger dataset is available for Big Fork Lake with regards to Secchi disk clarity (Figure 8.11.3-3). These data largely fall within the *Good* category for deep, lowland drainage lakes across the state. However, a weighted average value across all years falls below the median value for similar lakes state-wide and all lakes in the ecoregion. Interestingly, exceptional Secchi disk clarity values were recorded during the 2010 open water season. Four measurements of this parameter (June, July, August and October) ranged between 7.5 and 12.1 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 lakes such as the Three Lakes Chain, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Fork Lake contain many 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 wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. With regards to the 2010 data, it is possible that less rainfall brought fewer of these natural acids into the lake, which would result in temporarily clearer water. Other environmental anomalies may exist as well which would account for the greater water clarity in this year.

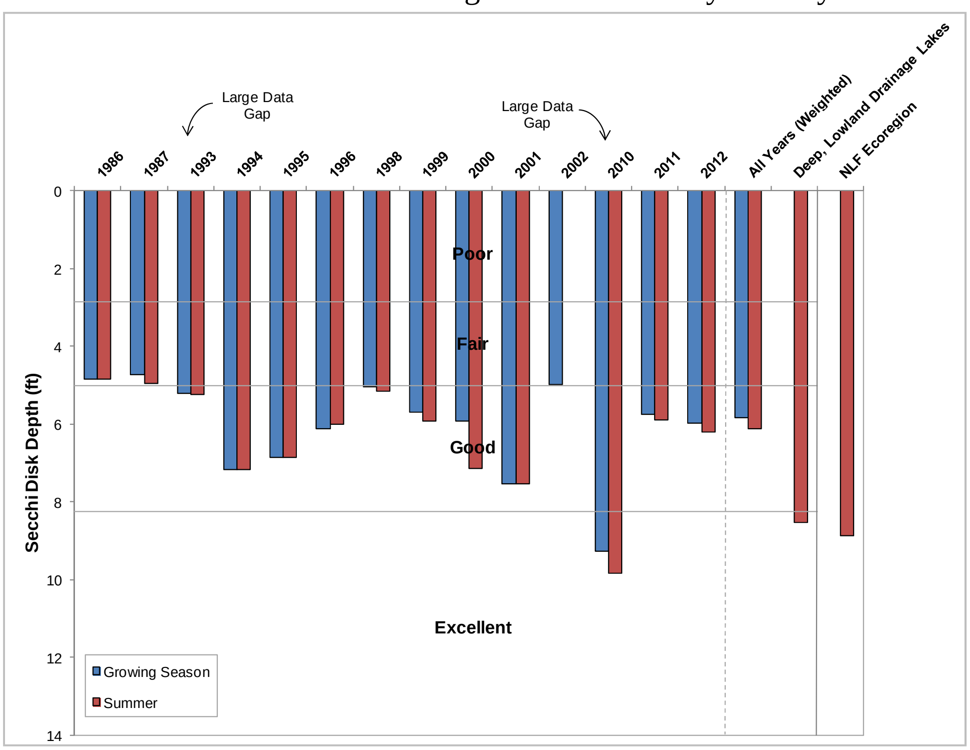


Figure 8.11.3-3. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Big Fork 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 8.11.3-4). 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 Big Fork Lake is in a lower eutrophic state.

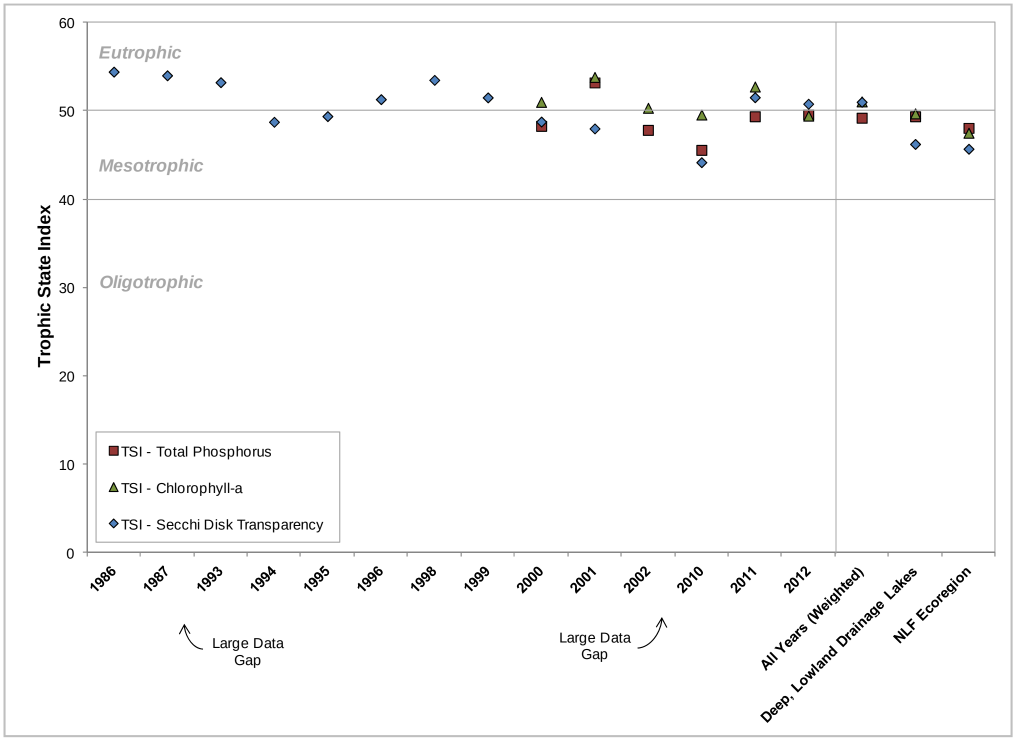


Figure 8.11.3-4. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Big Fork Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Fork Lake by Onterra staff. Graphs of those data are displayed in Figure 8.11.3-5 for all three sampling events. In April and October, the lake was completely mixed, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. During June, these parameters were higher in the epilimnion and dropped only slightly with depth. In July, Big Fork Lake became stratified, with a distinct warmer epilimnion and cooler hypolimnion. During this time, anoxic conditions were observed from 18 to 28 ft. Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being developed in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Despite the decrease in oxygen levels during the summer months, oxygen remained sufficient in the upper 18 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen depletion may be of concern during the winter months due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. Fortunately, dissolved oxygen was sufficient within the majority of the water column in February of 2013.

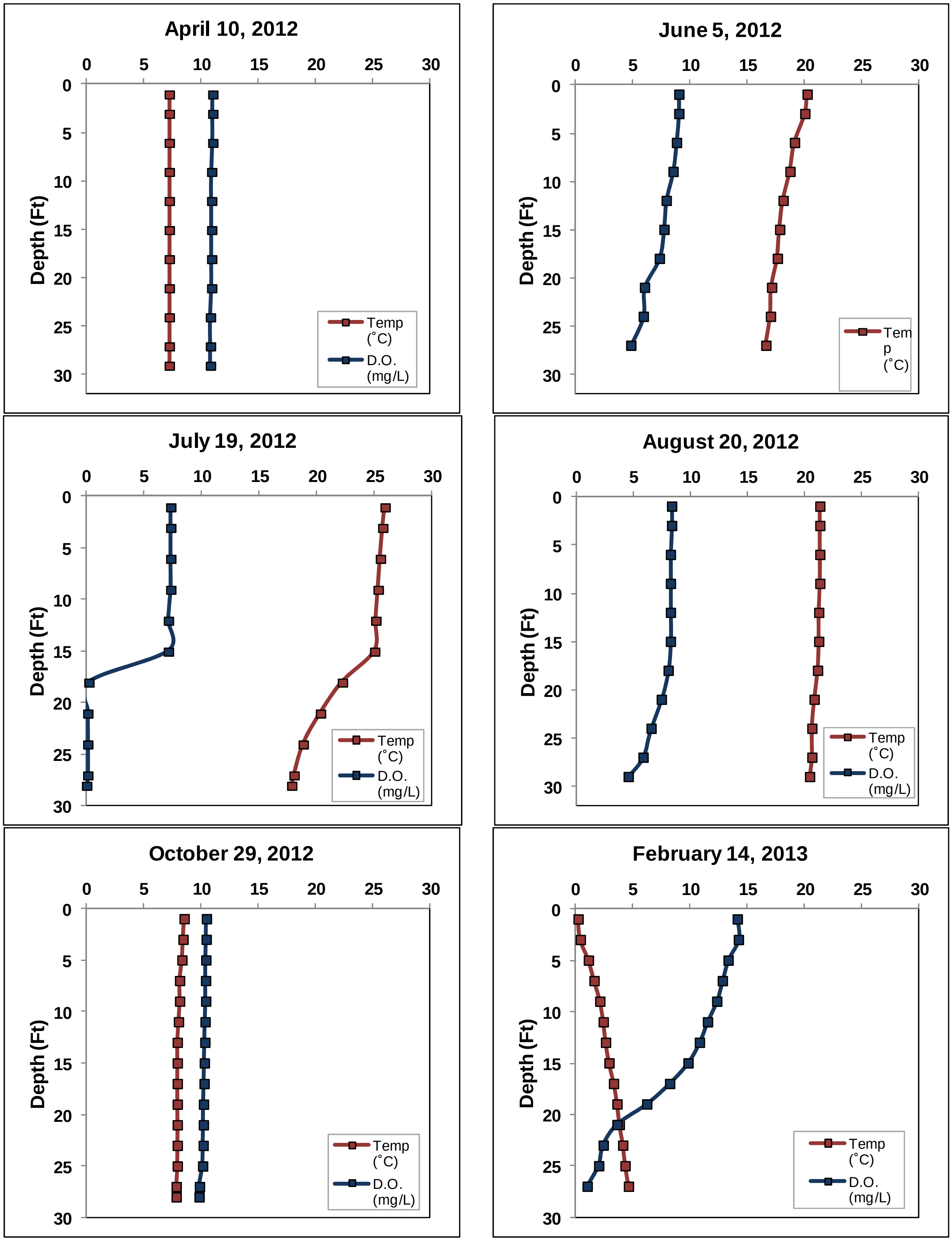


Figure 8.11.3-5. Big Fork Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big Fork 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 Big Fork 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 Chainwide 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. Big Fork Lake's pH was measured at 7.4 in July 2012. This value is near neutral and falls within the normal range for Wisconsin lakes.

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 Big Fork Lake was measured at 39.9 (mg/L as $CaCO_3$) near the surface in July, indicating 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 Big Fork Lake during the summer of 2012. Calcium is commonly examined because invasive and native mussels use the element to build shells 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 Big Fork Lake's pH of 7.0-8.6 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 Big Fork Lake was found to be 6.7 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.11.4 Big Fork Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Big Fork Lake on June 5, 2012. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants. One exotic plant, pale yellow iris, was found along the shorelines of the lake during subsequent surveys. This plant is discussed in detail at the end of this section.

The aquatic plant point-intercept survey was conducted on Big Fork Lake on July 17, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that same day to create the aquatic plant community map (Big Fork Lake Community Map). During these surveys, 38 species of native aquatic plants were located in Big Fork Lake (Table 8.11.4-1). 23 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while 15 species were found incidentally.

Aquatic plants were found growing to a depth of ten feet, which is slightly deeper than in the other lakes within the Three Lakes Chain, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 204 point-intercept locations sampled within the littoral zone, approximately 51% contained aquatic vegetation. Approximately 77% of the point-intercept sampling locations where sediment data was collected at were sand, 10% consisted of a fine, organic substrate (muck) and 14% were determined to be rocky.

Table 8.11.4-1. Aquatic plant species located in the Big Fork Lake during the 2012 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2012 (Onterra)
Emergent	*Carex vesicaria*	Blister sedge	7	I
	Decodon verticillatus	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	X
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	X
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	*Nymphaea odorata*	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Elatine minima	Waterwort	9	X
	Elodea nuttallii	Slender waterweed	7	I
	Heteranthera dubia	Water stargrass	6	I
	Isoetes spp.	Quillwort species	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	I
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	I
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	I
	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	I
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	I
	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

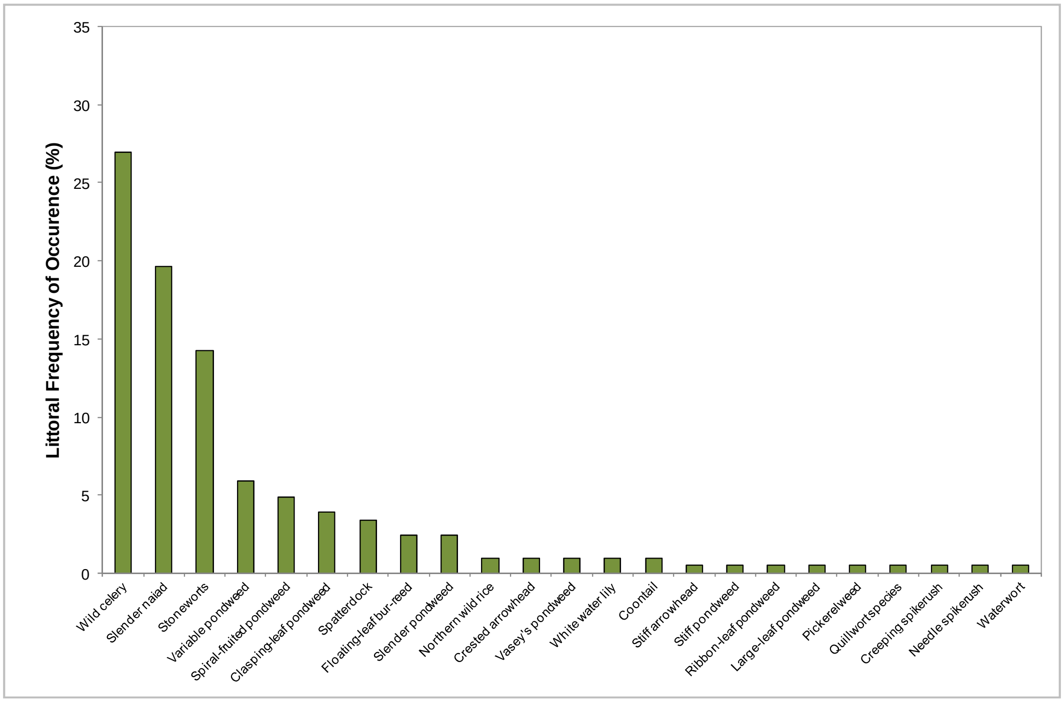


Figure 8.11.4-1 Big Fork Lake aquatic plant littoral frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

Figure 8.11.4-1 (above) shows that wild celery, slender naiad, and members of the stonewort grouping were the most frequently encountered plants within Big Fork Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Wild Celery has ribbon-like leaves that emerge in clusters along a creeping rhizome. The leaves have a prominant central stripe and cellophane-like consistency. The leaves are mostly submersed, with just the tips trailing on the surface of the water. Male and female flowers are produced on separate plants though they are very small (1 - 6.5 mm wide).

As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Nitella species, or stoneworts as they may be called, are actually a type 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.

38 species of aquatic plants (including incidentals) were found in Big Fork Lake and 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 Big Fork Lake's plant community (0.84) lies slightly below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds moderate diversity with respect to its aquatic plant community. The reason for this is discussed below.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, 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 27% of the sampling locations, its relative frequency of occurrence is 29%. Explained another way, if 100 plants were randomly sampled from Big Fork Lake, 29 of them would be wild celery. This distribution can be observed in Figure 8.11.4-2, where together two species account for 50% of the population of plants within Big Fork Lake, while the remaining species account for the other half of the pie. Because of this unevenness, the diversity of the aquatic plant community is somewhat lower than the ecoregion median value. Fifteen additional species were located from the lake but not from of the point-intercept survey, as indicated in Table 8.11.4-1 as incidentals.

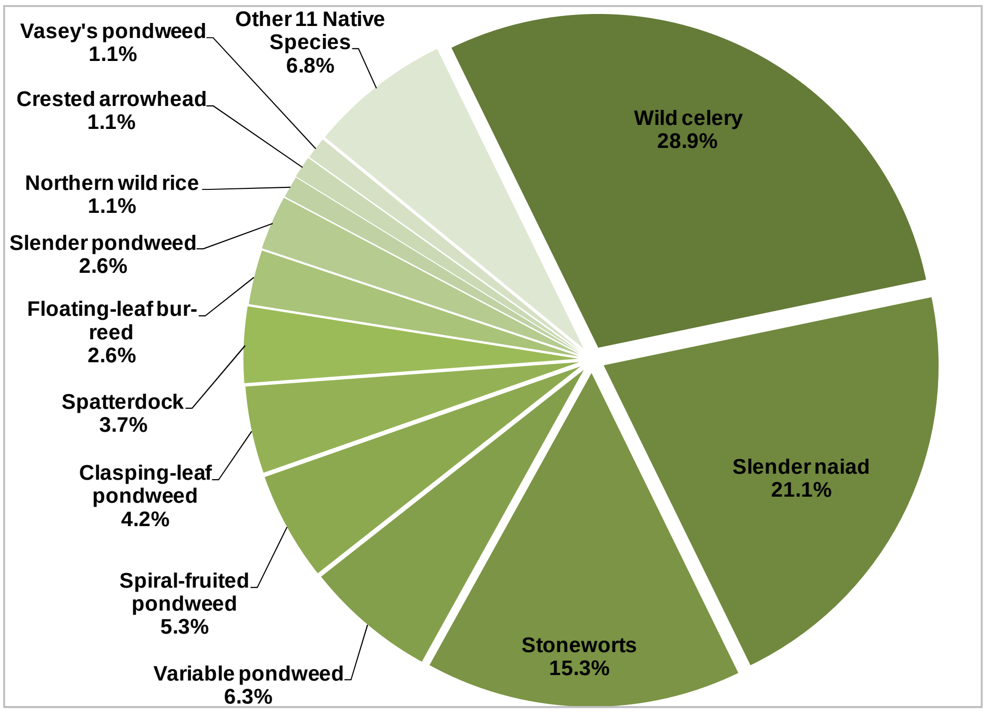


Figure 8.11.4-2 Big Fork Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

Despite the lower diversity value, Big Fork Lake's average conservatism value (7.2) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community holds a number of species that are sensitive to environmental degradation. In other words, although there is much wild celery and slender naiad in the lake (two species that are fairly tolerant of environmental degradation), there are also several species present that are sensitive to disturbance, such as those listed on Table 8.11.4-1 that have Coefficient of Conservatism values of 8, 9 or 10 (Vasey's pondweed, floating-leaf bur-reed, pickerelweed, blunt-leaf pondweed, quillwort species, etc.). Combining Big Fork Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 34.6 which is above the median values of the ecoregion (24.3) and state (22.2).

The quality of Big Fork Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 9.6 acres of the lake contains these types of plant communities (Big Fork Lake Map 2, Table 8.11.4-2). Fifteen floating-leaf and emergent species were located on Big Fork Lake (Table 8.11.4-1), all of which provide valuable wildlife habitat.

Table 8.11.4-2. Big Fork Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Acres
Emergent	2.2
Floating-leaf	3.7
Mixed Floating-leaf and Emergent	3.7
Total	9.6

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 Big Fork 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.

Aquatic Invasive Species in Big Fork Lake

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 much of the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Big Fork Lake can be viewed on Big Fork Lake Map 2.

.

8.11.6 Big Fork Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Fork Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Fork Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Fork Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Fork Lake's implementation plan is compiled by describing how Big Fork Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Big Fork Lake

Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant (Diagnostic/Feasibility Studies).

Description: Though studies have been completed on Big Fork Lake as part of this chain-wide project, it is up to Big Fork Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Big Fork Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Action Steps:

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: While Big Fork Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Big Fork Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Fork Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Fork Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Fork Lake or from Big Fork Lake elsewhere. If a Big Fork Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Big Fork Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Fork Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Big Fork Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Fork Lake and its stakeholders.

Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Fork Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

<u>Management Action:</u> Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, no volunteer water quality collection is occurring on Big Fork Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Big Fork Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

<u>Management Action:</u> Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Fork Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

<u>Management Action:</u> Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Big Fork Lake shoreline was categorized in terms of its development. According to the results from this survey, 17.0% of the shoreline is in an urbanized or developed-unnatural state, while 39.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

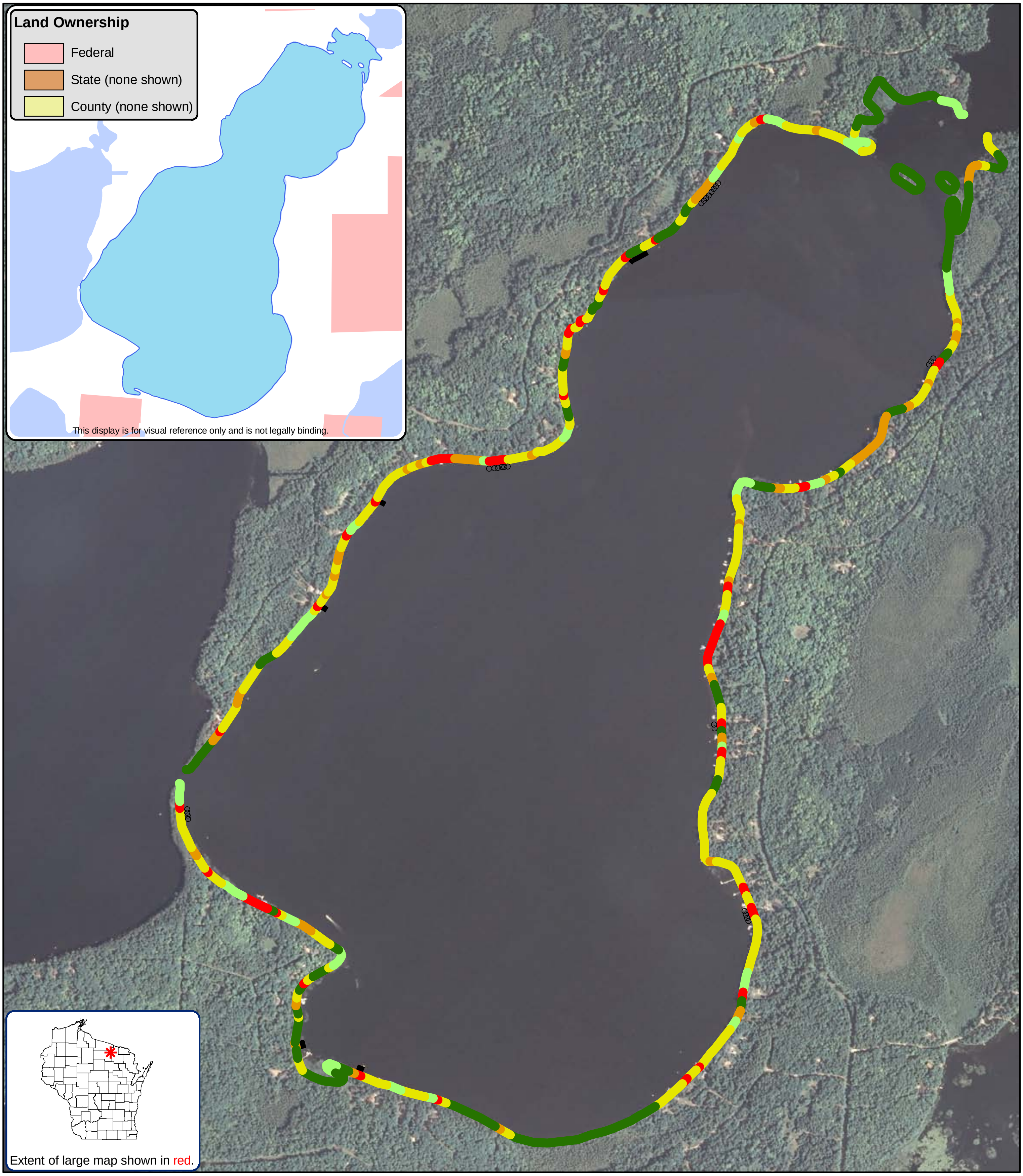
Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Big Fork Lake.

Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Fork Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Fork Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



1,100

Feet

Legend

Natural/Undeveloped

Developed-Natural

Developed-Semi-Natural

Developed-Unnatural

Urbanized

Seawall

Masonary/Wood

Rip-Rap

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

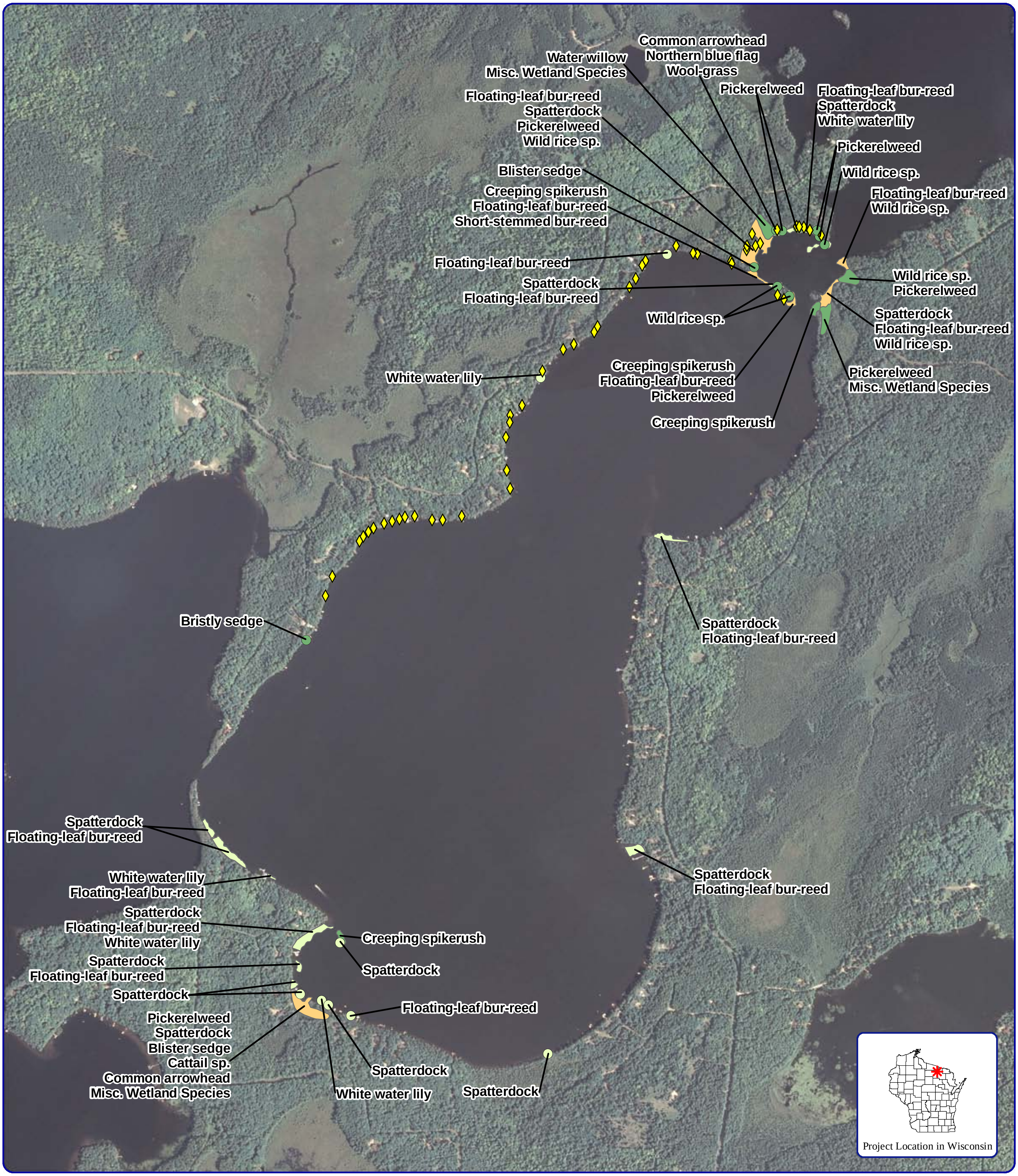
Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2012
Federal Land: USDA Forest Service
Map date: January 3, 2013
Filename: BigFork_ShorelineCondition_2012.mxd

Big Fork Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

Shoreland Condition



N
W E
S

1,350
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, 2012
Orthophotography: NAIP, 2010
Map date: November 26, 2012
***Filename:** BigFork_Comm_2012.mxd*

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

Big Fork Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

Aquatic Plant Communities