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

8.3 Voyageur Lake

An Introduction to Voyageur Lake

Voyageur Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 13 feet, a mean depth of 6.5 feet, and a surface area of approximately 143 acres. The lake is fed via the Eagle River from upstream Catfish Lake and drains into downstream Eagle Lake, and has a surficial watershed that encompasses approximately 102,751 acres. In a study conducted by Onterra in 2012, 22 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. Two non-native plants, Eurasian water milfoil and purple loosestrife, were recorded within the lake.

Field Survey Notes

Like many of the lakes within the Eagle River Chain, Voyageur Lake contains stained water which restricts aquatic plant growth to the shallower fringes of the lake. For its relatively small size, Voyageur Lake contains a relatively high number of aquatic plant species. The lake contains a large floating-leaf/emergent plant wetland along its northeast side which is comprised of white water lily, pickerelweed, and many other beneficial native plants.

Photo 8.3 Voyageur Lake, Vilas County

Lake at a Glance* – Island Lake

Morphology	
Acreage	143
Maximum Depth (ft)	13
Mean Depth (ft)	6.5
Volume (acre-feet)	923
Shoreline Complexity	9.9
Vegetation	
Curly-leaf Survey Date	July 8, 2014
Comprehensive Survey Date	August 1, 2012
Number of Native Species	22
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian water milfoil; Purple loosestrife
Simpson's Diversity	0.92
Average Conservatism	6.8
Water Quality	
Wisconsin Lake Classification	Shallow (Mixed), Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	738:1

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

8.3.1 Voyageur Lake Water Quality

Water quality data was collected from Voyageur Lake on six occasions in 2014/2015. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2014/2015, any historical data was researched and are included within this report as available.

Unfortunately, somewhat limited data exists for three water quality parameters of interest – total phosphorus, chlorophyll-*a*, and Secchi disk depths. In 2014, average summer phosphorus concentrations (30.4 µg/L) were less than the median value (33.0 µg/L) for other shallow, lowland drainage lakes in the state. The value is a little more than the median value (21.0 µg/L) for all lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *good* to *excellent* for a shallow, lowland drainage lake.

Near-surface total phosphorus concentrations from 2014 are compared with near-bottom total phosphorus concentrations collected during this same time frame in Figure 8.3.1-1. As displayed in this figure, on all occasions surface and bottom total phosphorus concentrations were similar. Voyageur Lake is relatively shallow and oxygenated water near the surface is able to be mixed down throughout the water column. This indicates that internal nutrient loading from bottom sediments in Voyageur Lake is not a concern.

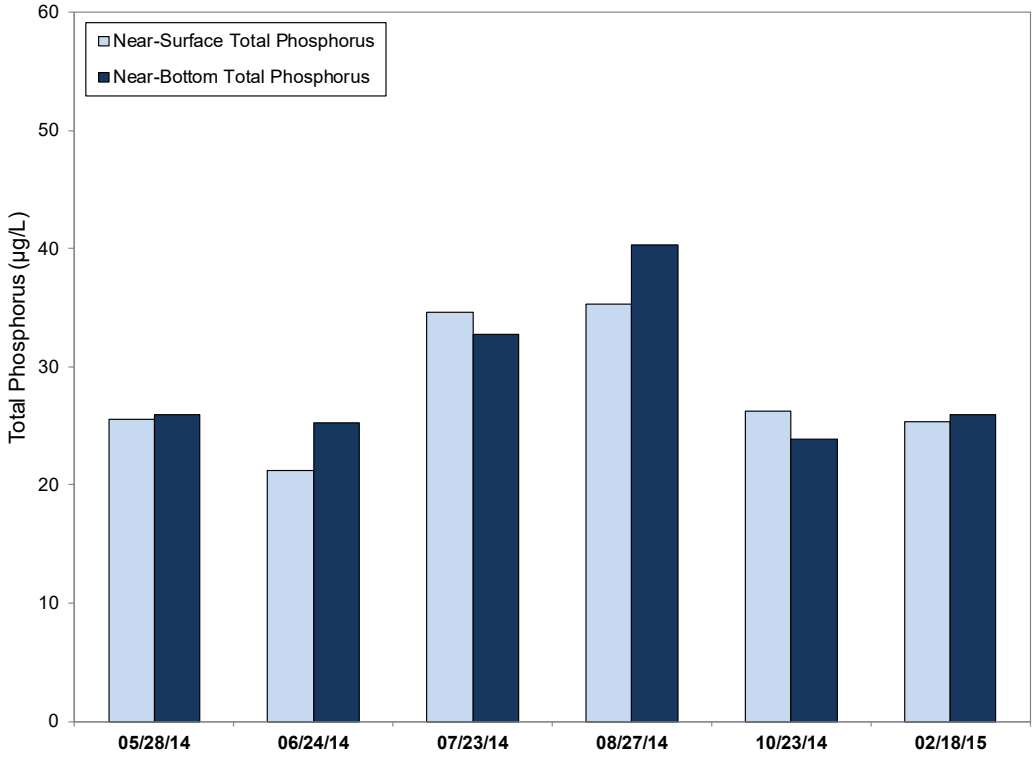


Figure 8.3.1-1. Voyageur Lake growing season 2014 and winter 2015 near-surface and near-bottom total phosphorus concentrations.

Growing season and summer chlorophyll-*a* concentrations fell within the *good* category for shallow, lowland drainage lakes in Wisconsin, with values of 12.4 µg/L and 15.7 µg/L, respectively. The summer value was slightly higher than the median value for shallow, lowland drainage lakes statewide (9.4 µg/L) and the median value for all lake types within the Northern Lakes and Forests ecoregion (5.6 µg/L). Historical chlorophyll-*a* data prior to 2014 are not available for Voyageur Lake.

Secchi disk transparency data are available from Voyageur Lake from 1993-1997 and 2014 (Figure 8.3.1-2). Over the time period for which data are available, average summer Secchi disk transparency has ranged from the *good* to *excellent* categories for shallow, lowland drainage lakes. Secchi disk transparency in 1993-1995 and 2014 fall in line with clarity values in upstream Catfish Lake and downstream Eagle Lake. However, clarity values from 1996 and 1997 are significantly higher than the other years for which data are available. No other lakes within the chain, including downstream Eagle Lake, exhibited detectable increases in water clarity in 1996 and 1997. Given the stained nature of the water within the lakes, the validity of these higher water clarity values in Voyageur Lake in 1996 and 1997 are suspect. Unfortunately, no chlorophyll-*a* or total phosphorus data are available from these years. If the data from 1996 and 1997 are removed, the weighted average summer Secchi disk transparency value for Voyageur Lake falls within the *good* category and is comparable to the median value for other shallow, lowland drainage lakes in Wisconsin.

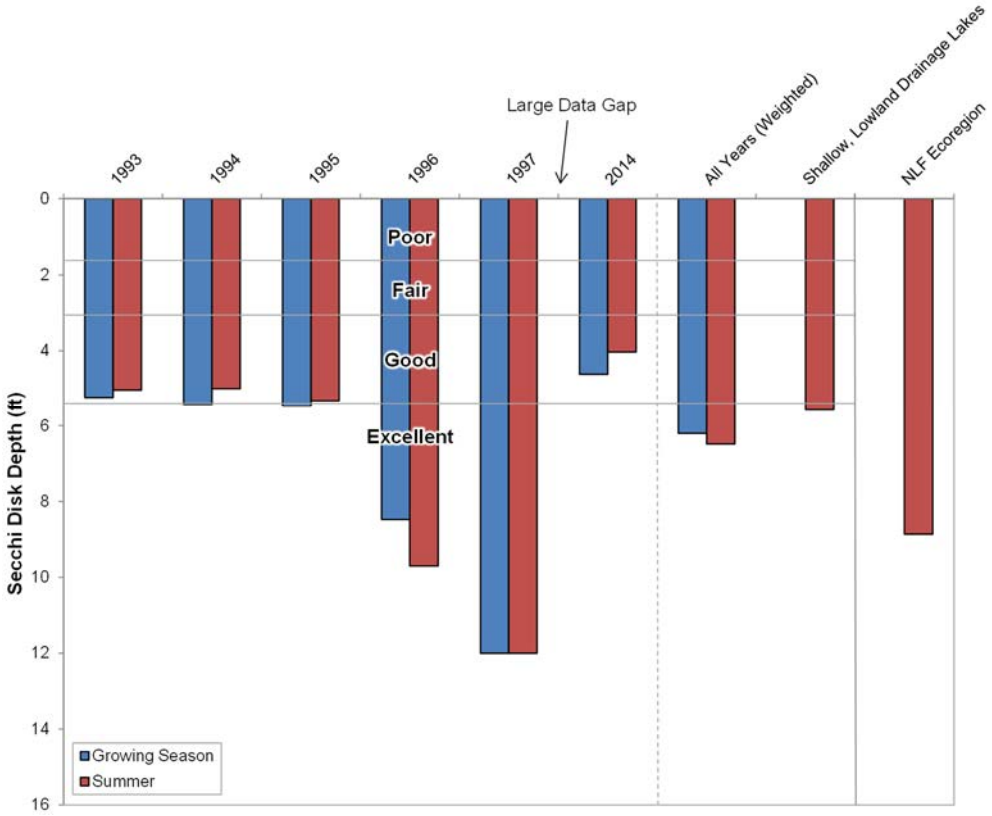


Figure 8.3.1-2. Voyageur Lake average annual Secchi disk transparency and median values for statewide shallow, lowland drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes. Water quality index values adapted from WDNR PUB WT-913.

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 Voyageur Lake as well as the other lakes in the Eagle River Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Voyageur Lake contain naturally occurring organic acids that are washed into the lake from wetlands and forests within the watershed. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

True color measures the dissolved organic materials in water. Water samples collected in May and July of 2014 were measured for this parameter, and were found to be 40 Platinum-cobalt units (Pt-co units, or PCU). Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color. This value indicates that Voyageur Lake's water has a tea-colored appearance.

Voyageur 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 8.3.1-3). 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 Voyageur Lake is in a eutrophic state.

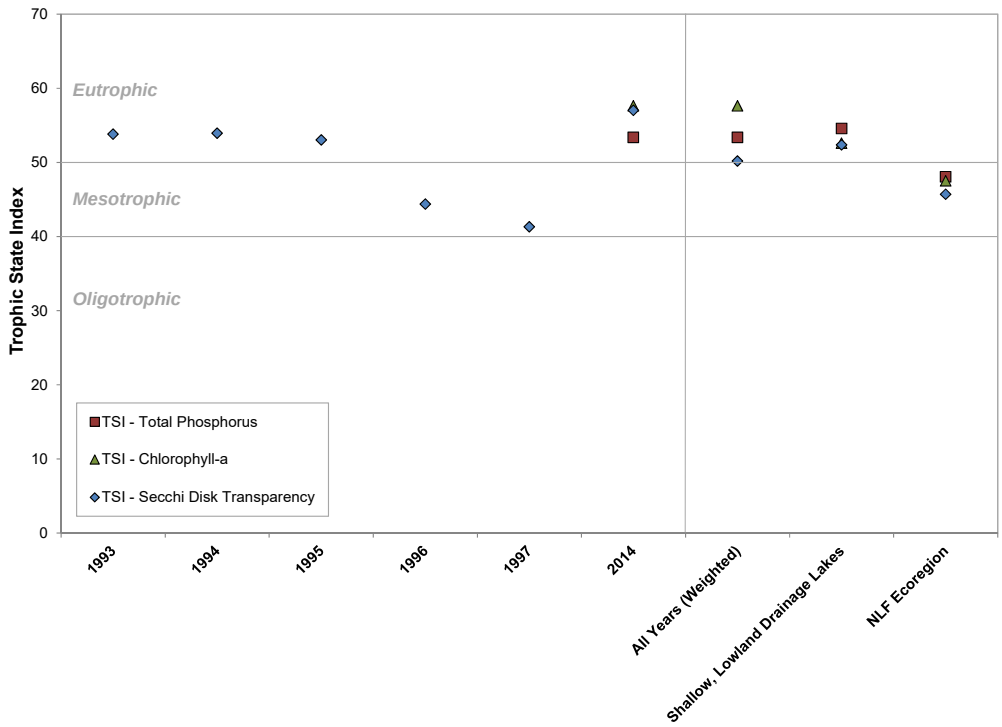


Figure 8.3.1-3. Voyageur Lake, statewide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Voyageur Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Voyageur Lake by Onterra staff. Graphs of those data are displayed in Figure 8.3.1-4 for all sampling events. Voyageur Lake is relatively shallow, and because of this, the lake does not strongly stratify during the summer months and the entire water column remains oxygenated. 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.

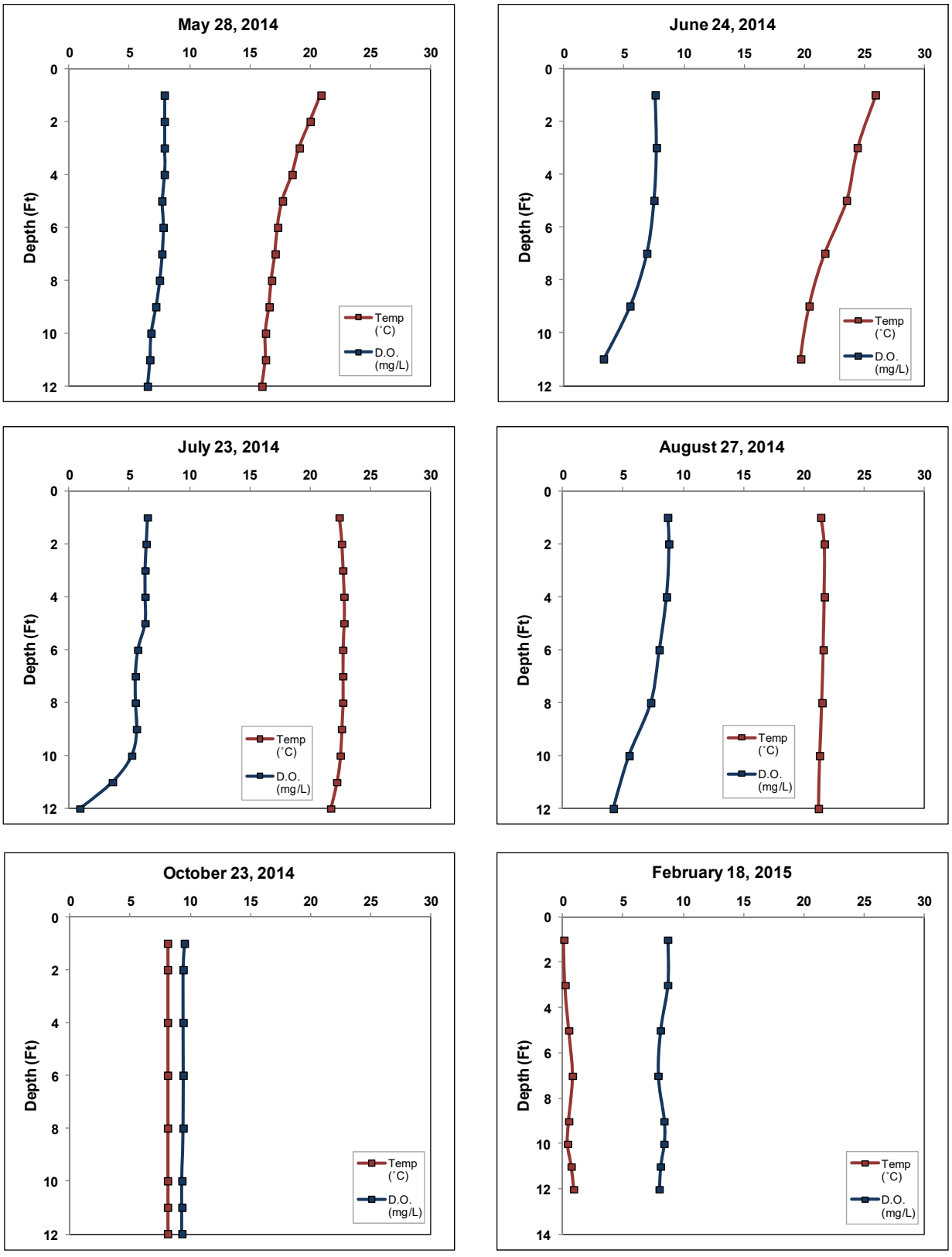


Figure 8.3.1-4. Voyageur Lake 2014/2015 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Voyageur 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 Voyageur 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. Voyageur Lake's surface water pH was measured at 7.3 in May and July of 2014. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Voyageur Lake was measured at 26.6 and 27.7 mg/L as $CaCO_3$ in May and July of 2014, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Voyageur Lake during 2014. 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 Voyageur 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 Voyageur Lake was found to be 7.14 mg/L in May and 7.32 mg/L in July of 2014, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not locate the presence of zebra mussel larvae (veligers) within the sample.

8.3.2 Voyageur Lake Watershed Assessment

Voyageur Lake's watershed is approximately 102,751 acres in size. Compared to its surface area of 139 acres, this makes for a large watershed to lake area ratio of 738:1.

Exact land cover calculation and modeling of nutrient input to Voyageur Lake will be completed towards the end of this project (in 2017-2018). 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.

8.3.3 Voyageur Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2014, Voyageur Lake's immediate shoreline was assessed in terms of its development. Voyageur Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.7 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.3.3-1). This constitutes about 47% of Voyageur Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.9 miles of urbanized and developed–unnatural shoreline (25%) was observed. If restoration of the Voyageur 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. Voyageur Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

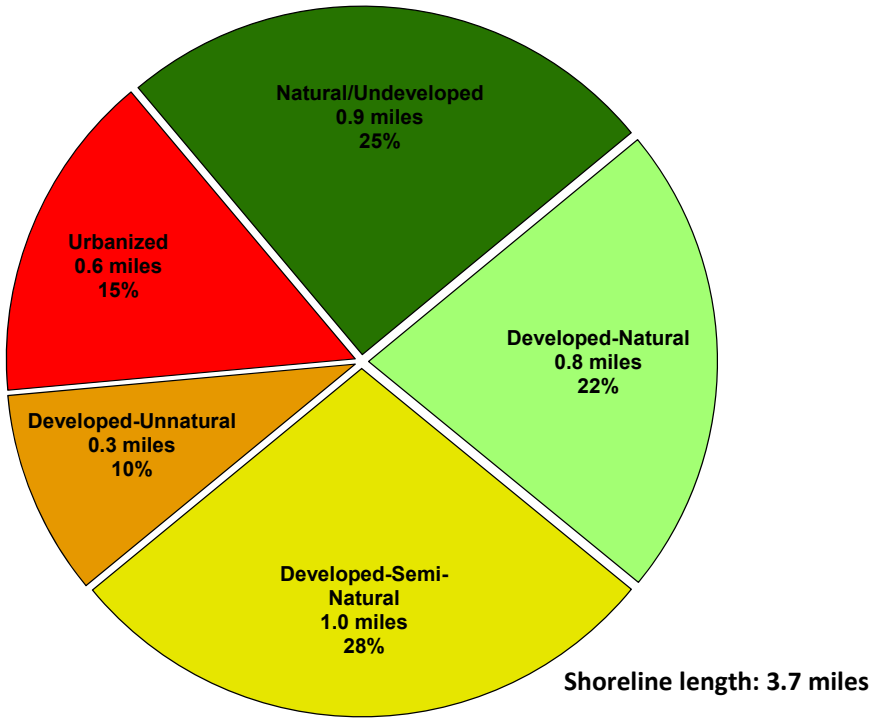


Figure 8.3.3-1. Voyageur Lake shoreland categories and total lengths. Based upon a late-summer 2014 survey. Locations of these categorized shorelands can be found on Voyageur Lake – Map 1.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in

the Eagle River Chain-wide document, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 64 total pieces of coarse woody habitat were observed along 3.7 miles of shoreline, which gives Voyageur Lake a coarse woody habitat to shoreline mile ratio of 17:1 (Figure 8.3.3-2). Locations of coarse woody habitat are displayed on Voyageur Lake – Map 2. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

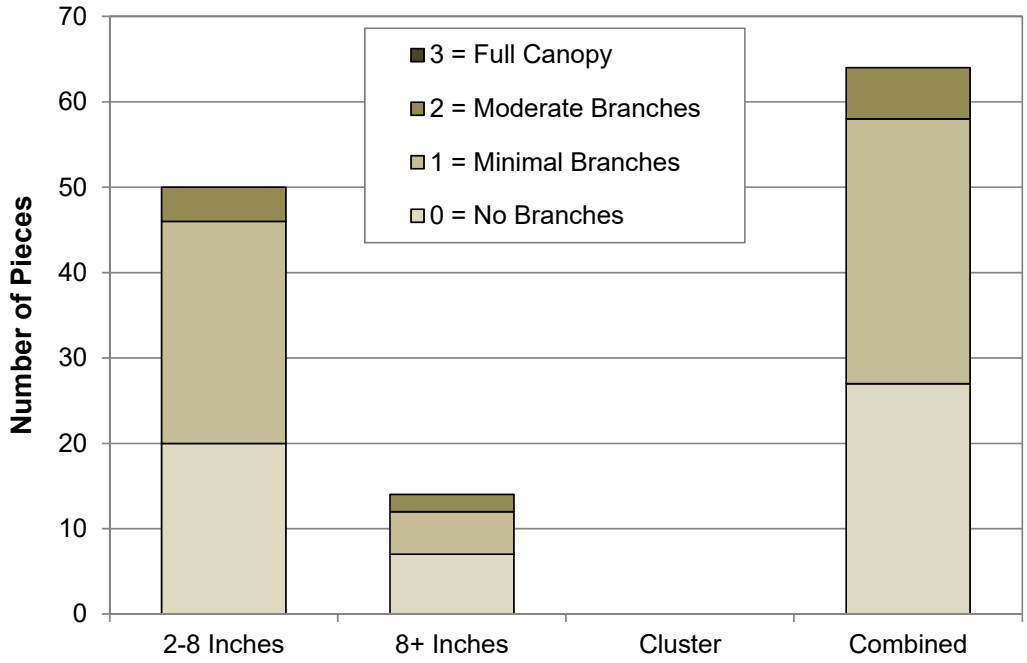


Figure 8.3.3-2. Voyageur Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of Voyageur Lake coarse woody habitat can be found on Voyageur Lake – Map 2.

8.3.4 Voyageur Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Voyageur Lake on July 7, 2014. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate potential occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed in Voyageur Lake.

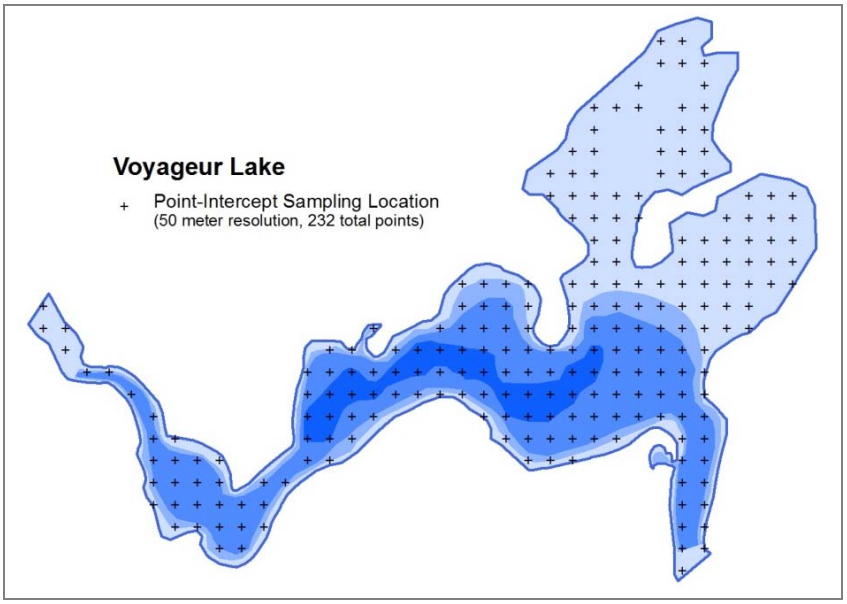


Figure 8.3.4-1. Point-intercept locations on Voyageur Lake.

The whole-lake aquatic plant point-intercept survey was conducted on Voyageur Lake by Onterra on July 31 and August 1, 2012 (Figure 8.2.4-1), while the aquatic plant community mapping survey was conducted on July 30, 2014. During these surveys, a total of 39 aquatic plant species were located, two of which are considered to be a non-native, invasive species: Eurasian water milfoil and purple loosestrife (Table 8.3.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 44% of the point-intercept locations within littoral areas contained sand, 51% contained fine, organic sediments (muck), and 5% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 12 feet, similar to 11 feet observed in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.3.4-1. Aquatic plant species located in Voyageur Lake during 2006, 2012, and 2014 aquatic plant surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2014 (Onterra)
Emergent	*Calla palustris*	Water arum	9		I
	Carex utriculata	Common yellow lake sedge	7		I
	Juncus effusus	Soft rush	4		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Pontederia cordata	Pickerelweed	9	X	I
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Sparganium eurycarpum	Common bur-reed	5		I
	Typha spp.	Cattail spp.	1		I
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		X
	Sparganium sp.	Bur-reed sp.	N/A	X	
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7		X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7		X
	Potamogeton alpinus	Apline pondweed	9		I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton natans	Floating-leaf pondweed	5	X	I
	Potamogeton praelongus	White-stem pondweed	8	X	
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus aquatilis	White-water crowfoot	8	X	
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria sp. (rosette)*	Arrowhead sp. (rosette)	N/A	X	

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidentally located
** = Species listed as 'special concern' in Wisconsin*

Of the 152 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 61% contained aquatic vegetation. This is the similar frequency of occurrence that was recorded during the 2006 survey of 60%. Voyageur Lake – Map 3 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore throughout the lake. Twenty-two percent of the point-intercept locations had a total rake fullness rating of 1, 16% had a total rake fullness rating of 2, and 22% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.3.4-1 displays the aquatic plant species located in Voyageur Lake during the Onterra 2012 point-intercept survey. All of the species recorded in 2006, with the exception of white-stem pondweed and white-water crowfoot, were relocated again in 2012. An additional four aquatic plant species were located in 2012 that were not located in 2006.

Of the 23 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, flat-stem pondweed, slender naiad, and coontail were the four-most frequently encountered (Figure 8.3.4-2). Wild celery, the most abundant aquatic plant in Voyageur Lake in 2012 with a littoral occurrence of nearly 35%, has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Flat-stem pondweed was the second-most abundant aquatic plant encountered in Voyageur Lake in 2012, with a littoral occurrence of approximately 21%. As its name indicates, flat-stem pondweed possesses a compressed or flattened stem which bears long, narrow, linear leaves. Often forming denser colonies, flat-stem pondweed provides valuable structural habitat and its fruit provides food sources of aquatic organisms.

Slender naiad was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 21%. Slender naiad is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Coontail was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 18%. Coontail is a free-floating submersed species that obtains the majority of its nutrients directly from the water. It is arguably the most common aquatic plant in Wisconsin, able to grow in a wide variety of conditions. Coontail produces whorls of stiff leaves and has the capacity to grow in very dense colonies. Its leaves and dense network of branches provide excellent structural habitat for aquatic organisms, and the fact it obtains most of its nutrients directly from the water aids in reducing nutrients that would otherwise be available to free-floating algae.

Vasey's pondweed was the sixth-most frequently encountered aquatic plant species in 2012 in Voyageur Lake. As discussed in the Chain-Wide Section, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Vasey's pondweed is a narrow-leaf pondweed with very fine linear leaves. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Voyageur Lake is an indicator of a high-quality environment.

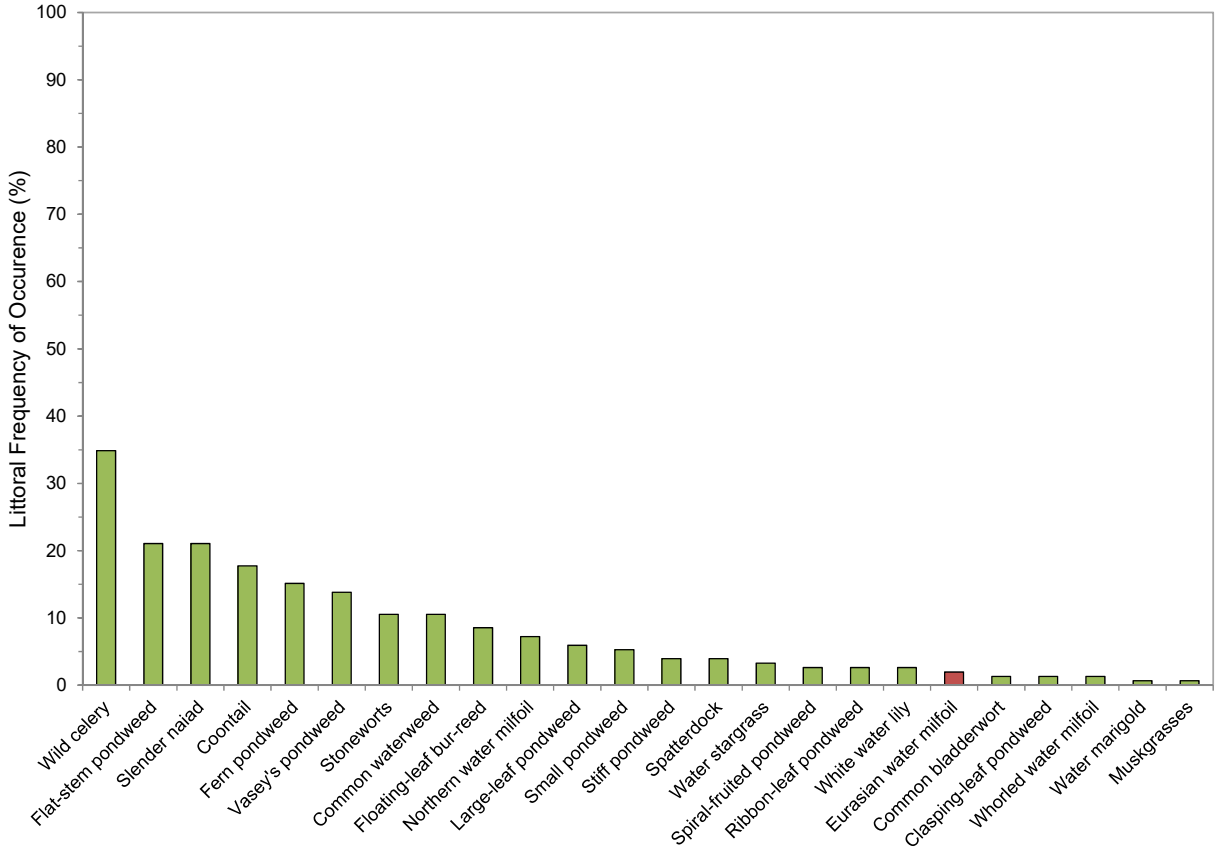


Figure 8.3.4-2. Voyageur Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

To determine if the 2008-2012 Eurasian water milfoil control project on Voyageur Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian water milfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.3.4-3 displays the littoral occurrences of Eurasian water milfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Voyageur Lake.

As illustrated, the occurrence of Eurasian water milfoil in Voyageur Lake was reduced by a statistically valid 77.4%, from an occurrence of 8.8% in 2006 to 2.0% in 2012. Three native aquatic plant species, spatterdock, whorled water milfoil, and small pondweed exhibited

statistically valid reductions in their occurrence between the 2006 and 2012 surveys. Like Eurasian water milfoil, spatterdock and whorled water milfoil are dicots and are sensitive to 2,4-D applications that have occurred in Voyageur Lake. However, unlike Eurasian water milfoil, small pondweed is a monocot and was historically not thought to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research conducted by the WDNR and US Army Corps of Engineers (USACE) is indicating that some of these species, including small pondweed, may be prone to decline following these types of treatments. It is possible that the declines observed in these native aquatic plants in Voyageur Lake are a result of the Eurasian water milfoil spatially targeted spot-treatments that have been occurring since 2008.

Four native aquatic plant species, wild celery, slender naiad, flat-stem pondweed, and stoneworts displayed statistically valid increases in their occurrence from 2006 to 2012. The occurrences of the other native aquatic plant species, including three dicots, were not statistically different from 2006 to 2012.

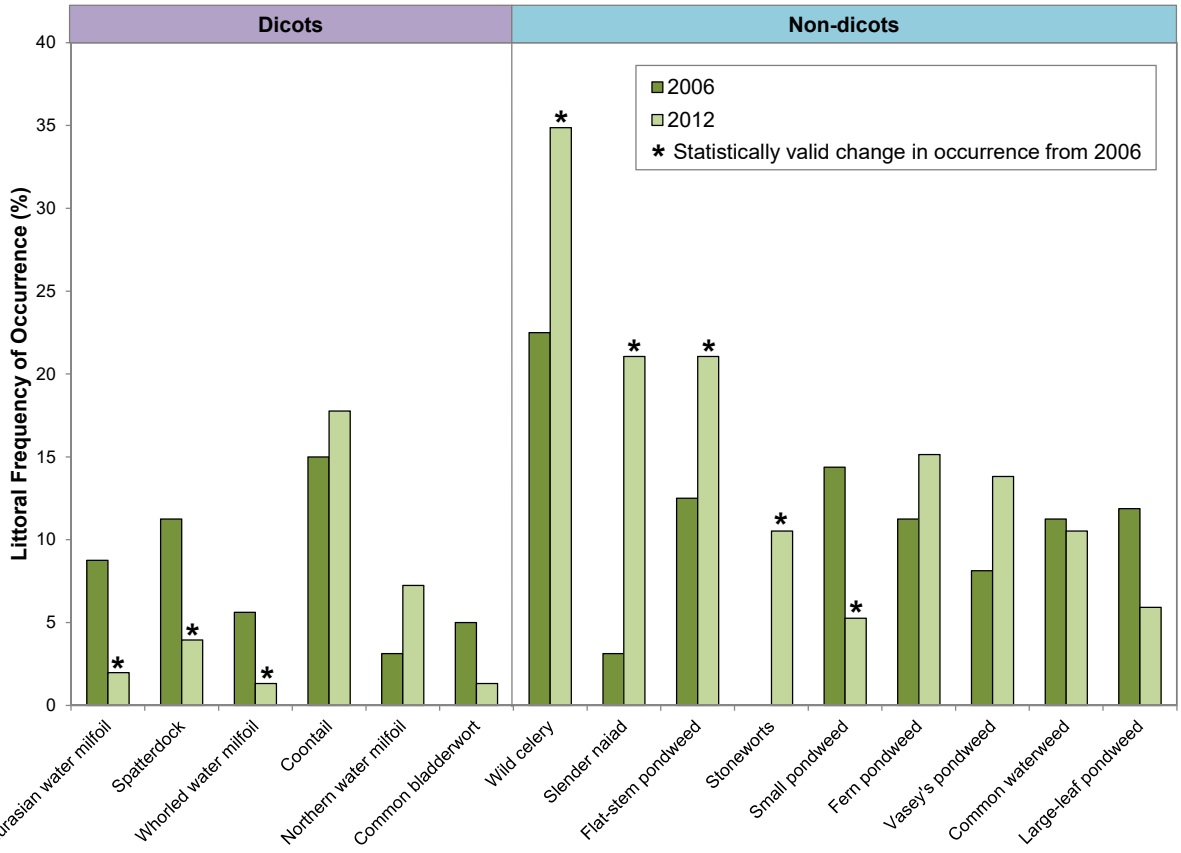


Figure 8.3.4-3. Voyageur Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total 37 native aquatic plant species were located in Voyageur Lake during the 2012 and

2014 surveys, 23 were encountered on the rake during the 2012 point-intercept survey. These 23 native species and their conservatism values were used to calculate the FQI of Voyageur Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.3.4-4 compares the FQI components of Voyageur Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Voyageur Lake's native species richness (23) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.8) is higher than both the median values for lakes in the ecoregion and the state. Combining Voyageur Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 32.7, which greatly exceeds the ecoregional and state median values (Figure 8.3.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Voyageur Lake's aquatic plant community has not been degraded by the Eurasian water milfoil control project. This analysis indicates that Voyageur Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

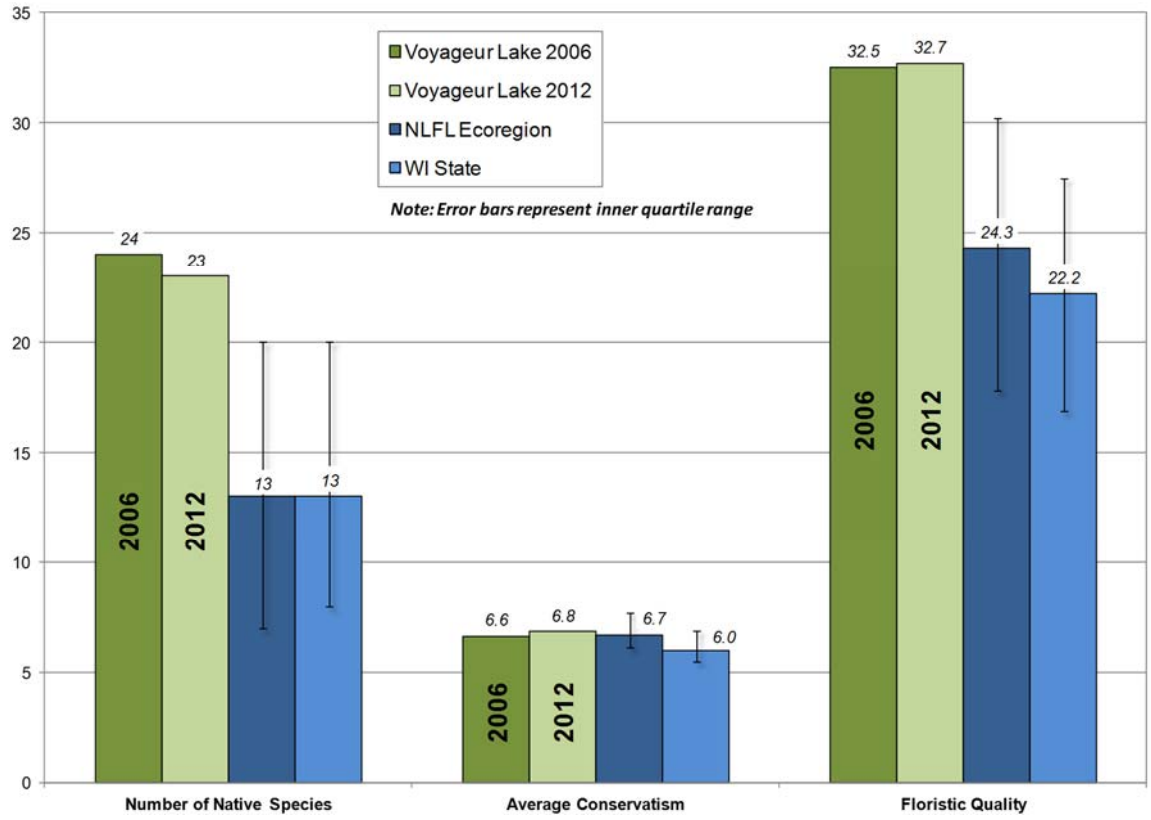


Figure 8.3.4-4. Voyageur Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Voyageur Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.3.4-5). Using the data collected form the 2012 point-intercept survey, Voyageur Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.92, falling above the upper quartile value for lakes in both the ecoregion and the state. Voyageur Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.93).

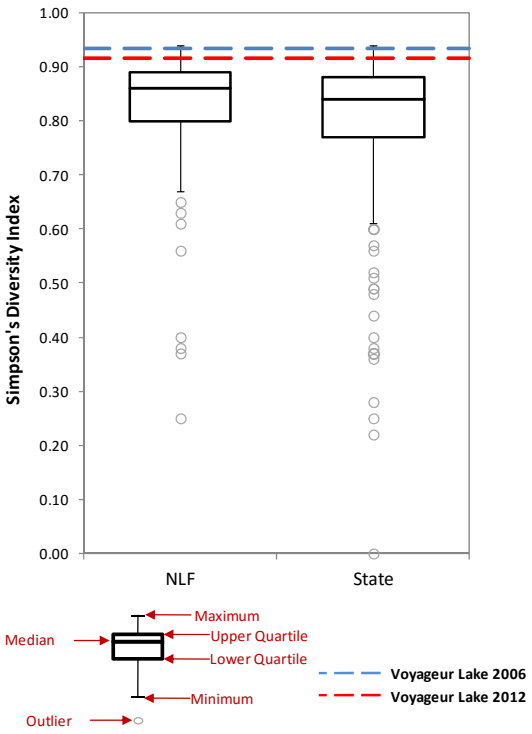


Figure 8.3.4-5. Voyageur Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 8.3.4-6 displays the relative frequency of occurrence of aquatic plant species in Voyageur Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

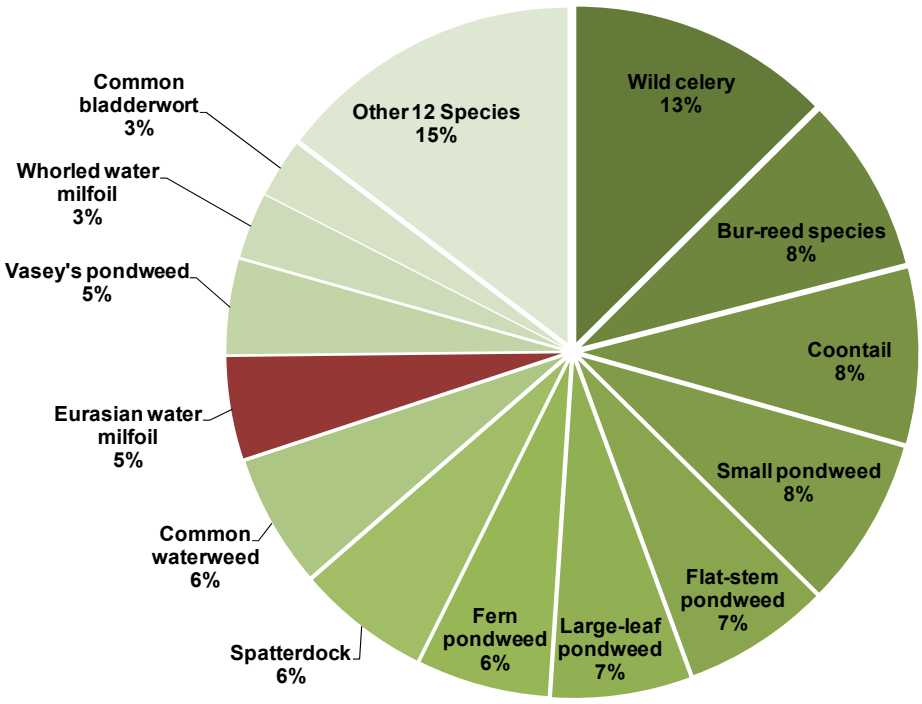


Figure 8.3.4-6. Voyageur Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

The 2014 aquatic plant community mapping survey revealed that Voyageur Lake contains approximately 29.7 acres of emergent and floating-leaf aquatic plant communities (Table 8.3.4-2, Voyageur Lake – Map 4). Thirteen emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2014 (Table 8.3.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Voyageur Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.3.4-2. Acres of emergent and floating-leaf aquatic plant communities in Voyageur Lake. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	2014 Acres
Emergent	5.3
Floating-Leaf	24.4
Mixed Emergent & Floating-Leaf	0.0
Total	**29.7**

8.3.4 Voyageur Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Voyageur Lake's Implementation Plan illustrates how Voyageur Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Voyageur Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Voyageur Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	David Tidmarsh, current Voyageur Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends will likely aid in an earlier definition of what may be causing the trend. The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality data on their lake. Volunteers trained as a part of the CLMN program begin by collecting Secchi disk transparency data annually. If funding is available, the lake group may enter into the *advanced program* and collect water chemistry data (chlorophyll-a and total phosphorus). The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. As a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

Volunteers from Voyageur Lake have been collecting water quality data intermittently since 1993. Voyageur Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Voyageur Lake currently has an active volunteer (David Tidmarsh) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis. Voyageur Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of David Tidmarsh, the current CLMN volunteer, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) will contact Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer.

Action Steps:

1. David Tidmarsh, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. David Tidmarsh, current CLMN volunteer, notifies Dave Mueller or current Lakes and Shores Committee chair when a new Voyageur Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Voyageur Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 25% (0.9 miles) of the shoreline are in an urbanized or developed-unnatural state, 28% (1.0 miles) is in a developed-semi-natural state, and 47% (1.7 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration

projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 25% of Voyageur Lake's shoreline is in a highly-developed state, approximately 47% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Voyageur Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Voyageur Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Voyageur Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Voyageur Lake shoreland assessment, approximately 17 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Voyageur Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.

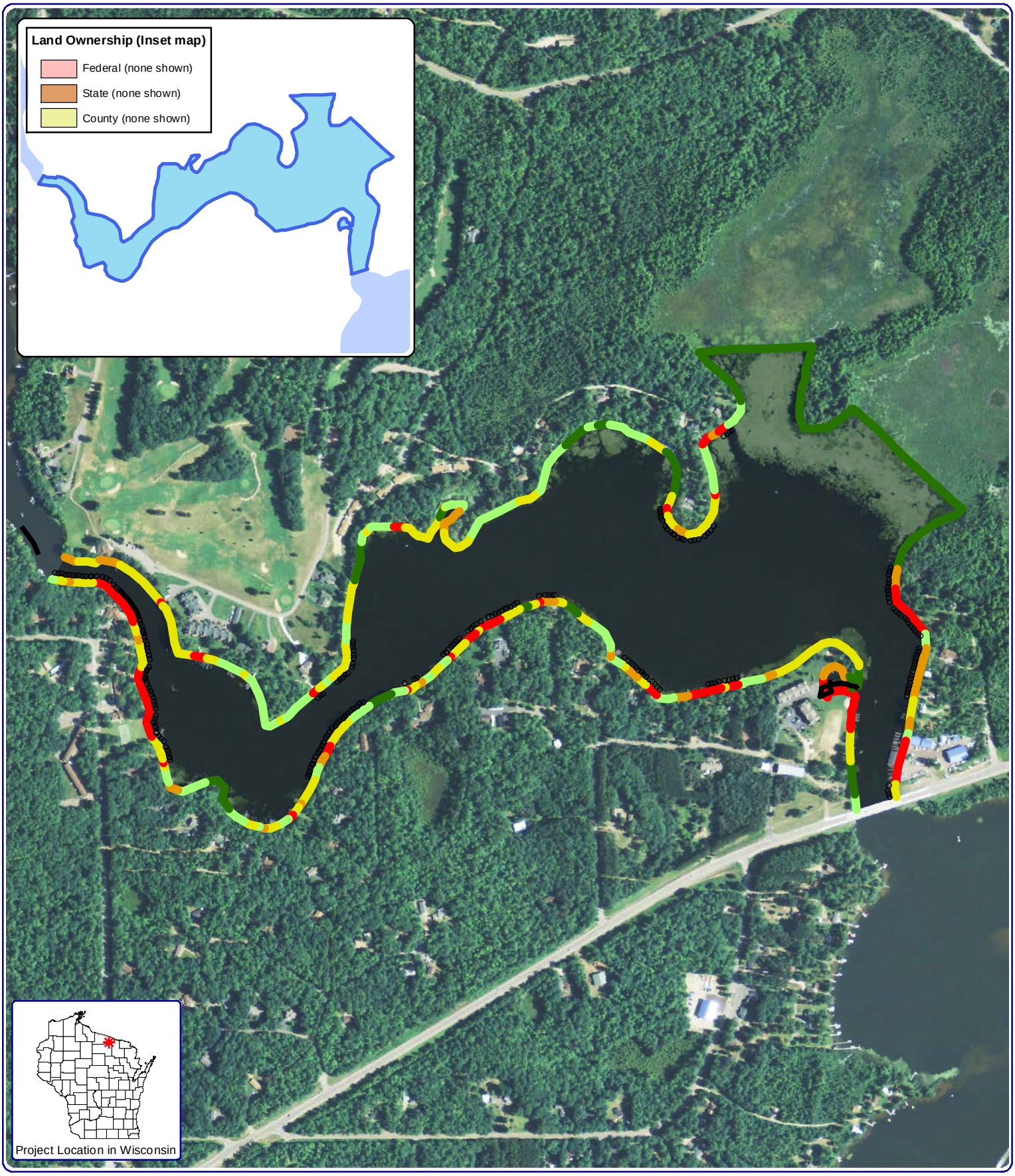
Description: Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian water milfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Voyageur Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Voyageur Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA.

Voyageur Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Voyageur Lake Association and ERCLA meetings. Voyageur Lake stakeholders can also participate in the active annual monitoring of Eurasian water milfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Voyageur Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Voyageur Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action: ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.

Description: Voyageur Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Voyageur Lake and its stakeholders.



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Onterra LLC
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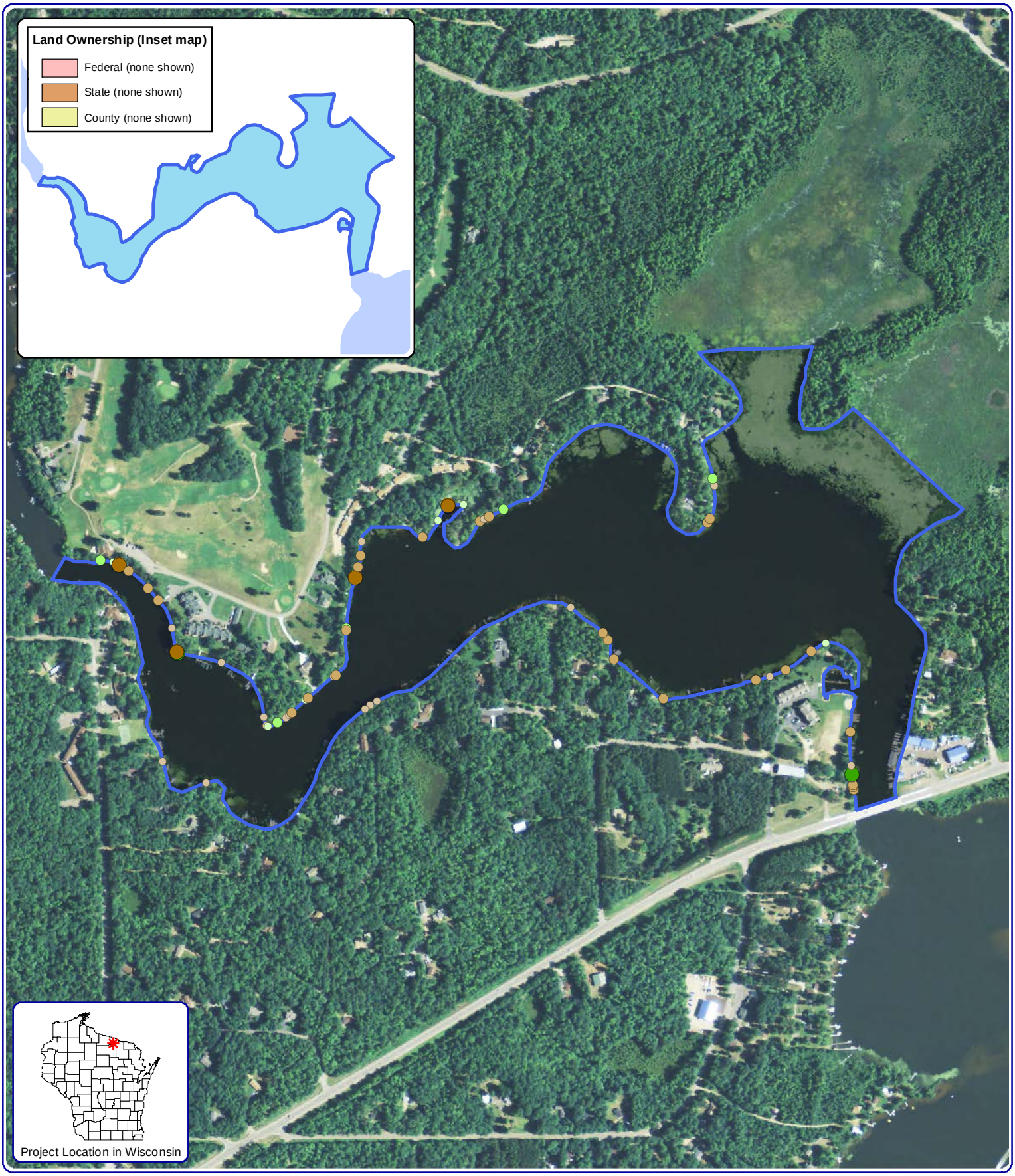
Sources:
Orthophotography: NAIP, 2013
SCA Survey: Onterra, 2014
Map date: October 13, 2014
Filename: Voyageur_Map1_SCA_2014.mxd

Legend

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

Seawall
- Masonary/Wood/Metal
- Rip-Rap

Voyageur Lake - Map 1
Lower Eagle River Chain of Lakes
Vilas County, Wisconsin
2014 Shoreland Condition Assessment



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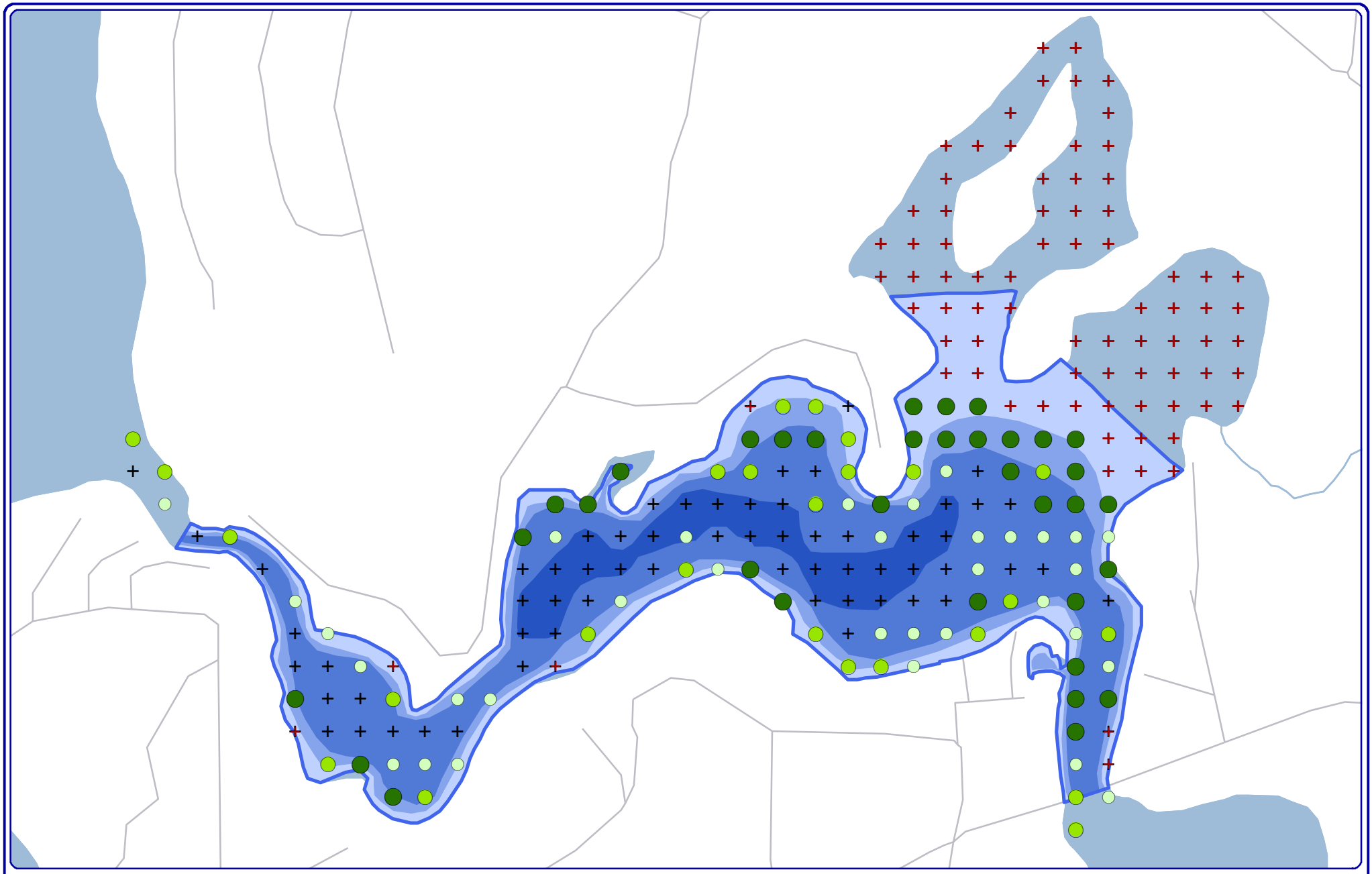
Sources:
Orthophotography: NAIP, 2013
SCA Survey: Onterra, 2014
Map date: October 13, 2014
Filename: Voyageur_Map2_CWH_2014.mxd

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

Voyageur Lake - Map 2
Lower Eagle River Chain of Lakes
Vilas County, Wisconsin
2014 Course Woody Habitat



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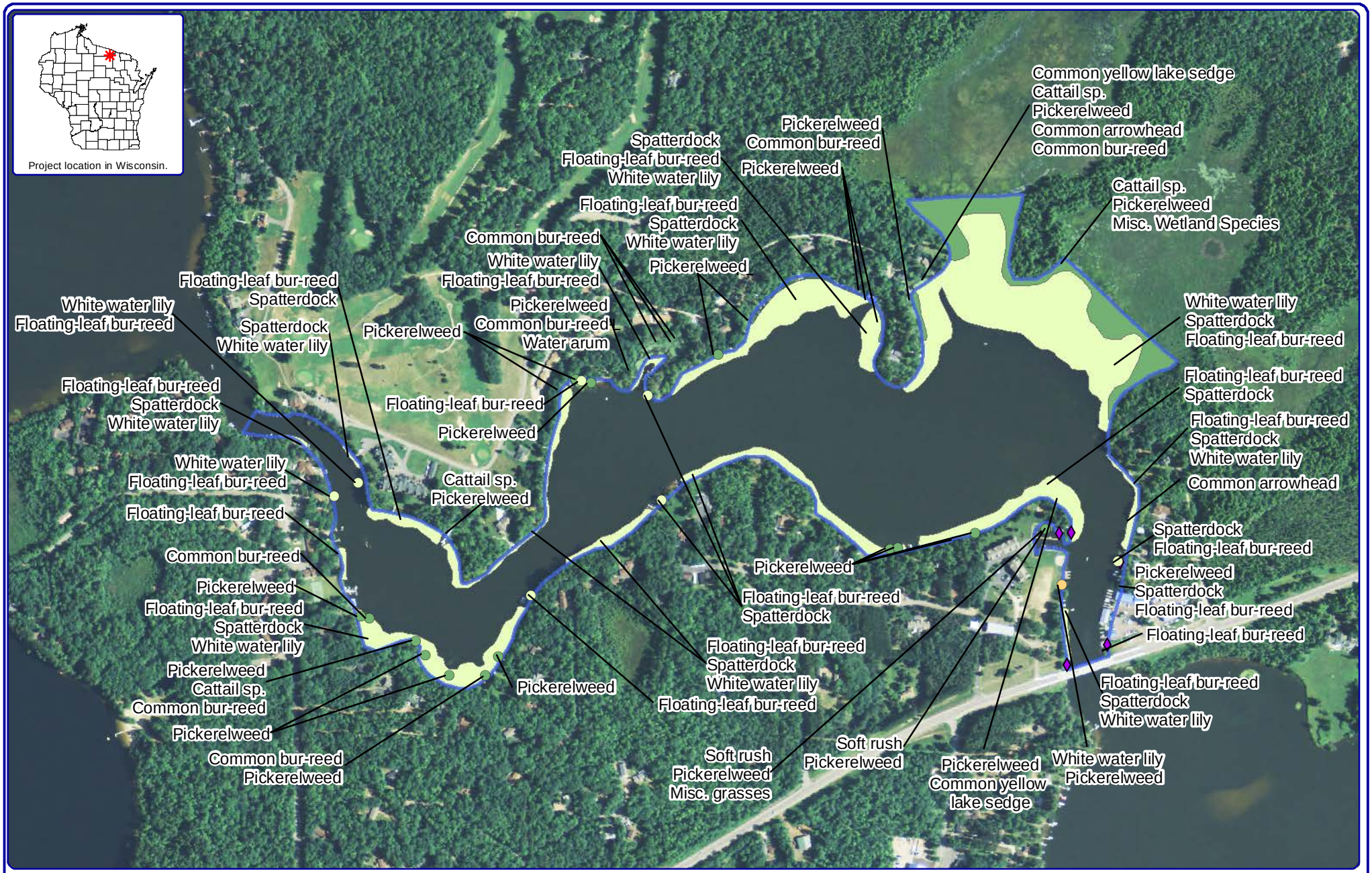
Sources:
Orthophotography: NAIP, 2013
Plant Survey: Onterra, 2012
Map date: October 13, 2014
Filename: Voyageur_Map3_TRFPI_2012.mxd

Voyageur Lake - Map 3
Lower Eagle River Chain of Lakes
Vilas County, Wisconsin
2012 Aquatic Plant Distribution



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Sources:
Orthophotography: NAIP, 2013
Plant Survey: Onterra, 2012
Map date: October 13, 2014
Filename: Voyageur_Map3_TRFPI_2012.mxd

Legend

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

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

Exotic Communities
- Purple Loosestrife

Voyageur Lake - Map 4
Lower Eagle River
Chain of Lakes
Vilas County, Wisconsin

Emergent & Floating-Leaf Aquatic Plant Communities