8.1 VIRGIN LAKE

8.1.1 An Introduction to Virgin Lake

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

Field Survey Notes

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

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

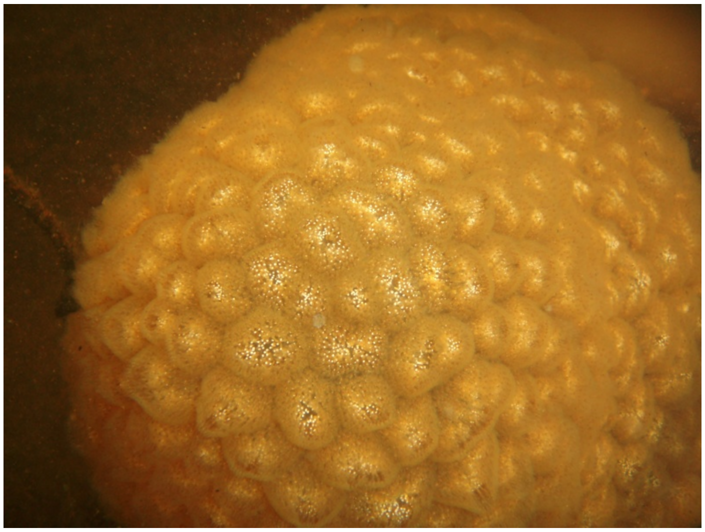

Photo 8.1.1-1 Bryozoan from Virgin Lake, Oneida County

Lake at a Glance – Virgin Lake

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

8.1.2 Virgin Lake Watershed Assessment

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

Exact land cover calculation and modeling of nutrient input to Virgin Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Virgin Lake's immediate shoreline was assessed in terms of its development. Virgin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles (25% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.2-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.6 miles of urbanized and developed–unnatural shoreline (20% of the total shoreline) was observed. If restoration of the Virgin Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Virgin Lake Map 1 displays the location of these shoreline lengths around the entire lake.

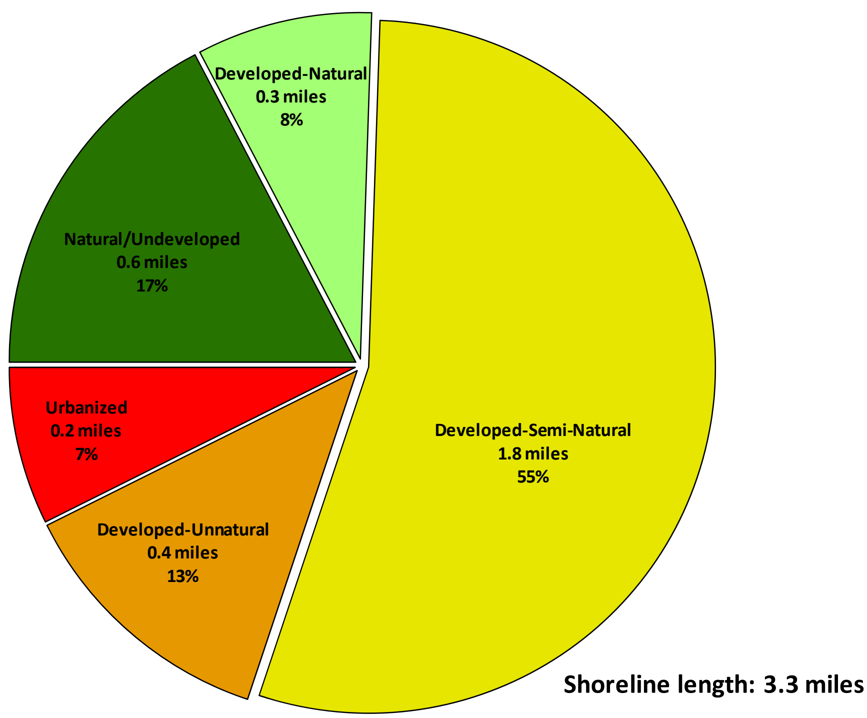

Figure 8.1.2-1. Virgin Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Virgin Lake Map 1.

8.1.3 Virgin Lake Water Quality

Water quality data was collected from Virgin Lake on six occasions in 2010/2011. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen.

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

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

From the examination of two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Virgin Lake's water can be described as *Excellent* in most years (Figure 8.1.3-1). A weighted average over this timeframe is above the median value for other deep, headwater lowland lakes in the state. Secondly, with exception to 2011, there is very little variation seen in this data set. In 2011, Onterra ecologists noted exceptionally stained water during visits to monitor a small Eurasian water milfoil infestation (see the Aquatic Plant Section for more details on this). Similar stained water was observed on the other lakes in the Three Lakes Chain of lakes, as well as other lakes within the Northwoods of Wisconsin.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Virgin Lake as well as the other lakes in the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Virgin Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

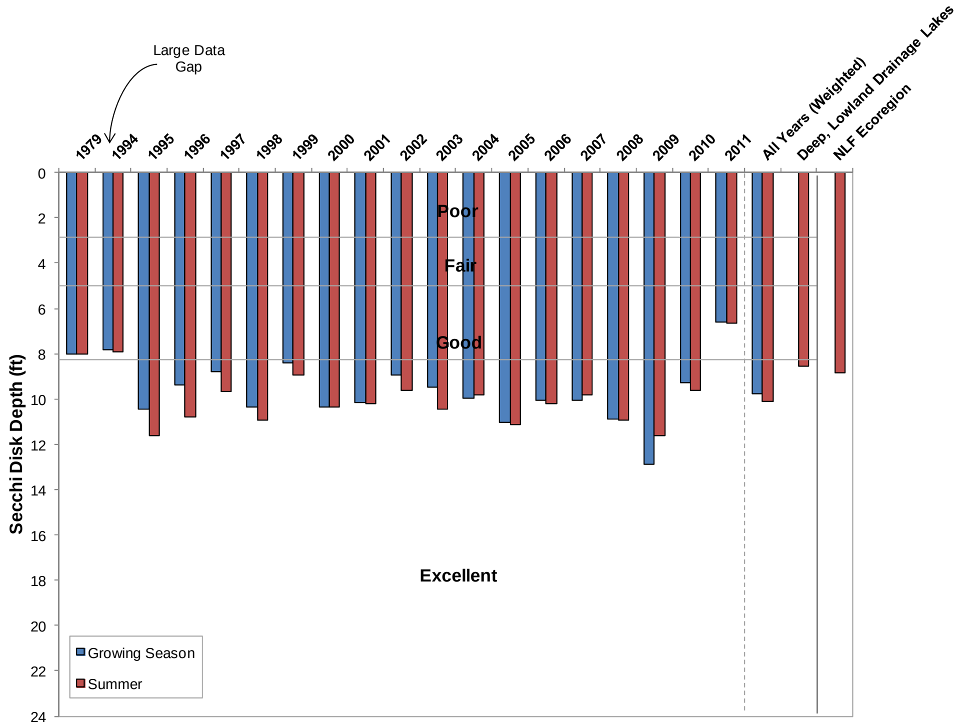

Figure 8.1.3-1. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Virgin Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.1.3-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Virgin Lake is in a mesotrophic state.

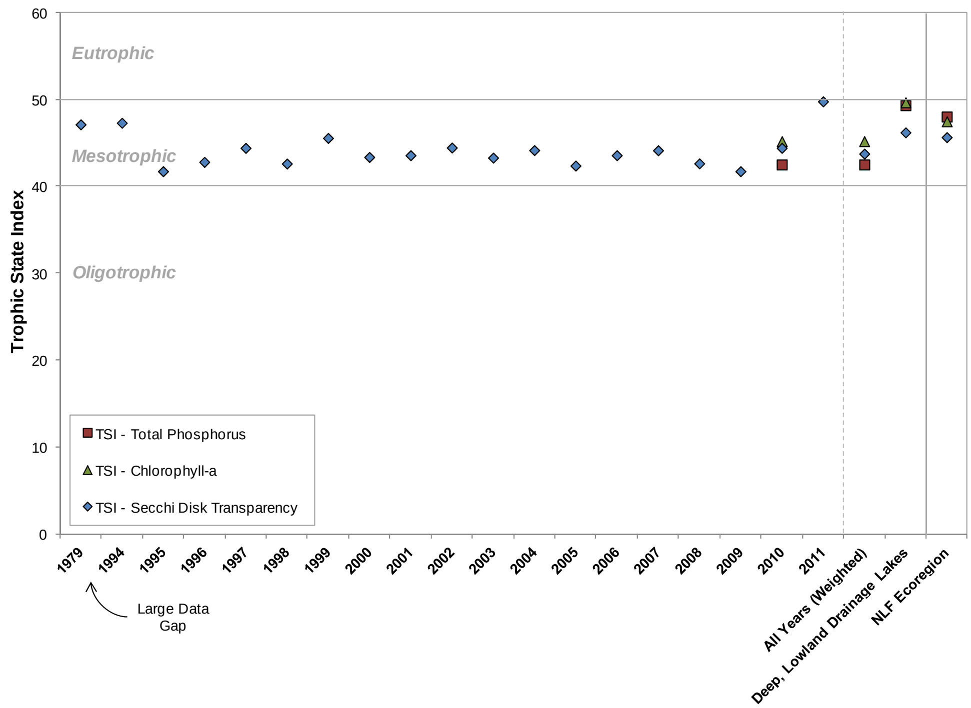

Figure 8.1.3-2. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Virgin Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Virgin Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.3-3 for all sampling events.

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

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2011, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

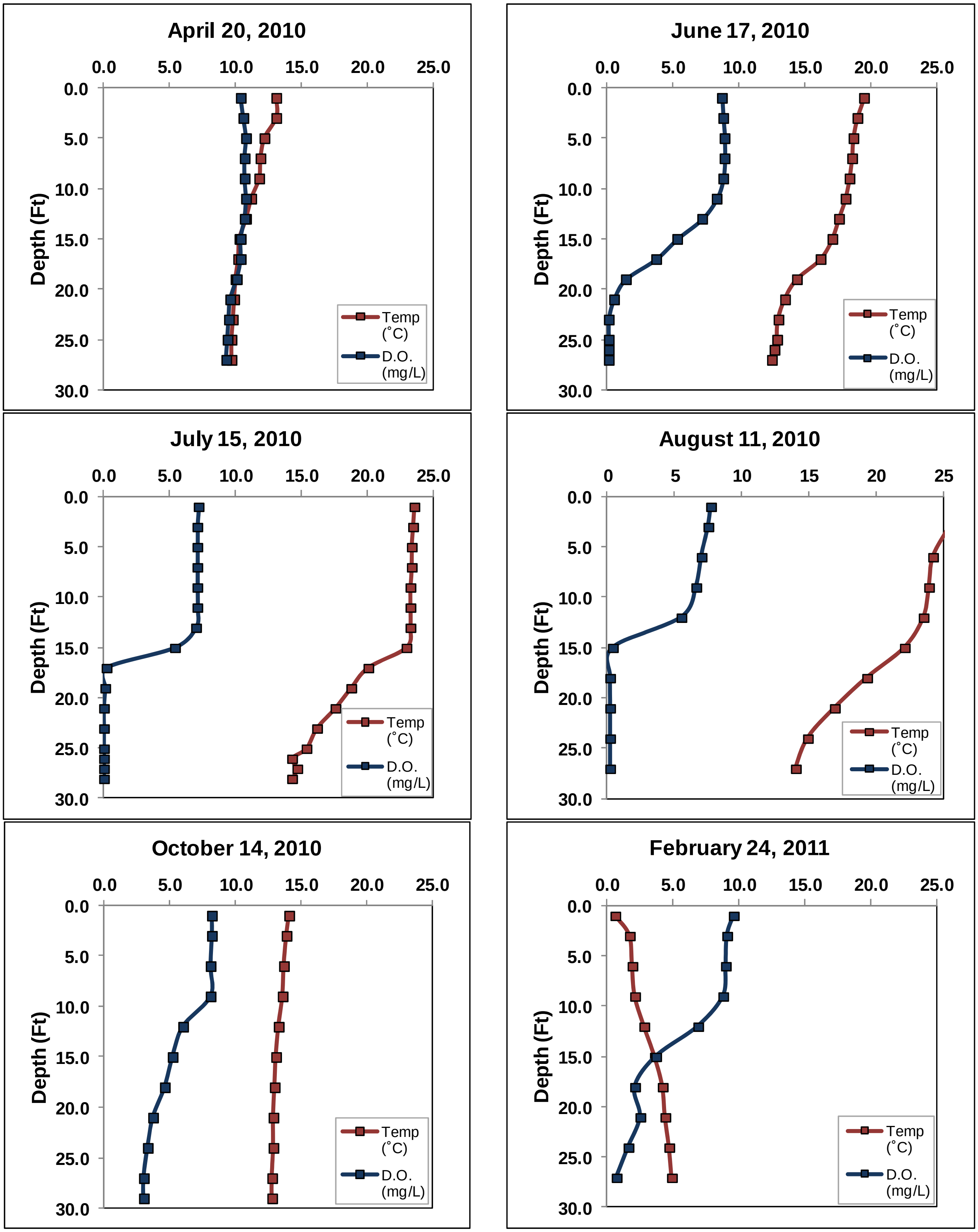

Figure 8.1.3-3. Virgin Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Virgin Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Virgin Lake's surface water pH was measured at roughly 7.8 during summer 2010. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The bicarbonate form is better at buffering acidity, so lakes with higher alkalinity are less resistant to acid rain than those with lower alkalinity. The alkalinity in Virgin Lake was measured at 48.2 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Virgin Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Virgin Lake's pH of 7.8 - 7.9 falls slightly outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Virgin Lake was found to be 12.0 mg/L, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (zebra mussels in the larval form) were found within these samples.

8.1.4 Virgin Lake Aquatic Vegetation

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

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

Of the 181 point-intercept locations sampled within the littoral zone, approximately 62% contained aquatic vegetation. Approximately 51% of the point-intercept sampling locations where sediment data was collected at were sand, 34% consisted of a fine, organic substrate (muck) and 15% were determined to be rocky (Chain-wide Fisheries Section, Figure 3.4-5).

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

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

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

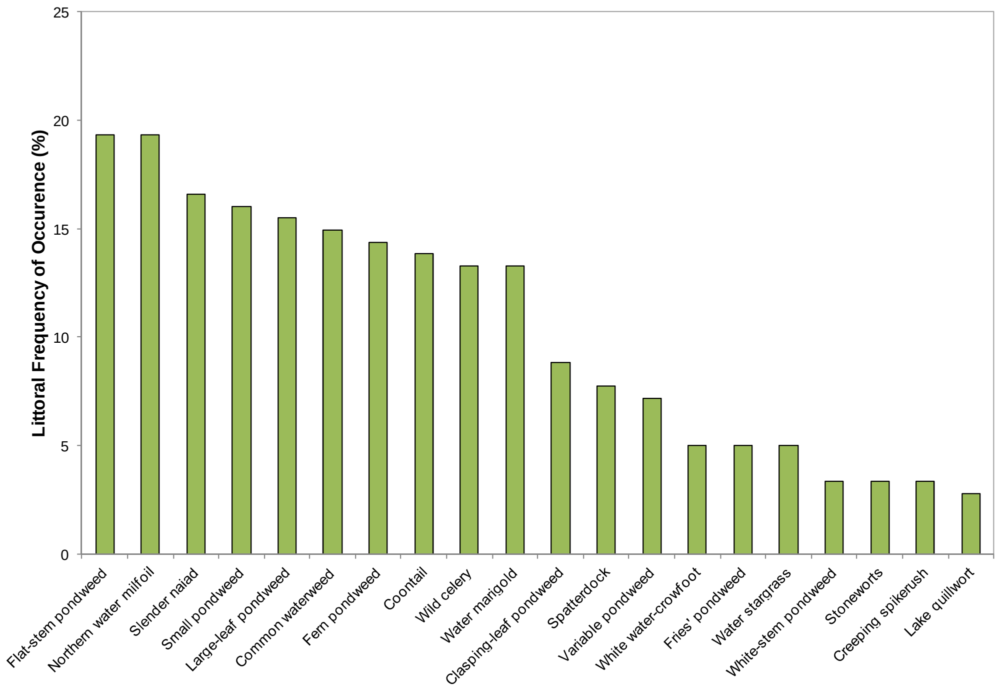

Figure 8.1.4-1 Virgin Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.1.4-1 (above) shows that flat-stem pondweed, northern water milfoil, and slender naiad were the most frequently encountered plants within Virgin Lake. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms.

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

An incredible 48 species of native aquatic plants (including incidentals) were found in Virgin Lake, along with one non-native plant. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Virgin Lake's plant community (0.94) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while northern water milfoil was found at 19% of the sampling locations, its relative frequency of occurrence is 9%. Explained another way, if 100 plants were randomly sampled from Virgin Lake, 9 of them would be northern water milfoil. This distribution can be observed in Figure 8.1.4-2, where together 10 species account for 71% of the population of plants within Virgin Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.1.4-1 as incidentals.

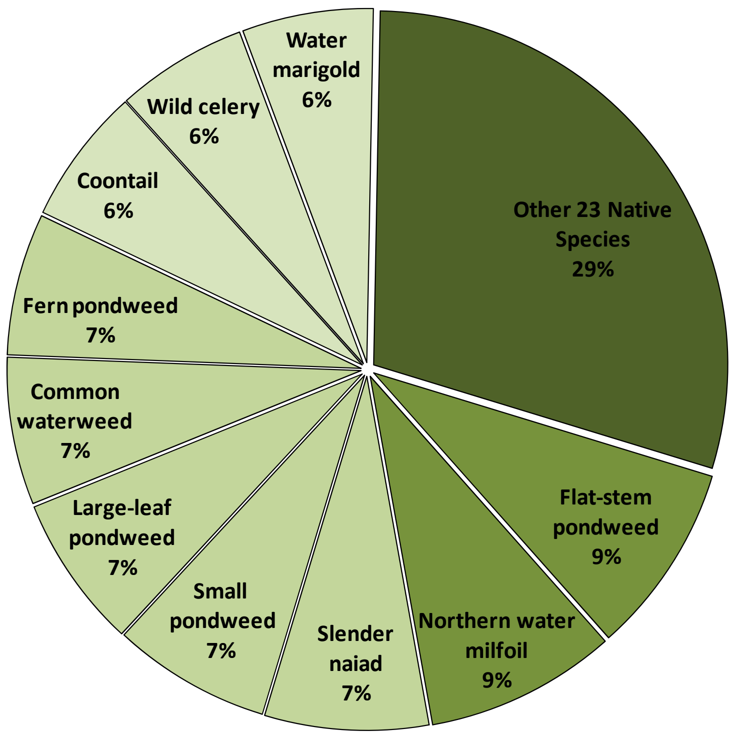

Figure 8.1.4-2 Virgin Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

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

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

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

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

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

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

Aquatic Invasive Species in Virgin Lake

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

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


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

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

The infestation of Eurasian water milfoil in Virgin Lake is still in its infancy, and has been aggressively attacked and monitored since its discovery. At this point in time, continued monitoring of the entire lake is necessary to identify expansion of the known colony and also identify any additional areas where Eurasian water milfoil may be located. Onterra staff will continue to visit the known Eurasian water milfoil colony and hand-remove plants as necessary. In the event the colonial expansion occurs to a point in which hand-harvesting is not possible, a more intensive control strategy, such as an herbicide application, may be necessary.

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