Eagle River Chain of Lakes
AIS Control & Prevention Project
Aquatic Plant Community Reassessment

Vilas County, Wisconsin

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1.0 INTRODUCTION

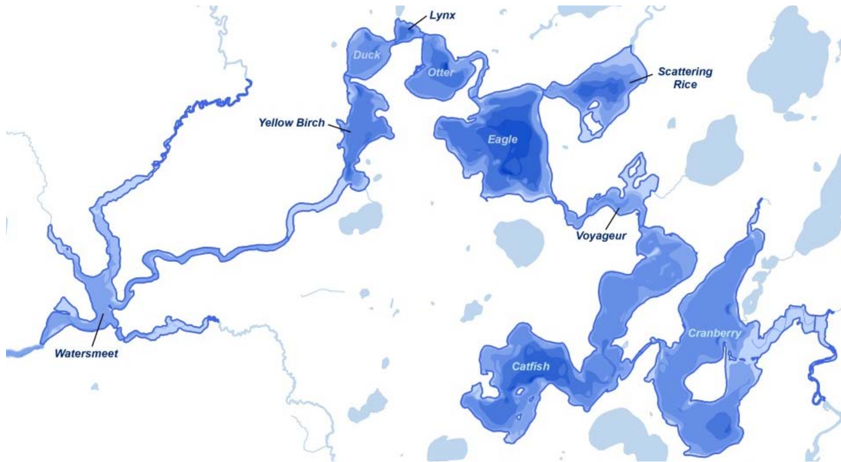


Figure 1.0-1. Lower Eagle River Chain of Lakes, Vilas County, Wisconsin.

The Lower Eagle River Chain of Lakes is comprised of 10 lake basins located in Vilas County, Wisconsin (Figure 1). This system includes 62 miles of shoreline and over 3,500 acres of surface water. The entire Eagle River Chain, which includes the upstream lakes known as the Three Lakes Chain of Lakes, encompasses approximately 11,295 acres. The Eagle River, along with the Wisconsin River, Rice Creek, and Mud Creek, converge in the downstream-most basin of the chain, Watersmeet.

Eurasian water milfoil (*Myriophyllum spicatum*) was first documented in the Lower Eagle River Chain in 1992, and since 2001, various lake groups throughout the chain have recognized the negative impacts the Eurasian water milfoil population was impressing on the lakes. In 2005, the Town of Washington successfully applied for multiple Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grants to fund the development of an aquatic plant management plan for each of the chain's lakes. Understanding that the degradation of the Lower Eagle River Chain of Lakes ecology and recreational impairment would be disastrous for the local and county economies, four municipalities including the Towns of Washington, Lincoln, and Cloverland, and the City of Eagle River partnered to fund the completion of the aquatic plant management plans. During the development of the aquatic plant management plans, it was realized that the Lower Eagle River Chain of Lakes must be viewed as one system if aquatic invasive species (AIS) were to be effectively managed. In 2006, following public discussion, the parties involved agreed to form a public/private partnership out of which a joint powers agreement was made forming the Unified Lower Eagle River Chain of Lakes Commission (ULERCLC).

The ULERCLC is a unique partnership and the first of its kind in the State of Wisconsin, consisting of representatives from each of the four municipalities bordering the Lower Eagle River Chain of Lakes and from each of the ten main waterbodies that comprise the chain. Following the completion of the aquatic plant management plans in 2007, the ULERCLC's primary concern was the impacts the Eurasian water milfoil was having on the ecological stability of the Lower Eagle River Chain of Lakes, and the potential effects it could have on the chain's fishery, aesthetics, and the economic vitality of the area.

It was evident from the 2006 plant surveys completed by Northern Environmental, Inc. that Eurasian water milfoil comprised a significant portion of the chain's aquatic plant community. In 2007, Onterra ecologists completed a Eurasian water milfoil peak-biomass survey of the entire Lower Eagle River Chain of Lakes and located approximately 278 acres of colonized Eurasian water milfoil. In 2008, the ULERCLC successfully applied for a WDNR AIS Control Grant to initiate a multi-phased project with a goal of reducing the Eurasian water milfoil population to more manageable levels and restore the ecological integrity of the chain. Following annual herbicide applications over areas of Eurasian water milfoil, colonial Eurasian water milfoil acreage has been reduced from the 278 acres in 2008 to 86 acres in 2012.

Each of the annual treatments on the Lower Eagle River Chain of Lakes from 2008 to 2012 were quantitatively monitored using data collected from point-intercept sampling locations within the Eurasian water milfoil herbicide application areas. At these locations, the presence of Eurasian water milfoil and native aquatic plant species were recorded. These locations were visited the summer prior to treatment and summer immediately following the treatment to produce pre- and post-treatment data. By comparing data from the two surveys, expressed as frequency of occurrence, a determination could be made on the effectiveness of the treatment as well as if there were any impacts to non-target species. However, these data could only be used to make those determinations within the treatment areas and could not be extrapolated to the effects on the aquatic plant community at a lake-wide level.

To determine if the multi-year Eurasian water milfoil control program has had detectable effects on the chain's aquatic plant communities at the lake-wide level, whole-lake point-intercept surveys were completed in 2012 that inventory a lake's entire aquatic plant community. These are repeat surveys of the surveys completed by Northern Environmental, Inc. in 2006 and the survey completed by Onterra on Yellow Birch Lake in 2005. This report compares the data collected in 2012 to the data collected in 2005/2006 before the Eurasian water milfoil control program was initiated with the intent of determining 1) if the Eurasian water milfoil control program had any detectable adverse impacts to the native aquatic plant community on a lake-wide level, and 2) if the control program was successful at reducing the chain's Eurasian water milfoil population. This report will provide first a chain-wide comparison of the aquatic plant community from 2005/2006 to 2012 followed by comparisons of each individual lake.

2.0 RESULTS & DISCUSSION

2.1 Aquatic Plants

Aquatic Plant Sampling Methodology and Data Analysis

Photo 2.1-1. Native aquatic plants, like those pictured above in Cranberry Lake, are an important component in maintaining a healthy lake ecosystem.

As discussed previously, whole-lake point-intercept surveys were conducted all 10 lakes of the Lower Eagle River Chain of Lakes in 2012 to assess their aquatic plant communities following five years of large-scale herbicide treatments to control Eurasian water milfoil. Native aquatic plants are an important element in every healthy aquatic ecosystem, providing food and habitat to wildlife, improving water quality, and stabilizing bottom sediments (Photo 2). Because most aquatic plants are rooted in place and are unable to relocate in wake of environmental alterations, they are often the first community to indicate that changes may be occurring within the system. Aquatic plant communities can respond in variety of ways; there may be increases or declines in the occurrences of some species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from certain areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions.

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on the Lower Eagle River Chain of Lakes in 2012. Based upon guidance from the WDNR, a point spacing (resolution) ranging from 30 to 80 meters was used resulting in 137 to 616 sampling points being evenly distributed across each lake (Table 2.1-1).

Table 2.1-1. Resolution and number of point-intercept sampling locations used in 2006 and 2012 surveys on the Lower Eagle River Chain of Lakes.

Lake	Number of Sample Locations	Resolution (m)
Cranberry	588	80
Catfish	616	80
Voyageur	232	50
Eagle	476	70
Scattering Rice	287	60
Otter	195	60
Lynx	137	30
Duck	168	50
Yellow Birch	416	45
Watersmeet	554	50

The **Littoral Zone** is the area of the lake where sunlight is able to penetrate to the sediment providing aquatic plants with sufficient light to carry out photosynthesis.

At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 2.1-1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 13 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 13 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 13 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

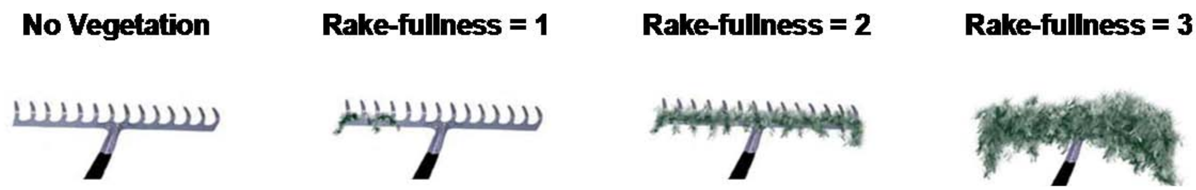


Figure 2.1-1. Aquatic plant rake-fullness ratings. Adapted from Hauxwell et al (2010).

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species, both native and non-native, that were located during the whole-lake point-intercept surveys 2012 on the Lower Eagle River Chain of Lakes. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept surveys conducted in 2005/2006 and 2012 on the Lower Eagle River Chain of Lakes, plant samples were collected from plots laid out on a grid that covered each lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, the occurrences of aquatic plant species are displayed as their *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake is calculated using its species richness and average species conservatism. Species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values (C-value) for each of those species in its calculation. A species coefficient of conservatism value indicates that species' likelihood of being found in an undisturbed system. The values range from 1 to 10. Species that can tolerate environmental disturbance and are can be located in disturbed systems have lower coefficients, while species that are less tolerant to environmental disturbance and are restricted to high quality systems have higher values. For example, coontail (*Ceratophyllum demersum*), a submergent native aquatic plant species with a C-value of 3, has a higher tolerance to disturbed conditions, often thriving in lakes with higher nutrient levels and low water clarity, while other species like algal-leaf pondweed (*Potamogeton confervoides*) with a C-value of 10, are intolerant of environmental disturbance and require high quality environments to survive.

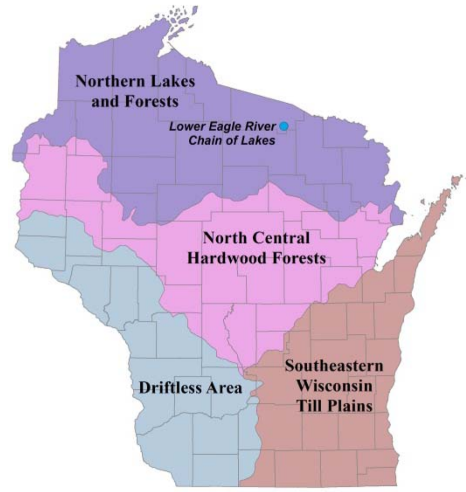


Figure 2.1-2. Location of the Lower Eagle River Chain of Lakes within the ecoregions of Wisconsin. After Nichols (1999).

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys. The Lower Eagle River Chain of Lakes falls within the Northern Lakes and Forests Ecoregion of Wisconsin, and the floristic quality of its aquatic plant community in 2005/2006 and 2012 will be compared to other lakes within this ecoregion as well as the entire state (Figure 2.1-2). The comparative data within this ecoregion has been divided into two groupings: Northern Lakes and Forest Lakes (NLFL) and Northern Lakes and Forest Flowages (NLFF). Although the Eagle River Chain of Lakes is an impounded system, it will be compared to other natural lakes within this ecoregion due to the fact that the majority (>50%) of each lakes' volumes are not due to the impounded condition.

Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. As defined previously, species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because species diversity also takes into account how evenly the species are distributed within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

An aquatic system with high species diversity is much more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity. Simpson's diversity index is used to determine this diversity in a lake ecosystem.
Simpson's diversity (1-D) is calculated as:

$$D = \sum (n/N)^2$$

where:
n = the total number of instances of a particular species
N = the total number of instances of all species and
D is a value between 0 and 1

Box Plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to the Lower Eagle River Chain of Lakes. Comparisons will be displayed using *boxplots* that showing median values and upper/lower quartiles of lakes in the same ecoregion (Figure 2.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

Aquatic Plant Survey Results

Photo 2.1-2. Close-up of floating leaves and flower spikes of state-listed special concern species Vasey's pondweed (*Potamogeton vaseyi*).

The whole-lake point-intercept surveys were completed on the Lower Eagle River Chain of Lakes by Onterra on July 31, August 1, 2, 3, and 6, 2012. A total of 51 aquatic plant species were located within the chain, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 2.1-2). One species, Vasey's pondweed (*Potamogeton vaseyi*) is listed by the Wisconsin Natural Heritage Inventory Program as special concern due to uncertainty regarding its population and distribution within Wisconsin (Photo 2.1-2). Vasey's pondweed was located in all 10 lakes in 2012, and was often one of the more dominant plant species encountered.

Table 2.1-2. Aquatic plant species located in the Lower Eagle River Chain of Lakes during the Onterra 2012 point-intercept surveys.

Growth Form	Species	Common Name	C-value	Cranberry	Catfish	Voyageur	Eagle	Scattering Rice	Otter	Lynx	Duck	Yellow Birch	Watersmeet
Emergent	*Eleocharis palustris*	Creeping spikerush	6				X						X
	Equisetum fluviatile	Water horsetail	7										X
	Pontederia cordata	Pickerelweed	9	X				X			X		X
	Sagittaria latifolia	Common arrowhead	3										X
	Schoenoplectus tabernaemontani	Softstem bulrush	4		X		X						X
	Typha spp.	Cattail spp.	1										X
	Zizania palustris	Northern wild rice	8										X
FL	*Brasenia schreberi*	Watershield	7	X									X
	Nuphar variegata	Spatterdock	6	X	X	X	X	X		X	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X		X			X	X	X
FL/E	*Sparganium androcladum*	Shining bur-reed	8	X				X					
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X	X								
	Sparganium emersum	Short-stemmed bur-reed	8				X						
	Sparganium eurycarpum	Common bur-reed	5							X			
	Sparganium fluctuans	Floating-leaf bur-reed	10	X		X							
Submergent	*Bidens beckii*	Water marigold	8	X	I	X	X	X					X
	Ceratophyllum demersum	Coontail	3	X	X	X	X	X	X	X	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	10	X									I
	Chara spp.	Muskgrasses	7		X	X	X						
	Elodea canadensis	Common waterweed	3	X	X	X	X	X	X	X	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X	X	X	X				X
	Isoetes spp.	Quillwort species	8		X		X						
	Lobelia dortmanna	Water lobelia	10										
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X	X	X	I	X	I	X	X	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X		X							
	Najas flexilis	Slender naiad	6	X	X	X	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	7	X	X	X	X	X	X	X	X	X	X
	Potamogeton alpinus	Alpine pondweed	9	I				X					
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X	X	X	X	X		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X	X	X	X	X	X		X	X
	Potamogeton foliosus	Leafy pondweed	6	X	X					X	X	X	X
	Potamogeton friesii	Fries' pondweed	8		X					X			
	Potamogeton hybrid	Hybrid pondweed	N/A	X									
	Potamogeton natans	Floating-leaf pondweed	5										X
	Potamogeton praelongus	White-stem pondweed	8		X								X
	Potamogeton pusillus	Small pondweed	7	X	X	X	X	X	X	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X	X	X	X	X	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X	X	X	X	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8					X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	8	X	X	X	X		X	X		X	
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X	X	X	X	X	X	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X	X	X	X	X	X	X
	Ranunculus aquatilis	White water-crowfoot	8										
	Utricularia minor	Small bladderwort	10					X					
	Utricularia vulgaris	Common bladderwort	7	X		X	X	X					X
	Vallisneria americana	Wild celery	6	X	X	X	X	X	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X								
	Sagittaria sp. (rosette)	Arrowhead rosette	N/A	X	X								
FF	*Lemna trisulca*	Forked duckweed	6	X				X					
	Lemna turionifera	Turion duckweed	2										X
	Riccia fluitans	Slender riccia	7					X					
	Spirodela polyrhiza	Greater duckweed	5		X		X						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 = Incidentially located
** = Species listed as 'special concern' in Wisconsin*

Eleven other aquatic plant species were located in all 10 lakes in 2012 (Table 2.1-2). These include: coontail, common waterweed, slender naiad, stoneworts, wild celery, Eurasian water milfoil, northern water milfoil, clasping-leaf pondweed, fern pondweed, flat-stem pondweed, small pondweed, and Vasey's pondweed.

Only two aquatic plant species present during Northern Environmental, Inc.'s (NEI) 2006 point-intercept surveys, water lobelia and white water-crowfoot, were not recorded during the 2012 surveys. During 2006, water lobelia was located at one point-intercept location in Catfish Lake, while white water-crowfoot was located at a few sampling locations in Voyageur Lake, Eagle Lake, and Watersmeet. It is not believed that these two species have disappeared from the system, but rather went undetected during the 2012 surveys because of their very low occurrence.

Photo 2.1-3. Alpine pondweed (*Potamogeton alpinus*) located in Cranberry and Scattering Rice Lakes.

Fourteen native aquatic plant species were located during the 2012 surveys that were not recorded during the surveys completed in 2005/2006 (Table 2.1-2). Some of these include relatively rare species with high coefficients of conservatism and are only found growing in high-quality conditions. For example, alpine pondweed (Photo 2.1-3), spiny hornwort, and small bladderwort were located in quiet, backwater areas of Cranberry Lake, Scattering Rice Lake, and Watersmeet. Small bladderwort belongs to a group of carnivorous plants in the genus *Utricularia*. As their name suggests, they produce sac-like bladders to trap and digest small aquatic organisms. Another species of bladderwort, common bladderwort, was also located in five of the 10 lakes in 2012 (Table 2.1-2).

Of the 48 aquatic plant species that were recorded on the rake during the 2012 point-intercept survey, slender naiad and wild celery were the most abundant, with a chain-wide littoral occurrence of nearly 22% (Figure 2.1-3). Small pondweed, coontail, common waterweed, Vasey's pondweed, and spiral-fruited pondweed were also common with littoral occurrences of 11-13%. Eurasian water milfoil had a chain-wide littoral occurrence of 1.7% in 2012. To determine if the 2008-2012 Eurasian water milfoil control program had any detectable adverse impacts to the populations of any native aquatic plant species, Chi-square distribution analysis was used to determine if there were statistically valid differences in their occurrences from 2005/2006 to 2012.

Figure 2.1-4 displays the littoral frequency of occurrence of native aquatic plant species from the 2005/2006 and 2012 point-intercept surveys. Only those species that had a littoral occurrence of at least 4% in one of the two surveys are displayed. As illustrated, four native aquatic plant species exhibited statistically valid reductions at the chain-wide level: spatterdock, flat-stem pondweed, large-leaf pondweed, and northern wild rice. Like Eurasian water milfoil, spatterdock is a dicot and may be susceptible to herbicide treatments that have been occurring since 2008. Unlike Eurasian water milfoil, flat-stem pondweed and large-leaf pondweed are monocots, and were not historically believed to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research from the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following these treatments. Northern wild rice is also a monocot, and studies have shown that it too is sensitive to 2,4-D applications. All of the northern wild rice documented in 2006 and 2012 was located in Watersmeet, and a more detailed discussion surrounding the northern wild rice population can be found in the Watersmeet individual lake section.

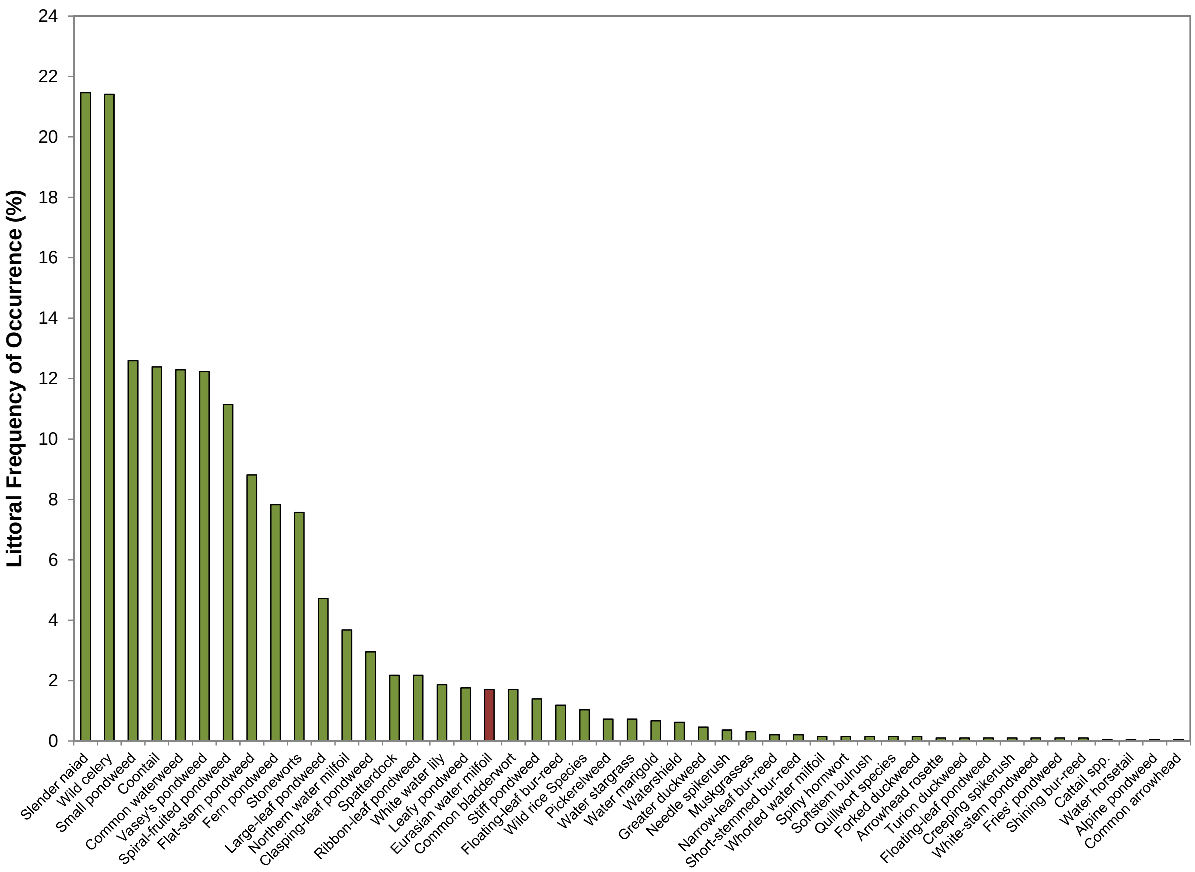


Figure 2.1-4. Lower Eagle River Chain of Lakes aquatic plant littoral occurrence analysis. Non-native species indicated with red. Created using data from 2012 point-intercept survey.

Figure 2.1-5 also indicates that four native aquatic plant species exhibited statistically valid increases in their occurrence from 2005/2006 to 2012, and include: wild celery, fern pondweed, slender naiad, and Vasey's pondweed. The occurrences of four other native aquatic plant species, coontail, northern water milfoil, small pondweed, and common waterweed were not statistically different from the 2005/2006 and 2012 surveys.

Figure 2.1-6 shows that of the 2,539 point-intercept sampling locations that fell at or below the maximum depth of aquatic plant growth within the chain in 2005/2006, 1,209 contained native aquatic vegetation. The total number of sampling locations that contained aquatic vegetation within the chain in 2012 fell to 1,007. The number of point-intercept locations containing native aquatic vegetation increased from 2005/2006 to 2012 in Cranberry, Otter, Lynx, and Yellow Birch Lakes, while Catfish, Eagle, Scattering Rice, Duck, and Watersmeet Lakes saw reductions in the number of points containing native vegetation. The number of sampling locations with native vegetation remained the same in Voyageur Lake (Figure 2.1-6).

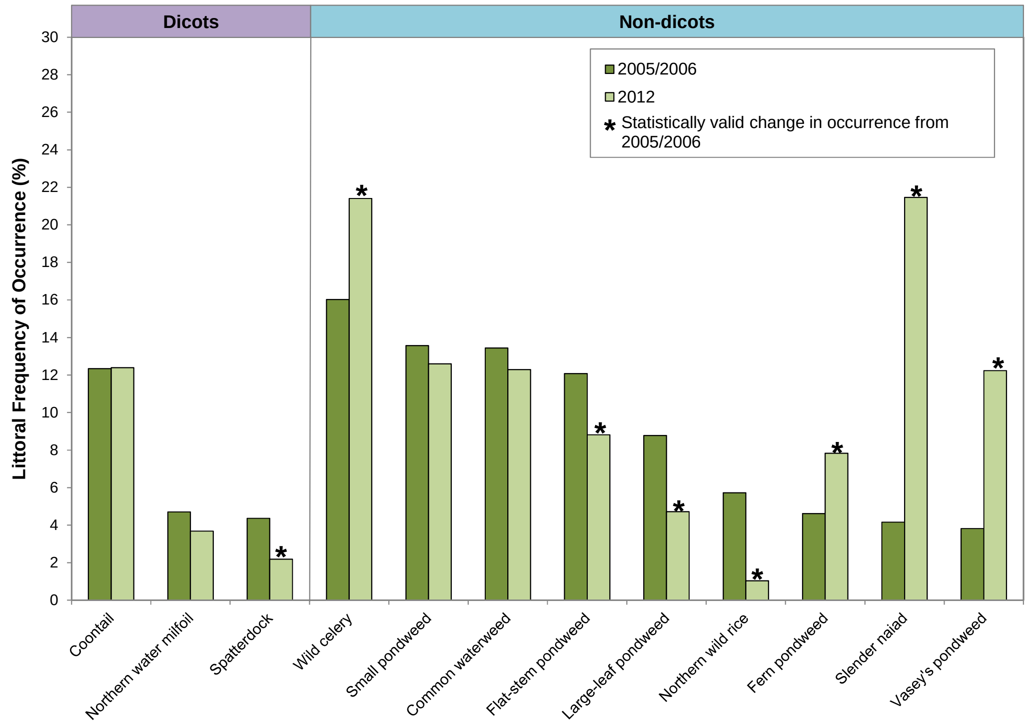


Figure 2.1-5. Lower Eagle River Chain of Lakes littoral occurrence of native aquatic plant species from 2005/2006 and 2012 point-intercept surveys. Please note that only those species with an occurrence of at least 4% in either survey are displayed. Created using data from 2005/2006 and 2012 point-intercept surveys.

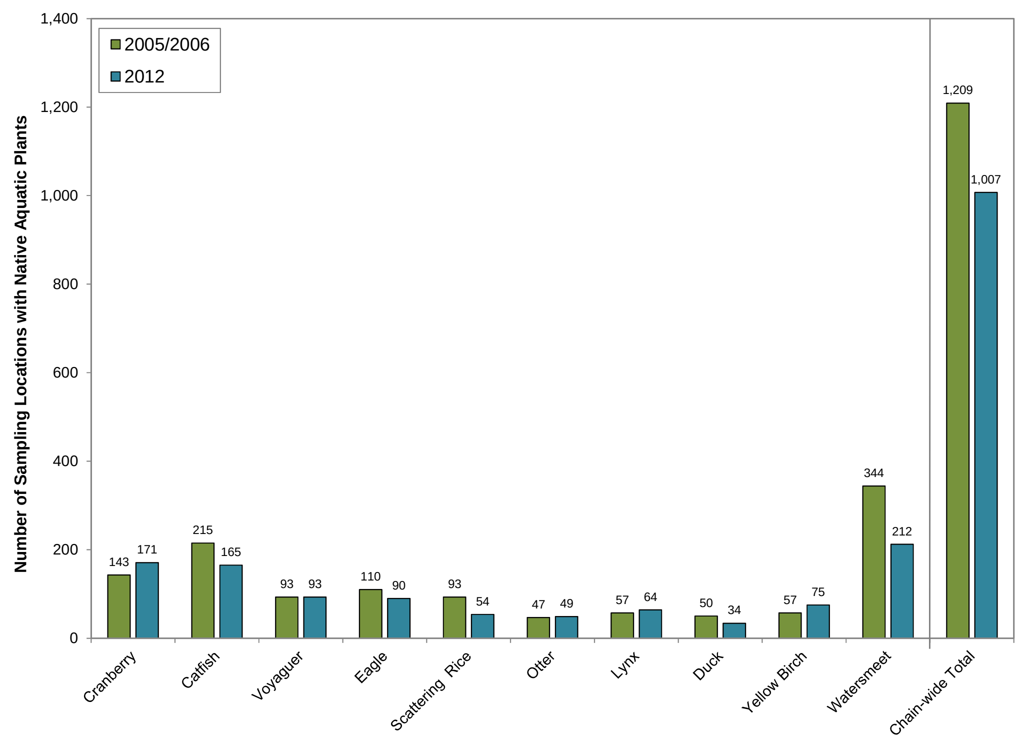


Figure 2.1-6. Number of point-intercept sampling locations containing native aquatic vegetation in 2005/2006 and 2012 point-intercept surveys. Created using data from 2005/2006 and 2012 point-intercept surveys.

In 2012, 1,929 point-intercept locations fell at or below the maximum depth of plant growth. Of these points that fell within the chain's littoral zone, 52% contained aquatic vegetation (Figure 2.1-7). Looking at the total rake-fullness (TRF) ratings, 21% had a total rake-fullness of 1, 17% had a total rake-fullness rating of 2, and 14% had a total rake-fullness rating of 3. The fact that 31% of the point-intercept sampling locations had a total rake-fullness rating of 2 or 3 indicates that aquatic vegetation in the chain is relatively dense where it occurs.

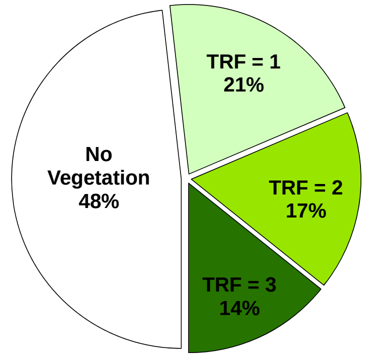


Figure 2.1-7. Lower Eagle River Chain of Lakes total rake-fullness ratings of aquatic vegetation from the 2012 point-intercept surveys. Created using data from 2012 point-intercept surveys.

Figure 2.1-8 illustrates that the average number of native aquatic plant species encountered at each point-intercept sampling location increased from an average of 1.3 in 2005/2006 to 1.7 in 2012. Cranberry, Catfish, Voyageur, Eagle, Otter, Lynx, Yellow Birch, and Watersmeet Lakes all saw increases in the number of native aquatic plant species per site, while Scattering Rice and Duck Lakes were the only ones to exhibit a reduction.

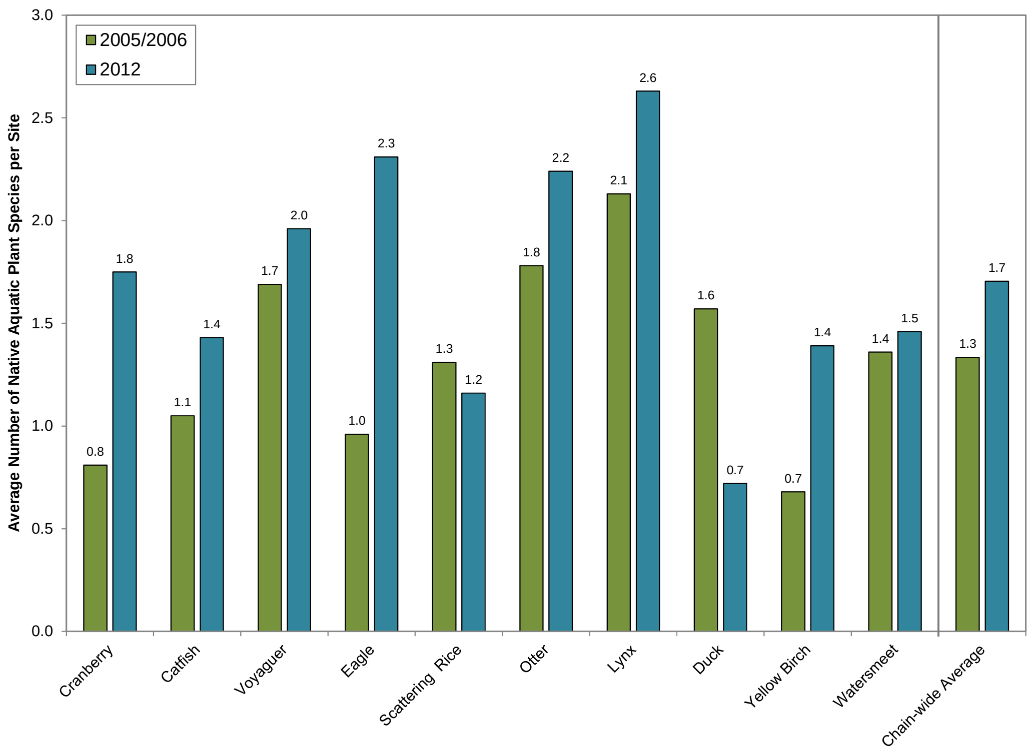


Figure 2.1-8. Lower Eagle River Chain of Lakes average number of native aquatic plant species per site. Created using data from 2005/2006 and 2012 point-intercept surveys.

In the Lower Eagle River Chain of Lakes, the number of plant species within each lake varied from 34 species in Watersmeet Lake to 16 species in Duck Lake, with an average of 24 species per lake in 2012; an increase of six species per lake from the average in 2005/2006. Figure 2.1-9 displays the native aquatic plant species richness values from the 2005/2006 and 2012 surveys.

Only those species physically encountered on the rake during the point-intercept surveys are included in the species richness value; incidentally located species are not included. Since the 10 lakes that comprise the Lower Eagle River Chain of Lakes are interconnected, they have relatively similar water chemistry and water clarity. The differences in the number of aquatic plant species between lakes is likely due to morphological attributes of the lakes themselves and the different habitat types they possess.

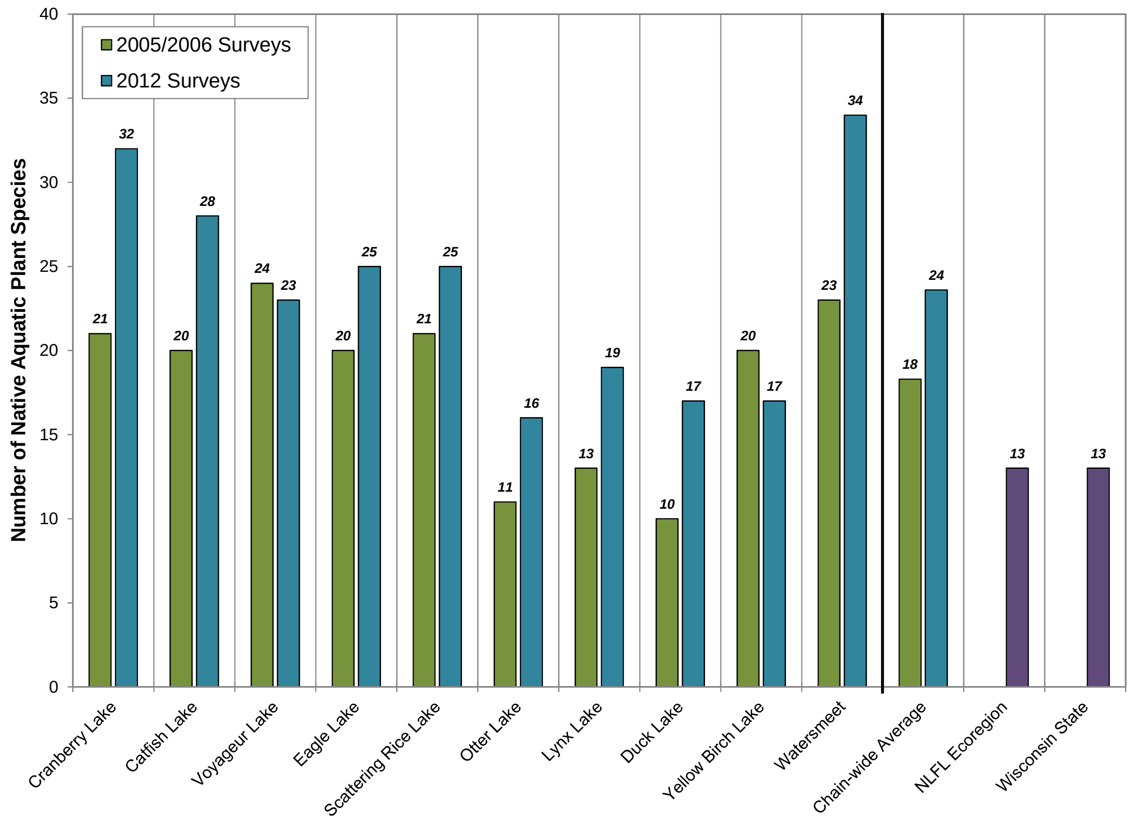


Figure 2.1-9. Lower Eagle River Chain of Lakes 2005/2006 & 2012 native species richness. Created using data from 2005/2006 and 2012 point-intercept surveys.

Studies have shown that the number of aquatic plant species within a lake increases as the lake's littoral area and its *shoreline complexity* increases (Vestergaard and Sand-Jensen 2000). Shoreline complexity is an index that relates the area of the lake to the perimeter of its shoreline. If a lake were a perfect circle, its shoreline complexity value would be 1.0. The farther a lake deviates from a perfect circle, the higher its shoreline complexity value is. Lakes with greater shoreline complexity harbor more areas that are sheltered from wind and wave action creating additional habitat types for aquatic plants.

Shoreline complexity values of the 10 lakes in the Lower Eagle River Chain of Lakes ranged from 1.3 in Duck Lake to 54.1 in Watersmeet (Table 2.1-3). Watersmeet and Cranberry Lake have the highest shoreline complexity values and were also found to have the highest aquatic plant species richness in 2012. However, shoreline complexity cannot be the sole attribute used to explain differences in species richness among these lakes. For example, Yellow Birch Lake has the third highest shoreline complexity value but the second-lowest species richness value. While Yellow Birch Lake has a relatively complex shoreline, it has a relatively small littoral area

(75 acres) when compared to some of the other lakes like Catfish or Cranberry; most of Yellow Birch Lake is too deep to support aquatic plant growth. As another example, Eagle Lake is nearly five times the size of Voyageur Lake, yet they have approximately the same amount of littoral area and thus a similar number of aquatic plant species. As Table 2.1-3 shows, the lakes in the chain with higher littoral acreages and higher shoreline complexities tend to have higher species richness. The acreage of littoral area for each lake was calculated using the maximum depth of plant growth from the 2012 surveys.

Table 2.1-3. Lower Eagle River Chain of Lakes 2012 aquatic plant species richness compared to littoral area and shoreline complexity. Littoral acreage determined from maximum depth of plant growth during 2012 point-intercept surveys.

Lake	Species Richness (2012)	Lake Area (acres)	Littoral Area (acres)	Shoreline Complexity
Watersmeet	34	415	391	54.1
Cranberry	32	929	515	7.9
Catfish	28	977	699	6.8
Scattering Rice	25	266	124	3.5
Eagle	25	581	137	2.2
Voyageur	23	106	137	6.7
Lynx	19	30	16	1.7
Yellow Birch	17	238	75	7.3
Duck	17	109	82	1.3
Otter	16	195	68	4.3

As discussed in the primer section, all of the native aquatic plants that were located on the rake during the 2012 are used in calculating each lake's Floristic Quality Index (FQI). These calculations do not include species that were located "incidentally" during the 2012 surveys. The FQI for each lake is calculated using the native species richness and the average conservatism value (equation shown below).

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

Figure 2.1-10 displays the average conservatism value for each lake from 2005/2006 and 2012 point-intercept surveys and compares them to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and to lakes throughout the State of Wisconsin. Average conservatism values in 2012 ranged from 7.0 in Cranberry Lake to 6.3 in Watersmeet. Three lakes exceeded the NLF Ecoregional median, while all of the lakes exceeded the median for lakes in Wisconsin. Higher average conservatism values indicate the lake contains a greater number of aquatic plant species that have higher coefficients of conservatism, or are less tolerant to environmental disturbance. The chain-wide average conservatism increased from 6.2 in the 2005/2006 surveys to 6.6 in 2012, falling just below the median value for lakes within the NLFL Ecoregion and exceeding the median for lakes state-wide. All of the lakes in 2012, except for Catfish which remained the same, had higher conservatism values than in 2005/2006.

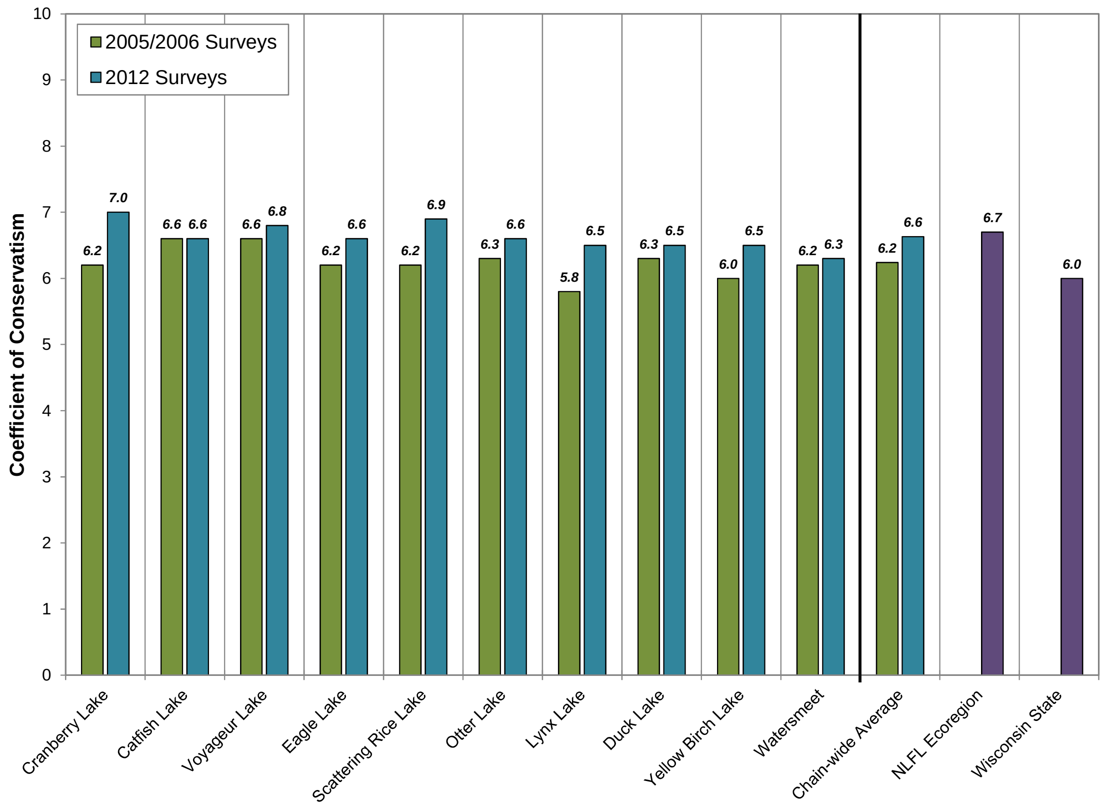


Figure 2.1-10. Lower Eagle River Chain of Lakes average coefficients of conservatism. Created using data from 2005/2006 and 2012 point-intercept surveys.

The average species richness and average conservatism values from the Lower Eagle River Chain of Lakes in 2005/2006 and 2012 were used to calculate their FQI values (Figure 2.1-11). The 2012 FQI values ranged from 39.6 in Cranberry Lake to 26.3 in Otter Lake, and all of the FQI values for all the lakes in 2012 exceeded the NLFL ecoregion and state medians. Each of the 10 lakes had higher FQI values in 2012 than in 2005/2006, and the chain-wide average FQI increased from 26.5 to 31.9. This indicates that the aquatic plant community of the Lower Eagle River Chain of Lakes is of higher quality than the majority of the lakes within the NLFL Ecoregion and lakes throughout Wisconsin.

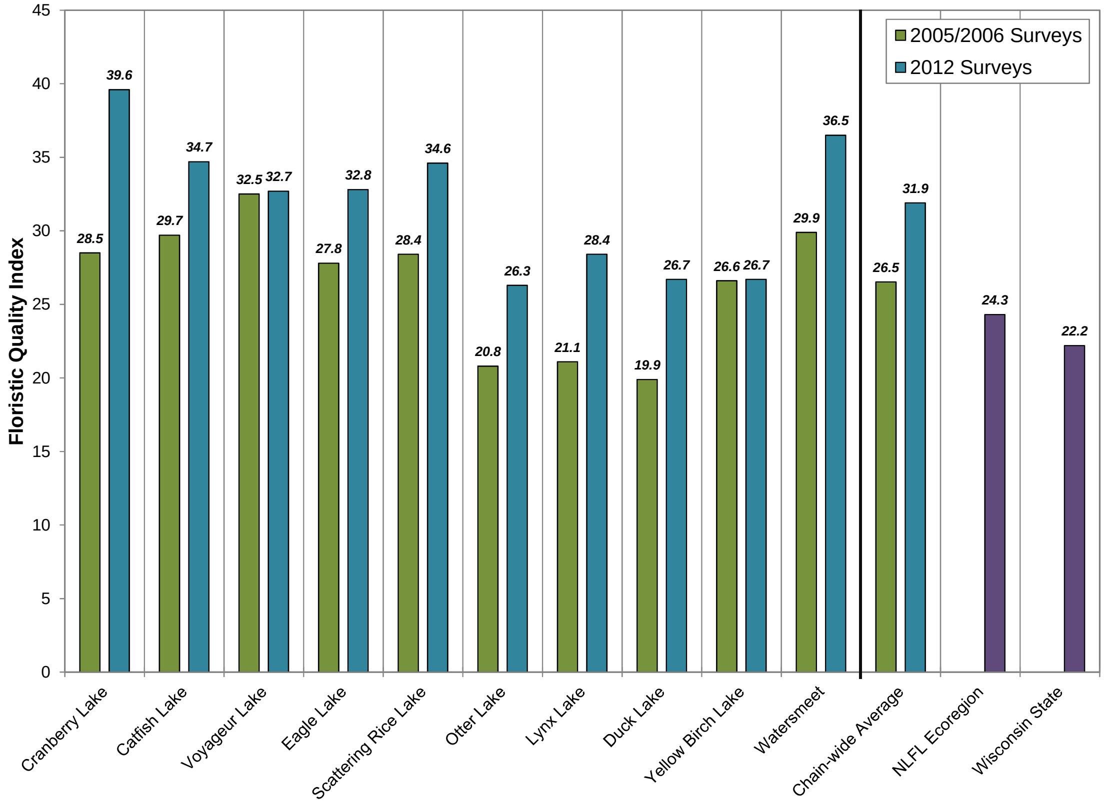


Figure 2.1-11. Lower Eagle River Chain of Lakes Floristic Quality Index values. Created using data from 2005/2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLF = Northern Lakes and Forests Ecoregion.

As explained earlier, 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 the Lower Eagle River Chain of Lakes contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, as discussed, 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 the chain's lakes' diversity values rank. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 2.1-12). Using the data collected from the 2005/2006 and 2012 point-intercept surveys, the diversity of each lake could be calculated. All 10 lakes exceeded the median value for lakes in the NLF Ecoregion in 2012, and eight exceeded the upper quartile. The chain-wide average diversity value increased from 0.89 in 2005/2006 to 0.91 in 2012, falling above the upper quartile for lakes in the NLF Ecoregion and indicating the aquatic plant community of the chain is exceptionally diverse. The loss of dominance of Eurasian water milfoil throughout many areas within the chain may be one of the reasons why diversity was shown to have increased in 2012.

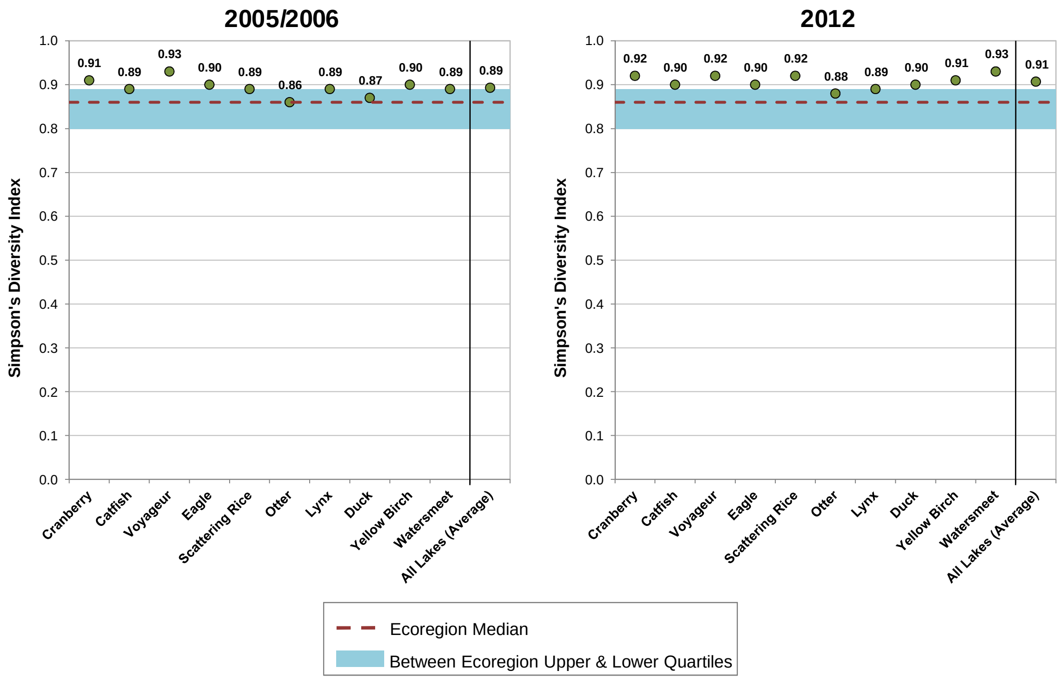


Figure 2.1-12. Lower Eagle River Chain of Lakes Simpson's Diversity Index. Created using data from 2005/2006 and 2012 point-intercept surveys.

Along with an assessment of the native aquatic plant community, another goal of the 2012 point-intercept surveys was to determine if the Eurasian water milfoil population within the chain had been reduced over the course of the 2008-2012 control project. As Figure 2.1-13 illustrates, seven of the 10 lakes saw a statistically valid reduction in the littoral occurrence of Eurasian water milfoil from 2005/2006 to 2012 (Chi-square $\alpha = 0.05$). No lakes saw an increase in Eurasian water milfoil occurrence over this time period. Most notable were the reductions observed in Scattering Rice Lake and Watersmeet, which in 2006 had a Eurasian water milfoil littoral occurrence of 17.6% and 23.3%, respectively. Even though Figure 2.1-13 indicates the littoral occurrences of Eurasian water milfoil within Scattering Rice and Lynx Lakes to be 0.0, Eurasian water milfoil is still present within these lakes. Eurasian water milfoil was present in such a low frequency in these lakes in 2012 that it was not detectable with the point-intercept survey methodology. Overall, Eurasian water milfoil within the Lower Eagle River Chain of Lakes has been reduced by a statistically valid 82% since 2005/2006.

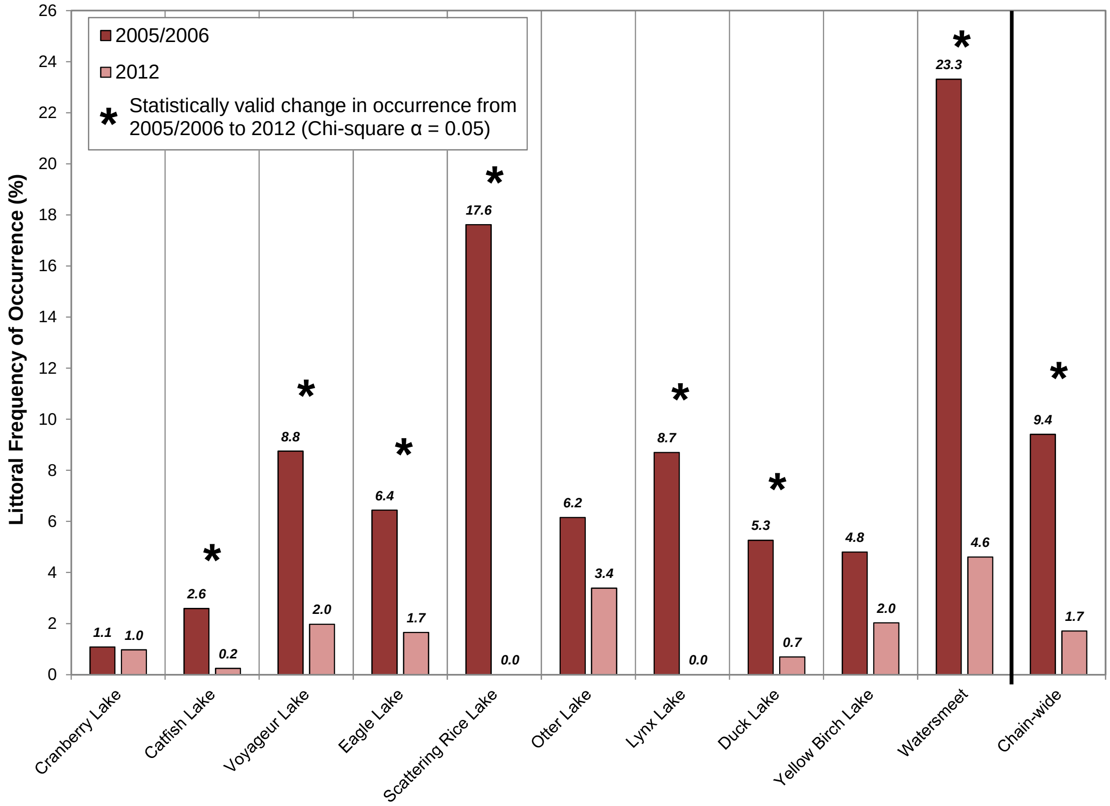


Figure 2.1-13. Lower Eagle River Chain of Lakes Eurasian water milfoil littoral occurrence from 2005/2006 to 2012. Created using data from 2005/2006 and 2012 point-intercept surveys.

3.0 SUMMARY & CONCLUSIONS

The goal of the 2012 point-intercept surveys on the Lower Eagle River Chain of Lakes were intended to fulfill two main objectives:

1) Determine if the multi-year Eurasian water milfoil control project has had detectable adverse impacts to the chain's native aquatic plant community at the lake-wide level.
2) Determine if the multi-year Eurasian water milfoil control project has been successful at reducing the chain's Eurasian water milfoil population.

These goals were fulfilled and have led to an understanding of present state of the Lower Eagle River Chain of Lakes' native aquatic plant community and Eurasian water milfoil population. The data presented indicate that there has been a substantial reduction in the chain's Eurasian water milfoil population, and the native aquatic plant community of the Lower Eagle River Chain of Lakes is of exceptional quality, and if anything, is of higher quality at present than in 2005/2006. However, these data indicate that the declines observed in the chain-wide spatterdock, flat-stem pondweed, and large-leaf pondweed populations may be a result of the ongoing Eurasian water milfoil control project.

As a part of a phased project being implemented during the summer of 2013, the Eagle River Chain of Lakes Association (ERCLA) will be updating each lake's management plan to reflect the success and limitations learned during this multi-year project. Along with establishing new thresholds (triggers) of when specific herbicide treatment strategies warrant implementation, the lake management planning process would also include a holistic understanding of the Eagle River Chain of Lakes ecosystem involving assessments of the water quality, watershed, shoreline condition, floating-leaf and emergent plant communities, and stakeholder perceptions.

4.0 INDIVIDUAL LAKE SECTIONS

4.1 Cranberry Lake

The whole-lake aquatic plant point-intercept survey was conducted on Cranberry Lake by Onterra on July 31, 2012 (Figure 4.1-1). During this survey, a total of 35 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.1-1). 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.

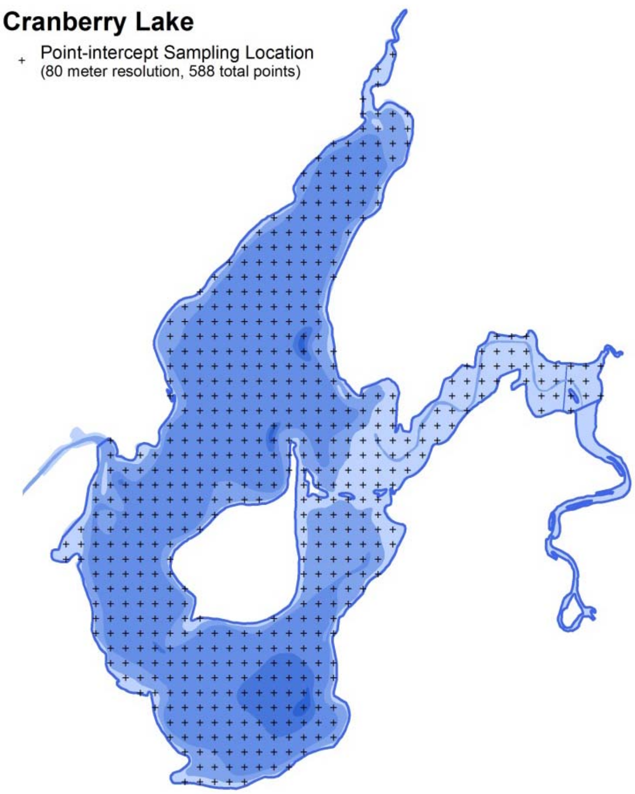


Figure 4.1-1. Point-intercept locations on Cranberry Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Cran-1 illustrates, 57% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 39% contained sand, and 4% 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 (Map Cran-1). 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, the same as in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 309 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 55% contained aquatic vegetation. This is higher than what was found in the 2006 survey where approximately 39% of the littoral sampling locations contained aquatic vegetation. Map Cran-2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake-fullness ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore and in the western portion of the lake up into the channel. Twenty-four percent of the point-intercept locations had a total rake-fullness (TRF) rating of 2, 17% had a total rake-fullness rating of 1, and 14% 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 4.1-1. Aquatic plant species located in Cranberry Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Pontederia cordata*	Pickerelweed	9		X
	Typha spp.	Cattail spp.	1	X	
FL	*Brasenia schreberi*	Watershield	7		X
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium androcladum*	Shining bur-reed	8		X
	Sparganium angustifolium	Narrow-leaf bur-reed	9		X
	Sparganium fluctuans	Floating-leaf bur-reed	10		X
Submergent	*Bidens beckii*	Water marigold	8		X
	Ceratophyllum demersum	Coontail	3	X	X
	Ceratophyllum echinatum	Spiny hornwort	10		X
	Chara spp.	Muskgrasses	7	X	
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		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	X
	Potamogeton alpinus	Apline pondweed	9		I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton hybrid	Hybrid pondweed	N/A		X
	Potamogeton natans	Floating-leaf pondweed	5	X	I
	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
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A		X
	Sparganium sp.	Bur-reed sp.	N/A	X	
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X
FF	*Lemna trisulca*	Forked duckweed	6		X

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

Table 4.1-1 displays the aquatic plant species located in Cranberry Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for cattail spp., were recorded in 2012. Cattails were observed within the emergent plant communities in Cranberry Lake, but they were not encountered at any of the sampling locations in 2012. An additional 13 native aquatic plant species were located in 2012 that had not been recorded in 2006, including two relatively rare, sensitive species: spiny hornwort and alpine pondweed.

Of the 33 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, spiral-fruited pondweed, wild celery, and Vasey's pondweed were the four-most frequently encountered (Figure 4.1-2). Slender naiad, the most abundant aquatic plant in Cranberry Lake in 2012 with a littoral occurrence of nearly 30%, 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.

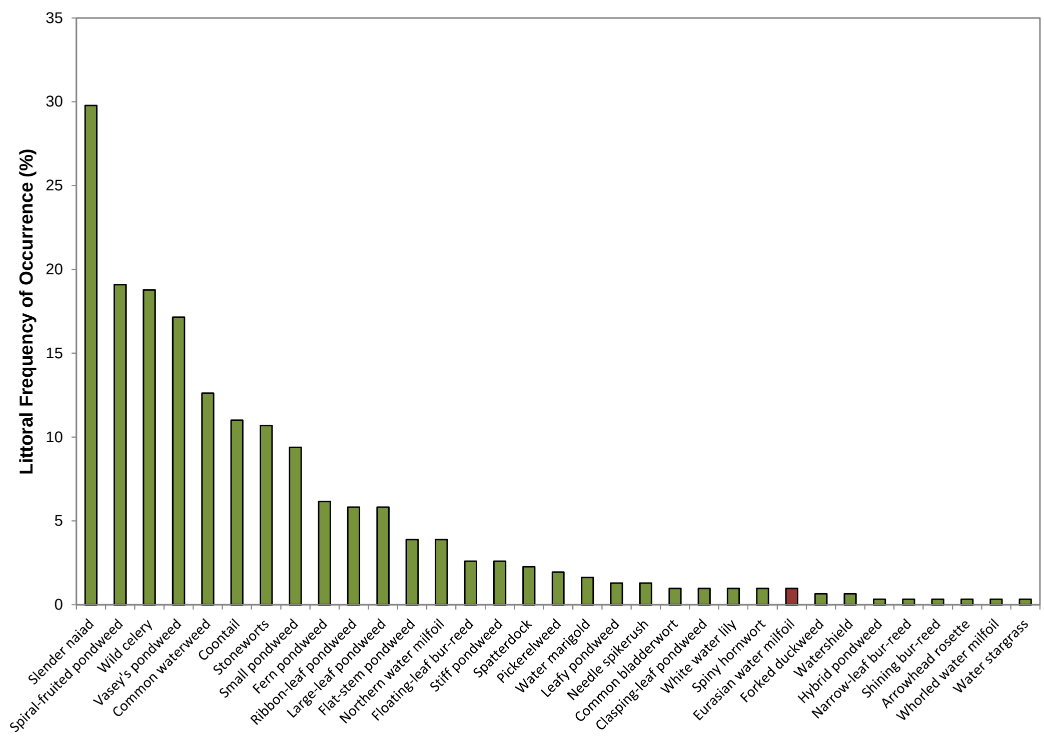


Figure 4.1-2. Cranberry Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Spiral-fruited pondweed was the second-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 19%. As its name indicates, this plant produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water (Photo 4.1-1). The submersed leaves are long and narrow, and are usually curved. Like slender naiad, spiral-fruited pondweed is food and habitat source for wildlife.

Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species 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).

Vasey's pondweed was the fourth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like spiral-fruited pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer than spiral-fruited pondweed. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Cranberry Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Cranberry 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 4.1-3 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 Cranberry Lake.

As illustrated, the occurrence of Eurasian water milfoil in Cranberry Lake was found to be not statistically different from 2006 to 2012, and had a littoral occurrence of around 1% in both surveys. However, from the annual Eurasian water milfoil mapping surveys, it is clear that Eurasian water milfoil within Cranberry Lake did increase since 2006. Had point-intercept surveys been conducted on an annual basis, this likely would have been captured. It is believed that the herbicide treatments have been effective at reducing and maintaining a low population of Eurasian water milfoil in Cranberry Lake. Five of the native aquatic plant species that had an occurrence of at least 5% in 2006 or 2012 saw statistically valid increases in their littoral occurrence, while the other five did not have statistically different occurrences from 2006 to 2012 (Figure 4.1-3). From these data, it appears that the Eurasian water milfoil control program has not had any detectable adverse effects on any of the aquatic plant species' populations in Cranberry Lake.

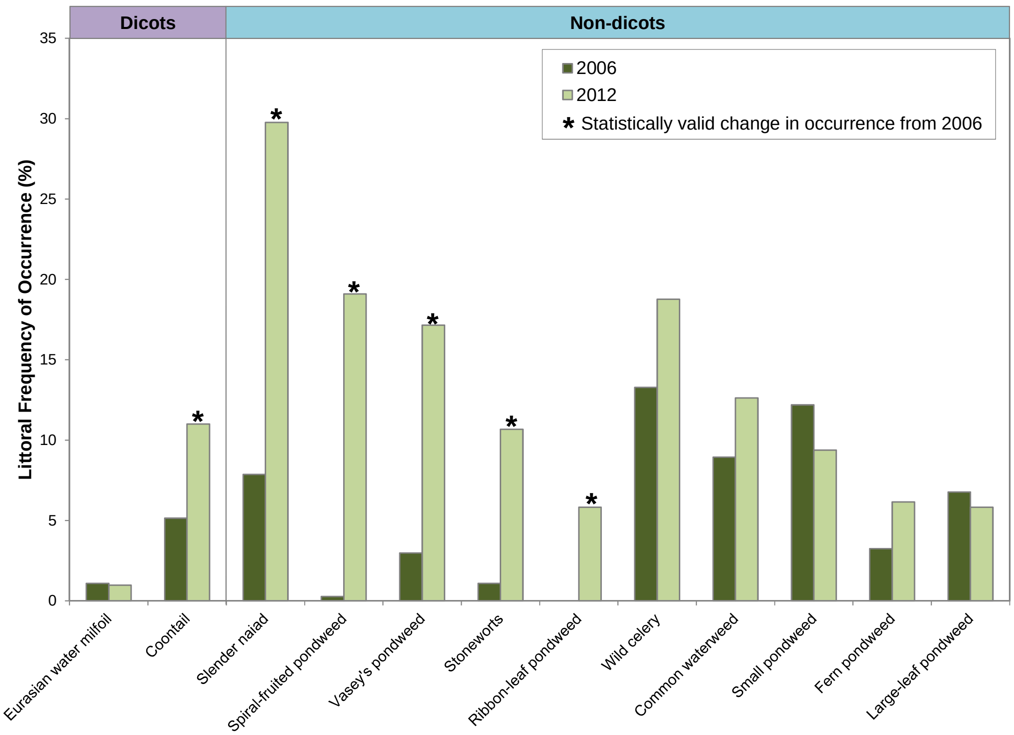


Figure 4.1-3. Cranberry Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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 34 native aquatic plant species were located in Cranberry Lake during the 2012 survey, 32 were encountered on the rake and two were incidentally located. These 32 native species and their conservatism values were used to calculate the FQI of Cranberry Lake's aquatic plant community in 2012 (equation on next page). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.1-4 compares the FQI components of Cranberry 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, Cranberry Lake's native species richness (32) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (7.0) is also exceeds the ecoregional and state medians. Combining Cranberry Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 39.6, which greatly exceeds the ecoregional and state median values (Figure 4.1-4). The FQI values from 2012 are also much higher than those calculated from point-intercept survey in 2006, indicating that the quality of Cranberry Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project.

This analysis indicates that Cranberry Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

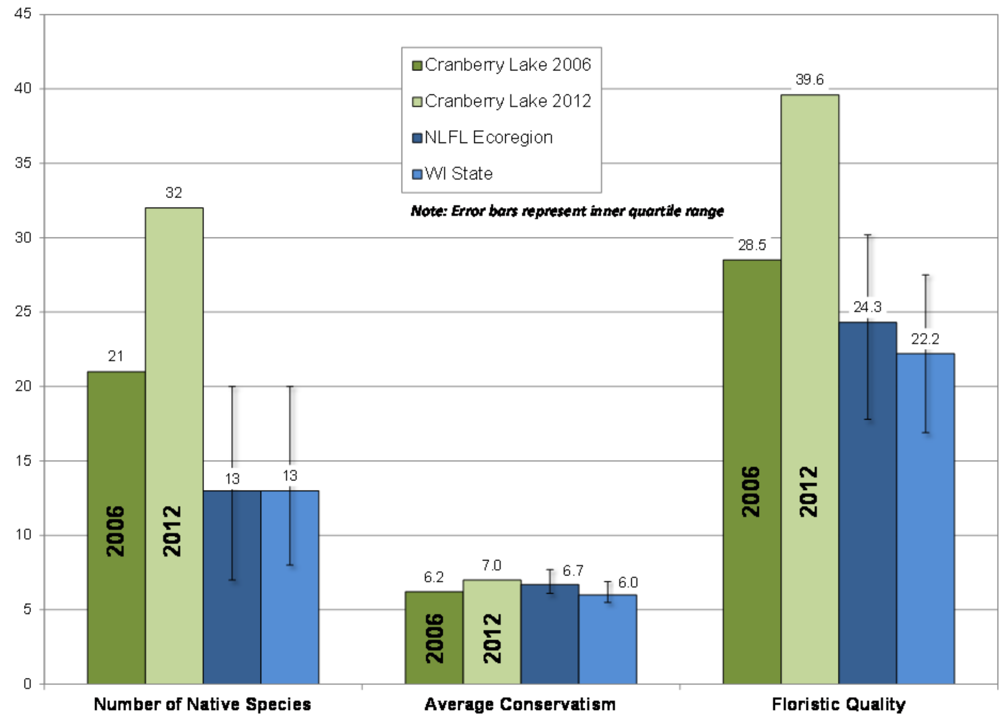


Figure 4.1-4. Cranberry Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Cranberry 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 Cranberry Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.1-5). Using the data collected form the 2012 point-intercept survey, Cranberry 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. Cranberry Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.91).

Figure 4.1-6 displays the relative frequency of occurrence of aquatic plant species in Cranberry 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.

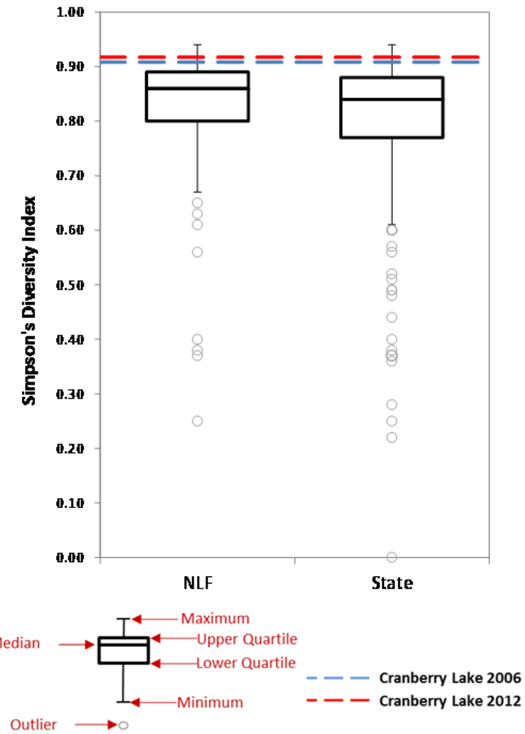


Figure 4.1-5. Cranberry Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

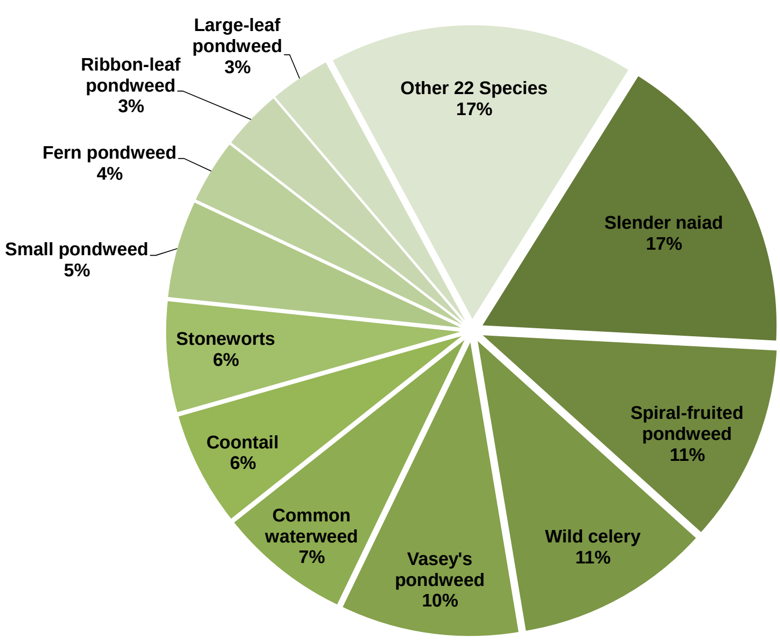
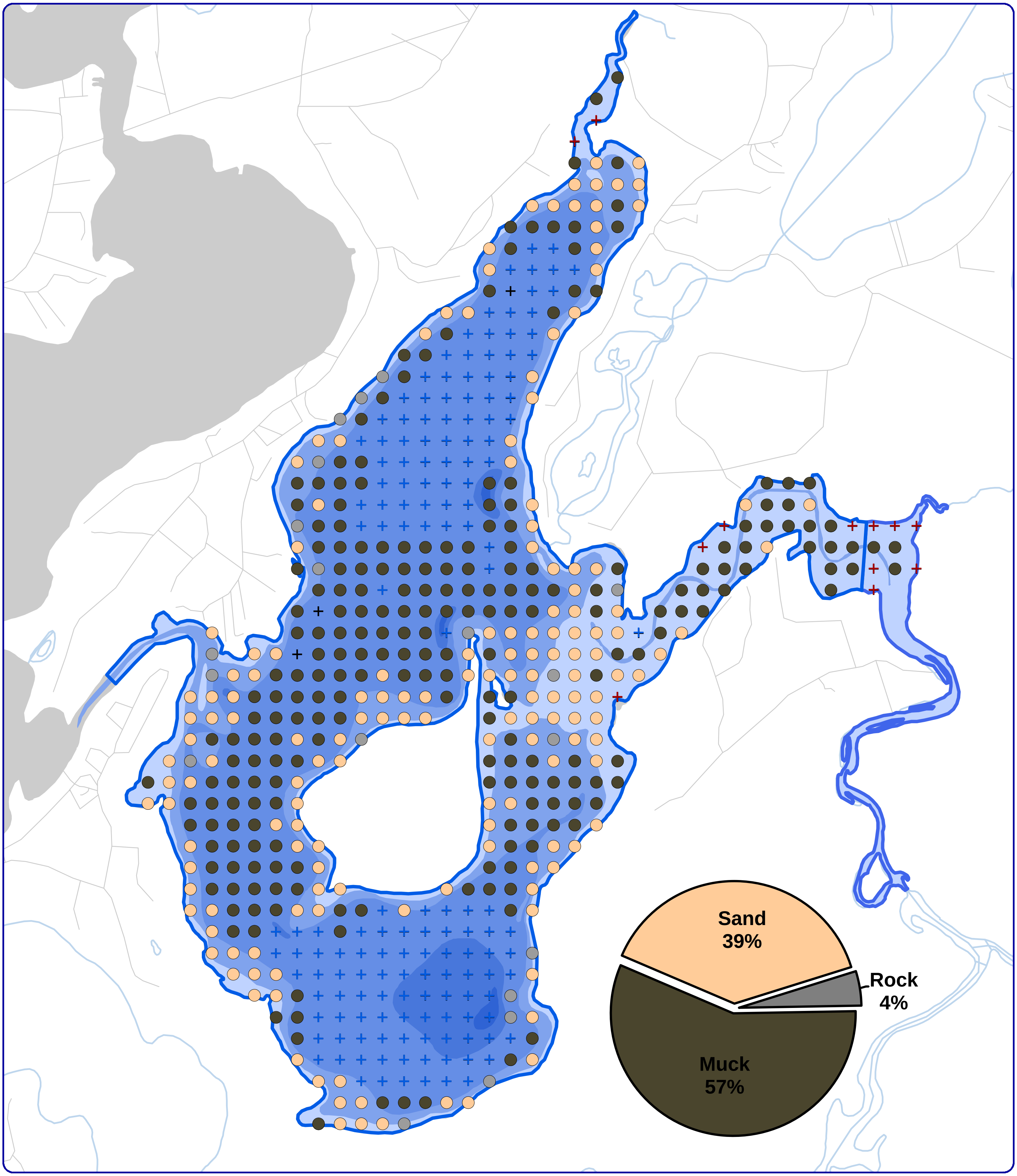


Figure 4.1-6. Cranberry Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Overall, the 2012 point-intercept survey on Cranberry Lake indicated that there have been no detectable adverse lake-wide impacts to any of the lake's native aquatic plant species and to the entire community over the course of the five-year Eurasian water milfoil control project. The native species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012. A Eurasian water milfoil treatment did occur in 2012 and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).



N
W E
S

1,600
Feet

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Lake Management Planning

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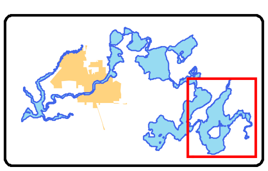
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Cran1_SubstratePI.mxd



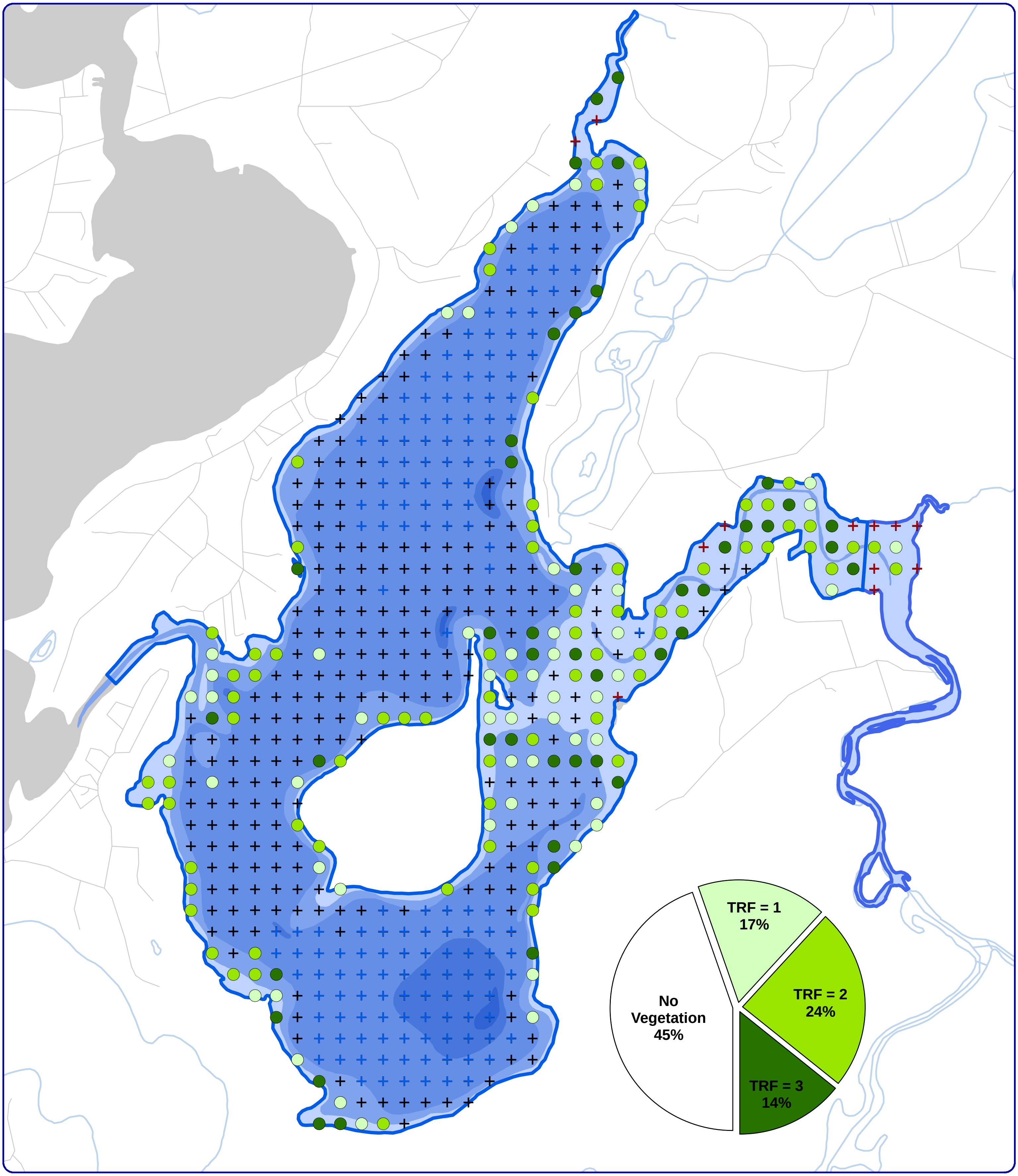
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- + Too Deep - No Data
- + Non-navigable

Cran-1
Cranberry Lake
Vilas-Oneida Counties, Wisconsin

2012 PI Survey: Substrate Types



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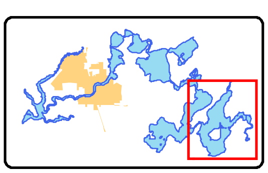

Extent of large map shown in red.

Legend

Total rake-fullness = 1	No Vegetation
Total rake-fullness = 2	Too Deep
Total rake-fullness = 3	Non-navigable

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Cran2_TRFPI.mxd

Cran-2

Cranberry Lake

Vilas-Oneida Counties, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.2 Catfish Lake

The whole-lake aquatic plant point-intercept survey was conducted on Catfish Lake by Onterra on July 31 and August 1, 2012 (Figure 4.2-1). During this survey, a total of 30 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.2-1). 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.

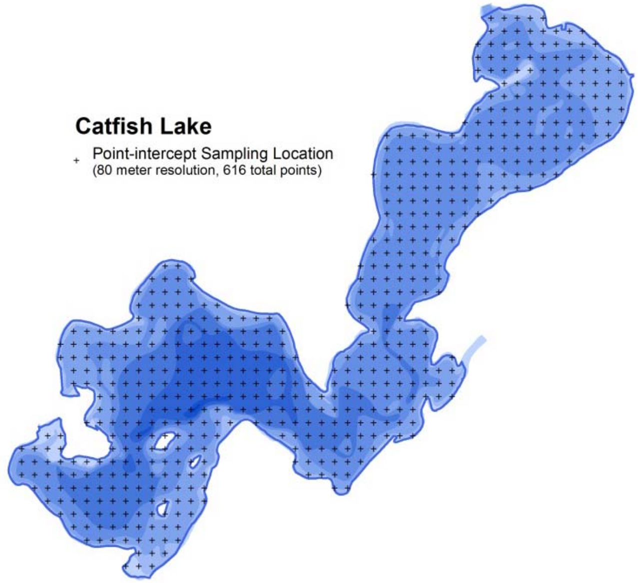


Figure 4.2-1. Point-intercept locations on Catfish Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Cat-1 illustrates, 48% of the point-intercept locations within littoral areas contained sand, 46% contained fine, organic sediments (muck), and 6% 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 (Map Cat-1). 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 14 feet, similar to 15 feet observed in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 407 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 35% contained aquatic vegetation. This is the same frequency that was recorded during the 2006 survey. Map Cat-2 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. Fifteen percent of the point-intercept locations had a total rake-fullness rating of 1, 13% had a total rake-fullness rating of 2, and 13% 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 4.2-1 displays the aquatic plant species located in Catfish Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except water lobelia, were recorded in 2012. Water lobelia is a small, inconspicuous species that was only located at one sampling location in 2006; it is not believed to have disappeared from the lake, but rather exists at a low occurrence and was not detected in 2012. An additional 10 native aquatic plant species were located in 2012 that had not been recorded in 2006 (Table 4.2-1).

Table 4.2-1. Aquatic plant species located in Catfish Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Schoenoplectus tabernaemontani*	Softstem bulrush	4	X	X
FL	*Nuphar variegata*	Spatterdock	6	X	X
FL	*Nymphaea odorata*	White water lily	6		X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		X
FL/E	*Sparganium sp.*	Bur-reed sp.	N/A	X	
Submergent	*Bidens beckii*	Water marigold	8	X	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
Submergent	*Chara spp.*	Muskgrasses	7	X	X
Submergent	*Elodea canadensis*	Common waterweed	3	X	X
Submergent	*Heteranthera dubia*	Water stargrass	6		X
Submergent	*Isoetes spp.*	Quillwort species	8	X	X
Submergent	*Lobelia dortmanna*	Water lobelia	10	X	
Submergent	*Myriophyllum sibiricum*	Northern water milfoil	7	X	X
Submergent	*Myriophyllum spicatum*	Eurasian water milfoil	Exotic	X	X
Submergent	*Najas flexilis*	Slender naiad	6	X	X
Submergent	*Nitella spp.*	Stoneworts	7	X	X
Submergent	*Potamogeton amplifolius*	Large-leaf pondweed	7	X	X
Submergent	*Potamogeton epihydrus*	Ribbon-leaf pondweed	8		X
Submergent	*Potamogeton foliosus*	Leafy pondweed	6		X
Submergent	*Potamogeton friesii*	Fries' pondweed	8		X
Submergent	*Potamogeton praelongus*	White-stem pondweed	8		X
Submergent	*Potamogeton pusillus*	Small pondweed	7	X	X
Submergent	*Potamogeton richardsonii*	Clasping-leaf pondweed	5	X	X
Submergent	*Potamogeton robbinsii*	Fern pondweed	8	X	X
Submergent	*Potamogeton spirillus*	Spiral-fruited pondweed	8	X	X
Submergent	*Potamogeton strictifolius*	Stiff pondweed	8		X
Submergent	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
Submergent	*Potamogeton zosteriformis*	Flat-stem pondweed	6	X	X
Submergent	*Sagitaria sp. (rosette)*	Arrowhead rosette	N/A		X
Submergent	*Vallisneria americana*	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

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

Of the 28 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, wild celery, small pondweed, and spiral-fruited pondweed were the four-most frequently encountered (Figure 4.2-2). Slender naiad, the most abundant aquatic plant in Catfish Lake in 2012 with a littoral occurrence of nearly 27%, 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.

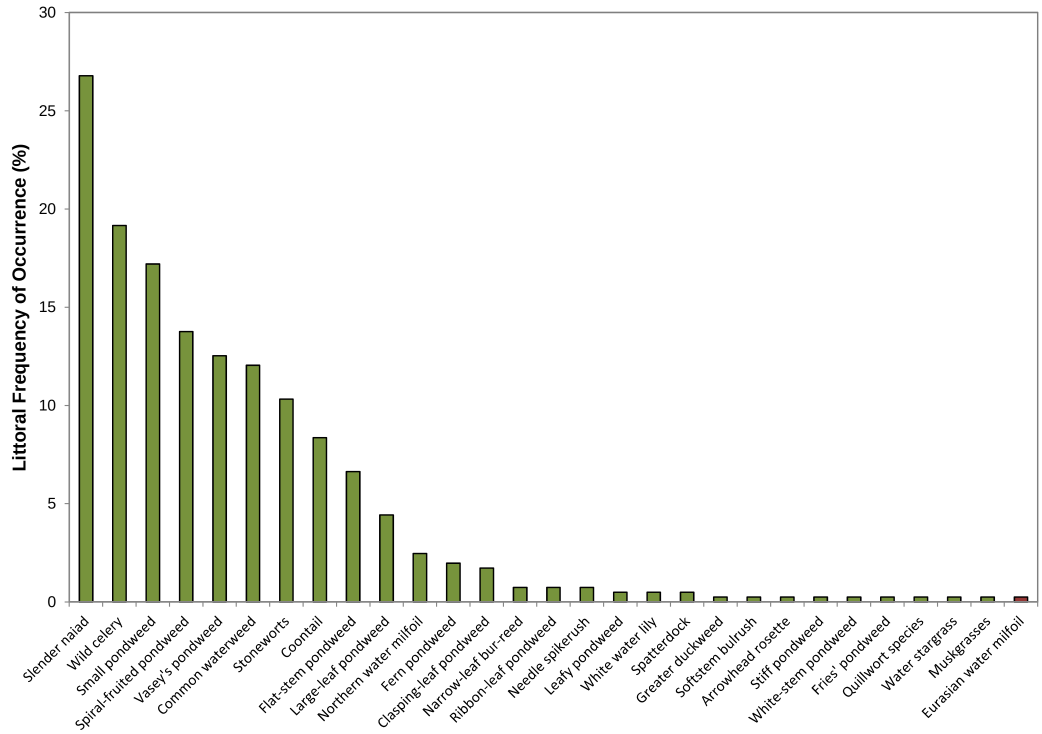


Figure 4.2-2. Catfish Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species 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).

Small pondweed was the third-most abundant aquatic plant encountered in Catfish Lake in 2012, with a littoral occurrence of approximately 17%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Catfish Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms.

Unlike two other narrow-leaved pondweed species located in Catfish Lake, spiral-fruited and Vasey's pondweeds, small pondweed does not produce floating-leaves.

Spiral-fruited pondweed was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 17%. As its name indicates, produces fruit with a distinct coiled embryo and like small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Spiral-fruited pondweed is a provider of food and habitat for wildlife.

Vasey's pondweed was the fifth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like spiral-fruited pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer than spiral-fruited pondweed. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Catfish Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Catfish 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 4.2-3 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 Catfish Lake.

As illustrated, the occurrence of Eurasian water milfoil in Catfish Lake was reduced by a statistically valid 91%, from an occurrence of 2.6% in 2006 to 0.2% in 2012. Three native aquatic plant species, northern water milfoil, small pondweed, and large-leaf pondweed exhibited statistically valid reductions in their occurrence from 2006 to 2012. Like Eurasian water milfoil, northern water milfoil is a dicot and is sensitive to the 2,4-D applications that have occurred on Catfish Lake. Unlike Eurasian water milfoil, small pondweed and large-leaf pondweed are monocots, and were 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 may be prone to decline following these types of treatments. It is possible that the declines observed in the small pondweed and large-leaf pondweed populations in Catfish Lake are a result of the Eurasian water milfoil spatially targeted spot-treatments that have been occurring since 2008. Four native aquatic plant species displayed statistically valid increases in their occurrence from 2006 to 2012, some of them very large gains like slender naiad and spiral-fruited pondweed. The occurrences of the remaining four native aquatic plant species, including one dicot (coontail), were not statistically different from 2006 to 2012.

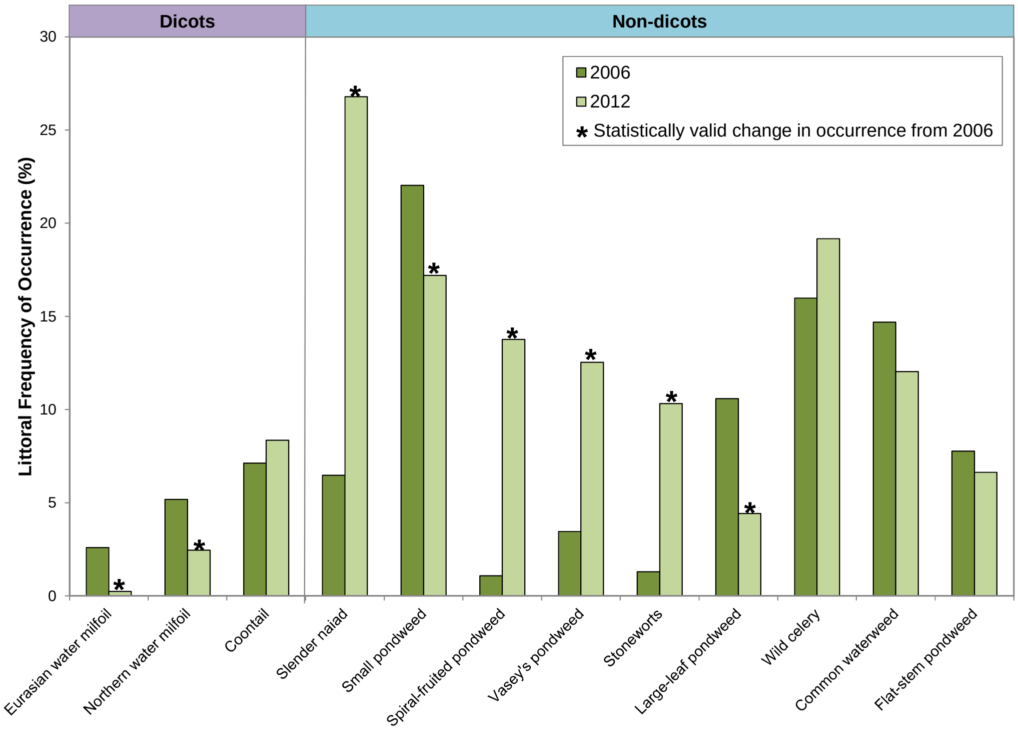


Figure 4.2-3. Catfish Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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 30 native aquatic plant species were located in Catfish Lake during the 2012 survey, 28 were encountered on the rake and two were incidentally located. These 28 native species and their conservatism values were used to calculate the FQI of Catfish Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.2-4 compares the FQI components of Catfish 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, Catfish Lake's native species richness (28) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.6) is slightly lower than the ecoregional median but above the state median. Combining Catfish Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 34.7, which greatly exceeds the ecoregional and state median values (Figure 4.2-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Catfish Lake's aquatic plant community has not been degraded by the Eurasian water milfoil control project. This analysis indicates that Catfish Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

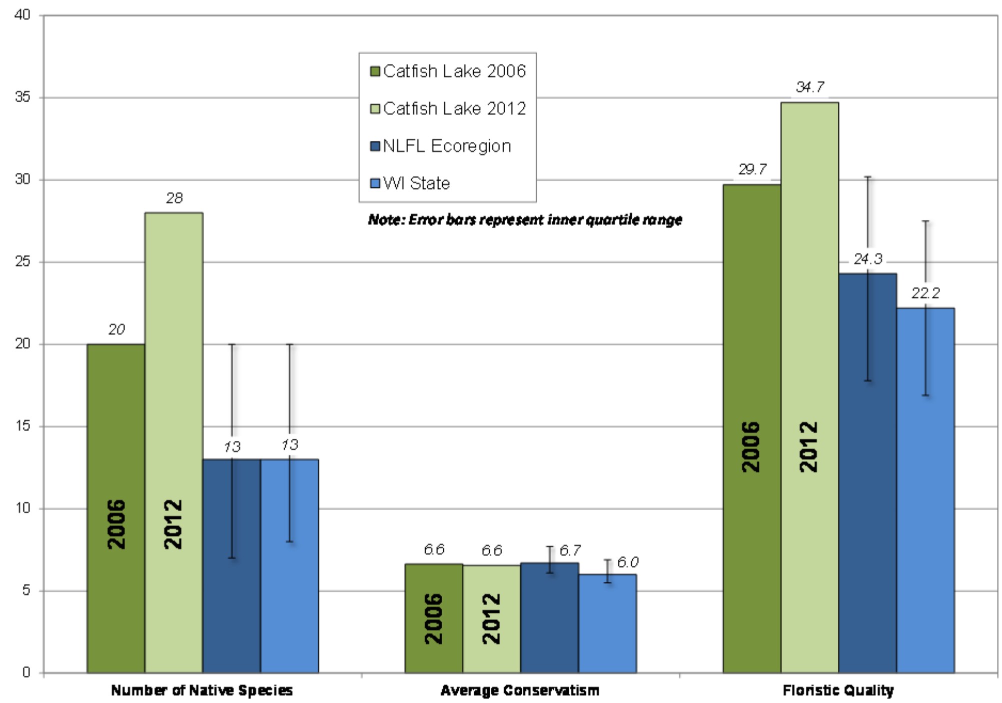


Figure 4.2-4. Catfish Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Catfish 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 Catfish Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.2-5). Using the data collected form the 2012 point-intercept survey, Catfish Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.90, falling above the upper quartile value for lakes in both the ecoregion and the state. Catfish Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.89).

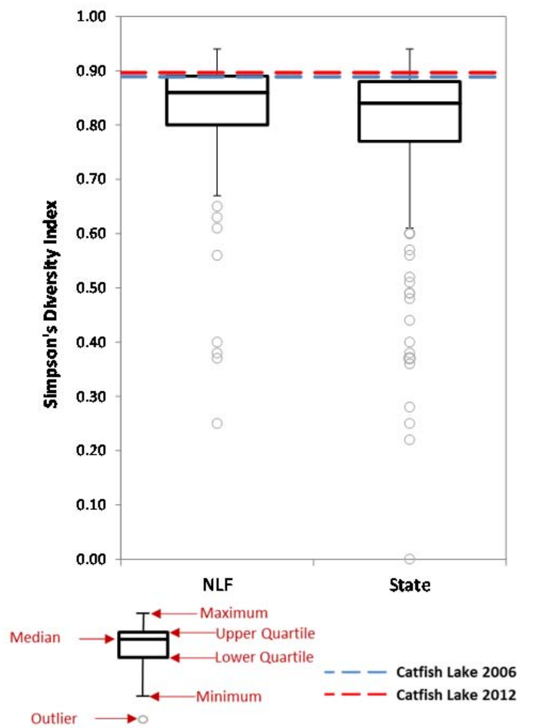


Figure 4.2-5. Catfish Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 4.2-6 displays the relative frequency of occurrence of aquatic plant species in Catfish 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.

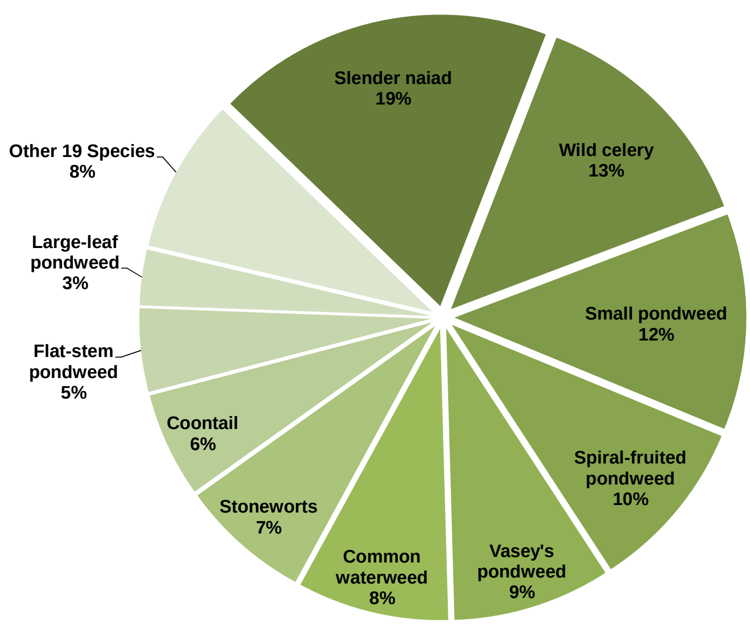
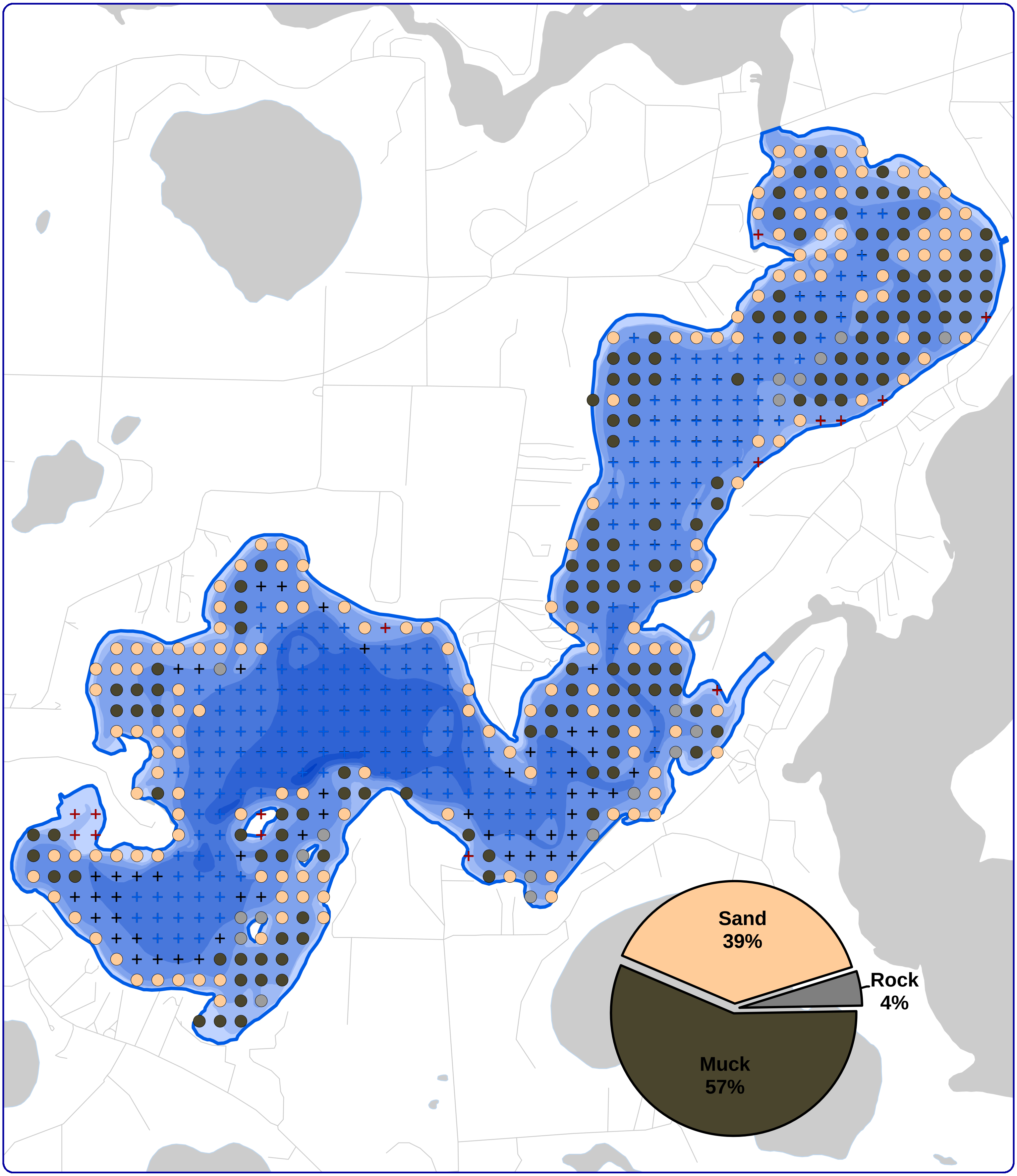


Figure 4.2-6. Catfish Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Overall, the 2012 point-intercept survey on Catfish Lake indicated that the Eurasian water milfoil control project may have had an adverse impact to populations of small pondweed and large-leaf pondweed, as indicated by statistically valid reductions in their occurrence from the 2006 to 2012 surveys. However, Catfish Lake still contains healthy populations of these two species, and four other native species saw large, statistically valid increases in their occurrence. In addition, average conservatism remained the same from 2006 to 2012, while native species richness, Floristic Quality, and species diversity increased, indicating there were no significant impacts to the overall quality of Catfish Lake's aquatic plant community. A Eurasian water milfoil treatment did occur and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).



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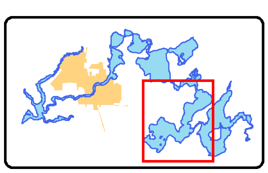
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969,
(digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Cat1_SubstratePI.mxd



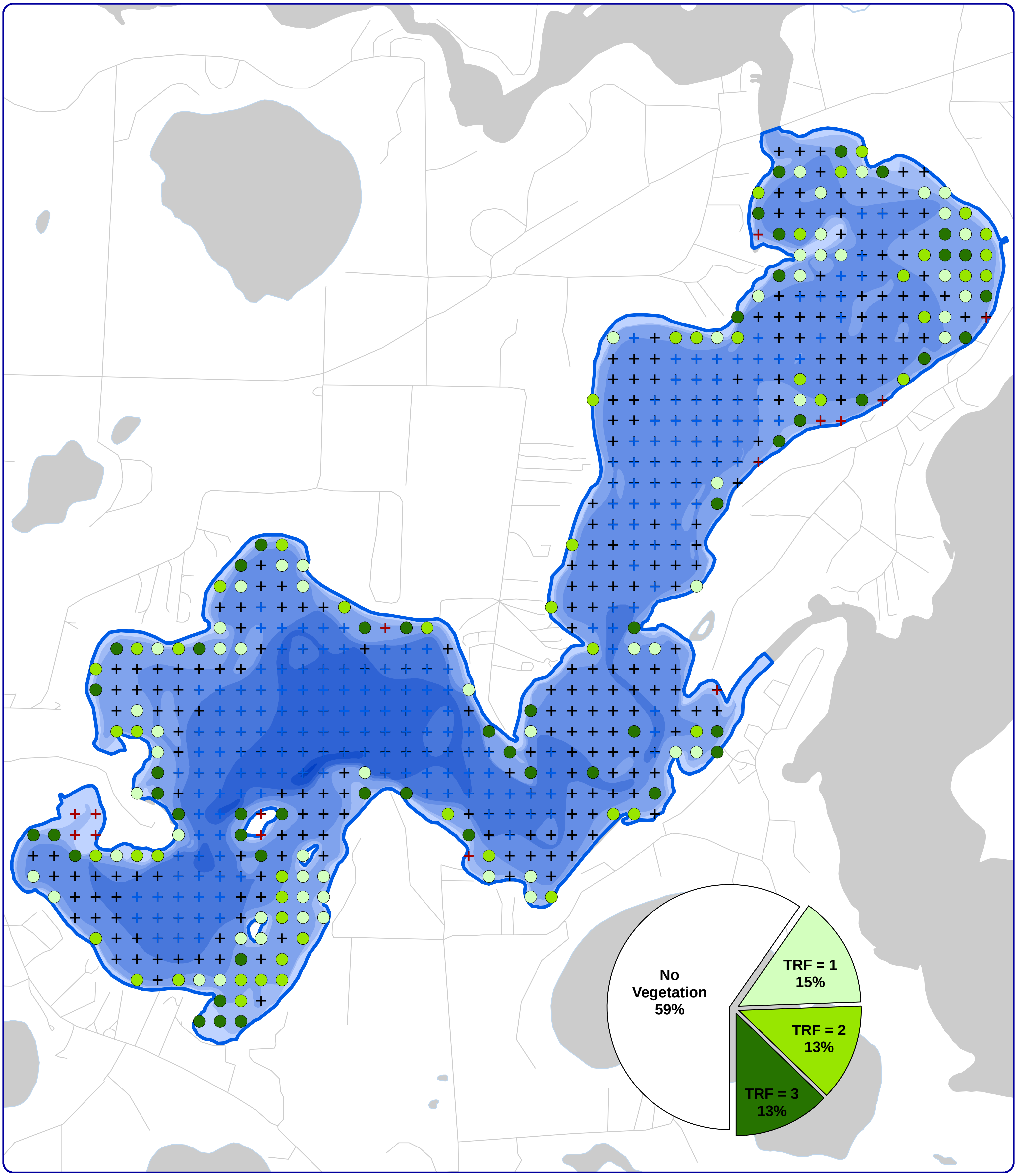
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

Cat 1
Catfish Lake
Vilas County, Wisconsin

2012 PI Survey:
Substrate Types



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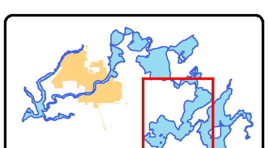
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Cat2_TRFPI.mxd



Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Cat 2
Catfish Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.3 Voyageur Lake

The whole-lake aquatic plant point-intercept survey was conducted on Voyageur Lake by Onterra on August 1, 2012 (Figure 4.3-1). During this survey, a total of 27 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.3-1). 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.

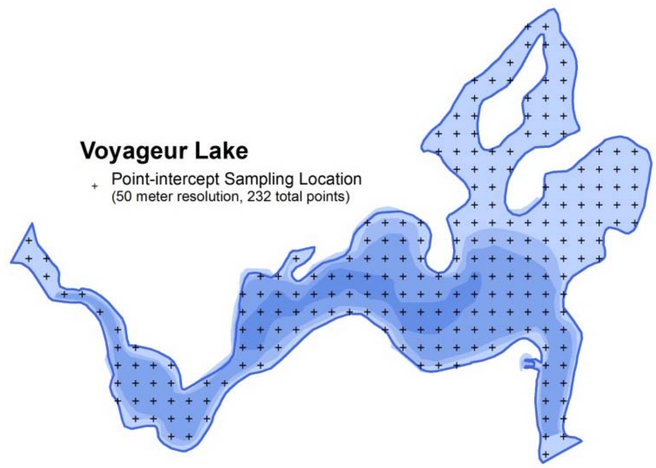


Figure 4.3-1. Point-intercept locations on Voyageur Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Voy-1 illustrates, 51% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 44% contained sand, 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 (Map Voy-1). 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 higher amounts of 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.

Of the 152 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 60% contained aquatic vegetation compared to 59% in 2006. Map Voy-2 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 within near-shore areas. 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 4.3-1 displays the aquatic plant species located in Voyageur Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for white-stem pondweed, white water-crowfoot, and arrowhead sp. (rosette), were recorded in 2012. The three species not re-recorded in 2012 were in low abundance during the 2006 surveys, and it is likely they were just not detected by the point-intercept survey in 2012. However, white water-crowfoot was located in 2006 within areas that have been treated for Eurasian water milfoil from 2008-2012, and like Eurasian water milfoil, white water-crowfoot is a dicot and is susceptible to 2,4-D. It is possible that the Eurasian water milfoil control program on Voyageur Lake did have an impact on the white water crowfoot population. Six native aquatic plant species were located in Voyageur Lake in 2012 that were not located during the 2006 surveys (Table 4.3-1).

Table 4.3-1. Aquatic plant species located in Voyageur Lake during 2006 and 2012 point-intercept surveys.

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

E = Emergent, 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
** = Species listed as 'special concern' in Wisconsin*

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 4.3-2). Wild celery, or tape grass, was the most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 35%. This species 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 is one of many pondweed species found in Wisconsin, and as its name indicates, has a conspicuously flattened stem. It possesses long, linear leaves, and when growing in large beds, provides excellent structural habitat for aquatic organisms. Its foliage and fruit also provide food to waterfowl, mammals, and other wildlife (Borman et al. 1997).

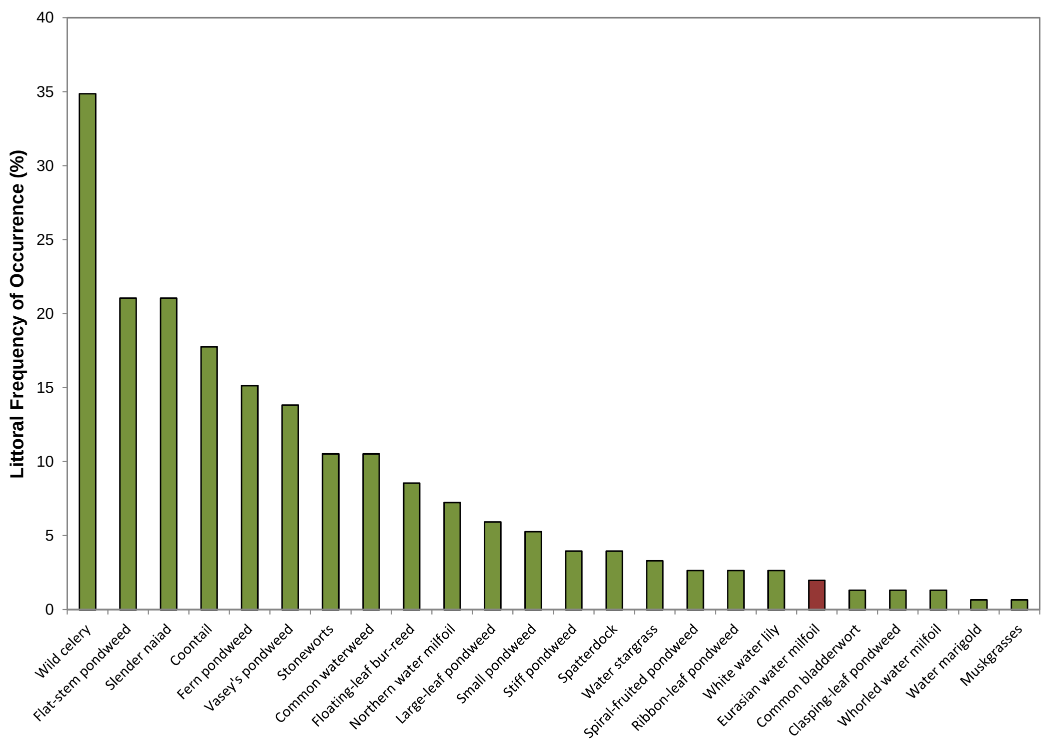


Figure 4.3-2. Voyageur Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Slender naiad, the third-most frequently encountered aquatic plant in Voyageur Lake in 2012 with a littoral occurrence of nearly 27%, 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 frequently encountered aquatic plant in Voyageur Lake in 2012. Resembling the shape of a raccoon's tail, coontail is arguably one of the most common aquatic plant species in Wisconsin. Able to grow in a range of conditions, its dense whorls of stiff leaves provide excellent habitat for macroinvertebrates and other wildlife.

Vasey's pondweed, while not as abundant in Voyageur Lake as other lakes in the chain, was the sixth-most frequently encountered aquatic plant species in 2012. As mentioned previously, 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 submersed leaves. This species 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.

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 4.3-3 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%, 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 from 2006 to 2012. Like Eurasian water milfoil, spatterdock and whorled water milfoil are dicots and sensitive to the 2,4-D applications that have occurred on Voyageur Lake. Unlike Eurasian water milfoil, small pondweed and large-leaf pondweed are monocots, and were historically not thought to be susceptible to dicot-selective herbicides like 2,4-D. But emerging research conducted by the WDNR and US Army Corps of Engineers (USACE) is indicating that some of these species may be prone to decline following these types of treatments.

However, the most acreage of Eurasian water milfoil treated on Voyageur Lake was 3.4 acres in 2008, and no more than 1.5 acres have been treated in subsequent years. While it is possible that these treatments have caused the observed declines observed in the aforementioned species, it is unlikely given the small scale of the treatments that have occurred in Voyageur Lake over the course of the Eurasian water milfoil control project. Four native plant species in Voyageur Lake saw statistically valid increases in their occurrence from 2006 to 2012, while the occurrences of seven were not statistically different (Figure 4.3-3).

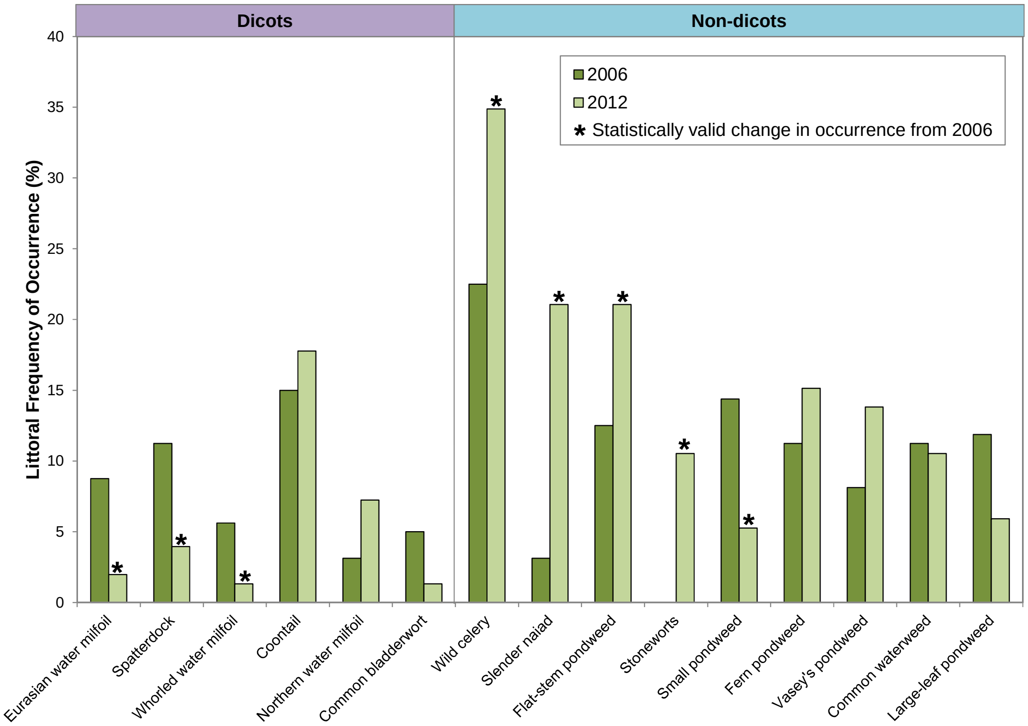


Figure 4.3-3. Voyageur Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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 26 native aquatic plant species were located in Voyageur Lake during the 2012 survey, 23 were encountered on the rake and three were incidentally located. 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.

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

Figure 4.3-4 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 slightly lower than the ecoregional median and above the state median. 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 4.3-4). The FQI values from 2012 are very similar to those calculated 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.

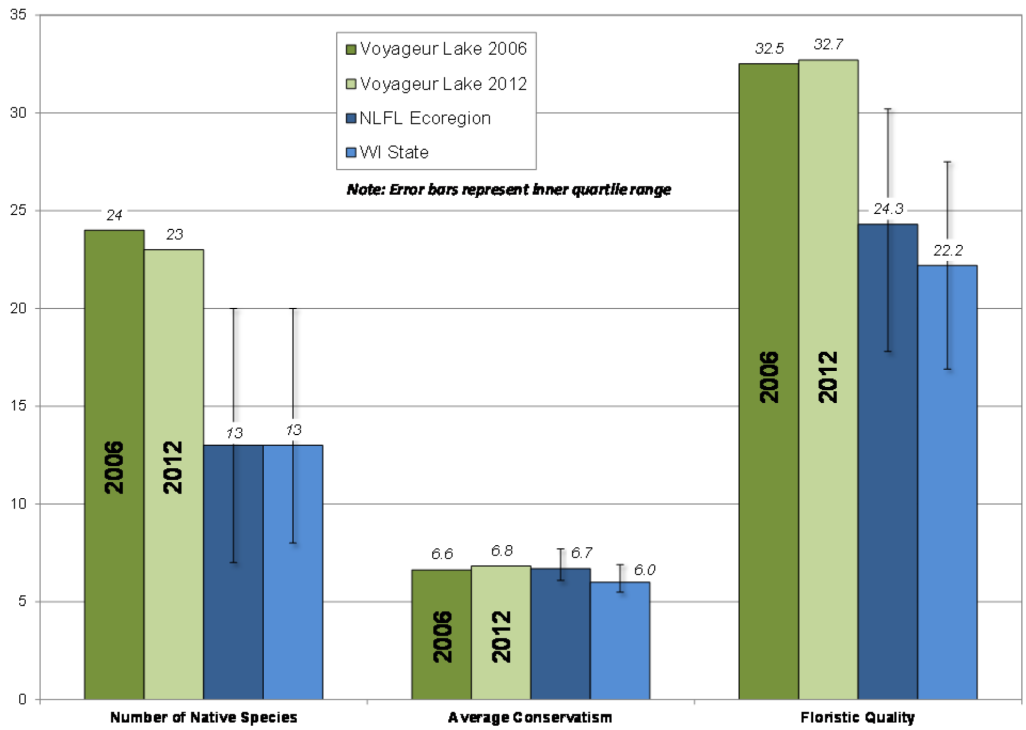


Figure 4.3-4. Voyageur Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 4.3-5). 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 4.3-6 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.

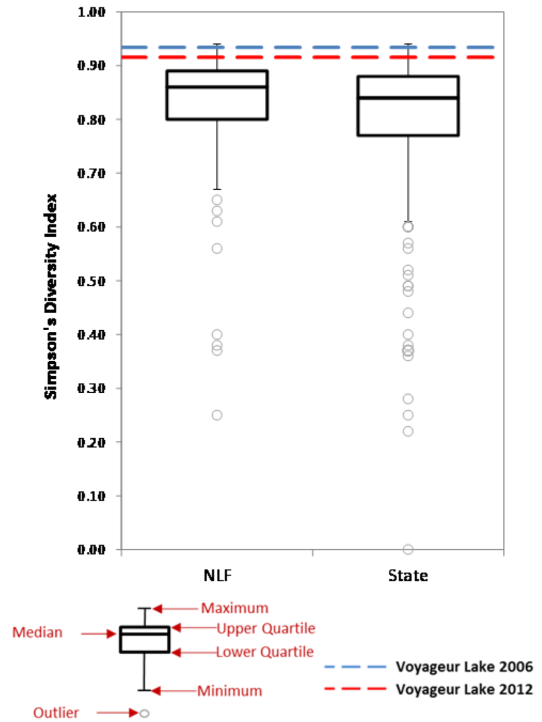


Figure 4.3-5. Voyageur Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

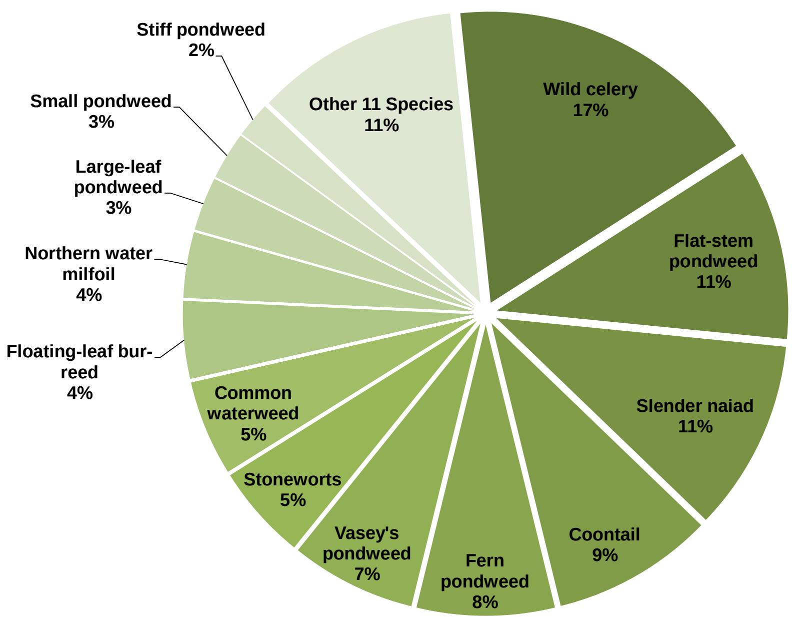
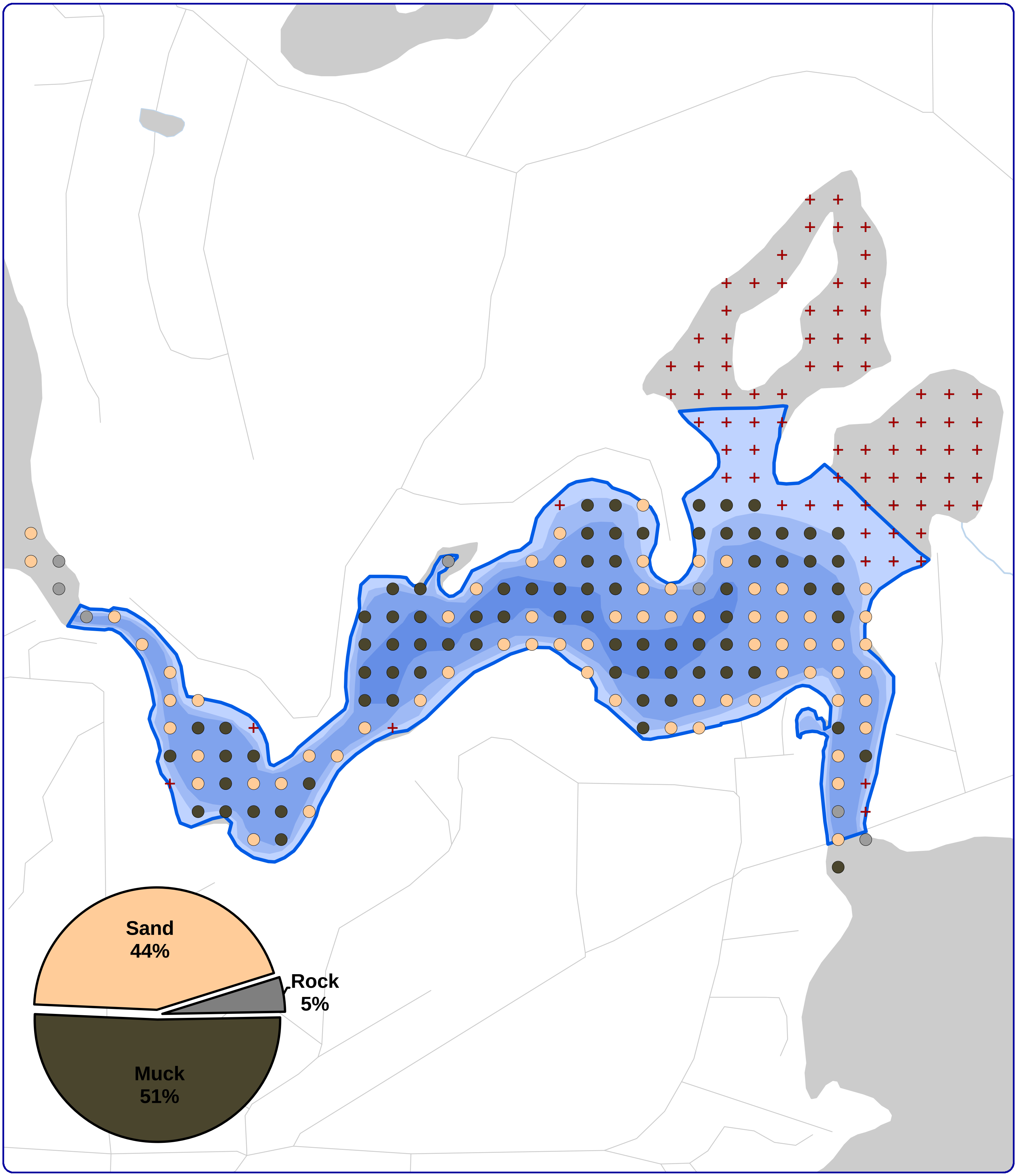
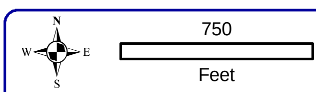


Figure 4.3-6. Voyageur Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Overall, the 2012 point-intercept survey on Voyageur Lake indicated that the Eurasian water milfoil control project may have had an adverse impact to populations of small pondweed and large-leaf pondweed, as indicated by statistically valid reductions in their occurrence from the 2006 to 2012 surveys. However, the small scales of the treatments that have occurred on the system make it unlikely that their declines were a result of the treatments. Voyageur Lake still contains healthy populations of these three species, and four other native species saw large, statistically valid increases in their occurrence. In addition, there were no significant changes in the Floristic Quality components indicating there were no significant impacts to the overall quality of Voyageur Lake's aquatic plant community. No Eurasian water milfoil treatment occurred in Voyageur Lake in 2012.





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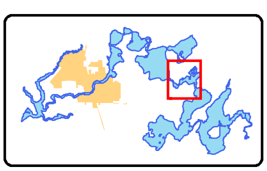
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969,
(digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Voy1_SubstratePI.mxd



Extent of large map shown in red.

Legend

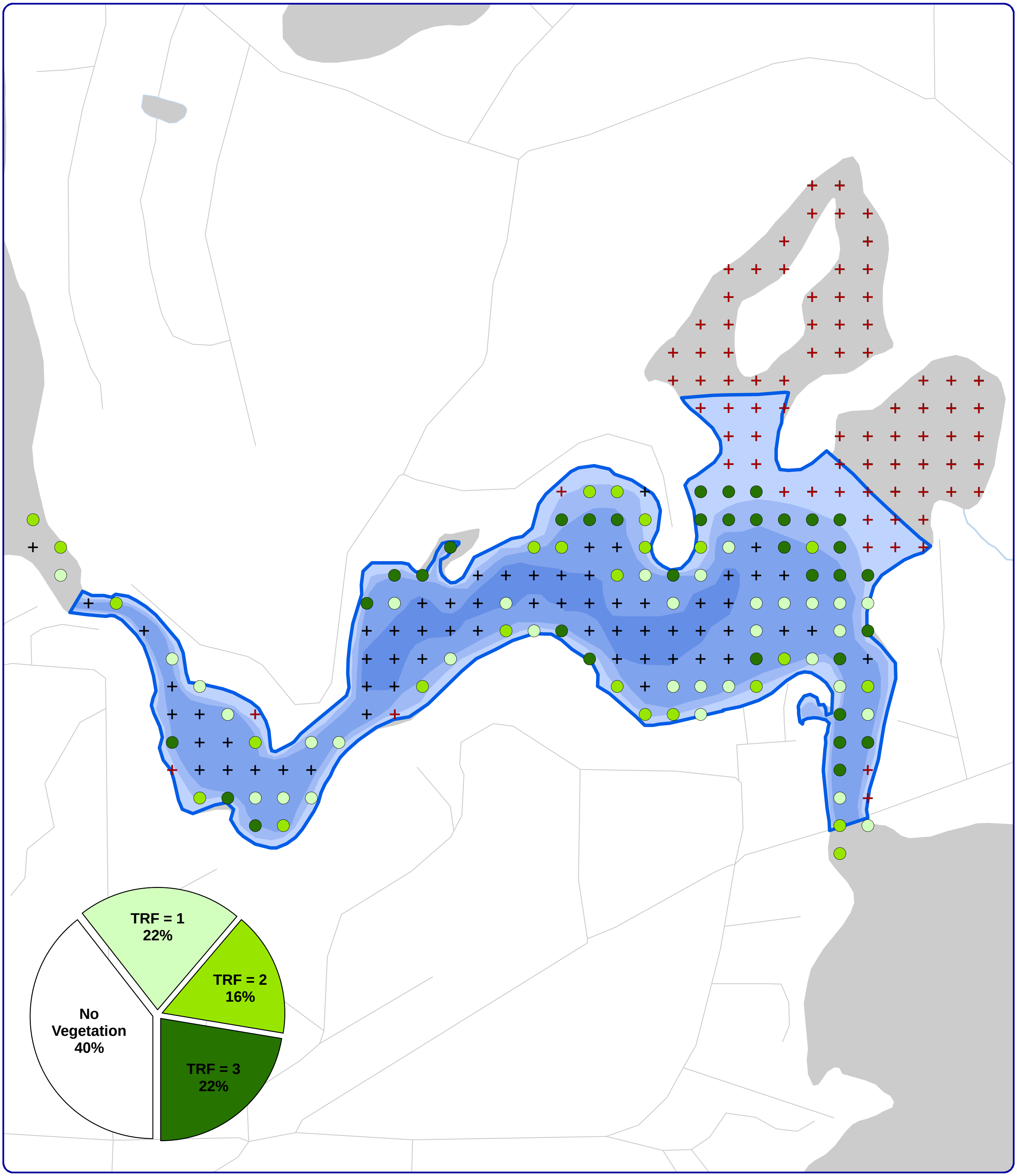
- Muck
- Sand
- Rock
- + Too Deep - No Data
- + Non-navigable

Voy 1

Voyageur Lake

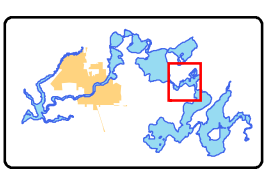
Vilas County, Wisconsin

2012 PI Survey: Substrate Types



N
W
E
S

750
Feet



Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Voy 2
Voyageur Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Voy2_TRFPI.mxd

4.4 Eagle Lake

The whole-lake aquatic plant point-intercept survey was conducted on Eagle Lake by Onterra on August 2, 2012 (Figure 4.4-1). During this survey, a total of 25 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.4-1). 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.

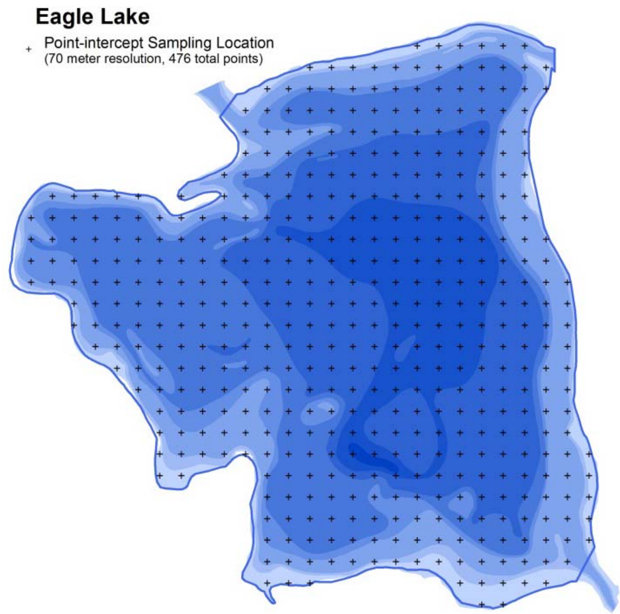

Figure 4.4-1. Point-intercept locations on Eagle Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Eagle-1 illustrates, the vast majority (84%) of the point-intercept locations within littoral areas contained sand, 10% contained rock, and 6% contained fine, organic sediments (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 9 feet, much lower than 17 feet recorded during the 2006 survey. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 121 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 74% contained aquatic vegetation compared to 48% in 2006. Map Eagle-2 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 within near-shore areas. Thirty-nine percent of the point-intercept locations had a total rake-fullness rating of 1, 24% had a total rake-fullness rating of 2, and 11% 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 4.4-1 displays the aquatic plant species located in Eagle Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for white water lily, white water-crowfoot, and arrowhead sp. (rosette), were

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recorded in 2012. The three species not re-located in 2012 were in low abundance during the 2006 surveys, and it is likely they were just not detected by the point-intercept survey in 2012. Eight native aquatic plant species were located in Eagle Lake in 2012 that were not located during the 2006 surveys (Table 4.4-1).

Table 4.4-1. Aquatic plant species located in Eagle Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Eleocharis palustris*	Creeping spikerush	6	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	X
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8		X
Submergent	*Bidens beckii*	Water marigold	8		X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes spp.	Quillwort species	8		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		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
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria sp. (rosette)*	Arrowhead sp. (rosette)	N/A	X	
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

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

Of the 25 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, wild celery, small pondweed, and Vasey's pondweed were the four-most frequently encountered (Figure 4.4-2). Slender naiad, the most abundant aquatic plant in Eagle Lake in 2012 with a littoral occurrence of nearly 44%, 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.

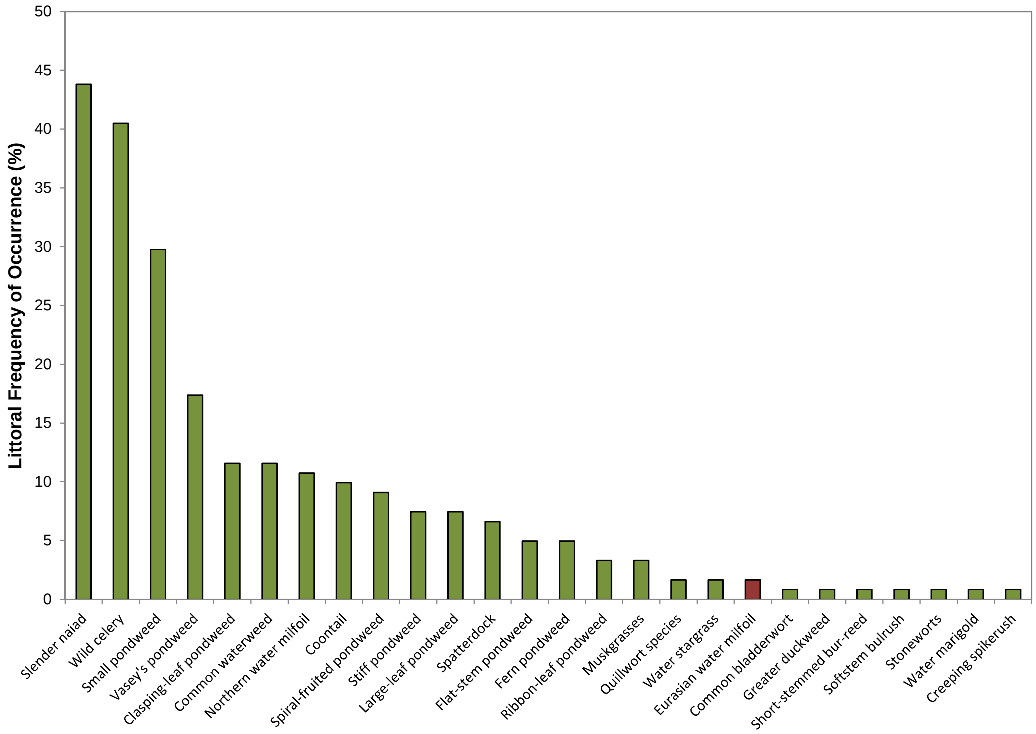


Figure 4.4-2. Eagle Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 41%. This species 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).

Small pondweed was the third-most abundant aquatic plant encountered in Eagle Lake in 2012, with a littoral occurrence of approximately 30%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin, and one of four narrow-leaved pondweeds located in Eagle Lake in 2012. It was observed growing in large stands in Eagle Lake, where its long, narrow submersed leaves provide excellent structural habitat for aquatic organisms.

Vasey's pondweed was the fourth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like small pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Eagle Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Eagle 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 4.4-3 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 Eagle Lake.

As illustrated, the occurrence of Eurasian water milfoil in Eagle Lake was reduced by a statistically valid 74%, from an occurrence of 6.4% in 2006 to 1.7% in 2012. No native plant species exhibited statistically valid reductions in their occurrence from 2006 to 2012, while eight species saw statistically valid increases in occurrence. The fact no native species were shown to have statistically valid declines in occurrence indicates that the Eurasian water milfoil control program on Eagle Lake did not have any detectable adverse impacts to the populations of native plants.

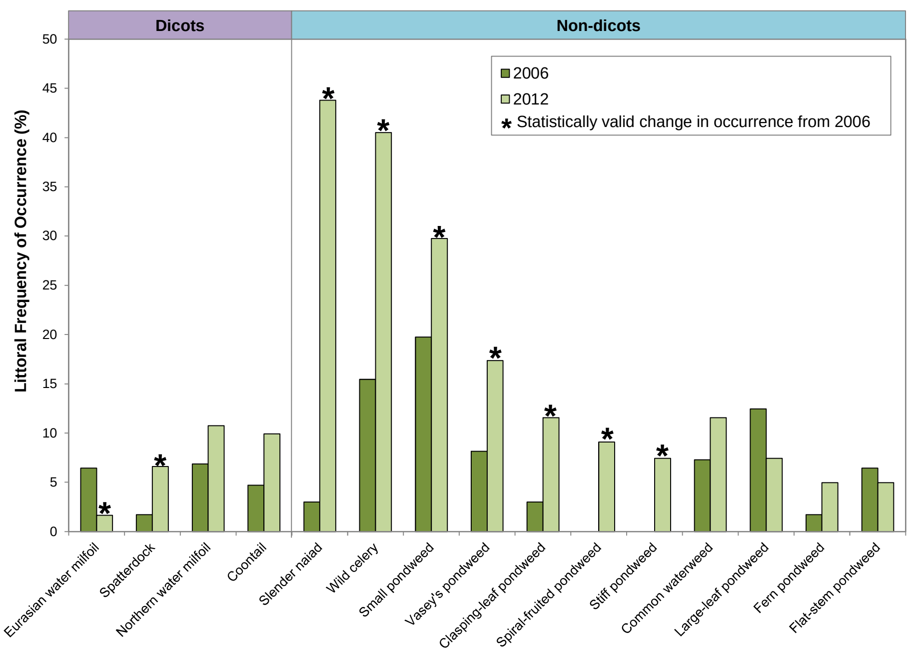


Figure 4.4-3. Eagle Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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. These 25 native species and their conservatism values were used to calculate the FQI of Eagle 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 = Average Coefficient of Conservatism * √Number of Native Species

Figure 4.4-4 compares the FQI components of Eagle 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, Eagle Lake's native species richness (25) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.6) falls slightly below the ecoregional median but above the state median. Combining Eagle Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 32.8, which greatly exceeds the ecoregional and state median values (Figure 4.4-4). The FQI values from 2012 also exceed those calculated in 2006, indicating that the quality of Eagle Lake's aquatic plant community has not been degraded by the Eurasian water milfoil control project. This analysis indicates that Eagle Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

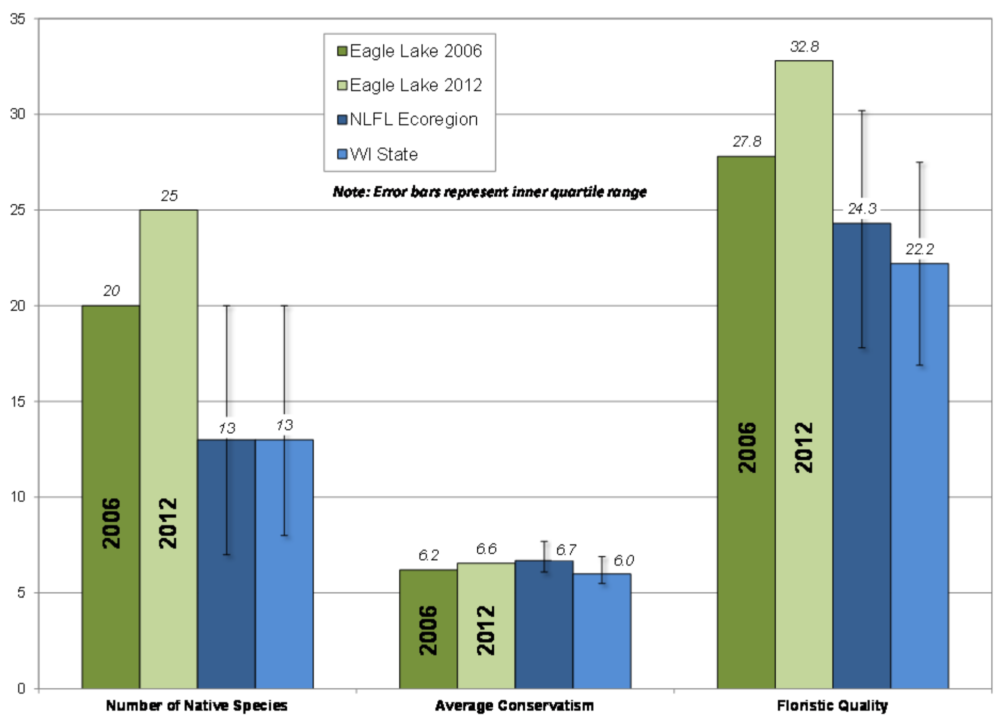


Figure 4.4-4. Eagle Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Eagle 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.

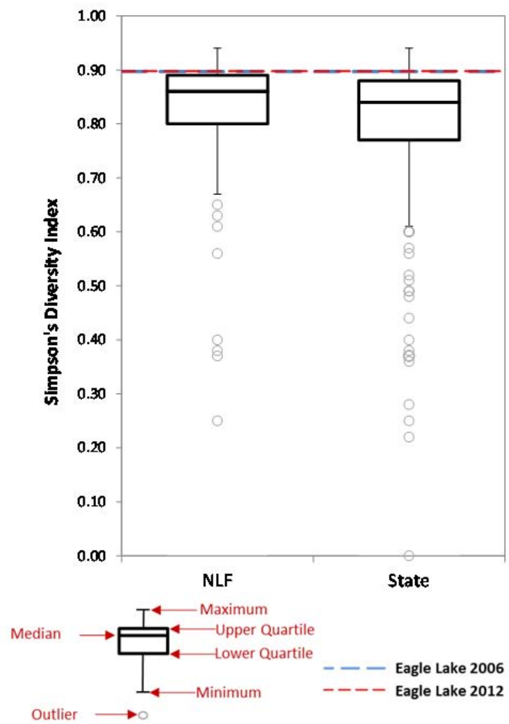


Figure 4.4-5. Eagle Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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 Eagle Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.4-5). Using the data collected form the 2012 point-intercept survey, Eagle Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.90, falling above the upper quartile value for lakes in both the ecoregion and the state. Eagle Lake's 2012 diversity was found to be the same as the diversity calculated from data collected in 2006.

Figure 4.4-6 displays the relative frequency of occurrence of aquatic plant species in Eagle 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.

Overall, the 2012 point-intercept survey on Eagle Lake indicated that there have been no detectable adverse lake-wide impacts to any of the lake's native aquatic plant species and to the entire community over the course of the five-year Eurasian water milfoil control project. The native species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012. A Eurasian water milfoil treatment did occur and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).

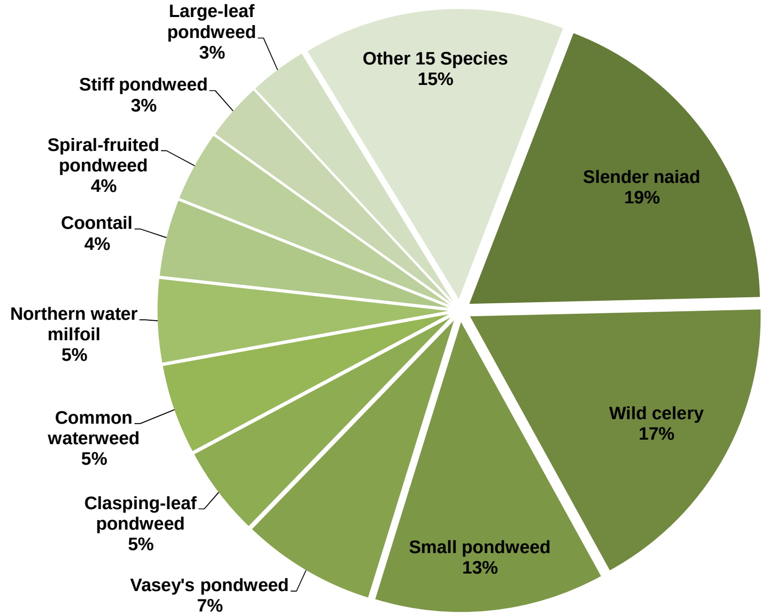
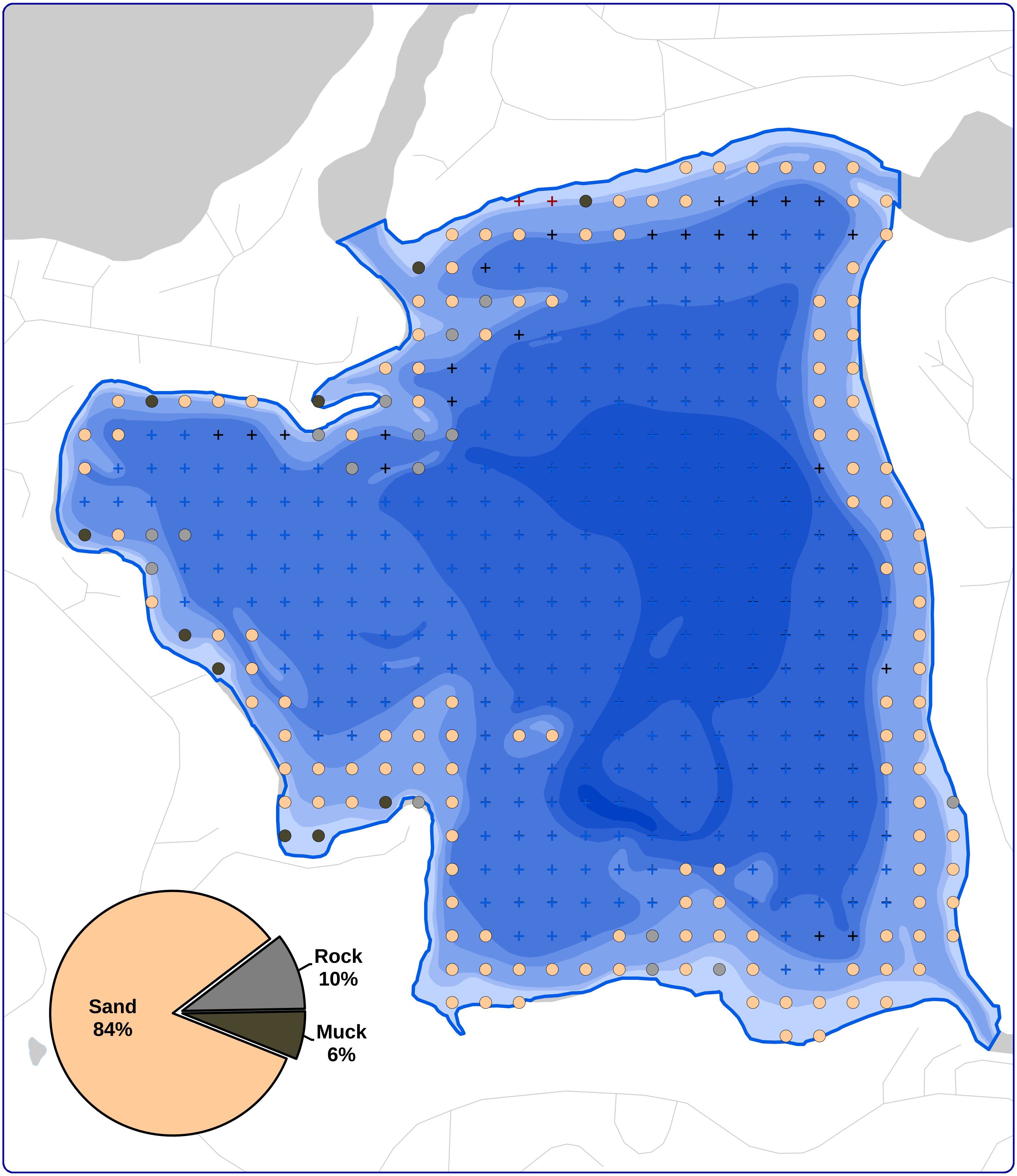
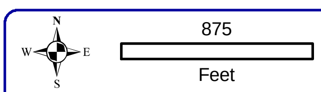


Figure 4.4-6. Eagle Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.





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Sources:
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Bathymetry: WDNR 1969, (digitized by Onterra)
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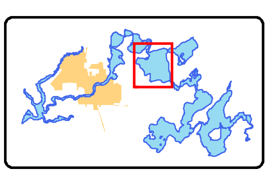
Map Date: March 22, 2013
Filename: Eagle1_SubstratePI.mxd



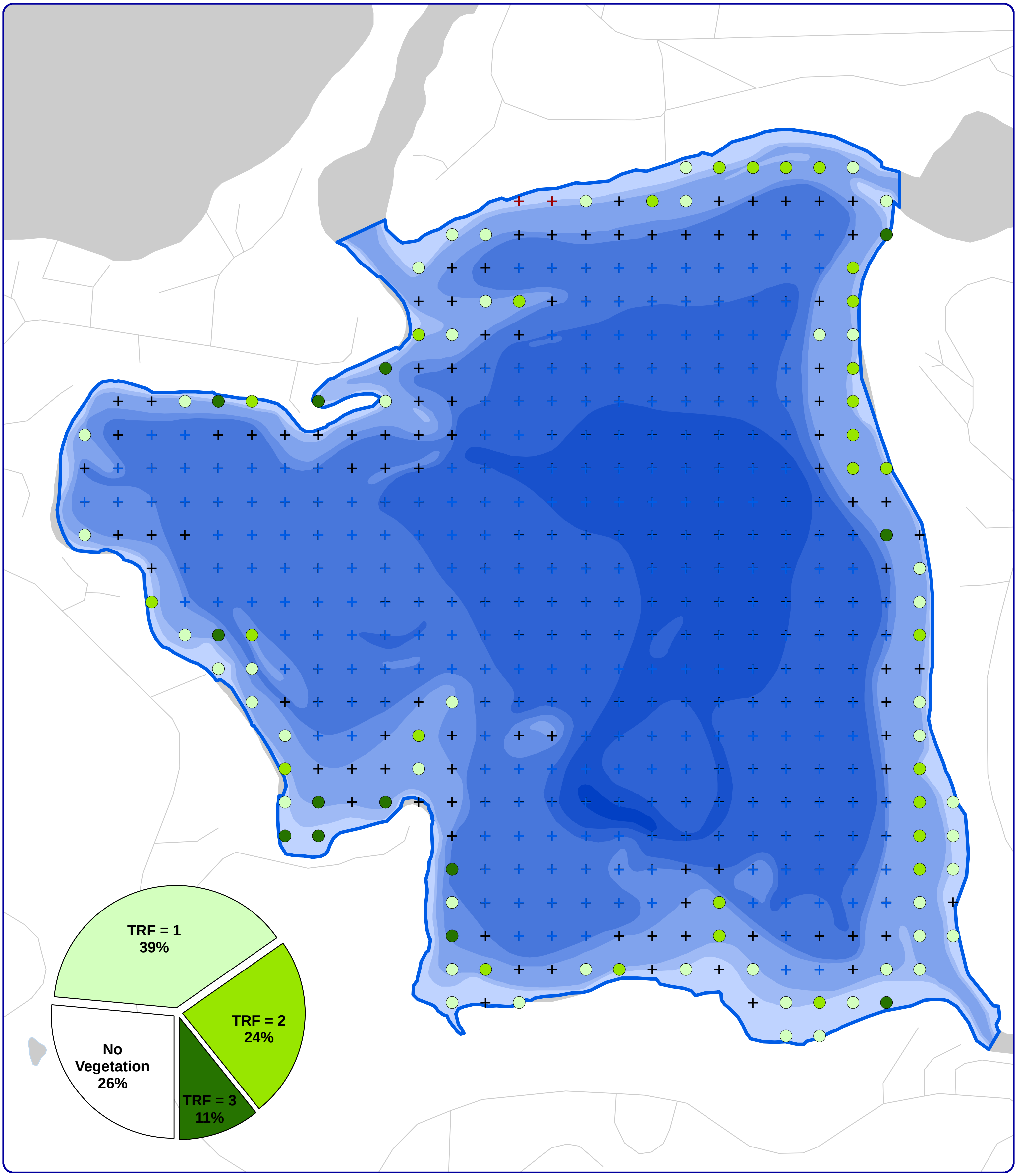
Extent of large map shown in red.

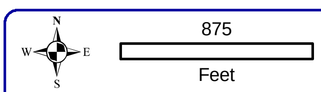
Legend

- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

Eagle 1
Eagle Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types





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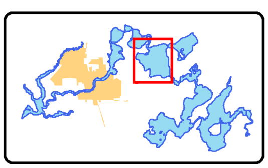
Map Date: March 22, 2013
Filename: Eagle2_TRFPI.mxd



Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Eagle 2
Eagle Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.5 Scattering Rice Lake

The whole-lake aquatic plant point-intercept survey was conducted on Scattering Rice Lake by Onterra on July 31, 2012 (Figure 4.5-1). During this survey, a total of 27 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.5-1). 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.

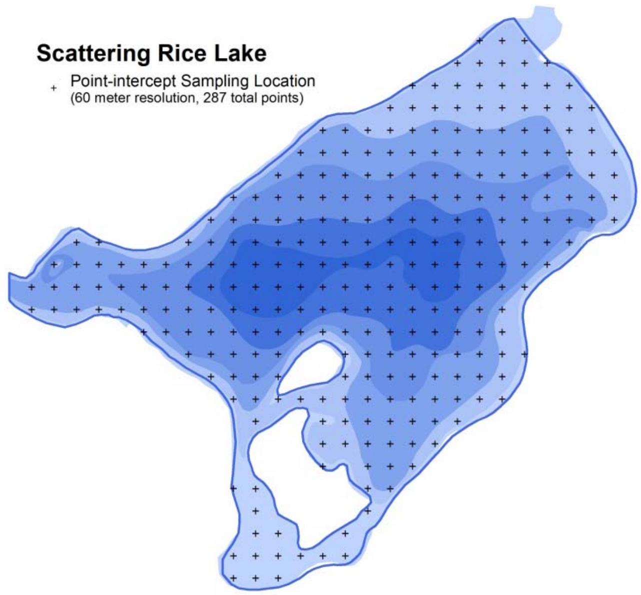


Figure 4.5-1. Point-intercept locations on Scattering Rice Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Scat-1 illustrates, 78% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 22% contained sand, and no point-intercept locations were found to contain rock. Most of the locations containing sand were located in shallower, near-shore areas. 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 9 feet, similar to 10 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 120 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 24% contained aquatic vegetation. This is lower than what was found in the 2006 survey where approximately 36% of the littoral sampling locations contained aquatic vegetation. Map Scat-2 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. Nineteen percent of the point-intercept locations had a total rake-fullness rating of 1, 17% had a total rake-fullness rating of 2, and 8% 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 4.5-1 displays the aquatic plant species located in Scattering Rice Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for arrowhead sp. (rosette), turion duckweed, and greater duckweed, were recorded in 2012. Arrowhead sp. (rosette) was only recorded at two sampling locations in 2006, so it is likely it just went undetected during the 2012 point-intercept survey due to its low abundance. Both turion duckweed and greater duckweed are small, free-floating species that were also recorded in low abundance in 2006. An additional eight native aquatic plant species were located in Scattering Rice Lake in 2012 that had not been recorded in 2006, including two environmentally sensitive species, alpine pondweed and small bladderwort.

Table 4.5-1. Aquatic plant species located in Scattering Rice Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Pontederia cordata*	Pickerelweed	9	X	X
FL	*Nuphar variegata*	Spatterdock	6	X	X
FL	*Nymphaea odorata*	White water lily	6	X	X
FL/E	*Sparganium androcladum*	Shining bur-reed	8		X
Submergent	*Bidens beckii*	Water marigold	8	X	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
Submergent	*Elodea canadensis*	Common waterweed	3	X	X
Submergent	*Heteranthera dubia*	Water stargrass	6	X	X
Submergent	*Myriophyllum sibiricum*	Northern water milfoil	7	X	X
Submergent	*Myriophyllum spicatum*	Eurasian water milfoil	Exotic	X	I
Submergent	*Najas flexilis*	Slender naiad	6		X
Submergent	*Nitella spp.*	Stoneworts	7		X
Submergent	*Potamogeton alpinus*	Alpine pondweed	9		X
Submergent	*Potamogeton amplifolius*	Large-leaf pondweed	7	X	X
Submergent	*Potamogeton epihydrus*	Ribbon-leaf pondweed	8		X
Submergent	*Potamogeton natans*	Floating-leaf pondweed	5	X	I
Submergent	*Potamogeton pusillus*	Small pondweed	7	X	X
Submergent	*Potamogeton richardsonii*	Clasping-leaf pondweed	5	X	X
Submergent	*Potamogeton robbinsii*	Fern pondweed	8	X	X
Submergent	*Potamogeton spirillus*	Spiral-fruited pondweed	8	X	X
Submergent	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
Submergent	*Potamogeton zosteriformis*	Flat-stem pondweed	6	X	X
Submergent	*Utricularia minor*	Small bladderwort	10		X
Submergent	*Utricularia vulgaris*	Common bladderwort	7	X	X
Submergent	*Vallisneria americana*	Wild celery	6	X	X
S/E	*Sagittaria sp. (rosette)*	Arrowhead sp. (rosette)	N/A	X	
FF	*Lemna trisulca*	Forked duckweed	6		X
FF	*Lemna turionifera*	Turion duckweed	2	X	
FF	*Riccia fluitans*	Slender riccia	7		X
FF	*Spirodela polyrhiza*	Greater duckweed	5	X	

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

Of the 25 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, fern pondweed, coontail, and slender naiad were the four-most frequently encountered (Figure 4.5-2). Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species 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).

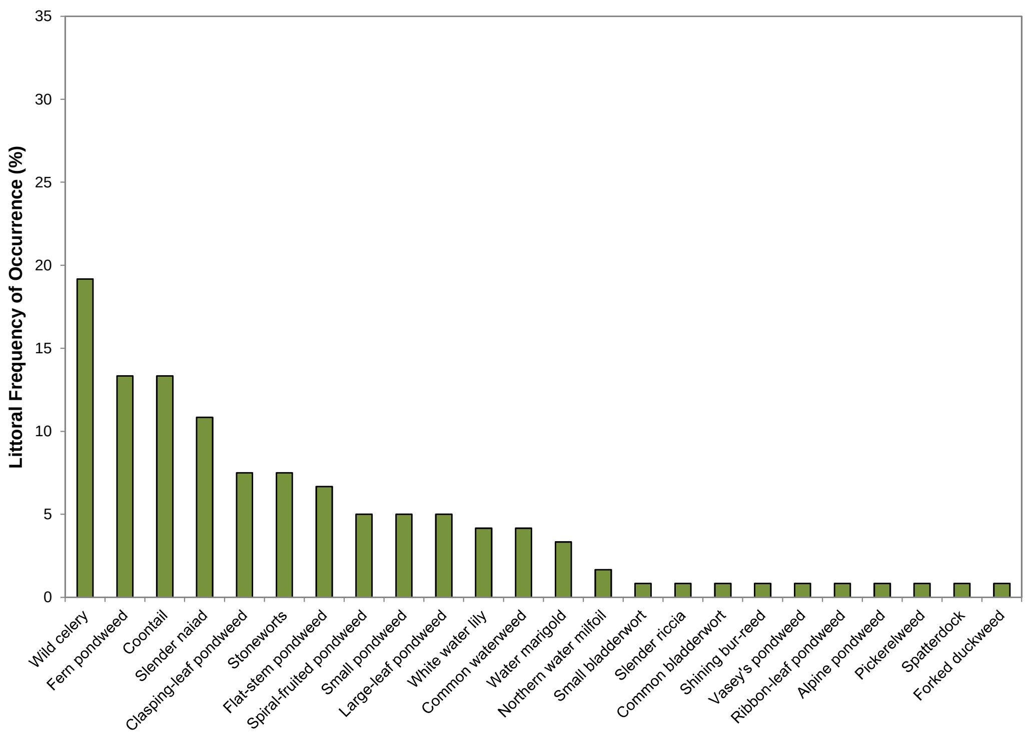


Figure 4.5-2. Scattering Rice Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Fern pondweed was the second-most abundant plant in Scattering Rice Lake in 2012 with a littoral occurrence of approximately 13%. As its name suggests, has the appearance of a fern's leaf and is a common pondweed found in lakes in northern Wisconsin. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish.

Coontail was the third-most frequently encountered aquatic plant in Scattering Rice Lake in 2012 with a littoral occurrence of approximately 13%. Resembling the shape of a raccoon's tail, coontail is arguably one of the most common aquatic plant species in Wisconsin. Able to grow in a range of conditions, its dense whorls of stiff leaves provide excellent habitat for macroinvertebrates and other wildlife.

Slender naiad, the fourth-most abundant aquatic plant in Scattering Rice Lake in 2012 with a littoral occurrence of nearly 11%, 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.

To determine if the 2008-2012 Eurasian water milfoil control project on Scattering Rice 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. Unlike the other lakes within the chain that only had spot treatments targeting specific areas for Eurasian water milfoil control over the course of the project, Scattering Rice Lake underwent a low-dose, whole-lake liquid 2,4-D treatment in 2010 with the intent of targeting Eurasian water milfoil at the lake-wide level.

Figure 4.5-3 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 have occurred in Scattering Rice Lake. As illustrated, the occurrence of Eurasian water milfoil in Scattering Rice Lake was reduced by a statistically valid 100%, from an occurrence of nearly 18% in 2006 to 0% in 2012. While Eurasian water milfoil was not recorded during the 2012 point-intercept survey, it is still present in very low abundance Scattering Rice Lake.

Five native aquatic plant species exhibited statistically valid reductions in their littoral occurrence from 2006 to 2012 (Figure 4.5-3). These include coontail, northern water milfoil, spatterdock, flat-stem pondweed, and common waterweed. Like Eurasian water milfoil, coontail, northern water milfoil, and spatterdock are dicots, and are susceptible to types of treatments that have occurred on Scattering Rice Lake. Flat-stem pondweed and common waterweed are monocots, and were not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research being conducted by the WDNR and US Army Corps of Engineers indicates that both flat-stem pondweed and common waterweed may be prone to decline following low-dose, whole-lake 2,4-D treatments. Five other native aquatic plant species saw statistically valid increases in their occurrence from 2006 to 2012, while the occurrences of three others were not statistically different (Figure 4.5-3).

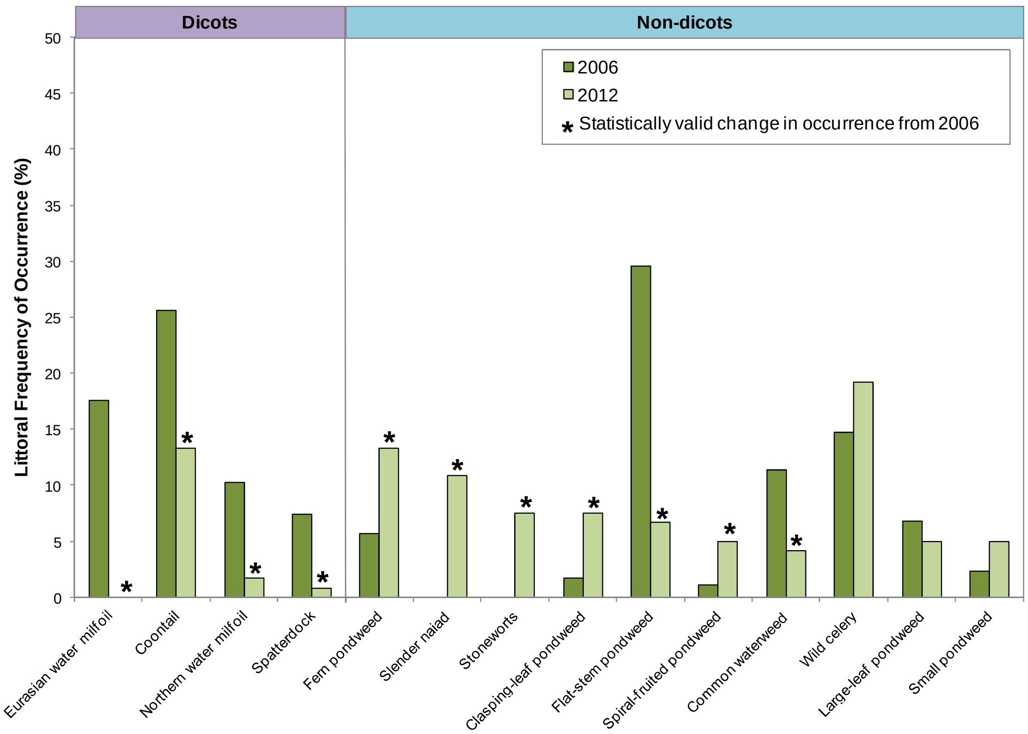


Figure 4.5-3. Scattering Rice Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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 of 26 native aquatic plant species were located in Scattering Rice Lake during the 2012 survey, 25 were encountered on the rake and one was incidentally located. These 25 native species and their conservatism values were used to calculate the FQI of Scattering Rice Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.5-4 compares the FQI components of Scattering Rice 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, Scattering Rice Lake's native species richness (25) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.9) also exceeds the ecoregional and state medians. Combining Scattering Rice Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 34.6, which greatly exceeds the ecoregional and state median values (Figure 4.5-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Scattering Rice Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Scattering Rice Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

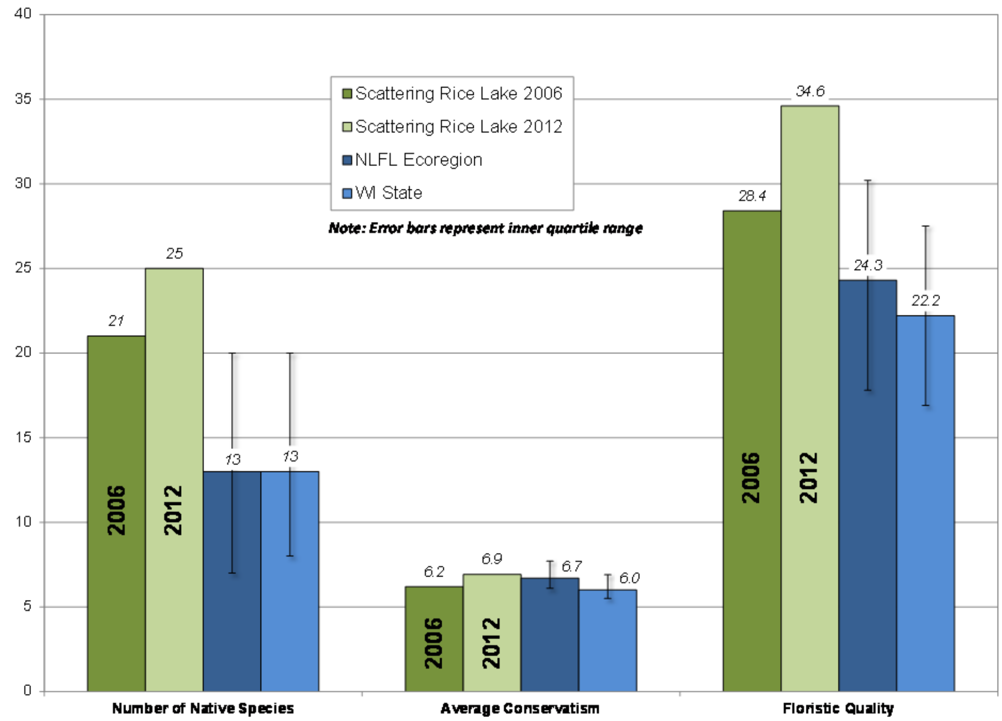


Figure 4.5-4. Scattering Rice Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Scattering Rice 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 Scattering Rice Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.5-5). Using the data collected from the 2012 point-intercept survey, Scattering Rice Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.92, exceeding the upper quartile value for lakes in both the ecoregion and the state. Scattering Rice Lake's 2012 diversity was also considerably higher than the diversity value of 0.89 calculated from data collected in 2006. The increase in diversity in 2012 is likely a result of the decline of the Eurasian water milfoil population as well as a reduction in the occurrences of some of the more dominant native aquatic plant species.

Figure 4.5-6 displays the relative frequency of occurrence of aquatic plant species in Scattering Rice 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 results in a more diverse community.

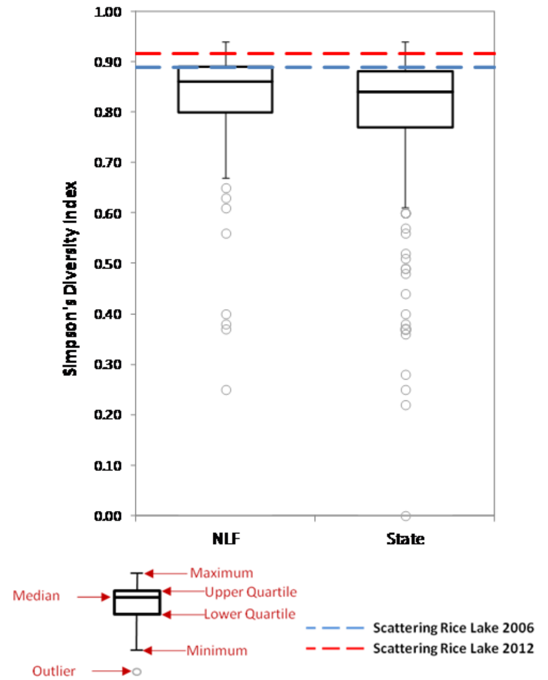


Figure 4.5-5. Scattering Rice Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

The 2012 point-intercept survey conducted on Scattering Rice Lake indicated that the Eurasian water milfoil control program likely did have some adverse impacts to the lake's native aquatic plant community, as indicated by the statistically valid reductions in occurrence of five native aquatic plant species. Their declines are most likely attributable to the 2010 low-dose, whole-lake 2,4-D treatment. However, no native aquatic plant species were lost from the lake over the course of this project, additional species were located within the lake in 2012, and eight native plant species saw statistically valid increases in their occurrence or no change at all. Of all the aquatic plants in Scattering Rice Lake, Eurasian water milfoil has seen the largest reduction, indicating the control program has been successful at targeting Eurasian water milfoil while minimizing impacts to native plant species. The native species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012.

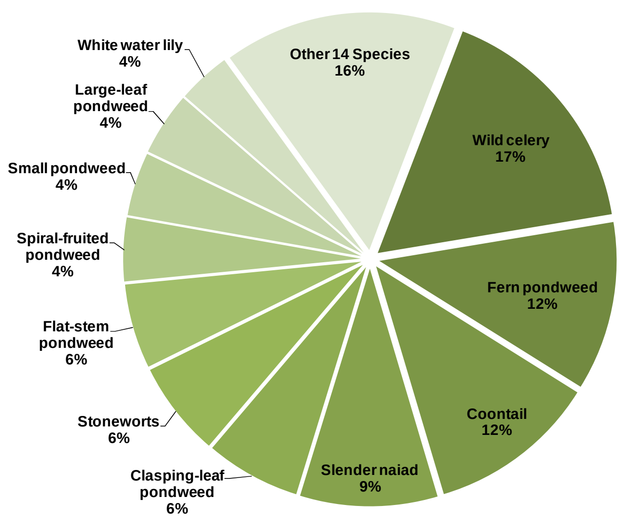
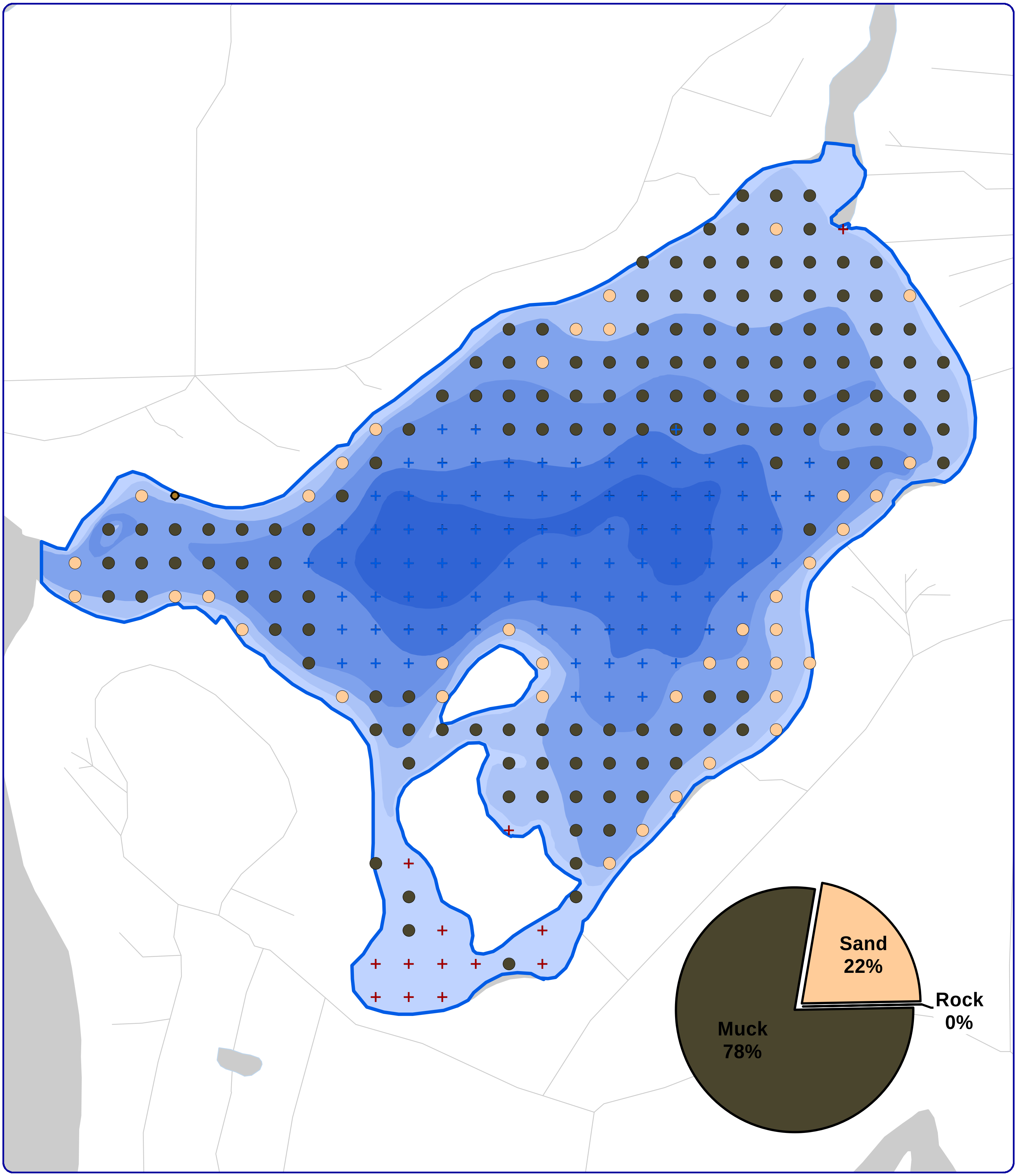


Figure 4.5-6. Scattering Rice Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.



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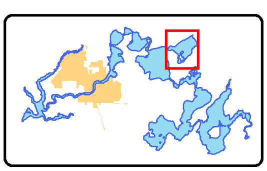
750

Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Scat1_SubstratePI.mxd



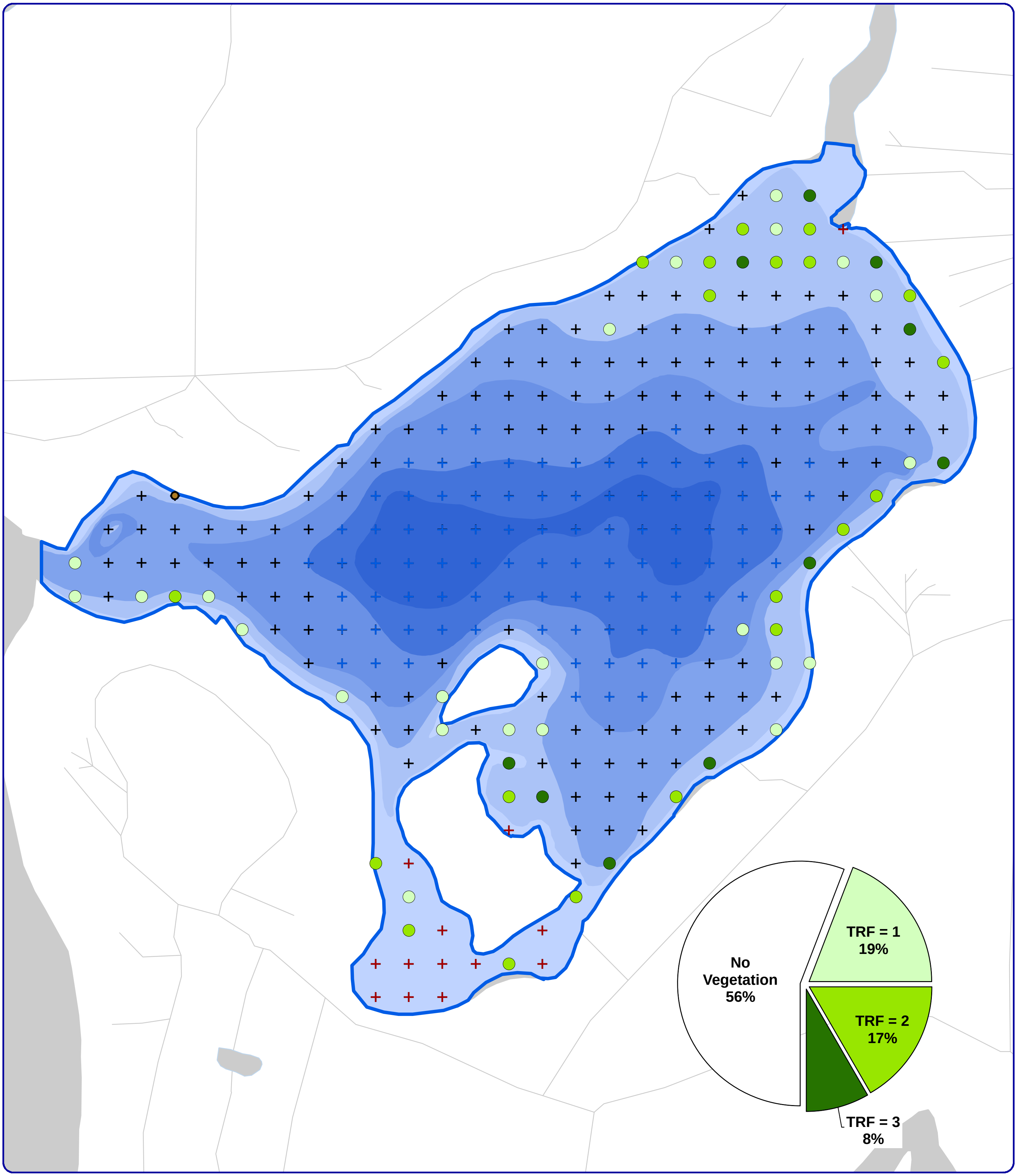
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- + Too Deep - No Data
- + Non-navigable

Scat 1
Scattering Rice Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types



N W E S

750
Feet

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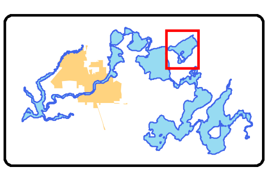
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Scat2_TRFPI.mxd



Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Scat 2
Scattering Rice Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.6 Otter Lake

The whole-lake aquatic plant point-intercept survey was conducted on Otter Lake by Onterra on August 2, 2012 (Figure 4.6-1). During this survey, a total of 17 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.6-1). 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.

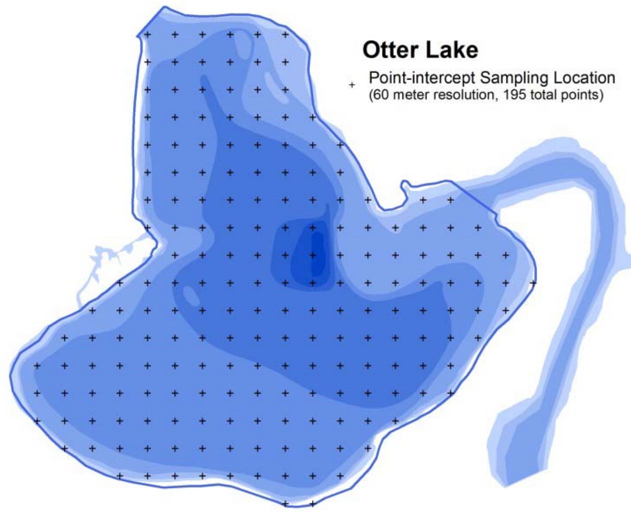


Figure 4.6-1. Point-intercept locations on Otter Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Otter-1 illustrates, 85% of the point-intercept locations within littoral areas contained sand, 15% contained fine, organic sediments (muck), and no sampling locations contained rock. The majority of the shallow, near-shore areas contained sand, while the deeper areas of the littoral zone were comprised of muck (Map Otter-1). 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 9 feet, which was similar to the 10 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 59 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 49% contained aquatic vegetation. This is higher than what was found in the 2006 survey where approximately 24% of the littoral sampling locations contained aquatic vegetation. Map Otter-2 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 near-shore areas and in the shallower eastern portion of the lake. Twenty-six percent of the point-intercept locations had a total rake-fullness rating of 1, 39% had a total rake-fullness rating of 2, and 20% 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 4.6-1 displays the aquatic plant species located in Otter Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 were re-recorded in 2012. An additional six native aquatic plant species were located during the 2012 survey that were not recorded in 2006.

Table 4.6-1. Aquatic plant species located in Otter Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
FL	*Nuphar variegata*	Spatterdock	6	X	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf 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
	Potamogeton strictifolius	Stiff pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Vallisneria americana	Wild celery	6	X	X

FL = Floating Leaf
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*

Of the 16 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, slender naiad, small pondweed and spiral-fruited pondweed were the four-most frequently encountered (Figure 4.6-2). Wild celery, or tape grass, was the most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 42%. This species 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).

Slender naiad, the second-most abundant aquatic plant in Otter Lake in 2012 with a littoral occurrence of nearly 41%, 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.

Small pondweed was the third-most abundant aquatic plant encountered in Eagle Lake in 2012, with a littoral occurrence of approximately 39% (Figure 4.6-2). Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin, and one of four narrow-leaved pondweeds located in Otter Lake in 2012. Its long, narrow submersed leaves provide excellent structural habitat for aquatic organisms.

Spiral-fruited pondweed was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 22%. As its name indicates, it produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Spiral-fruited pondweed is food and habitat source for wildlife.

Vasey's pondweed was the fifth-most frequently encountered aquatic plant species in 2012. As mentioned previously, 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 submersed leaves. It also produces floating leaves, which can be seen at the surface in shallow water (Photo 4.6-1). The occurrence of Vasey's pondweed within Otter Lake is an indicator of a high-quality environment.

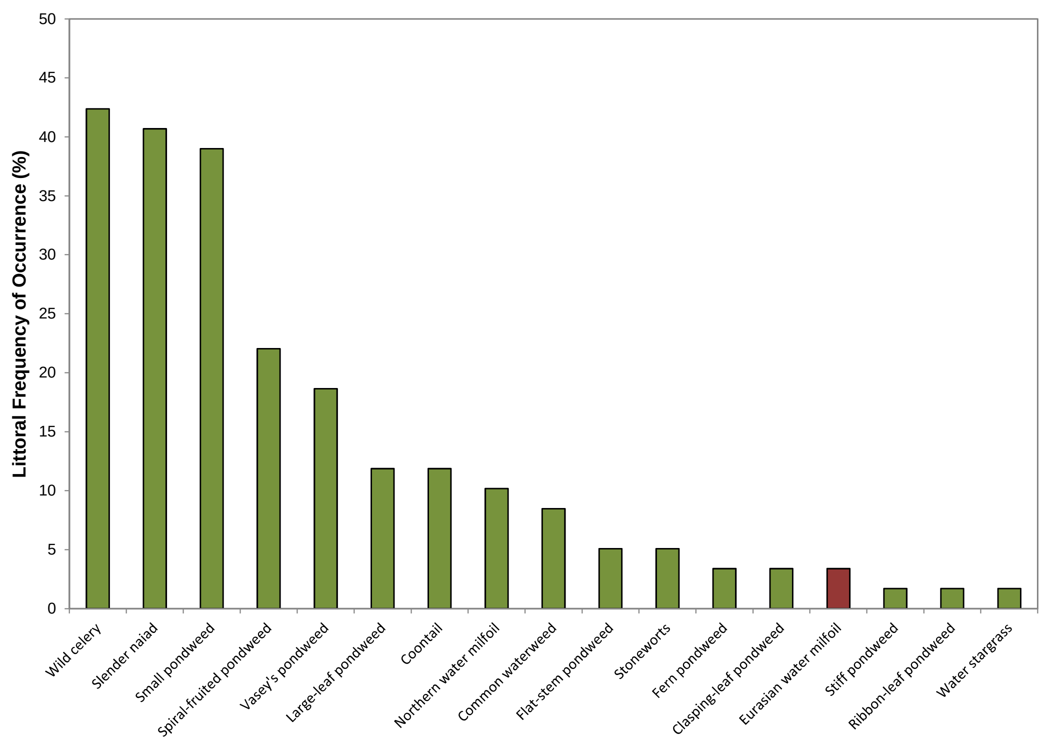


Figure 4.6-2. Otter Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

To determine if the 2008-2012 Eurasian water milfoil control project on Otter 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 4.6-3 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 Otter Lake.

As illustrated, the occurrence of Eurasian water milfoil in Otter Lake was found to be not statistically different from 2006 to 2012, and had a littoral occurrence of 6.2% in 2012 and 3.4% in 2006. Only one native aquatic plant species, common waterweed, exhibited a statistically valid decline in occurrence from 2006 to 2012 (Figure 4.6-3). Unlike Eurasian water milfoil, common waterweed is a monocot and was not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research by the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following the types of treatments that were conducted on Otter Lake. While Eurasian water milfoil treatments never exceeded 10 acres over the course of the Eurasian water milfoil control project, it is possible that the recurring spot treatments did impact the common waterweed population within the lake. Three native aquatic plant species saw statistically valid increases in their occurrence from 2006 to 2012, while the occurrence of seven native plant species was not statistically different (Figure 4.6-3).

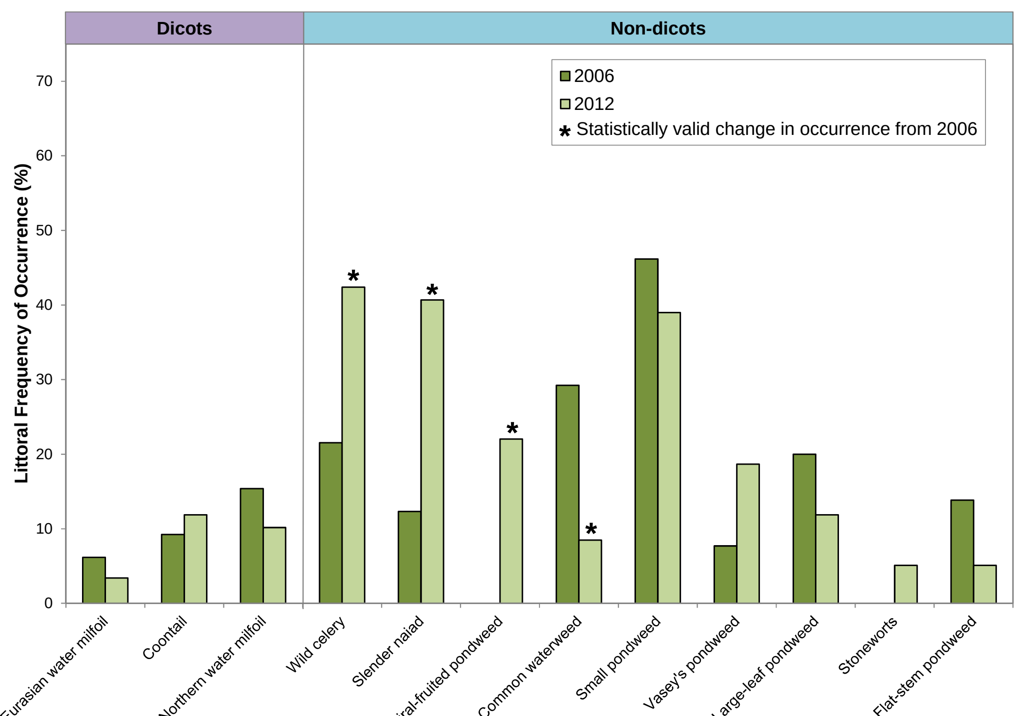


Figure 4.6-3. Otter Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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 of 17 native aquatic plant species were located in Otter Lake during the 2012 survey, 16 were encountered on the rake and one was incidentally located. These 16 native species and their conservatism values were used to calculate the FQI of Otter Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.6-4 compares the FQI components of Otter 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, while Otter Lake's native species richness (16) exceeded the median values for lakes within the ecoregion and the state, it had the lowest number of native species when compared to the other nine lakes in the Lower Eagle River Chain. As was discussed in the chain-wide section, Otter Lake has low shoreline complexity and a small littoral area, all which have been shown to be correlated with lower species richness.

The average conservatism value in 2012 (6.6) falls slightly below the ecoregional median but above the state median. Combining Otter Lake's 2012 native species richness and average conservatism values yields a high FQI value of 26.3, which exceeds both the ecoregional and state median values (Figure 4.6-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Otter Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Otter Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

As explained in the primer 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 Otter 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 Otter Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.6-5). Using the data collected form the 2012 point-intercept survey, Otter Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity value of 0.88, falling above the median value for lakes in both the ecoregion and the state. Otter Lake's 2012 diversity increased slightly from the diversity value of 0.86 calculated from data collected during the 2006 point-intercept survey.

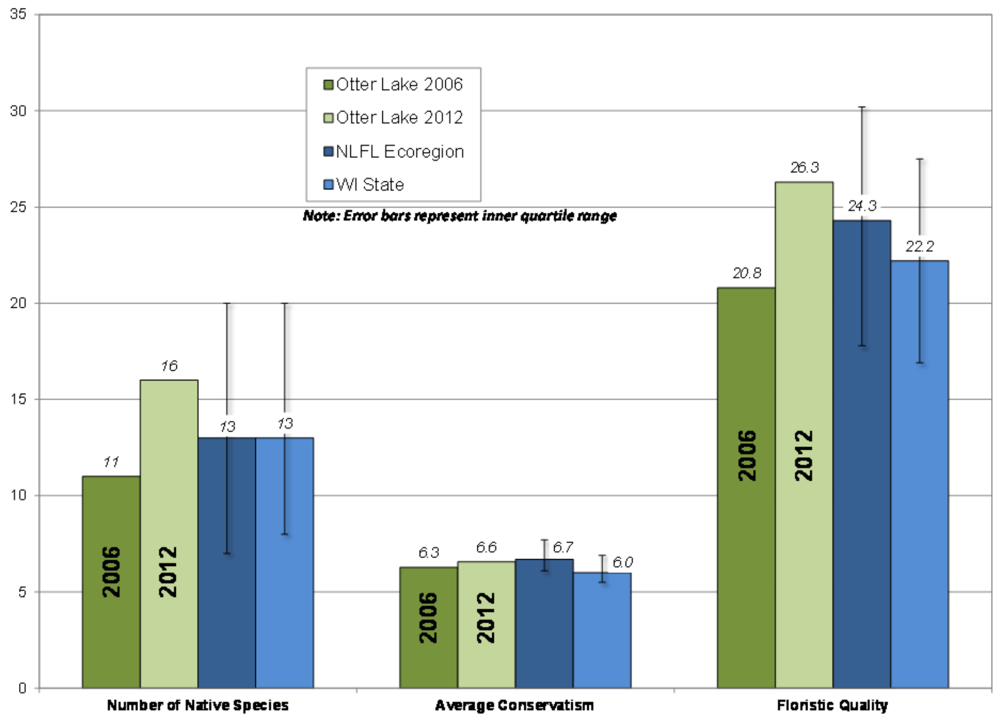


Figure 4.6-4. Otter Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

Figure 4.6-6 displays the relative frequency of occurrence of aquatic plant species in Otter 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.

The 2012 point-intercept survey on Otter Lake indicated that the 2008-2012 Eurasian water milfoil control program may have caused the decline observed in the lake's common waterweed population. However, it does not appear that any other native plant populations were impacted by the control program. The native species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012. A Eurasian water milfoil treatment did occur in 2012 and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).

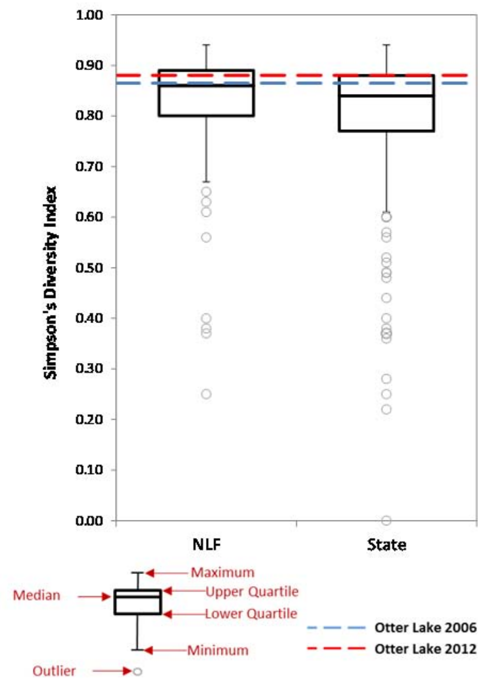


Figure 4.6-5. Otter Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

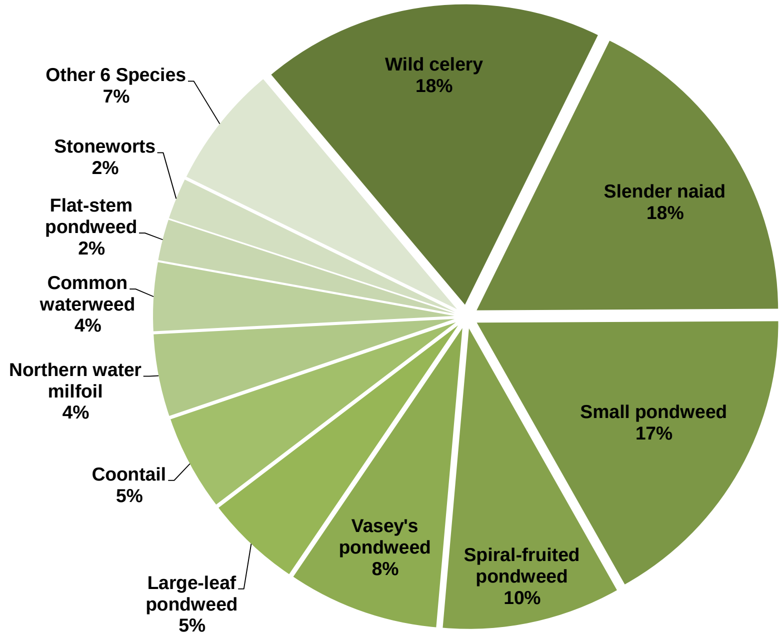
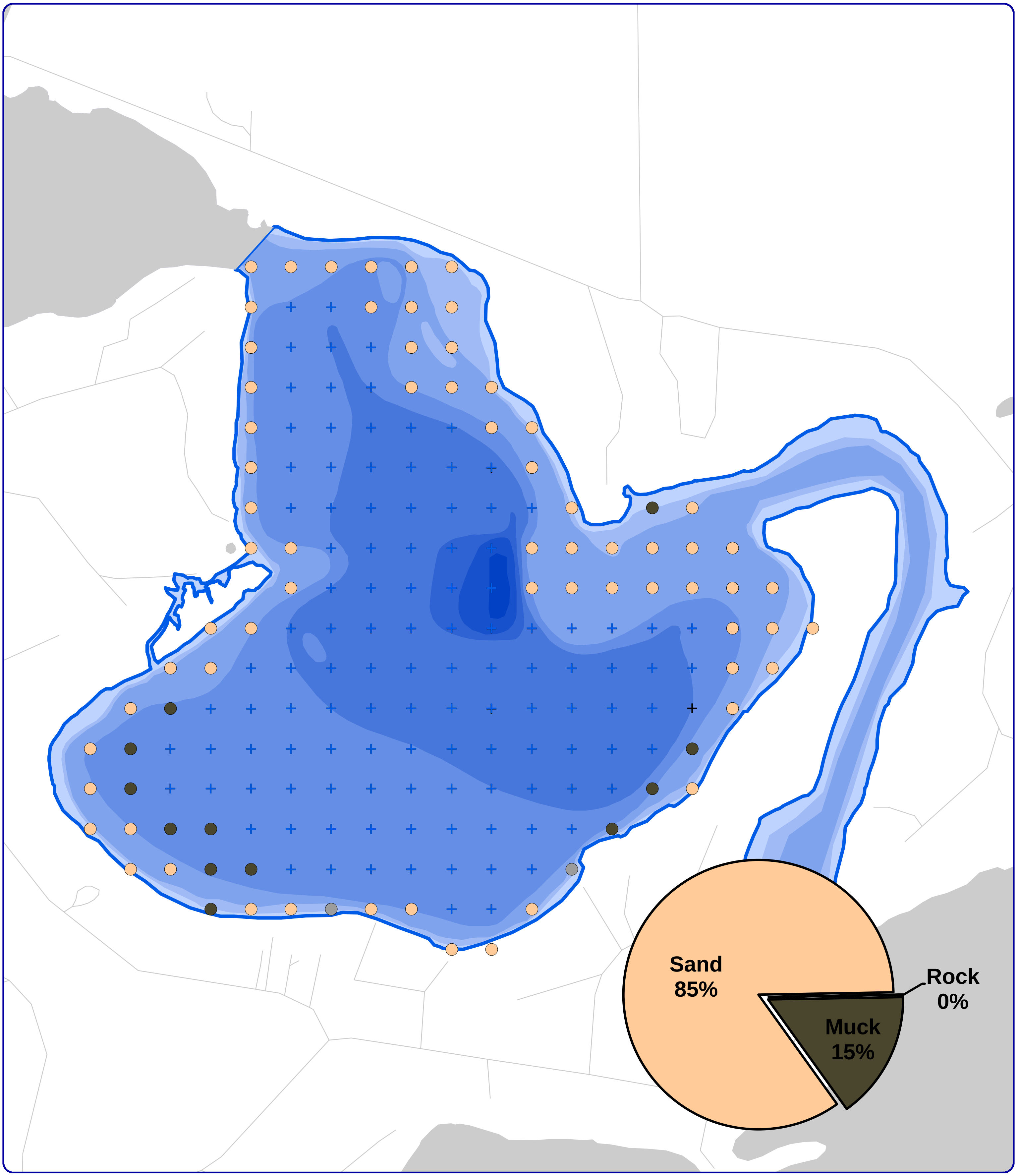


Figure 4.6-6. Otter Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.



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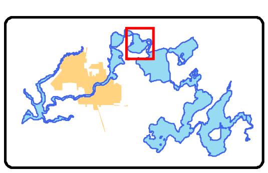
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Otter1_SubstratePI.mxd



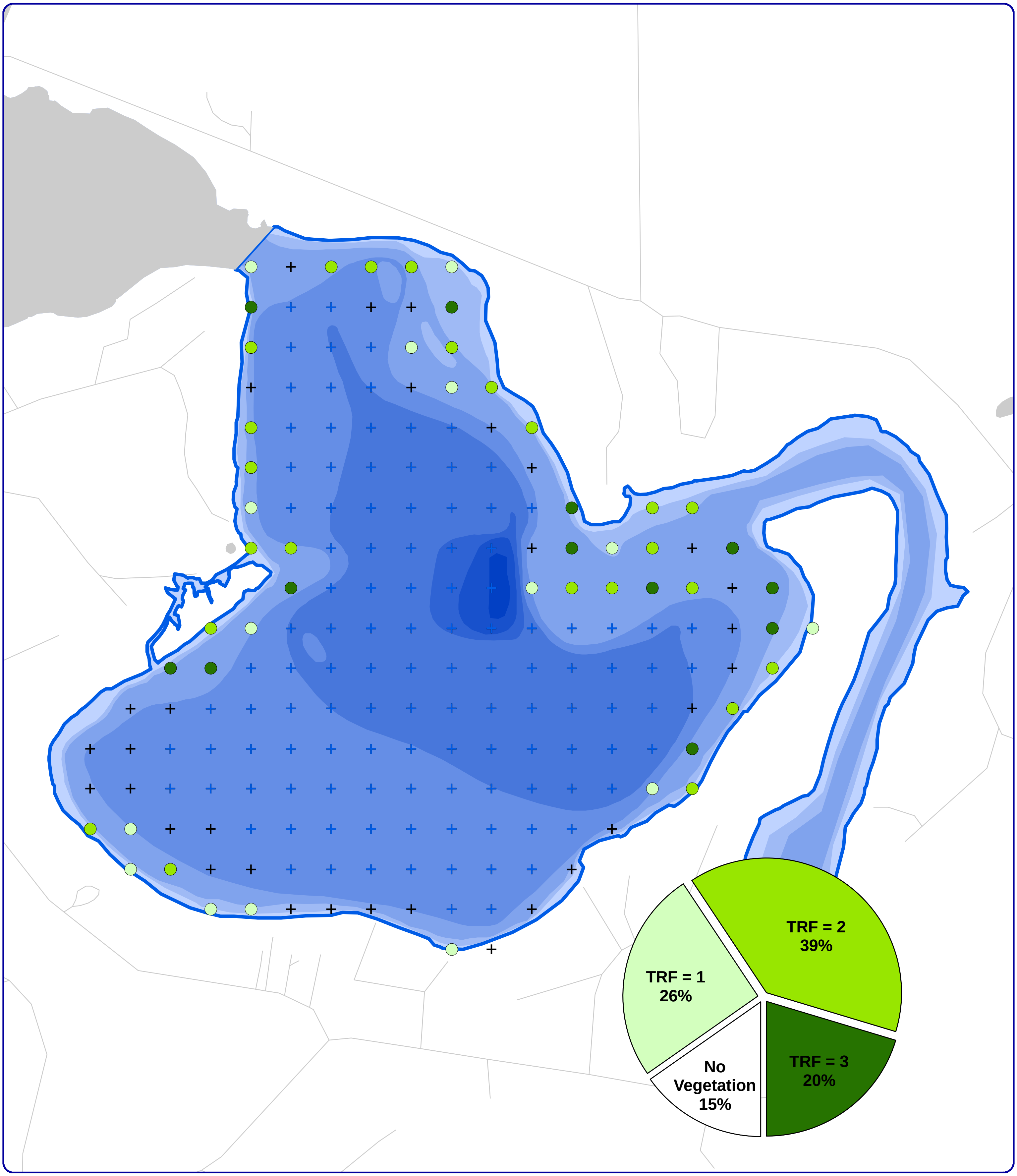
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

Otter 1
Otter Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types



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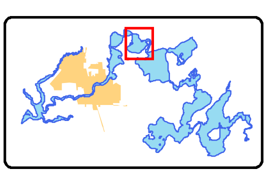
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Otter2_TRFPI.mxd



Extent of large map shown in red.

Legend

Total rake-fullness = 1	No Vegetation
Total rake-fullness = 2	Too Deep
Total rake-fullness = 3	Non-navigable

Otter 2
Otter Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.7 Lynx Lake

The whole-lake aquatic plant point-intercept survey was conducted on Lynx Lake by Onterra on August 2, 2012 (Figure 4.7-1). During this survey, a total of 20 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.7-1). 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.

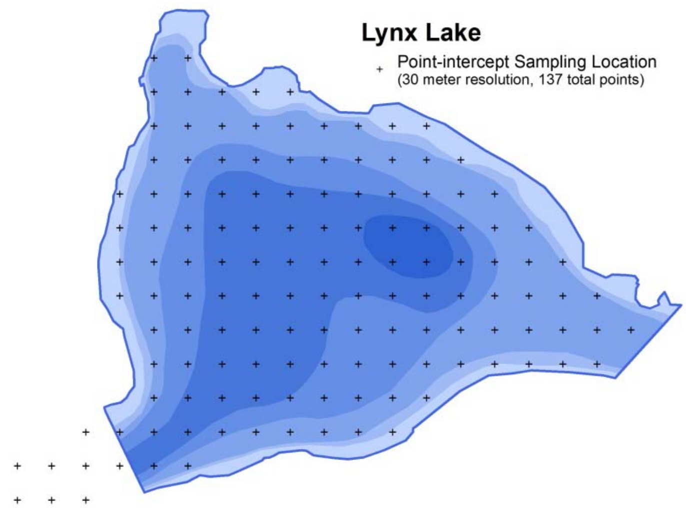


Figure 4.7-1. Point-intercept locations on Lynx Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Lynx-1 illustrates, 98% of the point-intercept locations within littoral areas contained sand, 2% contained fine, organic sediments (muck), and no sampling locations contained rock. The only littoral sampling locations that contained muck were located in bay in the northwestern portion of the lake (Map Lynx-1). 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 11 feet, which was slightly higher than the 9 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 78 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 65% contained aquatic vegetation. This is higher than what was found in the 2006 survey where approximately 42% of the littoral sampling locations contained aquatic vegetation. Map Lynx-2 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 near-shore areas around the lake. Nineteen percent of the point-intercept locations had a total rake-fullness rating of 1, 27% had a total rake-fullness rating of 2, and 36% 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 4.7-1 displays the aquatic plant species located in Lynx Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 except for cattail spp. were re-recorded in 2012. Cattails are still present within the emergent plant communities in Lynx Lake, they were just not present at any of the sampling locations in 2012. An additional six native aquatic plant species were located during the 2012 survey that were not recorded in 2006.

Table 4.7-1. Aquatic plant species located in Lynx Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Sparganium eurycarpum*	Common bur-reed	5		X
	Typha spp.	Cattail spp.	1	X	
FL	*Nuphar variegata*	Spatterdock	6		X
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	I
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8		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
	Vallisneria americana	Wild celery	6	X	X

E = Emergent, FL = Floating Leaf
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*

Of the 19 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, slender naiad, wild celery, spiral-fruited pondweed, and small pondweed were the four-most frequently encountered (Figure 4.7-2). Slender naiad, the most abundant aquatic plant in Lynx Lake in 2012 with a littoral occurrence of approximately 46%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 41%. This species 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).

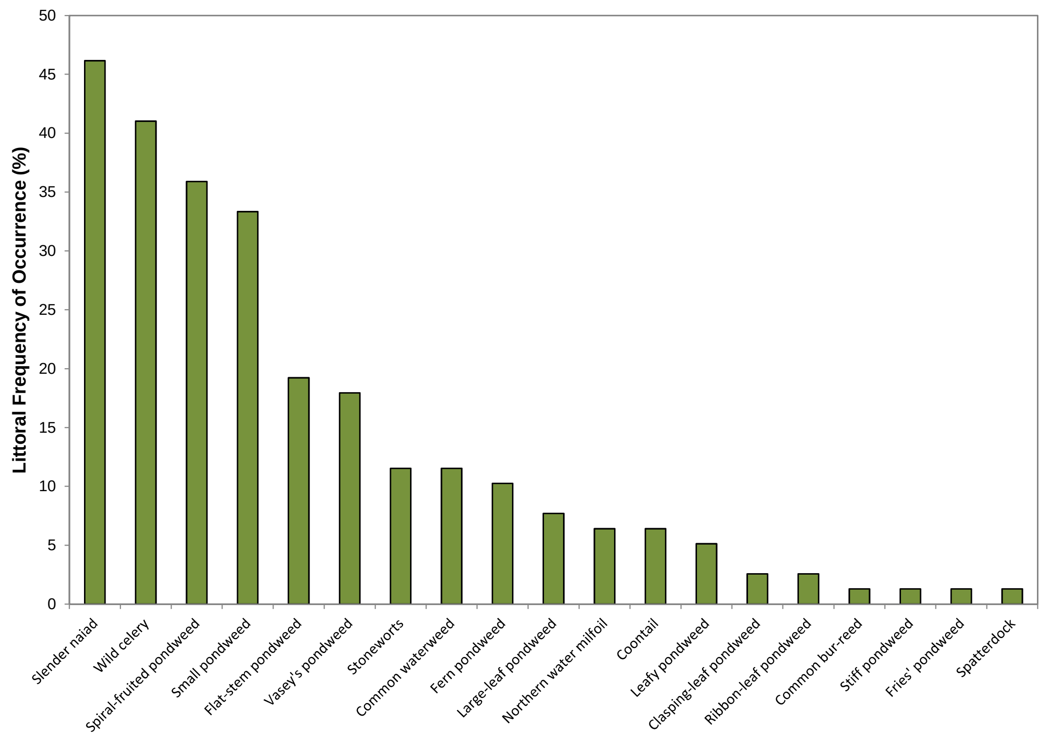


Figure 4.7-2. Lynx Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Spiral-fruited pondweed was the third-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 36%. As its name indicates, it produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Spiral-fruited pondweed is food and habitat source for wildlife.

Small pondweed was the fourth-most abundant aquatic plant encountered in Eagle Lake in 2012, with a littoral occurrence of approximately 33%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin, and one of four narrow-leaved pondweeds located in Lynx Lake in 2012. Its long, narrow submersed leaves provide excellent structural habitat for aquatic organisms.

Vasey's pondweed was the sixth-most frequently encountered aquatic plant species in 2012. As mentioned previously, 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 submersed leaves. It also produces floating leaves, which can be seen at the surface in shallow water . The occurrence of Vasey's pondweed within Lynx Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Lynx 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 4.7-3 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 Lynx Lake.

As illustrated, the occurrence of Eurasian water milfoil in Lynx Lake decreased by a statistically valid 100%, from 8.7% in 2006 to 0% in 2012. While Eurasian water milfoil was not recorded at any of the sampling locations during the 2012 point-intercept survey, it is still present in very low abundance in Lynx Lake. Two native aquatic plant species, coontail and common waterweed, exhibited statistically valid reductions in their occurrence from 2006 to 2012 (Figure 4.7-3). Coontail, like Eurasian water milfoil, is a dicot and is susceptible to the herbicide treatments conducted on Lynx Lake. Unlike Eurasian water milfoil, common waterweed is a monocot and was not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research being conducted by the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following these treatments. Another native dicot, northern water milfoil, had a lower occurrence in 2012 than in 2006; however, statistical analysis indicates that its occurrence between 2006 and 2012 is not statistically different. Four native aquatic plant species saw statistically valid increases in their occurrence from 2006 to 2012, while six species did not see a statistically valid change between the two years.

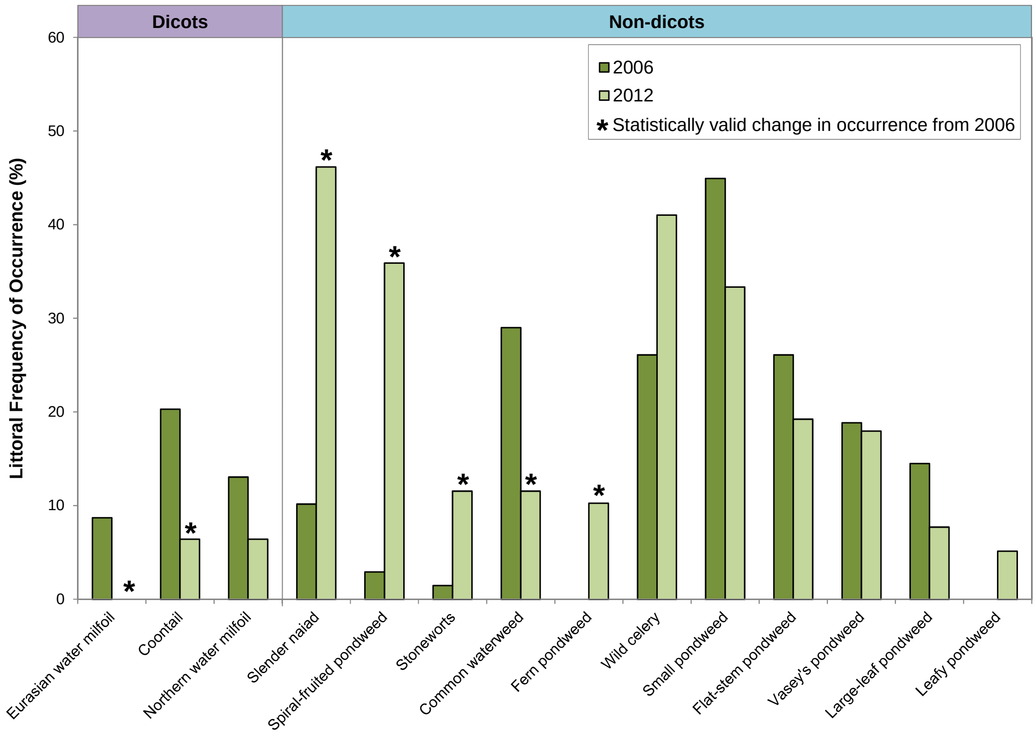


Figure 4.7-3. Lynx Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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. No incidental species were recorded in Lynx Lake in 2012, and the 19 native species located on the rake and their conservatism values were used to calculate the FQI of Lynx Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.7-4 compares the FQI components of Lynx 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, while Lynx Lake's native species richness (19) exceeded the median values for lakes within the ecoregion and the state, it had the third-lowest number of native species when compared to the other nine lakes in the Lower Eagle River Chain. As was discussed in the chain-wide section, Lynx Lake has low shoreline complexity and a small littoral area, all which have been shown to be correlated with lower species richness.

The average conservatism value in 2012 (6.5) falls slightly below the ecoregional median but above the state median. Combining Lynx Lake's 2012 native species richness and average conservatism values yields a high FQI value of 28.4, which exceeds both the ecoregional and state median values (Figure 4.7-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Lynx Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Lynx Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

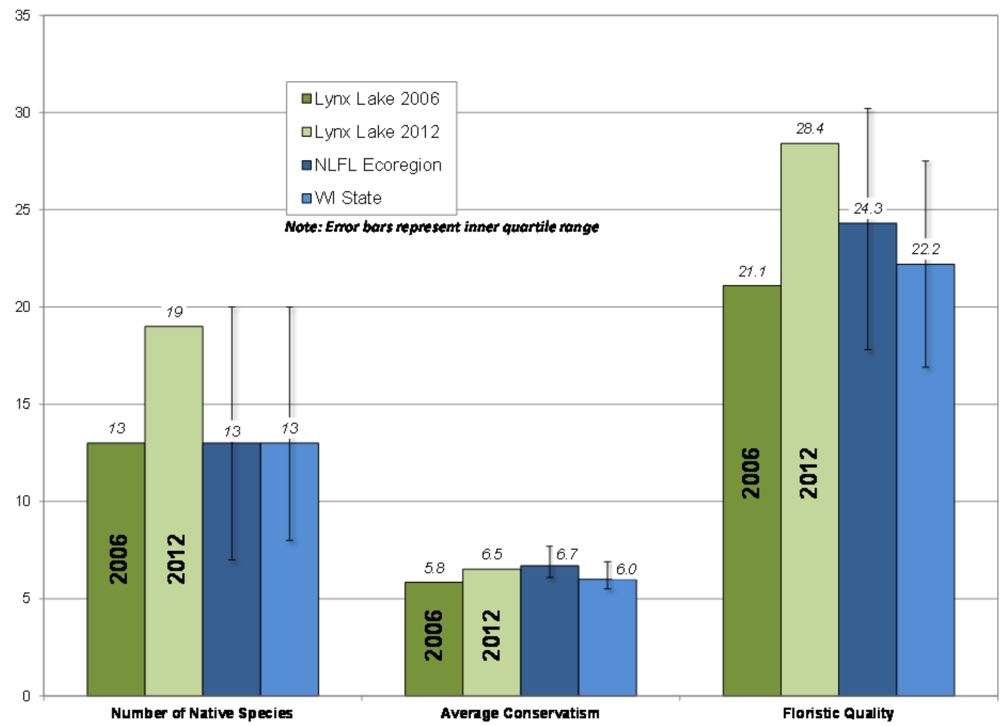


Figure 4.7-4. Lynx Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Lynx 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 Lynx Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLFL Ecoregion (Figure 4.7-5). Using the data collected form the 2012 point-intercept survey, Lynx Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity value of 0.89, falling above the median value for lakes in both the ecoregion and the state. Lynx Lake's 2012 diversity remained unchanged from the 2006 survey.

Figure 4.7-6 displays the relative frequency of occurrence of aquatic plant species in Lynx 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.

The 2012 point-intercept survey on Lynx Lake indicated that the 2008-2012 Eurasian water milfoil control program may have caused the decline observed in the lake's coontail and common waterweed populations. However, it does not appear that any other native plant populations were impacted by the control program. The native species richness, average conservatism, and Floristic Quality all increased from 2006 to 2012. A Eurasian water milfoil treatment did not occur in 2012.

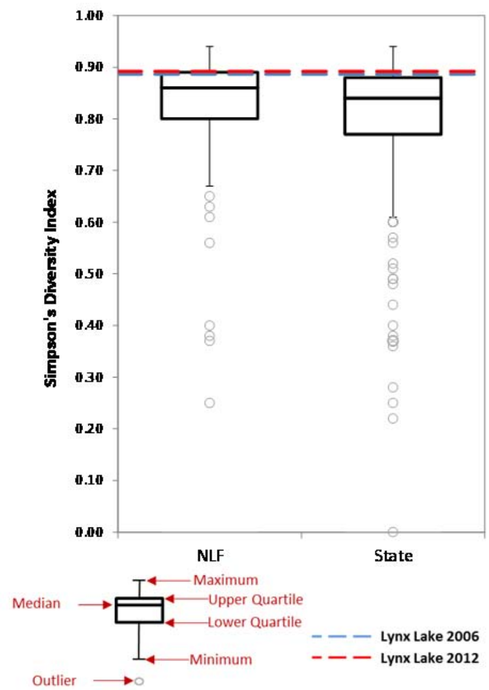


Figure 4.7-5. Lynx Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

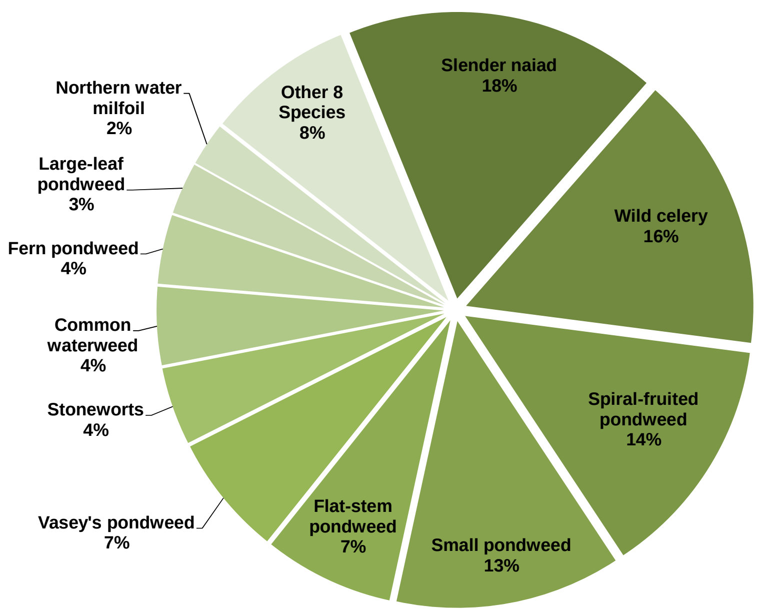
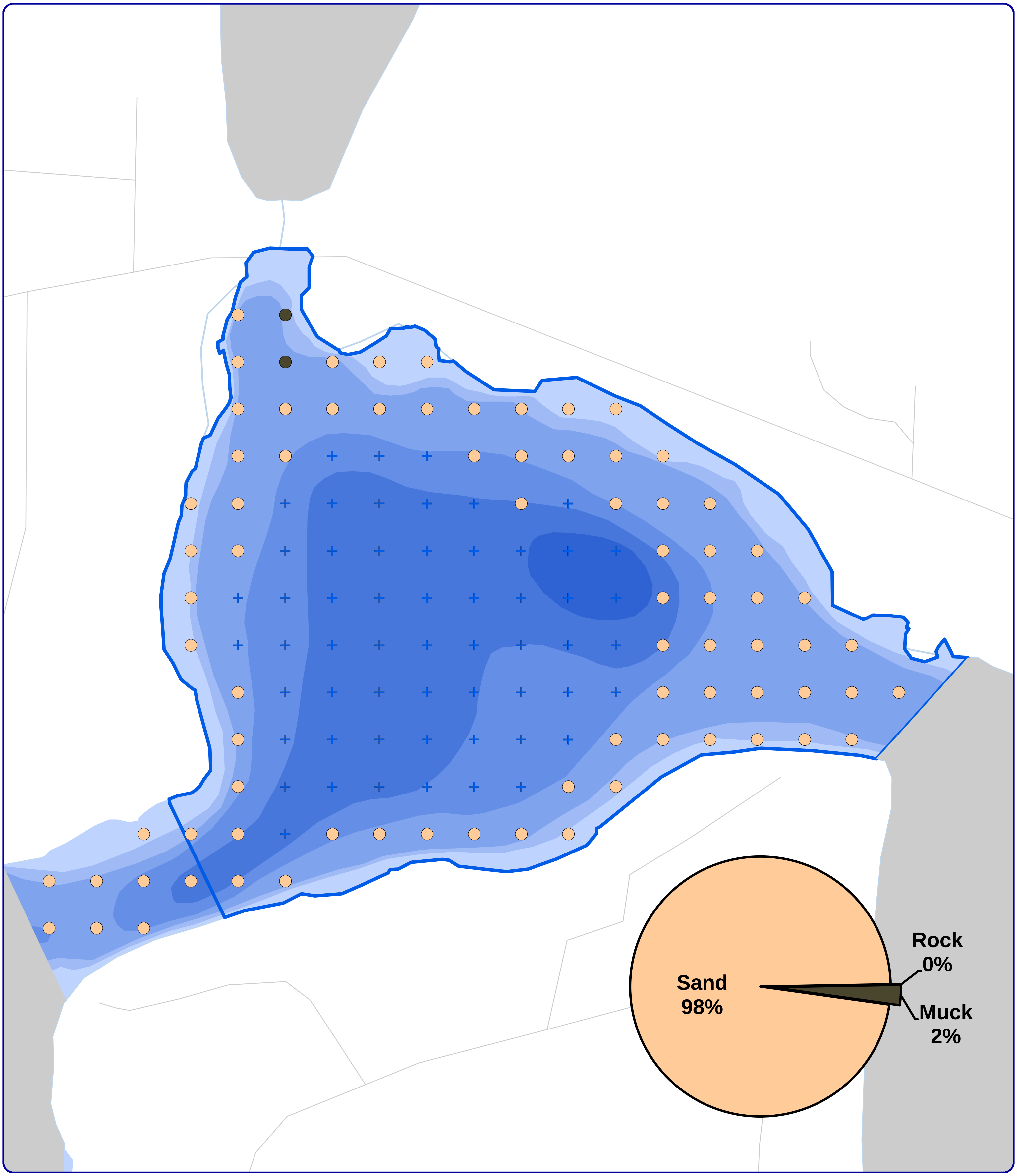


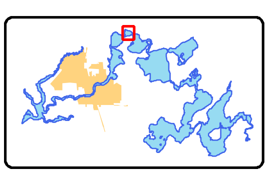
Figure 4.7-6. Lynx Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.



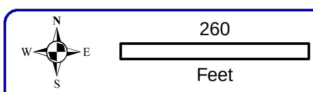
Lynx 1
Lynx Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types

Legend
- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable



Extent of large map shown in red.



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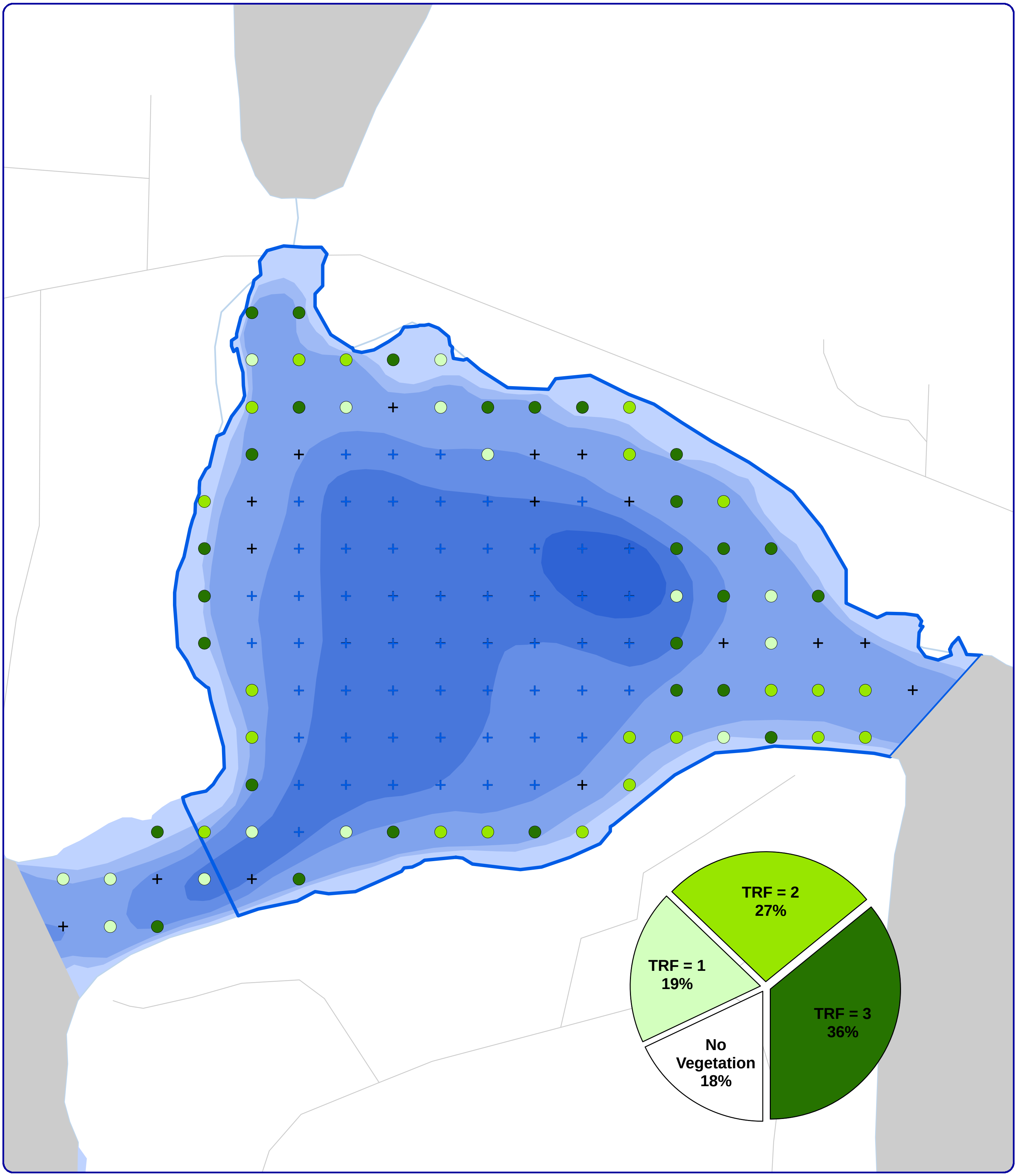
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Lynx1_SubstratePI.mxd



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
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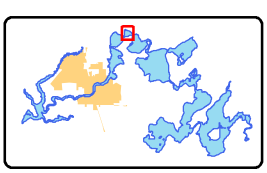

Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- + No Vegetation
- + Too Deep
- + Non-navigable

Lynx 2
Lynx Lake
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.8 Duck Lake

The whole-lake aquatic plant point-intercept survey was conducted on Duck Lake by Onterra on August 3, 2012 (Figure 4.8-1). During this survey, a total of 18 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.8-1). 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.

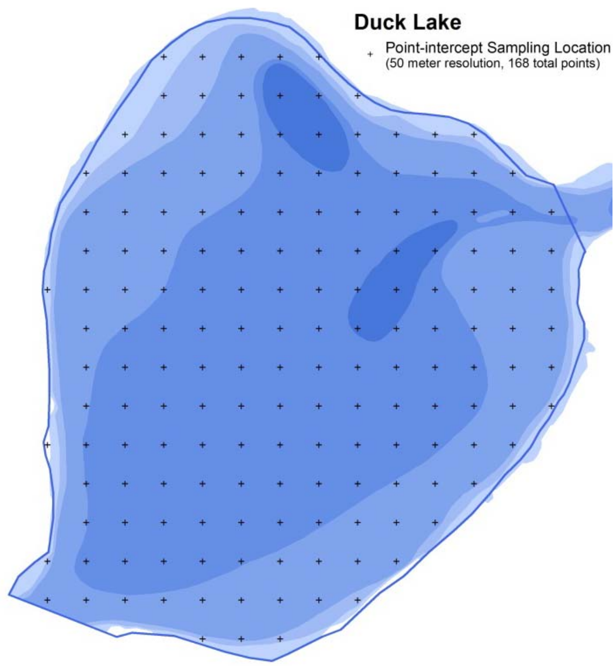


Figure 4.8-1. Point-intercept locations on Duck Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Duck-1 illustrates, 64% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 36% contained sand, and no sampling locations contained rock. The sampling locations with sand were located in shallower, near-shore areas, while areas of muck were located in deeper areas of the littoral zone (Map Duck-1). 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, which was slightly deeper than the 9 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 144 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 22% contained aquatic vegetation. This is lower than what was found in the 2006 survey where approximately 30% of the littoral sampling locations contained aquatic vegetation. Map Duck-2 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 near-shore areas around the lake. Six percent of the point-intercept locations had a total rake-fullness rating of 1, 9% had a total rake-fullness rating of 2, and 7% 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 4.8-1 displays the aquatic plant species located in Duck Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 were re-recorded in 2012. An additional seven native aquatic plant species were located during the 2012 survey that were not recorded in 2006.

Table 4.8-1. Aquatic plant species located in Duck Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Pontederia cordata*	Pickerelweed	9		X
FL	*Nymphaea odorata*	White water lily	6	X	X
	Nuphar variegata	Spatterdock	6		X
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6		X
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton foliosus	Leafy pondweed	6		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
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Vallisneria americana	Wild celery	6	X	X

E = Emergent, FL = Floating-leaf
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*

Of the 18 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, flat-stem pondweed, small pondweed, and Vasey's pondweed were the four-most frequently encountered (Figure 4.8-2). Wild celery, or tape grass, was the most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 12.5%. This species 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 frequently encountered aquatic plant in Duck Lake in 2012 with an occurrence of 11%. It is one of many pondweed species found in Wisconsin, and as its name indicates, has a conspicuously flattened stem. It possesses long, linear leaves, and when growing in large beds, provides excellent structural habitat for aquatic organisms. Its foliage and fruit also provide food to waterfowl, mammals, and other wildlife (Borman et al. 1997).

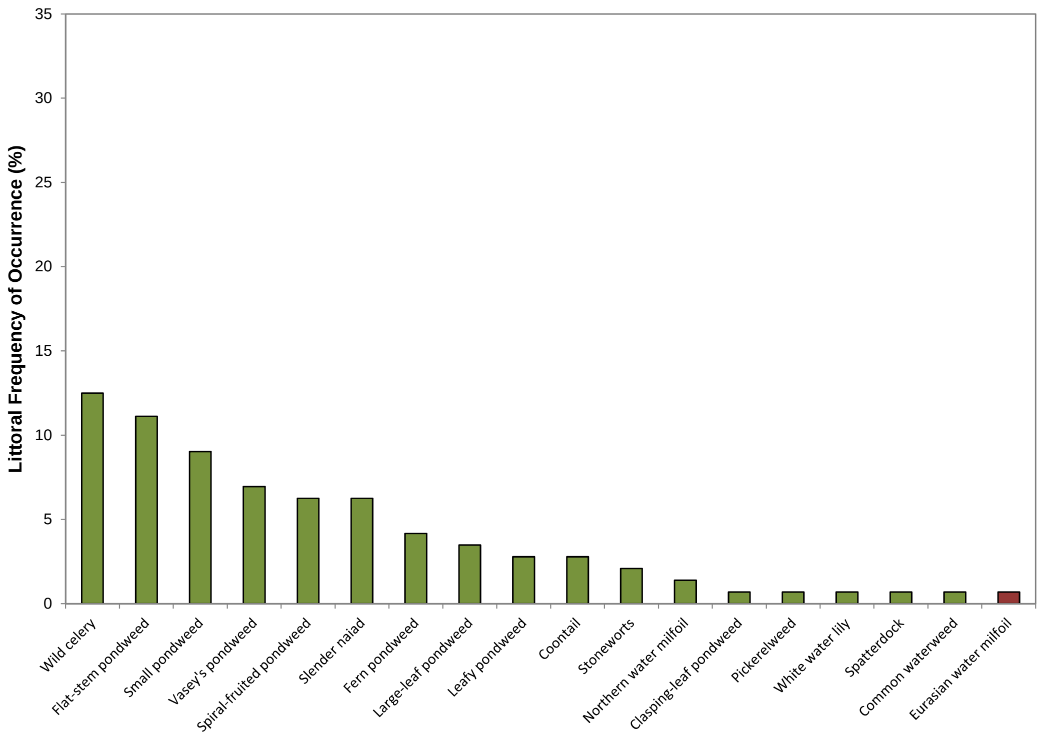


Figure 4.8-2. Duck Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Small pondweed was the third-most abundant aquatic plant encountered in Eagle Lake in 2012, with a littoral occurrence of approximately 9%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin, and one of four narrow-leaved pondweeds located in Duck Lake in 2012. Its long, narrow submersed leaves provide excellent structural habitat for aquatic organisms.

Vasey's pondweed was the fourth-most frequently encountered aquatic plant species in 2012 with an occurrence of 7%. As mentioned previously, 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 submersed leaves. It also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Duck Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Duck 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 4.8-3 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 Duck Lake.

As illustrated, the occurrence of Eurasian water milfoil in Duck Lake decreased by a statistically valid 87%, from 5.3% in 2006 to 0.7% in 2012. Five native aquatic plant species also exhibited statistically valid reductions in their occurrence from 2006 to 2012. Like Eurasian water milfoil, coontail and northern water milfoil are dicots and susceptible to the herbicide treatments that occurred on Duck Lake. Unlike Eurasian water milfoil, flat-stem pondweed, small pondweed, and common waterweed are monocots, which were not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research by the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following these herbicide treatments. Two native plant species, slender naiad and spiral-fruited pondweed, that were not located in 2006 saw statistically valid increases in their occurrence in 2012. The occurrences of four other native aquatic plant species were not statistically different from 2006 to 2012 (Figure 4.8-3).

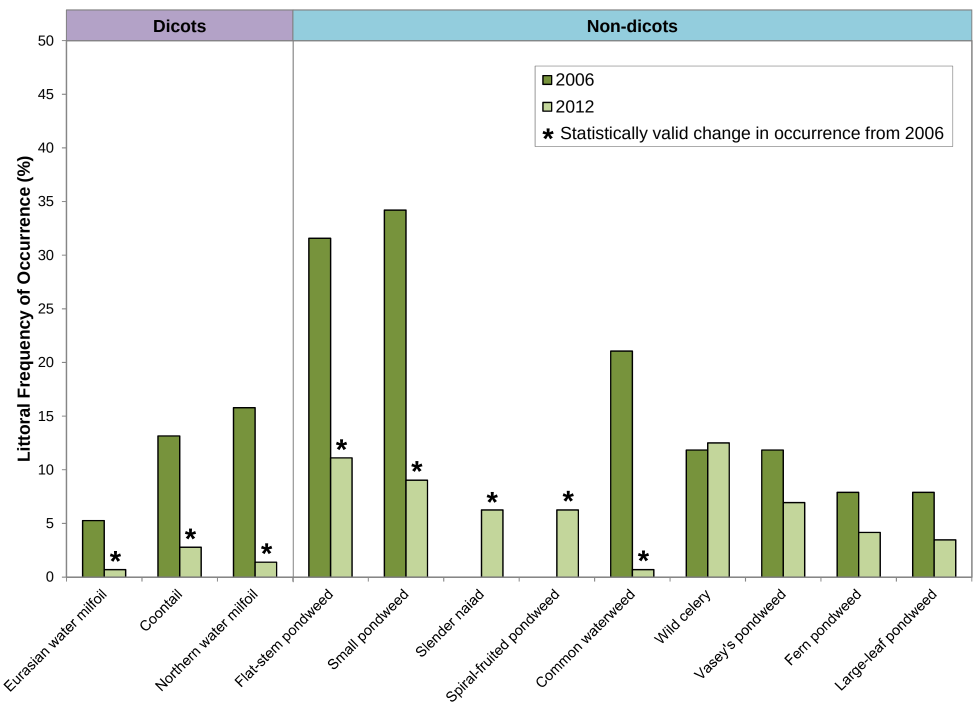


Figure 4.8-3. Duck Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept 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. No incidental species were recorded in Duck Lake in 2012, and the 17 native species located on the rake and their conservatism values were used to calculate the FQI of Duck 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 = Average Coefficient of Conservatism * √Number of Native Species

Figure 4.8-4 compares the FQI components of Duck 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, while Duck Lake's native species richness (17) exceeded the median values for lakes within the ecoregion and the state, it had the second-lowest number of native species when compared to the other nine lakes in the Lower Eagle River Chain. As was discussed in the chain-wide section, Duck Lake has low shoreline complexity and a small littoral area, all which have been shown to be correlated with lower species richness.

The average conservatism value in 2012 (6.5) falls slightly below the ecoregional median but above the state median. Combining Duck Lake's 2012 native species richness and average conservatism values yields a high FQI value of 26.7, which exceeds both the ecoregional and state median values (Figure 4.8-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Duck Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Duck Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

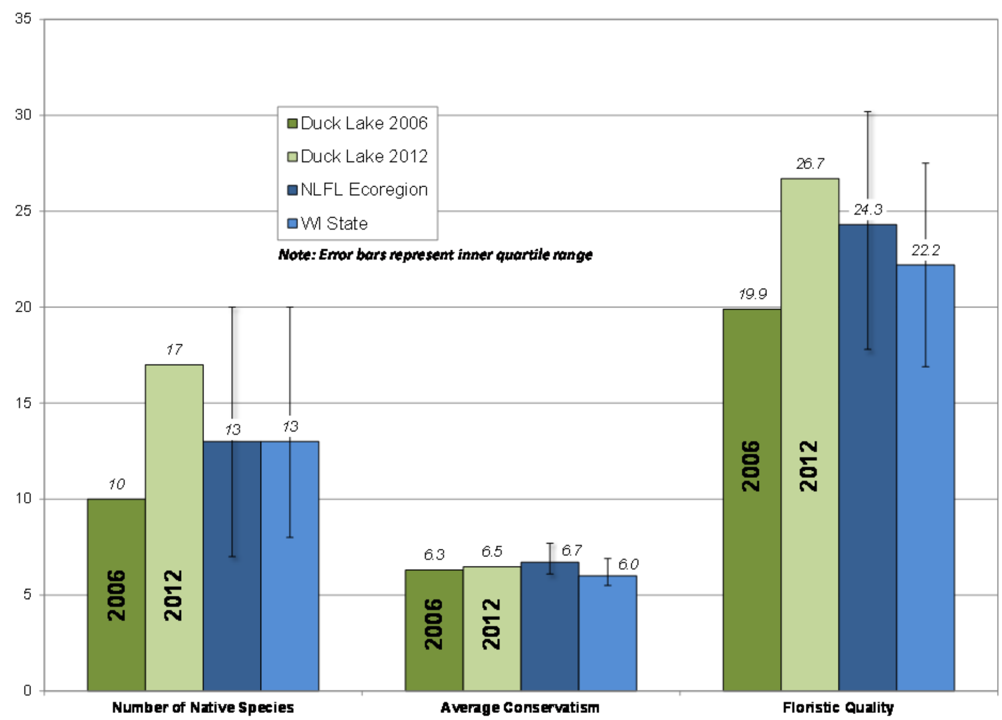


Figure 4.8-4. Duck Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer 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 Duck 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.

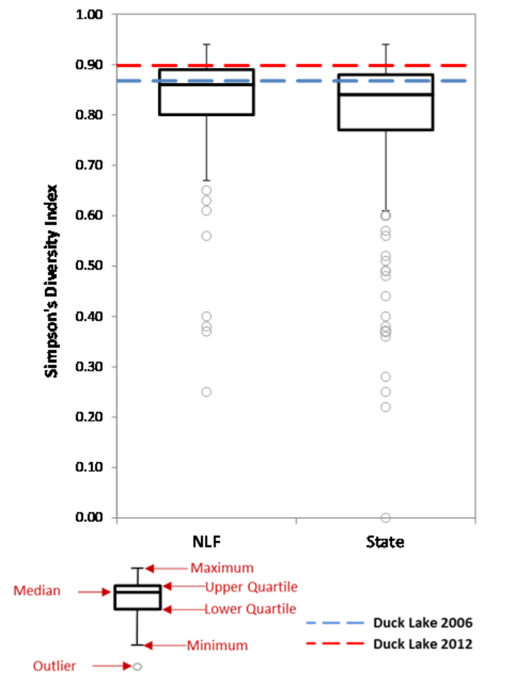


Figure 4.8-5. Duck Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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 Duck Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.8-5). Using the data collected form the 2012 point-intercept survey, Duck Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity value of 0.90, falling above the median value for lakes in both the ecoregion and the state. Duck Lake's 2012 diversity increased from a value of 0.87 calculated from the data collected in 2006.

Figure 4.8-6 displays the relative frequency of occurrence of aquatic plant species in Duck 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.

The 2012 point-intercept survey on Duck Lake indicated that the 2008-2012 Eurasian water milfoil control program may have caused the decline observed in the lake's coontail, northern water milfoil, flat-stem pondweed, small pondweed, and common waterweed populations. While the occurrence of these species declines, the Floristic Quality Analysis indicates that the quality of the aquatic plant community as a whole was not diminished; native species richness, average conservatism, Floristic Quality, and diversity all increased from 2006 to 2012. The decline of Eurasian water milfoil is an indicator that the 2008-2012 control program has been successful at reducing and maintaining a small Eurasian water milfoil population. A Eurasian water milfoil treatment did not occur in 2012 on Duck Lake.

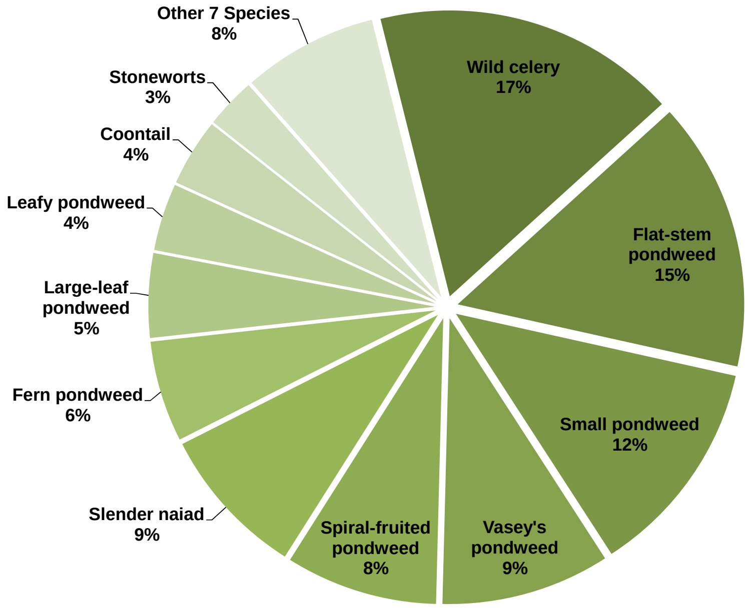
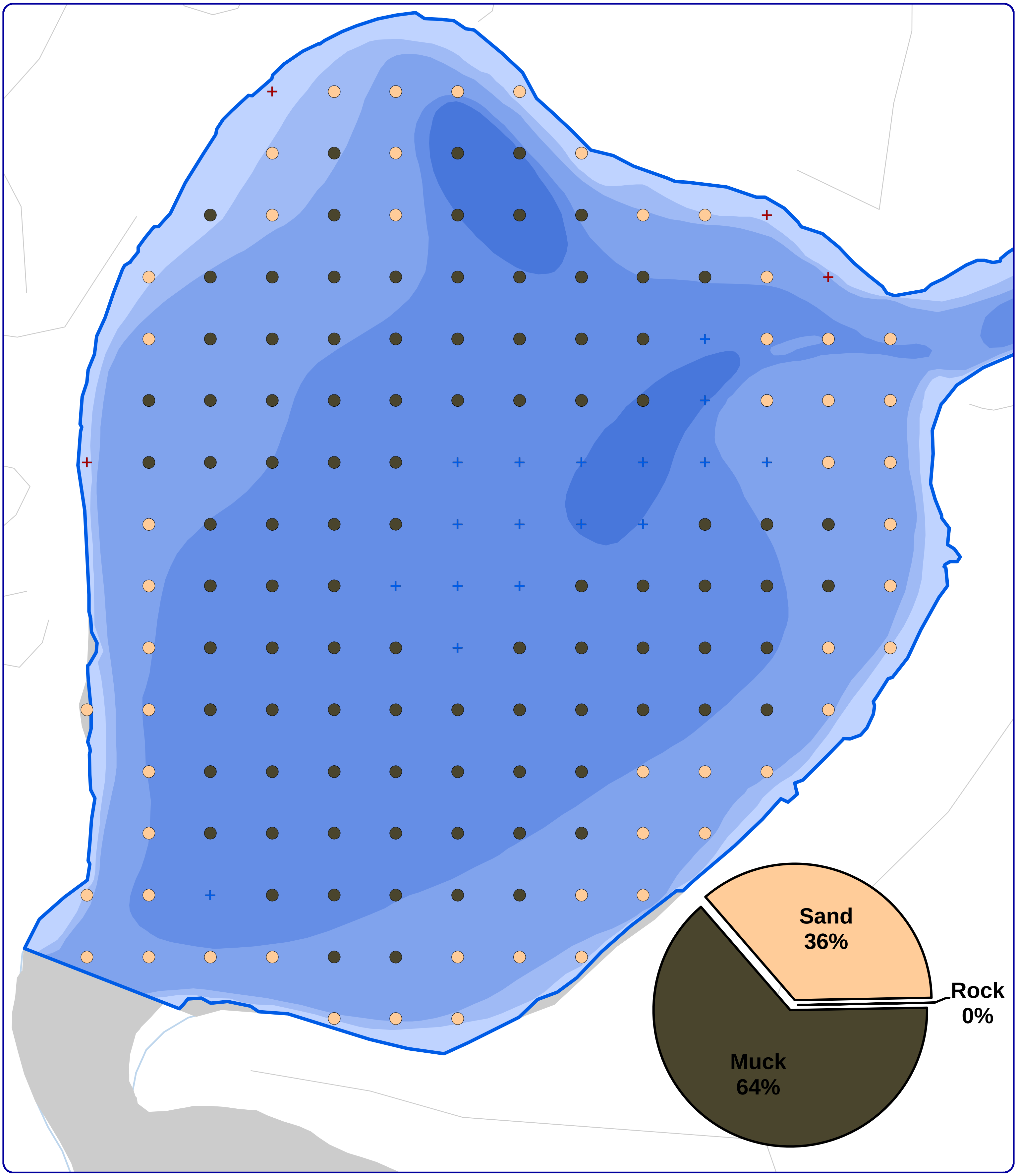
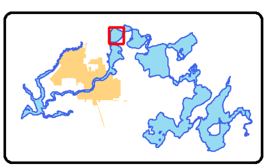


Figure 4.8-6. Duck Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.




Extent of large map shown in red.

Legend

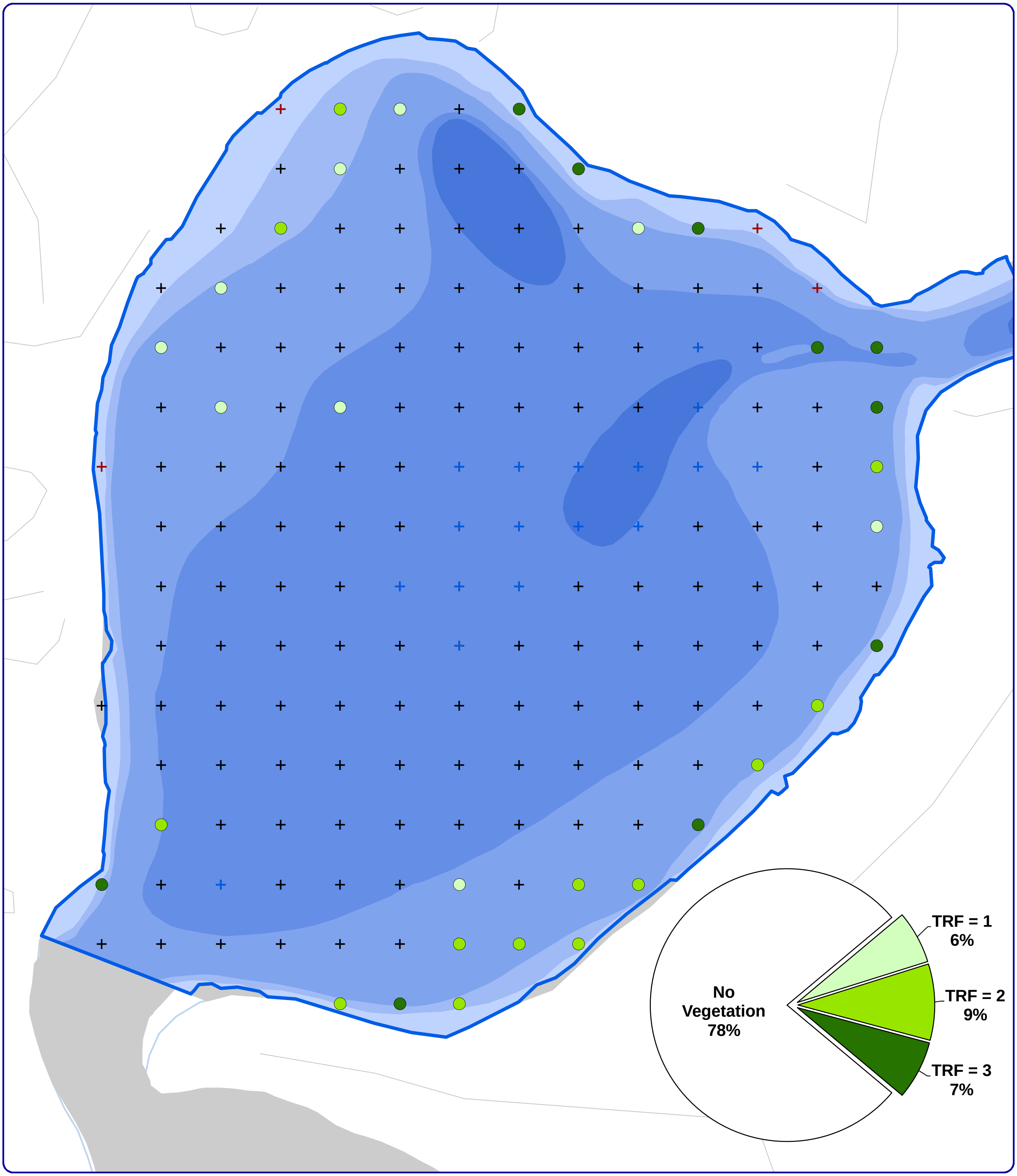
- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

Duck 1
Duck Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Duck1_SubstratePI.mxd



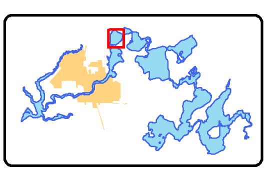
N
W E
S

350

Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Duck2_TRFPI.mxd



Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Duck 2

Duck Lake

Vilas County, Wisconsin

2012 PI Survey: Aquatic Plant Distribution

4.9 Yellow Birch Lake

The whole-lake aquatic plant point-intercept survey was conducted on Yellow Birch Lake by Onterra on August 3 and 6, 2012 (Figure 4.9-1). During this survey, a total of 19 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.9-1). 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.

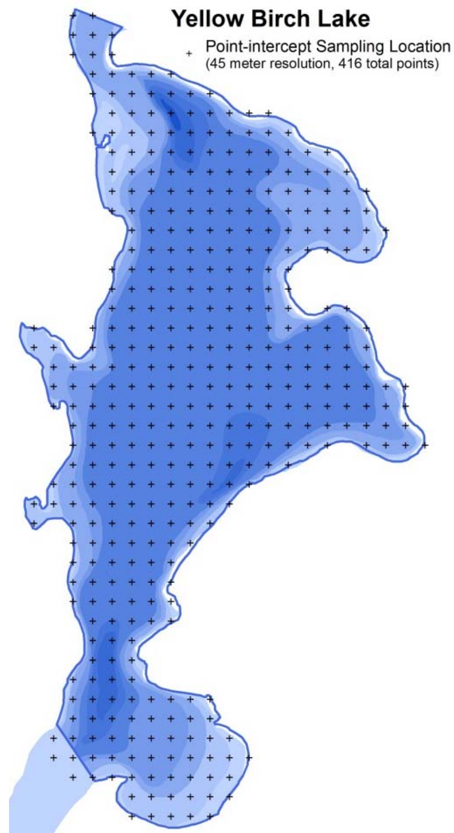


Figure 4.9-1. Point-intercept locations on Yellow Birch Lake.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Yellow Birch-1 illustrates, 63% of the point-intercept locations within littoral areas contained sand, 25% contained fine, organic sediments (muck), and 12% contained rock. The sampling locations with sand were located in shallower, near-shore areas, while areas of muck were located in deeper areas of the littoral zone (Map YBL-1). 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 10 feet, which was slightly shallower than the 12 feet recorded in 2005. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 148 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 50% contained aquatic vegetation. This is higher than what was found in the 2005 survey where approximately 26% of the littoral sampling locations contained aquatic vegetation. Map YBL-2 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 near-shore areas around the lake. Twenty-two percent of the point-intercept locations had a total rake-fullness rating of 1, 11% had a total rake-fullness rating of 2, and 17% had the highest total rake-fullness rating of 3. Total rake-fullness ratings were not recorded during the 2005 survey, so a comparison cannot be made.

Table 4.9-1 displays the aquatic plant species located in Yellow Birch Lake during the Onterra 2005 and 2012 point-intercept surveys. Cattail spp., narrow-leaf bur-reed, muskgrasses, water stargrass, large-leaf pondweed, and turion duckweed that were located in 2005 were not recorded during the 2012 survey. Four native aquatic plant species that were not recorded in 2005 were recorded in 2012.

Table 4.9-1. Aquatic plant species located in Yellow Birch Lake during 2005 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2005 (Onterra)	2012 (Onterra)
E	*Typha spp.*	Cattail spp.	1	X	
FL	*Nymphaea odorata*	White water lily	6	X	X
	Nuphar variegata	Spatterdock	6	X	X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	X	
	Sparganium emersum	Short-stemmed bur-reed	8	X	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	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
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Vallisneria americana	Wild celery	6	X	X
FF	*Lemna turionifera*	Turion duckweed	2	X	

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

Of the 18 aquatic plant species recorded on the rake during the 2012 point-intercept survey, Vasey's pondweed, slender naiad, wild celery, and fern pondweed the four-most frequently encountered (Figure 4.9-2). Vasey's pondweed was the most frequently encountered aquatic plant species in 2012 with an occurrence of 21%. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. It has very fine submersed leaves and also produces floating leaves which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Yellow Birch Lake is an indicator of a high-quality environment.

Slender naiad, the second-most abundant aquatic plant in Yellow Birch Lake in 2012 with a littoral occurrence of nearly 18%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 16%. This species 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).

Fern pondweed was the fourth-most abundant plant in Yellow Birch Lake in 2012 with a littoral occurrence of approximately 14%. As its name suggests, has the appearance of a fern's leaf and is a common pondweed found in lakes in northern Wisconsin. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish.

To determine if the 2008-2012 Eurasian water milfoil control project on Yellow Birch 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 2005 to 2012. Figure 4.9-3 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 Yellow Birch Lake.

As illustrated, the occurrence of Eurasian water milfoil (2%) in Yellow Birch Lake in 2012 was not found to be statistically different from its occurrence in 2005 (4.8%). Only one native aquatic plant species, common waterweed, exhibited a statistically valid reduction in occurrence from 2005 to 2012. Unlike Eurasian water milfoil, common waterweed is a monocot, which and was not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. Eight native aquatic plant species, including two dicots, saw statistically valid increases in their occurrences from 2005 to 2012, while the occurrences of two native species were not statistically different (Figure 4.9-3).

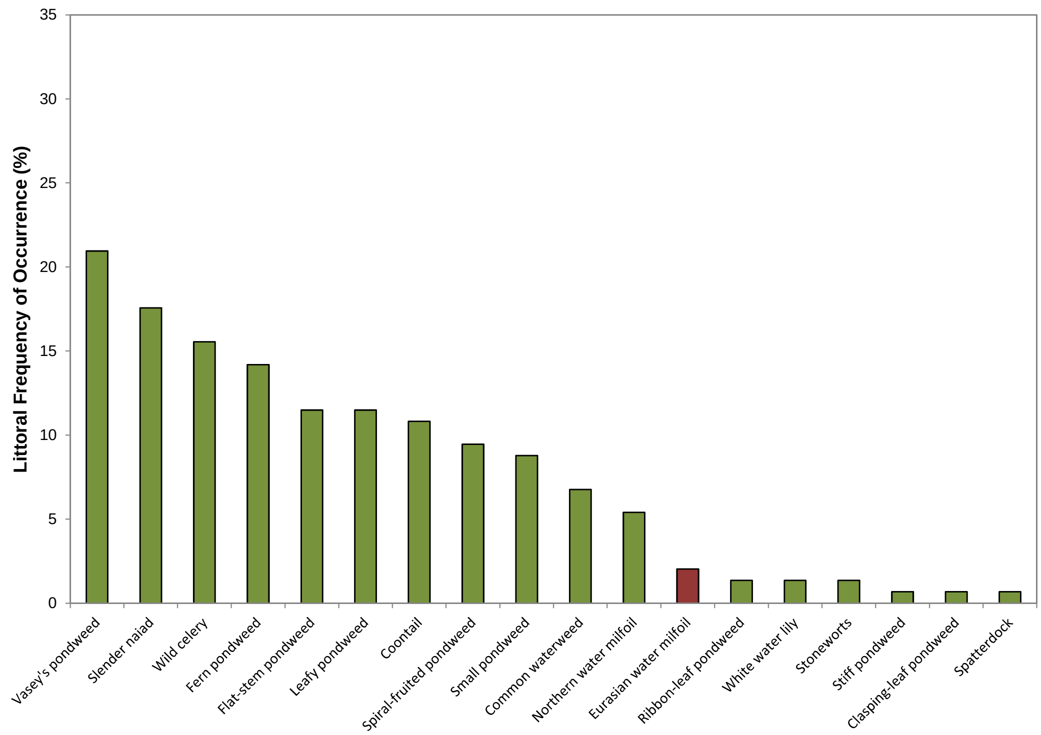


Figure 4.9-2. Yellow Birch Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

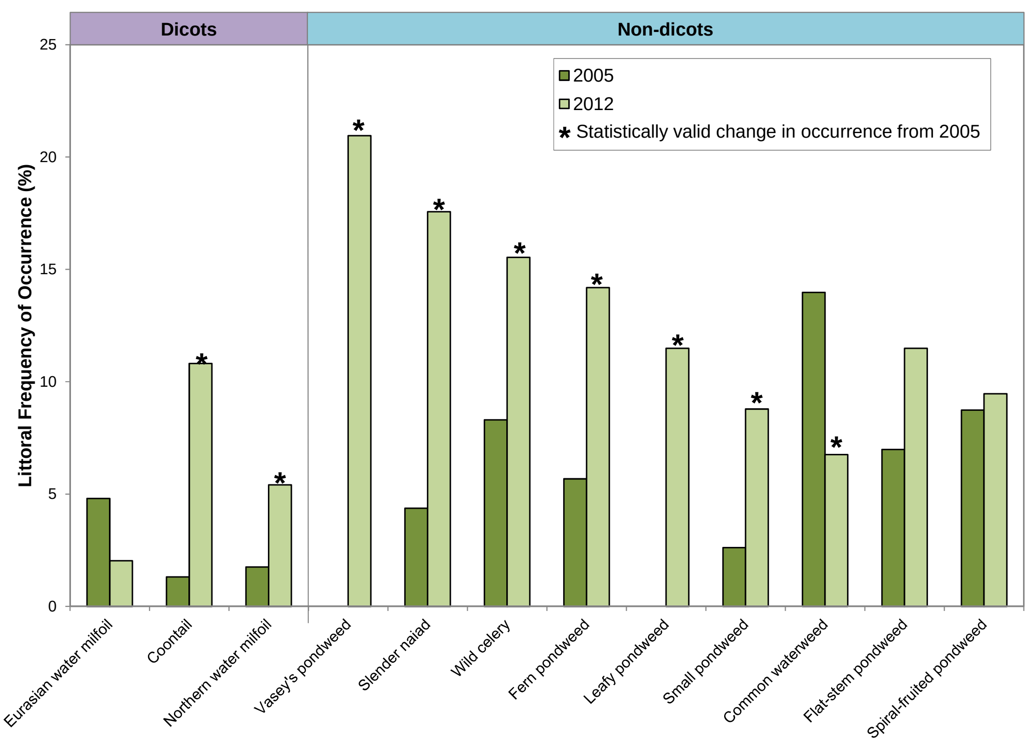


Figure 4.9-3. Yellow Birch Lake littoral frequency of occurrence of select aquatic plant species from 2005 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2005 and 2012 point-intercept 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 of 18 native aquatic plant species were located during the 2012 survey, 17 were recorded on the rake and one was incidentally located. The 17 native species located on the rake and their conservatism values were used to calculate the FQI of Yellow Birch Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2005 survey.

FQI = Average Coefficient of Conservatism * √Number of Native Species

Figure 4.9-4 compares the FQI components of Yellow Birch Lake from the 2005 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, while Yellow Birch Lake's native species richness (17) exceeded the median values for lakes within the ecoregion and the state, it had the second-lowest number of native species when compared to the other nine lakes in the Lower Eagle River Chain. As was discussed in the chain-wide section, although Yellow Birch Lake has relatively high shoreline complexity, it has a small littoral area; most of the lake is too deep to support aquatic plant growth.

The average conservatism value in 2012 (6.5) falls slightly below the ecoregional median but above the state median. Combining Yellow Birch Lake's 2012 native species richness and average conservatism values yields a high FQI value of 26.7, which exceeds both the ecoregional and state median values (Figure 4.9-4). The FQI values from 2012 were very similar to those calculated from data collected in 2005, indicating that the quality of Yellow Birch Lake's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Yellow Birch Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

As explained in the primer 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 Yellow Birch 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 Yellow Birch Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.9-5). Using the data collected form the 2012 point-intercept survey, Yellow Birch Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity value of 0.91, falling above the median value for lakes in both the ecoregion and the state. Yellow Birch Lake's 2012 diversity was the same as what was calculated from data collected in 2005.

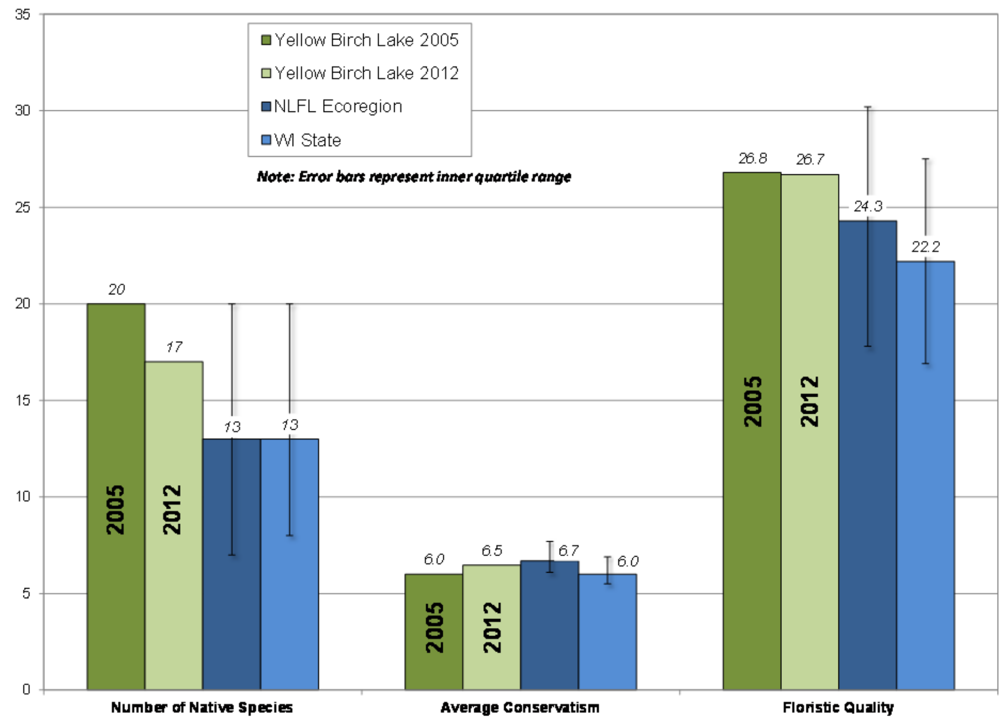


Figure 4.9-4. Yellow Birch Lake Floristic Quality Index values. Created using data from 2005 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

Figure 4.9-6 displays the relative frequency of occurrence of aquatic plant species in Yellow Birch 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.

The 2012 point-intercept survey on Yellow Birch Lake indicated that the 2008-2012 Eurasian water milfoil control program may have caused the decline observed in the lake's common waterweed population. However, eight other native aquatic plant species saw statistically valid increases in their occurrence. The Floristic Quality Analysis indicates that the quality of the aquatic plant community as a whole was not diminished. A Eurasian water milfoil treatment occurred in 2012 and specific information regarding this treatment can be found in the 2012 Eagle River Chain Treatment Report (January 2013).

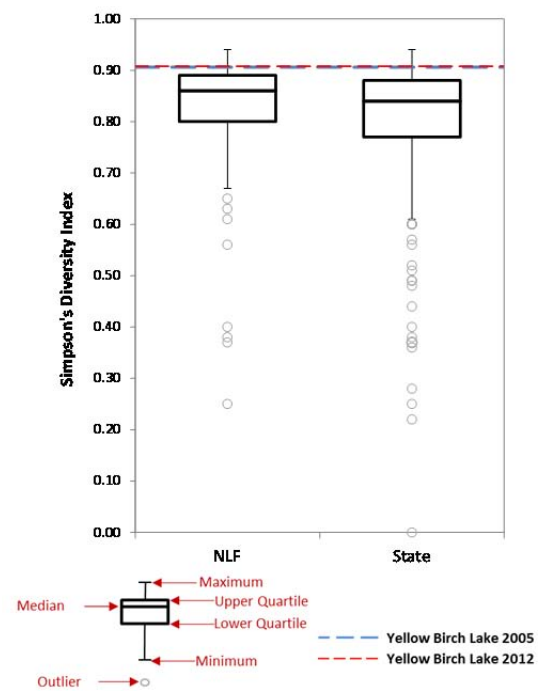


Figure 4.9-5. Yellow Birch Lake species diversity index. Created using data from 2005 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

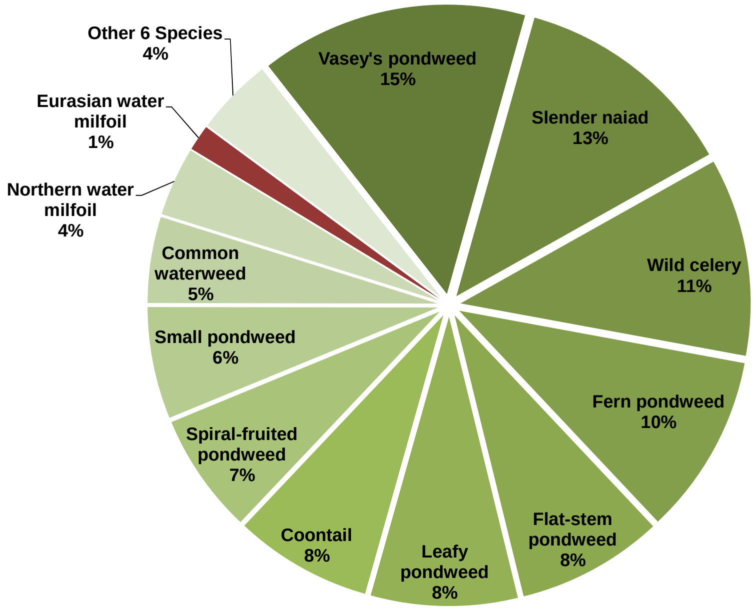
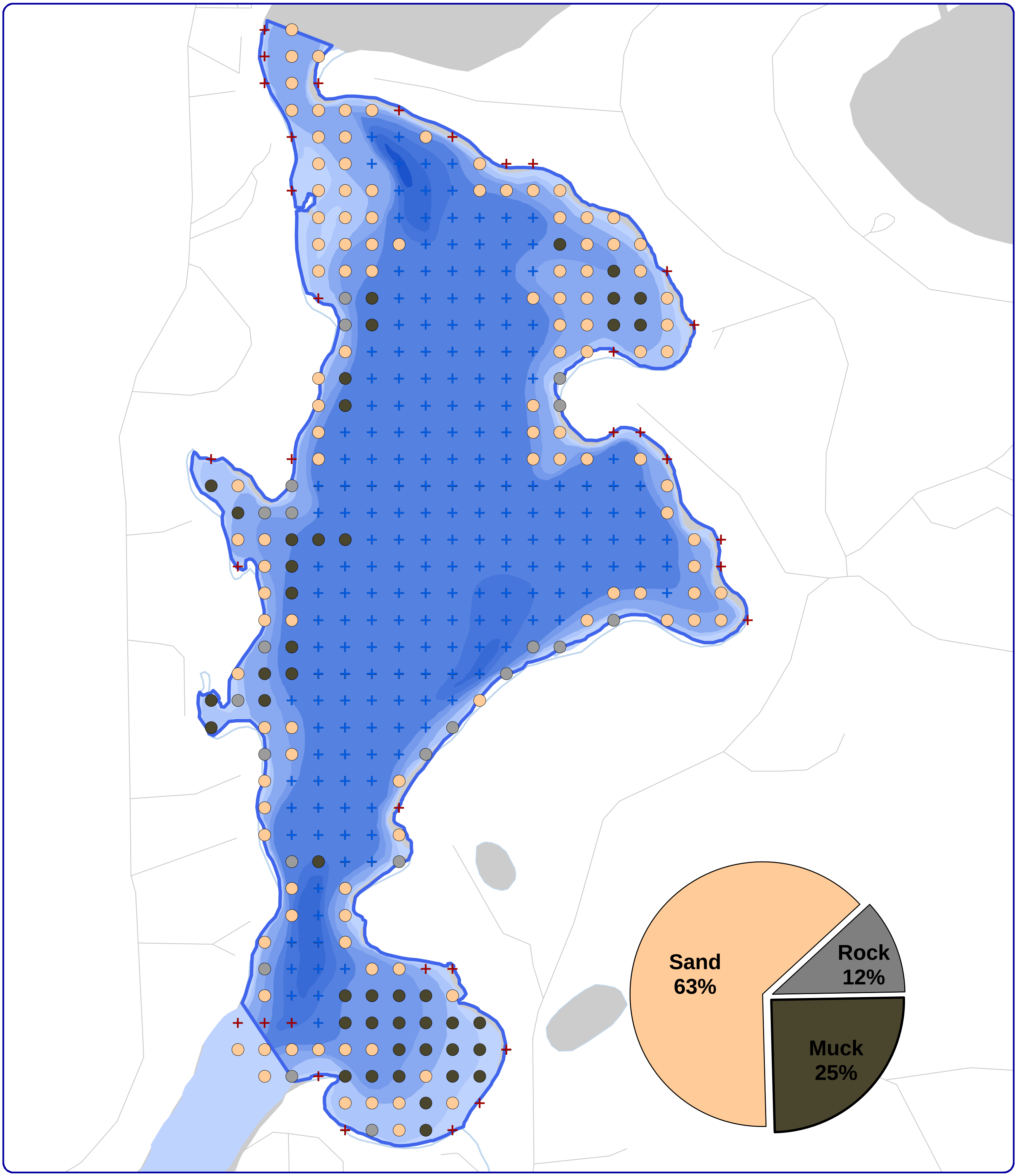


Figure 4.9-6. Yellow Birch Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.



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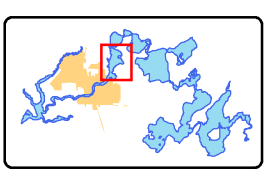
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: YBL1_SubstratePI.mxd



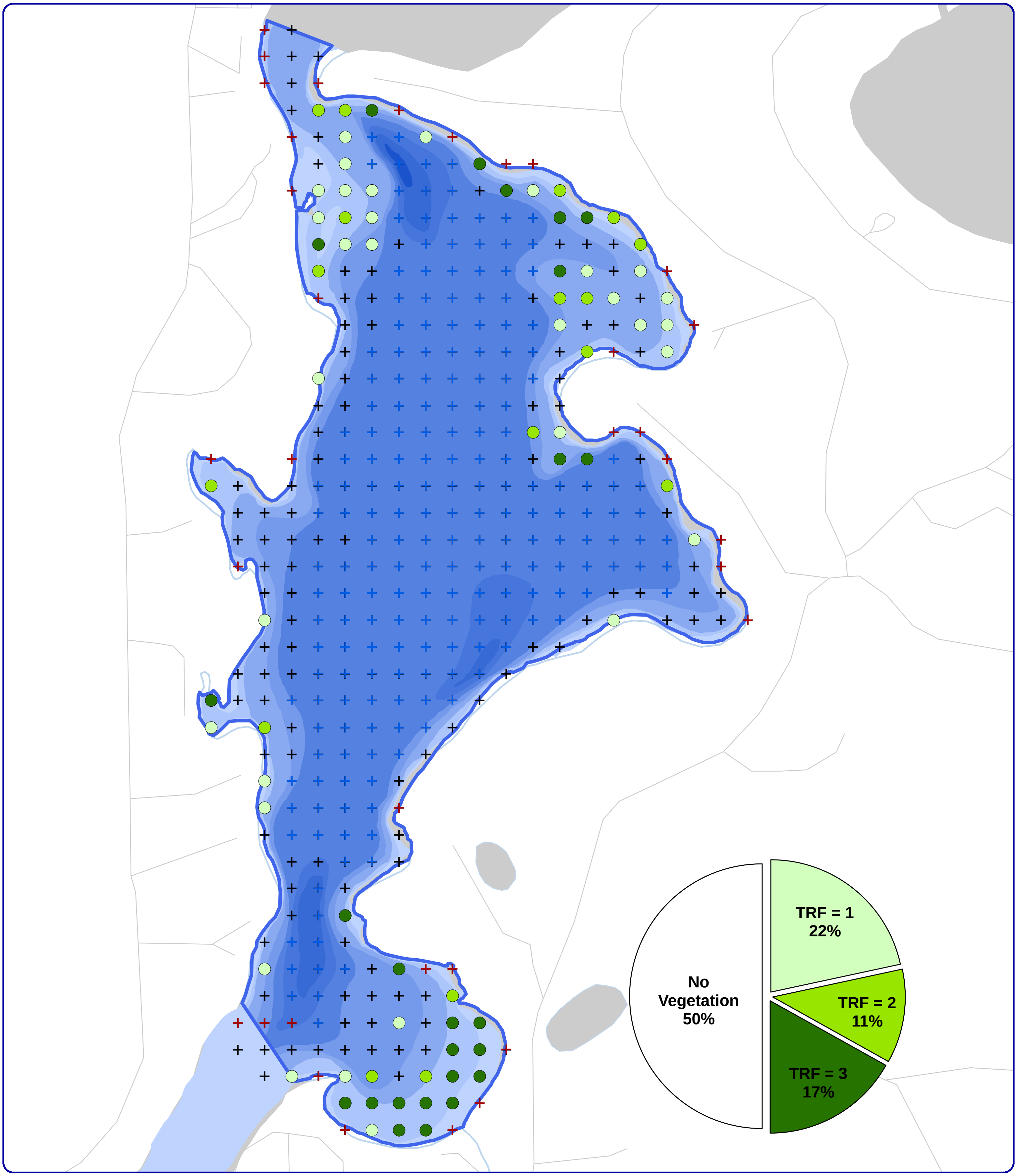
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

YBL 1
Yellow Birch Lake
Vilas County, Wisconsin

2012 PI Survey: Substrate Types



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Sources:
Roads and Hydro: WDNR
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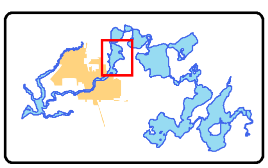


Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

YBL 2

Yellow Birch Lake

Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution

4.10 Watersmeet

The whole-lake aquatic plant point-intercept survey was conducted on Watersmeet by Onterra on August 6, 2012 (Figure 4.10-1). During this survey, a total of 34 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian water milfoil (Table 4.10-1). 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.

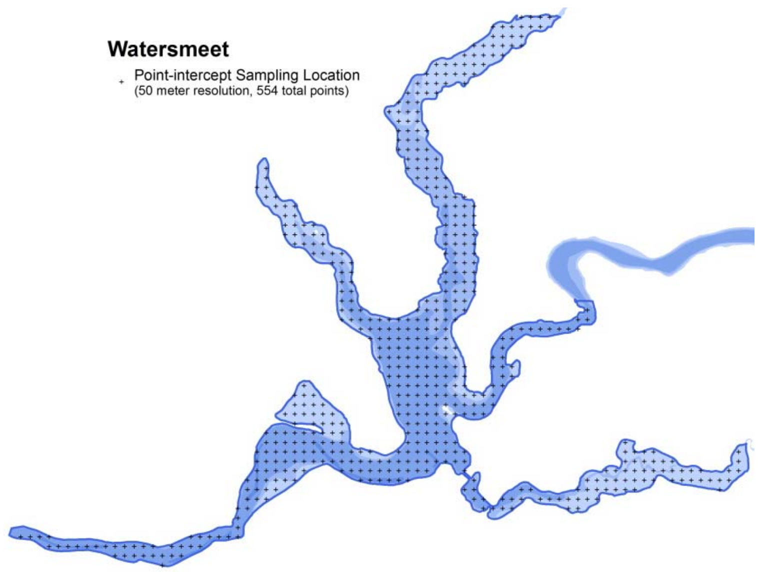


Figure 4.10-1. Point-intercept locations on Watersmeet.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. As Map Wat-1 illustrates, 73% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 25% contained sand, and 2% contained rock. The majority of the sampling locations that contained sand were located in the Wisconsin River and Eagle River sections of Watersmeet. 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 8 feet, shallower than the observed 12 feet in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of 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.

Of the 391 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 49% contained aquatic vegetation. This is lower than what was found in the 2006 survey where approximately 69% of the littoral sampling locations contained aquatic vegetation. Map Wat-2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake-fullness (TRF) ratings at those locations. Aquatic plant growth is widespread across Watersmeet, with only the deepest areas of the lake lacking vegetation. Twenty-seven percent of the point-intercept locations had a total rake-fullness rating of 2, 15% had a total rake-fullness rating of 1, and 12% 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 4.10-1. Aquatic plant species located in Watersmeet during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Eleocharis palustris*	Creeping spikerush	6		X
E	*Equisetum fluviatile*	Water horsetail	7		X
E	*Pontederia cordata*	Pickerelweed	9	X	X
E	*Sagittaria latifolia*	Common arrowhead	3		X
E	*Schoenoplectus tabernaemontani*	Softstem bulrush	4	X	X
E	*Typha spp.*	Cattail spp.	1		X
E	*Zizania palustris*	Northern wild rice	8	X	X
FL	*Brasenia schreberi*	Watershield	7	X	X
FL	*Nuphar variegata*	Spatterdock	6	X	X
FL	*Nymphaea odorata*	White water lily	6	X	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8		X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		X
Submergent	*Bidens beckii*	Water marigold	8		X
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
Submergent	*Ceratophyllum echinatum*	Spiny hornwort	10		I
Submergent	*Elodea canadensis*	Common waterweed	3	X	X
Submergent	*Heteranthera dubia*	Water stargrass	6		X
Submergent	*Myriophyllum sibiricum*	Northern water milfoil	7	X	X
Submergent	*Myriophyllum spicatum*	Eurasian water milfoil	Exotic	X	X
Submergent	*Najas flexilis*	Slender naiad	6	X	X
Submergent	*Nitella spp.*	Stoneworts	7		X
Submergent	*Potamogeton amplifolius*	Large-leaf pondweed	7	X	X
Submergent	*Potamogeton epihydrus*	Ribbon-leaf pondweed	8		X
Submergent	*Potamogeton foliosus*	Leafy pondweed	6		X
Submergent	*Potamogeton natans*	Floating-leaf pondweed	5		X
Submergent	*Potamogeton praelongus*	White-stem pondweed	8		X
Submergent	*Potamogeton pusillus*	Small pondweed	7	X	X
Submergent	*Potamogeton richardsonii*	Clasping-leaf pondweed	5	X	X
Submergent	*Potamogeton robbinsii*	Fern pondweed	8	X	X
Submergent	*Potamogeton spirillus*	Spiral-fruited pondweed	8		X
Submergent	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
Submergent	*Potamogeton zosteriformis*	Flat-stem pondweed	6	X	X
Submergent	*Ranunculus aquatilis*	White water-crowfoot	8	X	
Submergent	*Utricularia vulgaris*	Common bladderwort	7	X	X
Submergent	*Vallisneria americana*	Wild celery	6	X	X
FF	*Lemna trisulca*	Forked duckweed	6	X	
FF	*Lemna turionifera*	Turion duckweed	2		X
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

E = Emergent, FL = Floating Leaf; FL/E = Floating Leaf and Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*

Table 4.10-1 displays the aquatic plant species located in Watersmeet during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for white water-crowfoot and forked duckweed, were re-recorded in 2012. White water crow-foot was only located at three point-intercept locations in 2006, while forked duckweed was only located at two; it is not believed these species have disappeared from Watersmeet, but they went undetected in 2012 due to their very low occurrence. An additional 17 native aquatic plant species were located in Watersmeet in 2012 that were not recorded in 2006, including a relatively rare, sensitive species, spiny hornwort.

Of the 34 aquatic plant species recorded on the rake during the 2012 point-intercept survey, common waterweed, coontail, wild celery, and fern pondweed were the four-most frequently encountered (Figure 4.10-2). Common waterweed, the most abundant aquatic plant in Watersmeet in 2012 with a littoral occurrence of approximately 23%, can live in a variety of habitats and is widespread throughout North America. It often grows in large beds creating excellent sources of food and habitat for wildlife.

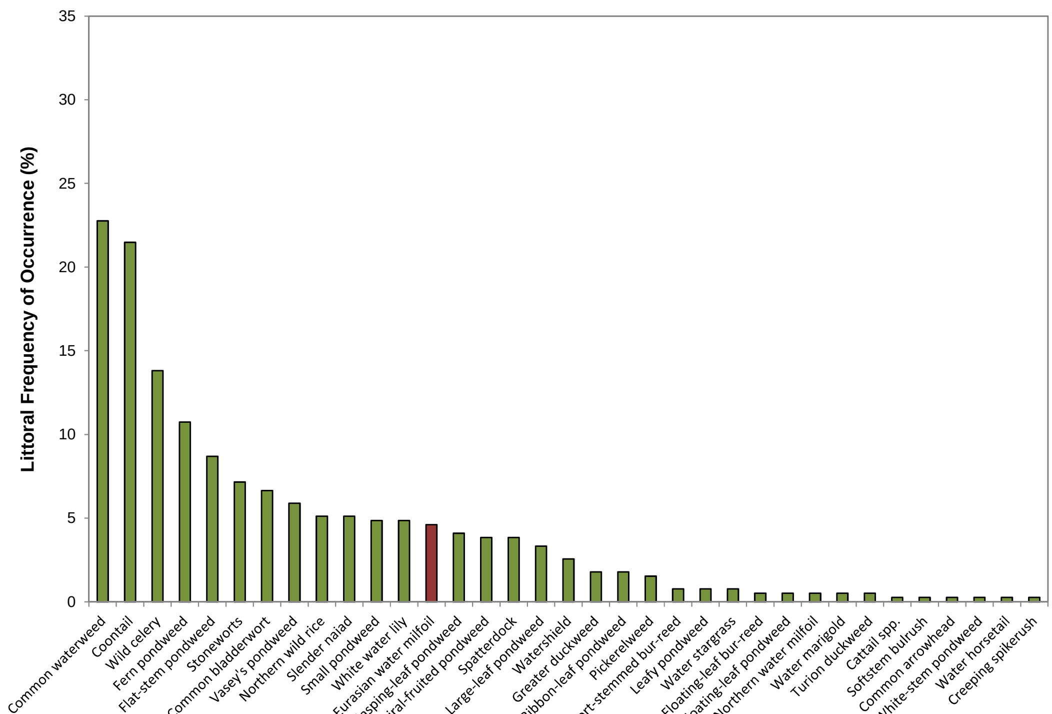


Figure 4.10-2. Watersmeet 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Coontail was the second-most frequently encountered aquatic plant in Scattering Rice Lake in 2012 with a littoral occurrence of approximately 22%. Resembling the shape of a raccoon's tail, coontail is arguably one of the most common aquatic plant species in Wisconsin. Able to grow in a range of conditions, its dense whorls of stiff leaves provide excellent habitat for macroinvertebrates and other wildlife. Coontail is a close relative to the relative rare and sensitive species, spiny hornwort, that was also located in Watersmeet.

Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 14%. This species 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).

Fern pondweed was the second-most abundant plant in Watersmeet in 2012 with a littoral occurrence of approximately 11%. As its name suggests, has the appearance of a fern's leaf and is a common pondweed found in lakes in northern Wisconsin. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish.

Vasey's pondweed had a littoral occurrence of approximately 6% in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. It has very fine submersed leaves and forms floating leaves when growing in shallow water (Photo 4.10-1). The occurrence of Vasey's pondweed within Watersmeet is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian water milfoil control project on Watersmeet 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 4.10-3 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 Watersmeet.

As illustrated, Eurasian water milfoil declined from an occurrence of 23.3% in 2006 to 4.6% in 2012, representing a statistically valid reduction of 80%. Four native aquatic plant species also exhibited statistically valid reductions in their occurrence from 2006 to 2012 and include: spatterdock, flat-stem pondweed, northern wild rice, and large-leaf pondweed. Like Eurasian water milfoil, spatterdock is a dicot and potentially susceptible to the herbicide treatments that have occurred on Watersmeet. Unlike Eurasian water milfoil, flat-stem pondweed and large-leaf pondweed are monocots and were not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research by the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following these types of treatments. Northern wild rice is also a monocot, but natural wild rice populations are known to fluctuate greatly and unpredictably from year to year; therefore, linking population changes of wild rice to herbicide use in field settings can be problematic. Five native aquatic plant species exhibited statistically valid increases in their occurrence within Watersmeet from 2006 to 2012, including the special concern species, Vasey's pondweed.

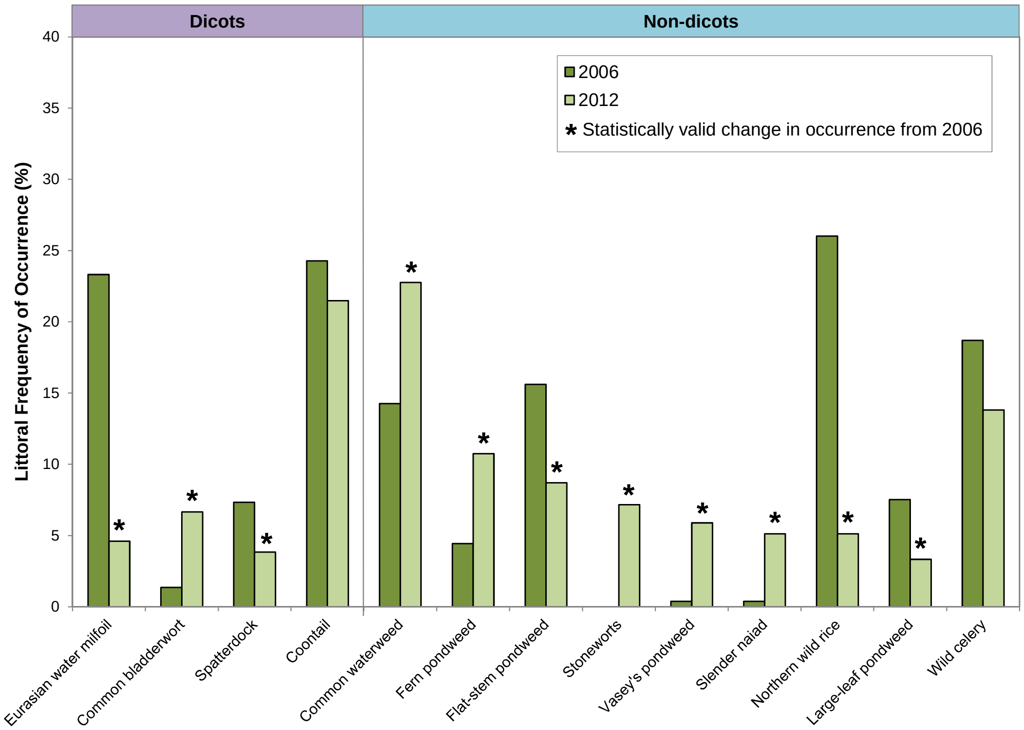


Figure 4.10-3. Watersmeet littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

Wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Wild rice has cultural significance to the Chippewa Tribal Communities as well as being an important component of their diets. In addition, it has great ecological importance as a valuable wildlife food source, wildlife habitat, soil stabilization, and nutrient uptake.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842, within which the Eagle River Chain of Lakes falls. The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) represent the eleven Chippewa Tribal Nations within the Upper Midwest to protect and enhance the natural resources of the ceded territory, particularly as they relate to the treaty rights of the member tribes. As discussed above, wild rice is a valuable emergent grass found within the Eagle River Chain of Lakes ecosystem. In addition to the ecosystem services this plant provides, it also holds great cultural significance to the Native American communities of this area. For this reason, GLIFWC focuses on the "preservation and enhancement of manoomin (wild rice) in ceded territory lakes." The state of Wisconsin works actively with GLIFWC to review all activities that have the potential to negatively impact wild rice populations. While the use of herbicides to control aquatic invasive species has broad intentions of benefiting the lake ecosystem, the herbicides may have the capacity to impact non-target plants such as wild rice.

Little information exists regarding the impacts of aquatic herbicides on wild rice, particularly as it applies to collateral effects on wild rice associated with targeted herbicide treatments of AIS in lakes. Two studies (Nelson et al 2003; Madsen et al. 2008) evaluated the effects of various herbicides and concentrations on wild rice within outdoor mesocosums (tanks that replicate natural conditions). While this research concludes that wild rice is susceptible to aquatic herbicides, closer investigation of this research may identify potential herbicide use patterns that would minimize the impact on wild rice.

In 2012, the wild rice population within Watersmeet was delineated (Map Wat-3) in an effort to begin tracking the density and size of the population. While it is understood that wild rice populations fluctuate from year to year, a multi-year dataset may provide insight to whether the herbicide application is directly affecting its population; therefore, this wild rice population will be delineated on an annual basis.

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 35 native aquatic plant species were located in Watersmeet during the 2012 survey, 34 were encountered on the rake and one was incidentally located. These 32 native species and their conservatism values were used to calculate the FQI of Watersmeet's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 4.10-4 compares the FQI components of Watersmeet from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests (NLF) Ecoregion as well as the entire State of Wisconsin. In 2012, Watersmeet's native species richness (34) is significantly higher than the median values for lakes within the ecoregion and the state. However, the average conservatism value in 2012 (6.3) falls below the median for lakes in the NLF Ecoregion but above the median for lakes in the state. Combining Watersmeet's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 36.5, which greatly exceeds the ecoregional and state median values (Figure 4.10-4). The FQI values from 2012 are also much higher than those calculated from point-intercept survey in 2006, indicating that the quality of Watersmeet's aquatic plant community has not been diminished by the Eurasian water milfoil control project. This analysis indicates that Watersmeet's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

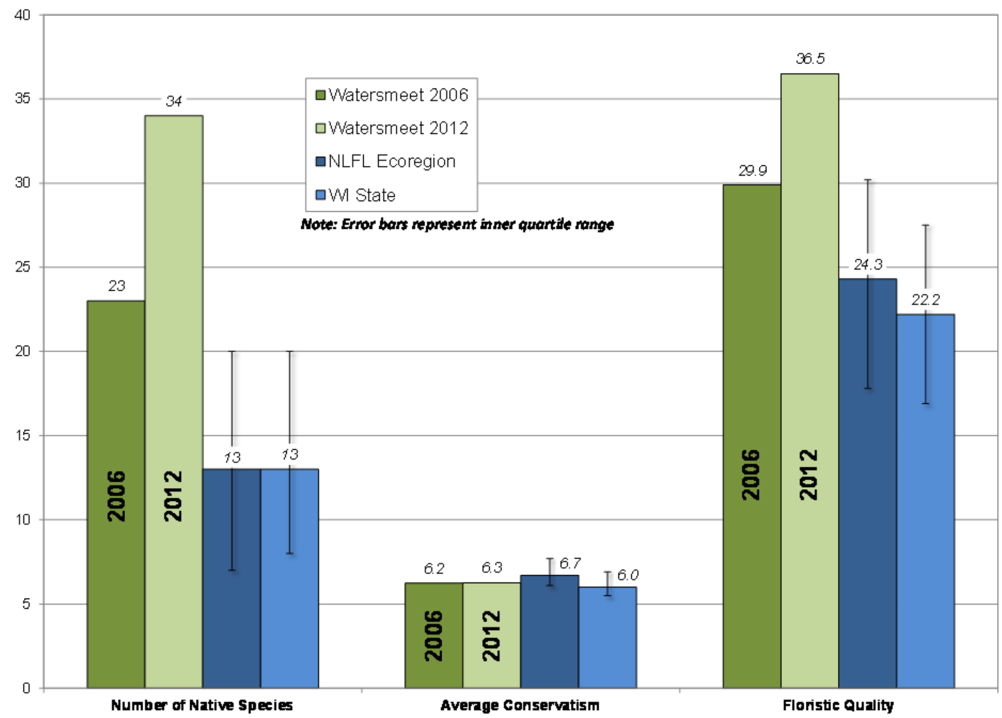


Figure 4.10-4. Watersmeet Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

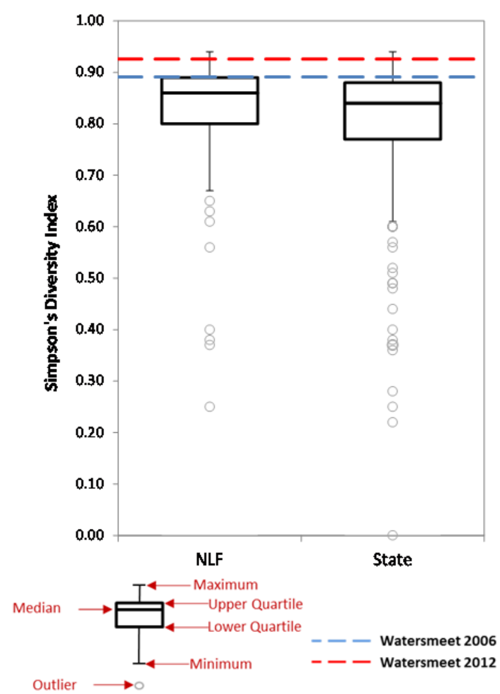


Figure 4.10-5. Watersmeet species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

As explained in the primer 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 Watersmeet 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 Watersmeet's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.10-5). Using the data collected form the 2012 point-intercept survey, Watersmeet's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.93, falling above the upper quartile value for lakes in both the ecoregion and the state. Watersmeet's species diversity was markedly higher in 2012 than in 2006, likely due to the reduction in the Eurasian water milfoil population which was the third-most dominant plant species in the lake in 2006.

Figure 4.10-6 displays the relative frequency of occurrence of aquatic plant species in Watersmeet 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.

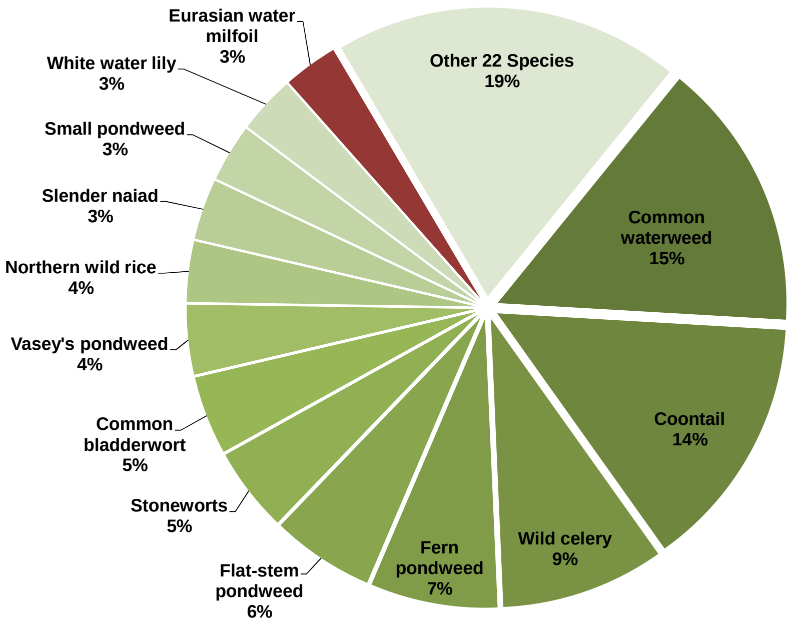
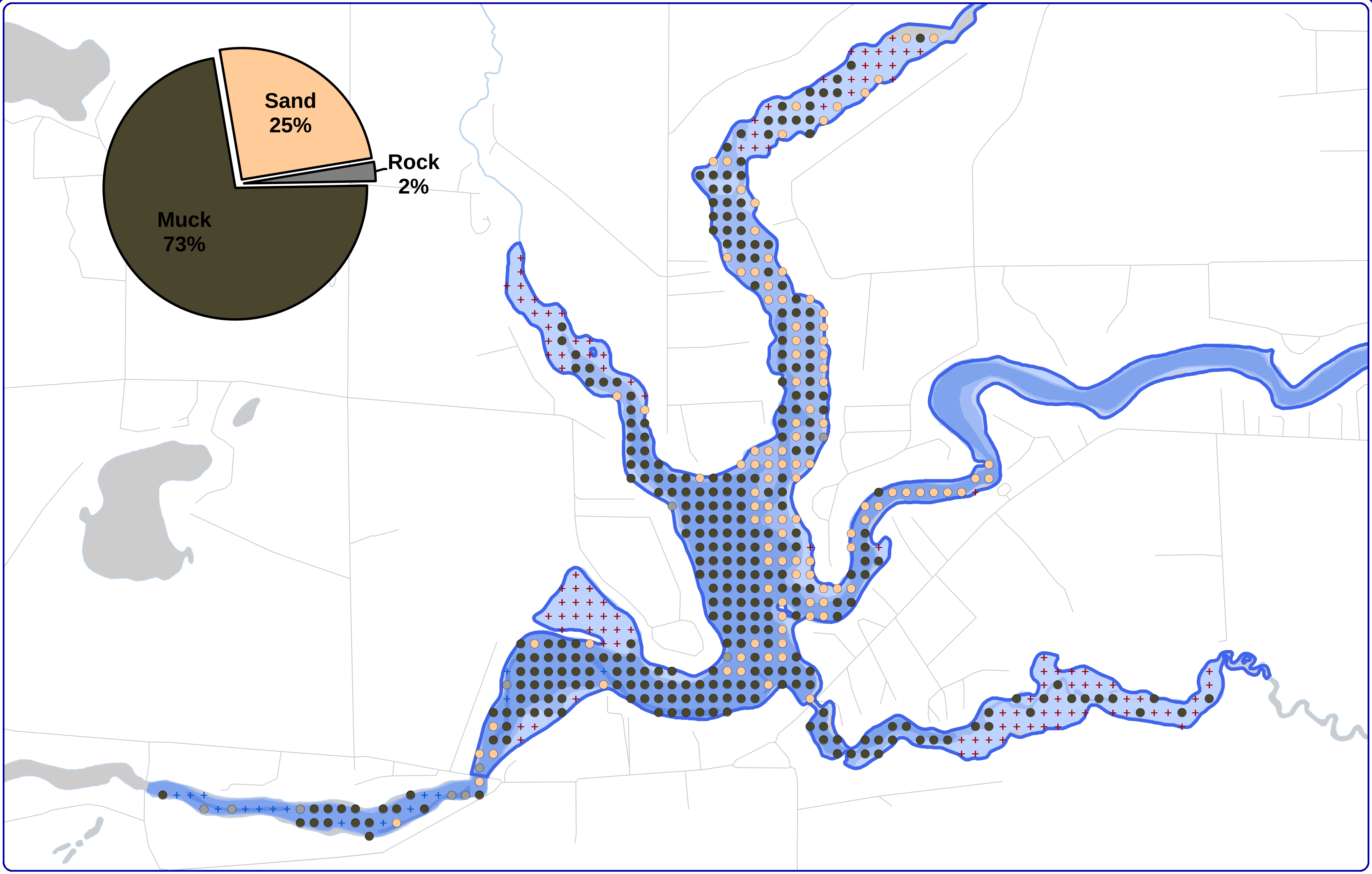
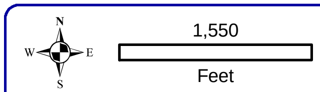


Figure 4.10-6. Watersmeet 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

The 2012 point-intercept survey on Watersmeet indicated that the Eurasian water milfoil control project may have caused the reduction in occurrence observed in a few native aquatic plant species. However, it is not known if the treatments were the cause of the reduced occurrence of northern wild rice of a result of its natural interannual variation. Native aquatic plant species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012. In addition, the Eurasian water milfoil population was greatly reduced, after once being one of the most abundant plants in the lake. A Eurasian water milfoil treatment did occur and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).





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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
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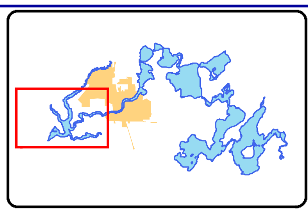


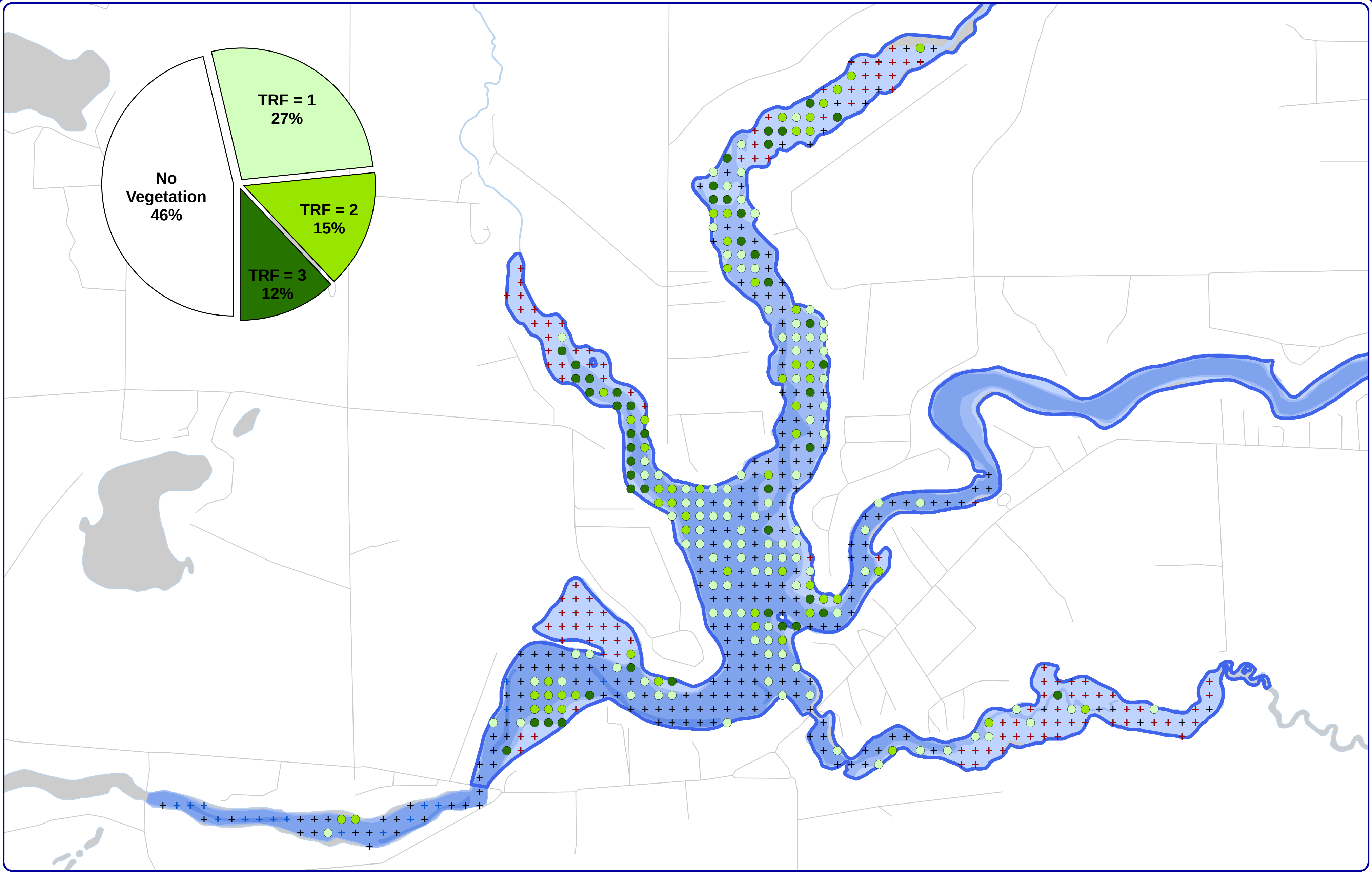
Extent of large map shown in red.

Legend

- Muck
- Sand
- Rock
- Too Deep - No Data
- Non-navigable

Wat 1
Watersmeet
Vilas County, Wisconsin

2012 PI Survey: Substrate Types



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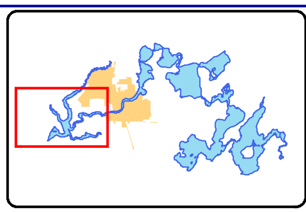

Extent of large map shown in red.

Legend

- Total rake-fullness = 1
- Total rake-fullness = 2
- Total rake-fullness = 3
- + No Vegetation
- + Too Deep
- + Non-navigable

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
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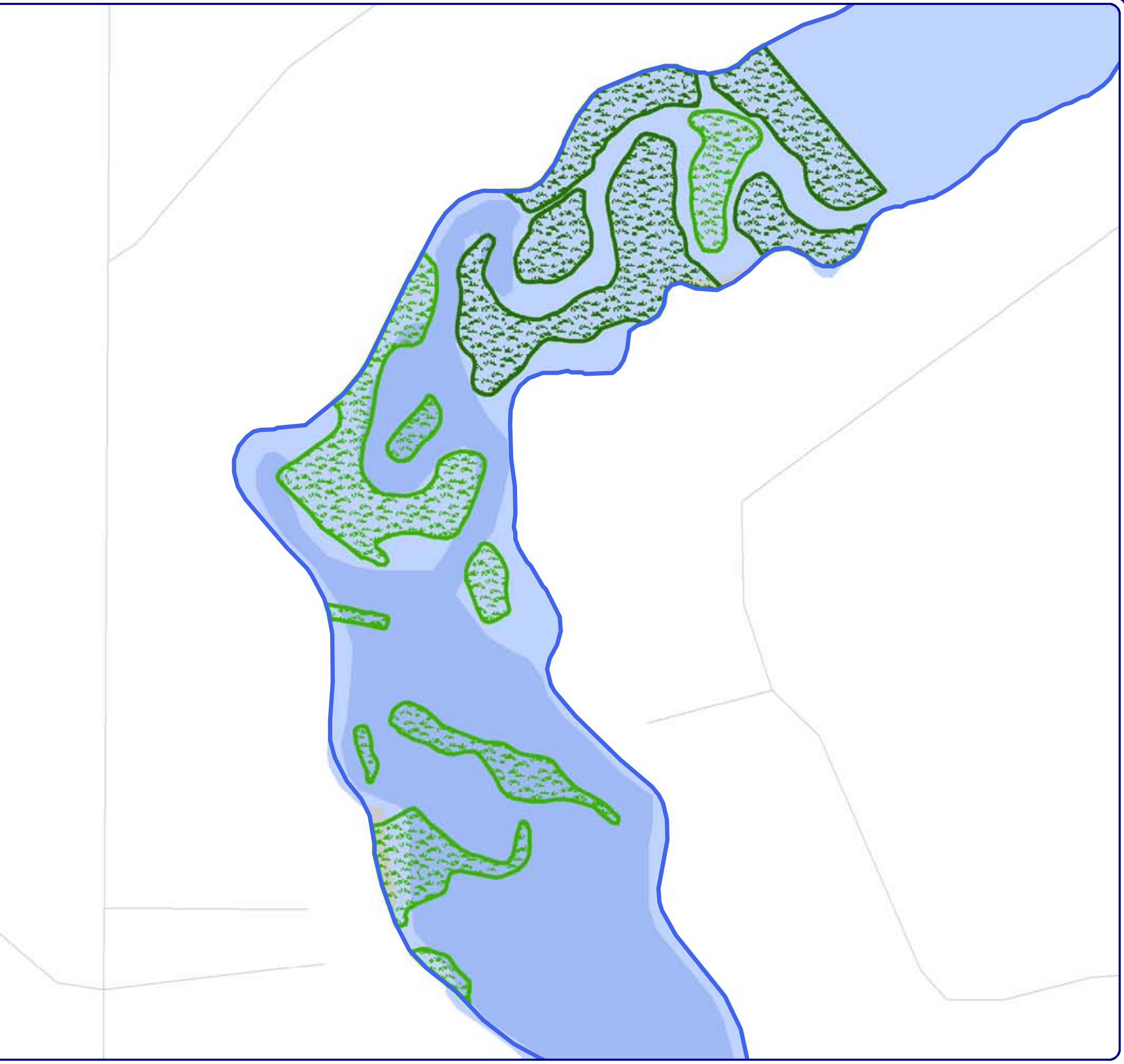
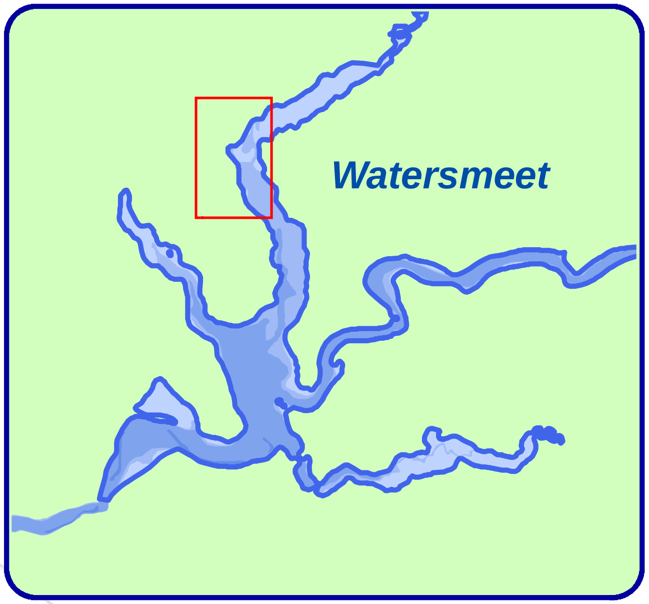
Filename: Wat2_TRFPI.mxd

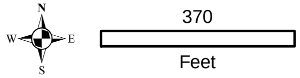
Wat 2
Watersmeet
Vilas County, Wisconsin

2012 PI Survey: Aquatic Vegetation Distribution





Extent of large map shown in red.



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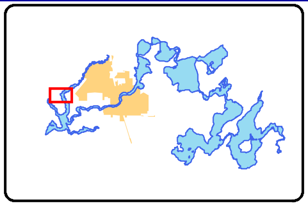
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1969, (digitized by Onterra)
PI Survey: Onterra, 2012
Map Date: March 22, 2013
Filename: Wat3_WildRice.mxd



Extent of large map shown in red.

Legend

2012 Northern Wild Rice

- Sparse
- Dense

Wat 3
Watersmeet
Vilas County, Wisconsin

2012 Northern Wild Rice Locations

5.0 LITERATURE CITED

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