Steve McComas: *Ballard Lake's Lilies and Trees*, **1999**

White Birch-Ballard-Irving Lakes Vilas County, Wisconsin Lake Management Plan

December 2000

Prepared by Steve McComas, Blue Water Science
with significant contributions from Ballard-Irving-White Birch Lakes Association, Inc. and Wisconsin Department of Natural Resources

Funded in part by the Wisconsin Lake Management Planning Grants Program Projects LPL 602 and LPL 613

White Birch-Ballard-Irving Lakes
Vilas County, Wisconsin
Lake Management Plan

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PREFACE

The Lake Planning Grant Program

The Lake Planning Grant Program consisted of two projects. The project covering Ballard and White Birch Lakes was designated LPL 602. The Irving Lake project was designated LPL 613. The objective behind these Planning Grant Projects was to gain better understanding and insights to the problems and dynamics associated with the three lake ecosystem represented by the Ballard-Irving-White Birch Chain-of-Lakes. In turn, this provided the basis for remedial action where required, as well as a firm foundation for future planning. The program involved gathering both current and historical information related to the lakes and their watersheds. Specifically, information was collected in several focus areas: lake(s) history, water quality, aquatic vegetation, fishery, shoreline vegetation, shoreland development, watershed, and lake usage. Work included characterizing the land and water environment, mapping watersheds, and sensitive areas, developing nutrient and water budgets, as well as conducting a lake usage survey.

The total budget for the program was $23,500. The State share of $17,200 covered the costs of a professional consultant, report production and distribution, as well as analyses at the State Laboratory of Hygiene. The local share of $6,500 was paid by way of 1300 hours of labor contributed by Association members. Mr. Steven McComas of Blue Water Science, St. Paul, MN, served as the Association's Consulting Ecologist with responsibility for the technical aspects of the program, as well as for providing expert guidance to the Association's volunteers.

The Grants covered the period April 1, 1999 through June 30, 2000, with an extension to December 31, 2000. This report integrates the information and recommendations from all of the focus areas into a comprehensive lakes management plan. The plan provides background information for each area, and specifically addresses actions requisite to the rehabilitation, improvement, and protection of the lakes for the present and future generations.

A companion Grant Program publication, *WISCONSIN LAKES: A Trilogy*, provides background information on Wisconsin's Lake Management Planning Grant Programs and an overview of the Ballard-Irving-White Birch Lakes Association's work from just after the 1995-96 winterkill through the Lake Planning Grant Projects. It also includes a narrative about Irving Lake and wild rice. The International Engineering Consortium sponsored the publication as a public service with a view toward facilitating its widespread distribution - to enable many others to benefit from the work done on these Grant Projects.

My thanks to our volunteers, to our consultant, Steve McComas, to the WDNR's Bob Young and Paul Garrison, and to all of the other contributors who worked to gain a better understanding of our lakes. Together, we will be better able to make the lakes safe, clean and enjoyable for this and future generations. It has been my pleasure to work with so many fine people for the past two years.

Frank G. Splitt
December 2000

DEDICATION

This Management Plan is dedicated to the memory of our friends and neighbors who died during the course of the work on the Lake Planning Grant Projects. These include Betty Abbott, Cecile Ellerman, Edith Fredrickson, Carl and Dolly Heitz, and Mary Louise Rismon. They all so loved our lakes.

ACKNOWLEDGEMENTS

Members of the Ballard-Irving-White Birch Lakes Association (BIWBLA), and many others contributed in various ways to the work effort on the projects that formed the basis for this Management Plan. They include:

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1. Introduction and Project Setting

The White Birch-Ballard-Irving chain of a lakes is located in Vilas County, Wisconsin (Figure 1). Irving is the shallowest of the three, Ballard is the largest, and White Birch is the deepest (Table 1).

The objectives of this study were to characterize existing lake conditions and to make recommendations to protect and improve the lake environment where feasible.

Table 1. Lake statistics.

	White Birch	Ballard	Irving
Size (acres)	117	505	403
Mean depth (ft)	12	9	4.5
Maximum depth (ft)	27	25	8

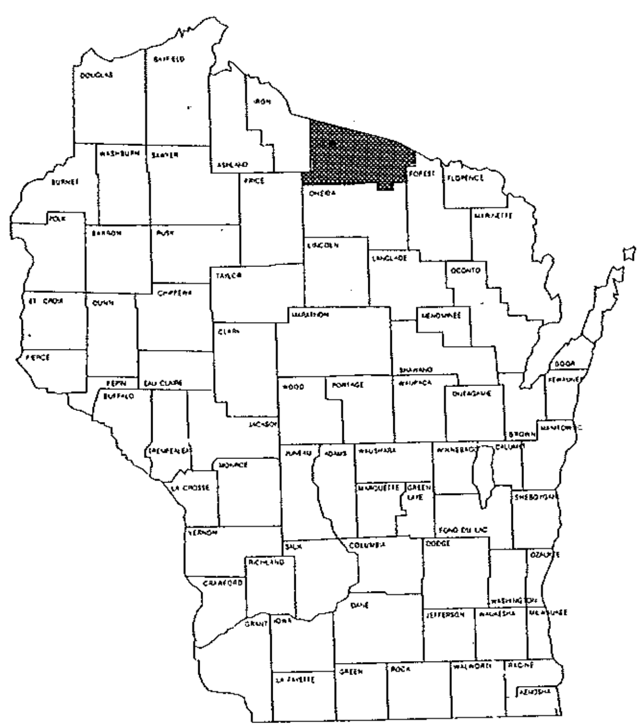


Figure 1. White Birch, Ballard, and Irving Lakes are located in Vilas County, WI.

2. Historical Highlights

2.1. Glaciers and Soils

The White Birch-Ballard-Irving chain of lakes was formed approximately 10,000 years ago during the last glacial retreat of the Wisconsin Valley glacial lobe (Figure 2). The soils deposited by the Wisconsin Valley glacier were primarily sands and loamy-sands. Beneath these soils, at depths of about 50-350 feet, is Precambrian bedrock that is over one billion years old. The bedrock is referred to as the North American shield.

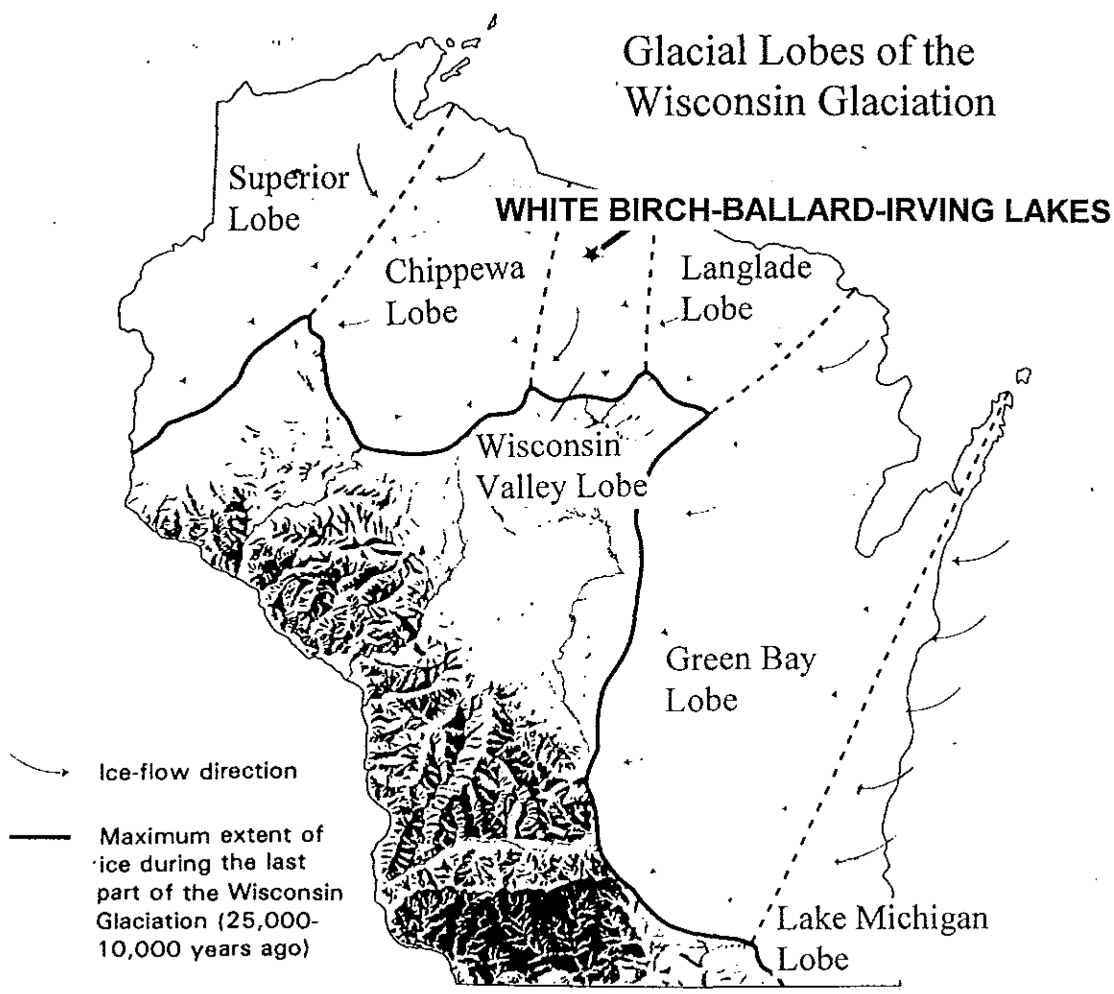


Figure 2. Glacial lobes of the Wisconsin glaciation. The White Birch-Ballard-Irving Chain of Lakes is located in the Wisconsin Valley lobe.

The soils sitting on top of glacial sands are some of the most acid (pH 5.5) and have some of the highest available phosphorus (138 lbs/acre) of any soil in Wisconsin. The White Birch-Ballard-Irving chain of lakes rests in Soils Group (21) referred to as the Vilas, Omega, Pence group (Figure 3).

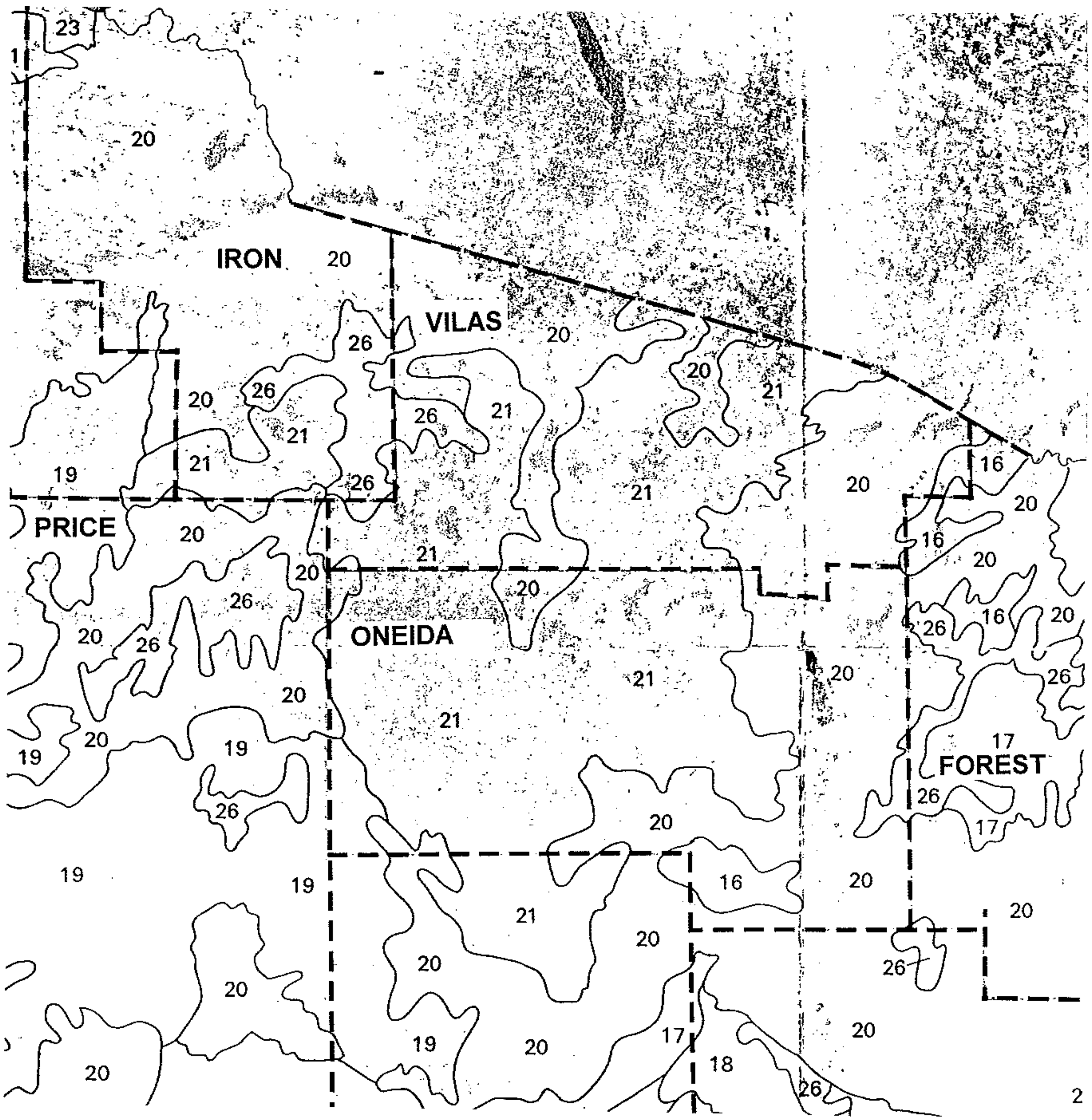


Figure 3. White Birch-Ballard-Irving chain of lakes is located in a depression in soil group 21.

2.2. Lake History from Written Accounts

prepared by: Carolyn Jacobs, John Bates, Carol Malmgren, and Frank Splitt

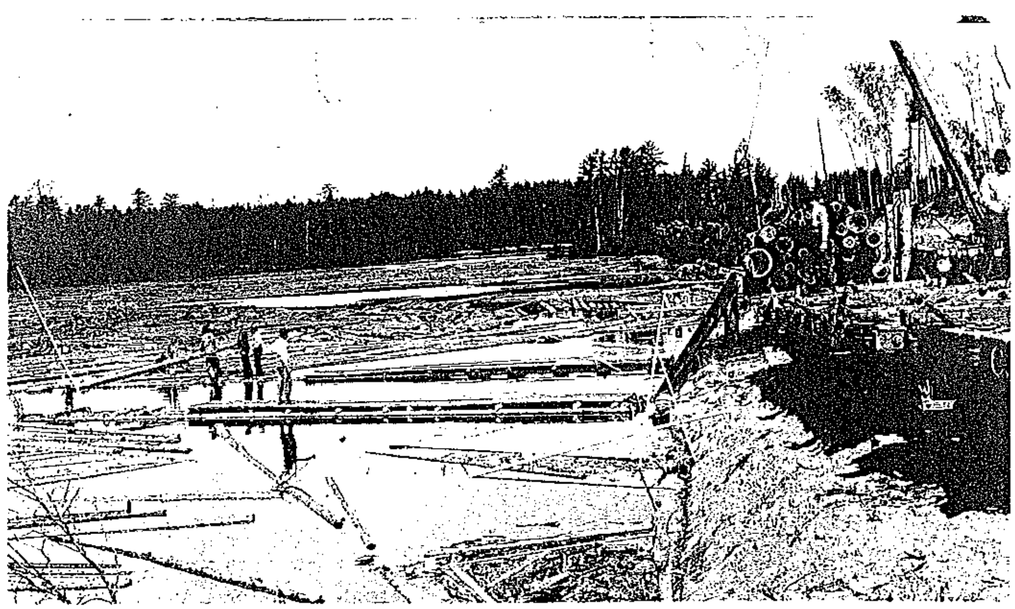
A narrative of government sponsored explorations made in 1847 describes a journey that coursed through forests to First White Elk Lake (later known as Little Muskalonge Lake and now White Birch Lake), second White Elk Lake (Ballard Lake) and third White Elk Lake (Irving Lake). The explorers found a number of deserted wigwams and the remains of a garden near White Birch Lake. According to the narrative, "The lake affords great numbers of fish, and the quantity of their remains scattered around show they are the principal article of food among the Indians who occasionally inhabit it."

The above, and later narratives indicate that the Ballard-Irving-White Birch territory was historically forested land before settlement. A few Native American settlements of the Ojibwa tribe found subsistance from these forests and lakes. They came through the rivers by canoe and by foot. Remnants of their camps have been found. Many came for seasonal camp-outs and only one large village is known, that of about two hundred inhabitants at Indian Lake, north of Lake Laura.

An additional observation from that 1847 exploration describes an interesting phenomenon in Irving: "October 1. A heavy frost this morning; the thermometer standing at 25 degrees Fah. at half-past six o' clock. We crossed First White Elk Lake, and by a stream twenty feet wide and a quarter of a mile long, passed into second White Elk Lake, which is about two miles long and one mile wide. From this we passed into Third White Elk Lake, by a stream ten yards wide and three hundred yards long. This lake is nearly circular, and about one mile in diameter. It is very shallow, not having a depth of more than three feet at any point, and has a mud bottom. We noticed here a phenomenon, not hitherto observed in any of the great number of small lakes we have seen in the territory. The whole surface of the lake was covered with bubbles of light carburetted gas, which were constantly ascending from the bottom."

In the late 1880's, government surveyors went through Northern Wisconsin in preparation for opening the area and early white settlers became excited about opening the wilderness to timber harvest. As more and more logging companies brought in people to cut the timber, the railroad operated as far north as Micocqua in 1888. As the railroad pushed north toward Star Lake, Williams and Salsich Logging Company moved their sawmill from McKenna to Star Lake. When the town was booming, over six hundred people lived here and railroad lines radiated out from the Star lake hub. One such line ran across the Ballard-Irving thoroughfare, turning west along the shore of Ballard to White Sand Lake.

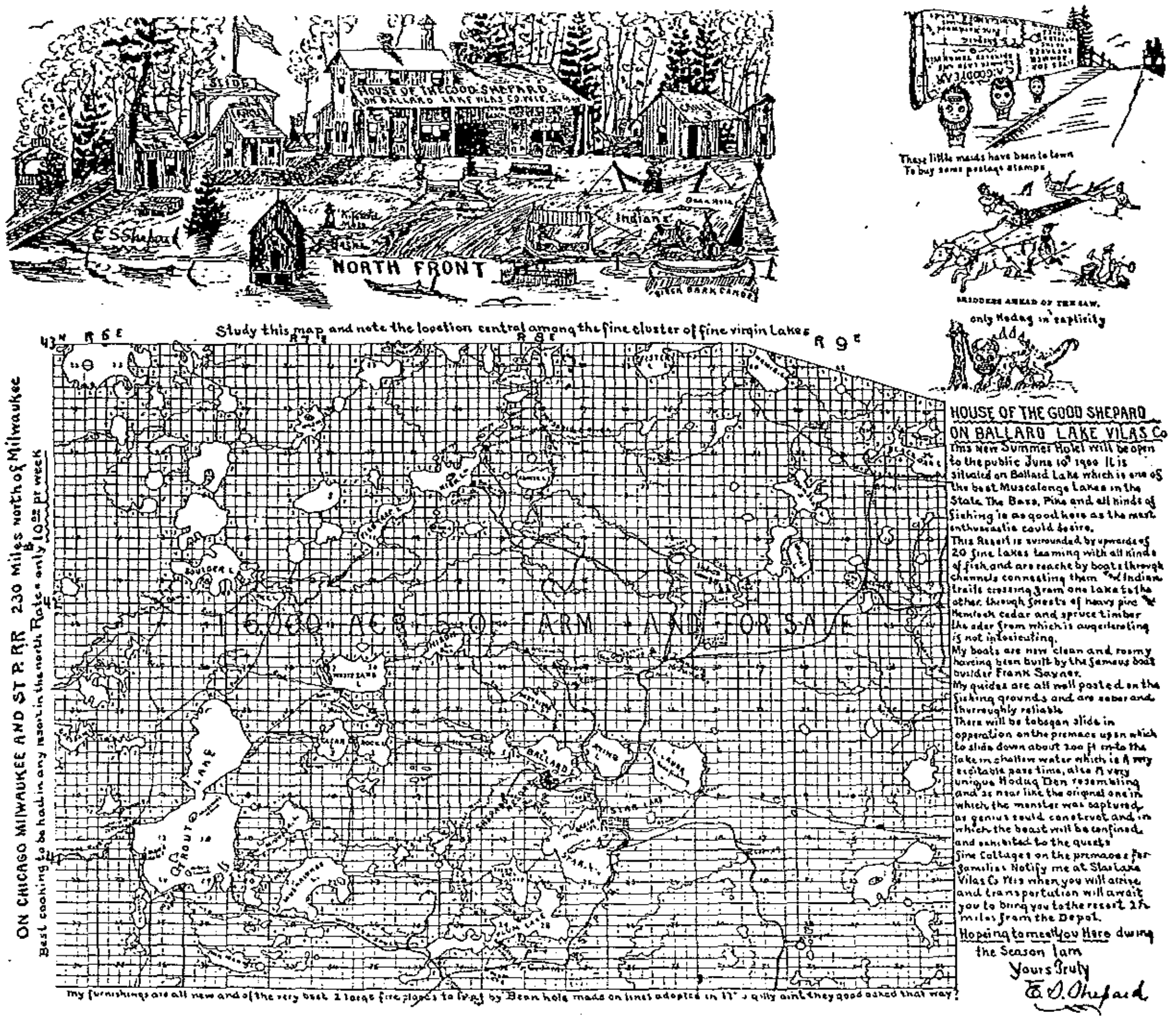
By the year 1912, logging and the mills has ceased to the mainstay of the economy. People by the hundreds were leaving and lumber barons were moving entire towns out . . . and eventually ceased all operations. The area resembled a vast wasteland. As far as the eye could see was a panorama of stumps and cuttings which had replaced the virgin timber that once reached high to the sky.



Loading logs at Little Muskie Lake (White Birch) about 1910.

The area was in transition. A short growing season made farming difficult. The hardy pioneers that had come needed to find a way to survive, and as early as 1900, tourism became their salvation.

In 1899, Gene Shepard, who had worked as a timber cruiser for Goodyear Lumber Company around Ballard and Irving Lakes, built a summer resort on the south shore of Ballard Lake on what is now the Gladys James property. He first named it the House of Good Shepard, and later, Ferncroft. People came by train to the Ballard Lake station and were then taken by boat across the lake. There were no roads, so once there, they made their own entertainment. It was here that Shepard invented the famous "Hodag" for his guest's entertainment.



THE GREATEST MUSKELLUNGE FISHING IN THE WORLD.

ADDRESS: E. S. Shepard, Star Lake, Vilas County, Wisconsin.

After operating the resort for a year or so, Mr. Shepard sold Ferncroft to H.L. Atkins who operated it from 1900 to 1904. The succeeding owner was Joseph Rothschild who built the Ballard Lake island home as a summer residence. The resort was leased and operated by Ole Rismon from 1908 to 1924.

In 1924 Ole Rismon purchased land on Ballard Lake and built his own resort. Rismon's Lodge opened for business on May 16, 1924. The Rismons raised four children there and the family continued to operate the lodge until 1998 when it was sold off and subdivided.

Following the establishment of Rismon's Lodge, several friends of Ole's bought land next to him and established some of the first summer homes in the area. Judge and Mrs. Marvin Rosenberry built right next door, followed along the shore by Mr. and Mrs. Frank Gould, Dr. and Mrs. Harry Moffatt, and Mr. and Mrs. Alfred Pickard. These homes still exist today as private residences for the Millar/Tucker family, Mr. and Mrs. Robert McKelvey, and Mr. and Mrs. Fred Gollash. The only other residence on the lake at the time was at the western end, that of Mr. and Mrs. Albert Norman. It is presently owned by their daughters, Helen Peterson and Lucy Blasius. It wasn't until the Ferncroft Resort was subdivided into 100 feet lots that most of the present permanent and summer homes were built. That took place in the late 1950's.

It is of interest to note, that in 1933, Mr. Frank Gould chaired a committee consisting of fellow Ballard Lake residents Mr. Frank Tucker, and State of Wisconsin, Chief Justice Marvin Rosenberry. With the approval of the Wisconsin Conservation Department, and working out of Rismon's Lodge, the committee organized and developed the Ballard Lake Trail Club. The objective of the Club was "the opening up, connecting and marking of trails so that the attractive region that is inaccessible by motor will be available to all tourists whether skilled in woodcraft or not." These trails are now being refurbished under the auspices of the WDNR, and the Star Lakers Club, with help from the families of the original organizers.

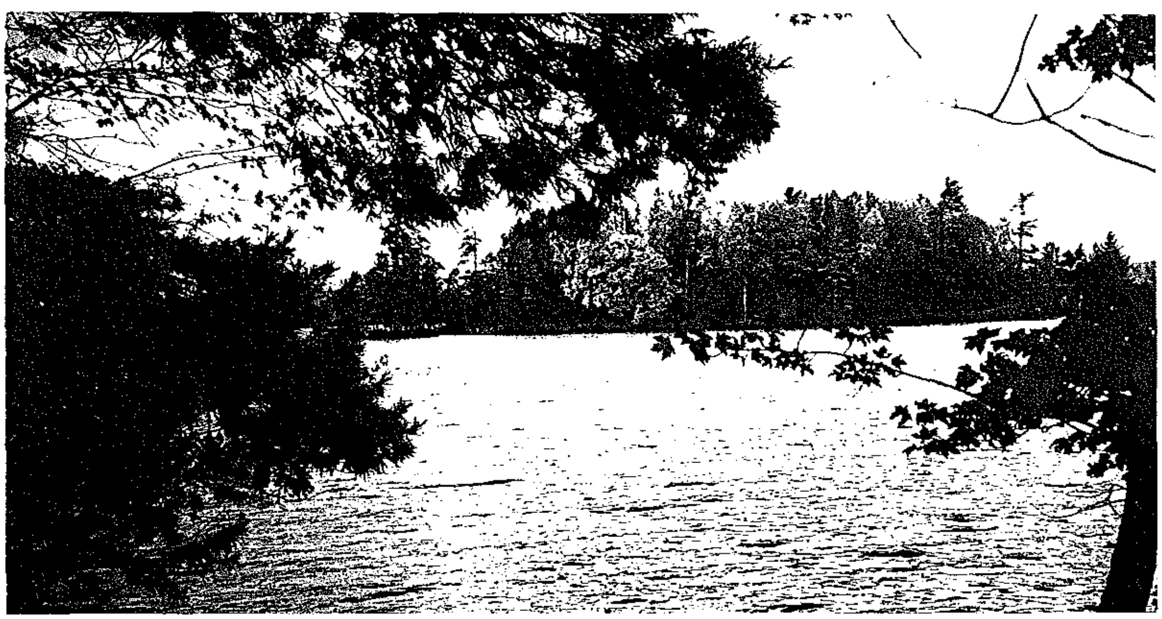
Another resort on Ballard was developed when land was purchased from President Grover Cleveland in 1885. A succession of owners and a lumber company owned it until Ole Rismon purchased the land. In 1923 he sold a piece on the other side of his resort to Ruth and Archie Alwin and it became Twin Pines Resort. In 1947 it was converted to a private residence by Vic Clark. The original main lodge is still being used today as a private home by the John Jacobs/Lou Truesdell families.

Irving Lake has never had more than three homes on it. Most of the land is state owned. The Kuechenmeister (Vaughan) and Frisbie homes are still occupied by the families since they were built in the 1920s. The third house, last owned by the Prasses, was sold to the State and bulldozed to enhance the wilderness look of the lake.

The land on White Birch Lake was first purchased from the U.S. Government in 1875. The area was logged by the Menasha Woodenware Company form 1897 to 1910. In 1922 a lodge was built (from plans in a Ward's catalog) and six cabins added to become a resort. It was owned by the White Birch Resort Corporation. Pat and Kelly Wilsie made it an American Plan Resort in 1941. They added an upstairs and four more cabins as a result of selling off part of the land to the Drewniaks. Pat built Aqualand across the road on Bob's Lake. Started as a private fish hatchery, it soon expanded to a "zoo" of native animals. It continued to operate as a tourist attraction until the 1970's. Presently Carol and Dick Malmgren are the owners, and they have expanded it, and turned it into housekeeping cottages at White Birch Village. The Drewiaks still reside next door in their summer homes.

At the present time there are seven permanent residents and 32 summer residents on the shores of the three lakes.

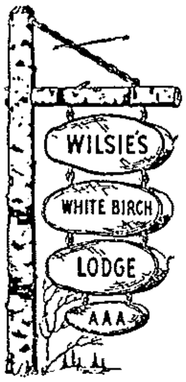
Ballard Lake about 1912. View of island from Ferncroft (James property).



Ballard Lake 1999. View of island from same site as above.

View near Ferncroft Inn (James property) circa 1909.

Photo taken in 1999 from approximately same location as above.



"The Sign of Hospitality"

WILSIE'S WHITE BIRCH LODGE
O-FISH-ALL HEADQUARTERS

FOR 1960 PRESENTS

MORE FISH AND BETTER FISHING *and*
"The 1959 Fish Review"

OHIO, ILLINOIS and WISCONSIN FISHERMEN
"HIT THE JACKPOT"

May 15th, Wilsie's White Birch Lodge, Boulder Junction

Brooks and Browns for Breakfast

MAY 1st at
BOULDER JUNCTION, WIS.

PLUM CREEK PRODUCES AGAIN—

Left home at 5:00 a.m. Arrived at Creek at 5:30 a.m. Fished for two hours. Returned home at 8:00 a.m. Everyone had his limit of Brooks and Browns. Breakfast at 8:30 a.m. What a feast . . . nothing like Trout for breakfast.

Great Northern Pike make real sporty fishing. We have fine catches and some real beauties caught in early May and June in our hundreds of acres of Northern Pike Waters. Some of the better lakes for early fishing are Star Lake, Helen Lake, Twin Island and Big St. Germain, and our Guides know where they are hitting best.

THE EARLY BIRDS CATCH THE WALLEYES

History Repeats Itself . . . As usual the first few weeks after the season opens, our Fishermen get beautiful catches of Walleyes.

This beauty (shown in photo at left) was taken from Star Lake. Lakes producing these catches (shown in

2.3. Lake Histories Interpreted from Sediment Cores

Results of Sediment Cores Taken From Ballard, White Birch, and Irving Lakes, Vilas County Wisconsin

Excerpts from a preliminary report prepared by: Paul Garrison, Wisconsin Department of Natural Resources, March-December 2000

Aquatic organisms are good indicators of a lake's water quality because they are in direct contact with the water and are strongly affected by the chemical composition of their surroundings. One of the most useful organisms for paleolimnological analysis are diatoms. These are a type of algae which posses siliceous cell walls which enables them to be highly resistant to degradation and are usually abundant, diverse, and well-preserved in sediments. Diatom species have unique features 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.

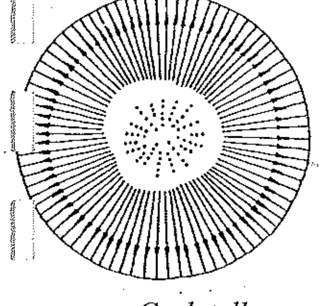
By determining changes in the diatom community it is possible to determine water quality changes that have occurred in the lake. The diatom community provides information about changes in nutrient and pH conditions as well as alternatives in the aquatic plant community.

I have examined the diatoms from the cores taken on 3 August 1999 from near the deep area of Ballard and White Birch Lakes. I examined sediment from the top of the core and a section deeper in the core. It is assumed that the upper sample represents present conditions while the deeper sample is indicative of water quality conditions at least 100 years ago. The core from Irving Lake was analyzed for terrestrial and aquatic plant pollen, diatoms, geochemical variables, and sedimentation rate. Several depths within the sediment core have been examined. Findings presented here represent work done up to December 2000.

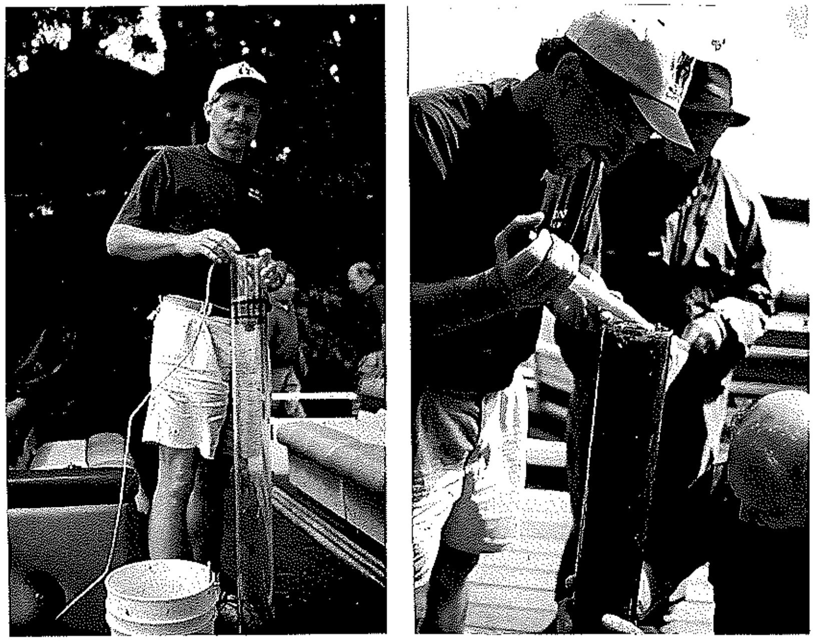
Ballard Lake

The core in Ballard Lake was extracted from a water depth of 20 feet. The deep section in the core was at 50-51 cm. The sediment was very flocculent with plant fragments visible in the upper portion of the core. The plant fragments appeared to be fernleaf pondweed.

In Ballard Lake, at the present time and historically, the major component of the diatom community was these species that grow on the lake bottom or are associated with aquatic plants. Planktonic diatoms (those that float in the open water area of the lake) comprise 32% of the community at the bottom of the core but decrease to 5% at the top of the core. The major genus of the planktonic diatoms is *Cyclotella*. The relatively low percentage of planktonic species is indicative of the relatively shallow depth in the lake as well as reduced levels of nutrients. If the lake experienced large and frequent algal blooms there would not be enough light reaching the lake bottom to allow the growth of benthic diatoms.



Cyclotella



[left] Paul Garrison, WDNR, is an expert on interpretting lake history from lake sediments and collected cores from White Birch, Ballard, and Irving. [right] Paul Garrison, WDNR, extracting lake sediments from a lake core sample. He is being assisted by Dick Malmgren (lower) and Frank Splitt (background).

The diatom community does indicate that there has been a significant increase in the macrophyte community in the lake. The decline in planktonic diatoms, (e.g. *Cyclotella*) and an increase in benthic. *Fragilaria* indicate this (Figure 4). Diatoms belonging to the latter group typically grow in filaments attached to substrates such as aquatic plants. This increase in macrophtyes has been found in other northern Wisconsin lakes with shoreland development. Studies have shown that one of the first indicators of increased nutrient input to a lake is increased plant growth. Water clarity does not appear to have decreased significantly during the last 100 years. If it had, planktonic diatoms would be more common as the increased turbidity would reduce the amount of light reaching the deeper depths and reduce the growth of diatoms which grow attached to plants and other substrates. Phosphorus levels do appear to have increased somewhat in the last 100 years. The increase is probably on the order of 5-7 $\mu g\ L^{-1}$.

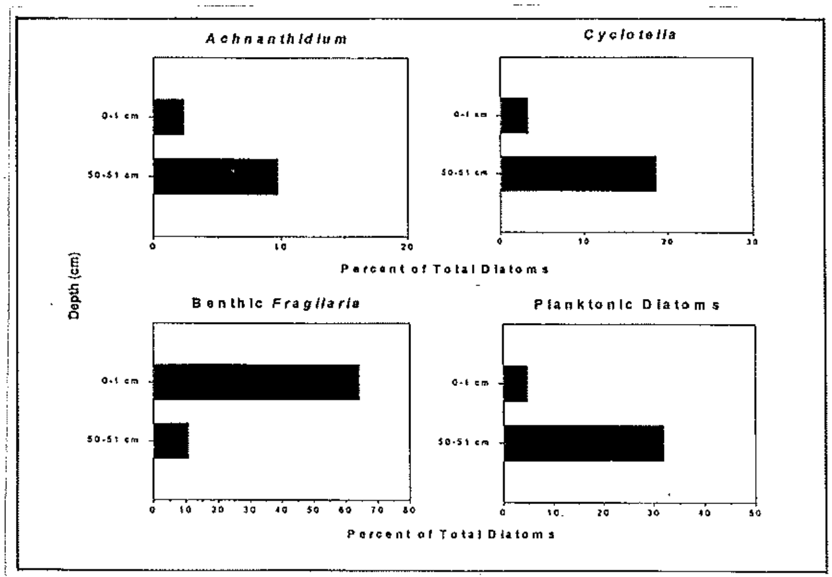
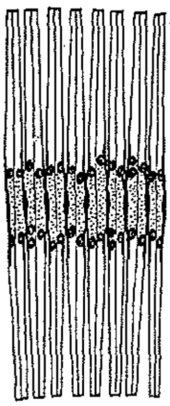


Figure 4. Changes in abundance of important diatoms found at the present and presettlement times for Ballard Lake, Vilas County.

White Birch Lake

The core in White Birch Lake was extracted from a water depth of 25 feet. The deep section in the core was at 45-46 cm. The sediment was very flocculent with a few plant fragments visible throughout the core. The plant fragments appeared to be fernleaf pondweed.

In White Birch Lake, at the present time and historically, the major component of the diatom community was those species that grow on the lake bottom or are associated with aquatic plants. Planktonic diatoms (those that float in the open water area of the lake) comprise 26% of the community at the bottom of the core but increase to 35% at the top of the core. The major genus of the planktonic species is Cyclotella. The relatively low percentage of planktonic species is indicative of the relatively shallow depth in the lake as well as reduced levels of nutrients.



Fragilaria.

As with Ballard Lake, the diatom community indicates that there has been an increase in the macrophyte community in the last 100 years. An increase in benthic *Fragilaris* species as well as an increase in *Achnanthidium* indicates this. These genera grow attached to substrates such as macrophytes. Since there has actually been a small increase in the amount of planktonic diatoms and the increase in benthic *Fragilaria* is not as great as in Ballard Lake it appears that he increase in the macrophyte community in White Birch Lake is less than that experienced in Ballard Lake.

Phosphorus levels have probably increased a small amount in the last 100 years. This is indicated by a decline in the genera *Cyclotella* (Figure 5) which was replaced by species usually found under higher nutrient levels. The increase in phosphorus concentration is most likely on the order 3-5 $\mu g\ L^{-1}$.

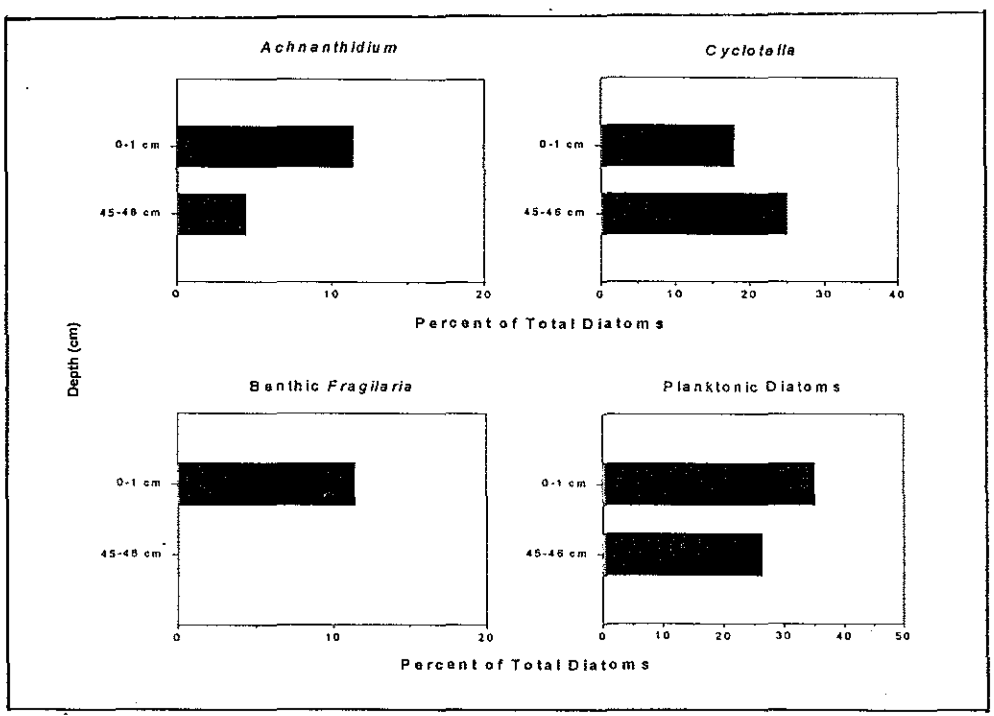


Figure 5. Changes in abundance of important diatoms found at the present and presettlement times for White Birch Lake, Vilas County.

Irving Lake

At the present time, Irving Lake has a large population of wild rice (*Zizania aquatica*). This is thought to have been absent from the lake until the last 40 years. A sediment core taken from the lake supports this. Pollen from wild rice was not found until 1960 (Figure 5a). This does not necessarily mean that rice was not present in the lake prior to this time for two reasons. Only 3 samples older than this date have been analyzed so far. Also if rice was present in low numbers this technique might not detect its presence. It is clear that since 1960 the amount of rice in Irving Lake has increased significantly.

As a consequence of the increase in rice, there has been a decline in some other aquatic plants. Both water stargrass and milfoil have declined in recent years although pondweed abundance appears to have not been unchanged (Figure 5a). Since not all aquatic plants produce sufficient pollen to detect, I am not able to determine the impact of the rice on other aquatic plants.

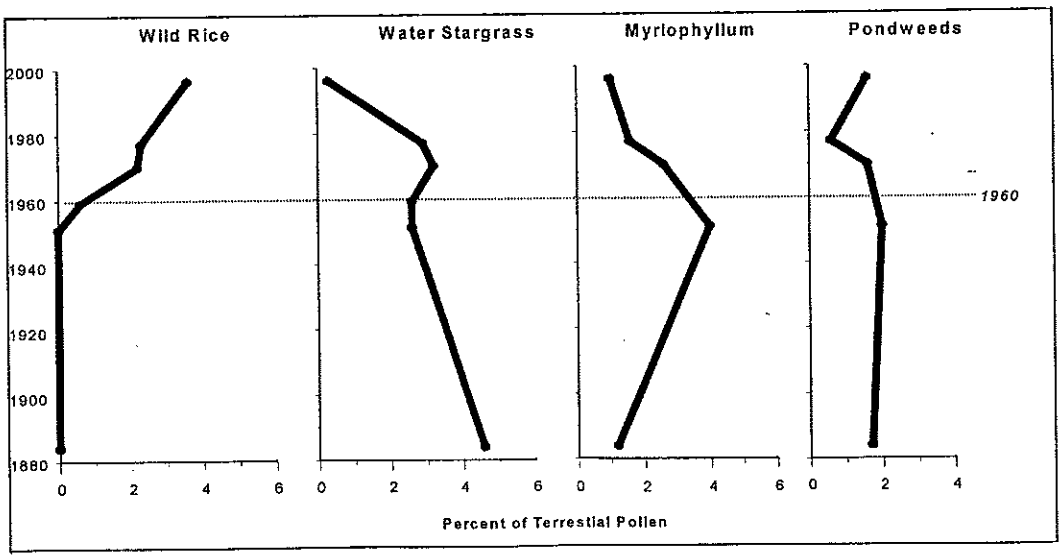


Figure 5a. Profile of aquatic plant pollen from the deep hole core. An additional sample was analyzed from a depth representing the time period of the mid-1700's. No rice pollen was found.

The mean sedimentation rate for the lake is very low (0.007 g/cm2/yr). In fact this is the lowest rate I have measured in 40 cores taken from lakes in Wisconsin. Although the mean sedimentation rate is low, the rate increased after logging which occurred in this area around 1900. The sedimentation rate increased much more after 1960, which is the time of the increase in wild rice. It may be that the production of straw from the wild rice has increased the sedimentation rate. Other possible reasons for the increased rate is translocation of sediment from other areas of the lake as a result of motor boat activity which is thought to have increased on this lake in the last 30 years.

The diatom community was analyzed to determine changes in the water quality of the lake. Planktonic diatoms are those that float in the open water and do not grow attached to substrates such as plants. Although their abundance was historically variable, their presence has been significantly reduced since the onset of the rice community (Figure 5b). The historical variability of these diatoms probably relates to changes in aquatic plant abundance caused by water level changes. The group of diatoms called benthic *Fragilaria* typically are found growing attached to plants. They are the most common diatoms throughout the core (Figure 5b). Their abundance initially increased by 1920. This may have been the result of logging that was done in this region around 1900. Following logging and subsequent fires, it is likely that more runoff occurred from the watershed which stimulated the plant growth in the lake. Although a significant increase in nutrients could cause a similar response in the diatom community without a change in the plant community this does not appear to have happened. It is likely that the increased abundance of benthic *Fragilaria* (during the 1960's) was the result of increased sites for growth, i.e. plants.

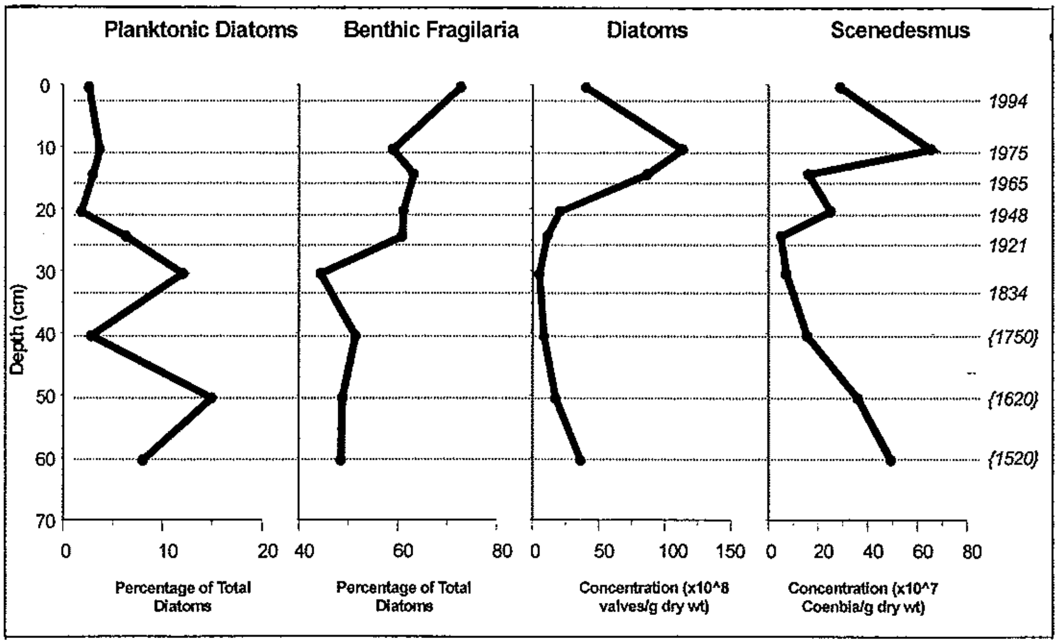


Figure 5b. Diatom diagram showing selected common species. Planktonic diatoms are those that are found growing in the open water. These species have declined since the introduction of the rice. These species were replaced by benthic *Fragilaria* which grow on plants. Productivity of diatoms and the green alga, *Scenedesmus*, have increased since the mid-1970's. (Dates in brackets were interpolated.).

Summary

The diatom community indicates that there has been an increase in macrophytes in the last 100 years in both Ballard and White Birch Lakes. The increase in the macrophyte community may be both the distribution of the plants around the lakes as well as an increase in density. The increase in macrophytes has been greater in Ballard Lake compared with White Birch Lake. Phosphorus levels have increased in both lakes. The increase in nutrient levels has been greater in Ballard Lake but neither lake has experienced a large increase. It is estimated that phosphorus levels have increased 3-5 $\mu g\ L^{-1}$ in White Birch Lake.

In Irving Lake it appears that wild rice has only been present in significant numbers in the last 40 years. It should be cautioned that rice may have been present at other times in the lake but either at low levels or the samples from the appropriate time period have not been examined. Although water quality changes that have occurred since the onset of rice have been relatively small, some changes are evident. The presence of rice has depressed other aquatic plants such as water stargrass and milfoil. Winter time oxygen levels have declined since the onset of the rice, which appears to be causing a small increase in phosphorus. This has resulted in an increase in the algal community.

3. Watershed Features

3.1. Drainage Area to the Lakes

Drainage areas to individual lakes are displayed in Table 2 and are shown in Figure 6. The size of the direct drainage watersheds that drain to the lakes are typical for northern Wisconsin glacial lakes.

Table 2. Watershed areas for White Birch, Ballard, and Irving (prepared by Blue Water Science).

	Direct Watershed (not including lake)(ac)	Lake Size (ac)	Total Watershed (including lake) (ac)	Contributing Watershed (ac)	Total Contributing Watershed Area (not including lake)(ac)
Irving	935	403	1,338	0	935
Ballard	935	505	1,440	1,338	2,273
White Birch	179	117	296	2,273	2,452

Definitions:
Direct watershed: *land area that drains to the lake.*
Total watershed: *encompasses direct watershed area plus the lake area.*
Contributing watershed: *land areas that drain to the lake by way of a defined channel or stream. For example Ballard Lake receives water by way of a channel from the contributing watershed of Irving Lake.*
Total contributing watershed area: *this is the direct drainage area plus the contributing watershed area.*

The drainage areas to the chain of lakes are dominated by forests and wetlands (Figure 7). Although the forests have been clear cut at least once in the last 300 years, existing conditions are dominated by undeveloped land use. This condition allows the potential for good water quality to runoff the land and into the lakes, thus sustaining good water quality in the lakes as well.

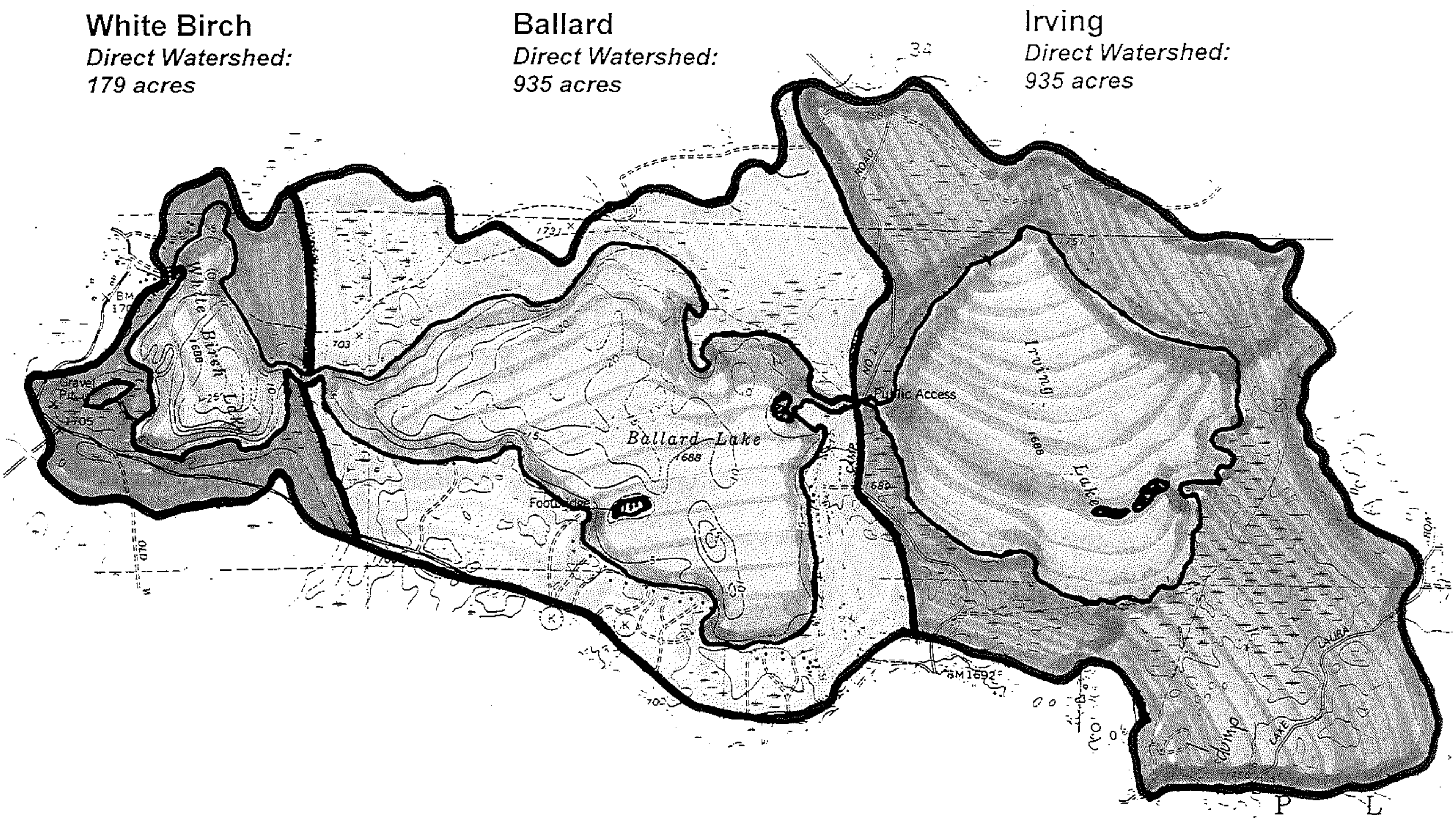


Figure 6. Watershed area for White Birch, Ballard, and Irving Lakes.

Figure 7. [top] Drainage to Irving Lake. Groundwater comes into Irving Lake through an open channel. An old railroad grade is still visible.
Ballard [middle] and White Birch [bottom] watersheds are dominated by forests.

3.2. Source of Water to the Lakes

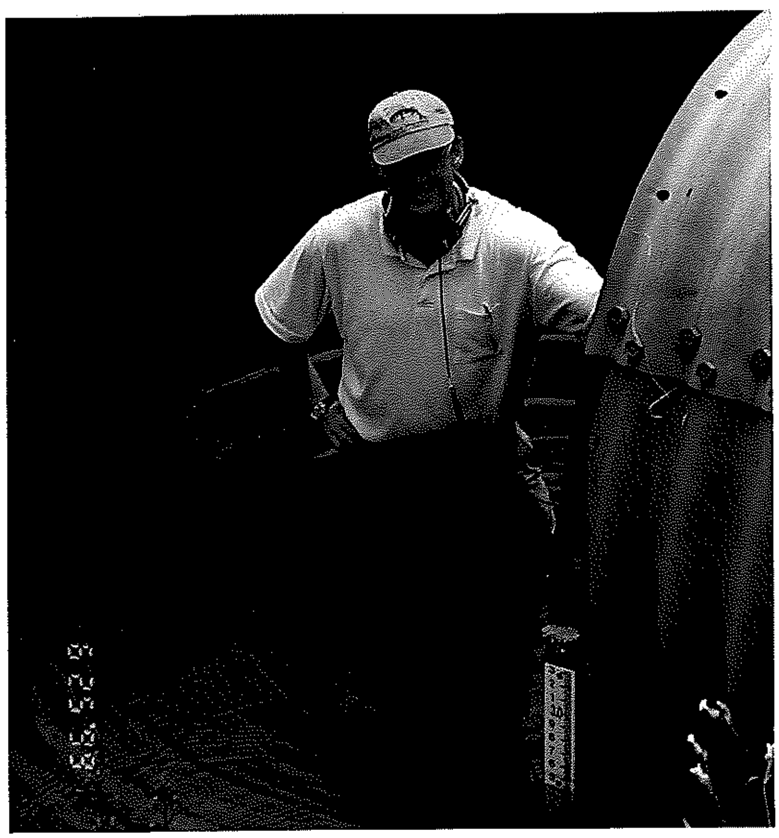
Source of water to all three lakes is from groundwater that seeps into the lakes from fringe wetlands and from surface runoff. The amount of water flowing into and out of Irving is estimated to be about 5 cubic feet per second. Flows were measured on three occasions in 1999 (Table 3). The estimated outflow from White Birch is shown in Table 4.

Table 3. Flows (measured out of Irving Lake).

Date	Gage Reading	Water Depth in Middle of Culvert (feet)	Velocity (middle) (feet per second)	Flow Rate (cubic feet per second)
6.9.99	2.60	2.21	0.72	7.3
6.25.99	2.46	2.1	0.67	5.6
7.24.99	2.68	2.3	0.42	4.26

Table 4. Flows measured out of White Birch Lake.

Date	Gage Reading	Water Depth (feet)	Width (feet)	Velocity (middle) (feet per second)	Flow Rate (cubic feet per second)
6.9.99	0.8	0.8	15	0.89	10.7
6.24.99	0.7	0.63	15	0.40	3.8



Several flow measurements were recorded from the Irving outflow.

3.3. Shoreland Status

The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. A photographic inventory of the Ballard, Irving, White Birch Lakes shoreline was conducted on July 23, 1999. The objective of the survey was to characterize existing shoreland conditions which will serve as a benchmark for future comparisons.

For each photograph we looked at the shoreline and the upland condition. Examples of shoreland conditions are shown in Figure 8. Our criteria for natural conditions were the presence of 50% native vegetation in the understory and at least 50% natural vegetation along the shoreline in a strip at least 15 feet deep. We evaluated shorelands at the 75% natural level as well.

A summary of the inventory results is shown in Table 5. Based on our subjective criteria over 95% of the parcels in the Ballard, Irving, White Birch Lakes shoreland area meet the natural rankings for shorelines and upland areas. This is good for a lake in northern Wisconsin. However in the next 10 years there could be pressure to reduce natural conditions. Proactive volunteer native landscaping should maintain existing conditions and improve other parcels.

The full shoreland inventory is found in a separate report with copies at the WDNR-Rhinelander and at the lake association archives.

Table 5. Summary of buffer and upland conditions in the shoreland area of Ballard, Irving, White Birch Lakes. Approximately 110 parcels were examined.

	Percent
Shorelines with >50% natural buffer	96%
Shorelines with >75% natural buffer	95%
Upland areas >50% natural conditions	98%
Upland areas >75% natural conditions	96%

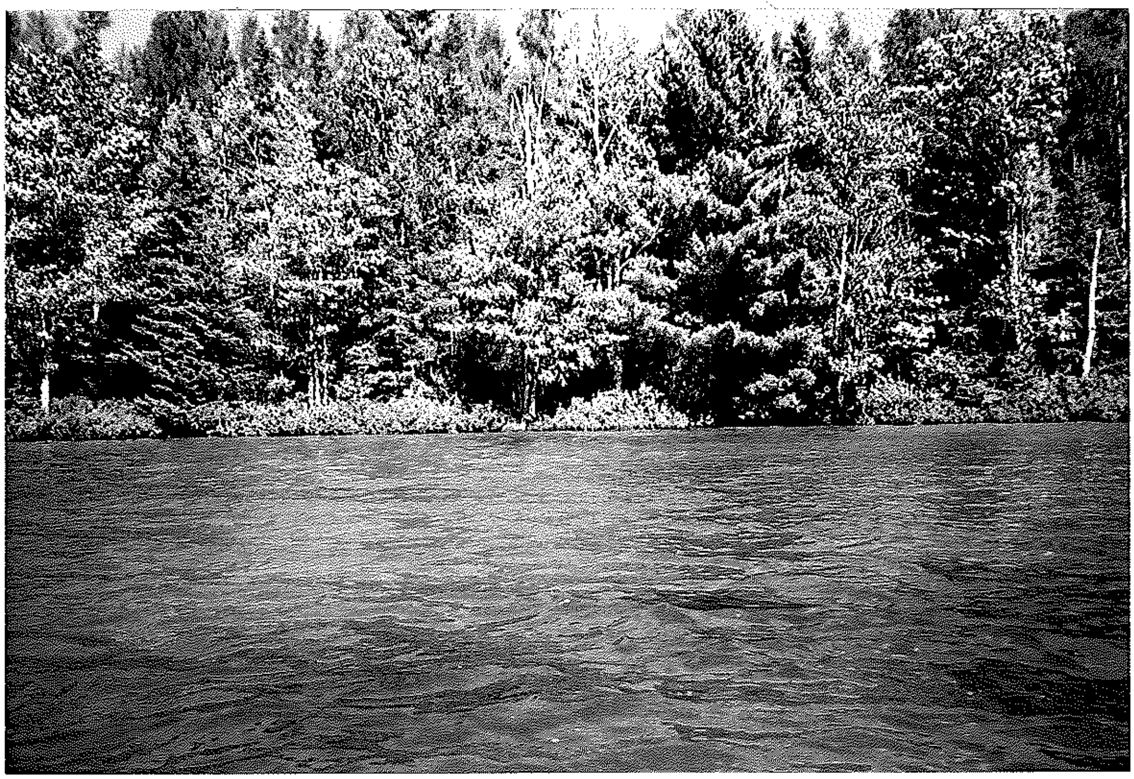


Figure 8. Typical shoreland conditions around the lakes. [top] An undeveloped shoreline on Ballard Lake. [bottom] An shoreland area with a residence on Ballard Lake.

3.4. On-site Wastewater Treatment Systems

The status of on-site wastewater treatment systems in the watershed are rated as satisfactory. A typical on-site system is shown in Figure 9.

There may be some movement of septic effluent toward the chain of lakes, but this occurs in nearly all lake settings. The septic tanks are not polluting the lakes. This is based on several factors:

- soils have infiltration capacity so any overland septic flow would be rare.
- homes and drainfields are set back from the lake allowing adequate septic tank effluent treatment.
- there is a low density of residences around the lakes.

With new regulations in place for Vilas County, water pollution problems from on-site systems are not anticipated in the future.

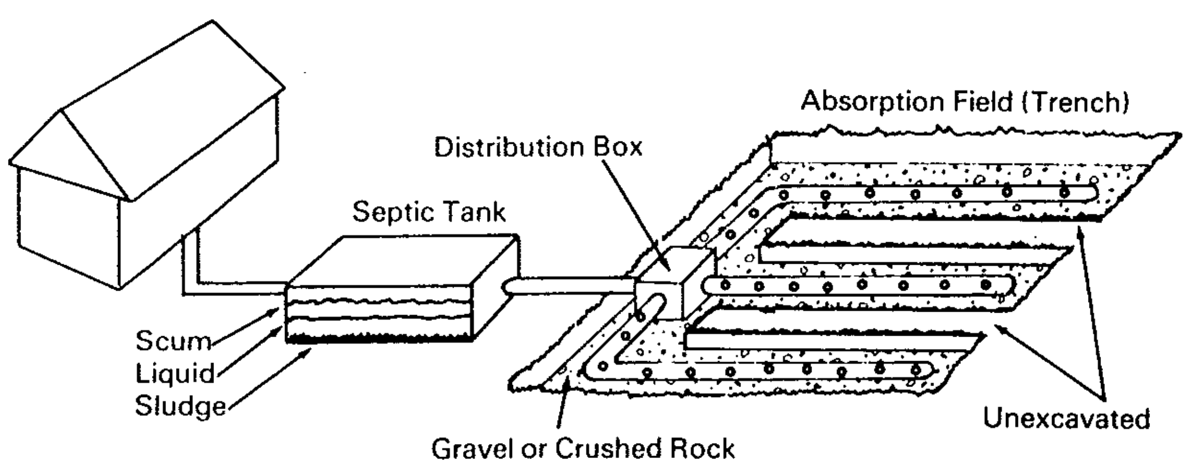
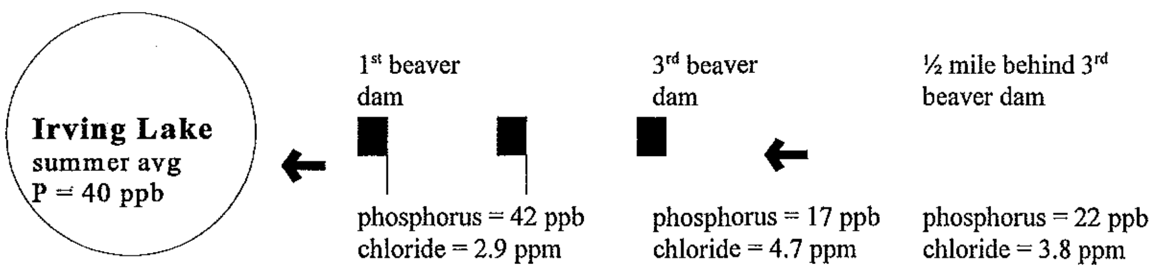


Figure 9. Typical septic tank/drainfield configuration (from McComas 1993. LakeSmarts).

3.5. Watershed Status

The watershed area that drains to the chain of lakes is in exceptional natural state compared to watersheds in other areas of the state. The land in the watershed is dominated by wilderness areas and is composed primarily of forests and wetlands.

Questions have been raised by lake users about the water quality coming into Irving Lake. Special efforts were conducted by lake volunteers to explore the watershed of Irving Lake. Results of the exploration and water testing indicate water coming into Irving Lake is typical for the region and is not polluted. Although there had been a county sanitary landfill in the Irving Lake watershed, there is no evidence that it is polluting groundwater that flows into Irving Lake.



Results of water testing in ponds feeding into Irving Lake are shown above. The phosphorus concentrations in the ponds are similar to what is found in Irving Lake.

Table 6. Watershed status summary.

Watershed	Status	Comments
Irving	excellent	Majority of shoreline is publically owned.
Ballard	excellent	Ongoing stewardship of forest land and shorelands is needed.
White Birch	excellent	Natural conditions are being protected.

[top] Ponded water behind the 1st beaver dam that flows into Irving Lake.
[middle] A pool discovered deep in the woods in the Irving Lake watershed. Water quality was good in this pond.
[bottom] The expedition consisted of lake residents that ventured back into the Irving Lake watershed.

4. Lake Features

4.1. Lake maps and lake statistics

The chain of lakes is shown in Figure 10 and lake characteristics are shown in Table 7.

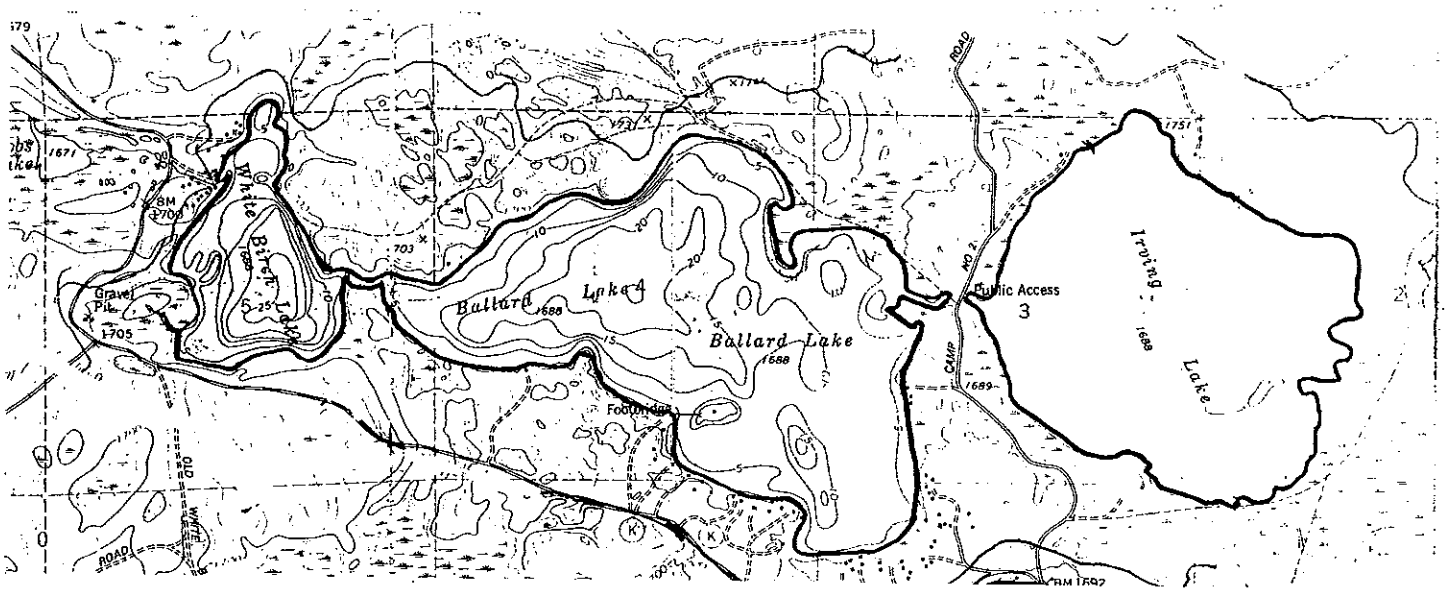


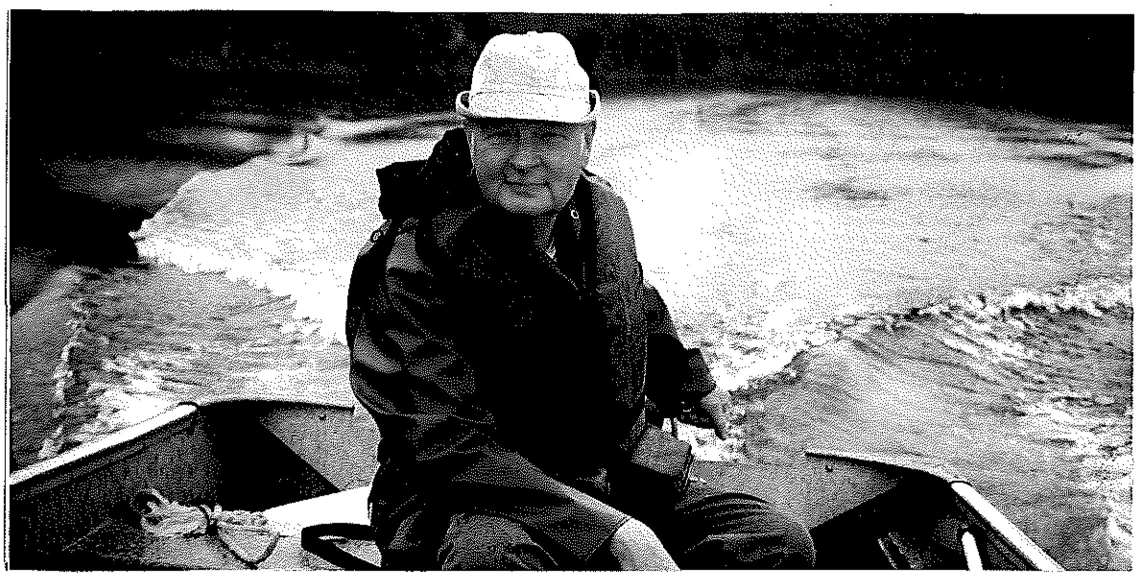
Figure 10. Lake maps of White Birch, Ballard, and Irving Lakes.

Table 7. Lake and watershed characteristics for White Birch, Ballard, and Irving Lakes.

	White Birch	Ballard	Irving
Area (ac)	117	505	403
Mean depth (ft)	12	9	4.5
Maximum depth (ft)	27	25	8
Volume (ac-ft)	1,404	4,545	2,015
Average inflows (cfs)	6	6	5
Watershed area (ac) (not including lake)	2,452	2,273	935
Watershed area:lake ratio	21:1	4.5:1	2.3:1
Estimated Average Water Residence Time (years)	0.3	1.0	0.6
Public Access	1	1	1
Inlets	1	1	1
Outlets	1	1	1

4.2. Water quality analysis: dissolved oxygen levels, clarity, and nutrients

Water testing was conducted by volunteers for the chain of lakes starting in 1993. More intensive efforts occurred from 1998 through 2000. Lake monitoring has characterized lake water quality conditions and helped us to understand factors influencing water quality in all three lakes.



[top] Dwight Sandman has been monitoring all three lakes since 1993.
[bottom] Bill Grunwald, working out of White Birch Village, has assisted Dwight since 1998. Dick Malmgren was the water quality coordinator.

Temperature and Dissolved Oxygen in the Lakes

Dissolved oxygen and temperature measurements reveal several things about a lake. If oxygen is absent in the bottom of the lake, phosphorus can be released from the lake sediments. If the temperature is the same from the top to the bottom of the lake in the open water season, all the water will mix. If oxygen is depleted over the winter, winterkill can occur. Examples of dissolved oxygen and temperature profiles are shown in Figure 11. Winter oxygen levels can be low in the bottom water of White Birch and Ballard Lakes.

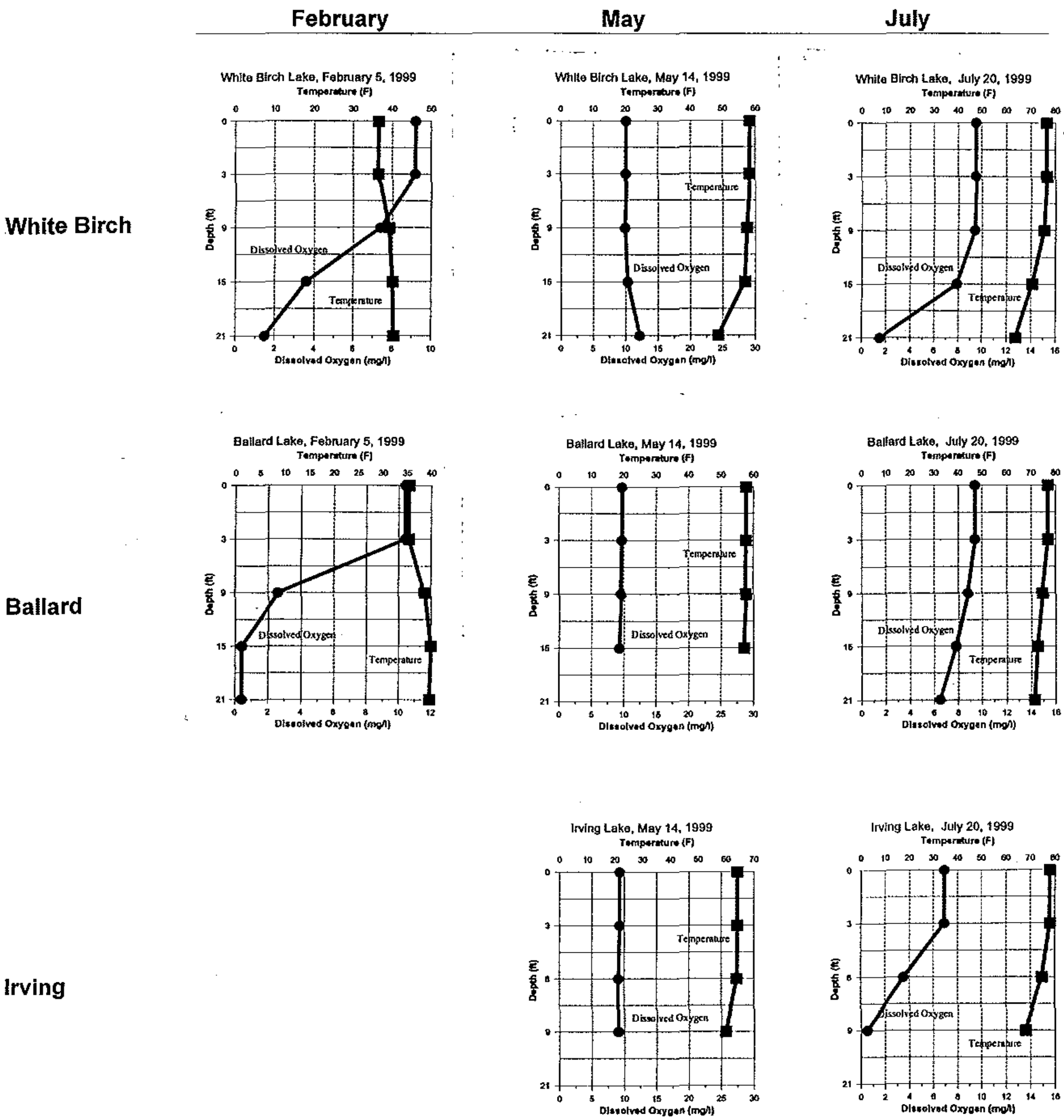


Figure 11. Dissolved oxygen/temperature profiles for White Birch, Ballard, and Irving Lakes.

Dissolved Oxygen in the Irving and White Birch Outlets

Dissolved oxygen concentrations for the outflow of Irving Lake at the culvert and for the outlet of White Birch Lake at the White Birch Lodge in 1998-2000 are shown in Figures 12 and 13. Dissolved oxygen (DO) concentrations were low at the Irving Lake outlet at the end of February, 1999 but not in 2000 (Figure 12).

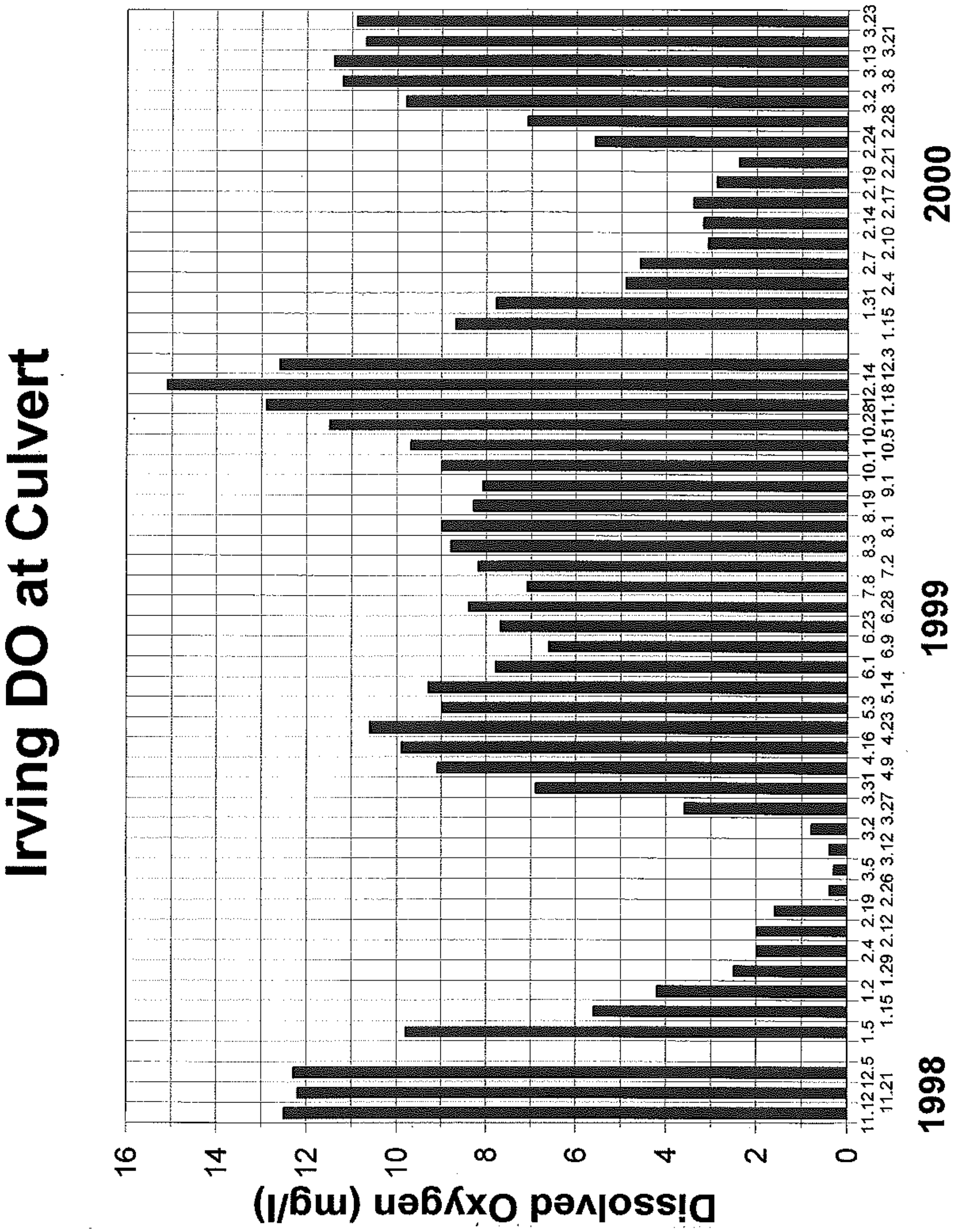


Figure 12. Dissolved oxygen for Irving Lake outlet.

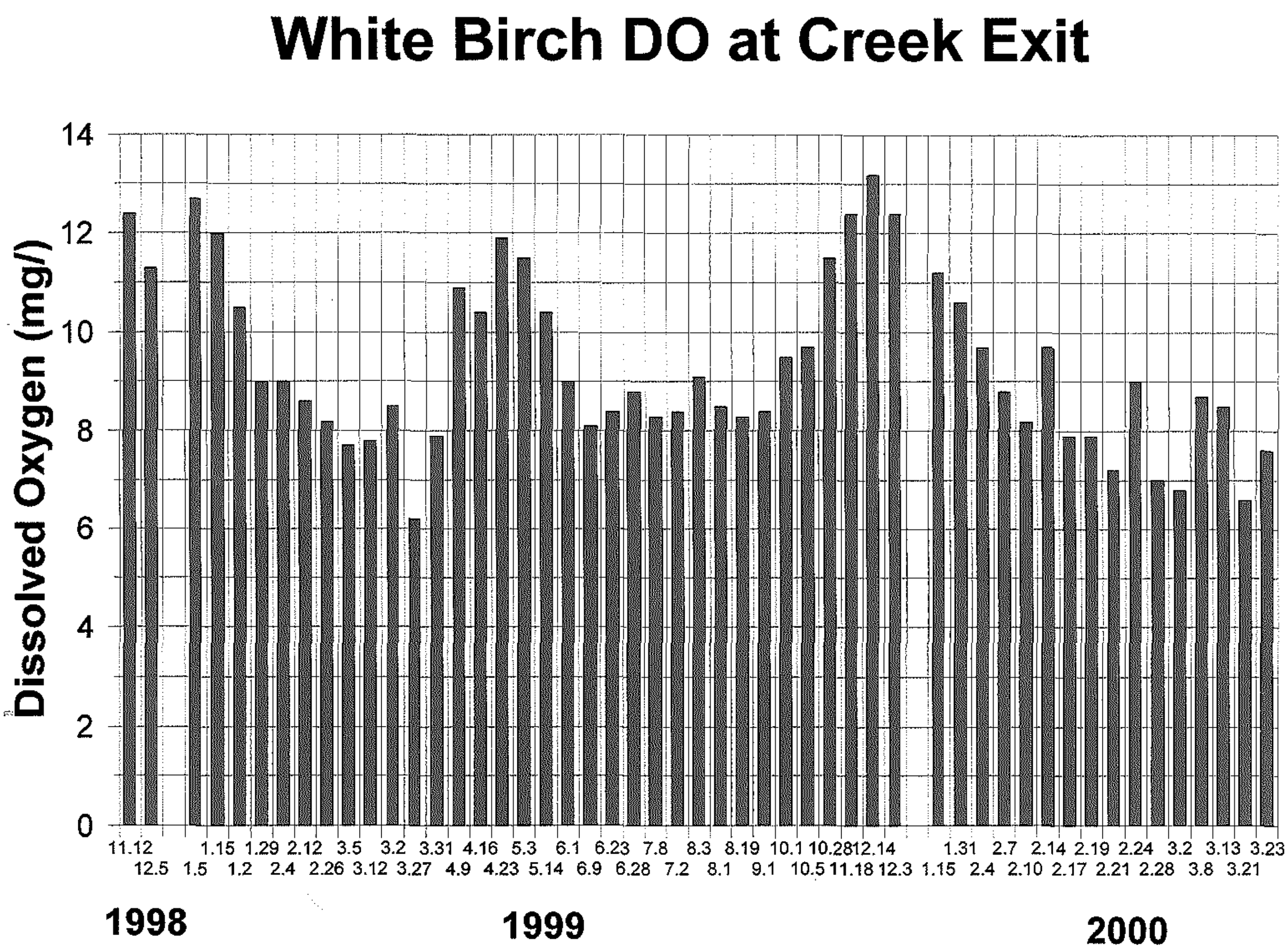


Figure 13. Dissolved oxygen for White Birch Lake at the outlet.

DO at the White Birch outlet has been good for the winters of 1998-99 and 1999-2000 (Figure 13).

Secchi Disc Transparency

Transparency in lakes is measured with a white and black disc (Secchi disc) that is lowered over the side of a boat into the water. The depth at which the disc is no longer visible is considered the Secchi disc measurement. The Secchi disc measurement gives some insight into the amount of nutrients in the lake. The deeper the Secchi disc transparency the clearer the lake is and the less algae present. Because nutrients make algae grow, we suspect good water transparency means low phosphorus concentrations in the lake.

Secchi disc measurements are an easy way to measure the trends of a lake. Measurements made over the years can help determine if the lake is improving or declining. Fluctuation of a couple feet is normal from year to year, but if the growing season average declines for several years, potential nutrient sources should be looked at more closely. White Birch, Ballard, and Irving Lake's yearly averages are about normal for mesotrophic lakes (Figures 14 and 15).

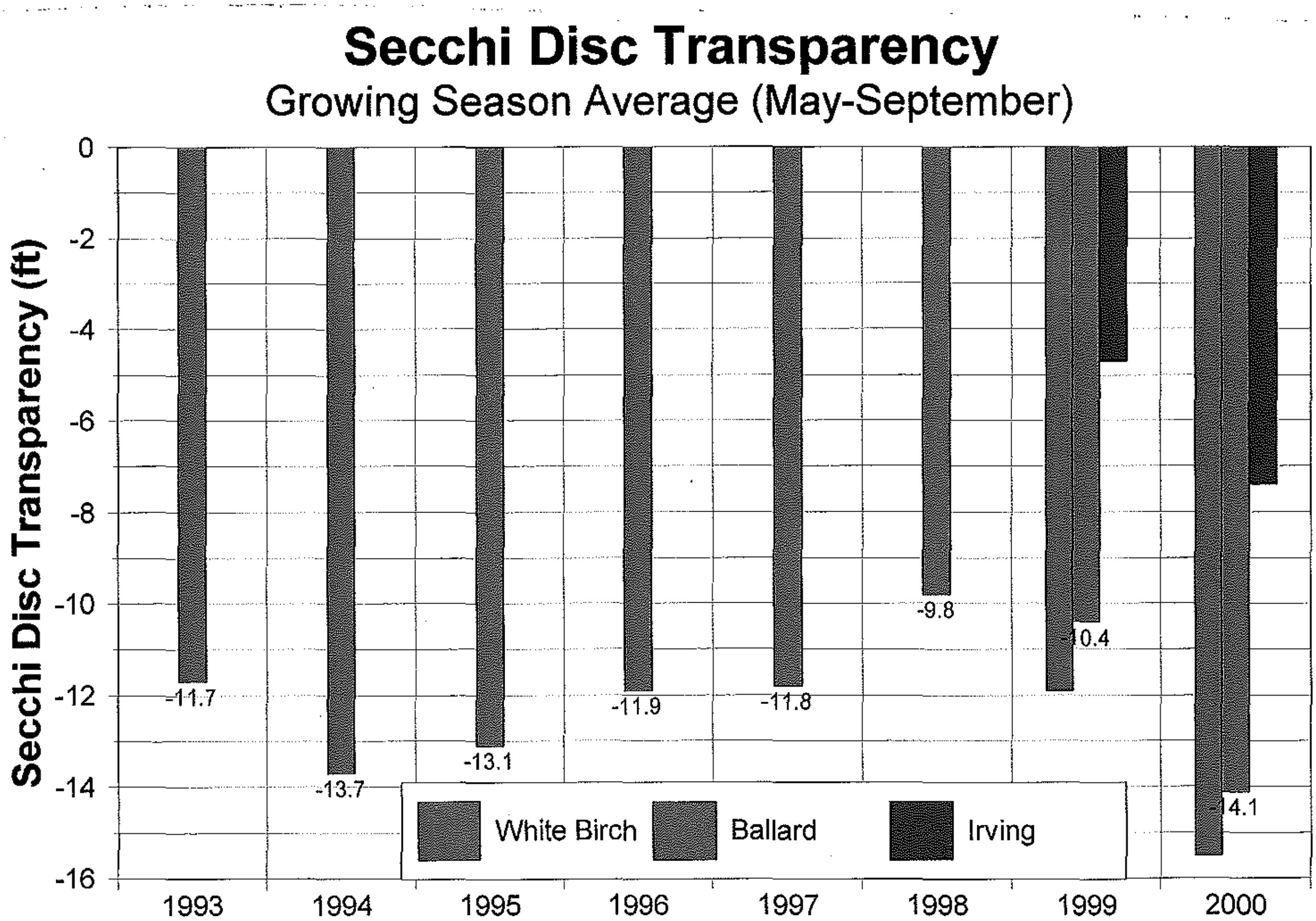


Figure 14. White Birch, Ballard, and Irving Lakes growing season mean secchi transparency.

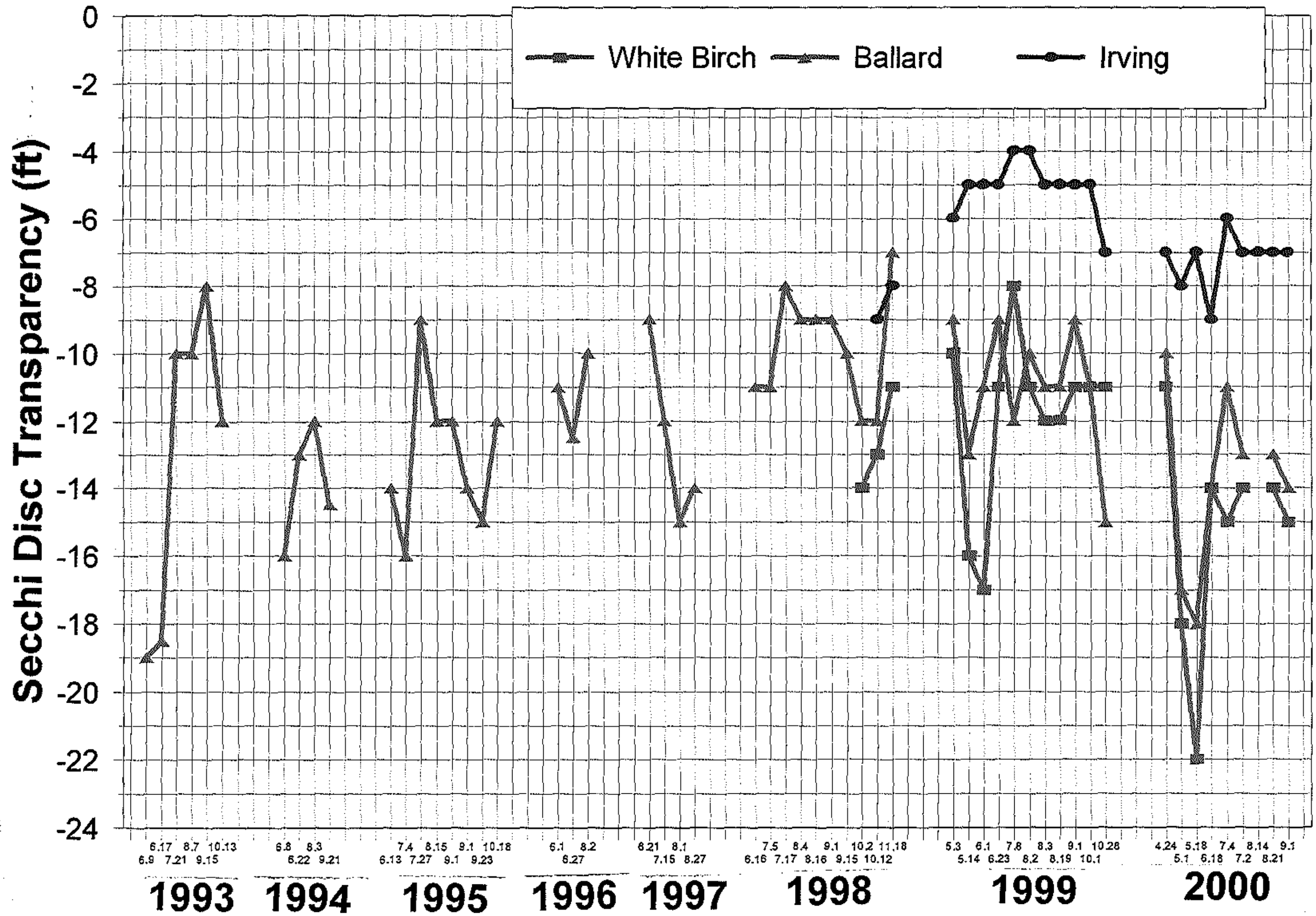


Figure 15. Secchi disc measurements from 1993 through 2000. Seasonal fluctuations are normal for lakes in this part of Wisconsin. White Birch Lake seems to have slightly better water clarity than Ballard Lake.

Water Chemistry and Nutrients

Total phosphorus: Summertime phosphorus levels in White Birch and Ballard in 1999 were low to moderate and are slightly elevated in Irving Lake. Average summer phosphorus concentrations (May-August) for 1999 are shown below:

- White Birch: 15 ppb
- Ballard: 18 ppb
- Irving: 40 ppb

A summary of other water chemistry data is shown in Table 8.

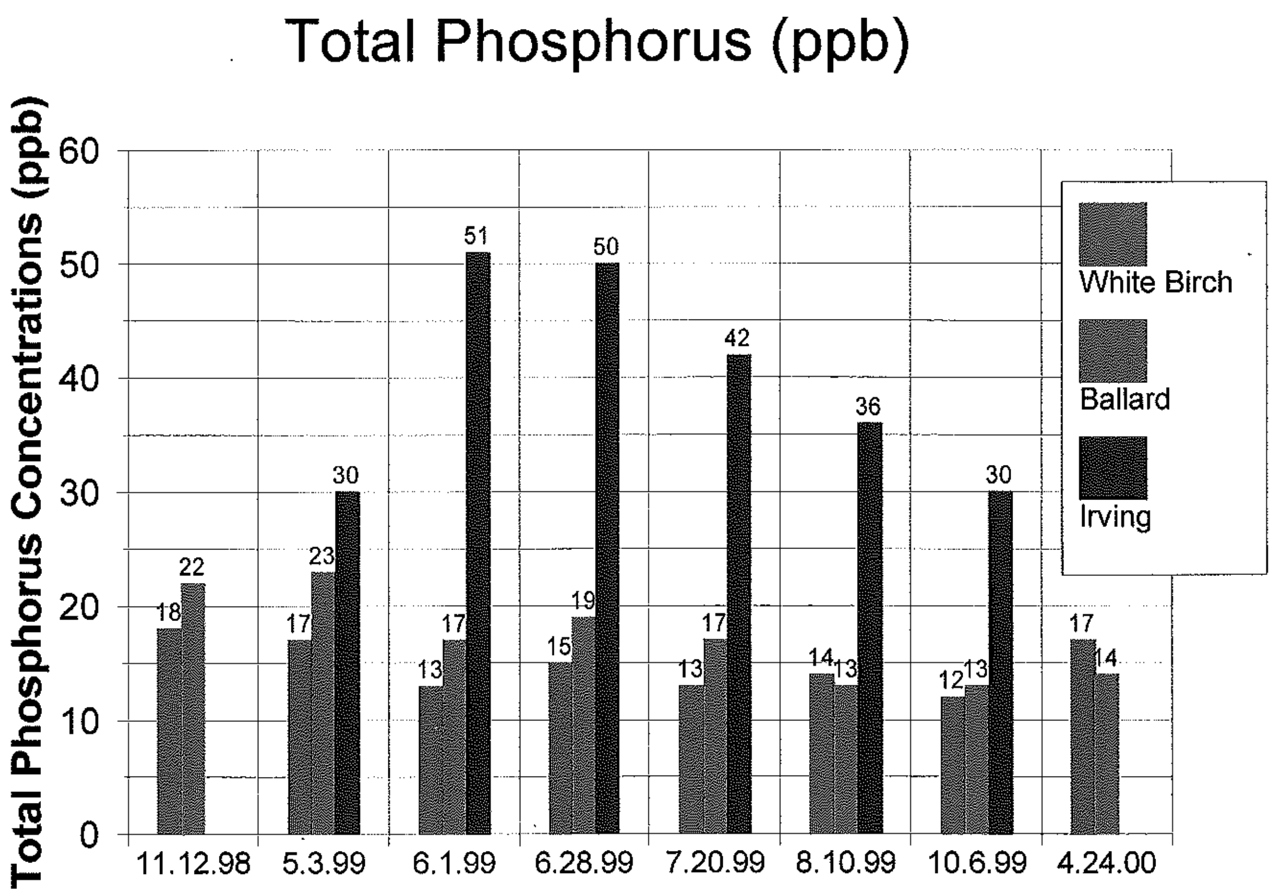


Figure 16. White Birch, Ballard, and Irving Lakes total phosphorus concentrations from November 1998 - April 2000.

Table 8. Water chemistry data summary since 1998.

	11.12.98			3.17.99			5.3.99			6.1.99			6.28.99			7.20.99			8.10.99			10.6.99			4.24.00		
	WB	B	I	WB	B	I	WB	B	I	WB	B	I	WB	B	I	WB	B	I	WB	B	I	WB	B	I	WB	B	I
Total phosphorus (ppb)	18	22					17	23	30	13	17	51	15	19	50	13	17	42	14	13	36	12	13	30	17	14	14
Chlorophyll a (ppb)	7.9	5.5					4.0	14.0	9.0	4.0	6.0	23.0	5.0	10.0	15.0	2.6	3.3	6.2	4.0	2.5	10.0	6.0	4.0	5.0			
Turbidity (NU)	1.6	2.5				4.9				0.9	1.9	18.5	1.0	1.2	2.5	1.1	1.3	2.9	1.3	1.2	2.3	1.6	1.0	1.2	1.2	1.0	1.7
Kjedahl N (mg/l)	0.61	0.90					0.55	0.66	0.61				0.76	0.72	1.20							0.48	0.53	0.64	0.49	0.51	0.30
Nitrate/nitrite (mg/l)	0.03	0.09					0.04	0.06	0.01					0.01											0.04	0.07	0.01
Ammonia (mg/l)	0.03	0.01					0.01	0.03	0.01													0.04	0.05	0.04	<0.01	0.01	<0.1
pH	7.5	7.5											8.4	8.2	7.5							7.2	7.2	7.2	7.8	8.0	7.6
Alkalinity	29	32											30	31	31							30	33	38	29	32	32
Conductivity	55	63											69	72	77									78	64	74	73
Chloride	<0.1	<0.1											0.24	0.23	0.24									0.27	0.2	4.6	0.2
Sulfate	2.10	2.5											2.74	2.81	4.02									3.56	2.9	5.1	3.3
BOD 5 day (mg/l)*						1.9												3.2						0.82			<2
Suspended solids (mg/l)*						3												6						<5			<5
Dissolved solids (mg/l)*						76.0												60.0									110
Volatile solids (mg/l)*						10.0												6.2						<5			<20
Sodium	1.10	1.20																							1.4	1.4	1.4
Potassium	0.40	0.40																							0.6	0.6	0.6
Magnesium	16.0	12.0																							7.6	7.0	10.6
Calcium	12.0	20.0																							20.4	21.0	21.4
Reactive phosphorus (ppb)	5	2																							5	5	9
Total nitrogen	0.640	0.990																							0.53	0.58	0.31
Total inorganic nitrogen	0.060	0.20																							0.04	0.08	0.01
Total hardness	28.0	32.0																							28.0	28.0	32
N/P ratio	35.6	45.0																							31.2	41.4	22.1

* samples collected at Irving outlet culvert.

Notes:

- These data establish a benchmark for future reference.
- Most chemical parameters are within the range for lakes located in northern Wisconsin (see Table 11, page 58 for some ranges).
- BOD 5 day for October 1999 and April 2000 are average for lakes in Fall and Spring.

Other Water Quality Parameters

A number of water quality parameters have been monitored in the last several years. One of these parameters is alkalinity which measures the buffering capacity of the lake water. Results show the lakes have adequate buffering to protect against any acid rain concerns.

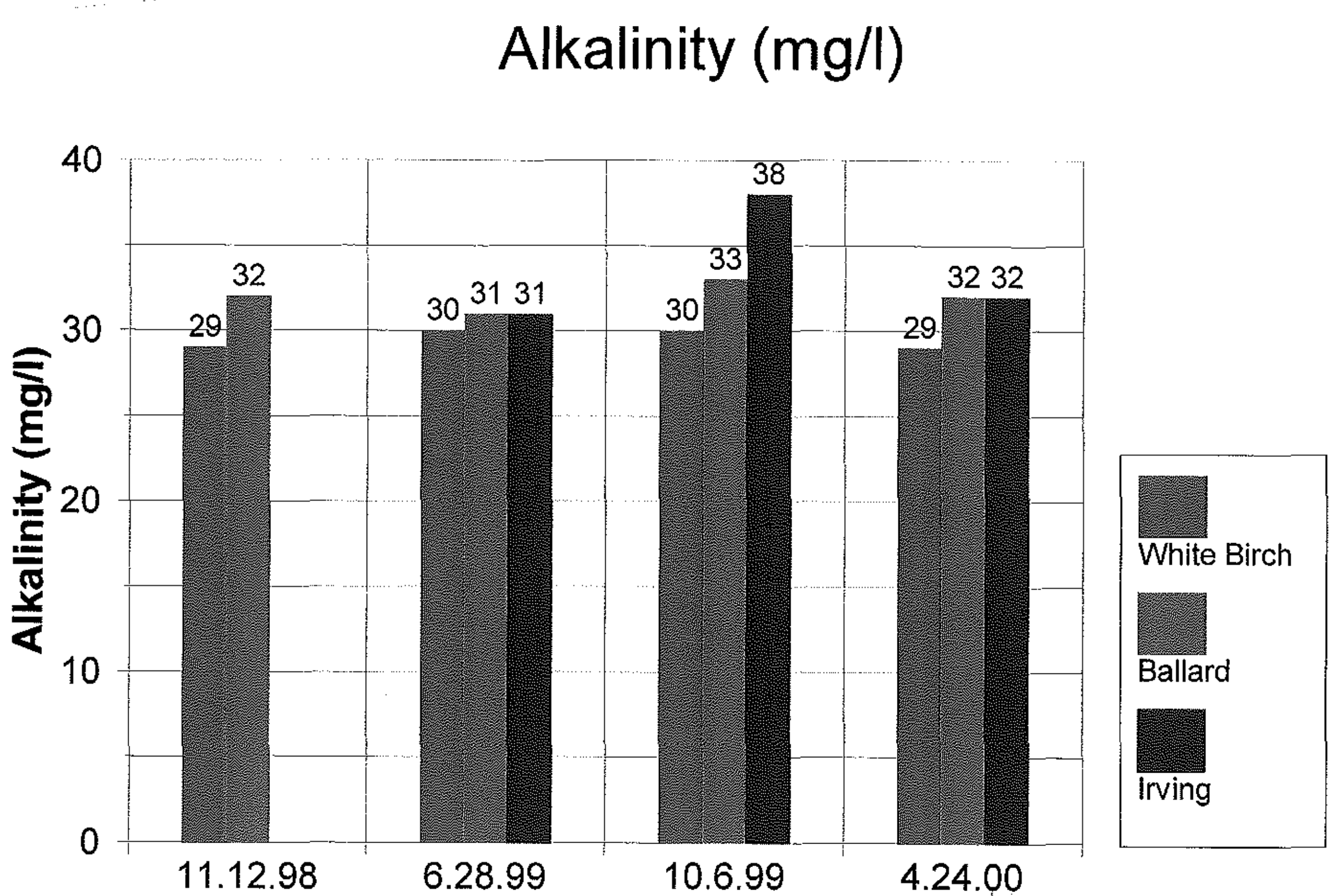


Figure 17. Alkalinity results for several dates in 1998, 1999, and 2000.

Chlorophyll a

Chlorophyll a is a rough measurement of the amount of algae there is in a lake. White Birch, Ballard, and Irving Lakes summer chlorophyll average for 1999 was 15, 19, and 40 μg/l respectively with a maximum concentration of 51 μg/l in Irving Lake.

Algae bloom intensities can be ranked by the amount of chlorophyll in a system (Table 9). Irving has the highest algae levels of the three lakes.

Table 9. Chlorophyll a concentrations related to algae blooms for 1999 (MPCA 1994).

	White Birch	Ballard	Irving
May 3	4	14	9
June 1	4	6	23
June 28	5	10	15
July 20	3	3	6
August 10	4	3	10
October 6	6	4	5
Average	4	7	11

Chlorophyll a concentrations	Degree of algae bloom
0-9 μg/l	No bloom
10 - 20 μg/l	Mild bloom
21 - 29 μg/l	Nuisance bloom
30 μg/l and greater	Severe bloom

4.3. Algae

The normal transition for algae in lakes over the summer months begins with diatoms which then die back while green algae become dominant. Next, the green algae die back and then blue-green algae become dominant. Chlorophyll concentrations are charted in Figure 18.

Examples of the type of algae found in the lakes are shown in Figure 19.

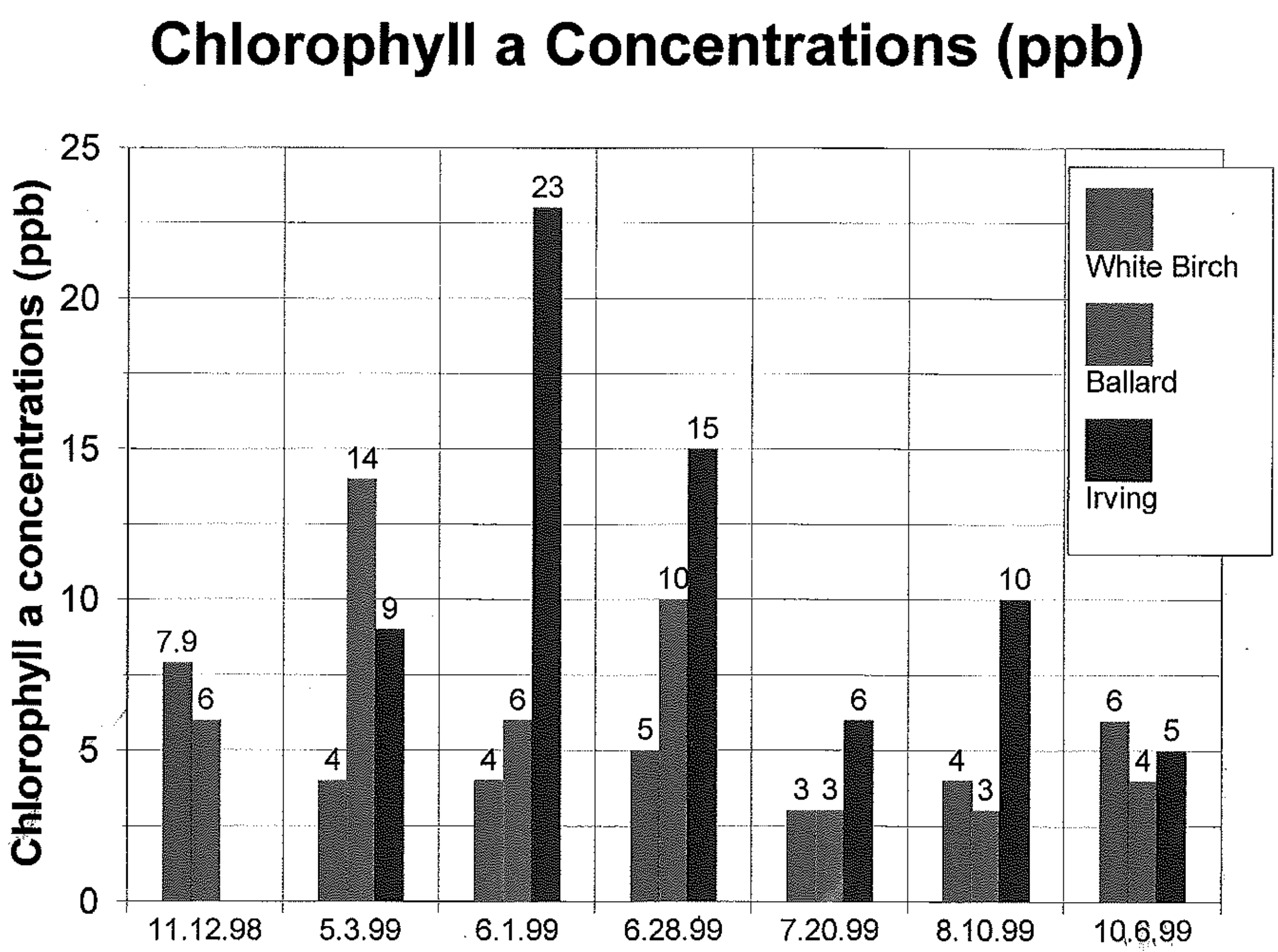


Figure 18. Chlorophyll levels for May, June, July, and August, 1999.

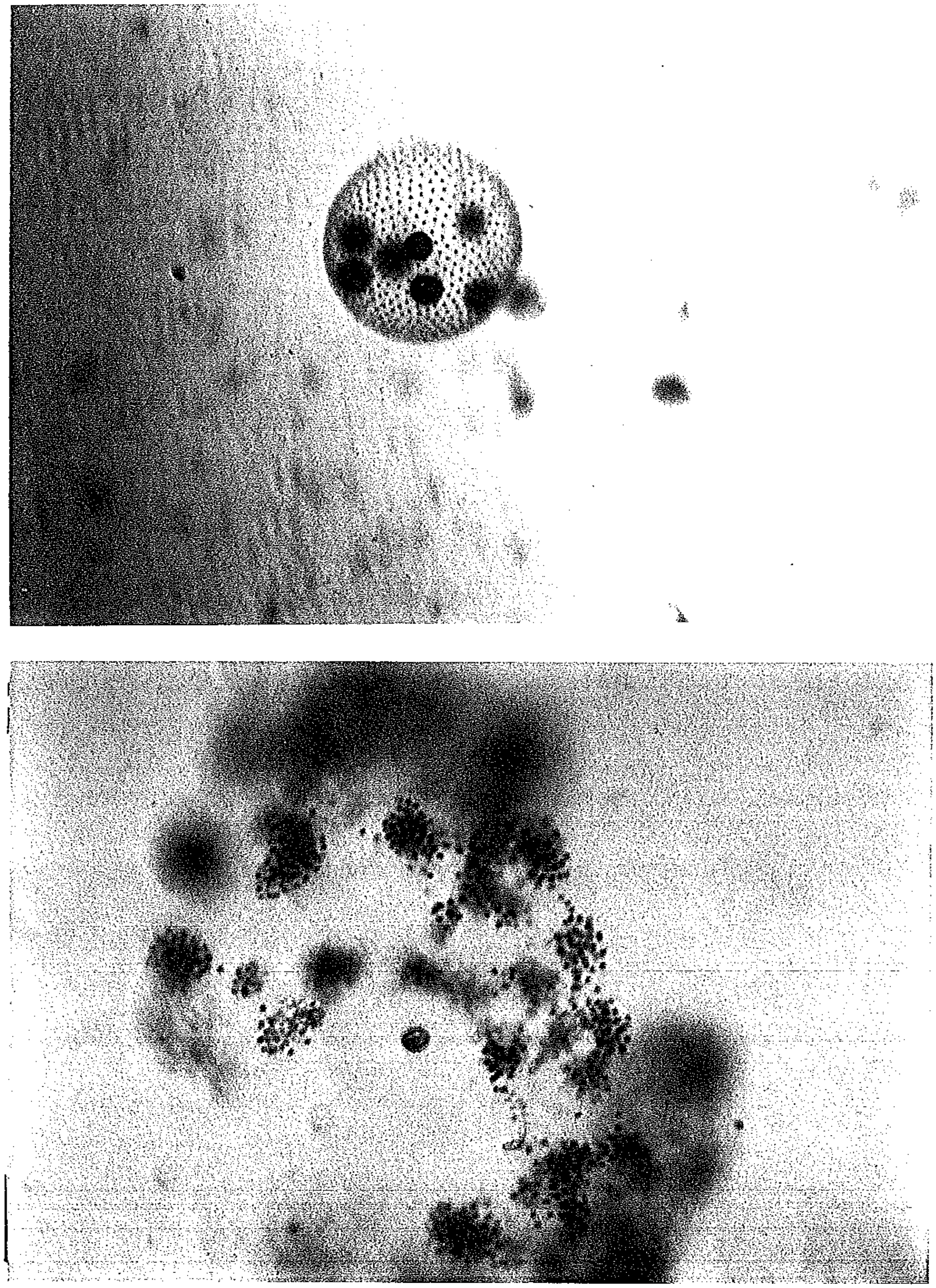


Figure 19. [top] An example of algae found in White Birch Lake on June 24, 1999. [bottom] Microcystis found in Ballard Lake on June 24, 1999.

4.4. Zooplankton and Other Invertebrates

Zooplankton are important in lakes. They graze on algae. If the algae population is composed of small algae cells, these are edible by zooplankton, and this grazing action can actually keep the lake relatively clear. The zooplankton community is composed of species of daphnia and copepods in the three lakes (Figures 20 and 21). The zooplankton communities are typical of lakes in this region.

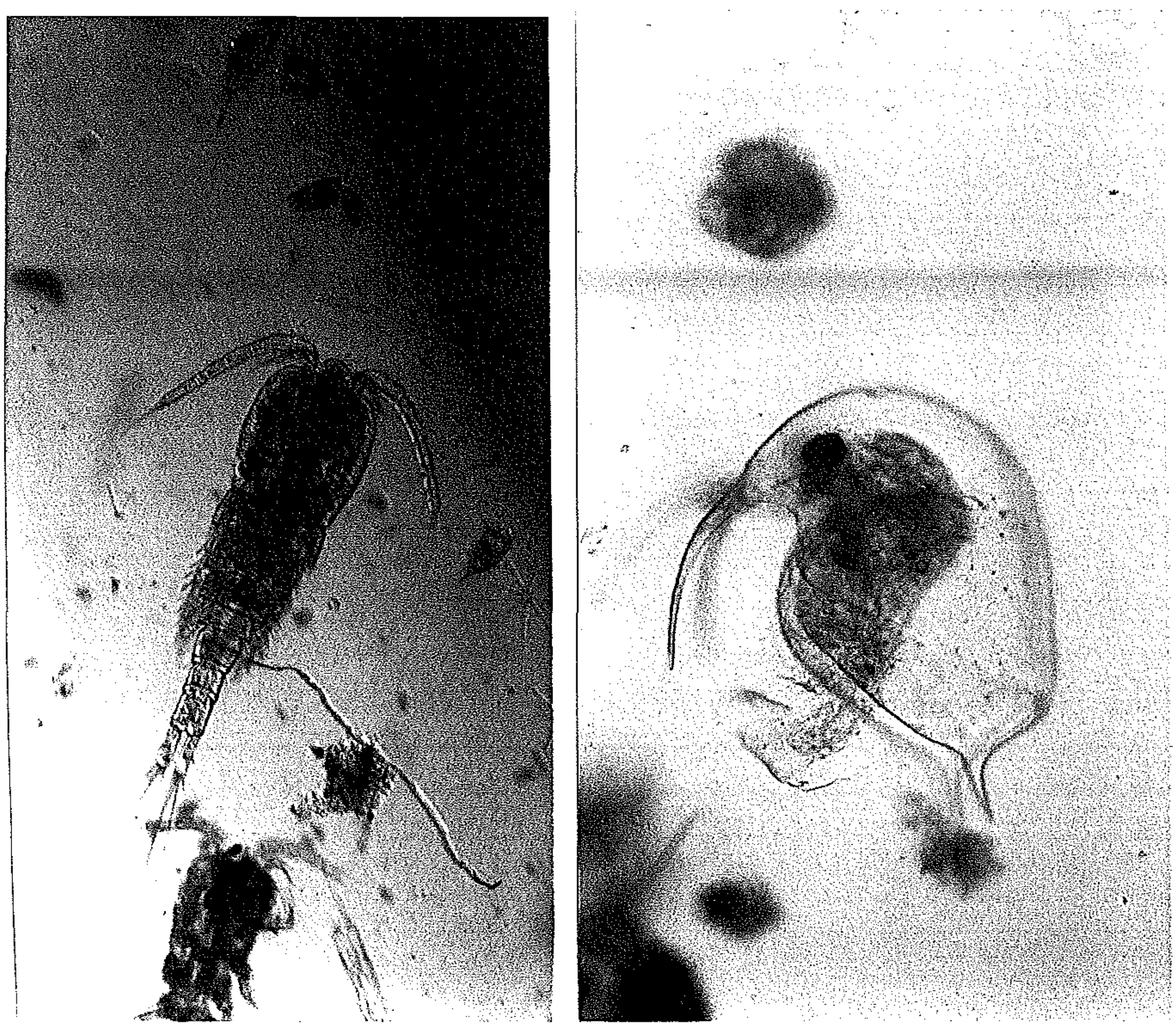


Figure 20. Examples of zooplankton species from White Birch Lake (May 25, 1999).

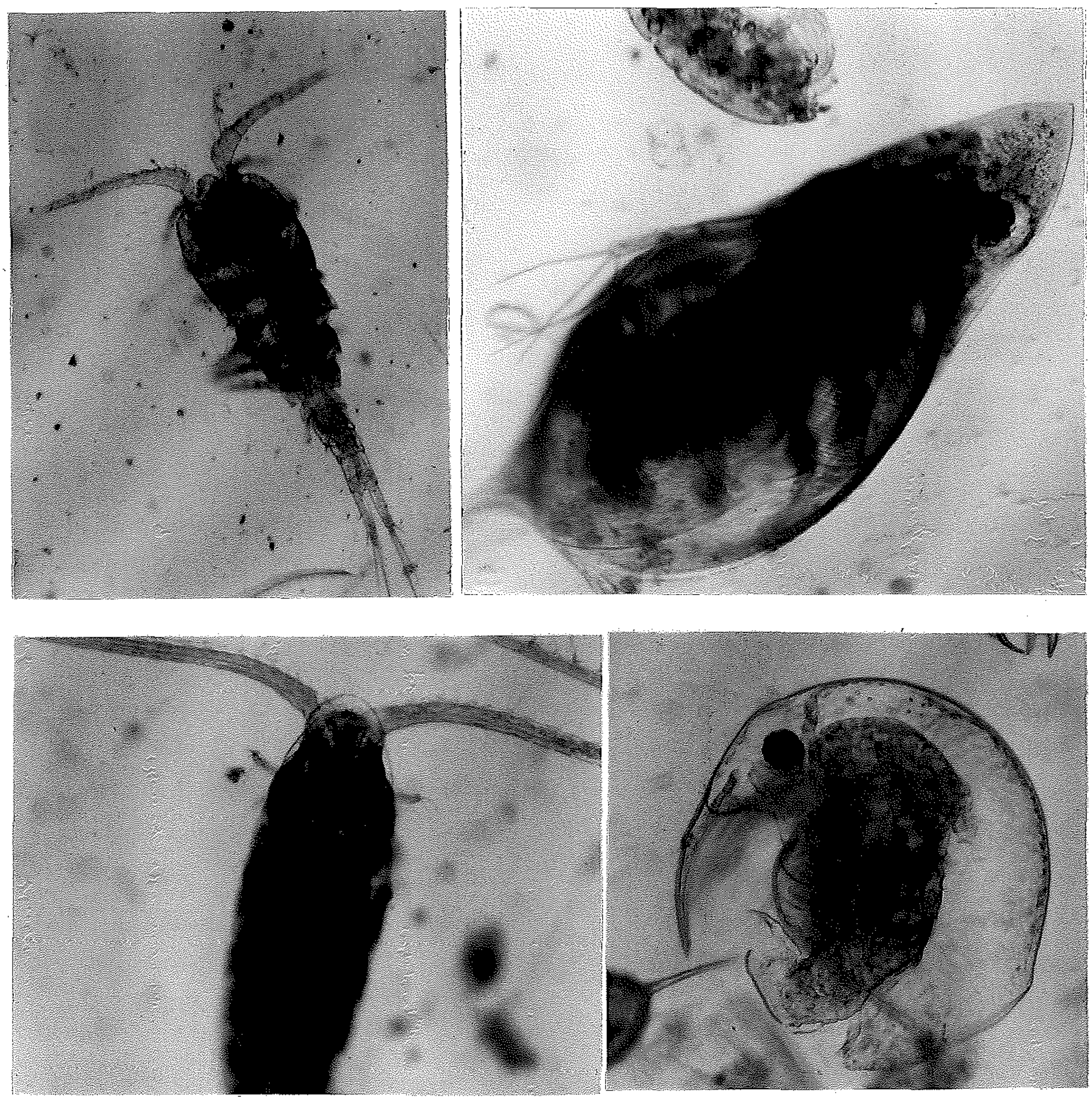


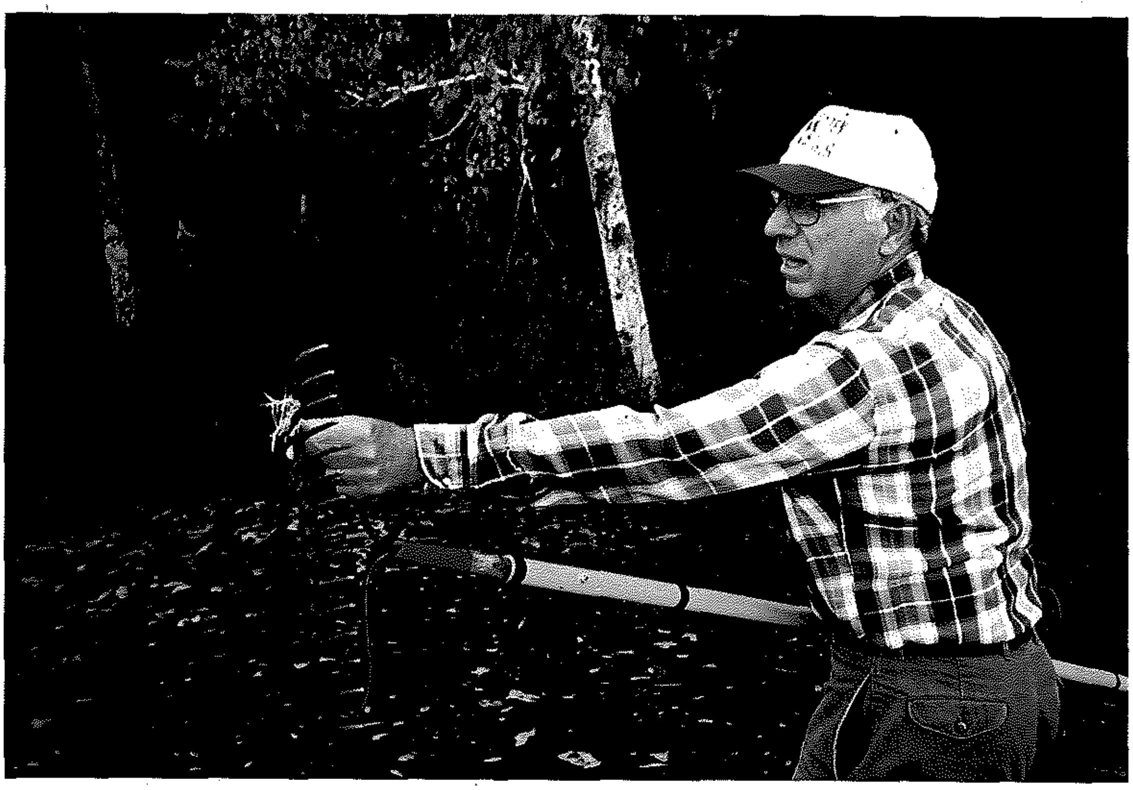
Figure 21. [top] Examples of zooplankton species from Ballard Lake (May 25, 1999). [bottom] Examples of zooplankton species from Irving Lake (May 25, 1999).

Figure 22. [top] Bryozoan colony found in Ballard Lake.
[bottom] Clams are found in White Birch Lake.

4.5. Aquatic plant status

Aquatic plants are very important to lakes. They act as nurseries for small fish, refuges for larger fish, and they help to keep the water clear. Currently White Birch, Ballard, Irving Lakes have a wide diversity of aquatic plants.

The coverage of aquatic plants over the lake bottoms for White Birch, Ballard, and Irving Lakes is shown in Figures 23, 24, and 25. Details on aquatic plant surveys are available in the Appendix.



Frank Splitt, Ballard Lake resident, examines an aquatic plant collected in Ballard Lake.

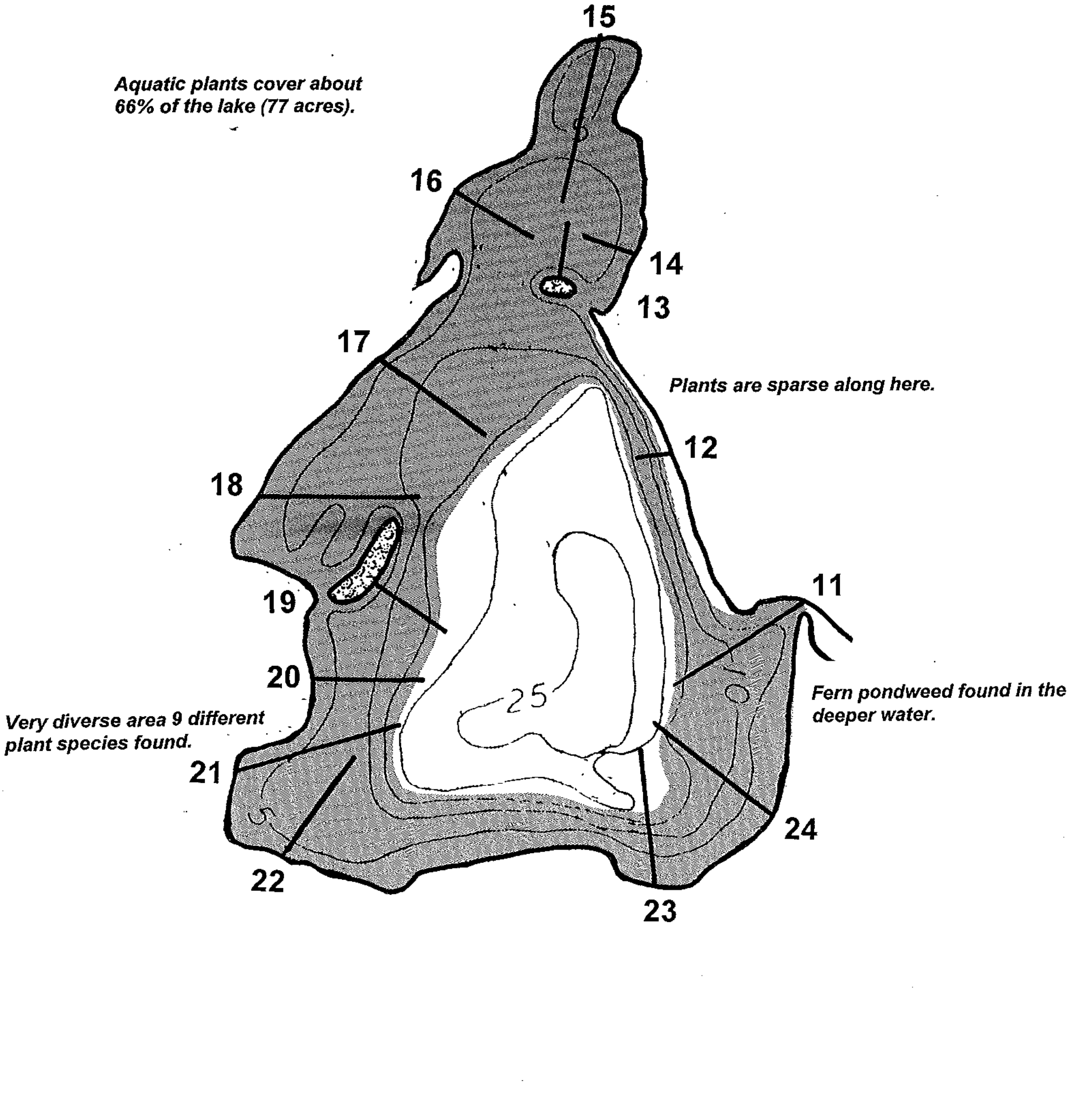


Figure 23. White Birch Lake aquatic plant map based on the 1999 survey conducted by Blue Water Science.

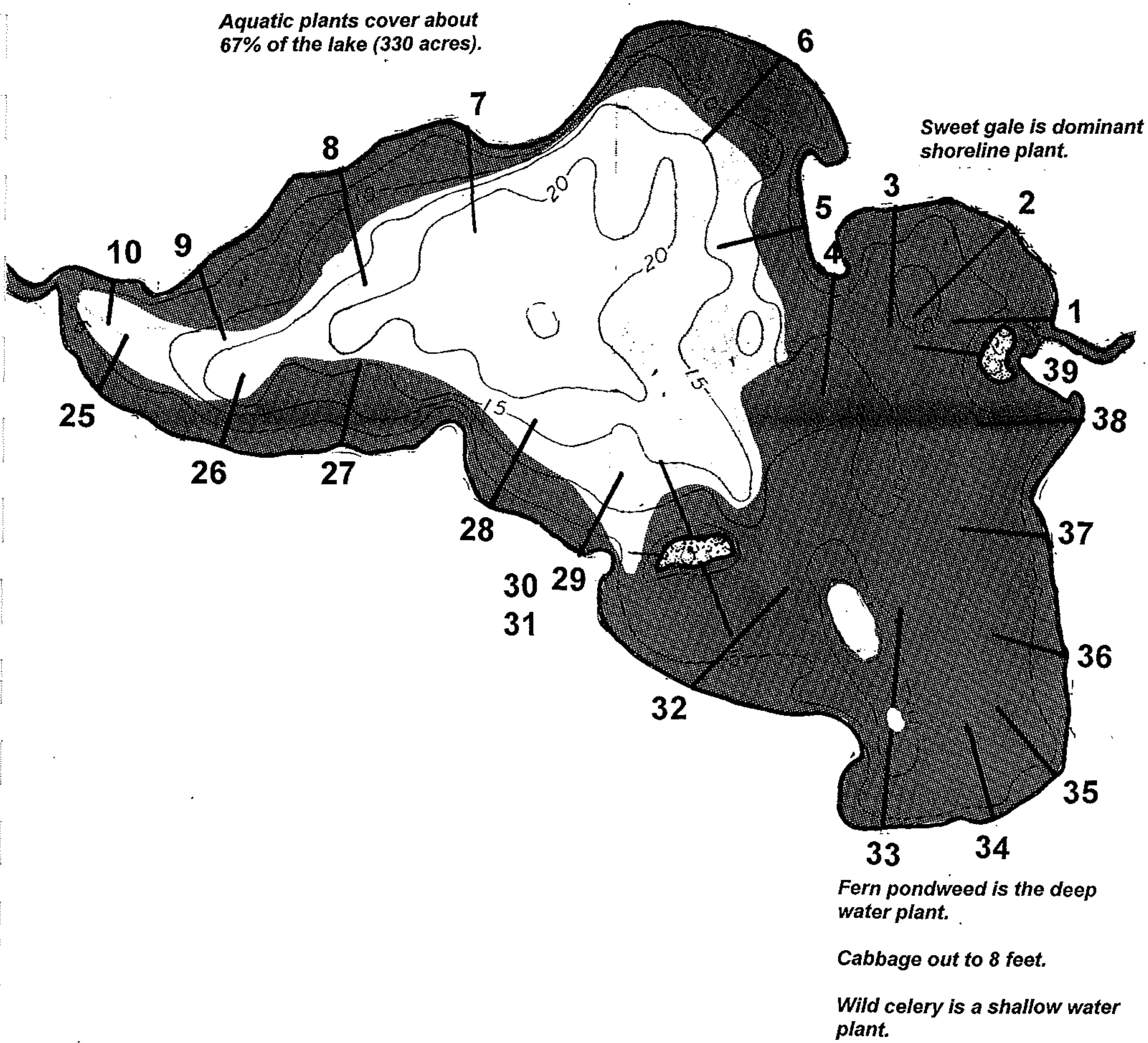


Figure 24. Ballard Lake aquatic plant map based on the 1999 survey conducted by Blue Water Science.

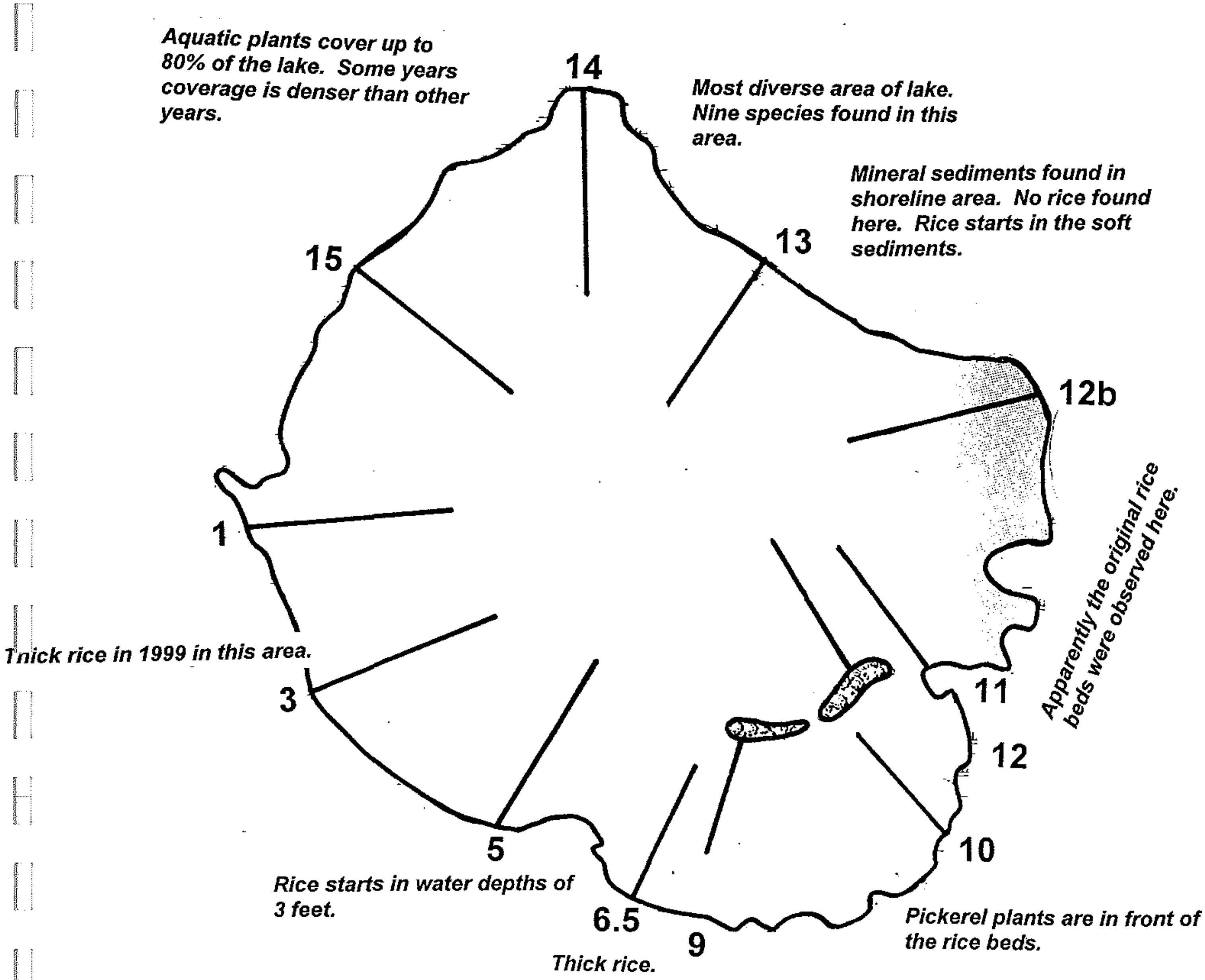
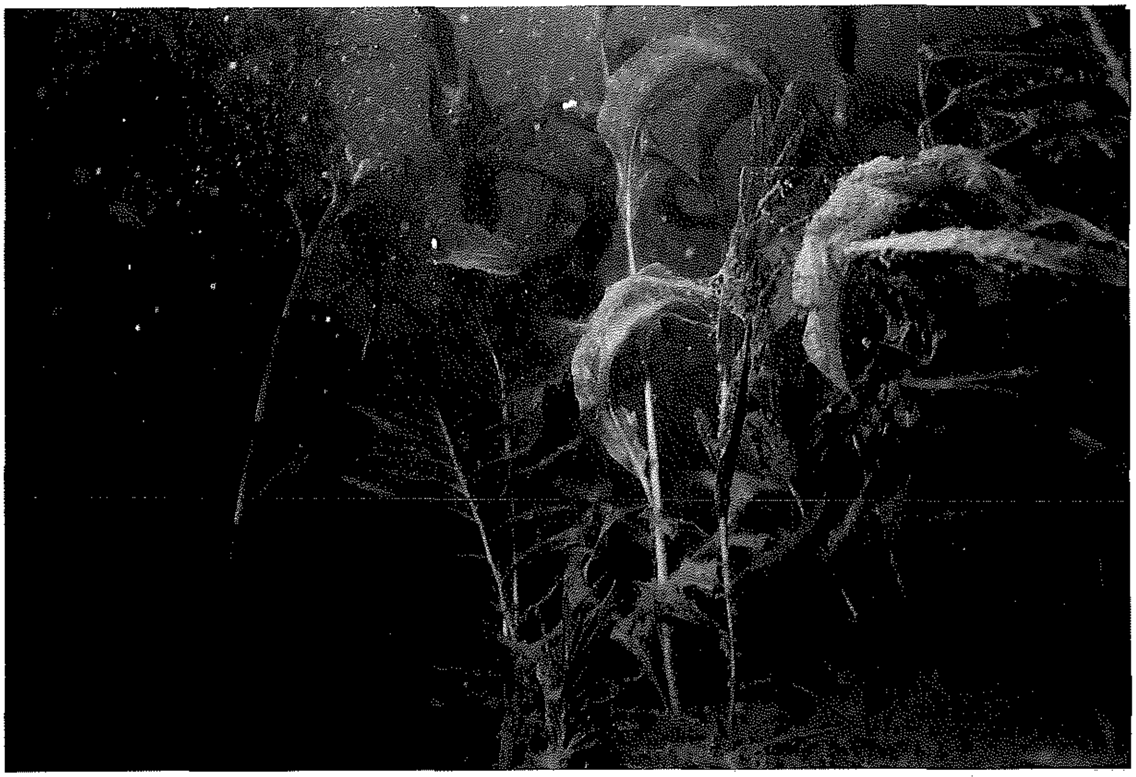
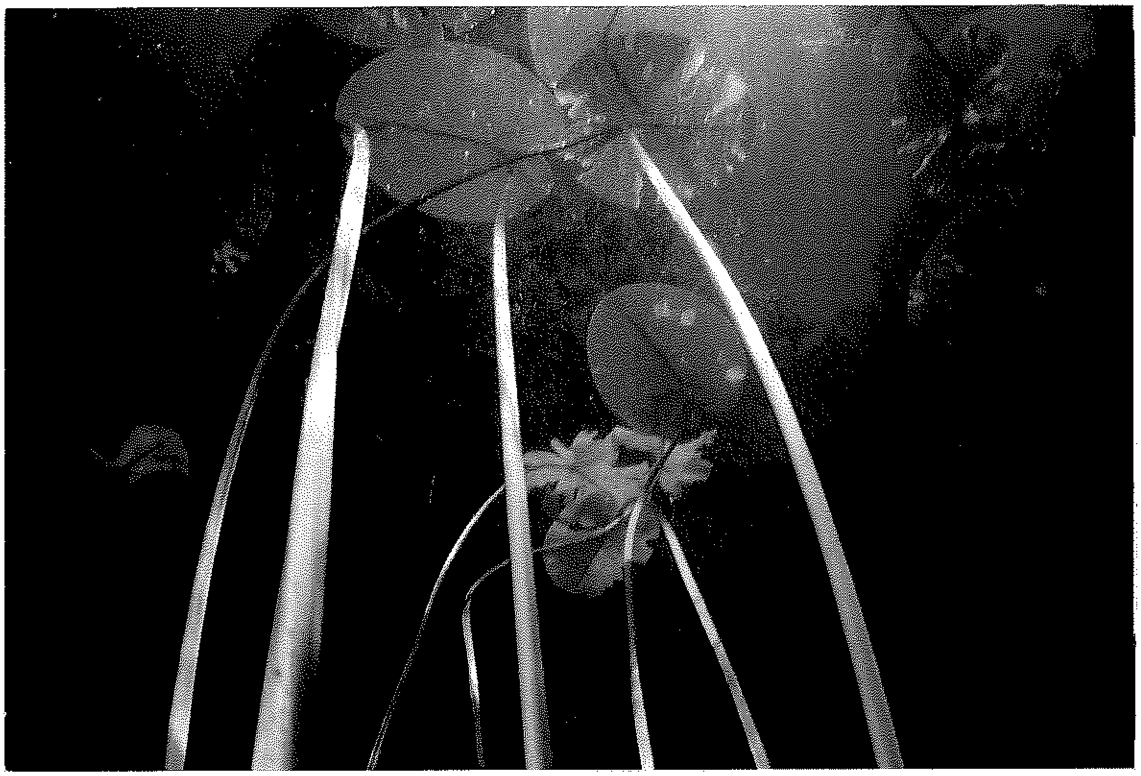


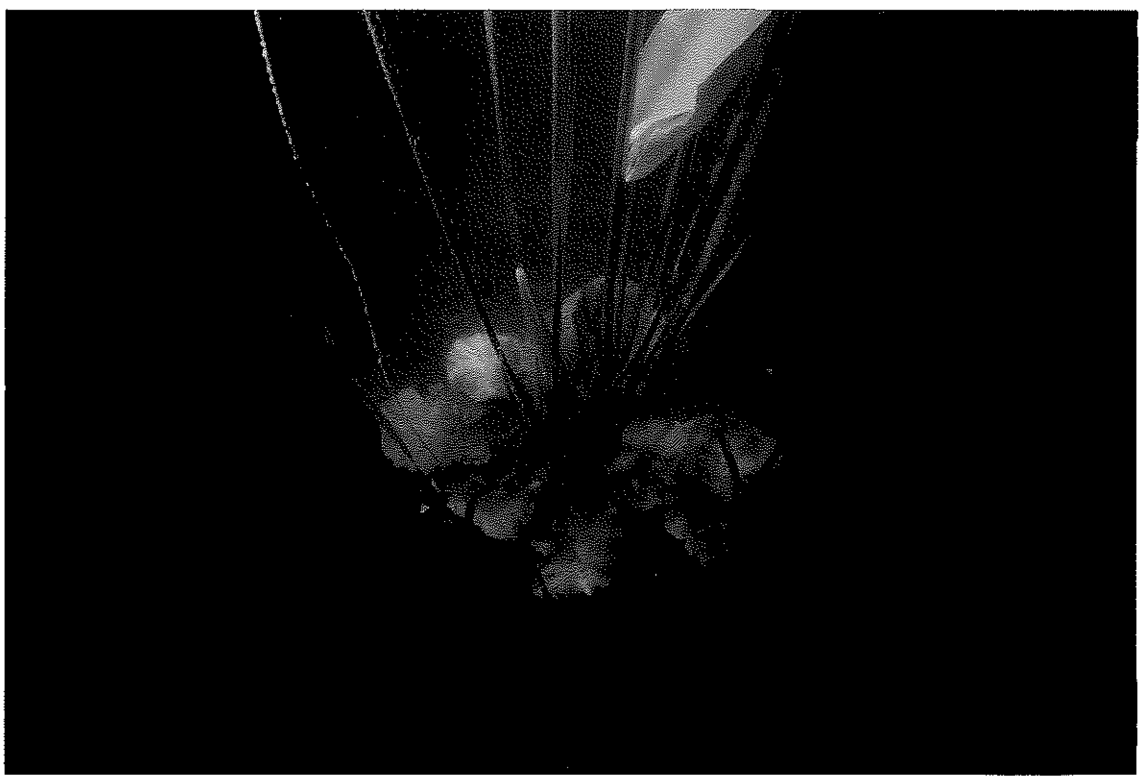
Figure 25. Irving Lake aquatic plant map based on the 1999 survey conducted by Blue Water Science.

Examples of aquatic plants found in the Ballard Lake. [top] Naiad, [bottom] quillwort.

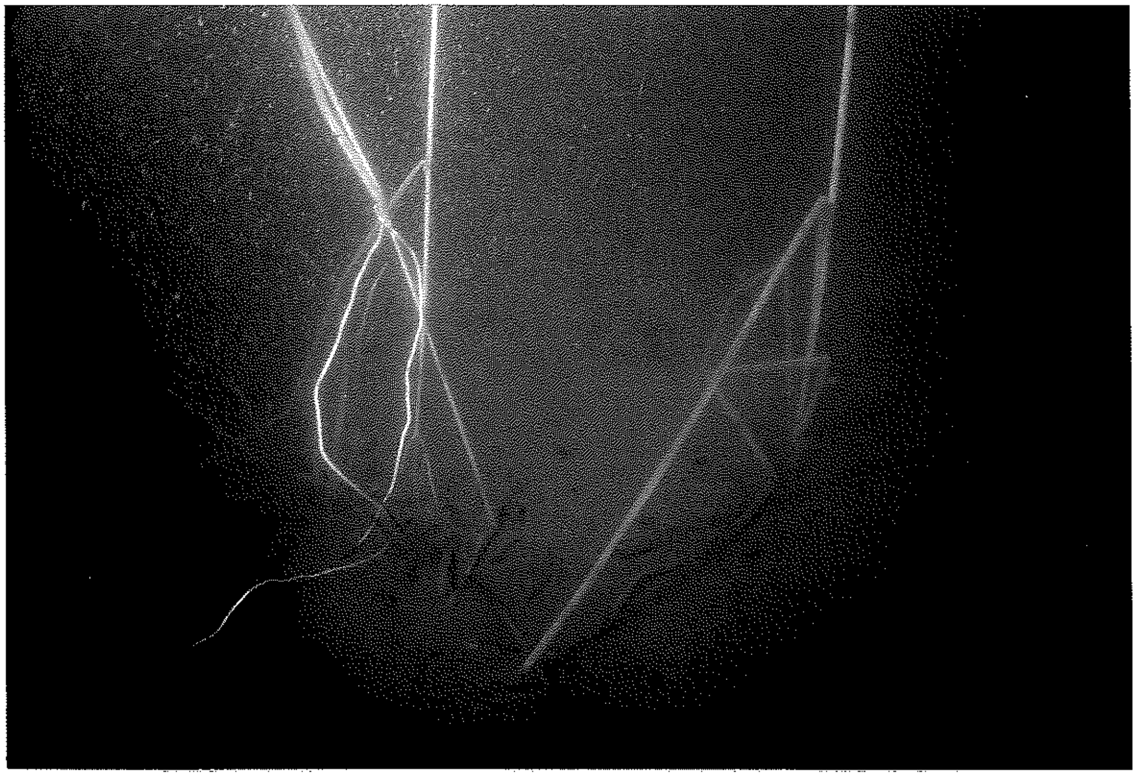


[top] Example of aquatic plant diversity found in Ballard Lake.
[bottom] Soft sediments are anchored by aquatic plants in Ballard. Here diver Steve McComas is sunk 4-feet into soft sediments and could go deeper.





[top] Looking up through the spatterdock.
[bottom] Last years leaves around the base of spatterdock.



Wild rice stems in Irving Lake.

Wild Rice Status

Wild rice is one of 15 aquatic plant species found in Irving Lake in the 1999 aquatic plant survey. Its been in Irving since the 1960s and maybe earlier. Wild rice is an annual plant and resprouts from seeds every year. The other plants in Irving are perennials.

The density and coverage of wild rice in Irving, as well as other lakes with wild rice in Wisconsin, varies from year to year. Wild rice seems to follow a 4-year pattern. There is typically a "boom" year, followed by two lean years and then a "bust" year.

The annual growth patterns for Irving Lake is shown in Figure 26.

The status of wild rice in Irving Lake is typical for Wisconsin wild rice lakes. Wild rice grows to a water depth of about 5 feet and its coverage varies from year to year.

The coverage of wild rice in Irving Lake as documented by aerial photos is shown in Figure 27.

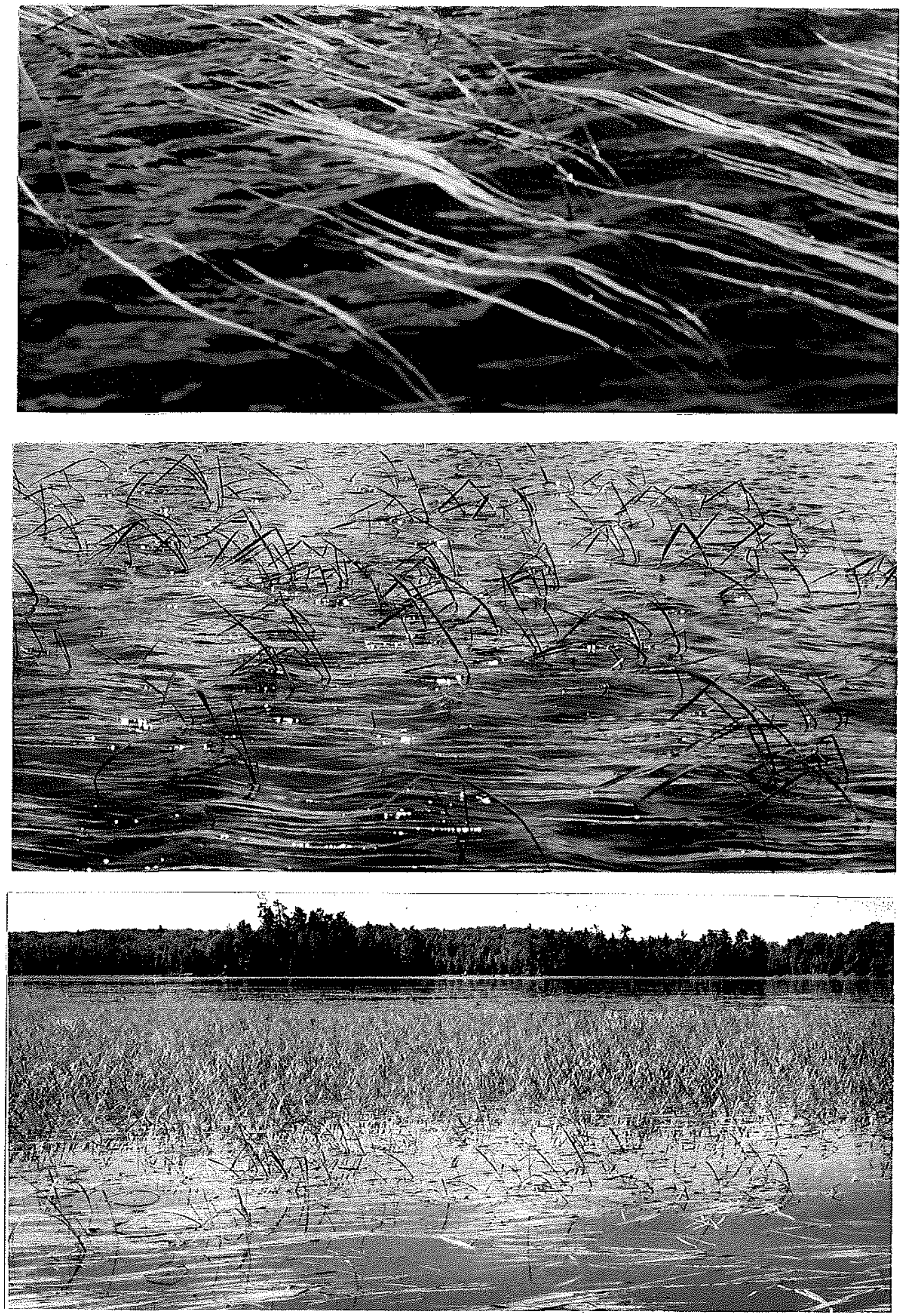


Figure 26. Wild rice has several growth stages. First is the submerged, then floatingleaf (top picture), then aerial (middle), and then eventually it produces seeds.

Wild Rice in Irving Lake Over the Years

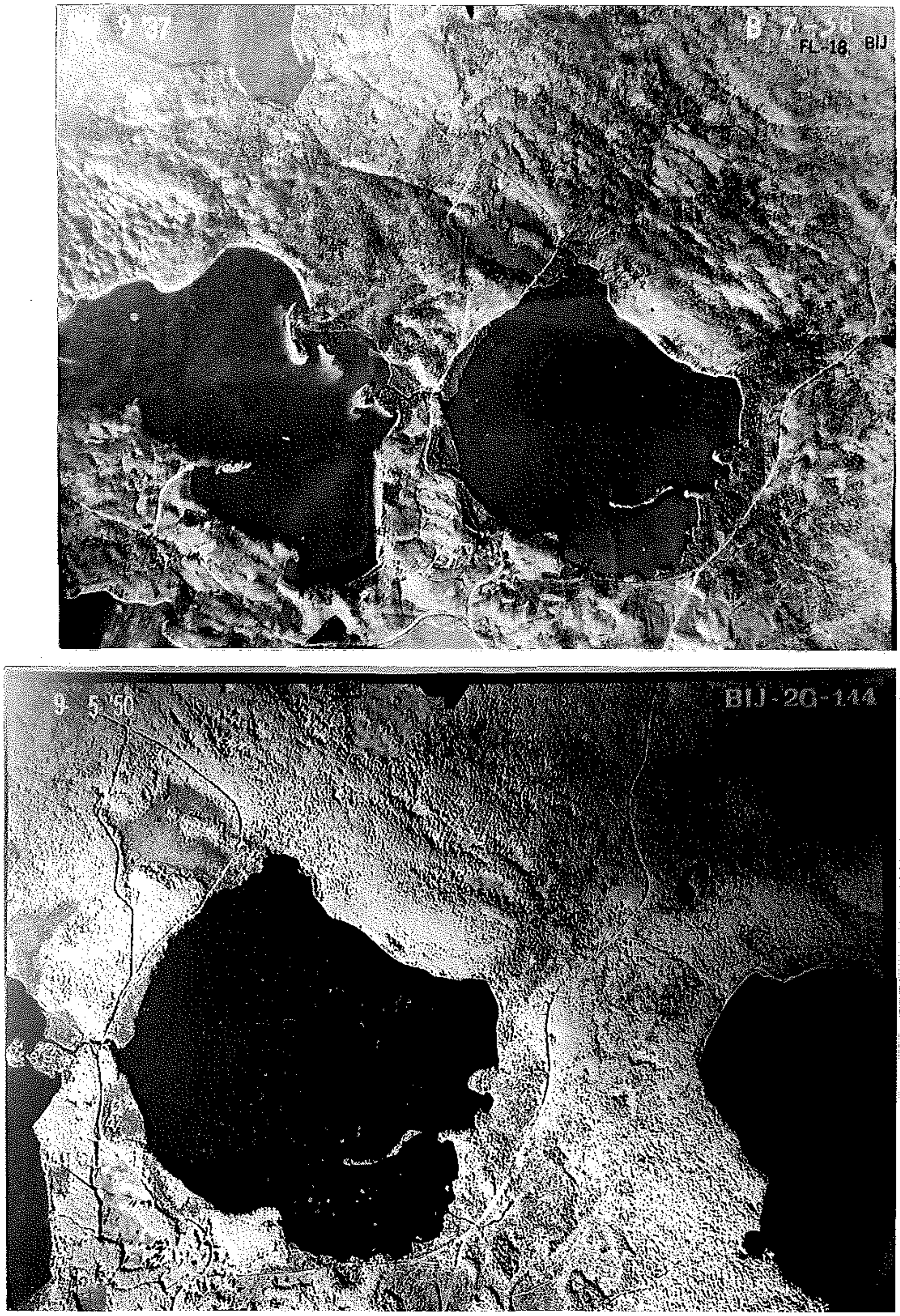


Figure 27. [top] Irving Lake on November 9, 1937.
[bottom] Irving Lake on September 5, 1950.

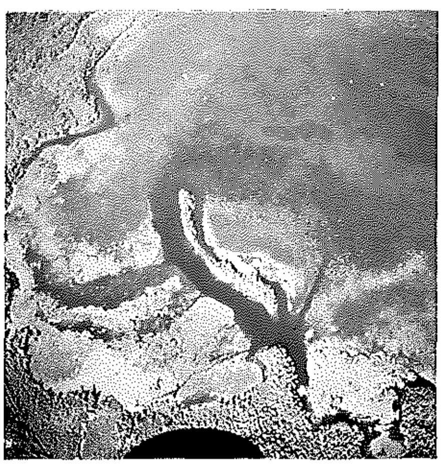
1987

1990: 44 acres, medium-dense, 293 pounds @ 48 pounds/trip.

1987

No
Picture
Available

1991: 140 acres, medium-dense, 94 pounds @ 10 pounds/trip.



1989

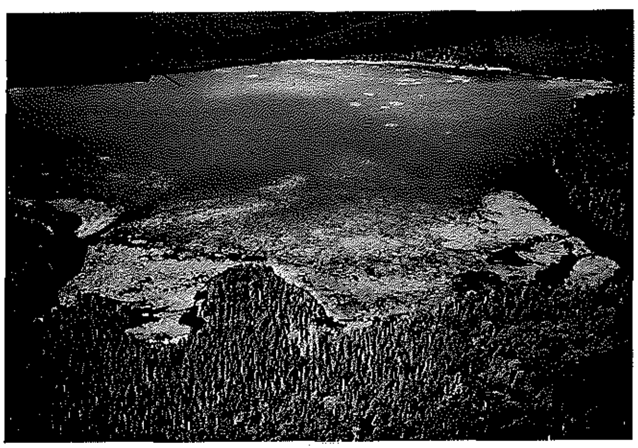
1992: 40 acres, sparse-medium, 0 pounds.

1993: 40 acres, medium-dense.

Figure 27. Aerial photographs of Irving Lake from 1987 through 1998 (continued). Acres of rice are estimated. The pounds of harvested wild rice are given for 1990-1998 [source: WDNR and Great Lakes Indian Fish and Wildlife Commission (GLFWC)].

1994: 100 acres, sparse-dense, 755 pounds @ 55 pounds/trip.

1995: 120 acres, sparse-dense, 89 pounds @ 35 pounds/trip.



1995

1996: 133 acres, sparse-dense, 4,060 pounds @ 81 pounds/trip.

1997: 150 acres, sparse-dense, 2,114 pounds @ 77 pounds/trip.

1998: 80 acres, sparse-dense, 1,087 pounds @ 44 pounds/trip.

1998: another view of Irving Lake (submitted by Lake Assoc.).

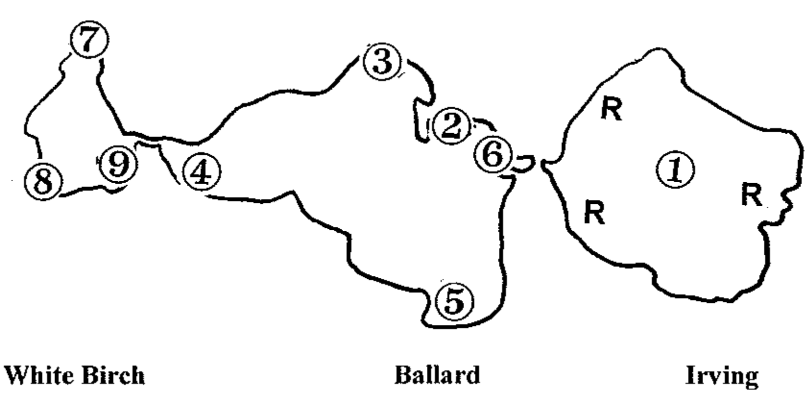
Figure 27. Concluded.

Where Will Wild Rice Grow in the Chain of Lakes?

Many factors affect the growth of wild rice. A question was posed concerning the areas wild rice could colonize within the chain of lakes. To address this question, lake sediments where collected from Irving in areas that supported wild rice growth. Then sediments where collected from Ballard and White Birch in shallow areas that had the potential to support rice based on water depths less than 5 feet. Lake sediments were analyzed at an agricultural soil testing laboratory. Soil test results are shown in Table 10. Wild rice probably will not expand dramatically into Ballard or White Birch Lakes based on the soil fertility results. However, Site 7 in White Birch Lake and Site 6 in Ballard Lake appear to have the high calcium and high organic matter content that could support wild rice growth in shallow water.

Table 10. Lake sediment analysis of shallow water sites compared sediment chemistry to three sites where rice currently grows.

	Reference Irving (avg of 3 sites)	1 Irving	2 Ballard	3 Ballard	4 Ballard	5 Ballard	6 Ballard	7 White Birch	8 White Birch	9 White Birch
Water Depth (ft)	--	6	2-3	2-3	2-3	2-3	2-3	4-5	4-5	2-3
Site Characteristics	rice	no rice	Soft sed, No plants	Sand, No plants	Sand, By outlet	Sand, No Plants	Channel, Sparse rice	North Bay	Diverse plants	Sand
Nitrate-N	0	29	7	64	47	49	82	0	13	44
Phos-Bray	5	11	5	4	4	4	9	8	3	3
Phos-Olsen	4	6	4	2	2	2	12	7	1	1
Potassium	31	16	14	29	8	9	49	85	8	8
Calcium	1,507	800	1,640	120	120	80	1,880	1,840	1,160	80
Magnesium	191	105	182	25	20	17	202	242	110	17
Sodium	71	66	18	46	56	4	78	162	76	24
Sulfate	418	91	117	9	15	7	305	235	108	7
Iron	67	64	64	6	12	5	66	67	59	8
Manganese	13	11	12	3	1	1	14	14	9	1
Zinc	6.1	2.2	3.0	0.26	0.38	0.54	17.3	10.6	4.4	0.16
Copper	0.97	0.74	0.42	0.14	0.10	0.16	0.78	1.10	0.42	0.10
Boron	3.27	0.54	0.57	0.16	0.19	0.23	3.04	2.48	0.39	0.06
Organic matter	28.6	43.2	48.4	0.9	0.7	0.2	26.7	29.1	16.0	0.3
pH	5.0	5.5	5.7	7.0	6.0	6.4	5.2	--	5.6	6.5
CEC	19.1	5.2	12.2	1.1	-7.4	0.6	21.2	12.1	5.9	0.7



4.6. Fishery Status

Prepared by Frank Splitt

Historical Perspective

In the late 1890s flyer announcing the opening of the House of the Good Shepard, Gene Shepard states: "*it is situated on Ballard Lake, which is one of the best Muscalonge lakes in the state. The Bass, Pike, and all kinds of fishing is as good here as the most enthusiastic could desire*". Prior accounts from the mid 1890s tell of abundant fisheries that helped to sustain the local Native American community and traders as well.

An examination of available documents and WDNR files as well as discussions with Harlan Carlson, WDNR Woodruff, Fisheries Biologist, affirmed that, over the years, fishery management for the Ballard-Irving-White Birch Chain has been focused on muskie and walleye. The Chain was stocked with these two species by the state on a regular basis although there were also occasional stockings of largemouth bass. A 1963 Wisconsin Conservation Department (WCD) Report states that Ballard is known as a muskie-walleye lake with both species considered abundant. It also notes that the principal fish species in Irving are muskie, walleye, largemouth bass, and panfish. A 1966 WCD Fish Management Report indicated that the fish populations on Ballard appeared to be in good order with the exception of an overabundance of bluegills. It was recommended that spot chemical treatment be administered to reduce the bluegill population to obtain a better balance with the other species.

Prior to the devastating, near total, 1995-96 winterkill, the Chain had come to the known as a "go to" spot with one of the finest fisheries in Vilas County. Muskie, walleye, largemouth bass, and smallmouth bass, as well as an abundant panfish population made the Chain popular for action with young and old alike. Fishing for muskie on Irving Lake was even described in a May 23, 1986, Wall Street Journal, Leisure and Arts column. The fine fisheries also contributed to the financial well being of two resorts . . . White Birch Village on White Birch Lake and Rismond's Lodge on Ballard Lake.

The severity of the 1995-96 winterkill on Ballard and White Birch came as a surprise, since the lakes did not have a history of winterkill, whereas Irving has history of such events. A quick recovery of the Chain's fishery required a focused and cooperative effort. The spring '96, post ice-out transfer of some 4,700 pounds of fish into White Birch, from the old Aqualand fishponds, helped to jump-start this effort. The transfer consisted of everything from minnows to muskies that migrated out of White Birch into the ponds as they sought higher dissolved oxygen (DO) levels downstream. Beginning in 1996, an extensive yearly fish stocking and transfer program by the WDNR brought about a significant rebound in the quality of the Chain's fisheries, particularly for muskie, walleye, and panfish. Additionally, the Town of Plum Lake, the Muskie Clubs Alliance of Wisconsin, the Starlakers Club, and the Star Lake Store supported the stocking of muskie, fingerling walleye, and largemouth bass.

Present Status

Recent shocking data for Ballard and White Birch, and informal creel surveys, indicate that the WDNR has successfully established solid year classes for muskie and walleye by means of its fry, fingerling and adult fish stocking initiatives. Healthy largemouth bass and panfish populations have been established as well.

Northern pike have also established a foothold in the Chain, no doubt aided and abetted by the 1995-96 winterkill, and the northern pike's ability to tolerate much lower DO levels than muskie, walleye, and most panfish. Although pike are present, it is difficult to predict what they will do. Spawning habitat conditions in the lakes appear to favor muskies over pike in the long run. However, since the pike spawn some tow to five weeks before muskies, and could possibly have a much higher hatching success rate, there is concern that muskie fry predation, by larger and more numerous pike fry, could place natural muskie reproduction at risk.

Although some smallmouth bass are present, no effort has been make to re-establish a robust fishery at this time since smallmouth bass compete directly with walleye for forage.

The future appears to be bright for angler action with all species. It is expected that a few legal muskies will be caught in 2000, certainly many more in 2001. Legal walleye, resulting from early stocking efforts, are to be anticipated in 2000. Harland Carlson expects the fishing to steadily improve with ever more fish growing to quality size. Local guide, Mike Errington agrees and looks forward to a great future for the Chain's fishery. He is particularly impressed with the superb quality of panfishing that is already available to anglers. Based on the progress made with fishery restoration, area guide Tommy Zinda has picked Ballard as one of his top ten fishing spots for 2000 and beyond.

Beaver damming at the culvert in the Ballard-Irving thoroughfare has become a chronic problem. There is a need to maintain a consistently clear path in the thoroughfare during the late fall and early winter months. This clear path would minimize avoidable "trapping" of the Irving fish community when decreasing DO levels in Irving trigger an instinctive fish migration into Ballard.

By way of extensive fish stocking and transfers, the Chain's fishery appears to be well on its way to being restored. All indications point to the fact that the Chain has an abundant fishery with a very large predator community . . . to the point where forage is scarce. Harland Carlson is encouraged with natural walleye, muskie, and black crappie reproduction. The development of the pike fishery and natural muskie reproduction needs to be watched closely. According to Harland, some time is now required for Mother Nature to sort out and stabilize the fish community. He recommends at least a two-year wait, and that is done without interfering with additional stocking . . . patience is the watchword.

5. Lake and Watershed Assessment

5.1. How Do the Lakes Rate?

The status of White Birch-Ballard-Irving Lakes are graded as good to excellent. Although clarity and phosphorus levels are out of range for Irving, they are about where they should be for White Birch and Ballard for lakes in this part of Wisconsin (Table 11). Values for phosphorus, chlorophyll and Secchi depth are within ecoregion ranges for 1999.

Irving Lake is a shallow lake and produces more algae from phosphorus inputs compared to deeper lakes where the same amount of phosphorus is assimilated and diluted. Irving Lake rates good compared to other shallow lakes in the region.

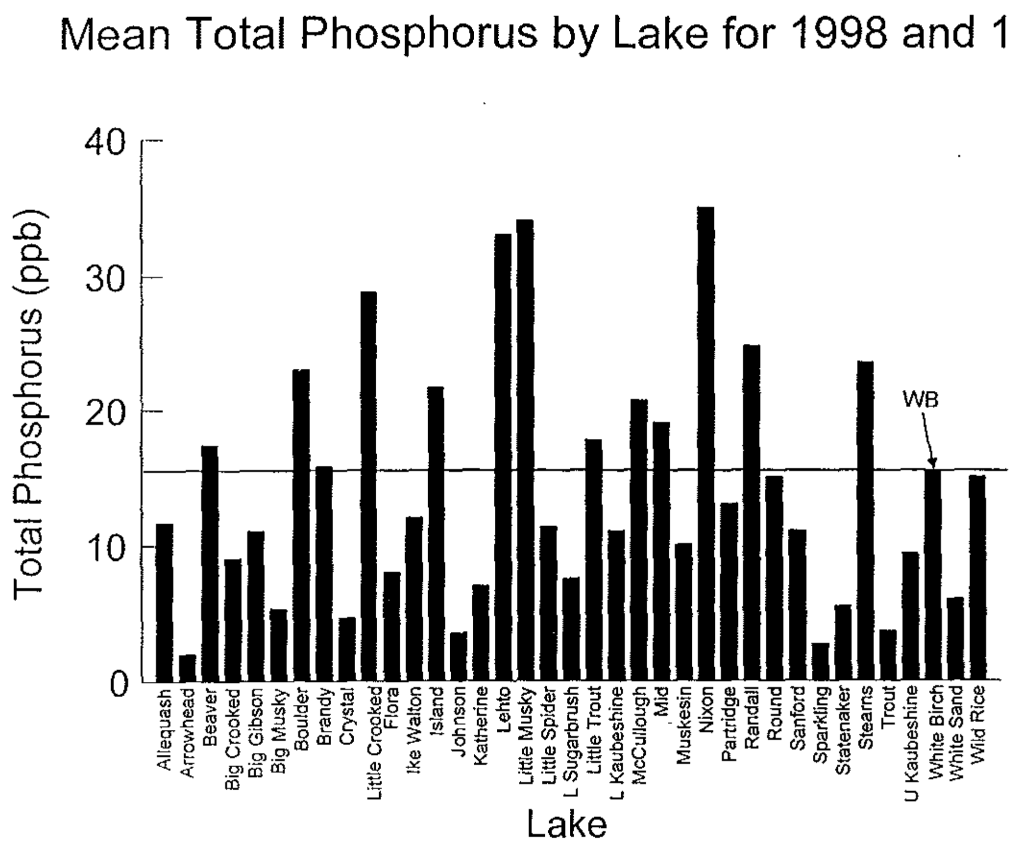
Table 11. Range of summer water quality characteristics for lakes in the Northern Lakes and Forest ecoregion, as noted in Descriptive Characteristics of the Seven Ecoregions in Minnesota, by G. Fandrei, S. Heiskary, and S. McCollar. 1988. Minnesota Pollution Control Agency.

Parameter	Northern Lakes & Forests	White Birch Lake	Ballard Lake	Irving Lake
Total Phosphorus (μg/l) (top water summer average)	14-27	15	18	40
Algae (chlorophyll mean (μg/l))	<10	5	7	11
Algae (chlorophyll maximum (μg/l))	<15	5	14	23
Secchi disc (feet)	8-15	11.9	10.4	4.7
Total Kjeldahl Nitrogen (μg/l)	<750	550	660	610
Nitrite + Nitrate N (μg/l)	<10	40	60	10
Conductivity (umhos/cm)	50-250	69	72	77
TN:TP Ratio	25:1-35:1	34:1	42:1	22:1

An important component to watch and to control is nutrient inputs -- both phosphorus and nitrogen. When phosphorus concentrations increase to around 30 ppb or above in deep lakes, nuisance algae blooms can develop. This causes a cascade of problems.

New construction and lake resident activities can have significant impacts on phosphorus inputs. Studies in Maine show that clearing the trees off your property, even a partial clearing can increase phosphorus inputs to the lake from the runoff. Maintaining natural shoreland vegetation will help reduce the amount of nutrients going into your lake.

White Birch was included in a regional lake landscape position study of lakes over the last couple of years by the UW-Madison Long Term Ecological Research Team headquartered at the UW/Trout Lake Station. It's phosphorus levels are moderate and nitrogen levels are slightly elevated compared to the other area lakes (Figure 28).



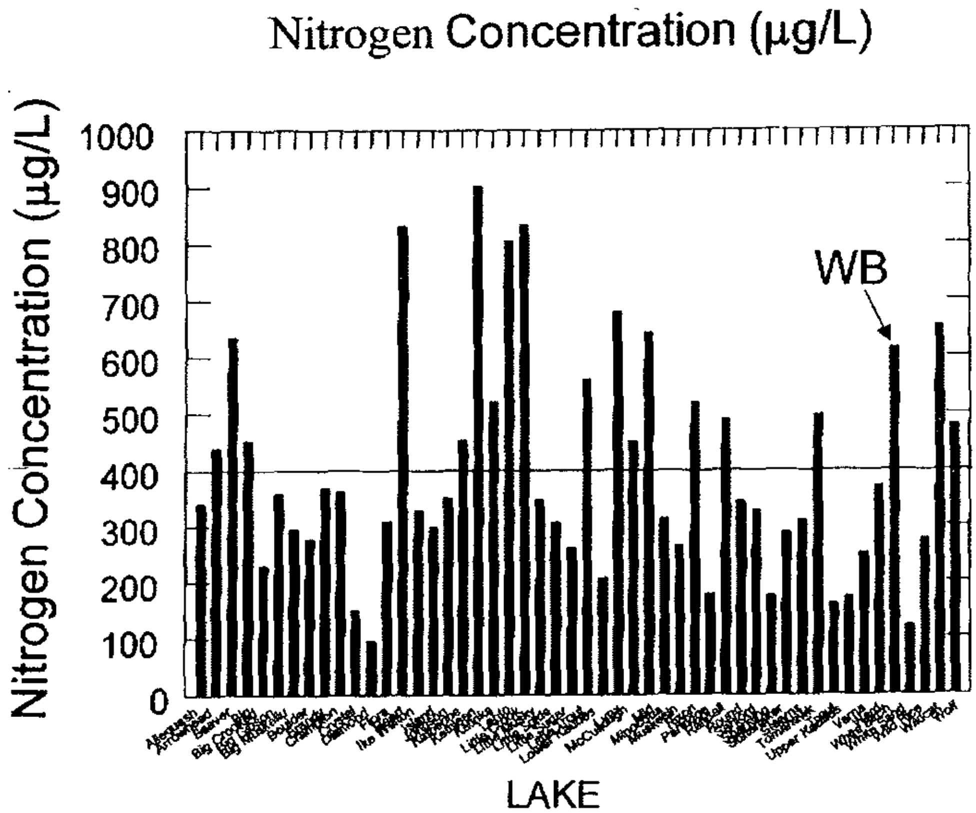


Figure 28. Phosphorus and nitrogen concentrations for area lakes. The horizontal line is the average across all the lakes during 1998 and 1999. WB = White Birch Lake (UW-Madison Long Term Ecological Research Team headquartered at the UW/Trout Lake Station, Dr. Thomas Hrabik, Principle Investigator).

5.2. Are the Lakes Getting Worse or Staying the Same?

Review of Historical Data: Based on water quality data the lakes are not getting worse and may be slightly improved since the 1920s based on Secchi disc readings and phosphorus concentrations (Figure 29, and Table 12 and 13).

Table 12. Historical secchi Disc transparency data. The number in parentheses in the 1990s indicates the number of readings. Data from the 1920s was supplied by the Department of Limnology, UW Madison and was collected by Drs. Birge and Juday.

Date	White Birch	Ballard	Irving
7.14.1927	7.3	5.0	--
8.18.1928	8.3	8.3	--
8.22.1929	9.9	6.6	--
6.27.1930	--	9.9	--
8.15.1960	--	--	5.5
7.10.1984	14.5	17+	--
10.18.1984	10.0	--	--
1993	--	11.7 (5)	--
1994	--	13.7 (4)	--
1995	--	13.1 (7)	--
1996	--	11.9 (3)	--
1997	--	11.8 (4)	--
1998	--	9.8 (7)	--
1999	11.9 (9)	10.4 (9)	4.7 (9)
2000	15.5 (7)	14.1 (7)	7.4 (8)

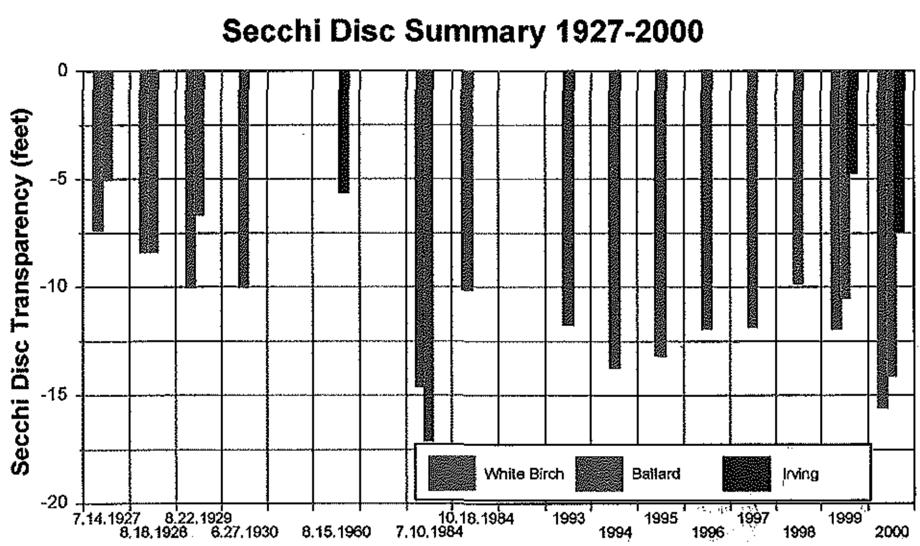


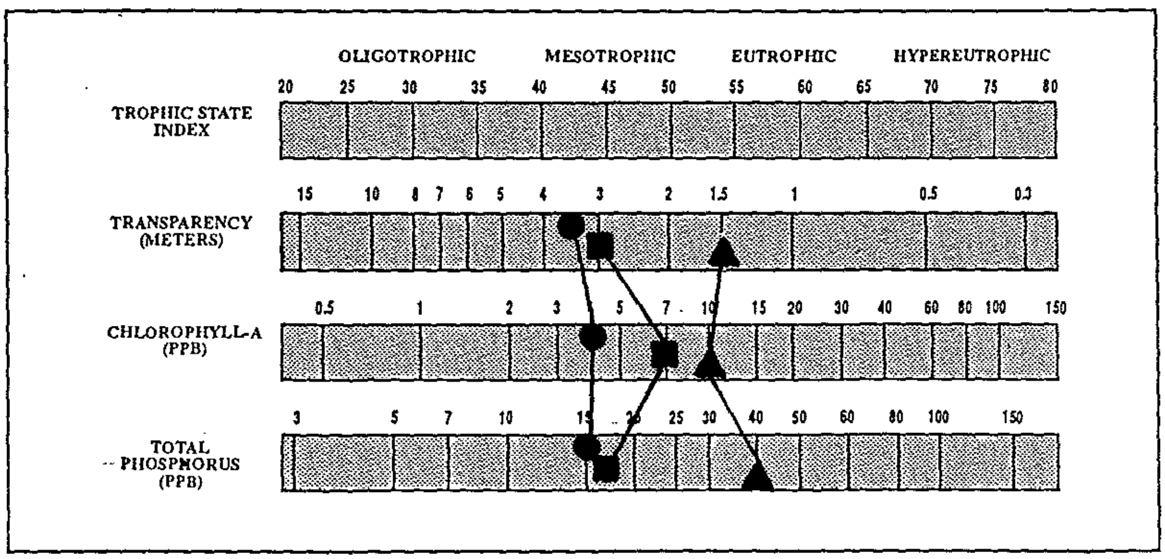
Table 13. Historical phosphorus and nitrogen water chemistry.

Date	Total Phosphorus Concentrations			Organic Nitrogen (1926-1978) + Kjel N (1984-present)		
	White Birch	Ballard	Irving	White Birch	Ballard	Irving
8.7.1926	19	30	28	520	590	480
7.14.1927	20	28	30	530	540	510
8.18.1928	17	15	23	500	580	630
8.22.1929	18	24	17	--	--	--
6.27.1930	--	--	--	--	--	--
5.1.1978	--	--	20	--	--	210
10.18.1984	20	--	--	600	--	--
11.12.1998	18	22	--	610	900	--
5.3.1999	23	17	30	550	660	610
6.1.1999	13	17	51	--	--	--
6.28.1999	15	19	50	760	720	1,200
7.20.1999	13	17	42	--	--	--
8.10.1999	14	16	36	--	--	--
10.6.1999	12	13	30	480	530	640
4.24.2000	17	14	14	490	510	300

5.3. Factors Affecting Water Quality

Water quality in White Birch and Ballard Lakes is excellent and it is good in Irving. The size of the watershed, land use, and the lake volume can account for the water quality observed in the three lakes. Lake phosphorus models were run using this information. Results are shown in Table 14. There is good agreement between the predicted lake phosphorus concentration and the observed phosphorus concentration for White Birch and Ballard. Irving has a broader range of predicted phosphorus concentrations, but the observed P is still within the model range.

A factor for high phosphorus in Irving Lake may be due to boat traffic and sediment resuspension. The chart below indicates that chlorophyll (a measure of algae) should be greater and the secchi disc lower compared to the observed phosphorus readings.



After Moore, l. and K. Thornton, [Ed.] 1988. Lake and Reservoir Restoration Guidance Manual. USEPA> EPA 440/5-88-002..

LEGEND

● = White Birch Lake
■ = Ballard Lake
▲ = Irving Lake

Table 14. Lake modeling results for the three lakes.

	White Birch			Ballard			Irving		
Size (acres)	117			505			403		
Mean depth (feet)	12			9			4.5		
Volume (ac-ft)	1,404			4,544			2,015		
Direct drainage area (not including lake)	179			935			935		
Total watershed area (not including lake)	2,452			2,273			935		
Estimated inflow in acre-feet based on cubic feet per second (cfs)	4,344 (6 cfs)			3,620 (5 cfs)			3,620 (5 cfs)		
Estimated inflow (ac-ft) based on 14 inches of runoff	2,914			2,652			1,091		
Land use and P inputs	Acres	lbs	%	Acres	lbs	%	Acres	lbs	%
Rainfall on lake	117	31	10.8	505		23.4	403		54.0
Forests	82	7	2.5	600		8.3	334		13.4
Wetlands	89	7	2.5	310	28	4.9	600		26.8
Residential shorelands	7	3	1.1	25	11	1.9	1	1	1.0
Septic systems	--	4	1.5	--	11	1.9	--		0.2
P from upstream lake	--	236*	81.6	--	343**	59.5	--	--	11
Total P input	--	289	*100*	--	578	--	--	200	--
P based on average P conc of 35 ppb at 5 cfs	--	--	--	--	--	--	--	386	71.9
Observed Lake P Conc (May-Sept, 1999)	**15 ppb**			**18 ppb**			**40 ppb**		
Predicted Lake P Conc (based on 2 different lake models)	**12-20**			**18-22**			**14-44**		

* 6 cfs @ 20 ppb from Ballard Lake
** 5 cfs @ 35 ppb from Irving Lake

What is the impact of aquatic plants on Irving and on the chain of lakes?

Water Quality Impacts of Aquatic Plants in Irving

- Aquatic plants help maintain good water clarity in Irving and have other benefits as well (Figure 30). Wild rice contributes to maintaining good water quality conditions in Irving Lake.

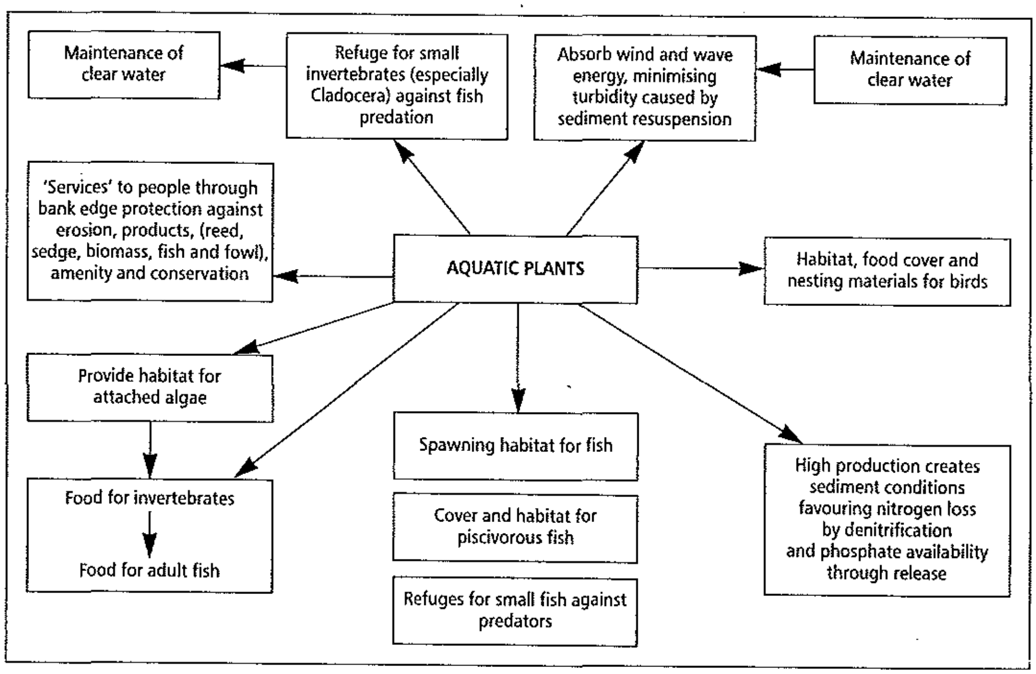


Figure 30. Links between aquatic plants and other organisms, including ourselves (source: Moss and others. 1996. A guide to the restoration of nutrient-enriched shallow lakes. Broads Authority Norwich, England).

- The type of plants in Irving Lake do not adversely impact water quality. Phosphorus levels do not appear to have changed significantly from the 1920s to the present.
- Wild rice growth in some years restricts motor boating in some areas of Irving Lake.
- Wild rice has a higher biomass based on a square-foot basis compared to water lilies and pickerel plants found in White Birch (Table 11). However, lilies and pickerel plants restrict motor boating to nearly the same degree as wild rice.
- There is over 60% bottom coverage by aquatic plants in all three lakes.

Comparing Wild Rice with Other Plants in Irving Lake: What if there was no wild rice in Irving? We assume other types of plants would grow. Lilies and pickerel plants have similar dry weights to wild rice when looking at dry weight per stem (Table 15). Cattails can have a biomass similar to wild rice based on other lake reports. Cattails are not abundant in Irving Lake. If wild rice was not present in Irving, lilies and pickerel plants would more than likely expand their range (Figure 31).

Table 15. Dry weights and weight per stem for lilies, pickerel plants, and wild rice in Irving Lake. Plants were collected on September 8, 1999.

Species	Location	Dry Weight ($g/0.1m^2$)	Number of Stems	Weight per Stem (g)
Lilies	T3	19.2	5	3.8
Lilies	T11	15.8	6	2.6
Pickerel plants	T10A	37.9	9	4.2
Pickerel plants	T10B	33.3	12	2.8
Wild rice	T3	106	33	3.2
Wild rice	T11	57.1	14	4.1

Figure 31. Pickerel plants grow as a mat in front of rice beds in Irving Lake. Pickerel plants, like wild rice, supply valuable aquatic habitat and can also hinder navigation.

Water Quality Impacts of Aquatic Plants on Ballard and White Birch

- Water quality in White Birch and Ballard has not changed and may, in fact, even got better since the 1920s based on water clarity and phosphorus concentrations. The dieback of rice in Irving Lake does not have long term adverse nutrient impacts on White Birch and Ballard Lakes. The phosphorus concentrations leaving Irving Lake in November, 1999 are not highly elevated.

Winterkill Potential the White Birch, Ballard, and Irving

- All three lakes have the potential for winterkill. As a rule of thumb, 25% of the lake should be 17 feet or deeper in northern Wisconsin to escape winterkill. White Birch and Ballard Lakes have the potential for winterkill independent of the influence of the Irving Lake outflow. Here is a breakdown for the lakes:

White Birch:	33% is deeper than 17 feet	(marginally susceptible)
Ballard:	20% is deeper than 17 feet	(susceptible)
Irving :	0% is deeper than 17 feet	(highly susceptible)

- Irving Lake appears to be susceptible to dissolved oxygen depletion if ice cover lasts longer than 80 days, when there has been a moderate rice crop the previous summer. Oxygen depletion rates in Irving monitored at the Irving culvert indicate an oxygen depletion rate of 0.18 mg-oxygen/l/day for the both the 1998-1999 and 1999-2000 winters for the first 55 days of ice cover (Figure 32).

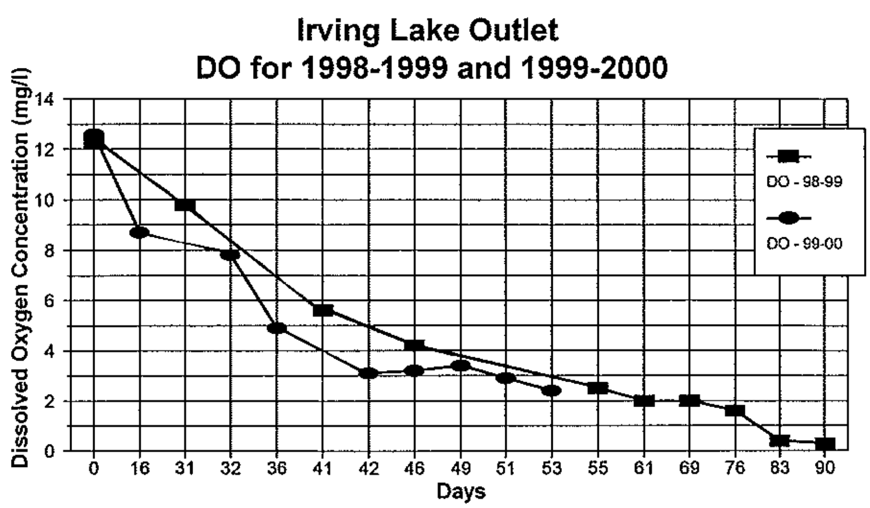


Figure 32. The first 50 days after ice-on exhibit a high DO depletion rate (0.18 mg-DO/l/day). After that, the DO depletion slows down.

5.4. Responses to Lake Usage Questionnaire

Prepared by Vicki Gillett

A lake use survey was mailed to 43 BIWBLA member households (comprising 80 individuals) and there were 35 surveys returned for a response rate of 81.4%. Three visitors also submitted a survey return. Responses are shown in the next few pages.

Wildlife viewing and fishing ranked as the most enjoyable activities on the lakes. Water quality was rated as good to excellent for Ballard and White Birch and as fair to poor for Irving with the perception that water quality has declined in Irving and remained the same in Ballard and White Birch.

The most serious lake problems mentioned by respondents varied from lake to lake. For White Birch it was split between poor fishing, water clarity, and noise. For Ballard the chief concern was shoreline development and for Irving it was wild rice.

BALLARD-IRVING-WHITE BIRCH LAKES ASSOCIATION

LAKE USAGE QUESTIONNAIRE

Summary of Responses

1. What do you enjoy most about Ballard, Irving, and/or White Birch Lakes?

(Activities are ranked from highest to lowest, with 1 being the highest rating. Numbers in each box represent how many people gave this activity the rating shown.)

BALLARD LAKE				Ratings of Activities						
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Swimming	10	6	4		4	3			1	
Fishing	15	6	5	1	1	1	1	3		
Ice Fishing			1		4		1	1	6	3
Motorized Boating	5	1	5	7	2	2	5	1		
Water Skiing	4	1	2	1	3	1	2	2	1	
Canoeing/Rowing	7	7	3	3	3	6		1		
Sailing/Windsurfing	2	1		2	4	2	6	1		1
Wildlife Viewing	9	6	7	4	2	1	1	3		
Viewing the Lake	6	5	1	4	2	1	1	3		
Other*		1		2				2	1	

*Other: Items mentioned were picnics, quietness, and low traffic.

For Ballard Lake, activities receiving the highest ratings by the greatest number of people were: Fishing (26), Wild Life Viewing (22), Swimming (20), Canoeing/Rowing (17), Viewing the Lake (12), and Motorized Boating (11).

1. Continued--What do you enjoy most about Ballard, Irving, and/or White Birch Lakes?

IRVING LAKE				Ratings of Activities						
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Swimming			2			1			2	
Fishing	10	6	4	1	1			2		1
Ice Fishing			1		1		1		1	2
Motorized Boating	5	1	5	3	1	1		1		1
Water Skiing			4			1		1	1	2
Canoeing/Rowing	6	7	3	4						
Sailing/Windsurfing			2		1	1	1			2
Wildlife Viewing	5	8	7		3					1
Viewing the Lake	4	7	6	1	1	1	1	3		1
Other*		1		2			1			

*Other: Items mentioned were quietness and low traffic.

For Irving Lake, activities receiving the highest ratings by the greatest number of people were: Fishing and Wild Life Viewing (tied at 20), Viewing the Lake (17), Canoeing/Rowing (16), and Motorized Boating (11).

WHITE BIRCH LAKE				Ratings of Activities						
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Swimming	2	1	1	1	2	3			2	1
Fishing	10	4	2	3	2	1		2		1
Ice Fishing		1					1		3	2
Motorized Boating	8	4	5	2	1			1		
Water Skiing	2	3	2			2	1	1	1	1
Canoeing/Rowing	5	4	4	3	1	1				
Sailing/Windsurfing		2			2	1	2	1		1
Wildlife Viewing	6	8	7	2			1			1
Viewing the Lake	6	7	4		2			2		1
Other*				2			1			

*Other: Items mentioned were quietness and low traffic.

For White Birch Lake, activities receiving the highest ratings by the greatest number of people were: Wild Life Viewing (21), Motorized Boating and Viewing the Lake (tied at 17), and Canoeing/Rowing (13).

Comments for item number 1. of the survey were as follows:

1 - No large motors should be allowed - no larger than 35 hp.
2 - Love the aesthetic beauty of the lake and shoreline and the tranquility of a fishing/boating lake.
3 - Swimming is not good like it was in the past due to the wild rice and the muck and sludge created by the rotting straw.
4 - Irving is not good for anything else besides fishing.
5 - I enjoy the "northwoods experience," which includes many of the enumerated items.
6 - It is a family gathering place which all can enjoy.
7 - Hard to rank as it's the total experience of the Northwoods. I don't just view the lakes; I have to be in or on them.

8 - I love the wilderness quality of our lakes.
9 - I appreciate the opportunity to see eagles, loons, otters, herons and other wildlife.
10 - I still marvel everyday at the pristine beauty that surrounds us. I hope we can keep it this way.
11 - The view is beautiful.
12 - I appreciate that at least one-half the shoreline is State forest - undeveloped - and that we don't have a large campground or big signs advertising our lakes.

2. What do you think of the current water quality?

(Water quality indicators are things such as water clarity, algae, weeds or plants, swimming conditions, fishing conditions, etc.) Numbers in each box in the charts below represent how many people gave each of the three lakes the ratings shown.

RATINGS	BALLARD	IRVING	WHITE BIRCH
EXCELLENT	7	0	9
VERY GOOD	17	2	9
GOOD	9	4	11
FAIR	3	10	0
POOR	0	15	1

3. During the time you have lived on or near the lakes, or have used the lakes, do you feel the water quality has:

RATINGS	BALLARD	IRVING	WHITE BIRCH
IMPROVED	0	0	0
REMAINED THE SAME	15	3	15
DECREASED SLIGHTLY	8	5	4
DECREASED CONSIDERABLY	1	14	0
NO OPINION OR CAN'T TELL	2	2	5

The numbers of years that people who responded to the survey have been using the lakes varied from as many as 68 years to as few as 3. A number of responders were in the range of range of 30 to 47 years of using the lakes.

4. What do you think are the most serious problems relating to the lakes?

(Items are ranked from highest to lowest, with 1 being the highest rating. Numbers in each box represent how many people gave this item the rating shown.)

BALLARD LAKE				Ratings of Activities							
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Poor fishing	1	4	2	3	1		2	2	1			
Weeds	3	3	1		1		1	2	1			
Wild rice	1	1	1	2	3	2				1		2
Algae		4		2		1	1		2	1	1	1
Water clarity		4		2		1	1		2	1	1	1
Water level	3	1			3			1	1	1		1
Shoreline development	9	3	4	2	1	1	1			1		1
Crowding on the lakes	2	6	2			2	1	1	1	3		1
Boating conflicts	2	3	3	1			1	1		4	2	1
Noise	4	2	1	5			1		1	5		1
Harassment of wildlife	1	1	3	1	3	3		1		4	1	2
Litter		1		2	3	2		1		2	2	
Other concerns*	3		1									

*Other concerns: Items mentioned were dissolved oxygen and potential for fish kill.

For Ballard Lake, items receiving a rating of 1, 2, or 3 by the greatest number of people were: Shoreline development (16), crowding (10), boating conflicts (8), and poor fishing, weeds, and noise (7 each).

IRVING LAKE				Ratings of Activities								
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Poor fishing	1	2	3	1	3	1	1	1			1	
Weeds	4	5	3	1	1							
Wild rice	22	2	1									
Algae	2	3	1	1	1		1			1		
Water clarity	4	4	5	4	2							
Water level	1		3		1	3	1		2	1		
Shoreline development	1			1						4	2	
Crowding on the lakes			1							4		3
Boating conflicts		1		1		1	2	1		4		
Noise		1		1				2	2	3		
Harassment of wildlife			1	3	2	2		2		3	1	
Litter			1		3		1	2		3		
Other concerns*	2		1									

Other concerns*

For Irving Lake, items receiving a rating of 1, 2, or 3 by the greatest number of people were: Wild rice (25), water clarity (13), weeds (12), and poor fishing and algae (6 each).

4. Continued--What do you think are the most serious problems relating to the lakes?

WHITE BIRCH LAKE				Ratings of Activities								
Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Poor fishing	3	3	4		1	1		1				
Weeds	2	1	1				1	2	1	1		
Wild rice			1			2				2	1	2
Algae		2	1	2			1		1	2	1	
Water clarity	2	3	3	2	1				1	2		1
Water level	4	1			2	1			3	1		
Shoreline development			1	3			2			3		1
Crowding on the lakes	4	1		4			2			3		1
Boating conflicts	1	4			1			1	1	3		1
Noise		2	5							4		1
Harassment of wildlife		1	3	4			1	1		4		1
Litter			2	1	4	1				1	2	
Other concerns*	2		1									

*Other concerns: no specific items were mentioned for White Birch.

For White Birch Lake, items receiving a rating of 1, 2, or 3 by the greatest number of people were: Poor fishing (10), water clarity (8), noise (7), and water level, crowding, and boating conflicts, (the last three each receiving a rating of 5).

Comments received for item 4. were as follows:

1. As long as we can continue to keep the lakes as they are and work to improve water quality in Irving, I don't think many of these problems apply to us.
2. Cut down at least 1/3 of the wild rice in Irving.
3. Wild rice on Irving can prove to be a really serious problem. Shoreline development has the potential of being a serious problem on Ballard.
4. Fishermen up to dock - talking loud.
5. Water level too high this year. My shoreline has been affected.
6. The water level this year in Ballard was way too high. High water level causes shore erosion much faster than anything else. Lake association should stop raising the water level and let nature take its course.
7. We watched skiers out one day - they sort of ran all the fishermen off the lake. However, compared to other lakes (I.e. Minocqua, Plum) not significant.
8. The fishing is improving on Ballard and Irving; however, I have a concern that this will bring higher boat traffic with the potential for conflicts and disregard for wildlife - especially the loons.

5. Where does the lake experience fit into your personal priorities?

Level of Priority		No. of Responses
HIGH Priority		28
MEDIUM Priority		0
LOW Priority		0

6. Do you think individuals have an impact on lake water quality? (either positively or negatively)

"YES" RESPONSES	27	"NO" RESPONSES	2

7. Of the following, which do you think are most responsible for protecting and improving the lakes?

	FIRST	SECOND	THIRD
A. Federal Government			1
B. State Government	15	2	2
C. County Government	2	6	5
D. Local Govt./Plum Lake Township	1	6	9
E. Lake Association	6	10	6
F. Individual Lake Property Owners	7	6	5
G. General Public		4	6
H. All of the above (equally)	6	1	2
I. Other (specify)*	1		

* Other: All should work together and be open to new information (can't always be equal). Not sure how much any of the government agencies really care about improving it or even really know how. Most equitable partnership possible.

8. Of the following, which do you think are most responsible for PAYING for the protection and improvement of the lakes?

	FIRST	SECOND	THIRD
A. Federal Government		1	
B. State Government	21		2
C. County Government	2	16	
D. Local Govt./Plum Lake Township	2	6	12
E. Lake Association	2	4	4
F. Individual Lake Property Owners	2	4	4
G. General Public		1	7
H. All of the above (equally)	3		2
I. Other (specify)*			

Comments:

County and local governments do not have the finances to pay for this.
Do what we have been doing for 60 years - let nature take its course.
Most equitable partnership possible.
All work together - each contributing what is possible.
No opinion.

9. What specific things would you like to see changed or improved in one or all of the three lakes? (Comments compiled from all survey participants.)

- Muck removal in Irving Lake.
- Eradicate rice on Irving.
- For Lake Irving, limit the amount of wild rice and weeds and lily pads covering the surface area to a maximum of 20%
- Get rid of wild rice in Irving and Ballard. Outlaw "ski-do's" (PWC). Improve water clarity in all three lakes.
- Control of rice.
- Quieter boat activity around Ballard in the evenings.
- Eradicate wild rice!
- These 3 lakes are some of the most pristine in the county. Selfishly, I would like to see them remain that way without more lakeshore development and with continued protection for fishing, wildlife, and water quality. I don't think we can rely on any government agencies to do that - it will have to be done by constant vigilance of local residents.
- I would like to see some of the muck removed from Irving Lake.
- Limit size of outboard motors to 90 HP.
- Irving - get rid of some of the rice.
- Cut down at least 1/3 of the wild rice in Irving.
- Wild rice in Irving eliminated.
- Water quality.
- Education of lake property owners and users regarding their impact on the lakes in all areas addressed by the Planning Grant Project teams.
- More education for property owners on the importance of caring for lakes - this is extremely important!
- First, get rid of the wild rice, and never again introduce any non-native plant or aquatic form of life on any of the lakes.
- Let things alone. No more misguided tampering. The DNR should return trash containers to all boat landings. Since the removal of the trash containers, a lot more trash (beer cans, etc.) is being dropped in the lakes.
- Ban jet skis and the like. Initiate campaign to protect loons on the lakes. Restrict boats pulling water skiers to certain hours.
- Find a way to keep Irving from freezing out.
- Irving - eliminate source of Ballard's problem - get rid of the wild rice.
- Weed control. Wild rice control - Irving/Ballard.
- Wild rice (Irving) erradication. Shoreline zone enforced. No jet skis (not a problem yet).
- Control wild rice in Irving.
- Consider special ordinance for lakefront lot size (i.e. 250 ft.). Consider special ordinance for aquaplaning (waterskiing, tubing, etc. and PWC's to hours of 11:00 a.m. to 7:00 p.m.
- Continue to monitor/test and aerate lakes as needed. If evidence points to wild rice issue, pursue DNR to reduce its impact. Add fish if needed.
- Ballard - lake level.
- All lakes: quality and quantity of fish. Ballard: quantity of houses built along shoreline and inland.
- Water quality in Irving and parts of Ballard. More cooperation with local zoning regulations regarding new construction, shoreline restoration or maintenance, and evaluation of old/outdated septic systems.
- I saw a big pontoon boat motoring down the creek to the Ballard boat landing - really churned it up. Seemed too big for the creek. I'd like to see a motor limit on our chain (I.e. to prevent big motors and no jet skis allowed).
- Ballard - horsepower restrictions on motor boats. Jet skis prohibited. Irving - wild rice management.
- Rice and weeds in Irving should be kept in check.

9. Continued--What specific things would you like to see changed or improved in one or all of the three lakes?

- Entry to Irving should be a channel, not a sewer. Remove some of wild rice from Irving. Stock more fish in White Birch.
- Iron in water?
- Please don't make too many changes. It's wonderful as it is, and in many ways it looks the same (shoreline, water quality) as it did decades ago. I think that's what I like most. But I applaud the efforts made to beautify white Birch.
- Deeper channels between lakes.

10. Are you a property owner on one of the lakes or in the watershed area, or are you a visitor who uses the lakes?

Property Owners	31	Visitors	5

11. Do you have any other comments or suggestions?

- BIWBLA is doing a fantastic job.
- Who knows what the future holds after all the Rismon's properties are sold?
- Keep up the BIWBLA! Focus on education of lake property owners and users as to their impact on the lakes in all areas addressed by the Planning Grant Project Teams.
- The State claims ownership of the lakes and uses the DNR to take care of them. Let them do a better job of what they already control before they buy more land.
- Thank you to the Lake Association!
- Thanks for all the hard work on the BIWBLA.
- I hope that through our lakes association, we as property owners will continue the work we've started to improve and preserve these lakes for future generations.

6. Lake Project Ideas for Protecting Water Quality and Wildlife

6.1. Watershed stewardship

- Protecting the natural character of the watershed helps maintain good runoff water quality.
- Other watershed topics include:
  - Maintaining the hiking trails around the lakes helps residents to enjoy the north woods environment.
  - Continue working with wildlife managers to control beaver dam construction in the Irving Lake outlet culvert.
  - Educating new water front property owners on the value of shoreline habitat and good landscaping practice.

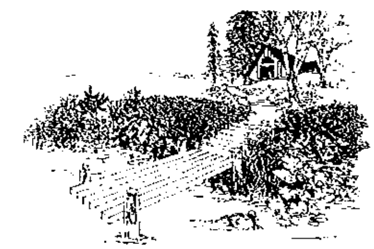
6.2. Shoreland protection

prepared by: Tiffany Lyden

Controls are in place at the county level to guide new shoreland development. Shoreland development guidelines are shown on the next several pages.

Ballard, Irving, and White Birch Lakes

Lake Classification Zoning Summary



The following is a summary of the new Vilas County Shoreland Zoning Ordinance adopted in May 1999. The ordinance includes a new classification system for lakes and streams. Lake classification is a way of grouping lakes into separate classes based on their sensitivity to development impacts, while recognizing existing levels of development.

*For more complete information on the county ordinance, contact the Vilas County Zoning office at (715) 479-3620. A full copy of the Vilas County General and Shoreland Zoning Ordinance is available for $10 through the Zoning office, or on the Internet at **www.uwex.edu/ces/cty/vilas/lakes/zoning**. (Some towns may have local ordinances that are more restrictive than these county provisions. Contact the town for more information on local ordinances.)*

How are Ballard, Irving, and White Birch Lakes Classified?

The criteria used to rate lakes for sensitivity to development impacts included lake surface area, shoreline shape, a flushing index, a stratification factor, and a soil development factor. Relative levels of current development on lakes over 50 acres were determined using Vilas County's computerized geographic information system. The number of visible structures mapped from 1996 aerial photos was calculated per mile of privately owned shoreline for each lake.

	Ballard	Irving	White Birch
Lake Sensitivity:	low	low	medium
Lake Development Level:	medium	low	high
Lake Size:	505 Acres	403 Acres	117 Acres

Many of the following zoning standards are tailored according to the lake's classification.

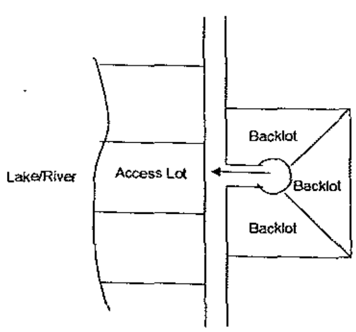
Lot Sizes for Newly Created Lots:

Lot size standards control the density of new development. Larger lot size requirements reduce the density of development along the shoreline in order to reduce the potential for negative impacts.

Minimum Frontage: **150 ft.**

Minimum Lot Area: **30000 sq. ft.**

(These minimum lot standards do not apply to pre-existing lots that were already recorded or filed before May 1, 1999)



Keyholing:

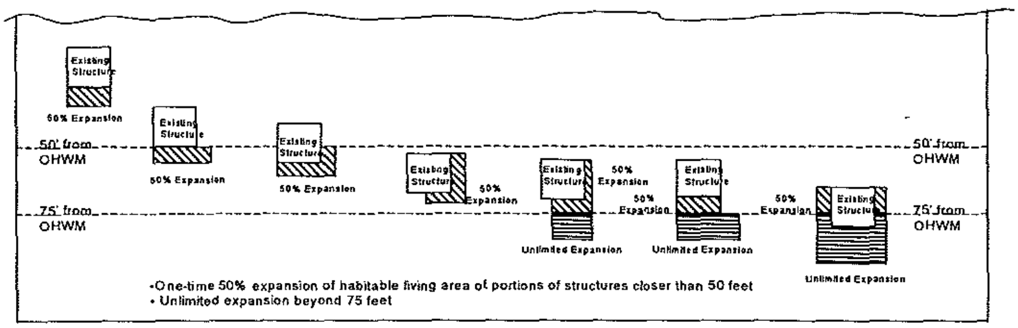
Keyhole development is when one shoreline lot serves as waterfront access for backlot developments. Vilas County prohibits new keyhole accesses on lakes less than 100 acres in size, on Class I rivers and streams, and in all areas zoned Single Family Residential (R-1). Where allowed, keyhole accesses are limited to a maximum of three units on the backlot(s).

Keyholing allowed on Ballard, Irving, & White Birch Lakes? yes

Keyhole access lots must meet the minimum lot width and area requirements for newly created lots. See zoning ordinance language for additional requirements.

Expansion of Existing Structures Closer than 75 Feet from the OHWM:

Structures that are located closer than 75 feet from the Ordinary High Water Mark (OHWM) have a higher potential impact on the water quality of a lake or river than structures that are located farther from the OHWM. Vilas County provides for a one-time 50% expansion of the portions of a principle structure located closer than 75 feet from the Ordinary High Water Mark (OHWM). For portions of structures closer than 50 feet from the OHWM, only rearward expansions are permitted. For portions of structures beyond 50 feet from the OHWM, rear, side and vertical expansions are allowed.



Septic System Stewardship:

New septic system requirements were driven by general lake water quality concerns over the pollution of surface waters resulting from failing older systems, and public health and safety concerns over direct pollution of groundwater from older systems due to lack of the three-foot groundwater separation. The intent is to gradually increase the number of properly constructed and functioning systems with new requirements that apply at the time of a zoning permit or property transfer.

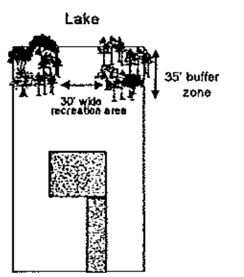
Requirements	Zoning Permit for an addition **less** than 150 ft^2 to a Dwelling Unit	Zoning Permit for an addition **greater** than 150 ft^2 to a Dwelling Unit	Property Transfer
Participate in 3-year Maintenance Program	X	X	X
Verify system is properly functioning		X	
Verify that the bottom of the drainfield is at least 3 feet above high groundwater		X	X

Note: If a septic system has been installed since 1980, the property should be already participating in the Three Year Maintenance Program, and the three foot vertical separation should have already been met.

Mitigation:

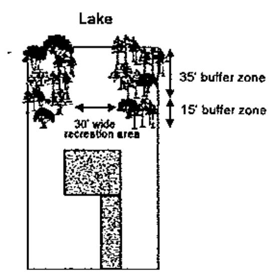
Mitigation is required whenever a property owner requests a zoning permit for construction involving more than 300 sq. ft. within 300 feet of the Ordinary High Water Mark. Different mitigation points are required for different lakes depending on the sensitivity and development level. Property owners choose mitigation options to reach the required number of points.

Mitigation points required: **Ballard & Irving = 4 points** **White Birch = 5 points**



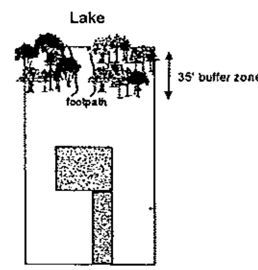
3 Points

Existence of 0-35 foot buffer zone in natural vegetative state. (Trees, shrubbery and underbrush.)



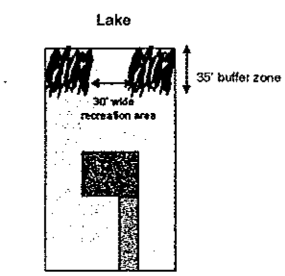
2 Additional Points

Existence of additional 15 foot buffer zone in depth beyond the 35 foot buffer zone (Trees, shrubbery and underbrush.)



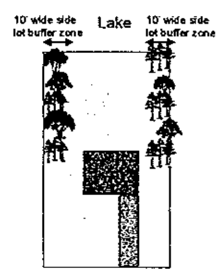
2 Additional Points

Return recreation area to natural vegetative area leaving only a footpath in the buffer area.



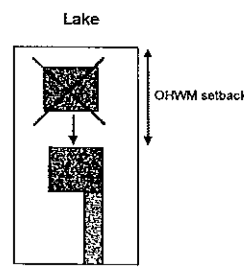
2 Points

Return mowed grass lawn/kept yard to unmowed/unkept grassy area between 0-35 ft.



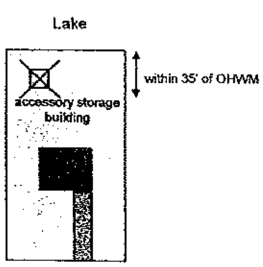
1 Point per sidelot

Existence of a 10 foot buffer zone to side lot line for depth of 100 feet from OHWM.
(1 point for each sidelot buffer.)



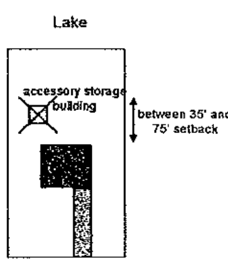
3 Points

Relocation of a principle structure located within 75' of the OHWM to the OHWM setback.



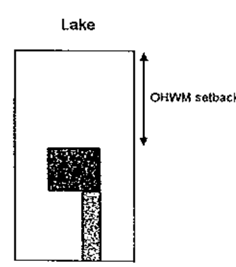
2 Points

Removal of all accessory storage buildings within 35 feet of OHWM.



1 Point

Removal of all accessory storage buildings between 35' and 75' from the OHWM.



1 Point

No accessory structures within the OHWM setback (not additive to removal).

Boathouses:

Large boathouses located very close to the shoreline have the greatest potential water quality impacts of any structures. Vilas County limits new boathouses on small lakes and rivers to marine-related equipments sheds, but allows larger boathouses on lakes over 100 acres.

Maximum Size for Boathouse/ Marine-Related Equipment Shed = **300 sq. ft.**

Shoreline Recreation Area:

Natural shoreline vegetative buffer zones are very important to maintain lake water quality, provide wildlife and fish habitat, prevent soil erosion and provide natural scenic beauty. Vilas County limits the removal of trees, shrubs and other natural vegetation to a shoreline recreational area no larger than 30 feet in width along the shoreline, extending 35 feet in depth from the OHWM.

Within this recreation area, no clearcutting is allowed. Select cutting of trees and shrubbery is permitted if such an area does not exist naturally.

Land Disturbance:

Removal of vegetative cover through land disturbing activities such as construction, filling, grading or excavating, exposes bare soils to erosion which can result in increased nutrient and sediment loading to the lake. A Shoreland Alteration Permit is required for land disturbance activities exceeding:

400 square feet between **35 and 75** feet from the OHWM
750 square feet between **75 and 300** feet from the OHWM
(unless the activity already requires a zoning or sanitary permit)

Impervious Areas:

Impervious surfaces are any surfaces that impede the infiltration of water - structures, decks, driveways, or walkways (including compacted gravel). Impervious surfaces result in increased volumes of runoff which can carry nutrients, sediments and other pollutants to lakes and streams.

For single-family residential lots, the maximum area of impervious surfaces cannot exceed:
15% of the lot area within **300 feet** of the OHWM **or 4,000 square feet,** whichever is greater (unless a Stormwater Management Plan is approved)

Summary provided by the Vilas County Land, Air, and Water Conservation Department - 5/99.
Contact Tiffany Lyden, Vilas County Lake Conservation Specialist, at (715)479-3648, for questions.

6.3. Aquatic plant management

A high priority lake protection approach is to maintain a robust native aquatic plant community in all three lakes. Currently, all three lakes have aquatic plant growth covering over 60% of the lake bottom. Aquatic plants are primarily of the submerged variety in White Birch and Ballard and are emergent in Irving Lake. In all three lakes, the aquatic plants are vital for helping sustain clear water conditions and contribute importantly to fish habitat.

Wild Rice Topics

Wild rice is one of the emergent plants in Irving Lake and is found in the channel and mouth of Ballard Lake. Pickerel plants are another emergent plant and water lilies are a common floating-leaf plant in these same areas.

Because of the shallow conditions in Irving Lake, there will likely always be some type of aquatic plant growth. If wild rice was not growing in Irving Lake, some other plant species covering the bottom would undoubtedly be present. When aquatic plants do not maintain their dominance, then algae blooms can become more severe.

Findings in this study indicate wild rice does not have a long term adverse impact on water quality in downstream lakes, and does not have an adverse impact on Irving Lake water quality. This is based on trends from historical water quality data collected before wild rice was documented in Irving Lake and from data collected since 1998. Wild rice probably exerts a higher oxygen demand in Irving Lake compared to a lake without rice over winter when decomposition is occurring. However because Irving Lake is so shallow, it would likely experience winterkill conditions in most years even if wild rice was not present. Aerating the Irving Lake outflow helps reaerate the water that flows into Ballard Lake and should prevent future winterkill occurrences in Ballard and White Birch Lakes.

The wild rice has significant beneficial attributes for wildlife and fish in Irving and in Ballard Lakes. The perceived adverse aspects are the hindrance to whole lake navigational use in Irving Lake.

However, navigation and fishing can still occur in Irving Lake. Because wild rice has a 4-year cycle with abundant growth in only one out of the four years, it is that "boom" year that makes navigation challenging and even then only when wild rice gets to the emergent stage which is toward the end of the summer.

A number of plant control options were considered, but the only aquatic plant control option recommended is to consider cutting an 8-foot wide navigational channel from residences to the Irving outlet and this would only be necessary in "boom" years. Cutting could be conducted using a boat-towed bottom cutter when rice is at the sub-aerial stage. Permits would be needed from the WDNR and Great Lake Indian Fish and Wildlife Commission (GLIFWC). Because wild rice is a protected plant species it is unlikely that anything more than a navigational route would be permitted.

Wild rice projects evaluated but not recommended: Several wild rice options were evaluated but not recommended. It turns out that a major wild rice control program would be expensive, environmentally damaging impacting the fish resources among other things, with no guarantee that control would be accomplished. Three options that were considered but not recommended are described below:

- Herbicide control on a lake-wide basis: A herbicide control project would need at least three consecutive years of treatment to deplete the rice seedbank. This is not an ecologically sound approach for fish and wildlife habitat and is not an acceptable project to the WDNR and GLFWC. Total cost: $360,000 based on $400/ac for herbicide treatment x 300 ac x 3 years.
- Mechanical harvesting on a lake-wide basis: Harvesting would cause an increase in turbidity with no guarantee it would give lasting control. A 3-year program would be the minimum in order to deplete the viable rice seed in the seedbank. A harvester would only cut 2 to 3 acres per day meaning it would have to be on the lake for over 100 days (most of the summer) to cut the wild rice. This would be noisy and a constant source of sediment resuspension. Total cost: $450,000, based on $500/ac for harvesting x 300 ac x 3 years. Total cost would be less if the Association purchased and operated the harvester.
- Water level manipulation: A water level control structure could be placed in the culvert between Irving and Ballard Lakes. However, a control structure would prevent fish movement from Irving to Ballard. The structure also would prevent boats from moving back and forth through the culvert. A dam permit from the WDNR would be needed for any structure placed in the Irving outlet culvert. Water level controls are, in effect, a dam and are difficult to get permitted these days. Several legal questions to be addressed include: who owns the property, who would own the dam, who would pay for it, who would be responsible for the liability, who would prepare the operation plan, and who would operate the dam. It is assumed the WDNR would not authorize an operational plan that was detrimental to the Irving Lake rice beds.

6.4. Fish management and Winter Aeration

Fish Management

Fishery management will continue to be focused on muskie and walleye as in years past. Future stocking plans will be based on a comprehensive fishery assessment that the WDNR plans to begin in the spring of 2003, and continue throughout the 2003 gamefishing season. In addition to stocking, this assessment will involve fyke netting, fin clipping, and angler harvest surveys. In the meantime, the WDNR will continue with its annual survey shocking of Ballard and White Birch to build up its data base for interim guidance to the Association.

During the past year, the Association established the Dr. Carl J. Heitz Memorial Fund, to help fund future fish stocking. The stocking plan will be recommended by the WDNR as the most appropriate for the Chain based on the results of its detailed assessment of the Chain's fishery with focus on walleye and muskie.

Winter Aeration

The fisheries in Ballard and White Birch were sustained during the winter of 1996-97 with the help of a temporary cascading aerator installed in the Ballard-Irving thoroughfare. The purpose of this aerator was to oxygenate oxygen deficient water flow from Irving into Ballard. The project was successful in that DO levels increased in the East End of Ballard while the aerator was in operation. In the winter of 1997-98, a permanent, but mobile, cascading aerator was installed in the same location though the cooperative efforts of the WDNR, the Town of Plum Lake, and the Ballard-Irving-White Birch Lakes Association (Figure 33).

The aerator continues to be deployed and maintained by the Town of Plum Lake, with the time of deployment triggered by a drop in the DO level of Irving outflow to three parts per million as measured at the Ballard-Irving culvert. Of present concern is the fact that the aerator does not provide oxygenation of Irving Lake, which is likely to suffer DO depletion on an annual basis with the degree of depletion directing dependent in the severity of the winter.

This DO depletion is due to Irving Lake's shallow nature, fertile sediments and tendency toward the profuse growth and subsequent decay of rooted aquatic plants.

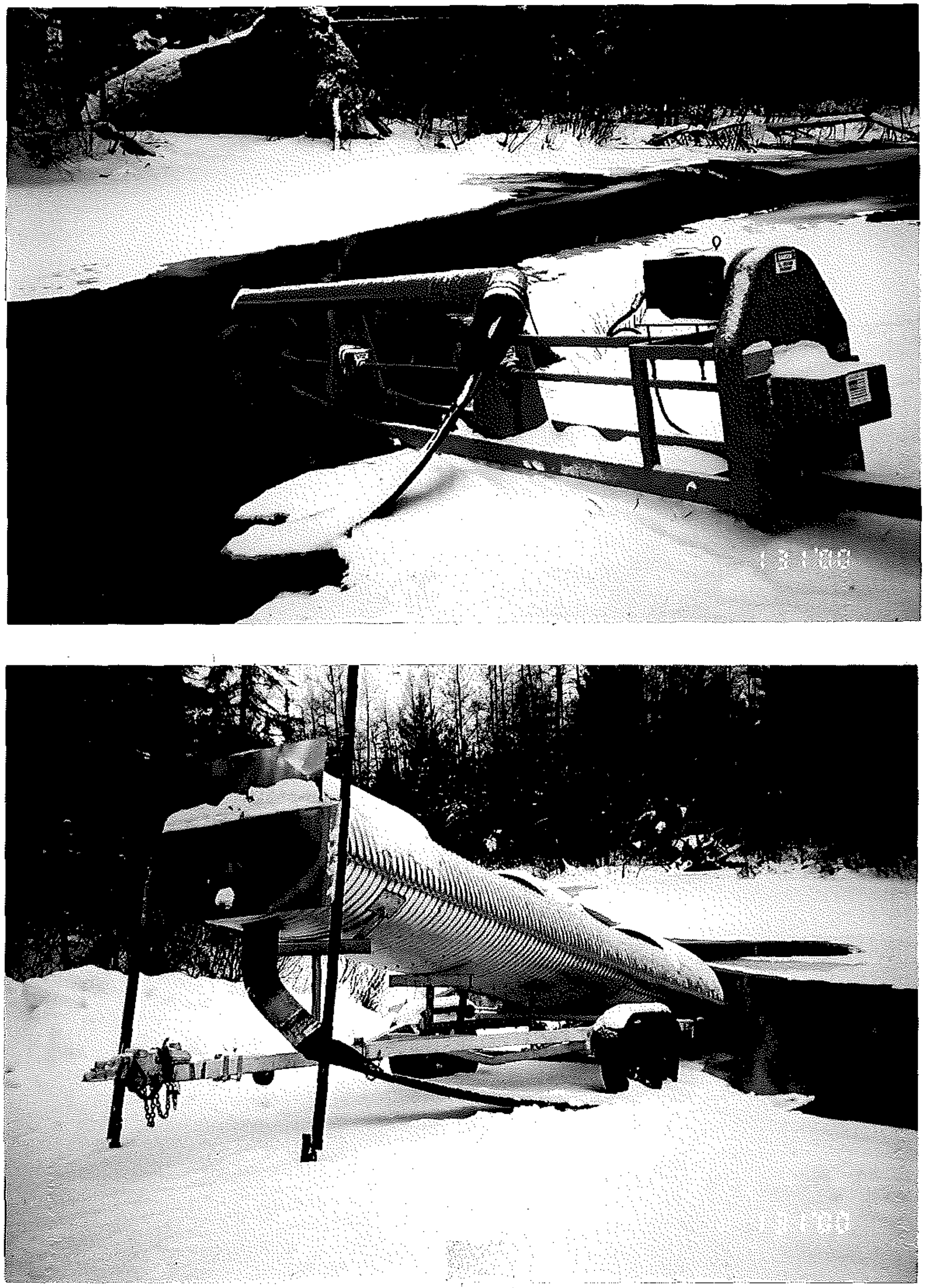
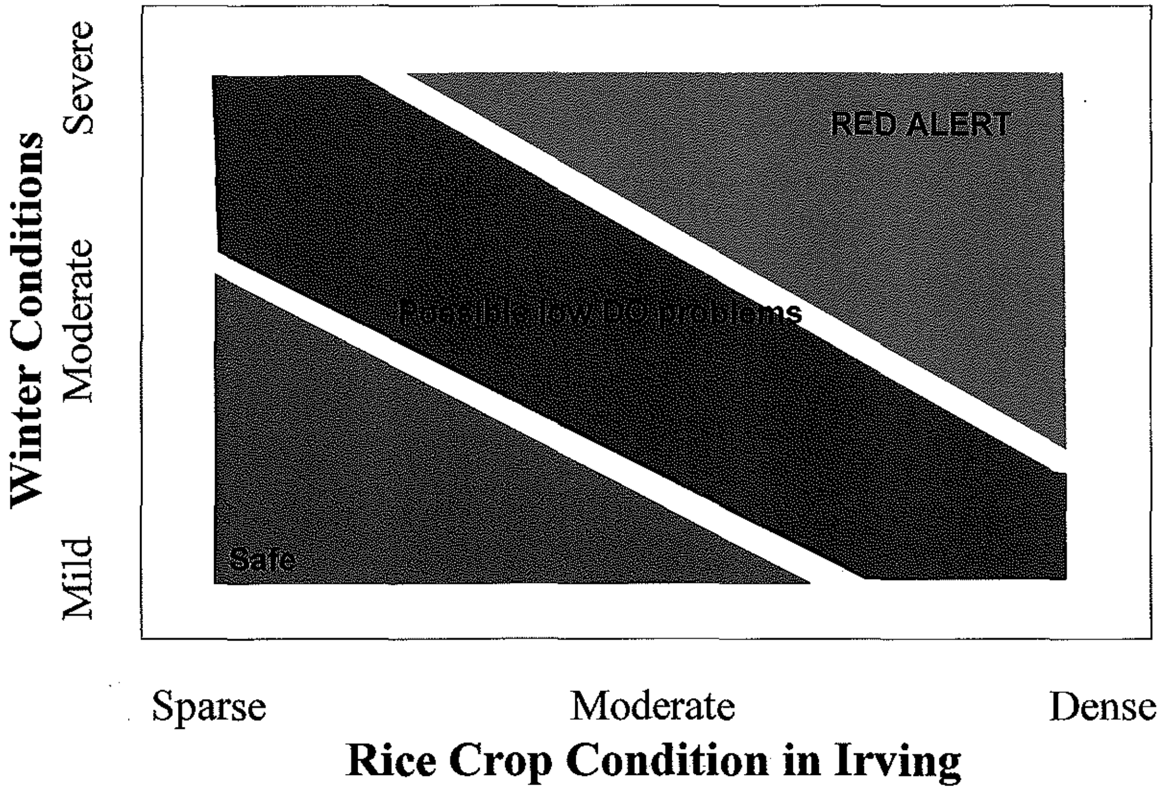


Figure 33. The winter cascading aerator used to re-oxygenate the outflow from Irving Lake as it enters Ballard Lake.

Winter Aeration Tracking Chart



KEY:

Winter conditions

mild winter: lake ice around November 25, snow pack less than 8 inches in mid January. Less than 50 days of ice cover in channel.

moderate winter: lake ice by mid November, snow pack less than 16 inches in mid January. Between 50-100 days of ice cover in channel.

severe winter: lake ice by early November, snow pack greater than 16 inches. More than 100 days of ice cover in channel.

Rice crop conditions

sparse crop: boat travel is easy in Irving, 50% open areas.

moderate crop: a common condition, boat travel occurs but typically will follow channels and openings in the rice beds.

dense crop: few travel channels for boats, low fishing pressure due to heavy rice, occurs about 1 out of 4 years.

Figure 34. The need for winter aeration at the Irving outlet based on winter conditions and on the previous season's rice crop.

6.5. Lake Monitoring Program

A lake monitoring program is outlined in Table 16. It is designed to be flexible to accommodate the volunteer work force and a fluctuating budget.

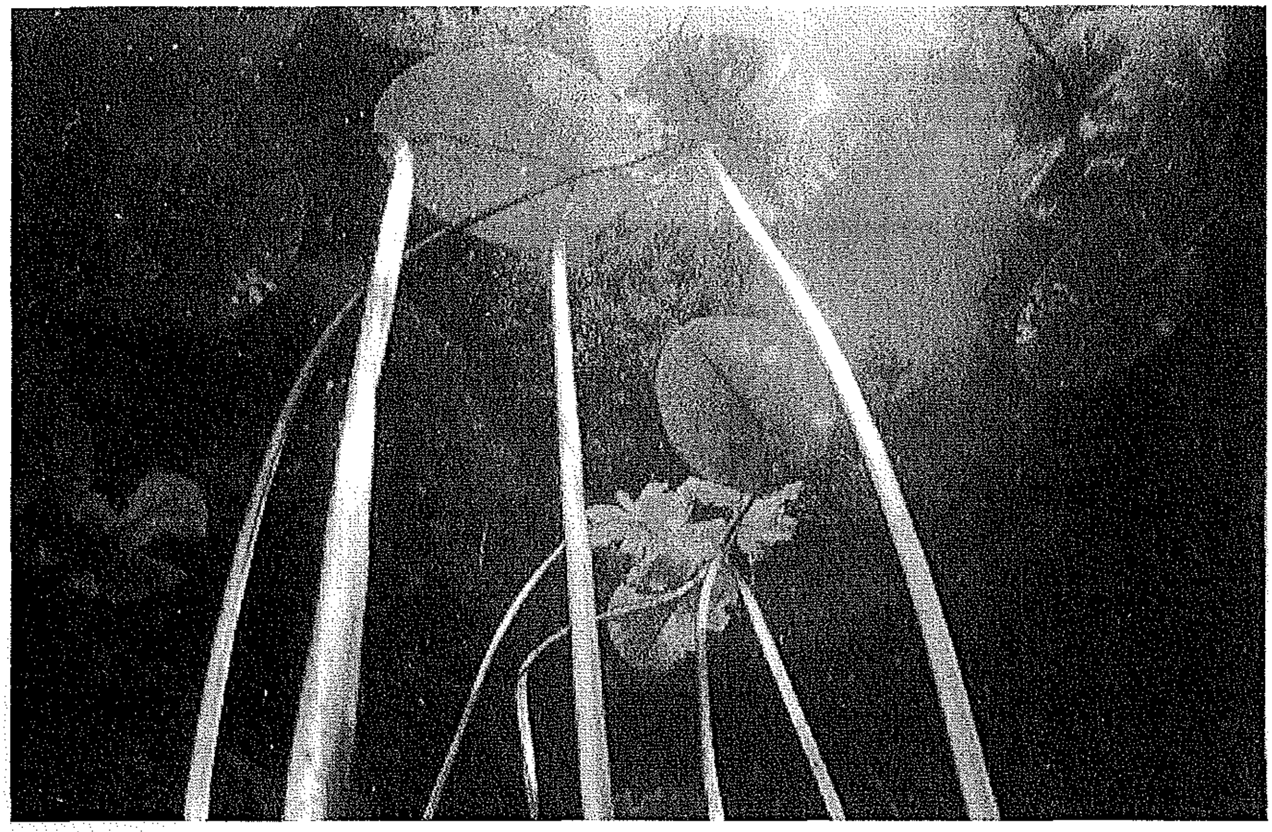
Table 16. BIWB Water Quality Monitoring Program

Category	Level	Alternative	Labor Needed	Cost/Year
A. Dissolved oxygen	1	Check dissolved oxygen at Irving outlet every one to two weeks in December, January, February, and March depending on winter conditions.	Moderate	$0
	2	Check dissolved oxygen at Irving outlet and White Birch outlet every one to two weeks in December, January, February, and March, depending on winter conditions.	Moderate	$0
	3	Check dissolved oxygen in several locations around Irving, Ballard, and White Birch Lakes in December, January, February, and March.	Moderate to high	$0
	4	Collect dissolved oxygen and temperature profiles in all three lakes, once or twice a month from May-September.	Moderate	$0
B. Water clarity	1	Secchi disc taken at spring and fall turnover.	Low	$0
	2	Secchi disc monitoring once per month May - October for all three lakes.	Low-moderate	$0
	3	Secchi disc monitoring twice per month, May - October for all three lakes.	Moderate	$0
C. Water chemistry	1	Spring and fall turnover samples from all three lakes are collected and sent to UW-Stevens Point. Selected parameters for analysis include: TP and chlorophyll.	Low	$200
	2	Spring and fall turnover samples from all three lakes are collected and sent to UW-Steven Point. Standard package of parameters is analyzed.	Low	$600
	3	Sample all three lakes for phosphorus and chlorophyll once per month from May - September (surface water only).	Low-moderate	$300
	4	Sample all three lakes for phosphorus and chlorophyll twice per month from May - October.	Moderate	$600
	5	Sample all three lakes for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N once per month (May-October)	Moderate	$960
	6	Sample all three lakes for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N twice per month (May-October).	Moderate	$1,920
D. Special samples	1	Special samples: suspended solids, BOD, chloride, turbidity, sampling bottom water, and other parameters as appropriate.	--	$50+

UW-Stevens Point Lab Analysis Costs:

Total phosphorus	$12.00	Total suspended solids	$8.00
Chlorophyll a	$20.00	Total volatile solids	$8.00
Kjeldahl-N	$12.00	Dissolved solids	$8.00
Nitrate/Nitrite-N	$10.00	Turbidity	$6.00
Ammonia-N	$10.00	BOD	$20.00

For 2001, a recommended program consists of Levels A1, B2, and C3.



Steve McComas: *Ballard Lake's Lilies and Trees*, 1999

White Birch-Ballard-Irving Lakes Vilas County, Wisconsin Lake Management Plan

2000

APPENDIX

Prepared by
Steve McComas
Blue Water Science

with significant contributions from Ballard-Irving-White Birch Lakes Association, Inc. and Wisconsin Department of Natural Resources

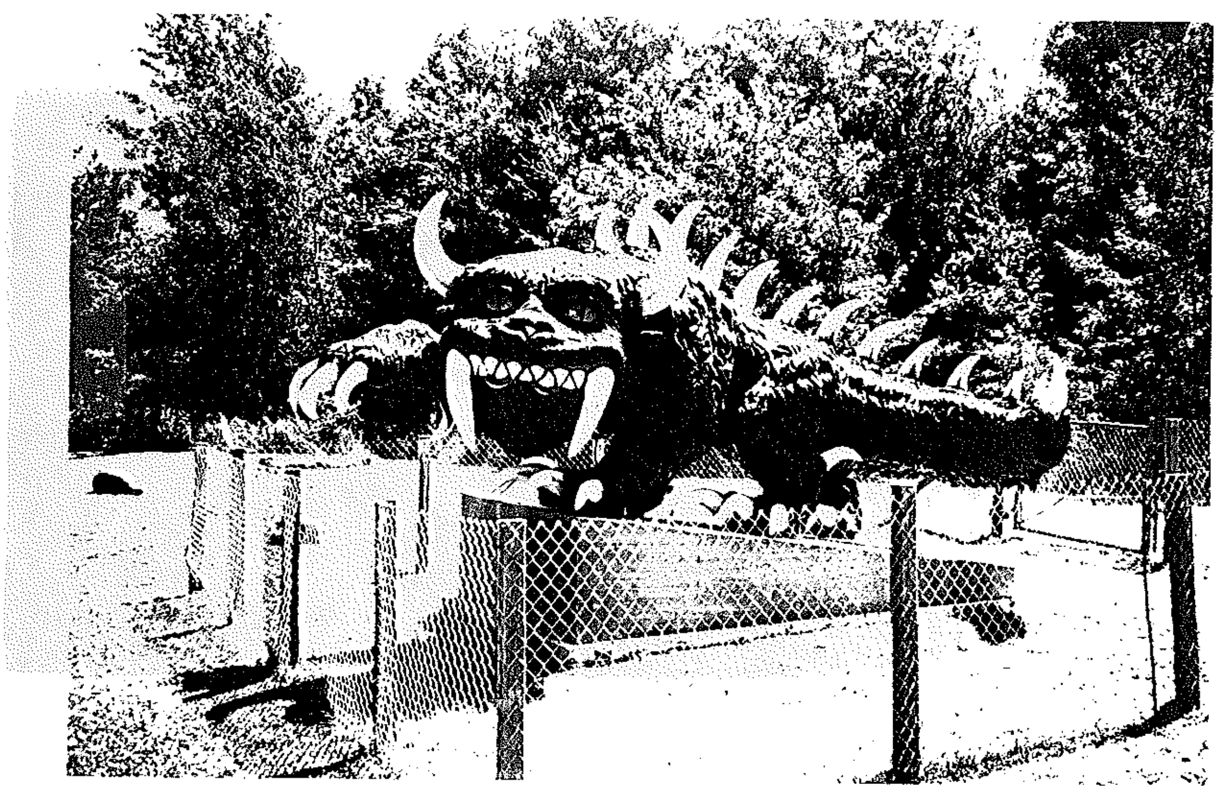
Technical Appendix

White Birch-Ballard-Irving Lakes
Technical Appendix

1. Introduction

This Appendix contains detailed materials that are included here so as not to impede the flow of the main body of the report.

Note that the Shoreland Inventory that is listed Appendix 5.0 has been provided to the WDNR and BIWBLA for their files. It has not been included for widespread distribution.

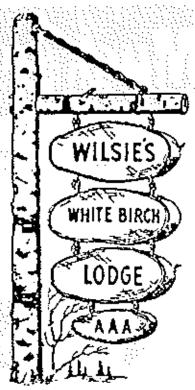


2. Historical Setting

2.1. More historical information

Ballard Lake about 1935

WILSIE'S WHITE BIRCH LODGE
O-FISH-ALL HEADQUARTERS



"The Sign of Hospitality"

FOR 1960 PRESENTS

MORE FISH AND BETTER FISHING *and*

"The 1959 Fish Review"

OHIO, ILLINOIS and WISCONSIN FISHERMEN

"HIT THE JACKPOT"

May 15th, Wilsie's White Birch Lodge, Boulder Junction

Brooks and Browns for Breakfast

MAY 1st at
BOULDER JUNCTION, WIS.

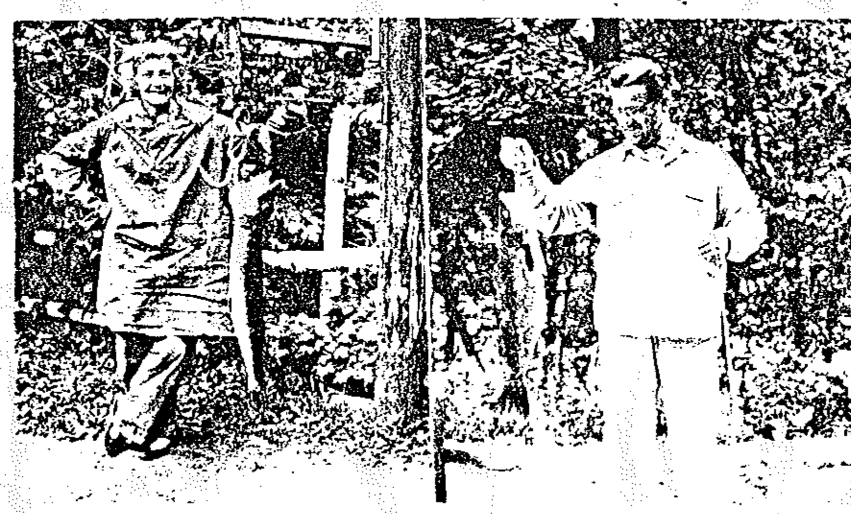
PLUM CREEK PRODUCES AGAIN—

Left home at 5:00 a.m. Arrived at Creek at 5:30 a.m. Fished for two hours. Returned home at 8:00 a.m. Everyone had his limit of Brooks and Browns. Breakfast at 8:30 a.m. What a feast . . . nothing like Trout for breakfast.

Great Northern Pike make real sporty fishing. We have fine catches and some real beauties caught in early May and June in our hundreds of acres of Northern Pike Waters. Some of the better lakes for early fishing are Star Lake, Helen Lake, Twin Island and Big St. Germain, and our Guides know where they are hitting best.

THE EARLY BIRDS CATCH THE WALLEYES

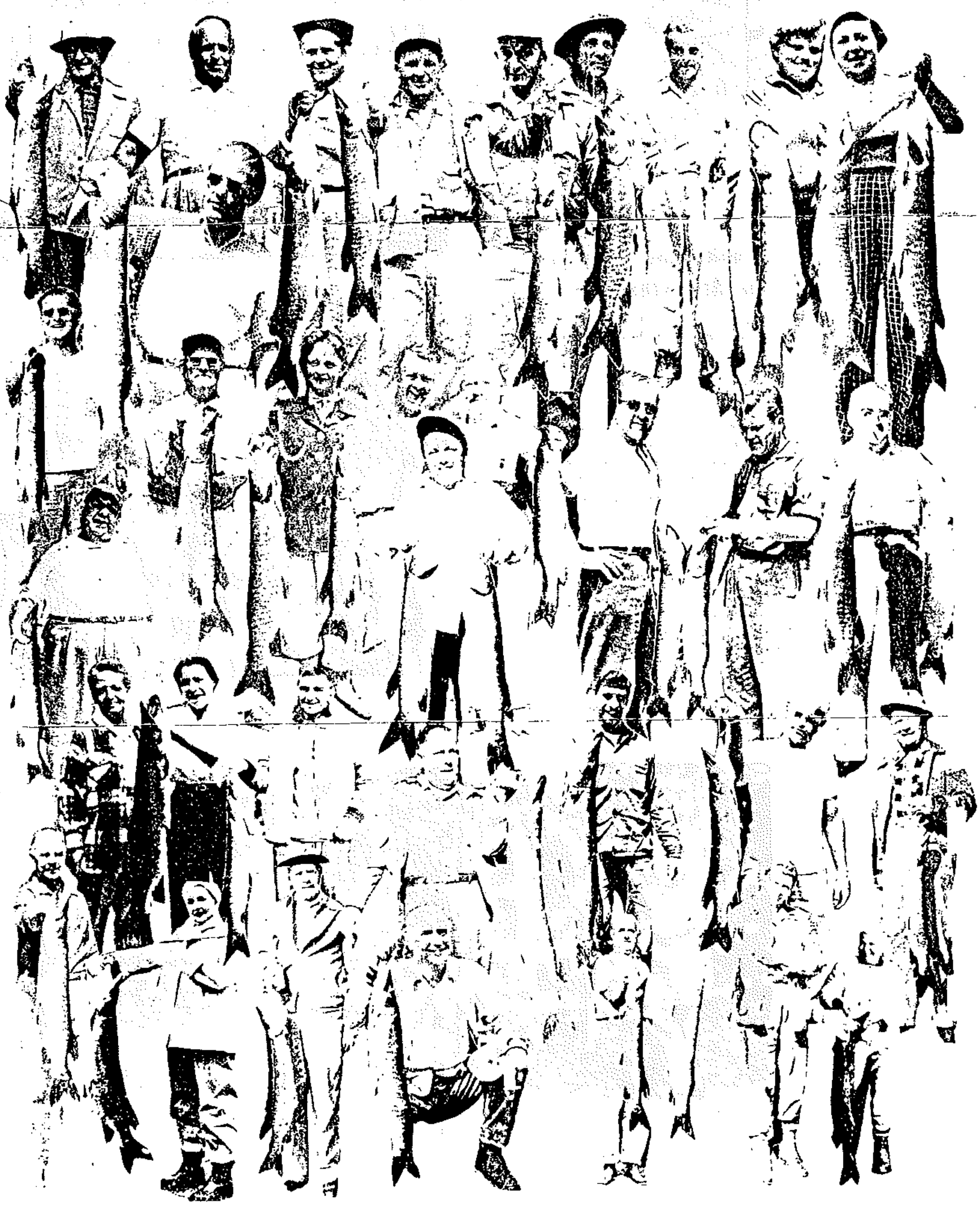
History Repeats Itself . . . As usual the first few weeks after the season opens, our Fishermen get beautiful catches of Walleyes.



This beauty (shown in photo at left) was taken from Star Lake. Lakes producing these catches (shown in

The 1959 Parade of Muskies

This lasted all season . . . May, June, July, August, September, October, November, musky fishing months at Wilsie's White Birch Lodge. The first Musky of the season was caught at 7:00 a.m. May 25th. The last Musky of the season was caught 3:51 p.m. November 7th.



Preliminary Report on Sediment Core Work at Irving Lake, Vilas County, WI

Paul J Garrison
Wisconsin Department of Natural Resources
December 2000

This report is a summary of the work done through early December, 2000 on the sediment cores extracted from Irving Lake, Vilas County during the summer of 1999. The purpose of this study was to reconstruct the history of aquatic plants, esp. wild rice, in the lake and to determine water quality changes that have occurred during the last 200 plus years. This analysis was done by analyzing terrestrial and aquatic plant pollen, the diatom community, geochemical variables, and sedimentation rate.

At the present time, Irving Lake has a large population of wild rice (*Zizania aquatica*). This is thought to have been absent from the lake until the last 40 years. A sediment core taken from the lake supports this. Pollen from wild rice was not found until 1960 (Figure 1). This does not necessarily mean that rice was not present in the lake prior to this time for two reasons. Only 3 samples older than this date have been analyzed so far. Also if rice was present in low numbers this technique might not detect its presence. It is clear that since 1960 the amount of rice in Irving Lake has increased significantly.

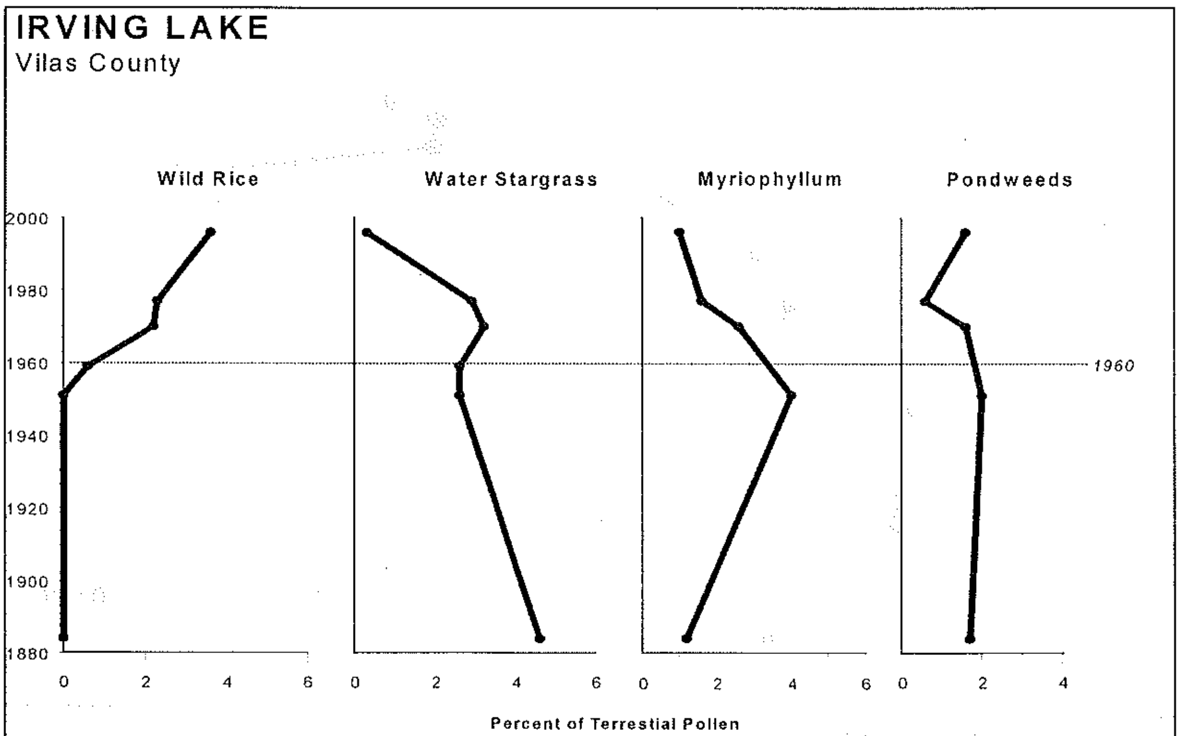


Figure 1. Profile of aquatic plant pollen from the deep hole core. An additional sample was analyzed from a depth representing the time period of the mid-1700's. No rice pollen was found.

As a consequence of the increase in rice, there has been a decline in some other aquatic plants. Both water stargrass and milfoil have declined in recent years although pondweed abundance appears to have not changed (Figure 1). Since not all aquatic plants produce sufficient pollen to detect, I am not able to determine the impact of the rice on other aquatic plants.

The mean sedimentation rate for the lake is very low (0.007 g/cm2/yr). In fact this is the lowest rate I have measured in 40 cores taken from lakes in Wisconsin. Although the mean sedimentation rate is low, the rate increased after logging which occurred in this area around 1900 (Figure 2). The sedimentation rate increased much more after 1960, which is the time of the increase in wild rice. It may be that the production of straw from the wild rice has increased the sedimentation rate. Other possible reasons for the increased rate is translocation of sediment from other areas of the lake as a result of motor boat activity which is thought to have increased on this lake in the last 30 years. It is unlikely that the increased sedimentation rate is a result of activities in the watershed. The watershed is entirely forested and only two cottages are present on the lake shore. These are set back from the lake and are likely to have minimal impact on the lake.

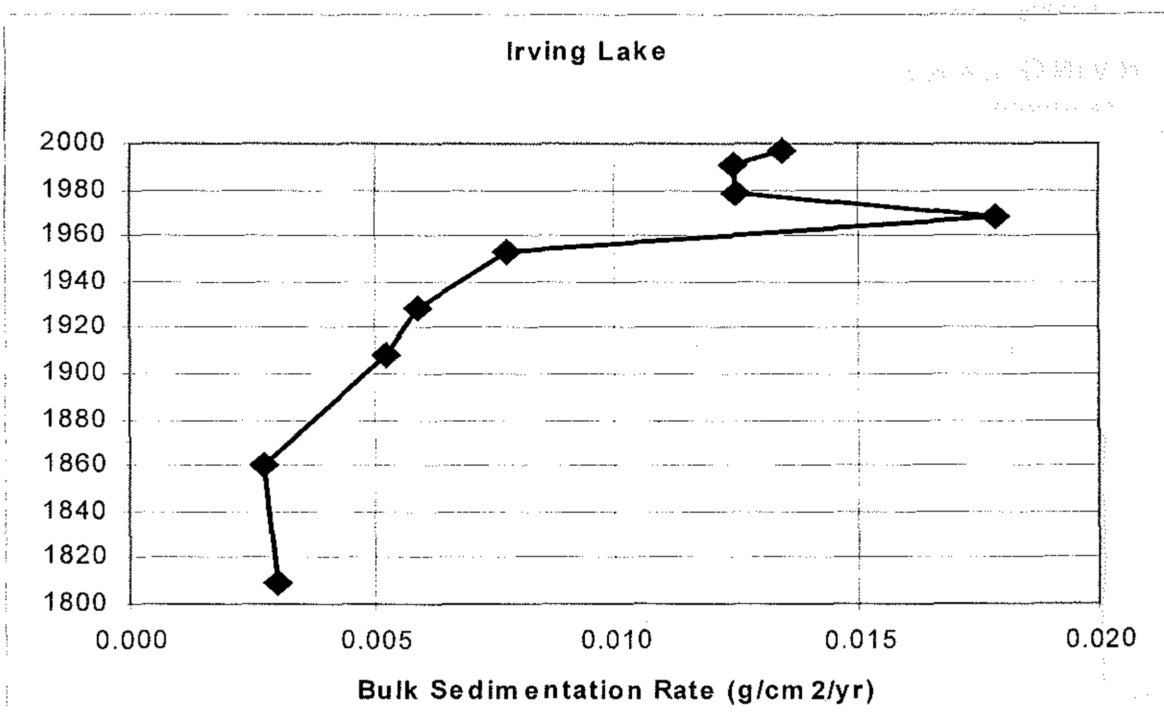


Figure 2. Sediment infilling rate at the deep hole. The increased rate after 1960 coincides with the introduction of wild rice.

The diatom community was analyzed to determine changes in the water quality of the lake. Since different diatoms grow in different environments they are useful in measuring lake ecosystem changes e.g. nutrients, pH, aquatic plant structure. Planktonic diatoms are those that float in the open water and do not grow attached to substrates such as plants. Although their abundance was historically variable, their presence has been significantly reduced since the onset of the rice community (Figure 3). The historical variability of these diatoms probably relates to changes in aquatic plant abundance caused by water level changes. The group of diatoms called benthic *Fragilaria* typically are found growing attached to plants. They are the most common diatoms throughout the core (Figure 3). Their abundance initially increased by 1920. This may have been the result of logging that was done in this region around 1900. Following logging and subsequent fires, it is likely that more runoff occurred from the watershed which stimulated the plant growth in the lake. Although a significant increase in nutrients could cause a similar response in the diatom community without a change in the plant

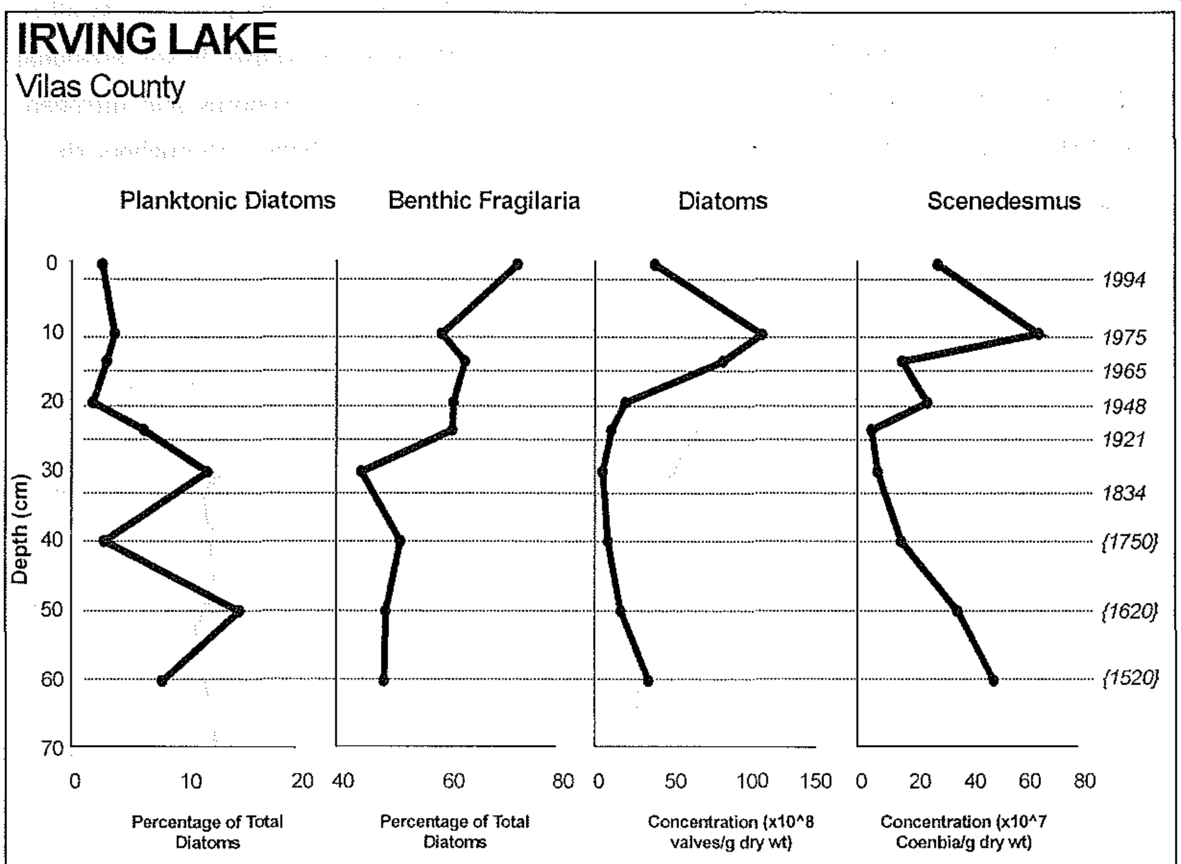


Figure 3. Diatom diagram showing selected common species. Planktonic diatoms are those that are found growing in the open water. These species have declined since the introduction of the rice. These species were replaced by benthic *Fragilaria* which grow on plants. Productivity of diatoms and the green alga, *Scenedesmus*, have increased since the mid-1970's. (Dates in brackets were interpolated.)

community this does not appear to have happened. Although the abundance of the benthic *Fragilaria* initially increased by 1920, the overall productivity of the diatom community did not increase as would be expected with increased nutrient levels. Figure 3 shows that the concentration of diatom fossils did not increase until much later, during the 1960's. Therefore it is likely that the increased abundance of benthic *Fragilaria* was the result of increased sites for growth, i.e. plants.

The concentration of both the diatom community and the green alga *Scenedesmus* have dramatically increased since the mid-1960's. This increased algal presence coincides with the increase of the rice. The increased algal levels may indicate that there has been an increase in nutrients during the last 40 years in this lake.

Most of the geochemical variables analyzed in the core were remarkably unchanged throughout the core. This reflects the fact that the watershed of the lake is relatively pristine. In all of the other lakes I have examined, during the last 150 years there are increases in soil erosional variables, e.g. titantium, aluminum, as well as nutrients such as phosphorus and nitrogen. Figure 4 shows the profiles of 4 chemical elements that showed small changes throughout the

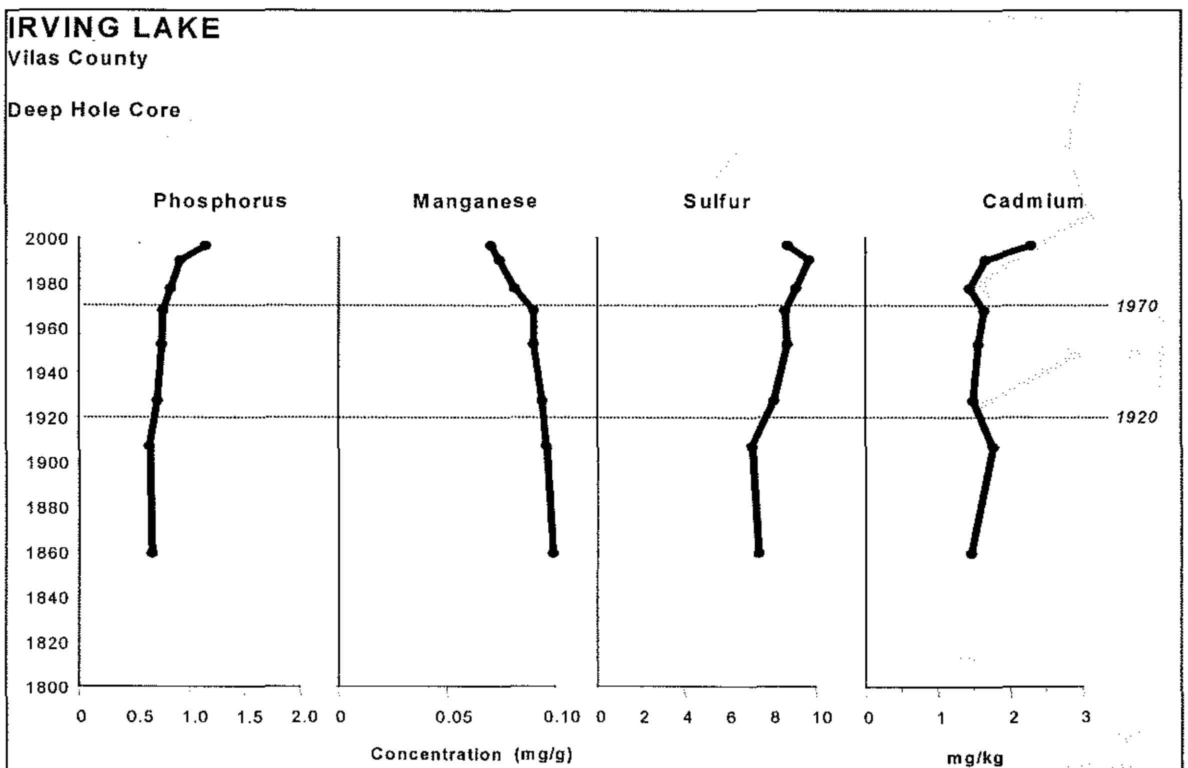


Figure 4. Profiles of selected geochemical variables. Phosphorus has increased since 1970 possibly as a result of incorporation into rice straw. The decline of manganese since 1970 indicates declining winter oxygen levels. Sulfur and cadmium profiles are the result of atmospheric deposition.

core. Phosphorus increased very slightly after 1920 but has increased more since 1970. The increase in phosphorus was likely a result of its incorporation into the rice straw. This resulted in more phosphorus being deposited in the sediments. It is not likely that phosphorus concentrations have significantly increased in the water column since this is not reflected in the diatom community.

The manganese profile was the opposite of phosphorus. Manganese concentrations decreased slightly from 1920 until 1970. During the last 30 years, the concentrations have declined significantly. This element is released from the sediments during anoxic periods which occur during ice cover in Irving Lake. While this element is in solution, it is removed from the lake by washing out of the lake. It appears that since 1970 the duration of low dissolved oxygen (DO) conditions has increased since the concentration of manganese declined. It is well known that during low DO levels phosphorus is released from sediments. This is because under the presence of oxygen, iron binds with phosphorus in a form that is insoluble. When the DO levels are below 1 mg L^{-1} iron changes to a form that is soluble. It appears that the recent increased levels of phosphorus may be the result of release from the sediments under anoxic conditions. It should be emphasized that the increase in phosphorus in this core is much less than has been found in other lakes throughout Wisconsin.

Concentrations of the last two elements, sulfur and cadmium, likely change as a result of atmospheric deposition. Sulfur is emitted in the form of sulfur dioxide from industrial processes, especially power generation. This chemical is the primarily cause of acid rain. Emissions of SO_2 increased throughout much of the twentieth century until the 1980's. In 1985, Wisconsin passed a law limiting SO_2 emissions. It appears that changes in atmospheric deposition of sulfur is reflected in the core from Irving Lake. Sulfur levels began increasing around 1920 and peaked around 1990. During the last decade the sulfur concentration has declined.

Cadmium also is deposited in the lake from the atmosphere. Studies have shown that its deposition in remote and semiremote lakes has increased in recent years. This apparently is the case in Irving Lake. Concentrations throughout the core are relatively unchanged until the top of the core (Figure 4).

In summary, it appears that wild rice has only been present in significant numbers in the last 40 years. It should be cautioned that rice may have been present at other times in the lake but either at low levels or the samples from the appropriate time period have not been examined. Although water quality changes that have occurred since the onset of rice have been relatively small, some changes are evident. The presence of rice has depressed other aquatic plants such as water stargrass and milfoil. Wintertime oxygen levels have declined since the onset of the rice, which appears to be causing a small increase in phosphorus. This has resulted in an increase in the algal community.

While the presence of rice appears to be having a slight detrimental effect upon the lake's ecosystem, I would caution against removal of the rice. Aside from the benefits to wildlife, a dramatic removal of plants likely would have a significant impact on the whole lake ecosystem. Given the nutrient levels currently present in the lake, if a large plant community was not present, these nutrients would be incorporated into algae. This would result in unsightly algal blooms and might adversely affect the fish community. Numerous studies in Europe and North America have found that when shallow lakes switch from macrophyte dominated communities to one dominated by algae, there is a decline in gamefish and an increase in bottom feeding fish such as carp and bullheads. Although the rice may have increased the sedimentation rate, the rate is still less than that found in 38 of 39 other lakes I have studied. While the rice may be decreasing winter oxygen levels, the aerator that is in place between Irving and Ballard lakes, is adequately replenishing the oxygen levels of the downstream lake. It is highly likely that Irving Lake experienced occasional winter fishkills prior to the onset of the rice.

3. Watershed Features

3.1. Soil Data

Table A1. Soil data for major soil groups in Wisconsin.

	Organic matter %				Available phosphorus lbs/A				Available potassium lbs/A				Soil reaction pH				Lime req. T/A	Representative corresponding soil names and symbols from Soils of Wisconsin color map, 1:710,000 (Hole, 1976)[2]
	Low 0-2	Med 2-5	High >5		Low 0-50	Med 51-100	High 101-200+		Low 0-200	Med 201-400	High 400+		Low 4.5-6.5	Med 6.5-7.5	High 7.5+			
	% of soil tests			Av.	% of soil tests			Av.	% of soil tests			Av.	% of soil tests			Av.	Av.	
1	0	96	4	3.7	55	31	14	60	44	48	8	229	30	69	1	6.6	0.79	Tama, Richwood (A1, 11)
2	0	90	10	3.9	59	28	13	55	40	52	8	239	31	68	1	6.6	0.87	Dodgeville, Tell (A2, 14)
3	35	65	0	2.2	65	25	10	51	70	27	3	175	34	65	1	6.6	0.36	Fayette, Seaton (A5-8, 12)
4	28	71	1	2.3	68	21	11	50	69	28	3	183	37	62	1	6.8	0.36	Dubuque, Palsgrove (A3, 4, 6, 9, 10, 13)
5	4	87	9	3.8	45	45	10	71	49	45	6	222	27	71	2	6.6	0.72	Plano, Ringwood (B5, 21-22, 32)
6	0	75	25	4.5	62	26	12	53	43	54	3	224	55	45	0	6.4	1.55	Varna, Elliott, Ashkum (B20)
7	35	65	0	2.2	44	37	19	70	63	35	2	138	29	69	2	6.7	0.28	Lapeer, Miami, Fox (B1, 3, 6-8, 10-18, 23-31, 33, 34)
8	20	79	1	2.4	63	27	10	52	61	37	2	188	54	45	1	6.4	1.16	Morley, Blount (B9, 19)
9	50	45	5	2.7	34	39	27	87	63	34	3	184	44	55	1	6.4	0.55	Casco, Rodman, Hochheim (B2, 4, 12)
10	94	6	0	1.5	24	33	43	102	76	23	1	146	60	39	1	6.2	0.38	Sparta, Dakota (C5, 8, 9, 16)
11	87	10	3	1.5	16	39	45	107	84	16	0	136	69	31	0	6.0	0.53	Plainfield, Nekoosa, Boone, (C1-7, 10-18)
12	42	55	3	1.7	48	31	21	56	73	24	3	156	53	46	1	6.8	1.05	Norden, Hixton, Gale (D1-7, 9, 10)
13	52	46	2	1.8	33	38	29	87	76	21	3	162	57	43	0	6.3	0.92	Elm Lake, Merrillan, Kert (D8, 11-13)
14	6	80	14	3.7	58	25	17	57	73	22	5	175	15	60	25	6.9	0.80	Emmet, Onaway, Longrie, Shawano (E1-13)
15	2	90	8	4.1	50	25	25	65	70	29	1	118	53	46	1	6.2	0.55	Jewett, Pillot (F8)
16	3	84	13	3.8	65	20	15	54	67	29	4	176	54	45	1	6.3	2.08	Santiago, Freer, Norrie (F1-7)
17	28	72	0	3.8	28	26	46	113	56	36	8	201	61	39	0	6.2	0.92	Antigo, Fenwood, Stambaugh (F10-17, 24, 25)
18	16	82	2	2.9	55	31	14	59	81	18	1	145	59	41	0	6.2	1.70	Spencer, Almena, Poskin (F21, 22, 26)
19	3	95	2	3.2	64	26	10	52	70	28	2	163	59	46	1	6.3	2.50	Clifford, Withee, Dolph (F9, 18-20, 23)
20	68	32	0	1.7	35	18	47	114	63	28	9	149	46	46	8	6.0	1.52	Iron River, Milaca, Kennan, Pence (G1-28)
21	33	55	12	2.9	29	8	63	138	76	23	1	170	81	19	0	5.5	1.94	Vilas, Omega, Pence (H1-7)
22	2	81	17	4.0	73	19	8	39	67	30	3	184	1	70	29	7.3	0.04	Kewaunee, Hortonville, Oshkosh (I1-6, 10-17, 20, 21)
23	9	83	8	3.6	96	3	1	19	59	40	1	190	67	33	0	6.3	2.09	Hibbing, Ontonagon, Superior (I1, 2, 7, 8, 18, 19, 22)
24	2	68	30	5.0	29	40	31	90	35	55	10	250	4	70	26	7.2	0.10	Arenzville, alluvial soils (J1, 2)
25	0	10	90	7.0	67	24	9	50	50	46	4	214	2	42	56	7.0	0.10	Newton, Pella, Navan (J3-11)
26	0	3	97	56.2	51	23	26	96	59	20	21	200	53	39	8	6.4	0.32	Peats and Mucks (J12-15)
State Total	22	73	5	2.9	50	30	20	67	70	27	3	175	40	55	5	6.5	0.94	All soils

[1] Wisconsin State Soil and Plant Analysis Laboratory, J. J. Genson, Director, 806 S. Park St., Madison, Wisconsin, 53706. Representative data were extracted from State and County summaries of soil test data for the period 1968-1973.

[2] Hole, F. D., 1976. Soils of Wisconsin, Bul. 87, Soil Series 62. University of Wisconsin Press.

3.2. Hydrology Staff Gage Readings

Table A2. 1999 BIWDLA staff gauge readings.

Date	Irving		White Birch		Creek	
	Reading (1)	Change(2)	Reading(1)	Change(2)	Reading(1)	Change(2)
Jun 9	2.6		1.60		.80	
18	2.48	-1.4"	1.50	-1.2"	.76	-.5"
22	2.48	NC	1.42	-1.0"	.66	-1.2"
23	2.48	NC	1.46	+.5"	.70	+.5"
29	2.40	-1.0"	1.40	-.7"	.64	-.7"
Jul 1	2.48	+1.0"	1.48	+1.0"	.74	+1.2"
3	2.58	+1.2"	1.56	+1.0"	.84	+1.2"
6	2.60	+.2"	1.60	+½"	.84	Even
8	2.60	Even	1.56	-½"	.84	Even
9	2.84	+3"	1.8	+3"	1.00	+2"
10	2.84	Even	1.74	-1"	.94	-¾"
20**	2.84	Even	1.60	-1½"	.8	-1¾"

(1) Readings are hundredth inches
(2) Change is in foot inches

* Staff Gauge Locations were established by Steve McComas on June 24 and were installed by WBV on June 24.

** On the afternoon of June 20, we opened the blocked culvert from Irving. On July 21 (am) the creek staff gauge saw an increase of ½" (from .80 to .84) without any rain during the period.

3.2. Hydrology - Daily Rainfall

Table A3. 1999 BIWBLA daily rainfall.

Date	Rainfall	Accumulation
May 1	0.0	
6	1.80	
7	1.50	3.30
8	.20	3.50
16	.11	3.61
17	.80	4.41
18	.36	4.77
21	.20	4.97
22	.62	5.59
31	.13	5.72
June 6	.56	
7	.76	1.32
9	.07	1.39
11	.20	1.59
12	.12	1.71
17	.10	1.81
23	.16	1.97

*Readings taken 8am Daily

3.3 Watershed Recon by Jim Vauhan and Joe Heitz

EXPLORATION OF UPPER REACHES OF STREAM
FEEDING SOUTHEAST CORNER OF LAKE IRVING
STAR LAKE, VILAS COUNTY, WISCONSIN

On July 1, 1999 Rae Frisbie and Jim Vaughan, who own the only two privately owned parcels of land on Lake Irving, explored the upper reaches of the stream that feeds water into Lake Irving from the southeast part of the lake.

Rae motored to Jim's place in his motor boat, picking up Jim's Grumman canoe for the trip to the island where the motor boat was tied to a tree. Rae and Jim then boarded the canoe and headed south through open water to the weeds and lily pads. The objective was to reach the beaver dam on the south shore of the lake.

On the trip to the dam care had to be taken to avoid areas where there was no depth to the water. The weeds hid these areas so they were difficult to see until the canoe was stalled on them. It was noted that there were more open water areas extending southward from the islands in heading to the dam than had existed in prior years. Before reaching the dam however the weeds and lily pads were so thick that it made progress in paddling the canoe very difficult.

When we reached the south shore of the lake we found a large beaver house at least four feet high off the water and possibly ten feet long from one side to the other along the water line. Proceeding eastward about 400 feet from the beaver house we found the dam which had been built by the beavers. This dam is about one foot high and at least 50 feet long. The water level above the dam was only about four inches above Lake Irving's level. (Note: When Jim Vaughan and his son, Jim, reached this dam on May 14, 1999 the water level behind the dam was only an inch or so below the top of the dam indicating that for some reason seepage through the dam had increased.

After inspecting the downstream face of the dam it was decided that the best place to stand on the dam and hoist the canoe over the dam was in the center of the dam. So after Rae hoisted the canoe over the dam, we climbed in and started up stream.

We could see, approximately 200 feet ahead, what appeared to be another beaver dam. The stream at this point was about 30 feet wide and free of weeds. When we reached this spot it turned out to be the start of a beaver dam which was never finished. We were able to maneuver around one end of this blockage and head upstream toward another beaver dam.

This second beaver dam was also about a foot high but better made than the first dam in that it was more impervious with water flowing over it near the top of the dam. Rae made a video record of this dam together with the sound of the water trickling over it. This dam was about 30 feet long.

In order to cross this dam we found a tuft of ground to stand on at the west end of the dam. Once more Rae hoisted the canoe over the dam.

From this point we proceeded up stream about 300 to 400 feet to what looked like an island in the middle of the stream. It appeared that there were channels around either side of this island. The channel to the east seemed more open so we attempted to maneuver through this channel. This was very difficult to do because the canoe was so long.

When we reached what would be the east west center line of the island we observed below the water line what must be the 100 year old hewn timbers used to construct the logging railroad trestle over this stream. These timbers appeared to be in very sound condsition. They were about 10 inches square and eight feet long, with several one inch diameter holes drilled through them so they could be put over the one inch diameter steel rods we had seen previously in the week when we had walked in from the old Star Lake dump, following the railroad right of way to the marshy area preceeding the stream we were now canoeing on. On this trek we noted many ancient supports that held up the railroad track where the wooden timbers above the ground had rotted away but left five one inch diameter steel rods sticking up in the air, evidently anchored to sound timbers below the ground and water level of the marsh.

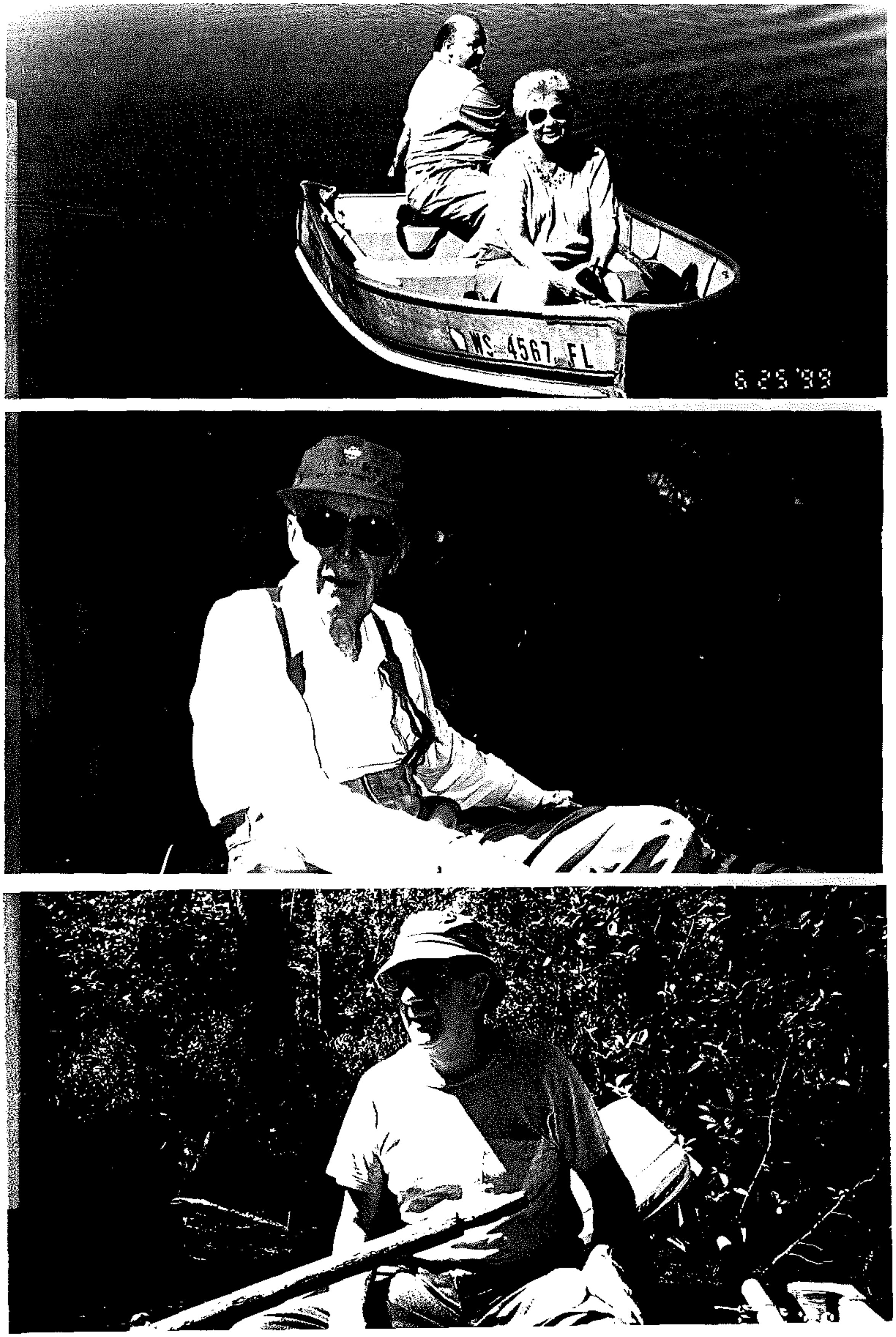
Having made it araound the railroad debris we found a beautiful, wider prtion of the stream that was open, i.e. without weeds or lily pads in it. This stream headed south for a few humdred feet before turning east, heading toward Lake Laura. We proceeded about 1,000 feet up the stream to where it divided into a Y with one leg heading for Lake Laura and the other heading north. We went as far as we could up these two ends of the stream.

The vegetation along the whole stream appeared to be dense tall grasses interspersed with some shrub growth. After admiring the peace and tranquility of the area on a bright sunny day, we headed back downstream.

We tried to get around the railroad island in the middle of the stream by using the other channel around the island but we got stuck and had to go back the way we came. The only other deviation from our upstream trip was that on the original dam we put the canoe over the dam on the western end next to a tree. For the record Rae came home with dry feet while Jim had dipped just half of his right foot in the water at the last portage.

The total time for the entire trip was about two hours.

Jim Vaughan
James S. Vaughan



Some of the watershed explorers in 1999. [top] Dick and Carol Malmgren; [middle] James Vaughan; and [bottom] Rae Frisbie.

August 22, 1999

Steve, 8.21.99

Yesterday I was able to find my way to the Irving beaver ponds with my kayak. I must say, that is quite a trip back there. I collected one sample just behind the first small dam and then portaged across. I also portaged over the second small dam and came up to the larger third dam and collected a sample just upstream from the dam. From there I portaged across the dam and kayaked as far as I could (1/4 to 1/2 mile) into the spruce swamp and collected a third sample. The channel was just slightly wider then my kayak and I dicovered how difficult it is to back up a kayak for a while. For awhile I was wishing I had brought a few flares along with me!! Behind the third dam I saw lots of sunken logs that had obviously been cut a long time ago. Could they have been related to the trains? Hope these samples provide some information.

Sincerely,

Joe

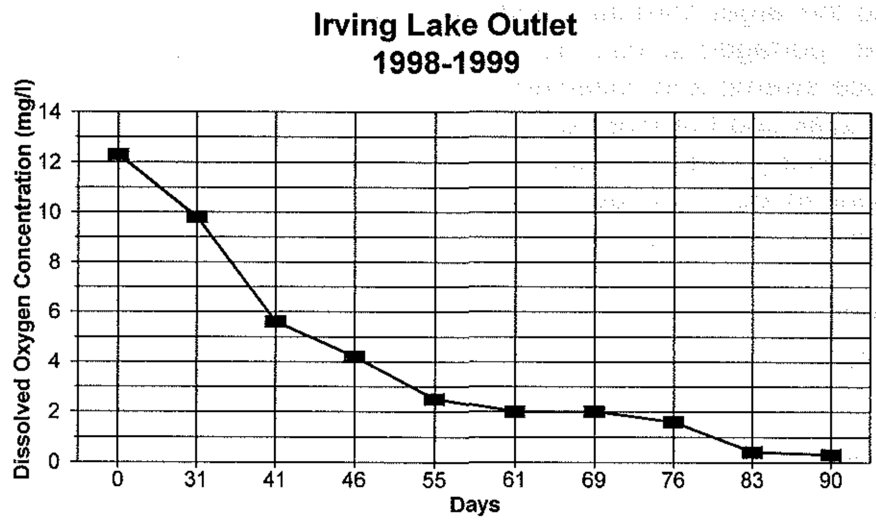
Joe Heitz

W4397 Eagle Ridge Lane
Merrill, WI 54452
715-539-2728

cc: Frank Splitt

4. Lake Characterization

4.1. Dissolved Oxygen and Temperature Profiles



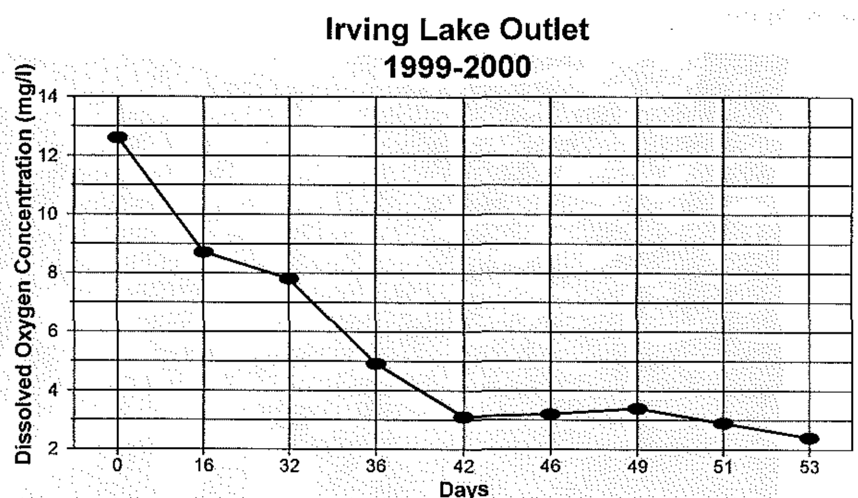


Table A4. Dissolved oxygen/temperature profiles for the deep hole at White Birch Lake.

November 12, 1998

	DO (mg/l)	Temp (F)
0	11.8	37.6
3	11.8	37.6
9	11.8	37.4
15	11.9	37.4
21	11.9	37

May 3, 1999

	DO (mg/l)	Temp (F)
0	11.6	60.3
3	11.6	60.3
9	12.3	55.1
15	13.5	48.4
21	12.7	46.4

June 23, 1999

	DO (mg/l)	Temp (F)
0	9.1	72.2
3	9.1	72.2
9	9.3	69
15	8.6	61.5
21	8.5	61.1

January 20, 1999

	DO (mg/l)	Temp (F)
0	11.7	35.6
3	11.7	35.6
9	6.8	39.7
15	6.1	39.9
21	3.6	40.4

May 14, 1999

	DO (mg/l)	Temp (F)
0	10.1	58.3
3	10.1	58.3
9	9.9	57.4
15	10.3	56.7
21	12.2	48.6

June 28, 1999

	DO (mg/l)	Temp (F)
0	8.5	74.4
3	8.5	74.4
9	8.5	73.7
15	8.1	66.5
21	6.7	62.4

January 29, 1999

	DO (mg/l)	Temp (F)
0	9.6	36.3
3	9.6	36.3
9	7.9	39.2
15	7.6	39.2
21	5.6	39.7

June 1, 1999

	DO (mg/l)	Temp (F)
0	9.1	64.2
3	9.1	64.2
9	9	63.8
15	9.2	58.2
21	8.4	56.8

July 8, 1999

	DO (mg/l)	Temp (F)
0	8.4	73.4
3	8.4	73.4
9	8.3	73.2
15	7.4	69.2
21	4.6	62.4

February 5, 1999

	DO (mg/l)	Temp (F)
0	9.2	36.5
3	9.2	36.5
9	7.4	39.2
15	3.6	40.1
21	1.5	40.4

June 9, 1999

	DO (mg/l)	Temp (F)
0	8.9	72.6
3	8.9	72.6
9	9.2	68.3
15	8.6	61.3
21	8.3	59.9

July 20, 1999

	DO (mg/l)	Temp (F)
0	9.5	76.4
3	9.5	76.4
9	9.4	75.3
15	7.9	70.5
21	1.5	63.8

Table A5. Dissolved oxygen/temperature profiles for the deep hole at Ballard Lake.

November 12, 1998

	DO (mg/l)	Temp (F)
0	11.9	34.7
3	11.9	34.7
9	11.9	34.7
15	11.9	34.9
21	11.9	35.1

January 20, 1999

	DO (mg/l)	Temp (F)
0	12.9	34.9
3	12.9	34.9
9	6.5	38.1
15	5.4	39.5
21	3.6	40.2

January 29, 1999

	DO (mg/l)	Temp (F)
0	11.1	35.2
3	11.1	35.2
9	3.7	38.3
15	0.8	39.7
21	0.6	39.5

February 5, 1999

	DO (mg/l)	Temp (F)
0	10.4	35.4
3	10.4	35.4
9	2.6	38.6
15	0.4	39.9
21	0.4	39.7

May 3, 1999

	DO (mg/l)	Temp (F)
0	11.5	58.4
3	11.5	58.4
9	11.5	57.9
15	11.6	53.6
21	11.3	53.4

May 14, 1999

	DO (mg/l)	Temp (F)
0	9.7	57.7
3	9.7	57.7
9	9.6	57.6
15	9.3	57
21		

June 1, 1999

	DO (mg/l)	Temp (F)
0	8.3	63.3
3	8.3	63.3
9	8.3	62.9
15	8.5	62.4
21	8.3	61.5

June 9, 1999

	DO (mg/l)	Temp (F)
0	8.9	72.1
3	8.9	72.1
9	8.5	70.5
15	7.6	68.1
21	6.4	65.4

June 23, 1999

	DO (mg/l)	Temp (F)
0	8.8	71.2
3	8.8	71.2
9	8.4	70.5
15	7.7	68.9
21	6.7	67.2

June 28, 1999

	DO (mg/l)	Temp (F)
0	8.5	70.7
3	8.5	70.7
9	8.5	70.5
15	8.5	70.3
21	8.5	70.1

July 8, 1999

	DO (mg/l)	Temp (F)
0	7.8	72.6
3	7.8	72.6
9	7.8	72.6
15	7.8	72.5
21	7.9	72.5

July 20, 1999

	DO (mg/l)	Temp (F)
0	9.4	76.8
3	9.4	76.8
9	8.8	74.6
15	7.8	72.5
21	6.5	71.4

Table A6. Dissolved oxygen/temperature profiles for the deep hole at Irving Lake.

October 12, 1998

	DO (mg/l)	Temp (F)
0	8.8	52
3	8.8	52
6	8.2	51
9	8.2	51

May 14, 1999

	DO (mg/l)	Temp (F)
0	9.3	64
3	9.3	64
6	9.1	63.8
9	9.1	59.9

June 1, 1999

	DO (mg/l)	Temp (F)
0	7	63.3
3	7	63.3
6	7.3	63.3
9	7.2	62.9

June 9, 1999

	DO (mg/l)	Temp (F)
0	7.4	75.2
3	7.4	75.2
6	6.8	71.7
9	4.9	69.6

June 23, 1999

	DO (mg/l)	Temp (F)
0	7.8	72.6
3	7.8	72.6
6	7.6	72.6
9	5.9	66.5

June 28, 1999

	DO (mg/l)	Temp (F)
0	7.5	73.9
3	7.5	73.9
6	6.4	73.4
9	3.9	71.8

July 8, 1999

	DO (mg/l)	Temp (F)
0	7.6	71.7
3	7.6	71.7
6	7.1	71.4
9	6.8	71

July 20, 1999

	DO (mg/l)	Temp (F)
0	6.9	77.8
3	6.9	77.8
6	3.5	74.6
9	0.5	68

Table A7. Dissolved oxygen readings for Irving outlet at the culvert and the White Birch outlet at the creek.

	Irving at Culvert	White Birch at Creek Exit
1998		
November 12	12.5	12.4
November 21	12.2	
December 5	12.3	11.3
1999		
January 5	9.8	12.7
January 15	5.6	12.0
January 20	4.2	10.5
January 29	2.5	9.0
February 4	2	9.0
February 12	2	8.6
February 19	1.6	
February 26	0.4	8.2
March 5	0.3	7.7
March 12	0.4	7.8
March 20	0.8	8.5
March 27	3.6	6.2
March 31	6.9	7.9
April 9	9.1	10.9
April 16	9.9	10.4
April 23	10.6	11.9
May 3	9	11.5
May 14	9.3	10.4
June 1	7.8	9.0
June 9	6.6	8.1
June 23	7.7	8.4
June 28	8.4	8.8
July 8	7.1	8.3
July 20	8.2	8.4
August 3	8.8	9.1
August 10	9.0	8.5
August 19	8.3	8.3
September 1	8.1	8.4
October 1	9.0	9.5
October 5	9.7	9.7
October 28	11.5	11.5
November 18	12.9	12.4
December 14	15.1	13.2
December 30	12.6	12.4

	Irving at Culvert	White Birch at Creek Exit
2000		
January 15	8.7	11.2
January 31	7.8	10.6
February 4	4.9	9.7
February 10	3.1	
February 14	3.2	9.7
February 17	3.4	7.9
February 19	2.9	7.9
February 21	2.4	7.2
February 24	5.6	9.0
February 28	7.1	7.0
March 2	9.8	6.8
March 8	11.2	8.7
March 13	11.4	8.5
March 21	10.7	6.6
March 23	10.9	7.6

4.2. Water Clarity - secchi disc data

Table A8. Secchi disc transparencies. Secchi disc data collected by Dwight Sandman from 1993-2000. Bill Grunwald assisted from 1998-2000.

	White Birch	Ballard	Irving
1993			
June 9		19.0	
June 17		18.5	
July 21		10.0	
August 7		10.0	
September 15		8.0	
October 13		12.0	
1994			
June 8		16.0	
June 22		13.0	
August 3		12.0	
September 21		14.5	
1995			
June 13		14.0	
July 4		16.0	
July 27		9.0	
August 15		12.0	
September 1		12.0	
September 10		14.0	
September 23		15.0	
October 18		12.0	
1996			
June 10		11.0	
June 27		12.5	
August 2		10.0	
1997			
June 21		9.0	
July 15		12.0	
August 10		15.0	
August 27		14.0	

	White Birch	Ballard	Irving
1998			
June 16		11	
July 5		11	
July 17		8	
August 4		9	
August 16		9	
September 1		9	
September 15		10	
October 2	14	12	
October 12	13	12	9
November 18	11	7	8
1999			
May 3	10	9	6
May 14	16	13	5
June 1	17	11	5
June 23	11	9	5
July 8	8	12	4
July 20	11	10	4
August 3	12	11	5
August 19	12	11	5
September 1	11	9	5
October 1	11	11	5
October 28	11	15	7
2000			
April 24	11	10	7
May 1	18	17	8
May 18	22	18	7
June 18	14	14	9
July 4	15	11	6
July 20	14	13	7
August 14	--	--	7
August 21	14	13	7
September 10	15	14	7

Secchi disc readings for the growing season (in feet).

	White Birch	Ballard	Irving
Growing Season Averages (May - Sept)			
1993	--	11.7 (5)	--
1994	--	13.7 (4)	--
1995	--	13.1 (7)	--
1996	--	11.9 (3)	--
1997	--	11.8 (4)	--
1998	--	9.8 (7)	--
1999	11.9 (9)	10.4 (9)	4.7 (9)
2000	15.5 (7)	14.1 (7)	7.4 (8)

() = number of readings.

4.3. Water Chemistry Data

Total phosphorus concentrations for 1999 (in ppb). Collected by Lake Association members for this study.

	White Birch	Ballard	Irving
May 3	17	23	30
June 1	13	17	51
June 28	15	19	50
July 20	13	17	42
August 10	14	16	36
Average	15	19	40

Birge and Juday Data from 1926-1936

Water chemistry data from 1926-1936 are shown in Table A9. Data were kindly supplied by Dr. John Magnuson, Director of the Center for Limnology, UW-Madison, and sent to Mr. James Vaughan, Irving Lake resident.

Table A9.

Irving Lake, Vilas Co

BJ#	Obs.	TRS	Typ.	Date	Z	TC	S.D.	Col.	Con.	pH	D.O.	Alk.	CO2	NH3-N	Org.-N	NO3-N
202	1	410802	2	80726	0	18	-999	26	57	7.2	7.35	12.8	2.2	-999	0.48	-888
202	2	410802	2	71427	0	21.7	-999	26	56	7.5	8.76	12.5	1.5	-888	0.51	0.015
202	3	410802	2	81828	0	21.2	-999	22	53	7.8	6.75	11.5	0.5	0.03	0.63	0.018
202	4	410802	2	82229	0	20.2	-999	26	53	7.3	8.28	16	1.5	-999	-9999	0.012
202	5	410802	2	62730	0	20.2	-999	32	56	7.2	8.3	13	2	-999	-9999	-999

BJ#	Obs.	TRS	Typ.	Date	Z	Sol.-P	Org.-P	TP	Cl	SO4	Si	Ca	Mg	Fe	Plank.	Res.
202	1	410802	2	80726	0	0.007	0.021	0.028	1.5	-999	4.9	-9999	-9999	-999	3.64	58.1
202	2	410802	2	71427	0	0.009	0.021	0.03	1.5	-999	5	-9999	-9999	-999	1.06	56.8
202	3	410802	2	81828	0	0.003	0.02	0.023	1	3.54	4.8	-9999	-9999	-999	0.91	58
202	4	410802	2	82229	0	0.001	0.016	0.017	0.6	-999	6.6	-9999	2.9	-999	0.8	59.5
202	5	410802	2	62730	0	-9999	-999	-999	-999	-999	-999	5.1	-9999	-999	1.35	50

Ballard Lake Vilas Co.

BJ#	Obs.	TRS	Typ.	Date	Z	TC	S.D.	Col.	Con.	pH	D.O.	Alk.	CO2	NH3-N	Org.-N	NO3-N
14	1	410804	2	80726	0	18.7	-999	26	63	7.2	7.15	13.7	2.3	-999	0.59	0.03
14	2	410804	2	71427	0	21.5	1.5	18	55	7.6	8.48	12.3	-0.9	0.01	0.54	0.01
14	3	410804	2	81828	0	21.7	2.5	14	55	7.7	6.85	12.5	1	0.02	0.58	0.015
14	4	410804	2	73129	0	23.5	2	26	52	7.6	5.78	13	1	-999	-9999	0.02
14	5	410804	2	62730	0	20.9	3	26	59	7.6	8.35	13	2.8	-999	-9999	-999

BJ#	Obs.	TRS	Typ.	Date	Z	Sol.-P	Org.-P	TP	Cl	SO4	Si	Ca	Mg	Fe	Plank.	Res.
14	1	410804	2	80726	0	0.006	0.024	0.03	1.2	-999	5.3	-9999	-9999	-999	3.53	54.6
14	2	410804	2	71427	0	0.007	0.021	0.028	1.2	-999	2.6	-9999	-9999	-999	1.44	50.5
14	3	410804	2	81828	0	0.003	0.012	0.015	1.5	5.08	3.5	-9999	-9999	-999	2.01	56.2
14	4	410804	2	73129	0	0.001	0.023	0.024	0.8	-999	5.6	-9999	-9999	-999	1.16	56.1
14	5	410804	2	62730	0	-9999	-999	-999	-999	-999	-999	5.85	2.92	-999	-999	48.6

White Birch Lake Vilas Co.

BJ#	Obs.	TRS	Typ.	Date	Z	TC	S.D.	Col.	Con.	pH	D.O.	Alk.	CO2	NH3-N	Org.-N	NO3-N
460	1	410805	2	80726	0	20	-999	8	63	7	6.29	14.5	3.2	-999	0.52	0.02
460	2	410805	2	81927	0	18.7	2.2	22	56	8	7.51	11.1	-0.8	0.01	0.53	0.03
460	3	410805	2	81828	0	23	2.5	14	56	7.7	7.32	12.4	0.8	0	0.5	0.013
460	4	410805	2	72929	0	22	3	20	52	7.1	7.75	13.4	1.2	-999	-9999	0.015
460	5	410805	2	62830	0	20.7	3.5	16	56	7.6	8.8	13.2	0.8	-999	-9999	-999
460	6	410805	2	72236	0	-999	-999	-99	-99	7.2	8	13.3	-999	-999	-9999	-999

BJ#	Obs.	TRS	Typ.	Date	Z	Sol.-P	Org.-P	TP	Cl	SO4	Si	Ca	Mg	Fe	Plank.	Res.
460	1	410805	2	80726	0	0.004	0.015	0.019	1.6	-999	3.5	-9999	-9999	-999	1.09	50.6
460	2	410805	2	81927	0	0.003	0.017	0.02	0.5	-999	2.8	-9999	-9999	-999	1.96	51.2
460	3	410805	2	81828	0	0.003	0.014	0.017	1.1	5.89	3.4	-9999	3.49	-999	1.4	57.7
460	4	410805	2	72929	0	0.002	0.016	0.018	1	-999	4.9	-9999	-9999	-999	1.14	48.3
460	5	410805	2	62830	0	-9999	-999	-999	-999	-999	-999	6.5	-9999	-999	1.35	50.4
460	6	410805	2	72236	0	-9999	-999	-999	-999	-999	3.6	8	4.4	0.08	-999	-999

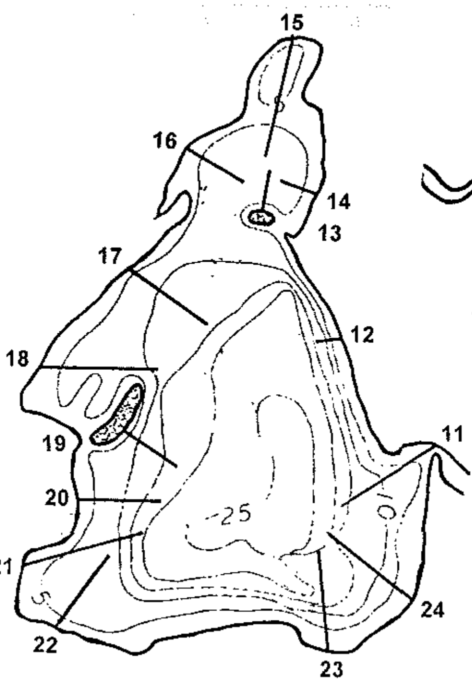
4.4. Zooplankton Data for May and June , 1999

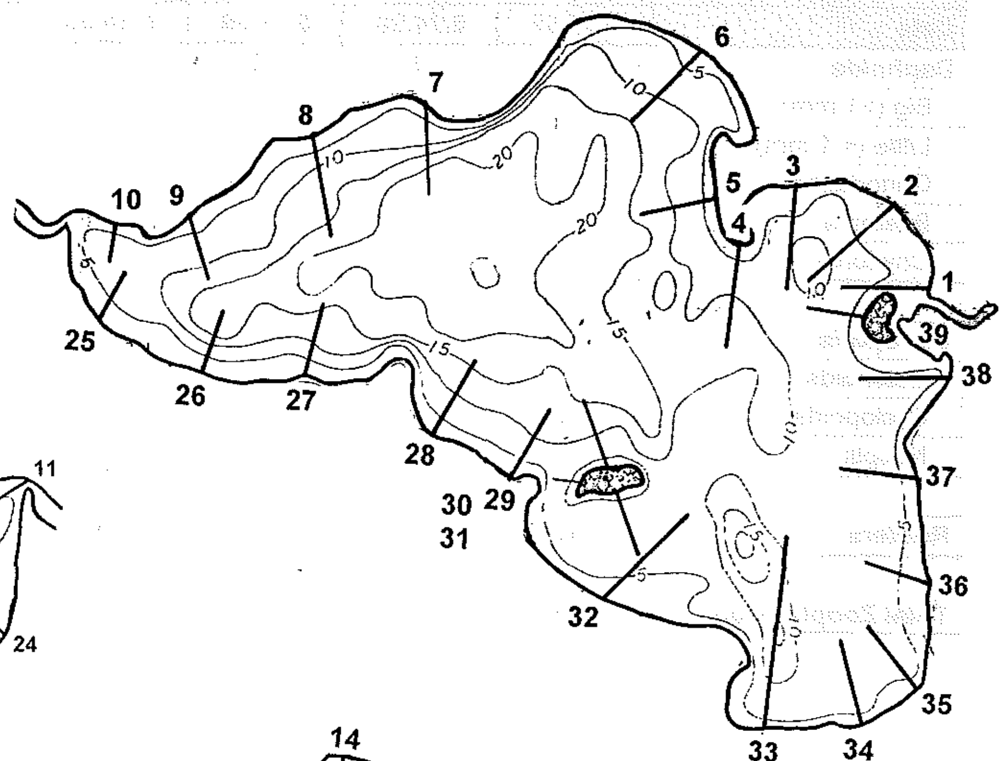
Table A10. White Birch, Ballard, and Irving Lake zooplankton 1999 data. Results are shown in number/liter.

	White Birch		Ballard		Irving	
Date	**5.17.99**	**6.24.99**	**5.17.99**	**6.24.99**	**5.17.99**	**6.25.99**
Daphnids	**7**	**2**	**22**	**4**	**15**	**6**
Big (>1 mm)	1	0	6	0	0	0
Little (< 1 mm)	2	1	9	1	1	5
Ceriodaphnia	0	0	0	0	0	0
Bosmina	3	1	5	0	11	1
Chydorus	1	0	2	3	3	0
Copepods	**32**	**7**	**39**	**2**	**39**	**7**
Calonoids	7	2	10	0	3	4
Cyclopoids	22	1	28	1	8	1
Nauplii	3	4	1	1	28	2
Rotifers	**50**	**13**	**74**	**3**	**273**	**3**
Total Zooplankton	**89**	**22**	**135**	**9**	**327**	**37**

4.5. Aquatic vegetation

4.5.1. Survey results from three lakes in 1999





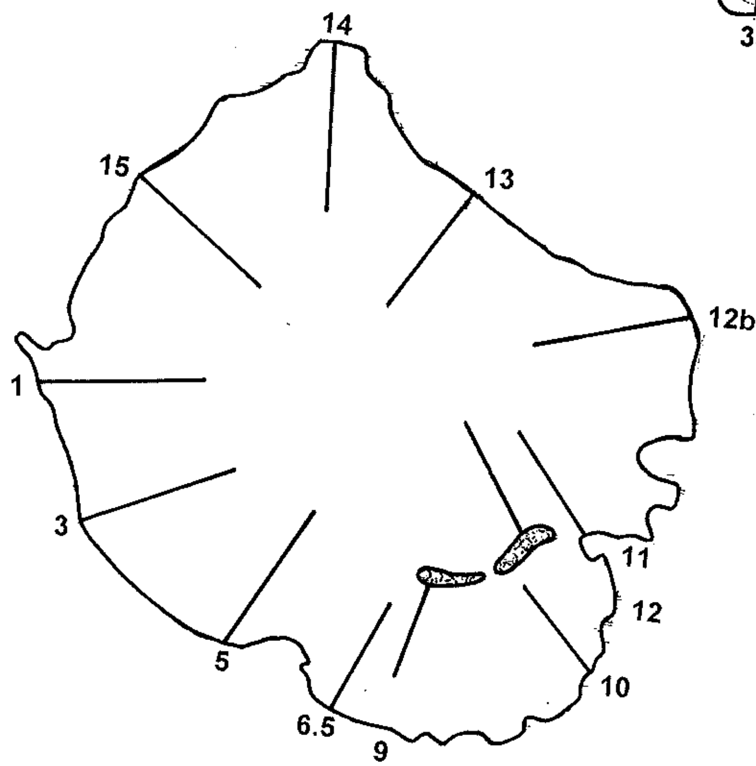


Table A11. White Birch Lake aquatic plant occurrences and densities for the September 8 & 9, 1999 survey based on 14 transects and 4 depths, for a total of 56 stations. Density ratings are 1-5 with 1 being low and 5 being most dense. The plant densities for the channel were not used for the statistics.

	Depth 0-4 feet (n=14)			Depth 5-8 feet (n=14)			Depth 9-12 feet (n=14)			Depth 13-16+ feet (n=14)			All Stations (n=60)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Arrowhead (*Sagittaria sp*)	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Bent grass (*Sagittaria sp)*	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Cabbage (*Potamogeton amplifolius*)	--	--	--	1	7	1	1	7	1	--	--	-	2	3	1
Cattails (*Typha sp*)	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Celery (*Vallisneria americana*)	7	50	1.6	3	21	1	--	--	--	--	--	--	10	17	1.4
Chara (*Chara sp*)	1	7	1	1	7	1	--	--	--	--	--	--	2	3	1
Dwarf milfoil (*Myriophyllum tenellum*)	--	--	--	1	7	1	--	--	--	--	--	--	1	2	1
Elodea (*Elodea canadensis*)	--	--	--	1	7	1	--	--	--	--	--	--	1	2	1
Fern pondweed (*Potamogeton robbinsii*)	1	7	1	1	7	1	4	29	2.3	4	29	1.8	10	17	1.8
Floatingleaf pondweed (*Potamogeton natans*)	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Lobelia (*Lobelia dortmanna*)	3	21	1.3	1	7	1	--	--	--	--	--	--	4	7	1.3
Naiads (*Najas sp*)	6	43	1.5	3	21	1	2	14	2	--	--	--	11	18	1.5
Pipewort (*Eriocaulon aquaticum*)	2	14	1	--	--	--	--	--	--	--	--	--	2	3	1
Quillwort (*Isoetes sp*)	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Spatterdock (*Nuphar variegatum*)	3	21	1	--	--	--	--	--	--	--	--	--	3	5	1
Stringy pondweed (*Potamogeton sp*)	2	14	2	1	7	1	--	--	--	--	--	--	3	5	1.7
Sweet gale (*Myrica gale*)	1	7	1	--	--	--	--	--	--	--	--	--	1	2	1
Variable pondweed (*Potamogeton gramineus*)	6	43	1	3	21	1	2	14	1	--	--	--	11	18	1
Waterlily (*Nymphaea sp*)	7	50	1.3	2	14	1	--	--	--	--	--	--	9	15	1.2
Watershield (*Brasenia schreberi*)	1	7	1	2	14	1	--	--	--	--	--	--	3	5	1

Table A12. Ballard Lake aquatic plant occurrences and densities for the September 8 & 9, 1999 survey based on 24 transects and 4 depths, for a total of 96 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-4 feet (n=24)			Depth 5-8 feet (n=24)			Depth 9-12 feet (n=24)			Depth 13-16+ feet (n=24)			All Stations (n=96)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Arrowhead (*Sagittaria sp*)	1	4	1.0	--	--	--	--	--	--	--	--	--	1	1	1.0
Bulrush (*Scirpus sp*)	2	8	1.5	1	4	1.0	--	--	--	--	--	--	3	3	1.3
Cabbage (*Potamogeton amplifolius*)	--	--	--	7	29	1.4	6	25	1.3	--	--	--	13	14	1.4
Celery (*Vallisneria americana*)	9	38	1.3	11	46	1.4	3	13	1.3	1	4	1.0	24	25	1.3
Chara (*Chara sp*)	2	8	1.0	--	--	--	--	--	--	--	--	--	2	2	1.0
Dwarf milfoil (*Myriophyllum tenellum*)	2	8	1.0	--	--	--	--	--	--	--	--	--	2	2	1.0
Fern pondweed (*Potamogeton robbinsii*)	1	4	1.0	8	33	2.0	6	25	2.2	3	13	2.3	18	19	2.1
Floatingleaf pondweed (*Potamogeton natans*)	1	4	1.0	--	--	--	--	--	--	--	--	--	1	1	1.0
Illinois pondweed (*Potamogeton illinoensis*)	3	13	1.0	3	13	1.0	--	--	--	--	--	--	6	6	1.0
Lobelia (*Lobelia dortmanna*)	7	29	1.6	1	4	2.0	--	--	--	--	--	--	8	8	1.6
Naiads (*Najas sp*)	2	8	1.0	3	13	1.0	--	--	--	--	--	--	5	5	1.0
Pickerel plant (*Pontederia cordata*)	2	8	1.0	--	--	--	--	--	--	--	--	--	2	2	1.0
Pipewort (*Eriocaulon aquaticum*)	--	--	--	1	4	1.0	--	--	--	--	--	--	1	1	1.0
Quillwort (*Isoetes sp*)	2	8	1.0	1	4	1.0	--	--	--	--	--	--	3	3	1.0
Slender arrowhead (*Sagittaria graminea*)	1	4	1.0	--	--	--	--	--	--	--	--	--	1	1	1.0
Spatterdock (*Nuphar variegatum*)	3	13	1.0	--	--	--	--	--	--	--	--	--	3	3	1.0
Sweet gale (*Myrica gale*)	2	8	1.0	--	--	--	--	--	--	--	--	--	2	2	1.0
Variable pondweed (*Potamogeton gramineus*)	7	29	1.0	2	8	1.0	--	--	--	--	--	--	9	9	1.0
Waterlily (*Nymphaea sp*)	3	13	1.7	--	--	--	--	--	--	--	--	--	3	3	1.7
Watershield (*Brasenia schreberi*)	3	13	1.0	--	--	--	--	--	--	--	--	--	1	1	1.0
Wild rice (*Zizania aquatica*)	1	4	1.0	--	--	--	--	--	--	--	--	--	1	1	1.0

Table A13. Irving Lake aquatic plant occurrences and densities for the September 8 & 9, 1999 survey based on 12 transects and 4 depths, for a total of 48 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-4 feet (n=12)			Depth 5-8 feet (n=12)			Depth 9-12 feet (n=12)			Depth 13-16+ feet (n=12)			All Stations (n=48)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bladderwort (*Utricularia sp*)	--	--	--	1	8	1.0	--	--	--	--	--	--	1	2	1.0
Celery (*Vallisneria americana*)	2	17	1.0	1	8	1.0	--	--	--	--	--	--	3	6	1.0
Chara (*Chara sp*)	1	8	1.0	1	8	2.0	--	--	--	--	--	--	2	4	1.5
Claspingleaf pondweed (*Potamogeton richardsonii*)	--	--	--	1	8	1.0	--	--	--	--	--	--	1	2	1.0
Elodea (*Elodea canadensis*)	1	8	1.0	--	--	--	--	--	--	--	--	--	1	2	1.0
Illinois pondweed (*Potamogeton illinoensis*)	--	--	--	1	8	1.0	--	--	--	--	--	--	1	2	1.0
Naiads (*Najas sp*)	--	--	--	1	8	1.0	--	--	--	--	--	--	1	2	1.0
Pickerel plant (*Pontederia cordata*)	4	33	1.8	2	17	2.0	--	--	--	--	--	--	6	13	1.8
Quillwort (*Isoetes sp*)	1	8	1.0	--	--	--	--	--	--	--	--	--	1	2	1.0
Sweet gale (*Myrica gale*)	1	8	1.0	--	--	--	--	--	--	--	--	--	1	2	1.0
Stringy pondweed (*Potamogeton sp*)	--	--	--	2	17	1.0	--	--	--	--	--	--	2	4	1.0
Variable pondweed (*Potamogeton gramineus*)	2	17	1.5	--	--	--	--	--	--	--	--	--	2	4	1.5
Watershield (*Brasenia schreberi*)	1	8	1.0	--	--	--	--	--	--	--	--	--	1	2	1.0
White waterlily (*Nymphaea sp*)	8	67	1.0	2	17	1.0	--	--	--	--	--	--	10	21	1.0
Wild rice (*Zizania aquatica*)	10	83	2.9	10	83	1.3	1	8	1.0	--	--	--	21	44	2.0

Individual transect data for White Birch Lake for September 8 and 9, 1999.

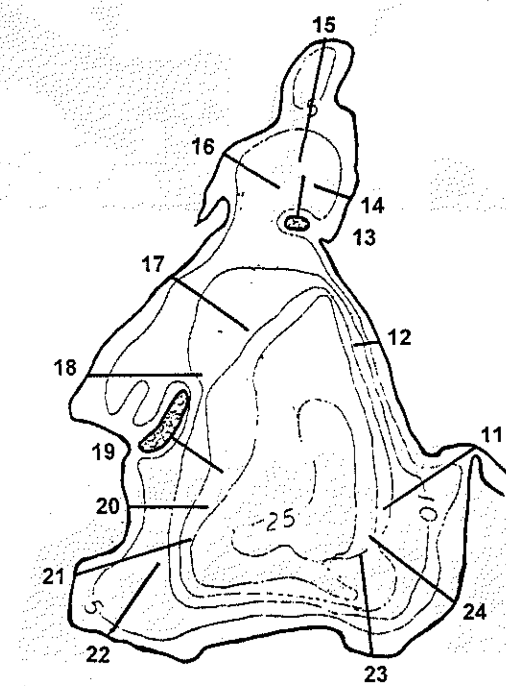
	T11				T12				T13				T14			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bent grass																
Cabbage																
Calla																
Cattails																
Celery	2	1											2			
Chara						1										
Dwarf milfoil						1										
Elodea																
Fern pondweed		1		3				1								
Floatingleaf pondweed																
Lobelia													2			
Naiads													1	1		
Pickerel plant																
Pipewort																
Quillwort	1															
Spatterdock	1															
Stringy pondweed																
Sweet gale	1															
Variable pondweed	1								1							
Waterlily													1			
Watershield																

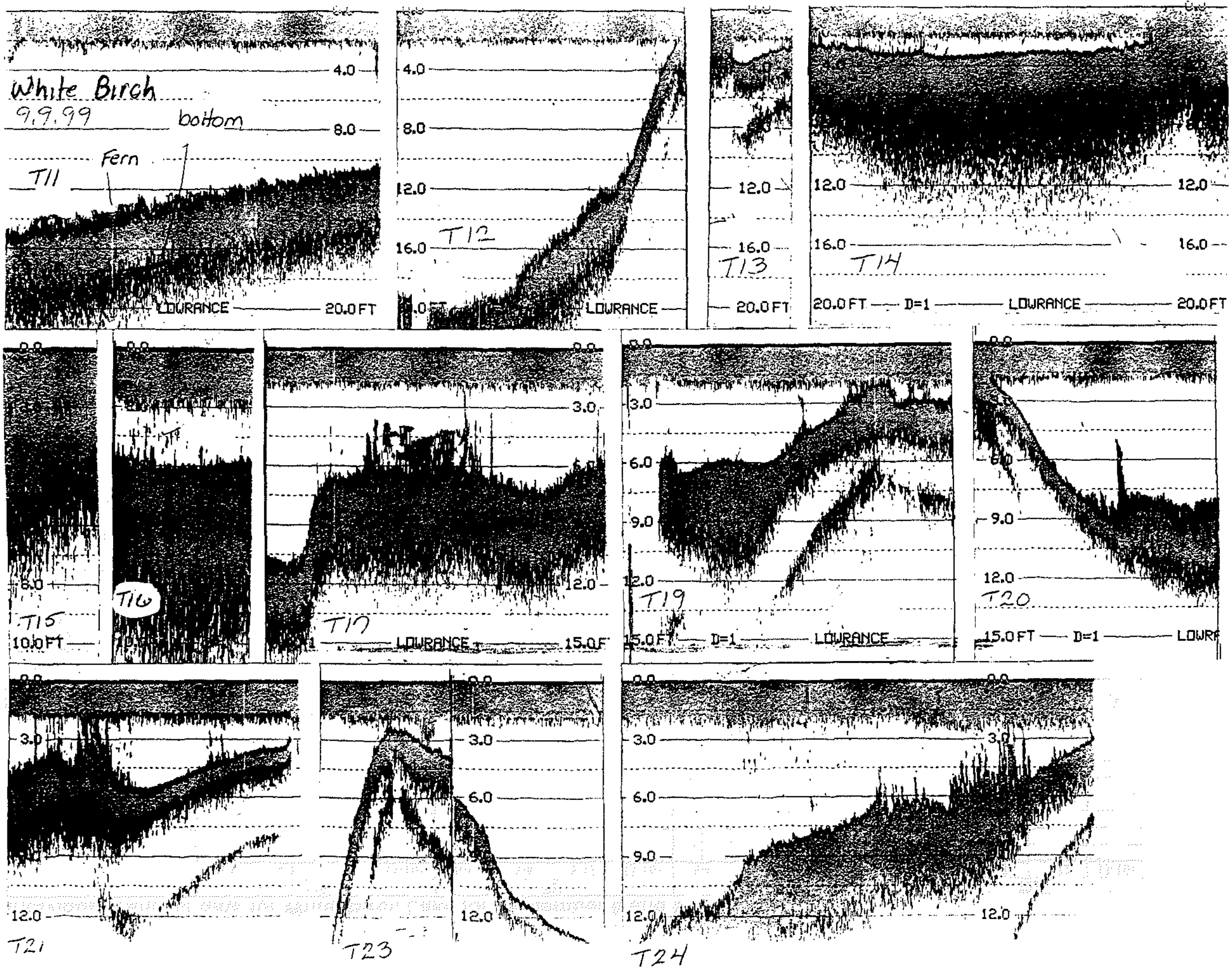
	T15				T16				T17				T18			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bent grass																
Cabbage																
Calla																
Cattails																
Celery	1								1							
Chara									1							
Dwarf milfoil																
Elodea																
Fern pondweed	1										3					
Floatingleaf pondweed																
Lobelia																
Naiads	4								1				1			
Pickerel plant																
Pipewort																
Quillwort																
Spatterdock									1							
Stringy pondweed	3															
Sweet gale																
Variable pondweed	1								1				1	1		
Waterlily	1				1				1				3	1		
Watershield	1					1								1		

Individual transect data for White Birch Lake for September 8 and 9, 1999.

	T19				T20				T21				T22			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead									1							
Bent grass									1							
Cabbage																
Calla																
Cattails									1							
Celery									2				2	1		
Chara																
Dwarf milfoil																
Elodea														1		
Fern pondweed							2					1			1	2
Floatingleaf pondweed									1							
Lobelia					1											
Naiads							1		1		3			1		
Pickerel plant																
Pipewort									1							
Quillwort																
Spatterdock									1							
Stringy pondweed													1	1		
Sweet gale																
Variable pondweed		1					1				1		1			
Waterlily									1				1	1		
Watershield																

	T23				T24				Channel
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	
Arrowhead									
Bent grass									
Cabbage						1	1		
Calla									1
Cattails									
Celery					1				
Chara									
Dwarf milfoil									
Elodea									
Fern pondweed			3						
Floatingleaf pondweed									2
Lobelia					1	1			
Naiads					1	1			
Pickerel plant									2
Pipewort					1				
Quillwort									
Spatterdock									2
Stringy pondweed									
Sweet gale									2
Variable pondweed						1			
Waterlily									
Watershield									1




White Birch
9.9.99
bottom
Fern
T11
T12
T13
T14
T15
T16
T17
T19
T20
T21
T23
T24
LOWRANCE
D=1
20.0 FT
15.0 FT
10.0 FT
4.0
8.0
12.0
16.0
3.0
6.0
9.0

Individual transect data for Ballard Lake for September 8 and 9, 1999.

	T1				T2				T3				T4			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bulrush																
Cabbage						1										
Calla																
Celery														1		
Chara													1			
Dwarf milfoil													1			
Fern pondweed																
Floatingleaf pondweed																
Illinois pondweed																
Lobelia									1				2			
Naiads																
Pickerel plant																
Pipewort																
Quillwort																
Slender arrowhead																
Spatterdock									1							
Sweet gale					1											
Variable pondweed																
Waterlily																
Watershield																
Wild rice	1															

	T5				T6				T7				T8			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bulrush	2	1											1			
Cabbage						1	1								1	
Calla																
Celery					1	1			1	1			1		2	
Chara																
Dwarf milfoil					1											
Fern pondweed						2	4								2	1
Floatingleaf pondweed																
Illinois pondweed					1	1			1	1						
Lobelia	3	2			1								1			
Naiads						1										
Pickerel plant																
Pipewort																
Quillwort																
Slender arrowhead																
Spatterdock																
Sweet gale																
Variable pondweed	1	1			1				1							
Waterlily																
Watershield																
Wild rice																

Individual transect data for Ballard Lake for September 8 and 9, 1999.

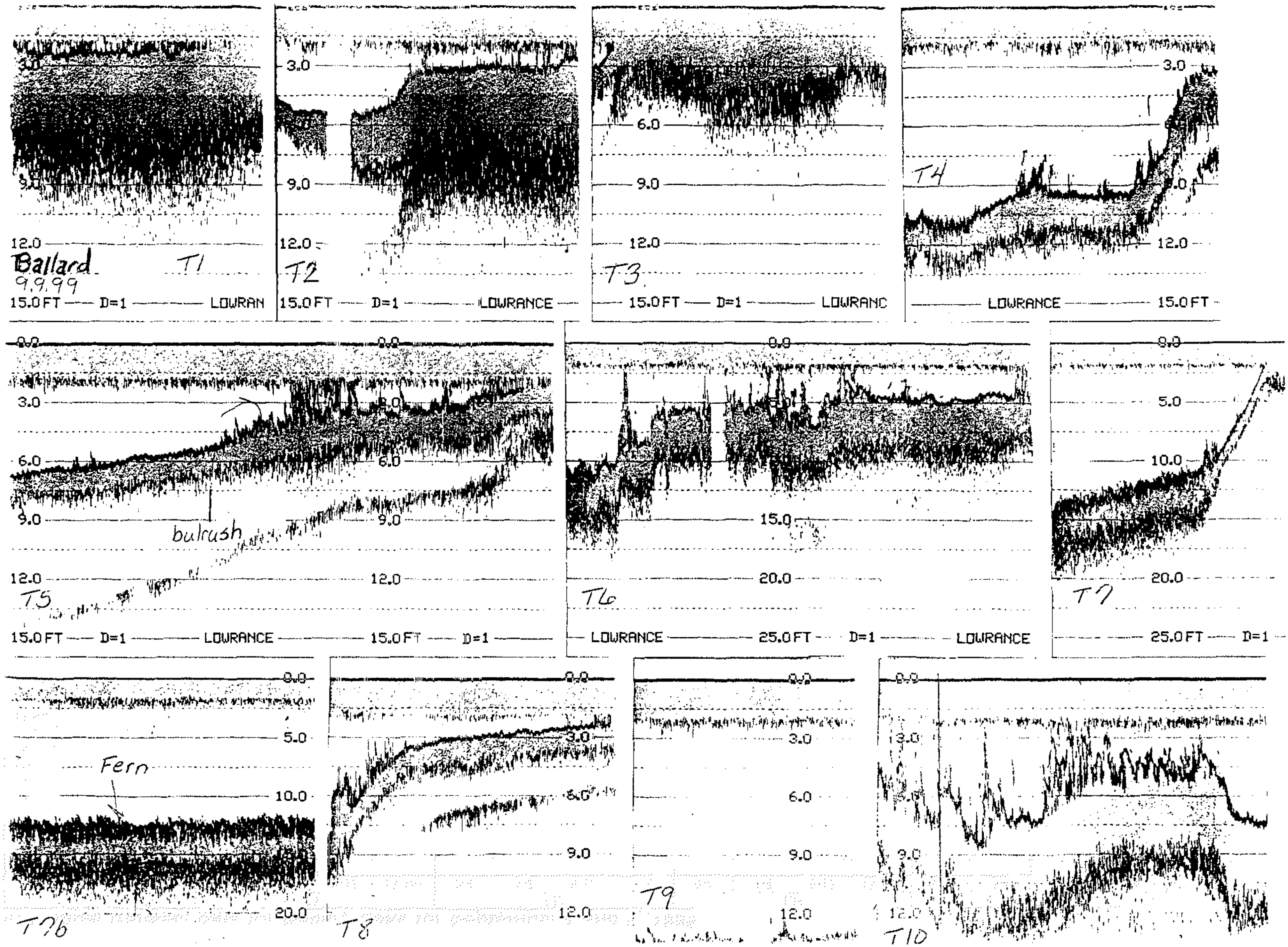
	T9				T10				T25				T26			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bulrush																
Cabbage														1		
Calla																
Celery		2	1						1						1	
Chara																
Dwarf milfoil																
Fern pondweed		3	2											1		4
Floatingleaf pondweed					1											
Illinois pondweed									1							
Lobelia	2															
Naiads		1							1							
Pickerel plant																
Pipewort																
Quillwort																
Slender arrowhead																
Spatterdock					1											
Sweet gale																
Variable pondweed	1															
Waterlily																
Watershield					1				1							
Wild rice																

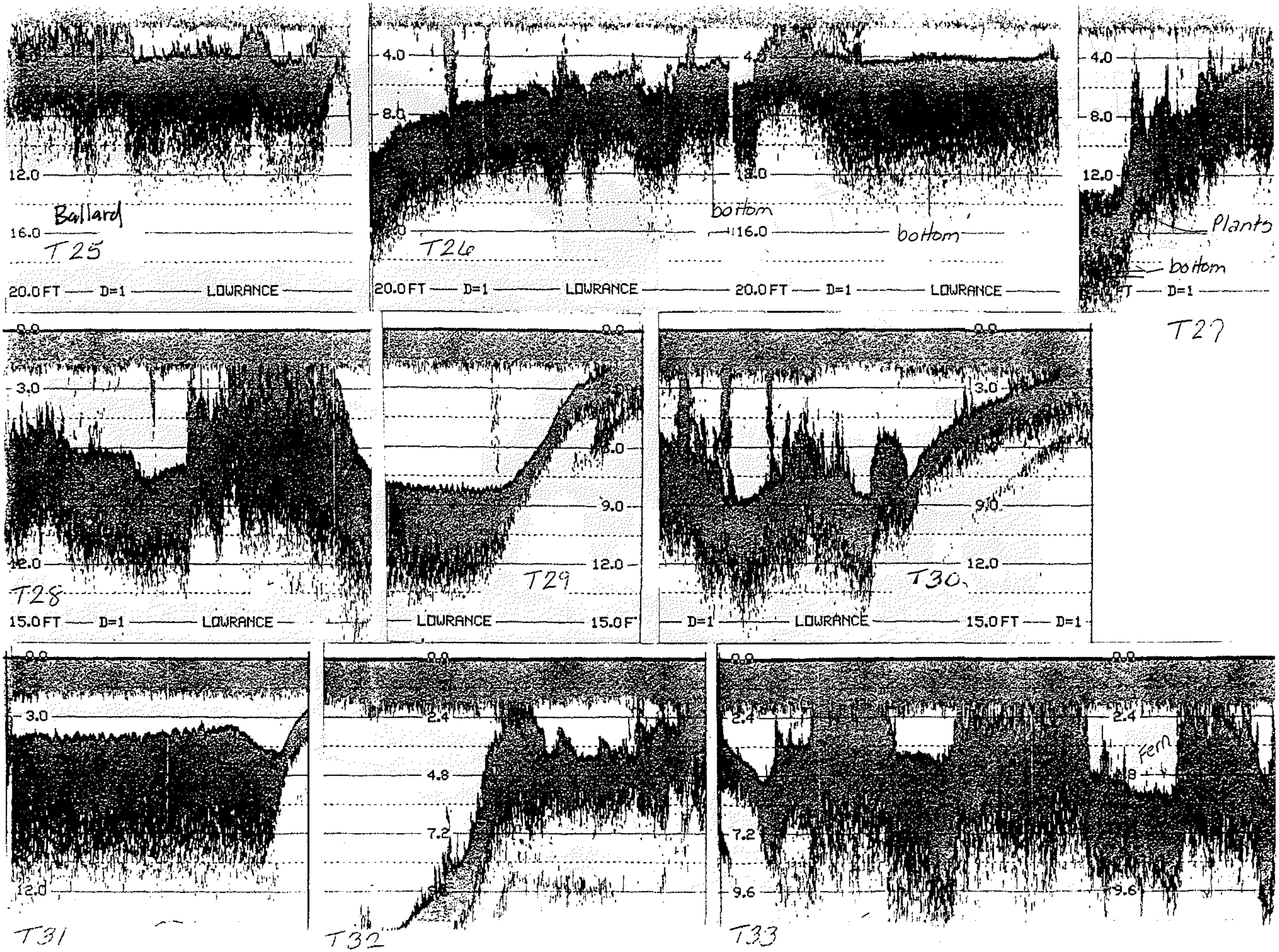
	T27				T28				T29				T30			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bulrush																
Cabbage							2								1	
Calla																
Celery		1		1	1				1				1	1		
Chara									1							
Dwarf milfoil																
Fern pondweed		1	1	2											3	
Floatingleaf pondweed																
Illinois pondweed																
Lobelia	1															
Naiads						1										
Pickerel plant																
Pipewort																
Quillwort	1								1							
Slender arrowhead																
Spatterdock																
Sweet gale																
Variable pondweed																
Waterlily																
Watershield																
Wild rice																

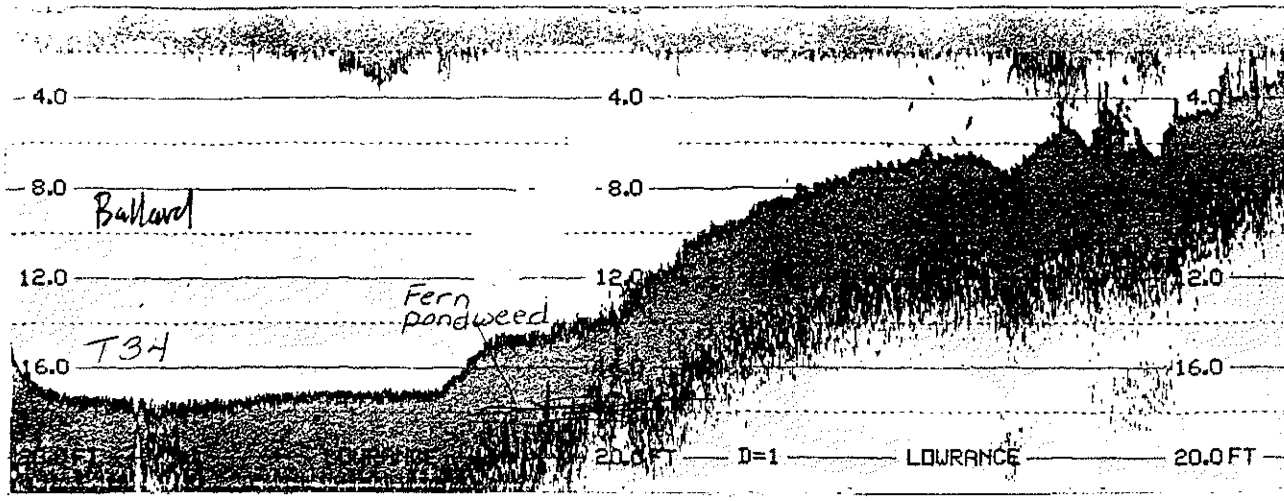
Individual transect data for Ballard Lake for September 8 and 9, 1999.

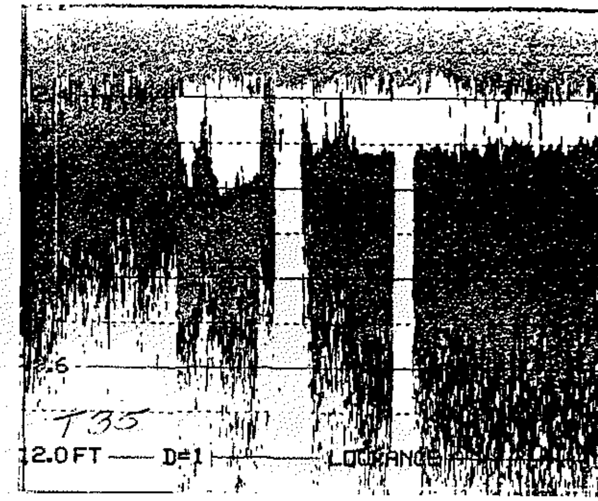
	T31				T32				T34				T35			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead																
Bulrush																
Cabbage						1	2			3						
Calla																
Celery					2	2				1			3	3		
Chara																
Dwarf milfoil																
Fern pondweed										3			1	2		
Floatingleaf pondweed																
Illinois pondweed										1						
Lobelia																
Naiads					1											
Pickerel plant					1											
Pipewort																
Quillwort																
Slender arrowhead																
Spatterdock																
Sweet gale	1															
Variable pondweed					1	1			1							
Waterlily	1				3											
Watershield																
Wild rice																

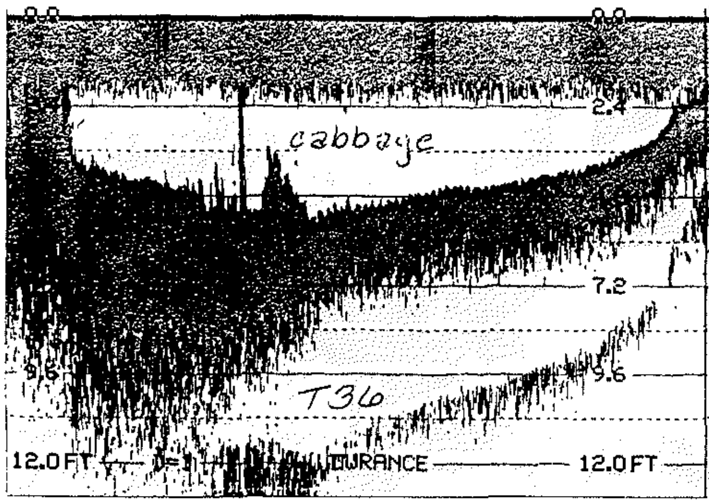
	T36				T37				T38				T39			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Arrowhead													1			
Bulrush																
Cabbage		1				2	1									
Calla																
Celery						1				1						
Chara																
Dwarf milfoil																
Fern pondweed		1				3	1									
Floatingleaf pondweed																
Illinois pondweed																
Lobelia																
Naiads																
Pickerel plant													1			
Pipewort						1										
Quillwort										1						
Slender arrowhead									1							
Spatterdock													1			
Sweet gale																
Variable pondweed													1			
Waterlily													1			
Watershield													1			
Wild rice																

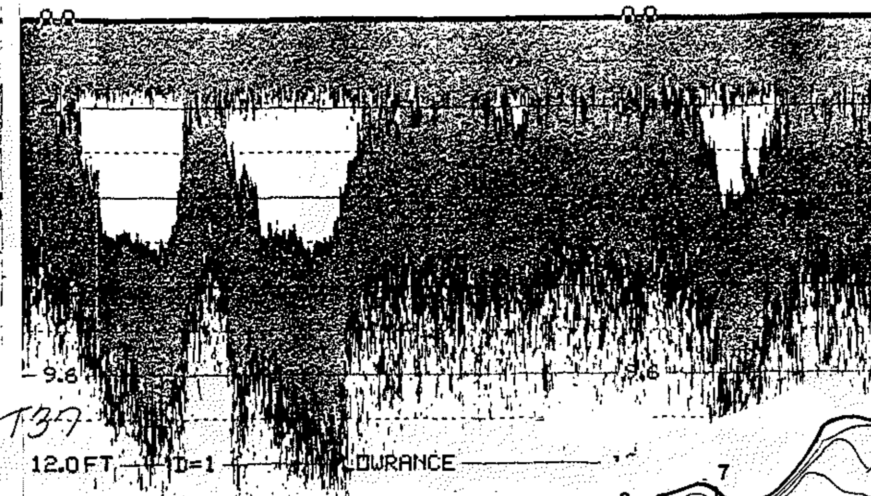

Ballard
9.9.99
T1
T2
T3
T4
T5
bulrush
T6
T7
T7b
Fern
T8
T9
T10
15.0 FT D=1 LOWRAN
15.0 FT D=1 LOWRANCE
15.0 FT D=1 LOWRANC
LOWRANCE 15.0 FT
15.0 FT D=1 LOWRANCE 15.0 FT D=1
LOWRANCE 25.0 FT D=1 LOWRANCE
25.0 FT D=1

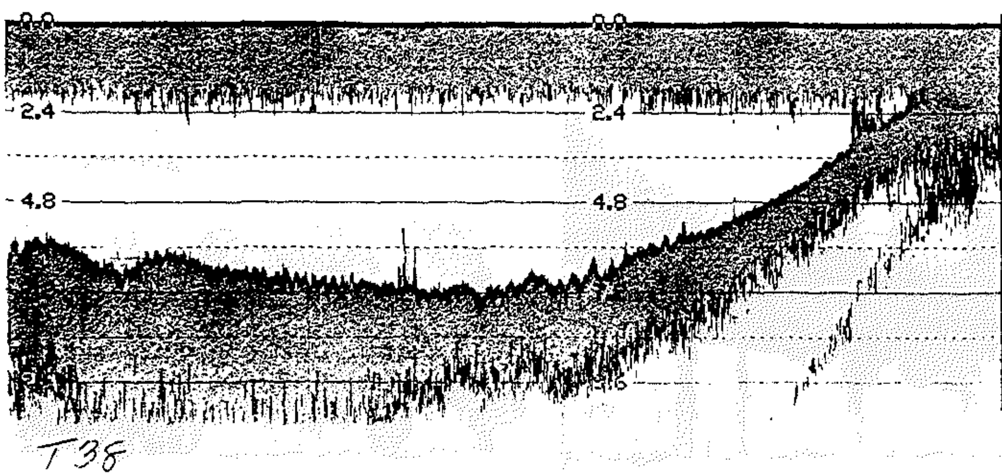

Ballard
T25
T26
bottom
bottom
Plants
bottom
T27
T28
T29
T30
T31
T32
T33
fern
20.0 FT — D=1 — LOWRANCE
15.0 FT — D=1 — LOWRANCE

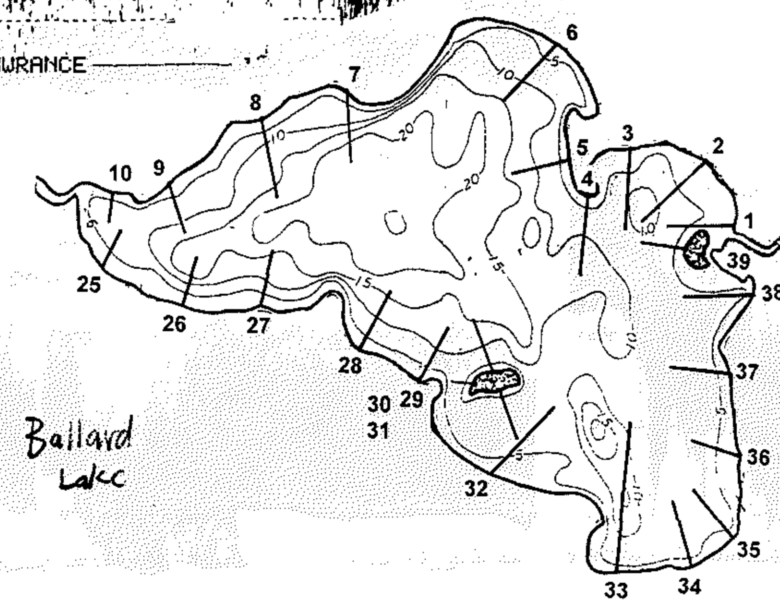

4.0
8.0
12.0
16.0
Ballard
Fern pondweed
T34
20.0 FT
D=1
LOWRANCE


T35
12.0 FT
D=1


0.0
2.4
7.2
9.6
cabbage
T36
12.0 FT
D=1
LOWRANCE


0.0
9.6
T37
12.0 FT
D=1
LOWRANCE


0.0
2.4
4.8
T38

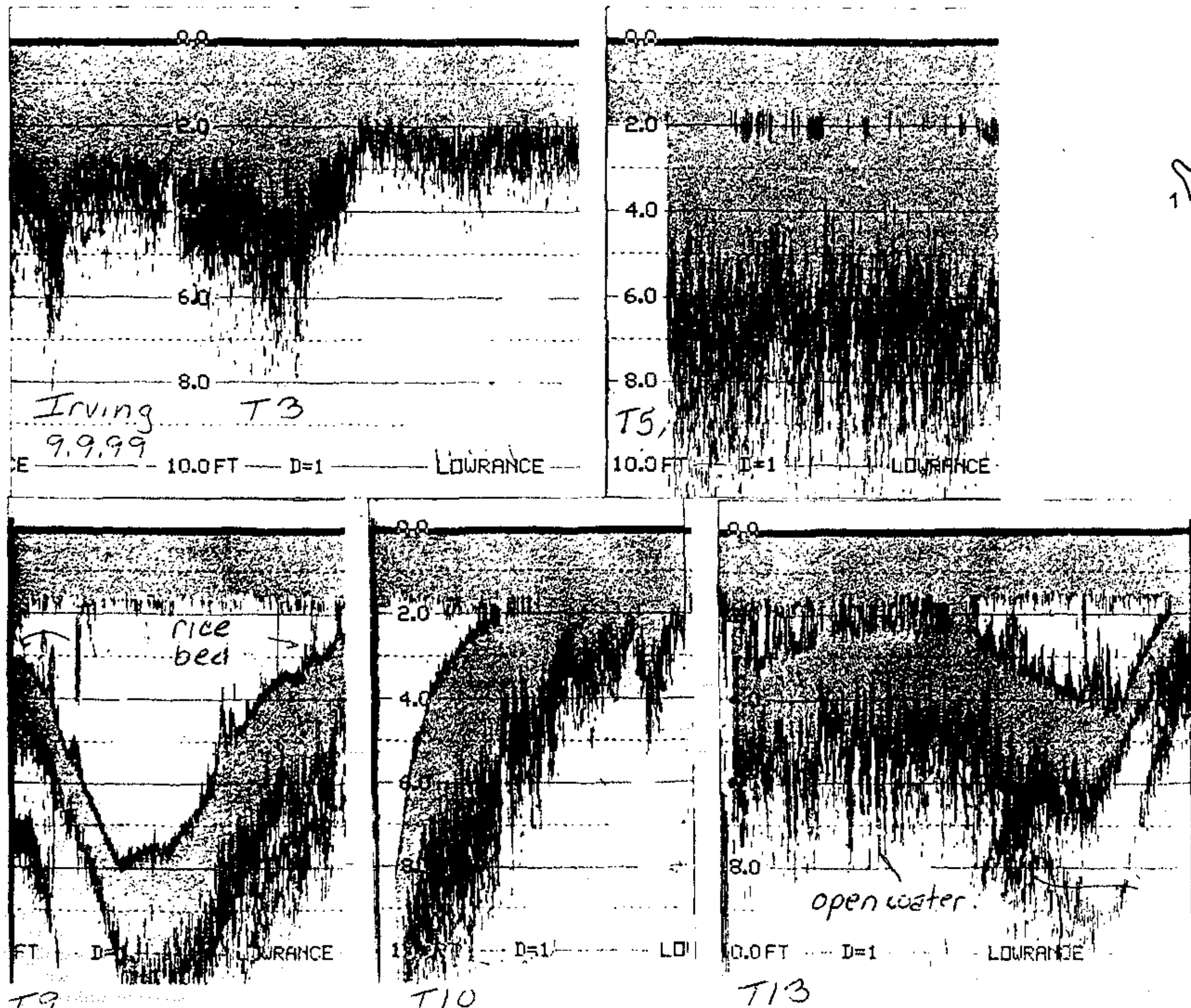

Ballard Lake
1
2
3
4
5
6
7
8
9
10
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39

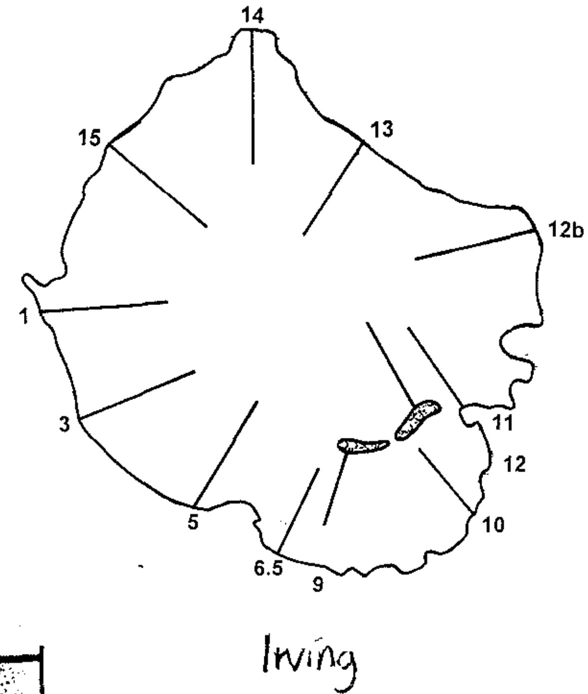
Individual transect data for Irving Lake for September 8 and 9, 1999.

	T1				T3				T5				T6.5			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Bladderwort																
Celery																
Chara																
Claspingleaf pondweed																
Elodea																
Illinois pondweed																
Naiads																
Pickerel plant	2								2							
Quillwort																
Sweet gale																
Stringy pondweed																
Variable pondweed	2															
Watershield																
White waterlily	1				1	1			1				1			
Wild rice	1	1			4	1			4	1			4	1		

	T9				T10				T11				T12			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Bladderwort						1										
Celery																
Chara																
Claspingleaf pondweed																
Elodea																
Illinois pondweed																
Naiads																
Pickerel plant						3										
Quillwort																
Sweet gale	1															
Stringy pondweed						1										
Variable pondweed																
Watershield																
White waterlily					1				1	1						
Wild rice		1	1		1				4	4			3	1		

	T12b				T13				T14				T15			
	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+	0-4	5-8	9-12	13-16+
Bladderwort																
Celery	1				1	1										
Chara					1	2										
Claspingleaf pondweed						1										
Elodea	1															
Illinois pondweed						1										
Naiads						1										
Pickerel plant									2	1			1			
Quillwort					1											
Sweet gale																
Stringy pondweed						1										
Variable pondweed					1											
Watershield									1							
White waterlily									1				1			
Wild rice		1			1				4	1			3	1		


0.0
2.0
4.0
6.0
8.0
Irving
9.9.99
T3
10.0 FT
D=1
LOWRANCE
T5,
rice bed
open water
T9
T10
T13


14
15
13
12b
1
3
11
12
5
10
6.5
9
Irving

(1)

Macrophyte Survey of Ballard, Irving and White Birch Lakes
August 25 and 26, 1998
Sandy Wickman and Cathy Cleland

Summary

Ballard - Ballard Lake seems to have a diverse plant community with a fair number of these species being of moderate densities. The bottom substrate is primarily sand and gravel. This substrate is conducive to the presence of quillworts and pipewort. Plant communities change through the years depending on light penetration (turbidity and presence of algae). During the 1998 survey, Potamogeton illinoensis was abundant in certain parts of the lake and Potamogeton amplifolius was fairly abundant. One of the lake residents told us during the plant survey that he was concerned about the pH of the water in Irving Lake and the effect it may have on Ballard. The Surface Water Resources of Vilas County (1963) states that the pH in Ballard Lake in 1963 was 8.2 and the pH in Irving Lake in 1963 was 9.1. It is difficult to interpret the results of a single pH reading - all chemical readings need to be taken over a period of time for proper interpretation.

Please refer to the attached map for locations.

Plants observed on **Ballard Lake** on August 25 and 26, 1998; weather conditions - sunny with stiff breeze:

Site #1: Bottom - muck with woody debris
Sweet gale (Myrica gale) and wild calla (Calla palustris) along shore.
Wild rice (Zizania palustris)-scattered and sparse,
white water lily (Nymphaea odorata)-sparse to common.

Site #2 Bottom - hard, sandy with woody debris
Wild celery (Vallisneria americana)-sparse,
spatterdock (Nuphar variegata)-present,
narrow-lead bur-reed (Sparganium angustifolium) - common;
common arrowhead (Sagittaria latifolia)-sparse,
pipewort (Eriocaulon aquaticum)-abundant,
dwarf water milfoil (Myriophyllum tenellum)-common to abundant,
needle spikerush (Eleocharis acicularis)-density was not noted - near shore;
wild rice - very sparse and scattered to non-existent.

Site #2A Variable pondweed (Potamogeton gramineus)-sparse,
clasping-leaf pondweed (Potamogeton richardsonii)-common,
large-leaf pondweed (Potamogeton amplifolius)-common.

Site #3 Same plants as site #2 near shore.
At 6 ft. deep:
Illinois pondweed (Potamogeton illinoensis)-common,
fern pondweed (Potamogeton robbinsii) - abundant
large-leaf pondweed (P. amplifolius) - abundant.

Site #4 Dwarf water milfoil (M. tenellum)-common
variable pondweed (P.gramineus)-common.
[deep drop-off near point]

Site #5 Large bed of softstem bulrush (Scirpus validus)-fairly abundant,
needle spikerush (E. acicularis)-sparse.

Site #6 Bottom - sand
Near shore -
needle spikerush (E. acicularis)-common,
quillwort (Isoetes spp)-common,
wild celery (V. americana)-common,
dwarf water milfoil (M. tenellum)-common,
fern pondweed (P. robbinsii)-density was not noted,
bushy pondweed (Najas flexilis)-common,
muskgrass (Chara spp)-sparse.
In deeper water -
Illinois pondweed (P. illinoensis) - abundant,
large-leaf pondweed (P. amplifolius) abundant.

Site #6A Wild celery (V. americana) - abundant
large-leaf pondweed (P amplifolius) - abundant.

Site # 6B Wild clery (V. americana) -abundant
Illinois pondweed (P. illioensis) abundant.
[Oak is dominant tree species on shore]

Site #7 Dwarf water milfoil (M. tenellum)-common,
water lobelia (Lobelia dortmanna)-sparse,
pipewort (E aquaticum)-abundant,
variable pondweed (P. gramineus)-density was not noted.
Small patch of bulrush (Scirpus spp).

Site #8 Bottom - sand
Scirpus spp. all along shore
Approximately 50 ft. off shore -
wild celery (V. americana) common,
large-leaf pondweed (P. amplifolius) common.

Site #9 Wild celery (V. americana)-common;
fern pondweed (P. robbinsii) - abundant off shore,

Site #10 Bottom - sand
Sedge and sweet gale along shore
Wild celery (V. americana) - common,
narrow-leaf bur-reed (S. angustifolium) - common,
bushy pondweed, (N. flexilis) - common
scattered white pond lily (N. odorata) near the channel to White Birch.

(site numbering goes from 10 to 25. Sites 11 - 24 are on White Birch Lake)

Site #25 Bottom - sand with logs and woody debris
White pond lily (N. odorata) sparce to common
floating leaf pondweed (Potamogeton natans) were sparse to common.

Site #26 Bottom - sand with logs and woody debris
Pipewort (E. aquaticum) common, no other aquatic plants.

Site #27 Bottom - sand
No plants observed

Site #28 Bottom - sand
No plants observed

Site #29 Bottom - sand
Dwarf water milfoil (M. tenellum) - common,
pipeworts (E. aquaticum) - common,
wild celery (V. americana) - common.

Site #30 Bottom - sand with thin muck cover, rocky near shore
No plants observed.

Site #31 Bottom - sand and rock
Wild celery (V. americana)-sparse to common,
white pond lily (N.odorata) - sparce to common,
narrow-leaf bur-reed (S angustifolium) sparse to common

Site #32 Pickerel weed (Pontederia cordata)-common,
white pond lily (N ordorata)-common
small amount of Scirpus near shore.

Site #33 Bottom - sand
Wild calla (C. palustris) - common along shore
pickerel weed (P. cordata) - common along shore
white pond lily were common along shore.
Bushy pondweed (N. flexilis) - common just off shore
wild celery (V. americana) common just off shore.

Site #34 Bottom - sand and rock
No plants observed

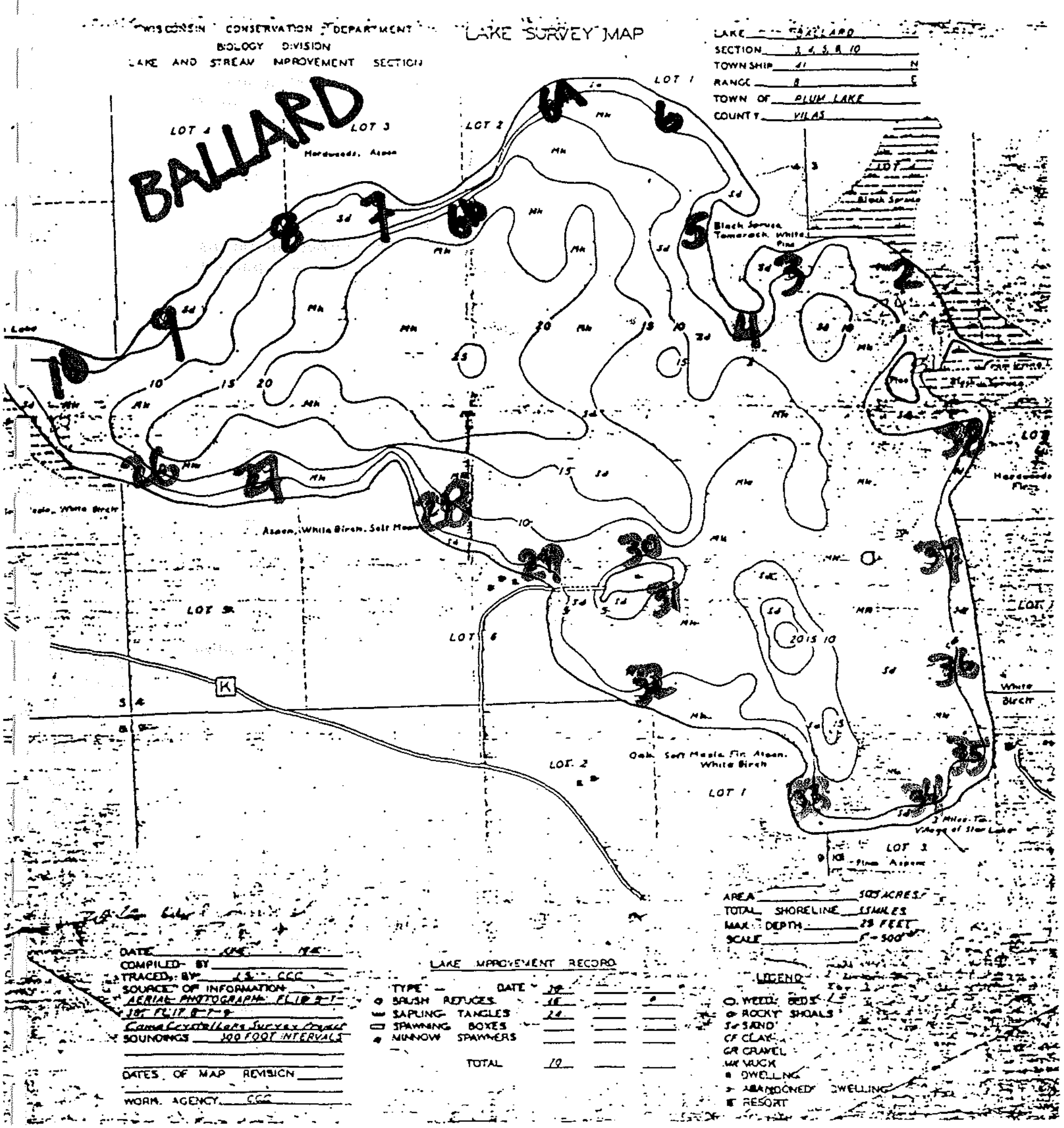
Site #35 Bottom - sand
Wild celery (V. americana) - densities were not noted
varible pondweed (P gramineus) - densities were not noted
brown-fruited rush (Juncus pelocarpus) - densities were not noted

Site #36 Pipewort (E. aquaticum)-common,
dwarf water milfoil (M. tenellum)- common,
water lobelia (Lobelia dortmanna)-sparse,
wild celery (V. americana)-sparse to common.

Site #37 Water lobelia (L. dortmanna) - sparce to common
brown-fruited rush (Juncus pelocarpus) - sparse to common.

Site #38 Bottom - muck, near shore
Pipewort (E. aquaticum)-sparse,
pickerelweed (P. cordata)-common,
narrow-leaf bur-reed (S angustifolium)-common,
arum-leaved arrowhead (Sagittaria cuneata) - sparce
floating leaved arrowhead (Sagittaria cuneata.) - sparse,
wild celery (V. americana)-sparse,
spatterdock (N. variegata)-common,
small duckweed (Lemna minor)-common
Bidens spp., cattails (Typha latifolia) and sedge observed along the shore.
At 4 ft. deep the bottom was sandy with woody debris and no plants.

Site #39 Bottom - muck, black spruce and tamarack along shore
Pickerelweed (P. cordata) - common to abundant,
wild rice (Z. palustris) - common to abundant
cattail (T. latifolia) common to abundant.



WISCONSIN CONSERVATION DEPARTMENT
BIOLOGY DIVISION
LAKE AND STREAM IMPROVEMENT SECTION
LAKE SURVEY MAP
SECTION 3, 4, 5, 8, 10
TOWNSHIP 41 N
RANGE 8 E
TOWN OF PLUM LAKE
COUNTY VILAS
BALLARD
LOT 4
LOT 3
LOT 2
LOT 1
LOT 6
LOT 2
LOT 1
LOT 3
Hardwoods, Aspen
Black Spruce, Tamarack, White Pine
Black Spruce
Aspen, White Birch, Soft Maple
Oak, Soft Maple, Fir, Aspen, White Birch
3 Miles To Village of Star Lake
K
AREA 503 ACRES
TOTAL SHORELINE 5 MILES
MAX DEPTH 25 FEET
SCALE 1"=500'
DATE
COMPILED BY
TRACED BY CCC
SOURCE OF INFORMATION
AERIAL PHOTOGRAPH
SOUNDINGS 100 FOOT INTERVALS
DATES OF MAP REVISION
WORK AGENCY CCC
LAKE IMPROVEMENT RECORD
TYPE
DATE
BRUSH REFUGES
SAPLING TANGLES
SPAWNING BOXES
MINNOW SPAWNERS
TOTAL
LEGEND
WEED BEDS
ROCKY SHOALS
Sd SAND
Cl CLAY
Gr GRAVEL
Mk MUCK
DWELLING
ABANDONED DWELLING
RESORT

Plants observed on White Birch Lake on August 25, 1998:

White Birch - White Birch Lake had a plant community with fair diversity. Floating-leaf vegetation was present in the shallow bays with muck bottoms. Good populations of panfish were observed in these bays amongst the vegetation.

In the channel connecting Ballard and White Birch Lakes the following plants were observed:

Wild calla (C. palustris), white pond lily (N. odorata), common arrowhead (S. latifolia), pickerelweed (P. cordata), floating leaf pondweed (Potamogeton natans), more bushy pondweed (N flexilis) as we approached White Birch Lake and ribbon-leaf pondweed.

Please refer to the attached maps for site locations:

Site #11 Mouth of the channel, Bottom - muck
Quillwort (Isoetes spp)-sparse,
wild celery (V. americana)-sparse,
muskgrass (Chara spp.)-sparse,
variable pondweed (P gramineus)-density not noted,
common arrowhead (S. latifolia)-sparse,
bushy pondweed (N flexilis)-common,
spatterdock (N. variegata)-common,
dwarf water milfoil (M. tenellum)-abundant,
floating leaved arrowhead (Sagittaria cuneata.)-sparse.

Site #12 Red and white pines on shore, sweet gale and Carex spp. along shoreline.
Appoximately 30 ft. off shore we observed:
fern pondweed (P. robbinsii) - common,
wild celery (V. americana)-density not noted,
minor amounts of spatterdock (N. variegata).

Site #13 Pickerelweed (P. cordata)-common,
white pond lily (N. odorata)-common,
spatterdock (N. variegata)-common.

Site #14 Watershield (Brasnia schreberi)-common,
white pond lily (N. odorata)-common,
floating leaf pondweed (Potamogeton natans)-density not noted,
northern water milfoil (Myriophyllum sibiricum)-density not noted

Site #15 Bottom - flocculant. Small panfish (perch, pumpkinseeds, etc.) observed.
White pond lily (N. odorata)-sparse,
spatterdock (N. variegata)-sparse,
watershield (Brasnia schreberi)-common along shoreline
watershield - scattered throughout north end of lake.
Patch of three-way sedge (Dulichium arundinaceum) along shore.
30-40 ft. off shore:
bushy pondweed (N flexilis) - abundant

Site #16 White pond lily (N. odorata)-sparse near shore,
wild celery (V. americana)-sparse.

Site #17 White pond lily (N. odorata), scattered but more abundant near shore.

Site #18 Bottom - sand
Floating leaf pondweed (Potamogeton natans)-common,
watershield (B. schreberi)-abundant,
white pond lily (N. odorata)-common,
pickerelweed (P. cordata)-abundant,
bushy pondweed (N flexilis)-density not noted.

Site #19 Fern pondweed (P. robbinsii)-common,
minor amount of white pond lily (N. odorata) near shore.

Site #20 Pickerelweed (P. cordata)-common,
white pond lily (N. odorata)-common,
watershield (B. schreberi)-common,
pipewort (E. aquaticum)-common.

Site #21 Bottom - sand; spruce, tamarack, and white pine along shore.
Watershield (B. schreberi)-common,
variable pondweed (P gramineus)-common,
white pond lily (N. odorata)-common,
bushy pondweed (N flexilis)-common,
brown-fruited rush (Juncus pelocarpus)-density not noted.
Sedge and cattail (Typha) along shore.

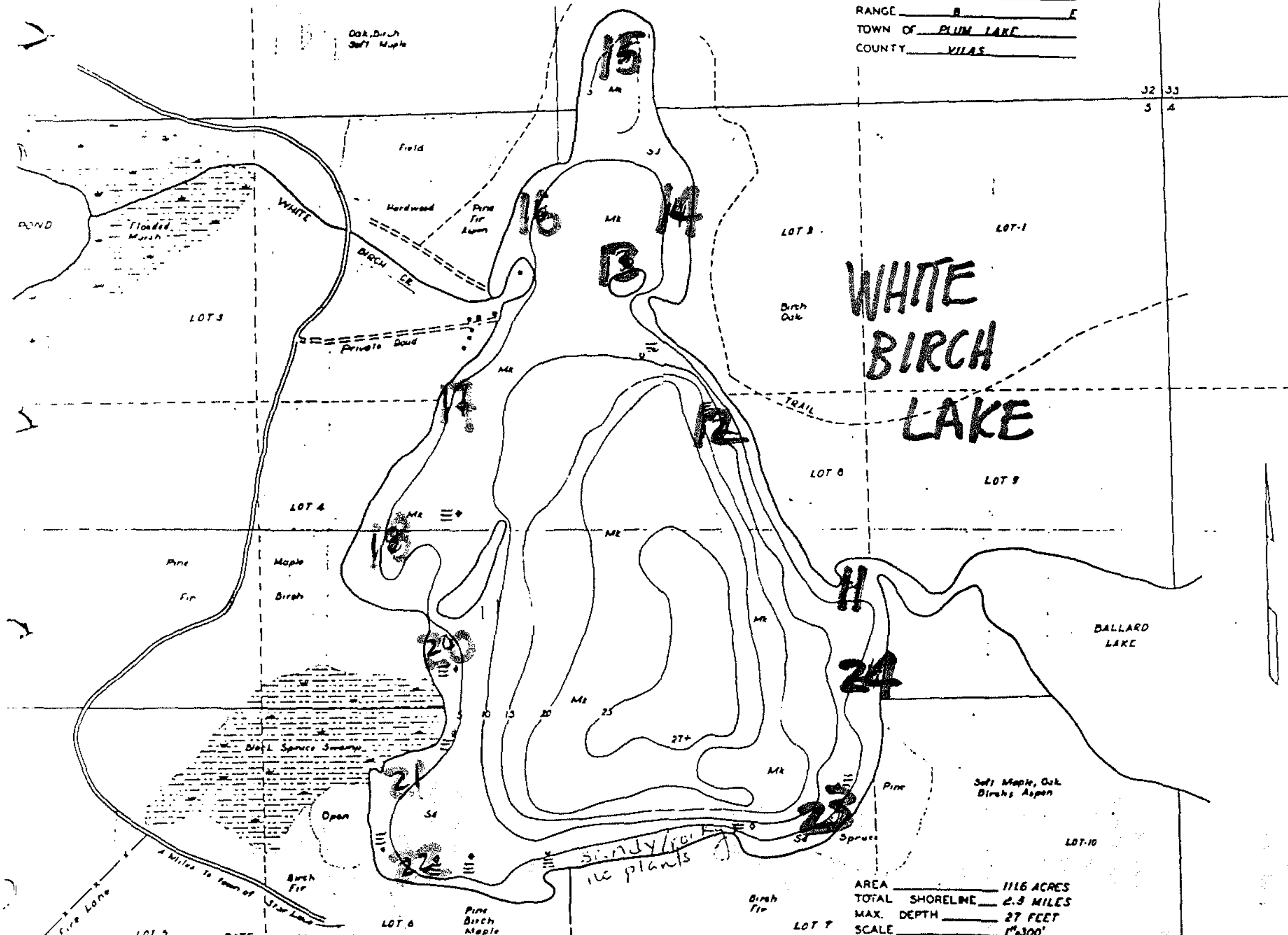
Site #22 Bottom - sandy
near shore:
Pipewort (E. aquaticum)-sparse to common
off shore:
wild celery (V. americana) - sparse to common
variable pondweed (P gramineus) - sparse to common
dwarf water milfoil (M. tenellum) - sparse to common;
muskgrass (Chara spp)-sparse.

Site #23 Bottom - sand
wild celery (V. americana) - present but sparce
variable pondweed (P gramineus) - present but sparce
dwarf water milfoil (M. tenellum) - present but sparce,
pipewort (E. aquaticum) - present but sparce.

Site #24 Pipewort (E. aquaticum) - densities not noted
wild celery (V. americana) - densities not noted.

LAKE AND STREAM IMPROVEMENT SECTION

TOWNSHIP 41 N
RANGE 8 E
TOWN OF PLUM LAKE
COUNTY VILAS



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COMPILED BY
TRACED BY B.W. CCC
SOURCE OF INFORMATION CAMP CRYSTAL LAKE—LAKE SURVEY PROJECT
AERIAL PHOTOGRAPH
SOUNDINGS 300' INTERVALS
DATES OF MAP REVISION

LAKE IMPROVEMENT RECORD

TYPE	DATE 1936		
BRUSH REFUGES	17		
SAPLING TANGLES	176		
SPAWNING BOXES			
MINNOW SPAWNERS			
TOTAL			

AREA 1116 ACRES
TOTAL SHORELINE 2.3 MILES
MAX. DEPTH 27 FEET
SCALE 1"=300'

LEGEND

- WEED BEDS
- ROCKY SHOALS
- Sd SAND
- Cl CLAY
- Gr GRAVEL
- Mk MUCK
- DWELLING
- ABANDONED DWELLING

Plants observed on Irving Lake on August 26, 1998:

Irving - The substrate of Irving Lake is muck with a large amount of detritus. Looking at the entire lake, plant diversity in Irving is more limited than Ballard and White Birch. Primary species include wild rice and bushy pondweed. Around the islands there are a greater variety of plants, with large beds of elodea. The deep spot near the island was 12 feet. Wildlife use while we were on Irving was great - we saw large numbers of ducks and songbirds.

The wild rice was less abundant and had deteriorated since our last visit on July 28, 1998 in the area from the channel along the southern portion of the lake almost to the islands. There appeared to be a little more open water than when we were here last on July 28 (it was a little easier to motor through the open areas). We observed insect larvae feeding on the wild rice. Some rice plants did not have developed seeds.

Please refer to attached map for Irving site locations:

Site #1 Bottom - muck
Patches of pickerelweed (P. cordata)-abundant
white pond lily (N. ordorata)-common
clumps of wild rice (Z. palustris) scattered throughout the open water area.

Site #2 Bottom - muck
Bushy pondweed (N flexilis) - scattered
wild rice (Z. palustris) - common to abundant.

Site #3 Bottom - muck
Bushy pondweed (N flexilis)-scattered,
wild rice (Z. palustris)-common to abundant,
variable pondweed (P. gramineus)-sparse,
white pond lily (N. ordorata)-sparse.

Site #4
Along the shoreline:
Common arrowhead (S. latifolia)-sparse
pickerelweed (P. cordata) - abundant patches along shoreline;
white pond lily (N. ordorata) - abundant patches beyond the pickerelweed
bushy pondweed (N flexilis)-scattered further from shore.
Wild rice (Z. palustris) - scattered in this area becoming heavier further from shore.

Site #5 Bottom - muck with detritis
Wild rice (Z. palustris)-common to abundant
white pond lily (N.ordorata)-sparse.

Site #6 Water depth - 6 ft., bottom - muck, but not as thick
Pickerelweed (P. cordata)-common along shoreline,
bushy pondweed (N flexilis) - scattered
white pond lily (N. ordorata) - scattered,
very little wild rice (Z. palustris) except some small patches near shore.

Site #7 Large patches of pickerelweed (P. cordata) and white pond lily (N. ordorata) were abundant.

Site #8 Small patch of cattails (Typha)

Site #9 Water depth - 12 ft. on south side of island, open water around islands.
Large-leaf pondweed (P. amplifolius)-common
bushy pondweed (N. flexilis)-scattered,
no wild rice in this area.
Sedge and sweet gale along shore of island.

Site #10 Patches of pickerelweed (P. cordata)-abundant
white pond lily (N. ordorata)-abundant
wild rice abundant between lilies and the open water around the islands.

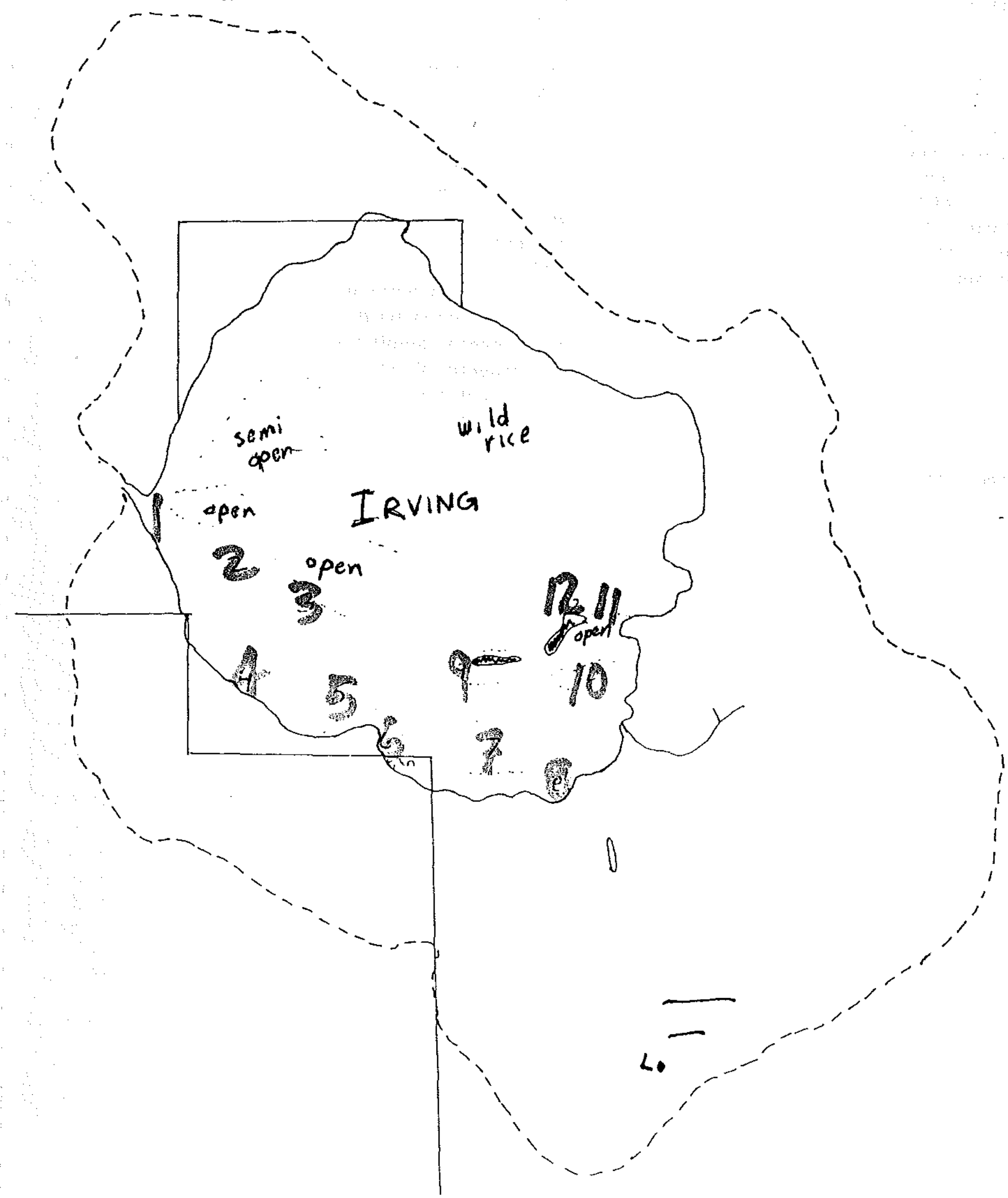
Site #11 Water depth - 5 ft.
Bushy pondweed (N flexilis)-common,
common waterweed (Elodea canadensis) - abundant
wild celerey (V. americana) - sparce
variable pondweed (P. gramineus) - sparse.

Site #12 Common waterweed (E. canadensis)-abundant
wild rice (Z. palustris) - scattered

North of the islands the wild rice was very abundant with scattered semi open areas visible. We did not motor to the north side of the lake because of the difficulty in keeping the prop operable and free of wild rice.

The following plants were observed and specimens collected in the channel between Ballard and Irving Lakes after passing through the culvert under Camp 2 Road on 7/28/98:

Blue flag (Iris)
Wild calla (Calla palustris)
Needle spikerush (Eleocharis acicularis)
Rush (Juncus spp)
Bushy pondweed (Najas flexilis)
Pickerelweed (Pontederia cordata)
Large-leaf pondweed (Potamageton amplifolius)
Ribbon-leaf pondweed (Potamogeton epihydrus)
Clasping-leaf pondweed (Potamogton richardsonii)
Fine-leafed pondweed (Potamogeton spirillus)
Stiff arrowhead (Sagittaria graminea)
Common arrowhead (Sagittaria latifolia)
Bur-reed (Sparganium spp)
Wild celery (Vallisneria americana)
Wild rice (Zizania palustris) - scattered in channel. mainly along the north side



semi open
wild rice
open
IRVING
open
1
2
3
4
5
6
7
8
9
10
11
12
open
Lo

List of macrophytes observed on White Birch, Ballard, and Irving Lakes on August 25 & 26, 1998.

Emergent

Bidens spp.
Calla palustris
Carex spp.
Dulichium arundinaceum
Pontederia cordata
Sparganium angustigolia
Sagittaria cuneata
Sagittaria latifolia
Sagittaria cuneata
Scirpus validus
Scirpus spp.
Typha latifolia
Zizania palustris

Floating Leaf

Brasnia schreberi
Nupar variegata
Nymphaea odorata

Submersed

Chara spp.
Eleocharis acicularis
Elodea canadensis
Eriocaulon aquaticum
Isoetes spp
Juncus pelocarpus
Lemna minor
Lobelia dortmanna
Myriophyllum tenellum
Myriophyllum sibiricum
Najas flexilis
Potamogeon gramineus
Potamogeton richardsonii
Potamogeton amplifolius
Potamogeton illinoenis
Potamogeton robbinsii
Potamogeton natans
Vallisneria americana

4.6. Fisheries - fish records

Fish Caught by White Birch Village Guests, June 11, 1999 through July 21, 1999

		Irving	Ballard	White Birch
Walleye:	8"	-0-	-0-	2
	10"	-0-	10	16
	12"	1	2	24
	15"	-0-	3	18
	19"	1	4	1
	20"	1	1	1
	22"	1	-0-	-0-
Muskie	14"	1	-0-	1
	18"	1	4	2
	20"	-0-	3	1
	22"	-0-	1	3
	24"	-0-	5	-0-
	26"	1	2	6
	28"	-0-	5	3
	30"	1	1	1
	34"	-0-	1	-0-
	40"	-0-	1	-0-
Large Mouth Bass	8"	-0-	1	45
	10"	-0-	-0-	21
	12"	1	4	24
	13"	1	2	-0-
	14"	1	2	11
	15"	-0-	-0-	4
	16"	1	-0-	-0-
	18"	-0-	-0-	1
Northern Pike	12"	-0-	1	-0-
	15"	1	1	-0-
	18"	-0-	1	-0-
	20"	1	-0-	-0-
	31"	-0-	1	-0-
Blue Gill	3-5"	-0-	15	33
	6-7"	-0-	2	125
	8-9"	-0-	3	38
	10"	-0-	-0-	17
Crappie	4-6"	-0-	-0-	7
	10-11"	-0-	3	-0-
	12"	-0-	3	1
Perch	3-6"	-0-	17	66
	7-9"	-0-	27	65
	10-11"	-0-	4	38
	12"	-0-	-0-	7
Small Mouth Bass	5-7"	-0-	-0-	2
	8-9"	-0-	-0-	1
	10-11"	-0-	-0-	3
	12-14"	-0-	-0-	3

Note Only a portion of guests report their catches

WISCONSIN LAKES:
A Trilogy

WISCONSIN LAKES: Challenges and Responses
WINTERKILL: Loss and Recovery
IRVING LAKE: A Wild Rice and Shallow Lake Story

BALLARD-IRVING-WHITE BIRCH
LAKES ASSOCIATION, INC.

"Finesse means abandoning frontal attacks for solutions that rely on the same kind of latent properties that led to the revenge effects in the first place. Sometimes it means ceasing to suppress a system. In medicine, finesse suggests closer attention to the evolutionary background of human health and illness, to the positive part that fever plays, for example, in fighting infection. At other times finesse means living with and even domesticating a problem organism."

Edward Tenner, Why Things Bite Back-Technology and the Revenge of Unintended Consequences, Knopf, 1996

***The International Engineering Consortium** sponsored the publication of this trilogy as a public service in support of the environmental initiative represented by Wisconsin Department of Natural Resources Lake Management Planning Grant Programs LPL 602 and LPL 613.*

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WISCONSIN LAKES: A Trilogy

WISCONSIN LAKES: Challenges and Responses
WINTERKILL: Loss and Recovery
IRVING LAKE: A Wild Rice and Shallow Lake Story

Frank G. Splitt

Ballard-Irving-White Birch Lakes Association, Inc.

December 1, 2000

Wisconsin Lake Management Planning Project Grant Program
Project Nos. LPL-602 and LPL-613

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WISCONSIN LAKES: Challenges and Responses

The United States has a treasure house of natural resources and Wisconsin holds the "Crown Jewels"...its more than 15,000 lakes. But Wisconsin's lakes are in jeopardy on numerous fronts, and many lakes need help. Many property owners and other lake users are not aware of their impact on the ecological health of the lakes. Much of the management of lakes in Wisconsin is limited by a lack of information about the lakes, their watersheds, and the people who use them. Additionally, the past decade has seen an unprecedented increase in the demand for ownership of shore lands and use of our waters. The sheer number of lakes dictates that much of the management of lakes in Wisconsin must rely on citizen and local government action as well as cooperation. These are the challenges before us.

What will life around our lakes look like in the future? The future health of our lakes and our lake communities will be determined by our degree of environmental responsibility and how well we manage the demand for waterfront property. We are now poised at a turning point in the history of the management of Wisconsin's lakes and waterways. The Lake Management Planning Grant and Lake Protection & Classification Grant Programs have been designed to help respond to the challenges outlined above. Specifically, these programs can provide the economic resources required to help meet the twin objectives of obtaining a better understanding of our lakes and of appropriately managing our lakes, both by way of local participation and responsibility.

The articles in this publication provide an illustrative example of how the Lake Management Planning Grant Program made it possible for a community of concerned citizens to respond to problems and issues relative to their chain of three shallow lakes. This program enabled funding of laboratory tests and analyses and, most importantly, allowed contracting the services of a lake expert to perform technical fieldwork as well as guide the efforts of local volunteers. Working in partnership with lake professionals from the Wisconsin Department of Natural Resources (WDNR) and the University of Wisconsin provided additional insights and a broad perspective on the lakes and their management requirements. More information on this program as well as the Lake Protection & Classification Program follows:

The Lakes Management Planning Grant Program offers grants to local governments and associations to gather data, conduct surveys, develop information campaigns, develop effective land-use regulations and undertake other activities to plan for lake protection and improvements. For more information or assistance, contact the WDNR Region Inland Lake Coordinator, the County Cooperative Extension Office, or UWEX-Lakes Partnership, UW-Stevens Point at 715-346-2116 for details.

Lake Protection & Classification Grants are designed to assist lake users, lake communities, and local governments as they undertake projects to protect and restore lakes and their ecosystems. These projects can involve the purchase of property or a conservation easement, restoration of wetlands, development of local regulations or ordinances, lake classification, and lake improvement. Contact your WDNR Region Lake Coordinator or Environmental Grant Specialist discuss your project plans and eligibility questions: Central Office, 608-261-6423, or visit the UWEX/UWSP lakes web site: www. uwsp.edu/cnr/uwexlakes.

Frank G. Splitt
November 20, 2000

SHALLOW LAKES

"Somewhere along the way, someone got the idea that a lake was a deep, clear blue, cool body of water with a sandy bottom and no weeds. Shallower waters that didn't fit this description needed improvements—bottoms dredged, shorelines filled and cleared of weeds, water raised—to make them more like "real" lakes.

Disappointment and frustration followed when the make-overs did not succeed. Like people, shallow water bodies have unique physical and biological attributes that are not easily or quickly altered.

Shallow waters account for more than one-third of Wisconsin's lake acreage, yet they remain one of the most misunderstood and abused of our natural resources. We are only beginning to understand how these amazingly productive aquatic systems function; the next step is to learn how to appreciate what shallow lakes can offer us."

Maureen Mecozzi, Shallow Lakes-Wisconsin's Most Misunderstood Waters, Wisconsin Natural Resources, 1995

WINTERKILL: Loss and Recovery
A Story of People Working Together to Benefit Their Lakes

January 1, 1996 marked the day the Big Ten was represented at the Rosebowl by its Conference Champions, the Northwestern University Wildcats. To college football fans, this was a highly unlikely event if there ever was one. Dreams collapsed in a just a few hours. Hard questions had to be answered. Who's to blame? What really happened? It would take time and a lot of hard work for the NU Football Program to recover from the loss. It did in 2000, with a remarkable bowl-bound season propelled by stunning late-season, last-second wins over Minnesota and Michigan. The essence of the recovery was captured by Daily Herald Sports Writer Lindsey Willhite after the Michigan game. "The grandkids are going to hear a story about this one day. They're not going to believe what they are hearing, but their belief is not what is important." There follows a story involving another unlikely event with striking parallels to the above.

Nothing so dramatic would take place at the Ballard-Irving-White Birch Chain-of-Lakes in Star Lake, Wisconsin. Nevertheless, the dreams of hundreds of fishermen and other vacationers were starting on a similar road to collapse as the Ballard Lake fishery was entering the first stages of winterkill. Though not known at the time, this was also a highly unlikely event. No one could recall it ever happening before. The fate of the fishery would be dictated by overwhelming natural forces, and it would take months before we learned the final devastating score. Newspaper and magazine articles heralded ***"Ballard Lake falls victim to winterkill loss"*** and ***"Winterkill wipes out popular musky chain of lakes."*** The questions around the lake were very much the same as they were around the Northwestern campus.

The question as to what really happened was not easy to answer. Theories abounded. "Ballard never had a winterkill problem before; it's the rice that did it." Nevertheless, no one knew for sure. As for blame, what else but shallow Irving Lake with all of its rotting wild rice plants? However, this was not the time for theorizing and blaming, or even resolving questions. We needed to act quickly and rely on the best judgement of seasoned professionals.

An extensive fish-stocking program by Harland Carlson, the Wisconsin Department of Natural Resources (WDNR) Fishery Biologist eventually led to a significant rebound in the overall fishing quality in the lakes. Solid year classes were successfully established via stocking of fry, fingerlings, and adult fish transfers. The Town of Plum Lake, the Muskie Clubs Alliance of Wisconsin, the Starlaker's Club, and the Star Lake Store supported additional stocking in the fall of 1996.

Mike Coshun, the WDNR Fishery Supervisor, recommended the installation of a temporary WDNR-designed cascading aerator in the Ballard-Irving thoroughfare to reoxygenate Irving Lake outflow as well as remove dissolved hydrogen sulfide gas. The Town of Plum Lake provided the installation, operation, and maintenance of the aerator with oversight by Wes Jahns, WDNR Fisheries Technician. The project was deemed successful in the sense that dissolved oxygen levels increased in the East End of Ballard when the aerator was in operation. To everyone's relief, Ballard exhibited no signs of fish kill at the end of the 1996-97 winter, but neither did un-aerated Irving Lake.

It seemed that progress was being made, but we still needed to understand what happened so that we could feel comfortable with the ability of our quick reaction type solution to work over the long run. We needed assurance that our significant investment in fish stocking would not be lost to some yet unknown force. It was at this point in early 1997 that Mike Coshun suggested that we form a Qualified Lake Association so that we could become eligible for state grants. He advised that grant funding would enable us to obtain the resources required to gain a better understanding of how our lakes worked and what, if any, impact the "suspect" wild rice in Irving Lake was having on downstream lakes. We contacted Tiffany Lyden, Vilas County Conservation Specialist, and Bob Korth, UWSP College of Natural Resources, to obtain more detailed information and advice on Qualified Lake Associations.

"...grant funding would enable us to obtain the resources required to gain a better understanding of how our lakes worked and what, if any, impact the "suspect" wild rice in Irving was having on downstream lakes."

The Ballard-Irving-White Birch Lakes Association, Inc. was formed later that year. We then began a Water Quality Monitoring Program, obtained an initial assessment of the aquatic plant community on Irving Lake by Laura Herman, WDNR Water Biologist, and a more detailed assessment on all three lakes by Cathy Cleland and Sandy Wickman, WDNR Water Quality Biologists. We also began gathering information on the Wisconsin Lake Management Planning Grant Program. In the meantime, it was decided that a permanent, but portable, cascading aerator was most likely to satisfy our needs over the long run. The design, fabrication, installation, and subsequent operation of this unit were cooperative efforts between the WDNR, the Town of Plum Lake, and our Lake Association. The portable aerator has been utilized every winter since its first turn-up in December 1997.

With fish stocking and aeration programs in place and a detailed aquatic plant survey in hand, we were then ready to work on Lake Planning Grant Applications. These applications would cover the development of a Comprehensive Management Plan for the three lakes. Two proposals were submitted to the WDNR in January 1999. Shortly thereafter, we selected Steve McComas of Blue Water Science as our technical consultant, should we be fortunate enough to have winning grant applications. Early April brought the announcement that we had been awarded two Planning Grants totaling $23,500 with a state share of $17,200 and a local share of $6,500 in volunteer labor or in-kind contributions. The finish date of the grants was scheduled for June 30, 2000. Bob Young, WDNR Northern Region Lakes Program Coordinator, was assigned the responsibility for technical oversight of our projects.

As planned, our volunteer workers were organized into Project Teams that focused on Lake History, Water Quality, Aquatic Vegetation, Fisheries, Shoreline Vegetation & Watershed, Shoreland Development & Private Waste Disposal, Lake Usage, and Communications. A Projects Manager was assigned the responsibility for coordinating activities and the management of the overall set of projects with Steve McComas providing expert technical guidance, in addition to his fieldwork. A kickoff meeting was held in May with Steve McComas, Mike Coshun, and representatives from each team in attendance. Our featured speaker Paul Garrison, WDNR Paleolimnologist, later became actively involved with our projects as they related to his complementary Shallow Lakes Initiatives Project. His analysis and interpretation of several sediment cores provided valuable insights into the history of the three lakes.

Work on the projects proceeded throughout 1999 and into the early part of 2000. Additional time was deemed necessary if we were to provide our consultant sufficient time to analyze and interpret the wealth of data he and our volunteers had amassed over the past year. More time would also allow the incorporation of input from the University of Wisconsin's Lake Landscape Positioning Project on White Birch Lake, as well as additional input from Paul Garrison's sediment coring. We received approval of our request for a time extension to December 31, 2000. So, with all of this expended time and effort, what were our findings?

BIRGE & JUDAY DATA: Application and Reliability Perspectives

A TIME COMPARATIVE STUDY OF WATER QUALITY ON BALLARD, IRVING, AND WHITE BIRCH LAKES:
A Contemporary Application of Birge & Juday Data

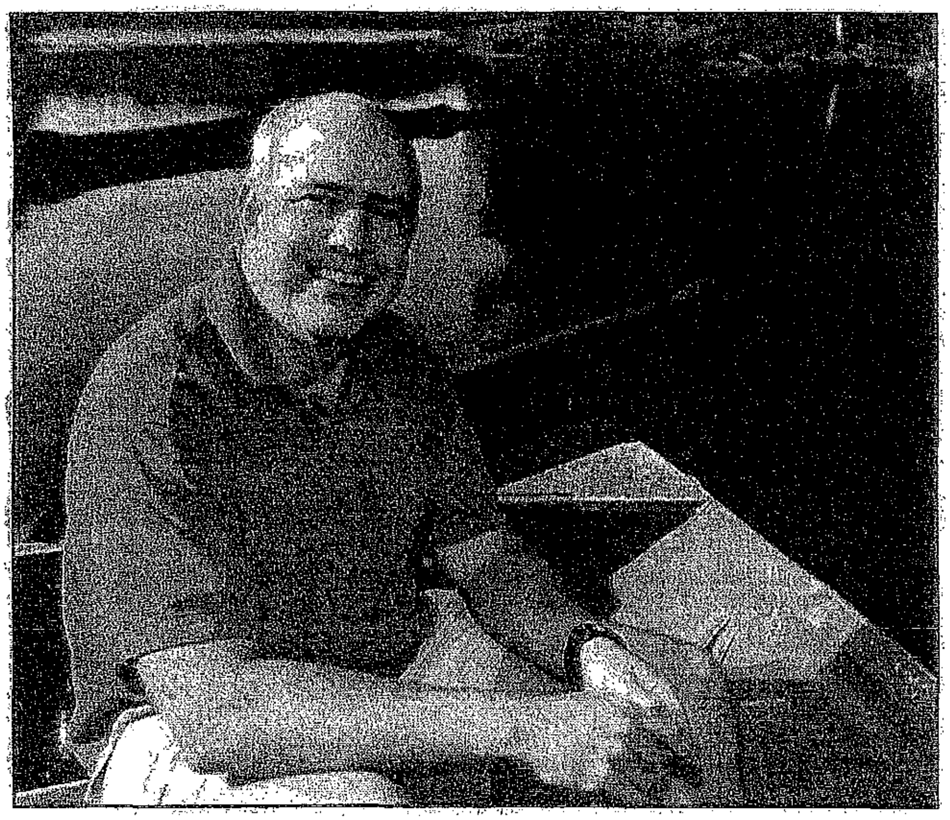
LAKE WATER SAMPLING AND TESTING IN THE 1920s:
A Glimpse into the Past

TOTAL PHOSPHORUS CONCENTRATION DETERMINATIONS IN THE 1926-1930 ERA: A Note on the Reliability of Birge & Juday Data

BALLARD-IRVING-WHITE BIRCH LAKES ASSOCIATION, INC

DEDICATION

This publication is dedicated to the memory of Dr. Thomas M. Frost, the late Associate Director of the Center for Limnology, University of Wisconsin – Madison, and Director of the Trout Lake Station. He was a superb and dedicated teacher as well as an internationally renowned scientist in his own right. His technical advice and personal counsel were invaluable contributions to the overall success of our Lake Planning Grant Program.



Dr. Thomas M. Frost

Photo by Jeff Miller
UW-Madison University Communications

The Lake Planning Grants led to an understanding of the natural history and ecology of the three lakes and an appreciation of the fact that they have been functioning the way they do now for hundreds of years. We also gained a better understanding of the interdependence of the three lakes and how they function with wild rice. Contrary to what most lake users believed, we found that the severity and long duration of the winter were the dominant causes of Ballard's 1995-96 winterkill, and not wild rice per se. Similarly, we found that wild rice does not pose a threat to the overall well being of the lakes. In fact, we found that the wild rice provides many ecological benefits for both the lakes and users of the lakes, although at the cost of restricted motor boat navigation for which alternatives are available. Most importantly, we found that the lakes cannot be all things, to all people, at all times.

"Contrary to what most lake users believed, we found that the severity and long duration of the winter were the dominant causes of Ballard's 1995-96 winterkill, and not wild rice per se."

The consideration of options related to the Lakes Management Plan provided exposure to several examples of how things could really run amok when careful consideration is not given to the downside risks of well-intended actions These examples can also serve as powerful educational tools aimed at changing the way we think about shallow lake ecosystems. These systems are fragile, extremely complex, "living bodies," which are not easy to manipulate or "quick fix." In almost all cases, it seems best to work with Mother Nature, rather than against Her.

The comprehensive data sets collected by our Project Teams and consultant provide a detailed characterization of the three lakes and their watersheds that will serve as a valuable reference for future studies and evaluations. By every measure, we found that the lakes have made a remarkable recovery and give every indication of good health with no mysterious forces at work. As for the fisheries, Harland Carlson expects the fishing to improve steadily with ever more fish growing to quality size. Local guide Mike Errington agrees and looks forward to a great future for the fishery. He is particularly impressed with the superb quality of pan fishing that is already available to anglers. Based on the progress made with fishery restoration, guide Tony Zinda picked Ballard as one of his top ten fishing spots for 2000 and beyond.

"By every measure, we found that the lakes have made a remarkable recovery and give every indication of good health with no mysterious forces at work."

As for the future, we see the challenge ahead to be the education of the community of lake users on topics vital to the health and protection of our lakes. Some priority items involve enhancing understanding of how the lakes work with aquatic plants in general, and with wild rice in particular; how and why WDNR environmental policy tightly constrains options for wild rice control to absolute minimal removal; and how water quality can be diminished by motorized boating in the sensitive shallow areas of the lakes, poor waterfront landscaping practices, and faulty septic systems. Intergenerational continuing education will be key to the long-term ecological health of our lakes.

Frank G. Splitt
November 7, 2000

GLOSSARY of TERMS

Anaerobic – Oxygen-depleted, here meaning that there is insufficient oxygen to sustain the life of fish and other aquatic organisms as well as maintain the stability of oxygen based chemical compounds.

Algae – A general term applied to photosynthetic single celled (phytoplankton) or multi-celled organisms that are either suspended in water (plankton) or attached to rocks and other substrates (periphyton). They may have a variety of colors depending on their characterizing pigment (green, blue-green, red-green, yellow-green etc.). Their abundance, as measured by chlorophyll *a* (green pigment) in an open-water sample, is commonly used to classify the trophic status of a lake. See Eutrophication.

Algal blooms – Surface scums of blue-green algae, which accumulate under calm weather conditions from populations that were previously distributed throughout the water.

Diatoms – A group of algae, brown or yellow colored, that is very common in natural waters. The cell wall is made of polymerized silicate, forming a sort of glass, and is readily preserved in sediments when the organic part of the organism decays. Because of long interest in this algal group, its ecology is reasonably well known and diatoms in fossil deposits can now be used to interpret changes in past environments.

Eutrophication – The process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Nutrient – Substances required by living organisms for growth and maintenance. Here the term is largely confined to nitrogen and phosphorus, which are usually scarce in available forms relative to need. Some 20 other elemental substances are ultimately needed, however, most are in relatively abundant supply.

Paleolimnology – Study of the history of freshwater lakes from an investigation of the contents of their sediments. Diatoms and pollen are useful in identifying past aquatic plant communities. Accurate dating of sediment core samples can be achieved via radioactive dating using Lead-210 and Cesium-137.

pH – An index of lake water acid level. A pH of 7 is neutral (distilled water that is free of carbon dioxide). In Wisconsin, pH ranges from 4.5 in some acid bog lakes to 8.4 in hard water lakes characterized by an abundance of calcium carbonate.

Secchi disc – An 8-inch diameter circular plate with alternating white and black quadrants that is used to measure water clarity (light penetration). The disc is lowered into the water from the shaded side of a boat until it disappears from view and then raised until it is just visible. An average of the two visible-depth readings is, by definition, the Secchi disc reading.

Wild Rice – A shallow rooted aquatic plant that sprouts from seed each spring. It is native; grows throughout the eastern half of the United States and neighboring portions of Canada, but is most abundant in Minnesota and northern Wisconsin.

Adapted, in large part, from Understanding Lake Data, UW Cooperative Extension Publication G3582, and Brian Moss, Reference 11.

IRVING LAKE: A Wild Rice and Shallow Lake Story

BACKGROUND

Every lake has a story, and Irving Lake is no exception. However, this lake story is also about wild rice. Located in the Northern Highland-American Legion State Forest, the lake forms the headwaters of the White Birch-Ballard-Irving Chain-of-Lakes. The lakes are just north of the village of Star Lake along Vilas County Highway K, Rustic Road 60.

The Wisconsin Department of Natural Resources (WDNR) awarded two Lake Planning Grants to the Ballard-Irving-White Birch Lakes Association, Inc. in April 1999. The three lakes then became the subjects of projects aimed at the development of a comprehensive Lakes Management Plan. The intent of the plan is to guide the WDNR, lake property owners, and the larger community in future years. Bob Young, WDNR Northern Region Lakes Program Coordinator, provided oversight and served as an advisor. The Lakes Association, with expert technical guidance from its consultant, Steve McComas of Blue Water Science, managed the projects. One of the important objectives of these projects was to determine whether wild rice presents a significant problem for the lakes. This determination is a focal point of the paper.

BEGINNINGS

The story begins when the last glacier left the Northern Highlands region of Wisconsin more than ten thousand years ago. As it left, it deposited immeasurable amounts of glacier-transported outwash, consisting of boulders, rocks, gravel, sand and clay, on an existing dome-shaped, granite base that is over one billion years old. Formidable glacial ice blocks melted and left numerous water filled depressions that were to become one of the largest concentrations of "kettle lakes" in the world. Hundreds of miles of streams and rivers and over 900 lakes now lie within the State Forest. One of these lakes has come to be known as Irving Lake.

When European contact occurred in the 1600s, the people of Wisconsin included the Menomonee (the Wild Rice People) and the Dakota Sioux. The Ojibwa, largest of the Great Lakes woodland tribal groups, arrived later. They found themselves in competition with the Dakota Sioux over the same set of natural resources. Both peoples harvested wild rice in the fall, hunted in the winter, made maple syrup in the spring, and farmed in the summer. Wild rice harvests were indeed an integral part of the lifestyle of native peoples who left a legacy of forest settlements. This was certainly true for the Ojibwa located near Lac du Flambeau and Trout Lake. Wild rice was important to early European and government explorers as well. Their journals contain many references to the plant they found growing on the lakes and rivers they traversed [1-3].

Some ten thousand years after the auspicious birth of the lake, a narrative of explorations made in the region during 1847 contained the following journal entry describing the country [4]:

"October 1-A heavy frost this morning; the thermometer standing at 25 degrees Fah. At half past six o' clock. We crossed First White Elk Lake, and by a stream twenty feet wide and a quarter of a mile long, passed into Second White Elk Lake, which is about two miles long and one mile wide. From this, we passed into Third White Elk Lake, by a stream ten yards wide and three hundred yards long. This lake is nearly circular and about one mile in diameter. It is very shallow, not having a depth of more than three feet at any point, and has a mud bottom. We noticed here a phenomenon, not hitherto observed in any of the great number of small lakes we have seen in the territory. The whole surface of the lake was covered with bubbles of light carburetted gas, which were constantly ascending from the bottom."

First, Second, and Third White Elk Lakes are now known as White Birch, Ballard, and Irving Lakes. Along with Lake Laura, they were also known as the White Deer Lakes, likely because of the numerous sightings of albino deer in the area.

"We noticed here a phenomenon, not hitherto observed in any of the great number of small lakes we have seen in the territory. The whole surface of the lake was covered with bubbles of light carburetted gas, which were constantly ascending from the bottom."

J.G. Norwood, 1847

IRVING LAKE TODAY

Irving is a shallow lake of some four hundred acres, with depths ranging up to thirteen feet, but only about four feet on average. It is likely that it was born a shallow lake, though, not nearly as shallow as we find it today. In addition to watershed runoff, Irving is fed by drainage from wetland spring ponds, as well as several lakebed springs. Because it is so shallow, it is very susceptible to winterkill. The lake is aptly described in a Wisconsin Conservation Department Lake and Stream Classification Project Report from the early 1960s [5]:

"Irving Lake is a moderately fertile drainage lake. It has clear alkaline water of low transparency depending somewhat on the algal response to the lake's fertility. Bottom materials consist chiefly of muck and sand, with some gravel and rock.... The principal fish species present are the muskellunge, walleye, largemouth bass and panfish. In the shallow, mucky areas of the lake, aquatic weeds are a problem to navigation.... There are two cottages on this lake. Due to the extensive public frontage, much of the wilderness character of the shoreline has been retained. Beaver are known to be present and the lake is of significance to waterfowl. The lake is used as a nesting site by mallard and black ducks and is used on the fall and spring migration by puddle ducks, diving ducks, coots and Canada geese."

Very little has changed in the years since. Today, many people find Irving to be one of the most beautiful and pristine public lakes in the state of Wisconsin.

Prior to a devastating winterkill on the three lakes in 1995-96, Irving was widely known as a "go to" lake with a superb fishery. The lake received national attention in 1986 when a *Wall Street Journal* Leisure and Arts column described fishing for Irving muskies [6]. The lake is now returning to fishing prominence by virtue of the execution of a rapid fisheries assessment and an aggressive fish-stocking program led by Harland Carlson, (now retired) WDNR Fishery Biologist. Additionally, an aeration system and a big hand from Mother Nature have led to the remarkable recovery from the fish kill as well as the present health of all three lakes.

WILD RICE and IRVING LAKE

Since Irving Lake is nutrient-rich and the shallow water allows sunlight to penetrate to almost all of the lakebed, rooted aquatic plants can grow in profusion. Among the fifteen identified species are wild rice, white water lily, pickerelweed, and variable pondweed. The aquatic plants cover up to 80% of the lake, with wild rice contributing up to 40% of the total plant coverage. Irving is ideally suited to grow wild rice and has done so ever since the relatively sparse rice beds of the 1940s and 1950s were said to be expanded by plantings some time in the late 1950s or early 1960s.

The wild rice on Irving can be seen to have several positive attributes. It serves as food for both human and wildlife consumption. Irving has become a popular spot for hunting migratory birds as well as a "fish factory" for muskie, walleye, bass, and panfish. The dense aquatic vegetation limits motorized boat traffic, so the lake is relatively peaceful and serves as a wildlife observatory in a setting of great natural scenic beauty. From these points of view, wild rice is really a good thing. So, what is the problem?

EXPRESSED CONCERNS ABOUT WILD RICE

The often-expressed downside attributes of the wild rice on Irving Lake are that during the summer months, riparian property owners become virtually "rice-bound," and the lake becomes effectively unusable for motorized boating. Since beauty is in the eyes of the beholder, some see the marsh-like summertime condition of the lake as undesirable.

There has also been serious concern that the winter water outflow from Irving may be increasing the likelihood of winterkill in downstream Ballard and White Birch Lakes. Why the serious concern? The oxygen-depleted winter water outflow can increase chemical and biological oxygen demands on these already winter-stressed lakes. Though not supported by historic data, some thought that this could be an annual event given the abundant nutrients in Irving's sediments. Wild rice converts dissolved nutrients into shoots that die off and decay, depleting Irving's dissolved oxygen and enriching its already nutrient-rich outflow. Based on this thinking, eutrophication of all three lakes could be accelerated.

Our Lake Usage Survey indicated that about 50% (15/31) of the respondents felt that the water quality of Irving Lake is poor, while about 60% (14/24) of the respondents felt that the water quality has decreased considerably over the time they have used the lakes, with this time ranging from 3 to 68 years. In the survey, subjective water quality indicators were described as such things as water clarity, algae, weeds or plants, swimming conditions, fishing conditions, and so forth. The survey also indicated that 88% (22/25) of the respondents think that the most serious problem relating to Irving Lake is the wild rice, and 44% (16/36) of their comments stated the wild rice should be eradicated or controlled in some way. Worthy of note were the following remarks: "Get rid of the wild rice and eliminate the source of Ballard's problem;" and "Get rid of the wild rice and never again introduce any non-native plant or aquatic form of life on any of the lakes." Consideration had to be given to a related sentiment as well, "Irving never had any wild rice, it was planted by somebody." All of these concerns have been expressed in a variety of other ways, such as "The lakes may be suffering from too much of a good thing." "Swimming is not good like it was in the past due to the wild rice and the muck and sludge created by the rotting straw," and "Entry to Irving should be a channel, not a sewer. Remove some of the wild rice from Irving."

Clearly, there are a large number of lake users who, for various reasons, not only believe that wild rice is a bad thing, but that it presents a serious problem as well. These deeply seated concerns reflect the fact that many of us in the Lake Association did not understand how the lakes worked in the past and how they really work now. With our almost total focus on winter conditions, we did not understand how wild rice and other aquatic plants work to benefit all of the lakes during the summer growing season. And further, that over the long term, the loss of wild rice, either by removal or by natural causes, will release sediments for colonization by competitive aquatic plants that would have essentially the same general effect on water quality and wintertime oxygen depletion as the wild rice.

"Sometimes, the knottiest dilemmas, when seen from the systems point of view, aren't dilemmas at all. They are artifacts of "snapshot" rather than "process" thinking, and appear in a whole new light once you think consciously of change over time."

Peter M. Senge, The Fifth Discipline-The Art & Practice of the Learning Organization, Doubleday, 1990

OXYGEN-DEPLETION and the 1995-96 WINTERKILL

Irving Lake has a history of depleted winter oxygen [7]. For example, a 1960 Wisconsin Conservation Department report on Irving Lake [8] stated: "Water smells bad, but melting snows will increase oxygen from this date on." The perception then developed that "the lake is sick," or, "it smells because of the rice." This should not be a surprising response from anyone who experiences the pungent "rotten eggs" smell associated with anaerobic (oxygen-depleted) lake water. Under anaerobic conditions, hydrogen sulfide, carbon dioxide, and methane can rise from decaying lake sediments and disperse into lake water and open air. This is a completely natural, but noxious process—dissolved hydrogen sulfide is toxic to fish and other aquatic organisms. Based on the earlier quote from the 1847 journal account, Irving Lake has a long history of generating an abundance of these gases from its age-old sediments, especially below winter ice and snow cover.

The winter of 1995-96 was unusually severe, with ice-on from November to May and with a deep covering of snow. Under these conditions, shallow lakes like Irving exhibit the characteristic signs of oxygen-depletion. In fact, Irving Lake was on the WDNR's winterkill list because of its history of fish kills. However, neither Ballard nor White Birch Lakes had such a history. So what happened this time? To answer this question let us first understand what is meant by winterkill.

Winterkill occurs when dissolved oxygen reaches critically low concentrations and is not able to sustain fish life. As ice and snow cover form, aquatic vegetation is denied the amount of sunlight it requires for photosynthesis. Without the ability to photosynthesize, the aquatic plants die off, decay, and become net oxygen consumers rather than suppliers. With no oxygen available from photosynthesizing plants or atmospheric mixing, and with fish, decaying plants, sediments, and other aquatic organisms consuming oxygen, it is only a matter of time before the available oxygen is exhausted. If relief is not provided soon enough by springtime ice-out, suffocation and the toxic effects of dissolved hydrogen sulfide kill fish. Now, to answer the question: Why Ballard and White Birch?

Ballard Lake is relatively shallow (no more than 20% of the lake has a depth greater than 17 feet) and has an abundance of aquatic vegetation. Because of these characteristics, the lake is inherently susceptible to winterkill, though to a lesser degree than Irving Lake. As the winter progressed, Irving Lake's outflow of oxygen-depleted, hydrogen-sulfide, and nutrient-rich water, as well as migrating fish, increased the biochemical oxygen demand on Ballard Lake. However, this incremental contribution to Ballard's oxygen depletion was likely small compared to the much larger self-demands of this already severely winter-stressed lake. Nonetheless, the long duration of the winter ice and snow cover did not allow the possibility for Ballard to escape winterkill by virtue of an early spring ice-out. Instead, Ballard and most northern Wisconsin lakes experienced the latest ice-out in recorded history. Even marginally susceptible White Birch could not escape the winterkill "domino effect" set in motion by the long duration of the severe winter. Here, winterkill conditions triggered the instinct-driven descent of numerous fish down White Birch Creek where they were able to survive in the relatively oxygenated Aqualand fishponds.

The conclusion that can be drawn is that wild rice per se had little to do with the winterkill in Ballard and White Birch Lakes. Put another way, natural factors, represented by extremely long ice and snow cover, dominated the fish kill in both relatively shallow lakes. These natural factors of weather and shallow water have likely been working this way on all three lakes for hundreds of years.

A cascading aerator was found particularly well suited to mitigate winterkill conditions in the downstream lakes. This type of aerator transfers dissolved hydrogen sulfide gas to the atmosphere while performing its primary task of re-oxygenation. Credit for the timely introduction of this type of aerator goes to Mike Coshun, (then) WDNR Woodruff Area Fishery Supervisor, who researched and then recommended cascading aeration for our application shortly after the 1995-96 winterkill.

WILD RICE and the HALSEY LAKE EXPERIENCE

During the course of our work on the Lake Planning Grant Projects, it was discovered that neighboring Florence County, Wisconsin, was having quite a different problem with wild rice on Halsey Lake. According to long-time lake resident and lake leader, Jeannie Nowak, Halsey is a shallow lake that supported beds of wild rice until the mid 1950s. The Halsey Lake residents had no idea why the wild rice went bust. Subsequent efforts to reseed the rice, in cooperation with the U.S. Forest Service have failed.

Since Jeannie and I were both attending a Lake Leaders Institute Seminar, we spoke with Sandy Engel to get his insights on the Halsey Lake situation. Sandy is a well-known expert on aquatic ecology, macrophytes, and the restoration of aquatic habitat [9]. Sandy laid out the wild rice story in essentially the same manner as our consultant, Steve McComas, had done at our last two Annual Meetings of our Lake Association. He said that rice crops can persist on lakes that have little water flow but will vary in abundance from year to year, with a typical four-year period that includes a boom year, two fair years, and a bust year. Sandy's main point was the need to sow the wild rice seeds in six inches to three feet of water (with one to two-foot depths preferred) and over several (at least 5 to 10) successive years. This can establish a seed bank that emulates the natural dormancy of wild rice seeds, and so allows the rice to survive successive years of crop failure.

In subsequent meetings with Sandy and Laura Herman, WDNR Water Biologist, other short-term causes for wild rice decline were discussed. Any of the following factors singly, or in combination, could have contributed to the loss of wild rice on Halsey Lake and downstream Fay Lake: an increase in water level or constant water level over several years; a reduction in lake nutrients below the level required to sustain the crop; wave action from high winds and boat wakes, especially in mid-June when the new plants are in their floating leaf stage; reduced water clarity (increased turbidity) that produces a sunlight shading effect, especially for submerged plants attempting to grow in two or more feet of water; polluted water; influx of exotic aquatic plant species and rough fish; lack of flowing water; muskrats that feed on springtime shoots and ripening blooms; and a change in a lake's water chemistry. Concerning water chemistry, wild rice stands usually need a pH of 6.8 to 8.8, a sulfate concentration of less than 10 parts per million, and alkalinity from 5 to 250 parts per million [10].

WILD RICE and IRVING LAKE's WATER QUALITY

How can a list of extinction factors be at all relevant to Irving Lake? Obviously, the list could serve as a "how-to" recipe for getting rid of the rice or controlling its growth. However, permission would have to be obtained from the WDNR because wild rice is a protected resource. It is highly unlikely that such permission would be granted unless the rice plants unduly restrict riparian property usage. The reasons for this are the very high overall value the WDNR, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and other agencies place on the ecological benefits of wild rice and their acute sensitivity to the fact that there has already been a substantial loss of historic rice beds in the state of Wisconsin [2].

Wild rice could very well be classified as a Goldilocks type of aquatic plant; things have to be "just right" for it to persist and prosper. Therefore, wild rice can serve as a rough biological health indicator. A natural loss of its healthy rice beds could signal a possible severe deterioration in the water quality of the lake.

Another rough indicator of good water quality is the Bryozoan colonies observed in the Ballard-Irving thoroughfare by Paul Garrison, Steve McComas, and the author. These colonies require good water quality to persist. The presence of both wild rice and Bryozoans indicates good water quality in Irving Lake.

Wild rice and other rooted aquatic plants act to improve water quality during the growing season. They do this in two ways. First, they consume nutrients that could otherwise fuel algal blooms and cause the lake to switch from rooted plants to algae, creating pea soup-like water [9,11,12]. Second, they help prevent the mobilization and resuspension of sediments by buffering wave action, stabilizing sediments, and discouraging motorized boating [13,14]. Therefore, under extended calm water conditions, Irving Lake should exhibit its best water clarity (lowest turbidity) during the growing season of a bumper rice crop and its poorest clarity (highest turbidity) during the growing season of a bust year. Fair rice years would be expected to give intermediate results. Water clarity should also be expected to decrease after the rice and other aquatic plants die off in the fall since the plants are no longer consuming available nutrients.

Should WDNR permission be granted for a large-scale physical removal of Irving's wild rice, Irving could become a murky, algae-dominated lake. The mobilization and resuspension of nutrient rich flocculent muck and other sediments into the water column would likely contribute most to the transformation. This would occur before other aquatic plants would have a chance to expand to fill the functional voids of nutrient consumption and sediment stabilization. Mondeaux Flowage in Taylor County provides an example [15]. After residents removed wild rice, one of the self-help volunteers noted that with the wild rice present, the water clarity was good, but with the removal of the wild rice, the water became more turbid, and algal blooms were more prevalent. It is important to note that once algae dominate a shallow lake, it is difficult to bring it back to a clear water state [14].

To emphasize the point that the large-scale removal of aquatic plants is detrimental to lake water quality, consider Thunder Lake in Oneida County that lost its submerged aquatic plants in the 1980s, likely to fish community changes set in motion by a severe winterkill and a subsequent explosion in bullhead population. The lake became algae dominated and subject to pea soup-like conditions for a number of years, with Secchi depths less than one foot. Kentuck Lake in Forest and Vilas Counties also lost its submerged aquatic plants in the 1980s after an invasion of rusty crayfish, with a response essentially the same as that for Thunder Lake [16]. A switchover from aquatic plant to algae domination has also been observed to occur naturally. Mason Lake in Adams County exhibited this characteristic. Rapid spring warm-up favored algae, which then dominated and shaded out rooted aquatic plants [17].

"Which is worse? The spread of the invader or the risk associated with containing it?"

Professor Joel Trexler, Florida International University
On the invasion of the Florida Everglades by the Asian swamp eel.

MORE on WILD RICE EXTINCTION

Recall an earlier statement: " The lake never had any wild rice...." The word *never* takes in a lot of time—in this case, over 10,000 years. It is difficult to tell what really took place on Irving Lake over the course of that many years. Today the lake is ideally suited to growing wild rice and is doing just that. However, according to Kay Vaughan, who spent summer long vacations from 1925 through 1936, canoeing and fishing the lake with her family, there was no wild rice to be seen at the time. Very clear aerial photos of the lake, taken in November 1937 and October 1950, corroborate this observation, as they show no visible indication of rice beds anywhere on the lake.

Further corroboration of these observations has come from Paul Garrison, WDNR Paleolimnologist, who has just completed a preliminary Irving Lake sediment core analysis [18]. Paul found no evidence of rice pollen in a sample "core-slice" corresponding to the 1950 period, while he found such evidence in slices corresponding to known rice crop years of 1995 and 1970. Of potential historical significance is the fact that Paul found no visible evidence of rice pollen in samples corresponding to 1880 and 1730 time frames.

It is to be noted that the on-the-lake, photographic, and core-sample visual observations discussed above do not altogether preclude the presence of sparse colonies of wild rice plants at the "time" of observation. The basis for this uncertainty is that with a sparse rice crop, there is correspondingly sparse evidence signaling the presence of rice plants. This "weak-signal" could have been below the minimum signal detection capability of the observer or observing device. Nevertheless, very long periods of wild rice extinction could very well have been part of the Irving Lake story. The typical four-year cycle of boom, fair, fair, and bust rice crops, could have been superimposed on a much longer cycle. Within this longer cycle there could have been extended times when the rice crop could go boom, go bust, or be limited to some intermediate range of development, all of which would have been determined by climatic changes, large-scale beaver damming, or other macro events.

SUMMARY of PROJECT FINDINGS

The following Lake Planning Grant Project findings and observations were based on Steve McComas's analysis and interpretation of extensive water quality monitoring data, lakebed sediments, lake/watershed structure, and lake usage surveys, as well as a detailed examination and study of aquatic vegetation. Consultation with other lake specialists provided critical affirmation of these findings and observations. Those relative to Irving Lake are summarized here. Additional information on these and other findings can be found in the Lake Management Plan that resulted from the Planning Grant Projects [19].

General – Irving Lake is a very shallow and nutrient rich lake that is presently aquatic plant-dominated as opposed to algae-dominated.

Water Quality – Irving Lake has poorer clarity and higher nutrient levels than downstream Ballard and White Birch Lakes and relatively better clarity and lower nutrient levels when compared to other shallow lakes in the region; there is no indication of pollutants leaching from the old county landfill into the water that is tributary to the lake; the lake can experience severe algal blooms and switchover to an algae-dominated lake if wild rice and other rooted aquatic plants do not maintain their dominance, for whatever reason; wild rice does not adversely affect the water quality of the lake but rather works to improve its water quality as measured by summertime water clarity.

Impact on Downstream Lakes – Wild rice does not have an adverse impact on Ballard and Irving Lakes during the summer growing season; water quality in these downstream lakes has not deteriorated but rather appears to have improved slightly since the late 1920s, based on water clarity and phosphorus levels; wild rice is not likely to encroach into Ballard and White Birch Lakes on a large scale because of the sediment and depth characteristics of these two lakes, however, relatively sparse colonization is possible; wild rice probably exerts slightly higher chemical and biological oxygen demands on the downstream lakes than would some other aquatic plants of comparable coverage during the winter season when decomposition takes place under ice and snow cover, however, cascading aeration of the winter water inflow to Ballard Lake from Irving Lake serves to reoxygenate the water, as well as remove dissolved hydrogen sulfide gas, thus mitigating any incremental oxygen demands placed on the downstream lakes.

Navigation – Wild rice is a hindrance to motorized whole lake navigation, however, it can still occur, even in boom years; the rice is a motorized navigational nuisance for two riparian property owners, especially during boom years; the rice is not a hindrance to canoeists and kayakers; wild rice hindrance to motorized navigation may be considered to be advantageous to both water quality and the fishery as it impedes the stirring up of lakebed sediments and reduces very heavy fishing pressure by making this popular lake more difficult to fish.

Fishery – Wild rice provides Irving Lake with an excellent habitat for spawning and for the entire food chain of a healthy fishery; decreasing dissolved oxygen levels and increasing dissolved hydrogen sulfide levels in Irving Lake triggers an instinctive winter migration of its fishery into Ballard Lake.

"...the lake can experience severe algal blooms and switchover to an algae-dominated lake if wild rice and other rooted aquatic plants do not maintain their dominance...."

RECOMMENDATIONS

The following is a partial list of Steve McComas's recommendations for maintaining and protecting the water quality and fisheries of Irving, Ballard, and White Birch Lakes. This list focuses on Irving-related recommendations. See Reference 19 for more detail.

1. Continue to manage Irving Lake as an aquatic plant-dominated shallow lake.
2. Continue to deploy the cascading aerator, with existing turn-on procedure, to re-oxygenate and remove hydrogen sulfide from the winter water outflow from Irving Lake.
3. Obtain approval from the WDNR to cut minimum-sized channels to provide riparian property owners access to the Ballard-Irving thoroughfare.
4. Continue to work with wildlife managers to control late fall time beaver dam construction in the Ballard-Irving culvert to maintain a clear path for migrating fish.
5. Continue to monitor water quality, specifically including testing for wintertime dissolved oxygen at the culvert, Secchi disk readings on all three lakes, and other trophic status indicators (total phosphorous and chlorophyll *a*) as budget and manpower constraints permit.
6. Provide educational materials and programs for the community of lake users to enhance understanding of how Irving Lake functions with aquatic plants in general and wild rice in particular; how and why WDNR environmental policy tightly constrains options for wild rice control to absolute minimal removal; and how water quality can be diminished by motorized boating in the sensitive shallow areas of the lake, poor waterfront landscaping practices, and faulty septic systems.

CONCLUDING REMARKS: WORKING on LAKE TIME

Work on the Lake Planning Grants resulted in a better understanding of the natural history and ecology of Irving Lake and an appreciation of the fact that it has likely been functioning as it does now for hundreds of years. A better understanding of the interdependence of the three lakes and how they function with wild rice was gained as well. We found that wild rice does not pose a threat to the overall well being of Irving, Ballard, or White Birch Lakes. In fact, it was found that the wild rice provides many ecological benefits for both the lakes and users of the lakes. Although these benefits come at the cost of restricted motor boat navigation, alternatives are available to address concerns. Most importantly, the lake simply cannot be all things, to all people, at all times.

The consideration of options related to the Lake Management Plan provided exposure to several examples of how things could really run amok when careful consideration is not given to the downside risks of well-intended actions. These examples can also serve as powerful educational tools aimed at changing the way we think about what can be done to enhance shallow lake ecosystems. These systems are fragile, extremely complex, "living bodies," which are not easy to manipulate or "quick fix." In almost all cases, it seems best to work in harmony with Mother Nature, rather than against Her.

Finally, it is difficult for most of us, who are not "lake professionals," to appreciate the complex nature of these ecologically valuable lake ecosystems due to our extremely narrow view of time and a cultural sense of urgency. Our lifelong view of time is but a blink of the eye in lake time. We simply need to do our best to gain in wisdom and work to understand the interdependent rhythms and workings of the natural world. We can then better visualize this world working on its own time—in this instance, with wild rice in a shallow headwaters lake called Irving.

> ***"We simply need to do our best to gain in wisdom and work to understand the interdependent rhythms and workings of the natural world."***

ACKNOWLEDGEMENTS

The work described in this paper was done under WDNR Lake Planning Grants LPL 602 and LPL 613. My profound thanks go to Bob Young, Steve McComas, Laura Herman, and Paul Garrison for their many helpful insights, suggestions, and patience while they taught me the intricacies of lake ecosystems, and to Sandy Engel, who provided all of this, as well as infectious enthusiasm and the initial motivation to write the paper. Each of these individuals reviewed the paper and made many helpful suggestions during its development and, along with Peter David and Ron Eckstein, reviewed the final draft.

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Frank G. Splitt
November 26, 2000

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On Wisdom

For it is (wisdom) who gave me unerring knowledge of what exists,
To know the structure of the world and the activity of the elements;
The beginning and end and middle of times,
The alternations of the solstices and the changes of the seasons,
The cycles of the year and the constellations of the stars,
The natures of animals and the tempers of wild animals,
The powers of spirits and the thoughts of human beings,
The varieties of plants and the virtues of roots;
I learned both what is secret and what is manifest,
For wisdom, the fashioner of all things, taught me.

The Book of Wisdom 7:17-22

BALLARD-IRVING-WHITE BIRCH LAKES ASSOCIATION, INC.
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BIRGE & JUDAY DATA: Application and Reliability Perspectives

A TIME COMPARATIVE STUDY OF WATER QUALITY ON BALLARD, IRVING, AND WHITE BIRCH LAKES:
A Contemporary Application of Birge & Juday Data

LAKE WATER SAMPLING AND TESTING IN THE 1920s:
A Glimpse into the Past

TOTAL PHOSPHORUS CONCENTRATION DETERMINATIONS IN THE 1926-1930 ERA: A Note on the Reliability of Birge & Juday Data

Frank G. Splitt

Ballard-Irving-White Birch Lakes Association, Inc.

February 13, 2001

Wisconsin Lake Management Planning Project Grant Program
Project Nos. LPL-602 and LPL-613

E. A. Birge, shown in his raft some 55 years after he arrived at UW-Madison in 1875 as a 24-year old instructor in natural history. He brought with him an insatiable curiosity about lakes and streams. With Chancey Juday, he founded the UW-Madison Trout Lake Station in 1925. The data gathered by Birge and Juday on Ballard, Irving, and White Birch Lakes, during the summers of 1926 through 1930, provided the basis for the comparative study.

CONTENTS

FOREWORD

When Edward Birge, Chancey Juday and their colleagues began their pioneering limnological investigations more than 70 years ago in northern Wisconsin, their goal was to uncover basic principles about lakes. They were extremely successful, writing in depth about various physical, chemical, and biological properties of lakes. Yet, one of the most valuable by-products of their research was a legacy of data that has served as a benchmark against which we can compare the present status of our lakes.

But comparisons of old and new data are seldom as straightforward as we would like. Field and laboratory methods change, the original sampling and analysis equipment is often long gone, and the original investigators can no longer clarify subtle points of procedure. It can be misleading, and even dangerous, to compare old and new data sets without a careful analysis of the potential problems and pitfalls such a comparison presents. That is why this report by Frank Splitt is so valuable. He has undertaken a careful and thorough analysis of the comparability of several of the Birge-Juday datasets with more modern data collected on a suite of lakes.

One of the goals of a research university is that the knowledge it helps to develop will find its way into the public domain. It is even more rewarding when public use of this knowledge leads to increased understanding and the creation of more knowledge. Such is the case here. I can't help but believe that Birge and Juday, the limnological pioneers, would have been proud to see their data still being used today.

Timothy K. Kratz, Ph.D.
Senior Scientist and Acting Associate Director
Trout Lake Station
Center for Limnology
University of Wisconsin-Madison

PREFACE

Wisconsin's lakes are in jeopardy on numerous fronts and many lakes need help. Many property owners and other lake users are not aware of their impact on the ecological health of the lakes. Much of the management of lakes in Wisconsin is limited by a lack of information about the lakes, their watersheds, and the people who use them. Little is known about the water chemistry of the lakes in years past. The sheer number of lakes dictates that much of the management of lakes in Wisconsin must rely on citizen and local government action as well as cooperation. These are the challenges before us.

Experience teaches that the single constant in nature is change. In years past, changes to our Wisconsin Lakes could be measured in decades, if not centuries. Unfortunately, this is no longer the case. Accelerated shoreland development, the invasion of exotic species, pollution, increasing lake usage by more and ever more powerful recreational vehicles, and other related problems are sharply accelerating the pace of change. This change is by no means for the good of the lakes, especially so for our highly sensitive shallow lakes. The future health of our lakes and our lake communities will be determined, to a large degree, by the extent to which lake residents and other lake users accept responsibility for environmental issues concerning the lakes. In addition, the environmental health of our lakes will depend on how well we manage the demand for waterfront property.

We are now poised at a turning point in the history of the management of Wisconsin's lakes and waterways. The Lake Management Planning Grant and Lake Protection & Classification Grant Programs have been designed to help respond to the challenges outlined above. Specifically, these programs can provide the economic resources required to help meet the twin objectives of obtaining a better understanding of our lakes and of appropriately managing our lakes, both by way of local participation and responsibility.

The articles in a companion Lake Planning Grant Program publication, *WISCONSIN LAKES: A Trilogy,* provide an illustrative example of how this program made it possible for a community of concerned citizens to respond to problems and issues relative to their chain of three shallow lakes. The program enabled funding of laboratory tests and analyses and, most importantly, allowed contracting the services of a lake expert to perform technical fieldwork as well as guide the efforts of local volunteers.

This special supplemental study component of our Lake Planning Grant Program Final Report provides historical insights and perspectives on the application and the reliability of data taken on our lakes some 70 years ago. It also provides a good example of the need to characterize lakes by means of standardized tests and procedures supported by well-defined documentation. Most importantly, they highlight the need to monitor the status of our Wisconsin Lakes on a regular basis. How else can we find out "what's happening, and determine what best to do about it?"

Frank G. Splitt

Star Lake, WI
January 30, 2001

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The investigations described herein were performed under WDNR Lake Management Planning Grant Projects LPL-602 and LPL-613. It was through these grant projects that we were first introduced to the work of Birge & Juday. Jim Vaughan [UW, BSCE '38], a long time Irving Lake resident, and a past chairman of the University of Wisconsin Foundation played a key role in this Birge & Juday story – aided and abetted by his wife Kay [UW, HE '39], an even longer time resident. Both Jim and Kay are staunch supporters of the University of Wisconsin, and the sponsors of three Bascom Professorships. Kay possesses a keen memory of her childhood summers spent at the Kuechenmeister family's Irving Lake cabin, dating back to 1924. Shortly after the grant awards, Jim visited John Magnuson at the UW-Madison Center for Limnology. Based on Kay's recollection of "the man with the funny hat on our lake", he sought to determine whether anything was ever documented on the apparent testing on Irving Lake sometime in the late 1920s. John responded by sending excerpts from the 1984 Mark Johnson report to Jim who gave them to me – "for possible future reference." Among those excerpts was a computerized Birge & Juday data sheet covering Ballard, Irving, and White Birch Lakes. My thanks to Jim, Kay and John for the "beginnings."

I am especially indebted to Katherine Webster, WDNR, who not only did the critical literature search that made this work possible, but also facilitated contacts with experts in the field, acted as a sounding board throughout both investigations, and reviewed the final drafts. Special thanks also go to Paul Garrison for his contributions, insights, encouragement, and reviews. The cooperative efforts on our Grant Projects by Tom Hrabik, and the late Tom Frost, UW-Madison, Center for Limnology, Trout Lake Station, are gratefully acknowledged as well.

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A TIME COMPARATIVE STUDY OF WATER QUALITY ON BALLARD, IRVING, AND WHITE BIRCH LAKES:
A Contemporary Application of Birge & Juday Data

BACKGROUND and PURPOSE

What do we know about water quality measures from years past; and of what value would these measures be anyway? This note addresses both questions in the context of concerns about water quality in the Ballard-Irving-White Birch Chain of-Lakes, Vilas County, Wisconsin.

Thanks to the persevering work of limnology pioneers, Edward Birge and Chancey Juday we have total phosphorus (TP) concentration and Secchi disc depth data on all three lakes for the period 1926 to 1930 [1]. Although these data are sparse, they appear to be sufficient to serve two important purposes. The first is to provide a basis for comparing present-day water quality with water quality from sometime before the late 1950s. The late 1950s time is of significance because this is when the relatively sparse wild rice beds that existed before this time were said to be expanded by multiple plantings [2]. The second purpose is to provide primary data that may be of value in a current paleolimnology study of Irving Lake by Garrison [3].

THE BIRGE & JUDAY DATA

The Birge & Juday data on the three lakes are portrayed below in Table 1. Note that Table 1 also appears in the TABLES Section on page five. Henceforth, all referenced tables appear in the TABLES Section. Here the data are shown in the form of SD, TP data points corresponding to the lake sampled and the sample date. The values and units in this table are the same as reported by Johnson [1].

Table 1 – Secchi Disc Depth and Total Phosphorous Concentration (SD, TP) Data Points From 1926 to 1930 – SD (meters), TP (milligrams/liter)

Sample Date	Irving SD, TP	Ballard SD, TP	White Birch SD, TP
8/07/26	__, 0.028	__, 0.030	__, 0.019
7/14/27	__, 0.030	1.5, 0.028	---
8/19/27	---	---	2.2, 0.020
8/18/28	__, 0.023	2.5, 0.015	2.5, 0.017
7/29/29	---	---	3.0, 0.018
7/31/29	---	2.0, 0.024	---
8/22/29	__, 0.017	---	---
6/27/30	---	3.0, __	---
6/28/30	---	---	3.5, __

Table 2 shows the same data as in Table 1 with the units of TP concentration changed from milligrams per liter to parts per billion (ppb), and SD depth units changed from meters to feet. Additionally, the original depth readings have been increased by 5% to account for the use of a 10-centimeter, rather than a 20-centimeter (approximately 8 inch), diameter Secchi disc for ease of field handling [1]. An average value for each of the data points has been added for convenience of future reference.

COMPARATIVE ANALYSIS – PART 1

Average SD depths and TP concentrations from 1999-2000 testing on Wisconsin Lake Management Planning Grant Projects LPL 602 and 613 [4] are shown in Table 3. The dates correspond closely with the days-of-the-year on which Birge and Juday did their sampling on the indicated lake. This was done for consistency, and does not imply a more accurate comparison, although this could very well be the case.

Also shown, are SD-depth readings taken in 1960 [5]. These partial data points represents the paucity of trophic status indicator data on the lakes covering the period after the Birge and Juday Survey up to 1960.

Let us now proceed with a comparison of the data from the two times. First we introduce the parameter TP*, which, by definition, represents the difference between a TP concentration measurement value from the Birge & Juday data on a given day, less the same measurement value taken in the 1999-2000 time period on, or reasonably close to, the same day-of- the-year. Similarly, we define the parameter SD*, the value of which is given by the difference between a SD depth measurement value from the Birge-Juday data, less the corresponding measurement value from the 1999-2000 time period.

Table 4 shows a summary of the data from Tables 2 and 3 in accordance with the above definitions. Here the data are expressed in terms of range (R) and average (A) data points. The ordering of the test dates is the same as in Table 2, again, for convenience of reference. Next, to facilitate a side-by-side comparative analysis of the lake data, we form the array of key parameters shown in Table 5. This table builds on the data in Tables 2, 3, 4 and our definitions. Observations, relative to each of the three lakes, follow from an examination of Table 5.

Irving Lake – Birge and Juday did not take Secchi Disc readings on this lake. Most likely, they did not have a detailed knowledge of the lake's structure, and were unaware of the whereabouts of the "deep" holes. Consequently, they were able to see the bottom in this mostly shallow lake (Paul Garrison, WDNR, personal communication). However, the 5.5-foot SD reading on 8/15/60 could possibly be compared to the 6 foot August average for 1999-2000. The past TP concentrations consistently measured less than they do now – about a 12-ppb difference on the average, with an difference range of 8 to 18-ppb less. Given the 24.5-ppb, average TP concentration in the 1926-1930 reference period, the average summertime TP concentration is now 51% greater.

Ballard Lake – Reference to Tables 4 and 5 will show that the early SD depths were consistently less than at present, 4 feet less on average with a range of 1.2 to 6.3-feet less. This represents about a 50% increase in average SD depth. Similarly, the Birge & Juday data show that past TP concentrations were consistently greater than at present, about 10-ppb greater on average with a range of 2-ppb to 17-ppb greater. The TP concentration is now seen to be over 40% less on average.

White Birch Lake – Reference to Tables 4 and 5 will show that the Birge & Juday depths were less than, or equal to, corresponding 1999-2000 depths, a little over 3-feet greater on average with a range of 0 to 5.4-feet greater. Here the early data show a TP concentration range consistently greater than at present, 4.6-ppb greater on average with a range of 3-ppb to 6-ppb greater. This represents about 25% less TP concentration today than existed in the 1926-1930 period.

COMPARATIVE ANALYSIS – PART 2

General – The foregoing data comparisons indicate that summertime TP concentration levels in Irving Lake are greater now than they were in the late 1920s, while the TP concentrations in Ballard and White Birch Lakes are now substantially less. Furthermore, SD depth readings on both Ballard and White Birch Lakes are also substantially greater relative to the late 1920s era. It would appear that Table 5 summarizes the whole story and that we can now move on to our conclusions – would, that this be so.

In making these comparisons, it has been tacitly assumed that the Birge & Juday data is completely trustworthy. However, on what basis can we have confidence in this seventy-year old data? Put another way, can conclusions based on this data really stand up to rigorous scientific challenge? These are difficult questions to answer since the test apparatus and procedures that were utilized at the time cannot be easily replicated. Nevertheless, according to Magnuson [6], considerable effort has been expended in scientific "detective work" to gain a better understanding of how a wide range of the early measurements were made. A better understanding of sensitivity and resolution considerations involving these early measurements would allow comparisons to be with made with a high degree of confidence. This confidence would be based on a good sense as to the limits of early testing capabilities. Fortunately, for our present purposes, we should be to able utilize the Birge & Juday data with a high degree of confidence. Here is why.

Secchi Disc Depth Measurements – As discussed previously, the Birge & Juday SD depth readings were increased by 5% to account for their use of a 5-centimeter, as opposed to a 10-centimeter, diameter disc. Additionally, five of the six data points conform to a linear model "track", while a reasonable explanation has been given for the non-conforming point; see End Note 1. Although SD depth readings are subjective by their very nature, there is no apparent basis for a lack of confidence in the overall accuracy of the Birge & Juday SD depth data. However, given their use of one-half meter measurement increments, there is an inherent one-half meter (20-inch) range of uncertainty associated with each of their depth measurements. This uncertainty can be accounted for with a (a more convenient to apply) +/- 1-foot uncertainty band when interpreting comparative data. If taken in this context, the Birge & Juday SD depth readings are considered sufficiently accurate for our purposes.

TP Concentration Measurements – According to Johnson [1], the Birge & Juday TP concentration data were obtained by a colorimetric-ceruleomolybdate reaction in an oxidized water sample. The procedure was modified in 1927, and possibly modified again in 1931. All of this was confirmed by a detailed literature search [7-10]. Modern automated-colorimetric procedures have a limit of detection of 5 ppb, (George Bowman, and Anthony Plourde personal communications). The sensitivity of the early procedures is currently suspect by some. However, Birge and Juday were not confronted with threshold level concentrations on any of these mesotrophic lakes. TP concentrations, ranging from 15 ppb to 30 ppb, were made on a routine basis during the 1926-1930 era [7]; see also End Note 2. However, questions remain as to potential issues with "sample-to-sample" repeatability, "lab-to-lab" data correlation, and the possibility of unknown sources of color contaminating interference. It would appear reasonable to assume that we can account for these and other related, vagaries by assigning a +/- 3-ppb uncertainty range to the Birge-Juday TP concentration data when using this data as a reference in comparisons with those obtained from the Lake Planning Grant Planning Grant Program. This amounts to a +/- 20%-uncertainty factor when applied to the lowest recorded measurement of 15 ppb.

Comparative Analysis with Uncertainty Factors – Table 6 is a modified version of Table 5 – reflecting the uncertainty factors discussed above. An examination of this table will show that, although the factors introduce relatively wide ranges of uncertainty, the range extents are not wide enough to overcome the margins represented by the original (unmodified) Birge & Juday data. For example, the only entry that shows a change in sign is the TP* Range over the Ballard Lake test dates, from 2 ppb to 17 ppb to –1 ppb to 20 ppb. This is considered to be negligible in view of the still relatively high value (6.8 ppb) of the low-side TP* Average, and the fact that it represents a less than 5% overlap.

"...although the uncertainty factors introduce relatively wide ranges of uncertainty, the range extents are not wide enough to overcome the margins represented by the original (unmodified) Birge & Juday data."

In light of all of the above, and with a high degree of confidence, we can now summarize the discussion by stating that:

Relative to the 1926-1930 Time Period:

Irving Lake *– Average TP concentrations are now 35% to 72% greater.*

Ballard Lake *– Average TP concentrations are now at least 28% less, and average SD depths are now at least 34% greater.*

White Birch Lake *– Average TP concentrations are now at least 7% less, and average SD depths are at least 20% greater.*

DISCUSSION

The increase in TP levels, in Irving Lake at the present time, agrees with results from a sediment core analysis by Garrison [3]. Phosphorus levels in the core are at their highest in the upper portion This increase in the summertime TP concentrations in Irving Lake appears to indicate that the lake's aquatic organisms, aquatic plant and algal communities have become quite efficient in "capturing" and retaining phosphorus from the atmosphere and various other organic sources through a variety of recycling mechanisms. No doubt, wild rice plays an important role in this recycling dance.

Garrison also took sediment cores from Ballard and White Birch Lakes with the aim of comparing present day water quality to pre-1900 conditions [4]. He was able to estimate phosphorus concentrations based on diatoms, and found that these concentrations have increased from 10 ppb to 13 ppb in Ballard Lake, and from 9 ppb to 11 ppb in White Birch Lake. The present day inferred levels are similar to those based on our 1999-2000 samples.

Garrison also found that the cores indicate that nutrient levels have only increased a small amount – certainly much less than indicated by the B&J data and commented as follows, *"I have seen this type of change in Curtis Lake, Waushara County. The only disturbance in the watershed of this lake was shoreline development. When I analyzed the top and bottom of the core there was very little change in nutrients. Later, we analyzed the whole core. It turned out that during the period 1960-1970 when homes were being built, and there was no agriculture, nutrients in the lake were much higher. Apparently, the same trend has occurred in Ballard and White Birch ,"* (Paul Garrison, January 24, 2001, personal communication).

What could account for the relatively high TP concentration levels in the 1926-1930 era? Perhaps, a part of the explanation can be based on "abnormal" local conditions a few years before the advent of the Birge & Juday survey. For example, the Ballard-Irving-White Birch Lakes area was the scene of large-scale logging activities and extensive slashing fires in the early 1900s. Another widespread slashing fire occurred in 1920. Consequently, the watershed was exposed, and, therefore susceptible to more soil erosion and attendant nutrient loading with a likely increase in TP levels. As seen in the above, these higher levels, compared to present-day levels, correlate with the Secchi Disc trends on both Ballard and White Birch Lakes.

CONCLUSIONS

Two basic conclusions can be drawn from the comparative analysis and the above discussions. The first is that, relative to a late 1920s baseline, the water quality in Ballard and White Birch Lakes, as indicated by lower TP concentrations and higher SD depth readings, has not deteriorated. The second conclusion is that summertime TP concentrations in Irving Lake are greater than they were in the late 1920s. On the other hand, the single Irving Lake depth measurement taken in 1960 would appear to indicate that there has been no substantial change in depth readings *since that time*. However, natural year-to-year variability in this measure, and the lack of additional depth as well as corroborating TP concentration data from this period, effectively negates this conclusion.

Based on all of the above, there is a very high degree of confidence that, relative to a 1926 to 1930 baseline, the water quality in Ballard and White Birch Lakes has not been degraded as a consequence of the late 1950s to early 1960s multiple plantings, and subsequent profuse growth, of wild rice in Irving Lake. On the contrary, the water quality in these lakes appears to be better now than it was in the 1920s.

Finally, a word about the importance of long-term data gathering and careful documentation. It was Johnson's documentation and quality assurance report, on the Birge and Juday Survey of Wisconsin Lakes of the Northern Highlands [1], that made it possible to gain insights, make observations, and draw meaningful conclusions from seventy-year old data.

Frank G. Splitt
January 25, 2001

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TABLES

Table 1 – Secchi Disc Depth and Total Phosphorous Concentration (SD, TP) Data Points From 1926 to 1930 – SD (meters), TP (milligrams/liter)

Sample Date	Irving	Ballard	White Birch
8/07/26	__, 0.028	__, 0.030	__, 0.019
7/14/27	__, 0.030	1.5, 0.028	---
8/19/27	---	---	2.2, 0.020
8/18/28	__, 0.023	2.5, 0.015	2.5, 0.017
7/29/29	---	---	3.0, 0.018
7/31/29	---	2.0, 0.024	---
8/22/29	__, 0.017	---	---
6/27/30	---	3.0, __	---
6/28/30	---	---	3.5, __

Table 2 – Secchi Disc Depth and Total Phosphorous Concentration (SD, TP) Data Points From 1926 to 1930 – SD (feet), TP (ppb)

Sample Date	Irving	Ballard	White Birch
8/07/26	__, 28	__, 30	__, 19
7/14/27	__, 30	5.2, 28	---
8/19/27	---		7.6, 20
8/18/28	__, 23	8.6, 15	8.6, 17
7/29/29	---	----	10.3, 18
7/31/29	---	6.9, 24	---
8/22/29	__, 17	----	---
6/27/30	---	10.3, __	---
6/28/30	---	---	12.0, __
1926-1930 Average	__, 24.5	7.8, 24.3	9.6, 18.5

Table 3 – Secchi Disc Depth and Total Phosphorous Concentration (SD, TP) Data Points From 1960, 1999 and 2000 – SD (feet), TP (ppb)

Sample Date	Irving	Ballard	White Birch
8/15/60	5.5, __	8.5, __	10.0, __
1999- 2000			
6/27, 28	6.0, 50	11.5, 19	12.0, 15
7/14	5.5, 42	11.5, 17	12.5, 13
7/29, 31	6.0, 39	12.0, 15	13.0, 13.5
8/07	6.0, 36	12.0, 13	13.0, 14
8/18-22	6.0, 35	12.0, 13	13.0, 14

Table 4 – Secchi Disc Depth and Total Phosphorous Concentration Data Difference Points (SD*, TP*) for Corresponding Test Dates in the 1926-1930 and 1999-2000 Time Periods – SD* (feet), TP* (ppb)

Sample Date	Irving SD*, TP*	Ballard SD*, TP*	White Birch SD*, TP*
8/07	__, - 8	__, 17	__, 5
7/14	__, -12	-6.3, 11	-----
8/19	----	----	-5.4, 6
8/18	----	----	-2.7, 4.5
7/31	----	-5.1, 9	---
8/22	__, -18	---	---
6/27	----	-1.2, __	---
6/28	----	----	0.0 , __

Table 5 – Secchi Disc Depth and Total Phosphorus Concentration Parameter Comparisons – SD (feet), TP (ppb)

Parameter	Irving	Ballard	White Birch
A1, SD Average over 1926-1930	---	7.8	9.6
A2,,SD* Average over test dates	---	-4	-3.1
SD* Range over test dates	---	-1.2 to –6.3	0 to –5.4
% Change in SD Average over 1999-2000 = 100(A2/A1)		(51%)	(32%)
A3, TP Average over 1926-1930	24.5	24.3	18.5
A4, TP* Average over test dates	-12.5	9.8	4.6
TP* Range over test dates	-8 to -18	2 to 17	3 to 6
% Change in TP Average over 1999-2000 = 100(A4/A3)	(51%)	40%	25%

Table 6 – Secchi Disc Depth and Total Phosphorus Concentration Parameter Comparisons with Uncertainty Factors for Birge & Juday Data – SD (+/- 1 foot), TP (+/- 3 ppb)

Parameter	Irving	Ballard	White Birch
A1, SD Average over 1926-1930	---	6.8 to 8.8	8.6 to 10.6
A2, SD* Average over test dates	---	-5 to -3	-4.1 to –2.1
SD* Range over test dates	---	-0.2 to -7.3	1.0 to -6.4
% change in SD Average over 1999-2000 = 100(A2/A1)	---	(34% to 74%)	(20% to 48%)
A3, TP Average over 1926-1930	21.5 to 27.5	21.3 to 27.3	15.5 to 21.5
A4, TP* Average over test dates	-15.5 to –9.5	6.8 to 12.8	1.6 to 7.6
TP* Range over test dates	-21 to -5	-1 to 20	0 to 9
% change in TP Average over 1999-2000 = 100(A4/A3)	(-35% to -72%)	28% to 47%	7% to 49%

END NOTES

Note 1: On Linear SD, TP Data Relationship – It is of interest to note that, over the observed range of data, the Birge & Juday (ST, TP) data points for Ballard and White Birch Lakes, conform closely with the linear relationship,

SD = 12.6 – 0.262 TP feet; 30 ppb = /> TP >/= 15 ppb.

However, there is a non-conforming point corresponding to the 7/29/29 measurements on White Birch Lake. The anomaly could indeed represent a unique condition at the time. On the other hand, it could also be an artifact of the half-meter increment of SD depth measurement that Birge and Juday used on these lakes beginning in 1928. These relatively large increments, coupled with a high-side round-off error for a reading between 2.5 and 3.0 meters could also explain the anomalous data point – this point is 1.8 feet (0.545 meters) "off" the value given by the linear equation. It is likely that this was indeed the situation that prevailed, rather than an unusual lake condition.

Note 2: On TP Concentration Measurement Readings – The set of integers, (15, 17, 17, 18, 19, 20, 23, 24, 28, 28, 30, 30), corresponds to the numeric values of the twelve Birge & Juday TP concentration data points. If we put aside the origin and physical interpretation of this set of numbers, we can focus on the statistical implications of the numbers themselves. To begin, we see that the numbers are whole, and range from 15 to 30 with an average value of 22.41 that can be compared to the average value of 22.5 for an equally likely distribution of the numbers in this range. Second, we see that the integers are not clustered about multiples of 5 or any other value. Third, in this range of sixteen-possible reported whole numbers, seven are non-reported, six are reported once, and three are reported twice. This mix of seven 0s, six 1s, and three 2s is slightly "lumpy", in the sense that the relative frequency of 0s, 1s, and 2s is uneven, compared to that of a uniformly random process with its most-likely mix of eight 0s, and eight 1s. Nevertheless, all of this strongly suggests the possibility of a uniform, random distribution of the integer data values reported for TP concentration measurements. A Chi-Square test of just such a hypothesis indicates about a 20% likelihood of agreement. Based on this measure, we can state that from a statistical point of view, the Birge & Juday TP concentration data can be represented by a very-near uniformly random process. This means that any one of the sixteen possible integer data values, ranging from 15 to 30, was almost as likely to be reported as any other. Simply stated, there is little evidence of statistical bias for any of the measurement values.

Based on the above, it seems that the 1926-1930 era lab analysts thought that they were capable of measuring TP concentrations to within 1 ppb between 15 ppb to 30 ppb. Furthermore, based on their reputation for good science, Birge and Juday more than likely, would have challenged the lab analysts if their reported data reflected sensitivity and resolution beyond their capabilities. Though by no means a proof, the foregoing appears to be a persuasive argument for the integrity of the Birge & Juday data *in this application.* Nonetheless, there is always the possibility that the lab analysts were dealing with sources of error not considered here, such as water samples or fixing reagents containing unknown color affecting "contaminants." The revelation of credible evidence to this effect would necessitate a modification of the +/- 3-ppb uncertainty factor.

"The lake is the one true microcosm, for nowhere else is the life of the great world, in all of its intricacies, so clearly disclosed to us as in the tiny model offered by the inland lake."

E. A. Birge, from an address entitled: *A House Half Built,* given to the Madison Literary Club on October 12, 1936.

LAKE WATER SAMPLING AND TESTING IN 1920s: A Glimpse into the Past

Thanks to the efforts of Annamarie Beckel and others, we can get a sense of the times and a feel for what was really "going on" when our lakes were being sampled during the 1926-1930 era. For example, just getting to and from the Madison campus of the University of Wisconsin was a major feat in its self. At the onset of the Survey of the Lakes of the Northern Highland Lake District in 1925, there were only 20 miles of paved roads between Madison and the Trout Lake Limnological Laboratory of the Wisconsin Geological and Natural History Survey, as the Trout Lake Station was called by Birge and Juday. The other 200 miles of the trip was rough gravel.

Getting to and on the lakes to be sampled was even more difficult. According to Rex Robinson, a student of analytical-chemist George Kemmerer, who worked as an assistant to Birge and Juday at TLS during the summers of 1926 through 1929: " *We used a Model T Ford for transportation to the neighboring lakes. The "improved" roads were gravel and became very rough during heavy summer usage. Remote lakes were served with dirt roads, usually of very poor quality. Many lakes were inaccessible except by trail. We made use of rowboats at resorts whenever available. If no boat was available, we set up a portable wood-frame canvas boat or inflated a portable rubber boat. A few times one of us would swim out a distance from shore to take a water temperature and obtain a sample.*

"During the summers I was at Trout Lake, we investigated over 500 lakes in Vilas and adjoining counties.... As most of the lakes had not been investigated limnologically before, we would first sound the lakes for depth with lead and calibrated line to establish our station at the location of the deepest depth. Water temperatures were taken at different depths to establish the thermocline. Samples of water and plankton were taken at appropriate depths. Readings for turbidity were usually taken with a Secchi disc.

"After our samples were taken, we would hurry home to the laboratory for the analytical work. Thousands of analyses were made during a summer's work. The normal list included: pH, dissolved oxygen, free and fixed carbon dioxide, soluble phosphate, organic phosphorus, soluble silicate, nitrate, nitrite, ammonia, organic nitrogen. Each day the results were reported to Dr. Birge or Dr Juday.... Our lives were busy ones, breakfast at 7 a.m. and off to the selected lake(s) of the day as soon as we could load up the auto with the necessary bottles and needed equipment. We worked seven days a week. The only diversion was fishing on Trout Lake or the Saturday night dance at the Trout Lake Dance Pavilion at the south end of Trout Lake. But those were pleasant summers and I treasure the memories."

Robinson received his Ph.D. in 1929. He then joined the Chemistry Department faculty at the University of Washington, retiring as Emeritus Professor of Chemistry in 1971. Here we note the importance of the chemists. All of the lake-water sampling would have been for naught if reliable measurements could not be made on the samples. The essential players in this area were George Kemmerer and Villiers Meloche. It was Kemmerer who directed all of the critical analytical-chemical work for Birge and Juday at Trout Lake and in Madison... covering a complete set of field determinations spanning 19 different chemical physical and biological items. Following the death of Kemmerer in 1928, direction of the analytical-chemical work was taken over by Villiers Meloche, who was a pioneer in the applications of new instruments to chemical analyses. Much of the credit for the success of the Survey can be attributed to the contributions of these outstanding chemists. Without their breakthrough thinking in the application of micro-analytical chemistry, there would be no meaningful Birge & Juday data to investigate, or, for that matter, even consider for use as a basis for comparison with data obtained by present-day methods.

The Robinson quotations and background information from: Annamarie L. Beckel's *Breaking New Waters – A Century of Limnology at the University of Wisconsin*, Transactions of the Wisconsin Academy of Science, Arts, and Letters, Special Issue, Wisconsin Academy of Science, Arts, and Letters, Madison, WI, 1987.

TOTAL PHOSPHORUS CONCENTRATION DETERMINATIONS IN THE 1926-1930 ERA: A Note on the Reliability of Birge & Juday Data

Background and Purpose

A recent time comparative study of water quality on three Vilas County Lakes [1], used Birge & Juday (B&J) data from the 1926-1930 era. The B&J data was used to provide a reference to which 1999-2000 data was compared. During the course of this study, questions arose relating to the limitations of the test procedures used in the determination of the total phosphorus concentration levels in B&J lake-water samples. Specifically, the questions were these: *"On what basis can we have confidence in this seventy-year old data?"* and *"Can conclusions based on this data really stand up to rigorous scientific challenge?"* These are difficult questions to answer since the test apparatus and procedures that were utilized at the time cannot be easily replicated. Although these questions were addressed in the study paper, the discussion was ad hoc and necessarily brief. It soon became apparent that the complex issues surrounding the questions were such that further discussion would tend to overshadow the main topic of the study. It was also apparent that the issue deserved discussion on its own merits since the unresolved questions would continue to impede the use of B&J data. This note provides the vehicle for just that discussion.

The reference sources for this investigation are four related articles [3-6] that appeared in the Transactions of the Wisconsin Academy of Sciences, Arts, and Letters during the 1928 to 1931 period. These articles not only provided detailed descriptions of the methods for making chemical determinations, but insights into potential operational problems and the concerns of the authors as well. Briefly stated, they provided all of the "clues and evidence" upon which this investigation was based. In a manner of speaking, this evidentiary-reconstructive type of investigation can be described as scientific "detective work." Magnuson [7], provides relevant commentary based on a similar UW-TLS investigation of Birge and Juday methods during the 1980s. Previous efforts to gain a better understanding of how 1926-1930 era measurements were made, appear to have been motivated by concern about acidification of lakes caused by atmospheric deposition. These efforts focused on a broad range of chemicals and lake-water properties such as calcium, alkalinity, conductivity, and pH, c.f. Eilers [8]. Notably absent from this broad range of parameters is total phosphorus. No doubt, its absence can be attributed to the difficult task of duplicating a very complex analytical method to enable comparison with modern day methods, c.f. Lathrop [9].

This note is focused on the measurement of total phosphorus in the lake water samples obtained by Birge and Juday. A better understanding of the limits to which the data from these early measurements can be trusted, would allow comparisons to be with made with some degree of confidence when the data is used within its range of applicability. By its very nature, this subject is not deterministic and, ultimately, must be described in the language of probabilities. The establishment of meaningful statistical confidence limits is necessarily based on their application and on a good sense as to the limits of early testing capabilities.

The aim of this note, is to identify as well as quantify sources of two types of measurement error. The first type involves the precision with which the lab analysts were able to make measurements on known chemical samples. The second type of error involves making precise measurements on samples contaminated by material that can affect the measurement of the target chemical. These contaminants can deceive by a virtue of a false high-side reading or a false low-side reading, and can be a by-product of the measurement process itself. As such, this type of error affects the accuracy of measurement. A reliable measurement is herein taken to mean a measurement that can be described in terms of the range of uncertainty corresponding to these errors. This note also aims to provide a reasonable range of uncertainty that can be used to establish confidence limits

Phosphorus in Lake Water

General – In 1925 Birge and Juday began a survey of the lake waters of the Highlands District of northeastern Wisconsin that continued through the summer of 1930. During this period, they collected samples of lake water and of lake-water residues from over 500 bodies of water. Although various chemical determinations were made on these samples. our present interest is the total phosphorus concentration levels reported by Birge and Juday via Johnson [2]. Since this methodology is an extension of that employed for the determination of soluble phosphorus, we will be discussing both. The unit of concentration measure for phosphorus that is used in this paper is parts per billion (ppb); see End Notes 1 and 2. Definitions of the three working measures for phosphorus concentration in lake water follow:

Soluble Phosphorus Concentration (SP): *The measure of pentavalent, "phosphate" phosphorus that is in solution.*

Organic Phosphorus Concentration (OP): *The measure, of the phosphorus contained in the plankton, other organic material, and as soluble non-pentavalent phosphorus compounds present in the water.*

Total Phosphorus Concentration (TP = SP + OP): *Soluble plus Organic Phosphorus*

In 1925, the first year of the survey, measurements were confined to SP. However as the survey progressed, it became evident to Birge and Juday that the determination of TP would contribute to a better understanding of the role phosphorus plays in lakes and a method was devised for such a determination [3].

1926-1930 Era Test Procedures for Phosphorus Concentration

General – Quantitative determination of SP was based on the Deniges colorimetric-ceruleomolybdic method as modified by Florentin and Atkins [3]. Hereafter, this method will be referred to as the DFACC method. This method determines the quantity of pentavalent, "phosphate" phosphorus that is dissolved in the water sample; see End Note 2. However, it will not determine the quantity of soluble non-pentavalent phosphorus compounds that may be present. It is of significance to note that Deniges reported on this technique in 1921 as a method for the quantitative determination of phosphate phosphorus in biological products. In the same year, Florentin reported on an adaptation of the method to enable determination of phosphate phosphorus in water. According to Robinson [4], Florentin stated in his report *"that the acidity of the solution for the colorimetric determination of phosphorus must be carefully regulated to secure accurate results."* Atkins' contribution, in 1923, was to report on a modification of the Florentin method that provided a substantial increase in accuracy by means of ten-fold increase in the volume of the water sample – from 10 to 100 cubic centimeters. No mention is made in the referenced material as to the change in the sensitivity of the process to this change in water sample volume.

A review of the B&J SP data on water samples taken from several Wisconsin lakes in 1926 indicates that they were using the DFACC method to measure SPs as low as 4 ppb and resolve SPs to within 1 ppb in the low range, i.e., SP < about 20 ppb or so. This is indeed noteworthy because it gives us a clue as to the resolution and sensitivity capabilities of the method, including the colorimeter or Nessler tube type color comparator in use at the time. TP was determined by the same DFACC method after the organic material in the sample was thoroughly "digested," i.e., oxidized. The organic phosphorus is that which is contained in the plankton and other truly organic material that is present in the water. The oxidation process releases the phosphorus combined in organic compounds and oxidizes all of the dissolved non-pentavalent phosphorous compounds to the pentavalent state. Thus, the process also picked-up the phosphorus that was "missed" when determining SP. Although this would contribute to the measure of OP rather than SP, this artifact of the process is of no consequence to the measurement of TP.

The Original Oxidation Procedure – In the original procedure, 4 drops of sulfuric acid (H_2SO_4) and 10 drops of nitric acid were added to a 100 cubic centimeter water sample. This was followed by an evaporation during which the organic material was broken down into pentavalent form. The evaporation of the mix was taken just to the point where sulfur trioxide (SO_3)fumes of sulfuric acid were liberated, (H_2SO_4 + Heat – > H_20 + SO_3). At this point, 10 to 20 cubic centimeters of water and 3 cubic centimeters of concentrated hydrochloric acid were added . The evaporation process was then repeated. In this second evaporation, excess nitric acid was broken down by the hydrochloric acid. When cool, the sample was diluted to 100 cubic centimeters. The sample was then ready for treatment via the addition of prescribed quantities of stannous chloride and the molybdate reagent; see End Note 3. The blue color rendered by this treatment developed within 10 minutes and could then be compared with those developed from standard phosphate solutions (see End Note 1) that had been treated in exactly the same manner [2,3].

The Robinson and Kemmerer Modified Oxidation Procedure – Robinson and Kemmerer [4] reported on the development of a procedure that would eliminate one of the evaporation steps in the original procedure, and so speed-up the measurement. This procedure required only one evaporation *"just to the point where sulfur-trioxide (SO_3) fumes of sulfuric acid are liberated."* This modification to the original procedure may have led to more accurate, possibly higher TP determinations due to the fact that it was less likely that some of the phosphorus would be lost due to volatilization of phosphoric acid during the oxidation procedure. Although the author's limited data indicates this possibility, based on a comparison of this process and the original, the approximately 1-ppb deviation is within the limits of experimental error for the determination. The important thing to note is that the two procedures yield essentially the same results. Put another way, the original procedure may have rendered determinations that were *possibly* 1-ppb less than this simplified procedure. Practically speaking, this should mitigate concern about a possible change in procedure during the 1926-1930 period as reported by Johnson [2].

The Titus and Meloche Modified Oxidation Procedure – In an attempt to develop an oxidation procedure that would permit SO_3 fuming without the loss of phosphorus, Titus and Meloche [5] performed a number of investigative experiments that resulted in the recommendation of a further modification in procedure. Since this was reported in 1931, one year after the last samples were taken, it is highly doubtful that the recommended procedure was ever used on reported field samples. As we shall see, the effort to achieve their objective produced data that provide a valuable insight into one of the potential sources of measurement error. The potential for this error was very worrisome to the Birge & Juday team, most likely because it was not well understood when they began TP measurements in 1926. More to the point, they did not have the benefit of the focused work of Titus and Meloche on oxidation fuming without a loss of phosphorus – that came some four to five years later at the end of the project.

Error Sources in the Determination of TP Concentration With the DFACC Method

General – In addition to errors related to matching the color intensity of the processed water sample with that of a set of prepared standards, the oxidation process introduced additional opportunities for errors of a much more complex nature. The process presented a dilemma for these early workers because it was vulnerable to two distinct, but related, forms of interference. This interference could possibly cause the DFACC method give low-side determinations. The first type of interference involved the presence of residual H_2SO_4 in the oxidized water sample at the time of its treatment with the molybdate reagent. The excess H_2SO_4 would, in effect, increase the amount of this component of the molybdate reagent. This would, in turn, render a non- standard reagent, and an alteration of the test protocol. The second form of interference was the potential loss of phosphorus via a volatilization mechanism during the oxidation procedure, which would lead to a low-side TP reading. The H_2SO_4 dilemma faced by the Birge & Juday team was precisely this: If they used too little, the target phosphorus compounds would not be completely oxidized. On the other hand, if they used too much, the excess tended to inhibit proper color development. Both situations would render less than the correct TP measurement. Some sense of the magnitude of the potential errors comes from Robinson and Kemmerer [4], and Titus and Meloche [5].

Error Due to Excess H_2SO_4 – From Robinson we learn of the effect of excess H_2SO_4 on colorimetric comparison. Robinson's data on the effect of sulfuric acid upon the intensity of the blue color rendered by the DFACC method can be used to develop a matrix that provides good insight to the subject at hand, namely, the sensitivity of the method to over-acidification. This data matrix is shown in the following table.

Table –Present and Lost Phosphorus Concentrations as a Function of H_2SO_4 Concentration– Concentrations: Phosphorus in ppb, H_2SO_4 in one drop incremental additions to Phosphorus Solution (j), j = 1,2,3,4.

Phosphorus Present	10	20	30	40	50	60
Phosphorus Lost (1)	1	0	0	1	0	0
Phosphorus Lost (2)	0	1	0	0	0	0
Phosphorus Lost (3)	1	0	2	2	1	3
Phosphorus Lost (4)	0	0	3	5	4	8

Data from Robinson and Kemmerer, 1930

Inspection of the table will show, that given small amounts of phosphorus (about 20 ppb or less), the loss of phosphorus is not appreciably affected by the use of even an additional 4 drops of H_2SO_4 (effectively doubling the prescribed 4 drops). We also see, that with larger phosphorus concentrations, 2 drops of H_2SO_4 (a 50% increase in the prescribed amount) would have no measurable effect, but given phosphorus concentrations greater than 30 ppb, more than 2 drops can lead to a considerable loss of phosphorus. To appreciate what this data implies we first note that the TP values in most of the lakes covered by the B&J data are less than 35 ppb [3,4,6]. For example, the maximum reading reported in our recent study [1], was 30 ppb. Second, we note that some of the H_2SO_4 will be used to oxidize the target compounds of phosphorus and some will be neutralized by the carbonate in the water [4]. Based on this, a worst-case approximation for the upper bound on error attributable to excess acidification would be about –1 ppb. Returning to the example, of the 12 TP data points in the recent study, six were above 20 ppb. Taken together, these points caused an increase of less than 0.1 ppb in the average TP and a downshift of 2ppb in the estimated TP range when using this upper bound. Even this may have been an over-correction.

The data provided by Robinson can be also be considered from the point of view of excess H_2SO_4. One drop can be interpreted as a 25% excess, 2 drops as 50% excess, and so forth. A close look at the data indicates, that if 50% of the $H_2SO_4$is used in the oxidation procedure, then, within a +/- 1 ppb range of experimental error, there is no measurable error up to phosphorus concentrations of 60 ppb. This argument demonstrates that the oxidation procedure was much more tolerant to excess acidity than the Birge & Juday team realized. It also fortifies the basis for a conjecture that, for all practical purposes, this type of error should contribute a negative bias of no more than of 1 ppb to the "error pool", so long as the of B&J data is limited to applications on lakes that had TPs less than 50 ppb. Here we note that, "*In the great majority of the lakes the quantity of total phosphorus in the surface water ranged from 0.015 to 0.030 mg. per liter* (15 to 30 ppb)...*The mean quantity of total phosphorus in the surface water of 479 lakes is 0.023 mg per liter* (23 ppb)" [6].

Error Due to Volatilization Loss – In a 1928 report describing the original procedure [3], the authors make the following cautionary statement, "*There is a danger of losing phosphorus if fumes are allowed to pass out of the flask.*" The original procedure was clear in stating that evaporation of the mix takes place just to the point where sulfur trioxide (SO_3) fumes of sulfuric acid are liberated. As evidenced by the cautionary remark, and the work to develop modified procedures, these early workers were well aware of the potential loss of phosphorus during the oxidation process. Apparently, quantification of this threat did not take place until the work of Titus and Meloche., and then, only indirectly.

Clues that help determine how large a loss of phosphorus this could have been, and the conditions under which this loss could take place, can be found in the data provided by Titus and Meloche [5]. The experiments that generated the data involved tests for the possible loss of phosphorus under various oxidation conditions. *Their experiments indicated that there was no loss of phosphorus over a wide range of temperature-time protocols even when SO_3 fumes were allowed to escape.* In fact, they found that with a temperature of 210-220 degrees Centigrade, fuming could take place for 55 minutes with considerable evaporation of H_2SO_4 and with no loss of phosphorus. Of interest, is the result when the previous protocol was extended 5 minutes, to the point where the H_2SO_4 was completely evaporated. In this extreme case, 30% of the phosphorus was lost, and *the only case where there was a measurable loss of phosphorus outside the range of experimental error.*

Titus and Meloche drew the conclusion, from these and other data that temperature-time protocols can be selected such that oxidation can take place with no loss of phosphorus even though SO_3 fumes are allowed to escape. A review of all of the Titus data indicates that it is unlikely that there was a significant loss of phosphorus with the oxidation procedures used to develop the B&J data. Given their sensitivity to the issue, it is more than likely that the lab analysts heeded the charge to take evaporation *just* to the point of fuming. *Most likely, this procedure would have reduced volatilization errors to relatively negligible proportions while tending to maximize the errors related to excess H_2SO_4.* With no evidence to the contrary, there appears to be little else that can be said about volatilization errors. Nevertheless, it would seem that comparative tests would have been done to determine whether the procedure recommended by Titus and Meloche would render larger values of TP than the original and modified procedures.

Other Sources of Error – The DFACC method of determining TP was quite complex and required great care in its execution. Potential sources of error seemed to be everywhere. Though by no means exhaustive, there follows a list of potential sources of error that are not covered in the above. Included among these, is the one that proved to be the most vexing of all – the possibility of external sources of color contamination.

Color Comparison Errors – These "errors" came about when the lab analysts made judgement calls when comparing the intensity of the treated oxidized water sample with prepared standards in colorimetric TP concentration determinations. Such calls tend to be skewed by suspended material, lighting conditions, and operator variability. There is abundant evidence in the cited references [3-6] for a procedure using standard increments adequate to the determination of TP concentrations with a resolution (precision) of 1ppb.

B&J data, covering up to 25 lakes in northeastern Wisconsin in 1926 and 1927 is tabulated in two of the cited references [3,6]. Of significance is the fact that the data is presented at different depths. It was the hope of Birge and Juday that the gathering of this data would confirm a theory (Atkins) involving the relationship between SP and phytoplankton. Though they were not able to confirm the theory, their data trail provides strong evidence in the area of lab analyst judgement calls on data runs. These runs correspond to a sequence of samples taken at various depths, in the same place, on the same day, and on the same lake. This is just the type of data required to gauge the resolution capability presumed by the lab analysts of that era. When examining sequential differences in the data set corresponding to each run, one sees a fairly even distribution of differences of 1 ppb, 2 ppb, and so forth. This strongly corroborates a conjecture that the lab analysts presumed to color match to within +/- 1 ppb of TP concentration. This would imply, but not prove, that they had the capability to do just that. Although documentation on the procedure for colorimetric comparison of samples and the color reference standards has not been found, a discussion of how this could have been done, and the likelihood of associated errors, is provided in End Note 4.

Of further interest is an observation indicating very strong autocorrelation of the above B&J data with digit shifts of 5 ppb. Major spikes occur at 15 ppb, 20 ppb, and 30 ppb. Additionally, low values were observed for +/- 1-ppb shifts about these spikes. Simply put, the data indicates "piling-on" at these spike values at the expense of the adjacent values, as for example, 19 ppb and 21 ppb in the case of a 20 ppb reading. Calculations indicate that averaging the data over the three data bins can smooth the distribution, and would be recommended in applications of B&J data involving comparative data ranges.

Lab Related Errors – This broad category of error sources covers deviations from strict adherence to protocols such as the use of altered color comparison standards that could have come about in the preparation, storage, and handling of standard solutions as well as the molybdate reagent. For example, the intensity of the blue color rendered by the method was time sensitive, fading at about 1%/hour over a period of 25 hours [3]. This could have led to readings that were greater or lesser than they should have been. Additionally, overexposure of the molybdate reagent to light would have altered the chemical composition of this reference color-producing reagent, and so alter the test results, as would excessive temperature differences between the treated standards and samples; see End Note 3. It is most likely that measurement errors involving these types of error sources were minimal. The nature of the project demanded state-of-the-art laboratory equipment and well disciplined laboratory practice, It especially required strict adherence to their well-documented test protocols. Though lacking the benefit of today's ISO-9000 and Environmental Sciences standards [12}, there is every evidence of conscientious and dedicated workmanship that may have provided a level of quality exceeding that of some modern-day commercial labs. Furthermore, this was a high profile project headed by the past president of the university. Although some of the above borders on pure speculation, Kemmerer and Meloche were premier analytic chemists, and their laboratories did have a reputation for excellent work.

Color Interference Errors – These errors involve the introduction of potential color "contaminants" that can either present the characteristic blue-color reaction in this procedure or interfere with color comparisons by adding color(s) of their own. This type of error could have been introduced via both internal and external mechanisms. For example, silica leaching [3] from solution and reagent containers would be internal, while dissolved organic carbon or silica contained in silted lake water samples would be representative of an external type of interference. With respect to the interference caused by the contaminants, we can state the following:

1. Internal contamination was likely negligible for the reasons given above. The testing did require a clean laboratory, but not the ultimate in clean-room standards. Most importantly, it required precautionary measures so to avoid the introduction of color contaminants – of this they were well aware, and were likely able to keep this source of interference to negligible levels.

2. External contamination by blue color rendering agents was certainly possible, however, there is no evidence that any such contaminants were present in the lakes of the Northern Highlands at the time when Birge and Juday were taking water samples. Since the DFACC method was susceptible to this type of interference, it is difficult to make a definite statement or draw a clear conclusion. Put another way, one would have the difficult task of "proving a negative." Likely, there may be some that will always consider the DFACC method's susceptibility to extraneous color contamination to be the Achilles heel of the method, and how could anyone really blame them? Unfortunately, such skepticism has cast a cloud of doubt over the trustworthiness of B&J TP data. This may already have led to the dismissal of this data as inconclusive, or worse yet, unusable. Such a dismissal would amount to a tragic loss of precious historical data. Therefore, consider the following.

   Juday [3] reported that none of the lake waters contained enough silica, *"49 mg per liter or more,"* to interfere with phosphorus determinations as the maximum found in the lakes was 16 mg per liter. An undated laboratory notebook covering the determination of phosphorus contained the following statement: *"So far we have found no inland lake in Northern Wisconsin which contained more than 35.2 parts per million, most of them being much lower."* From the same notebook, we learn that the analysts were also concerned about colored lake-water samples. It was their practice to match the standard to the sample before treating it with the molybdate reagent. This was *"done with Bismark brown, since most of the colored water has a brownish tinge."* All of this tells us that these early workers were alert to the susceptibility of the method to color contaminants and, were "on-guard" so to speak. Therefore, it would seem unlikely that anomalous measurements of this sort would have escaped the watchful eyes of the Birge & Juday team, particularly the lead chemists, Kemmerer and Meloche. Furthermore, although the DFACC method was susceptible to color contaminants in the B & J water samples, that does not mean that there was a high risk involved. In the field of electronic countermeasures, one would say that although the system was susceptible, it might very well have not been vulnerable to the threat.

   To reduce concern, one would have to show evidence that this type of interference was not present on the lake(s) to which the B & J data is to be applied. Consideration need also be given to naturally brown-colored, or otherwise "stained," lake waters to gauge possible interference effects. Similarly, the possibility of high (> 50 mg/l) ferric iron content that could have led to a loss of orthophosphate via precipitation needs to be considered [12]. Sediment core analysis can also be used as a tool to probe further to determine the likelihood of external interference in specific applications of B&J data. Garrison [10] has performed preliminary sediment core analyses on Irving Lake, and has already begun to work with this in mind, personal communication, January 24, 2001. Quite possibly, this information may already exist in other forms. Cross correlation with B&J Secchi disc data as well as anecdotal "evidence" could also be used in this regard as was done on our recent study [1], so too could information from the Lake Landscape Position Project and other components of the UW-M/TLS Long Term Ecological Research Project, c.f. Riera [11].

   Notwithstanding the weight of the foregoing "arguments," we may never know the possible impact of this type of interference with absolute certainty. In view of this uncertainty, these "pathological" types of interference will be considered as the source of indeterminate random errors. These can then be grouped with other such errors, all of which can be covered by a probability distribution that characterizes the degree of uncertainty of the mix.

BIRGE & JUDAY DATA RELIABILITY

Based on all of the above, we can summarize with the following statements about the reliability of the B&J data for applications on lakes where B&J TP measurements indicated concentrations less than about

50 ppb and where the lake water was not stained or very high in iron content. As previously mentioned, the great majority of the lakes tested by Birge and Juday fall well inside the TP concentration bounds.

1. Process related errors due to phosphorus volatilization and over acidification, in combination, appear to require no more than a 1-ppb downward bias adjustment of the B&J data. A convenient representation of this process error is by a normal distribution with – 1-ppb mean and a standard deviation, "sigma," of 0.333 ppb (3-sigma = 1 ppb).

2. Color comparison errors can also be described by a normal distribution with a zero mean and a sigma of 0.723 ppb; see End Note 4. This renders an uncertainty band of +/- 1.2 ppb (+/- 1.65 sigma) surrounding reported B&J TP measurements for 95% confidence that the "correct" measure falls inside this band.

All other errors can be aggregated as a group and represented by a "catch-all" random variable that characterizes the degree of uncertainty represented by the mix of its constituent variables. This variable can be represented by a normal distribution with a zero mean and sigma of N ppb. Since these error contributions are independent of one another, we can express the band of uncertainty surrounding B&J TP data by a normal distribution having a mean of – 1 ppb (attributable to the process bias discussed above) and a sigma given by the square-root of the sum of the squares of the individual distribution sigmas, i.e., $(N^2 + 0.634)^{1/2}$ ppb. If we designate the B&J TP measure as $TP_{B\&J}$ and the correct measure as TP, then with a probability of 0.95, TP will fall within the uncertainty band defined by,

$$[TP_{B\&J} - 1 + 1.65\,(N^2 + 0.634)^{1/2}]\ \text{ppb} \ \geq\ TP \ \geq\ [TP_{B\&J} - 1 - 1.65\,(N^2 + 0.634)^{1/2}]\ \text{ppb}$$

In general, the uncertainty bandwidth, BW, is given by,

$$BW = 3.3(N^2 + 0.634)^{1/2}\ \text{ppb; 95 \% confidence}$$

Given the stated assumptions and limitations, this means that the correct value of TP will fall within a band of this width centered on ($TP_{B\&J}$ - 1)with a probability of 0.95. Again, N is the standard deviation of the normal variate we selected to characterize vagaries associated with error mechanisms that are statistically indeterminate in form. These mechanisms can produce errors that range from more than likely negligible errors to the highly unlikely large errors associated with undetected pathological-interference phenomena. Conceptually, the possibility of such errors, however remote, can be thought of as being represented by the probability of error associated with $TP_{B\&J}$ values that fall outside the uncertainty band.

In the end, the choice of the uncertainty bandwidth will reflect the confidence of the users in the arguments presented herein, as well as their personal confidence in the work done so long ago. Nevertheless, from a practical point of view, it would appear reasonable to consider an uncertainty bandwidth of 6 ppb (N = 1.63 ppb, 1.65 N = 2.7 ppb). This bandwidth would provide a +/- 2.7-ppb margin for other random process errors. In-lake sample variations, sample splitting (if done), and analyst (operator) variability are representative contributors to this error pool, Katherine Webster, personal communication, February 8, 2001. Based on estimates of the variability associated with each of these contributors, the +/- 2.7-ppb margin should be able to accommodate the root-mean-square sigma of the aggregate.

A more conservative approach would involve an uncertainty bandwidth greater than 6 ppb. However, when selecting an uncertainty bandwidth in this regard, consideration need be given to the range of applicability of these relationships ($TP_{B\&J}$ < 50 ppb), and that the great majority of B&J TP data ranged from 15 ppb to 30 ppb. Further grounding, when consideration is given to a BW > 6 ppb, stems from the fact that a BW of 6 ppb already represents 20% of the 30-ppb high-end measurement and 40% of a 15-ppb low-end measurement The point is that *unjustifiable conservatism can substantially reduce the value of B&J data even in applications where it is eminently well suited.*

In addition to its merit as a very close approximation, selection of a 6-ppb uncertainty bandwidth provides a sense of definiteness in the sometimes-confusing world of statistics. It would also provide the following easy-to-use guideline for the application of B&J TP data: Subtract 1 ppb from the B&J measurement and then, with 95% confidence, consider the result accurate to within +/- 3 ppb. Additionally, given a 6-ppb BW and the 1-ppb bias adjustment, it can be shown that the maximum % absolute error (100 x 3 ppb/$TP_{B\&J}$) averaged over a $TP_{B\&J}$ range of 15 ppb to 30 ppb is about 14 % with 95% confidence. Similarly, the average % absolute error (100 x 1.5 ppb/ $TP_{B\&J}$) averaged over the same $TP_{B\&J}$ range can be shown to be about 7% with 95% confidence. These are to be compared to modern day automated methods that can provide 6% to 10 % accuracy with 99% confidence over a much wider range of concentrations, George Bowman, personal communications, February 2001.

CONCLUSIONS

The evidence found in the cited references indicates that the concerns of the Birge and Juday team about excess acidity and volatilization during the oxidation procedure, though well founded, did not appear to materialize as significant errors in their TP measurements. The investigative work of their analytical chemists was essential to unraveling this piece of the story associated with these limnology pioneers. The experimental data related to this work provided the key evidence in the case.

The offset and the uncertainty band surrounding the Birge and Juday TP data points clearly shows that the Birge & Juday team was not perfect. However, considering the tightness of the band and the relatively minor 1-ppb offset, one must conclude that they did excellent work, within 20% measurement accuracy compared to modern day methods of 6% to 10% accuracy. Given proper attention to applicability considerations, Birge and Juday TP data should be accurate to +/- 3 ppb with 95% confidence after accounting for the 1-ppb bias.

We may never know the possible impact of color contaminating interference with absolute certainty. In view of this uncertainty, these pathological-interference types need to be considered as the source of indeterminate random errors described by a probability distribution. The probability distribution should enable characterization of the degree of uncertainty associated with these statistically random phenomena. Future work, along avenues suggested herein, may reveal answers to the vexing questions surrounding this issue. In no significant way does any of this detract from the comparative studies of Birge and Juday.

Perhaps, in retrospect, it was the lead micro-analytical chemists, Kemmerer and Meloche, and their seeming over-concern with the water-sample oxidation process, and the possible loss of phosphorus that kept them so focused on this subject – to the extent that they directed the work that left, what later proved to be, a critical data trail. Ultimately, it was their attention to detail, and their pursuit of ever-improved analytical methods, that revealed this story – a story about the high overall quality and the present value of the study of the phosphorus content of the lake waters in the Highland Lake District of Wisconsin.

Frank G. Splitt
February 13, 2001

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END NOTES

Note 1: The Standard Phosphate Solution – The standard for comparison in the DFACC method was prepared by dissolving a precisely weighed amount (4.394 grams) of anhydrous potassium di-hydrogen phosphate, KH_2PO_4, which was air dried over sulfuric acid, in phosphorus-free water, to render a one-liter solution. This one-liter solution was "designed" to contain one gram of phosphorus or 1 milligram of phosphorus per cubic centimeter. Subsequent dilutions produced the known *phosphorus* concentration standards for color comparisons.

Note 2: Phosphorus vs. Phosphate Concentrations – The word phosphorus was italicized in End Note 1 to emphasize the point that color comparisons were based on phosphorus concentrations and not on phosphate-phosphorus, PO_4, concentrations. Apparently, there has been some misunderstanding associated with terminology in this area. Most likely, a good deal of this misunderstanding is attributable to the use of the term, phosphate phosphorus in the early literature. Misunderstandings of this type may have added to a lack of confidence in the results obtained from comparisons of Birge & Juday data with those obtained by present-day methods. It is also of interest to note that Lathrop [9] has reported that the method along with others, including a variant *"that was eventually recognized as a "standard method,"... all produced results within a range of +/- 0.01 mg P/L* (10 ppb) *to results obtained from current procedures for DRP* (dissolved reactive phosphorus) *concentrations of 0.004 – 0.16 mg P/L* (4 ppb – 160 ppb)."

Note 3: The Molybdate Reagent and Phosphorus Determination – This reagent is the essential element of the DFACC method. The reagent was prepared by dissolving 10 grams of ammonium molybdate in 100 cubic centimeters of distilled water and then adding this "molybdate solution" to 300 cubic centimeters of cold sulfuric acid (50% by volume). The molybdate reagent so formed was sensitive to light and it was expected that it be stored in the dark when not in use. Since the molybdate solution was not sensitive to light before it was added to the sulfuric acid it was suggested that the two solutions be kept separate and mixed only before using. The phosphorus determination was made by measuring 100 cc of the water to be tested into a graduated colorimeter or into a Nessler tube along with 2 cc of the molybdate reagent and 3 or 4 drops of a stannous chloride solution. The stannous chloride solution was made by dissolving 1 gram of tin in 20 cc of concentrated hydrochloric acid by warming and adding 2 or 3 drops of a 5% solution of copper sulfate. When the tin was dissolved, the solution was diluted to 100 cc with distilled water and a piece of tin added. According to George Bowman (personal communication), *"the Stannous Chloride method was prone to some timing and temperature problems. For example, the color measurement had to be made between 10-12 minutes after adding the reagents. The temperature of the standard and the sample had to be held to within 2 degrees centigrade during the color reaction process. Failure to do so would have resulted in a 1% error per degree difference."*

Note 4: Color-Comparator Errors – Although it is difficult to reconstruct exactly how the lab analysts set-up and used the colorimeter or color-comparator in the DFACC method, we do have some clues. First, we need to keep in mind that most of their measurements were confined to a TP range of from 15 ppb to 30 ppb, and second, that the preparation of these standards was a very labor-intensive job. No doubt, every effort was made to eliminate unnecessary steps in an already complicated procedure. Based on this, and the reported data, it appears likely that their standard operating procedure would have called for the preparation color standards *after* the color was rendered from the sample(s) via the molybdate reagent. By virtue of their accumulated experience, this would have allowed them to "center" the color references on a good estimate of the concentration range. The conjecture is that they prepared 8-10 color standards of 2-ppb bandwidth. These would have been centered on even-integer values of TP concentration (1000 x mg/l in their units of measure). In view of the data, most of the reference color sets would have started at 16 ppb and run up to 30 ppb. This could be an explanation for the pile-on effect at 15, 20, and 30 ppb in the sequential data runs, and not at 25 ppb which sits at a band edge. The 16-ppb "standard" would likely have had an extended reach to pick up concentrations even a bit less than 14 ppb and then "called" 15 ppb.

To determine the likelihood of errors associated with the above procedure, we first assume that each 2 ppb band is divided into 3 parts...a mid-band of 1-ppb width, and side-bands of 0.5 ppb each. The adjacent bands would, of course, supply the additional 0.5-ppb bandwidth so that all of the integer values for concentration levels would be covered by a 1-ppb window. We now inquire as to the probability of making a decision error given that the sample color falls somewhere in the mid-band range, say 20 ppb for the sake of discussion. Ideally, the correct decision would be 20 ppb no matter where the sample color falls in the 19.5 to 20.5 ppb mid-band. However, a correct decision does depend on where the sample color falls in the mid-band. An incorrect decision could be made, especially near band edges – 19 ppb for a low-end mid-band color and 21 ppb for a high-end mid-band color. The probability of making a +/- 1-ppb error with this arrangement of standard concentrations requires knowledge of the error probability distribution function associated with the decision making process.

To obtain a representative distribution function, we first assume that the analysts were not likely to miscall a "perfect match," i.e., a sample that is centered at 20 ppb, and second, that a sample color that fell at the ends of the mid-band would have a 50% chance of being called in the adjacent side-band. Given these reasonable assumptions, we can choose a triangular probability distribution with a 1-ppb bandwidth as representative. If the entire mid-band range of sample positioning is considered, then there would be a 17% likelihood of a +/- 1-ppb error with this distribution. Put another way, the analysts would make the right call about 83% of the time. The advantage of the triangular distribution is that it allows for a straightforward calculation of the error probabilities. One of these is the probability that a mid-band color sample can cause an error greater than +/- 1 ppb. There is a zero probability of this occurring with this distribution. To account for this shortcoming, and to provide a mathematically convenient way of combining this and other error distributions, we substitute a normal distribution instead. The normal distribution requires a standard deviation, "sigma," of 0.723 ppb to match the 17% likelihood of a +/- 1ppb error of the triangular distribution. This distribution provides 95% confidence that the true TP falls inside a +/- 1.2-ppb (+/- 1.65 sigma) band centered on the "called" integer value for the TP concentration level.

Through the ages, every generation of humankind thinks of its own era as the time when things are really "done right." A good part of this perception is an insistence on our own significance and the work of our time. Sometimes, lost on the way is the significance and merit of the work of those that have gone before us. We simply do not take the time to understand and appreciate the real value of the work done by our predecessors, and, more importantly, the process by which we truly come to wisdom.

BIRGE, JUDAY, AND THE TROUT LAKE STATION

Edward A Birge was the first Dean of the College of Letters and Science at the University of Wisconsin, serving from 1891 to 1918, and President of the University from 1918 to 1925. Birge and Chancey Juday are two of the founders of limnology – the study of inland waters – as an ecosystem science. Building on their earlier comparative approach to lake studies in southern Wisconsin, Birge and Juday worked to establish the University of Wisconsin's Trout Lake Station (TLS) as a warm-season field facility in 1925. Birge remained active through the 1930s when he was in his 80s. Primarily under the direction of Juday, a crew of scientists with diverse research interests staffed the station through 1941. During this time they compiled extensive information on lakes throughout the Northern Highland Region...three of these lakes comprise a shallow lake ecosystem... the Ballard-Irving-White Birch Chain-of-Lakes.

TLS has a long and internationally recognized history of research in limnology and ecology. Their work in the 1950s and 1960s is generally recognized as an essential stage in the development of the field of whole- ecosystem experimentation. Work in this field has provided critical insights into anthropogenic stress, and has substantially advanced the understanding of how ecosystems function. Today, TLS is focused on Long Term Ecological Research (LTER) sponsored by the National Science Foundation. White Birch Lake was one of a number of lakes studied on the LTER Lake Landscape Position Project: Contrasting Geographic Characteristics and Water Chemistry as Determinants of Biodiversity and Biotic Community Structure. Applicable material from this study was provided by TLS for incorporation into the Ballard-Irving-White Birch Lakes Association's Final Report on Wisconsin Lake Management Planning Grant Projects LPL 602 and 613.

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