INVENTORY OF CHIPPEWA COUNTY LAKES IN THE CHIPPEWA COUNTY FOREST,WISCONSIN

Final Report to the Chippewa County Forest and Parks

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EXECUTIVE SUMMARY

The purpose of this study was to inventory as many lakes as possible in the Chippewa County Forest. To that end, 96 lakes were sampled for various limnological variables. All of the lakes were sampled for chemistry, plankton, and macrophytes. The fish community was sampled in 43 lakes and a paleolimnological analysis was performed in 18 lakes.

The Chippewa County Forest contains a relatively large number of lakes. This study sampled 82 natural lakes and 13 man made lakes. The Forest lakes are generally small, median size 5 acres, but they exhibit a large diversity of depth and limnological characteristics. The shallowest lakes have a maximum depth of less than 2 feet while the deepest was 66 feet. Because of their small size and relatively deep depth, there are three meromictic lakes. (Meromictic lakes remain permanently stratified.) This lake type is exceedingly rare in North America. The three meromictic lakes are Little Beaver, Fishpole, and UNNAMED T32N R08W S25-3 (Tinman).

The ionic strength (conductivity) of these lakes also exhibited a wide range which is reflective of the source of their water. Many of the lakes receive nearly all of their water from precipitation and are some of the softest lakes in the state. Other lakes possess higher levels of conductivity which reflects increasing amounts of input from ground water and surface streams. Although the flowages had some of the highest conductivity values reflecting most of their water is from streams, Big Twin and Little Plummer lakes have no inflowing streams. These two lakes receive most of their water from ground water.

The Forest lakes exhibit a wide range of water color. This reflects the variable influence of wetlands on the hydrology of the lakes. Lakes with higher color have wetlands adjacent to them which provide dissolved organic matter which stains the water. The high color levels in some of the lakes restrict light penetration and thus primary productivity in these systems. Consequently, many of these lakes experience low dissolved oxygen levels and therefore have a depauperate fish community.

The lakes have a wide range of trophic states. Many of the lakes are dystrophic, meaning they are stained and unproductive. Other lakes are highly productive with phosphorus levels exceeding 100 µg L^{-1} which places them in the eutrophic category. Other lakes had low nutrient levels and are classified oligotrophic. It is unclear what the source of nutrients are to the eutrophic lakes. A weak relationship was found between hydrology (conductivity) or color and phosphorus levels. Some of the lakes experience significant internal loading of phosphorus during the summer. These lakes are shallow and the sediments are the source of this phosphorus.

In order to understand the long term trends in water quality for these lakes, sediment cores were extracted and the diatom community examined. Diatoms are a special type of algae that possess siliceous shells which allows them to fossilize. Since most diatom taxa have narrow environmental requirements they can be used to reconstruct a lake's water quality history. The lakes with elevated nutrient levels appear to be that way naturally. The paleolimnological study found that changes in nutrients during the last century may be due in part to the amount of groundwater entering the lakes which is climatically determined. Also water levels have varied which is also regulated by the climate.

The biological communities of the lakes was investigated. There were a wide range of algal communities, reflecting the diversity of nutrients, color and conductivity. Two unique species were found. A filamentous blue green algae, *Tychonema*, which has not previously been described, occurred in Tamarack Lake and a rare variety of *Ceratium hirundella* was found in Little Plummer Lake. Forty species of zooplankton were found in these lakes. The cladoceran *Daphnia rosea* was found in 9 lakes. This taxa is rare in Wisconsin. The lakes possess a diverse macrophyte community. There were 185 species found which included the threatened specie *Carex lenticularis* (shore sedge) which was found in one lake. Eight species of special concern were also found in the study lakes. The lakes with the most listed species were Miller Lake and UNNAMED T32N R08W S32-2 (Island). The floristic quality of the macrophyte communities in the lakes was diverse, reflecting the wide range of chemistries in the lakes.

Fish were found in 34 of the 43 lakes sampled. All of the lakes that were likely to contain fish were sampled. Nineteen species were found. The number of species is relatively low because of the small size of the lakes in the Forest. Four fish communities were found. They are: 1)fishless, 2) panfish/ northern pike, 3) fathead minnows, and 4) central mudminnows. A portion of the Yellow River was also sampled. The biotic integrity of this stretch of the river was good indicating the watershed is in good condition. Some of the lakes possessed a good recreational fishery. This fishery was made up of panfish and gamefish (northern pike and largemouth bass).

A lake classification scheme was developed for the Forest lakes. The primary variable was conductivity, which reflects hydrological source, and the secondary variable was color. Twenty one lakes were chosen as reference lakes. These lakes encompass all of the lake classes and should be sampled on a three year rotational basis. Changes in the water quality of these lakes will be an indication that watershed practices are having an adverse impact on the lakes.

Two areas of special significance were identified. These are the Dorothy and Fishpole lakes areas. The Dorothy lakes area contains 4 lakes with diverse limnological characteristics. One of the lakes is meromictic. The Fishpole lakes complex possesses 6 lakes with diverse limnological characteristics.

This complex includes a meromictic lake as well as an extensive wetland complex associated with Fishpole Lake. Other lakes of special significance are Miller and UNNAMED T32N R08W S32-2 (Island) because of their diverse macrophyte communities. Bass Lake No. 3 is also of special significance because it contains the only threatened macrophyte specie found in the study.

As the Forest lakes are a unique community, it is important to preserve their status as much as possible. Especially important is retention of course woody habitat (downed trees) on their lakeshores. Also standing trees on the shore should also be preserved so they will provide habitat in the future. A buffer area around each lake should not be logged to retard input of sediment and nutrients as a result of land disturbance during logging operations.

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INTRODUCTION

The Chippewa County forest encompasses 33,000 acres and includes numerous terrestrial habitats and over 100 lakes. While there is good information about the tree resources the information about the rest of the terrestrial fauna and flora is limited. It is possible that the forest contains many species that are considered rare and endangered. Likewise there is limited information on the lake resources in the forest. The surface water inventory for the county was published in 1963 but since then data has been collected only on a limited number of lakes in 1988 and 1989. The county lakes generally are small seepage lakes. Many of the lakes are stained with a wide range of nutrient status.

The purpose of this study is to inventory the terrestrial and aquatic flora and fauna to help prepare the Forest master plan. By having a comprehensive inventory, the Forest can be more ecologically managed. This is especially important to preserve critical habitat for rare and endangered species. Because around nearly all of these lakes the only land cover is Forest it would further our understanding of lake ecology to determine why there is such a variety of trophic states in these lakes.

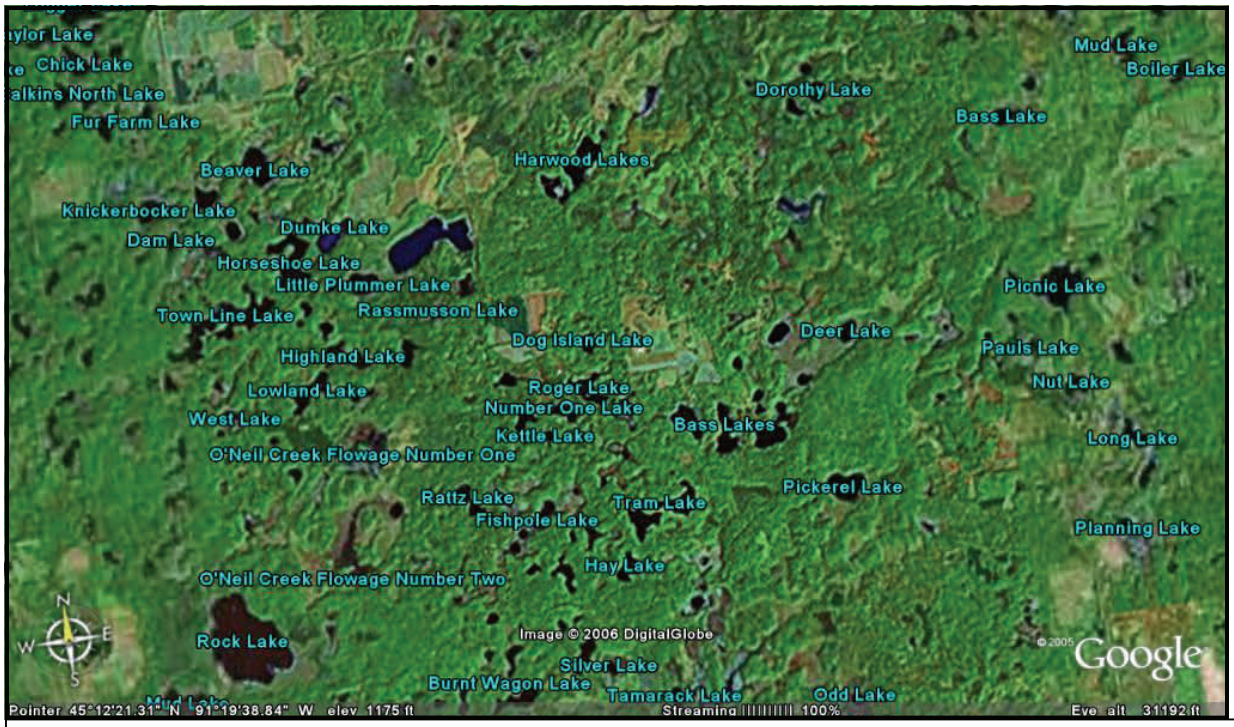

Figure 1. Satellite photograph of Chippewa County Forest area. Photo was provided by Google Earth.

METHODS

Chemistry

All of the lakes that could be reasonably accessed by canoe in the Chippewa County Forest were sampled at least twice. Water chemistry samples were collected soon after ice out and again in August. A total of 96 lakes were sampled. Chemical and physical samples were collected for calcium, magnesium, alkalinity, pH, conductivity, color, phosphorus, nitrogen species, Secchi disc depth, chlorophyll, phytoplankton, and zooplankton. Dissolved oxygen and temperature profiles were also performed. Samples were collected during the period 2001-03. Samples for calcium, magnesium, alkalinity, phosphorus, and nitrogen species were analyzed at the State Laboratory of Hygiene in Madison, WI. Conductivity, pH and color were analyzed the same day as they were collected by Research staff. Samples for chlorophyll analysis were filtered the same day as they were collected and the filters were placed in 90% acetone and placed in the freezer. Within 28 days they were analyzed in the Research lab using a spectrophotometer 88. Chlorophyll *a* values were calculated using the equations for trichromatic chlorophyll.

Paleolimnology

Sediment cores were collected from 18 lakes. Sediment cores were collected from the deepest areas of the lakes and the top and bottom sections of the cores were kept. It is assumed that the top section represents conditions during the last few years, while the bottom section represents a time period prior to the arrival of European settlers in the mid to late-1880s when much of the area was initially logged. Changes in the diatom community in bottom and top samples were used to estimate water quality changes in the lakes. The principal taxonomic keys used for diatom identification were Patrick and Reimer (1966, 1975), and Krammer and Lange-Bertalot (1986, 1988, 1991a,b).

Phytoplankton

Surface water phytoplankton samples were collected in 250-mL bottles from each lake and were preserved with Lugol's solution (2001 & 2003 samples) or 3% glutaraldehyde (2002 samples). A total of 110 lake samples were examined which included 6 field replicates and 9 temporal replicates (from the 2003 sampling period). Phytoplankton species were counted after concentrating samples in a manner adapted from USGS standard methods (Britton & Greeson 1987). A known volume of thoroughly shaken and mixed phytoplankton sample was placed in a 15-mL glass test tube and centrifuged for 15 minutes. Algae were enumerated as algal units consisting of filaments of filamentous forms, coenobia of coenobial green algae, cells of single-celled algae, or groups of cells of coccoid cyanobacteria. Colonial chrysophytes were often broken apart in processing, so single cells were counted. Between 10 and 60 fields were examined at 400x in a Palmer-Maloney counting cell with a volume of 0.1 mL. Twenty fields were counted for the majority of samples, but fewer fields were counted for very dense

samples and more fields were counted for dilute samples. The number of fields in which individual taxa occurred was recorded on a separate tally sheet during the count, for estimation of dominance after the methods of Lillie et al. (1993). The primary taxonomic literature used were Prescott (1962), Whitford & Schumacher (1984), and Wehr & Sheath (2003).

Macrophytes

Macrophyte surveys were done on 95 of the lakes in 2002 or 2003. The study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines.

Transects were placed on each lake. Generally the number of transects equaled the number of acres the lake covered, with a minimum of two transects placed and a maximum of 30 transects. The shoreline was divided into the appropriate number of segments, based on acreage, and a transect, perpendicular to the shoreline, was randomly placed within each segment.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a steel thatching rakes, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5) based on the number of rake samples on which it was present at each sampling site.

A rating of 1 indicates that a species was present on one rake sample
a rating of 2 indicates that a species was present on two rake samples
a rating of 3 indicates that it was present on three rake samples
a rating of 4 indicates that it was present on all four rake samples
a rating of 5 indicates that a species was abundantly present on all rake samples

Species recorded were all submergent and floating leaf species and all emergent species that were rooted in the water.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet deep was evaluated. The percentage of each cover type within this 100' x 30' rectangle was visually estimated and verified by a second re-

searcher.

Zooplankton

Zooplankton samples were taken by towing a net with a 75 micron mesh net with a 13 cm diameter from the bottom to the top of the water column. Samples were preserved with buffered formalin. In the laboratory, samples were examined under a dissecting microscope and the relative abundance of the species was determined. When necessary for positive identification, individuals were permanently mounted in polyvinyl lactophenol and examined under a compound microscope. The principal taxonomic keys used were Brooks (1957) and Balcer et al. 1984.

Fish Community

The fish community was surveyed in 43 lakes. Lakes were chosen that were known to possess fish or winter oxygen levels were thought to be sufficient for fish to survive most years. Standard sampling effort was applied to each of the lakes. Many of the lakes have no developed access, precluding use of heavy equipment or large boats that require launching from a vehicle and trailer (boat-mounted electrofishing, fyke nets). The steep shores of several bog lakes made seines highly impractical. A combination of minnow traps, gillnets, and angling was chosen for effectiveness, because these gears are deployable in lakes with carry-in access, or access through shallow streams with navigation obstructed with logs and beaver dams. A combination of gears samples different habitats and sizes of fishes, allowing a high probability of detecting the presence of most species.

Six Gee minnow traps (9”x 17.5”x1/4”) were baited with a commercial dog food and set overnight in each lake. The number of traps was based on evaluations of effort required to detect species with a variety of gears deployed in Wisconsin lakes (Jennings et al. 1999). Captured fishes were identified, enumerated, and released.

Each lake was also sampled with an overnight experimental gillnet. Gillnets were constructed of five panels, each 25 feet in length and 8 feet in depth. The panels had variable monofilament mesh sizes of 1, 1.5, 2, 2.5 and 3 inches. Captured fishes were identified, measured (total length, inches), and released.

Because minnow traps sample small nongame fishes and juvenile gamefish and catch rates in gillnets were low, this combination of gears yielded little information regarding potential of the lake for recreational fishing opportunity. Lakes in which catchable fish species were sampled with other gears or observed in the water were also sampled with a standard 1.5 hours of angler effort, using jig and spin-

ners with light spinning tackle. This provided an additional gear to complete species lists, and provided a rapid assessment of potential fishery quality.

Sampling of the Yellow River reach followed the WDNR baseline monitoring procedures for wadable streams. Sampling was conducted by WDNR Fisheries Management staff based in Chippewa Falls. The length of the sampling station was 2870 feet, which is approximately 35 times the mean stream width of 82 feet. The sampling length of the station is based on the distance necessary to sample more than three pool-riffle sequences. A single electrofishing run was done using a DC-towed electrofishing unit from the downstream to upstream end of the sampling station. Captured fishes were identified, enumerated, and released.

RESULTS

Lake Names

Many of the lakes in the Forest are unnamed. These lakes are identified by township, range, section, and quarter section. We unofficially named most of the "unnamed" lakes. These names are shown in Table 1. Many of these names are descriptive of observations made while on the lakes. For lakes near Dorothy Lake, we appropriated names from the Wizard of Oz. A few of the unnamed lakes had names posted on their shores.

Morphometry

Morphometry is important in lakes because it can play an important role in how a lake assimilates pollutants. Larger and deeper lakes possess a greater water volume and thus they are able to dilute incoming nutrients. In contrast, smaller lakes respond more quickly to delivery of pollutants to the lake. Shallow lakes can not handle incoming nutrients as well as deep lakes. Sediments are a repository of nutrients and other elements. In deep lakes, a good portion of the sediments are isolated from the upper waters during most of the summer. In shallow lakes, periodic mixing events can bring higher nutrients found in the sediments in contact with the upper waters which results in a more productive system.

All of the lakes in the Forest are relatively small. Table 2 shows the range, mean and median of the morphometric values. Their areas ranged from less than 1 acre to a maximum of 91 acres and the median surface area was 5 acres. Although these lakes were small, there was a wide range of depth. The minimum depth 1.6 ft but the maximum depth was 66 feet.

Table 1. Proposed names for unnamed lakes.

UNNAMED T31N R07W S4-2	Thunder
UNNAMED T31N R07W S6-5D	Orange Gloves
UNNAMED T31N R08W S1-6D	Hourglass
UNNAMED T31N R08W S2-11C	Pat's
UNNAMED T31N R08W S2-11D	Karl
UNNAMED T31N R08W S2-12	Klister
UNNAMED T31N R08W S03-16CB	Fishtail
UNNAMED T31N R08W S4-3	Deerfly
UNNAMED T31N R08W S9-13	WhereAreWe
UNNAMED T31N R08W S9-14	Difficult
UNNAMED T31N R08W S9-15	Leech
UNNAMED T31N R08W S10-3	Hickory Ridge
UNNAMED T31N R08W S10-4	Okay
UNNAMED T31N R08W S10-9	Coffee Can
UNNAMED T31N R08W S10-10C	Lost
UNNAMED T31N R08W S10-11A	Arrowhead
UNNAMED T31N R08W S10-11C	Green Cloud
UNNAMED T31N R08W S11-6	Birke
UNNAMED T31N R08W S11-7	
UNNAMED T31N R08W S11-10	Red
UNNAMED T31N R08W S15-1	
UNNAMED T32N R07W S15-10	Tea
UNNAMED T32N R07W S18-1	Snorting Otter
UNNAMED T32N R07W S19-11	Bladderwort
UNNAMED T32N R07W S19-15A	Beaver Pond
UNNAMED T32N R07W S27-13	
UNNAMED T32N R07W S30-6	Blackberry Brambles
UNNAMED T32N R07W S31-8BC	Crash
UNNAMED T32N R08W S25-3	Tinman
UNNAMED T32N R08W S25-8	Invisible
UNNAMED T32N R08W S25-14C	Strawman
UNNAMED T32N R08W S25-14D	Toto
UNNAMED T32N R08W S28-16	Elodea
UNNAMED T32N R08W S29-10B	Hidden
UNNAMED T32N R08W S29-11A	Lily Pond
UNNAMED T32N R08W S29-15	
UNNAMED T32N R08W S29-16BC	Easy
UNNAMED T32N R08W S30-13A	Trail
UNNAMED T32N R08W S30-13C	
UNNAMED T32N R08W S30-16	Teal
UNNAMED T32N R08W S31-1B	
UNNAMED T32N R08W S31-1D	Disenchanting
UNNAMED T32N R08W S32-1	Portage
UNNAMED T32N R08W S32-2	Island
UNNAMED T32N R08W S32-8	Watershield
UNNAMED T32N R08W S32-5A	Hole
UNNAMED T32N R08W S33-10	Moraine
UNNAMED T32N R08W S33-4BA	Duckweed
UNNAMED T32N R08W S33-4CA	Beaver
UNNAMED T32N R08W S36-3	Rainy

Table 2. Summary of morphometry and water chemistry for the study lakes.

	Minimum	Maximum	Mean	Median
Area (acres)	1	91	9	5
Maximum Depth (ft)	1.6	66	13	8
pH	5.6	8.9	6.6	6.5
Alkalinity (μeq L^{-1})	31	1540	208	87
Conductivity (uS cm^{-1})	8.13	142.4	28.2	17.7
Calcium (mg L^{-1})	0.5	18.7	2.9	1.5
Magnesium (mg L^{-1})	0.3	7.3	1.0	0.6
Color (PTU)	7.5	280	59	52
Spring Total P (μg L^{-1})	9	109	33	28
Summer Total P (μg L^{-1})	9	224	43	32
Total Kjeldahl N (μg L^{-1})	430	3080	950	890
Nitrate-N (μg L^{-1})	4	3260	990	900
Total Nitrogen (μg L^{-1})	442	3138	971	904
Nitrogen:Phosphorus	7.6	130.8	33.2	30.1
Secchi Depth (m)	0.3	5.0	1.4	1.2
Chlorophyll (μg L^{-1})	2.0	132.9	21.4	11.4

Since some of these small lakes were relatively deep, this resulted in some of the lakes being very strongly stratified during much of the year. Typically lakes that stratify during the summer mix in the fall and may mix in the spring. Meromictic lakes never mix and thus the bottom waters are permanently isolated from the atmosphere. These types of lakes are highly unusual and there are probably less than 20 of these lakes in the United States. We found three meromictic lakes in the Forest. The three lakes are Little Beaver, Fishpole, and Tinman. All of these lakes possess small surface areas and are highly colored. The meromictic lakes in the Forest are considered endogenic, meaning their meromixis results from an accumulation of salts in the bottom waters which are liberated by means of decomposition in the sediments and sedimenting organic matter. It is possible that Fishpole and Tin-

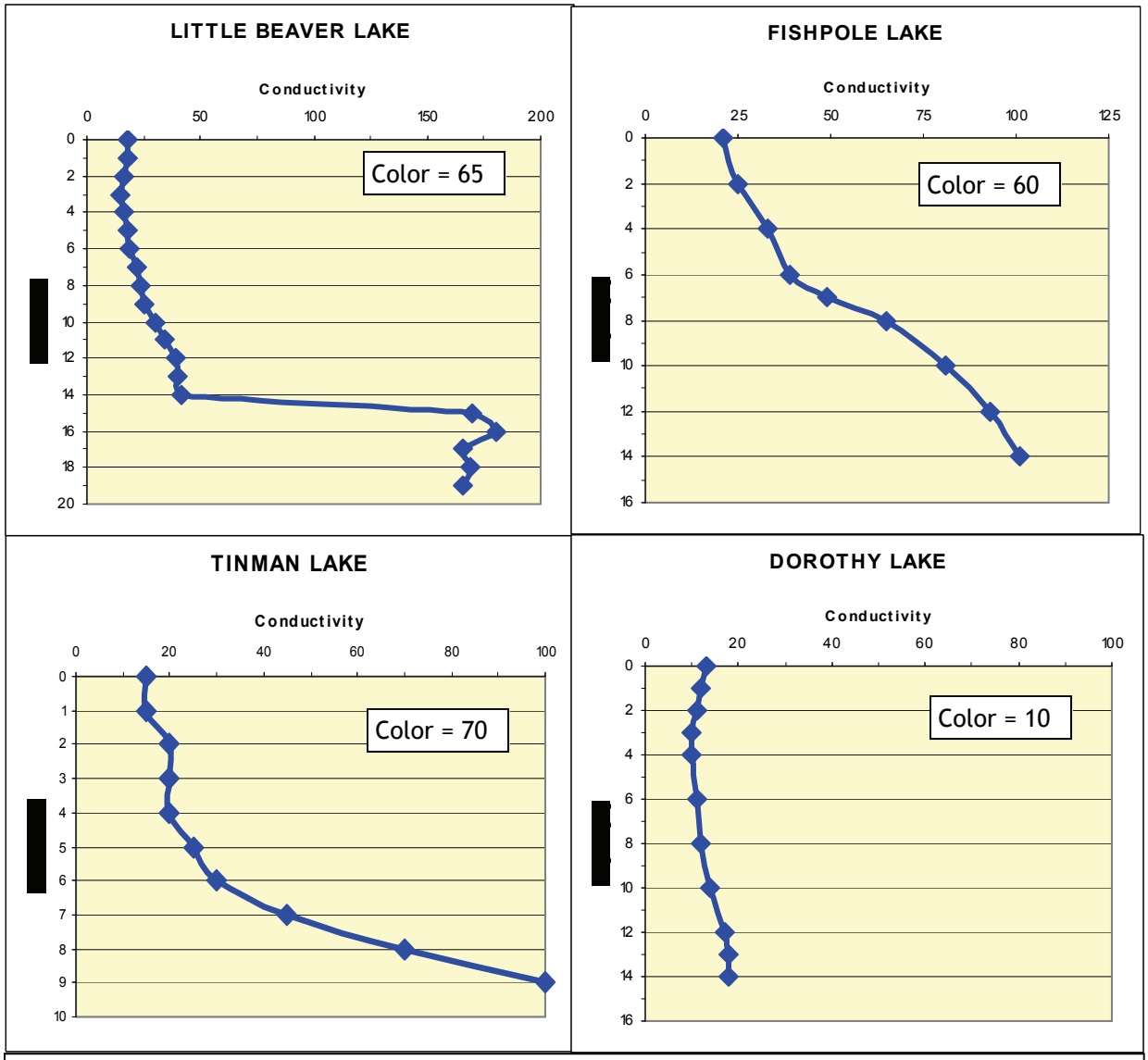

Figure 2. Conductivity profiles of the 3 meromictic lakes. Dorothy Lake also has a small surface area and is deep yet it is not meromictic. This is because the other lakes are highly colored which restricts light penetration and thus their stability is greater.

man may occasionally mix if climatic conditions are right. The conductivity profile of Little Beaver Lake indicates this lake is likely permanently meromictic. Consequently conductivity profiles show highest levels at the bottom of the lake (Figure 2). These lakes are meromictic, in part, because they are highly stained. The color, along with their depth prevent mixing. Color retards mixing since light penetration is restricted and thus the water column that is mixed is shallow. In contrast to these lakes is Dorothy Lake which is also small and deep (maximum depth 51 ft) but has low color. This lake is not meromictic.

From a management standpoint, the relative small size of the Forest lakes is an indication of how sensitive they are to watershed disturbances. Since many of the lakes are shallow, as well as small, small increases in nutrient delivery from their watersheds will have a profound affect upon their nutrient status.

Conductivity

Conductivity gives a indication of the ionic concentration of the water in a lake. Low conductivity indicates that most the water entering the lake does not come from the watershed as precipitation has very low conductivity. Increasing conductivity levels, to some extent, are an indication of the chemical makeup of the soils in the lake's watershed. Lakes in areas with calcareous soils tend to possess higher conductivity levels as calcium carbonate is very soluble. Lakes in areas with granitic soils usually have lower conductivities since these elements that makeup these soils are not as easily dissolved. Since ground water percolates through soil while it is underground, this water possesses higher conductance. In the Forest lakes, the conductivity levels are a relative indication of how much ground water or stream flow enters a lake.

There was a wide range of chemistries in the study lakes. Table 2 shows the range, mean and median concentrations. The pH values ranged from 5.6 to 8.9. Although the lowest values are acidic these lakes are not suffering from acid rain but are naturally low because they likely receive nearly all of the water from precipitation, and the presence of naturally produced organic acids are depressing the pH. All of the lakes with low pH values were highly colored. Alkalinity and conductivity, which are related, also exhibited a wide range of values. Lakes with low alkalinity and conductivity values are seepage lakes and receive little ground water input. Seepage lakes that receive all of their water input from precipitation are sensitive to acidification because rain in the Upper Midwest typically has a pH of less than 5.0. The low pH of rainfall is the result of low chemical content of rain and production of acids (sulfuric and nitric) from industrial sources and automobiles. Lakes with higher conductivity are either flowages, drainage lakes, or seepage lakes that receive large amounts of ground water inputs. Ground water typically possesses higher amounts of ions and thus conductivity because as rain

water percolates through the soil is dissolves chemicals attached to soil particles. Since on an annual basis, ground water is the major portion of stream flow, streams also contain elevated amounts of ions and thus possess higher conductivity values.

Three lakes possessed some of the highest conductivity values of the study lakes. These lakes, Little Plummer, Plummer, and Big Twin, likely receive a significant amount of ground water. Little Plummer and Big Twin do not have inflowing streams but instead ground water must act in this capacity. The lake with the lowest conductivity was Harwood 1 which must receive almost no ground water input. The pH in this lake was 6.4 which indicates the lack of influence of acid precipitation on lakes in the region of the state.

Conductivity levels of lakes are useful for management purposes because it gives an indication of the size of the contributing watershed in the lakes. Lakes with low conductivity values have very small watersheds. Lakes with higher values either have inflowing streams or significant ground water entering the lake. This means that their watersheds are larger and thus activities away from the lake can influence a lake's water quality.

Color

The amount of coloration in the water is important because it can indicate the importance of interactions with nearby wetlands as well as have a profound effect on a lake's productivity. Much of the color is the result of dissolved organic compounds that are produced in wetlands. Color attenuates light penetration so that higher levels restrict light penetration to the upper few feet and thus primary productivity. This can limit the overall productivity of the system as well as result in low oxygen levels in the deeper waters.

The Forest lakes possess a wide range of color (Table 2). Color values range from 7.5 (clear water) to 280 which is highly stained. Many of the lakes in the Forest are classified as dystrophic, meaning they receive high amounts of organic matter from surrounding wetlands. These lakes typically are highly stained and often are referred to as brown-water lakes. The elevated color is the result of wetlands and bogs in the watersheds which impart tannic acids to the water. The amount of color can have a significant influence on a lake's chemistry since organic acids are associated with stained lakes and this can depress a lake's pH. The presence of high color in the water restricts light penetration meaning the sufficient light may not reach the lake bottom for macrophyte growth and the narrow photic zone restricts phytoplankton productivity.

Dissolved Oxygen

Many of the lakes exhibited dissolved oxygen problems. Part of the reason for the low DO was that many of these lakes are dystrophic. This means the lakes are colored which restricts light penetration thus limiting primary productivity to the top few feet of the water column. Some of the lakes had oxygen levels in the surface waters below 5 mg L^{-1} during the summer even in the middle of the day. All of these lakes were colored. Many of these lakes were susceptible to winter fish kills because of their dystrophic nature and shallow depth.

Phosphorus

Phosphorus is an important nutrient regulating plant production. Many studies have found that phosphorus is the nutrient that most limits algal production. Therefore with high phosphorus levels more algae will be produced. This is important from an aesthetic perspective as well as an ecological one. High algal levels can inhibit productivity of attached plants because of shading and also lead to low oxygen levels when the algae dies.

Since phosphorus is such an important nutrient in determining a lake's productivity, thresholds have been established to characterize a lake's trophic status. Lakes with phosphorus levels less than 10 µg L^{-1} are oligotrophic, while 10-20 µg L^{-1} are mesotrophic and phosphorus levels greater than 25 µg L^{-1} are eutrophic.

The study lakes exhibited a wide range of phosphorus values. Concentrations ranged from 9 to 224 µg L^{-1}. This means that the trophic state of the lakes ranges from oligotrophic to eutrophic. Oligotrophic

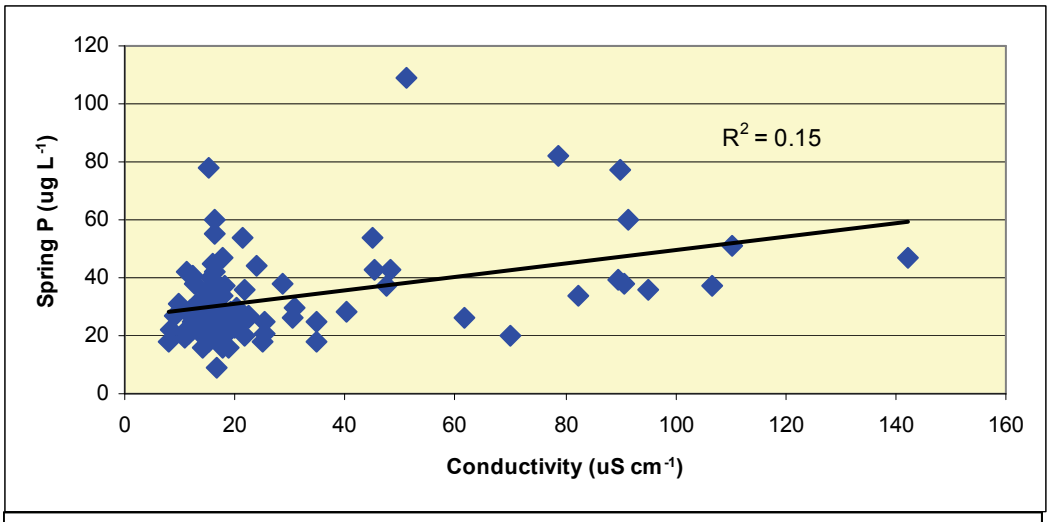

Figure 3. Relationship between conductivity (indicates input of water from watershed) and spring phosphorus. A significant relationship would indicate an important

lakes have low phosphorus concentrations, clear water, and low incidence of algal blooms. Eutrophic lakes have high phosphorus concentration, turbid water and frequent algal blooms. Mesotrophic lakes are intermediate between the other two lake states.

Since the landuse surrounding all of these lakes is forested and wetlands, typically these lakes would be expected to have good water quality and classified as oligo- or mesotrophic. In a general sense, there are two main sources of phosphorus to a lake: runoff from the watershed and internal sources, e.g. sediments and plants. Since the conductivity values show that these lakes receive varying amounts of water from ground water and inflowing streams, if external sources were a major source of phosphorus there should be a significant relationship between conductivity (relative input of water from outside the lake) and phosphorus. Figure 3 shows there is a weak relationship. While the source of water does contribute some phosphorus to the lakes, since the relationship is relatively weak other factors are also important. Three of the highest spring phosphorus concentrations were lakes that either had a high input of ground water (Little Plummer) or were flowages (Spring Creek No. 2 and Willow Creek No. 1).

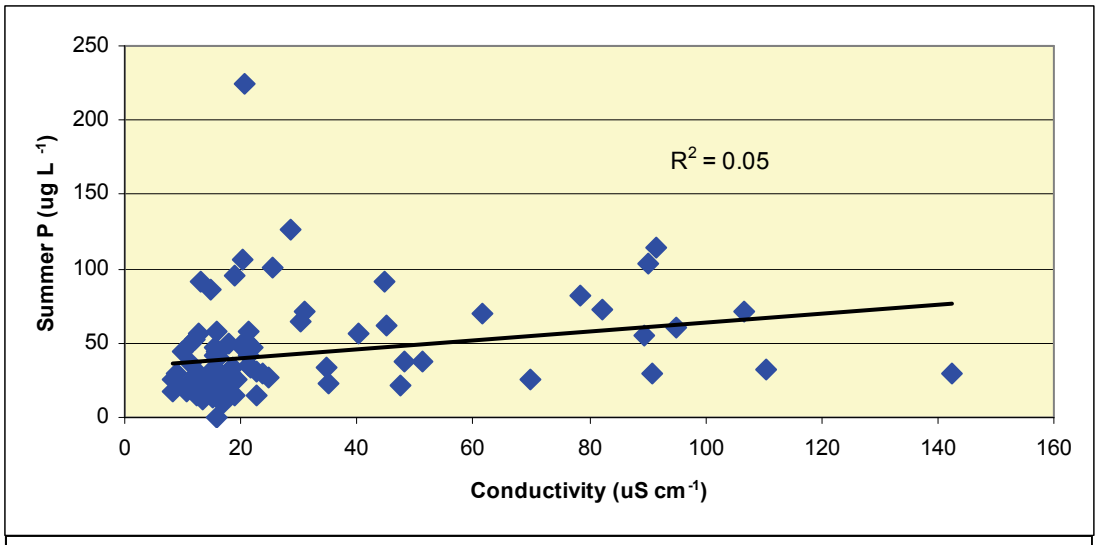

Figure 4. Relationship between color (indicates input of water from wetlands) and summer phosphorus. A significant relationship would indicate an important nutrient source would be the wetlands.

Since many of these lakes are highly colored we also examined the relationship between color and phosphorus (Figure 4). As with conductivity there is a significant, but relatively weak relationship. Since most of the color in the lakes is derived from surrounding wetlands, they are providing some of the phosphorus to the lakes. However this analysis indicates that the water source (amount of water input from the watershed or wetlands) is not a large determinant in phosphorus levels in the lakes.

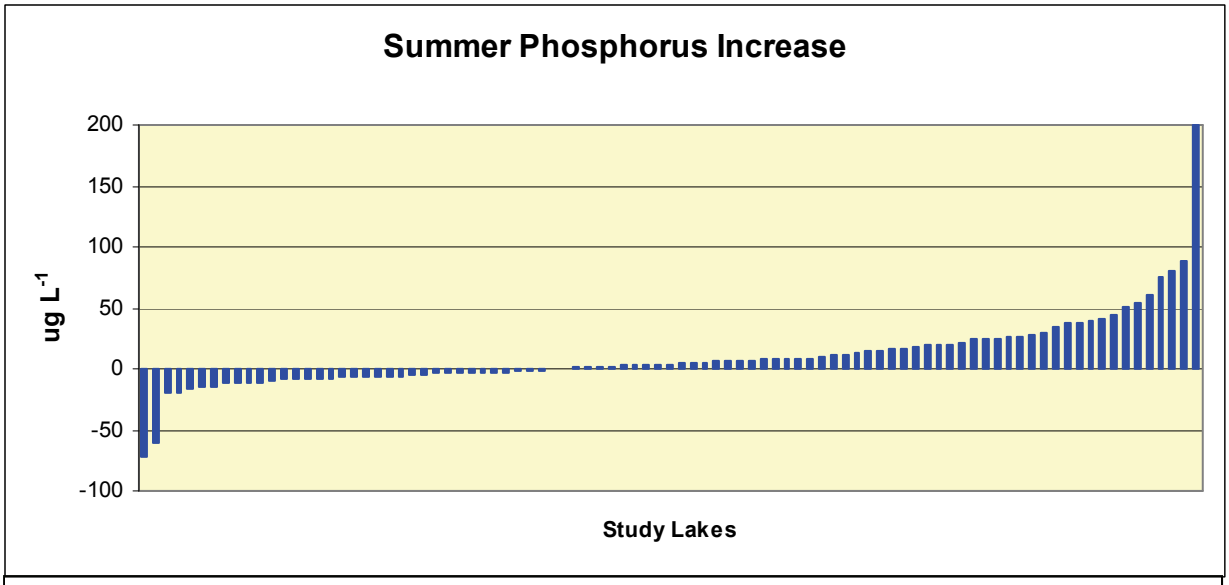

Figure 5. Difference between spring and summer phosphorus concentrations. An increase in P indicates internal loading. Most of the lakes with the greatest increase are shallow lakes. A decrease in phosphorus is more common in deeper lakes since spring runoff often delivers considerable phosphorus to lakes.

The lake with the highest summer phosphorus concentration (UNNAMED T32N R08W S29-11A, Lily Pond) had a moderate color level and no wetland associated with it.

The source of phosphorus for the lakes may be from internal sources, e.g. sediments. This is not uncommon in lakes, especially shallow lakes. If the bottom waters become devoid of oxygen or pH values exceed 9, chemical reactions occur that result in the movement of phosphorus from the sediments to the overlying water. Figure 5 shows the difference in phosphorus concentration between spring and summer. An increase indicates internal loading. Nearly one half the lakes had higher values in August compared with spring. This indicates that internal loading is significant in some of these lakes. Four of the five greatest increase in P levels occurred in shallow lakes. These lakes in decreasing order of summer phosphorus increase were UNNAMED T32N R08W S29-11A (Lily Pond), UNNAMED T31N R08W S211-6 (Birke), UNNAMED T32N R08W S25-8 (Invisible), and UNNAMED T32N R08W S31-1D (Disenchanting). Interestingly, the lake that experienced the greatest decline in phosphorus was Little Plummer, which had a high concentration during the spring. This lake was sampled during the spring in two different years and the concentration was high both years.

Nitrogen

Nitrogen, like phosphorus, is an important nutrient for plant growth. While nitrogen is usually not the limiting nutrient it can influence the type of algae that are present. For example, many blue green algae are able to fix nitrogen from the atmosphere so if nitrogen levels are low in the water they

grow better than algae that can not fix nitrogen. Nearly all algae that form noxious blooms are blue green algae.

Nitrogen values ranged from 430 to 3138 µg L^{-1}. As with the range of phosphorus, the trophic status of the lakes based upon nitrogen ranges from oligotrophic to eutrophic. The relationship between nitrogen and color and conductivity is less significant than it is for phosphorus. Not surprisingly, the lakes with the highest phosphorus levels also have the highest nitrogen concentrations. Generally the limiting nutrient for lakes is phosphorus. Occasionally it is nitrogen. If the nitrogen to phosphorus ratio (N:P) is less than 10:1 then the lake is nitrogen limited but if it is greater than 15:1 it is phosphorus limited. Only two lakes had a N:P ratio less than 10 and 91 lakes had a ratio greater than 15:1. As is typical for Wisconsin lakes, these lakes are phosphorus limited.

Chlorophyll

Chlorophyll is an important pigment in algae and it is what gives plants their green color. Chlorophyll is measured as an indication of the level of planktonic algae in a water body. Generally concentrations greater than 30 µg L^{-1} are considered bloom levels. Chlorophyll levels in the study lakes ranged from 2 to 133 µg L^{-1} with a median value of 11 µg L^{-1}. These values range from oligotrophic to eutrophic levels which is to be expected given the phosphorus and nitrogen concentrations. Twenty two of the lakes had summer chlorophyll values greater than 30 µg L^{-1}. The algal levels for many of the lakes are higher than might be expected since all of their watersheds are forested. The elevated levels are due in part to the shallow depth and small size of many of the lakes.

Paleolimnology

Paleolimnology is the study of changes in a lake ecosystem over long time periods. This is typically done by collecting sediment cores from the lake. The paleolimnological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include diatom frustules, cell walls of certain algal species, and subfossils from aquatic plants. Using the fossil remains found in the sediment, one can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

One of the most useful organisms for paleolimnological analysis are diatoms. These are a type of algae which possess siliceous cell walls, which enables them to be highly resistant to degradation and are usually abundant, diverse, and well-preserved in sediments. They are especially useful, as they

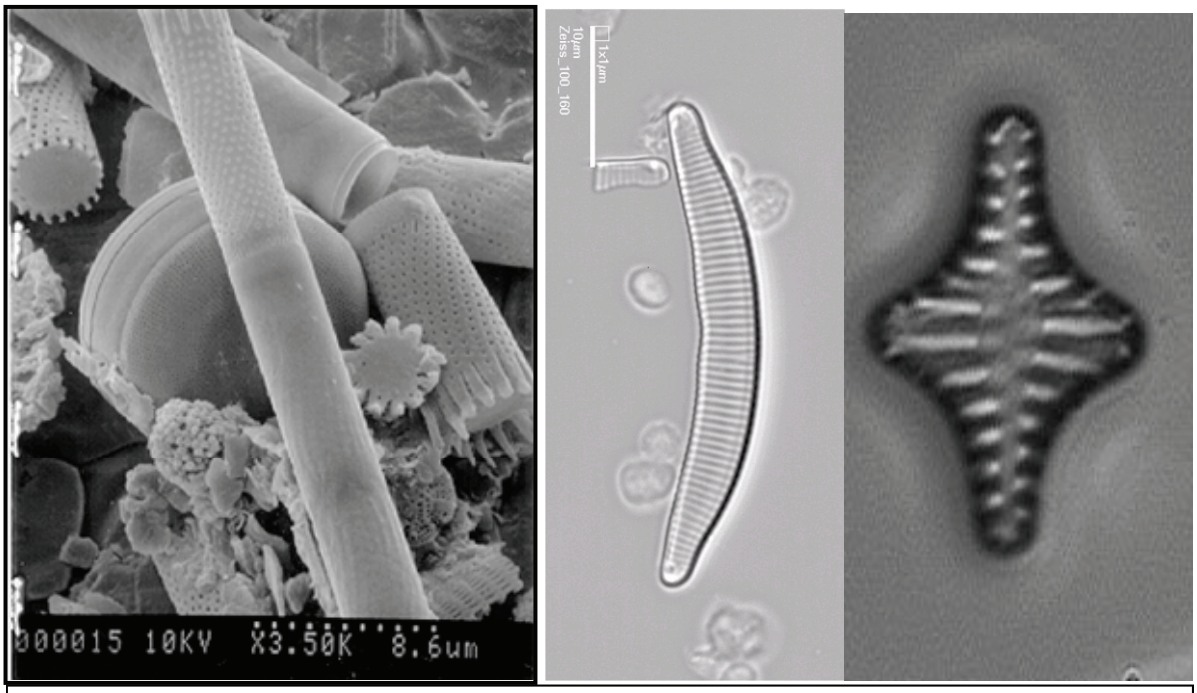

Figure 6. Photomicrographs of diatoms common to lakes found in the Chippewa County Forest. The diatom on the left typically is found in open water environments while the other two pictures are of diatoms commonly found attached to substrates such as downed trees and aquatic plants.

are ecologically diverse. Diatom species have unique features as shown in Figure 6, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom.

For the present study, sediment cores were collected from 18 lakes in the forest (Table 3). The lakes cored had a wide range of nutrient, conductivity, and color values. Most of the lakes with elevated nutrient levels were sampled to determine if these conditions were natural or had changed during the last century. Sediment cores were collected from the deepest areas of the lakes and the top and bottom sections of the cores were kept. It is assumed that the top section represents conditions during the last few years, while the bottom section represents a time period prior to the arrival of European settlers in the mid to late-1880s when much of the area was initially logged. Changes in the diatom community in bottom and top samples were used to estimate water quality changes in the lakes.

Most of the lakes that currently have high nutrient levels also exhibited these traits in the bottom sediment samples. Changes in water quality during the last century did occur in some lakes, but it mostly was an increase in nitrogen. Lakes that receive a considerable amount of groundwater input (highest conductivity), showed the greatest changes. The changes could be the result of changes in the relative contribution of groundwater to these lakes. This likely is the result of climatic variation

Table 3. List of lakes that were cored and some of their Morphometric and chemical characteristics.

Lake	Depth (meters)	Conductivity ($\mu S\ cm^{-1}$)	Color	Phosphorus ($\mu g\ L^{-1}$)	Nitrogen ($\mu g\ L^{-1}$)
Bass No. 2	10.2	13.5	7.5	12	650
Bass No. 3	10.8	22.6	16.3	15	680
Bass Section 30	11.2	47.6	30	21	740
Dorothy	15.5	16.8	10	9	440
Dumke	6.8	16.2	7.5	30	1450
Knickerbocker	7.4	20.0	45	48	1040
Little Plummer	7.0	51.1	85	37	1080
Plummer	10.5	142.4	25	29	1130
Strawman	6.7	10.7	20	18	730
Tamarack	2.8	16.4	70	16	1020
Tinman	9.8	20.3	70	106	1480
Townline	6.8	14.1	25	23	780
Unnamed 32 07 19-11	5.3	8.9	17.5	30	900
Unnamed 32 08 29-10B	3.8	14.7	60	86	1790
Unnamed 32 08 30-13A	0.8	30.8	110	71	1490
Unnamed 32 08 30-16	2.1	12.3	40	29	900
Unnamed 32 08 31-1B	2.1	16.2	25	22	730
Unnamed 32 08 31-1D	2.8	13.0	45	91	1560

since landuse in the watersheds of these lakes has not significantly changed. The changes in the diatom community in some of the shallower lakes suggested that there have been changes in water levels. Most of the lakes with this indication generally have deeper water at the present time. Changes in water levels of these shallow seepage lakes is not surprising. Other studies have found that these types of lakes often undergo large water level fluctuations in response to changes in precipitation. In fact some of the lakes in the forest appeared to have lower water levels during our study period based upon vegetation along the shoreline, while other lakes had higher water levels. The lakes with higher levels had outflowing streams and beavers had constructed dams, raising the water levels.

In summary, the paleolimnological portion of the study indicates that the water quality at the present time is similar to what it was historically given climatic variation. In order to better assess the impacts of forestry practices upon nutrient levels in the lakes a more detailed study would need to be done. Such a study would involve analyzing numerous sections from a core collected in the lake. Other paleolimnological studies have found that logging near lakeshores has a short term impact on nutrient levels in the lakes. These studies have been done in the Rocky Mountains in USA and Canada.

These studies found that following logging, the landscape is quickly revegetated and thus runoff is reduced within 1-2 years. Logging practices can have a much greater impact on nearshore habitat. For example, removal of downed trees along the lakeshore or removal of standing trees that eventually would fall into the lake is more significant. This woody debris provides important habitat to fish and invertebrates and herptiles.

Phytoplankton

Phytoplankton are microscopic plants that are found in water. They are frequently referred to as algae. These organisms are an important part of the lower food chain. They provide food for zooplankton which are eaten by insects and fish. While all of the lakes contain phytoplankton, their abundance and types are very important. Certain algae, e.g. blue greens, generally can not be eaten by zooplankton and thus they don't contribute in a meaningful way to a lake's food chain. In part because they are largely inedible, they can reach high levels if adequate nutrients are present. Blue green algae can also produce toxins. These are harmful to wildlife, and in extreme circumstances, humans.

Phytoplankton also contribute to a lake's biodiversity. A more diverse community generally indicates a more healthy one. Also the composition of the algal community is an indication of the general health of the lake.

Algae found in the samples belonged to 8 groups: chloromonads, cryptomonads, dinoflagellates, euglenoids, chrysophytes, diatoms, chlorophytes or green algae, and cyanobacteria or blue-green algae. Most of these are distinct taxonomic divisions, while cryptomonads and dinoflagellates are both within Division Pyrrhophyta (Wehr & Sheath 2003). Species richness ranged from 9 to 38. Only nine taxa were found in the unnamed lakes T32N R08W S30-16 Teal) and T31N R08W S10-10C (Lost). These samples could easily contain more species, since some algae were identified only to genus. The mean richness for the 110 samples was 23 taxa.

Chrysophytes, cyanobacteria, and green algae were the most abundant algae in the greatest number of lakes. Of the positively identified algae, flagellated *Cryptomonas* cells occurred in the greatest number of lakes. *Cryptomonas* spp. were found in 89 lakes, with *C. erosa* occurring in 67 lakes and *C. ovata* occurring in 57 lakes. *Phormidium* spp. were the next most common taxa, occurring in 76 lakes, with the very small, skinny *Phormidium* sp. 268 occurring in 66 of the samples. *Peridinium* spp. were found in 72 lakes and included several species. *P. inconspicuum* was the most commonly occurring dinoflagellate species and was found in 45 lakes. *P. wisconsinense* was found in 31 lakes, *P. cinctum* was found in 24 lakes, and the large dinoflagellate species *P. limbatum* was found in 13 lakes. *Ankistrodesmus* spp. were the most commonly encountered green algae and were found in 71 lakes.

Dinobryon spp. (mostly *D. acuminatum* and *D. divergens*) were the most commonly identified chrysophytes. They occurred in 68 lakes. Other common taxa include *Trachelomonas* spp. from 54 lakes, *Oocystis* spp. from 52 lakes, and *Gonyostomum semen* from 49 lakes.

There are various criteria generally used to measure dominance. We chose to use cutoffs of 20% and 50% of relative abundance to examine taxa dominance in our samples. Algal taxa with relative abundances greater than 20% were considered dominant, and taxa with more than 50% relative abundance were considered as the majority of cells in a count. Some of our counting conventions, such as counting individual cells of colonial chrysophytes may have artificially inflated the relative abundance of chrysophytes in our counts, but the increased numbers still reflect the greater biomass in the samples of the larger chrysophyte cells.

Green algae (6 lakes), euglenoids and dinoflagellates (2 lakes each), chrysophytes (21 lakes), and cyanobacteria (14 lakes) had division-level counts in the majority (>50%) of cells counted. The algal divisions dominant in the most lakes were chrysophytes (73 lakes), cyanobacteria (43 lakes) and greens (29 lakes).

Fourteen samples had majority abundances of cyanobacteria. Dumke Lake, sampled on 8/21/03, had the highest numbers with 87% of the units counted belonging to cyanobacteria. The small skinny species of *Phormidium* comprised 82% of the total count in this lake. Green algae were the majority of cells counted in 6 samples.

Our data reflect only the diversity of algae in the lake plankton at the time of sampling. Many more species undoubtedly could be found if different microhabitats in the lake were sampled, such as on macrophytes or on littoral sediments. Tamarack Lake had an unusually large cyanobacterial filament (*Tychonema* sp.) (Figure 7) that was found in a mat of filaments that floated up from the lake bottom. The filament is probably new to science but did not occur in the samples for the counts. Another lake (Little Plummer) had an unusual form of the dinoflagellate *Ceratium hirundinella* (Figure 8) that has been previously reported only from Ohio (Susan Carty, pers. comm.).

The phytoplankton found in the Forest lakes is very diverse. The composition of the community is strongly influenced by the level of nutrients in the water, especially phosphorus. Lakes with higher phosphorus tend to possess greater quantities of blue green algae which generally are less desirable.

Macrophytes

Macrophytes are attached plants in the lakes. Some species grow beneath the water surface and these

Figure 7. Photomicrograph of the cyanobacterium *Tychonema* sp. which was found in Tamarack Lake. It is believed that this alga is previously undiscovered.

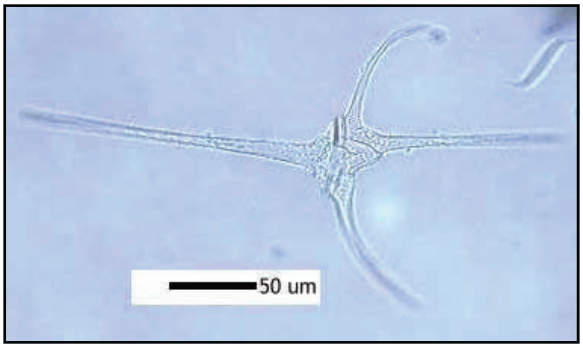

Figure 8. Unusual form of *Ceratium hirundinella* found in Little Plummer Lake.

are referred to as submergents. Other species grow from the lake bottom and extent above the surface of the lake. These are referred to as emergents. These tend to grow in shallower water. The third type of plants are those that grow attached to the lake bottom but at least part of their leaves float on the water surface. These are referred to as floating leaved species.

Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation. The composition of the plant community also indicates the health of the lake. This is frequently measured with the floristic quality index.

185 macrophyte species were found in the Chippewa County Forest Lakes. Five non-native species, 1 threatened species *(Carex lenticularis)* and 8 species of special concern *(Ceratophyllum echinatum, Eleocharis robbinsii, Myriophyllum farwelli, Potamogeton diversifolius, P. vaseyii, Scirpus torreyii, Utricularia geminiscapa, U. purpurea*) were found in the Forest lakes.

The emergent species that occurred in the largest number of lakes in the Chippewa County Forest was *Dulichium arundinaceum* (3 way sedge). The most common submergent species was *Utricularia vulgaris* (common bladderwort). The most common floating leaf species was *Nuphar variegata* (yellow water lily).

The Simpson's Diversity Index of individual lakes ranged from a high of 0.97 (excellent diversity) in Silver Lake, Deer Lake, Hay Meadow Flowage No. 4 and UNNAMED T31N R08W S10-4 (Okay Lake) to a low of 0.79 (low diversity) in UNNAMED T31N R08W S10-4 (Birke Lake) (Table 4). A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable).

The total number of species found in each lake ranged from a high of 50 species found in Horseshoe Lake (T31N R08 S10) to a low of 9 species found in UNNAMED T31N R08W S1-6D (Hourglass) and UNNAMED T31N R08W S11-6 (Birke Lake).

The Average Coefficient of Conservatism for Chippewa County Forest lakes was in the upper quartile for all Wisconsin lakes analyzed and above the mean for lakes in the Northern Lakes and Forest Region (NLFL). This suggests that the aquatic plant community of the Chippewa County Forest lakes is among the lake communities least tolerant of disturbance in Wisconsin and more intolerant of disturbance

Table 4. Summary of Macrophyte Metrics. Mean values and range in parenthesis.

	Wisconsin	Northern Lakes and Forests	Chippewa Forest
Diversity			0.93 (0.79-0.97)
Species Richness			25 (9-50)
C*	6.0	6.7	6.9 (5.0-8.3)
FQI**	22.2	24.3	31.7 (16.7-46.4)

*Coefficient of Conservatism
**Floristic Quality Index

than the average lake in the Northern Lakes and Forest Region. The Average Coefficient of Conservatism for each lake ranged from a high of 8.29 in UNNAMED T32N R07W S18-1 (Snorting Otter Lake) to a low of 5.0-5.29 in the three Willow Flowages. In this range, the Chippewa County Forest Lakes covered the entire gamut from lakes within the lowest quartile in the state and region (within those quartile of lakes most tolerant of disturbance) to the highest quartile (within those quartile of lakes least tolerant of disturbance).

The Floristic Quality of the plant community in Chippewa County Forest lakes in the upper quartile for Wisconsin lakes and Northern Lakes and Forest Region. This suggests that the plant community in Chippewa County Forest lakes as a whole is among the lake communities in Wisconsin and the region closest to an undisturbed condition. The Floristic Quality Index of each Chippewa County Forest lake ranged from a high of 46.88 for Horseshoe Lake (T31N R08 S10) to a low of 9.92 for UNNAMED T31N R08W S11-6 (Birke Lake) and covered the gamut of lakes in the lowest quartile of lakes in the state and region (within the group of lakes farthest from an undisturbed condition) to the highest quartile of lakes in the state and region (well within those group of lakes closest to an undisturbed condition).

Nine listed species were recorded in the Chippewa County Forest Lake Aquatic Plant Surveys. There was one threatened species: *Carex lenticularis* – Bass Lake No. 3. There were eight special concern species:

Ceratophyllum echinatum – in 44 lakes
Eleocharis robbinsii – in 3 lakes
Myriophyllum farwelli – in 28 lakes
Potamogeton diversifolius – in 14 lakes
Potamogeton vaseyi – in 3 lakes
Scirpus torreyi – in 2 lakes
Utricularia geminiscapa – in 43 lakes
Utricularia purpurea – in 11 lakes

Of the 96 lakes studies, at least one listed species was found in 69 lakes and no listed species were found in 27 lakes. Miller Lake and UNNAMED T32N R08W S32-2 (Island Lake) each supported 5 listed species, the most found in one lake.

The macrophyte communities indicated that was a wide range of water quality conditions. The Floristic Quality Index in the Forest lakes exhibited a wide range and was generally reflective of nutrient levels in the lakes.

The complete macrophyte report is in Appendix 4.

Zooplankton

Zooplankton are an important part of the lake ecosystem. They provide for various life stages of fish and herptiles. Many juvenile fish strongly rely on zooplankton for a part of their lifecycle. In lakes without fish, the zooplankton remain an important part of the food chain. They can be an important food item for invertebrates and herptiles. Zooplankton also contribute to the biodiversity of the lake ecosystems.

There were 40 species of zooplankton found in the lakes along with 3 midge species. The list of species and their frequency of occurrence is presented in Table 5.

The most common zooplankters were *Bosmina longirostris, Diaphanosoma birgei, Tropocyclops prasinus mexicanus, Leptodiaptomus minutus* and the predator *Mesocyclops edax*. All of these are commonly found in Wisconsin lakes. One species of note is *Daphnia rosea*. This species has rarely been reported from Wisconsin lakes but it was present in 9 lakes (UNNAMED T31N R08W S2-12, Klister; UNNAMED T31N R08W S9-15, Leech; UNNAMED T31N R08W S10-10C,Lost; UNNAMED T31N R08W S10-11A, Arrowhead; UNNAMED T31N R08W S11-7; UNNAMED T32N R07W S30-6, Blackberry Brambles; UNNAMED T32N R08W S31-1D, Disenchanting; UNNAMED T32N R08W S32-5A, Hole). These are all small relatively shallow lakes.

In addition to these open water species there were a number of species found that typically live among vegetation. None of these were found in more than 6 lakes and then in relatively low numbers.

Table 5. List of zooplankton taxa found and their number of occurrences.

Taxa	Number of Occurrences
Cladocera	
Daphnia ambigua	2
D. catawba	21
D. galeata mendota	2
D. longiremis	2
D. parvula	17
D. pulex	5
D. pulicaria	1
D. retrocurva	2
D. rosea	11
D. schoedleri	4
Ceriodaphnia lacustris	15
Acroperus harpae	3
Alona setulosa	6
Disparalona acutirostris	3
Graptoleberis testudinaria	1
Scaphaleberis aurita	1
Wlassicsia sp.	1
Bosmina longirostris	49
Eubosmina coregoni	9
Holopedium gibberum	35
Diaphanosoma birgei	60
Chydorus sphaericus	15
Sida crystallina	3
Ophryoxus sp.	1
Simocephalus sp.	5
Ilyocryptus sp.	2
Macrothrix sp.	2

Taxa	Number of Occurrences
Cyclopoidae	
Acanthocyclops vernalis	2
Diacyclops nanus	6
Diacyclops bicuspidatus thomasii	1
Eucyclops speratus	4
Macrocyclops albiduss	4
Mesocyclops edax	54
Paracyclops fimbriatus poppei	3
Tropocyclops prasinus mexicanus	42
Leptodiaptomus ashlandi	2
L. minutus	38
L. siciloides	2
Skistodiaptomus oregonensis	23
Skistodiaptomus passidus	5
Chaoboridae	
Chaoborus americanus	10
C. flavicans	5
C. punctipennis	18

Undoubtedly more of these would have been found if a special effort was made to collect samples in the macrophyte beds. The fact that a number of them were found is reflective of the small size and often shallow nature of these lakes. Some species were present that are highly susceptible to fish predation. Their presence indicates that in the lakes were they were found, fish are absent or only present in very low numbers.

The zooplankton communities found in the Forest lakes exhibited a wide diversity of lake ecosystems. These plankton confirmed the absence of fish in some of the lakes. These lakes also possess some relatively rare species, e.g. *Daphnia rosea*. Since this taxa is rarely found, efforts should be made to preserve the water quality in lakes where this species was found.

Fish Community

The fish community is an important component of the lake ecosystem. In many cases this the part of the lake ecosystem that is most important to the public. Even when a recreational fishery is not found, the fish provide an integral component of the food chain. Other wildlife, e.g. herons, utilize these small fish. Fish also contribute to the lake's biodiversity whether they are a recreational fishery or not.

Nineteen fish species were collected in 43 Forest lakes, although surveys in nine lakes detected no fish. Most species detected in the survey were sampled by minnow traps, however, black crappie were sampled only with gillnets and angling and white sucker were sampled only in gillnets. Several species reaching small adult sizes were sampled only in minnow traps; these species include brook stickleback, northern redbelly dace, fathead minnow, Iowa darter, blacknose shiner, bluntnose minnow, and central mudminnow. No state or federally listed endangered or threatened species were encountered in the Forest lakes.

Linear regression models revealed consistent relations between fish species richness and limnological attributes. Species richness of lakes increased with larger lake surface area. Also, species richness was positively related to increasing alkalinity, productivity, conductivity and pH of the lakes. Analysis of variance revealed a greater number of species in lakes with defined inlets or outlets than in unconnected (seepage) lakes ($F=49.99$, $P=<0.001$). Connected lakes averaged 6.0 ± 0.74 species per lake, while unconnected lakes average 1.69 ± 0.25 species per lake. Bluntnose minnow, white sucker, Iowa darter, blacknose shiner, creek chub and yellow bullhead were sampled only in connected lakes.

An ordination of assemblage data (PCA) revealed three clusters of assemblages and explained 40 percent of the variation in the data set in the first two principal components (Figure 9). One group con-

tained panfish/northern pike, the second was dominated by fathead minnows, and the third by central mudminnows. A fourth lake group, not included in the PCA analysis, was characterized by absence of fish. Differences in the communities were associated with the water chemistry and potential habitat.

A total of 777 fish representing twenty-seven fish species was collected in the Yellow River. Six intolerant species were collected including, rainbow darter, fantail darter, Iowa darter, banded darter, northern hog sucker, and smallmouth bass. Only 14 individual fish were species considered tolerant of degraded conditions. These aspects of the fish community help give this reach of the river an excellent biotic integrity rating (IBI score of 90). Exotic fish species were not sampled, nor did collections include any fishes listed as endangered, threatened, or special concern.

Recreational Fishery

Panfish (bluegill, pumpkinseed, yellow perch, and black crappie) and gamefish (northern pike and largemouth bass) were sampled in several lakes and provide a potential recreational fishery. In addition, three bullhead species were collected. These species providing potential for recreational fishing were sampled in 22 lakes. Not surprisingly, the largest lakes, such as Townline and Horseshoe T32-R08-S33 generally provided the most diverse assemblages for recreational fishing. These results are consistent with other findings in Wisconsin lakes (Jennings et al. 1999, and Magnuson et al. 1998). The variety of access types for the Forest lakes presents a range of angler opportunities that includes developed boat ramps, drive-up shore access, and the option of walk-in access for a different angling experience. This range of options caters to diverse interests, and is increasingly rare in Wisconsin.

Lakes with catchable fish but without road access showed evidence of population size structure with a greater proportion of larger fish. Large yellow perch were sampled in Dam Lake and Highland Lake, and large bluegills were sampled in Spence Lake. Calculation of proportional stock density, although from limited data, supports this observation. Although no creel data are available, this association suggests that size structure is impacted by higher angling pressure in easily accessible lakes. Populations are small in these lakes and a slight increase in angling pressure may result in rapid change in size structure. Having a few lakes with walk-in access not only provides a rare angling experience, but can also help shape population size structure and the diversity of angling opportunities.

Despite its small size, accessibility, and apparently high angling pressure (indicated by large amounts of trash, including bait containers, line, etc. left on the shore), Bass Lake #2 contained a fishery including largemouth bass and northern pike up to 28” in total length. Catch of northern pike was limited to a small number of fish in lakes where they were detected. Bass appeared to be more abun-

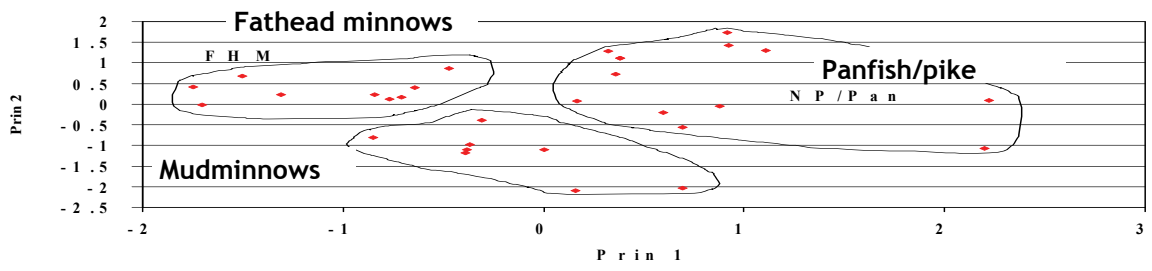

Figure 9. Plot of first 2 principal components representing the fish community types in the Forest lakes.

dant than pike where they were present but their distribution was limited to 6 lakes. The presence of pike and bass in larger sizes suggest that severe fish kills are infrequent in these lakes, although the possibility of unauthorized field transfers of adult fish can not be ruled out.

Several lakes within the Forest have historically provided a fishery for panfish and/or gamefish (WDNR 1995a). Dorothy, Rattz, Spring Creek #1, Star and Tram lakes did not contain viable fisheries during the 2002-03 sampling, most likely as a result of anoxia resulting in fish kills. Management of these lakes susceptible to partial fish kills could include maintenance of recreational fisheries as a goal; however, success may be limited and costs prohibitive. Such management would include periodic stocking to maintain populations. Some stocked year classes would likely be lost before reaching catchable sizes. Alternatively, winterkill or low summer dissolved oxygen could be addressed with costly intervention (such as mechanical aeration) to maintain oxygen concentrations. The limited benefits that a fishery would provide in these small lakes would probably not justify the cost of intensive management. For instances, the start up cost for a 4-panel solar aeration unit that would protect 5 to 10 acres from winterkill would be approximately 4,500 dollars (L.Damman, personal comm., WDNR, Spooner). These startup cost does not cover the yearly maintenance cost or the potential liability associated with open water during the winter.

Implications for forest management

Fish sampling in the Forest lakes detected assemblages typical of lakes of similar size within the region. The processes influencing assemblage structure are largely dependent on natural features of the landscape, and are related to water chemistry, climate, and connections among aquatic systems. The fish species present in the lakes include a couple of species intolerant of degraded conditions (blacknose shiner, Iowa darter), but no threatened or endangered species. No unique features of the

fishery were identified that would suggest the necessity of any steps beyond normally prescribed forestry BMP's for water quality (WDNR 1995b). For example, course woody habitat is extremely important for fish production. It provides cover for small fish and prey. Its presence also provides a substrate so that algae and insects are able to thrive. These in turn provide food for insects and small fish which is important for a healthy fish community. Forestry practices that don't remove downed trees along the lakeshore are strongly encouraged. Forestry practices should also be adopted which do not remove standing trees along the lakeshore as these will eventually provide course woody habitat when they fall over.

The IBI results for the Yellow River suggest that the watershed is in good condition, and that the river contains the number and type of species typically found in lightly impacted streams of the region. Continued sound riparian management, including BMP's for water quality (WDNR 1995b) will help maintain the quality of the river.

The complete fish community assessment report is in Appendix 5

DISCUSSION

Classification

The lakes within the Forest exhibit a diverse and wide range of limnological characteristics. Many of the lakes are dystrophic, meaning that they are highly colored and exhibit low open water productivity and potential low oxygen problems. The trophic status of other lakes range from oligotrophic to eutrophic. Many of the oligotrophic lakes are deep while a majority of the eutrophic lakes are small and shallow. The surface area of the lakes is relatively small, with the largest lake being a flowage. The largest natural lake is Horseshoe Lake with a surface area of 48 acres. Many of the lakes are very small with surface areas less than 1-2 acres. Despite their small size, the lakes exhibit a wide range of depths. Some of the lakes are very shallow having a maximum depth of less than 3 feet. Other lakes are fairly deep with maximum depths over 60 feet. The small surface areas combined with deep depths and highly colored water have combined to produce three meromictic lakes. These are lakes that never completely mix. These lakes are Fishpole, Little Beaver, UNNAMED T32N R08W S25-3 (Tinman). Meromictic lakes are exceedingly rare in Wisconsin and the United States. There are thought to be less than 20 meromictic lakes in the country.

Because these lakes are so diverse a lake classification was developed. This is primarily based upon conductivity and secondarily on color levels. Conductivity was used as the primary classification scheme since it indicates the relative amount of ground water and surface water input into the lakes.

TABLE 6. Proposed Reference Lakes.

Conductivity less than or equal to 20									
	Surface Area	**Sample Depth**							**Total P**
Name	(acres)	(meters)							(mg/L)
Class I (conductance ≤20)									
DOROTHY LAKE	5	15.5	T	32N	R	08W	S	25	0.009
MILLER	5	5.1	T	32N	R	07W	S	22	0.015
STRAWMAN	5	6.7	T	32N	R	08W	S	25	0.018
UNNAMED T32N R08W S32-2	9	1.6	T	32N	R	08W	S	32	0.018
UNNAMED T32N R08W S30-16	4	2.1	T	32N	R	08W	S	30	0.029
SPENCE LAKE	13	20	T	32N	R	08W	S	2	0.032
KNICKERBOCKER LAKE	14	7.4	T	32N	R	08W	S	28	0.048
BURNT WAGON	15	4.5	T	31N	R	08W	S	10	0.050
UNNAMED T32N R08W S31-1D	7	2.8	T	32N	R	08W	S	31	0.091
Class II (conductance >20 and ≤40)									
BASS LAKE No 3 T31N R08W S01	9	10.8	T	31N	R	08W	S	1	0.015
UNNAMED T32N R07W S18-1	2	2.6	T	32N	R	07W	S	18	0.027
TOTO	1	7.9	T	32N	R	08W	S	25	0.042
FISHPOLE LAKE	20	15.0	T	31N	R	08W	S	3	0.049
HAY MEADOW FLG NO. 4	24	7.3	T	31N	R	08W	S	11	0.064
TINMAN	3	9.8	T	32N	R	08W	S	25	0.106
UNNAMED T31N R08W S11-6	6	1.8	T	31N	R	08W	S	11	0.126

	Surface Area	Sample Depth							Total P
Name	(acres)	(meters)							(mg/L)
Class III (conductance >40)									
BASS LAKE T32NR07W S30	6	11.2	T	32N	R	07W	S	30	0.021
LITTLE PLUMMER	10	7.0	T	32N	R	08W	S	34	0.037
UNNAMED T32N R07W S27-13	7.2	0.8	T	32N	R	07W	S	27	0.055
HORSESHOE FLOWAGE	8	1.6	T	32N	R	07W	S	34	0.092
WILLOW CREEK FLG #1	21	1.5	T	32N	R	07W	S	18	0.103

Lakes with less than 20 μS cm^{-1} receive little or no ground water, lakes with a conductivity of 20-40 μS cm^{-1} receive a moderate amount of ground water or stream input and those with a conductivity greater than 40 μS cm^{-1} receive a significant amount of input from external water sources. The classification of each lake can be found in Appendix 2. Class I (conductivity < 20 μS cm^{-1}) has the most lakes. These are seepage lakes that receive very little ground water and no stream water input. Many of these lakes are dystrophic and their trophic state range from oligotrophic to eutrophic. There are about the same number of lakes in Class II and Class III. Most of these lakes are highly colored and their trophic status also ranges from oligotrophic to eutrophic. These classes have all of the lakes with phosphorus concentrations greater than 100 μg L^{-1}. Nearly all of the flowages are in Class III. They are in this class because they receive substantial stream flow and streams have high conductivity because ground water makes up the base flow. The 5 natural lakes in Class III have streams entering the lakes or have streams draining them, indicating they receive a significant amount of ground water.

Based on the above classification system it is recommended that 21 lakes in the Forest be sampled on a regular basis. These proposed lakes should be considered as reference lakes for each lake class. Monitoring of these lakes would assist management of these lakes by alerting managers when significant impacts are occurring in the watershed. The suggested lakes can be found in Table 6. These lakes should be sampled for nutrients, pH, conductivity, color, dissolved oxygen, temperature, and water clarity on a rotating 3 year basis.

Special Lake Areas

Although all of the lakes in the Forest are important we suggest two areas that possess a unique group of lakes that should be of special concern. The lakes in each of these areas represent a variety of lake types.

Dorothy Lake Group (Figure 10)

This group consists of 4 lakes located in close proximity in section 25 township range designation 32 08. The lakes are: Dorothy, UNNAMED T32N R08W S25-14C (Strawman), UNNAMED T32N R08W S25-14D (Toto), and UNNAMED T32N R08W S25-3 (Tinman). All of these lakes are seepage lakes. Tinman and Toto are highly colored lakes. Tinman is relatively deep and appears to be a meromictic lake and is part of a larger wetland complex. Toto Lake is smaller and shallower and is surrounded by a small fringing bog. Dorothy and Strawman lakes have little color. Neither has much wetland associated with it. Dorothy Lake is one of the deepest lakes in the Forest (max. depth 51 ft) yet it is not meromictic because its clear water allows deeper light penetration and thus stratification is not as strong.

Fishpole Lake Group (Figure 11)

This group consists of 6 lakes located in sections 2, 3, and 11 in township range designation 31 08. These lakes exhibit a range of depths from 3 - 49 feet. Fishpole Lake is meromictic and highly colored. It is part of a large wetland complex. The other lakes are not associated with wetlands but range in color and productivity. These lakes exhibit a wide range of macrophyte communities. UNNAMED T31N R08W S11-6 (Birke) seems to be naturally eutrophic. This lake exhibited the worse Floristic Quality Index of all the lakes in the Forest and experienced elevated nutrient and algal levels.

Two other lakes are of special concern because they contain the largest number of listed macrophyte species. These lakes are Miller and UNNAMED T32N R08W S32-2 (Island). Bass Lake No. 3 is also of concern since it contained the only threatened species (*Carex lenticularis*) found in the study.

Comparison of the terrestrial and lacustrine inventories

The DNR Bureau of Endangered Resources conducted a biotic inventory of terrestrial and wetland resources in the Chippewa County Forest. The terrestrial inventory found a number of rare and unique species of plants and animals. They also identified a number of unique forest communities. They identified 14 ecologically important sites in the area. Some of these sites were outside of the area included in the lacustrine portion of the study area. Although the terrestrial areas were larger than areas of special significance identified in the lacustrine inventory, there was some overlap. The Dorothy lakes complex was identified in both the lacustrine and terrestrial analysis. The Fishpole lakes complex is included in the terrestrial site identified as O'Neil Creek Hardwoods. The terrestrial inventory also identified the Bass lakes complex. Although the lacustrine inventory did not recommend this complex it did suggest Bass Lake No. 3 because of the presence of a threatened plant species.

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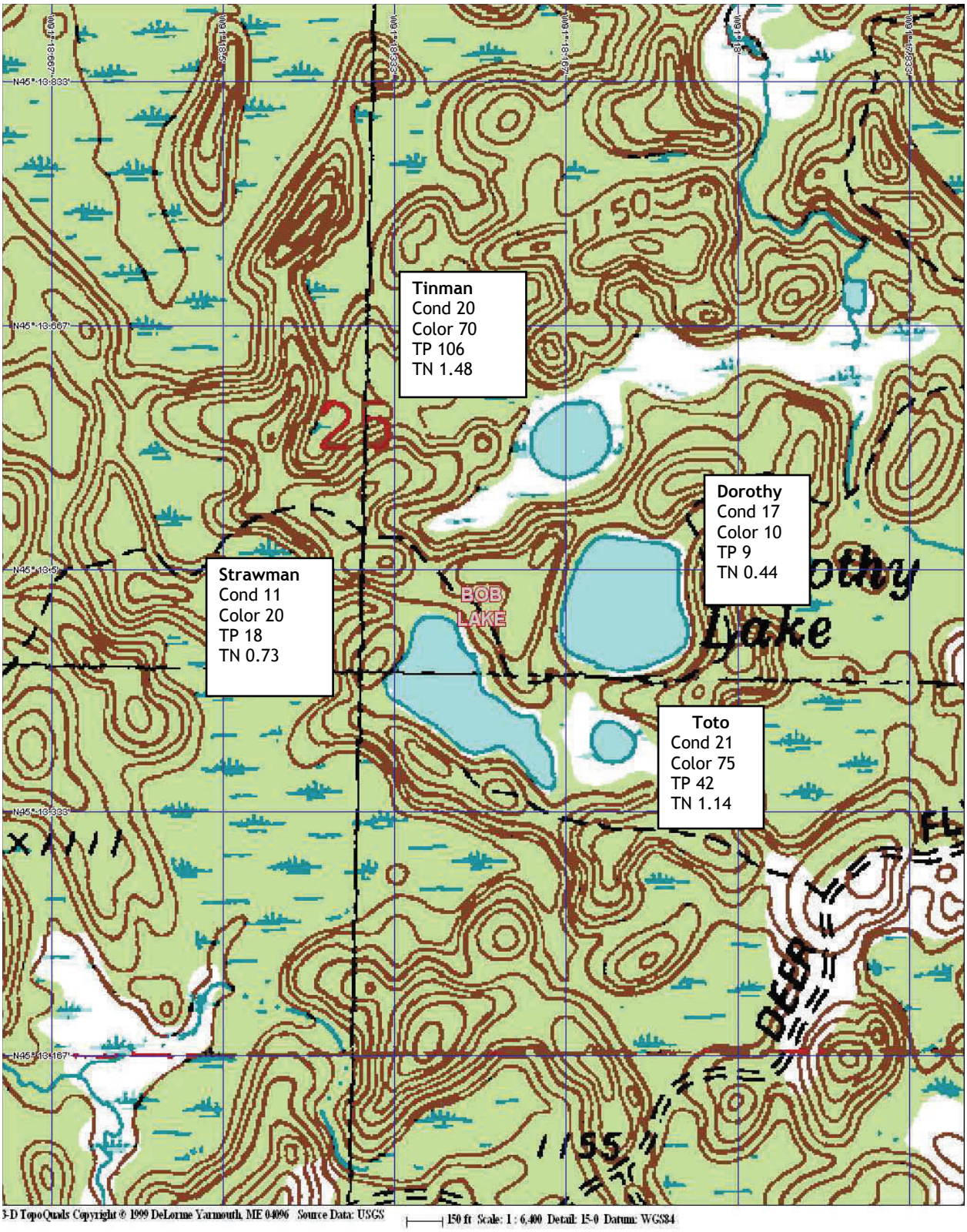

Figure 10. Dorothy Lake Group. This group has a diversity of lake types. Tinman is a meromictic lake because of its depth and high color. Dorothy is deeper but it is not meromictic because its clear water allows greater light penetration and thus reduced stability. Toto lake is a typical bog lake.

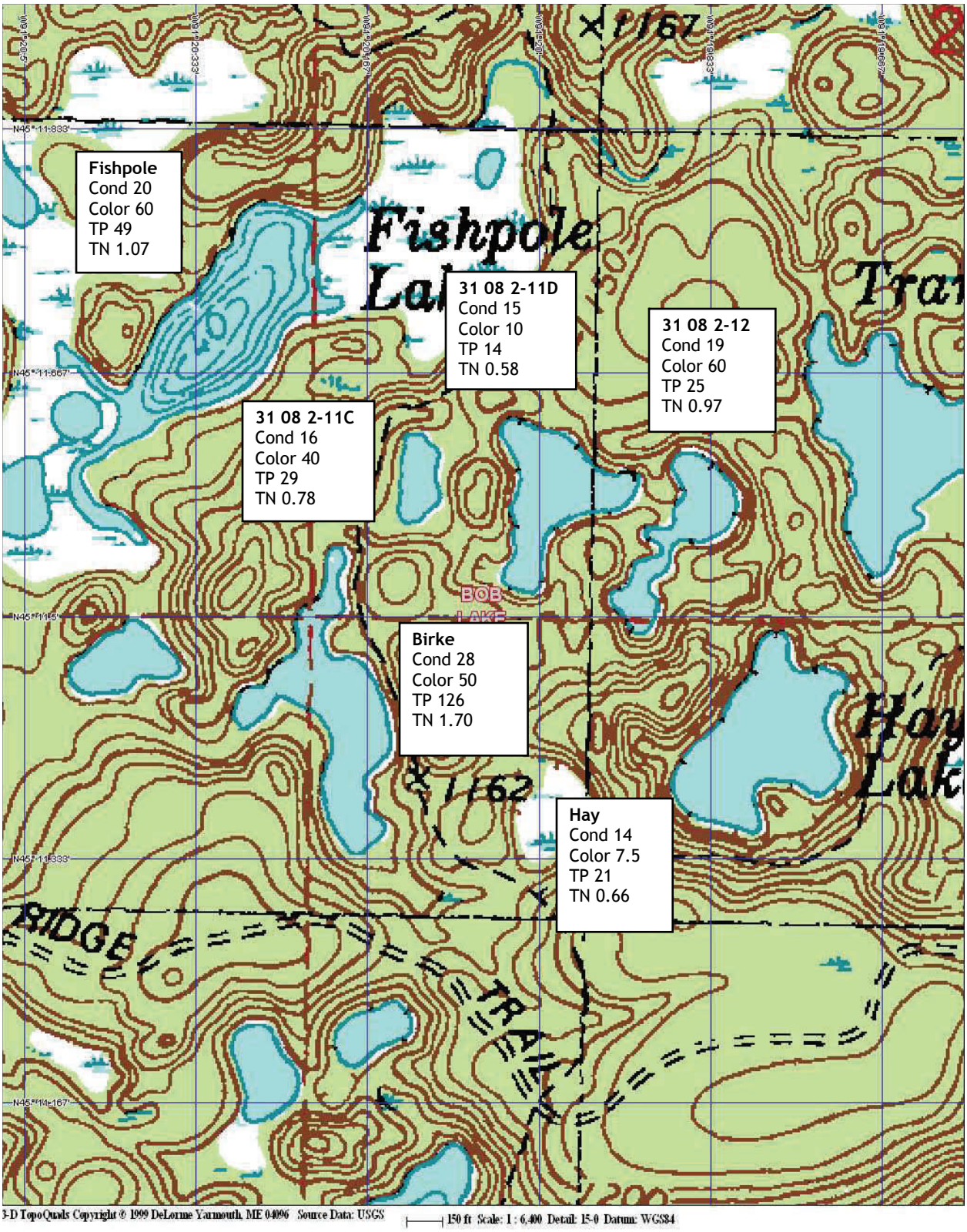

Figure 11. Fishpole Lake Group. This group has a diversity of lake types. Fishpole is a meromictic lake because of its depth and high color. These lakes have a high diversity of macrophyte communities even though many of them are relatively shallow and have similar morphometries.

Appendix 1. Morphometric and chemical characteristics of the Forest Lakes.

Appendix 2. Classification listing of each lake.

Appendix 3. Complete macrophyte report by Debra Konkel

Appendix 4. Complete Fish Community Assessment Report by Gene Hatzenbeler and Martin Jennings.

APPENDIX 1. MORPHOMETRIC AND CHEMICAL CHARACTERISTICS OF THE CHIPPEWA COUNTY FOREST LAKES

Name	Surface Area (acres)	Sample Depth (meters)						WIBC	lat	long	Basin
BASS LAKE No 2 T31N R08W S1-2	12	10.2	T 31N	R 08W	S	2	1833600	45 12.023	91 19.021	UC01
BASS LAKE No 3 T31N R08W S01	9	10.8	T 31N	R 08W	S	1	2347400	45 11.933	91 18.685	UC01
BASS LAKE No 5 T32N R08W S36	6.4	5.2	T 32N	R 08W	S	36	2347100	45 12.395	91 18.59	UC01
BASS LAKE T32NR07W S30	6	11.2	T 32N	R 07W	S	30	2347900	45 13.253	91 16.916	UC01
BIG TWIN LAKE	1	10.8	T 32N	R 07W	S	29	1835400	45 14.024	91 16.459	UC01
BIRCH CREEK FLOWAGE NO. 2	5	1.2	T 32N	R 07W	S	22	2185700	45 14.512	91 13.452	UC01
BOG LAKE	6	1.7	T 32N	R 08W	S	10	1836300	45 16.32	91 20.958	UC01
BURNT WAGON	15	4.5	T 31N	R 08W	S	10	1838200	45 11.088	91 20.645	LC21
DAM LAKE	4	5.2	T 32N	R 08W	S	28	1843000	45 13.219	9122.459	LC21
DEER LAKE	5.0	shore	T 32N	R 08W	S	36	2347500	45 12.352	91 18.135	LC21
DUMKE LAKE	11	6.8	T 32N	R 08W	S	33	1846100	45 13.140	91 21.449	UC01
DOROTHY LAKE	5	15.5	T 32N	R 08W	S	25	1845700	4513.480	91 18.109	UC01
FISHPOLE LAKE	20	15.0	T 31N	R 08W	S	3	1849200	45 11.690	91 20.314	LC21
HARWOOD NO. 1	9	2.1	T 32N	R 08W	S	26	1852800	45 13.199	91 19.909	UC01
HARWOOD NO. 2	14	6.1	T 32N	R 08W	S	26	1852900	45 13.355	91 19.643	UC01
HARWOOD NO. 3	1	2.6	T 32N	R 08W	S	26	1853000	45 13.343	91 19.551	UC01
HAY LAKE	7	4.7	T 31N	R 08W	S	11	1853300	45 11.419	91 19.777	LC21
HAY MEADOW FLG NO. 1	24	11.3	T 31N	R 08W	S	14	2178900	45 10.462	91 19.342	LC21
HAY MEADOW FLG NO. 2	40	2.0	T 31N	R 08W	S	11	2180100	45 10.850	91 19.234	LC21
HAY MEADOW FLG NO. 3	19	2.4	T 31N	R 08W	S	11	2180700	45 11.007	91 19.265	LC21
HAY MEADOW FLG NO. 4	24	7.3	T 31N	R 08W	S	11	2180900	45 11.205	91 19.377	LC21
HIGHLAND LAKE	10	6.1	T 32N	R 08W	S	34	2173300	45 12.552	91 21.37	LC21
HORSESHOE FLOWAGE	8	1.6	T 32N	R 07W	S	34	2186500	45 12.968	91 13.378	LC21
HORSESHOE LAKE T31N R08W S10	17	5.5	T 31N	R 08W	S	10	1854200	45 10.722	91 20.648	LC21
HORSESHOE LAKE T32N R08W S33	24	7.5	T 32N	R 08W	S	33	1854300	45 13.018	91 21.71	UC01
KETTLE LAKE	2	2.6	T 31N	R 08W	S	2	1857800	45 12.076	91 20.184	LC21
KNICKERBOCKER LAKE	14	7.4	T 32N	R 08W	S	28	1858300	45 13.374	91 22.56	UC01
LITTLE BEAVER LAKE	6	>14	T 32N	R 08W	S	28	1860800	45 13.388	91 22.198	UC01
LITTLE PLUMMER	10	7.0	T 32N	R 08W	S	34	2348800	45 12.891	91 21.241	UC01
LOWLAND LAKE	11	6.4	T 32N	R 08W	S	33	2173400	45 12.402	91 21.763	LC21
MILLER	5	5.1	T 32N	R 07W	S	22	2185800	45 14.173	91 13.860	UC01
O'NEIL CREEK FLOWAGE No#1	25	1.5	T 31N	R 08W	S	3	2173000	45 12.035	91 21.362	LC21
O'NEIL CREEK FLOWAGE No. 2	91	0.5	T 31N	R 08W	S	4	2172800	45 11.814	91 21.546	LC21
PLUMMER	41	10.5	T 32N	R 08W	S	34	2348700	45 12.976	91 20.960	UC01
RAT LAKE	4	1.6	T 31N	R 08W	S	3	1876200	45 12.170	91 20.332	LC21
RATTZ LAKE	6	7.0	T 31N	R 08W	S	3	1876300	45 11.869	91 20.780	LC21
SILVER	2	8.5	T 31N	R 08W	S	11	1881000	45 10.967	91 19.987	LC21
SPENCE LAKE	13	20	T 32N	R 08W	S	2	2346400	45 17.247	91 18.989	UC01

Name	Surface Area (acres)	Sample Depth (meters)							WIBC	lat	long	Basin
SPRING CREEK FLOWAGE NO. 1	16	1.4	T	32N	R	07W	S	33	2177300	45 12.670	91 14.926	LC21
SPRING CREEK FLOWAGE NO. 2	16	1.2	T	32N	R	07W	S	33	2177300	45 12.550	91 15.950	LC21
STAR	6.0	4.2	T	31N	R	08W	S	9	1883400	45 21.701	91 21.701	LC21
STRAWMAN	5	6.7	T	32N	R	08W	S	25	1907200	45 13.418	91 18.989	UC01
TAMARACK LAKE T31N R08W S11	2	2.8	T	31N	R	08W	S	11	2180300	45 10.789	91 19.591	LC21
TINMAN	3	9.8	T	32N	R	08W	S	25	1907100	45 13.590	91 18.176	UC01
TOTO	1	7.9	T	32N	R	08W	S	25	1907300	45 13.385	91 18.125	UC01
TOWN LINE LAKE	48	6.8	T	32N	R	08W	S	33	2172600	45 12.821	91 22.003	LC21
TRAM LAKE	20	9.7	T	31N	R	08W	S	2	1886300	45 11.621	91 19.634	LC21
WILLOW CREEK FLG #1	21	1.5	T	32N	R	07W	S	18	2345000	45 15.17	91 17.327	UC01
WILLOW CREEK FLG # 2	2	1.8	T	32N	R	07W	S	17	2345200	45 15.016	91 16.468	UC01
WILLOW CREEK FLG #3		1.9	T	32N	R	07W	S	20	2345400	45 14.671	91 16.189	UC01
WORDEN	17	2.7	T	32N	R	07W	S	17	2047200	45 15.576	91 15.737	UC01
UNNAMED T31N R07W S4-2		1.3	T	31N	R	07W	S	4	3000012	45 12.553	91 13.715	LC21
UNNAMED T31N R07W S6-5D	1	shore	T	31N	R	07W	S	6	2347725	45 12.168	91 17.278	UC01
UNNAMED T31N R08W S1-6D	3	2.5	T	31N	R	08W	S	1	1895600	45 12.116	91 18.781	UC01
UNNAMED T31N R08W S2-11C	1	1.1	T	31N	R	08W	S	2	1895800	45 11.598	91 20.119	LC21
UNNAMED T31N R08W S2-11D	3	1.4	T	31N	R	08W	S	2	1895900	45 11.589	91 19.988	LC21
UNNAMED T31N R08W S2-12	1	1.0	T	31N	R	08W	S	2	1895750	45 11.575	91 19.843	LC21
UNNAMED T31N R08W S03-16CB	2	5.1	T	31N	R	08W	S	3	1896200	45 11.578	91 20.508	LC21
UNNAMED T31N R08W S4-3	2	1.8	T	31N	R	08W	S	4	1896600	45 12.06	91 21.87	LC21
UNNAMED T31N R08W S9-13	3.0	2.2	T	31N	R	08W	S	9	1897100	45 10.916	91 21.572	LC21
UNNAMED T31N R08W S9-14	2.1	1.2	T	31N	R	08W	S	9	1897150	45 11.003	91 21.785	LC21
UNNAMED T31N R08W S9-15	2.1	1.8	T	32N	R	07W	S	19	1903200	45 10.667	91 21.958	LC21
UNNAMED T31N R08W S10-3	2	1.8	T	31N	R	08W	S	10	1897300	45 11.268	91 20.716	LC21
UNNAMED T31N R08W S10-4	1	1.5	T	31N	R	08W	S	10	1897200	45 11.185	91 20.267	LC21
UNNAMED T31N R08W S10-9	6	0.9	T	31N	R	08W	S	10	1897400	45 10.812	91 21.016	LC21
UNNAMED T31N R08W S10-10C	3	1.0	T	31N	R	08W	S	10	1897500	45 11.057	91 20.847	LC21
UNNAMED T31N R08W S10-11A	4.5	1.2	T	31N	R	08W	S	10	1897570	45 10.789	91 21.207	LC21
UNNAMED T31N R08W S10-11C	2.0	1.0	T	31N	R	08W	S	10	1897600	45 10.698	91 21.402	LC21
UNNAMED T31N R08W S11-6	6	1.8	T	31N	R	08W	S	11	1897690	45 11.437	91 20.189	LC21
UNNAMED T31N R08W S11-7	1.2	1.0	T	31N	R	08W	S	11	1897695	45 11.212	91 20.168	LC21
UNNAMED T31N R08W S11-10	8	4.25	T	31N	R	08W	S	11	1897700	45 11.041	91 20.154	LC21
UNNAMED T31N R08W S15-1	3.0	1.0	T	31N	R	08W	S	15	1897925	45 10.516	91 20.238	LC21
UNNAMED T32N R07W S15-10	10	6.1	T	32N	R	07W	S	15	2186100	45 15.305	91 14.004	UC01
UNNAMED T32N R07W S18-1	2	2.6	T	32N	R	07W	S	18	1902800	45 15.722	91 16.592	UC01
UNNAMED T32N R07W S19-11	6	5.3	T	32N	R	07W	S	19	2348300	45 14.132	91 17544	UC01
UNNAMED T32N R07W S19-15A	2.0	2.0	T	32N	R	07W	S	19	2348155	45 14.194	91 16.882	UC01
UNNAMED T32N R07W S27-13	7.2	0.8	T	32N	R	07W	S	27	2186360	45 13.423	91 12.855	UC01

Name	Surface Area (acres)	Sample Depth (meters)							WIBC	lat	long	Basin
UNNAMED T32N R07W S27-13	7.2	0.8	T	32N	R	07W	S	27	2186360	45 13.423	91 12.855	UC01
UNNAMED T32N R07W S30-6	2.0	1.8	T	32N	R	07W	S	30	1903280	45 14.013	91 17.648	UC01
UNNAMED T32N R07W S31-8BC	3	1.5	T	32N	R	07W	S	31	1903325	45 12.841	91 17.340	UC01
UNNAMED T32N R08W S25-8	1	2.9	T	32N	R	08W	S	25	1907050	45 13.558	91 18.545	UC01
UNNAMED T32N R08W S28-16	5	2.0	T	32N	R	08W	S	28	1908300	45 13.205	91 21.557	UC01
UNNAMED T32N R08W S29-10B	3	3.8	T	32N	R	08W	S	29	1909000	45 13.564	91 23.835	UC01
UNNAMED T32N R08W S29-11A	3	1.8	T	32N	R	08W	S	29	1909200	45 13.363	91 23.712	UC01
UNNAMED T32N R08W S29-15		1.4	T	32N	R	08W	S	29	1908800	45 13.277	91 23.064	UC01
UNNAMED T32N R08W S29-16BC	2	1.1	T	32N	R	08W	S	29	1908650	45 13.278	91 22.942	UC01
UNNAMED T32N R08W S30-13A	12	0.8	T	32N	R	08W	S	30	1909100	45 13.494	91 23.974	UC01
UNNAMED T32N R08W S30-13C	2	1.3	T	32N	R	08W	S	30	1909700	45 13.472	91 24.104	UC01
UNNAMED T32N R08W S30-16	4	2.1	T	32N	R	08W	S	30	1909900	45 13.187	91 23.364	UC01
UNNAMED T32N R08W S31-1B	3.0	2.1	T	32N	R	08W	S	31	1910300	45 13.170	91 24.109	UC01
UNNAMED T32N R08W S31-1D	7	2.8	T	32N	R	08W	S	31	1910400	45 13.086	91 23.954	UC01
UNNAMED T32N R08W S32-1	2.0	1.1	T	32N	R	08W	S	32	1911700	45 13.163	91 22.657	UC01
UNNAMED T32N R08W S32-2	9	1.6	T	32N	R	08W	S	32	1911800	45 12.993	91 23.079	UC01
UNNAMED T32N R08W S32-8	6	3.4	T	32N	R	08W	S	32	1912200	45 12.928	91 23.520	UC01
UNNAMED T32N R08W S32-5A		1.6	T	32N	R	08W	S	33	1912000	45 13.114	91 23.274	UC01
UNNAMED T32N R08W S33-10	4	8.3	T	32N	R	08W	S	33	1913400	45 12.561	91 22.604	LC21
UNNAMED T32N R08W S33-4BA		1.5	T	32N	R	08W	S	33	1912900	45 12.911	91 21.578	UC01
UNNAMED T32N R08W S33-4CA	1	1.5	T	32N	R	08W	S	33	1912900	45 12.819	91 21.649	LC21
UNNAMED T32N R08W S36-3	11	2.6	T	32N	R	08W	S	36	2346800	45 12.944	91 18.341	UC01
UNNAMED T32N R08W S36-11	3	1.4	T	32N	R	08W	S	36	1913750	45 12.944	91 18.341	UC01

Name	Calcium (mg/L)	Magnesium (mg/L)	Alkalinity (ueq/L)	Field pH	Summer Secchi (m)	Color	Conductivity (uS/cm)	Spring Total P (mg/L)	Summer Total P (mg/L)
BASS LAKE No 2 T31N R08W S1-2	1.2	0.40	88	6.65	3.2	7.5	13.5	0.023	0.012
BASS LAKE No 3 T31N R08W S01	2.5	0.85	180	7.22	2.8	16.3	22.59	0.027	0.015
BASS LAKE No 5 T32N R08W S36	9.0	3.10	747	7.33	1.9	50	69.9	0.020	0.025
BASS LAKE T32NR07W S30	5.6	2.3	570	7.09	1.3	30	47.6	0.037	0.021
BIG TWIN LAKE	7.3	2.50	527	7.28	0.4	105	61.7	0.026	0.070
BIRCH CREEK FLOWAGE NO. 2	4.4	1.6	252	6.51	0.3	280	45.2	0.043	0.062
BOG LAKE	1.5	0.49	80	6.07		80	15.8	0.022	
BURNT WAGON	1.2	0.64	66	6.59	1.2	35	11.43	0.021	0.050
DAM LAKE	1.5	0.55	100	6.41	1.5	55	18.2	0.020	0.029
DEER LAKE			929	6.93					
DUMKE LAKE	1.4	0.50	122	8.91	1.2	7.5	16.2	0.060	0.030
DOROTHY LAKE	1.8	0.65	92	6.59	5.0	10	16.8	0.009	0.009
FISHPOLE LAKE	2.1	0.78	147	6.53	1.2	60	20.2	0.028	0.049
HARWOOD NO. 1	0.8	0.3	44	6.37	VAB	25	8.13	0.018	0.025
HARWOOD NO. 2	1.1	0.4	71	6.32	3.1	30	12.22	0.022	0.015
HARWOOD NO. 3	0.9	0.4	76	5.83	1.2	70	15.63	0.034	0.029
HAY LAKE	1.1	0.45	73	6.61	1.8	7.5	14.00	0.020	0.021
HAY MEADOW FLG NO. 1	5.1	1.80	366	6.92	1.0	90	48.1	0.043	0.037
HAY MEADOW FLG NO. 2	3.8	1.4	198	6.46	0.7	120	40.1	0.028	0.056
HAY MEADOW FLG NO. 3	3.4	1.40	285	6.52	0.9	60	35.0	0.018	0.023
HAY MEADOW FLG NO. 4	2.8	1.00	216	6.39	0.8	110	30.3	0.026	0.064
HIGHLAND LAKE	1.3	0.47	51	6.47	2.5	30	14.03	0.027	0.023
HORSESHOE FLOWAGE	6.0	1.70	354	6.99	0.4	120	44.85	0.054	0.092
HORSESHOE LAKE T31N R08W S10	1.5	0.64	114	6.80	1.5	25	16.2	0.021	0.040
HORSESHOE LAKE T32N R08W S33	1.2	0.46		6.95	3.1	15	12.84	0.029	0.021
KETTLE LAKE	1.5	0.48	82	6.60	1.6	40	16.1	0.037	0.045
KNICKERBOCKER LAKE	1.7	0.61	127	6.57	1.1	45	20.0	0.023	0.048
LITTLE BEAVER LAKE	2.0	0.63	139	6.45	ND	65	21.9	0.036	0.047
LITTLE PLUMMER	9.1	3.2	702	7.95	1.0	85	51.1	0.109	0.037
LOWLAND LAKE	1.5	0.53	57	6.52	1.8	40	15.12	0.034	0.026
MILLER	1.4	0.60	75	6.46	2.0	12.5	18.82	0.016	0.015
O'NEIL CREEK FLOWAGE No#1	14.0	4.40	1110	7.50	1.4	40	110.4	0.051	0.032
O'NEIL CREEK FLOWAGE No. 2	11.4	3.7	797	7.05	1.0	70	82.4	0.034	0.073
PLUMMER	18.7	7.3	1540	8.67	1.7	25.0	142.4	0.047	0.029
RAT LAKE	1.1	0.43	72	6.70	1.4	17.5	12.0	0.027	0.052
RATTZ LAKE	1.1	0.41	47	6.35	3.5	17.5	14.2	0.016	0.026
SILVER	3.1	1.3	197	6.10	0.3	160	34.8	0.025	0.033
SPENCE LAKE	2.1	0.57	92	6.33	0.9	100	18.2	0.037	0.032

Name	Calcium (mg/L)	Magnesium (mg/L)	Alkalinity (ueq/L)	Field pH	Summer Secchi (m)	Color	Conductivity (uS/cm)	Spring Total P (mg/L)	Summer Total P (mg/L)
SPRING CREEK FLOWAGE NO. 1	7.3	2.6	552	6.96	1.2	95	95.1	0.036	0.061
SPRING CREEK FLOWAGE NO. 2	9.9	3.00	713	7.01		110	78.6	0.082	0.082
STAR	1.8	0.67	87	6.78	1.2	12.5	14.6	0.023	0.025
STRAWMAN	1.1	0.39	42	6.10	3.2	20	10.71	0.019	0.018
TAMARACK LAKE T31N R08W S11	1.2	0.56	33	5.79	1.7	70	16.44	0.020	0.016
TINMAN	1.8	0.52	131	6.24	1.0	70	20.31	0.030	0.106
TOTO	1.8	0.65	61	6.02	1.4	140	21.2	0.026	0.042
TOWN LINE LAKE	1.3	0.55	72	6.58	2.2	25	14.1	0.031	0.023
TRAM LAKE	1.5	0.56	65	6.88	2.4	12.5	14.95	0.030	0.020
WILLOW CREEK FLG #1	10.0	3.00	685	7.35	1.0	60	90.1	0.077	0.103
WILLOW CREEK FLG # 2	7.0	2.3	530	7.36	1.4	55	90.7	0.038	0.029
WILLOW CREEK FLG #3	10.0	3.20	780	7.21	1.0	200	91.4	0.060	0.114
WORDEN	1.6	0.5	119	6.31	1.3	40	14.6	0.023	0.026
UNNAMED T31N R07W S4-2	2.2	0.7			0.8	90	18.8		0.095
UNNAMED T31N R07W S6-5D	1.9	0.66	117						
UNNAMED T31N R08W S1-6D	1.7	0.52	86	6.59	2.2	40	18.7	0.022	0.034
UNNAMED T31N R08W S2-11C	2.0	0.58	97	6.03	VOB	40	16.26	0.036	0.029
UNNAMED T31N R08W S2-11D	1.7	0.54	63	6.56	VOB	10	15.27	0.018	0.014
UNNAMED T31N R08W S2-12	1.5	0.62	73	6.03	0.8	60	19.3	0.028	0.025
UNNAMED T31N R08W S03-16CB	2.0	0.70	133	6.43	1.2	50	21.66	0.020	0.033
UNNAMED T31N R08W S4-3	1.1	0.39	68	6.31	VOB	40	13.17	0.026	0.028
UNNAMED T31N R08W S9-13	0.9	0.4		6.18	VAB	20	11.57	0.023	0.021
UNNAMED T31N R08W S9-14	1.3	0.5	101	6.32	VAB	75	17.72	0.034	0.030
UNNAMED T31N R08W S9-15					0.8	120	21.05		0.051
UNNAMED T31N R08W S10-3	0.9	0.37	43	6.25	1.2	17.5	11.3	0.042	0.036
UNNAMED T31N R08W S10-4	1.2	0.5	67	6.29	1.6	90	22.60	0.026	0.031
UNNAMED T31N R08W S10-9	1.6	0.57	74	6.20	VOB	25	12.10	0.029	0.020
UNNAMED T31N R08W S10-10C	1.2	0.5	40	6.42	0.8	50	15.26	0.078	0.017
UNNAMED T31N R08W S10-11A	1.4	0.5	75	6.54	VAB	55	16.18	0.042	0.031
UNNAMED T31N R08W S10-11C	1.3	0.5		6.36	1.8	25	15.86	0.045	0.026
UNNAMED T31N R08W S11-6	2.6	0.85	145	6.88	1.2	17.5	28.5	0.038	0.126
UNNAMED T31N R08W S11-7	1.5	0.5	81	6.57	0.9	90	21.32	0.054	0.058
UNNAMED T31N R08W S11-10	1.3	0.60	74	6.44	VOB	25	15.32	0.021	0.041
UNNAMED T31N R08W S15-1	0.9	0.3	81	6.15	0.9	75	17.66	0.023	0.030
UNNAMED T32N R07W S15-10	2.4	0.84	84	6.10	0.4	140	23.8	0.044	0.030
UNNAMED T32N R07W S18-1	1.9	0.72	51	5.63	0.5	80	24.86	0.018	0.027
UNNAMED T32N R07W S19-11	0.54	0.40	31	6.20	1.5	17.5	8.9	0.027	0.030
UNNAMED T32N R07W S19-15A	3.6	1.4	230	6.48		105	25.3	0.025	

Name	Calcium (mg/L)	Magnesium (mg/L)	Alkalinity (ueq/L)	Field pH	Summer Secchi (m)	Color	Conductivity (uS/cm)	Spring Total P (mg/L)	Summer Total P (mg/L)
UNNAMED T32N R07W S27-13	8.4	2.6	578	7.12	VAB	70	89.6	0.039	0.055
UNNAMED T32N R07W S30-6	1.5	0.5	105	6.32	1.3	55.0	17.66	0.016	0.022
UNNAMED T32N R07W S31-8BC	1.3	0.44	74	6.10	1.0	60	17.65	0.027	0.020
UNNAMED T32N R08W S25-8	1.5	0.54	80	5.95	1.0	140	25.3	0.021	0.101
UNNAMED T32N R08W S28-16	1.6	0.53		6.60	VOB	60	12.60	0.038	0.056
UNNAMED T32N R08W S29-10B	1.8	0.63	66	6.42	1.1	60	14.7	0.035	0.086
UNNAMED T32N R08W S29-11A	1.4	0.47	48	6.50	0.6	40	20.55	0.024	0.224
UNNAMED T32N R08W S29-15	0.9	0.43	42	6.18	1.0	55	12.3	0.041	0.027
UNNAMED T32N R08W S29-16BC	1.3	0.45		6.35	1.0	55	15.5	0.040	0.047
UNNAMED T32N R08W S30-13A	1.9	0.78	49	5.89	0.3	110	30.8	0.030	0.071
UNNAMED T32N R08W S30-13C	1.5	0.52	114	6.07	VOB	40	16.3	0.055	0.044
UNNAMED T32N R08W S30-16	1.1	0.41	45	5.85	VOB	40	12.3	0.025	0.029
UNNAMED T32N R08W S31-1B	1.1	0.5	52	6.51	VAB	25	16.2	0.026	0.022
UNNAMED T32N R08W S31-1D	1.3	0.46	72	6.99	0.95	45	13.0	0.031	0.091
UNNAMED T32N R08W S32-1	1.1	0.4	95	6.22	VAB	50	15.1	0.031	0.032
UNNAMED T32N R08W S32-2	1.1	0.36	92	6.55	VOB	17.5	8.27	0.022	0.018
UNNAMED T32N R08W S32-8	1.1	0.43	49	6.27	1.1	40	9.91	0.031	0.045
UNNAMED T32N R08W S32-5A	1.1	0.4	41	6.08	VAB	35	14.34	0.028	0.022
UNNAMED T32N R08W S33-10	2.1	0.75	73	6.23	1.1	70	17.87	0.047	0.050
UNNAMED T32N R08W S33-4BA	1.1	0.37		6.38	VOB	60	15.8	0.031	0.058
UNNAMED T32N R08W S33-4CA	1.2	0.42	34	5.90	VOB	70	15.81	0.030	0.044
UNNAMED T32N R08W S36-3	9.6	2.90	666	7.38	0.8	105	106.8	0.037	0.071
UNNAMED T32N R08W S36-11	1.5	0.58	93	5.86	0.8	60	21.4	0.026	0.035

Name	Kjeldahl-N (mg/L)	Nitrate-N (mg/L)	Total N (mg/L)	Chlorophyll (ug/L)
BASS LAKE No 2 T31N R08W S1-2	0.65	<0.01	0.65	4.76
BASS LAKE No 3 T31N R08W S01	0.66	0.024	0.68	4.81
BASS LAKE No 5 T32N R08W S36	0.60	<0.01	0.60	7.56
BASS LAKE T32NR07W S30	0.74	LT 0.01	0.74	15.34
BIG TWIN LAKE	0.88	<0.01	0.88	35.65
BIRCH CREEK FLOWAGE NO. 2	1.07	LT 0.01	1.07	7.82
BOG LAKE	0.61	0.026	0.64	
BURNT WAGON	1.13	<0.01	1.13	48.25
DAM LAKE	1.03	<0.01	1.03	38.45
DEER LAKE				
DUMKE LAKE	1.43	<0.022	1.45	12.08
DOROTHY LAKE	0.43	0.012	0.44	3.11
FISHPOLE LAKE	1.02	0.054	1.07	57.57
HARWOOD NO. 1	0.69	LT 0.01	0.69	11.24
HARWOOD NO. 2	0.64	LT 0.01	0.64	7.87
HARWOOD NO. 3	0.60	LT 0.01	0.60	9.59
HAY LAKE	0.64	0.016	0.66	7.91
HAY MEADOW FLG NO. 1	1.14	0.062	1.20	10.54
HAY MEADOW FLG NO. 2	1.02	LT 0.01	1.02	61.39
HAY MEADOW FLG NO. 3	0.74	0.175	0.92	10.60
HAY MEADOW FLG NO. 4	1.30	0.146	1.45	67.86
HIGHLAND LAKE	0.75	0.019	0.77	19.38
HORSESHOE FLOWAGE	1.36	<0.01	1.36	33.41
HORSESHOE LAKE T31N R08W S10	0.88	0.015	0.90	23.88
HORSESHOE LAKE T32N R08W S33	0.64	0.030	0.67	10.25
KETTLE LAKE	0.96	0.015	0.98	5.46
KNICKERBOCKER LAKE	1.02	0.015	1.04	25.47
LITTLE BEAVER LAKE	0.93	0.010	0.94	10.67
LITTLE PLUMMER	1.08	LT 0.01	1.08	48.10
LOWLAND LAKE	0.81	0.027	0.84	16.92
MILLER	0.56	0.010	0.57	9.64
O'NEIL CREEK FLOWAGE No#1	0.79	<0.01	0.79	7.58
O'NEIL CREEK FLOWAGE No. 2	1.04	LT 0.01	1.04	69.61
PLUMMER	1.08	0.031	1.13	14.66
RAT LAKE	0.96	<0.01	0.96	42.98
RATTZ LAKE	0.69	0.010	0.70	8.70
SILVER	0.91	LT 0.01	0.91	28.17
SPENCE LAKE	0.91	<0.01	0.91	2.79

Name	Kjeldahl-N (mg/L)	Nitrate-N (mg/L)	Total N (mg/L)	Chlorophyll (ug/L)
SPRING CREEK FLOWAGE NO. 1	0.945	0.015	0.96	11.81
SPRING CREEK FLOWAGE NO. 2	0.91	0.038	0.95	
STAR	0.74	0.013	0.75	12.33
STRAWMAN	0.70	0.030	0.73	5.22
TAMARACK LAKE T31N R08W S11	0.92	0.097	1.02	12.52
TINMAN	1.31	0.167	1.48	132.87
TOTO	1.14	<0.01	1.14	59.98
TOWN LINE LAKE	0.78	<0.01	0.78	14.64
TRAM LAKE	0.69	0.047	0.74	13.67
WILLOW CREEK FLG #1	1.23	0.072	1.30	111.94
WILLOW CREEK FLG # 2	0.75	0.046	0.80	12.80
WILLOW CREEK FLG #3	1.24	0.106	1.35	43.14
WORDEN	0.76	0.043	0.80	12.55
UNNAMED T31N R07W S4-2	1.85	LT 0.01	1.85	83.75
UNNAMED T31N R07W S6-5D				
UNNAMED T31N R08W S1-6D	0.79	0.081	0.87	11.23
UNNAMED T31N R08W S2-11C	0.78	<0.01	0.78	8.94
UNNAMED T31N R08W S2-11D	0.58	<0.01	0.58	4.43
UNNAMED T31N R08W S2-12	0.93	0.042	0.97	4.32
UNNAMED T31N R08W S03-16CB	0.89	<0.01	0.89	36.37
UNNAMED T31N R08W S4-3	0.82	<0.01	0.82	4.85
UNNAMED T31N R08W S9-13	0.70	LT 0.01	0.70	10.01
UNNAMED T31N R08W S9-14	0.82	LT 0.01	0.82	9.57
UNNAMED T31N R08W S9-15	1.32	0.066	1.39	32.22
UNNAMED T31N R08W S10-3	0.79	0.012	0.80	18.30
UNNAMED T31N R08W S10-4	0.68	LT 0.01	0.68	1.98
UNNAMED T31N R08W S10-9	0.78	0.016	0.80	5.17
UNNAMED T31N R08W S10-10C	0.59	LT 0.01	0.59	
UNNAMED T31N R08W S10-11A	0.65	0.012	0.66	3.98
UNNAMED T31N R08W S10-11C	0.57	LT 0.01	0.57	8.27
UNNAMED T31N R08W S11-6	1.63	0.070	1.70	
UNNAMED T31N R08W S11-7	1.08	LT 0.01	1.08	32.25
UNNAMED T31N R08W S11-10	1.12	0.012	1.13	17.32
UNNAMED T31N R08W S15-1	1.02	LT 0.01	1.02	9.36
UNNAMED T32N R07W S15-10	0.88	0.004	0.88	29.78
UNNAMED T32N R07W S18-1	1.15	0.113	1.26	9.70
UNNAMED T32N R07W S19-11	0.89	0.013	0.90	15.07
UNNAMED T32N R07W S19-15A	0.7	LT 0.01	0.70	

Name	Kjeldahl-N (mg/L)	Nitrate-N (mg/L)	Total N (mg/L)	Chlorophyll (ug/L)
UNNAMED T32N R07W S27-13	0.97	LT 0.01	0.70	33.59
UNNAMED T32N R07W S30-6	0.73	LT 0.01	0.70	2.57
UNNAMED T32N R07W S31-8BC	0.80	0.012	0.81	6.49
UNNAMED T32N R08W S25-8	1.56	<0.01	1.56	
UNNAMED T32N R08W S28-16	1.18	0.026	1.21	19.94
UNNAMED T32N R08W S29-10B	1.77	0.015	1.79	
UNNAMED T32N R08W S29-11A	3.08	0.058	3.14	
UNNAMED T32N R08W S29-15	0.91	0.022	0.93	4.42
UNNAMED T32N R08W S29-16BC	0.94	0.047	0.99	6.88
UNNAMED T32N R08W S30-13A	1.46	0.026	1.49	68.38
UNNAMED T32N R08W S30-13C	0.86	0.014	0.87	5.92
UNNAMED T32N R08W S30-16	0.89	0.014	0.90	
UNNAMED T32N R08W S31-1B	0.73	LT 0.01	0.73	4.11
UNNAMED T32N R08W S31-1D	1.54	0.016	1.56	2.95
UNNAMED T32N R08W S32-1	0.82	LT 0.01	0.82	11.98
UNNAMED T32N R08W S32-2	0.62	0.011	0.63	8.25
UNNAMED T32N R08W S32-8	0.97	<0.01	0.97	38.50
UNNAMED T32N R08W S32-5A	0.53	LT 0.01	0.53	4.08
UNNAMED T32N R08W S33-10	1.21	<0.01	1.21	38.14
UNNAMED T32N R08W S33-4BA	0.98	0.004	0.98	6.88
UNNAMED T32N R08W S33-4CA	0.98	0.073	1.05	8.91
UNNAMED T32N R08W S36-3	1.19	0.071	1.26	11.39
UNNAMED T32N R08W S36-11	0.97	0.016	0.99	10.27

APPENDIX 2. CLASSIFICATION LISTING OF EACH LAKE

Classification I-A (Conductivity ≤20 Color <40)

BASS LAKE No 2
BURNT WAGON
DOROTHY LAKE
DUMKE LAKE
HARWOOD NO. 1
HARWOOD NO. 2
HAY LAKE
HIGHLAND LAKE
HORSESHOE LAKE Sec 33
HORSESHOE LAKE T31N R08W S10
MILLER
RAT LAKE
RATTZ LAKE
STAR
STAR
STRAWMAN
TOWN LINE LAKE
TRAM LAKE
UNNAMED T31N R08W S10-11C
UNNAMED T31N R08W S10-3
UNNAMED T31N R08W S10-9
UNNAMED T31N R08W S11-10
UNNAMED T31N R08W S2-11D
UNNAMED T31N R08W S9-13
UNNAMED T32N R07W S19-11
UNNAMED T32N R08W S31-1B
UNNAMED T32N R08W S32-2
UNNAMED T32N R08W S32-5A

Classification I-B (Conductivity ≤20 Color 40-60)

DAM LAKE
KETTLE LAKE
KNICKERBOCKER LAKE
LOWLAND LAKE
WORDEN
UNNAMED T31N R08W S10-10C
UNNAMED T31N R08W S10-11A
UNNAMED T31N R08W S1-6D
UNNAMED T31N R08W S2-11C
UNNAMED T31N R08W S4-3
UNNAMED T32N R07W S30-6
UNNAMED T32N R08W S29-15
UNNAMED T32N R08W S29-16BC
UNNAMED T32N R08W S30-13C
UNNAMED T32N R08W S30-16
UNNAMED T32N R08W S31-1D
UNNAMED T32N R08W S32-1
UNNAMED T32N R08W S32-8

Classification I-C (Conductivity ≤20 Color 60-90)

BOG LAKE
HARWOOD NO. 3
SPENCE LAKE
TAMARACK LAKE
UNNAMED T31N R07W S4-2
UNNAMED T31N R08W S15-1
UNNAMED T31N R08W S2-12
UNNAMED T31N R08W S9-14
UNNAMED T32N R07W S31-8BC
UNNAMED T32N R08W S28-16
UNNAMED T32N R08W S29-10B
UNNAMED T32N R08W S33-10
UNNAMED T32N R08W S33-4BA
UNNAMED T32N R08W S33-4CA

Classification II-A (Conductivity 20-40 Color <40)

BASS LAKE No 3
UNNAMED T31N R08W S11-6

Classification II-B (Conductivity 20-40 Color 40-60)

UNNAMED T32N R08W S29-11A
UNNAMED T31N R08W S03-16CB

Classification II-C (Conductivity 20-40 Color 60-90)

FISHPOLE LAKE
HAY MEADOW FLG NO. 3
LITTLE BEAVER LAKE
TINMAN
UNNAMED T31N R08W S10-4
UNNAMED T31N R08W S11-7
UNNAMED T32N R07W S18-1
UNNAMED T32N R08W S36-11

Classification II-C (Conductivity 20-40 Color ≥90)

HAY MEADOW FLG NO. 4
SILVER
TOTO
UNNAMED T31N R08W S9-15
UNNAMED T32N R07W S15-10
UNNAMED T32N R07W S19-15A
UNNAMED T32N R08W S25-8
UNNAMED T32N R08W S30-13A

Classification III-A (Conductivity >40 Color <40)

BASS LAKE SECTION 30
PLUMMER

Classification III-B (Conductivity >40 Color 40-60)

BASS LAKE No 5
O'NEIL CREEK FLOWAGE No#1
WILLOW CREEK FLG # 2

Classification III-C (Conductivity >40 Color ≥90)

HAY MEADOW FLG NO. 1
LITTLE PLUMMER
O'NEIL CREEK FLOWAGE No. 2
SPRING CREEK FLOWAGE NO. 1
WILLOW CREEK FLG #1
UNNAMED T32N R07W S27-13

Classification III-C (Conductivity >40 Color ≥90)

BIG TWIN LAKE
BIRCH CREEK FLOWAGE NO. 2
DEER LAKE
HAY MEADOW FLG NO. 2
HORSESHOE FLOWAGE
SPRING CREEK FLOWAGE NO. 2
WILLOW CREEK FLG #3
UNNAMED T32N R08W S36-3

APPENDIX 3. MACROPHYTE REPORT

The Aquatic Plant Communities of the Chippewa County Forest Lakes, Chippewa County 2002-2003

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in the lakes of the Chippewa County Forest was conducted during July and August 2002 and 2003 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and University of Wisconsin-Eau Claire students. This was the first quantitative vegetation study conducted in many of these lakes.

Aquatic plant surveys were conducted in 96 of the lakes wholly or partially within the Chippewa County Forest during 2002 and 2003. Water quality data was also collected on these 96 lakes.

Quantitative studies were conducted on 92 lakes.
Qualitative assessments were made on 4 lakes.
47 lakes were sampled during July, August and September 2002.
48 lakes were sampled during July, August and September 2003.
One lake was surveyed in July 1995.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake due to the important ecological role of aquatic vegetation in the lake ecosystem and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the county forest, including fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management, and water resource regulations. The baseline data that it provides will be compared to future macrophyte inventories and offer insight into any changes occurring in the lakes.

II.METHODS

Field Methods

The study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines.

Transects were placed on each lake. Generally the number of transects equaled the number of acres the lake covered, with a minimum of two transects placed and a maximum of 30 transects. The shoreline was divided into the appropriate number of segments, based on acreage, and a transect, perpendicular to the shoreline, was randomly placed within each segment.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a steel thatching rakes, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that

were present on each rake sample were recorded. Each species was given a density rating (0-5) based on the number of rake samples on which it was present at each sampling site.
A rating of 1 indicates that a species was present on one rake sample
a rating of 2 indicates that a species was present on two rake samples
a rating of 3 indicates that it was present on three rake samples
a rating of 4 indicates that it was present on all four rake samples
a rating of 5 indicates that a species was abundantly present on all rake samples at that sampling site.
Species recorded were all submergent and floating leaf species and all emergent species that were rooted in the water.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet deep was evaluated. The percentage of each cover type within this 100' x 30' rectangle was visually estimated and verified by a second researcher.

Data Analysis

The data was analyzed separately for each lake and combined for a total aquatic plant community within the forest lakes. The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites). Relative frequency was calculated (number of occurrences of a species/total occurrence of all species). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites). Relative density was calculated (sum of a species density/total plant density). A "mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred). The relative frequency and relative density was summed to obtain a dominance value. Species diversity was measured by calculating Simpson's Diversity Index.

The Average Coefficient of Conservatism and Floristic Quality (FQI) was calculated, as outlined by Nichols (1998), to determine disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients for all species found in the lake. The FQI is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

MACROPHYTE DATA

SPECIES PRESENT

185 macrophyte species were found in the Chippewa County Forest Lakes. Five non-native species, 1 threatened species *(Carex lenticularis)* and 8 species of special concern *(Ceratophyllum echinatum, Eleocharis robbinsii, Myriophyllum farwelli, Potamogeton diversifolius, P. vaseyii, Scirpus torreyii, Utricularia geminiscapa, U. purpurea*) were found in the forest lakes.

PRESENCE WITHIN ALL FOREST LAKES

FREQUENCY OF OCCURRENCE

The percent of lakes in which a species occurred was calculated (Appendix I). The species that occurred in the largest number of lakes in the Chippewa County Forest were *Dulichium arundinaceum* (emergent species in 94% of the lakes), *Utricularia vulgaris* (submergent species, 88% of the lakes) and *Nuphar variegata* (floating-leaf species, 80% of the lakes). Other commonly occurring species, (20%or more of the lakes):

Emergent Species	Frequency	Floating-leaf species	Frequency
Calamagrostis canadensis	75% of lakes	Brasenia schreberi	77%
Scirpus cyperinus	67%	Nymphaea odorata	76%
Glyceria canadensis	59%	Lemna minor	64%
Spiraea tomentosa	58%	Polygonum amphibium	50%
Sagittaria latifolia	54%	Sparganium fluctuans	32%
Typha latifolia	49%	Spirodela polyrhiza	23%
Eleocharis palustris	48%		
Leersia oryzoides	42%		
Iris versicolor	40%		
Cicuta bulbifera	38%		
Triadenum fraserii	35%		
Chamaedaphne calyculata	34%		
Potentilla palustris	33%		
Juncus effusus	32%		
Calla palustris	27%		
Carex comosa	25%		
Carex rostrata	25%		
Alnus incana	24%		
Lycopus uniflorus	24%		
Carex aquatilis	22%		
Scirpus validus	20%		
Submergent species	**Frequency**	**Submergent species**	**Frequency**
Potamogeton pusillus	58%	Myriophyllum farwellii	34%
Sagittaria sp.	55%	Ceratophyllum demersum	32%
Potamogeton epihydrus	52%	Eleocharis acicularis	23%
Utricularia geminiscapa	52%	Potamogeton zosteriformis	23%
Aquatic moss	50%	Najas gracillima	22%
Ceratophyllum echinatum	49%	Eleodea canadensis	21%
Utricularia gibba	45%	Potamogeton foliosus	21%
Potamogeton amplifolius	36%		

Filamentous algae occurred in 88% of the lakes.

Diversity and Floristic Quality of the Forest Lakes Community as a Whole

The Simpson's Diversity Index for the entire county forest lakes system was 0.99, indicating excellent species diversity. A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable).

The Average Coefficient of Conservatism for Chippewa County Forest lakes was in the upper quartile for all Wisconsin lakes analyzed and above the mean for lakes in the Northern Lakes and Forest Region (NLFL) (Table 1). This suggests that the aquatic plant community of the Chippewa County Forest lakes is among the lake communities least tolerant of disturbance in Wisconsin and more intolerant of disturbance than the average lake in the Northern Lakes and Forest Region.

Table 1. Floristic Quality and Coefficient of Conservatism of Chippewa County Forest lakes, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	(C)Average Coefficient of Conservatism †	Floristic Quality (FQI)
Wisconsin Lakes *	5.5, 6.0, 6.9	16.9, 22.2, 27.5
NLFL *	6.1, 6.7, 7.7	17.8, 24.3, 30.2
Chippewa County Forest lakes	6.93	31.67

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.
† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

The Floristic Quality of the plant community in Chippewa County Forest lakes in the upper quartile for Wisconsin lakes and Northern Lakes and Forest Region (Table 1). This suggests that the plant community in Chippewa County Forest lakes as a whole is among the lake communities in Wisconsin and the region closest to an undisturbed condition.

Disturbances can be of many types:

1. Direct disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2. Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3. Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by the fish population.

Frequency And Density of Aquatic Plant Species Over All Sample Sites

The aquatic plant species present in the forest lakes were analyzed as one community by combining all sample sites into one community. This analysis approximates a species frequency, density and dominance by acreage within the forest lakes (Appendices II-IV).

FREQUENCY

The most frequently occurring aquatic plant, by acreage, was the floating -leaf species, *Nymphaea odorata* (31% of all sites; 6% of all plant occurrences). The most frequently occurring submergent species was *Utricularia vulgaris* (30% of all sample sites; 6% of all plant occurrences). The most frequently occurring emergent species was *Calamagrostis canadensis* (15% of all sample sites; 3% of all plant occurrences). *Brasensia schreberi* was also commonly occurring at the sample sites (29% of all sample sites; 5% of all plant occurrences).

Filamentous algae occurred at 25% of the sample sites and comprised 5% of all plant occurrences.

DENSITY

Brasenia schreberi, another floating-leaf species, had the highest mean density (0.76, scale of 0-5) by sample sites. *Utricularia vulgaris* and *Calamagrostis canadensis* were the submergent and emergent

species that also had the highest mean densities (0.58 and 0.34 on a density scale of 0-5) in the Chippewa County Forest lakes (Appendix III).

The "mean density where present" indicates species that exhibited a dense or aggregated growth form, even though the species may occurred at a limited number of sites. *Carex castanea* and *Juncus canadensis* had "mean densities where present" of (4.0 on a scale of 0-5). *Brasenia schreberi* (2.59*), Carex lacustris* (2.83), *Ceratophyllum demersum* (3.44), *Elodea canadensis* (2.69*), Juncus compressus* (3.0), *Potamogeton robbinsii* (3.19*), P. zosteriformis* (2.58*), Sagittaria cristata* (2.78*), S. rigida* (2.96*)* and *Spirodela polyrhiza* (2.56) had "densities where present" of 2.5 or more, indicating that they exhibited a growth form of above average density in the Chippewa County Forest Lakes (Appendix III).

DOMINANCE

Combining relative frequency and relative density into a Dominance Value illustrates how dominant a species is within the macrophyte community (Appendix IV). Based on the Dominance Value, *Brasenia schreberi,* watershield, was the dominant floating-leaf species, *Utricularia vulgaris*, common bladderwort,

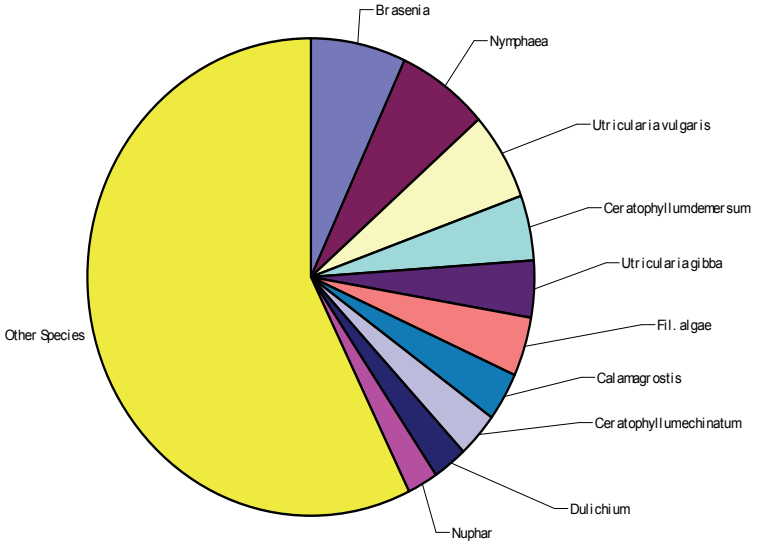

Figure 1. Dominance within the macrophyte community, of the most prevalent aquatic macrophytes in Chippewa County Forest lakes, 2002-2003.

COMPARISONS OF THE LAKES

The aquatic plant species that occurred within the forest lakes were analyzed for frequency, density and dominance within each lake to analyze the plant community by lake (Appendices V).

Species diversity of individual lakes ranged from a high of 0.97 (excellent diversity) **in Silver Lake, Deer Lake, Hay Meadow Flowage #4 and Lake 310810-4 (Okay Lake)** to a low of 0.79 (low diversity) in **Birkie** Lake (Lake 310811-6). A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable). A complete list of lakes, ranked by Simpson's Diversity Index is found in Table A-2.

The total number of species found in each lake ranged from a high of 50 species found in **Horseshoe Lake (T31R08S10)** to a low of 9 species found in **Lake 31081-6b** and **Lake 310811-6 (Birkie Lake)** (Table A-2).

The Average Coefficient of Conservatism for each lake ranged from a high of 8.29 in **Lake 320718-1 (Snorting Otter Lake)** to a low of 5.0-5.29 in the three **Willow Flowages** (Appendix VII)**.** In this range, the Chippewa County Forest Lakes covered the entire gamut from lakes within the lowest quartile in the state and region (within those quartile of lakes most tolerant of disturbance) to the highest quartile

(within those quartile of lakes least tolerant of disturbance) (Table 2).

Table 2. Floristic Quality and Coefficient of Conservatism of Chippewa County Forest lakes, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	Floristic Quality ‡ Based on Relative Frequency
Wisconsin Lakes *	5.5, 6.0, 6.9	16.9, 22.2, 27.5	
NLFL *	6.1, 6.7, 7.7	17.8, 24.3, 30.2	
Chippewa County Forest lakes 2003-2004	5.00 - 8.29	16.67 - 46.39	9.92 - 46.88

***** - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.
† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition)

The Floristic Quality Index of each Chippewa County Forest lake ranged from a high of 46.39 for **Horseshoe Lake T31R8S10** to a low of 16.67 for **Birkie Lake (Lake 310811-6)** (Table 2)**.** These values covered the gamut of lakes in the lowest quartile of lakes in the state and region (within the group of lakes farthest from an undisturbed condition) to the highest quartile of lakes in the state and region (well within those group of lakes closest to an undisturbed condition) (Table 2).

The Floristic Quality values were based only on the presence or absence of tolerant and intolerant species. The frequency of these species within the plant community was not taken into consideration. The Floristic Quality Index was recalculated by weighting a species coefficient with its relative frequency. The resulting values again ranged from a high of 46.88 for **Horseshoe Lake T31R8S10** to a low of 9.92 for **Birkie Lake (Lake 310811-6)** (Table 2) and covered the gamut of lakes in the lowest quartile of lakes in the state and region (within the group of lakes farthest from an undisturbed condition) to the highest quartile of lakes in the state and region (well within those group of lakes closest to an undisturbed condition) (Table 2).

LISTED SPECIES

9 listed species were recorded in the Chippewa County Forest Lake Aquatic Plant Surveys.

One threatened species: *Carex lenticularis* – Bass Lake #3
Eight special concern species: *Ceratophyllum echinatum* – in 44 lake lakes
Eleocharis robbinsii – in 3 lakes
Myriophyllum farwelli – in 28 lakes
Potamogeton diversifolius – in 14 lakes
Potamogeton vaseyi – in 3 lakes
Scirpus torreyi – in 2 lakes
Utricularia geminiscapa – in 43 lakes
Utricularia purpurea – in 11 lakes

Of the 96lakes studies, at least one listed species was found in 69 lakes and no listed species were found in 27 lakes.
One (1) listed species was recorded in 26 lakes.
Two (2) listed species was recorded in 18 lakes.
Three (3) listed species was recorded in 16 lakes.
Four (4) listed species was recorded in 6 lakes.
Five (5) listed species was recorded in 2 lakes.

Miller Lake and Lake #320832-2 (Island Lake) each supported 5 listed species, the most found in one lake.

The lakes that ranked the highest in the most number of parameters (Simpson's Species Diversity, number of species, Average Coefficient of Conservatism, Floristic Quality Index, Relative Frequency of Sensitive species and number of listed species) were: **Townline Lake and Lake #320832-2 (Island Lake)**. The lake that ranked the lowest in all parameters was: **Lake #310811-6 (Birkie Lake).**

Highest Quality Lakes

The highest quality and lakes and those lakes that are most critical for protection are the lakes that ranked highest in community indices. These lakes were the lakes that supported listed species, in the excellent category for diversity of plant species, in the upper quartile of lakes least tolerant of disturbance and/or in the upper quartile of lakes closest to an undisturbed condition. The highest quality lakes are listed in Appendix VI.

Simpson's Diversity index was used to measure species diversity; Wisconsin Natural Heritage Inventory list was used to classify listed species; the Average Coefficient of Conservatism and the Floristic Quality Index were used to measure the lake communities disturbance tolerance and closeness to an undisturbed condition. Nichols (1998) analysis of lakes throughout the state of Wisconsin was used to compare the Chippewa County Forest Lakes with other lakes in the Northern Forest and Lakes Region of Wisconsin.

Determinants Of Community

Correlation analysis was used to determine if any measures of the plant community were related to water chemistry parameters.

The strongest relationship was spring phosphorus and average coefficient of conservatism. As spring phosphorus increased, the disturbance tolerance of the plant community increased. The increase in phosphorus can explain 22% of the increase in disturbance tolerance (R^2= 0.2171); however, this relationship was not significant.

The average coefficient of conservatism was significantly correlated to:

1. pH of the lake water ($p<0.01$); increased pH explaining 20% of the increase in disturbance tolerance (R^2= 0.2042)
2. Calcium in the lake water ($p<0.01$); increased Calcium explaining 18% of the increase in disturbance tolerance (R^2= 0.2042)
3. Alkalinity of the lake water ($p<0.01$); increased alkalinity explaining 20% of the increase in disturbance tolerance (R^2= 0.2042).

The Florsitic Quality Index (measure of the closeness of a community to an undisturbed condition) was significantly ($p < 0.05$) correlated to pH. As the pH decreased, the Floristic Quality Index (weighted for relative frequency of species) increased. The decrease in pH explained 4% of the increase in closeness to an undisturbed condition (R^2= 0.0482).

The species diversity of the plant community (as measured by Simpson's Diversity Index) was significantly correlated to:

1. Spring and summer phosphorus concentrations in the lake water ($p<0.01$); increased phosphorus explaining 12% of the decrease in species diversity (R^2= 0.1215; R^2= 0.1198).
2. pH of the lake water ($p<0.05$); increased pH explaining 6% of the decrease in species diversity (R^2= 0.0622)
3. Color in the lake water ($p<0.01$); increased color explaining 10% of the increase in species diversity (R^2= 0.1015).

Color was also significantly correlated ($p<0.05$) to the number of species found in a lake. An increase in color explained 5% of the increase in the number of species in a lake ($R^2= 0.0475$).

The number of listed species (endangered, threatened, special concern) found in a lake was significantly correlated to many water parameters.

1. Increased alkalinity and increased magnesium concentrations in the lake water were significantly correlated ($p<0.05$; $p<0.01$) to a decrease in the number of listed species in a lake.
2. Increased alkalinity and increased magnesium concentrations explained 6% and 7% of the decrease in the number of listed species ($R^2= 0.0668$; $R^2= 0.0732$).
3. Increased color of the water was significantly correlated ($p<0.01$) to a decrease in the number of listed species in a lake. Increased color explained 18% of the decrease in the number of listed species ($R^2= 0.1894$).
4. Increased spring and summer phosphorus concentrations in the water were significantly correlated ($p<0.01$; $p<0.05$) to a decrease in the number of listed species in a lake.
5. Increased phosphorus explained 11% (spring) and 4% (summer) of the decrease in the number of listed species ($R^2= 0.1107$; $R^2= 0.0489$).
6. Increased nitrogen concentration in the water was also significantly correlated ($p<0.05$) to a decrease in the number of listed species in a lake. Increased total nitrogen explained 5% of the decrease in the number of listed species ($R^2= 0.056$)
7. Increased water clarity as measured by Secchi Disc was significantly correlated ($p<0.01$) to an increase in the number of listed species in a lake.
8. Increased spring water clarity explained 16% and increased summer water clarity explained 19% of the increase in the number of listed species ($R^2= 0.1675$; $R^2= 0.1995$).

Table A-I. Frequency of species by lake: Percent of lakes in which it occurred

Species	Total Occur.	%Freq.	Relative Freq.
Acorus calamus	3.00	3.1%	0.0011
Agalinis purpurea	1.00	1.0%	0.0004
Agrostis stolonifera	3.00	3.1%	0.0011
Alnus incana	23.00	24.0%	0.0083
Alnus viridis	4.00	4.2%	0.0015
Amelanchier laevis	4.00	4.2%	0.0015
Andromeda glaucophylla	12.00	12.5%	0.0044
Aronia melanocarpa	7.00	7.3%	0.0025
Asclepias incarnata	11.00	11.5%	0.0040
Aster simplex	1.00	1.0%	0.0004
Bidens beckii	2.00	2.1%	0.0007
Bidens cernua	8.00	8.3%	0.0029
Bidens connata	3.00	3.1%	0.0011
Bidens coronatus	2.00	2.1%	0.0007
Bidens discoidea	13.00	13.5%	0.0047
Bidens frondosa	1.00	1.0%	0.0004
Bidens tripartitus	1.00	1.0%	0.0004
Boehmeria cylindrica	4.00	4.2%	0.0015
Brasenia schreberi	74.00	77.1%	0.0269
Calamagrostis canadensis	72.00	75.0%	0.0261
Calapogon tuberosa	2.00	2.1%	0.0007
Calla palustris	26.00	27.1%	0.0094
Campanula aparinoides	5.00	5.2%	0.0018
Carex aquatilis	22.00	22.9%	0.0080
Carex atherodes	1.00	1.0%	0.0004
Carex castanea	1.00	1.0%	0.0004
Carex comosa	24.00	25.0%	0.0087
Carex crawfordii	2.00	2.1%	0.0007
Carex crinita	8.00	8.3%	0.0029
Carex emoryi	2.00	2.1%	0.0007
Carex hystericina	1.00	1.0%	0.0004
Carex lacustris	6.00	6.3%	0.0022
Carex lasiocarpa	17.00	17.7%	0.0062
Carex lenticularis	1.00	1.0%	0.0004
Carex limosa	1.00	1.0%	0.0004
Carex pseudocyperus	3.00	3.1%	0.0011
Carex rostrata	24.00	25.0%	0.0087
Carex sartwelli	3.00	3.1%	0.0011
Carex scoparia	8.00	8.3%	0.0029
Carex sp.	28.00	29.2%	0.0102

Carex sterilis	1.00	1.0%	0.0004
Carex stricta	11.00	11.5%	0.0040
Carex tuckermanii	2.00	2.1%	0.0007
Carex urticulata	10.00	10.4%	0.0036
Carex vesicaria	17.00	17.7%	0.0062
Glyceria grandis	1.00	1.0%	0.0004
Ceratophyllm demersum	31.00	32.3%	0.0112
Ceratophyllm echinatum	47.00	49.0%	0.0171
Chamaedaphne calyculata	33.00	34.4%	0.0120
Chara sp.	3.00	3.1%	0.0011
Chelone glabra	1.00	1.0%	0.0004
Cicuta bulbifera	36.00	37.5%	0.0131
Cladium marisicoides	1.00	1.0%	0.0004
Daucus carota	1.00	1.0%	0.0004
Drosera intermedia	9.00	9.4%	0.0033
Drosera rotundifolia	11.00	11.5%	0.0040
Dulichium arundinaceum	90.00	93.8%	0.0327
Elatine minima	6.00	6.3%	0.0022
Eleocharis acicularis	22.00	22.9%	0.0080
Eleocharis palustris	46.00	47.9%	0.0167
Eleocharis robbinsii	3.00	3.1%	0.0011
Eleocharis spp.	15.00	15.6%	0.0054
Elodea canadensis	20.00	20.8%	0.0073
Elodea nuttallii	4.00	4.2%	0.0015
Equisetum fluviatile	4.00	4.2%	0.0015
Eriocaulon aquaticum	8.00	8.3%	0.0029
Eriophorum angustifolium	4.00	4.2%	0.0015
Eriophorum tenellum	1.00	1.0%	0.0004
Eriophorum virginicum	7.00	7.3%	0.0025
Eupatorium perfoliatum	4.00	4.2%	0.0015
Eupatorium purpureum	1.00	1.0%	0.0004
Fil algae	85.00	88.5%	0.03
Galium labradoricum	4.00	4.2%	0.0015
Galium tinctorium	1.00	1.0%	0.0004
Galium trifidum	2.00	2.1%	0.0007
Glyceria borealis	12.00	12.5%	0.0044
Glyceria canadensis	57.00	59.4%	0.0207
Hypericum boreale	11.00	11.5%	0.0040
Hypericum ellipticum	9.00	9.4%	0.0033
Ilex verticillata	1.00	1.0%	0.0004
Impatiens capensis	4.00	4.2%	0.0015
Iris versicolor	38.00	39.6%	0.0138
Isoetes echinospora	5.00	5.2%	0.0018
Juncus brevicaudatus	5.00	5.2%	0.0018

Juncus bufonius	2.00	2.1%	0.0007
Juncus canadensis	1.00	1.0%	0.0004
Juncus compressus	2.00	2.1%	0.0007
Juncus effusus	31.00	32.3%	0.0112
Juncus pelocarpus	3.00	3.1%	0.0011
Juncus torreyi	1.00	1.0%	0.0004
Larix laricina	6.00	6.3%	0.0022
Ledum groenlandicum	2.00	2.1%	0.0007
Leersia oryzoides	40.00	41.7%	0.0145
Lemna minor	61.00	63.5%	0.0221
Lemna trisulca	8.00	8.3%	0.0029
Ludwigia palustris	3.00	3.1%	0.0011
Lycopodium inundatum	1.00	1.0%	0.0004
Lycopus americanus	17.00	17.7%	0.0062
Lycopus uniflorus	23.00	24.0%	0.0083
Lycopus virginicus	6.00	6.3%	0.0022
Lysimachia quadriflora	13.00	13.5%	0.0047
Lysimachia terrestris	7.00	7.3%	0.0025
Lysimachia thyrsiflora	7.00	7.3%	0.0025
Menyanthes trifoliata	4.00	4.2%	0.0015
Moss	48.00	50.0%	0.0174
Myriophyllum farwelli	33.00	34.4%	0.0120
Myriophyllum humile	2.00	2.1%	0.0007
Myriophyllum sibiricum	2.00	2.1%	0.0007
Najas flexilis	4.00	4.2%	0.0015
Najas gracillima	21.00	21.9%	0.0076
Nasturtium officinale	3.00	3.1%	0.0011
Nitella sp.	13.00	13.5%	0.0047
Nuphar variegata	77.00	80.2%	0.0279
Nymphaea odorata	73.00	76.0%	0.0265
Onoclea sensibilis	11.00	11.5%	0.0040
Osmunda cinnamomea	1.00	1.0%	0.0004
Panicum flexile	1.00	1.0%	0.0004
Phalaris arundinacea	18.00	18.8%	0.0065
Picea mariana	2.00	2.1%	0.0007
Pogonia ophioglossoides	3.00	3.1%	0.0011
Polygonum amphibium	48.00	50.0%	0.0174
Polygonum arifolium	2.00	2.1%	0.0007
Polygonum pensylvanicum	1.00	1.0%	0.0004
Polygonum punctatum	2.00	2.1%	0.0007
Polygonum sagittatum	13.00	13.5%	0.0047
Pontederia cordata	1.00	1.0%	0.0004
Potamogeton amplifolius	35.00	36.5%	0.0127
Potamogeton bicupulatus	4.00	4.2%	0.0015

Potamogeton diversifolius	17.00	17.7%	0.0062
Potamogeton epihydrus	50.00	52.1%	0.0181
Potamogeton foliosus	20.00	20.8%	0.0073
Potamogeton illinoensis	4.00	4.2%	0.0015
Potamogeton natans	18.00	18.8%	0.0065
Potamogeton nodosus	1.00	1.0%	0.0004
Potamogeton oakesianus	10.00	10.4%	0.0036
Potamogeton obtusifolius	4.00	4.2%	0.0015
Potamogeton pusillus	56.00	58.3%	0.0203
Potamogeton robbinsii	7.00	7.3%	0.0025
Potamogeton spirillus	11.00	11.5%	0.0040
Potamogeton vaseyi	3.00	3.1%	0.0011
Potamogeton zosteriformis	22.00	22.9%	0.0080
Potentilla palustris	32.00	33.3%	0.0116
Rhynchospora alba	5.00	5.2%	0.0018
Rhyncospora capitellata	1.00	1.0%	0.0004
Riccia fluitans	10.00	10.4%	0.0036
Rumex orbiculatis	5.00	5.2%	0.0018
Sagittaria cristata	1.00	1.0%	0.0004
Sagittaria graminea	1.00	1.0%	0.0004
Sagittaria latifolia	52.00	54.2%	0.0189
Sagittaria rigida	8.00	8.3%	0.0029
Sagittaria sp.	53.00	55.2%	0.0192
Salix pedicellaris	4.00	4.2%	0.0015
Sarracenia purpurea	7.00	7.3%	0.0025
Scheuchzeria palustris	1.00	1.0%	0.0004
Scirpus cyperinus	64.00	66.7%	0.0232
Scirpus subterminalis	7.00	7.3%	0.0025
Scirpus torreyi	2.00	2.1%	0.0007
Scirpus validus	19.00	19.8%	0.0069
Scutellaria galericulata	8.00	8.3%	0.0029
Scutellaria laterifolia	3.00	3.1%	0.0011
Solidago graminifolia	7.00	7.3%	0.0025
Sparganium androcladum	1.00	1.0%	0.0004
Sparganium chlorocarpum	7.00	7.3%	0.0025
Sparganium emersum	2.00	2.1%	0.0007
Sparganium fluctuans	31.00	32.3%	0.0112
Sparganium sp.	5.00	5.2%	0.0018
Spiraea alba	17.00	17.7%	0.0062
Spiraea tomentosa	56.00	58.3%	0.0203
Spirodela polyrhiza	22.00	22.9%	0.0080
Stachys palustris	6.00	6.3%	0.0022
Thelyptris palustris	18.00	18.8%	0.0065
Triadenum fraseri	34.00	35.4%	0.0123

Typha latifolia	47.00	49.0%	0.0171
Utricularia geminiscapa	50.00	52.1%	0.0181
Utricularia gibba	43.00	44.8%	0.0156
Utricularia intermedia	5.00	5.2%	0.0018
Utricularia minor	4.00	4.2%	0.0015
Utricularia purpurea	13.00	13.5%	0.0047
Utricularia vulgaris	85.00	88.5%	0.0308
Vaccinium angustifolium	2.00	2.1%	0.0007
Vaccinium macrocarpon	9.00	9.4%	0.0033
Vaccinium oxycocos	4.00	4.2%	0.0015
Vallisneria americana	1.00	1.0%	0.0004
Viola macloskeyi	2.00	2.1%	0.0007
Wolffia columbiana	3.00	3.1%	0.0011
Xyris montana	1.00	1.0%	0.0004
Zizania palustris	1.00	1.0%	0.0004
Totals	2756.00	28.71	1.00
Number lakes	96.00		

Table A-2. Macrophyte metrics for each lake.

		Simpson's Diversity	Total # of species	Coefficient of Conservatism	FQI	FQI by Rel. Freq.
31074-2	Thunder Lake	0.93	19	6.9	30.86	29.4
31076-5d		0.95	19	5.74	25.01	20.95
310810-10C	Lost Lake	0.91	15	6.27	24.27	24.57
310810-11A	Arrowhead Lake	0.92	15	6.2	24.01	19.75
310810-11C	Green Cloud Lake	0.92	16	6.06	24.25	19.73
310810-3	Hickory Ridge Lake	0.91	10	5.6	17.71	13.7
310810-4	Okay Lake	0.97	29	6.69	36.02	32.64
310810-9	Coffee Can Lake	0.87	11	6.91	22.91	17.93
310811-10	Red Lake	0.93	24	6.79	33.27	28.36
310811-6	Birkie Lake	0.79	9	5.56	16.67	9.92
310811-7		0.88	14	5.29	19.78	17.86
310815-1		0.95	38	6.97	42.99	40.65
31081-6b		0.84	9	6.22	18.67	12.81
31081-6d	Houglass Lake	0.94	23	6.35	30.44	25.36
31082-11c	Pat's Lake	0.86	15	5.33	20.66	21.82
31082-11d	Karl Lake	0.88	11	6.45	21.41	15.98
31082-12	Klister Lake	0.94	25	6.4	32	28.5
31083-16bc	Fishtail Lake	0.95	30	6.9	37.79	36.01
31084-3	Deerfly Lake	0.95	22	6.09	28.57	25.97
31089-13	Lake WhereAreWe	0.95	24	6.46	31.64	28.72
31089-14		0.95	27	6.44	33.49	30.09
31089-15	Leech Lake	0.96	31	6.77	37.72	31.09
320715-10	Tea Lake	0.95	39	7.31	45.64	40.08
320718-1	Snorting Otter	0.92	14	8.29	31	25.93
320719-11	Bladderwort Lake	0.93	24	6.88	33.68	33.97
320727-13		0.94	32	6.13	34.65	31.43
320730-6	Blackberry Brambles	0.95	33	6.91	39.69	35.23
320731-8bc	Crash Lake	0.94	22	6.68	31.34	23.37
320828-16	Elodea Lake	0.94	24	5.83	28.58	27.61
320829-10b	Hidden Lake	0.91	16	6.25	25	24.65
320829-10c	Beaver Dam	0.94	27	6.48	33.68	32.41
320829-11a	lily pond	0.93	21	6.52	29.9	26.53
320829-15	Ribbon Lake	0.95	23	6.3	30.23	27.95
320829-16bc	Easy Lake	0.86	12	5.83	20.21	16.68
320830-10		0.93	17	5.82	24.01	24.44
320830-13	Trail Lake	0.93	17	5.71	23.53	21.88
320831-1b		0.85	11	6.91	22.91	23.75
320831-1d	Disenchanting Lake	0.92	19	6.79	29.59	23.95
320832-1	Portage Lake	0.92	20	6.65	29.74	26.45
320832-2	Island Lake	0.95	32	6.94	39.24	34.69
320832-8	Watershield Lake	0.94	27	6.44	33.49	31.94
320833-10	Moraine Bog	0.94	21	6.05	27.71	25.57
320833-4ba	Duckweed Bog	0.93	16	6.19	24.75	19.31
320836-15		0.93	17	5.71	23.63	20.12
320836-3	Rainy	0.94	22	5.5	25.8	23.75

	Simpson's Diversity	Total # of species	Coefficient of Conservatism	FQI	FQI by Rel. Freq.
Bass 2	0.94	34	6.06	35.33	32.91
Bass 3	0.92	21	6.48	29.68	27.74
Bass section 30	0.92	22	7.41	34.75	31.94
Bass5	0.93	25	6.44	32.2	28.43
Big Twin	0.92	13	6.31	22.74	22.74
Birch Creek 1	0.94	24	6.21	30.41	29.65
Birch Creek 2	0.95	28	6.04	31.94	28.69
Burnt Wagon	0.93	40	6.48	40.95	39
Dam	0.91	23	6.74	32.32	31.46
Deer	0.97	32	5.88	33.23	33.23
Dorothy	0.92	23	7.45	35.66	34.74
Dumke	0.85	19	5.84	25.47	18.89
Fishpole	0.94	35	6.89	40.74	35.77
Harwood 1	0.94	37	6.73	40.94	40.6
Harwood 2	0.95	40	7.2	45.54	42.97
Harwood3	0.94	26	7.04	35.89	22.27
Hay	0.93	24	6.71	32.86	32.21
Hay Meadow 1	0.95	35	5.89	34.82	31.61
Hay meadow 2	0.93	34	6.26	36.53	28.86
Hay meadow 3	0.93	28	6.43	34.02	35.29
Hay Meadow 4	0.97	23	6.61	31.69	28.35
Highland	0.93	23	6.74	32.32	32.39
Horseshoe 310810	0.95	50	6.56	46.39	46.88
Horseshoe 320833	0.91	22	6.05	28.36	30.44
HorseshoeFlowage	0.96	30	6.63	36.33	33.32
Kettle	0.96	26	6.38	32.56	26.89
Knickerbocker	0.92	27	6	31.18	28.63
Little Beaver	0.93	31	6.23	34.66	34.21
Little Plummer	0.94	35	6.09	36	30.59
Lowland	0.93	20	6.35	28.4	22.28
Miller	0.92	25	7.12	35.6	36.73
O'Neill 1	0.94	27	5.7	29.64	25.84
O'Neill 2	0.96	39	5.51	34.43	30.48
Plummer	0.87	19	5.47	23.86	20.82
Raatz	0.93	29	6.38	34.35	36.29
Rat	0.93	19	7.23	33.9	26.01
Sepnce Lake	0.96	44	6.45	42.81	43.72
Silver	0.97	40	7.08	44.75	41.86
Spring creek 1	0.92	29	5.93	31.94	26.23
Spring creek 2	0.93	31	6.23	34.66	29.47
Star	0.95	33	5.97	34.29	33.62
Strawman	0.96	37	7.03	42.74	42.83
Tamarack	0.94	22	7.36	34.54	34.31
Tinman	0.93	27	7.37	38.3	32.06
Toto	0.95	27	7.78	40.41	37.93
Townline	0.93	33	7.36	42.3	39.16
Tram	0.95	33	6.36	36.56	34.42
Willow 1	0.89	20	5	22.36	15.81
Willow 2	0.93	27	5.04	26.17	19.07
willow 3	0.93	28	5.29	27.97	22.99
Worden	0.88	19	6.11	26.61	25.47

		Dominant Species	Sub-dominant Species	# of Listed Species
31074-2	Thunder Lake	brasc	utrvu	2
31076-5d		brasc	dular/nymod	
310810-10C	Lost Lake	spafl	nupva	1
310810-11A	Arrowhead Lake	scicy	sagri	
310810-11C	Green Cloud Lake	sagri	junef	1
310810-3	Hickory Ridge Lake	calca/caraq/ junef/leeor	utrvu	1
310810-4	Okay Lake	hypbo		
310810-9	Coffee Can Lake	spafl	nupva	
310811-10	Red Lake	nupva	potam	3
310811-6	Birkie Lake	lemmi	potam	1
310811-7		lemmi	calca	
310815-1		utrvu	potpu	1
31081-6b		potam	calca	
31081-6d	Houglass Lake	calca	potam	3
31082-11c	Pat's Lake	lemmi	cerec	1
31082-11d	Karl Lake	carve	calca	
31082-12	Klister Lake	brasc	utrvu	
31083-16bc	Fishtail Lake	brasc	utrvu	
31084-3	Deerfly Lake	potam	glyca	1
31089-13	Lake WhereAreWe	potdi/utrvu	sagla	4
31089-14		brasc	nupva	2
31089-15	Leech Lake	potzo	nymod	2
320715-10	Tea Lake	nymod	utrvu	
320718-1	Snorting Otter	chaca	utrge	1
320719-11	Bladderwort Lake	utrgi	utrvu	3
320727-13		spipo	lemmi/potpu	2
320730-6	Blackberry Brambles	brasc	nymod	
320731-8bc	Crash Lake	nymod	nupva/dular	1
320828-16	Elodea Lake	elonu	utrgi	2
320829-10b	Hidden Lake	utrvu	cerec	3
320829-10c	Beaver Dam	potdi	brasc	3
320829-11a	lily pond	brasc	nymod	1
320829-15	Ribbon Lake	spafl	glyca	1
320829-16bc	Easy Lake	lemmi	caraq	
320830-10		lemmi	carve	
320830-13	Trail Lake	lemmi	calca	
320831-1b		spafl	utrvu	1
320831-1d	Disenchanting Lake	utrvu	potpu	3
320832-1	Portage Lake	brasc	utrvu	2
320832-2	Island Lake	brasc	calca/myrfa/utrgi	5
320832-8	Watershield Lake	brasc	utrgi	3
320833-10	Moraine Bog	utrgi	brasc	1
320833-4ba	Duckweed Bog	lemmi	nupva	1
320836-15		nupva	cerde	1
320836-3	Rainy	cerde	spipo	

	Dominant Species	Sub-dominant Species	# of Listed Species
Bass 2	calca	eriaq/utrvu	4
Bass 3	nymod	caraq	2
Bass section 30	brasc	utrgi	
Bass5	cerde	nymod	1
Big Twin	nymod/carla	cerec	1
Birch Creek 1	utrvu	nymod	1
Birch Creek 2	nymod	potpu	1
Burnt Wagon	utrvu	brasc	2
Dam	brasc	cerec	1
Deer	nymod	cerde	
Dorothy	utrgi	myrfa	3
Dumke	eloca	nymod	
Fishpole	utrvu	brasc	2
Harwood 1	utrgi	myrfa	3
Harwood 2	myrfa	utrgi	4
Harwood3	nymod	brasc	
Hay	utrvu	potpu	3
Hay Meadow 1	potro	cerde	2
Hay meadow 2	cerde	utrvu	2
Hay meadow 3	brasc	nymod/utrgi/utrvu	2
Hay Meadow 4	brasc	utrgi	1
Highland	myrfa	utrgi/vu	4
Horseshoe 310810	utrvu	cerec	4
Horseshoe 320833	utrgi	nitsp	3
HorseshoeFlowage	brasc	spipo	3
Kettle	lemmi	moss	2
Knickerbocker	brasc	moss	3
Little Beaver	cerec	nymod	2
Little Plummer	cerde	brasc	1
Lowland	calca	utrvu	2
Miller	utrpu	brasc/nymod	5
O'Neill 1	cerde	nymod/potzo	
O'Neill 2	eloca	cerde	
Plummer	cerde	potzo	
Raatz	utrvu	myrfa	2
Rat	utrvu	cerec	4
Sepnce Lake	nymod	brasc	1
Silver	utrvu	chaca	1
Spring creek 1	cerde	nymod	
Spring creek 2	cerde	spipo	
Star	brasc	potdi	4
Strawman	spafl	utrvu	
Tamarack	utrgi	chaca	3
Tinman	cerec	chaca/potpu	2
Toto	nymod	brasc	1
Townline	nymod	najgr	4
Tram	calca	utrvu	3
Willow 1	cerde	spipo	
Willow 2	cerde	potzo	
willow 3	cerde	potzo	
Worden	brasc	utrgi	2

APPENDIX 4. FISH COMMUNITY REPORT

Chippewa County Forest Fish Community Assessment

By

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Introduction

The Chippewa County Forest (CCF) features numerous wetlands, streams, and small lakes. Many of these lakes, including several that have provided a recreational fishery, have not been surveyed for several decades. A survey of aquatic resources, including fishes, was conducted to support a revision of the CCF Master Plan. In this paper, we report the results of a fish survey of 43 lakes and a section of Yellow River in CCF. The objectives of the survey were to describe the fish species composition and recreational angling opportunity. In addition, we relate the results to features of the landscape, and discuss the processes influencing fish assemblage structure.

Materials and Methods

Study Area

Lakes

The survey was conducted in 43 lakes of the central and northern sections of CCF. The lakes are small, with surface area ranging from 1-48 acres (Table 1). The dominant land cover within the watersheds is forest. Lakes surveyed for fish were a subset of lakes sampled for water quality (Garrison, 2004), and included lakes in which fish were observed or where limnological data suggested the occurrence of conditions likely to support fish. Most of the named lakes within the CCF were sampled.

Yellow River

The Yellow River originates in Taylor County and flows southwest 34 miles until it drains into Lake Wissota. The river flows through a small portion of the CCF for about a mile. The sampling station was located (T30N-R5W-S29-20) within the CCF, and includes a stretch from the small park along CTH S to 150th avenue.

Fish Sampling

Lakes

Standard sampling effort was applied to each of the lakes. Many of the lakes have no developed access, precluding use of heavy equipment or large boats that require launching from a vehicle and trailer (boat-mounted electrofishing, fyke nets). The steep shores of several bog

lakes made seines highly impractical. A combination of minnow traps, gillnets, and angling was chosen for effectiveness, and because these gears are deployable in lakes with carry-in access, or access through shallow streams with navigation obstructed with logs and beaver dams. A combination of gears samples different habitats and sizes of fishes, allowing a high probability of detecting the presence of most species.

Six Gee minnow traps (9”x 17.5”x1/4”) were baited with a commercial dog food and set overnight in each lake. The number of traps was based on evaluations of effort required to detect species with a variety of gears deployed in Wisconsin lakes (Jennings et al. 1999). Captured fishes were identified, enumerated, and released.

Each lake was also sampled with an overnight experimental gillnet. Gillnets were constructed of five panels, each 25 feet in length and 8 feet in depth. The panels had variable monofilament mesh sizes of 1, 1.5, 2, 2.5 and 3 inches. Captured fishes were identified, measured (total length, inches), and released.

Because minnow traps sample small nongame fishes and juvenile gamefish and catch rates in gillnets were low, this combination of gears yielded little information regarding potential of the lake for recreational fishing opportunity. Lakes in which catchable fish species were sampled with other gears or observed in the water were also sampled with a standard 1.5 hours of angler effort, using jig and spinners with light spinning tackle. This provided an additional gear to complete species lists, and provided a rapid assessment of potential fishery quality.

Yellow River

Sampling of the river reach followed the WDNR baseline monitoring procedures for wadable streams. Sampling was conducted by WDNR Fisheries Management staff based in Chippewa Falls. The length of the sampling station was 2870 feet, which is approximately 35 times the mean stream width of 82 feet. The sampling length of the station is based on the distance necessary to sample more than three pool-riffle sequences. A single electrofishing run was done using a DC-towed electrofishing unit from the downstream to upstream end of the sampling station. Captured fishes were identified, enumerated, and released.

Statistical Analyses

Relationships between fish species richness and limnological variables were evaluated

Table 1. Limnological features of lakes sampled on the Chippewa County Forest

Lake	Acres	Depth	pH	Calcium	Magnesium	Alkalinity	Sec-chi	Color	Conductivity	Spring Total P
Bass #2	12	33	6.6	1.2	0.4	88	3.2	8	13.5	23
Bass #3	9	35	7.2	2.5	0.9	180	2.8	16	22.6	27
Burnt Wagon	15	15	6.6	1.2	0.6	66	1.2	35	11.4	21
Dam	4	17	6.4	1.5	0.5	100	1.5	55	18.2	20
Dorothy	5	51	6.6	1.8	0.7	92	5.0	10	16.8	9
Highland	10	20	6.5	1.3	0.5	51	2.5	30	14.0	27
Horseshoe T31	17	18	6.8	1.5	0.6	114	1.5	25	16.2	21
Horseshoe T32	24	25	7.0	1.2	0.5		3.1	15	12.6	29
Knickerbocker	14	24	6.6	1.7	0.6	127	1.1	45	20.0	23
L. Beaver	6	49	6.5	2.0	0.6	139		65	21.9	36
L. Plummer	10	23	7.9	9.1	3.2	702	1.0	85	51.1	109
Lowland	11	21	6.5	1.5	0.5	57	1.8	40	15.1	34
Miller	5	17	6.5	1.4	0.6	75	2.0	13	18.8	16
Rattz	6	23	6.4	1.1	0.4	47	3.5	18	14.2	16
Spence	13	66	6.3	2.1	0.6	92	0.9	100	18.2	37
Spring Creek 1	16	5	7.0	7.3	2.6	552	1.2	95	95.1	36
Spring Creek 2	16	4	7.0	9.9	3.0	713			78.6	82
Star	6	14	6.8	1.8	0.7	87	1.2	13	14.6	23
Strawman	5	22	6.1	1.1	0.4	42	3.2	20	10.7	19
Tinman	3	32	6.2	1.8	0.5	131	1.0	70	20.3	30
Townline	48	22	6.6	1.3	0.6	72	2.2	25	14.1	31
Tram	20	32	6.9	1.5	0.6	65	2.4	13	15.0	30
Willow Creek 1	21	5	7.4	10	3.0	685	1.0	60	90.1	77
Willow Creek 3		6	7.2	10	3.2	780	1.0	200	91.4	60
T31 R08 S1-6D	3	8	6.6	1.7	0.5	86	2.2	40	18.7	22
T31 R08 S10-9	6	3	6.2	1.6	0.6	74	B	25	12.1	29
T32 R07 S15-10	10	20	6.1	2.4	0.8	84	0.4	140	23.8	44
T32 R07 S18-1	2	9	5.6	1.9	0.7	51	0.5	80	24.9	18
T32 R07 S19-11	6	17	6.2	0.5	0.4	31	1.5	18	8.9	27
T32 R08 S28-16	5	7	6.6	1.6	0.5		B	60	12.6	38

Table 1. Continued

Lake	Acres	Depth	pH	Calcium	Magnesium	Alkalinity	Sec-chi	Color	Conductivity	Spring To-tal P
T32 R08 S29-10B	3	12	6.4	1.8	0.6	66	1.1	60	14.7	35
T32 R08 S29-10C	12	3	5.9	1.9	0.8	49	0.3	110	30.8	30
T32 R08 S29-15		5	6.2	0.9	0.4	42	1.0	55	12.3	41
T32 R08 S29-16B	2	4	6.4	1.3	0.5		1.0	55	15.5	40
T32 R08 S30-B	2	4	6.1	1.5	0.5	114	B	40	16.3	55
T32 R08 S30-16	4	7	5.9	1.1	0.4	45	B	40	12.3	25
T32 R08 S31-1D	7	9	7.0	1.3	0.5	72	0.95	45	13.0	21
T32 R08 S32-2	9	5	6.6	1.1	0.4	92	B	18	8.3	22
T32 R08 S32-8	6	11	6.3	1.1	0.4	49	1.1	40	9.9	31
T32 R08 S33-4BA		5	6.4	1.1	0.4		B	60	15.8	31
T32 R08 S33-4CA	1	5	5.9	1.2	0.4	34	B	70	15.8	30
T32 R08 S36-11	3	4	5.9	1.5	0.6	93	0.8		21.4	26
T32 R08 S11	8	14	6.4	1.3	0.6	74	B	25	15.3	21

Table 1. Continued

Lake	Summer Total P	TKN	NO_3-N	Total N	Chlorophyll A
Bass #2	12	0.65	0.01	0.65	4.8
Bass #3	15	0.66	0.02	0.68	4.8
Burnt Wagon	50	1.13	0.01	1.13	48.3
Dam	29	1.03	0.01	1.03	38.5
Dorothy	9	0.43	0.01	0.44	3.1
Highland	23	0.75	0.02	0.77	19.4
Horseshoe T31	40	0.88	0.02	0.90	23.9
Horseshoe T32	21	0.64	0.03	0.67	10.3
Knickerbocker	48	1.02	0.02	1.04	25.5
L. Beaver	47	0.93	0.01	0.94	10.7
L. Plummer	37	1.08	0.01	1.08	48.1
Lowland	26	0.81	0.03	0.84	16.9
Miller	15	0.56	0.01	0.57	9.6
Rattz	26	0.69	0.01	0.70	8.7
Spence	32	0.91	0.01	0.91	2.8
Spring Creek 1	61	0.95	0.02	0.96	11.8
Spring Creek 2	82	0.91	0.04	0.95	
Star	25	0.74	0.01	0.75	12.3
Strawman	18	0.70	0.03	0.73	5.2
Tinman	106	1.31	0.17	1.48	132.9
Townline	23	0.78	0.01	0.78	14.6
Tram	20	0.69	0.05	0.74	13.7
Willow Creek 1	103	1.23	0.07	1.30	111.9
Willow Creek 3	114	1.24	0.11	1.35	43.1
T31 R08 S1-6D	34	0.79	0.08	0.87	11.2
T31 R08 S10-9	20	0.78	0.02	0.80	5.2
T32 R07 S15-10	30	0.88	0.01	0.88	29.8
T32 R07 S18-1	27	1.15	0.11	1.26	9.7
T32 R07 S19-11	30	0.89	0.01	0.90	15.1
T32 R08 S28-16	56	1.18	0.03	1.21	19.9

Table 1. Continued

Lake	Summer Total P	TKN	NO_3-N	Total N	Chloro-phyll A
T32 R08 S29-10B	86	1.77	0.02	1.79	265.1
T32 R08 S29-10C	71	1.46	0.03	1.49	68.4
T32 R08 S29-15	27	0.91	0.02	0.93	4.4
T32 R08 S29-16B	47	0.94	0.05	0.99	6.9
T32 R08 S30-B	44	0.86	0.01	0.87	5.9
T32 R08 S30-16	29	0.89	0.01	0.90	115.6
T32 R08 S31-1D	91	1.54	0.02	1.56	3.0
T32 R08 S32-2	18	0.62	0.01	0.63	8.3
T32 R08 S32-8	45	0.97	0.01	0.97	38.5
T32 R08 S33-4BA	58	0.98	0.01	0.98	6.9
T32 R08 S33-4CA	44	0.98	0.07	1.05	8.9
T32 R08 S36-11	35	0.97	0.02	0.99	10.3
T32 R08 S11	41	1.12	0.01	1.13	17.3

using linear regression analysis (REG procedure, SAS 1996). Models were considered significant at alpha ≤ 0.05.

Connectivity of a lake is known to be an important variable in predicting species richness by modifying the rate of colonization and extinction (Rahel 1986). Comparisons were made between connected lakes (presence of inlet or outlet) and unconnected (seepage) lakes with analysis of variance (GLM procedure, SAS 1996). A lake effect was included as a random effect and connectivity as a fixed effect in the models. Paired comparisons between the connectivity types were evaluated with Student-Newman-Keuls multiple range test.

Fish assemblage structure was evaluated with principal component analysis (PCA; Princomp procedure, SAS 1996). This procedure summarizes the variation contained in multiple variables, in this case abundance of each fish species, and reduces it to fewer dimensions. Reducing the number of variables allows visualization of similarities or differences among lakes, and provides a basis for grouping lakes. These groups can then be used to model relations between limnological variables and the fish fauna. The analysis was performed on those species that occurred in greater than 5 % of the lakes. The flowages (Willow Creek and Spring Creek) were dropped from this analysis because they represent distinctively different lake types then the other lakes in the CCF.

We compared differences in limnological variables of the fish community groupings with analysis of variance (GLM procedure, SAS 1996). These models tested a null hypothesis of no differences in limnological parameters among the lakes groups. A lake effect was included as a random effect and fish community type as a fixed effect in each model. Paired comparisons between fish community types were evaluated with the Student-Newman-Keuls multiple range test.

Catch per effort was calculated for those species only captured by angling**.** Size data for panfish and gamefish were summarized from angling and gillnet data. Also, Proportional Stock Density (PSD) was calculated from angling and gillnet data. The PSD index is the proportion of fish within population that are of "Quality" size (Anderson and Gutreuter 1983). The index is expressed as a percentage and is calculated as; the number of fish ≥ minimum "quality" length of that species divided by the number of fish ≥ minimum "stock" length of that species. PSD was calculated for populations of largemouth bass, bluegill and yellow perch.

Index of Biotic Integrity (IBI) was calculated for the river reach using Wisconsin DNR

baseline-monitoring procedures for wadable streams. IBI is a composite index of several fish assemblage attributes, taking into account several measures of species richness, relative abundance of various taxonomic and functional groups, and proportion of diseased individuals (Lyons 1992). IBI has demonstrated relations to independent measures of watershed conditions, and serves as an objective measure of the overall health of the aquatic community.

Results

Lakes

Nineteen fish species were collected in the 43 CCF lakes (Table 2, Table 3), although surveys in nine lakes detected no fish. Most species detected in the survey were sampled by the minnow traps, however, black crappie were sampled only with gillnets and angling and white sucker were sampled only in gillnets. Several species reaching small adult sizes were sampled only in minnow traps; these species include brook stickleback, northern redbelly dace, fathead minnow, Iowa darter, blacknose shiner, bluntnose minnow, and central mudminnow. No state or federally listed endangered or threatened species were encountered in the CCF lakes.

Linear regression models revealed consistent relations between fish species richness and limnological attributes. Species richness of lakes increased with larger lake surface area (Figure 1,Table 4). Also, species richness was positively related to increasing alkalinity, productively, conductivity and pH of the lakes (Table 4). Analysis of variance revealed a greater number of species in lakes with defined inlets or outlets than in unconnected (seepage) lakes ($F=49.99$, $P=<0.001$). Connected lakes averaged 6.0 ± 0.74 species per lake, while unconnected lakes average 1.69 ± 0.25 species per lake. Bluntnose minnow, white sucker, Iowa darter, blacknose shiner, creek chub and yellow bullhead were sampled only in connected lakes.

An ordination of assemblage data (PCA) revealed three clusters of assemblages and explained 40 percent of the variation in the data set in the first two principal components (Table 5a and 5b, Figure 2). One group contained panfish/northern pike, the second was dominated by fathead minnows, the third by central mudminnows. A fourth lake group, not included in the PCA analysis, was characterized by absence of fish. Differences in the communities were associated with the water chemistry and potential habitat.

Table 2. Fish species present in the named lakes.

Lake	Yellow Perch	Northern pike	Fathead minnow	Golden shiner	Bluegill	Pumpkinseed	Black bullhead	Yellow bullhead	Brown bullhead	Black nose shiner	Central mudminnow	Large mouth bass	N. red belly dace	Creek chub	Black crappie	Iowa darter	White sucker	Brook stickleback	Blunt nose minnow	Species richness
Bass Lake # 2		X			X							X								3
Bass Lake #3				X					X		X	X								4
Burnt Wagon			X										X					X		3
Dam Lake	X				X	X	X	X	X		X									7
Dorothy											X									1
Highland	X										X									2
Horseshoe T31		X		X					X											3
Horseshoe T32		X			X	X						X								4
Knickerbocker	X			X	X		X				X	X								6
Little Beaver	X					X	X				X									4
Little Plummer		X			X		X								X					4
Lowland	X	X			X	X														4
Miller					X				X											2
Rattz											X									1
Spence					X							X								2
Spring Creek 1			X	X			X				X		X	X				X	X	8
Spring Creek 2			X	X			X						X					X		5
Star			X	X					X											3
Strawman																				0
Tinman											X		X							2
Townline	X	X	X	X	X	X	X	X	X	X										10
Tram			X																	1
Willow Creek 1	X			X	X	X	X								X	X	X			7
Willow Creek 2	X			X		X	X				X		X	X		X	X			9

Table 3. Fish species present in unnamed lakes.

Lake	Fathead minnow	Bluegill	Pumpkinseed	Blackbullhead	Brownbullhead	Central mudminnow	Largemouthbass	N. redbelly dace	Brook stickleback	Species Richness
T31N R08W S1-6D										0
T31N R08W S10-9										0
T31N R08W S11	X							X		2
T32 N R07 W S15-10		X		X						2
T32 N R07 W S18-1				X		X				2
T32 N R07 W S19-11	X					X		X	X	4
T32N R08W S28-16		X	X		X	X			X	5
T32N R08W S29-10B	X						X			2
T32N R08W S29-10C	X				X	X				3
T32N R08W S29-15										0
T32N R08W S29-16BC										0
T32N R08W S30-B										0
T32N R08W S30-16										0
T32N R08W S31-1D	X								X	2
T32N R08W S32-2						X				1
T32N R08W S32-8	X									1
T32N R08W S33-4BA										0
T32N R08W S33-4CA										0
T32N R08W S36-11						X				1

Figure 1. Relationship between species richness of lakes and lake area.

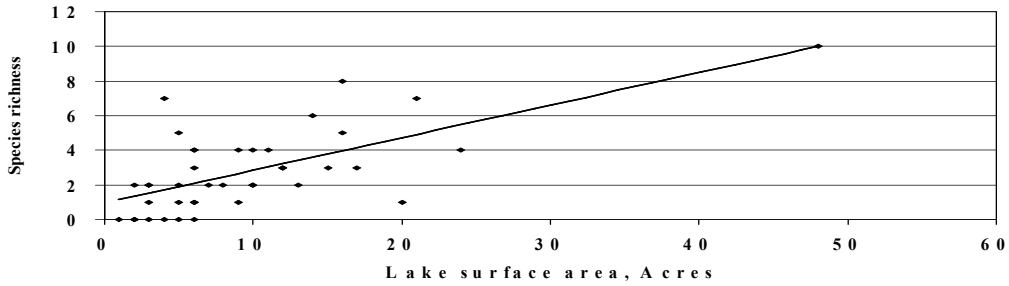


Table 4. Summary of results for linear regression analysis evaluating relationships between species richness of lakes and limnological features.

Parameter	Parameter Estimate	Model R-square	Model P-value
Acres	0.19	0.443	<0.001*
Depth	0.03	0.003	0.730
pH	2.94	0.267	<0.001*
Calcium	0.55	0.299	<0.001*
Magnesium	1.78	0.316	<0.001*
Alkalinity	0.01	0.341	<0.001*
Secchi	-0.26	0.010	0.526
Color	0.02	0.101	0.043*
Conductivity	0.07	0.349	<0.001*
Spring total P	0.04	0.094	0.046*
Summer total P	0.03	0.106	0.033*
TKN	1.73	0.032	0.249
NO_3-N	3.73	0.002	0.756
Total N	1.62	0.031	0.260
Chlorophyll A	0.01	0.01	0.610

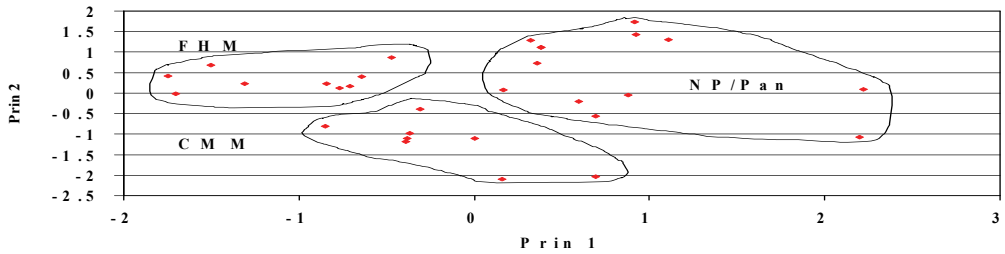
Table 5A. Summary statistics for principal component analysis of fish species occurring in 5 percent of the lakes.

	Principal Component 1	Principal Component 2
Eigenvalues	2.933	1.966
Difference	0.967	0.362
Percent of variation	24.4	16.4

Table 5B. Eigenvalues of loading of fish species on first 2 principal components.

Species	Principal Compo-nent 1	Principal Component 2
Yellow perch	0.346	-0.273
Northern pike	0.396	0.175
Fathead minnow	-0.419	0.157
Golden shiner	0.146	0.275
Bluegill	0.310	0.315
Pumpkinseed	0.396	-0.136
Black bullhead	0.230	-0.397
Brown bullhead	0.139	0.270
Central mudminnow	-0.066	-0.552
Largemouth bass	0.163	0.348
Brook stickleback	-0.245	0.141
Northern redbelly dace	-0.332	-0.007

Figure 2. Plot of the first 2 principal components representing the fish community types in the lakes of the CCF.



Analysis of variance revealed that depth (F=4.65, P=0.008), pH (F=4.42, P=0.012), and lake area (F=3.76, P=0.020) were the most important variables in models describing fish assemblage composition. Panfish/northern pike lakes were deeper, larger in surface area, and less acidic than lakes with no fish (Table 6). Winter dissolved oxygen is another important variable in determining the fish assemblage of a lake (Tonn and Magnuson 1982). Winter dissolved oxygen was not collected for this survey.

Table 6. Summary of results from ANOVA's evaluating differences among community types for limnological variables. Values for each community type are mean (±) one standard error.

Variable	Panfish/ pike	Central Mudminnow	Fathead Minnow	No fish	F-ratio	P-value
Secchi	1.8±.23	2.12±.62	1.56±.38	1.63±.25	.42	0.738
Ca	2.23±.58	1.56±.13	1.38±.14	1.28±.09	1.31	0.287
Mg	0.79±.20	0.54±.04	0.57±.04	0.45±.02	1.23	0.313
Alkalinity	153.7±55.7	87.0±12.6	62.11±5.53	62.43±11.22	1.60	0.209
Conductivity	19.75±2.8	17.73±1.9	14.84±2.14	14.39±.87	1.33	0.281
pH	6.70±.13A	6.27±.12B	6.45±.12AB	6.18±.08B	4.42	0.012*
Color	48.23±10.98	41.57±10.99	39.88±10.22	45.00±5.46	.15	0.932
Spring Total P	34.76±6.58	23.0±3.02	26.55±1.75	32.44±3.73	1.16	0.337
Summer Total P	29.53±3.64	36.37±10.71	51±8.69	35.67±4.48	1.90	0.148
TKN	0.85±.05	0.85±.10	1.14±.12	0.87±.03	3.01	0.055
NO_3-N	0.01±.002	0.04±.02	0.02±.003	0.03±.01	1.84	0.157
Total N	0.86±.05	0.90±.12	1.16±.12	0.90±.03	2.57	0.07
Chlorophyll A	19.18±3.8	25.37±15.44	53.51±27.36	18.92±12.11	1.12	0.355
Surface Area	14.00±3.2A	5.53±1.02AB	9.22±1.8AB	3.29±.68B	3.76	0.020*
Depth	7.69±1.2A	7.38±1.99A	4.31±.79AB	2.11±.60B	4.65	0.008*

Recreational Fishery

Panfish (bluegill, pumpkinseed, yellow perch, and black crappie) and gamefish (northern pike and largemouth bass) were sampled in 18 lakes (Table 2, Table 3). Three bullhead species were collected in 4 additional lakes. These species providing potential for recreational angling were sampled in 22 lakes.

Several lakes within the CCF have historically provided a fishery for panfish and/or gamefish (WDNR 1995a, Table 7). Five of the lakes identified as supporting a fishery from

WDNR file data did not contain viable fisheries during the 2002-03 sampling; these lakes included Dorothy, Rattz, Spring Creek #1, Star and Tram. In addition, six other lakes had at least one fish species from their historical recreational fishery that was not detected in our surveys. Historically, Lowland Lake contained a largemouth bass fishery but no northern pike fishery. During the 2002-03 sampling, a northern pike fishery was detected but no largemouth bass fishery.

Table 7. Historical fishery data for the named lakes in the CCF.

Lake	Largemouth bass	Walleye	Panfish	Trout	Northern Pike
Bass # 2	XZ		XZ		
Bass #3	XZ		XZ		Z
Burnt wagon					
Dam	XZ		XZ		X
Dorothy	X		X		
Highland	X		XZ		
Horseshoe T31			X		XZ
Horseshoe T32	XZ	X	XZ		XZ
Knickerbocker	XZ		XZ		X
L. Beaver	XZ		XZ		X
L. Plummer	X		XZ		XZ
Lowland	X		XZ		Z
Miller			XZ		
Rattz	X				X
Spence	XZ		XZ		
Spring #1				X	
Spring #2					
Star			X		
Townline	X		XZ		XZ
Tram	X		X		
Willow Creek #1			XZ		
Willow Creek #2			XZ		

X= Historical data (WDNR 1995a)
Z= Data from present study

Angling effort and size structure

Yellow perch were detected in eight lakes but were only angled in seven lakes for a mean catch rate of 1.74 fish per hour (Figure 3). Yellow perch averaged a total length of 8.2 (±0.22) inches with a range of 4.0 to 12.2 inches. (Figure 4). The largest yellow perch occurred in Dam, Highland and Lowland (Figure 5).

Figure 3. Angling catch per effort for bluegill, yellow perch, largemouth bass, black crappie, and northern pike in the CCF lakes.

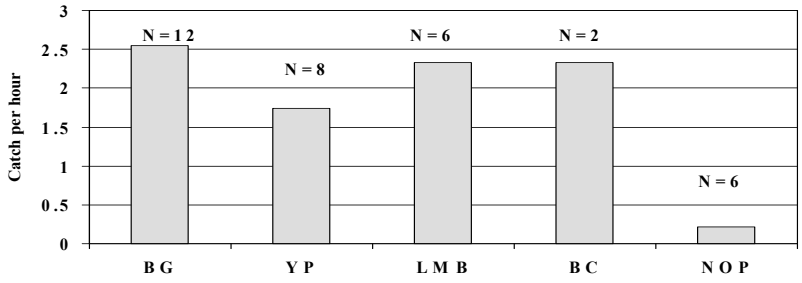


Figure 4. Mean total length of yellow perch in CCF lakes. The study average contains lengths of yellow perch captured by angling and gill netting in all lakes.

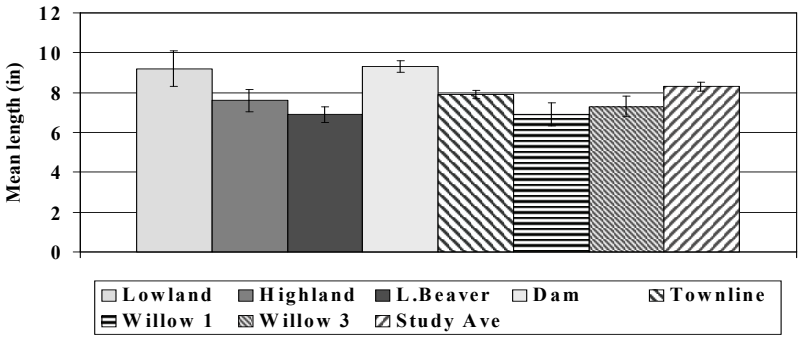
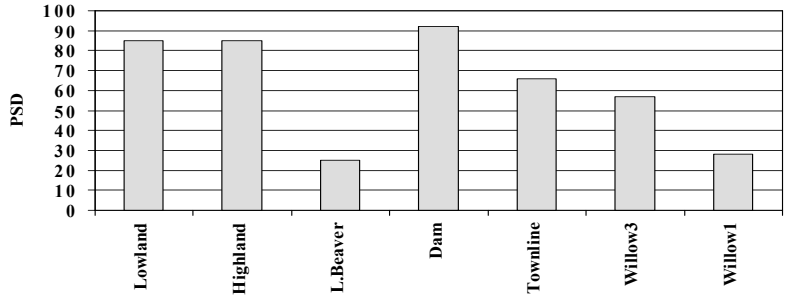


Figure 5. Proportional stock density (PSD) of yellow perch in CCF lakes.



Bluegills were detected in 12 lakes but were only angled in seven lakes. The mean bluegill catch rate was of 2.5 fish per hour (Figure 3). Bluegill total length averaged 5.6 (± 0.17) inches with a size range of 4.0 to 8.5 inches (Figure 6). Spence and Little Plummer lakes contained bluegill populations with good size structures (Figure 7).

Figure 6. Mean total length of bluegill in CCF lakes. Study average contains lengths of bluegill captured by angling and gill netting in all lakes.

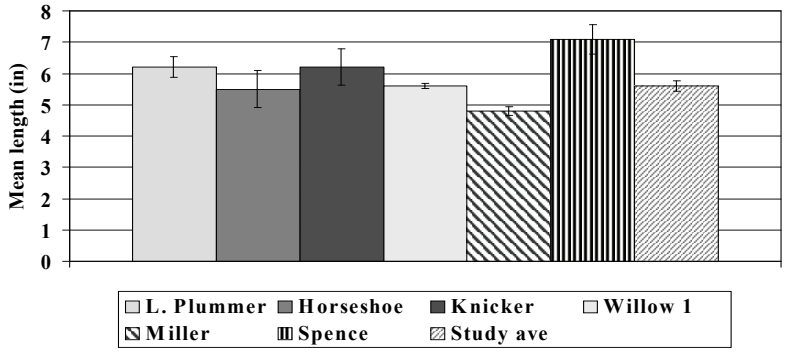
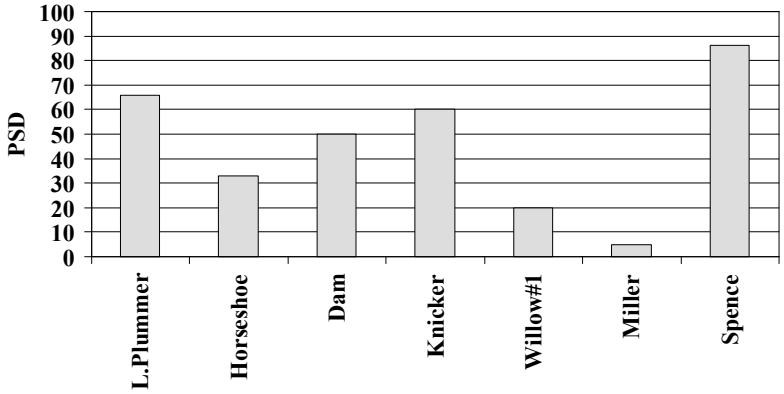


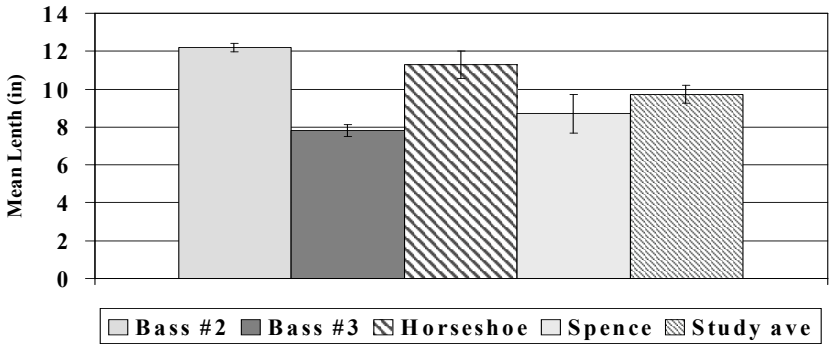
Figure 7. Proportional Stock density (PSD) of bluegill in CCF lakes.



Black crappie were detected in two lakes with an average catch rate of 2.33 fish per hour (Figure 3). The total length of angled black crappie averaged 7.3 (±0.70) in., ranging from 5.0 to 12.5 in. Black crappies were only caught in lakes with connections to other aquatic systems.

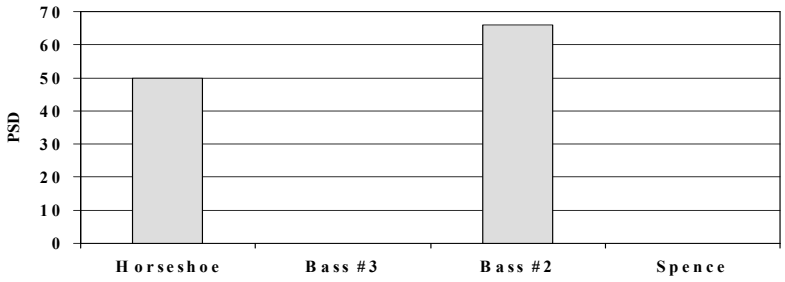
Largemouth bass were detected in six lakes and were angled out only four lakes for an average catch rate of 2.33 fish per hour (Figure 3). Largemouth bass in the six lakes averaged 9.7 (± 0.49) inches in total length, and ranged in size from 6.5 to 18.0 inches (Figure 8). Bass size structure was best in Bass Lake #2 and Horseshoe T32 (Figure 9). We did capture several

Figure 8. Mean total length of largemouth bass in CCF lakes. The study average contains lengths of largemouth bass that were captured by angling and gill netting in all lakes.



Combining all gears, northern pike were captured in six lakes. Northern pike were only angled from two lakes for a mean catch rate of 0.22 fish per hour (Figure 3). Northern pike averaged 18.8 (±1.1) inches in total length, ranging from 11.5 to 28.3 inches.

Figure 9. Proportional stock density (PSD) of largemouth bass in CCF lakes.



Yellow River

A total of 777 fish representing twenty-seven fish species was collected in the river (Table 8). Six intolerant species were collected including, rainbow darter, fantail darter, Iowa darter, banded darter, northern hog sucker, and smallmouth bass. Only 14 individual fish were species considered tolerant of degraded conditions. These aspects of the fish community help give this reach of r an excellent biotic integrity rating (IBI score of 90). Exotic fish species were not sampled, nor did collections include any fishes listed as endangered, threatened, or special concern.

Recreational Fishery

The recreational fishery in the sampled reach of the Yellow River is composed of mostly smallmouth bass, black crappie, and bluegill with occasional walleye, northern pike, and largemouth bass. The average length of the smallmouth bass was 9.4 inches with the largest fish being 13.4, just under the legal size limit. Only one larger walleye (22.5-in. total length) was captured.

Discussion

Small lakes in Wisconsin are characterized by simple fish assemblages (Hatzenbeler et al. In press), and are typically dominated by a small number of common species. Most of Wisconsin's fish diversity is found in rivers and streams. Of the 113 species known to occur within the Chippewa River drainage, only 19 were sampled in the 43 lakes and 27 were sampled in the Yellow River. Of the 19 species sampled in the lakes, 13 were sampled in unconnected

(seepage) lakes. No exotic fish species were sampled. The overall survey results for the CCF lakes were typical of lakes in the region.

Table 8. Species and number captured in the Yellow River (T30N-R5W-S29-20). Data collected by Joe Kurz, WDNR, Chippewa Falls, Wisconsin.

Species	Number
Rainbow darter	240
Largescale stoneroller	158
Longnose dace	76
Smallmouth bass	70
Fantail darter	41
Golden redhorse	24
Banded darter	22
Northern hogsucker	22
Shorthead redhorse	19
Blackside darter	15
Black crappie	14
Hornyhead chub	14
White sucker	11
Bluegill	10
Burbot	9
Johnny darter	8
Logperch	6
Stonecat	5
Common shiner	3
Central mudminnow	2
Largemouth bass	2
American brook lamprey (ammocoete)	1
Iowa darter	1
Northern pike	1
Silver redhorse	1
Walleye	1
Yellow bullhead	1

Fish assemblage structure

Lakes could be grouped into four main assemblage types, including pike/panfish lakes, fathead minnow-dominated lakes, mudminnow lakes, and fishless lakes. Several fishes dominating the catch in fathead minnow and mudminnow lakes are tolerant of low oxygen concentrations and are associated with winterkill lakes. These results are consistent with the findings of Tonn and Magnuson (1982), who found that fish assemblages dominated by fathead minnows, central mudminnows, brook sticklebacks and northern redbelly dace were associated with winterkill lakes.

The presence of gamefish and panfish is associated with a reduction in catch rates of cyprinids (minnows), resulting in distinctly different assemblages. Predation by gamefish and panfish is a likely mechanism contributing to the decrease in cyprinid abundance where sunfish, perch, and pike are present (Findlay et al. 2000). Of the lakes lacking centrarchid (sunfish) species, two general assemblage types were observed. Fathead minnows dominated some lakes, whereas others were characterized by a catch composed primarily of central mudminnows. Lakes with fathead minnows sometimes contained brook sticklebacks, central mudminnows and northern redbelly dace. Lakes dominated by fathead minnows typically have more refuges from anoxic conditions, such as an outlet, inlet, or spring than lakes dominated by central mudminnows (Magnuson et al 1985). In addition to refuge from low DO, inlets and outlets provide routes for recolonization; species such as fathead minnows with high reproductive capacity can rapidly repopulate fishless waters. Where fathead minnows were present in the CCF, they were generally encountered in large numbers.

Mudminnows are not easily sampled, so catch rates may not be reliable indicators of abundance (Becker 1983). Although they were not encountered in large numbers, mudminnows were fairly ubiquitous throughout the study lakes. Mudminnows can persist over a wide range of conditions, and in lakes where they were the dominant fish, extreme conditions (oxygen and pH) were likely to lead to frequent extirpation of other species. Thus, simple communities are a function of both periodic extirpation, and the frequency of recolonization. We see the dynamics modified in lakes where winterkill is infrequent, and populations of gamefish can further modify the assemblage through biotic interactions such as predation.

Colonization through natural movements of fish is an obvious factor influencing assemblage composition but human-mediated transfers of fish, including deliberate actions of fish

managers and both intentional and unintentional bait transfers provide additional routes of colonization. The past establishment of fishable populations in several lakes, and their subsequent extirpation demonstrate the dynamic nature of fish species assemblages, as well as the practical limits of managing these smaller systems for long-term objectives. The limits are tied to limnological features, as suggested by the modeling. Larger lakes have more species; the link between area and species richness is well documented in many ecological studies. Large lakes are likely to have a wider range of habitats, more refuge from anoxia, and larger populations that decrease the chance of stochastic extirpation. Chemistry also plays a role, with more acidic or otherwise marginal waters limiting successful establishment of colonizing species, and increasing the chance of extirpation under stressful conditions. Limological features such as depth, and basin characteristics that affect wind-aided mixing and stratification can also limit the potential to successfully establish and maintain species. Thus, introducing panfish or gamefish in small basins with acidic or otherwise marginal conditions may work temporarily but these lakes will inevitably experience periodic extirpation.

Several lakes were either fishless or contained fish in very low densities. These appear to be susceptible to anoxic conditions and were more acidic than the other lakes, limiting persistence of fish species. However, these lakes provide habitat for a variety of amphibians (central newts and several species of frog adults and tadpoles were observed but not quantified), invertebrates and nesting waterfowl. Management for fish would be impractical in these lakes; however, decisions regarding management of riparian areas should consider other biota.

Recreational Fishery

Panfish (bluegill, pumpkinseed, yellow perch, and black crappie) and gamefish (northern pike and largemouth bass) were sampled in several lakes and provide a potential recreational fishery. In addition, three bullhead species were collected. These species providing potential for recreational fishing were sampled in 22 lakes. Not surprisingly, the largest lakes, such as Townline and Horseshoe T32-R08-S33 generally provided the most diverse assemblages for recreational fishing. These results are consistent with other findings in Wisconsin lakes (Jennings et al. 1999, and Magnuson et al. 1998). The variety of access types for CCF lakes presents a range of angler opportunities that includes developed boat ramps, drive-up shore access, and the option of walk-in access for a different angling experience. This range of

options caters to diverse interests, and is increasingly rare in Wisconsin.

Lakes with catchable fish but without road access showed evidence of population size structure with a greater proportion of larger fish. Large yellow perch were sampled in Dam Lake and Highland Lake, and large bluegills were sampled in Spence Lake. Calculation of psd, although from limited data, supports this observation. Although no creel data are available, this association suggests that size structure is impacted by higher angling pressure in easily accessible lakes. Populations are small in these lakes and a slight increase in angling pressure may result in rapid change in size structure. Having a few lakes with walk-in access not only provides a rare angling experience, but can also help shape population size structure and the diversity of angling opportunities.

Despite its small size, accessibility, and apparently high angling pressure (indicated by large amounts of trash, including bait containers, line, etc. left on the shore), Bass Lake #2 contained a fishery including largemouth bass and northern pike up to 28" in total length. Catch of northern pike was limited to a small number of fish in lakes where they were detected. Bass appeared to be more abundant than pike where they were present but their distribution was limited to 6 lakes. The presence of pike and bass in larger sizes suggest that severe fish kills are infrequent in these lakes, although the possibility of unauthorized field transfers of adult fish can not be ruled out.

Several lakes within the CCF have historically provided a fishery for panfish and/or gamefish (WDNR 1995a). Dorothy, Rattz, Spring Creek #1, Star and Tram did not contain viable fisheries during the 2002-03 sampling, most likely as a result of anoxia resulting in fish kills. Management of these lakes susceptible to partial fish kills could include maintenance of recreational fisheries as a goal; however, success may be limited and costs prohibitive. Such management would include periodic stocking to maintain populations. Some stocked year classes would likely be lost before reaching catchable sizes. Alternatively, winterkill or low summer dissolved oxygen could be addressed with costly intervention (such as mechanical aeration) to maintain oxygen concentrations. The limited benefits that a fishery would provide in these small lakes would probably not justify the cost of intensive management. For instances, the start up cost for a 4-panel solar aeration unit that would protect 5 to 10 acres from winterkill would be approximately 4,500 dollars (L.Damman, personal comm., WDNR, Spooner). These startup cost does not cover the yearly maintenance cost or the potential liabil-

ity associated with open water during the winter.

Implications for forest management

Fish sampling in the CCF lakes detected assemblages typical of lakes of similar size within the region. The processes influencing assemblage structure are largely dependent on natural features of the landscape, and are related to water chemistry, climate, and connections among aquatic systems. The fish species present in the lakes include a couple of species intolerant of degraded conditions (blacknose shiner, Iowa darter), but no threatened or endangered species. No unique features of the fishery were identified that would suggest the necessity of any steps beyond normally prescribed forestry BMP's for water quality (WDNR 1995b).

The IBI results for the Yellow River suggest that the watershed is in good condition, and that the river contains the number and type of species typically found in lightly impacted streams of the region. Continued sound riparian management, including BMP's for water quality (WDNR 1995b) will help maintain the quality of the river.

Acknowledgments

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