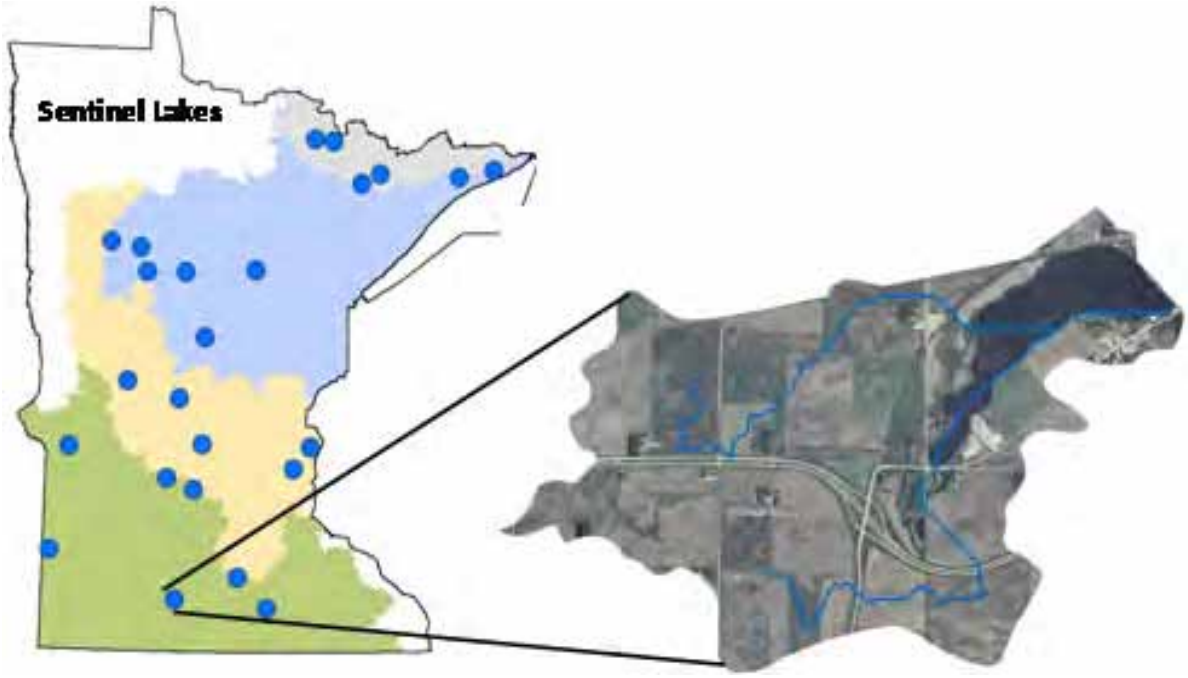
Sentinel Lake Assessment Report
St. James Lake (83-0043)
Watonwan County, Minnesota

Minnesota Pollution Control Agency Water

Minnesota Department of Natural Resources



Minnesota Pollution Control Agency

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Minnesota Pollution Control Agency

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Executive Summary

The Minnesota Pollution Control Agency (MPCA) is working in partnership with the Minnesota Department of Natural Resources (MDNR) on the Sustaining Lakes in a Changing Environment (SLICE) Sentinel Lakes Program. The focus of this interdisciplinary effort is to improve understanding of how major drivers of change such as development, agriculture, climate change, and invasive species can affect lake habitats and fish populations, and to develop a long-term strategy to collect the necessary information to detect undesirable changes in Minnesota Lakes (Valley 2009). To increase our ability to predict the consequences of land cover and climate change on lake habitats, SLICE utilizes intensive lake monitoring strategies on a wide range of representative Minnesota lakes. This includes analyzing relevant land cover and land use, identifying climate stressors, and monitoring the effects on the lake's habitat and biological communities.

The Sentinel Lakes Program has selected 24 lakes for long-term intensive lake monitoring (Figure 1). The "Deep" lakes typically stratify during the summer months only. "Shallow" lakes are defined as mixing continuously throughout the summer. "Cold Water" lakes are defined as lakes that either harbor cisco, lake whitefish, or lake trout and are the focus of research funded by the Environmental Trust Fund (ETF). "Super sentinel" lakes also harbor cold-water fish populations and research on these lakes is also funded by the ETF.

St. James was selected to represent a shallow lake in the Western Corn Belt Plains (WCBP) ecoregion. St. James is a 83 hectare (206 acre) lake, located near the city St. James, Watonwan County, within the Minnesota River basin watershed. The lake has a maximum depth of 4.9 meters (16 feet) and a mean depth of 1.2 meters (4 feet). The lake is 100% littoral with two public accesses on the south shore of the lake. The total contributing watershed for St. James Lake is 945 hectares (2,337 acres). Frequent dredging in the northern basin of the lake since 1971 has increased the maximum depth of the lake by 10 feet (3.05 Meters).

St. James is a shallow lake that exhibits minimal stratification in the summer months and fully mixes in fall and in the spring, following ice-out. Based on recent water quality data (2008-2010), St. James Lake is considered eutrophic with total phosphorus (TP), chlorophyll-a (chl-a), and Secchi values of: 55 micrograms per liter (µg/L), 24.5µg/L, and 1.4 meters (4.6 feet) respectively.

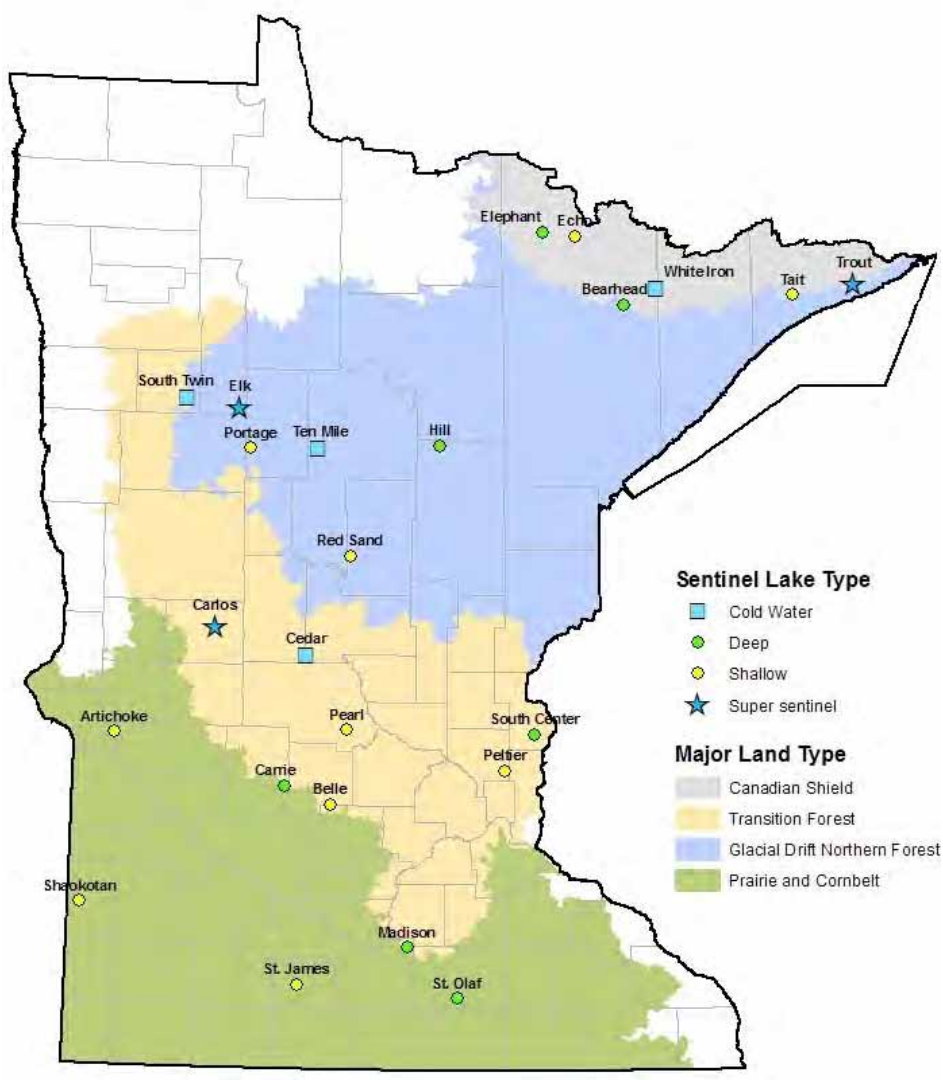
TP is better than the typical ranges (based on reference lakes) for WCBP ecoregion. Nuisance algal blooms were not observed and transparency was typically high on most sample dates over the three-year period. Trophic status data collected since 1998 suggest declining TP and chl-a over the past decade. Water quality on St. James Lake is much better than predicted by the MINLEAP model. St. James Lake is considered to be fully supporting aquatic recreation use.

Due to its moderate water quality and shallowness, aquatic plants are abundant in most areas throughout St. James Lake. Although the invasive curly-leaf pondweed (first documented in 1986) has been abundant in the recent past, the plant has recently declined for uncertain reasons. Curly-leaf pondweed is known to grow abundantly in spring in productive lakes like St. James and then senesce in mid-summer, releasing nutrients that may contribute to excess algal growth. Typically, few native aquatic plants persist after summer die-offs of curly-leaf pondweed. St. James is an exception and native aquatic plants persist throughout the summer presumably due to the lake's water quality regime remaining just below a threshold that still allows light penetration to bottom areas even after curly-leaf pondweed die-offs. This condition is precarious and it will be important to manage the lake, shoreland, and watershed in ways that minimize external and internal loading of sediments and nutrients.

Water quality declined appreciably following a partial fish winterkill in 1994. Game fish declined and common carp and bullhead increased. A rotenone treatment in fall 2001 killed bullhead and carp populations. A reclamation of game fish species followed in spring of 2002. Water quality and aquatic plants quickly improved and habitat conditions for reclaimed species remain good today. Common carp have not been sampled since the reclamation, bullhead are rare, and the lake supports naturally reproducing, fishable populations of largemouth

bass, northern pike, bluegill, and black crappie. Walleye continue to be stocked and the lake managed as a put-grow-take walleye fishery.

Figure 1. MDNR map of Sentinel lakes and major land types



Introduction

This report provides a relatively comprehensive analysis of physical, water quality and ecological characteristics of St. James Lake in Watonwan County, Minnesota (MN). This assessment was compiled based on Minnesota Department of Natural Resources (MDNR) surveys of the lake's fish and aquatic plant communities, Minnesota Pollution Control Agency (MPCA) and volunteer water quality monitoring, and analyses of various other sources of data for the lake. The water quality assessment focuses on data collected during the 2008, 2009 and 2010 seasons; however, historical data are used to provide perspective on variability and trends in water quality. A 1990 study, conducted by MPCA in conjunction with the Lake St. James Improvement Committee (Weir and Snyder 1991), is one source of historic data. Water quality data analyzed will include all available data in MPCA's EQuIS water quality database. Further detail on water quality and limnological concepts and terms in this report can be found in the Guide to Lake Protection and Management: (**http://www.pca.state.mn.us/water/lakeprotection.html**).

St. James Lake is located just southwest of the city of St. James. Much of the lake's shore is undeveloped and is a part of the St. James Game Refuge. The northeast end of the lake is a popular recreation area with two park and two public accesses. The lake is small and shallow with robust plant community. The lakeshed (area of land draining to the lake) is also relatively small, comprised mostly of agriculture land followed by water and wetland.

Background

History

St. James was formed by irregular deposition of Glacial till from the Des Moines lobe. Lakes of this type are typically shallow with gently sloping shoreland areas (Zumberge, 1952). The City began dredging the lake in 1971 in order to increase lake depth and improve fish habitat. The dredging has not included the far southwest end of the lake, (~40 acres) which serves as a wildlife refuge. The first lake monitoring efforts began with Secchi transparency in 1988 taken by volunteer in the Citizens Lake Monitoring Program (CLMP). Local residents have been historically concerned about sedimentation and excessive aquatic plant growth. Fish kills due to low dissolved oxygen in winter has been common throughout the lake's history. Winter aeration began in 1988 and has presumably lessened the frequency and duration of hypoxia. The following is a brief history of the lake assembled from MDNR, MPCA, and City of St. James records.

Timeline

1920's Railroad engineers used lake water for their steam engines; lake was almost dry

1926 City of St. James excavated an 18-foot diversion ditch from St. James Creek

1943 Fish winterkill (presumed to be partial)

1945-51 Documented fish winter kills.

1948 Initial lake vegetation survey noted sparse emergent vegetation and no submersed vegetation growth. Total phosphorus = 80 µg/L

1948-79 Periodically open to promiscuous fishing during severe winters due to threat of winterkill

1948 Partial winterkill

1950 Pollution study by Minnesota Department of Health (MDH) finds polluted conditions from sewage effluent from residences, the LaValle Hatchery, "Fuehl's Beer Parlor," stock pens, and other underdetermined sources. Study discovers widespread "weed fibers" as historical evidence of widespread vegetation growth. Dredging recommended as a management option.

1951-52 Partial winterkill

1959 Partial winterkill

1954-62 Bullheads stocked almost annually to facilitate a recreational fishery that is perhaps more accurately described as a harvestfishery for local and out of state anglers.

1957 Initial fisheries survey. Secchi clarity = 0.8 feet (0.024m) and total phosphorous (TP) = 80 ppb (8/14/1957).

1960's (mid) A culvert and drop structure was constructed to manage water levels and downstream flooding.

1971 MDNR Waters permit to excavate a 4000 ft long x 600 ft wide x 20 ft deep (1.5 million cubic yds) area of St. James Lake to "deepen lake and improve boating and fishing." The City of St. James purchases a dredge.

1971-2001 Regular dredging of the lake basin removed an estimated 1,189,738 cubic yards of lake sediment deepening the northeast part of the lake by several feet to a maximum depth of 15 feet. Dredge spoils are deposited in multiple shoreland areas surrounding the lake. Estimates cost of dredging operations over the 30 years exceed $1 million (Source City of St. James).

1976 Cooperative lake management plan between City of St. James and MN DNR to deepen lake for fish, enhance upland habitat for wildlife by filling in an adjacent wetland with dredge spoils, and establishing a recreation area adjacent to the lake. Lake is stocked with largemouth bass, bluegill, and northern pike.

1979 Partial winterkill

1981-86 Yellow perch, northern pike, black crappie, bluegill, and walleye stocked by MN DNR Fisheries

1986 First documented occurrence of invasive curly-leaf pondweed but given its extensive growth at the time of discovery by DNR staff and pre-existing establishment in other nearby lakes, it is likely the plant was present in the lake for some time prior to 1986.

1986 Fisheries survey documents 16 culverts and drain tiles contributing runoff into the lake.

1988 Winter aeration system installed to reduce hypoxia and probability of fish winterkills.

1989 "Weed growth" cited as a problem and motivation for a lake assessment study by the MPCA.

1990 Water level maintained at 1078 ft through manipulation of diversion inlet and outlet structure. Runoff into the lake is described as periodic.

1990 MPCA completes a lake water quality assessment on the St. James.

1994 Partial winterkill reduces game species while promoting increased abundance of black bullhead and common carp. Water quality and aquatic plants decline in years following.

1994 Aeration system upgraded

2002-present In cooperation with the City of St. James, St. James Lake is re-stocked with desirable game fish species (i.e., "reclaimed") in spring after the preceding fall rotenone treatments that killed the undesirable fish community. Common carp have remained absent from samples since the reclamation and water quality and aquatic plant habitats remain better than average compared with other similar lakes in the region.

2010 Partial fish winterkill

Lake Morphometric and Watershed Characteristics

St. James Lake is a shallow lake by the MPCA's lake assessment standards. The lake is 100 percent littoral, meaning all of the lake (206 acres) is less than 4.5m (15 feet) in depth (Table 1). Because of the extensive rooted plant (macrophyte) beds and shallow bottom, the southern portion is general un-navigable for motor boats. Lake dredging has kept the lake from filling but in doing so has changed the lake bottom.

St. James Lake is located in the Minnesota River watershed in the Watonwan River Basin (Figure 2). St. James River drains through the lake and connects into the Watonwan River just west of the city of Madelia. The St. James lakeshed is relatively small considering the size of the lake with a watershed to lake ratio of 11:1.

Figure 2. Lake bathymetry maps

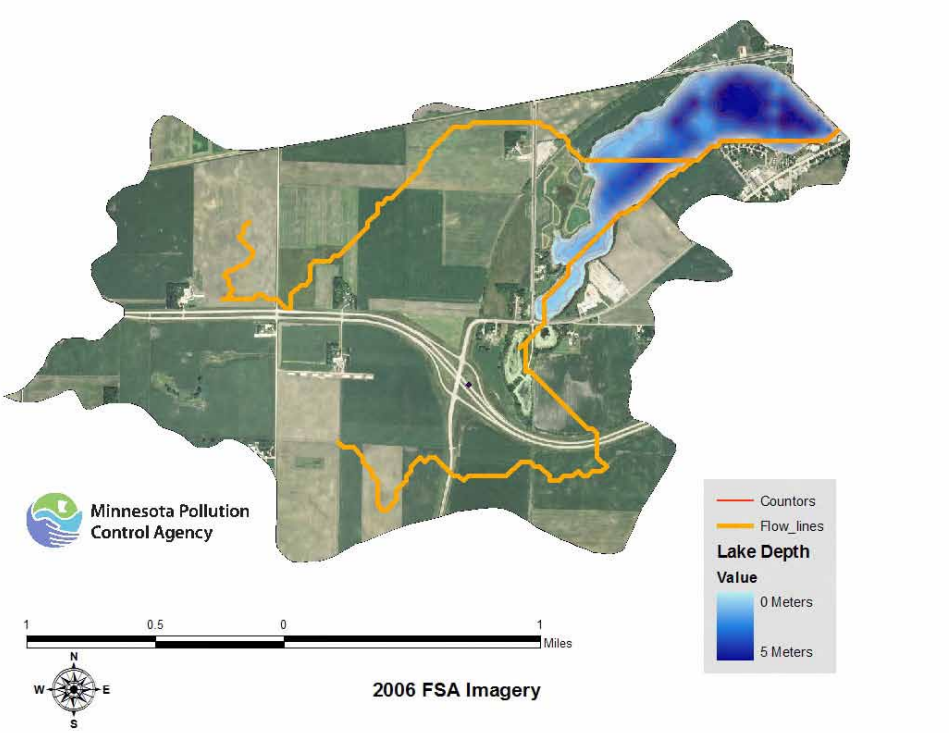


Table 1. St. James Lake and watershed morphometric characteristics**.**

Lake Basin hectares (acres)	Littoral Area (%)	Watershed: Lake (acres)	Max. Depth meters (feet)	Mean Depth meters (feet)	Watershed To Lake Ratio	Lake Volume acre-ft
83 (206)	100	945 (2,337)	4.9 (16)	1.2 (4)	11:1	824

Lake Mixing and Stratification

Lake depth and mixing has a significant influence on lake processes and water quality. *Thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 9 meters or more) often stratify (form layers) during the summer months and are referred to as *dimictic* (Figure 3). These lakes fully mix or turn over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 6 meters or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Lakes, with moderate depths, may stratify intermittently during calm periods, but mix during heavy winds and during spring and fall. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well mixed or stratified. The depth of the thermocline (zone of maximum change in temperature over the depth interval) can also be determined. In general, dimictic lakes have an upper, well-mixed layer (epilimnion) that is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. This low oxygen environment in the hypolimnion is conducive to TP being released from the lake sediments. During stratification, dense colder hypolimnion waters are separated from the nutrient hungry algae in the epilimnion. Intermittently (weakly) stratified polymictic lakes are mixed in high winds and during spring and fall. Mixing events allow for the nutrient rich sediments to be re-suspended and are available to algae.

Figure 3. Lake Stratification diagram

Polymictic Lake: Shallow, no layers, mixes continuously

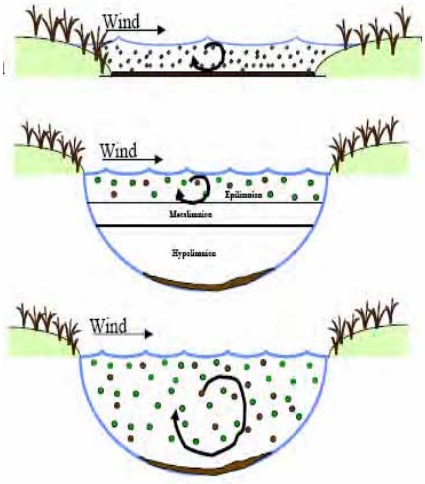
Spring, Summer & Fall

Dimictic Lake: Deep, forms layers,

mixes Spring/Fall

Intermittently Stratified:

Moderately deep, mixes during high winds

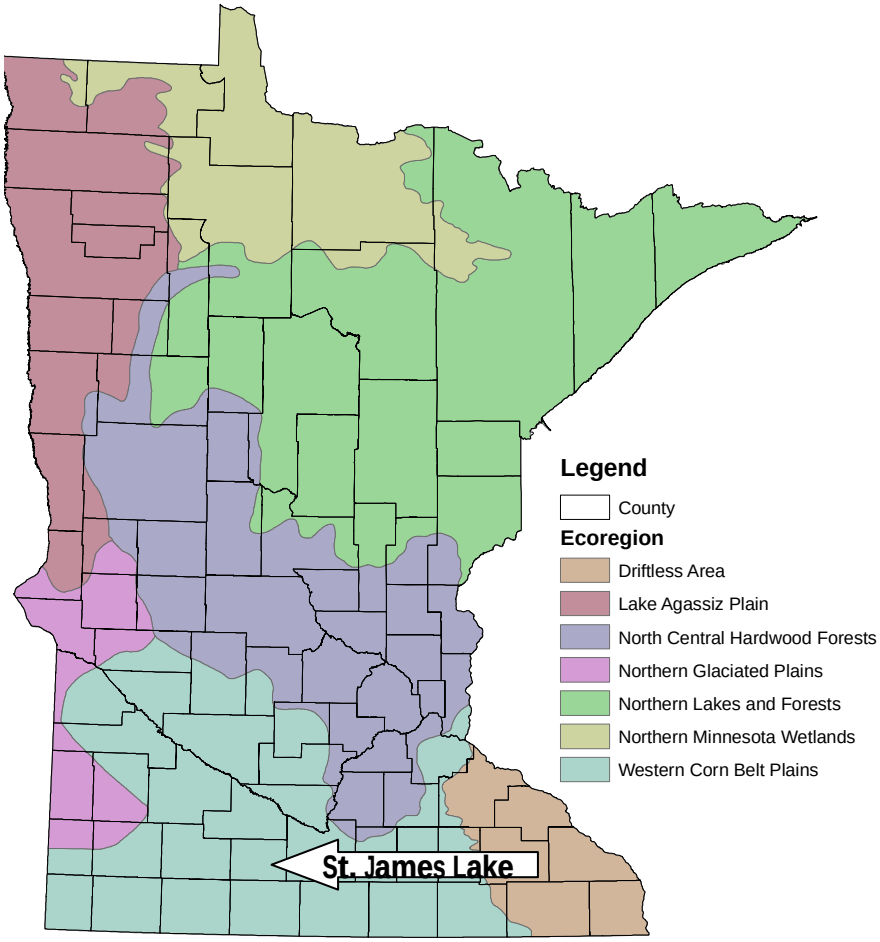


Ecoregion and Land Use Characteristics

Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally impacted (reference)

lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. St. James Lake lies within the Western Corn Belt Plain (WCBP; Figure 4). WCBP values will be used for land use (Figure 6) and summer-mean water quality comparisons (Table 7). Additionally, the WCBP inputs will be used for the model application.

Figure 4. Minnesota ecoregions as mapped by United States Environmental Protection Agency



Land Use

Since land use affects water quality, it has proven helpful to document the composition of landuses in the watershed of the lake. The St. James Lake watershed is dominated by agriculture landuse (Figure 5 and Figure 6), which is typical for a WCBP lake. The extensive wetlands in the wildlife refuge, along the west and southwest may serve to modify the quality and quantity of runoff from the western part of the watershed. The northeastern portion, immediately adjacent to the lake, is developed (urbanized) and impervious areas may be a source of storm water and road runoff loading to the lake. Land use has changed slightly compared to prior assessment with increases in developed area and decreases in cropland..

Figure 5 St. James Landuse map

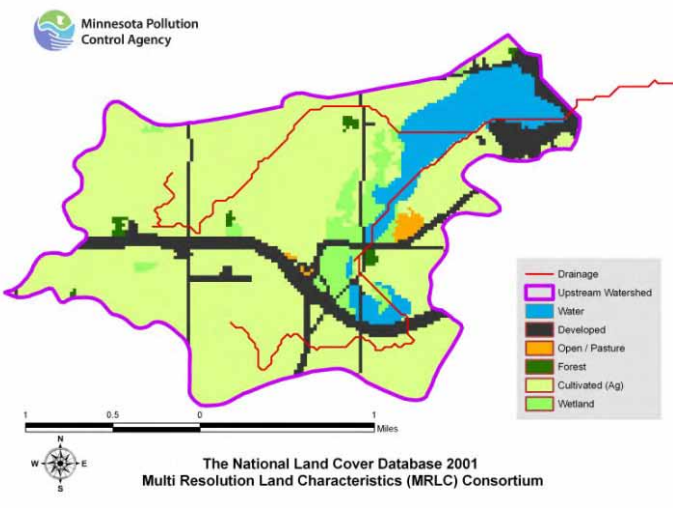
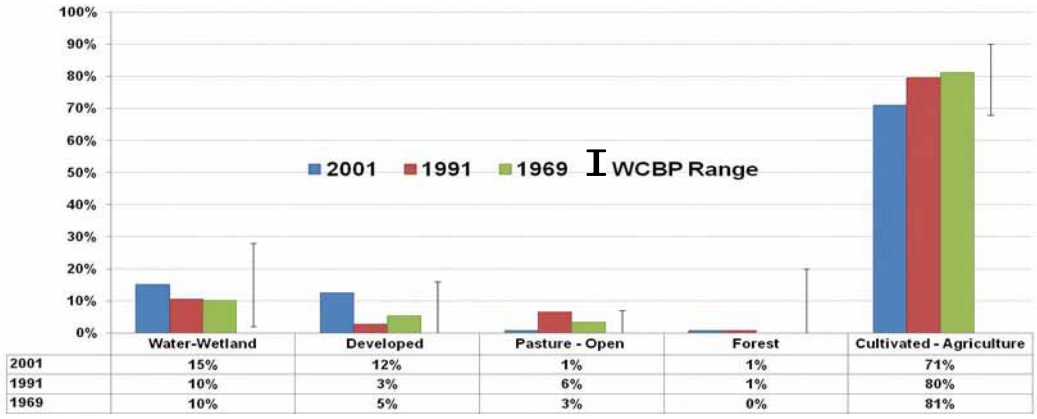


Figure 6 St. James Lake ecoregion land use comparison



	Water-Wetland	Developed	Pasture - Open	Forest	Cultivated - Agriculture
2001	15%	12%	1%	1%	71%
1991	10%	3%	6%	1%	80%
1969	10%	5%	3%	0%	81%

1National Land Cover Database www.mrlc.gov/index.php

[2]Minnesota Land Management Information Center **http://www.mngeo.state.mn.us/chouse/metadata/luse69.html**

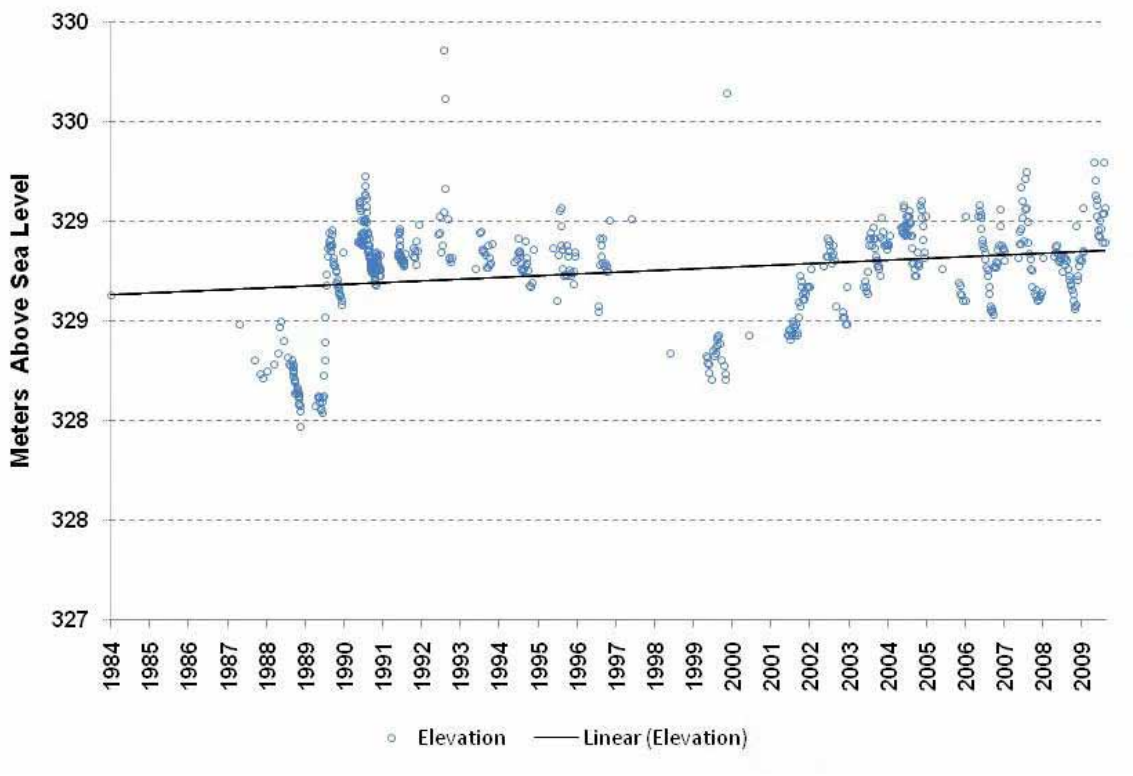
3Minnesota Land Cover Map 1991-1992: http://www.mngeo.state.mn.us/chouse/land_use_DNRmap.html

Lake Level and Ice On/Off

The MDNR Division of Waters has been measuring water levels on St. James Lake since 1984 (Figure 7). A total of 620 lakes level measurements have been collected on St. James. During the period of record, the lake level has ranged 1.9 meter. Records show low water periods in the late 1980s and again from 1998-2000. A weak trend toward increasing water levels was noted based on the available data. The complete water level record may be obtained from the MDNR web site at: **http://www.dnr.state.mn.us/lakefind/showlevel.html?id=29025000**.

Ice records on St. James Lake are slim with only two periods of ice records are available. In 2007 ice on began November 4th and continued to April 4th of 2008. The total number of ice on days was 149 for that period. The next season ice was on the lake from November 26th 2008 to March 24th of 2009 totaling 118 days of ice on the lake.

Figure 7. Long term lake level results for St. Jame Lakes



Precipitation and Climate Summary

Temperature and precipitation influence many aspects lake chemistry and biology. Large rain events often increase runoff into the lake and may influence in-lake water quality and lake levels. The National Weather Service has a station in the city of St. James (#217326). Monthly total precipitation comparisons (Figure 8) during Sentinel lake monitoring period (2008-2010) allow us to compare lake level comparisons as well as water quality influences. One inch or greater events can have a significant impact for runoff contribution. Each of the three years have several one inch or greater event (Figure 9). The extreme nature of the September 23, 2010 event is evident in Figure 9.

Figure 8. Monthly Temperature and Precipitation from the St. James Station #217326

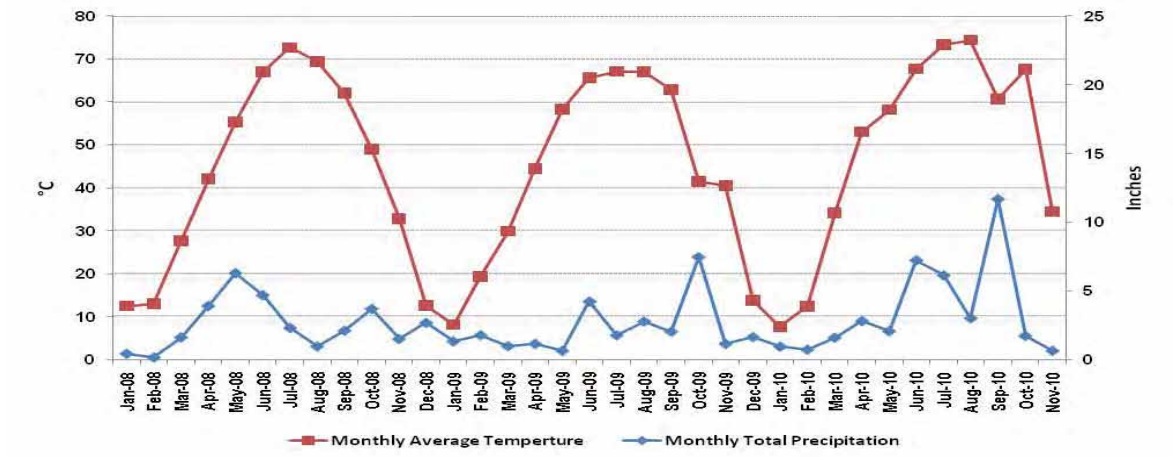
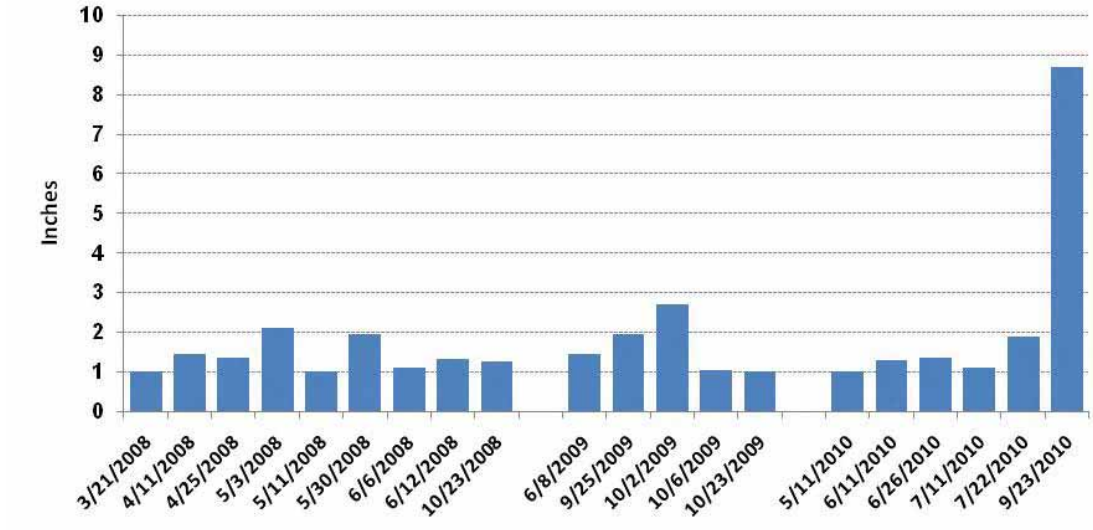


Figure 9. One inch or greater rain event 2008 - 2010



Fisheries and Aquatic Plants

Frequency of occurrence of aquatic plant species was assessed using the point-intercept method (Madsen 1999). This method entailed visiting sampling points on a grid within the vegetated zone of the lake, throwing a two-sided rake over one side of the boat at each point, raking the bottom approximately 1 m, then retrieving the rake and identifying all species present, and recording the depth. Survey points were spaced approximately 80-m (0.7 points per littoral acre). Most recent fisheries surveys follow guidelines outlined by MDNR Special Publication 147 (1993; Manual of Instructions for Lake Survey). Fish community integrity surveys were also completed on each Sentinel lake following methods described by Drake and Pereira (2002).

Water Quality

Recent samples collection was done monthly from ice-out (April/May) through October in 2008. In 2009 and 2010 samples were collected after ice-out, July and October for a large suite of parameters. Lake surface samples were collected by MPCA staff with an integrated sampler, a poly vinyl chloride (PVC) tube 2 meters (6.6 feet) in length, with an inside diameter of 3.2 centimeters (1.24 inches). Zooplankton samples were collected with an 80 µm mesh Wisconsin zooplankton net. Phytoplankton (algae) samples were taken with an integrated sampler. Temperature and DO profiles and Secchi disk transparency measurements were also taken. Samples were collected at site 101. Sampling procedures were employed as described in the MPCA Standard Operating Procedure for Lake Water Quality document, which can be found here: http://www.pca.state.mn.us/publications/wq-s1-16.pdf.

Laboratory analysis was performed by the laboratory of the MDH using United States Environmental Protection Agency-approved methods. Samples were analyzed for nutrients, color, total suspended solids (TSS), pH, alkalinity, conductivity, chloride, metals, and chl-*a*. Phytoplankton samples were analyzed at the MPCA using a rapid assessment technique.

Zooplankton

Zooplankton samples were collected monthly from ice-out (April/May) through October in 2008. And only in April/May July and October in 2009 and 2010. Two replicate vertical tows were taken at each sampling event. The net was lowered to within 0.5 meter of the bottom and withdrawn at a rate of approximately 0.5 meters per second. Contents were rinsed into sample bottles and preserved with 100% reagent alcohol. Analysis was conducted by MDNR personnel.

Each zooplankton sample was adjusted to a known volume by filtering through 80 µg/L mesh netting and rinsing specimens into a graduated beaker. Water was added to the beaker to a volume that provided at least 150 organisms per 5-milliliter aliquot. A 5-milliliter aliquot was withdrawn from each sample using a bulb pipette and transferred to a counting wheel. Specimens from each aliquot were counted, identified to the lowest taxonomic level possible (most to species level), and measured to the nearest .01 millimeter using a dissecting microscope and an image analysis system. Densities (#/liter), biomass (µg/L), percent composition by number and weight, mean length (millimeter), mean weight (µg) and total counts for each taxonomic group identified were calculated with the zooplankton counting program ZCOUNT (Charpentier and Jamnick 1994 in Hirsch 2009).

Results and Discussion

Fisheries Assessment

MDNR fisheries managers utilize netting survey information to assess the status of fish communities and measure the efficacy of management programs. Presence, absence, abundance, physical condition of captured fishes, and community relationships among fish species within survey catch information also provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson, 1993). These data are stored in a long-term fisheries survey database, which has proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time.

An ecological classification of Minnesota lakes (Schupp 1992) stratified lakes within Minnesota into 44 types. St. James was classified as a type 42 lake typical of lakes found in the south-central to southwestern portion of Minnesota. St. James Lake has had a history of good water quality, abundant aquatic vegetation and a robust fish community since fish management began in the mid-1940s. St. James Lake also has a history of dredging in order to create depths that would sustain a fishable population of sport fish. Dredging successfully created deeper water habitat up to 16 feet deep.

Although there are adequate depths for sport fish within St. James, hypoxic (i.e., "winterkill") conditions during winter have been common throughout the lake's documented history. Prior to 1994, St. James Lake supported a quality sunfish (mainly bluegill) population. As a result of a partial winterkill during the winter of 1993-1994 the bluegill population abundance experienced a significant reduction. In the spring of 1994 following the winterkill, subsequent stocking of bluegill, as well as other species (walleye, pumpkinseed, and largemouth bass) failed to restore these populations to the pre-winterkill abundances.

By 1999, St. James Lake had reduced water clarity, was virtually devoid of macrophytes, bullhead and carp were abundant, and the lake continued to experience lower oxygen levels during winter. With support from the St. James community and local anglers, St. James Lake was reclaimed with the use of rotenone in the fall of 2001 by the MDNR Windom area office in cooperation with the city of St. James. By the spring of 2002, water clarity and aquatic vegetation returned to create suitable habitat for sport fish reintroduction. An added benefit of the reclamation in 2002 was the removal of black bullhead in St. James Lake. Following the reclamation, black bullhead weren't sampled again until 2007 but their abundance has remained low presumably due to the persistence of good water quality conditions and abundant predator populations. Since reclamation in 2002, walleye, yellow perch, largemouth bass, and bluegill have returned and maintained fishable populations within St. James Lake.

Interestingly, a partial winterkill during the winter of 2009-2010 did not suppress the fish community presence or abundance in St. James Lake. From the summer survey in 2009 to the summer survey in 2010 the catch rate (number/net) of black crappie, largemouth bass, and bluegill have all increased. The winterkill of 2009-2010 may have reduced the size structure of bluegill and largemouth bass populations. A strong year class of northern pike was observed during the summer 2010 survey. St. James Lake appears to have adequate habitat to sustain fishable sport fish populations even through adverse conditions such as a partial winterkill. Better habitat conditions in addition to a more intensive post-reclamation management plan for St. James Lake should continue to improve the density and stability of the fish community.

The fish community in St. James is rather simple and comprises mostly a mixture of stocked walleye, northern pike, largemouth bass, and bluegill (Table 3). Despite its winterkill history that tends to favor bullhead and common carp, these species have been rare in St. James since the reclamation in 2002. Consequently, index of biotic integrity (IBI) scores in St. James Lake are are better than other lakes of similar productivity with a score of 57 out of 160 (2008 and 2009 IBI surveys; Drake and Valley 2005). For continued viability of game fish

populations and biotic integrity in general in St. James Lake, high aquatic plant cover and abundance throughout summer and low abundance of carp and bullhead should be maintained.

Table 2 First documented catch for each species in MN DNR fish surveys and corresponding trophic guild, thermal guild, and environmental tolerance for each species

Common name	Species name	Trophic guild	Thermal guild	Environmental tolerance	First documented
Bluegill sunfish	*Lepomis macrochirus*	Insectivore	Warm	Neutral	1986
Green sunfish	*Lepomis cyanellus*	Insectivore	Warm	Neutral	1986
Pumpkinseed sunfish	*Lepomis gibbosus*	Insectivore	Warm	Neutral	1986
Orangespotted sunfish	*Lepomis humilis*	Insectivore	Warm	Neutral	1999
Yellow perch	*Perca flavescens*	Insectivore	Cool-warm	Neutral	1986
Black bullhead	*Ameiurus melas*	Omnivore	Warm	Tolerant	1957
Brown bullhead	*Ameiurus nebulosus*	Omnivore	Warm	Neutral	1999[a]
Yellow bullhead	*Ameiurus natalis*	Omnivore	Warm	Neutral	1999[a]
White sucker	*Catostomus commersonii*	Omnivore	Cool-warm	Tolerant	1986
Black crappie	*Pomoxis nigromaculatus*	Predator	Warm	Neutral	1986
Largemouth bass	*Micropterus salmoides*	Predator	Warm	Neutral	1957
Northern pike	*Esox lucius*	Predator	Cool-warm	Neutral	1986
Common carp	*Cyprinus carpio*	Omnivore	Warm	Tolerant	1957
Walleye	*Sander vitreus*	Predator	Cool-warm	Neutral	1986
Channel catfish	*Ictalurus punctatus*	Predator	Warm	Neutral	1986

Thermal guilds were classified by Lyons et al. (2009) and environmental tolerances were categorized by Drake and Pereira (2002). [a]Species may have been lumped as "bullheads" in previous surveys

Fish species assessments

Black Bullhead

Stocking history reports that bullhead were stocked as early as 1922 and as recent as 1963, presumably to support a recreational and subsistence fishery for local residents and out of state anglers. As the predator species within St. James Lake began to disappear due to winterkill, the black bullhead population persisted and became a major component of the fish community. Prior to the lake reclamation in the fall of 2001, bullhead numbers in gillnet and trap net catches were consistently near the upper quartile for lake class 42 for gillnets (91.4 fish/gillnet) and trap nets (60.5 fish/trap net) (Figure 8). Since the rotenone reclamation treatment in 2001, bullhead abundance has been absent or very low. Only 3 bullhead have been captured with gillnets since 2001 (1 in 2005 and 2 in 2007) and only 4 have been captured with trap nets during the same time frame (1 in 2007, 1 in 2008, and 2 in 2010). If winterkill conditions continue to exist in St. James Lake there is a potential for a strong year class of bullhead given the remnant population that remains. Maintaining high water quality and a strong population of predator species (i.e. northern pike, walleye, or largemouth bass) in St. James will likely keep black bullhead populations low. Continued management of black bullhead at their current state should include the presence of a strong predator population.

Black Crappie

Black crappie in St. James Lake exhibit variable recruitment. Variable recruitment of black crappie is typical in most southern MN systems, even with supplemental stocking (Table 4). For uncertain reasons, large catch rates of black crappie have been observed prior to and after the reclamation in 2001. High catch rates were observed in 1986, 1999, and 2007 and were between the mean (5.6 fish/net) and upper quartile (15.1 fish/net) for trap

nets in lake class 42 (Figure 10). In 2010, only 6 fish from 3 year classes (2004, n=1; 2007, n=1; 2008, n=4) were present in the sample ranging in length from 12.7-20.3 cm (5.0-8.0 inches) with a mean length of 15.0 cm (5.9 inches; Table 5).

Given the variable nature of black crappie recruitment and the popularity of black crappie as a sport fish, it is difficult to manage a crappie population at a level that all anglers will find adequate. All that can be expected for the St. James crappie population is to provide an opportunity to catch the fish when their abundance is great enough.

Bluegill

A stable population of bluegill has been present in St. James since 1991. Prior to 1991 bluegill were maintained with stocking (Table 5). The earliest stocking report was in 1975 and the latest was in 2002 (post–reclamation). As the water quality and macrophyte community declined in St. James during the mid-1990s, so did the bluegill population. From 1991 to 1999, the bluegill catch rate declined from 82.1 bluegill/net (almost 3 times the upper quartile value of 29.5 bluegill/net) to 5.5 bluegill/net (about half of the expected mean catch rate of 10.8 bluegill/net). After the lake reclamation in 2001 and subsequent bluegill reintroduction in 2002, the catch rate of bluegill peaked to a record catch of 101.9 bluegill/net in 2003 (Figure 10). With the establishment of abundant macrophytes and increased water clarity, it was apparent that suitable spawning habitat existed for bluegill. Since 2003, catch rates have declined and are currently at a rate of 8.0 bluegill/net, which is within the expected quartiles. In the 2010 survey, bluegill from 6 year classes (2004-2009) were present and they ranged in length from 9.4-21.3 cm (3.7-8.4 inches) with a mean length of 16.5 cm (6.5 inches). The decline of bluegill in 2010 may be characteristic of natural reservoir evolution (Hayes et al. 1999). The reclamation in 2001 opened the potential of the entire lake creating seemingly unlimited resources for the bluegill population to expand. As the population expanded (along with other species such as walleye, largemouth bass, and northern pike) resources became limited and predator interactions increased. The decrease in numbers may also be due to increased macrophytes which may decrease fish movement and thus capture in passive gear (trap nets and gill nets). While the bluegill population has decreased, the average weight per individual is the highest recorded (136.2 g/bluegill) and their relative weight indicates they are above average compared to other populations of bluegill.

The St. James bluegill population appears to be robust and healthy. The current alignment of proportional size structure for bluegill (Table 6) in relation to largemouth bass (a major predator of bluegill) indicates that St. James falls under the panfish management strategy outlined by Willis et al. (1993; PSS_Q bluegill = 50-80 and PSS_P = 10-30 with PSS_Q largemouth bass = 20-40 and PSS_P = 0-10). St. James was historically a quality bluegill lake and it appears that water quality and habitat improvements gained through the reclamation will continue to allow St. James Lake to be managed for quality bluegill.

Common Carp

Common carp were first formally documented in St. James Lake in 1984 when 1,117 lbs were removed from MN DNR's former roughfish removal program. The source of common carp for St. James Lake was likely a result of immigrants into the lake from a diversion channel from a local stream and, to a lesser extent, from accidental introductions through unauthorized stocking or bait buckets. Common carp were abundant until 2001 when St. James Lake was reclaimed with a fall rotenone treatment (the diversion channel was disconnected at the same time to minimize reintroduction sources). Common carp both cause and are a response to poor water quality conditions (Bajer and Sorensen 2010, Egertson and Downing 2004). While the water quality and macrophyte community within St. James Lake was declining during the mid 1990s, the common carp abundance was increasing. From 1991 to 1999, the common carp population increased from 2.6 fish/net to 9.4 fish/net (trap nets) (Figure 11). Winterkill conditions through the lakes history may have allowed the population of common carp to spawn successfully (Bajer and Sorensen 2010). After reclamation in 2001 there have been no common carp caught in fish community surveys (2003, 2005, 2007, 2008, 2009, and 2010). The common carp population within St. James appears to be extirpated.

Largemouth Bass

Largemouth bass were stocked in St. James on four occasions, the earliest stocking was sometime between 1922 and 1944 and the other stocking events occurred in 1994, 1998, and in 2002 (post-reclamation) (Table 3). The primary method for determining largemouth bass abundance is by electrofishing as largemouth bass are net shy (avoid passive capture nets such as trap nets and gillnets). Largemouth bass were first collected by electrofishing in 1995 (7 fish/h; mean weight = 862.6 g [1.9 lbs]) as a result of the 1994 stocking and again in 1999 as a result of the 1998 stocking (17 fish/h; mean weight = 317.8 g [0.7 lbs]). These catch rates were considered low, most likely due to habitat degradation experienced during the mid-1990s as a result of winterkill conditions and proliferation of undesirable species such as black bullhead and common carp. After reclamation in 2001, largemouth bass catch rates were significantly higher at 394 fish/h (mean weight = 90.8 g [0.2 lbs]) in 2003. Since then, catch rates have decreased, but remained good during 2005 (104 fish/h), 2007 (128 fish/h), and 2008 (127.7 fish/h). The decrease in the catch rate is most likely due to increased macrophyte abundance and difficulty sampling fish effectively through the vegetation. Along with an increase and stabilization in catch rate, there was also an increase in mean weight from 136.2 g/largemouth bass (0.3 lbs/fish) in 2005 to 317.8 g/largemouth bass (0.7 lbs/fish) in 2008. Currently, the largemouth bass population has an average weight of 272.4 g/fish (0.6 lbs/fish) with a catch rate of 75 fish/h. In 2010, there were 8 year classes of largemouth bass (n=59 total fish) with the oldest fish in the sample coming from the 2003 year class and the strongest year classes coming from the 2005 (age 5; n=15), 2007 (age 3; n=12), and 2008 (age 2; n=13) year classes. Largemouth bass ranged in length from 12.2-43.4 cm (4.8-17.1 inches) with an average length of 25.1 cm (9.9 inches).

Largemouth bass appear to have reached carrying capacity in St. James Lake. Largemouth bass are being collected in the net catches indicating a high density of largemouth bass. Largemouth bass were sampled in 2003, 2005, and 2007 in gillnets (0.3-2.0 fish/net) and were sampled in every survey since 1999 (n=7 surveys) in trap nets (0.1-0.8 fish/net) (Table 4). The PSS of largemouth bass (PSS_Q=31; PSS_P=3) indicates that the population may be experiencing density dependent suppression in its size structure although relative weights are high at a mean value of 115 indicating healthy individuals (Table 6). A decrease in the abundance of largemouth bass in St. James may help to increase the population's size structure (Table 6) and may even allow for a few trophy individuals to be found in the population given the continuation of an adequate forage base and presence of suitable spawning habitat.

Northern Pike

Northern pike have been stocked on several occasions since the early 1920s in St. James Lake (Table 4). Northern pike catch rates were variable (0.5-17.0 fish/gillnet and 0.13-0.86 fish/trap net) prior to lake reclamation in the fall of 2001. After reclamation and subsequent reintroductions of adult northern pike in 2003 and 2006 catch rates have stabilized to 2.3 fish/gillnet (2007) and 3.9 fish/trap net (2010) (Figure 10). All of the northern pike collected in trap nets during the 2010 survey were naturally produced young of the year. The young of the year pike ranged in length from 21.6-31.2cm (8.5-12.3 inches) with an average length of 25.7cm (10.1 inches). There appears to be adequate reproduction of northern pike in St. James Lake as a result of the increase in water clarity and macrophyte abundance created by the lake reclamation in 2001. St. James has the potential to exhibit a stable northern pike population if spawning habitat remains within the lake.

Walleye

The walleye population in St. James Lake is maintained through stocking due to the absence of natural reproduction Table 4 Stocking history including size and number for fishes stocked into St. James Lake, 1989-2009**Error! Reference source not found.**. Walleye were first stocked in 1976 due to their popularity as a sport fish. Stocking walleye has become a regularly occurring management practice. Prior to the reclamation in 2001, the gillnet catch rate never exceeded 6.3 walleye/net and after 2001 the catch rate has reached 13.3 walleye/net (almost twice the upper quartile for lake class 42; 7.3 walleye/net) (Figure 10). Stocking efforts in St. James appear to be successful after the reclamation. Continued stocking of walleye will need to occur in St. James to maintain a fishable population of walleye as reproduction does not appear to be occurring (0 young of the year sampled in fall electrofishing during 2008 and 2010).

Yellow Perch

Yellow perch have been stocked in St. James on only 5 occasions since the 1920s (Table 5). Following the reclamation, yellow perch were last stocked in 2003. Unless significant winterkill occurs and yellow perch are extirpated, Windom Area Lakes typically have enough natural reproduction to maintain their abundance. Like walleye abundance, yellow perch abundance is best monitored with gillnet catch rates. Yellow perch catch rates are highly variable and ranged from 3.0-59.0 fish/net prior to the 2001 reclamation and catch rates ranged from 2.7-14.3 fish/net after the reclamation (Figure 10). The average weight of yellow perch have remained stable with a rate of approximately 5 fish/lb and an average relative weight of 109 indicating healthy individuals. During the 2010 survey, 3 year classes of yellow perch were present with an average length of 19 cm (7.5 inches; range=5.8-8.9 inches). Yellow perch most likely provide the primary food for walleye and northern pike in St. James Lake.

Other Species

Species that were recorded in the net catches prior to lake reclamation in St. James were channel catfish, green sunfish, orangespotted sunfish, pumpkinseed sunfish, white crappie, white sucker, and yellow and brown bullhead (Table 4). All species were found in trace amounts (less than 1 fish/net) except for yellow and brown bullhead and pumpkinseed sunfish which had catch rates up to a maximum of 6 fish/net .

Table 3 Average lengths in inches for fish measured in MN DNR summer surveys and special assessments since 1986.

Species	Sampling Gear	Year Sampled									
		1986	1991	1995	1999	2003	2005	2007	2008	2009	2010
BLB	GN	NA	NA	5.3	8.1		9.5	11.3			
	TN	NA	NA	10.2	8.3			10.5	13.31		13.5
BLC	GN	NA	NA	8.5	5.1		6.7				
	TN	NA	NA	9.3	5.8	6.1	8.7	6.5	8.2	11.2	5.9
BLG	GN	NA	NA	8.3		5.2	6.7	6.7			
	TN	NA	NA	5.2	6.3	5.1	6.6	5.8	6.1	4.9	6.5
CAP	GN	NA	NA	8.3	11.9						
	TN	NA	NA	17.0	17.7						
LMB	GN	NA	NA			6.9	9.6	12.5			
	TN	NA	NA		15.3	7.0	9.2	12.7	15.5	9.1	
	EF	NA	NA	14.0	9.5	6.5	9.1	10.6	10.5		9.9
NOP	GN	NA	NA	19.7	25.1	19.3	27.9	23.9			
	TN	NA	NA	18.6	22.2		26.5	27.0			10.1
WAE	GN	NA	NA	11.1	13.7		11.7	17.2			
	TN	NA	NA	18.7	12.7	7.9	15.7	14.6	9.5		22.6
YEP	GN	NA	NA	8.0	7.9	8.2	8.0	7.5			
	TN	NA	NA	7.6	7.2	7.8		7.4	7.0		7.5

Values in bold are measurements of a single fish and are not an average. Black bullhead is BLB

black crappie is BLC, bluegill is BLG, common carp is CAP, largemouth bass is LMB, northern pike is NOP, walleye is WAE, and yellow perch is YEP. Gillnets are coded GN, trap nets are TN, and electrofishing is EF.

Table 4 Stocking history including size and number for fishes stocked into St. James Lake, 1989-2009

Year	Species	Size	Number
1989	Walleye	Fingerling	10,080
1992	Walleye	Fingerling	1,984
	Walleye	Yearling	409
1993	Northern pike	Adult	16
	Northern pike	Fingerling	3,025
1994	Black Crappie	Adult	58
	Bluegill	Adult	452
	Largemouth bass	Adult	16
	Pumpkinseed	Adult	30
	Walleye	Fry	190,000
	Largemouth bass	Yearling	40
1997	Walleye	Fry	213,500
1998	Largemouth bass	Adult	26
2002	Bluegill	Adult	856
	Largemouth bass	Adult	30
	Walleye	Yearling	6,120
2003	Black Crappie	Adult	680
	Northern pike	Adult	110
	Yellow perch	Adult	3,186
	Walleye	Fingerling	13,299
2005	Walleye	Fingerling	9,684
2006	Northern pike	Fingerling	2,651
2007	Walleye	Fingerling	1,908
	Walleye	Yearling	1,912
2009	Walleye	Fingerling	8,414
	Walleye	Yearling	20

Table 5 Sample size and Density in frame net sets, seining, or night electrofishing in St. James during 2010

Gear		Proportional Size Structure				Relative Weight					
Species	n	PSS_Q	PSS_P	PSS_M	PSS_T	S-Q	Q-P	P-M	M-T	T	Overall
Overall[a]											
BLB	2	0	0	0	0	---	---	---	---	---	96
BLC	6	20	0	0	0	---	---	---	---	---	93
BLG	71	75	10	0	0	128	121	---	---	---	124
LMB	75	31	3	0	0	100	111	---	---	---	115
NOP	34	---	---	---	---	---	---	---	---	---	93
WAE	1	100	100	0	0	---	---	---	---	---	---
YEP	21	60	0	0	0	108	---	---	---	---	109

Sample size (n; ≥ stock length), stock density indices (proportional size structure; PSS) for quality (Q), preferred (P), memorable (M), and trophy (T) length categories (Gablehouse 1984) and mean relative weight (Wr; where n ≥ 3) of various fish species captured. Species codes are as follows, Black bullhead (BLB), Black crappie (BLC), Bluegill (BLG), Largemouth Bass (LMB), Northern Pike (NOP), Walleye (WAE), and Yellow Perch (YEP).

Figure 10. MDNR individual fish survey results 1986-2010

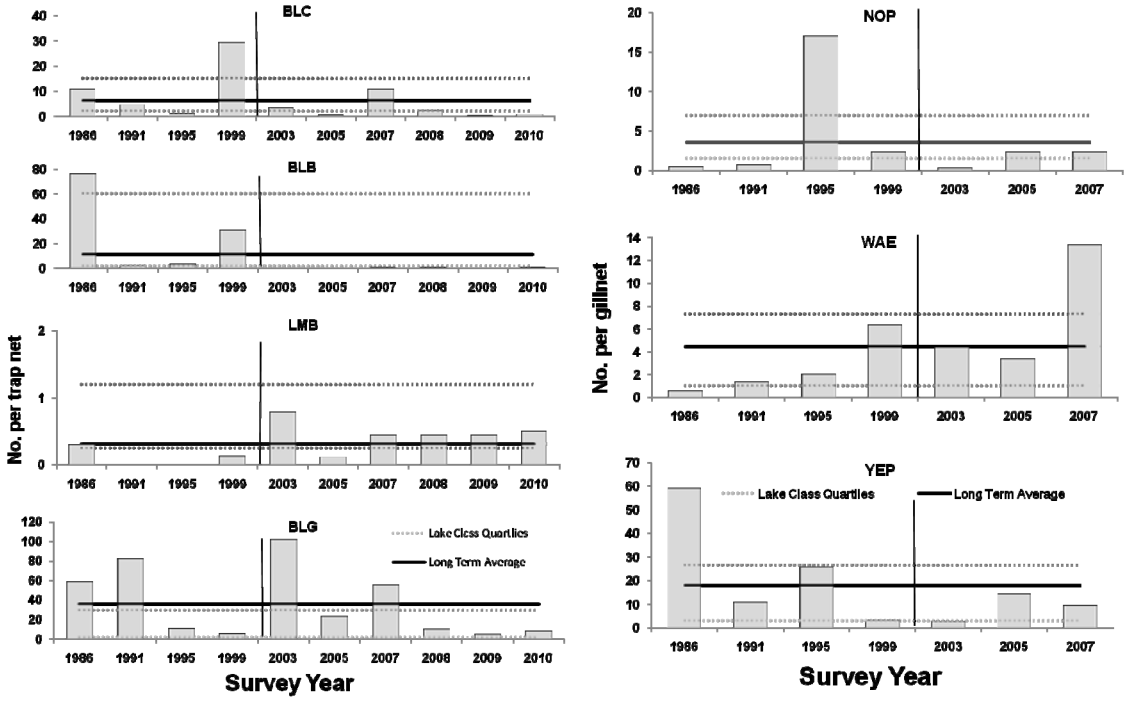
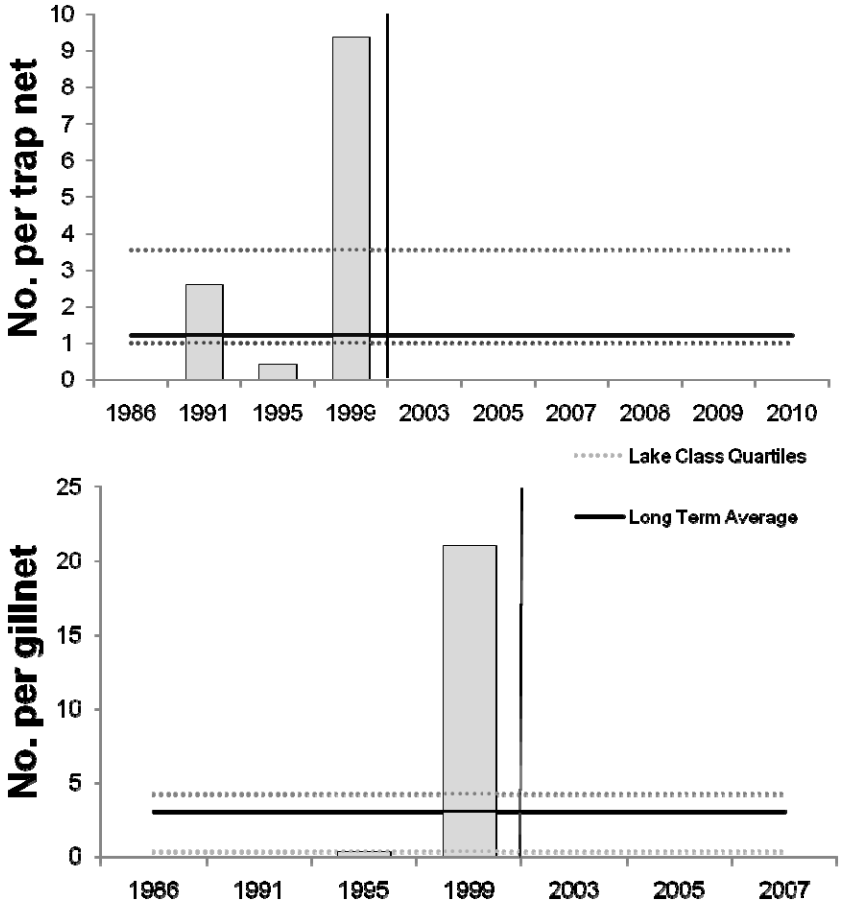


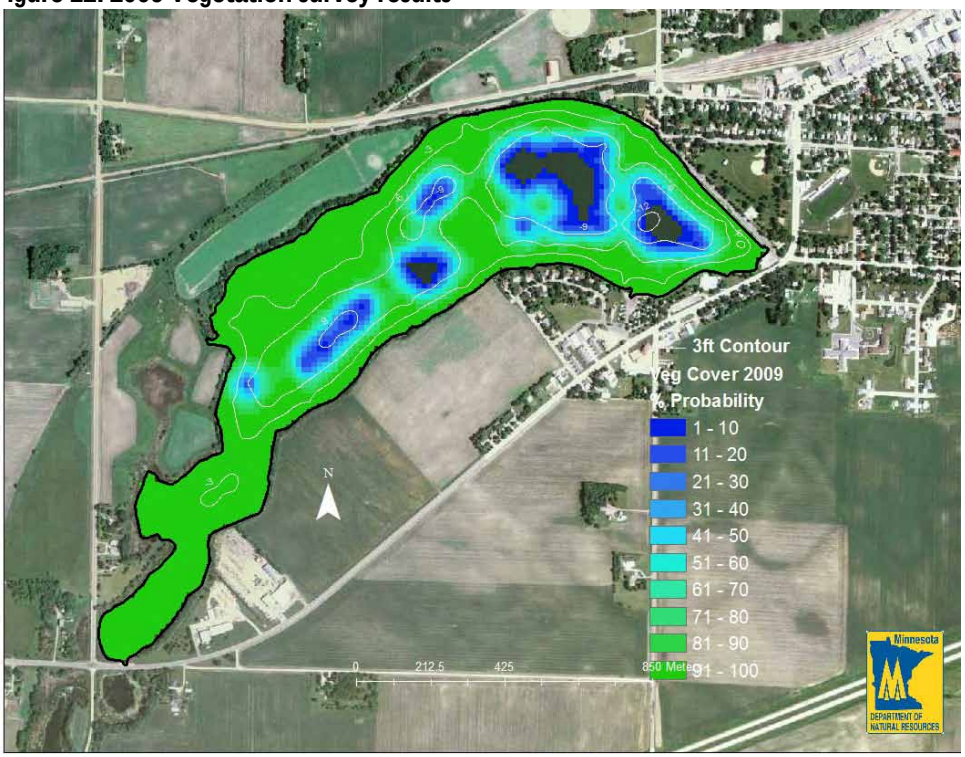
Figure 11. MDNR Common Carp survey results



Aquatic Plant Assessment

Presumably due to shading from phytoplankton that was the result of high phosphorus concentrations, emergent and submersed aquatic plants were rare in historic surveys of St. James (Table 6). As water quality in the lake has improved so has the cover and abundance of aquatic plants and the overall quality of fish habitat. In summer 2009, native plants covered approximately 79% of the lake bottom (Figure 12 and Table 7) including muskgrass (Chara sp.), a plant important for juvenile fish habitat and maintenance of water clarity (Kufel and Kufel 2002; Valley et al. 2010). Observations of high native plant cover throughout summer are unique for a lake in the cornbelt southwest part of the state. Especially given the often prolific spring and summer growth of the non-native invasive curly-leaf pondweed which was first detected in 1986. Elimination of benthivorous fish such as carp and black bullheads may be key in promoting the growth of rooted macrophytes in this ecoregion.

Figure 12. 2009 Vegetation survey results



Curly-leaf pondweed

Curly-leaf pondweed is a non-native invasive submerged aquatic plant that is widespread throughout the southern part of the state. The exact date of introduction into Minnesota is unknown, but it is believed to have been present in Minnesota lakes since the early 1900's when carp were brought into the state. Curly-leaf pondweed grows most abundantly during early spring and senesces by mid-summer. When curly-leaf pondweed is abundant, mid-summer diebacks often promote algae blooms which limit light penetration for native aquatic plants. Consequently, aquatic plant growth during mid- to late-summer is typically sparse in lakes where curly-leaf pondweed is abundant in spring; however, that pattern does not appear consistent in St. James and abundant native plant growth remains after curly-leaf pondweed senescence (Figure 13).

Curly-leaf pondweed thrives in nutrient-rich conditions and at some threshold of nutrients (exact quantity unknown), is presumed to be a self-sustaining internal driver of poor water quality conditions. These self-perpetuating conditions of curly-leaf booms followed by large summer die-offs and algae blooms with little rooted plant growth in summer are most common in eutrophic to hypereutrophic lakes in the southern half of the state. Due to the moderate phosphorous levels in St. James and lack of benthivorous fish, it occupies a state somewhere in the middle; that is, abundant curly-leaf pondweed *and* abundant native plants that persist throughout summer. Additional nutrient loading into St. James would likely greatly reduce if not eliminate summer aquatic plant growth and have negative consequences for water quality and fish habitat.

In contrast to southern eutrophic Minnesota lakes, curly-leaf pondweed is less abundant (if present at all) and typically is integrated with other aquatic plants in northern mesotrophic lakes. Because the plant needs to photosynthesize during winter, curly-leaf pondweed is sensitive to long periods of snow and ice cover on lakes. Reduced snow and ice cover due to climate change may favor increases in this plants abundance in infested lakes and latitudinal range of viability.

Curly-leaf pondweed cover was assessed with point-intercept vegetation surveys in springs 2008-2010 (Table 7. Interestingly, we have observed a steep decline of curly-leaf pondweed frequency of occurrence over the three years the plant was assessed (46% in 2008 to 26% in 2009 to 3% in 2010; Table 7). In 2010, despite the warmer than normal spring with early ice-out conditions, we actually observed lower curly-leaf pondweed abundance in St. James and several other infested lakes across the sentinel network (unpublished survey data). In contrast, the springs and summers of 2008 were slightly to modestly cooler than the 1971-2000 normal (Winnebago NWS station growing degree base 40 F analysis). The effect of climate time-lags on curly-leaf pondweed growth should be evaluated. Surveys in 2011 are planned and will help us determine whether curly-leaf pondweed responds favorably in 2011 due to the presumed favorable growth conditions in 2010.

For an "urban" lake, shoreline development is relatively low on St. James Lake and restricted to the eastern arm of the lake. Only 11 dock structures were enumerated from aerial photos acquired from the Farm Service Administration in summer 2009. Consequently, current aquatic plant removal activities probably have a very small impact on fish habitat in the lake. Minimal removal of aquatic plants will be required for maintaining quality fish habitat in St. James Lake.

Figure 13. September 2009 St. James Curly-leaf photo

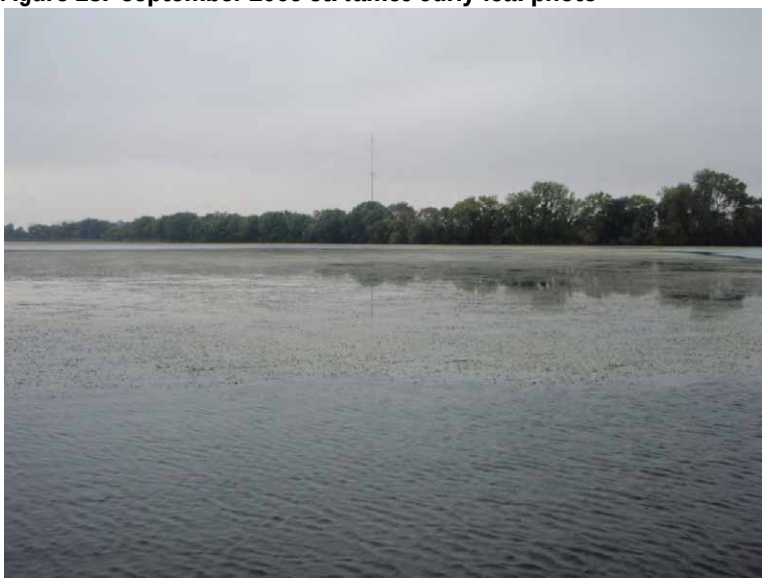


Table 6 Commonly occurring aquatic plants during historical lake surveys prior to 2008.

Year	Common Name	Species Name	Growth Form
1948	*Scarce or occasional cover of emergent vegetation; no submersed vegetation*		
1957	River bulrush	*Scirpus fluviatilis*	Emergent
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed
	Sago pondweed	*Stuckenia pectinata*	Submersed
1986	Narrow-leaf cattail	*Typha angustifolia*	Emergent
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Submersed
	Sago pondweed	*Stuckenia pectinata*	Submersed
	Common cattail	*Typha latifolia*	Emergent
	Narrow-leaf cattail	*Typha angustifolia.*	Emergent
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Submersed
	Sago pondweed	*Stuckenia pectinata*	Submersed
1995	Bushy pondweed	*Najas flexilis*	Submersed
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed
	Muskgrass	*Chara sp.*	Submersed
	Sago pondweed	*Stuckenia pectinata*	Submersed
2003	Filamentous Algae		
	Common cattail	*Typha latifolia*	Emergent
	River bulrush	*Scirpus fluviatilis*	Emergent
	Water arum	*Calla palustris*	Emergent
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Submersed
	Illinois pondweed	*Potamogeton illinoensis*	Submersed
	Muskgrass	*Chara sp.*	Submersed
	Sago pondweed	*Stuckenia pectinata*	Submersed

Table 7. Percent frequency of occurrence of aquatic plant species at depths ≤ 15 feet sampled during point-intercept surveys on 27 August 2008, 11 August 2009, and 26 July 2010 at St. James Lake, Watonwan County, MN.

Season	Common Name	Species Name	Growth Form	Frequency (%) 2008	2009	2010
Spring[a]	All rooted			88.9[b]	88.7[b]	69.8[b]
	Filamentous algae			84.1	66.7	25.5
	Northern watermilfoil	*Myriophyllum sibiricum*	Submersed	47.9	54.0	45.6
	Curly-leaf pondweed[c]	*Potamogeton crispus*	Submersed	45.7	26.7	2.7
	Coontail	*Ceratophyllum demersum*	Submersed	42.8	59.3	48.3
	Sago pondweed	*Stuckenia pectinata*	Submersed	26.1	29.3	16.1
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed	21.7	22.6	9.4
	Flat-stem pondweed	*Potamogeton zosteriformis*	Submersed	16.7	0	0
	Lesser duckweed	*Lemna minor*	Free-floating	8.7	0	0.7
	Cattail	*Typha sp.*	Emergent	4.3	1.3	0
	Muskgrass	*Chara sp.*	Submersed	0	8.0	6.0
	Stonewart	*Nitella sp.*	Submersed	0	0	0.7
	Greater duckweed	*Spirodela polyrhiza*	Free-floating	0	0	0.7
Summer	All rooted			71.5	81.2	84.7
	Northern watermilfoil	*Myriophyllum sibiricum*	Submersed	50.3	65.8	52.0
	Filamentous algae			43.0	49.0	44.7
	Coontail	*Ceratophyllum demersum*	Submersed	34.4	64.4	72.7
	Sago pondweed	*Stuckenia pectinata*	Submersed	25.8	7.4	6.7
	Clasping-leaf pondweed	*Potomogeton richarsonii*	Submersed	16.6	14.8	8.0
	Bushy pondweed	*Najas flexilis*	Submersed	6.0	0	2.7
	Lesser duckweed	*Lemna minor*	Free-floating	5.3	5.4	
	Cattail	*Typha sp.*	Emergent	4.0	4.7	4.0
	Muskgrass	*Chara sp.*	Submersed	3.9	20.1	12.7
	Curly-leaf pondweed[c]	*Potamogeton crispus*	Submersed	3.3	3.4	4.0
	Naiad	*Najas sp.*	Submersed	0	12.1	2.0
	Narrow-leaf pondweed	*Potamogeton sp.*	Submerged	0	6.0	0
	Duckweed	*Lemna sp.*	Free-floating	0	0	0.7
	Narrow- & float leaf pondweed	*Potamogeton sp.*	Submerged	0	0	0.7
	Max depth of veg growth (ft)[d]			7.3	8.8	10.5

[a]Surveys targeting curly-leaf pondweed
[b]surveyed on 9 June 2008, 4 June 2009, 26 May 2010
[c]Non-native
[d]Depth of 95% of all plant occurrence

Water Quality

Standard summer-mean water quality results from 1990, 2008 2009 and 2010 are presented in Table 3. Individual monitoring and sampling results are in Appendix C. Summer mean values for chl-*a*, TP and Secchi were better than typical WCBP lakes, based on ecoregion reference lake range (Table 8). For most parameters including color, alkalinity and TSS summer results were below or within the WCBP interquartile range. Summer mean chloride levels were above the ecoregion range in each of the four summers (Table 8).

Phosphorus

Phosphorus is typically considered the limiting nutrient for algal growth on Minnesota lakes, and was monitored in all four years of sampling. Summer-mean total phosphorus (TP) levels were similar among all four years on St. James. Based on summers with monthly monitoring: 1990, 2008 and 2009 TP levels declined somewhat from May to September (Figure 14). This is not consistent with other shallow lakes that often exhibit an increase in TP over the summer; typically as a result of internal recycling of P. Dissolved ortho-phosphorus (DOP), also referred to as soluble reactive P, was below detection (5 µg/L) on all six dates when it was measured (Appendix A). This further indicates that P is the limiting nutrient in St. James Lake.

Chlorophyll-a

Chlorophyll-a (chl-*a*) is a measure of the concentration of algae in lakes. Chl-*a* varied through each summer with higher results often observed in June or July. A significant bloom was noted in June 2009; however following this bloom chl-*a* was relatively low the remainder of the summer. TP and chl-*a* concentration were generally correlated with the exception of the May 2008 results. Seasonally there is no distinct trend among the four years (Figure 14). On average, chl-*a* was lower in 2008 and 2009 as compared to 1990 (Table 8).

Secchi disk transparency

Long-term Secchi depth averages around 1 meter. The 2008 and 2009 Secchi observation show a typical pattern of mid-summer reduction in clarity (Figure 14). There is reasonably good correspondence among chl-*a* and Secchi in most summers (e.g. 1990); however there are a few dates when correspondence was very poor (e.g. 2009), which suggests additional factors may influence transparency in St. James. The highest observed transparencies were observed in early and late summer.

Figure 14. Phosphorus, Chlorophyll-a and Secchi: 1990, 2008-2010.

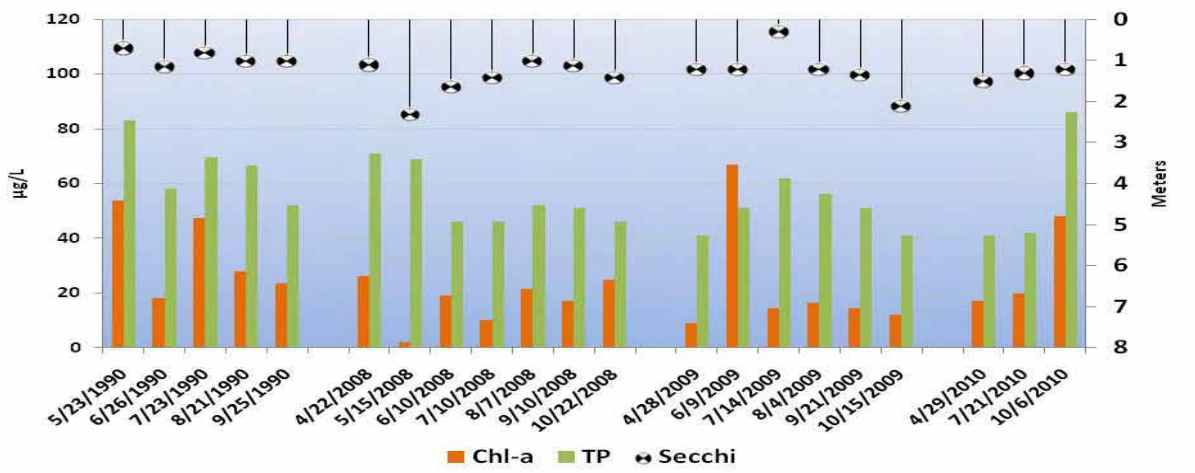


Table 8. 1990,2008 2009 and 2010 water chemistry compared to typical range for WCBP ecoregion reference lakes

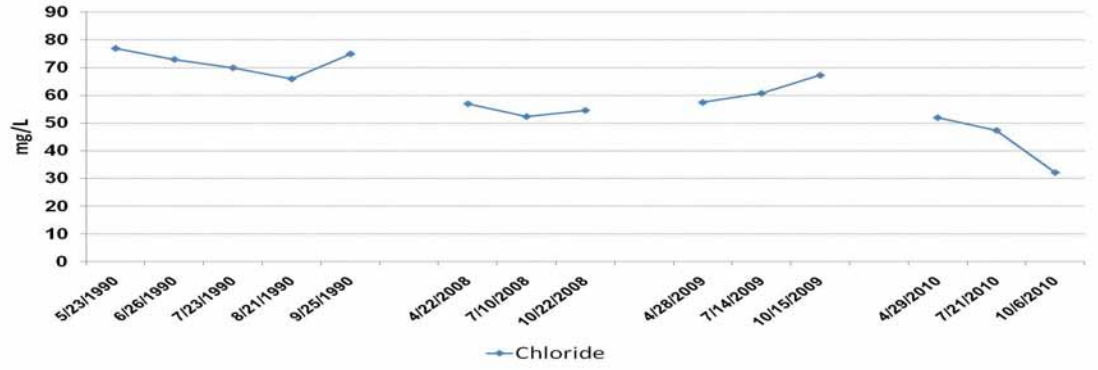
Parameter	1990	2008	2009	2010 April July & Oct. only	WCBP Reference Lake Inter-quartile
Number of reference lakes					16
Total Phosphorus (µg/L)	62	54	50	47	65 – 150
Chlorophyll mean (µg/L)	29.2	15.9	22.2	28	30 – 80
Secchi Disk (Meters) (feet)	0.84 (2.7)	1.5 (4.9)	1.2 (3.9)	1.3 (4.2)	0.5-1.0 (1.6 - 3.2)
Total Kjeldahl Nitrogen (mg/L)	2.1	1.1	1.2	1.3	1.3 – 2.7
Alkalinity (mg/L)	126	156	133	133	125 – 165
Color (Pt-Co U)	22	16.6	20	23	15 – 25
pH (SU)	8,9	8.8	8.9	8.8	8.2 – 9.0
Chloride (mg/L)	71	55	62	44	13 – 22
Total Suspended Solids (mg/L)	8.5	3.6	5.9	6.0	7 – 18
Total Suspended Inorganic Solids (mg/L)	3.6	1.2	3.1	1.5	3 – 9
Conductivity (µmhos/cm)	732	535	551	601	300 – 650
TN:TP ratio	56:1	21: 1	22.6	22	17:1 – 27:1

µg/L = micrograms per liter	Pt-Co-U = Platinum Cobalt Units
mg/L = milligrams per liter	SU = Standard Units
µmhos/cm = micromhos per centimeter	

Chloride

Chloride (Cl) is considered a good indicator of anthropogenic impact on a lake. Road salt is often a large contributor to elevated Cl in lakes. Given St. James Lake's proximity to the city and existence of several "conduits" for stormwater runoff to enter the lake (Appendix B and C) slightly elevated Cl does not come as a surprise; however, based on the four years of data Cl inSt. James is much higher than the typical range for WCBP lakes (Table 8). The most recent Cl measurements suggest a slight decline as compared to 1990 summer chloride levels (Figure 15).

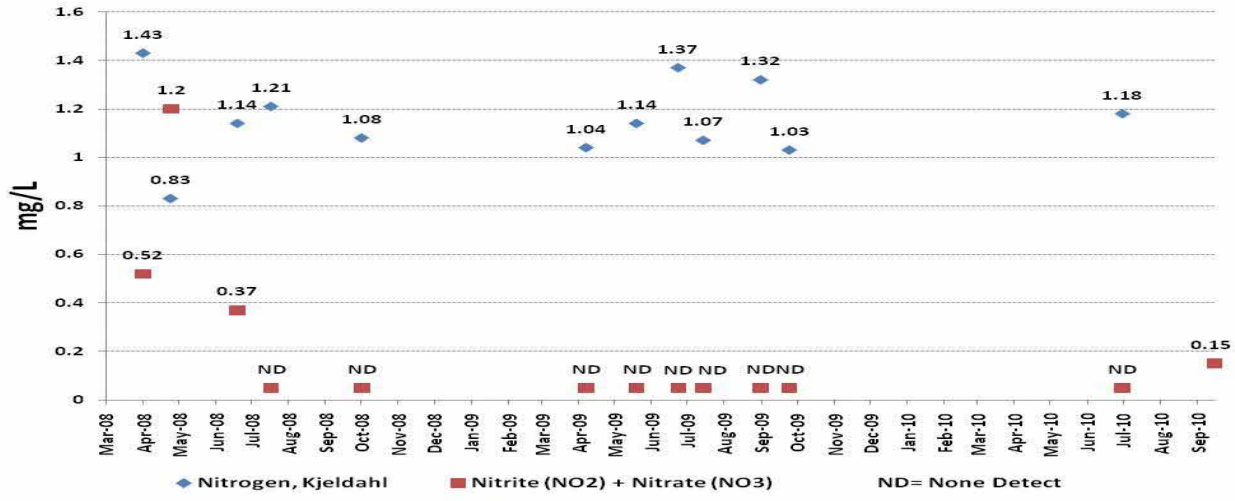
Figure 15. St. James Lake Chloride Results



Nitrogen

Nitrogen measured as total Kjeldahl nitrogen (TKN), is a primary nutrient required for algal and plant growth was on the low end of the typical range for WCBP lakes. Nitrate-N, which is readily used by algae and rooted plants was at or below detection on most sample dates (Appendix A). TKN and nitrate-N ranges were rather similar for the 2008-2010 time period; however concentrations were much higher in 1990 by comparison (Figure 16). Weir and Snyder (1991) note in the 1990 study the possibility of runoff from a chemical/fertilizer plant along the north shore of the lake. Absent any other "point source" this could explain these very high values. The TN:TP ratio is higher than the typical range indicating St. James Lake is strongly P-limited.

Figure 16. TKN and nitrate-N for St. James Lake: 1990, 2008-2010.



Dissolved minerals and organic carbon

Dissolved minerals and organic carbon were measured in 2008, 2009 and 2010 as part of the long-term monitoring of St. James and other Sentinel lakes including the major cations, anions, silica, iron and organic carbon (Table 9). St. James results for all three years show hard water conditions with results for most ions above the 2007 National Lakes Assessment (NLA). The NLA study looked at 50 randomly selected lakes across Minnesota provides one means for placing these data in perspective.

Total organic carbon (TOC) is in the interquartile range of the 2007 NLA study (Table 9). Lakes that receive a majority of their water inputs from forest and wetland runoff often have correspondingly higher color and TOC values as a result of incompletely dissolved organic matter (plants, leaves, and other organic material). TOC values for St. James are fairly typical for a WCBP lake.

Calcium (Ca) and magnesium (Mg) are the dominant cations and concentrations of both are within the typical range of the state-wide data (Table 9). The other two major cations – sodium (Na) and potassium (K) are well within the typical range as well. Bicarbonate is the dominant cation, followed by chloride (Cl) and sulfate (SO_4). Ca and Mg results were highest in April compared to the other results. Elevated Cl is most often attributed to application of road salt on roads in the watershed. Sulfate is high relative to the NLA data (Table 9). The average cation and anion balances (cation-anions expressed as a % of cations) for 2008, 2009 and 2010 were within 5% which is well within values exhibited by the NLA lakes.

Table 9.James Lake cation, anion, and total organic carbon measurements

	Ca[1]	Mg	Na	K	Alk	SO_4	Cl	TOC
	mg/L	mg/L	mg/L	mg/L	mg/L eq	mg/L	mg/L	mg/L
4/22/2008	60	41.0	21.0	3.5	190	76.4	57.0	7.1
7/10/2008	35	38.0	19.0	2.8	140	76.8	52.4	8.5
10/22/2008	38	41.0	21.0	3.2	140	75.4	54.6	8.7
4/28/2009	48	37.8	21.4	3.5	170	68.5	57.5	9.2
7/14/2009	25	37.0	22.8	2.87	110	65.1	60.8	10.0
10/15/2009	29	36.7	24.0	3.43	120	65.0	67.3	9.7
4/29/2010	53	34.5	20.7	3.23	150	63.9	52.0	8.7
7/21/2010	31	31.7	33.6	3.95	110	67.4	47.4	7.4
10/6/2010	42	27.1	13.3	3.66	140	52.8	32.2	6.7
Average	40.1	36.1	21.9	3.3	141	67.9	53.5	8.4
µeq/L	2,295	4,113	914	84	2,820	1,271	1,495	
NLA IQ range (mg/L)	19.1 – 33.7	6.7 – 26.9	2.2 – 9.0	0.9 – 4.8		2.2 – 14.0	1.5 – 18.4	7.3 – 14.2

Dissolved Oxygen and Temperature

Profile measurements were taken regularly at 1 meter intervals through the water column. Temperature profile measurements were relatively uniform from the surface to the bottom of the lake on most sample dates (Figure 17 – 19). The consistent temperature from top to bottom would allow the lake to mix readily with windy conditions and generally helps maintain dissolved oxygen (DO) in the lower portions of the lake. DO profiles were not as uniform as the temperature measurements. On some dates, DO declined with depth (e.g. July 2010 DO concentration dropped to below 2 mg/L). This "stratification" of DO is most common during quiescent conditions when DO in the upper layer is not readily mixed into the lower layer of the lake. Other related factors include temperature and its influence on DO solubility, algal photosynthesis near surface of lake and bacterial consumption of DO near the bottom of the lake. Regardless of the cause, low DO (<2.0 mg/L) increases the likelihood of P release from the sediments of the lake

Figure 17. 2008 Temperature and DO profiles

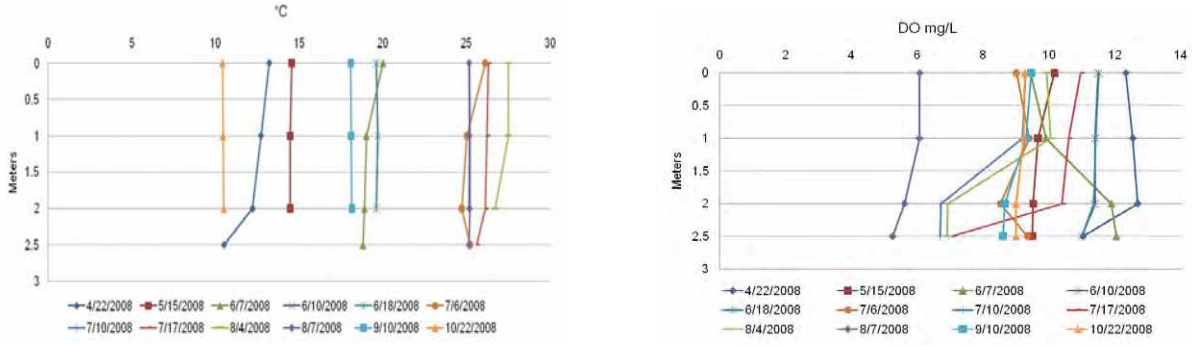


Figure 18. 2009 Temperature and DO profiles

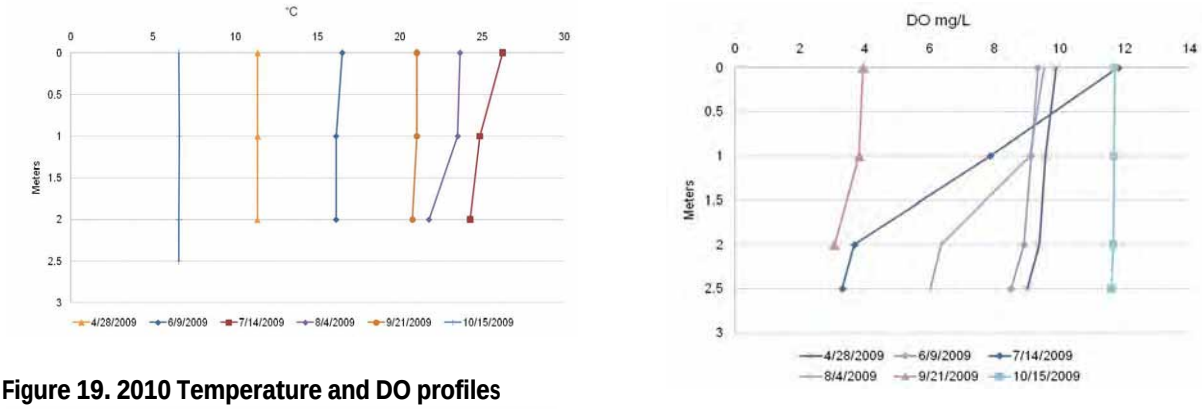
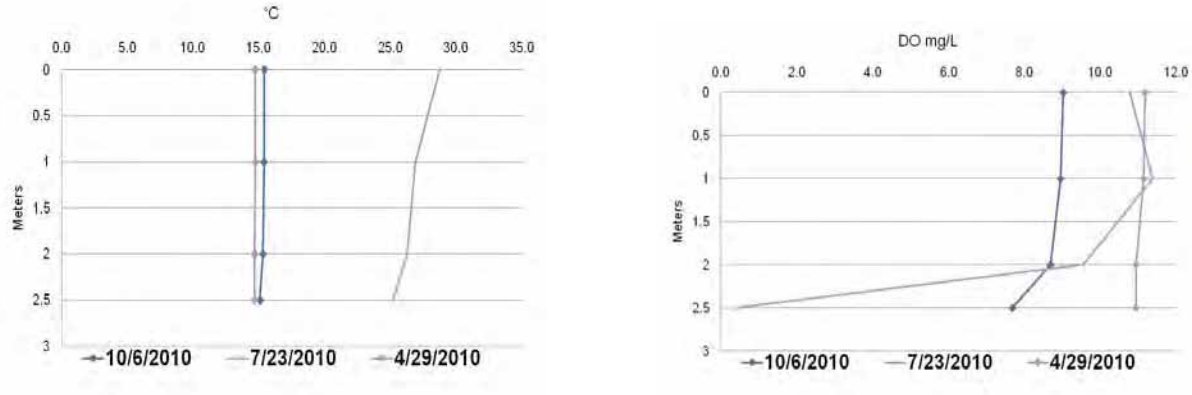
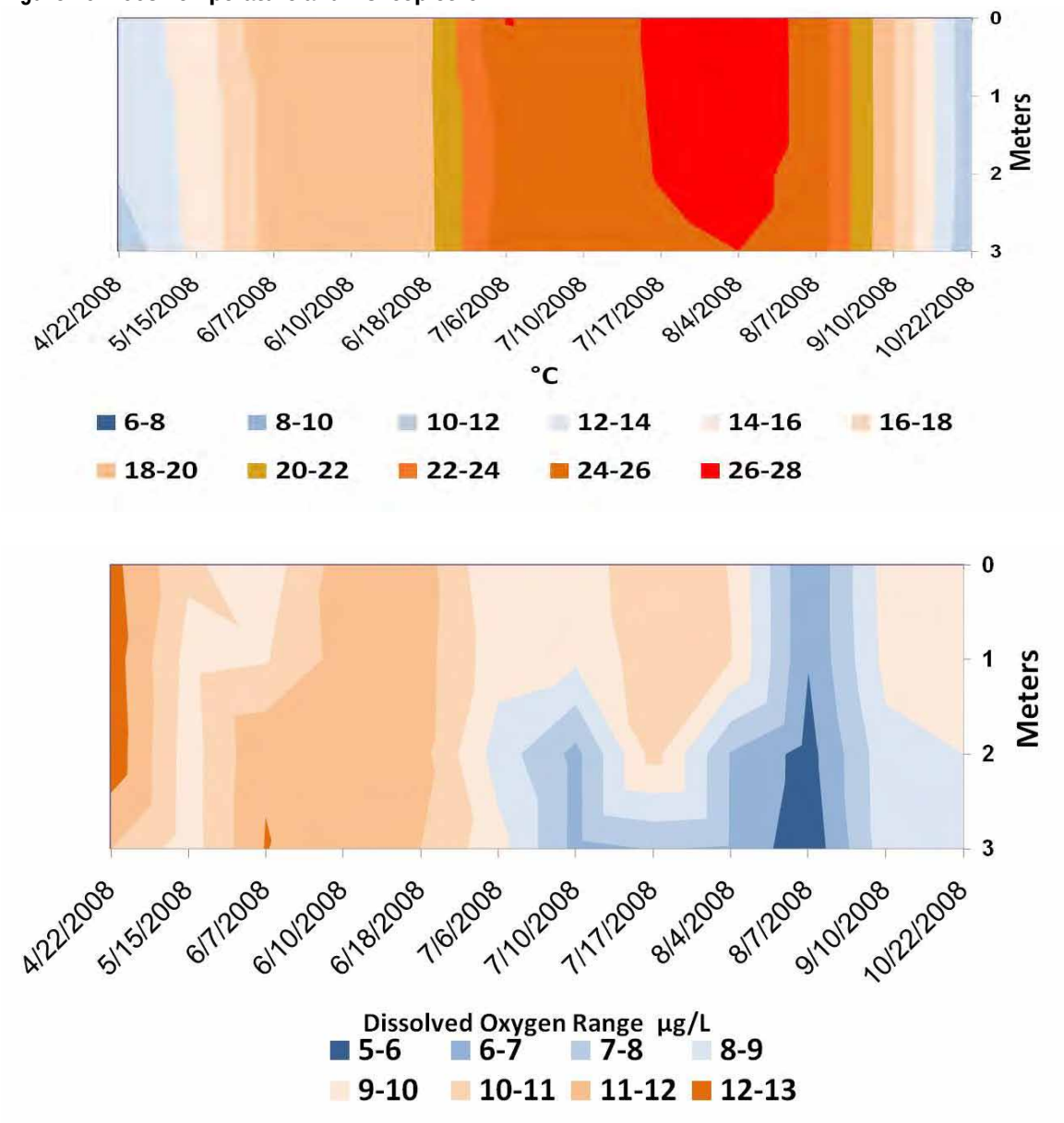


Figure 19. 2010 Temperature and DO profiles



Another way to look at the temperature change over time is fill in the gaps between observations with interpolations using an isopleth (Figure 20). In 2008 the isopleths show well-mixed conditions May through July. In late July, temperatures at depth were slightly cooler than surface temperature for a short period and were uniform thereafter. The isopleths reveal the subtle stratification of DO with depth but in general,indicate there was adequate DO for fish throughout the water column during the 2008 monitoring season.

Figure 20. 2008 Temperature and DO isopleths



Phytoplankton (algae)

Chl-*a* provides an estimate of algal biomass, is often used to describe algal bloom intensity and frequency; however, it is often important to understand which algal forms contribute to the blooms and how dominance of the various forms changes from spring to fall. For this purpose, algae samples were collected during the three seasons of Sentinel lake monitoring. Only the 2008 and 2009 samples have been analyzed to date (Figure 21).

Algal composition varied slightly between the two years. Diatoms were dominant in May in both years (Figure 21). In 2009 diatoms maintained their dominance into June, which was characterized by a significant bloom of diatoms.. In general, diatoms prosper under cool well-mixed conditions in the spring when both nutrients and silica are abundant. They typically die-back by June in response to declining silica concentrations and warming of the lake. Based on Figures 17 and 18, 2008 June temperatures were warmer than 2009 and this may explain the difference in the transition of the algal forms for these two years.

Blue-green algae were dominant in May through October 2008. In 2009, blue-green taxa were much less dominant as compared to 2008 and dinoflagellates (a somewhat uncommon form) were dominant in September and October 2009. The most commonly identified blue-green were *Anabaena*, *Microcystis* and *Aphanizomenon*. Commonly observed diatoms were *Fragilaria*, *Asterionella* and *Pennates* (Figures 22 and 23).

Figure 21.. Major phytoplankton group composition 2008 and 2009

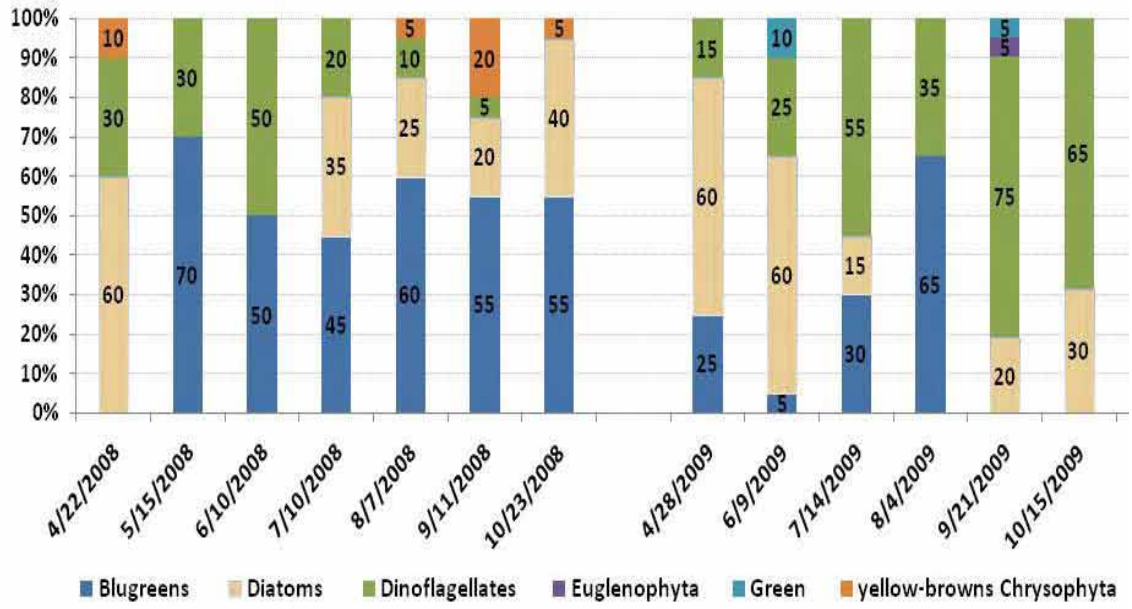


Figure 22. Phytoplankton image July 10 2008

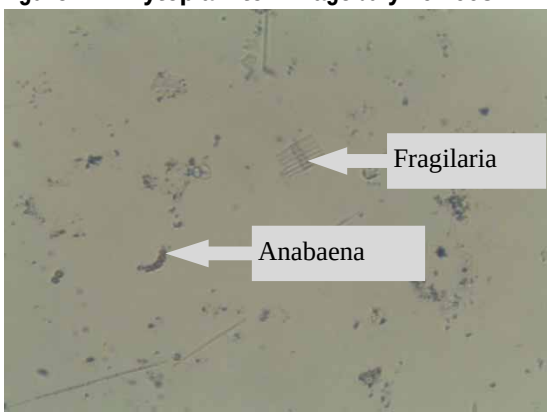


Figure 24. Phytoplankton image April 28 2009

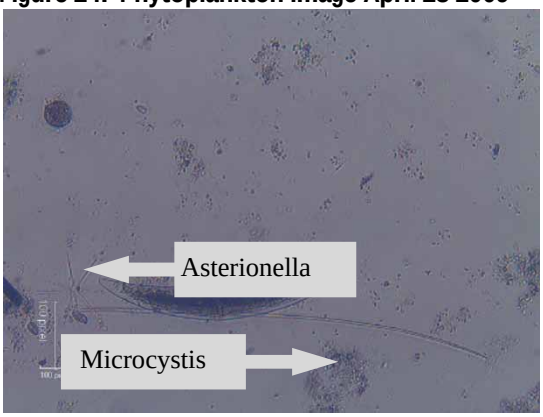


Figure 23. Phytoplankton image Oct. 23 2008

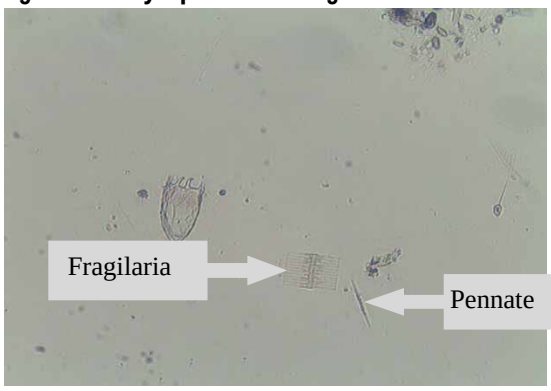
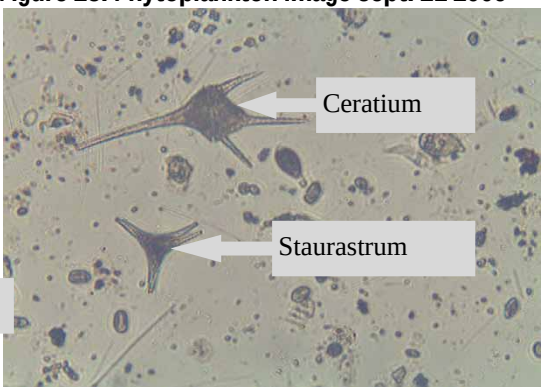


Figure 25. Phytoplankton image Sept. 21 2009



Zooplankton

Zooplankton samples were analyzed by Jodie Hirsch at the MDNR. A summary report was prepared that included information for all the Sentinel lakes sampled in 2008 (Hirsch 2009). Results from 2009 and 2010 were charted by MPCA staff and will be included in the discussion below. Zooplankton biomass on St. James was low but mean densities were intermediate compared to other Sentinel lakes in the WCBP ecoregion (Table 10).

Table 10. Sentinel Lake study zooplankton summary (Hirsch 2009)

Sentinel Lakes Zooplankton 2008	Mean Annual Densities (#/L)	Mean Annual Biomass (µg/L)	Total# Taxa
Western Corn Belt Plains			
Artichoke	139.64	724.05	12
Shaokotan	107.55	1070.97	11
St. James	**62.73**	**108.56**	**10**
St. Olaf	60.23	336.20	15
Carrie	56.41	254.21	13
Madison	52.78	310.93	14
North Central Hardwood Forest			
Peltier	78.75	1098.39	12
Pearl	59.68	221.13	14
Belle	57.67	340.06	12
South Center	24.72	123.71	18
Carlos	19.66	73.49	16
Cedar	11.31	41.85	11
Northern Lakes and Forests			
Portage Lake	100.10	277.38	10
Cedar	79.31	127.96	18
South Twin	25.83	54.93	12
Hill	17.73	147.29	11
Elk	16.95	47.10	12
Ten Mile	14.94	44.89	14
Border Lakes			
Echo	37.03	89.68	12
Elephant	13.26	75.50	12
White Iron	10.00	38.64	14
Trout	6.28	29.52	13
Bearhead	5.15	38.37	14
Northern Light	1.03	4.16	13

The zooplankton community in St. James Lake appears to be typical in numbers, but small in size relative to other WCBP lakes (Table 10). Zooplankton biomass was highest in April in all three years and dominated by copepods (Figure 25). Zooplankton levels declined through late summer and increased in October of each year. Much of the seasonal decrease was associated with the copepods and the relative proportion of cladocerans increased in the summer as compared to spring.

Cladocera size and composition varies among the three years of sample collection on St. James (Figure 26). There were no consistent patterns in cladoceran size nor composition based on these data. The two most commonly occurring (~11 of 14 samples) cladocerans were *Bosmina longirostris* and *Chydorus sphaericus*, both of which are small forms (~0.3 mm on average). *Daphnia pulex* was the largest on average (~1.14 mm), but was present in only 6 of 14 samples. Larger (>1mm) cladocerans are associated with high plankton grazing, which in turn can improve water clarity. Over the three year period cladoceran length averaged 0.6 mm across the various forms of cladocera (Figure 27). A combination of low zooplankton density and paucity of large zooplankton, such as was the case on July 14, 2009 (Figure 26 and 27), can allow for distinct algal blooms and very low transparency (Figure 14).

Figure 26. Biomass comparison between zooplankton types

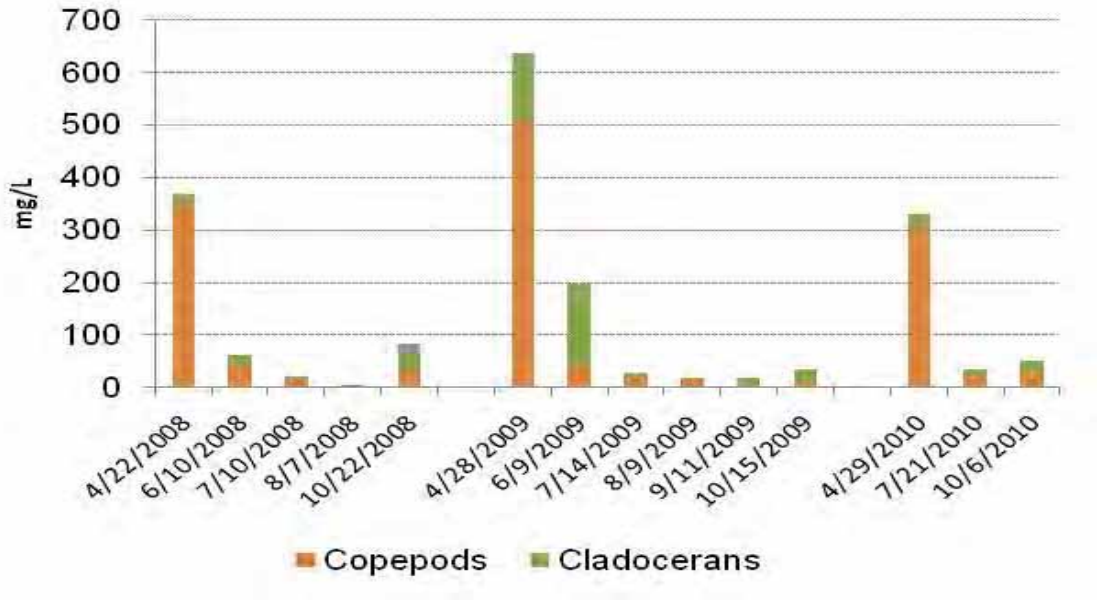
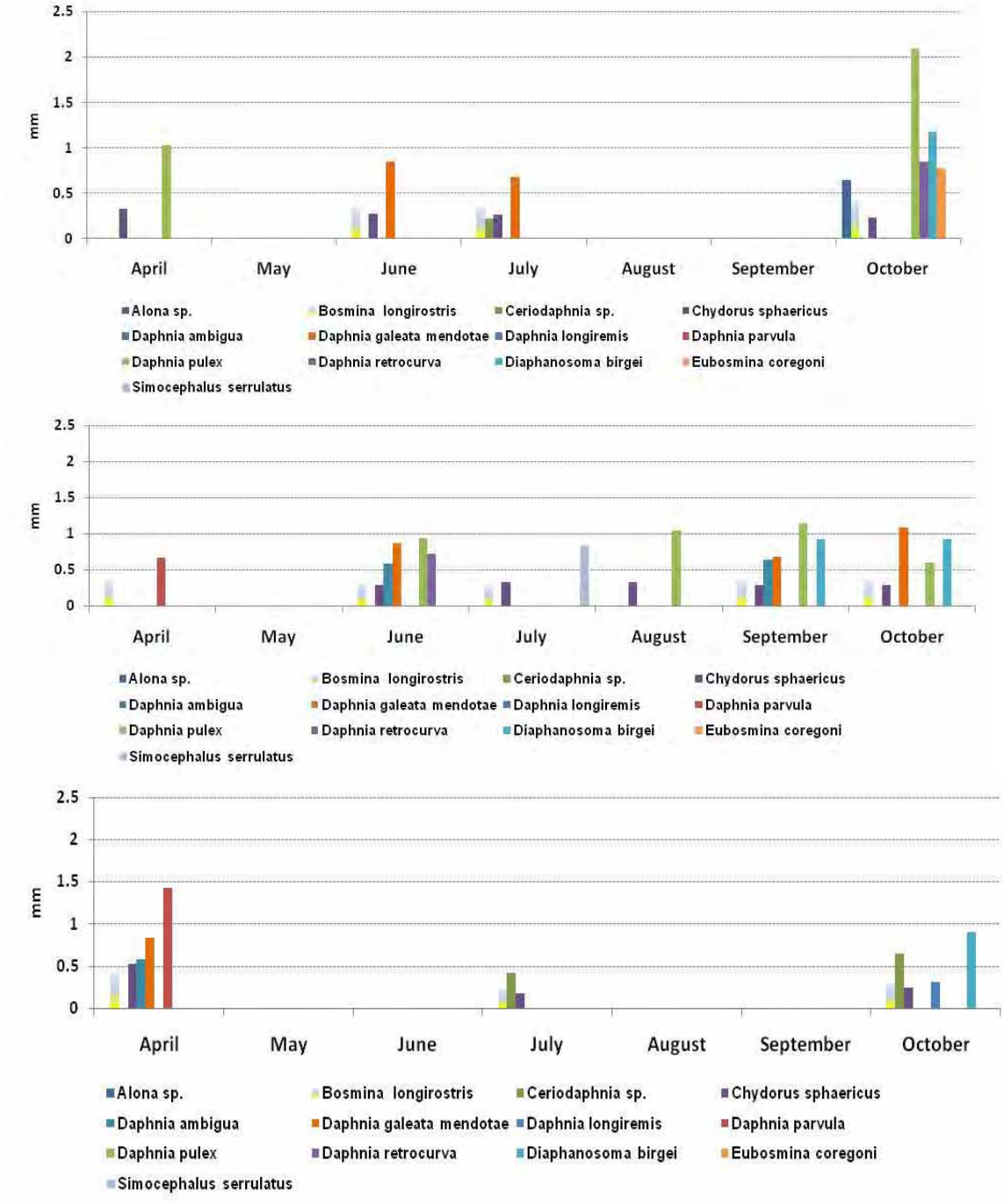


Figure 27. Mean Cladoceran length 2008-2010. Months left blank indicate no collection was made



Trophic State Index

One way to evaluate the trophic status of a lake and to interpret the relationship between TP, chl-*a*, and Secchi disk transparency is Carlson's Trophic State Index (TSI) (Carlson 1977). TSI values are calculated as follows:

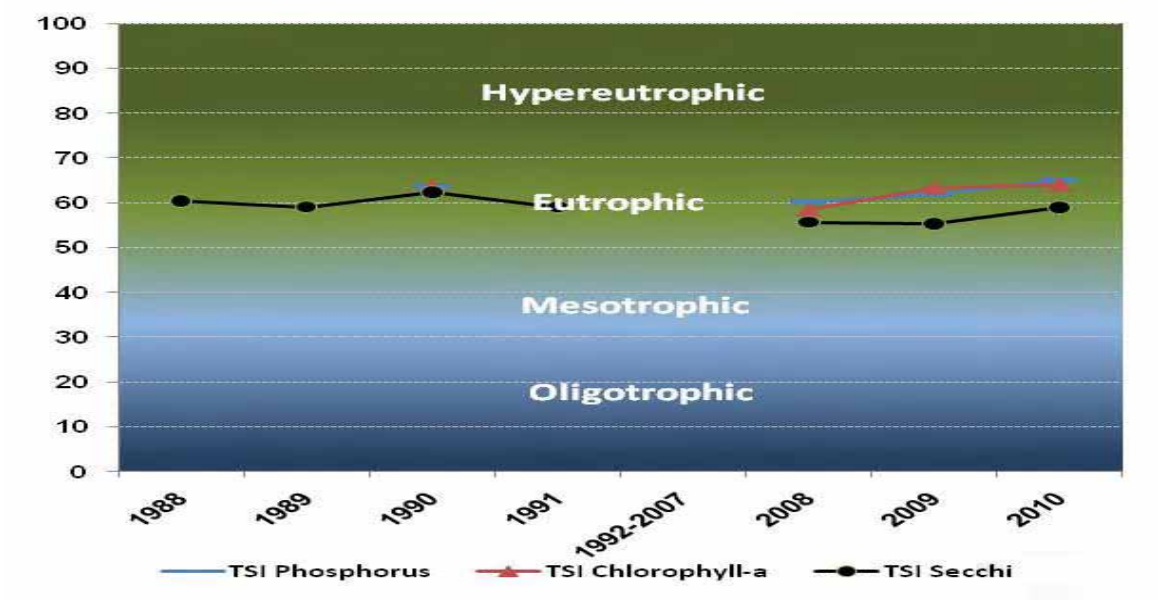
Total Phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

Chlorophyll-*a* TSI (TSIC) = 9.81 ln (chl-*a*) + 30.6

Secchi disk TSI (TSIS) = 60 – 14.41 ln (SD)

TP and chl-*a* are in µg/L and Secchi disk is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass. Comparisons of the individual TSI measures provides a basis for assessing the relationship among TP, chl-*a*, and Secchi (Figure 28). In general, the TSI values are in close correspondence with each other. The TSI values also correspond with observations for 2008. Based on an average TSI score of 62 St. James Lake would be characterized as eutrophic (nutrient rich). In recent years Secchi TSI values were lower (better) that the chl-*a* and TP values. No long-term trend is evident based on the available data.

Figure 28 St. James Trophic Index Trends



Modeling

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake. To analyze the predicted water quality as compared to the St. James Lake, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model (Wilson and Walker, 1989) was used. A comparison of MINLEAP predicted vs. observed values is presented in Table 11.

MINLEAP was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). The model predicts in-lake TP from these inputs and subsequently predicts chl-*a* based on a regression equation of TP and Secchi based on a regression equation based on chl-*a*. For analysis of St. James Lake, MINLEAP was applied as a basis for comparing the observed TP, chl-*a*, and Secchi values with those predicted by the model based on the lake size and depth and the area of the watershed.

St. James Lake is located in the WCBP ecoregion. MINLEAP was run using WCBP ecoregion-based inputs and also NCHF to provide additional perspective. The observed TP, chl-*a*, and Secchi values for St. James Lake are much lower than predicted based on the WCBP-MINLEAP inputs (Table 11). NCHF inputs provide an additional basis for evaluating lake condition and suggest that observed values for St. James Lake are more similar to the NCHF prediction as compared to the WCBP. This implies P loading rates to the lake are likely closer to the NCHF as compared to the WCBP estimate. Estimated "background" TP (Vighi & Chiaudani) is lower than the modern-day TP for St. James Lake (Table 11). Based on the model, water residence time is on the order of 0.8 years and St. James retains about 60-70% of the P loaded to the lake.

Table 11. MINLEAP model predictions for St. James Lake. WCBP & NCHF ecoregion inputs used.

Parameter	2008 Mean	2009 Mean.	2010 Mean	MINLEAP Predictions WCBP	MINLEAP Predictions NCHF
TP (µg/L)	54	48	47	156 ± 56	66±20
Chl-*a* (µg /L)	20	12	28	107 ± 67	30±17
Secchi (m)	1.3	1.2	1.1	0.5 ± .2	1.0±0.4
P loading rate	-	-	-	725	207
P retention (%)	-	-	-	0.72	0.6
P inflow conc.	-	-	-	567	164
Water Load (m/yr)	-	-	-	1.54	1.51
Outflow volume	-	-	-	1.28	1.26
Residence time	-	-	-	0.8	0.8
Vighi & Chiaudani	-	-	-	36	36

303(d) Assessment and Goal Setting

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing and swimming. The standards are set on a wide range of pollutants, including

bacteria, nutrients, turbidity and mercury. A water body is "impaired" if it fails to meet one or more water quality standards.

Under Section 303(d) of the Clean Water Act, the state is required to asses all waters of the state to determine if they meet water quality standards. Waters that do not meet standards (i.e., impaired waters) are added to the 303(d) list and updated every even-numbered year. In order for a lake to be considered impaired for aquatic recreation use, the average TP concentration must exceed the water quality standard for its ecoregion. In addition, either the chl-*a* concentration for the lake must exceed the standard or the Secchi data for the lake must be below the standard. A minimum of eight samples collected over two or more years are needed to conduct the assessment. There are numerous other water quality standards for which we assess Minnesota's water resources. An example is mercury found in fish tissue. If a water body is listed, an investigative TMDL study must be conducted to determine the sources and extent of pollution, and to establish pollutant reduction goals needed to restore the resource to meet the determined water quality standards for its ecoregion. In Minnesota, the MPCA is responsible for performing assessment activities, listing impaired waters, and ensuring that TMDL studies are carried out.

St. James Lake is considered to be fully supporting aquatic recreation use standards (Table 12). Given that it meets water quality standards and model predictions suggest the lake is performing better than anticipated based on the ecoregion it is located in there is a need to protect the current condition of the lake. Various aspects to consider include:

Where possible make reductions in P loading to the lake. This implies the importance of minimizing nonpoint source (e.g. stormwater and agricultural) runoff into the lake and maintaining riparian wetland areas.Aquatic plants are naturally abundant in St. James and under pristine conditions should occupy most of the lake's volume. Protecting native macrophytes and not removing excessive amounts of plant biomass (both native and non-native) will be important to ensure that the lake does not "switch" to an algal-dominated state that no longer supports vegetation growth. Make every effort to ensure that carp are not re-introduced into the lake (or at a minimum do not become dominant in the lake) as the lake's current water quality and plant composition is in part due to the lack of carp in this lake.

Table 12. Eutrophication standards and St. James Lake long-term summer-mean values.

Ecoregion	TP µg/L	Chl-*a* µg/L	Secchi meters
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7
St. James Lake 2008 – 2010 June – September	51	22	1.3

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Appendix A. Recent water quality records St. James Lake.

PARAMETER		4/22/08	7/10/08	10/22/08	4/28/09	7/14/09	10/15/09	4/29/10	7/21/10	10/6/10
Alkalinity, Total (total hydroxide+carbonate+bicarbonate)	mg/L	190	140	140	170	110	120	150	110	140
Calcium	mg/l CaCO3	150	88	96	48	25	29	53	63	42
Carbon, Total Organic (Toc)	mg/l	7	9	9	9	10	10	9	15	7
Chloride	mg/l	57	52	55	58	61	67	52	95	32
Chlorophyll a,	ug/l	26	10	25	9	14	12	17	20	48
Color, Apparent	PCU	10	20	20	20	20	20	20	20	30
Iron	ug/l				23	17	15	15		
Magnesium	ug/l	41	38	41	38	37	37	35	63	27
Nitrogen, Kjeldahl	mg/l	1.43	1.14	1.08	1.04	1.37	1.03	1.26	1.18	1.32
Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	mg/l	1		< 0.05	< 0.05	< 0.05	< 0.05		< 0.05	
Orthophosphate, Dissolved	mg/l				< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Pheophytin-a	ug/l	2	7	2	3	2	< 0.7	4	15	8
Phosphorus as P	ug/l	71	46	46	41	62	41	41	42	59
Potassium		4	3	3	4	3	3	3	4	4
Silica	mg/l				9	7	12	2	12.7	17
Sodium	mg/l	21	19	21	21	23	24	21	34	13
Solids, Total Suspended (TSS)	mg/l	4.40	3.60	2.80	4.00	7.60	6.20	8.80	4.00	5.20
Solids, Volatile	mg/l	3.20	2.40	2.40	1.60	4.00	2.80	5.20	3.60	4.80
Total inorganic Solids	mg/l	1	1	0	2	4	3	4	0	0
Sulfur, sulfate (SO4) as SO4	mg/l	76	77	75	69	65	65	64	67.4	53

Appendix B. Lake inlets as documented in the 1990 assessment

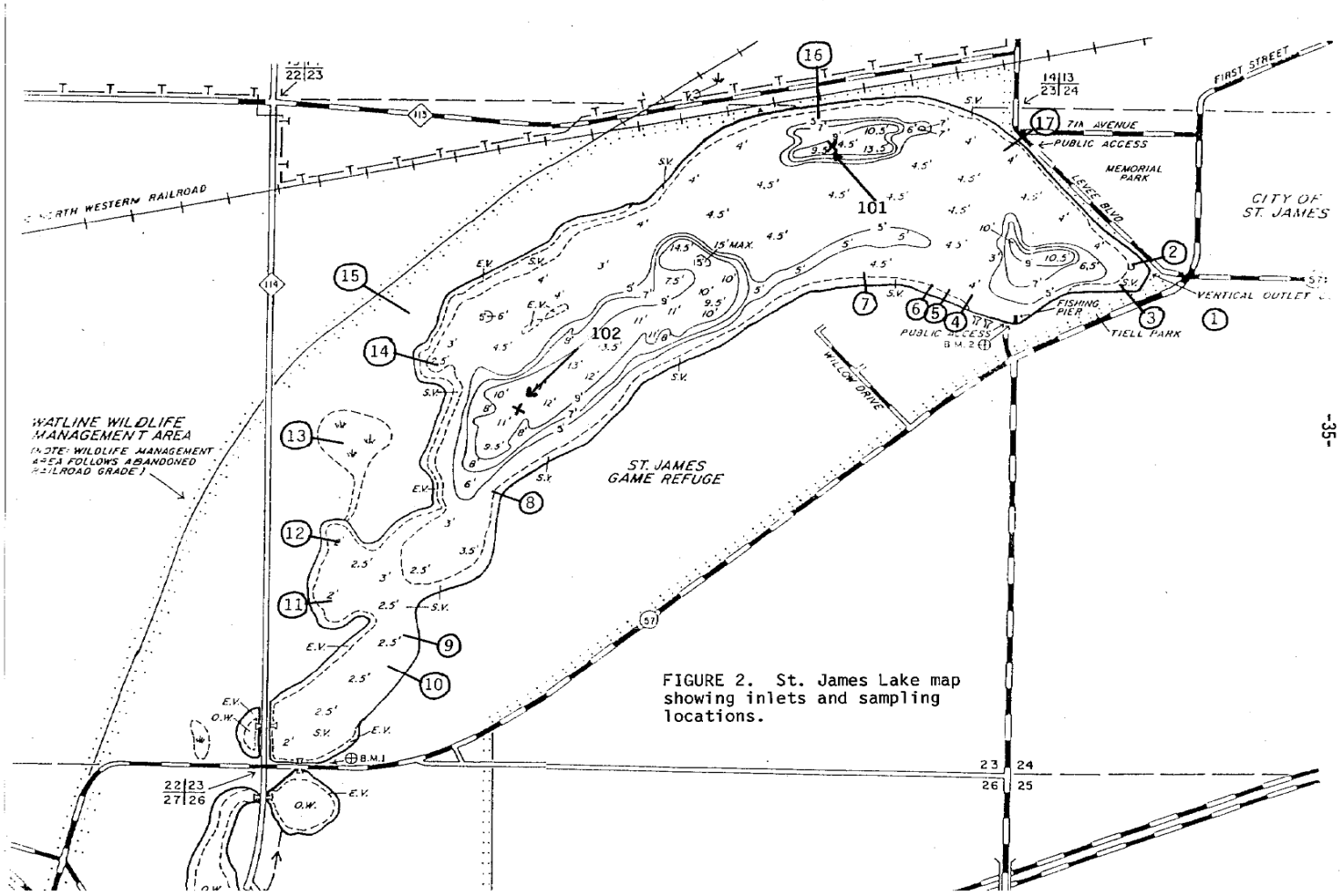

FIGURE 2. St. James Lake map showing inlets and sampling locations.

Appendix C

FIGURE 2 (cont). ST. JAMES LAKE INLETS

Number	Size	Type	Flowing*	Connected To
1	Lake Outlet	Cement	No	Connects to St. James Creek
2	16"	Concrete	No	Storm sewer to highway
3	36"	Concrete	Yes	Storm sewer to highway
4	8"	Concrete	No	Unknown (covered up)
5	15"	Concrete	No	Dredge lot drainage
6	18"	Concrete	No	Willow View storm sewer
7	8"	Plastic	No	Unknown (3-4 feet in ground)
8	8"	Plastic	Yes	Field drain
9	6"	Plastic (inside steel)	Yes	Unknown
10	6"	Plastic (PVC)	No	Possibly REA Drain
11	4"	Clay	No	House basement drain to Burnells
12	10"	Plastic (PVC)	No	Field tile to west Garland property
13	6"	Clay	No	Field tile to west Garland property
14	30"	Plastic	Yes	Dredge spoil site
15	36"	Steel	No	Railroad property culvert
16	40"	Concrete	No	Railroad property culvert
17	8"	Plastic	No	Storm sewer for Levee Blvd. & 7th Ave. South

*No flow may mean intermittent flow