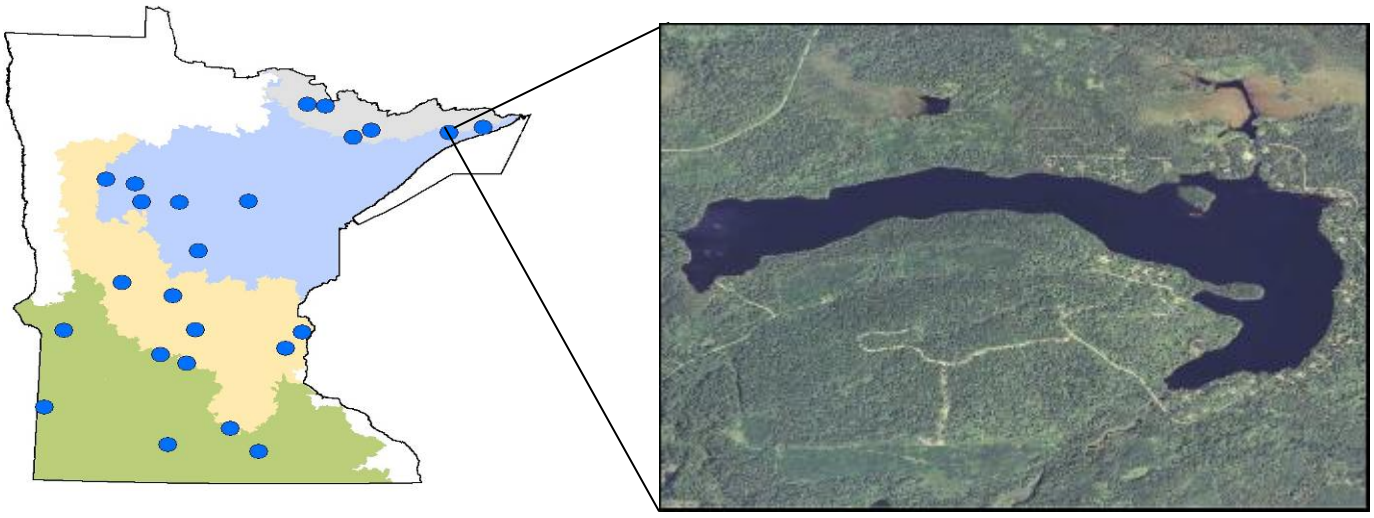
Sentinel Lake Assessment Report
Tait Lake (16-0384)
Cook County, Minnesota



Minnesota Pollution Control Agency
Water Monitoring Section
Lakes and Streams Monitoring Unit
And
Minnesota Department of Natural Resources
Section of Fisheries

June 2012

Minnesota Pollution Control Agency

Minnesota
DEPARTMENT OF NATURAL RESOURCES

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2009-11 Lake Assessment of Tait Lake (16-0384) Cook County, Minnesota
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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. "Shallow" lakes typically remain well mixed throughout the summer. "Cold Water" lakes are defined as lakes that both harbor cisco, lake whitefish, or lake trout and are the focus of research funded by the Environment and Natural Resources Trust Fund (ENTF). "Super sentinel" lakes also harbor cold-water fish populations and research on these lakes is funded by the ENTF.

Tait Lake is located in Cook County within the Lake Superior North Watershed, and forms the headwaters of the Poplar River subwatershed. Tait Lake is located north of Lutsen, Minnesota, within Superior National Forest. The watershed is dominated by forested and wetland land use. The eastern portion of the lake is developed; the western portion is undeveloped except for the public access. It is a moderate-size lake at 143 hectares (354 acres) with a maximum and mean depth of 4.5 meters (m) (15 feet) and 2.3 m (7.7 feet), respectively. With a shallow basin and a fetch of almost 2.4 kilometers (1.5 miles), the lake is well mixed.

Tait Lake supports a relatively simple fish community. Among the major fish species present, northern pike (*Esox lucius)*, white sucker (*Catostomus commersonii*), and yellow perch (*Perca flavescens*) were probably native, while pumpkinseed (*Lepomis gibbosus*), bluegill (*L. macrochirus*), and walleye (*Sander vitreus*) have been introduced. Tait Lake has been managed for walleye and northern pike since 1939. Walleye were introduced in 1939, and were stocked again in 1948, 1953, 1966, and 1967. Largemouth bass were stocked in 1963, but apparently failed to become established. There has been no stocking of any species since 1967.

Tait Lake was sampled by MPCA staff from May through October of 2009 and then on three occasions in both 2010 and 2011. Epilimnetic dissolved oxygen (DO) concentrations exceeded five milligrams per liter (a concentration needed to sustain a productive cool and warm water fishery) throughout the water column in all three years. The lake remained well mixed during the open water season in all years. Mid-summer water temperatures peaked near 20 C (68 F).

Total phosphorus (TP) concentrations did not change significantly among years, averaging 15 micrograms per liter (µg/L). Patterns in TP were relatively stable among the three years, and were expected given the lake's polymictic condition, aerobic bottom waters, and small forested watershed. Algal biomass, as measured by chlorophyll-a (Chl-a), responds to changes in TP and small increases are noted, consistent with increased TP; however, overall algae levels were sparse. Secchi transparency changed in direct response to changes in Chl-a. All three trophic state indicator summer-means: TP, Chl-a, and Secchi are well within the typical range for minimally impacted lakes in the Northern Lakes and Forest (NLF) ecoregion. Tait Lake has a strong dataset of historical Secchi readings, dating back to 1993. Data indicate no statistically significant trend in transparency over time. The long-term summer mean transparency is 2.2 m (7.2 feet).

Tait has a moderate bog stain originating from incompletely dissolved organic matter from forest and wetland runoff. At high concentrations, "bog stain" may limit transparency; however at the modest concentrations observed in Tait, its impact is minimal and transparency is likely correlated with algal productivity. The low alkalinity and ion concentrations indicate Tait has very soft water. This is a function of

the thin soils, exposed bedrock, and minimal amounts of carbonate in the soils and parent material. Collectively, these data indicate that Tait has good water quality that is typical for a lake in the northeast region of the state.

In 2009, Tait had what is considered a somewhat "typical" transition of algae in NLF lakes with relatively low productivity- a diverse population in spring after ice-out, followed by dominance of diatoms, and then blue greens by late summer and early fall. Chl-a concentrations were low and nuisance levels of blue green algae were not observed. Zooplankton density was highest in June, and declined throughout the remainder of the season. Zooplankton density and biomass in Tait are near the level anticipated, based on its nutrient levels and the region where it is located.

Two empirical water quality models, BATHTUB and MINLEAP, were run on Tait Lake using data from 2009-20011, lake morphometry, and watershed information. MINLEAP predicts a TP loading rate of about 105 kilograms (kg) per year entering Tait Lake from its small, forested watershed. The model predicts approximately 51 percent of the TP is retained in the lake, a reasonable estimate given the lake's small watershed, volume, and moderate residence time (estimated at approximated 1.3 years). The BATHTUB model provides a further basis for estimating water and nutrient budgets for Tait Lake using a combination of runoff and TP export coefficients based on land use in the watershed. The only human-induced loadings to account for were estimates of the P that may seep from on-site septic systems to the lake. This was estimated based on the number of cabins/homes around the lake, standard per-capita loading values (assuming seasonal usage), and on-site system and soil retention of 80 percent of the load that enters the systems. Based on model inputs, relative contributions from the three source categories were as follows: watershed runoff ~ 67 percent, precipitation and atmospheric deposition on the lake ~ 26 percent and on-site septic systems ~4 percent. It is important to note these are only estimates and are based on available data. These relative contributions seem realistic for a lake of this size, with a relatively small, forested watershed and limited lakeshore development.

Tait Lake meets water quality standards for waters that support a cool and warm water fishery in Minnesota's Northern Lakes and Forests Ecoregion. In summary, water quality in Tait is very good and relatively stable, which is reflective of the lake's setting and small forested watershed.

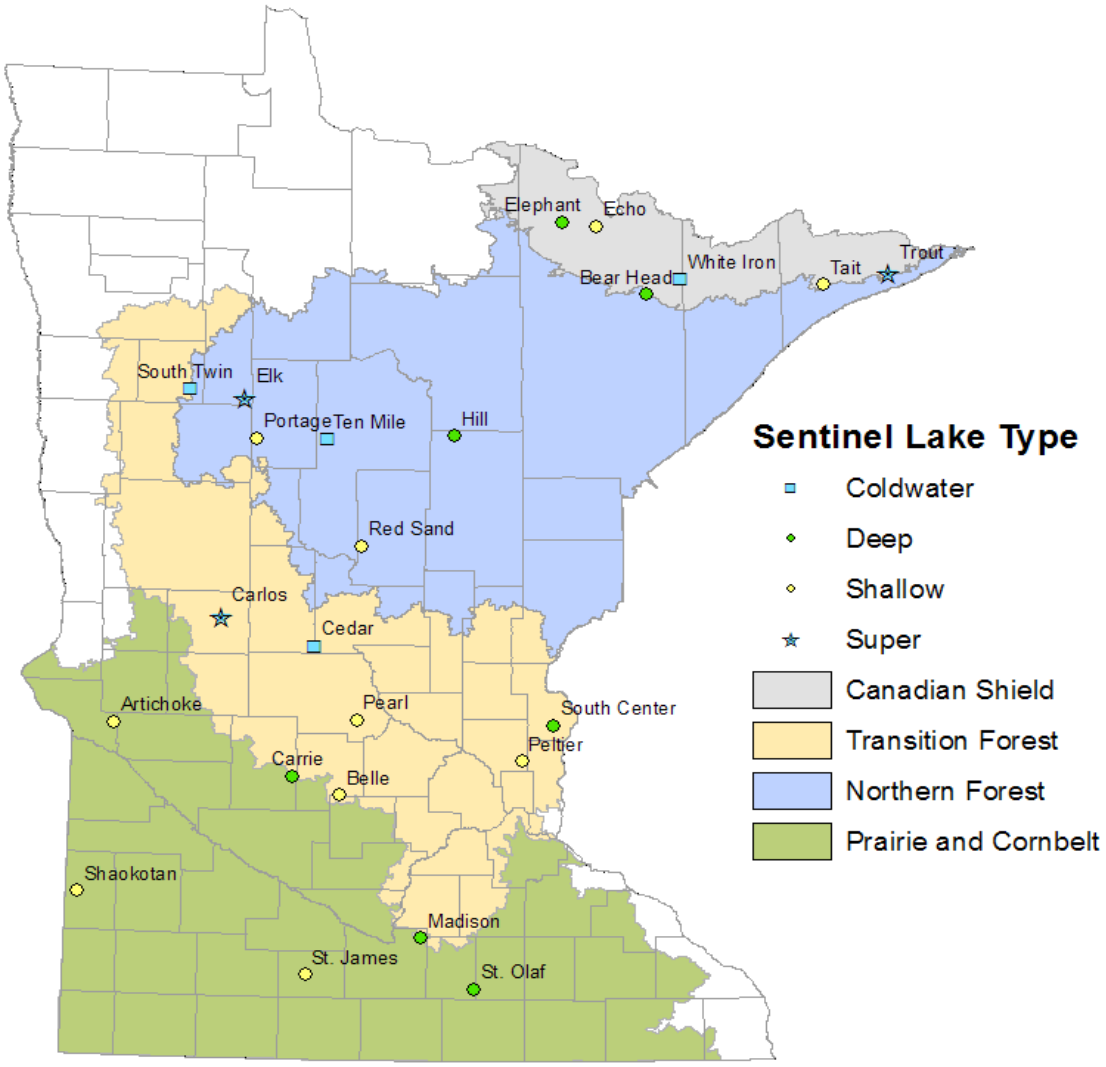


Figure 1. MDNR map of Sentinel Lakes and major land types. "Deep" lakes stratify during the summer. "Shallow" lakes are defined here as those that mix continuously throughout the summer. "Cold Water" lakes are those that both harbor cisco, lake whitefish, or lake trout and are the focus of research funded by the Environmental Trust Fund (ETF). "Super sentinel" lakes also harbor cold-water fish populations and research on these lakes is funded by the ENTF.

Introduction

This report provides a relatively comprehensive analysis of physical, water quality, and ecological characteristics of Tait Lake in Cook County Minnesota (MN). This assessment was compiled based on Minnesota Department of Natural Resources (MDNR) surveys of the lake's fish community and aquatic plant communities, Minnesota Pollution Control Agency (MPCA), and citizen water quality monitoring, and analysis of various other sources of data for the lake. The water quality assessment focuses on data collected during the 2009-2011 seasons. Water quality data analyzed include all available data in EQuIS, the MPCA's 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).

Background

Lake morphometric and watershed characteristics

Tait Lake is located in Cook County within the Poplar River Watershed, part of the Lake Superior basin. Tait Lake is located 12 miles north of Lutsen, Minnesota. The majority of the watershed is within Superior National Forest. The eastern portion of the lake is developed, including private roads and a boat ramp owned by the Tait Lake Association. The Western Portion of the lakeshore is public and undeveloped, except for a public access in the southwest corner.

Tait Lake's morphometric characteristics are summarized in Table 1. Tait is a moderate-sized lake covering 143 hectares (354 acres). The lake has a mean depth of 2.3 meters (7.7 feet), a maximum depth of 4.5 meters (15 feet), and 100 percent of the lake is considered littoral (portion 15 feet or less in depth). Lakes with a high percentage of littoral area and non-rocky substrates often have extensive rooted plant (macrophyte) beds. Tait lacks extensive beds of native rooted plants, likely due to the predominance of rocky substrates and shorelines.

Tait is a shallow lake, with a deep spot of 4.5 m in its eastern basin, much of the western basin is less than three m deep (Figure 1); therefore, the lake does not typically stratify by mid-summer. Tait Lake has one significant surface water inlet, an unnamed stream draining south of Lichen Lake (Figure 3). The Tait River originates at the outlet of Tait Lake, and is part of the headwaters of the Poplar River Watershed.

Tait Lake has a relatively small lake to watershed ratio (7:1) and a highly forested watershed that is typical for a northern Minnesota lake. Water residence time is estimated at 1.3 years, reflective of the lake's shallow depth and relatively small watershed.

Table 1. Tait Lake and watershed morphometric characteristics

Lake Name	Lake ID	Lake Basin hectares (acres)	Littoral Area (percent)	Total Watershed Area hectares (acres)	Total Watershed: Lake	Max. Depth meters (feet)	Mean Depth meters (feet)	Lake Volume acre-ft
Tait	16-0384	143 (354)	100	1,103 (2,726)	7.7:1	4.5 (15)	2.3 (7.7)	20,990

Lake bathymetry based on original surveys in 1960

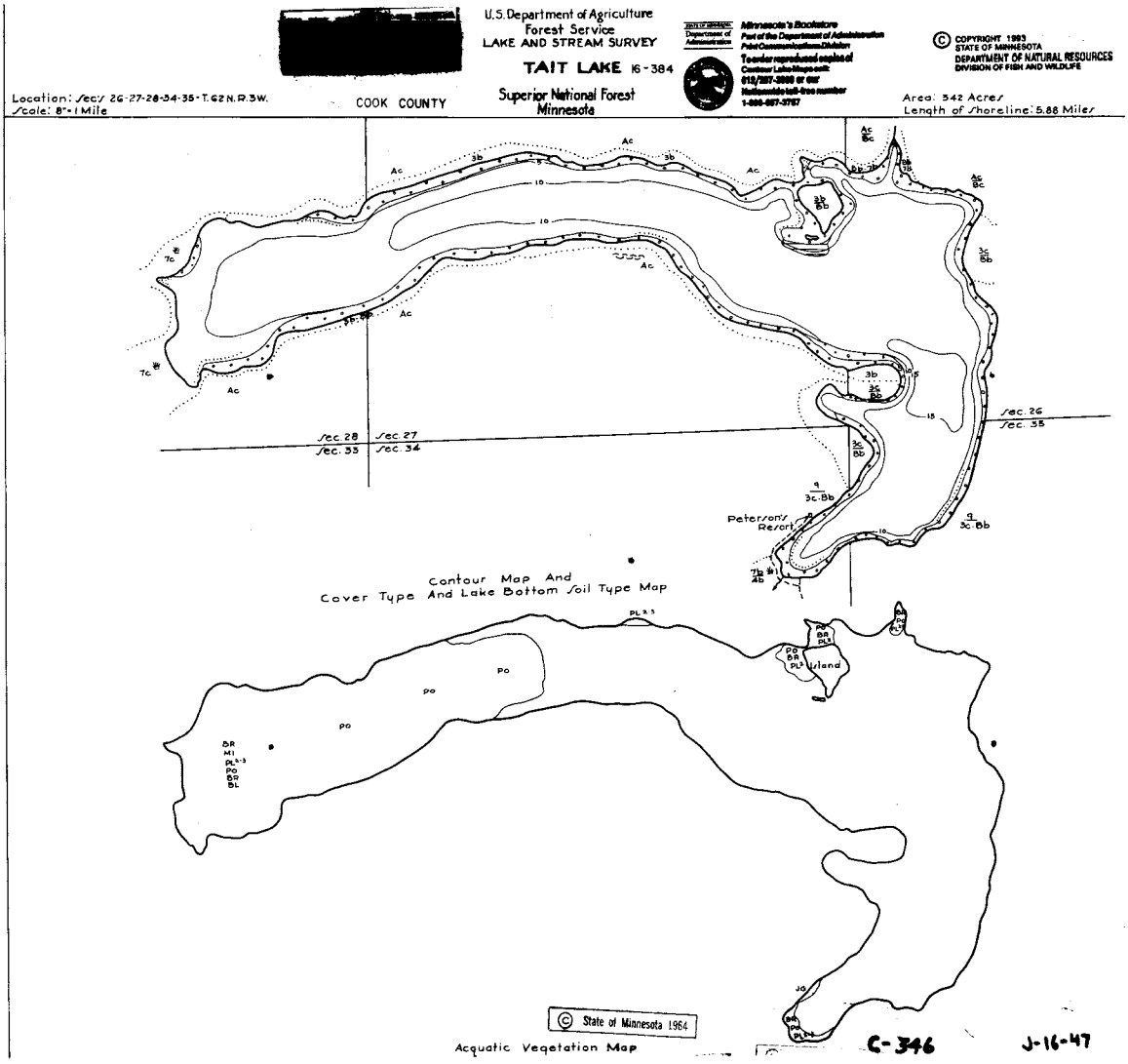


Figure 2. Tait Lake bathymeric map. Primary sampling site #201 is in east bay over point of maximum depth

Figure 3. The Tait Lake Watershed (from USGS' streamstats website -http://water.usgs.gov/osw/streamstats/minnesota.html)

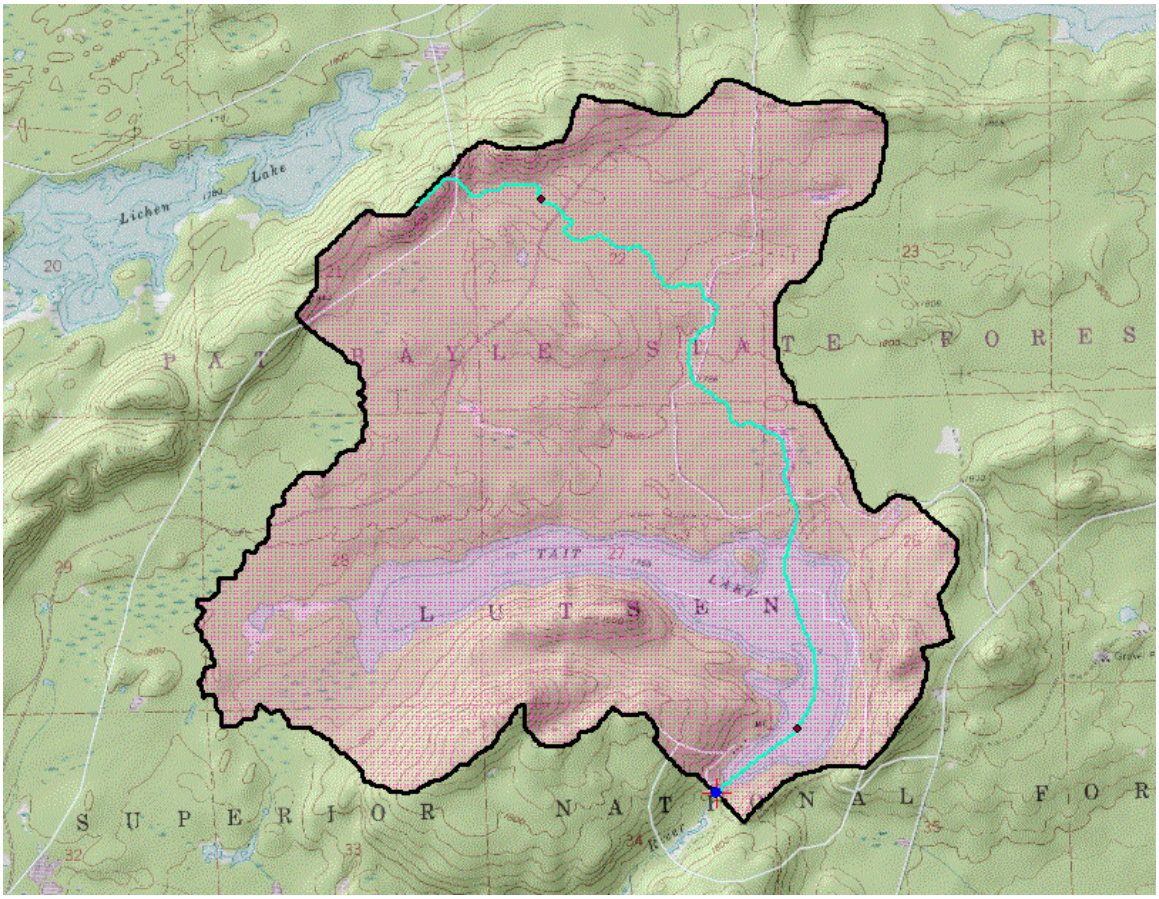


Table 2. Tait Lake Watershed and NLF land use data

Land use	Tait Lake watershed land use percentage	NLF typical land use percentage
Developed	<1	0 – 7
Cultivated (Ag)	0	<1
Pasture & Open	0	0 – 6
Forest	85	54 – 87
Water & Wetland	14	14 – 31

Ecoregion and land use characteristics

Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, potential natural vegetation, and land use (Omernik 1987). 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. Tait Lake lies within the Northern Lakes and Forest (NLF; Figure 4) ecoregion. NLF values will be used for land use (Table 2) and summer-mean water quality comparisons. Additionally, the NLF ecoregion will be used for model applications. Omernik level III and IV ecoregions provided a basis for the "land type" delineations noted in Figure 1. This step was taken prior to selection of the Sentinel lakes and provided a means to characterize geomorphologic differences in lake condition. In the NLF ecoregion, this allowed for differentiation between the "Canadian Shield" lakes and "Glacial Drift Northern Forest" lakes.

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Land use within the Tait Lake watershed is nearly all forest, wetland, and open water (Table 2).

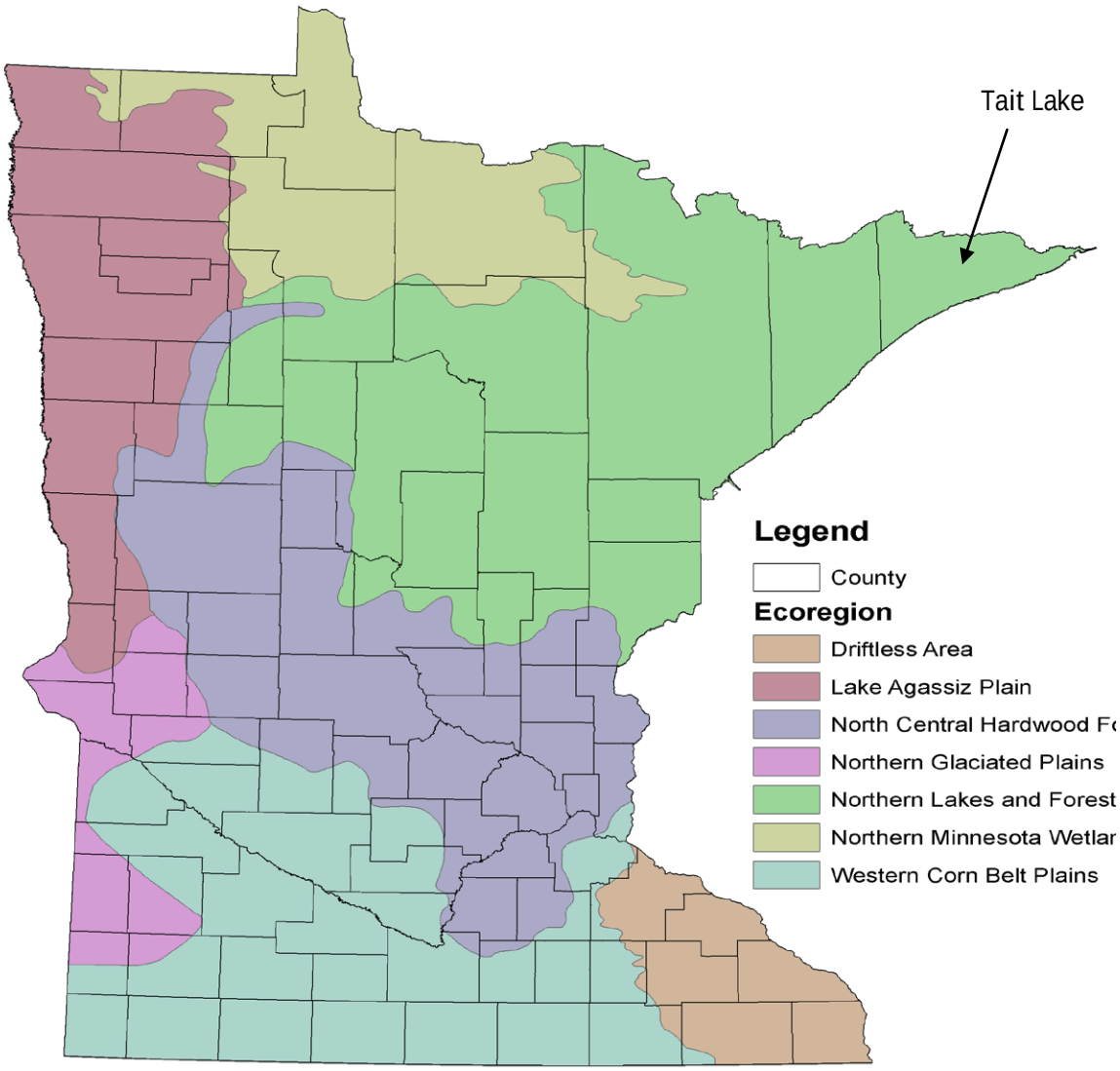


Figure 4. Minnesota ecoregions as mapped by United States Environmental Protection Agency

History

There are minimal historical records for Tait Lake in MDNR and MPCA files. Much of the history of the development of Tait Lake was provided by a series of "Historical Reflections" articles authored by Jacelyn Thornton and published by the Cook County News Herald between August 2009 and March 2010.

1890's – 1920's - Intense logging of pine stands in Cook County seems to have started in the late 1890s, and was largely done by the 1920s. Early logging was accompanied by intense fires that burned through much of the area in the early 1900s. Aerial photos of the Tait Lake area from the 1930s show little forest cover remaining around the west half of the lake, while the eastern half was apparently still forested.

1930's – 1950's - Property on the east half of Tait Lake was acquired by Martin ("Cap") and Mathilde ("Billie") Petersen in the 1930s, who were attracted to the lake by the "towering white pines" along its shore. Development of what became Tait Lake Lodge started with the Petersen's' construction of a tarpaper shack at the lake in 1936. The resort was located in the bay in the southeast end of the lake. The first three cabins for the resort were built starting in 1937, before any roads had reached the lake. In the 1940's, construction of the Caribou Trail was completed past the east end of Tait Lake. The resort lodge was built in 1950-51, with the help of Lloyd and Agnes Bowman. MDNR lake survey in 1956 found one resort with four cabins, with no other cabins or homes.

1960's – Present- In 1961, the resort land was sold to another party; the remaining property passed to various family members, and resort operations ceased in 1973. A boat launch in the far west end of the lake was constructed by the US Forest Service in 1987. A 1995 MDNR Fisheries lake survey counted 22 homes and cabins on the lake, while a count of structures shown in a 2010 aerial photos showed 43 homes or cabins, plus another 8-10 sites under development. In 2010, it appeared that most private land on the lake was either developed or in the process of being developed.

Lake level

Tait Lake has a rather short water level record with 69 records total. The MDNR initiated lake level monitoring on Tait in 2009 as a part of the SLICE program. The highest elevation of record is 1770.75 (October 31, 2010) and lowest of record is 1769.67 (November 2, 2011) for a total range of 1.08 feet. The true range of elevations is higher than one foot, based on anecdotal observations of lake level by MPCA staff. The average monitored elevation is 1770.1 feet. A distinct seasonal cycle in elevation is evident each year with high levels in the spring because of snowmelt and spring runoff, followed by declining levels as runoff from the watershed declines and evaporative losses increase (Figure 5). Fall rain events in 2010 (Figure 7) served to increase lake levels.

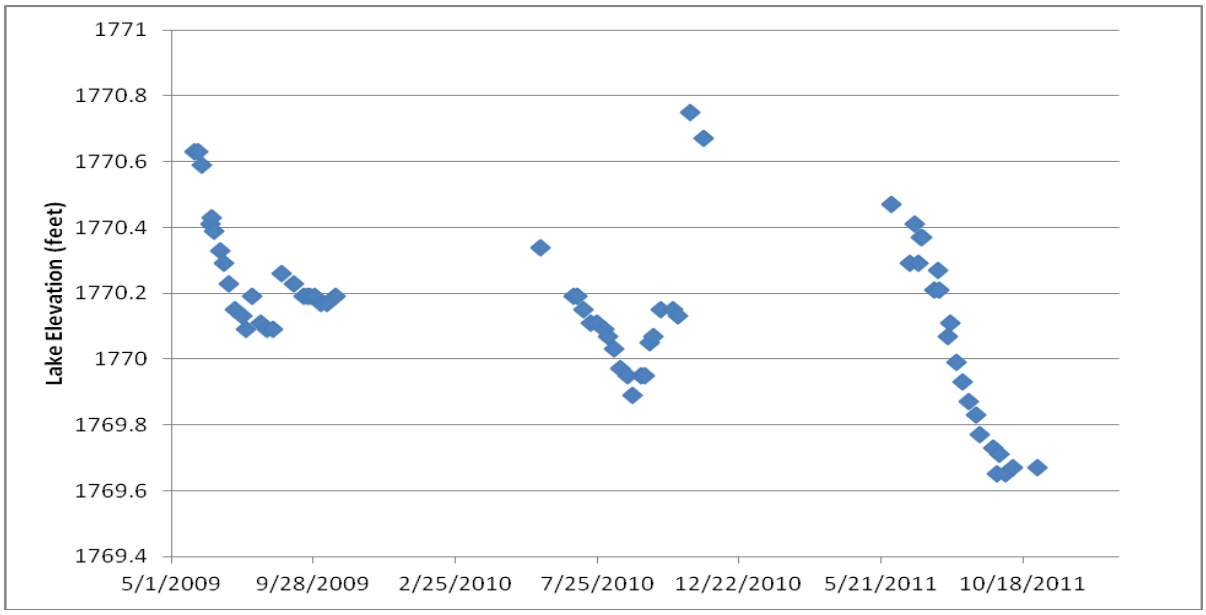


Figure 5. Tait Lake level elevations in 2009 and 2011. MDNR data.

Precipitation and climate summary

Climate and precipitation records for the 2009-2010 field seasons varied considerably. Rain gage records from Cascade Lake (the nearest long-term climate station, immediately northeast of Tait Lake) show no +2.5 centimeter (cm; one inch) rain events during the 2009 or 2010 field seasons (Figure 6 and Figure 7). Large rain events will increase runoff into the lake and may influence in-lake water quality and lake levels. Precipitation records for the 2009 water year (October 2008 through September 2009) showed conditions were average near Tait Lake (Figure 8). Precipitation for the 2010 water year was slightly below normal.

Ice in and out records for Tait lake have also been monitored since 2002 (Table 3). 2012 was a historic year for early ice out, many lakes in northeast Minnesota opened up to a month earlier than their median ice-out date, and many large lakes in northeast Minnesota had the earliest ice-out on record (http://climate.umn.edu/lake_ice/).

Table 3. Tait Lake ice-in and ice-out dates

Year	Ice In	Ice Out	Days of Ice Cover
2002	NA	5/4/2002	NA
2003	NA	5/4/2003	NA
2004	NA	5/1/2004	NA
2005	NA	4/18/2005	NA
2006	11/11/2006	4/19/2006	NA
2007	11/16/2007	4/23/2007	163
2008	11/18/2008	5/8/2008	174
2011		5/10/2011	NA
2012		3/28/2012	NA

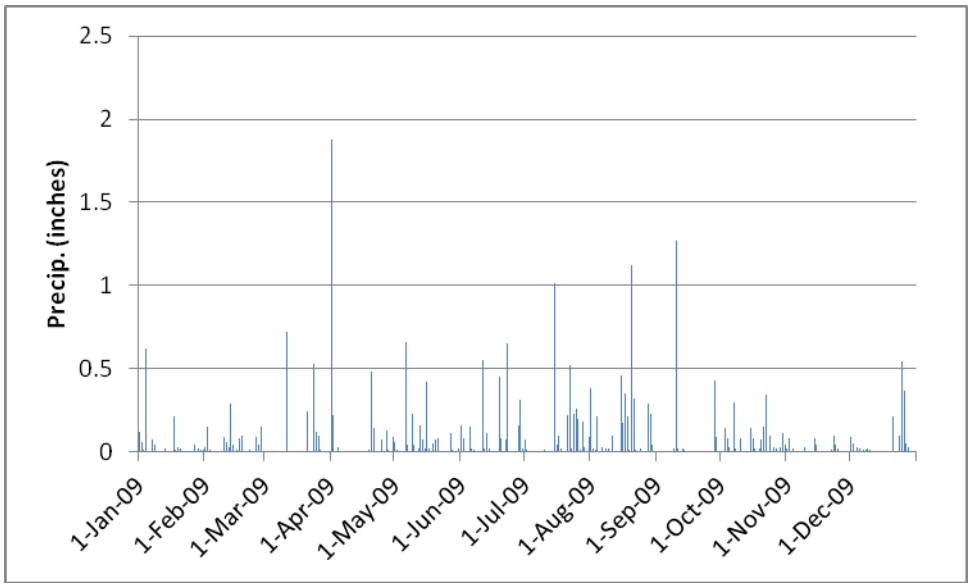


Figure 6. 2009 precipitation based on records for Cascade Lake, Minnesota State Climatology Office Data

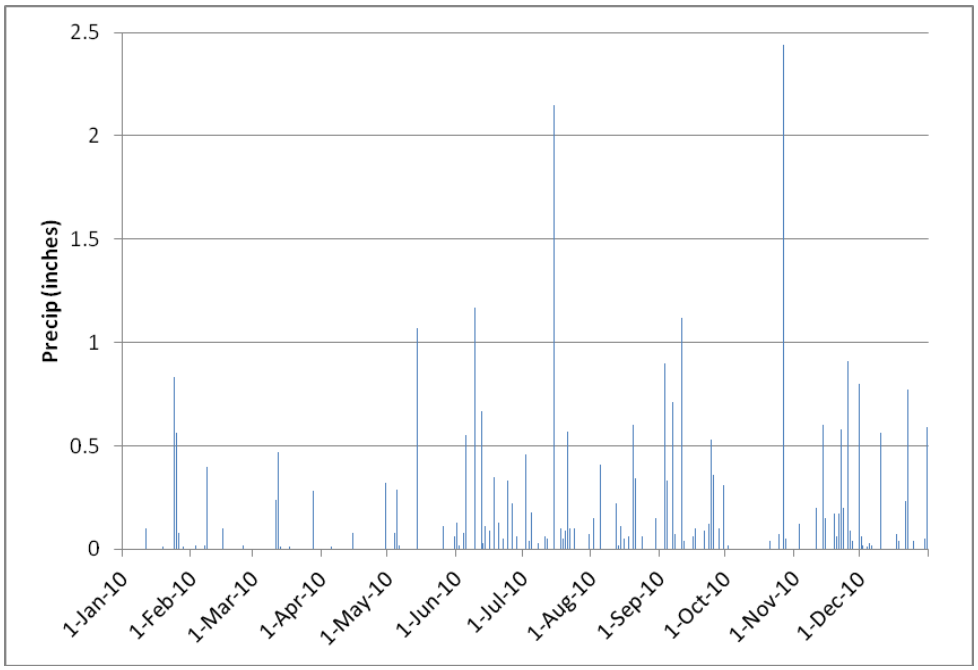


Figure 7. 2010 precipitation based on records for Cascade Lake, Minnesota State Climatology Office Data

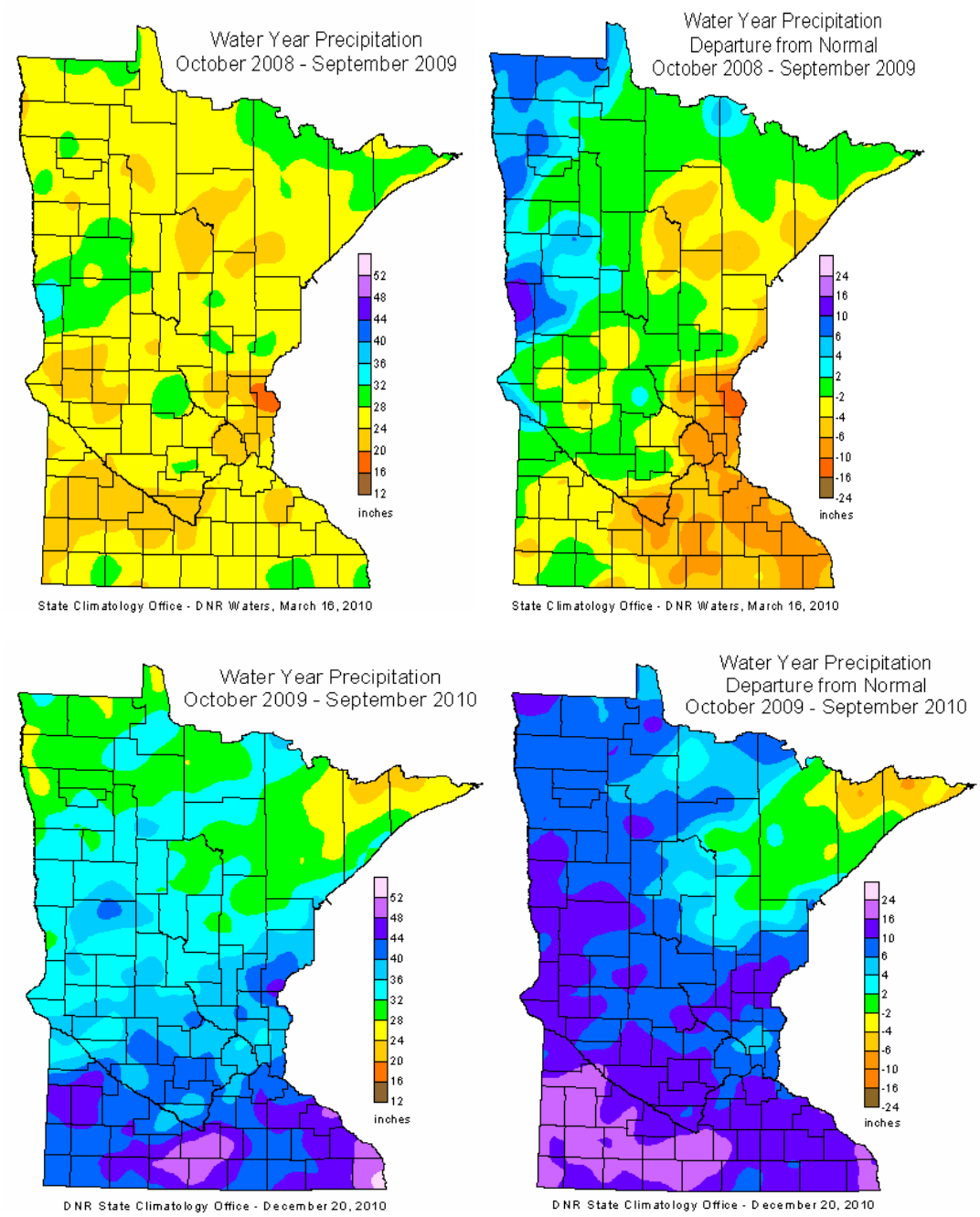


Figure 8. 2009-2010 Minnesota water year precipitation and departure from normal (State Climatology Office Data)

Methods

Fisheries and aquatic plants

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 provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson, 1993). This data is stored in a long-term fisheries survey database, which has proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time. Most recent fisheries surveys follow guidelines outlined by MDNR Special Publication 147 (1993; Manual of Instructions for Lake Survey). Near-shore non-game fish surveys were also completed on each Sentinel lake following methods described by Drake and Pereira (2002).

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 meter (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).

In early 2009, Tait Lake replaced Northern Light Lake in the SLICE program because Northern Light Lake was considered too riverine. Sampling under the SLICE program began on Tait Lake in 2009. Sampling to date has included ice-out trap netting (targeting northern pike) in 2009, 2010, and 2011, June electrofishing targeting smallmouth bass (*Micropterus dolomieu*) in 2009 and 2010, regular water quality and water level sampling over the open water seasons of 2009, 2010, and 2011, population assessments in 2009 and 2011, and a special assessment using only 3/4-in and 1/4-in-mesh trap nets in July 2010. In addition, point-intercept vegetation surveys and zooplankton assessments were done in 2009, 2010, and 2011, and sampling of the nearshore fish community by seining and backpack electrofishing was done in 2009.

Water quality

In 2009-2011, water quality data on Tait Lake were collected by the MPCA; MDNR collected dissolved oxygen and temperature profiles as well. MPCA staff sampled Tait monthly from May through October in 2009 and 'seasonally' – May, July, and October - in 2010 and 2011. Samples were collected at the lake's maximum depth, in the southeast portion of the lake (MPCA site # 201; Figure 2). MPCA lake surface samples were collected with an integrated sampler, a poly vinyl chloride (PVC) tube 2 meters (6.6 feet) in length, with an inside diameter of 3.2 cm (1.24 inches). Zooplankton samples were collected with an 80 micron (µm) mesh Wisconsin zooplankton net. Phytoplankton (algae) samples were taken with an integrated sampler. Depth total phosphorous (TP) samples were collected with a Kemmerer sampler. Secchi measurements were also collected through the Citizens Lake Monitoring Program. Sampling procedures were employed as described in the MPCA Standard Operating Procedure for Lake Water Quality Sampling document, which can be found here: http://www.pca.state.mn.us/publications/wq-s1-16.pdf .

Laboratory analysis was performed by the Minnesota Department of Health using United States Environmental Protection Agency-approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, chloride, metals, and chlorophyll-*a* (Chl-*a*). Phytoplankton samples were analyzed at the MPCA using a rapid assessment technique.

Zooplankton

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

Each zooplankton sample was adjusted to a known volume by filtering through 80 micron (µm) 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

Tait Lake has a reputation as a good walleye lake and summer fishing pressure has probably increased substantially since the construction of the public access. Winter fishing pressure is probably low. Roads serving the public access have usually not been plowed in the winter. No creel survey data are available for Tait Lake; fishing pressure, harvest, and yield are unknown.

Tait Lake supports a relatively simple fish community. Among the major fish species present (Table 4), northern pike (*Esox lucius)*, white sucker (*Catostomus commersonii*), and yellow perch (*Perca flavescens*) were probably native, while pumpkinseed (*Lepomis gibbosus*), bluegill (*L. macrochirus*), and walleye (*Sander vitreus*) have been introduced. Tait Lake lies within the Lake Superior North watershed, at the head of the Tait River sub-watershed, with a chain of several lakes lying below it (from upper to lower, Wills, Williams, Clara, White Pine, and Christine). Fish passage up and downstream between the lakes in the chain is probably possible, since gradients in connecting stretches of the Tait River are low. Fish communities in other lakes in the chain are similar to that found in Tait Lake. Walleye were introduced in the chain in 1931 (stocked in Christine Lake) and 1939 (stocked in Tait Lake). Some evidence suggests bluegill and pumpkinseed have spread through the chain from Christine Lake, where bluegill were first stocked in 1978 and pumpkinseed were first seen in 1969. Table 4 was composed from data available from standard gill netting, 3/4-in-mesh trap netting, 1/4-in-mesh trap netting, and nearshore sampling using backpack electrofishing and a one-eighth-in-mesh seine; trophic guild and tolerance were taken from information provided by Drake and Valley (2005) and from various EPA and PCA sources.

Table 4. Historical fisheries assessment results

Common name	Species name	Trophic guild	Environmental Tolerance	First Documented
Blacknose shiner	*Notropis heterolepis*	Insectivore	Intolerant	2009
Bluegill	*Lepomis macrochirus*	Insectivore	Neutral	2000
Central mudminnow	*Umbra limi*	Insectivore	Neutral	2011
Common shiner	*Luxilus cornutus*	Insectivore	Neutral	1995
Finescale dace	*Phoxinus neogaeus*	Insectivore	Neutral	1995
Golden shiner	*Notemigonus crysoleucas*	Insectivore	Neutral	2011
Johnny darter	*Etheostoma nigrum*	Insectivore	Neutral	1956
Northern pike	*Esox lucius*	Predator	Neutral	1956
Pumpkinseed	*Lepomis gibbosus*	Insectivore	Neutral	1990
Slimy sculpin	*Cottus cognatus*	Insectivore	Intolerant	2009
Walleye	*Sander vitreus*	Predator	Neutral	1955
White sucker	*Catostomus commersonii*	Omnivore	Tolerant	1956
Yellow perch	*Perca flavescens*	Insectivore	Neutral	1955

No fish community data are available for the Tait River. The river below Christine Lake is listed as a designated trout stream, and angler reports indicate it supports a wild brook trout (*Salvelinus fontinalis*) population. Barrier falls prevent the movement of fish from the lower Tait River (and the Poplar River) into Christine Lake and the rest of the lake chain. The rare presence of longnose dace (*Rhinichthys cataractae*) and slimy sculpin (*Cottus cognatus*) in some of the lakes may indicate populations of those species reside in the upper Tait River.

Tait Lake has been managed for walleye and northern pike since 1939. Walleye were introduced in 1939, and were stocked again in 1948, 1953, 1966, and 1967. Largemouth bass were stocked in 1963, but apparently failed to become established. There has been no stocking of any species since 1967. An initial Lake Management Plan (LMP) for Tait Lake was completed in 1991. The current long range goal for walleye (a minimum gill net catch of 5.0 fish/set) was established at that time. In 1991, Tait Lake was considered a Class 16 lake, for which the lake class median gill net catch was 7.0 fish/net. The goal of 5.0 fish/net was probably set at a level that was considered the minimum that would ever be observed in Tait Lake if natural reproduction continued to be adequate to support the fishery. That goal, continued in all subsequent plan revisions, is now close to the median of 5.42 fish/gill net for Class 12 lakes. The current long range goal for northern pike (a minimum gill net catch of 2.0 fish/set, with some fish larger than 25 inches) was first established in the 2001 LMP revision. It was set at the first quartile for the lake class, on the basis of historically low catches observed in this lake. The most recent LMP for Tait Lake was approved on 18 March 2011.

The earliest sampling of Tait Lake for which we have any record was an assessment using six 1/4-in-mesh seine hauls in August 1955. The reported catch in that assessment included 322 yellow perch, one walleye, five “suckers”, and one “minnow.” Seining conditions were reported to have been very poor.

An initial survey of Tait Lake in August 1956 utilized nine gill net sets and collected northern pike, white sucker, yellow perch, and walleye. Six trap net sets were also used and collected the same species. Seven shoreline seine hauls collected 1,152 “minnows”, 25 walleye, 36 yellow perch, and one johnny darter (*Etheostoma nigrum*). The 1956 survey included blacknose shiner (*Notropis heterolepis*) and Iowa darter (*E. exile*) on a list of fish species present, but unless they were among the minnows reported taken in seine hauls, there was no record of their capture in that or any previous survey.

Assessments utilizing three or six gill net sets and four to six 0.75-in-mesh trap net sets were done in 1970, 1977, 1983, and 1990. A resurvey was done in 1995, and additional assessments were completed in 2000, 2009, and 2011. Timing of earlier surveys and assessments varied from early July to early September, but since 1990, all surveys and assessments have been done in July. Because of the low number of net sets used, catch-per-unit-effort data from 1970 through 1990 are not very reliable.

Fish community status and trends

Walleye gill net catches have ranged from 5.7 fish/set in 1970 to 17.7 fish/set in 1977, with no apparent trend (Table 5). Mean weight for walleye collected in gill nets has been stable since 1983, at about 1.0 pound. Walleye size distributions have included fish up to 30 inches; however, most have been under 20 inches, especially in recent years. Walleye growth rates have been close to average for the area (Table 7); age-four fish collected in 2011 reached a mean length of 13.6 in at last annulus formation, compared to an area mean of 13.8 in for Class 12 lakes. The walleye population in Tait Lake has been entirely self-sustained since 1967. Spawning habitat for walleye was rated 'excellent' in the 1995 survey.

Spring electrofishing assessments of the walleye population were done by the Fond du Lac band and the 1854 Treaty Authority in 2009 and 2011. In both years, sampling targeted spawning walleye, and all walleye 10-inches or more in length were marked (dorsal clips in 2009, red tags in 2011). Based on recaptures of marked fish in summer gill net assessments done by MDNR Fisheries, estimated numbers of 10-inch or larger walleye present in the springs of 2009 and 2011 were 2,207 and 1,604 fish, respectively, with 95 percent confidence intervals of 1,590-2,823 and 880-2,328 fish, respectively. Based on aging results from fish collected during 2011 spring electrofishing, total annual mortality for the walleye population was estimated to have been 35.3 percent (Borkholder and Edwards 2012).

Fall electrofishing assessments were also done by Fond du Lac and the 1854 Treaty Authority in 2009-2011. Those assessments targeted age-0 walleye. Catches of age-0 walleye in 2009, 2010, and 2011 were 138.2, 283.3, and 64.4 fish/hour, respectively (Borkholder and Edwards 2010, 2011, 2012). Mean lengths for age-0 walleye collected in 2009, 2010, and 2011 were 112, 116, and 124 mm, respectively. Sampling dates varied; sampling was done on 2 September, 9 September, and 20 September in 2009, 2010, and 2011, respectively.

Northern pike gill net catches have varied widely, ranging from 0.3 fish/set in 1970 to 4.3 fish/set in 1977, with no apparent trend (Table 5). Average size of northern pike collected in gill nets has also fluctuated, ranging from 1.09 to 3.55 lb/fish, with no obvious trend. Northern pike size distributions have included fish up to 38 inches in length; however, in most years most have been less than 20 inches. Growth rates for northern pike collected in 2011 had been slower than average for this area; age-4 fish averaged 18.8 inches in length at last annulus formation, compared to an area mean of 20.0 inches in Class 12 lakes. Northern pike spawning habitat was rated as 'poor' in the 1995 survey.

Northern pike catches in ice-out trap net assessments in Tait Lake have been low compared to catches observed in the limited number of similar assessments done on other lakes in the Grand Marais area (16 ice-out assessments on eight lakes in 1969-2010). Catches in Tait Lake in 2009, 2010, and 2011 (0.75, 1.21, and 1.38 fish/set, respectively) were all close to, or below, the first quartile value of 1.26 fish/set for similar assessments in this area. The size distribution for northern pike taken in ice-out trap netting in 2009 was similar to the distribution obtained for fish taken in gill nets in the summer assessment, and included no fish larger than 22 inches in length. Northern pike collected in ice-out trap netting in 2010 were slightly larger, and the catch included one 35-in fish. Fish collected in 2011 were larger still, with one 37-inch fish taken. Based on a stock size of 14 inches, and a quality size of 21 inches, RSD-21s for spring trap catches in 2009, 2010, and 2011 were 5.6, 13.6, and 20.0, respectively. Improvements in the northern pike size distribution from 2009 to 2011 appeared to have mainly been due to the growth of fish from one strong year class that reached stock size in 2009 and was entering the quality size range in 2011.

Yellow perch gill net catches have ranged from 0.3 fish/set in 1983 to 8.3 fish/set in 1956, with no apparent trend (Table 5). Some of the yellow perch collected recently would have been large enough to have been of interest to anglers. In the 2000 assessment, mean weight for perch collected in gill nets was 0.27 lb, and 33 percent of the fish collected were nine in or larger. Yellow perch collected in 2009 were larger still, with a mean weight of 0.53 lb.

In recent years, centrarchids have appeared in Tait Lake (Figure 9, Table 6). Pumpkinseeds were first observed in 1990, and bluegills were found in 2000. In 2000, no fish of either species larger than four inches were collected. No bluegills were taken in 2009 or 2010. The 2010 special assessment yielded a catch of 14 pumpkinseed sunfish (1.17 fish/trap net set), with no fish larger than 6.0 inches. In 2011, a single 10-inch bluegill was taken during spring ice-out trap netting, and several small bluegill (under four inches in length) were collected in the summer assessment. Thirty-one pumpkinseeds were collected in 3/4-in-mesh trap nets in 2011 (2.58 fish/set), but none were over six inches in length.

Bass have not yet become established in Tait Lake. June electrofishing in 2009 and 2010 failed to collect any smallmouth bass. The species has not been taken in any other sampling gear used in this lake, nor have any anglers reported catching smallmouth bass. Smallmouth bass are present in high numbers in lakes in the upper Poplar River watershed, but have not yet been found in any lakes in the Tait River sub-watershed. Largemouth bass (*M. salmoides*) were stocked at various locations within the sub-watershed prior to 1970; however, those stockings appear to have failed, since that species has also not been found in any of the lakes in the Tait River sub-watershed.

Table 5. Catch (fish/set) and mean weight (lb) of northern pike, walleye, white sucker, and yellow perch in gill nets set in Tait Lake, Cook County, Minnesota, 1956-2011, with median and first-third quartile (1st Q-3rd Q) values for Class 12 lakes in Minnesota (data through 1995).

		Northern pike		Walleye		White sucker		Yellow perch	
Survey Date	Number Of Nets	Catch	Mean Weight	Catch	Mean Weight	Catch	Mean Weight	Catch	Mean Weight
8/4/1956	9	1.44	1.60	14.33	0.95	11.33	1.14	8.33	0.07
7/13/1970	3	0.33		5.67	1.38	15.67	2.36	1.67	0.06
8/11/1977	3	4.33	1.95	17.67	1.28	8.33	2.64	5.00	0.27
9/8/1983	3	1.67	1.18	9.00	1.02	13.33	2.79	0.33	
7/5/1990	3	0.67		9.67	0.87	15.33	1.86	4.00	0.18
7/5/1995	6	3.00	1.09	7.83	1.08	12.33	1.96	3.50	0.39
7/10/2000	6	2.50	1.66	7.83	1.01	7.33	2.43	4.50	0.27
7/30/2009	6	0.78	1.17	11.33	1.13	5.22	2.52	5.22	0.53
7/25/2011	6	1.00	3.55	6.11	1.05	5.56	1.56	6.00	0.36
Median		4.00	1.75	5.42	1.21	7.58	1.98	6.00	0.16
1stQ - 3rdQ		2.00-6.29	1.25-2.45	3.00-9.81	0.86-1.64	3.63-14.05	1.47-2.35	2.18-14.58	0.11-0.25

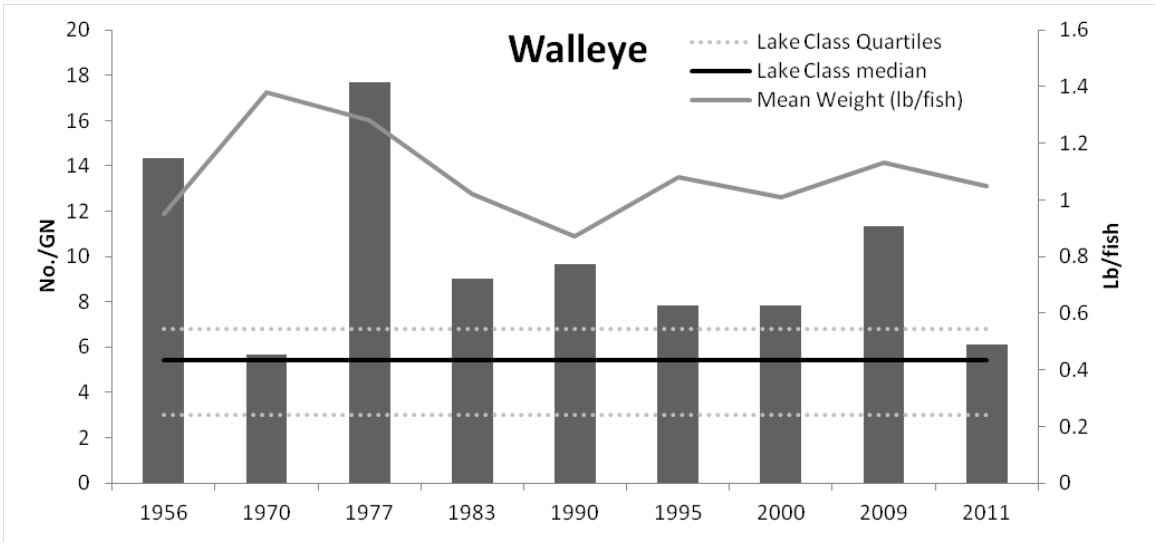
Table 6. Catch (fish/set) and mean weight (lb) of bluegill, pumpkinseed, and yellow perch in 3/4-in-mesh trap nets set in Tait Lake, Cook County, Minnesota, 1956-2011, with median and first-third quartile (1stQ - 3rdQ) values for Class 12 lakes in Minnesota (data through 1995).

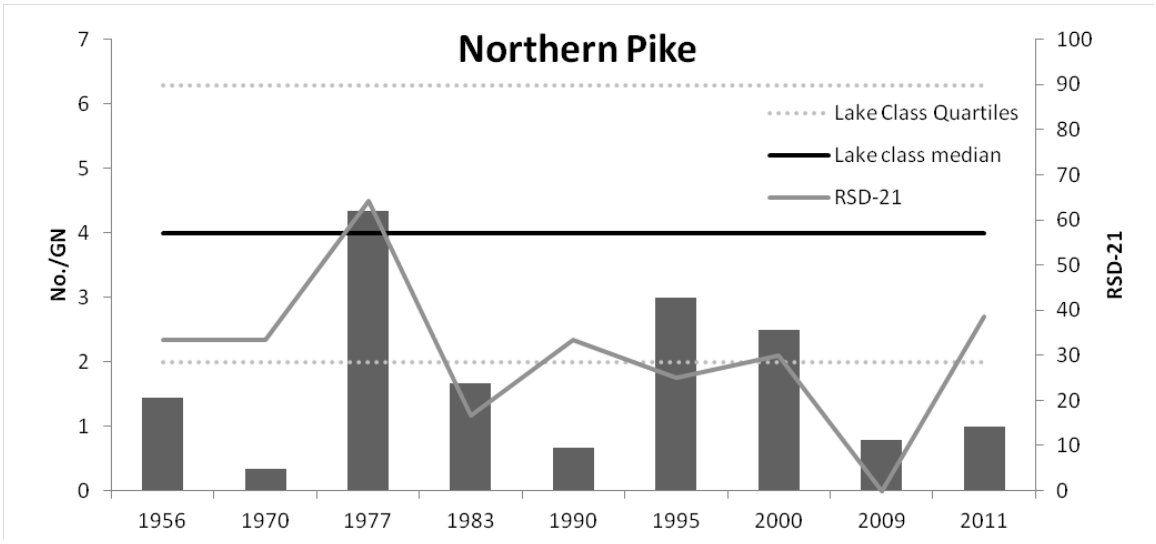
		Bluegill		Pumpkinseed		Yellow perch	
Survey Date	Number Of Nets	Catch	Mean Weight	Catch	Mean Weight	Catch	Mean Weight
8/4/1956	6	0		0		0.67	0.26
7/13/1970	4	0		0		0.75	0.07
8/11/1977	4	0		0		0.25	
9/8/1983	4	0		0		0.25	
7/5/1990	5	0		1.00		0.40	
7/5/1995	6	0		1.00	0.07	0	
7/10/2000	6	0.17		0.33		0.33	
7/30/2009	12	0		3.42	0.05	0	
7/13/2010	12	0		1.17	0.07	0.08	
7/25/2011	12	0.33	0.03	2.58	0.07	0.42	0.11
Median		1.50	0.16	0.75	0.17	0.86	0.20
1stQ - 3rdQ		0.25-6.35	0.10-0.28	0.37-2.65	0.10-0.21	0.40-2.10	0.10-0.30

Table 7. Recent survey focal species catch rates compared to similar lake classes

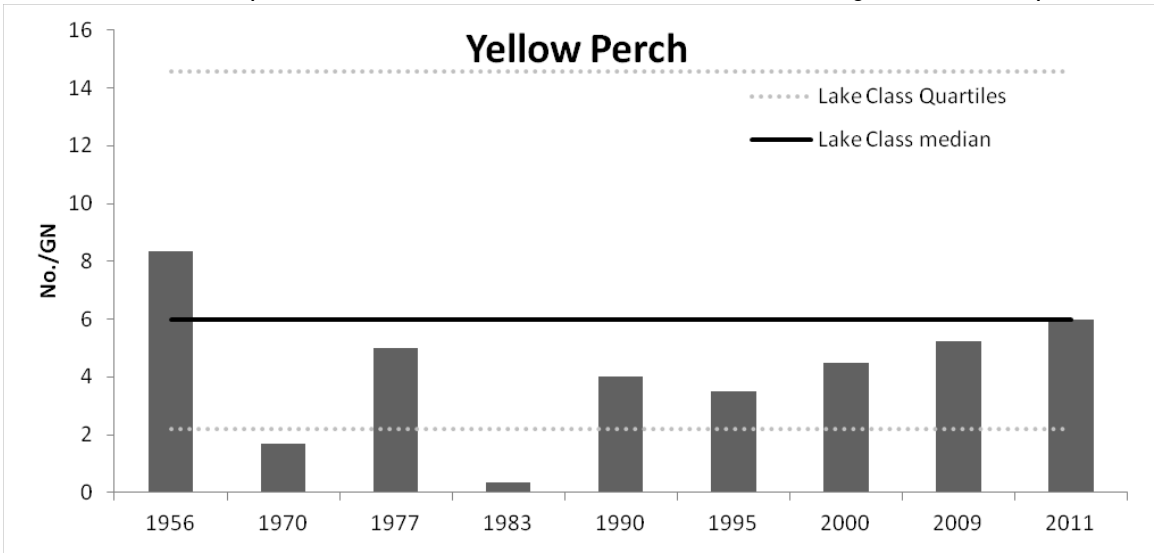
Species	Stocked	Abundance	Size	Trend
Walleye*	No	Above Average	Average	Stable
Northern pike*	No	Below Average	Average	Fluctuating
Bluegill	No	Low	Small	Unknown
Pumpkinseed	No	Average	Small	Increasing
Yellow perch	No	Average	Large	Stable

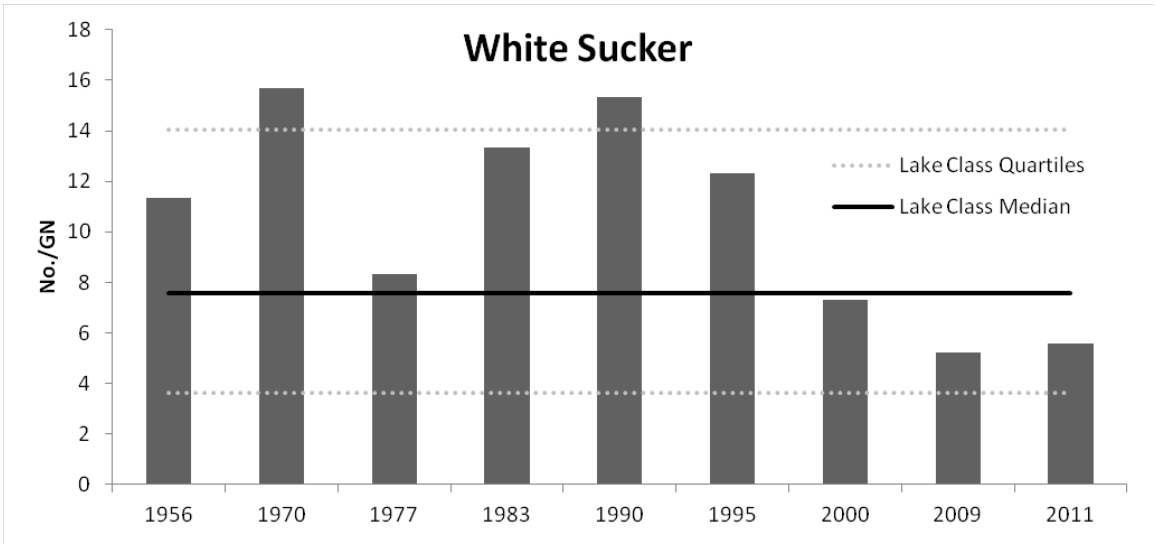
*Management emphasis on these species

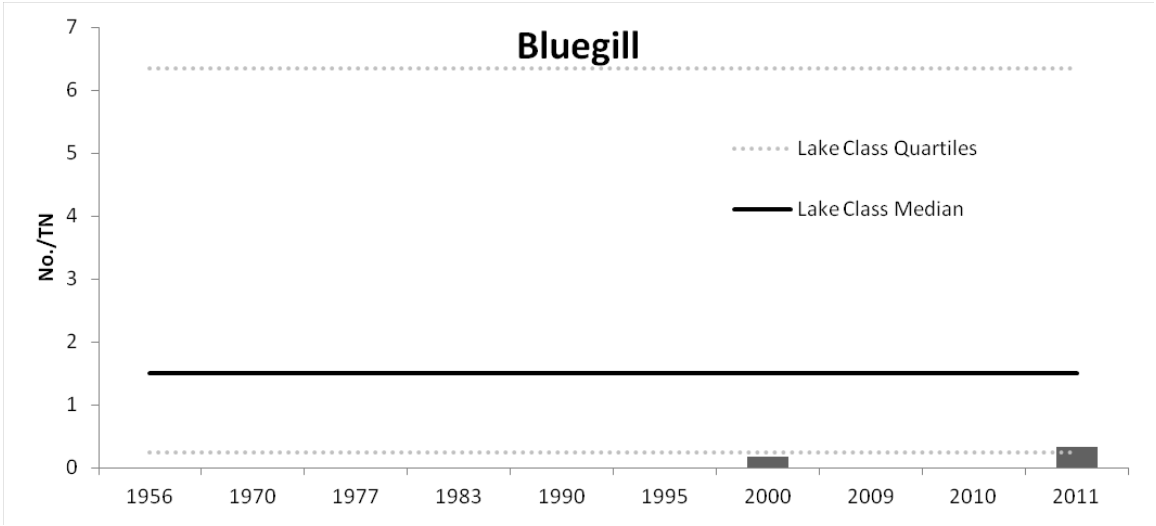




RSD-21 for northern pike was based on the combined catch in summer gill nets and trap nets







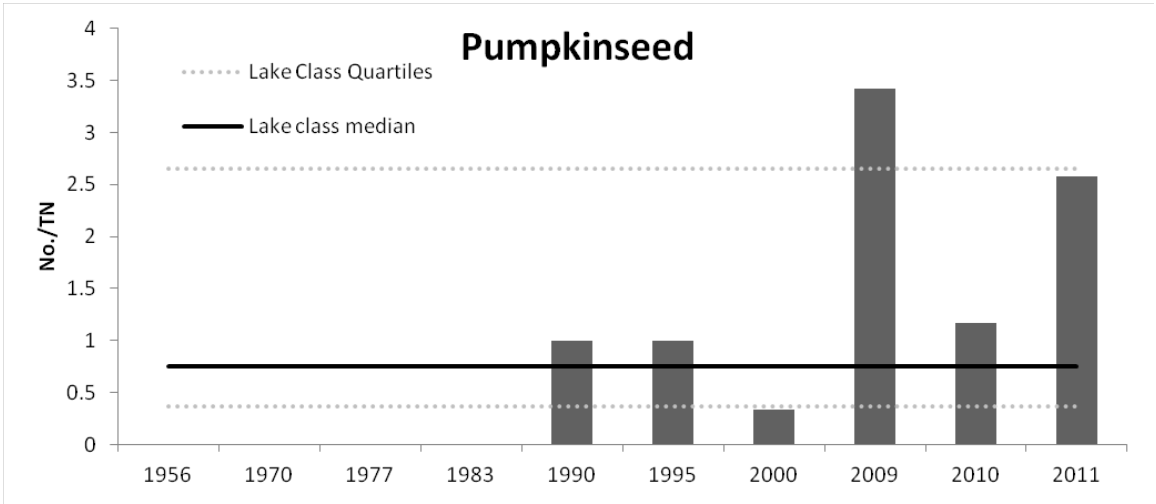


Figure 9. Historical net catches by species for Tait Lake

Aquatic plant assessment

Due to low nutrient levels and rocky substrates, aquatic plants in Tait Lake are naturally sparse; however, species diversity has been high. Twenty-three plant species or groups were identified during the 1995 lake survey, and 33 species or groups (including 12 shoreline or wetland species) were noted by a Minnesota County Biological Survey botanist in 2009 (Tables 8 and 9). Species or groups most commonly seen in vegetation surveys include horsetail, burreeds, northern milfoil, and waterlilies (yellow and white; Table 8). As of 2011, the lake apparently remained free of invasive aquatic plant species. Ninety-five percent of plant occurrences in 2009-2011 were at depths less than or equal to 4.3-5.5 ft.

Table 8. Common species sampled during past lake vegetation surveys. Species were deemed common if they were noted as "common" or "abundant" (1956) or if they were encountered at greater than 10 percent of transects (1995) or two percent of sampling points (2009-2011) surveyed.

Survey Year	Common Name	Species Name	Growth Form
1956	Yellow waterlily	*Nuphar sp.*	Floating-leaf
	Horsetail	*Equisetum sp.*	Emergent
	Hardstem bulrush	*Scirpus acutus*	Emergent
	Burreed sp.	*Sparganium sp.*	Floating-leaf
	Largeleaf pondweed	*Potamogeton amplifolius*	Submersed
1995	Water willow	*Decodon verticillata*	Emergent
	Water horsetail	*Equisetum fluviatile*	Emergent
	Quillwort group	*Isoetes sp.*	Submersed
	Northern milfoil	*Myriophyllum sibiricum*	Submersed
	Common yellow waterlily	*Nuphar variegate*	Floating-leaf
	Narrowleaf pondweed group	*Potamogeton sp.*	Submersed
	Floating-leaved burreed group	*Sparganium sp.*	Floating-leaf
	Arrowhead group	*Sagittaria sp.*	Emergent
2009	Horsetail group	*Equisetum sp.*	Emergent
	Water celery	*Vallisneria americana*	Submersed
2010	Horsetail group	*Equisetum sp.*	Emergent
	Burreed group	*Sparganium sp.*	Floating-leaf
	Common bladderwort	*Utricularia vulgaris*	Submersed
	Northern milfoil	*Myriophyllum sibiricum*	Submersed
	Water celery	*Vallisneria Americana*	Submersed
2011	Burreed group	*Sparganium sp.*	Floating-leaf
	Water celery	*Vallisneria americana*	Submersed
	Water marigold	*Bidens beckii*	Submersed

Table 9. Percent frequency of occurrence of aquatic plant species at depths £ 15 feet sampled during point-intercept surveys on 14 July 2009, 1 July 2010, and 1 July 2011, and species identified during a Minnesota County Biological Survey (MCBS) on 19 July 2009 at Tait Lake, Cook County, MN. P indicates a species was present.

			Frequency (%)			
Common Name	**Species Name**	**Growth Form**	**2009**	**2010**	**2011**	**MCBS**
All rooted plants			10.0	11.6	10.8	N/A
Common bladderwort	*Utricularia vulgaris*	Submersed	0.8	2.8	0.8	P
Bladderwort group	*Utricularia sp.*	Submersed	0.8			
Sedge	*Carex aquatilus*	Emergent		0.4		
Beaked sedge, bottle-shaped	*C. utriculata*	Emergent				P
Sedge group	*Carex sp.*	Emergent	0.4			
Waterweed group	*Elodea sp.*	Submersed	0.4	0.4		
Water horsetail	*Equisetum fluviatile*	Emergent				P
Horsetail group	*Equisetum sp.*	Emergent	3.6	4.0	1.6	
Farwell's watermilfoil	*Myriophyllum farwellii*	Submersed				P
Northern watermilfoil	*M. sibiricum*	Submersed	1.6	2.0	0.4	
Common white waterlily	*Nymphaea odorata*	Floating-leaf	1.2	0.4		P
White waterlily group	*Nymphaea sp.*	Floating-leaf			0.8	
Common yellow waterlily	*Nuphar variegata*	Floating-leaf	0.4			P
Yellow waterlily group	*Nuphar sp.*	Floating-leaf		1.6	1.6	
Robbins' pondweed	*Potamogeton robbinsii*	Submersed	0.8		0.8	
Largeleaf pondweed	*P. amplifolius*	Submersed		0.4	1.2	P
Flatstem pondweed	*P. zosteriformis*	Submersed		0.4		
Floating-leaf pondweed	*P. natans*	Floating-leaf			0.8	
Northern pondweed	*P. alpinus*	Submersed				P
Ribbon-leaved pondweed	*P. epihydrus*	Submersed				P
Variable pondweed	*P. gramineus*	Submersed				P
Burreed group	*Sparganium sp.*	Floating-leaf	1.6	3.6	2.8	
Wide floatingleaf burreed	*S. fluctuans*	Floating-leaf				P
Floating-leaved burred group	*Sparganium sp.*	Floating-leaf	0.4			
Hardstem bulrush	*Scirpus acutus*	Emergent	0.8		0.4	
Broadleaf arrowhead	*Sagittaria latifolia*	Emergent				P
Arrowhead group	*Sagittaria sp.*	Emergent	1.2		0.8	
Wild celery	*Vallisneria americana*	Submersed	2.0	2.0	2.8	
Water shield	*Brasenia schreberi*	Floating-leaf		0.4		
Muskgrass group	*Chara sp.*	Submersed		0.8		
Spikerush	*Eleocharis smallii*	Emergent		0.8		
Bald spikerush	*E. erythropoda*	Emergent				P
Water lobelia	*Lobelia dortmanna*	Submersed			0.4	
Water marigold	*Bidens beckii*	Submersed			2.4	P
Bushy pondweed group	*Najas sp.*	Submersed			0.8	
Mare's-tail	*Hippuris vulgaris*	Submersed				P
Braun's quillwort	*Isoetes echinospora*	Submersed				P
Northern manna grass	*Glyceria borealis*	Emergent				P
Rattlesnake grass	*G. canadensis*	Emergent				P
Blue flag	*Iris versicolor*	Emergent				P
Buck-bean	*Menyanthes trifoliata*	Emergent				P
Marsh cinquefoil	*Potentilla palustris*	Emergent				P
Filamentous algae		Submersed	0.4	0.4	0.4	
Water moss	*Drepanocladus sp.*	Submersed			0.4	
Maximum depth of vegetation growth (ft)[a]			4.8	5.5	4.3	N/A

The MCBS survey also identified the following shoreline plants: speckled alder (*Alnus incana*), bog-rosemary (*Andromeda glaucophylla*), sedge (*Carex echinata)*, wooly sedge (*C. lasiocarpa*), scoparia sedge (*C. scoparia*), hummock sedge (*C. stricta),* leather-leaf *(Chamaedaphne calyculata),* northern bugleweed *(Lycopus uniflorus*), sweet gale (*Myrica gale*), black-spiked bulrush (*Scirpus atrocinctus),* dark-green bulrush (*S. atrovirens*), and meadowsweet (*Spiraea alba*).

Water quality

One complete year of spring through fall data are available for 2009 while 2010 and 2011 had only three seasonal collections: spring, mid-summer, and fall. Summer-mean water quality data for 2009-2011 are summarized in Table 10 (July samples from 2010 and 2011 are included in the calculations) and raw data results are provided in Appendix A. In addition, major cations, anions, total organic carbon (TOC), and dissolved organic carbon (DOC) were summarized based on available summer data. Typical ranges, as derived from the National Lakes Assessment (NLA) database for Minnesota are provided for comparison (Table 11). The NLA was a statistically-based survey of the nation's lakes administered by the United States Environmental Protection Agency in 2007. The typical range provided in is based on 64 Minnesota lakes that were included in that NLA study and is intended to provide a state-wide perspective.

Table 10. Tait Lake 2009-2011 summer- mean water quality data. Typical range based on 32 NLF ecoregion reference lakes (Heiskary and Wilson 2008) noted for comparison.

Parameter	Tait Lake 2009-2011	NLF
Total phosphorus (µg/L)	15	14 - 27
Chlorophyll mean (µg/L)	2.7	4 - 10
Chlorophyll max (µg/L)	3.4	<15
Secchi disk (feet) (meters)	7.5 2.3	8 – 15 2.4 – 4.6
Total Kjeldahl Nitrogen (mg/L)	0.4	<0.4 – 0.75
Alkalinity (mg/L)	18	40 - 140
Color (Pt-Co Units)	43	10 - 35
pH (SU)	6.8	7.2 – 8.3
Chloride (mg/L)	<1	0.6 – 1.2
Total suspended solids (mg/L)	2.8	<1 - 2
Total suspended inorganic solids (mg/L)	1.3	<1 - 2
Conductivity (µmhos/cm)	36	50 - 250
Total nitrogen: Total phosphorus ratio	26:1	25:1 - 35:1

Table 11. Tait Lake cation, anion, and organic carbon measurements. Typical (IQ) range derived from 64 NLA lakes sampled in 2007 is provided as a basis for comparison. A value of half the detection limit was substituted for those values reported as less than the detection limit, unless the majority of values were non-detects.

	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	HCO_3 mg/L	SO_4 mg/L	Cl mg/L	TOC mg/L	DOC mg/L
2009-2011 Average	4.9	1.6	<0.3	1.1	18	2.2	<1	7.7	7.6
NLA IQ range	19.1-33.7	6.7-26.9	0.9 - 4.8	2.2 - 9.0		2.2-14.1	1.5-18.4	7.3-14.2	
	µeq/L								
2009-2011 Average	245	132	<8	48	360	46	<28		

Continuous temperature and dissolved oxygen and temperature profiles

Continuous surface water temperature was measured by a remote recording device from 2009-2011. Some among year differences are evident from this detailed dataset. Spring temperatures in 2009 and 2011 were rather similar, while 2010 exhibited very rapid warming (Figure 10). Temperatures remained warm through spring 2010 but by June, temperature was in the range of the other three years. Peak summer temperature occurred in 2010 with measurements near 25 C. Midsummer temperatures in 2009 were somewhat cooler than 2010 and 2011. Temperature declined rapidly by late September in all three years.

Profile data from 2009 provide a basis for examining seasonal patterns in dissolved oxygen (DO) and temperature for Tait Lake (Figure 11). As anticipated given the lake's shallow depth, Tait was isothermal on all visits in 2009, and DO was relatively consistent from top to bottom. Peak temperatures occurred in early August at 20 C; as expected, temperatures recorded at monitoring site 201 (at the lake's maximum depth) were slightly cooler than those recorded by the continuous meter that was placed in shallower water near shore.

DO concentrations were at their maximum in early spring and late fall (Figure 11), corresponding to cooler water temperatures. On all dates, DO concentrations remained well above the 5 mg/L water quality standard, sufficient for supporting a healthy cool water fishery.

Midsummer temperature and oxygen profiles from 2009-2011 are shown in Figure 12. Conditions were very similar among years, again indicating isothermal conditions and sufficient DO concentrations throughout the water column.

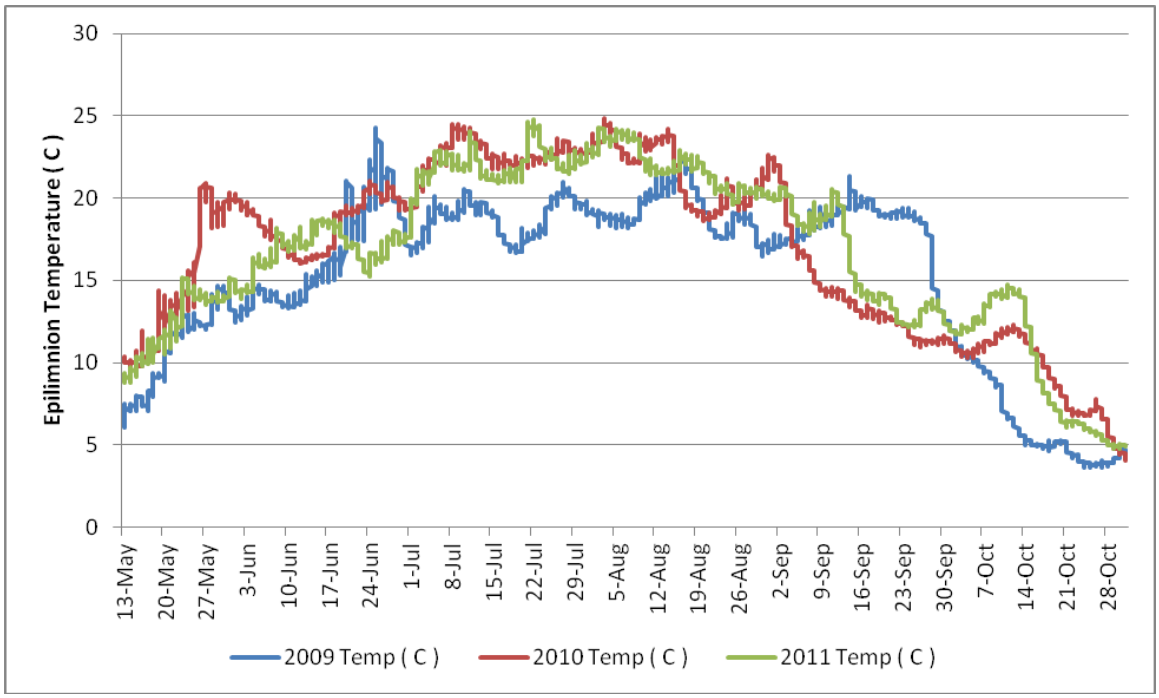


Figure 10. Tait Lake continuous temperature data, 2009-2011

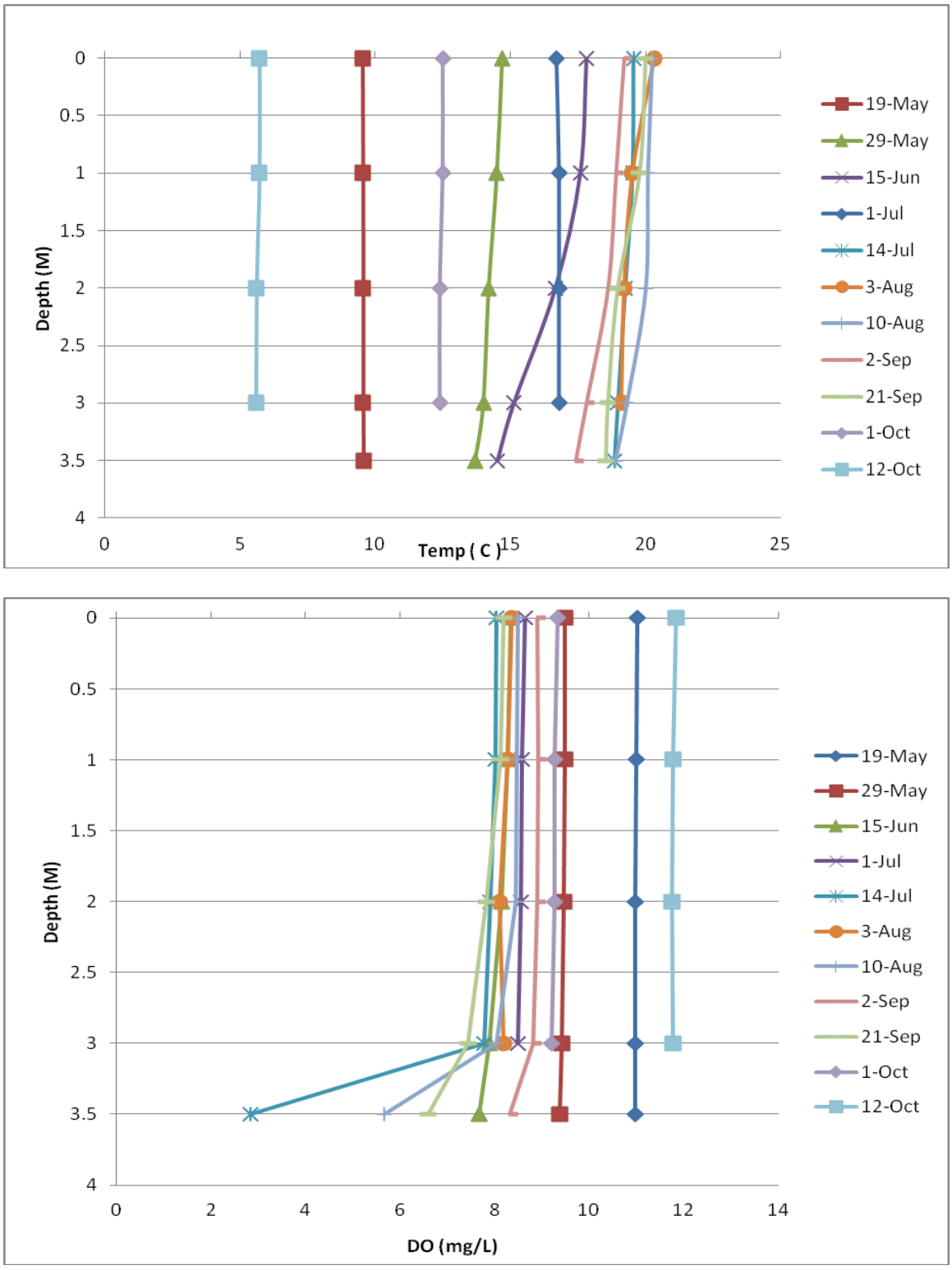


Figure 11. Tait Lake temperature and dissolved oxygen (DO) profiles for 2009

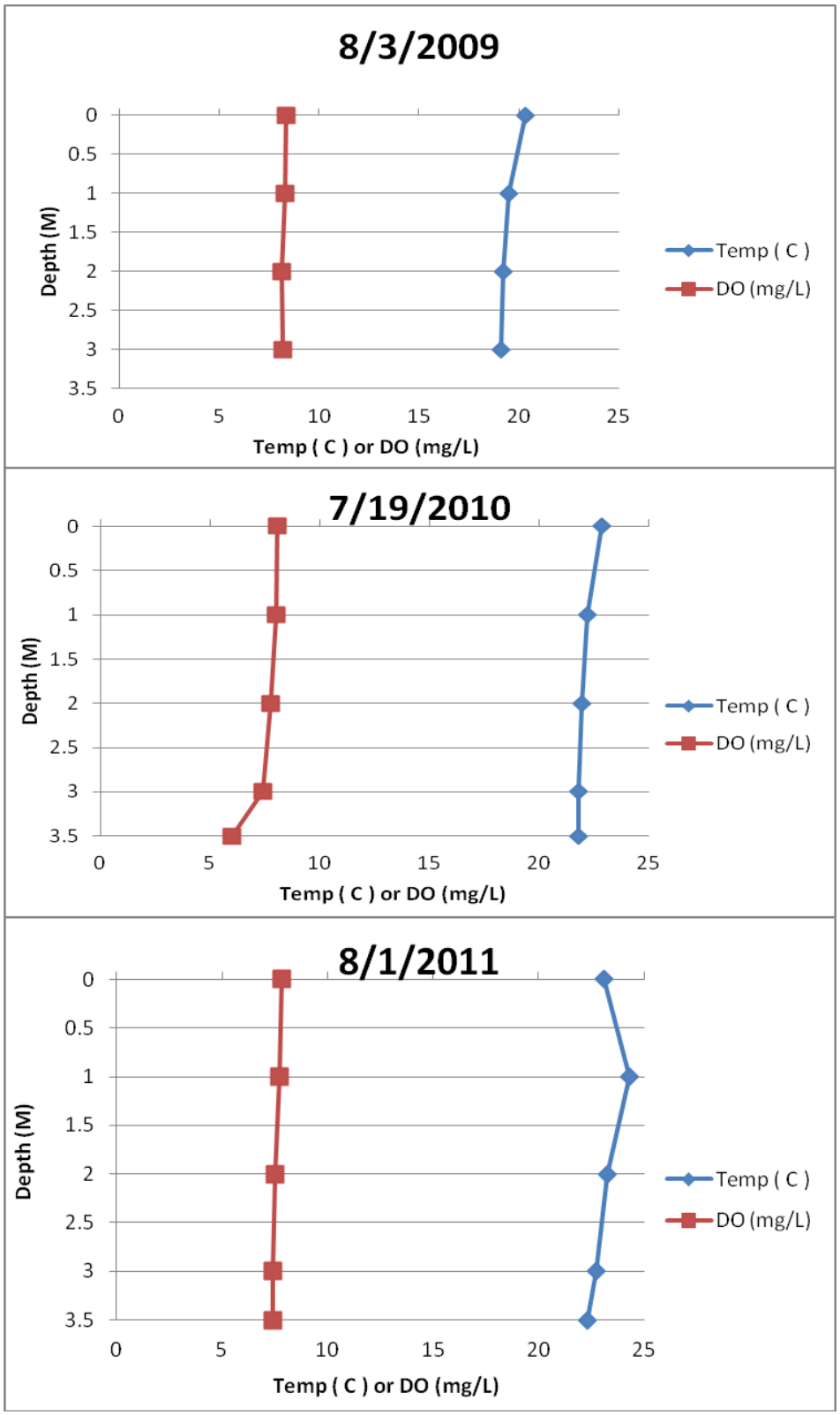


Figure 12. Tait Lake mid-summer temperature and DO profiles for 2009, 2010, and 2011

Total phosphorus (TP) concentrations were consistent from 2009-2011, averaging 15 µg/L. In 2009, the year with the most samples collected, TP remained relatively consistent throughout the sampling season, but was slightly lower in May and June (Figure 13). The stable TP concentrations were expected given the lake's polymictic condition, aerobic bottom waters, and small forested watershed. Overall, TP values in Tait Lake indicate mesotrophic conditions.

Chlorophyll-*a* (Chl-a) concentrations provide an estimate of the amount of algal production in a lake. Summer-mean Chl-a averaged 2.7 µg/L from 2009-2011, and concentrations were very similar among years (Figure 13). 2009 exhibited a subtle increase in Chl-a from May through October. Concentrations greater than 10 µg/L will typically be perceived as a mild algal bloom in northern Minnesota lakes (Heiskary and Walker 1988). No sampling events exceeded 10 µg/L; the highest recorded concentration was 4.2 µg/L in October 2009. Nuisance-level blooms were not observed on Tait Lake from 2009-2011, and during most sampling events algae levels in the epilimnion were sparse.

Secchi disk transparency averaged 2.8, 2.3, and 2.1 meters, respectively, in 2009, 2010, and 2011. Transparency was quite stable among years. In general, Secchi declined as algal biomass (Chl-a) increased (Figure 13). Tait has a moderate bog stain (43 Platinum-Cobalt units) originating from forest and wetlands within the watershed, which (when elevated) can influence transparency. However, color values in Tait are moderate and have minimal impact on transparency.

CLMP, MPCA, and MDNR collected Secchi measurements for 2009-2011 were combined to allow for a more comprehensive record of transparency (Figure 14). These data reveal elevated transparency measures in the spring and fall and further re-affirm the rather stable mid-summer (July) transparency among years. Overall, transparency was greater in 2010, perhaps because it was a slightly drier year (Figure 8). The peak transparency occurred shortly after ice-out in late April of 2010 when the disk was visible on the lake bottom at a depth of 4 m. The relationships between climate, water temperatures, and transparency are important toward understanding conditions in Tait Lake, and further reinforce that long-term Secchi measurement will be a valuable means for tracking the trophic status of Tait Lake over time.

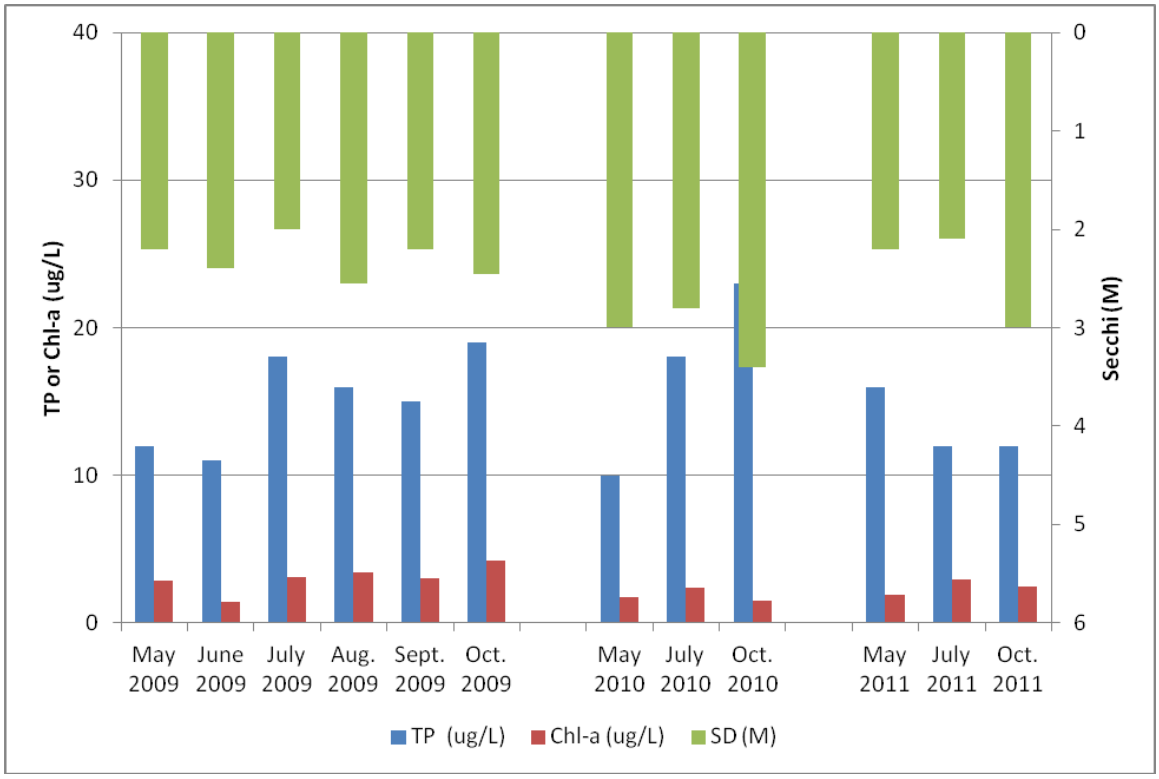


Figure 13. Tait Lake 2009-11 total phosphorus, chlorophyll-*a* and Secchi depth

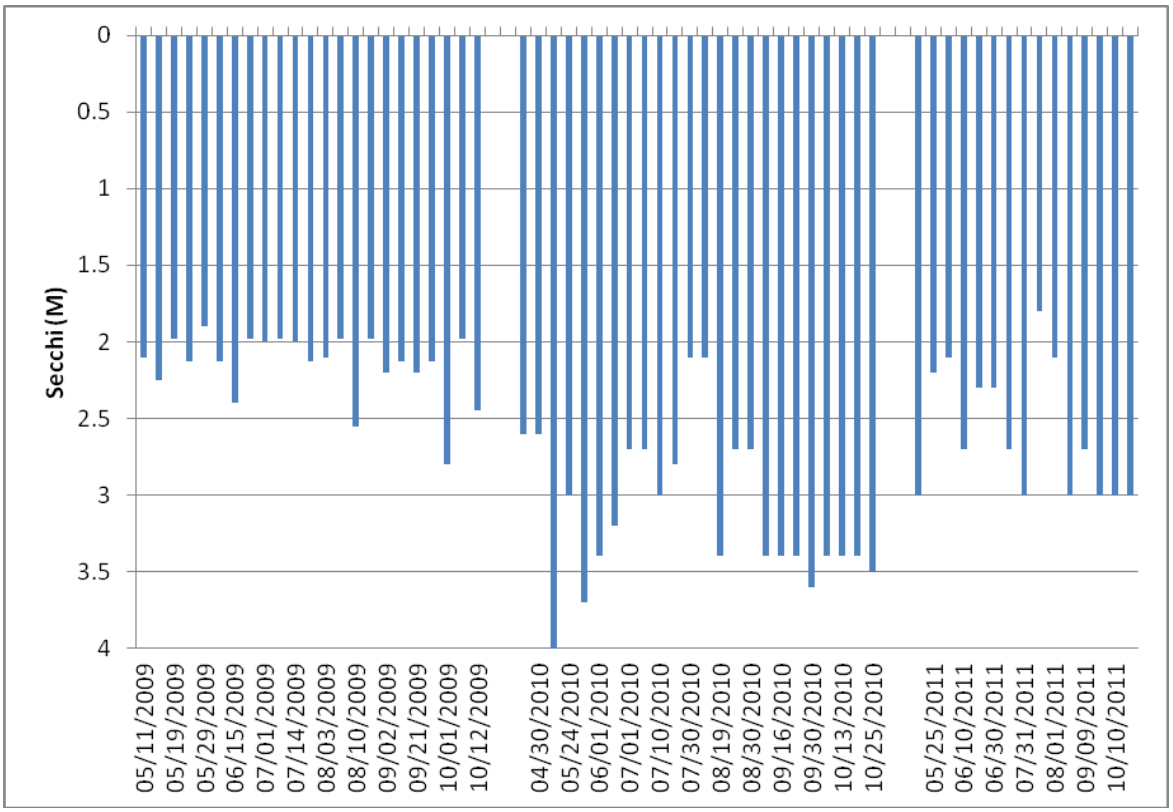


Figure 14. Tait Lake Secchi transparency readings from 2009-2011

Dissolved minerals and organic carbon were measured in 2009-2011, as part of the long-term monitoring of Tait and other Sentinel lakes. This includes some of the standard LAP measures of total suspended solids (TSS), alkalinity, conductivity and color (Table 10), as well as major cations, anions, silica, iron, and organic carbon. While several of these parameters have "typical" ecoregion-based concentrations, some do not. For parameters without ecoregion–based values, comparative data from the 2007 National Lakes Assessment (NLA) study were used to provide perspective on reported concentrations. Since the NLA lakes were randomly selected, they provide a reasonable basis for describing typical ranges and distributions at the statewide level.

The moderate color value on Tait indicates the water has some coloration and moderate amounts of dissolved organic carbon (DOC). Total organic carbon (TOC) is near the typical range, based on the NLA data and the majority of the TOC is in the DOC form, which is consistent with the statewide data (Figure 11). Lakes that receive a majority of their water inputs from forest and wetland runoff (as does Tait) often have higher color and TOC values because of incompletely dissolved organic matter (plants, leaves, and other organic material).

Alkalinity and conductivity are below the typical range for NLF lakes and are indicative of very soft water, similar to other lakes in the area. Most cation and anion concentrations were quite stable across sample events and years (Figure 15), which is consistent with the literature. Mg, Na, K, and Cl are noted to be relatively conservative and undergo only minor spatial and temporal change (Wetzel 2001). Mg is required by algae to produce Chl-a and Ca is used by rooted plants. Silica (Si), which is required by diatoms to form their "glass" shells, varied slightly from spring to fall. A slight decline in fall may be caused by a fall diatom bloom.

Calcium (Ca) and magnesium (Mg) are the dominant cations and concentrations of both are below the typical range of the statewide data. The other two major cations – sodium (Na) and potassium (K) are well below the typical range as well. Bicarbonate is the dominant anion. Chloride is within the typical range for

NLF reference lakes (Table 10); however, it is low relative to statewide NLA data, and several samples were below the laboratory's detection limit. Elevated Cl is most often attributed to application of road salt in the watershed. Of all the ions, Ca and HCO_3 are the most variable seasonally and this is likely the result of rooted plant growth, photosynthesis, and senescence.

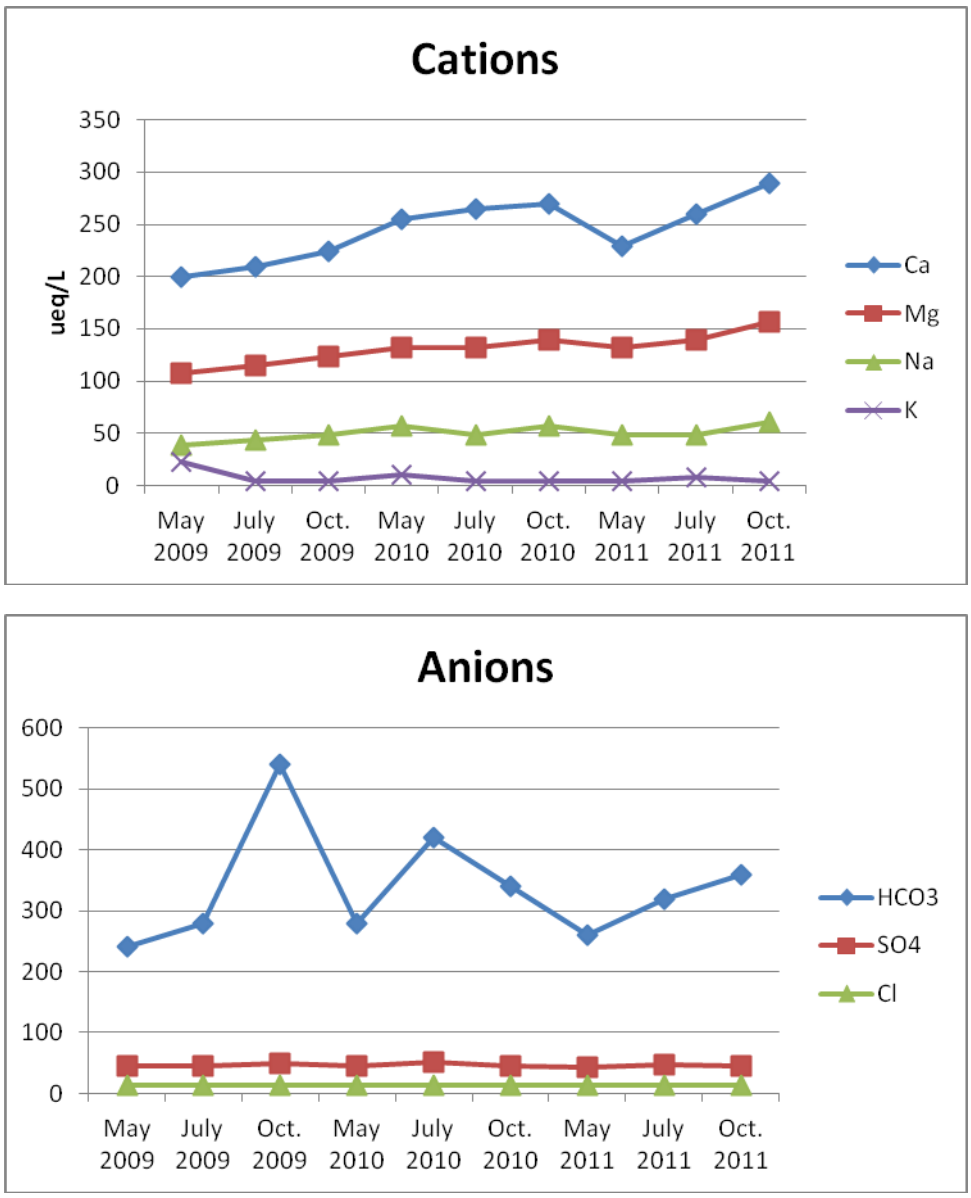


Figure 15. Tait Lake cation and anion values for 2009-2011

Phytoplankton (algae) data for Tait Lake in 2009 and 2010 are presented in terms of algal type (Figure 16). Algal composition was variable among sample dates and years; however, across most dates and samples, diatoms, yellow-brown, and blue-green algae were the most common forms. Of the two sample years, 2009 had what is considered a somewhat "typical" transition of algae in NLF lakes with relatively low productivity- a diverse population in spring after ice-out, followed by dominance of diatoms, then blue greens by late summer and early fall. This is in contrast to 2010, which was dominated by yellow-browns on all sample dates. Diatoms often grow abundantly in the spring following ice-out and turnover when temperatures are cool and there is abundant phosphorus and silica (which is required for their "glass-like" shells). As the water warms diatoms dieback and settle to the bottom of the lake, allowing other algal forms to prosper.

Because only three samples were collected in 2010, direct comparison of seasonal transition among years is difficult. However, direct comparison of May, July, and October 2009 and 2010 suggest algal composition varies among seasons and years. Compared to other northern Sentinel lakes, levels of blue-green algae and algal productively are low on Tait.

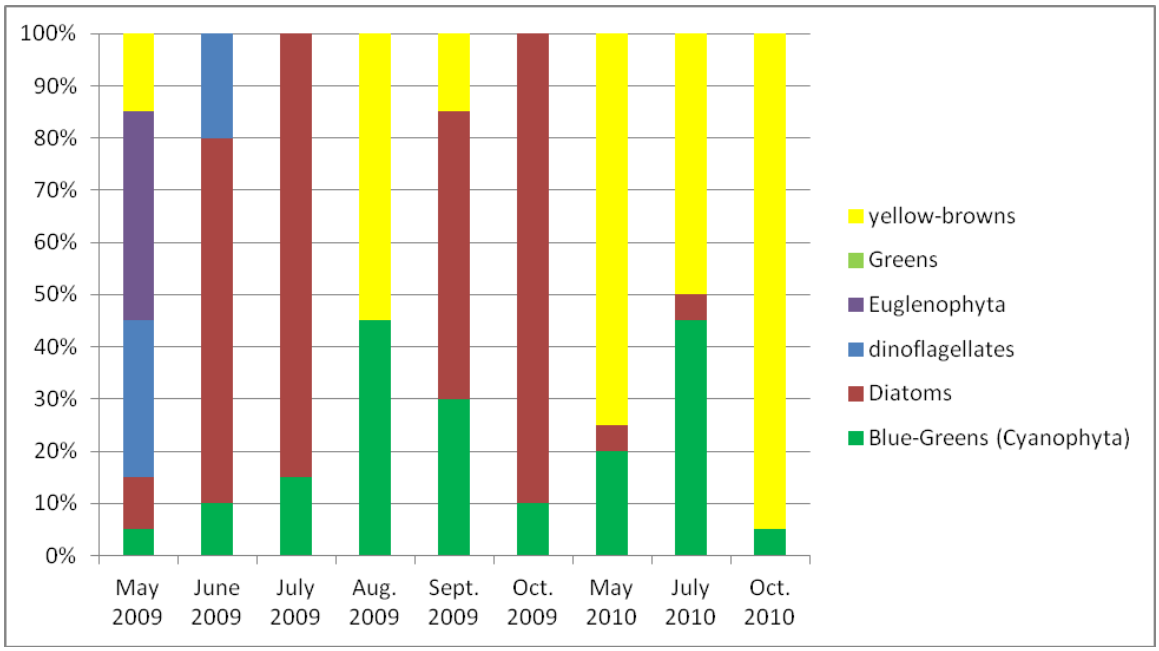


Figure 16. Algal composition for Tait Lake 2009 and 2010

Zooplankton

Zooplankton samples were analyzed by Jodie Hirsch at the MDNR. A summary report was prepared that included information for all the Sentinel lakes and that report is the basis for the following comments on Tait Lake (Hirsch 2011). Mean 2009-2010 zooplankton densities in Tait were higher than two other Border region sentinel lakes (Table 12). Hirsch (2009) found that, in general, as lake productivity increased (e.g. TP or Chl-a) the relative abundance (biomass) of zooplankton increased as well. This appears to be the case for Tait, as its mean density and biomass were similar to other lakes of similar trophic status.

Mean monthly zooplankton density was highest in June and then declined somewhat in July, then increased slightly for the rest of the monitoring season (Figure 17). Mean monthly biomass peaked in June, declined rapidly in July, and increased slightly in October. This pattern was similar to what was observed in Echo and Elephant Lakes. Fish predation, in particular bluegill, pumpkinseed, and black crappie, is a likely cause of the seasonal decline in zooplankton density and biomass.

Table 12. Mean summer total phosphorus (µg/liter), mean annual zooplankton densities (number individuals/liter), and biomass (µg/liter) for the 24 sentinel lakes, 2008-2010. Lakes arranged by landtype and TP.

Sentinel Lakes Zooplankton	Lake Type	Mean Summer TP (2000-2009)	Mean Annual Densities (2008-2010)	Mean Annual Biomass (2008-2010)
Prairie				
Artichoke	shallow	248	87.97	636.49
Shaokotan	shallow	167	129.46	1588.75
Madison	deep	78	52.59	245.04
St. James	shallow	52	75.94	134.52
St. Olaf	deep	37	68.23	287.02
Carrie	deep	22	51.89	196.58
Transition				
Peltier	shallow	266	62.21	657.47
Belle	shallow	55	43.80	307.74
South Center	deep	51	21.26	98.81
Pearl	shallow	40	52.31	229.52
Carlos	deep-cisco	16	14.60	55.21
Cedar	deep-cisco	13	14.08	49.27
Forest				
Portage	shallow	56	86.51	199.91
Hill (south)	deep	37	32.27	154.08
Red Sand	shallow	24	76.23	109.95
Hill (north)	deep	23	14.38	86.23
Elk	deep-cisco	17	12.67	36.42
South Twin	deep-cisco	17	30.90	55.22
Ten Mile	deep-cisco	12	12.58	37.56
Shield				
Echo	shallow	43	33.01	126.18
Elephant	deep	21	15.95	94.96
White Iron	deep-cisco	21	9.34	31.45
Tait	shallow	16	17.04	61.46
Bearhead	deep	14	5.53	23.36
Trout	deep-cisco	7	5.02	26.00

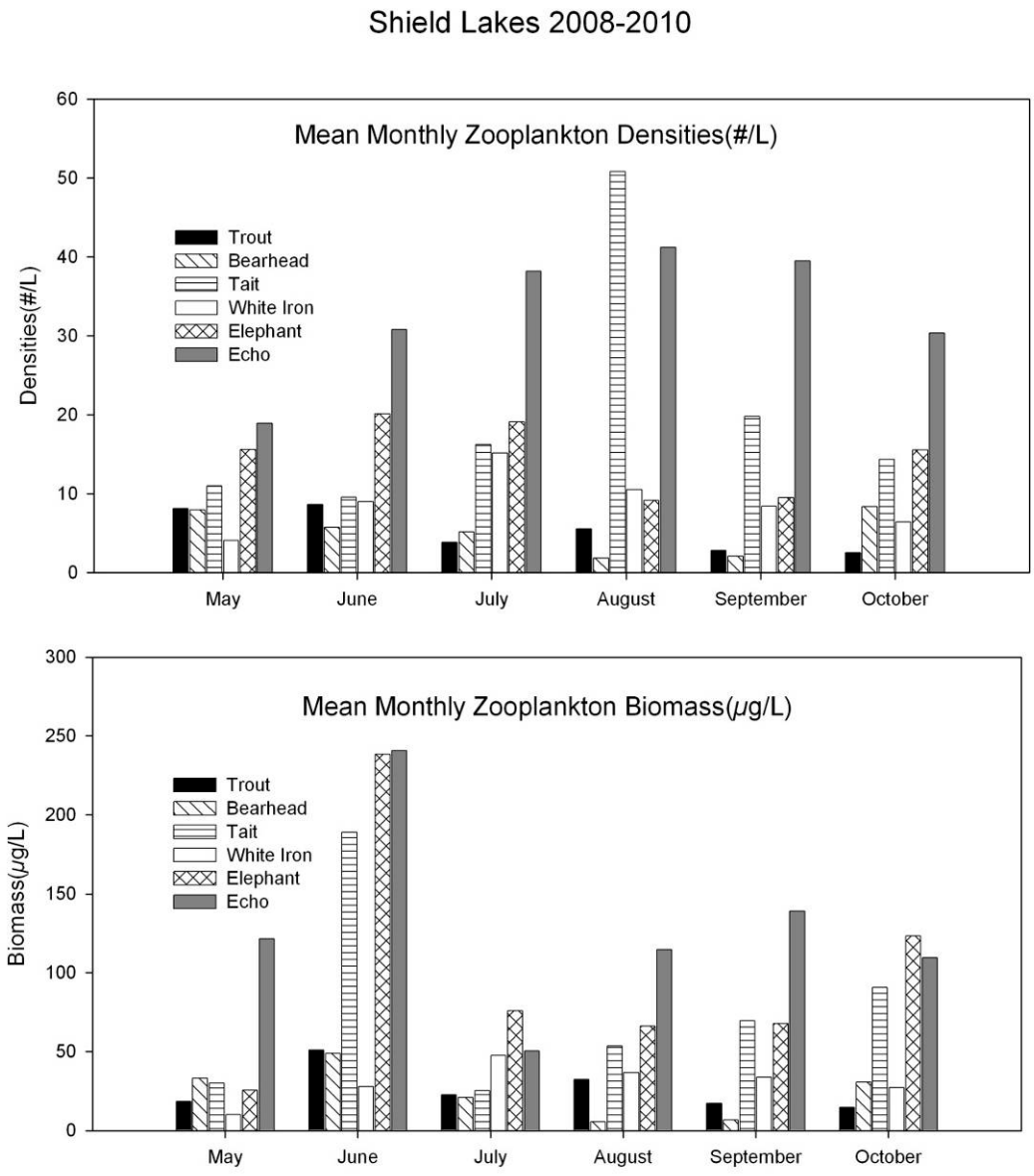


Figure 17. Mean monthly zooplankton densities (#/liter) and biomass (µg/liter) in the Sentinel lakes of the shield landtype 2008-2010. (Lakes are listed by increasing phosphorus levels)

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:

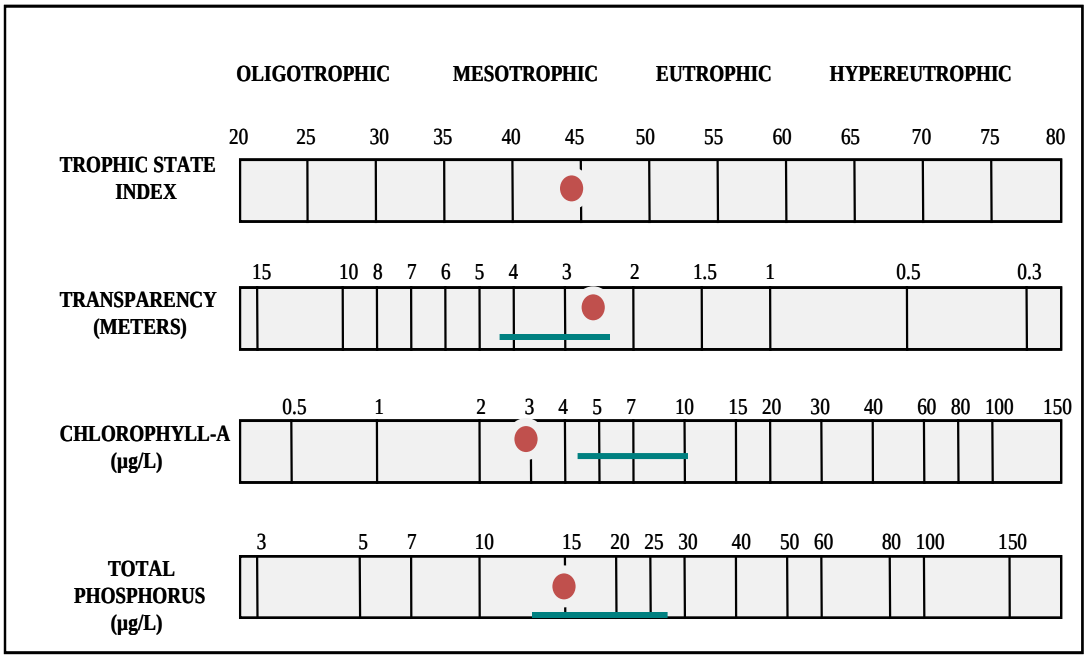
Total Phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

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 provide a basis for assessing the relationship among TP, Chl-a, and Secchi (Figure 18). The TSI values are shown based on MPCA data for 2009-2011 (Figure 18). In general, the phosphorus, Chl-a, and Secchi TSI values for Tait Lake are in relatively close correspondence with each other. The Secchi TSI is slightly higher (implies lower Secchi reading) than anticipated, based on Chl-a and this may be because of the slight bog stain, which can serve to reduce transparency. Based on an average TSI score of 44, Tait Lake would be characterized as mesotrophic. These values also affirm that continued Secchi monitoring via CLMP should provide a good basis for assessing trends in trophic status for Tait Lake.

TSI < 30	Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



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NLF Ecoregion Range — Tait Lake 2009-2011

Figure 18. Tait Lake TSI values from 2009-2011 MPCA Sentinel Lake monitoring data

Trophic status trends

One aspect of lake monitoring is to assess trends in the condition of the lake, where possible, based on data gathered through the MPCA's Citizen Lake Monitoring Program (CLMP) or other available data in EQuIS. A review of EQuIS data indicates that historical data are significant on Tait, with measurements collected from 1993-2003, and 2006 to the present (Figure 19). The majority of the available data were gathered through CLMP (from volunteers in the Tait Lake Association) and the Sentinel monitoring effort. Additionally, a lake assessment was completed in 2003 by the MPCA, Cook County, and the Association.

Current data are sufficient for trend analysis, and data indicate no statistically significant trend in transparency over time. Some year-to-year variability is evident in the dataset, likely due to differences in climate and water levels (such as higher than average clarity in 2010); however, annual standard errors are low, typically ~ 0.1 m. The long term annual mean transparency is 2.2 m (7.2 feet). Continued monitoring through CLMP, combined with future Sentinel monitoring, will be critical to continue to assess trends over time in Tait Lake.

Phosphorus, Chl-a, and Secchi transparency in 2003 averaged 15 µg/L, 4 µg//L, and 2.5 m respectively, and were very similar to average values from 2009-2011 collected through the Sentinel Lakes program- (15 µg/L, 2.7 µg/L, and 2.3 m; Table 3). Collectively all available data indicate relatively stable water quality in Tait Lake.

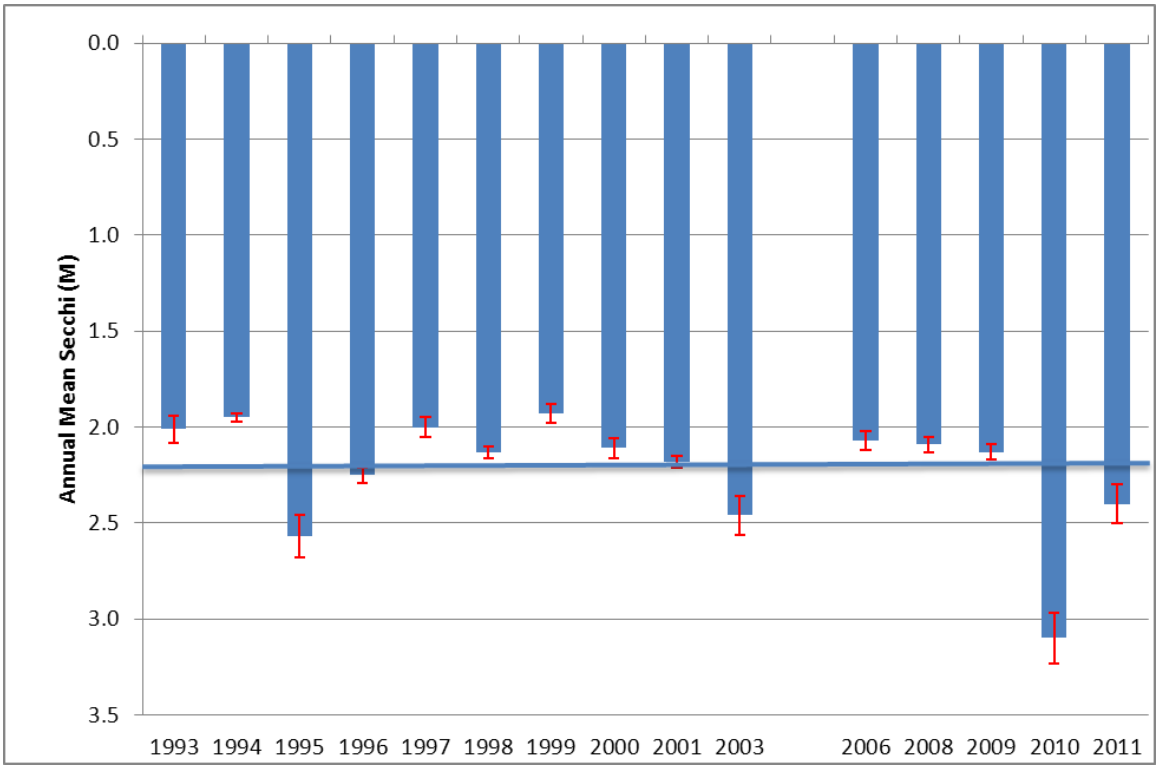

Figure 19. Tait Lake summer-mean Secchi. Standard error of mean noted in red, long term mean transparency noted by blue line

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 2009-11 water quality of Tait Lake, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model (Wilson and Walker 1989) was used.

MINLEAP was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is routinely used as a screening tool for estimating lake conditions with minimal input data and is described in more detail in Wilson and Walker (1989). The model predicts in-lake TP from these inputs. Chl-a and Secchi predictions are derived from Minnesota-based regression equations. For analysis of Tait Lake, MINLEAP was applied as a basis for comparing the observed (2009-11 average) 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.

The BATHTUB model (Walker 2004) provides a further basis for estimating water and nutrient budgets for Tait Lake using a combination of runoff and P export coefficients based on land use in the watershed and data from similar watersheds in this ecoregion. The number of residences (~43 homes or cabins) was used as a basis to estimate potential on-site septic system inputs into the lake. For purposes of this modeling, standard per capita estimates of P loading to septic systems were used (based on seasonal usage). Since we had no details on the status of septic systems around the lake, a conservative value of 80 percent retention was used, which implies that the system and soils retain 80 percent of the P loaded to them. If systems are up-to-code and properly maintained this should be a reasonable estimate.

Tait Lake is located in the NLF ecoregion and the MINLEAP model was run using NLF-based inputs. The observed and predicted TP values for Tait Lake were not significantly different (Table 13). Observed Chl-a and Secchi were consistent with the predicted values. An additional subroutine in the MINLEAP model estimates the "background" TP for the lake based on its alkalinity and mean depth and a regression equation developed by Vighi and Chiaudani (1985). For Tait Lake, the estimated value is 15 µg/L, which is equal to the observed concentration (Table 12). Overall, these results indicate that Tait's trophic status is quite similar to that expected based on its size, depth, size of watershed, and the ecoregion it is located in.

MINLEAP predicts a P loading rate of about 105 kilograms per year entering Tait Lake from its watershed and atmospheric deposition on the lake surface. Since predicted and observed TP are not significantly different, the predicted P loading rate is likely a reasonable estimate. The model predicts approximately 51 percent of the TP will be retained in the lake, a reasonable estimate given the lake's small watershed, volume, and moderate residence time (estimated at ~ 1.3 years; Table 13).

BATHTUB predicted in-lake P at 25 µg/L, which is not significantly different from the observed P (Table 14), and an annual loading rate of 151 kg/yr. (which is likely a bit high). Predicted Secchi was comparable to observed, although predicted Chl-a was higher than observed, but is consistent with the predicted TP. Estimates of watershed, atmospheric (deposition on surface of the lake), and on-site P loading were used to estimate in-lake P. This allowed for estimates of the relative contribution for each source category as follows: watershed ~67 percent, atmospheric ~26 percent and on-site septic systems ~4 percent. These are estimates only and were based on the limited information that was available. More refined estimates would require measurement of runoff from the watershed, more accurate estimate of precipitation on the lake, and more detailed information on the actual number, usage, and maintenance of on-site systems around the lake. The BATHTUB framework, as used in this current effort is included in Appendix B and could be modified in the future should more accurate estimates be required.

Table 13. MINLEAP model results for Tait Lake

Parameter	2009-2011 Tait Lake Observed	MINLEAP Predicted NLF Ecoregion
TP (µg/L)	15 ±1.3	20 ±6
Chl-*a* (µg /L)	2.7 ±0.4	5.3 ±2.8
Secchi (m)	2.3 ±0.1	2.9 ±1.1
P loading rate (kg/yr.)	-	105
P retention (percent)	-	51
P inflow conc. (µg/L)	-	41
Water Load (m/yr.)	-	1.79
Outflow volume (hm^3/yr.)	-	2.57
Residence time (yrs)		1.3
Vighi & Chiaudani P (µg/L)		14.8

Table 14. BATHTUB model results for Tait Lake

Parameter	2009- 2011 Tait Lake Observed	BATHTUB Predicted
TP (µg/L)	15 ±1.3	25
Chl-*a* (µg /L)	2.7 ±0.4	9
Secchi (m)	2.3 ±0.1	1.7
P loading rate (kg/yr.)	-	151
P retention (percent)	-	78
P inflow conc. (µg/L)	-	39
Water Load (m/yr.)	-	
Outflow volume (hm^3/yr.)	-	2.9
Residence time (yrs)		1.1

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, Minnesota 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, which are used to assess Minnesota's water resources. An example is mercury found in fish tissue. If a water body is listed, an investigative Total Maximum Daily Load (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. The MPCA is responsible for performing assessment activities, listing impaired waters, and conducting TMDL studies in Minnesota.

Tait Lake was assessed relative to the NLF Class 2B ecoregion standards (Table 14). The 2009, 2010, 2011, and long-term summer-mean TP, Chl-a-a and Secchi for Tait Lake fully meet the water quality standards (Table 15). Based on these results, Tait Lake is meeting eutrophication standards for NLF ecoregion 2B waters (i.e. those waters that support a cool and warm water fishery).

Table 15. Eutrophication standards by ecoregion and lake type (Heiskary and Wilson, 2005). Tait Lake long-term means provided for comparison

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	**< 30**	**< 9**	**> 2.0**
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7
Tait Lake long-term mean	**15**	**3.0**	**2.2**

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Appendix A

Tait Lake water quality data from 2009-2011; all water quality data can be accessed at: http://www.pca.state.mn.us/data/eda.

Sample Date	Type	Depth	BOD	Chl-a	Trans	DO	TKN	NO2NO3	pH	Pheo	TP	TSS	Turb	FC	Ecoli	Secchi
10-13-11	Routine	0 m		2.46		9.3	0.37	< 0.05		0.88	0.012	3.2				3
10-13-11	Routine	1 m				9.24										
10-13-11	Routine	2 m				9.2										
10-13-11	Routine	3 m				9.12										
10-10-11	Routine	0 m														3
09-30-11	Routine	0 m														3
09-09-11	Routine	0 m														2.7
08-07-11	Routine	0 m														3
08-01-11	Routine	0 m		2.91			0.41	< 0.05		1.28	0.012	1.6				2.1
08-01-11	Routine	1 m				7.84										
08-01-11	Routine	2 m				7.72										
08-01-11	Routine	3 m				7.5										
08-01-11	Routine	3.6 m				7.42										
08-01-11	Routine	0 m														1.8
08-01-11	Routine	1 m				8.13										
08-01-11	Routine	2 m				8.02										
08-01-11	Routine	3 m				7.67										
07-31-11	Routine	0 m														3
07-25-11	Routine	0 m				8.0										2.7
07-25-11	Routine	.915 m				8.0										
07-25-11	Routine	1.829 m				8.0										
07-25-11	Routine	2.744 m				8.0										
07-25-11	Routine	3.354 m				8.0										
07-25-11	Routine	3.659 m				8.0										
06-30-11	Routine	0 m														2.3
06-30-11	Routine	1 m				8.95										
06-30-11	Routine	2 m				8.62										
06-30-11	Routine	3 m				8.47										
06-30-11	Routine	3.5 m				7.9										
06-30-11	Routine	0 m				9.0										2.3

06-30-11	Routine	1.006 m				9.0										
06-30-11	Routine	2.012 m				8.6										
06-30-11	Routine	3.018 m				8.5										
06-30-11	Routine	3.537 m				7.9										
06-10-11	Routine	0 m														2.7
06-01-11	Routine	0 m				9.3										2.1
06-01-11	Routine	1.006 m				9.2										
06-01-11	Routine	2.012 m				9.1										
06-01-11	Routine	3.018 m				9.1										
06-01-11	Routine	3.659 m				8.9										
05-25-11	Routine	0 m		1.86			0.50	< 0.05		0.96	0.016	2.0				2.2
05-25-11	Routine	1 m				8.04										
05-25-11	Routine	2 m				8										
05-25-11	Routine	3 m				7.97										
05-25-11	Routine	3.8 m				2.6										
05-19-11	Routine	0 m														3
10-25-10	Routine	0 m				10.8										> 3.5
10-25-10	Routine	1 m				10.8										
10-25-10	Routine	2 m				10.9										
10-25-10	Routine	3 m				10.9										
10-25-10	Routine	3.5 m				10.8										
10-19-10	Routine	0 m														3.4
10-13-10	Routine	0 m														3.4
10-11-10	Routine	0 m		1.52		9.42	0.67	< 0.05		< 0.42	0.023	14				3.4
10-11-10	Routine	1 m				9.42										
10-11-10	Routine	2 m				9.37										
10-11-10	Routine	3 m				9.06					0.009					
10-11-10	Routine	3.7 m				8.26										
09-30-10	Routine	0 m				10.2										> 3.6
09-30-10	Routine	1 m				10.2										
09-30-10	Routine	2 m				10.2										
09-30-10	Routine	3 m				10.2										
09-29-10	Routine	0 m														3.4
09-16-10	Routine	0 m														3.4
09-01-10	Routine	0 m														3.4
08-30-10	Routine	0 m				8.3										2.7

08-30-10	Routine	1 m				8.4										
08-30-10	Routine	2 m				8.4										
08-30-10	Routine	3 m				8.2										
08-30-10	Routine	0 m				8.3										2.7
08-30-10	Routine	1 m				8.4										
08-30-10	Routine	2 m				8.4										
08-30-10	Routine	3 m				8.2										
08-19-10	Routine	0 m														3.4
07-30-10	Routine	0 m				8.3										2.1
07-30-10	Routine	1 m				8.2										
07-30-10	Routine	2 m				8.0										
07-30-10	Routine	3 m				7.7										
07-30-10	Routine	4 m				0.2										
07-30-10	Routine	0 m				8.3										2.1
07-30-10	Routine	1 m				8.2										
07-30-10	Routine	2 m				8.0										
07-30-10	Routine	3 m				7.7										
07-30-10	Routine	4 m				0.2										
07-19-10	Routine	0 m		2.37		8.07	0.58	< 0.05		0.68	0.018	3.6				2.8
07-19-10	Routine	1 m				8.02										
07-19-10	Routine	2 m				7.78										
07-19-10	Routine	3 m				7.42					0.009					
07-19-10	Routine	3.6 m				5.99										
07-10-10	Routine	0 m														3
07-01-10	Routine	0 m				8.8										2.7
07-01-10	Routine	1 m				8.7										
07-01-10	Routine	2 m				8.7										
07-01-10	Routine	3 m				7.9										
07-01-10	Routine	4 m				7.2										
07-01-10	Routine	0 m				8.8										2.7
07-01-10	Routine	1 m				8.7										
07-01-10	Routine	2 m				8.7										
07-01-10	Routine	3 m				7.9										
07-01-10	Routine	4 m				7.2										
06-15-10	Routine	0 m														3.2
06-01-10	Routine	0 m				8.6										> 3.7

06-01-10	Routine	1 m				8.5										
06-01-10	Routine	2 m				8.5										
06-01-10	Routine	3 m				8.5										
06-01-10	Routine	0 m														3.4
06-01-10	Routine	0 m				8.6										
06-01-10	Routine	1 m				8.5										
06-01-10	Routine	2 m				8.5										
06-01-10	Routine	3 m				8.5										
05-24-10	Routine	0 m		1.77		8.56	0.37	< 0.05		< 0.21	0.010	< 1				3
05-24-10	Routine	1 m				8.78										
05-24-10	Routine	2 m				8.77										
05-24-10	Routine	3 m				8.8					0.007					
05-24-10	Routine	3.7 m				8.28										
05-20-10	Routine	0 m														4
04-30-10	Routine	0 m				7.9										2.6
04-30-10	Routine	.6 m				7.7										
04-30-10	Routine	1.2 m				7.6										
04-30-10	Routine	1.8 m				7.6										
04-30-10	Routine	2.4 m				7.6										
04-30-10	Routine	3 m				7.8										
04-30-10	Routine	3.7 m				7.6										
04-30-10	Routine	0 m				7.9										2.6
04-30-10	Routine	1 m				7.7										
04-30-10	Routine	2 m				7.6										
04-30-10	Routine	3 m				7.8										
04-30-10	Routine	3.2 m				7.6										
10-12-09	Routine	0 m		4.19		11.84	0.26	< 0.05		1.22	0.019	3.2				2.45
10-12-09	Routine	1 m				11.77										
10-12-09	Routine	2 m				11.76										
10-12-09	Routine	3 m				11.78					0.019					
10-12-09	Routine	3.2 m				11.51										
10-06-09	Routine	0 m														1.98
10-01-09	Routine	0 m				9.34										2.8
10-01-09	Routine	1 m				9.28										
10-01-09	Routine	2 m				9.26										
10-01-09	Routine	3 m				9.21										

09-22-09	Routine	0 m														2.13
09-21-09	Routine	0 m		3.00			0.41	< 0.05		0.69	0.015					
09-21-09	Routine	.2 m				8.2										2.2
09-21-09	Routine	1 m				8.13										
09-21-09	Routine	2 m				7.82										
09-21-09	Routine	3 m				7.43					0.017					
09-21-09	Routine	3.3 m				6.61										
09-08-09	Routine	0 m														2.13
09-02-09	Routine	0 m				8.9										2.2
09-02-09	Routine	1 m				8.92										
09-02-09	Routine	2 m				8.9										
09-02-09	Routine	3 m				8.82										
09-02-09	Routine	3.5 m				8.33										
08-25-09	Routine	0 m														1.98
08-10-09	Routine	0 m		3.42			0.42	< 0.05		1.40	0.016					
08-10-09	Routine	.1 m				8.5										2.55
08-10-09	Routine	1 m				8.47										
08-10-09	Routine	2 m				8.44										
08-10-09	Routine	3 m				8.05					0.016					
08-10-09	Routine	3.3 m				5.67										
08-03-09	Routine	0 m				8.36										2.1
08-03-09	Routine	1 m				8.28										
08-03-09	Routine	2 m				8.11										
08-03-09	Routine	3 m				8.18										
08-03-09	Routine	0 m														1.98
07-15-09	Routine	0 m														2.13
07-14-09	Routine	0 m		3.12			0.46	< 0.05		0.98	0.018	3.4				
07-14-09	Routine	.1 m				8.05										2
07-14-09	Routine	1 m				8.02										
07-14-09	Routine	2 m				7.9										
07-14-09	Routine	3 m				7.79					0.013					
07-14-09	Routine	3.4 m				2.84										
07-03-09	Routine	0 m														1.98
07-01-09	Routine	0 m				8.65										2
07-01-09	Routine	1 m				8.58										
07-01-09	Routine	2 m				8.55										

07-01-09	Routine	3 m				8.49										
06-22-09	Routine	0 m														1.98
06-15-09	Routine	0 m		1.43			0.42	< 0.05		0.24	0.011					
06-15-09	Routine	.1 m				8.35										2.4
06-15-09	Routine	1 m				8.27										
06-15-09	Routine	2 m				8.14										
06-15-09	Routine	3 m				7.88					0.011					
06-15-09	Routine	3.4 m				7.67										
06-11-09	Routine	0 m														2.13
05-29-09	Routine	0 m				9.48										1.9
05-29-09	Routine	1 m				9.49										
05-29-09	Routine	2 m				9.47										
05-29-09	Routine	3 m				9.43										
05-29-09	Routine	3.5 m				9.38										
05-26-09	Routine	0 m														2.13
05-19-09	Routine	0 m		2.87			0.41	0.06		0.51	0.012	2.8				
05-19-09	Routine	.1 m				11.02										2.25
05-19-09	Routine	1 m				10.99										
05-19-09	Routine	2 m				10.98										
05-19-09	Routine	3 m				10.98					0.011					
05-19-09	Routine	3.3 m				10.91										
05-19-09	Routine	0 m														1.98
05-11-09	Routine	0 m				8.25										2.1
05-11-09	Routine	1 m				7.98										
05-11-09	Routine	2 m				7.73										
05-11-09	Routine	3 m				7.53										
05-11-09	Routine	4 m				7.27										

Appendix B. BATHTUB Model Inputs for Tait Lake

BATHTUB Inputs and Model Output

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.75	0.2
Evaporation (m)	0.66	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km²	Depth m	Length km	Mixed Depth (m) Mean	Mixed Depth (m) CV	Hypol Depth Mean	Hypol Depth CV	Non-Algal Mean
1	Main Basin	0	1	1.43	2.34	2	2.3	0.12	0	0	0.37

Segment Observed Water Quality

Seg	Conserv Mean	Conserv CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV
1	0	0	15	1.3	500	0	2.7	0.4	2.3	0.1	0	0

Segment Calibration Factors

Seg	Dispersion Rate Mean	Dispersion Rate CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV
1	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km²	Flow (hm³/yr) Mean	Flow (hm³/yr) CV	Conserv. Mean	Conserv. CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (p Mean
1	Tait Direct	1	2	11	0	0	0	0	0	0	0
2	tait on-site	1	1	0	0.001	0	0	0	7000	0	0

Tributary Non-Point Source Drainage Areas (km²)

Trib	Trib Name	Land Use Category---> 1	2	3	4	5	6	7	8
1	Tait Direct	10.5	0.5	0	0	0	0	0	0
2	tait on-site	0	0	0	0	0	0	0	0

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	Runoff (m/yr) CV	Conserv. Subs. Mean	Conserv. Subs. CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Ortho P (ppb) Mean	Ortho P (ppb) CV
1	wetlands / forest	0.25	0	0	0	30	0	0	0	0	0
2	developed	0.3	0	0	0	150	0	0	0	0	0
3	landuse3	0	0	0	0	0	0	0	0	0	0
4	landuse4	0	0	0	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m²/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Main Basin**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	2	Tait Direct	2.8	72.1%	101.3	67.0%	36
2	1	tait on-site	0.0	0.0%	7.0	4.6%	7000
PRECIPITATION			1.1	27.9%	42.9	28.4%	40
TRIBUTARY INFLOW			0.0	0.0%	7.0	4.6%	7000
NONPOINT INFLOW			2.8	72.1%	101.3	67.0%	36
***TOTAL INFLOW			3.8	100.0%	151.1	100.0%	39
ADVECTIVE OUTFLOW			2.9	75.5%	73.1	48.3%	25
***TOTAL OUTFLOW			2.9	75.5%	73.1	48.3%	25
***EVAPORATION			0.9	24.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	78.1	51.7%	

Hyd. Residence Time =	1.1520	yrs
Overflow Rate =	2.0	m/yr
Mean Depth =	2.3	m