# Executive Summary

Lake Hallie is an oxbow lake of the Chippewa River located about 500 feet from that river approximately midway between Eau Claire and Chippewa Falls. It has an area of 79.9 acres, a maximum depth of 13 feet, and a shoreline of 2.9 miles. About one-half of the shoreline is natural and wooded mainly because of steep hillsides and wetland areas. About one-half mile is heavily developed and another half-mile lies alongside an 18-hole golf course.

The lake was originally dammed and used as a log holding area for the Blue Mills sawmill that was constructed in 1843 at the southwest corner of the lake. The dammed water source was a series of groundwater seeps, particularly in the northeast corner of the lake. The mill closed in the 1890's, and in the early 1900's, lake usage turned to recreation and fishing, which use continues to the present day.

In February 1998, the Lake Hallie Lake Association was formed to monitor and protect the quality of this recreational resource. In the fall of 2002, this association obtained a lake planning grant from the DNR to collect and analyze information about the lake for the purpose of developing a comprehensive lake management plan. Subsequently, the association entered into an agreement with the Chippewa County Land Conservation Committee, under the terms of which the Land Conservation Department (LCD) would compile specific information necessary to developing a lake management plan.

Included in this information is an overview of the history and physiographic setting of Lake Hallie (including a series of maps), a compendium of historic water quality data, detailed DNR plant and fish management studies, a summary of management recommendations, and an information and education plan to support lake management efforts.

In March 2003, a survey of residents of the watershed was conducted to obtain feedback on management recommendations made by the DNR and Village of Lake Hallie on plant, fish, and water quality issues specific to Lake Hallie. Response rate was 36%. Results show strong support for all recommendations, except increasing the shoreline buffer zone from 35 to 50 feet and lukewarm support for a size and bag limit on northern pike (more than 1/3 not sure).

Plant management strategies call for continuation of mechanical harvesting during the early season, harvesting channels in dense plant beds in mid and late summer, and developing a budget for operation of the plant harvester.

Fish management strategies include maintaining the current regulations on panfish and largemouth bass, improving winter oxygen conditions, dredging the groundwater discharge area, and monitoring the impact of these activities on the fishery.

Water quality management strategies stress the implementation of best management practices in the riparian zone and further study to determine the causes of variable groundwater flow and impacts of the culvert discharge at the northeast corner of the lake.

**Management Recommendations from The Aquatic Plant Community of Lake Hallie (1991-2001)**
(Dec. 2002)

1. Preserve and expand the natural buffer zones of native vegetation around the lake shoreline. Replace mowed lawn at the shoreline with a buffer of natural, non-mowed vegetation at least 50 feet deep.

2. Cooperate with programs to manage run-off and erosion in the watershed.

3. Develop an aquatic plant management plan. Include mechanisms for modifications as the plant community changes.

4. Develop a lake association budget that will provide funds for repair and maintenance of the plant harvester and pay harvester operators.

5. Continue the mechanical harvesting program during the early season to remove curly-leaf pondweed biomass from the lake before the early summer die-off and nutrient release.

6. Harvest channels in dense plant beds in mid and late summer to improve habitat and boat access and reduce amount of vegetation decomposing in the winter under the ice. Avoid harvesting in areas with valuable habitat plants.

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Konkel, Deborah, 2002. The Aquatic Plant Community of Lake Hallie 1991-2001. Wisconsin Department of Natural Resources. 32pp.

# Conclusions and Management Recommendations from The Status and Management of Fish Populations in Lake Hallie

(Jan. 2003)

*1).Discontinue the stocking of rainbow trout beginning in 2002.*

The illegal introduction and expansion of a northern pike population in Lake Hallie has resulted in a major decline in a stocked, rainbow trout fishery. The return of trout to the angler's creel has declined dramatically even within the first month after stocking. A winter fishery for trout, which existed up to the early 1990s, has been eliminated and replaced with a very popular northern pike fishery. Northern pike removal to continue a trout fishery would be costly. In addition, high summer water temperatures and periodic, low winter oxygen levels may no longer favor trout stocking. It is recommended that trout stocking be discontinued in 2002.

*2) Consider a size limit and a reduced bag limit on northern pike.*

The interest in northern pike fishing, specifically during winter, has grown with the notoriety Lake Hallie has received for producing large fish. Without the presence of trout, the fast growth rates of northern pike will undoubtedly slow to average or possibly below average rates. In addition, efforts to improve winter oxygen levels will produce better fishing action with an expected increase in northern pike harvest. A county resolution at the 1998 spring rules hearing recommended that there should be no size limit on northern pike because of their predation on trout. This is no longer applicable with the curtailment of trout stocking In order to maintain a quality northern pike fishery, it may be prudent to control harvest by enacting a minimum size limit and/or reduce the daily bag limit. With the current set of regulations available for use with northern pike, the 26" minimum size limit with a daily bag limit of 2 is the most appropriate regulation to consider. It is recommended that a local resolution be proposed at the spring rules hearing to determine the interest by local anglers for a change in northern pike regulations.

*3). Maintain the current regulations on largemouth bass*

A county resolution passed at the 1998 spring rules hearing proposed a reduction of the largemouth bass daily bag limit of five to two. The justification for this proposal was that most legal-size bass ($\geq$14") were being harvested during the first few weeks of the fishing season. The 2001 survey shows a very high density of legal-size bass in the lake. The minimum size limit apparently has done much to improve bass size structure, however, dense aquatic vegetation restricts the angler's ability to catch bass during much of the open-water season. It is recommended that the current bass regulations remain, and that bass populations be monitored to determine what impact mechanical harvesting of aquatic plants may have on angler harvest.

*4). Maintain the current regulations on panfish*

A county resolution passed at the 1998 spring rules hearing proposed a reduction in the daily, aggregate bag limit of panfish from 25 to 15. Bluegill is the dominant panfish in the lake. Their dense population currently has a good size structure. Current and proposed lake management practices could indirectly affect density and size structure through increased predation and/or angler harvest. It is recommended that daily bag limits on panfish remain at 25/day. However, future studies should be conducted to determine what impacts mechanical harvesting and improved winter oxygen levels have on panfish size structure, in particular bluegills. If increased angler harvest reduces the quality of the size structure, then a reduced bag limit should be considered.

*5). Continue the mechanical harvesting program of submerged aquatic plants.*

The mechanical harvesting program was designed to control curly-leafed pondweed (*P. crispus*) populations and to improve fish habitat and angling opportunities. Reducing plant growth also may lower winter oxygen demand. It is recommended that mechanical harvesting of aquatic plants be continued, however, the current harvesting plan should be reevaluated to determine its effectiveness in reaching the above objectives. Additional areas of dense vegetation may need to be included to further improve fish habitat

6). *Improve winter oxygen conditions in the lake*

Despite the low, winter oxygen conditions experienced during the winters of 1999-2000 and 2000-2001, fish populations are in relatively good shape. However, if this winter oxygen condition persists, fish populations may begin to suffer. The northeast corner of the lake provides a winter oxygen refuge. However, concentrating fish into a smaller area increases the stress level of individuals. This may lead to post-winter fish kills due to bacterial or viral infections. The temporary aeration system used in early 2001 did an excellent job of providing dissolved oxygen levels above the water quality standard. Anglers found greatly improved action on fish once this system was in place. The winter of 2001-2002 was a mild winter, and low oxygen levels were not experienced. A 4-inch stoplog was removed from the bottom draw structure to aid in the removal of oxygen-poor water from the bottom. However, because of the mild winter, it is unknown how much, if any, this practice aided in providing higher oxygen levels. Prior to the winter of 2002-2003, two stoplogs were removed (10") from the bottom draw structure. It is recommended that winter oxygen levels continue to be monitored to determine if this practice aids in maintaining higher oxygen levels. If this practice does not maintain adequate oxygen levels, then a permanent aeration system should be installed.

7). *Consider dredging of the groundwater discharge area*

The groundwater discharge area in the northeast end of the lake once provided a large area of open water during winter. Discharge measurements at the dam have not changed appreciably from 1963 to 1996. But, despite similar outlet flows, the open water area has decreased considerably in size over the past 10 years indicating a change in the thermal regime for this area during winter. Because of dense plant growth, water depths in this area have decreased due to the deposition of decomposing plant matter. It is unknown if the location of groundwater inputs to the lake have changed and if increased sediments in this area impact the ability of groundwater to effectively flow into this lake area. This area provided a source of oxygen to the lake during winter via open water. It also provided coolwater habitat for fish during summer. Consideration should be given to dredging the northeast corner of the lake to improve winter and summer habitat conditions for fish.

8). *Monitor the impact of lake and fish management activities*

Lake Hallie is undergoing some major management activities including, mechanical harvesting of plants, efforts to improve winter oxygen conditions, and the curtailment of rainbow trout stocking. These activities have the potential of impacting fish populations, in particular largemouth bass, bluegill and northern pike. The results of this survey will act as a baseline of information for these management activities. It is recommended that future surveys be conducted to evaluate the impacts of management activities on the size structure of bass, bluegill and northern pike, bass recruitment, angler harvest, and the growth rates of bass, bluegills and northern pike. An evaluation should occur no sooner than five years after implementation of a new management activity.

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**Management Recommendations from Town of Hallie Water Quality Management Planning Project**
(July 1997)

1. Best management practices should be implemented to protect and improve water quality in Lake Hallie, particularly in the following critical areas that have the potential to contribute the most pollutants associated with stormwater runoff:
   Hallie Golf Course (pesticide and nutrient runoff)
   Residential neighborhood adjacent to Lake Hallie (possible septic system leaching from drainfields into the lake, as well as other pollutants).

2. Nuisance plant growth should be controlled through reducing nutrient inputs and harvesting rooted aquatic plants.

3. The impact of the stormwater discharge near the northeast end of the lake, both existing and future, should be further evaluated.

4. Encourage Lake Hallie residents to form a Lake Association, converting the existing Lake Hallie Dam Committee to a Lake Association.

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Ayres Associates, 1997. Town of Hallie Water Quality Management Planning Project.
Project No. 11-0351.00

**Management Recommendations from Lower Chippewa River Basin Water Quality Management Plan**
(May 1996)

1. Bureau of Water Resources Management (WRM) staff should find a self-help lakes monitoring volunteer for Lake Hallie.

2. WRM should consider Lake Hallie a high priority for receiving a lake planning grant.

3. WRM should consider Lake Hallie a high priority for receiving a lake protection grant.

4. Water Regulation and Zoning and WRM should assist local land use decision makers and riparian residents in developing and implementing land use management programs that protect the water quality of Lake Hallie.

5. WRM should assist local lake management interest groups in organizing and/or working to improve and protect the water quality of Lake Hallie.

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Koperski, C., LaLiberte, P., Sorge, B., Larson, N., Ryan, D., and C. Roesler, 1996. Lower Chippewa River Basin Water Quality Management Plan. Wisconsin Department of Natural Resources. PUBL-WR-216-96-REV

## Management Recommendations from Nonpoint Source Control Plan for the Duncan Creek Priority Watershed Project
(Sept. 1995)

1. Develop and implement a construction site erosion control ordinance for construction sites not currently regulated.

2. Develop and implement a stormwater management plan.

3. Include an I and E component in the stormwater management plan.

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Simonson, D., Tetzloff-Jensen, J., and L. Hess., 1995. Nonpoint Source Control Plan for the Duncan Creek Priority Watershed Project. Department of Natural Resources. Publication WR-427-95.

# Table of Contents

**Lake Data**

- DNR Water Chemistry Data for 1991, 2001, 7 2002
- DNR Dissolved Oxygen Data at Specific Sites for 1999 – 2003
- DNR Zone of Refuge Study – January 2001
- Self-Help Lake Monitoring Data collected by George Wanserski for 1995 – 2002
- Lake Hallie Piezometric Testing - 10/26/2002
- Lake Elevation Gauge Data Record Sheets

**Survey**

- Lake Hallie Watershed Community Opinion Survey
- Lake Hallie Watershed Community Opinion Survey Results
- Map of Parcels included in Lake Hallie Watershed
- List of Residents in Lake Hallie Watershed

# Geology and Physiography of Lake Hallie

The physical development of the Lake Hallie area occurred slowly over the course of the last few billion years. Evidence in rocks in the surrounding areas indicates that about three billion years ago during the Archean period of the Precambrian era, pressure from within the earth exploded, and molten mantle material was forced to the surface. This process was repeated many times as the earth heated, cooled, and again rebuilt new features, only to be redesigned by the forces of wind and water. In such a manner, the complex igneous and metamorphic bedrock of northern Wisconsin was formed through these processes of volcanism, erosion and sedimentation.

Examples of these Precambrian rocks can be found today in the Chippewa River at Jim Falls and at the Lake Wissota dam and along the Eau Claire River at Big Falls. These exposed rock layers formed collectively what is known as the "fall line." They made places such as Black River Falls, River Falls, and Chippewa Falls ideal sites for early saw and grist mills because of the easy availability of water power as rivers dropped over the hardened Precambrian rock.

More mountain building activity occurred about 2.4 billion years ago in the northern parts of our region when Flambeau Ridge and the Blue Hills of Barron and Rusk counties were formed during the Animikian period. By about 1.5 billion years ago, the mountains that had formed earlier had largely eroded away, leaving these latter two monadnock formations still in place. About this time, another change occurred in our area, when the earth entered the Keweenawan period, and the deposition and formation of sandstone began.

This was a cooling period, which lasted until about 500 million years ago, overlapping into the Paleozoic Era. During this period, Wisconsin was submerged, possibly four times, by great seas and oceans. Great sediments formed at the bottom of these oceans, burying the Precambrian landscape beneath as much as several thousand feet of sedimentary rocks. The earliest of these, the Mount Simon sandstone, forms the present day bedrock in the Lake Hallie area. It consists of poorly sorted fine-grained to very coarse grained sandstones that are generally poorly consolidated. A general color change occurs downward from white to yellowish gray to grayish red below. Outcroppings occur in numerous places in the area, including the east side of Duncan Creek in Irvine Park in Chippewa Falls, as well as at its namesake Mt. Simon in Eau Claire.

Beginning in the late Paleozoic Era, perhaps 250 million years ago, a period of gentle uplift occurred, and this has continued to the present day. During this time, the land surface was carved continuously by rain, wind, and running water.

Glaciation of the area occurred only recently in geologic time, during the Pleistocene epoch or "Ice Ages," which began about one million years ago. There were four separate glacial advances through Wisconsin, interspersed with interglacial periods when the ice receded. The last ended about ten thousand years ago, and the Chippewa lobe, ending just east and north of Bloomer, was its furthest southward advance in our county. As the Chippewa lobe retreated, meltwater streams flowing from its terminal moraine carried thick sediments of Copper Falls Formation outwash southward and then southwestward over the Lake Hallie area and into Eau Claire County.

Later, postglacial sediments were deposited along a sharp turn in the Chippewa River forming terraces, which eventually cut off a portion of the river to form the oxbow lake that today is known as Lake Hallie

# Lake Hallie Area


Digital orthophoto taken by USDA Natural Resources Conservation Service in 1998

1000 0 1000 2000

Feet

Chippewa County Land Conservation Dept

May 7, 2003

# Lake Hallie Area

Color photography taken by USDA Natural Resources Conservation Service in 2002

N

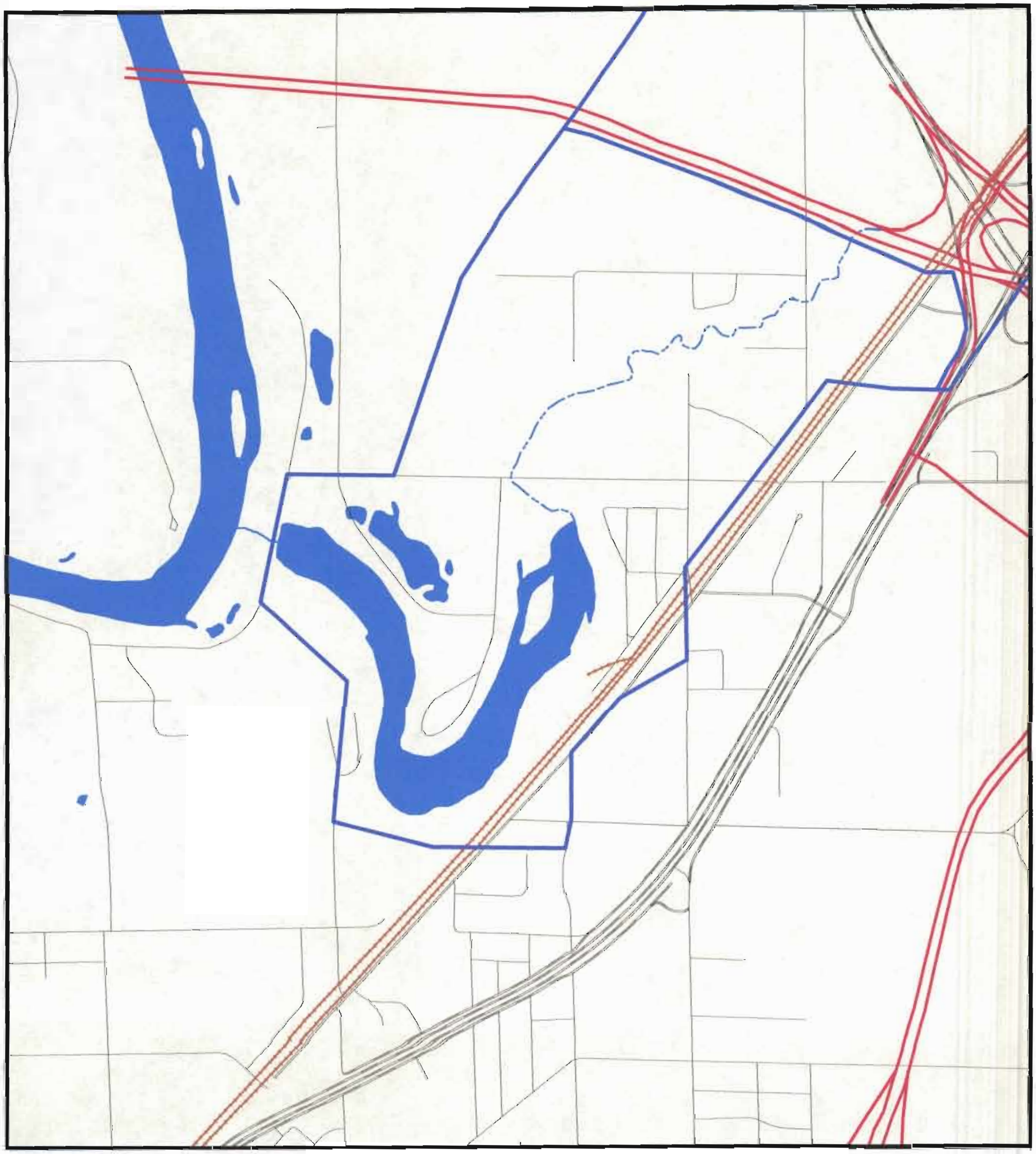
1000 0 1000 2000

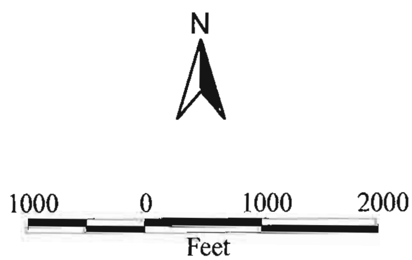
Feet

Chippewa County Land Conservation Dept.

June 10, 2003

# Lake Hallie Watershed



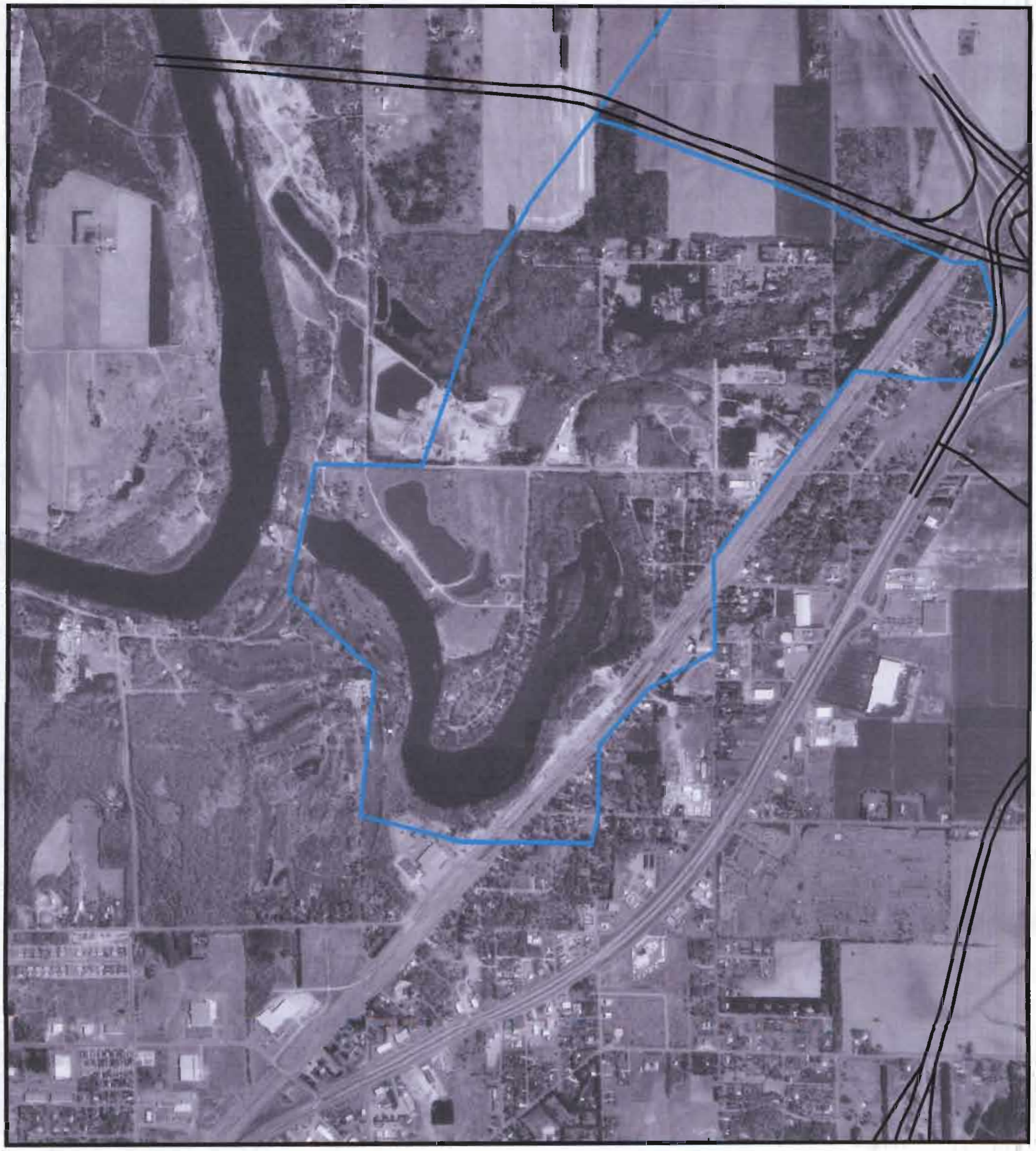



Watershed boundaries delineated by Ayres Associates in 1997 and modified by new road construction (shown in red).

Chippewa County
Land Conservation Dept.

May 7, 2003

# Lake Hallie Watershed



Digital orthophoto taken by USDA Natural Resources Conservation Service in 1998

Watershed boundaries delineated by Ayres Associates in 1997 and modified by new road construction.

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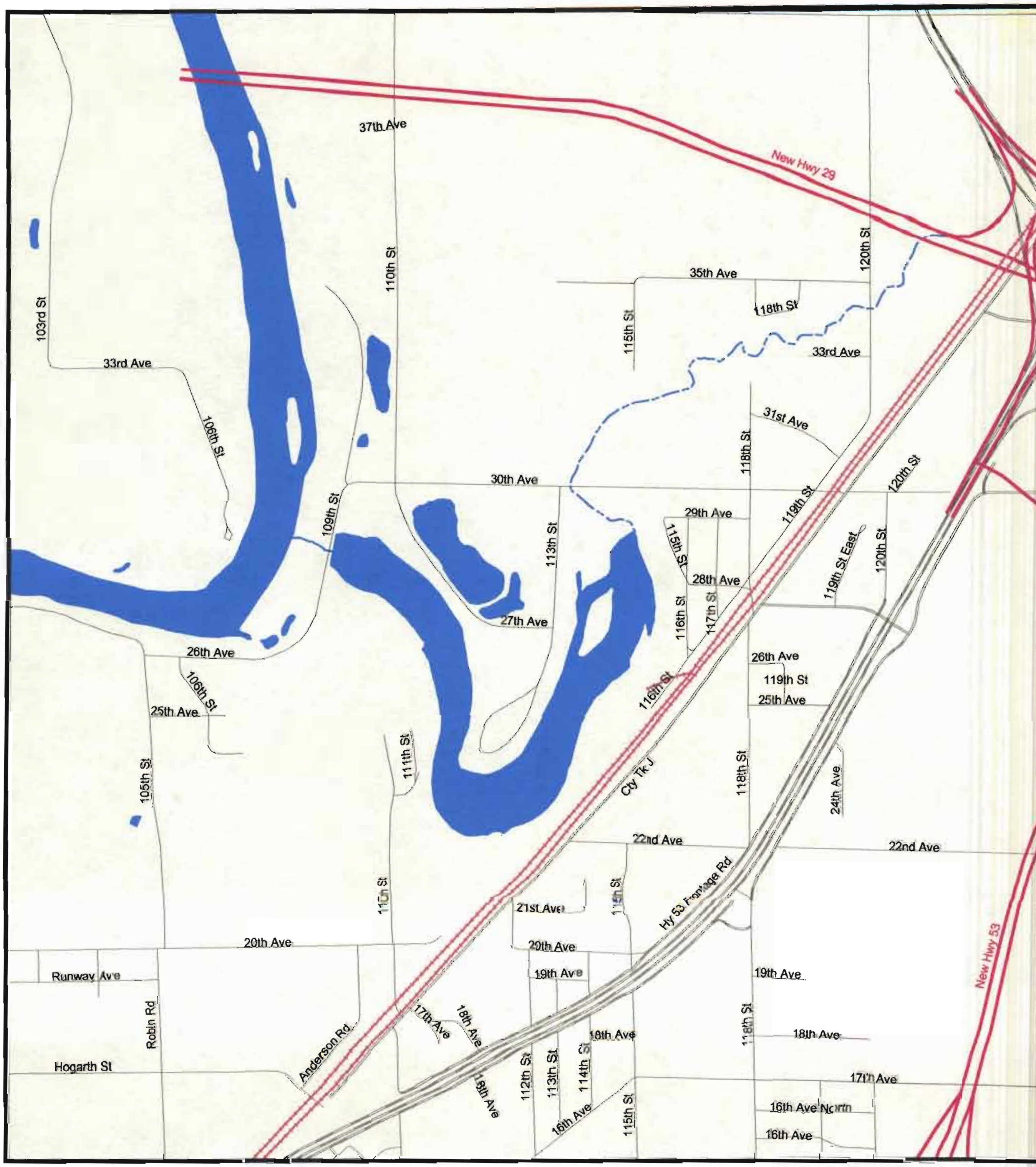
Feet

Chippewa County Land Conservation Dept.

May 7, 2003

# Lake Hallie Area Street Map

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Roads GPS'd and digitized by
Chippewa County Land Records
Department staff

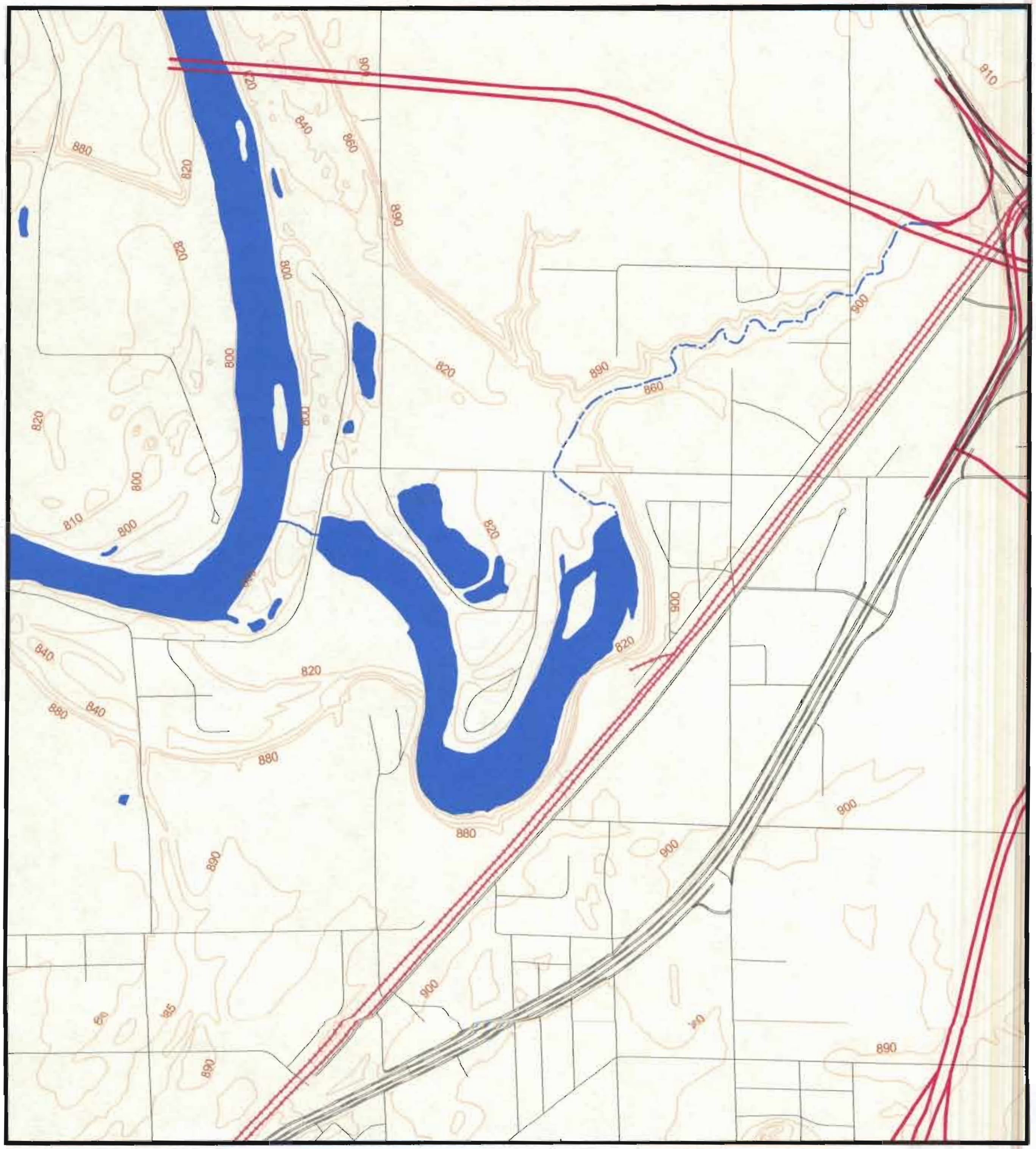
1000 0 1000 2000

Feet

Chippewa County
Land Conservation Dept

June 6, 2003

# Lake Hallie Area Surface Topography




Contour lines digitized from USGS 7.5" quadrangles.

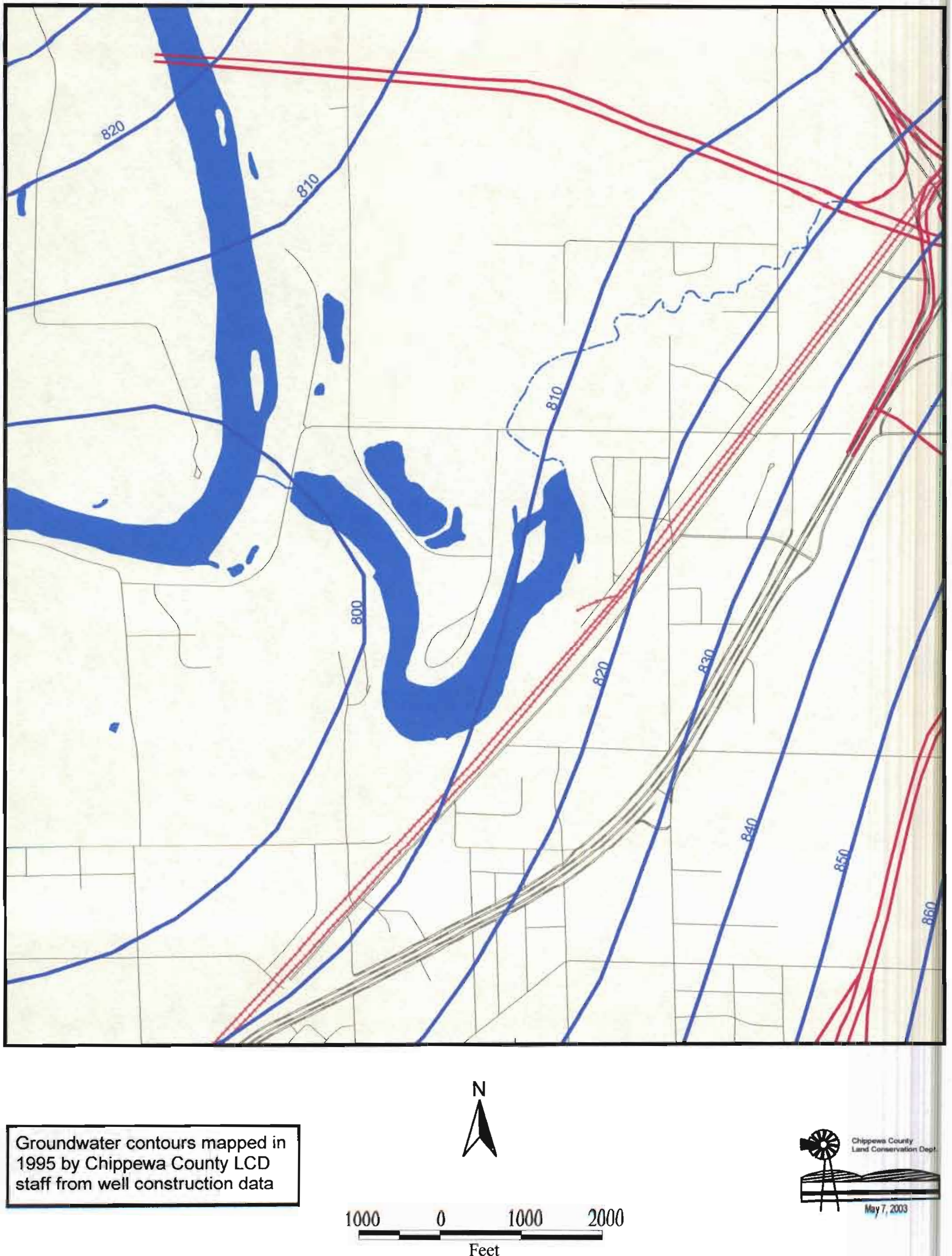
N

1000 0 1000 2000
Feet

Chippewa County
Land Conservation Dept.

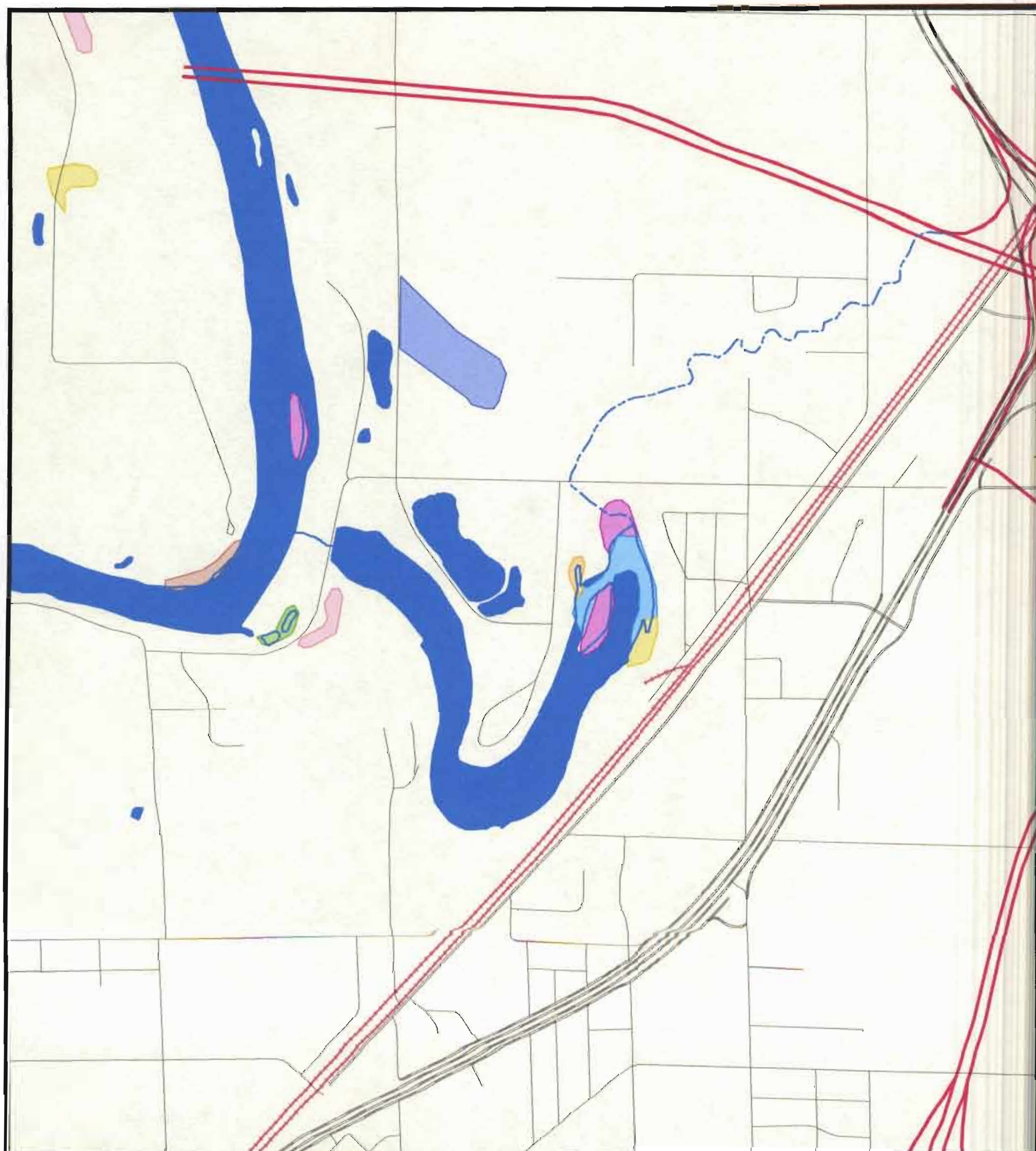
May 7, 2003

# Lake Hallie Area Groundwater Flow

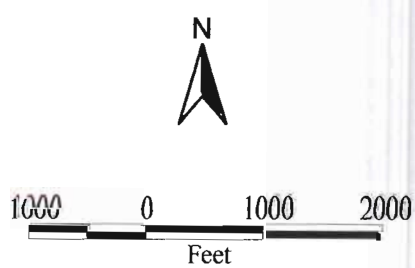



Groundwater contours mapped in 1995 by Chippewa County LCD staff from well construction data

# Lake Hallie Area Wetlands Vegetation



A4L -- Free floating, lake
E1/W0H -- Persistent emergent/wet meadow or open water
E2/W0Hx -- Narrow-leaved persistent emergent/wet meadow or open water
S3/E1K -- Broad-leaved deciduous shrub/Persistent emergent
S3K -- Broad-leaved deciduous scrub/shrub
T3/E2K -- Broad-leaved deciduous forested or Narrow-leaved persistent emergent/wet meadow
T3/S3K -- Broad-leaved deciduous forested or Broad-leaved deciduous scrub/shrub
T3K -- Broad-leaved deciduous forested, wet soil



From ***Wisconsin Wetland Inventory Classification Guide***, published by WiDNR, 1992
(Note: Vegetated mapping units are classified by the uppermost layer of vegetation which covers 30% or more of the area)

**A4L** -- Aquatic bed plants which float freely on the water surface (Ex: Duckweed, water meal, surface algae)

**E1/W0H** -- Plant remains persist into next year's growing season (Ex: Narrow- or broad-leaved plants; undetermined vegetation in open water)

**E2/W0Hx** -- Persistents with grass-like leaves without petioles or Undetermined bottom characteristics (Ex: Cattail, most sedges & grasses; undetermined vegetation in open water) Artificially excavated.

**S3/E1K** -- Deciduous shrubs other than tamarack or Plant remains that persist into next year's growing season (Ex: Willows, alder, young green ash/Narrow or broad-leaved plants)

**S3K** -- Deciduous shrubs other than tamarack (Ex: Willows, alder, young green ash)

**T3/E2K** -- Deciduous trees other than tamarack or Persistent emergents with grass-like leaves without petioles (Ex: Black ash, elm, silver maple/Cattail, most sedges & grasses)

**T3/S3K** -- Deciduous trees other than tamarack or Deciduous shrubs other than tamarack (Ex: Black ash, elm, silver maple/Willows, alder, young green ash)

**T3K** -- Deciduous trees other than tamarack (Ex: Black ash, elm, silver maple)

# The Aquatic Plant Community
# of
# Lake Hallie 1991-2000

Chippewa County, Wisconsin

Deborah Konkel
Wisconsin Department of Natural Resources
Eau Claire, WI

December 2002

## EXECUTIVE SUMMARY

The aquatic plant community in Lake Hallie is of average quality for Wisconsin lakes and is characterized by average diversity, abundant plant growth and a greater than average disturbance tolerance. Because of the good water clarity and shallow basin, vegetation can colonize the entire lake.

As a shallow water resource, Lake Hallie will naturally support abundant plant growth. The aquatic plants in shallow lakes provide habitat, protect the lake bottom from resuspension of sediments and compete with algae for nutrients. Without the aquatic plant community, a shallow lake can become turbid.

Lake Hallie is characterized by good water quality, fair water clarity, periodic planktonic algae blooms and abundant filamentous algae. The dense growth of aquatic vegetation is indicative of a eutrophic lake. Although the aquatic plants in Lake Hallie provides important benefits, the dense growth can hinder recreational use of the lake, consume oxygen during the winter through decomposition of the plant material and compromise the fishery by hindering the movement of predatory fish and overprotecting prey fish. Lake Hallie will likely always require management for plants, but managing with the goal of producing a community of sparse plant growth would be detrimental.

*Elodea canadensis* has been the dominant species within the plant community and *Potamogeton crispus* is sub-dominant during its peak growth in June. *Wolffia columbiana* became the dominant species in August 2001.

The aquatic plant community has undergone significant changes since 1991. Since a mechanical harvesting program was began in 2000, water clarity has increased, the dominance of *Potamogeton crispus* has decreased, disturbance indices have decreased, the number of species has increased and a plant species that are valuable as habitat components have increased.

**Management Recommendations for Lake Hallie Lake Association**

1) Preserve and expand buffer zones of native vegetation around the lake shoreline; replace mowed lawn with a buffer of natural, non-mowed vegetation at least 50 feet deep.
2) Cooperate with programs to manage run-off in the watershed.
3) Develop an aquatic plant management plan. Include mechanisms for plant modification as the plant community changes.
4) Develop a lake association budget that will provide funds for repair and maintenance of the plant harvester and pay harvester operators.
5) Harvest during the early season to remove curly-leaf pondweed biomass from the lake before the early summer die-off and nutrient release.
6) Harvest channels in dense plant beds in mid and late summer to improve habitat and boat access and reduce amount of vegetation decomposing in the winter under the ice.

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# The Aquatic Plant Community in Lake Hallie
## Chippewa County
## 1991-2001

## I. INTRODUCTION

Studies of the aquatic macrophytes (plants) in Lake Hallie were conducted during July 1991 and during June and August of 1998 and 2001 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR). These studies were primarily conducted to determine changes in the dominance of *Potamogeton crispus* (curly-leaf pondweed) and to provide information that the Lake Hallie Lake Association could use in formulating a management plan for the curly-leaf pondweed and evaluating management success.

The study will also provide information that is important for effective management of other aspects of the lake, including fish habitat improvement, protection of sensitive wildlife areas and water resource regulations. The added data that it provides will be compared to past and future plant inventories and track changes occurring in the lake.

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

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

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

**Background and History:** Lake Hallie is a 79-acre oxbow lake near the Chippewa River in Chippewa County, Wisconsin. The maximum depth of Lake Hallie is 11 feet. Lake Hallie was once a bend in the Chippewa River that became cut-off. The northeast end of the lake has been completely cut off from the Chippewa River, but the west end of the lake still drains into the Chippewa River. Springs contribute water to the lake and the dam controls and maintains the water level.

The lake was used as a log reservoir for saw mill operations during the mid- to late-1800's. The sawmill closed in 1890 and the lake became a recreational site. By 1990, the dam had deteriorated and needed to be repaired or removed. The dam repair at Lake Hallie was completed October 1997.

There are records of complaints pertaining to disagreeable odors from algae growth, as early as 1952. Swimmer's itch was reported in 1970. Algae/swimmer's itch treatments with copper sulfate were attempted for a few years (Table 1). Copper compounds have no long-term impact on the algae and require continuous treatments. Continual copper treatments become expensive and result in a build up of copper in the sediment. The copper contaminated sediments are toxic to some aquatic animals.

**Table 1. Chemical Treatments for Algae Control.**

| | Copper Sulfate |
|---|---|
| 1972 | 500 |
| 1973 | 250 |
| 1974 | 400 |
| Totals | 1150 |

In April 1998, a lake association was formed to address current issues and protect the lake.

In 2000, an 18-acre parcel of land was partially donated by American Materials and partially purchased by the lake association, with grants and moneys from Wisconsin DNR and Chippewa County, to protect the wetlands and springs at the northeast end of the lake.

In 2000, the lake association also received a grant to purchase a used aquatic plant harvester and started a harvesting program for curly-leaf pondweed. The main goal was to reduce the coverage and density of *Potamogeton crispus* in Lake Hallie and reduce the severity of the algae blooms that occur as the *P. crispus* decays. Other goals are:

1) Remove nutrients from the lake by harvesting plant material before the plant material dies and releases nutrients to the water.
2) Improve water quality resulting from reduced nutrient release which may eventually lead to the growth of species that are intolerant of poor clarity, creating a more diverse plant community that can support more diversity in the fish and wildlife community.
3) Immediately increase accessibility of more areas in the lake to navigation.
4) Modify the habitat by cutting openings in the dense plant beds to increase the success of predatory fish and promote a more balanced fish community.
5) Remove part of the curly-leaf pondweed from the lake and hamper its cycling of nutrients from the sediments to the water.
6) Open areas in dense beds of curly-leaf to encourage species intolerant of shading and therefore increase plant diversity.

During the winter of 2000-01, anglers reported some dead fish under the ice in Lake Hallie. Dissolved oxygen, tested in January 2001, was recorded at less than 5mg/l over most of the lake and less than 2mg/l in more than half of the lake. This is below the water quality standards for fish (5mg/l). Decay of the abundant aquatic vegetation is likely contributing to the loss of oxygen in the winter. Aeration has been used to correct the situation; removal of flashboards to pull water with low dissolved oxygen off of the bottom of the lake also appeared to keep oxygen levels higher.

## II.METHODS

Field Methods

The same methods and sampling sites were used for the 1991, 1998 and 2001 aquatic plant studies, based primarily on the rake-sampling method developed by Jessen and Lound (1962). Transects (16) were place equidistant along the shoreline, perpendicular to the shoreline and mapped.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft, and 10-20ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded and each species was given a density rating (0-5) based on the number of rake samples on which it was present at each sampling site.
A rating of 1 for each species present on one rake sample;
A rating of 2 for each species present on two rake samples;
A rating of 3 for each species present on three rake samples;
A rating of 4 for each species present on four rake samples;
A rating of 5 indicates that a species was abundant on all rake samples at that sampling site.

The sediment type at each sampling site was recorded. The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet back from the shore, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was recorded.

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

Data Analysis

Data from each survey was analyzed separately and compared. The percent frequency of each species was calculated (number of sampling sites at which it occurred / total number of sampling sites) and relative frequency was calculated based on the number of occurrences of a species relative to total occurrence of all species (Appendix I-V). The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites); relative density was calculated based on a species density relative to total plant densities; a "mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which the species occurred) (Appendix VI-X). The relative frequency and relative density was summed to obtain a Dominance Value (Appendix XI-XV).

Simpson's Diversity Index was calculated (Appendix I-V) to measure species diversity and Coefficients of Community Similarity were calculated.

The Aquatic Macrophyte Community Index (AMCI) developed by Weber et. al. (1995) was applied to Lake Hallie. Values between 0 and 10 are given for each of six categories that characterize the quality of the aquatic macrophyte community.

Floristic Quality Index evaluates the closeness of an aquatic plant community to an undisturbed condition (Nichols 1998). A Coefficient of Conservatism (C) is an assigned value, 0-10, based on the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservatism ($\hat{C}$) is the mean of the coefficients of conservatism for all species found in a lake. Floristic quality (I), calculated from the coefficients, is a measure of plant community's closeness to an undisturbed condition.

## II. RESULTS

### PHYSICAL DATA

Many physical parameters are important determinants of the type of macrophyte community that will ultimately inhabit a lake. Water quality (nutrient concentrations, algae growth, clarity, pH) impact the macrophyte community as the macrophyte community can in turn modify these parameters. Lake Morphology, sediment composition and shoreline land use also impact the macrophyte community.

**WATER QUALITY** - The trophic state of a lake is an indication of its water quality. Phosphorus concentration, chlorophyll concentration, and water clarity data are collected and combined to determine the trophic state.

**Eutrophic lakes** are high in nutrients and support a large biomass.

**Oligotrophic lakes** are low in nutrients and support limited plant growth and smaller fish populations.

**Mesotrophic lakes** have intermediate levels of nutrients and biomass.

**Nutrients**

Phosphorus is a limiting nutrient in many Wisconsin lakes. So, increases in phosphorus in a lake can feed algae blooms and excess plant growth.

**2001 mean summer phosphorus in Lake Hallie was 23 ug/l.**

The summer phosphorus ranged from 22 ug/l-25ug/l (Appendix XII). This concentration of phosphorus in Lake Hallie was indicative of a mesotrophic lake (Table 2). Phosphorus has decreased since 1991.

**Table 2. Trophic Status**

| | Quality Index | Phosphorus ug/l | Chlorophyll ug/l | Secchi Disc ft. |
|---|---|---|---|---|
| Oligotrophic | Excellent | <1 | <1 | > 19 |
| | Very Good | 1-10 | 1-5 | 8-19 |
| Mesotrophic | Good | 10-30 | 5-10 | 6-8 |
| Eutrophic | Fair | 30-50 | 10-15 | 5-6 |
| | Poor | 50-150 | 15-30 | 3-4 |
| Hypereutrophic | Very Poor | >150 | >30 | >3 |
| Lake Hallie 1991 | Good | 30 | 8.67 | 8.4 |
| Lake Hallie 2001 | Good | 23 | 5.67 | 6.8 |

After Lillie & Mason (1983)
Shaw et. al. (1993)

### Algae

Measuring the concentration of chlorophyll in the water gives an indication of algae levels. Algae is natural and essential in lakes, but high algae levels can increase turbidity and reduce the light available for plant growth.

**2001 mean summer chlorophyll in Lake Hallie was 5.67 ug/l.**

Chlorophyll concentrations also indicate that Lake Hallie was a mesotrophic lake (Table 2). The chlorophyll (algae) concentration in Lake Hallie has decreased since 1991.

### Water Clarity

Water clarity is a critical factor for plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity can be measured with a Secchi disc that shows the combined impact of turbidity and color.

**2001 Mean summer Secchi Disc Clarity was 6.8 ft.**

The water clarity indicates that Lake Hallie was a mesotrophic lake that had fair water clarity in 2001 (Table 2).
Water clarity has decreased since 1991 (Table 2). Water clarity data can be used to calculate a predicted maximum rooting depth for plants in the lake (Dunst 1982).

**Based on the clarity, the predicted maximum rooting depth was 11 ft. in the Lake Hallie.**

George Wanserski has been monitoring the water clarity in Lake Hallie since 1995 as a volunteer lake monitor in the Self-Help

Lake Monitoring Program. The Self-Help Volunteer Monitoring data is valuable because the volunteer collects data more frequently throughout the season and for more consecutive years than Department of Natural Resource monitoring.

George Wanserski's data showed that the mean water clarity was greatest in 1996 (10.5 feet). The 1997 mean clarity decreased to 7.3 feet (Figure 1). Water clarity has been increasing since 1997.

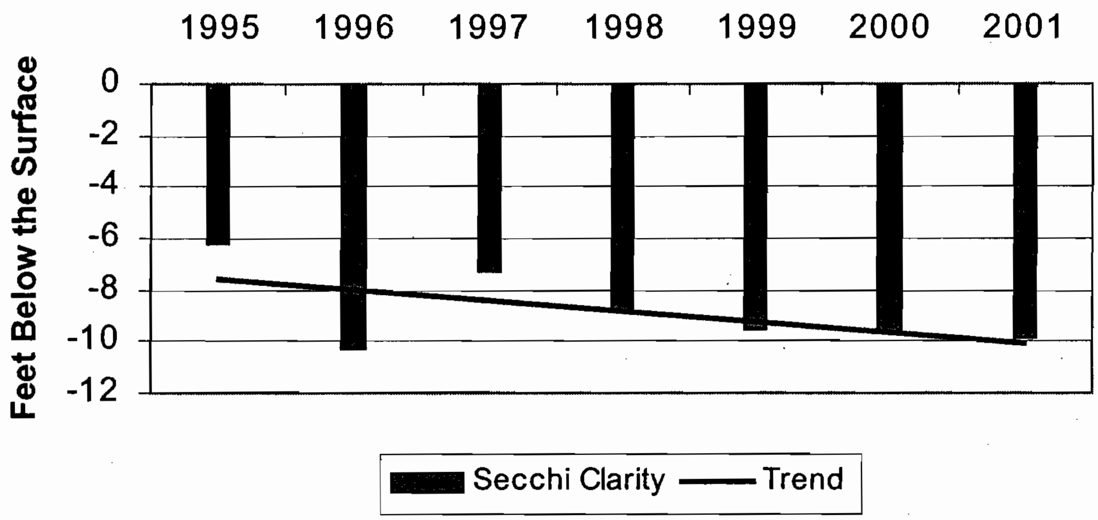


**Figure 1. Mean water clarity in Lake Hallie, 1995-2001.**

The data collected by George Wanserski also shows that the clarity changes during the season. The 1995-2001 mean clarity for each week increases early to the greatest clarity in Late-May. The clarity decreases to its lowest clarity in Late-July. The clarity increases again to a second maximum in Late-September and remains fairly constant during the autumn (Figure 2).

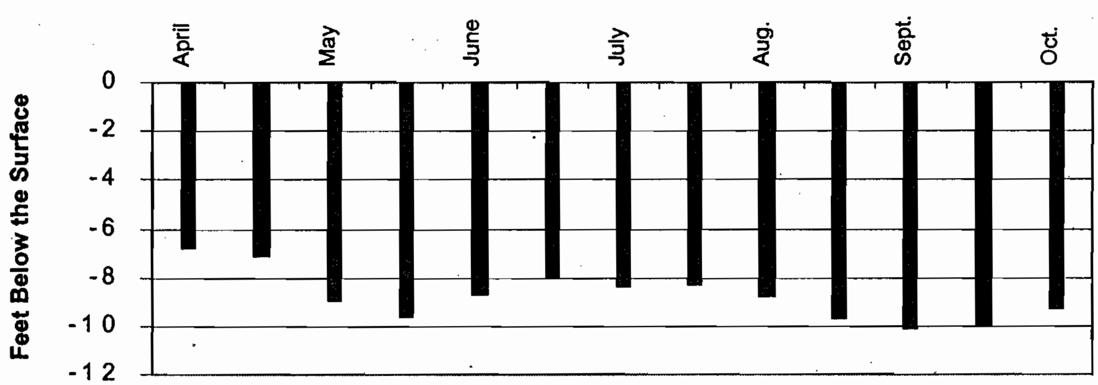


**Figure 2. Changes in mean clarity during the season, 1995-2001.**

Table 3. Sediment Composition

| | | 0-1.5 ft | 1.5-5 ft | 5-9 ft | 9-10.5 ft | Overall |
|---|---|---|---|---|---|---|
| **Soft Sediments** | Silt | 12% | 38% | 100% | 100% | 49% |
| | Peat | 6% | | | | 2% |
| **Mixed Sediments** | Sand/Silt | 6% | 44% | | | 17% |
| **Hard Sediments** | Sand | 44% | 12% | | | 19% |
| | Sand/Gravel | 19% | 6% | | | 8% |
| | Rock | 12% | | | | 4% |

**SHORELINE LAND USE** - Land use practices strongly impact the aquatic plant community and, therefore, the entire aquatic community. Practices on shore can directly impact the plant community through increased sedimentation from erosion, increased nutrients from fertilizer run-off and soil erosion and increased toxics from farmland and urban run-off.

Native herbaceous cover was the most frequently encountered shoreline cover at the transects. Shrub, wooded and cultivated lawn were also commonly encountered (Table 4). Cultivated lawn had the highest mean coverage, it covered more than one-third of the shoreline (Table 4).

Table 4. Shoreline Land Use

| | **Cover Type** | **Frequency of Occurrences at Transects** | **Mean % Coverage** |
|---|---|---|---|
| Natural Shoreline | Native Herbaceous | 75% | 15% |
| | Shrub | 50% | 15% |
| | Wooded | 44% | 32% |
| Disturbed Shoreline | Cultivated Lawn | 56% | 38% |
| | Eroded Soil | 6% | 0.3% |
| | Hard Structures | 6% | 1% |

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at all of the sites and covered of 62% of the shoreline. Some type of disturbed shoreline (cultivated lawn, shoreline. Some type of disturbed shoreline (cultivated lawn, eroded and hard structures) was found at 62% of the sites and covered 39% of the shoreline.

**MACROPHYTE DATA**

**SPECIES PRESENT**

A total of 32 species was found in Lake Hallie. Of the 32 species, 14 were emergent species, 4 were a floating-leaf species, and 14 were submergent species (Table 5).

No endangered or threatened species were found.
One species of special concern was found in 1991: *Eleocharis robbinsii*.
One non-native species was found: *Potamogeton crispus*

**Table 5. Lake Hallie Aquatic Plant Species**

| Scientific Name | Common Name | I. D. Code |
|---|---|---|
| **Emergent Species** | | |
| 1) *Calla palustris* L. | water arum | calpa |
| 2) *Carex comosa* F. Boot. | bristly sedge | carco |
| 3) *Eleocharis robbinsii* Oakes. | Robbin's spikerush | elero |
| 4) *Impatiens biflora* . | pale jewelweed | impbi |
| 5) *Iris versicolor* L. | blue flag iris | irive |
| 6) *Juncus effusus* L. | soft rush | junef |
| 7) *Leersia oryzoides* (L.) Swartz. | rice cut-grass | leeor |
| 8) *Myosotis laxa* Lehm. | smaller forget-me-not | myola |
| 9) *Phalaris arundinacea* L. | reed canary grass | phaar |
| 10) *Rorippa nasturtium-aquatica* (L.) Hay. | water-cress | rorna |
| 11) *Sagittaria rigida* Pursh. | stiff arrowhead | sagri |
| 12) *Scirpus validus* Vahl. | softstem bulrush | sciva |
| 13) *Typha angustifolia* L. | narrow-leaf cattail | typan |
| 14) *Typha latifolia* L. | common cattail | typla |
| Floating Species | | |
| 15) *Lemna minor* L. | small duckweed | lemmi |
| 16) *Lemna trisulca* L. | forked duckweed | lemtr |
| 17) *Spirodela polyrhiza* (L.) Schleiden. | greater duckweed | spipo |
| 18) *Wolffia columbiana* Karsten. | common watermeal | wolco |
| Submergent Species | | |
| 19) *Ceratophyllum demersum* L. | coontail | cerde |
| 20) *Chara* sp. | muskgrass | chasp |
| 21) *Elatine minima* (Nutt.) Fisch. & Meyer | waterwort | elami |
| 22) *Eleocharis acicularis* (L.) Roemer & Schultes. | needle spikerush | eleac |
| 23) *Elodea canadensis* Michx. | common water-weed | eloca |
| 24) *Najas flexilis* (Willd.) R. & S. | northern water-nymph | najfl |
| 25) *Nitella* sp. | nitella | nitsp |
| 26) *Potamogeton amplifolius* Tuckerman. | large-leaf pondweed | potam |
| 27) *Potamogeton crispus* L. | curly-leaf pondweed | potcr |
| 28) *Potamogeton foliosus* Raf. | leafy pondweed | potfo |
| 29) *Potamogeton pusillus* L. | slender pondweed | potpu |
| 30) *Potamogeton robbinsii* Oakes. | fern-leaf pondweed | potro |
| 31) *Potamogeton zosteriformis* Fern. | flatstem pondweed | potzo |
| 32) *Ranunculus longirostris* Godron. | white watercrowfoot | ranlo |

**FREQUENCY OF OCCURRENCE**

Of the 32 species found in Lake Hallie, 19 occurred at sampling sites in 1991; 14-18 species occurred at the sampling sites in 1998; 20-21 occurred at the sampling sites in 2001.

The species with the highest frequency of occurrence in all surveys was *Elodea canadensis* (Table 6). *Potamogeton robbinsii* has increased since 1991; *Chara* and *Spriodela polyrhiza* have decreased since 1991.

The frequency of *Potamogeton crispus* has been higher during June surveys: *P. crispus* increased in 1998, but declined substantially in 2001 (Table 6).

**Table 6. Most frequently occurring species**

| | Jul'91 | Jun'98 | Jun'01 | Aug'98 | Aug'01 |
|---|---|---|---|---|---|
| *Elodea canadensis* | **94%** | **88%** | **94%** | **86%** | **88%** |
| *Ceratophyllum demersum* | 29% | 4% | 51% | 14% | 59% |
| *Chara* sp. | 73% | 8% | 4% | 30% | |
| *Potamogeton crispus* | 14% | 73% | 40% | 24% | 4% |
| *Lemna minor* | 65% | 25% | 34% | 26% | 49% |
| *Wolffia columbiana* | 63% | 25% | 49% | 36% | 86% |
| *Spirodela polyrhiza* | 55% | 6% | | 6% | 4% |
| *Potamogeton robbinsii* | | 12% | 66% | 46% | 78% |

Filamentous algae occurred at 100% of the sample sites in 1991.
67% of the sites in June 1998.
69% of the sites in August 1998.
96% of the sites in June and August 2001

**DENSITY**

*Elodea canadensis* had the highest mean density (2.44-3.33 on a density scale of 1-4) of any species in Lake Hallie (Table 7), except in August 2001; *Wolffia columbiana* had the highest mean density (2.69) in August 2001.

The density of *Potamogeton crispus* decreases from June to August. *P. crispus* density has decreased substantially since 1998 (Table 7). Since 1991, the density of *Potamogeton robbinsii* has increased substantially and *Chara* has decreased substantially (Table 7).

**Table 7. Species with the highest mean density.**

| | Jul'91 | Jun'98 | Jun'01 | Aug'98 | Aug'01 |
|---|---|---|---|---|---|
| *Elodea canadensis* | **3.33** | **2.44** | **3.06** | **3.20** | 2.69 |
| *Ceratophyllum demsersum* | 0.45 | 0.06 | 1.17 | 0.20 | 1.24 |
| *Chara* sp. | 2.47 | 0.13 | 0.04 | 0.56 | |
| *Potamogeton crispus* | 0.27 | 2.21 | 0.72 | 0.40 | 0.04 |
| *Wolffia columbiana* | 1.63 | 0.73 | 1.74 | 1.08 | **2.96** |
| *Lemna minor* | 1.12 | 0.75 | 0.85 | 0.56 | 0.86 |
| *Potamogeton robbinsii* | 0 | 0.25 | 1.70 | 1.00 | 2.35 |

**DOMINANCE**

Combining relative frequency and relative density into an dominance value indicates the dominance of species within the macrophyte community (Appendix X-XV). Based on the dominance value, *Elodea canadensis* was the dominant species within the macrophyte community in 1991 and through the early summer of 2001 (Figure 3). *Wolffia columbiana* became the dominant species in August 2001.

*Potamogeton crispus* was sub-dominant during June 1998 (Figure 3). The dominance of *P. crispus* decreased in August surveys due to its early season life cycle. Its dominance also decreased in 2001.

*Chara* sp., which has declined in dominance, requires good water clarity. *Potamogeton robbinsii* has increased in dominance, becoming sub-dominant since late summer of 1998 (Figure 3). The sum of the other species' dominance has decreased, suggesting lowered diversity.

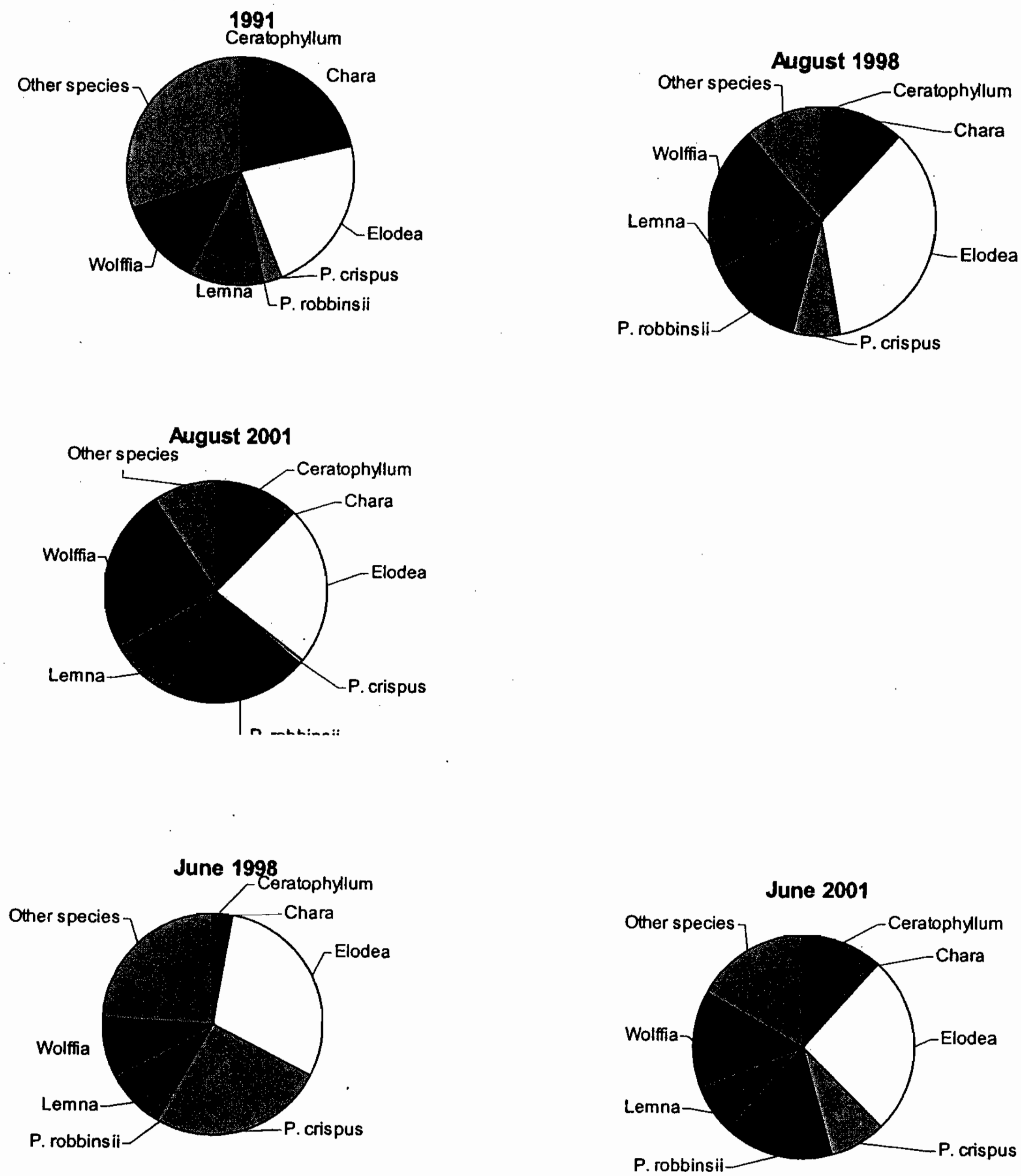


Figure 3. Dominance within the macrophyte community, of prevalent aquatic plants.

**DISTRIBUTION**

Aquatic plants were found growing at 94 - 100% of the sampling sites in Lake Hallie. The prevalent species were found throughout the Lake Hallie and all depth zones have had a high percentage of vegetated sites (90% or more) in all studies *Ceratophyllum demersum*, *Chara*, *Elodea canadensis* and *Potamogeton crispus*, *P. robbinsii* were found at the maximum rooting depth of 11.5 ft.

The 0-1.5 ft. depth zone had the highest total occurrence and total density of plants, in all studies (Figure 4, 5). The occurrence and density of macrophyte growth decreased with increasing depth. The highest total occurrence and density of plant growth in all depth zones occurred in July 1991.

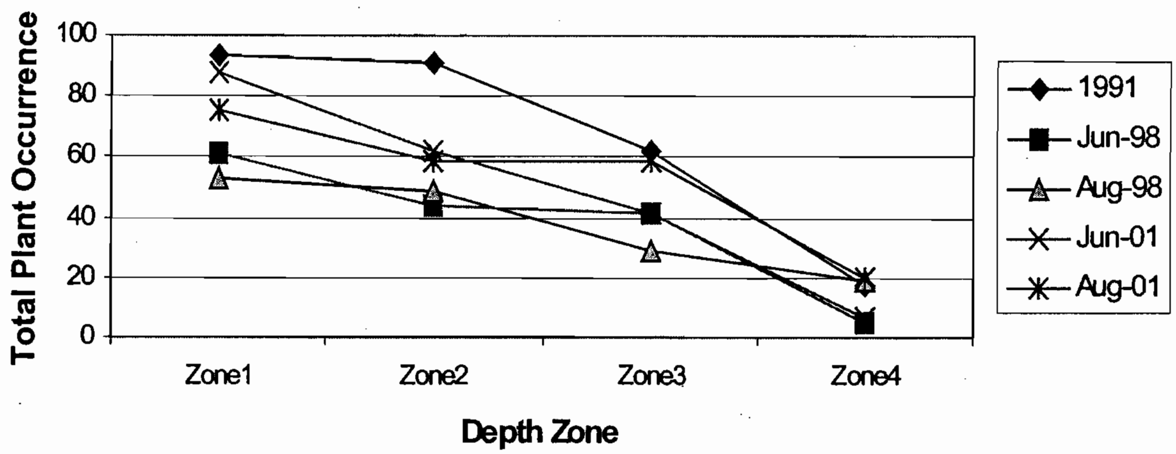


**Figure 4. Total occurrence of plants by depth zone**

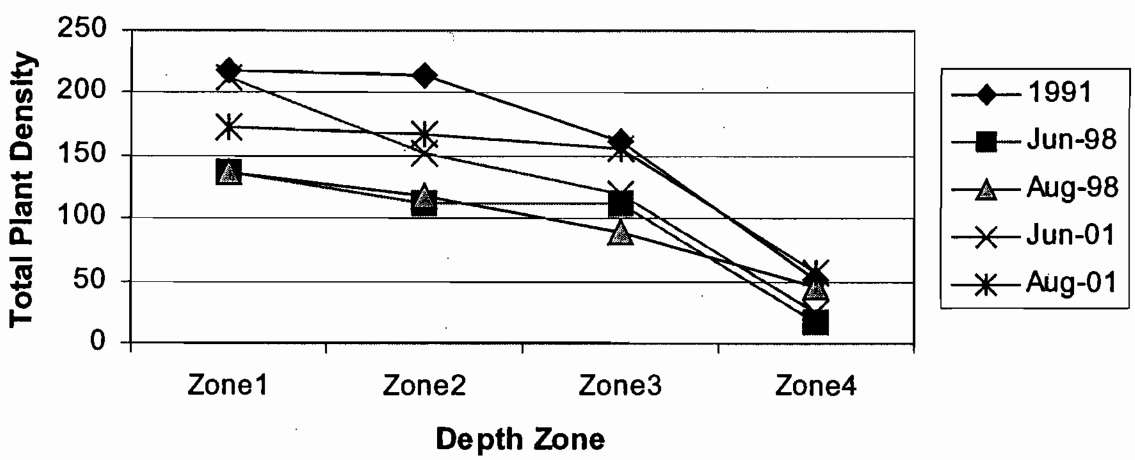


**Figure 5. Total density of plants by depth zone.**

The frequencies and densities of individual species varied in different years and with depth zone. *Potamogeton crispus* occurred at its highest frequency and density in June 1998 (Figure 6, 7) when it was the dominant species at depths greater than 5ft. Because of its life cycle, *P. crispus* has been more frequent and dense in June than in August in both 1998 and 2001. The frequency and density of *P. crispus* was lowest in 2001, especially in August. The late summer decrease in frequency and density of *P. crispus* followed a different pattern in 1998 and 2001. The greatest decrease of *P. crispus* was in the shallower depth zone in 1998 (likely due to the colder water in the deeper zones). The greatest was in the deeper depth zones in 2001 (likely due to the harvesting).

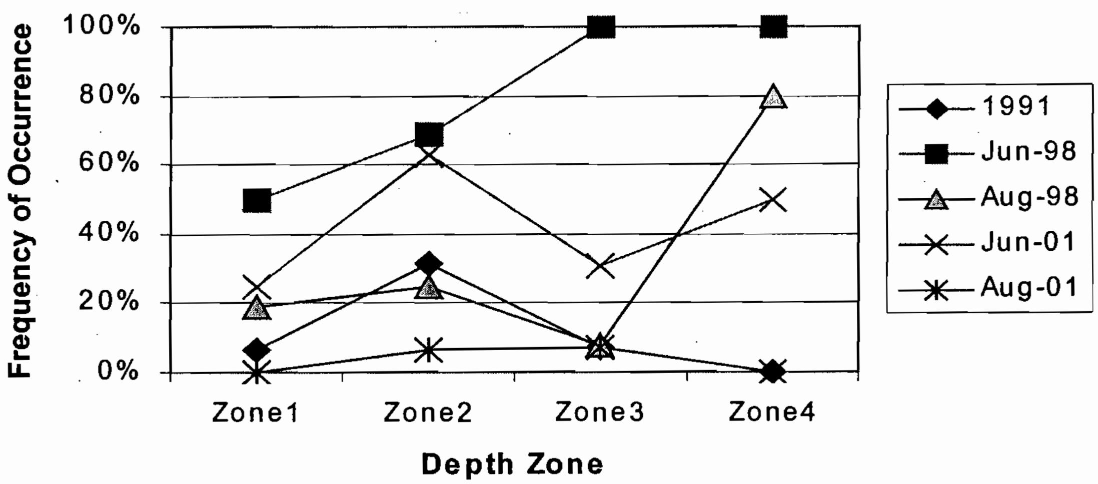


**Figure 6. Frequency of *Potamogeton crispus* by depth zone.**

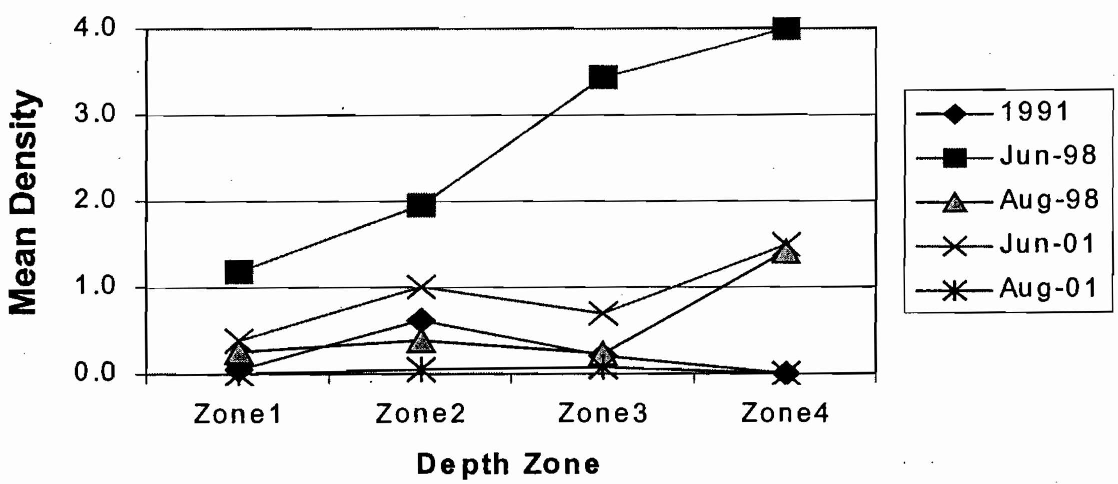


**Figure 7. Density of *Potamogeton crispus* by depth zone.**

*Elodea canadensis* was the dominant species overall in each study (Figure 8, 9) and the dominant species in the 1.5-5ft depth zone.

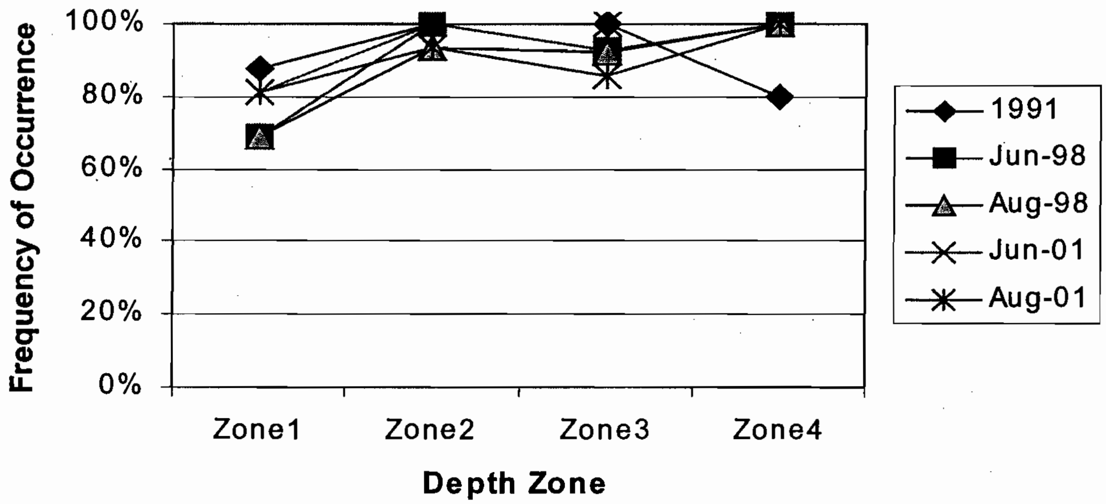


**Figure 8. Frequency of *Elodea canadensis* by depth, 1991-2001.**

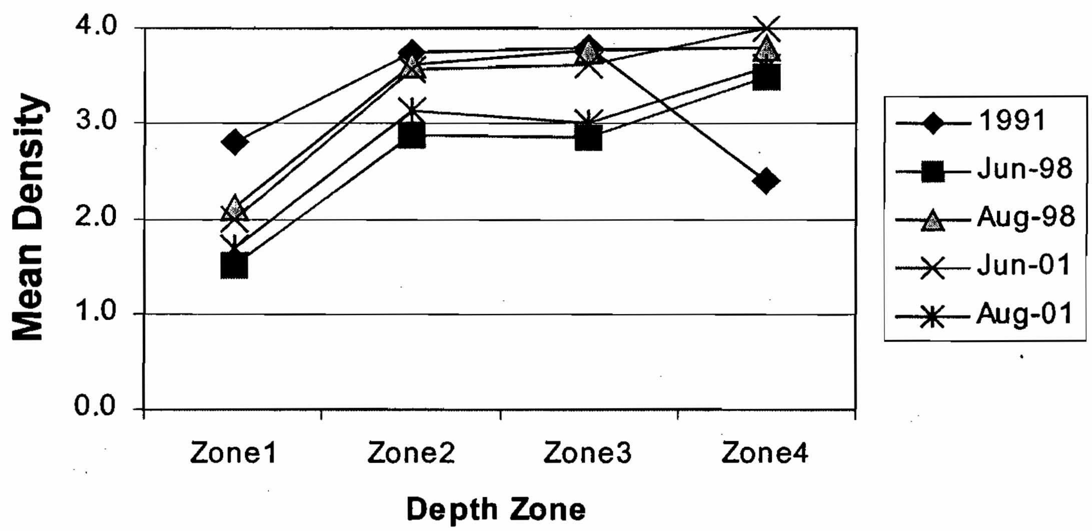


**Figure 9. Density of *Elodea canadensis* by depth, 1991-2001.**

*Chara* sp. has steadily declined in Lake Hallie, first in the shallower depth zones (Figure 10, 11). It was not found in August 2001.

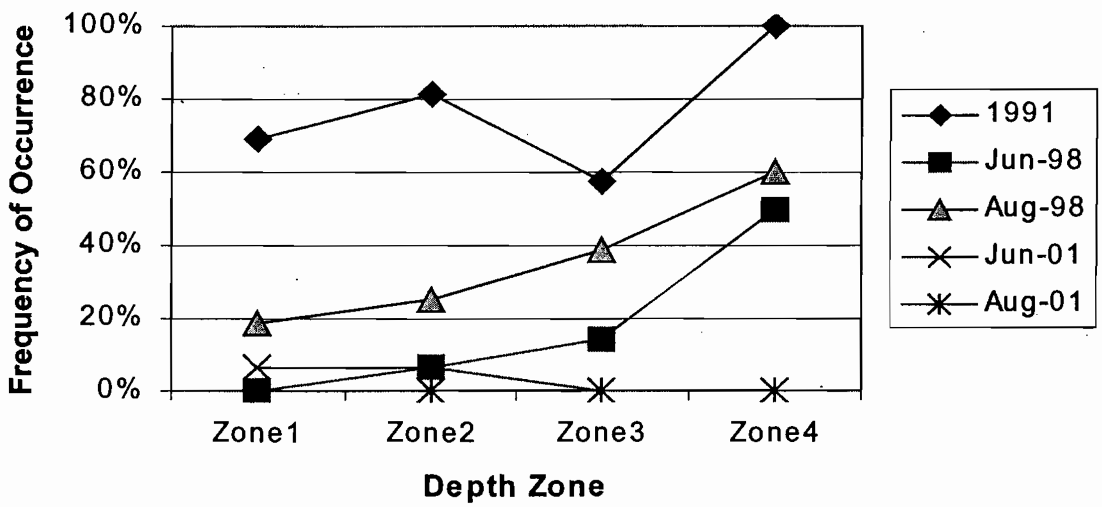


**Figure 10.** **Frequency of *Chara* sp. by depth zone, 1991-2001.**

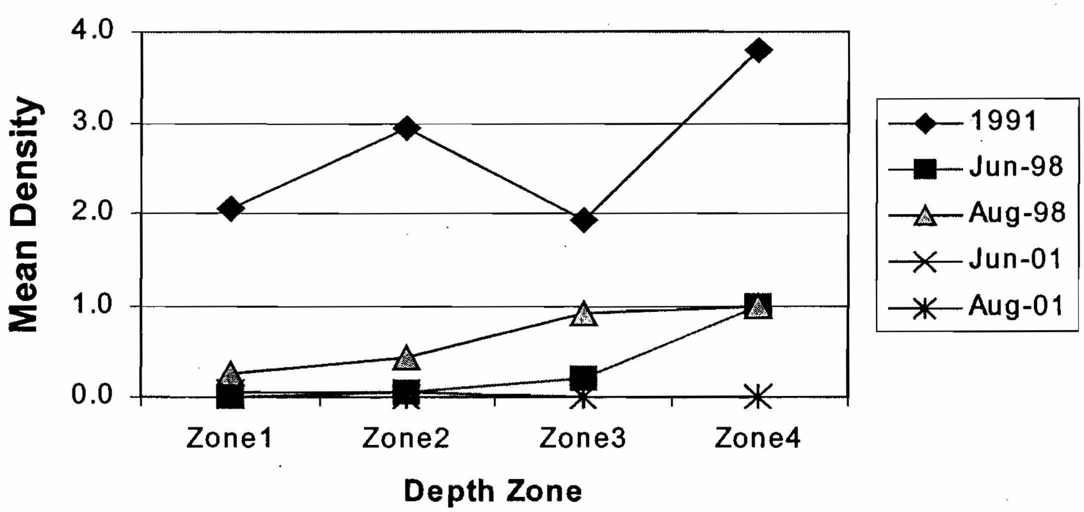


**Figure 11.** **Density of *Chara* sp. by depth zone, 1991-2001.**

The combined densities of all the duckweed species (*Lemna minor, Spirodela polyrhiza, Wolffia columbiana*) decreased from 1991-1998 (Figure 12). From 1998-2001, the density of the duckweed species have increased. The frequency and density of duckweeds have been greatest in the 0-1.5 ft. depth zone. *W. columbiana* became the dominant species in the shallow zone in 2001.

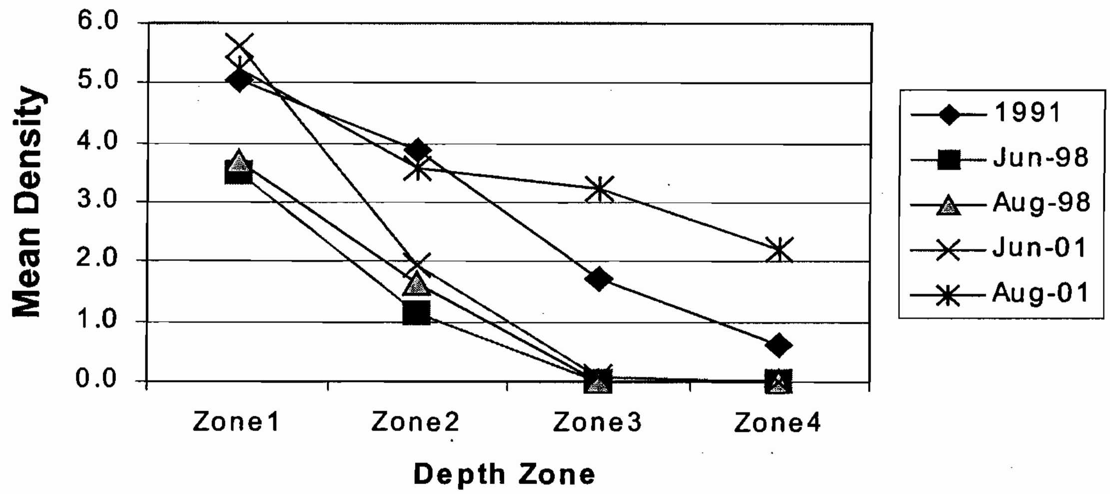


**Figure 12. Density of duckweed species by depth zone.**

*Potamogeton robbinsii* did not occur at the sample sites in 1991, but its frequency and density has been steadily increasing, epsecially in the deeper depth zones (Figure 13, 14). In June 2001, *P. robbinsii* was co-dominant in the 10ft depth zone. In August 2001, it was co-dominant in the 1.5-5ft depth zone and dominant in the 5-10ft depth zone.

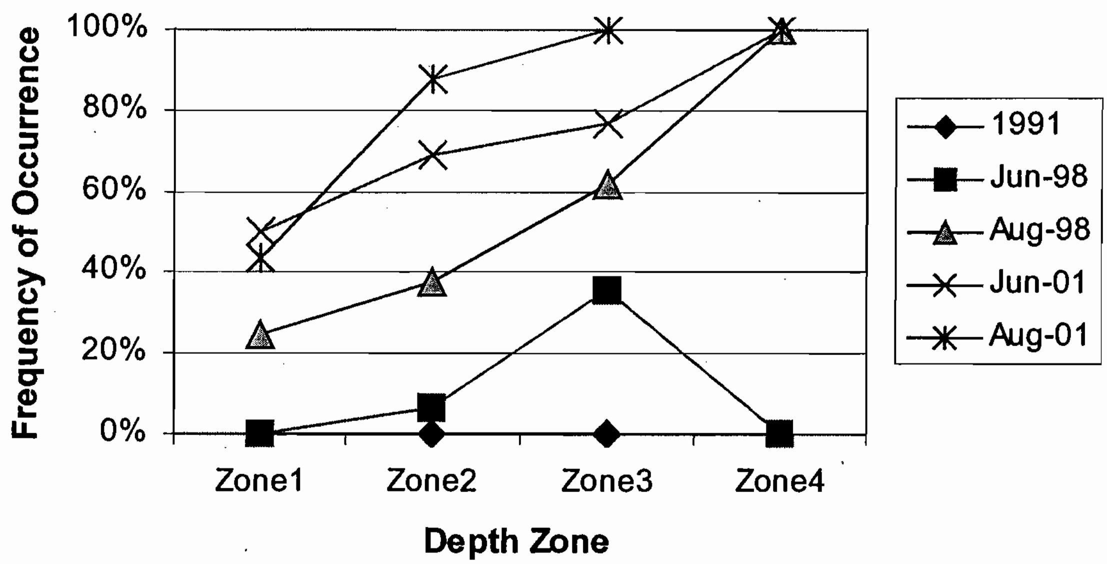


**Figure 13. Frequency of *Potamogeton robbinsii* by depth zone.**

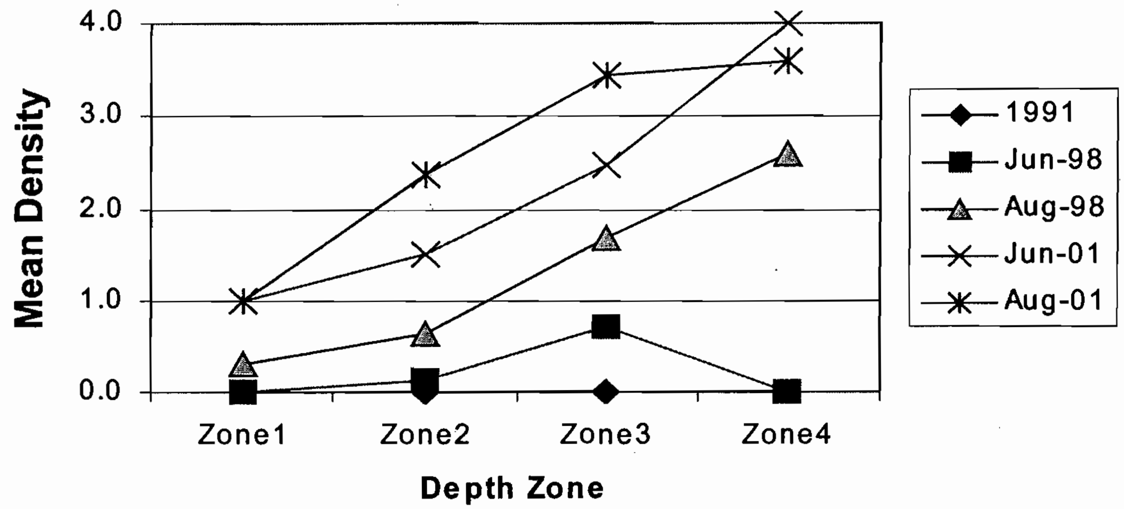


**Figure 14. Density of *Potamogeton robbinsii* by depth zone.**

In 1991, *C. demersum* had been the dominant species in the 10ft depth zone. In 1998, the frequency of *Ceratophyllum demersum* had decreased at the sample sites (Figure 15, 16). In 2001, the frequency and density of *C. demersum* increased to its highest frequency and density (Figure 15, 16).

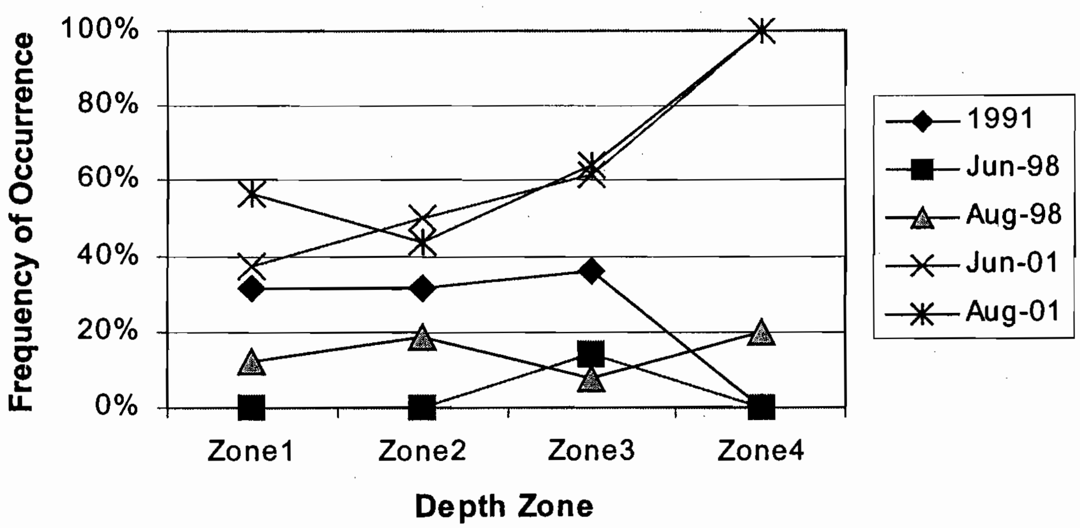


**Figure 15. Frequency of *Ceratophyllum demersum* by depth zone.**

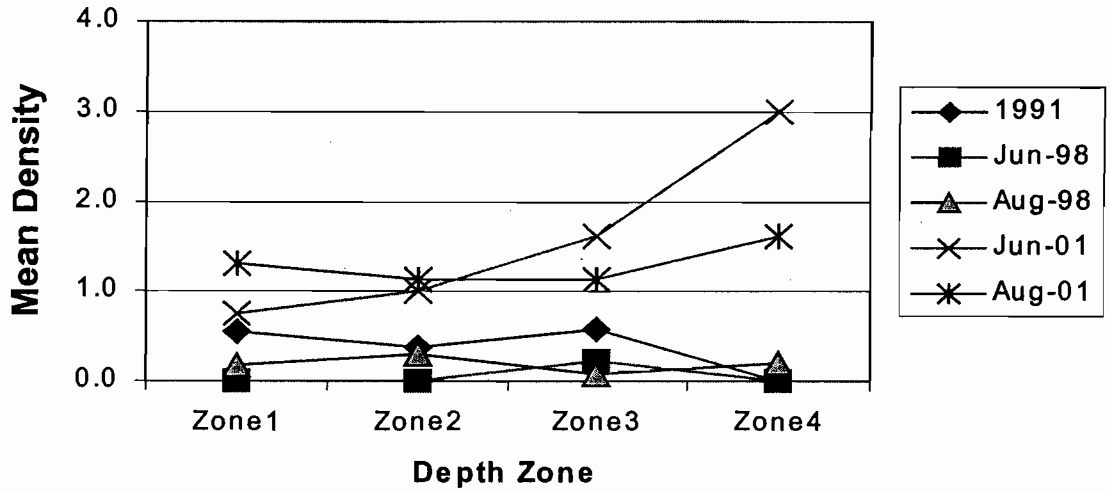


**Figure 16. Density of *Ceratophyllum demersum* by depth zone.**

**THE COMMUNITY**

The Coefficients of Community Similarity is a measure of the percent similarity between two communities. Coefficients less than 0.75 indicate that the two communities are only 75% similar and are considered significantly different.

The coefficients for Lake Hallie indicate that the late summer aquatic plant communities were significantly different each year (Table 8). The 1991 and 1998 communities were only 63% similar and the 1998 and 2001 August plant communities were only 66% similar. The change in the late summer plant communities accumulated over the ten years so that the 1991 and 2001 communities were only 53% similar (Table 8).

The early summer (June) aquatic plant communities have also changed significantly. The June 1998 and June 2001 plant communities were only 65% similar (Table 8).

The plant communities in Lake Hallie change during the year due to the dominance and later die-back of *Potamogeton crispus*. In 1998, there was a significant change, as expected, in the plant community with the die-back of *P. crispus;* the June and August plant communities were only 70% similar. However, in 2001, there was not a significant change; the June and August plant communities were 78% similar (Table 8).

**Table 8. Coefficients of Community Similarity**

| | Coefficient | % Similarity |
|---|---|---|
| **Late Summer Plant Community** | | |
| 1991-98 | 0.6301 | 63% |
| 1998-2001 | 0.6602 | 66% |
| 1991-2001 | 0.5267 | 53% |
| **June Plant Community** | | |
| 1998-2001 | 0.6475 | 65% |
| **June-August** | | |
| 1998 | 0.6963 | 70% |
| 2001 | 0.7799 | 78% |

Different parameters and indices can be used to determine what changes have occurred in the plant community. In Lake Hallie, several parameters decreased from 1991 to 1998 and subsequently increased from 1998-2001: the number of species at the sampling sites, the percent of the littoral zone that was vegetated, the percent coverage of emergents, submergent and free-floating species and the Floristic Quality (discussed later in this document) (Table 9).

Simpson's Diversity Index decreased from good diversity in 1991 to average diversity in 2001. An index of 1.0 would mean that each individual plant in the lake was a different species (the most diversity achievable).

**Table 9. Changes in the Lake Hallie Macrophyte Community**

| | 1991 | 1998 | 2001 | Change 1991-2001 | % Change |
|---|---|---|---|---|---|
| **Number of Species** | 19 | 14 | 20 | 1 | 5% |
| **% Littoral Zone Vegetated** | 100 | 94 | 100 | 0 | 0 |
| **%Sites w/ Emergernts** | 14 | 4 | 20 | 6 | 43% |
| **%Sites w/ Submergernts** | 98 | 94 | 96 | -2 | -2% |
| **%Sites w/ Free-floating** | 69 | 42 | 88 | 19 | 28% |
| **Simpson's Diversity Index** | 0.89 | 0.85 | 0.84 | -0.05 | -6% |
| **Floristic Quality** | 19.8 | 17.8 | 20.5 | 0.76 | 4% |

The Aquatic Macrophyte Community Index (AMCI) for Lake Hallie was slightly below average (40) for lakes in Wisconsin in 1991 and early 1998. The quality increased to average in late summer 1998 and above average quality in early 2001 (Table 10). The highest value for this index is 60.

**Table 10. Aquatic Macrophyte Community Index**

| Category | July 1991 | June 1998 | August 1998 | June 2001 | August 2001 |
|---|---|---|---|---|---|
| **Maximum Rooting Depth** | 6 | 6 | 6 | 6 | 6 |
| **% Littoral Zone Vegetated** | 10 | 10 | 10 | 10 | 10 |
| **Simpson's Diversity** | 9 | 8 | 9 | 9 | 8 |
| **# of Species** | 5 | 5 | 3 | 7 | 7 |
| **% Submersed Species** | 7 | 8 | 8 | 7 | 5 |
| **% Sensitive Species** | 0 | 0 | 4 | 4 | 4 |
| **Totals** | 37 | 37 | 40 | 43 | 40 |

The Average Coefficients of Conservatism for Lake Hallie, 1991-2001, were in the lowest quartile for all Wisconsin lakes and lakes in the North Central Hardwood Region (Table 11). This indicates that Lake Hallie was in the group of lakes that are most disturbance tolerant, likely from being subjected to disturbance.

**Table 11. Mean Coefficient of Conservatism and Floristic Quality of Little Falls Lake, Compared to Wisconsin Lakes and Region Lakes.**

| | ($\hat{C}$) Average Coefficient of Conservatism | (I) Floristic Quality | (I) Based on Relative Frequency |
|---|---|---|---|
| Wisconsin Lakes | 5.5, 6.0, 6.9* | 16.9, 22.2, 27.5* | |
| NCHF | 5.2, 5.6, 5.8* | 17.0, 20.9, 24.4* | |
| 1991 | 4.94 | 19.75 | 19.83 |
| June 1998 | 4.44 | 17.75 | 12.76 |
| August 1998 | 4.92 | 17.75 | 16.62 |
| June 2001 | 4.83 | 20.51 | 17.65 |
| August 2001 | 4.83 | 20.51 | 19.95 |

* upper limit of lower quartile, mean, lower limit of upper quartile
Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
The lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).
The North Central Hardwood Forest Region (NCHF) is the region in which Lake Hallie is located.

The Floristic Quality Index for Lake Hallie (1991-2001) was below the mean for Wisconsin Lakes and for lakes in the North Central Hardwood Region (Table 11). This indicates that Lake Hallie was farther from an undisturbed condition than the average lake in Wisconsin and the North Central Hardwood Region. The disturbance appears to have increased during 1998 and decreased in 2001.

Disturbances can be of many types:

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

These values and conclusions were based only on the occurrence of disturbance-tolerant and disturbance-sensitive species. The frequency or dominance of these tolerant or sensitive species in the plant community in Lake Hallie was not taken into consideration. The Floristic Quality was recalculated by weighting each species Coefficient of Conservatism with its relative frequency.

The resulting values, based on the relative frequency of tolerant and intolerant species, provides more detail. The plant community in Lake Hallie was below the mean for all Wisconsin lakes and all North Central Hardwood Region Lakes in 1991, in the lowest quartile in 1998 and below the mean in 2001. The Floristic Quality decreased from 1991 to 1998 and increased in 2001, indicating an increased disturbance in 1998 and decreased disturbance in 2001.

## V. DISCUSSION

Based on 2001 water quality data, Lake Hallie is a mesotrophic lake with good water quality and fair water clarity. However, the dense growth of filamentous algae and aquatic plants indicate a eutrophic lake. Filamentous algae was abundant in Lake Hallie and has increased since 1991.

Water monitoring conducted by the DNR in 1991 and 2001 indicate that the nutrient concentrations and planktonic algae have decreased since 1991. In spite of the decrease in nutrients and planktonic algae, the water clarity has decreased during the same time period. There may be siltation and erosion problems that are impacting water clarity.

Although water clarity has declined overall since 1991, volunteer monitoring data indicates that water clarity has been increasing since 1997. The aquatic plant harvesting program may be removing enough plant material to decrease nutrient release and therefore improve water clarity.

### The Plant Community

The adequate nutrients, high frequency of favorable silt sediments, gradual-sloped littoral zone and shallow depths over much of the lake favor plant growth.

The aquatic plant community in Lake Hallie is characterized by high density of growth, an average diversity, average quality (AMCIndex) and a greater than average tolerance to disturbance. Dense plant growth is found throughout Lake Hallie to the maximum depth of the lake; aquatic plants were found at 94-100% of the sites and more than 90% of the sites in all depth zones. The highest occurrence and density of plants was found in the July 1991 survey and in the 0-1.5 foot depth zone in all surveys. The most prevalent species are found throughout the lake.

*Elodea canadensis* (common waterweed) has been the dominant plant species in Lake Hallie, especially in the 1.5-5ft depth zone; *Wolffia columbiana* (watermeal) became the dominant species in August of 2001. Common waterweed is adapted to low water clarity due to the placement of its chloroplasts near the leaf surface; watermeal is adapted to low clarity because of its growth on the surface of the water.

*Potamogeton crispus* (curly-leaf pondweed) was the sub-dominant plant species in June 1998. The dominance of this non-native species declined in August and in 2001. The frequency and density of *P. crispus* declined substantially since June 1998.

### Changes in the Plant Community

The plant community in Lake Hallie has changed significantly, both during the year and from year to year.

JUNE TO AUGUST CHANGES

A plant community with abundant *Potamogeton crispus* (curly-leaf pondweed) would be expected to change significantly from June to August due to the early summer dominance and mid-summer die-back of the *P. crispus*. Curly-leaf pondweed survives the winter under the ice and resumes growth early in the year while the water is still cold. This provides a head start for growth. As the water temperature rises in early June, curly-leaf reaches its peak growth, produces turions (seed-like structures) and undergoes a die-back. The turions will sprout in the fall when water temperatures cool and these sprouts live through the winter under the ice. In 1998, the June plant community was only 70% similar to the August community with the decline of *Potamogeton crispus* **least** noticeable in the deeper depth zones. This is likely due to the colder water in the deeper zones that could support it further into the summer.

The June plant communities have changed. The June 1998 community was only 65% similar to the June 2001 community and the June and August plant communities in 2001 were not significantly different. This suggests that the curly-leaf pondweed has declined to the extent that it may not be impacting the plant community as it once did. The June to August decline of *P. crispus* in 1998, though not sufficient to cause a significant change in the plant community, was **most** noticeable in the deeper depth zones, likely due to mechanical harvesting.

CHANGES AMONG YEARS

The August plant communities have changed significantly. The Lake Hallie plant community in 2001 was only 66% similar to the 1998 community and only 53% similar to the 1991 plant community, based on the Coefficients of Community Similarity.

Simpson's Diversity Index indicates that the diversity of aquatic plant species in Lake Hallie declined from good diversity in 1991 to average diversity in 1998 and 2001. Although the diversity index has decreased, the number of species at the sampling sites has increased.

Other changes in the plant community in Lake Hallie from 1991 to 2001:

1) The decrease in *Chara* sp. (muskgrass) and *Spriodela polyrhiza* (greater duckweed).
2) The increased dominance of *Potamogeton robbinsii* (fern-leaf pondweed).
3) An increase in the quality of the plant community as measured by the AMCIndex.
4) The decrease in total occurrence and density of aquatic plant growth.

Some changes may be attributable to the mechanical harvesting. These parameters decreased from 1991 to 1998 as the curly-leaf pondweed was becoming more dominant in Lake Hallie and subsequently increased from 1998 to 2001 after the mechanical harvesting program was put into effect.

a) number of species occurring at the sample sites
b) Floristic Quality Index (which suggests and increase and then decrease in disturbance)

*Potamogeton crispus* (curly-leaf pondweed) may have been determining the composition of the aquatic plant community in Lake Hallie via light availability to other species and cycling of nutrients into the lake during the growing season.

Light availability would be decreased by the early season dominance and shading of the other species of curly-leaf pondweed and the lower water clarity resulting from algae growth after its die-back. Many of the species in Lake Hallie (*Ceratophyllum demersum, Eleocharis acicularis, Elodea canadensis, Lemna minor, Potamogeton foliosus, P. pusillus, Sagittaria, Spirodela polyrhiza, Typha latifolia*) are tolerant of lower water clarity.

The nutrient release from the decaying curlyleaf pondweed cycles nutrients into the lake during the grwoing season. *Ceratophyllum demersum, Chara, Elodea canadensis, Lemna minor, Potamogeton robbinsii* and *Spirodela polyrhiza* can grow to over-abundance when there is an excess of nutrients in the lake (Nichols and Vennie 1991).

*Eleocharis robbinsii* has disappeared from Lake Hallie. It is a species of special concern and may be a sensitive species whose decline may indicate disturbance.

*Potamogeton amplifolius* is considered an indicator of good water clarity and has increased slightly since 1998. Its increase may indicate the removal of curly-leaf pondweed is reducing shading when it first sprouts.

The occurrence of natural shoreline (wooded, shrub and native herbaceous growth) on Lake Hallie was high. Native herbaceous cover occurred at three-quarters of the sites. Although natural shoreline was frequent, cultivated lawn occurred at more than half of the sites and covered more than one-third of the shore. Cultivated lawn can result in increased run-off of fertilizers, pet wastes and other nutrients. Expanding and preserving the buffer of natural vegetation along the shore will protect the water quality of the lake from toxic run-off, nutrient run-off and erosion.

## VI. CONCLUSIONS

Lake Hallie is a eutrophic lake with good water quality, fair water clarity, periodic planktonic algae blooms and abundant filamentous algae.

The plant community in Lake Hallie is of average quality for Wisconsin lakes and is characterized by average diversity, dense plant growth and a greater than average disturbance to the plant community. Because of the good water clarity and shallow basin, vegetation can colonize the entire lake bed and will require management. The aquatic plant community has changed significantly since 1991.

*Elodea canadensis* has been the dominant species within the plant community and curly-leaf pondweed is sub-dominant during its peak growth in June. *Wolffia columbiana* became the dominant species in August 2001.

Several changes have been seen since the harvesting program began in 2000.

1) Water clarity has increased since 1997.
2) The dominance of *Potamogeton crispus* has decreased, especially in the deeper depth zones
3) The Floristic Quality has increased, suggesting the harvesting is causing less disturbance to the plant community than the dominance of *P. crispus* caused
4) Less significant change between the June and August plant communities, implying the *P. crispus* is having less impact on the aquatic plant community
5) The number of species at the sampling sites has increased
6) The frequency of *Potamogeton amplifolius*, an aquatic plant that is valuable for habitat, has increased.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the benefits that plants provide in
1) improving water quality 2) providing valuable resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, therefore reducing the diversity.

1) Plant communities improve water quality in many ways: they trap nutrients, debris, and pollutants entering a water body; they absorb and break down some pollutants; they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms; they remove nutrients that would otherwise be available for algae blooms (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources (Table 12). Plants (including algae) start

the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish. Cover within the littoral zone should be about 25-85% to support a healthy fishery.

The plant growth in Lake Hallie in 2001 provided 100% cover within the littoral zone for habitat. This amount of plant growth provides over-abundant cover and may limit fish and wildlife use.

Compared to non-vegetated lake bottoms, plant beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of plants support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

**Management Recommendations**

1) Preserve and expand the natural buffer zones of native vegetation around the lake. This will benefit water quality and wildlife habitat. Replace mowed lawn at the shoreline with a buffer of natural vegetation 50 feet deep.
2) Cooperate with programs to manage run-off and erosion in the watershed.
3) Develop an aquatic plant management plan. Include mechanisms for modifications as the plant community changes.
4) Develop a lake association budget that will provide funds for repair and maintenance of the harvester and pay harvester operators.
5) Continue the mechanical harvesting program during the early season to remove curly-leaf pondweed from Lake Hallie before its die-off and thus the nutrients that are released during the die-back. Reducing this nutrient source may eventually reduce the algae blooms.
6) Harvest in mid and late summer in dense plant beds to improve habitat.
    a) Harvesting improves fish habitat by opening up cruising lanes for predatory fish. These openings improve the hunting success of the predatory fish and promote a better balanced fishery.
    b) Avoid harvesting in areas with valuable habitat plants
    c) Harvesting will immediately open areas for easier boating.

Lake Hallie's proximity to an urban area makes it an important resource that deserves protection. These practices will protect the water quality and wildlife habitat in the lake.

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# The Status and Management of Fish Populations in Lake Hallie, Chippewa County (WBIC 2150200)

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## Summary

A 2001 survey of Lake Hallie was the first comprehensive look at fish populations since the lake was chemically treated in 1968. Survey objectives were: 1) to characterize the status of the fish population, 2) to document the abundance of northern pike and their impact on a stocked trout fishery, 3) to document the impact of low, winter oxygen levels on fish community health, 4) to establish a baseline of data to evaluate an aquatic plant harvesting program, and 5) to collect data for the statewide trends, lake monitoring program.

Ten fish species were collected in netting and electrofishing surveys. Bluegill was the most abundant species in the spring net catch, followed by northern pike and black crappie. The spring electrofishing catch was dominated by bluegill, followed by largemouth bass and pumpkinseed. Ninety-six percent of the summer net catch was comprised of young-of-the-year bluegills.

Northern pike were introduced into Lake Hallie in the early 1980s. Since then, the population has expanded, and a popular winter fishery has developed with some fish exceeding 20 pounds. Northern pike have above average growth rates for six of eight age classes. A high percentage of quality-size fish (41% ≥21") are present. The 2001 net catch of northern pike was 12.4 times greater than in the 1984 survey.

The introduction of northern pike is considered the primary factor affecting a stocked, rainbow trout fishery. Since the late 1990s, anglers reported lower catch rates for trout in spring and early summer. A winter trout fishery, which existed up to the early 1990s, is no longer existent. The above average growth rate of northern pike is most likely due to their predation on trout, a high nutrition fish. With a well-established northern pike population in the lake, rainbow trout stocking was discontinued in 2002.

Larger, older individuals dominate the largemouth bass population. A high density of legal-size fish are present, partially a result of a 14-inch minimum size limit. Mortality of older fish is somewhat low, most likely due to low angler harvest. The thick growth of aquatic plants in the lake hampers the angler's ability to catch bass during the open water season, and also may affect the bass's ability to forage. Most age classes have below average growth rates. Spawning habitat for bass is widespread in the lake, however problems with recruitment are evident. The 1997-2001 age classes were poorly represented in all sampling efforts. Predation may be a factor controlling bass recruitment.

Bluegill is the dominant species in Lake Hallie. The size structure of the bluegill population is within the recommended range for a quality bluegill fishery, but slightly above the recommended range for a balanced bass/bluegill population. Bluegills older than 2-years have above average growth rates. The total annual mortality of fish older than 3-years is slightly high (74%). Low, winter oxygen levels may reduce angler catch and harvest at a time when bluegill harvest is generally the highest in Wisconsin lakes. During the open water season, bluegill angling may be affected by the dense growth of aquatic plants.

Few black crappies were caught in spring surveys. The 2001 net catch was 65% lower than the 1984 catch. The size structure of the catch is below the recommended range for a quality crappie population, with 80% less than quality size (8"). Age 4 fish, which represent 78.5% of the catch, have average growth rates. The total annual mortality of fish older than 3-years is high compared to other Wisconsin populations.

The 2001 net catch for yellow perch decreased 96% from the 1984 survey. Few perch were caught in 2001 indicating a major decline in the perch population. It is suspected that predation by northern pike was a major factor in this decline.

The discontinuation of trout stocking, the harvesting of aquatic plants and the improvement of winter oxygen levels are lake management activities that may impact largemouth bass, bluegill and northern pike populations. These activities will likely affect predator-prey interactions, growth rates, size structure and angler harvest of these species. Future monitoring should be conducted to evaluate the response of fish populations as well as angler catch and harvest to lake management activities. If quality of fish populations deteriorates appreciably, consideration should be given to changes in size or bag limits.

# Introduction

**Study area**

Lake Hallie lies within 100 yards of the Chippewa River midway between Chippewa Falls and Eau Claire. It is shaped like an oxbow lake, and given the local topography it is likely an old oxbow of the Chippewa River. The lake is 79 acres with a maximum depth of 13 feet and 2.9 miles of shoreline. Approximately one-half of the shoreline is natural and wooded due to steep hillsides and wetland areas. About ½-mile is heavily developed, and an 18-hole golf course lies along another ½-mile of shoreline.

In 1843, the Blue Mills and Badger State Lumber Company constructed the original dam that formed Lake Hallie. The dammed water source was most likely a series of groundwater seeps that formed a small tributary to the Chippewa River. The dam was repaired in the 1950s and had a height of 10 feet. By 1990, the dam deteriorated to a point where it needed major structural repairs or removal. A local fund raising campaign was held, and in 1997 the entire structure was rebuilt.

The lake initially was used as a log holding area for a sawmill in the southwest corner of the lake. The sawmill closed in 1890 (Frye 1978). The spillway, where the sawmill once stood, was later used as a fish hatchery. A small powerhouse, constructed at the main outlet at the west end of the lake, furnished electricity for nearby farms (Frye 1978). In the early 1900s, emphasis on lake use turned to recreation. A boat rental, excursion boats and a barge used for dancing provided recreation for local residents and visitors. In 1922, an 18-hole golf course was established adjacent to the lake.

A large, groundwater discharge area lies in the lake's northeast end. As an indication of groundwater influence, bottom water temperature was around 54°F in less than 5-feet of water in July 1999. Groundwater discharge provided a large open water area throughout winter with several acres of open water during the mid-1980s. In recent years, less than an acre of open water is present. Preliminary results from a fall 2002 mini-piezometer study indicate at least two points of good groundwater flow to the northeast portion of the lake. One area of flow is present in the current area of open water. Anglers now fish a portion of the lake that used to be open water during winter. Groundwater discharge also is evident along the high banks of the eastern shore. In 1963, the outlet flow was 7.1 cubic feet per second (cfs) with approximately 70% of the flow discharged through the spillway portion of the dam. In 1996, the outlet flow was measured at 7.3 cfs. This provides some indication of the amount of groundwater discharge to the lake, less any evaporation. Despite similar outlet flows over a period of 33 years, it is not known why the winter, open water area has diminished in size.

**Fisheries management history**

The lake became a popular fishery in the early 1900s. Fisheries management activities began in 1939 with the stocking of northern pike. From 1939-1955, northern pike fry were stocked for 13 years (Appendix 1). Largemouth bass fingerlings were stocked in 1945 and 1951, and walleye fry were stocked in 1955. In 1954, largemouth bass, bluegills and crappies were noted as abundant, and the lake experienced heavy fishing pressure.

By the late 1950s, carp had become a major problem in the lake. Because of their abundant population, rooted aquatic vegetation disappeared; algae and high turbidity became problems. Occasional winterkills occurred. In the early to mid-1960s, several attempts were made to remove carp with nets and electrofishing gear, however these attempts were unsuccessful at alleviating the problem. In October 1968, the lake was drawn down four feet and chemically treated with antimycin to remove carp. An estimated 46,000 pounds of carp were killed. Prior to treatment, gamefish and panfish were removed and placed in a private, 3-acre pond adjacent to the lake. Largemouth bass were common, but few large bass were present. Black crappies were very abundant, but small in size and in poor condition. Many bluegills >6 inches were present. Despite the repeated stocking of northern pike, small numbers of them were found. A few walleye also were present.

In April 1969, rainbow trout were stocked to provide an immediate fishery after chemical treatment. Trout growth was excellent the first year, but complaints of trout exiting the lake through the spillway section were received. The initial plan was to stock rainbow trout for three years following chemical treatment. In May 1972, a decision was made to continue stocking rainbow trout as long as they experienced good growth. With few exceptions, stocking continued through 2001. Largemouth bass and bluegills were restocked in the lake in 1970 and 1971. In fall 1969, 80 musky fingerlings were stocked as an additional predator and sport fish.

A one-night electrofishing survey in May 1970 found a healthy trout population with fish up to 20 inches. Many trout were ending up in the angler's creel. By October 1970, *Elodea* and filamentous algae had become abundant, very likely due to increased water clarity. Muskies stocked at 11"-13", were now 22"-24" in length. A one-night electrofishing run in October 1972 documented healthy bass and bluegill populations with reproduction of both species. Two nights of electrofishing in October 1973 found good bass reproduction but no large bass. Bluegill catch was the highest since reintroduction. This prompted concerns that good reproduction and survival of bluegills could eventually lead to a stunted population.

A creel survey conducted from October 1981 through September 1982 documented extremely high fishing pressure in the lake (Newman 1984). Total estimated pressure was 369 hours/acre compared to 134 hours/acre for Half Moon Lake in Eau Claire during the same time period. May received the highest level of fishing pressure (39%) due to a large number of anglers pursuing rainbow trout. In 1982, over 120 anglers were counted on opening weekend of the fishing season, with most anglers fishing for trout.

Over 70% of the total trout catch occurred in May. Very little fishing pressure for trout occurred in other months. Approximately 50% of the trout stocked in April were harvested in May. Winter provided a limited trout fishery with the highest harvest in February. In December 1981, 5,000 rainbow trout fingerlings were stocked to evaluate the harvest of fall fingerlings versus spring holdovers. Only 9.2% of the fingerlings were caught, and 8.3% were returned to the creel. For holdover fish, an estimated 69% of the total stocked were caught and 61% were returned to the creel. Stocking spring holdovers provided a more effective put and take trout fishery.

Despite the interest for trout early in the fishing season, 70% of all anglers targeted panfish compared to 10% for trout. Panfish comprised 84% of the total harvest (Appendix 2), with the highest harvest occurring during winter. Anglers complained about the size of bluegills, which ranged from 4"-6". The average length harvested was 6.4". Black crappies, caught in large numbers during winter, also were on the small side, ranging from 4.5"-6.5". The average length harvested was 6.7". For largemouth bass, the highest harvest rate occurred during winter, and the average length harvested was 10.8". No northern pike were reported caught. During the survey, the panfish bag limit was 50/day, and the bag limit for bass was 5/day with no size limit.

Bluegill dominated the catch of a spring 1984 netting survey, followed by black crappie, pumpkinseed and yellow perch. This survey yielded the first evidence of northern pike in the lake since chemical treatment. Eleven northern pike ranged from 18.5"-30.9". In November 1986, two muskellunge (33" and 36") and six northern pike were collected for mercury analysis. Northern pike ranged from 29"-36" and 5-14 pounds. All fish were in excellent condition. The presence of these species result from introductions outside of any Department approved stocking effort. Spawning habitat is available for northern pike, however it is doubtful that natural reproduction of musky is occurring. In recent years, several reports have been received of large northern pike (20+ lbs.) being caught during winter.

Recent regulation changes include a 14" minimum size limit for bass introduced in 1989, and a reduction in the daily bag limit for panfish from 50 to 25 in 1997. In 1998, several local resolutions were presented and passed at the spring rules hearing. These resolutions included: no size limit on northern pike because of their predation on trout; reduce the bag limit of largemouth bass from 5 to 2; and reduce the bag limit of panfish from 25 to 15.

**Water quality**

In 1974, a chemical analysis of groundwater entering the lake indicated extremely high nitrate levels. This was considered the greatest source of nutrients to the lake. Thoughts were given to dredging out the upper end of the lake to increase groundwater flow into the lake, thereby increasing the lake's flushing rate.

Low, winter oxygen levels were first recorded in February 1956. Oxygen levels were 8.9 parts per million (ppm) in the northeast end, 1.1 ppm at the lake bend and 0.3 ppm at the outlet. In January 1956, thousands of bluegills and crappies, and several hundred largemouth bass were found dead below the main spillway. It is assumed that this mass emigration was a combination of low oxygen levels and a damaged screen across the spillway. Another fish kill was reported in March 1959. The northeast corner of the lake had sufficient oxygen levels, but oxygen levels from the bend to the outlet were extremely low. Again, live fish were reported exiting the outlet, most likely in search of higher oxygen levels. For a period of about 40 years, there is no file record of any further fish kills, or attempts to monitor winter oxygen levels.

On February 7, 2000, dead bass, northern pike and crappie were reported on the bottom near the lake bend. On February 8, dissolved oxygen levels above the water quality standard of 5 ppm were present in the upper third of the lake only. In the lower half, surface oxygen levels were <2.5 ppm. Near the outlet, they were 0.5 ppm. Extremely warm weather in late winter produced an early ice-out, possibly averting a larger fish kill.

Starting November 30, 2000, oxygen levels were measured biweekly throughout the lake. Adequate oxygen levels existed at least up to December 15. By January 8, 2001 surface oxygen levels dropped below 3 ppm in the lower two-thirds of the lake. Only the upper third of the lake had oxygen levels sufficient to support healthy fish populations. On January 18, 2001, three floating aeration units were installed in the upper third of the lake. By February 12, these units, aided by the limited flow through the lake, provided oxygen levels above 5 ppm throughout the entire lake. Anglers, who previously had poor fishing success in the lower two-thirds of the lake, reported improved angling success with the aeration units running.

The winter of 2001-02 was a mild winter, with late ice formation and very little snow cover. Oxygen levels near the outlet were above 7 ppm throughout the water column on January 10. On February 6, oxygen levels near the outlet were 12.6 ppm immediately below the ice and 4.3 ppm at 7-feet. Before ice-up, the lake association removed a 6" stop log from the bottom draw, outlet structure under the town road. Since oxygen levels are lowest on the lake bottom, it was assumed that increasing the flow through this outlet would draw low oxygen water from the lake. Low oxygen levels were not experienced, but because of a mild winter, it is not known if this practice aided in providing higher oxygen levels. For the winter of 2002-03, the lake association removed two stop logs (10") from the bottom draw outlet to provide higher flows. As of January 30, 2003, oxygen levels were above 5 ppm throughout the lake.

<u>Aquatic plants</u>

Dense aquatic vegetation was first documented in the mid-1940s. With an abundant population of carp, rooted aquatic vegetation disappeared and algae and high turbidity became problems by the late-1950s. Carp were removed through chemical treatment in 1968, and by May 1972, aquatic vegetation once again became excessive in the lake. From 1972-1974, chemical treatments were conducted for algae control. By August 1979, thick mats of floating, filamentous algae had become a problem, and rooted aquatic vegetation was documented as extremely thick in the upper end of the lake. The heavy growth of vegetation in this area was evident during the 2001 fish survey, along with anaerobic, organic sediments and few fish observed.

An aquatic plant survey was conducted in 1998. The primary objective was to document changes in the population of curly-leaf pondweed (*Potamogeton crispus*) since the 1991 plant survey (Konkel 1999). Curly-leaf pondweed is an exotic species that starts its growth early in the year while the water is still cold. This growth feature allows the plant to get a head start in spring over other plant species, quickly dominating the plant community. It reaches its peak growth in June, and then starts to die back as water temperatures rise.

The 1998 survey documented 26 plant species – 10 emergent, 3 floating-leaf, and 13 submergent species. Silt is the predominant substrate in the lake, followed by sand and gravel. Since soft sediments influence the distribution of aquatic plants, rooted plants were found at 98% of the survey sites in 1991 and at 94% of the 1998 sites. In 1998, aquatic plants covered 94% of the littoral zone providing over-abundant cover to fish. Common waterweed (*Elodea canadensis),* the dominant species in the plant community, increased from 1991 to 1998. *P. crispus* populations also increased since 1991 with a high frequency of occurrence in June. *Chara* , a rooted form of algae that is an indicator of good water clarity, declined from 1991-1998. Filamentous algae occurred at 100% of the sites in 1991 and at 68% of the 1998 sites.

The plant community experienced a decrease in diversity from 1991 to 1998. The 1998 community was only 57%-64% similar to the 1991 community because of changes in the presence and abundance of individual species. Five plant species present in 1991 were not found in 1998. Six species were noticeably reduced in abundance, two had a significant increase, and one species found in 1998 was not present in 1991. The early season growth of *P. crispus* is followed by a thick filamentous algae growth that results from the summer die-off of *P. crispus.* The dense growths of *P. crispus* and filamentous algae shade the growth of other plant species. This is a major factor determining the composition of the plant community. Many plant species in the lake are tolerant of low water clarity.

In 1991, the mean, summer secchi disc reading was 8.4 feet. Based on this mean, the predicted maximum rooting depth for the lake is 13 feet. The actual, observed rooting depth in 1998 was 11.5 feet, the maximum depth encountered in the lake. Mean summer secchi disc readings taken by volunteers were 6 feet in 1995, 10.5 feet in 1996, and 8 feet in 1997. "Based on the 1991 water quality data, Lake Hallie does not fit into one trophic state. Nutrient levels indicate that it is a eutrophic/mesotrophic lake; algae (phytoplankton) levels indicate that it is a mesotrophic lake, and water clarity indicates that it is a mesotrophic/oligotrophic lake with fair to good water quality. This discrepancy is most likely due to the predominance of filamentous algae in Lake Hallie." (Konkel 1999).

Konkel's (1999) report concluded that harvesting of *P. crispus* has the potential to remove a major source of nutrients that feed summer algal blooms. Harvesting could potentially improve plant diversity in areas where *P. crispus* is the dominant species. In 1999, a harvesting plan was designed for the lake. It includes an early season cutting to control the growth and spread of *P. crispus*. A late season cutting in July and August is designed to cut channels in areas of thick *Elodea* growth and other areas where plant growth has reached nuisance levels. This cutting is intended to improve fish habitat and boating accessibility, and remove floating mats of filamentous algae. In 2000, the Lake Hallie Lake Association began implementing the harvesting plan.

**Study objective**

A survey was conducted in 2001 to characterize the status of fish populations in the lake. A major objective was to document the abundance of northern pike and how this population may be impacting a put and take trout fishery. Other objectives included documenting the impacts of low, winter oxygen levels on the health of the fish community and establishing a baseline of information to evaluate the plant harvesting program. Sampling for the statewide, baseline monitoring program was incorporated into the comprehensive portion of the survey.

# Methods

Fyke nets were set at ice-out to catch northern pike during their spawning run. Five nets were set on April 3 in the upper third of the lake, while the remainder of the lake remained ice-covered. As the remainder of the lake became ice-free, two additional nets were set on April 14. Nets were checked daily, and all nets were pulled out on April 17. A total of 78 net lifts were made. All fish caught were identified, counted and measured. The bluegill catch was very high, so starting on April 13, bluegills <5" were counted only.

Four, nighttime electrofishing runs were made of the entire lakeshore. The April 18 run was used as the recapture run for northern pike and as the initial run for bass and panfish. Electrofishing runs on May 10, 17, and 29 targeted bass and panfish. Bass and panfish were counted and measured, with the exception of bluegills <5" which were counted only. A one-half mile, index site was set up for the baseline monitoring component. At this site, all fish species were collected, identified and counted.

All fish were given a left pectoral fin clip, with the exception of bluegills <5" and bullheads. Aging materials were collected from northern pike, largemouth bass, bluegills and black crappie. Five scale samples were collected from each half-inch group for male, female and unknown sex northern pike. In addition to scales, the anterior ray of the pectoral fin was collected for all northern pike ≥21". Five scale samples were collected for each half-inch group of largemouth bass, and a dorsal fin spine was collected from all bass ≥12". Ten scale samples were collected from each half-inch group of bluegills and crappies. Weights were taken on all fish for which aging materials were collected.

Late summer sampling was conducted as part of the baseline monitoring component. Four mini-fyke nets were set out for one night and 10 shoreline sites were selected for a stream shocker survey. Survey sites were supposed to be random, however, thick aquatic vegetation forced sampling to be conducted where it was feasible. Stream shocker sites were 30 meters long and extended out to the one-meter depth. All fish observed were collected. For both survey methods, all fish were identified and counted. Gamefish and panfish, other than young-of-the-year, were measured.

Catch per unit effort (CPE) is determined for all survey methods. The Bailey modification of the Peterson estimate is used to calculate a largemouth bass population estimate. The Schnabel formula is used with the netting data for a northern pike population estimate.

The balance or structure of individual fish populations is evaluated using the Proportional Stock Density (PSD) and Relative Stock Density (RSD-P) indices. PSD is the percentage of quality-size fish within the minimum stock-size, while the RSD-P assesses the population of preferred-size fish within the minimum stock-size. The formulas are as follows:

PSD = (number of quality-size fish/number of stock-size fish) x 100
RSD-P = (number of preferred-size fish/number of stock-size fish) x 100

The terms stock-size, quality-size, and preferred-size compare a fish's length to the angling, world record length for that particular species. For any given species, minimum stock-size is 20-26% of the world record length, quality-size is 36-41% and preferred-size is 45-55% (Anderson and Weithman 1978, Anderson 1980). The minimum stock, quality, and preferred-sizes of fish used in this study were obtained from Gabelhouse (1984) (Table 1).

**Table 1. Minimum stock, quality and preferred-sizes of fish (inches)**

| Species | Stock size | Quality size | Preferred size |
|---|---|---|---|
| largemouth bass | 8 | 12 | 15 |
| northern pike | 14 | 21 | 28 |
| bluegill | 3 | 6 | 8 |
| black crappie | 5 | 8 | 10 |
| yellow perch | 5 | 8 | 10 |

Growth rates of individual species are compared to average growth rates of fish in other Wisconsin lakes. In most cases, rates are compared to lakes in northwest or west central Wisconsin to obtain regional comparisons. However, where regional growth rates were not available, statewide averages are used.

The length-weight relationship of fish is equally as important as the length-age relationship (growth rate) in fisheries management. This relationship evaluates the health or condition of a fish. It can be influenced by prey availability, prey size and predator-prey relationships. The relative weight ($W_r$) index (Wege and Anderson 1978, Anderson 1980) compares the measured weight of a fish to a standard weight. Standard weights for individual species have been developed using length and weight measurements from a wide range of fish surveys. McComish et al. (1974) found a direct relationship between relative weight values and the fat content of bluegills, the more fat the higher the $W_r$ value. Fat content is dependent on the types and amount of food eaten.

Total, annual mortality rates for individual species were determined using a catch curve analysis (Ricker 1975). Mortality rates are compared to fish in other Wisconsin lakes (WDNR 1984).

## Results

Ten fish species were captured in spring netting and electrofishing surveys. Bluegill was the dominant species in the net catch followed by northern pike and black crappie (Table 2). In electrofishing surveys, bluegill again dominated the catch followed by largemouth bass and pumpkinseed.

**Table 2. Spring netting catch per unit effort in Lake Hallie**

| Species | 1984 | | | 2001 | | | Percent change in catch rate |
|---|---|---|---|---|---|---|---|
| | No. of net lifts | Total catch | No. of fish per net lift | No. of net lifts | Total catch | No. of fish per net lift | |
| largemouth bass | 40 | 5 | 0.13 | 78 | 51 | 0.65 | 423% |
| northern pike | 40 | 7 | 0.18 | 78 | 183 | 2.35 | 1241% |
| bluegill | 40 | 518 | 12.95 | 78 | 1851 | 23.73 | 83% |
| black crappie | 40 | 225 | 5.63 | 78 | 154 | 1.97 | -65% |
| pumpkinseed | 40 | 166 | 4.15 | 78 | 37 | 0.47 | -89% |
| yellow perch | 40 | 126 | 3.15 | 78 | 9 | 0.12 | -96% |
| rainbow trout | 40 | 2 | 0.05 | 78 | - | - | - |
| walleye | 40 | 5 | 0.13 | 78 | - | - | - |
| bowfin | 40 | - | - | 78 | 1 | 0.01 | - |
| central mudminnow | 40 | - | - | 78 | 7 | 0.09 | - |
| yellow bullhead | 40 | 9 | 0.23 | 78 | 120 | 1.54 | 584% |
| white sucker | 40 | 6 | 0.15 | 78 | 19 | 0.24 | 62% |

**Northern pike**

Nets yielded the most northern pike. Netting CPE was 12.4 times greater than when northern pike were first collected in 1984 (Table 2). Northern pike ranged from 5.8"-39.3" and averaged 20.1" (Figure 1). Males ranged from 11.5"-31.9" with an average of 20.3", and females ranged from 11.3"-38.5" with an average of 25" (Figure 2). The ratio of males to females was 2.5:1. The PSD value of 47 (95% CI of 39-55) is within the recommended range of 30-60 (Anderson and Weithman 1978). The RSD-P value is 9. Quality size fish (≥21") comprised 40.7% of the catch. The population density is estimated at 3.6 fish/acre. However, this estimate has a high variability (95% CI of 1.2-10.9 fish/acre) due to a low number of recaptures encountered during the survey. No recaps were collected in the April 18 electrofishing run.

Figure 1. Northern pike length frequency in Lake Hallie, spring 2001

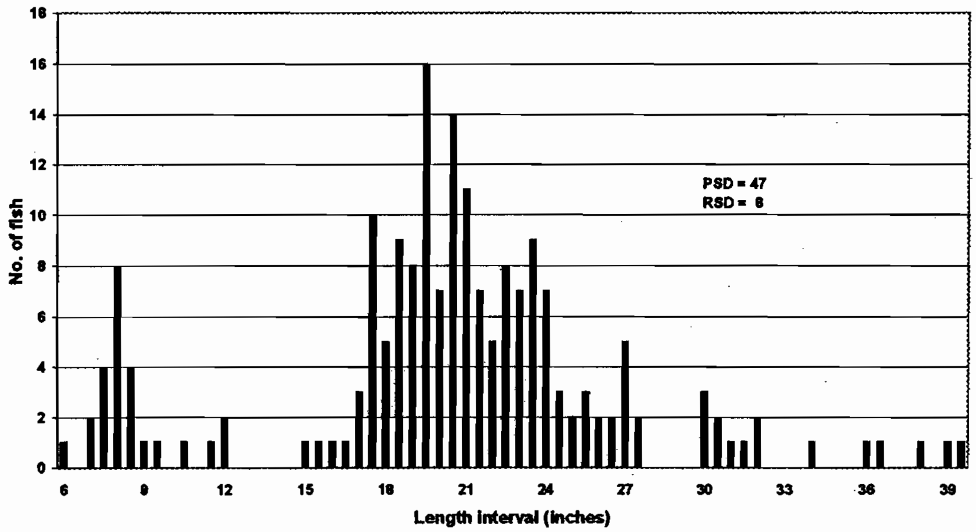
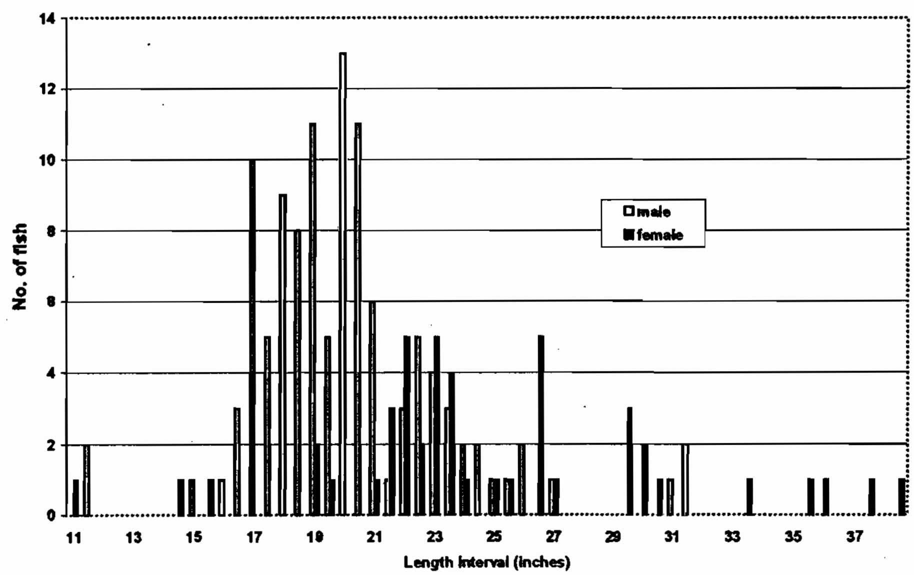



Figure 2. Northern pike length frequency by sex for Lake Hallie, spring 2001




Eight age classes (1-8) were present. Fish ages 3-5 years constituted 78% of the catch (Figure 3). Age 2 fish have significantly (P=0.05) slower growth than fish in NW Wisconsin waters, while ages 3-8 have significantly faster growth rates (Figure 4). Females are represented by seven age classes (2-8) and males by six (2-7). Age 2 females and males ages 2 and 4 have significantly (P=0.05) slower growth rates than statewide averages. Females ages 3 and 5-7 have significantly faster growth rates (Figures 5 & 6). The total annual mortality rate for ages 3-8 is 54.1% ($R^2$=0.861), which is comparable to similar age classes in other Wisconsin lakes. Relative weight values generally fell within ±10% of standard weights (Figure 7). Several high values for fish ≥35" are based on single fish, which may not be representative of those size classes. The heaviest northern pike weighed 15¾ pounds.

Figure 3. Northern pike catch curve for ages 1 to 8 in Lake Hallie, spring 2001


Figure 4. Northern pike growth rate in Lake Hallie compared to NW Wisconsin lakes

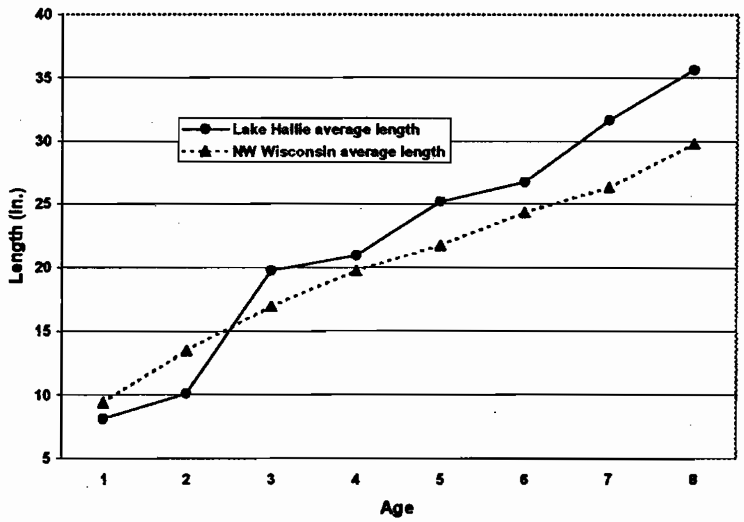



Figure 5. Growth rate of female northern pike in Lake Hallie compared to statewide lakes

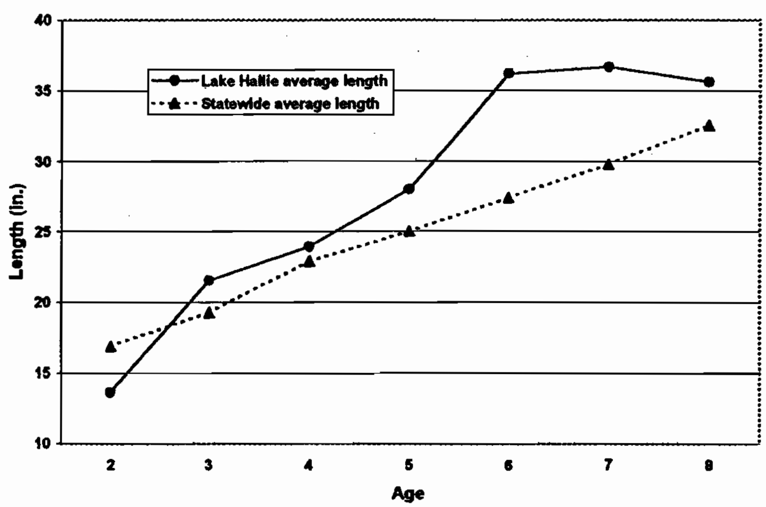


Figure 6. Growth rate of male northern pike in Lake Hallie compared to statewide lakes

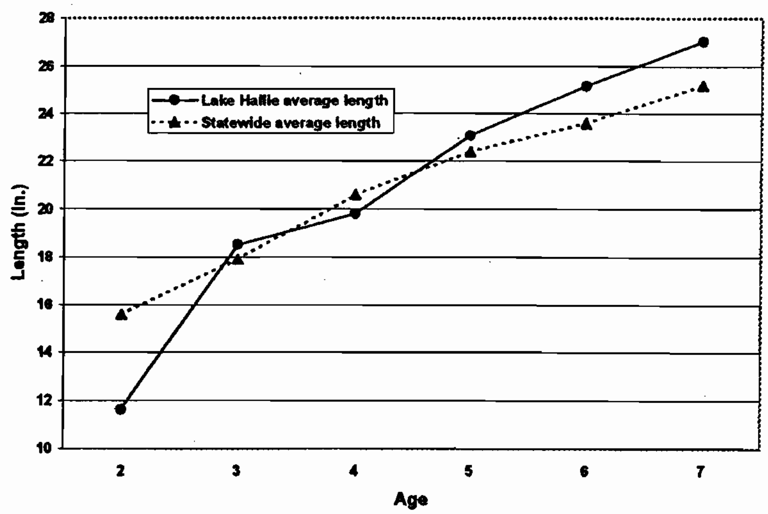



Figure 7. Northern pike relative weight in Lake Hallie, spring 2001

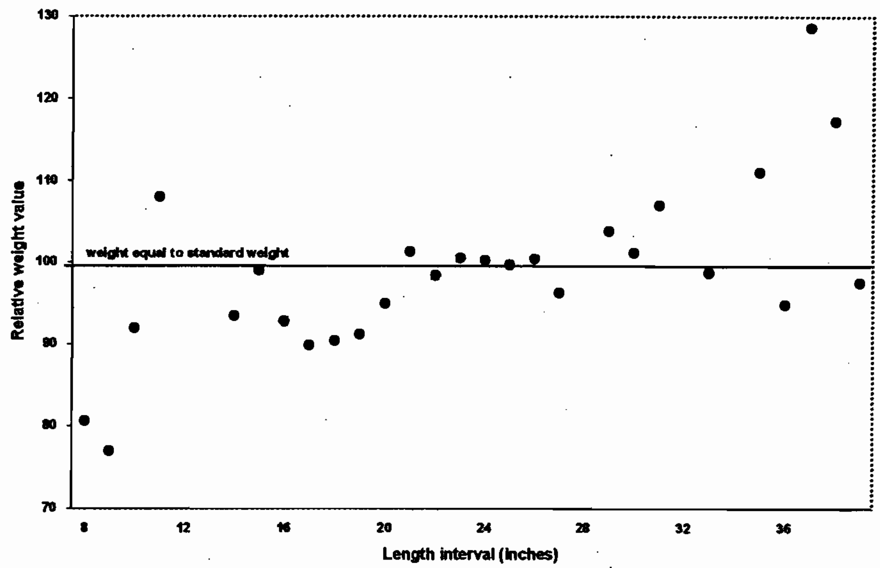
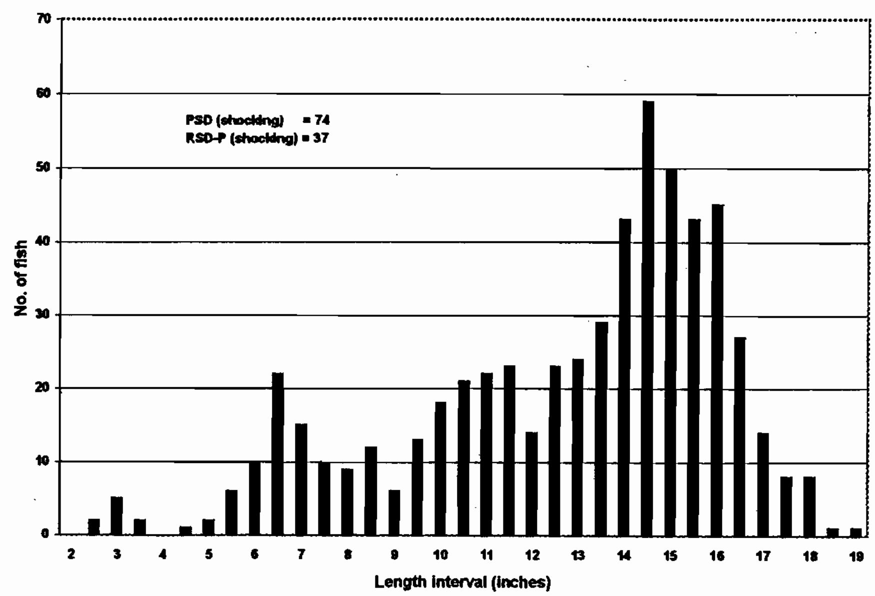



Figure 8. Largemouth bass length frequency in Lake Hallie, spring 2001



## Largemouth bass

Electrofishing surveys captured 92% of the entire spring catch with a CPE of 67.7 fish/hour. Netting CPE increased 423% over the 1984 net catch (Table 2). The population density for all size classes is estimated at 31.2 fish/acre (95% CI of 21.3-41.2). The density of bass ≥14" is 15 fish/acre (95% CI of 8.8-21.3), which is high compared to bass populations in other west central Wisconsin lakes (Table 3).

**Table 3. Regional largemouth bass population densities**

| Lake | County | Acres | Survey period | No. of fish per acre ≥8" | ≥10" | ≥12" | ≥14" | ≥15" |
|---|---|---|---|---|---|---|---|---|
| **Lake Hallie** | **Chippewa** | **79** | **May-01** | **24.2** | **22.8** | **18.9** | **15.0** | **7.8** |
| Lake Como | Chippewa | 96 | Apr-00 | 12.2 | 10.6 | 9.7 | 6.6 | 3.2 |
| Half Moon Lake | Eau Claire | 132 | Sep-99 | 36.6 | 23.9 | 14.8 | 7.0 | 3.0 |
| Bass Lake | St. Croix | 417 | Apr-97 | 12.4 | 8.0 | 3.2 | 0.6 | na |
| Glen Lake | St. Croix | 84 | Apr-95 | 63.7 | 30.2 | 13.0 | 2.6 | na |
| Perch Lake | St. Croix | 43 | Apr-94 | 13.3 | na | na | na | na |
| Spring Valley Lake | St. Croix | 126 | Apr-95 | 19.1 | 17.2 | 10.9 | 2.7 | na |
| Squaw Lake | St. Croix | 129 | Apr-96 | 16.5 | 15.6 | 12.9 | 9.8 | na |
| Nugget Lake | Pierce | 116 | Apr-95 | 15.3 | 15.1 | 14.5 | 3.2 | na |

Bass ranged from 1.5"-19.2" with larger fish dominating the population (Figure 8). Bass ≥14" represented 51% of the catch. The PSD value of 74 (95% CI of 70-78) is above the recommended range of 40-70 for balanced bass/bluegill populations but within the range of 50-80 for quality bass fishing (Gabelhouse 1984). The RSD-P value of 37 is within the range for both balanced bass/bluegill populations (10-40) and quality bass fishing (30-60). The age structure of the catch is dominated by older fish, with 77% being 5 years and older (Figure 9). Nine age classes (2-10) are present. Age classes 2-6 and 8 have significantly (P=0.05) slower growth rates than fish in other west central Wisconsin waters (Figure 10). Total annual mortality of 5-10 year old fish is 48.3% ($R^2$ =0.839), which is somewhat low compared to mortality rates of similar age classes in other Wisconsin waters. Relative weight values are generally within ±10% of standard weight values (Figure 11).

Summer survey efforts yielded six young-of-the-year (YOY) bass from netting and 22 from electrofishing efforts. Only four older bass were caught with both gear types.

**Figure 9. Largemouth bass catch curve for ages 2-10 in Lake Hallie, spring 2001**

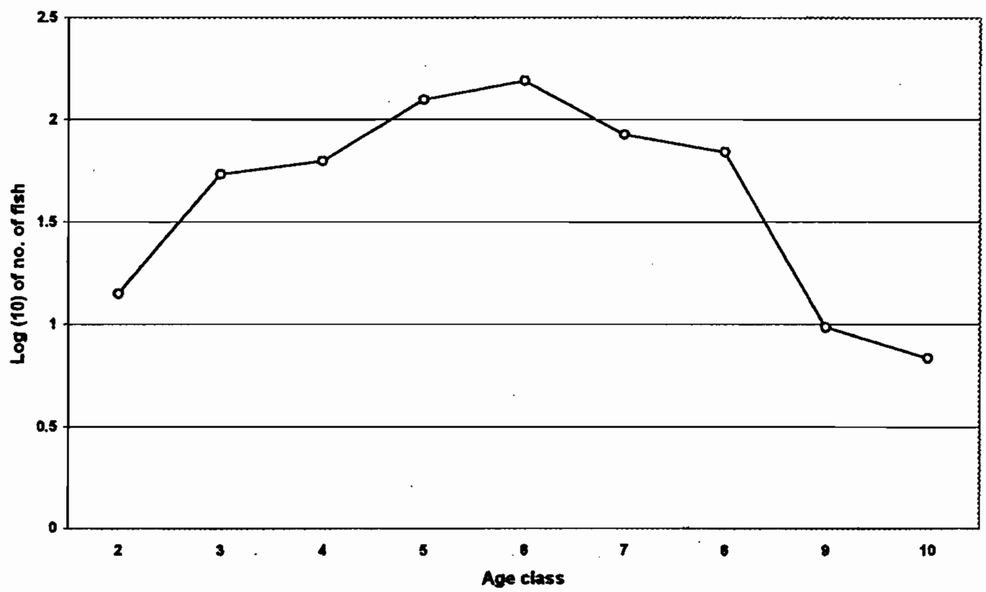


**Figure 10. Largemouth bass growth rate in Lake Hallie compared to west central Wisconsin waters**

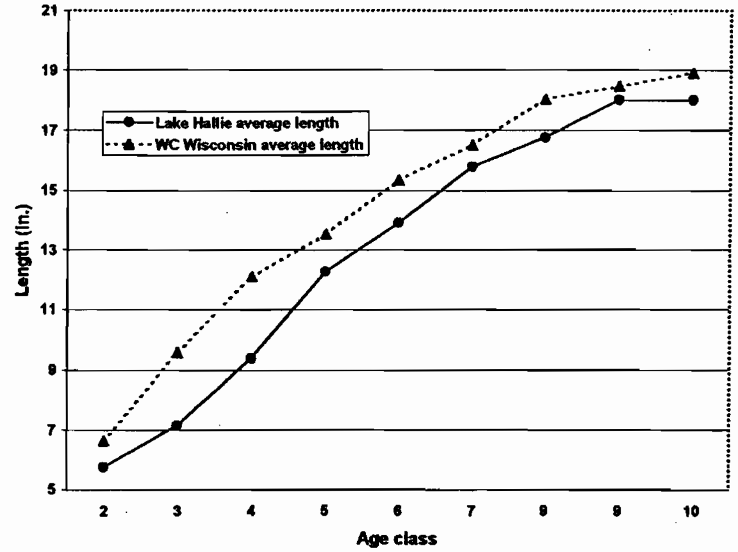



**Figure 11. Largemouth bass relative weight in Lake Hallie, spring 2001**

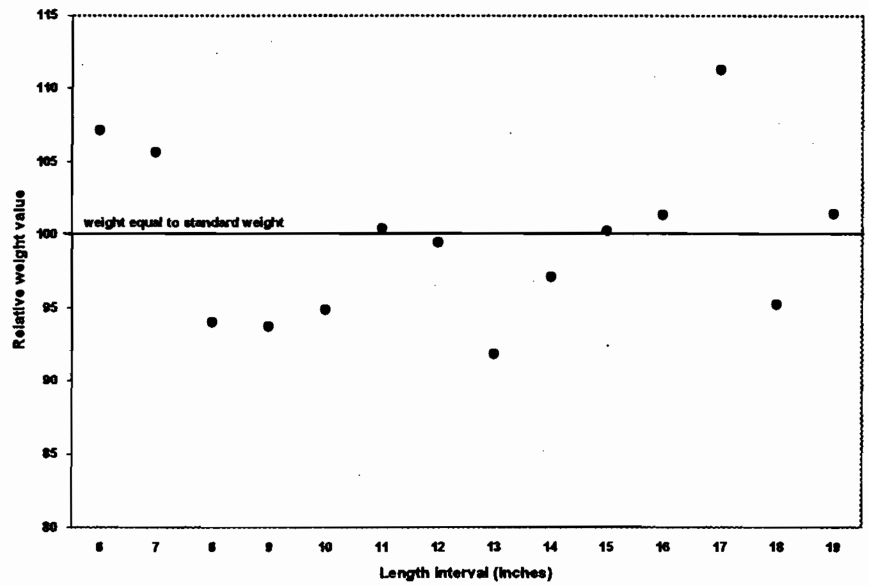
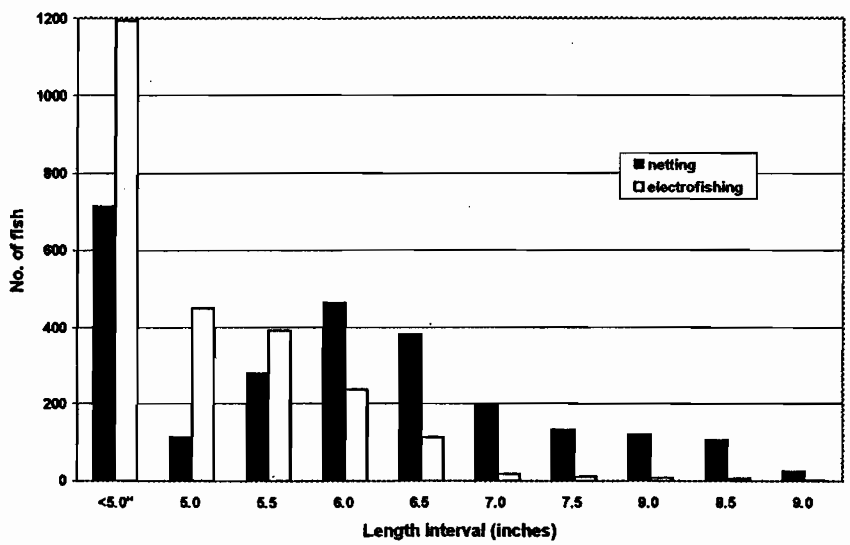



**Figure 12. Bluegill length frequency by gear type for Lake Hallie, spring 2001**



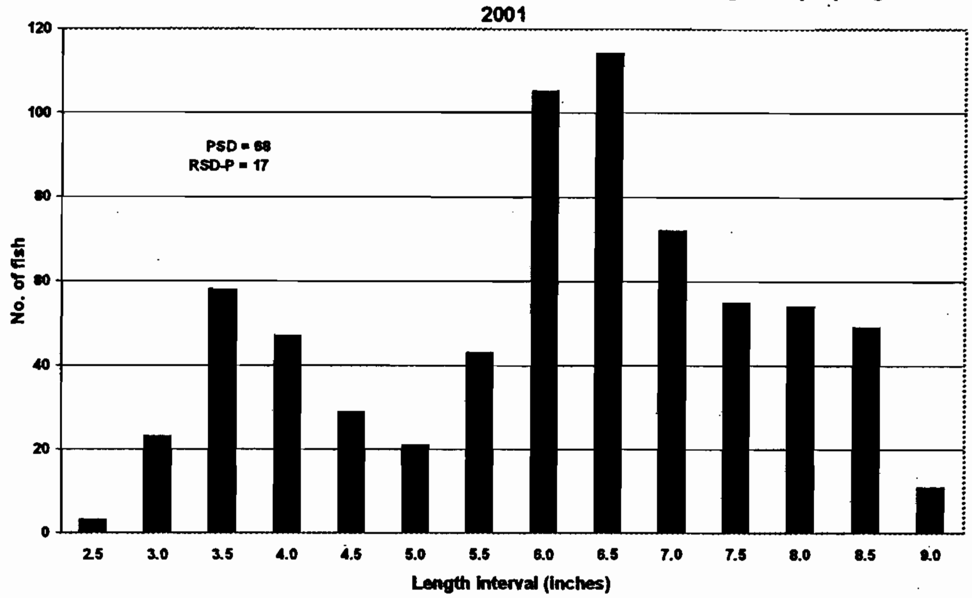
**Bluegill**

Spring survey efforts captured 4,962 bluegills. Approximately half were collected with each gear type. Netting CPE was 83% greater than the 1984 net catch. Electrofishing CPE was 545 fish/hour. The entire catch ranged from 2.5"-9.4", with 38.5% <5" and 77.4% <6 ".

Gear bias is evident in the catch size structure. Fyke nets captured a greater percentage of larger fish than electrofishing (Figure 12). Preferred-size fish (≥8") comprised 10% of the net catch and 0.6% of the electrofishing catch. Bluegills <6" comprised 84% of the electrofishing catch and 43% of the net catch.

The net catch through April 12 (684 fish) is used to evaluate population size structure (Figure 13). The average length during this period was 6.3", with preferred size fish comprising 17% of the catch. The PSD value of 68 (95% CI of 64-71) is above the recommended range for balanced bass/bluegill populations (20-60) but within the range for quality bluegill fishing (50-80). The RSD-P value of 17 is within the recommended ranges for balanced bass/bluegill populations (5-20) and quality bluegill fishing (10-30) (Anderson 1985, Willis et al 1993).

**Figure 13. Bluegill length frequency from the Lake Hallie netting survey, spring 2001**




The catch is represented by seven age classes (1-7). Age 3 fish have significantly (P=0.05) slower growth than fish in NW Wisconsin lakes, while ages 4-7 have significantly faster growth (Figure 14). Age 4 fish, which average 5.7", dominate the catch. Total annual mortality is calculated using fish ≥5". For fish 4-7 years old, the mortality rate is 74% ($R^2$ = 0.942). This rate is on the high side when compared to bluegills in other Wisconsin lakes. Relative weights (Figure 15) increase with length up to the 9-inch class, and then drop precipitously.

Summer survey efforts yielded 685 YOY in the net catch and 62 in electrofishing efforts. Only 56 bluegills one year and older were caught using both gears.

**Black crappie**

Few crappies (176) were caught in spring surveys, and summer surveys yielded only four YOY. Netting yielded 86% of the spring catch. Netting CPE was 65% lower than the 1984 catch (Table 2). The spring electrofishing CPE was 4.4 fish/hour. Crappie ranged from 2.7"-13.7" and averaged 7.5" (Figure 16), with 80% less than quality-size (8") and only 3.4% ≥10", the preferred-size. The PSD value of 21 (95% CI of 14-28) is below the recommended range of 30-60, and the RSD-P value (4) is below the recommended range of >10 (Gabelhouse 1984). These low values may reflect the poor representation (low sample size) of the population.

Aging samples collected from fish ≥5" contained five age classes (3-7). Age 4 fish (average 7.8") represented 78.5% of the sample (Figure 17). Age 3 fish have significantly (P=0.05) slower growth than fish in NW Wisconsin lakes, while age 4 fish show no significant difference (Figure 18). Aging samples for ages 5-7 were too small to detect significant differences. The total annual mortality rate of age 4-7 fish is 79.1% ($R^2$ = 0.864). This is high compared to rates in other Wisconsin lakes. Relative weight values predominantly are within –10% of standard weight values (Figure 18). However, sample sizes for fish <6" and >9" are small and may not be representative of the population.

Figure 14. Bluegill growth rate in Lake Hallie compared to NW Wisconsin lakes

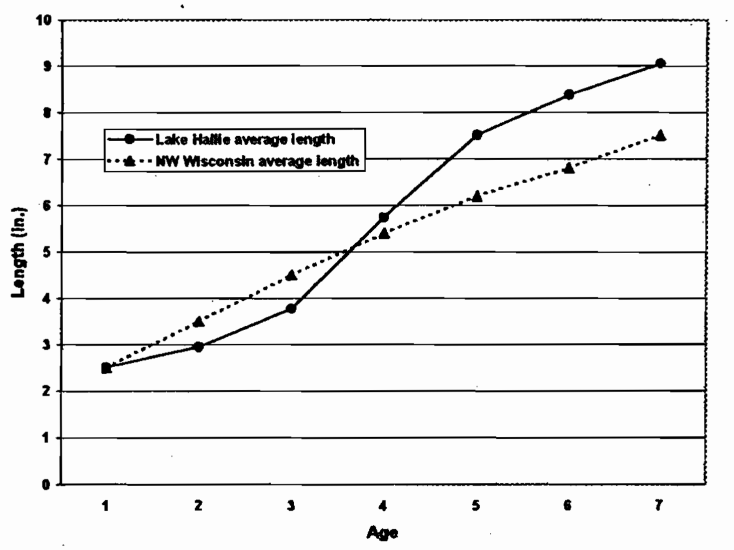



Figure 15. Bluegill relative weight in Lake Hallie, spring 2001

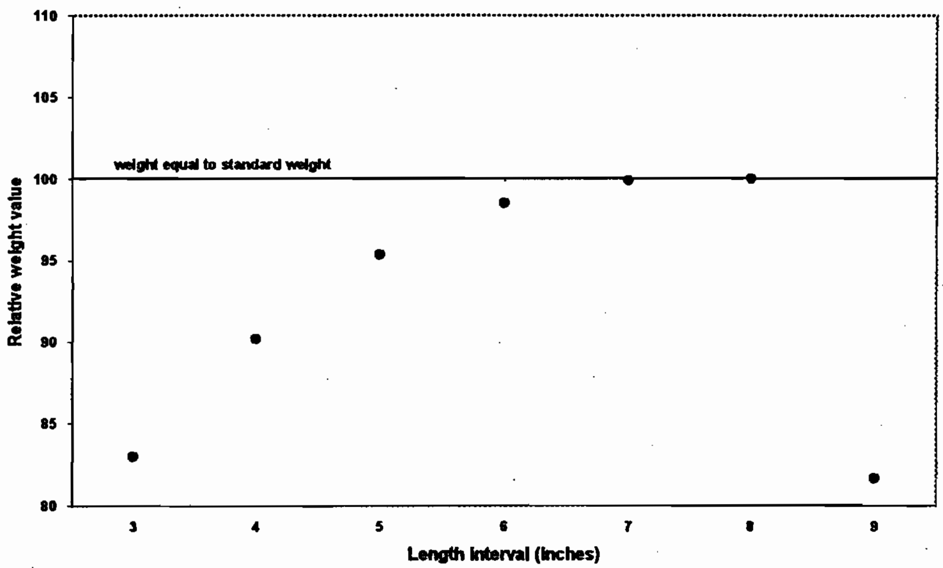



Figure 16. Black crappie length frequency in Lake Hallie, spring 2001

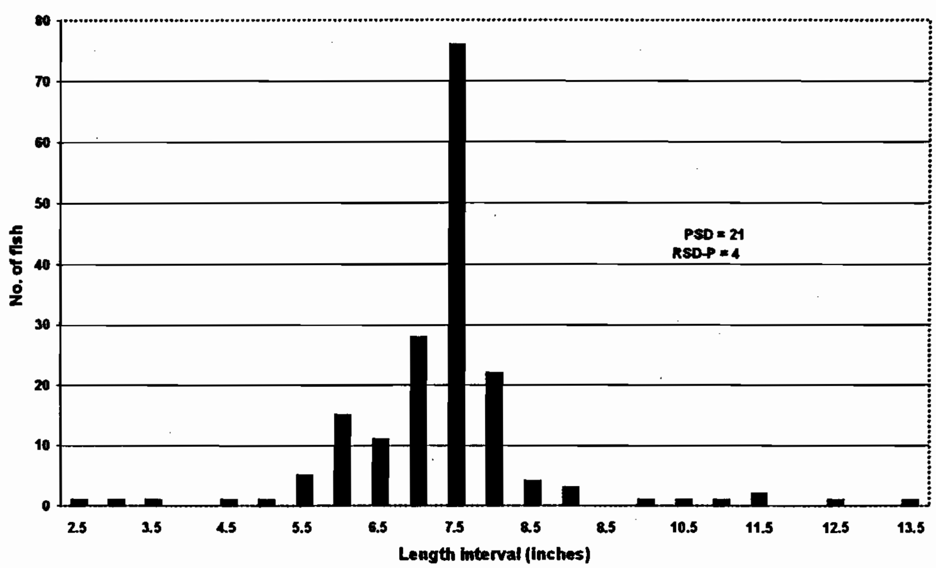


Figure 17. Black crappie catch curve for ages 3-7 in Lake Hallie, spring 2001

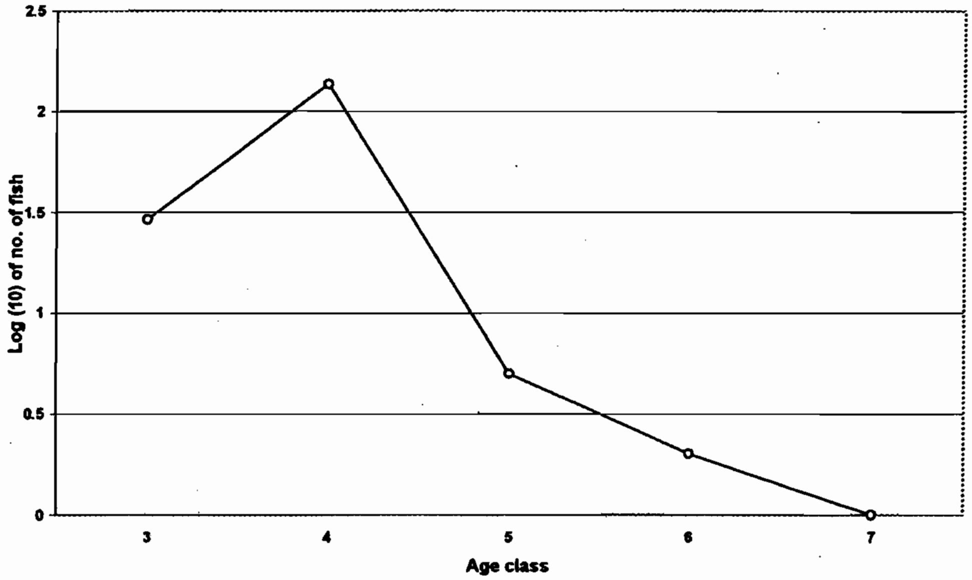
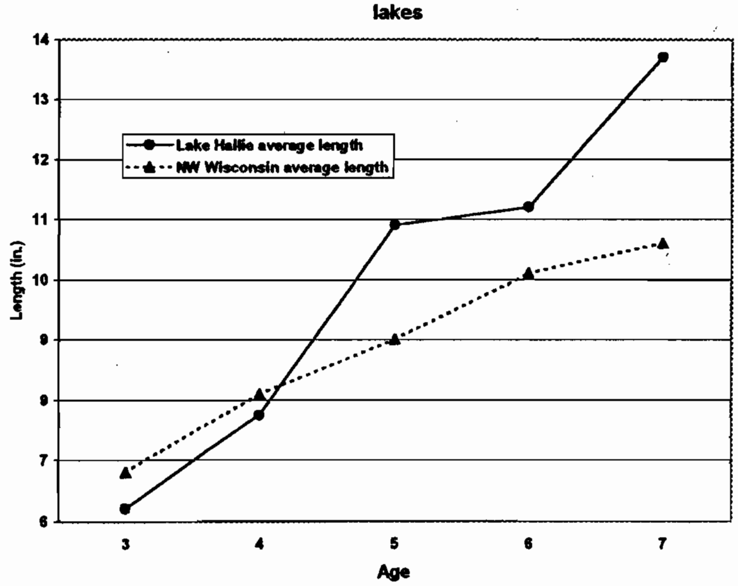



Figure 18. Black crappie growth rate in Lake Hallie compared to NW Wisconsin lakes




**Other species**

The spring catch of pumpkinseed was 118 fish. The spring netting CPE was 89% lower than the 1984 net catch (Table 2). Electrofishing CPE was 18.3 fish/hour. Pumpkinseed ranged from 3.0"-7.4" and averaged 5.8".

Only nine yellow perch were caught, all in the spring net catch. Netting CPE for yellow perch was 96% lower than the 1984 net catch (Table 2).

Netting CPE for yellow bullhead and white sucker increased 584% and 62%, respectively, from the 1984 netting survey (Table 2).

# Discussion

**Northern pike - yellow perch - rainbow trout**

Northern pike were first discovered in Lake Hallie during the spring 1984 netting survey. Eleven fish were captured, which ranged from 18.5"-30.9". The expansion of the Lake Hallie northern pike population is similar to what occurred in Lake Como (Kurz 2001). Both lakes experienced introductions of northern pike in the early 1980s. Once populations became established, they flourished with the available habitat and food resources. The 2001, Lake Hallie netting CPE for northern pike was 12.4 times greater than in 1984, while Lake Como experienced a 15.5 fold increase in netting CPE from 1985-2000. Significant changes in the fish community occurred with the expansion of northern pike populations in both lakes.

Lake Hallie experienced a significant decrease in the yellow perch population, similar to Lake Como. Net catch rates of perch declined 96% in Lake Hallie and 91% in Lake Como. In spring 1984, perch up to 11" were present in Lake Hallie. Northern pike are assumed to be the reason for the collapse in these perch populations.

Yellow perch are a preferred prey item for northern pike (Reed and Parsons 1996, Seaburg and Moyle 1963, Diana 1979), and in some waters northern pike have caused major declines in perch populations (Kempinger and Carline 1978, Anderson and Schupp 1986). Northern pike prefer soft-rayed fishes to spiny-rayed fishes as food items (Coble 1973, Beyerle and Williams 1968). One of the primary reasons for this preference is the typical, cylindrical body shape of soft-rayed fishes (He and Kitchell 1990). Johnson (1969) found that 84% of the food items in northern pike stomachs had body depths ranging from 0.5 to 1.5 inches, and that length of a prey item did not seem to be a critical factor in a pike's ability to swallow prey. Even though perch are a spiny-rayed fish, it's their cylindrical body shape that makes them an ideal prey item for northern pike.

A rainbow trout fishery was established in Lake Hallie in 1969 to provide an immediate fishery following chemical treatment of the lake. Stocking was supposed to last for only 3 years but was sustained for over 30. However, a trout fishery was maintained for only a little more than 20 years because of good growth and survival of trout. In the late 1980s, ice anglers were still catching trout > 20" in the upper half of the lake. However, in the early 1990s, the winter trout fishery became non-existent. By the late 90s, anglers noticed a significant decrease in their open-water catch, even within the first month after stocking. Trout were stocked in the upper third of the lake, one to six weeks prior to the fishing opener.

With the discovery of low winter oxygen levels in 2000, it was suspected that over-winter survival might be due, in part, to periodic, low winter oxygen. However, these conditions likely existed prior to the 1990s with little or no impact on the winter trout fishery. The winter trout fishery existed in the upper portion of the lake where oxygen levels have been found to be adequate to support healthy fish populations. And, although rainbow trout prefer well-oxygenated water, they can survive at low oxygen levels (Becker 1983). The next consideration for poor trout survival was with summer water temperatures. Rainbow trout are tolerant of a wide temperature range, from about 0° to 83°F. When water temperatures are below 70°F, rainbow trout are usually near the surface, but as the upper water layer warms trout move downward tending to reside at levels between 60-70°F (Becker 1983). Rainbow trout had cool water refuges available to them in groundwater discharge areas and in deeper portions of the lake. Thus, water temperatures are not considered to be a reason for poor trout survival. The only reasonable explanation for poor survival is predation by northern pike.

Stocked rainbow trout are ideal prey items for northern pike because of their cylindrical body shape (Coble 1973, Beyerle and Williams 1968, He and Kitchell 1990). Add to that, fish raised in hatcheries are less wary and have poorer survival instincts than native fish. Hunt (1965) found that trout constituted 54% of the food items in northern pike stomachs, with rainbow trout showing up more frequently than brown trout. He surmised that rainbow trout appeared to have a higher vulnerability than brown trout to predation due to their tendency to inhabit less sheltered sites in addition to them being less wary in nature. In a study of northern pike life history and their competition with trout (author unknown), northern pike ≥21" fed mostly on rainbow trout that were stocked at 6"-8". Trout were found in 75.6% of the northern pike stomachs containing food.

Northern pike in Lake Hallie have significantly faster growth rates for most age classes, especially females. This may be attributed to their predation on trout, which are high nutrition fish. Beyerle (1971) found that age 2 northern pike in a pike-minnow-salmon lake were on average 4.2" longer than age 2 fish in a pike-bluegill lake and 2.6" longer than age 2 fish in a pike-minnow lake. He attributed the growth difference in the pike-minnow-salmon lake to the introduction of stocked salmon. Beyerle (1971) found growth rates of northern pike in a pike-bluegill lake were somewhat less than the state average, and nowhere near the potential growth considering the amount of food present.

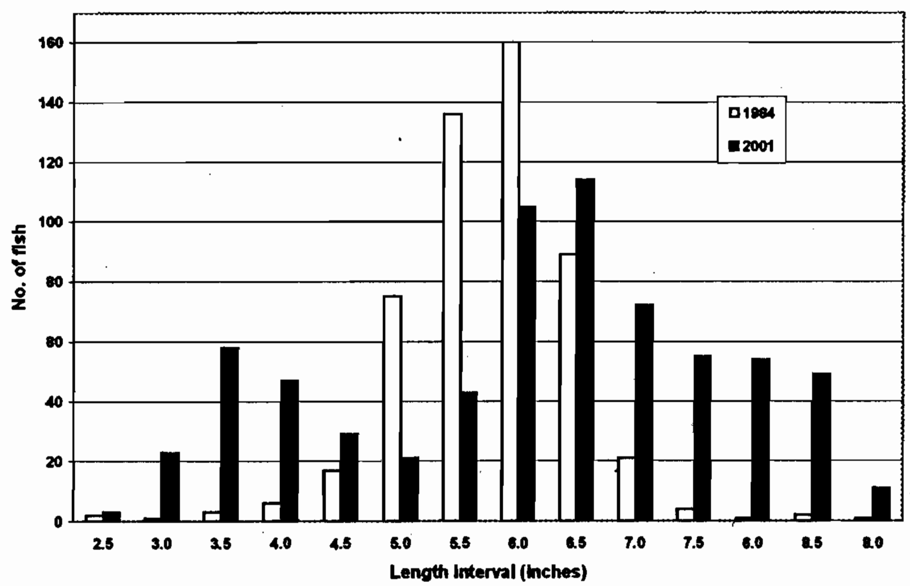
At present, the lake has a quality northern pike fishery that is popular with winter anglers. Winter is typically a high harvest period for northern pike. The Department and the lake association are working on means to improve winter oxygen conditions in the lake. With suitable oxygen levels, northern pike will remain active and become more susceptible to winter harvest. An increase in angler harvest may shift northern pike size structure towards a population dominated by smaller fish, similar to Lake Como (Kurz 2001). In addition, with the absence of rainbow trout, prey items for northern pike consist primarily of juvenile bluegill, black crappie and largemouth bass. With these species as prey, it is likely that northern pike will not retain above average growth rates. To maintain a quality northern pike fishery, it may be necessary to limit angler harvest.

**<u>Largemouth bass and bluegill</u>**

Lake Hallie has a high density of legal-size bass when compared to other west central Wisconsin lakes. No historical data is available to compare the current size structure to populations prior to the 14" minimum size limit. However, if bass in Lake Hallie responded to the size limit similar to other area lakes (Kurz 2001, Parkhurst and Kurz, 2001), the minimum size limit undoubtedly had a beneficial impact on improving size structure. The size and age structure of the bass population is skewed towards larger, older fish, and the mortality rate of fish 5 years and older is somewhat low. This may be indicative of low angler harvest. Given the summer conditions of dense aquatic vegetation and filamentous algae, boating and angling activities are hampered. Six of nine age classes have significantly slower growth rates than fish in other west central Wisconsin lakes. This may be attributed to the dense growth of aquatic vegetation, which makes predation difficult. Konkel (1999) found rooted aquatic plants covering 94% of the littoral zone in 1998 resulting in an over abundance of cover to fish.

The bluegill populations of 1984 and 2001 vary in size structure (Figure 19). The 1984 population had a balanced ratio of quality-size (≥6") to stock-size fish (≥3) (PSD), but a poor ratio of preferred-size (≥8") to stock-size fish (RSD-P). The reverse is present in the 2001 population, which has a higher percentage of quality-size fish. The 2001 population has an unbalanced ratio of fish ≥6" to fish ≥3" (above the recommended range), but a balanced ratio of fish ≥8" to fish ≥3". Reproduction appears excellent as shown by the summer young-of-the-year catch. The 4-year old age class is very strong and should provide excellent angling opportunities in 2002 and beyond. Fast growth rates and good length-weight relationships both reflect a healthy bluegill population.

**Figure 19. Bluegill length frequency in spring netting surveys of Lake Hallie**




The size structure of largemouth bass and bluegill populations often determines the angling quality of either or both species. Anderson and Weithman (1978) define a balanced fish population as one that is intermediate between the extremes of a large number of small fish and small number of large fish, which indicates that the rates of recruitment, growth and mortality may be satisfactory. Size structure indices provide optimum ranges for several management goals – a balanced bass/bluegill fishery where size structure is a consideration for angling of both species, a quality bass fishery that emphasizes larger bass, or a quality bluegill fishery where developing populations of larger bluegills is the goal. In balanced fish populations the interacting forces of reproduction, growth, and predation lead to a compromise. The principles involved suggest that it is not possible to have superior bluegill and bass fishing simultaneously (Davies, et al. 1979). Recruitment, growth and mortality are affected by numerous community dynamics, including but not limited to, predator-prey interactions, food availability, interspecies competition, habitat quality, and the impact of angler harvest.

Figures 20 and 21 reflect size structure relationships for bass and bluegill in conjunction with various management goals for a bass/bluegill fishery. Similar relationships are shown for Lake Como and Half Moon Lake for comparison. The RSD graph reflects a balanced bass/bluegill population in Lake Hallie. The PSD graph reflects a higher than recommended ratio of quality- to stock-size fish for both species. This high ratio for bass is likely due to the combination of a low mortality rate of 5-10 year old fish and the low number of 1-4 year old fish. Since bluegill PSD was determined from the net catch, the high ratio of fish ≥6" to fish ≥3" may be a result of gear bias. Electrofishing gear was more efficient at capturing 3"-5.9" bluegill. If these fish were more prevalent in the net catch, a lower PSD value would have resulted. However, Reynolds and Simpson (1978) found that electrofishing underestimates the size structure of a bluegill population.

Figure 20. Largemouth bass and bluegill Proportional Stock Density

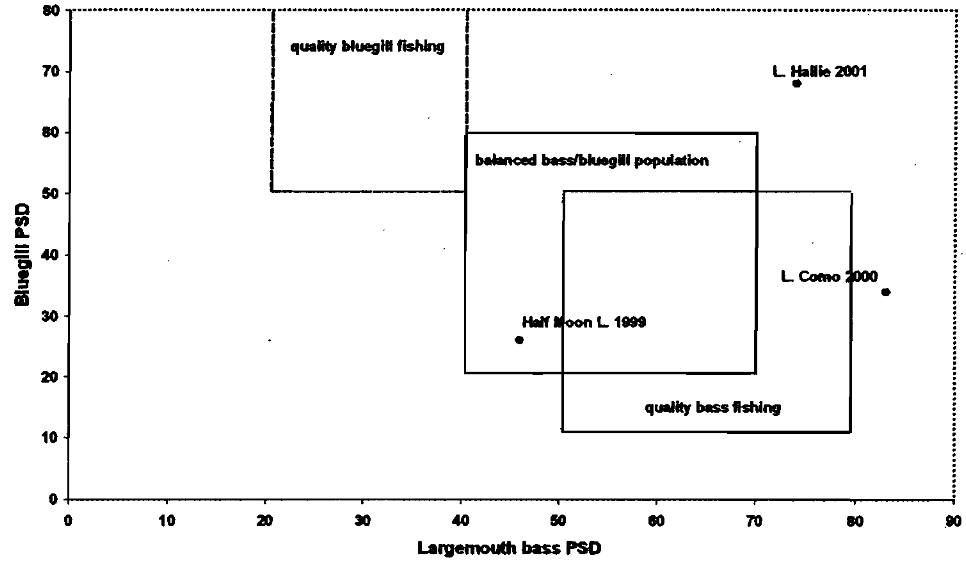
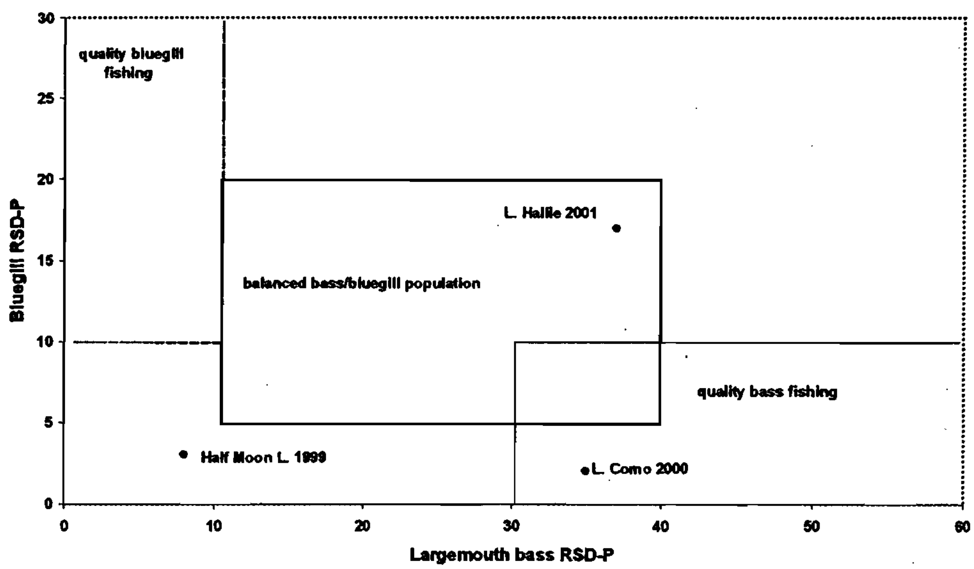



Figure 21. Largemouth bass and bluegill Relative Stock Density




A concern exists with the poor representation of largemouth bass less than 5 years old. In addition to what appears to be poor recruitment from 1997-2000, very few YOY bass were collected in summer 2001. Bass spawning habitat is widespread in the lake, and it seems unlikely that spawning conditions, primarily water temperatures, were poor for five consecutive years. It is possible that predation may be a major factor controlling bass recruitment. Post et al (1998) found that successful recruitment of young-of-the-year fish is not correlated with number of fish hatched; instead, predation and overwinter mortality were more likely constraints on recruitment through the first year of life. They also found that in years of high adult and juvenile bass abundance that most young-of-the-year bass were cannibalized. With a moderate population of northern pike and a dense population of adult bass, predator density in Lake Hallie is high. Lake Como experienced a similar problem with poor representation of young to middle-aged bass (Kurz 2001). The Lake Como bass population was about half the density of Lake Hallie's, but 52% of the population was 8-12 years old. The northern pike population in Lake Como was approximately 7 times greater than Lake Hallie's.

In the absence of rainbow trout, prey items for northern pike consist primarily of centrarchid panfish (bluegill, pumpkinseed and black crappie) and juvenile largemouth bass. Bluegill is the most abundant prey item in the lake, however northern pike are ineffective predators of bluegills (Snow 1974, Mauck and Coble 1971, Beyerle 1971). Northern pike will prey on young centrarchid panfish; but they are unable to swallow larger individuals because of a small gullet. Juvenile largemouth bass, which have a more cylindrical body shape than centrarchid panfish, may be an easier prey for northern pike to ingest.

Mechanical harvesting of rooted aquatic plants has been conducted in Lake Hallie since 2000. Half Moon Lake experienced an increase in bluegill size structure after a harvesting program was initiated (Parkhurst and Kurz 2001). Since bass can effectively prey on bluegill only along the periphery of dense macrophyte beds, mowing vegetation to create additional edge may improve growth rates and size structure of both species (Trebitz et al. 1997). Olson et al. (1998) found that the growth rates of some age classes of largemouth bass and bluegill improved after mechanical harvesting removed approximately 20% of the vegetation in the littoral zone. In another study, bass growth rates increased after most simulated vegetation removals, but bluegill grew fastest when about 30% of the vegetation was cut. Bluegills responded negatively to mowing more than 50% of the plants (Trebitz et al. 1997).

Improving winter oxygen conditions may have the greatest impact on bluegill populations. Low winter oxygen levels, which reduce fish activity, likely reduce bluegill harvest at a time when harvest is typically the highest in Wisconsin lakes. Providing adequate winter oxygen levels will likely reverse this trend. This was evident in January 2001 after a temporary aeration system increased oxygen levels throughout the lake. With improved oxygen levels, anglers reported improved fishing conditions.

The mechanical harvesting of plants and the improvement in winter oxygen levels have the potential of increasing angler harvest of bluegills by providing improved angling conditions. Angler harvest can be a major influence on bluegill size structure. This was evident in Half Moon Lake where few bluegill were found >7" (Kurz and Parkhurst 2001). With a greater harvest of quality-size fish (≥6"), the PSD may decrease to within the recommended range for balanced bass/bluegill populations. However, a high harvest of preferred-size bluegills (≥8") may drop the RSD below the recommended range for balanced bass/bluegill populations. If angler harvest effectively reduces the quality of the bluegill size structure, consideration should be given to reducing angler harvest through more stringent regulations.

## Conclusions and Management Recommendations

*1).<u>Rainbow trout stocking</u>*

A stocking program for rainbow trout, which originally was to last for only 3 years, has been ongoing for over 30. Since the late 1990s, the return of trout to the angler's creel has declined dramatically, even within the first month after stocking. A winter fishery for trout, which existed up to the early 1990s, has disappeared. In the mid-1980s, northern pike were introduced to the lake. The subsequent expansion of the population has resulted in a very popular winter fishery. However, northern pike predation on trout is considered the prime reason for the decline in the trout fishery. For the small return trout stocking brought in recent years, it is no longer practical to stock trout on top of a healthy northern pike population. Stocking was eliminated in 2002.

*2) <u>Northern pike management</u>*

A quality northern pike population currently exists in Lake Hallie. A popular, winter fishery has developed with notoriety for producing large fish. Above average growth rates are attributed to their predation on rainbow trout, a high nutrition prey. In the absence of trout, growth rates will undoubtedly slow to average or possibly below average. Efforts to improve winter oxygen levels are expected to produce better fishing action, which may lead to higher harvest levels and a possible reduction in northern pike size structure. In order to maintain quality in the northern pike fishery, it may be prudent to control harvest by enacting a minimum size limit and/or reduce the daily bag limit. With the current set of regulations available for use with northern pike, a 26" minimum size limit with a daily bag limit of 2 is the most appropriate regulation to consider. Refer to the monitoring recommendation below.

*3) <u>Largemouth bass management</u>*

Bass have below average growth rates but a good length-weight relationship. Poor recruitment, which was documented for five year classes, may be a result of predation on juvenile fish. A county resolution passed at the 1998 rules hearing proposed a reduction of the bass bag limit of five to two. The justification was that most legal-size bass (≥14") were being harvested during the first few weeks of the fishing season. The 2001 survey indicated a high density of adult and legal-size bass in the lake. Based on survey results, the current bass regulation should be retained. The minimum size limit apparently was instrumental in improving bass size structure. Dense aquatic vegetation impedes the angler's ability to catch bass during much of the open-water season. Mechanical harvesting of aquatic plants is expected to improve angler catch and harvest of bass. The harvesting program may improve bass growth rates by creating additional edge habitat that is suitable for bass foraging activity. Refer to the monitoring recommendation below.

4) *Panfish management*

Bluegill is the dominant panfish, followed by black crappie and yellow perch. The bluegill population has a good size structure, above average growth rates and a high recruitment rate. Crappies have a lower density and a smaller than desirable size structure. The yellow perch population has declined significantly since the 1984 survey, which is most likely attributed to predation by northern pike. Current lake management activities could indirectly affect density and size structure of panfish populations through increased predation and/or angler harvest. Stocking should be considered as an option to restore yellow perch populations. However, introduction of perch may only act as a food resource for northern pike. If a viable perch population could be reestablished, careful consideration should be given to the competition perch may pose with bluegills and crappies. A county resolution passed at the 1998 rules hearing proposed a reduction in the bag limit of panfish from 25 to 15. Based on survey results, it is recommended that the panfish bag limit remain at 25. However, if increased angler harvest reduces size structure quality, then a reduced bag limit may be appropriate. Refer to the monitoring recommendation below.

5) *Aquatic plant management*

Mechanical harvesting of aquatic plants was implemented to control the curly-leaf pondweed population and to improve fish habitat and angling opportunities. Reducing plant biomass also may lower winter oxygen demand. It is recommended that mechanical harvesting be continued. The current harvesting plan should be reevaluated to determine its effectiveness in reaching the above objectives. Additional areas of dense vegetation may need to be included to further improve habitat conditions.

6) *Winter oxygen levels*

Despite low oxygen levels during the winters of 1999-2000 and 2000-2001, fish populations are in relatively good shape. If this winter condition persists, fish populations may begin to suffer. The upper third of the lake provides a winter oxygen refuge. However, concentrating fish into a smaller lake area increases the stress level of individuals, which may lead to post-winter fish kills due to bacterial or viral infections. A temporary aeration system used in early 2001 did an excellent job of providing higher oxygen levels throughout the lake. Anglers found improved fish activity with this system in place. For the winters of 2001-02 and 2002-03, stoplogs have been removed from the bottom draw, outlet structure to remove oxygen-poor water from the bottom. With this practice, oxygen levels above 5 ppm have been maintained throughout the lake. Winter oxygen concentrations should be monitored to determine if continued use of this practice provides adequate oxygen levels. If oxygen levels cannot be maintained with this practice, then plans for installation of a permanent aeration system should go forward.

7) *Groundwater discharge*

An area of groundwater discharge in the northeast end of the lake once provided a large area of open water during winter. This area provided a source of oxygen to the lake during winter via open water, and also provided coolwater habitat for fish during summer. A temperature profile in July 1999 and a piezometer study in fall 2002 indicate the contribution of groundwater to this area. The outlet discharge has not changed appreciably from 1963 to 1996, but despite similar outlet flows, the winter, open water area has decreased in size considerably over the past 10 years. Because of dense plant growth, water depths in the northeast corner have decreased due to deposition of decomposing plant matter. The organic sediments are anaerobic, and during fishery surveys few fish were observed in this area. It is not known if the location of groundwater inputs to the lake has changed appreciably, or if sedimentation has impacted the ability of groundwater to effectively flow into this area. Consideration should be given to dredging the northeast corner to improve winter and summer habitat conditions for fish. This proposal is similar to spring pond dredging done by the Department to improve habitat conditions for brook trout. Department staff should work with the lake association to conduct sediment probes in this area. Probing should be conducted during winter in a grid format to determine depth of the original lake bed as well as depth of the sediments.

8) *Monitoring of fish populations and angler activity*

Current management activities in Lake Hallie include mechanical harvesting of plants, efforts to improve winter oxygen conditions, and the curtailment of rainbow trout stocking. These activities have the potential of impacting fish populations, in particular largemouth bass, bluegill and northern pike. The results of this survey will act as a baseline of information for these management activities. It is recommended that future surveys be conducted to evaluate the impacts of lake management activities on the size structure and growth rates of bass, bluegill and northern pike before any changes in fishing regulations are implemented. The bass population should be monitored periodically to determine if recruitment continues to be a problem. A creel survey should be conducted to assess the extent of angling pressure and the impact of angler catch and harvest on fish populations.

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**Appendix 1. Stocking history of Lake Hallie**

| Date | Species | No. stocked | Size | Stage |
|---|---|---|---|---|
| 1939 | northern pike | 9,000 | | fry |
| 1940 | northern pike | 15,000 | | fry |
| 1941 | northern pike | 8,000 | | fry |
| 1942 | northern pike | 80,000 | | fry |
| 1945 | largemouth bass | 400 | | fingerling |
| | northern pike | 10,000 | | fry |
| 1946 | northern pike | 15,000 | | fry |
| 1947 | northern pike | 15,000 | | fry |
| 1948 | northern pike | 55,152 | | fry |
| 1949 | northern pike | 58,000 | | fry |
| 1950 | northern pike | 14,000 | | fry |
| 1951 | northern pike | 14,000 | | fry |
| | largemouth bass | 200 | | fingerling |
| 1952 | northern pike | 21,000 | | fry |
| 1954 | northern pike | 14,000 | | fry |
| 1955 | walleye | 200,000 | | fry |
| 1956 | largemouth bass | 200 | | |
| | black crappie | 2,000 | | |
| | bluegill | 10,000 | | |
| | walleye | 200,000 | | fry |
| 1969 | rainbow trout | 5,000 | 9" | holdover |
| | largemouth bass | 3,600 | 3" | fingerling |
| | largemouth bass | 83 | 9" | adult |
| | musky | 80 | 11-13" | fingerling |
| 1970 | rainbow trout | 5,000 | 9" | holdover |
| | bluegill | 250 | 5" | adult |
| | largemouth bass | 5,000 | 1"-3" | fingerling |
| | rainbow trout | 2,000 | 7" | fingerling |
| 1971 | rainbow trout | 5,840 | 9"-11" | holdover |
| | bluegill | 250 | | yearling and adult |
| | largemouth bass | 13,200 | 1"-3" | fingerling |
| 1972 | rainbow trout | 11,000 | 9" | holdover |
| 1973 | rainbow trout | 5,000 | 8"-9" | holdover |
| 1974 | rainbow trout | 5,000 | 9" | holdover |
| 1975 | rainbow trout | 5,000 | 11" | holdover |
| 1976 | rainbow trout | 5,000 | 9" | holdover |
| 1977 | rainbow trout | 5,000 | 10" | holdover |
| 1979 | rainbow trout | 5,000 | 4" | fingerling |
| | rainbow trout | 5,000 | 11" | holdover |
| 1980 | rainbow trout | 6,000 | 8"-9" | holdover |
| | rainbow trout | 8,000 | 6" | fingerling |
| 1981 | rainbow trout | 5,000 | 7" | holdover |
| | rainbow trout | 5,000 | 5" | fingerling |
| 1982 | rainbow trout | 5,000 | 8" | holdover |
| 1983 | rainbow trout | 5,000 | 10" | holdover |
| 1984 | rainbow trout | 2,500 | 9" | holdover |
| | brook trout | 1,400 | 8"-9" | holdover |
| | brown trout | 1,116 | 8" | holdover |
| 1985 | rainbow trout | 5,000 | 11" | holdover |
| 1987 | rainbow trout | 7,200 | 7"-9" | holdover |
| 1988 | rainbow trout | 7,500 | 7"-9" | holdover |
| 1989 | rainbow trout | 5,500 | 7"-8" | holdover |
| 1990 | rainbow trout | 5,000 | 9" | holdover |
| 1991 | rainbow trout | 5,000 | 9" | holdover |
| 1992 | rainbow trout | 5,000 | 9" | holdover |
| 1993 | rainbow trout | 5,000 | 9.4" | holdover |
| 1994 | rainbow trout | 5,000 | 6"-9.8" | holdover |
| 1995 | rainbow trout | 4,000 | 9.5" | holdover |
| 1996 | rainbow trout | 4,692 | 9.3" | holdover |
| 1997 | rainbow trout | 3,500 | 10.5" | holdover |
| 1998 | rainbow trout | 4,150 | 8.7" | holdover |
| 1999 | rainbow trout | 4,000 | 9.4" | holdover |
| 2000 | rainbow trout | 3,525 | 9.3" | holdover |
| 2001 | rainbow trout | 4,668 | 8.8"-9.1" | holdover |
| | rainbow trout | 888 | 9.1" | holdover |

Appendix 2. Summary of the 1981-82 creel survey of Lake Hallie

| | Estimated total catch | % of total catch | Estimated total harvest | % of total harvest | % of catch harvested | Average length (in.) | Harvest rate fish/hour |
|---|---|---|---|---|---|---|---|
| largemouth bass | 21820 | 20.6% | 2368 | 6.5% | 10.9% | 10.8 | 0.202 |
| bluegill | 26968 | 25.5% | 9436 | 25.8% | 35.0% | 6.4 | 0.684 |
| black crappie | 15511 | 14.7% | 5936 | 16.3% | 38.3% | 6.7 | 0.582 |
| pumpkinseed | 34536 | 32.6% | 13523 | 37.0% | 39.2% | 5.8 | 0.904 |
| walleye | 17 | 0.0% | 11 | 0.0% | 64.7% | 10.6 | |
| rock bass | 6 | 0.0% | 0 | 0.0% | 0.0% | 6 | |
| yellow bullhead | 54 | 0.1% | 24 | 0.1% | 44.4% | 11.6 | |
| yellow perch | 2956 | 2.8% | 1752 | 4.8% | 59.3% | 7.2 | 0.59 |
| rainbow trout | 3932 | 3.7% | 3466 | 9.5% | 88.1% | 11 | 0.336 |
| **totals** | 105800 | | 36516 | | | | |

# DNR Water Chemistry Data
# for
# 1991, 2001, & 2002

LAKE: Lake Hallie

YEAR 1991

COUNTY: Chippewa

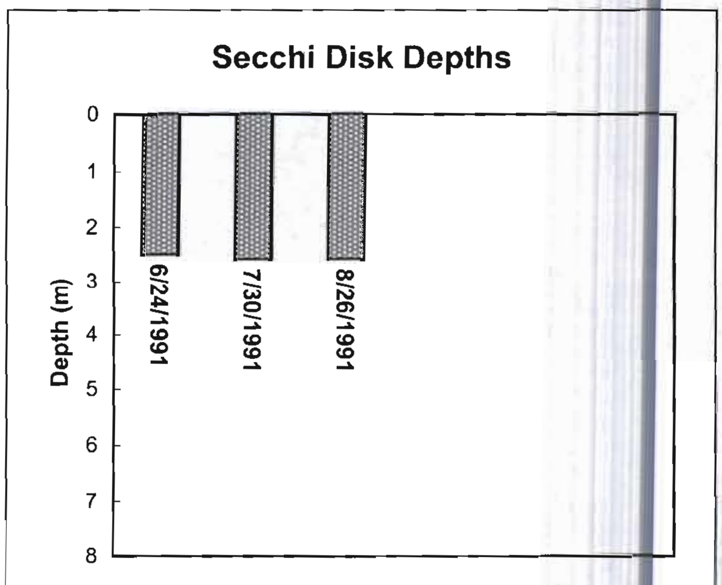
WATERBODY #: 2150200

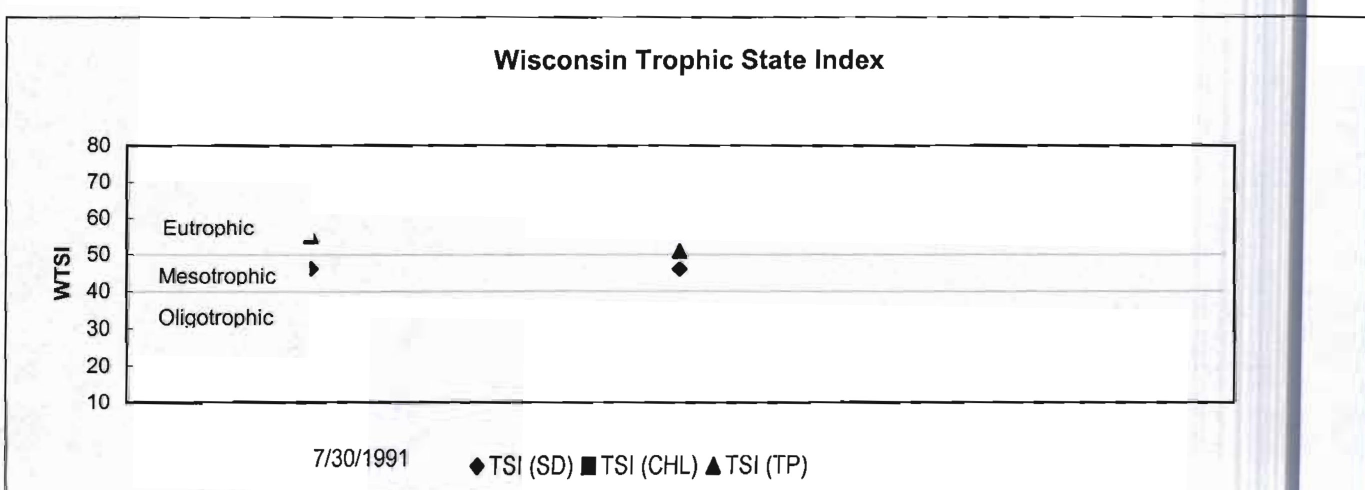
STORET #:

| DATE | SD (m) | CHL (ug/l) | TP (ug/l) | TSI (SD) | TSI (CHL) | TSI (TP) |
|---|---|---|---|---|---|---|
| 3/14/1991 | | | 69 | | | 61 |
| 6/24/1991 | 2.5 | | 40 | 47 | | 57 |
| 7/30/1991 | 2.6 | | 30 | 46 | | 55 |
| 8/26/1991 | 2.6 | | 20 | 46 | | 51 |

| DATA SUMMARY: | |
|---|---|
| Average SD (m): | 2.6 |
| Minimum SD (m): | 2.5 |
| Maximum SD (m): | 2.6 |
| Average CHL (ug/l): | |
| Minimum CHL (ug/l): | 0.0 |
| Maximum CHL (ug/l): | 0.0 |
| Spring Turnover TP (ug/l): | 40.0 |
| Fall Turnover TP (ug/l): | 20 |
| GSE* Avg TP (ug/l): | 25.00 |

*Growing Season Epilimnetic



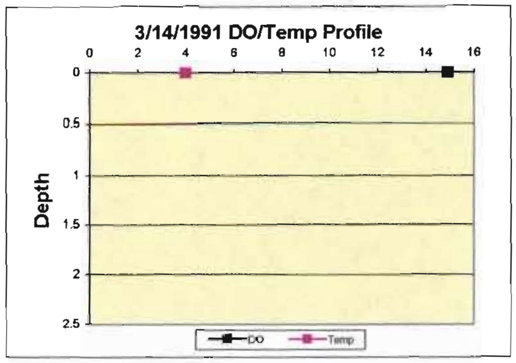



# Dissolved Oxygen / Temperature Profiles, 1991

Depth = Meters DO = mg/L

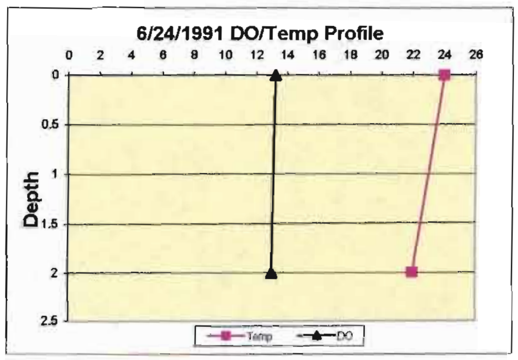
**3/14/1991**

| DO | Temp | Depth |
|---|---|---|
| 14.90 | 4.00 | 0 |



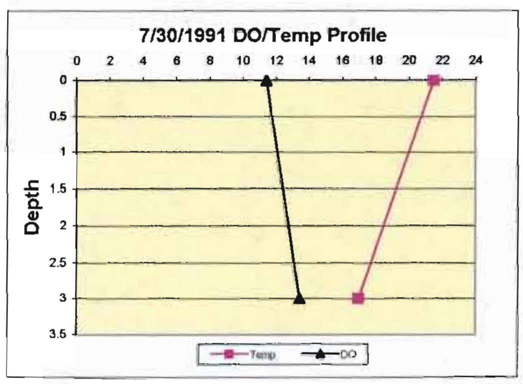

**6/24/1991**

| DO | Temp | Depth |
|---|---|---|
| 13.20 | 24.00 | 0 |
| 13.00 | 22.00 | 2 |



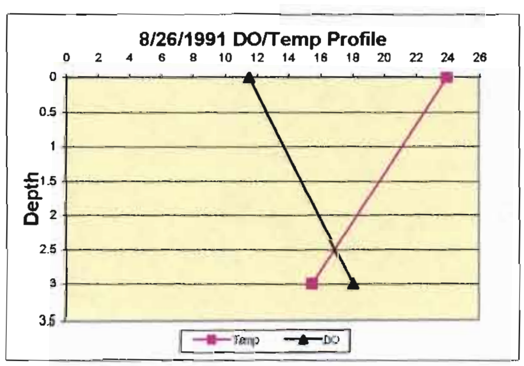

**7/30/1991**

| DO | Temp | Depth |
|---|---|---|
| 11.40 | 21.50 | 0 |
| 13.40 | 17.00 | 3 |




**8/26/1991**

| DO | Temp | Depth |
|---|---|---|
| 11.50 | 24.00 | 0 |
| 18.00 | 15.50 | 3 |



LAKE: Lake Hallie

YEAR 2001

COUNTY: Chippewa

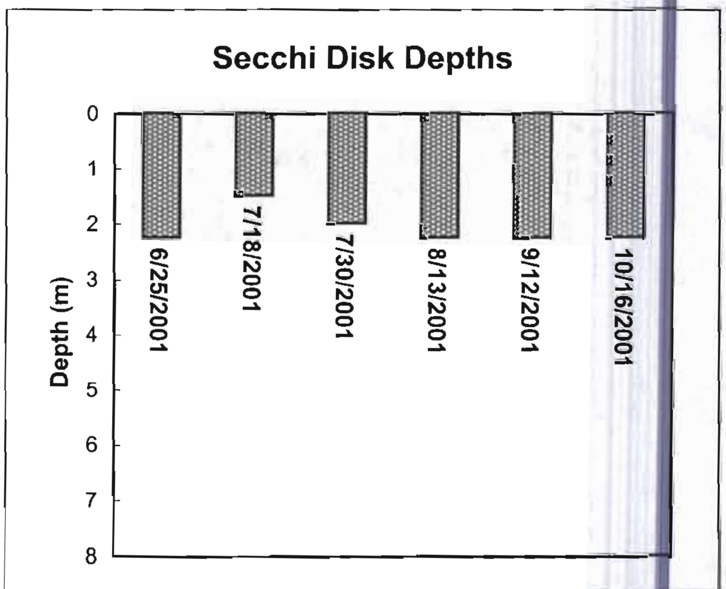
WATERBODY #: 2150200

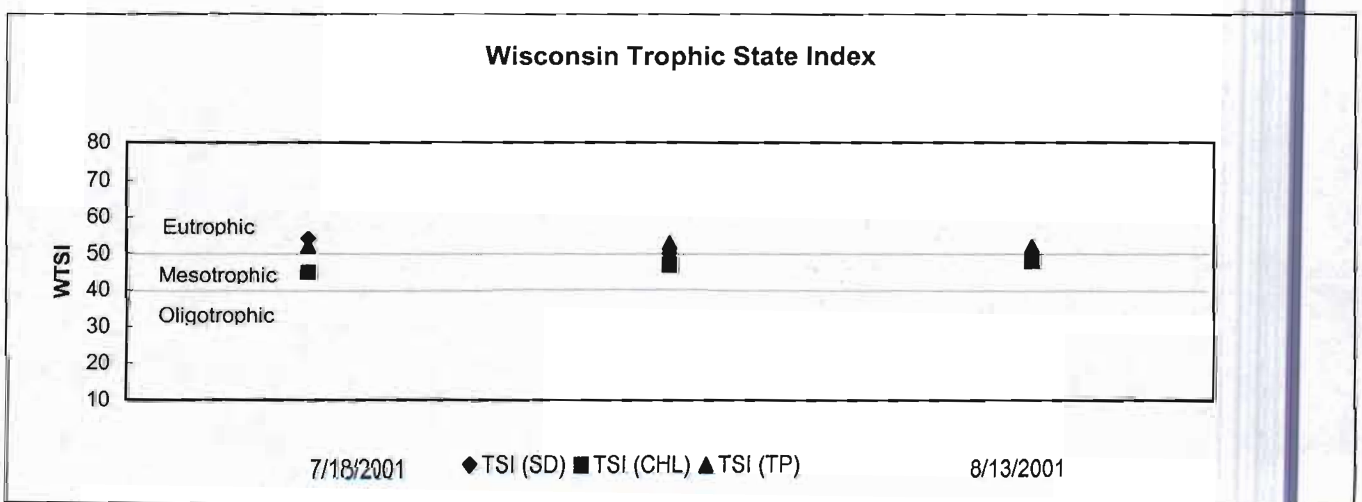
STORET #:

| DATE | SD (m) | CHL (ug/l) | TP (ug/l) | TSI (SD) | TSI (CHL) | TSI (TP) |
|---|---|---|---|---|---|---|
| 4/23/2001 | 1 | | 48 | 60 | | 58 |
| 6/25/2001 | 2.25 | 6.2 | 25 | 48 | 48 | 53 |
| 7/18/2001 | 1.5 | 4 | 22 | 54 | 45 | 52 |
| 7/30/2001 | 2 | 5 | 24 | 50 | 47 | 53 |
| 8/13/2001 | 2.25 | 6 | 22 | 48 | 48 | 52 |
| 9/12/2001 | 2.25 | 3 | 13 | 48 | 43 | 48 |
| 10/16/2001 | 2.25 | 5 | 20 | 48 | 47 | 51 |

| DATA SUMMARY: | |
|---|---|
| Average SD (m): | 1.9 |
| Minimum SD (m): | 1.0 |
| Maximum SD (m): | 2.3 |
| Average CHL (ug/l): | 4.9 |
| Minimum CHL (ug/l): | 3.0 |
| Maximum CHL (ug/l): | 6.2 |
| Spring Turnover TP (ug/l): | 25.0 |
| Fall Turnover TP (ug/l): | 20 |
| GSE* Avg TP (ug/l): | 22.67 |

*Growing Season Epilimnetic



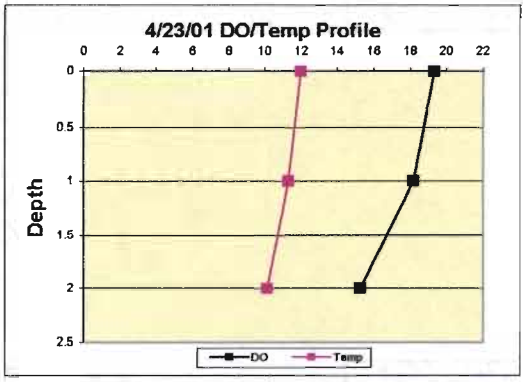



# Dissolved Oxygen / Temperature Profiles, 2001

Depth = Meters    DO = mg/L

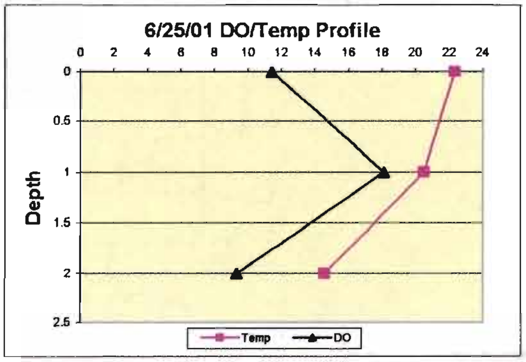
**4/23/2001**

| DO | Temp | Depth |
|---|---|---|
| 19.31 | 11.96 | 0 |
| 18.19 | 11.29 | 1 |
| 15.24 | 10.14 | 2 |



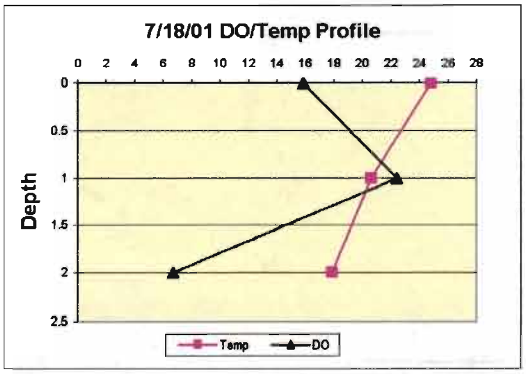

**6/25/2001**

| DO | Temp | Depth |
|---|---|---|
| 11.41 | 22.32 | 0 |
| 18.10 | 20.47 | 1 |
| 9.31 | 14.57 | 2 |




**7/18/2001**

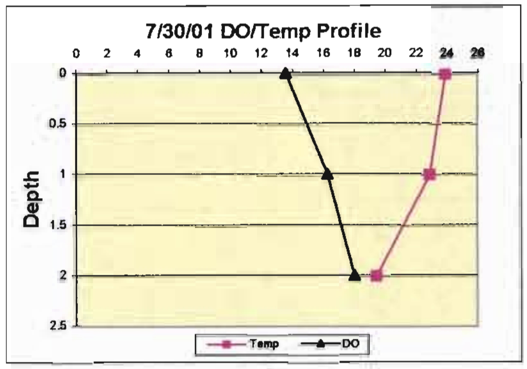
| DO | Temp | Depth |
|---|---|---|
| 15.84 | 24.82 | 0 |
| 22.41 | 20.62 | 1 |
| 6.72 | 17.87 | 2 |



# Dissolved Oxygen / Temperature Profiles, 2001

**7/30/2001**

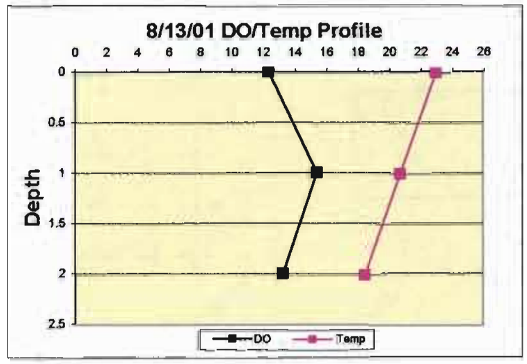
| DO | Temp | Depth |
|---|---|---|
| 13.55 | 23.94 | 0 |
| 16.25 | 22.93 | 1 |
| 18.00 | 19.49 | 2 |



7/30/01 DO/Temp Profile

**8/13/2001**

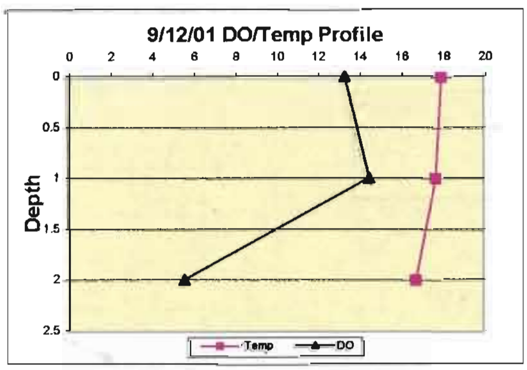
| DO | Temp | Depth |
|---|---|---|
| 12.31 | 23.04 | 0 |
| 15.38 | 20.75 | 1 |
| 13.20 | 18.51 | 2 |



8/13/01 DO/Temp Profile

**9/12/2001**

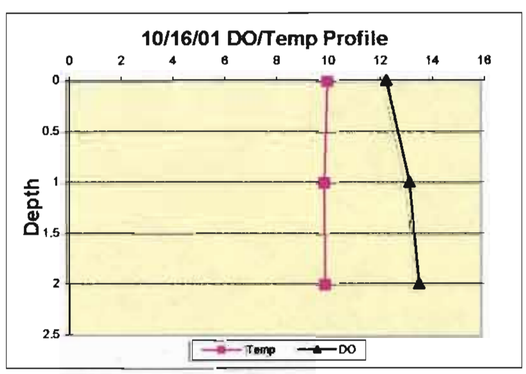
| DO | Temp | Depth |
|---|---|---|
| 13.22 | 17.97 | 0 |
| 14.38 | 17.69 | 1 |
| 5.53 | 16.72 | 2 |



9/12/01 DO/Temp Profile

**10/16/2001**

| DO | Temp | Depth |
|---|---|---|
| 12.21 | 10.08 | 0 |
| 13.10 | 9.96 | 1 |
| 13.47 | 9.97 | 2 |



10/16/01 DO/Temp Profile

LAKE: Lake Hallie YEAR 2002

COUNTY: Chippewa

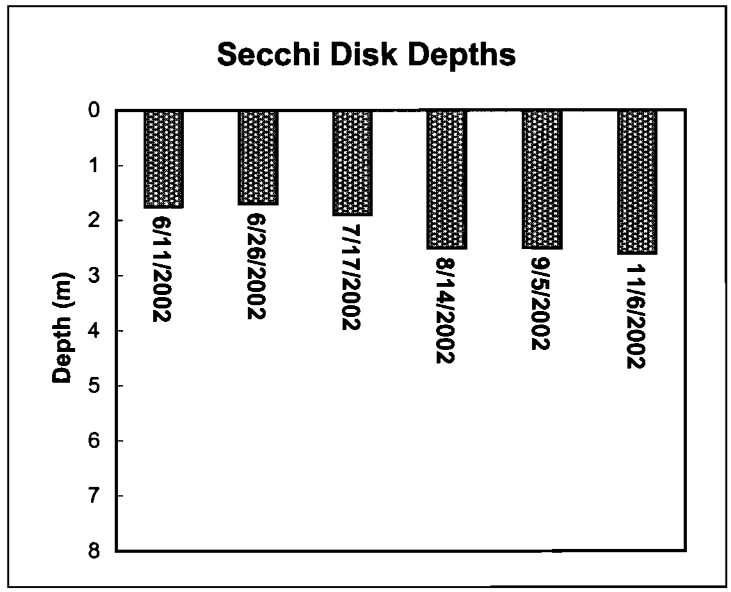
WATERBODY #: 2150200

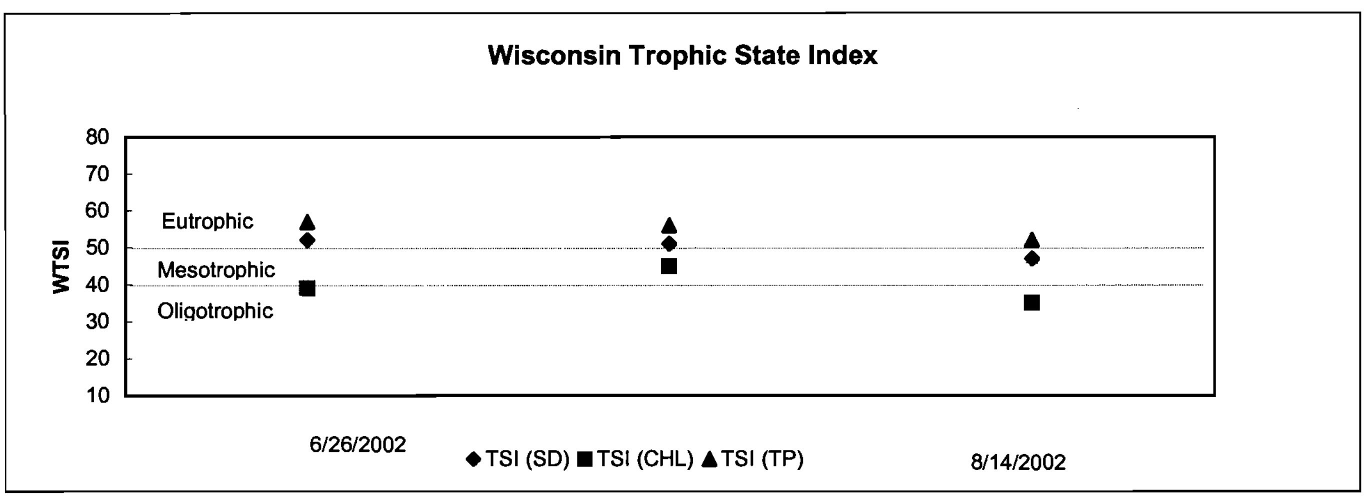
STORET #:

| DATE | SD (m) | CHL (ug/l) | TP (ug/l) | TSI (SD) | TSI (CHL) | TSI (TP) |
|---|---|---|---|---|---|---|
| 4/23/2002 | 1.25 | | 69 | 57 | | 61 |
| 6/11/2002 | 1.75 | | 45 | 52 | | 58 |
| 6/26/2002 | 1.7 | 1.65 | 43 | 52 | 39 | 57 |
| 7/17/2002 | 1.9 | 3.73 | 38 | 51 | 45 | 56 |
| 8/14/2002 | 2.5 | 1.1 | 22 | 47 | 35 | 52 |
| 9/5/2002 | 2.5 | 4.19 | 19 | 47 | 46 | 51 |
| 11/6/2002 | 2.6 | 1.28 | 16 | 46 | 37 | 50 |

| DATA SUMMARY: | |
|---|---|
| Average SD (m): | 2.0 |
| Minimum SD (m): | 1.3 |
| Maximum SD (m): | 2.6 |
| Average CHL (ug/l): | 2.4 |
| Minimum CHL (ug/l): | 1.1 |
| Maximum CHL (ug/l): | 4.2 |
| Spring Turnover TP (ug/l): | 45.0 |
| Fall Turnover TP (ug/l): | 20 |
| GSE* Avg TP (ug/l): | 34.33 |

*Growing Season Epilimnetic



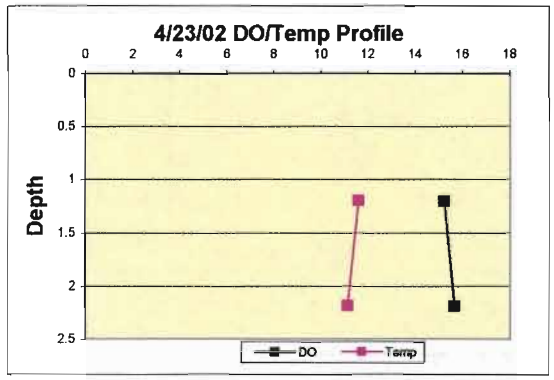



# Dissolved Oxygen / Temperature Profiles, 2002

Depth = Meters DO = mg/L

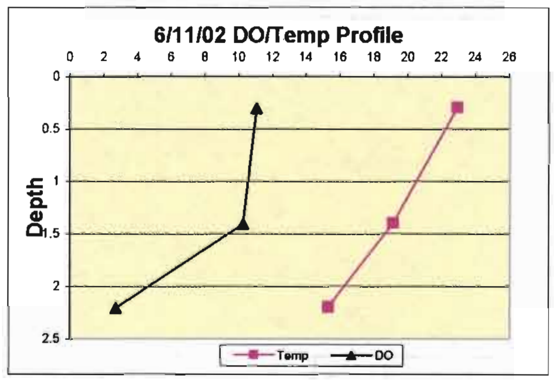
**4/23/2002**

| DO | Temp | Depth |
|---|---|---|
| 15.22 | 11.58 | 1.2 |
| 15.67 | 11.13 | 2.19 |



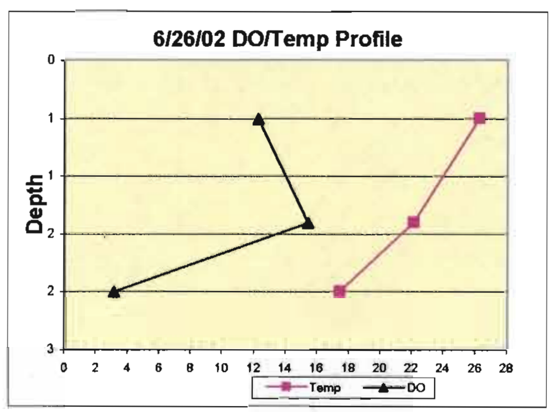

**6/11/2002**

| DO | Temp | Depth |
|---|---|---|
| 11.05 | 22.89 | 0.3 |
| 10.28 | 19.11 | 1.4 |
| 2.72 | 15.26 | 2.2 |




**6/26/2002**

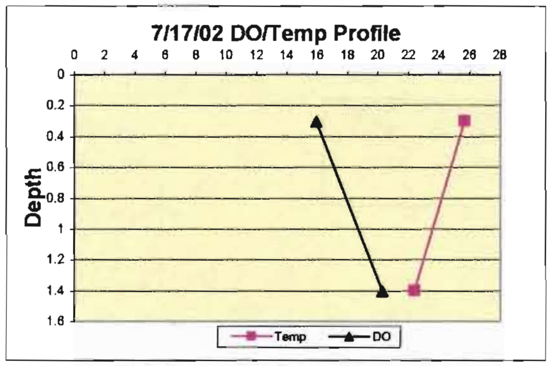
| DO | Temp | Depth |
|---|---|---|
| 12.28 | 26.21 | 0.5 |
| 15.45 | 22.06 | 1.4 |
| 3.17 | 17.41 | 2 |



# Dissolved Oxygen / Temperature Profiles, 2002

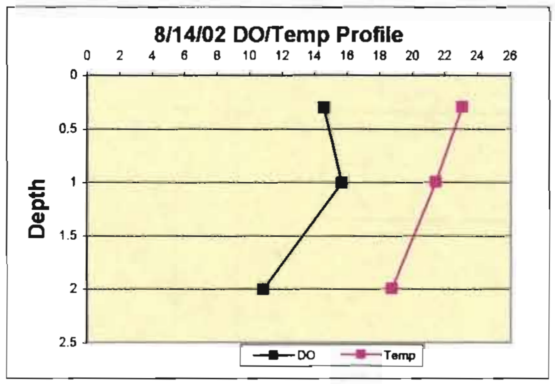
**7/17/2002**

| DO | Temp | Depth |
|---|---|---|
| 15.95 | 25.62 | 0.3 |
| 20.29 | 22.37 | 1.4 |



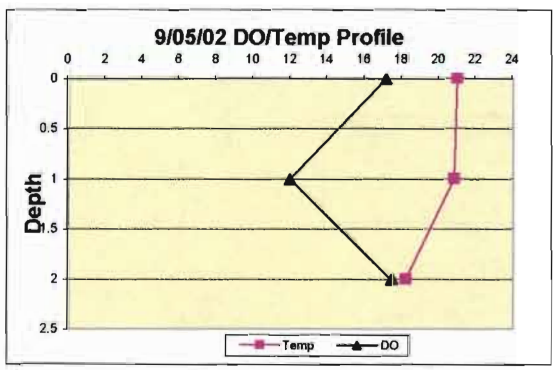

**8/14/2002**

| DO | Temp | Depth |
|---|---|---|
| 14.58 | 23.01 | 0.3 |
| 15.69 | 21.40 | 1 |
| 10.88 | 18.71 | 2 |



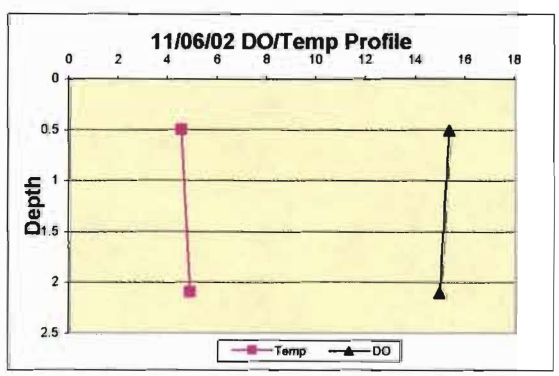

**9/5/2002**

| DO | Temp | Depth |
|---|---|---|
| 17.20 | 21.00 | 0 |
| 12.00 | 20.80 | 1 |
| 17.50 | 18.20 | 2 |




**11/6/2002**

| DO | Temp | Depth |
|---|---|---|
| 15.38 | 4.51 | 0.5 |
| 15.00 | 4.86 | 2.1 |



# Dissolved Oxygen, Winter 1999 - 2000

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 1.5 | 3 | 3.3 | 5 | 6.5 | 7 | 8 | |
| 2/8/00 | 1 | 15” | 0.5 | – | – | – | 0.4 | – | – | 0.3 | DO (mg/l) |
| | 1A | 14” | – | 1.6 | – | – | – | – | – | – | |
| | 2 | 11” | 2.3 | – | – | – | 1.4 | – | 0.9 | – | |
| | 2A | 10” | 3.7 | – | 1.8 | – | 1.3 | 1.0 | – | – | |
| | 2B | 11” | 7.8 | – | 5.2 | – | 3.2 | – | – | – | |
| | 3 | 6” | 8.6 | – | – | – | 8.5 | – | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 1.5 | 3 | 3.3 | 5 | 6.6 | 7 | 8 | |
| 2/14/00 | 1 | 16” | – | 1.1 | – | 0.9 | 0.4 | – | – | – | DO (mg/l) |
| | 1A | 14” | – | 1.8 | – | 1.4 | – | 0.9 | – | – | |
| | 2 | 11” | – | 4.0 | – | 2.6 | – | – | 1.3 | – | |
| | 2A | 11” | – | 3.8 | 2.6 | – | 2.1 | – | – | – | |
| | 2B | 12” | – | 7.8 | 5.3 | – | 4.1 | – | – | – | |
| | 3 | 6” | – | 8.9 | – | 8.4 | – | – | – | – | |

# Dissolved Oxygen, Winter 2000 - 2001

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | |
| 11/30/00 | 1 | 2.5" | 13.8 | – | – | 13.6 | – | 12.7 | – | – | DO (mg/l) |
| | 2B | 2.5" | 11.8 | – | – | 13.2 | – | – | 13.4 | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | |
| 12/15/00 | 1 | 6" | 12.1 | – | – | 8.5 | – | 7.6 | – | – | DO (mg/l) |
| | 1A | 7" | 9.7 | – | – | – | 8.4 | – | – | 8.2 | |
| | 2 | 7" | 6.4 | – | – | 5.3 | – | – | 4.8 | – | |
| | 2B | 7" | 6.6 | – | – | 4.6 | – | – | 4.5 | – | |
| | 3 | 5" | 5.4 | – | – | 5.1 | – | – | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3.3 | 4 | 5 | 7 | 8 | 9 | |
| 2/2/00 | 1 | 13" | 2.2 | – | – | 1.0 | – | 1.1 | – | – | DO (mg/l) |
| | 1A | 10" | 5.6 | – | – | – | 1.2 | – | – | 0.6 | |
| | 2 | 9" | 1.5 | – | – | 1.2 | 0.7 | – | 0.4 | – | |
| | 2B | 10" | 2.7 | – | – | 2.0 | – | – | 1.7 | – | |
| | 3 | 8" | 5.6 | – | 5.8 | 5.5 | – | – | – | – | |

# Dissolved Oxygen, Winter 2000 – 2001 (cont'd)

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 2.5 | 3.5 | 4.5 | 5 | 8 | 9 | DO (mg/l) |
| 1/8-9/00 | 1 | – | 3.0 | – | – | – | – | <1.5 | – | – | |
| | 1A | – | 2.8 | – | – | – | <1.5 | – | – | – | |
| | 2 | – | 1.8 | – | – | – | – | <1.5 | – | – | |
| | 2A | – | 1.7 | – | – | <1.5 | – | – | – | – | |
| | 2B | – | 3.8 | – | 2.9 | – | – | – | – | – | |
| | 3 | – | 6.9 | 7.7 | – | – | – | – | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 3.5 | 4.5 | 5 | 7 | 8.5 | DO (mg/l) |
| 1/18/00 | 2 | – | 2.4 | – | – | – | 1.6 | – | – | <1.5 | |
| | 2B | – | 3.4 | – | – | 3.1 | – | – | 3.0 | – | |
| | 3 | – | 7.6 | – | 8.0 | – | – | 5.1 | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 3.5 | 4.5 | 6 | 7 | 8 | DO (mg/l) |
| 1/25/00 | 1 | 15" | 2.1 | – | 1.8 | – | – | – | 1.2 | – | |
| | 1A | 13" | 5.8 | – | – | 1.4 | – | – | – | <1.0 | |
| | 2 | 12" | 9.2 | – | 2.1 | – | – | – | <1.5 | – | |
| | 2A | 12" | 8.9 | – | 4.7 | – | – | 3.0 | – | – | |
| | 2B | 11" | 8.6 | – | 4.6 | – | – | 3.6 | – | – | |

# Dissolved Oxygen, Winter 2000 – 2001 (cont'd)

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | |
| 2/12/00 | 1 | 18" | 10.9 | – | – | 4.3 | – | – | 2.5 | – | |
| | 1A | 16" | 11.0 | – | – | 2.7 | – | – | – | 2.7 | |
| | 2 | 16" | 9.7 | – | – | 6.9 | – | – | – | 2.6 | DO (mg/l) |
| | 2A | 14" | 10.3 | – | – | 3.9 | – | 3.2 | – | – | |
| | 2B | 14" | 10.4 | – | – | 8.8 | – | 4.0 | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | |
| 3/2/00 | 1 | 21" | 9.8 | – | – | 3.1 | – | 2.7 | – | – | |
| | 1A | 20" | 10.7 | – | – | – | 5.0 | – | – | 2.0 | |
| | 2 | 21" | 12.1 | – | – | – | 4.1 | – | 3.7 | – | DO (mg/l) |
| | 2A | 16" | 15.7 | – | – | – | 6.2 | 5.1 | – | – | |
| | 2B | 15" | 11 | – | – | 11.2 | – | – | – | – | |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 2 | 3 | 3.5 | 5 | 7 | 8 | 9 | |
| 3/26/00 | 1 | 16" | 15.0 | – | 15.2 | – | – | – | 12.7 | – | |
| | 1A | 20" | 12.9 | – | – | 12.0 | – | 11.7 | – | – | DO (mg/l) |
| | 2 | 19" | 13.8 | – | 12.7 | – | – | – | 12.2 | – | |

- At the Feb. 15 lake association meeting, it was decided to shut off the single unit plugged into Fred Sanberg's residence to reduce costs.
- Starting March 9, Mr. Nelson shut aerators down at night to reduce the noise level and save the association money.
- March 20, last two aerators were shut down. Sufficient open water to facilitate atmospheric aeration.

## Dissolved Oxygen, Winter 2001 - 2002

| Date | Site | Ice Thickness | Depth (ft.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 3 | 4 | 7 | |
| 1/10/02 | 1 | 7.5" | 7.2 | 8.1 | – | 8.4 | DO (mg/l) |

| Date | Site | Ice Thickness | Depth (ft.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 3 | 4 | 7 | |
| 1/24/02 | 1 | 9" | 11.1 | 5.6 | – | 4.8 | DO (mg/l) |

| Date | Site | Ice Thickness | Depth (ft.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 3 | 4 | 7 | |
| 2/6/02 | 1 | 9.5" | 12.6 | – | 4.8 | 4.3 | DO (mg/l) |

| Date | Site | Ice Thickness | Depth (ft.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 3 | 4 | 7 | |
| 3/12/02 | 1 | 11.0" | 15.7 | 14.2 | – | 13.7 | DO (mg/l) |

# Dissolved Oxygen, Winter 2002 - 2003

| Date | Site | Ice Thickness | Depth (ft.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 4 | 5 | 7 | 9 | |
| 1/3/03 | 1 | – | 7.5 | 9.0 | – | 15.0 | – | DO (mg/l) |

| Date | Site | Ice Thickness | Depth (ft.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 4 | 5 | 7 | 9 | |
| 1/30/03 | 1 | 15" | >20 | 18.8 | – | 18.4 | – | DO (mg/l) |
| | 1A | 16" | 14.8 | 11.0 | – | – | 10.5 | |
| | 2 | 15" | 10.2 | – | 10.8 | – | 10.1 | |
| | 2B | 14" | 8.4 | 6.5 | – | 6.2 | – | |
| | 3 | 13" | 7.4 | – | 5.2 | – | – | |