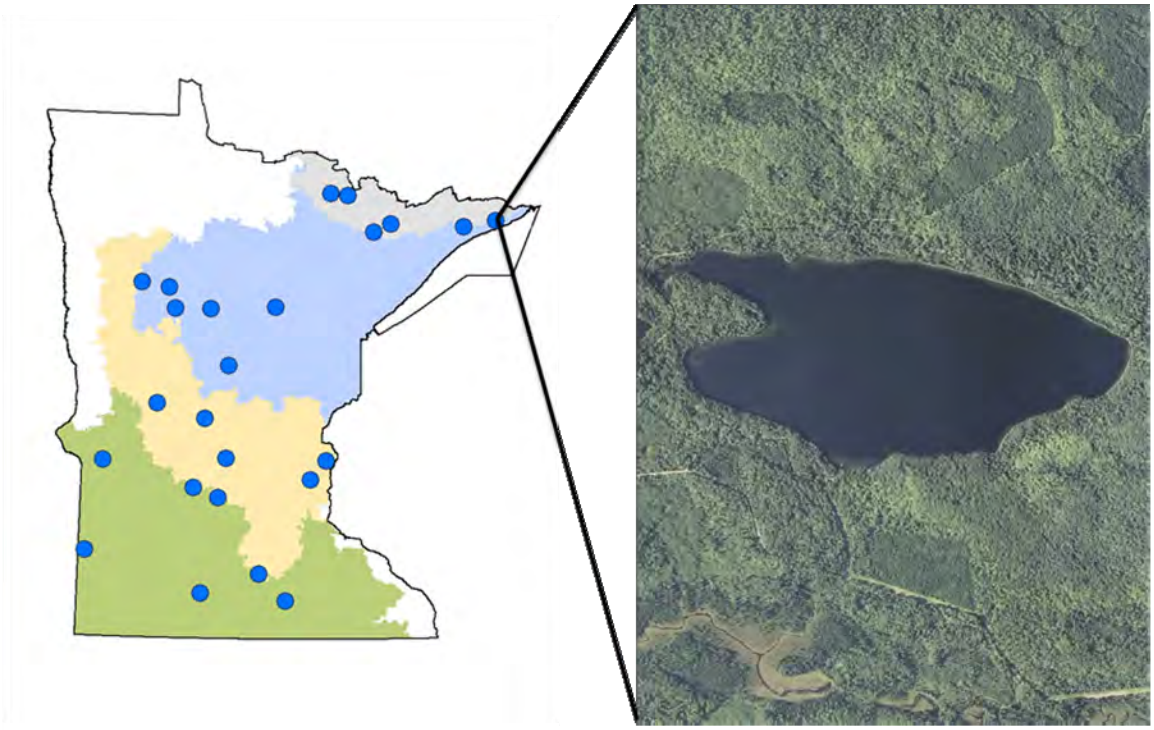
Sentinel Lake Assessment Report
Trout Lake (16-0049)
Cook County, Minnesota



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

April 2011

Minnesota Pollution Control Agency
520 Lafayette Road North
Saint Paul, MN 55155-4194
http://www.pca.state.mn.us
651-296-6300 or 800-657-3864 toll free
TTY 651-282-5332 or 800-657-3864 toll free
Available in alternative formats

Minnesota Pollution Control Agency

Minnesota
DEPARTMENT OF NATURAL RESOURCES

Contributing Authors

Jesse Anderson, MPCA

Ray Valley and Steve Persons, MDNR

Jason Butcher, US Forest Service

Editing

Steve Heiskary and Dana Vanderbosch, MPCA

Peter Jacobson, MDNR

Sampling

Jesse Anderson, Brittany Story, Alex Jackson, Don Carlson, Andrew Streitz, Matt Lindon, Dereck Richter, Mike Kennedy - MPCA

Kimberly Strand, Steve Persons, Paul Eiler, MDNR

Richard Kiesling and Emily Resseger, U.S. Geological Survey

Jason Butcher, Darren Lilja, Brent Flatten, Jacob Garcia, Paul Flicek, Amy Wilfahrt,

Dave Grosshuesch US Forest Service, Superior National Forest

Cook County Soil and Water Conservation District

Volunteers from Trout Lake Resort and Trout Lake property owners

Volunteers from the Master Naturalist Program

2008-10 Lake Assessment of Trout Lake (16-0049) Cook County, Minnesota

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&
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Section of Fisheries

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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 are defined as mixing continuously throughout the summer. "Cold Water" lakes are defined as lakes that 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. Trout is one of three super sentinel lakes where lake and watershed models are being built by the U.S. Geological Survey (USGS) to forecast various outcomes of climate change on coldwater habitat.

Trout Lake was selected to represent a deep oligotrophic lake in the Northern Lake and Forest (NLF) ecoregion. Trout Lake is located in Cook County approximately 10 miles northeast of Grand Marais, MN, within Superior National Forest. Trout Lake is located in a bedrock basin, and is surrounded by forested land. Land use within the Trout Lake watershed is dominated by forest and open water. There has been little change in land use since 1969, primarily because most of the watershed is within the public lands of Superior National Forest.

Based on recent water quality data (2008-2010), Trout Lake is considered to be oligotrophic with total phosphorus (TP), chlorophyll-*a* (chl-*a*), and Secchi transparency values of: seven micrograms per liter (µg/L), 1.2 µg/L, and 5.4 meters (m; 18 feet) respectively. Secchi and chl-*a* are at expected levels relative to TP.

Bi-weekly temperature and dissolved oxygen profiles were collected by MPCA and MDNR in 2008-2010; additional data were collected in 2010 by the USGS. Trout was stratified by late May each year, and stratification remained until October. Overall, water temperatures peaked in late July or early August each year. Optimal lake trout temperatures (8-12 C) were confined to the hypolimnion (depths > 10 m) by mid-summer. Cold temperatures (< 10 C) were maintained at depths greater than approximately 14 m (45 feet) throughout the open water season. Dissolved oxygen concentrations peaked in the metalimnion and recent monitoring and modeling indicate Trout has excellent cold water habitat. These characteristics are due to the lake's morphology and good water quality.

The fish species community of Trout Lake is naturally low in diversity due to its low productivity. However, a large number of species that are present in the lake are intolerant to increases in nutrients and temperature. With future increases in either productivity and/or lake temperature due to climate warming or other watershed impacts (e.g., development), many of the lake's intolerant species may be displaced by extant species more tolerant of higher nutrient levels and warmer water temperatures. Even though higher water temperatures and nutrients in nutrient-poor lakes like Trout could potentially support greater fish species diversity, the isolated nature of Trout Lake's watershed limits new species introductions.

Trout Lake is a native lake trout lake, and lake trout are the only game fish species native to the lake. Other major native fish species include cisco, white sucker, and yellow perch. Splake, brown trout, and rainbow trout have been present when stocked, while rainbow smelt were probably introduced when smelt buckets were cleaned in the lake in the 1970s. Remnant brook trout are probably migrants from the Kadunce River, a designated trout stream that is the outlet of Trout Lake. Brook trout were not native to the upper reaches of the Kadunce, and were probably introduced sometime early in the 1900s. The Kadunce River may also support a small brown trout population, with an occasional fish migrating to Trout Lake. Since the smelt introduction, cisco has declined to undetectable levels presumably due to competition and/or predation by rainbow smelt. Ongoing monitoring will be needed to determine the viability of any remnant cisco population.

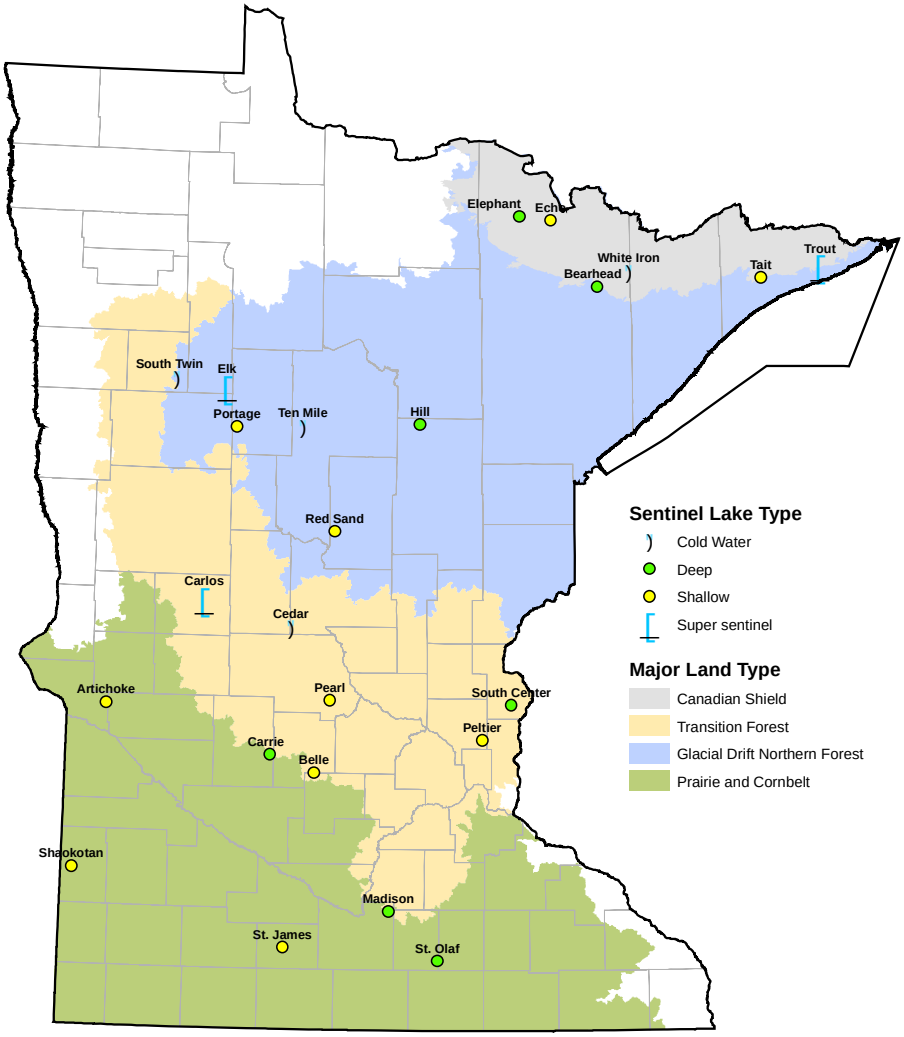
The benchmark measure of coldwater habitat (temperature at three milligrams per liter of dissolved oxygen - TDO_3; Jacobson et al., 2010) suggests that coldwater habitat in Trout Lake is excellent. The mean TDO_3 was 6.6°C during the period of greatest oxythermal stress. On a scale of 0 to 100 (with 0 being worst and 100 best), Trout Lake has a Cisco Habitat Suitability Index of 100 and a Lake Trout Habitat Suitability Index of 27.

Due to its low nutrient productivity and rocky substrates, aquatic plants (especially submersed ones) in Trout Lake are sparse.

An ecoregion-based eutrophication model was used to predict in-lake TP based on Trout Lake's size, depth, and watershed area using inputs from the NLF ecoregion. The model predicted an in-lake TP of 8 µg/L, which is nearly identical to the observed 7 µg/L. A separate subroutine within the model estimated "background" TP for the lake at 8 µg/L. The model predictions, along with the overall assessment of Trout Lake's water quality data, clearly indicate the lake's water quality is meeting NLF nutrient criteria for a lake of its size in this portion of the State. Intensive water quality monitoring (TP and chl-*a* sampling) occurred in the late 1980's, 2003, 2006, and 2008-2010. These data show stable concentrations of TP and chl-*a* within the last decade, with perhaps a decline in TP since the 1980's. Annual average TP and chl-*a* concentrations are consistently near 7 and 1 µg/L respectively, indicating excellent water quality. Transparency averaged 8 m from 1986-1990, versus 5.8 m from the last decade (2003, 2006, and 2008-2010); a decline of 2.2 m (seven feet). The cause of this decline is unknown, given the stability of land use in the lake's forest-dominated watershed.

As a Super-Sentinel lake (Figure 1), future monitoring of Trout Lake will be frequent and cover a wide range of climate, watershed, water quality, habitat, and fish indicators.

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 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.



Introduction

This report provides a relatively comprehensive analysis of physical, water quality, and ecological characteristics of Trout 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), US Geological Survey (USGS) and volunteer water quality monitoring, and analysis of various other sources of data for the lake. The water quality assessment focuses on data collected during the 2008-2010 seasons; however, historical data are used to provide perspective on variability and trends in water quality. Water quality data analyzed includes all available data in EQuiS, the state repository for water quality data. 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).

History

Compiled by Steve Persons, MDNR Grand Marais Area Fisheries Manager, Nancy Waver from Trout Lake Resort, and Jesse Anderson, MPCA

Early logging

During original land surveys of the area, surveyors described cover types at section corners within the Trout Lake watershed as forest (north and east sides of watershed) or swamp (west side of watershed). Bearing trees at the corners in forested locations were fir and birch, while bearing trees listed in the swamp location were cedar and fir. The presence of large stumps (two feet in diameter or more) in the watershed probably indicates at least some of the watershed was covered by large pine (white or red). Intense logging of pine stands in the area seems to have started in the late 1890s, and was largely done by the 1920s. The fact that many of those stumps have been burned out suggests that the initial logging was followed by intense fires. In aerial photos from the 1930's, it looks like areas south and east of Trout Lake might have been burned some years previously, and Nancy Waver reports burned-out stumps on resort property. The 1939 lake-sounding map shows forest cover around most of the shoreline consisting of aspen and birch "saplings", with larger aspen found only on the western end of the lake.

Lakeshore development

Property on the south side of the lake was acquired from the Forest Service sometime in the early 1900s. It was immediately sold to a logging company, who cut it all and then went out of business. A resort was first operated at the Trout Lake Resort site in 1938, by Grace and Bill Boissenin. When they arrived, they found an icehouse and a cook shack (now Cabin two at the resort) that had been left by the logging company. They built two other cabins and moved them to Trout Lake. The resort is the only development shown on the 1939 map. Bud and Charlotte Kratoska purchased the resort in 1946. Remaining private land on the south side of the lake was sold, and other private cabins were built in the 1950s. A 1999 MDNR lake survey counted 10 cabins, in addition to the resort, all on the south side of the lake.

Present day

Other than development of the resort and cabins on the south side of the lake, land use within the watershed has remained unchanged since the early 1900s. Silvicultural activity continues in the vicinity, and timber harvest has occurred at various times and in various locations. Logging in the immediate lake-shed has not recently occurred, although aerial photos from the early 1990's appear to show some logging north of the lake. Current access roads in the area (logging and otherwise) can be seen in more-or-less their present locations on aerial photos from the 1930s. Fisheries management in Trout Lake has also changed little over time. The lake has been stocked with rainbow trout on a regular basis since the 1930s, and it has been managed for lake trout for as long as there has been any fisheries management presence in the area. Trout Lake has had a fair amount of historical water quality monitoring: In the mid 1980's it was chosen by the MPCA as an ecoregion reference lake; in 2003 lake-shore property owners and the MPCA completed an assessment (Klang, 2004), in 2006 it was monitored again by local volunteers and Cook County Soil and Water Conservation District (SWCD) staff, and it has been sampled annually since 2008 as part of the MDNR's Sentinel Lakes Program.

Background

Lake morphometric and watershed characteristics

Trout Lake is located in Cook County within the Kadunce River watershed (Figure 2), part of the Lake Superior basin. Trout Lake is located approximately 16 kilometers (10 miles) northeast of Grand Marais, MN, within Superior National Forest. A public canoe access is located on the west shore; a private access is located on the south shore at Trout Lake Resort. Trout is a deep lake and the water column routinely stratifies by late spring. Trout Lake has been designated by the State of Minnesota as an Outstanding Resource Value Water (Minnesota Rules, Chapter 7050.0470).

Trout Lake is located in a bedrock basin, and is surrounded by forested land (Figure 3). Quaternary geology includes thin, unconsolidated materials (gravel and boulders) over bedrock (Olcott et. al., 1978). The lake has a comparatively small watershed, made up of forest and water (principally Marsh Lake- a small, shallow lake covering 16 acres). The main surface tributary is the Marsh Lake outlet, which flows into the southwest shore of Trout Lake (Figure 2). The Trout Lake outlet is on the southern shore, and forms part of the Kadunce River headwaters, a designated trout stream. Most of the lakeshore is undeveloped and managed by Superior National Forest. The developed portion of the lake is limited to areas of the south shore, and includes Trout Lake Resort and other adjacent private parcels and cottages.

Trout Lake's morphometric characteristics are summarized in Table 1. Trout is a moderately sized lake covering 103 hectares (255 acres). The lake has a mean depth of 10 meters (33 feet), a maximum depth of 23.5 meters (77 feet), and 23 percent of the lake is considered littoral. The lake is separated into two deep basins (Figure 4), each ranging from 12 – 21 meters (40 - 70 feet) in depth, separated by a ridge that rises up to approximately nine meters in depth (30 feet).

Percent littoral area refers to that portion of the lake that is 4.6 meters (15 feet) or less in depth, which often represents the depth to which rooted plants may grow in the lake; on Trout this is limited to near-shore areas. The volume of Trout Lake was estimated at 8,542 acre-feet, and the residence time was estimated at 10-11 years, reflective of the lake's deep basins, limited inlets and small outlet.

Table 1. Trout Lake and watershed morphometric characteristics

Lake name	Lake ID	Lake basin hectares (acres)	Littoral area (%)	Total watershed area hectares (acres)	Watershed: lake	Max. depth meters (feet)	Mean depth meters (feet)	Lake volume acre-ft.
Trout	16-0049	103 (255)	23	465 (1,149)	4.5 : 1	23.5 (77)	10.2 (33.5)	8,542

Lake bathymetry based on original surveys in 1939 and 1964

Figure 2. Trout Lake watershed



Figure 3. Trout Lake watershed land-use

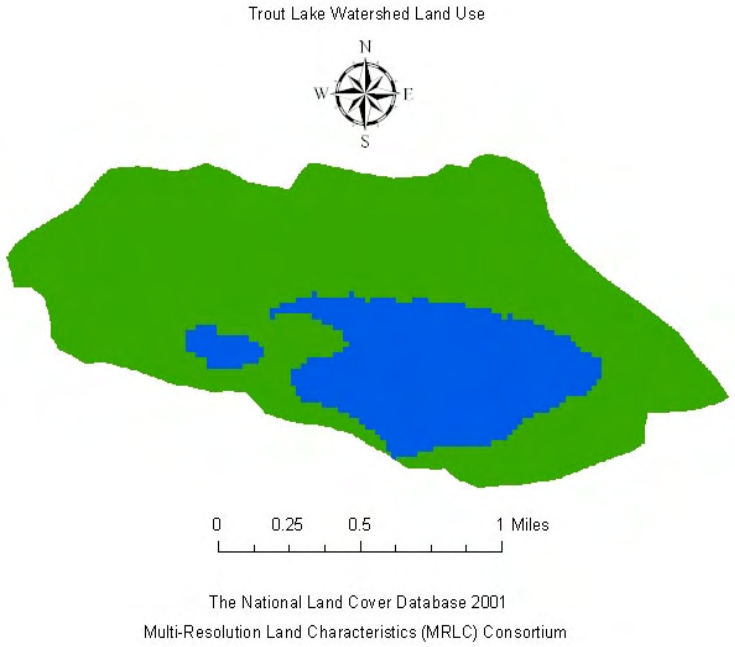
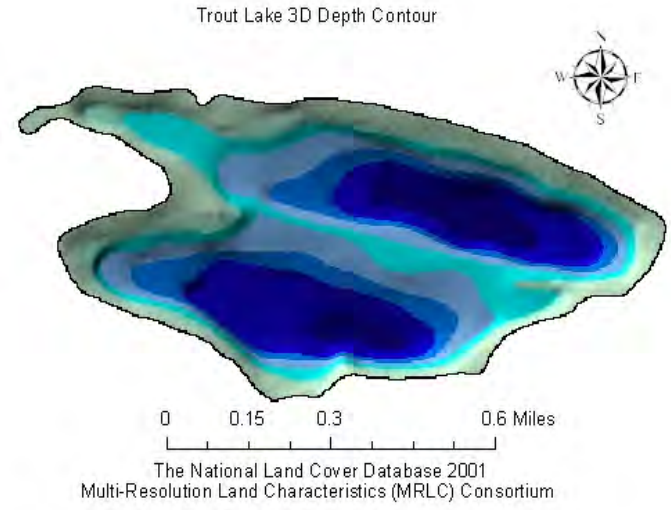


Figure 4. Trout Lake depth contours



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. Trout Lake lies within the Northern Lakes and Forest (NLF; Figure 5) 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 most closely characterize geomorphological 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 Trout Lake watershed is nearly all forest and open water. There has been little change in land use since 1969 (Table 2), primarily because most of the watershed is within the public lands of Superior National Forest.

Figure 5. Minnesota ecoregions as mapped by United States Environmental Protection Agency

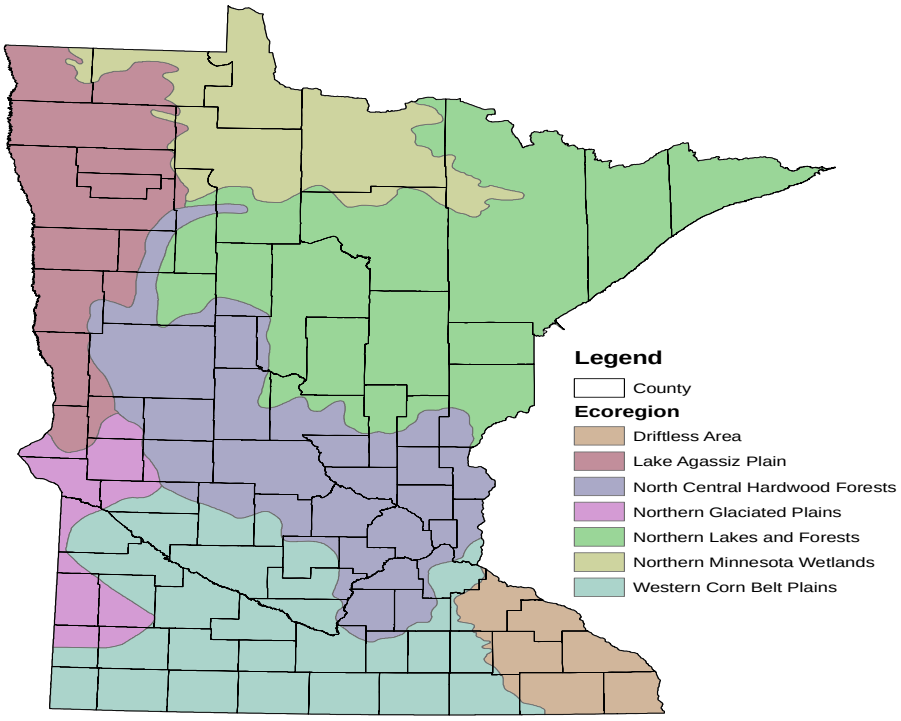


Table 2. Trout Lake watershed ecoregion land use comparison. Typical (interquartile) range based on NLF ecoregion reference lakes noted for comparison (Heiskary and Wilson 2005).

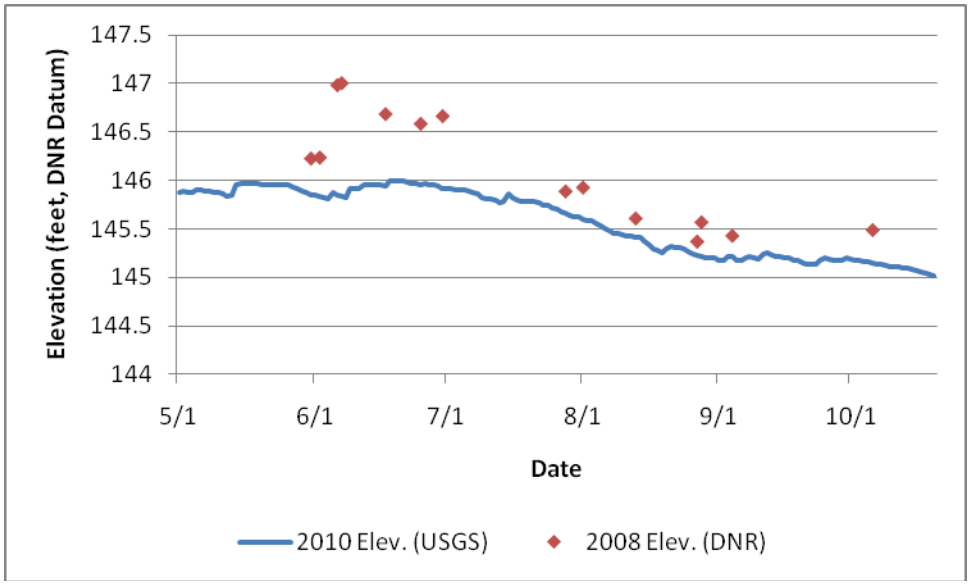
Land Use (%)	Trout (2001)[1]	NLF ecoregion	Applicable (1969)[2]	Applicable (1991)[3]
Developed	<1	0 - 7	<1	<1
Cultivated (Ag)	0	< 1	0	0
Pasture & Open	<1	0 - 6	<1	<1
Forest	76	54 - 81	80[4]	76
Water & Wetland	24	14 - 31	20[4]	24

[1]National Land Cover Database www.mrlc.gov/index.php
[2]Minnesota Land Management Information Center www.lmic.state.mn.us/chouse/metadata/luse69.html
[3]Minnesota Land Cover 1991-1992:MAP www.lmic.state.mn.us/chouse/land_use_DNRmap.html
[4] differences from 2001 data likely due to interpretations of forested wetlands, and do not reflect an actual change in land use within the watershed

Lake level

The MDNR Division of Waters began lake level monitoring on Trout in 2008, with several instantaneous readings. In 2010, the USGS installed instrumentation that recorded the lake level every 15 minutes; daily average values are shown in Figure 6 (data from 2009 are not available). Levels in 2008 were consistently higher, because it was a wetter year (see below). In 2010, the total fluctuation in water level was approximately 0.3 meters (1 foot).

Figure 6. Trout Lake level elevations in 2008 and 2010. MDNR and USGS data.



Precipitation and climate summary

Climate and precipitation records for the 2008-2010 field seasons varied considerably. Rain gage records from Grand Marias (the closest long-term climate station to Trout Lake) show eight 2.5 centimeter (cm; 1 inch) plus rain events during the 2008 field season (including a 4.7 inch storm event in early June) and three during 2009 (Figures 7 and 8). Large rain events will increase runoff into the lake and may influence in-lake water quality and lake levels. Precipitation records for the 2008 water year (October 2007 through September 2008) showed conditions were much wetter than average, with a large portion of Cook County 15.25-25.5 cm (6-10 inches) above normal (Figure 9). Precipitation for the 2009 and 2010 water years were near and slightly below normal, respectively. An examination of the monthly average temperatures for the Grand Marias climate station indicate that the 2008 field season was near normal, 2009 was cooler than average, and 2010 much warmer than average (Table 3; also see http://www.climate.umn.edu/doc/journal/warm_summer2010.htm).

Table 3. Departure from normal temperatures (F) at the Grand Marias climate station, 2008-2010 field seasons (State Climatology Office data)

Month and year	Departure from normal temperature	Month and year	Departure from normal temperature	Month and year	Departure from normal temperature
May 2008	-1.4	May 2009	+0.1	May 2010	+0.9
June 2008	- 0.3	June 2009	-1.3	June 2010	+1.7
July 2008	-0.9	July 2009	-1.4	July 2010	+5.4
August 2008	+0.2	August 2009	-4.2	August 2010	-0.4
Sept. 2008	+0.7	Sept. 2009	+3.3	Sept. 2010	-2.7
October 2008	+1.4	October 2009	-1.8	October 2010	+2.0

Figure 7. 2008 monitoring season rainfall based on records for Grand Marais, Minnesota State Climatology Office Data

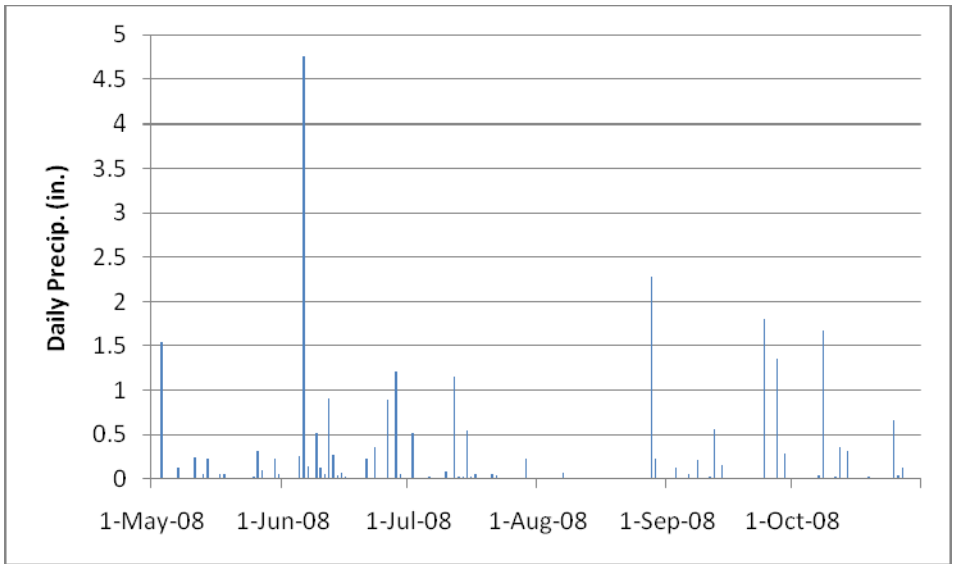


Figure 8. 2009 monitoring season rainfall based on records for Grand Marais, Minnesota State Climatology Office Data

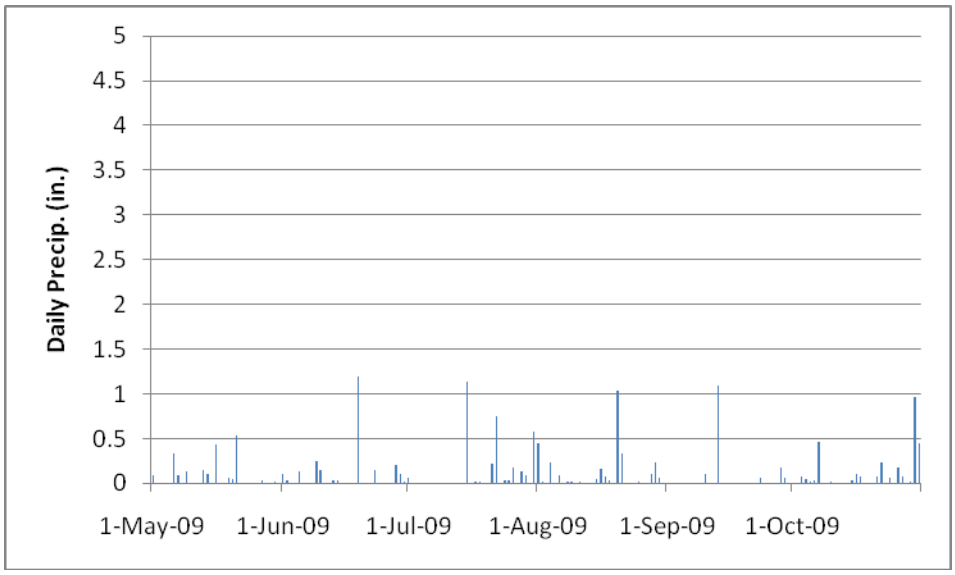
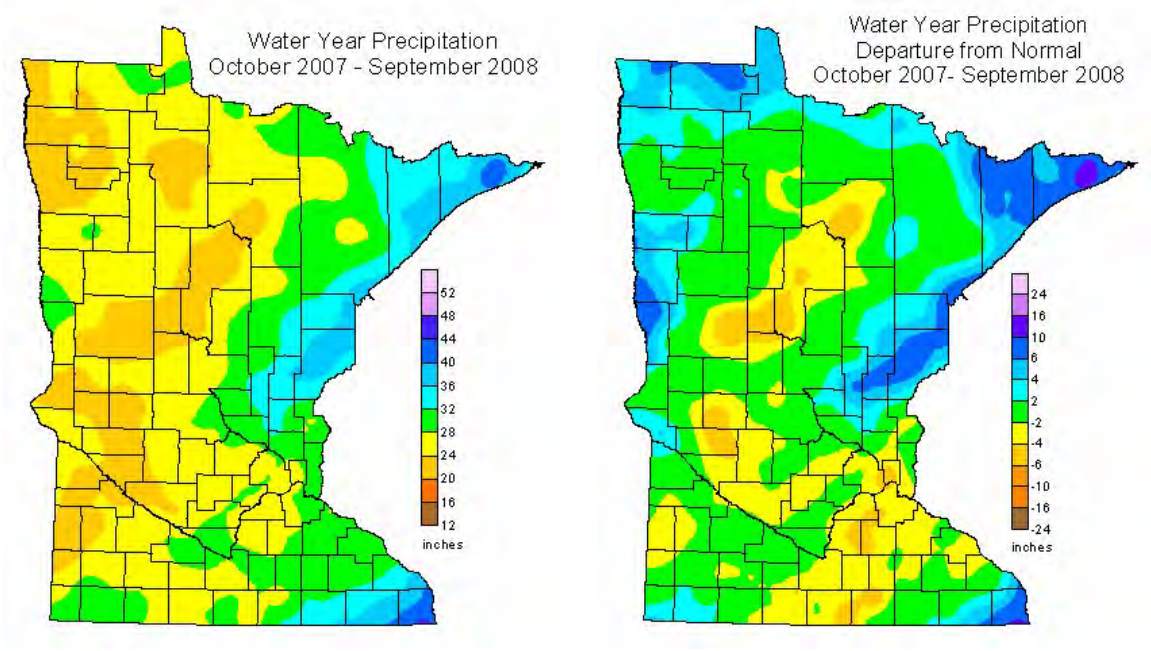
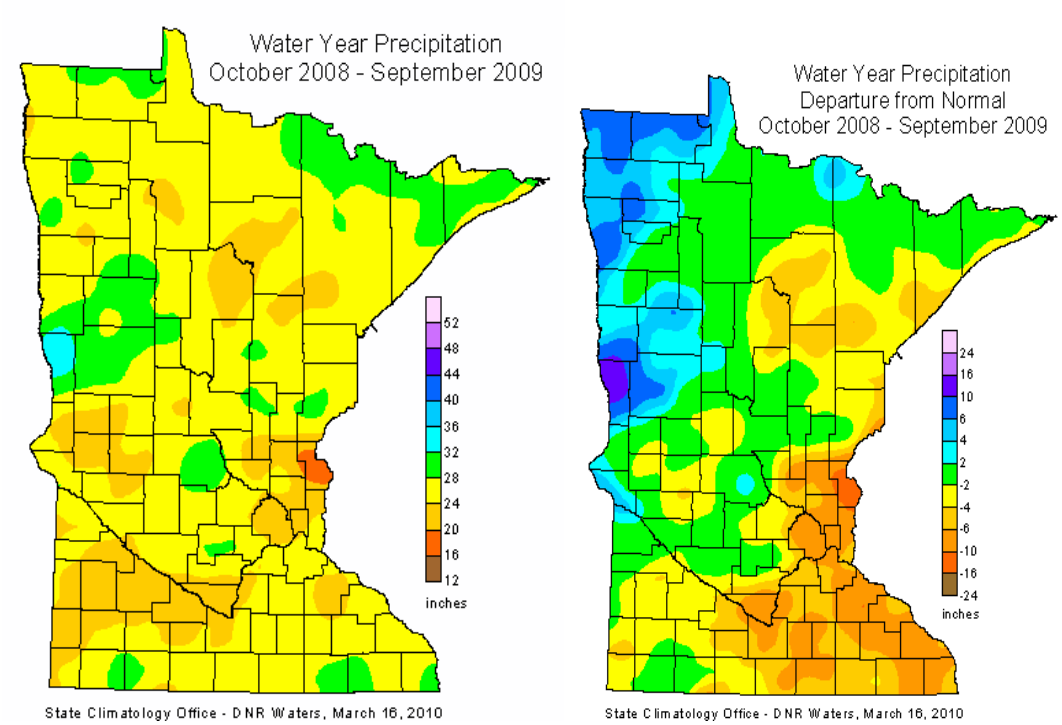


Figure 9. 2008-2009 Minnesota water year precipitation and departure from normal (State Climatology Office data)





Methods

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 one 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).

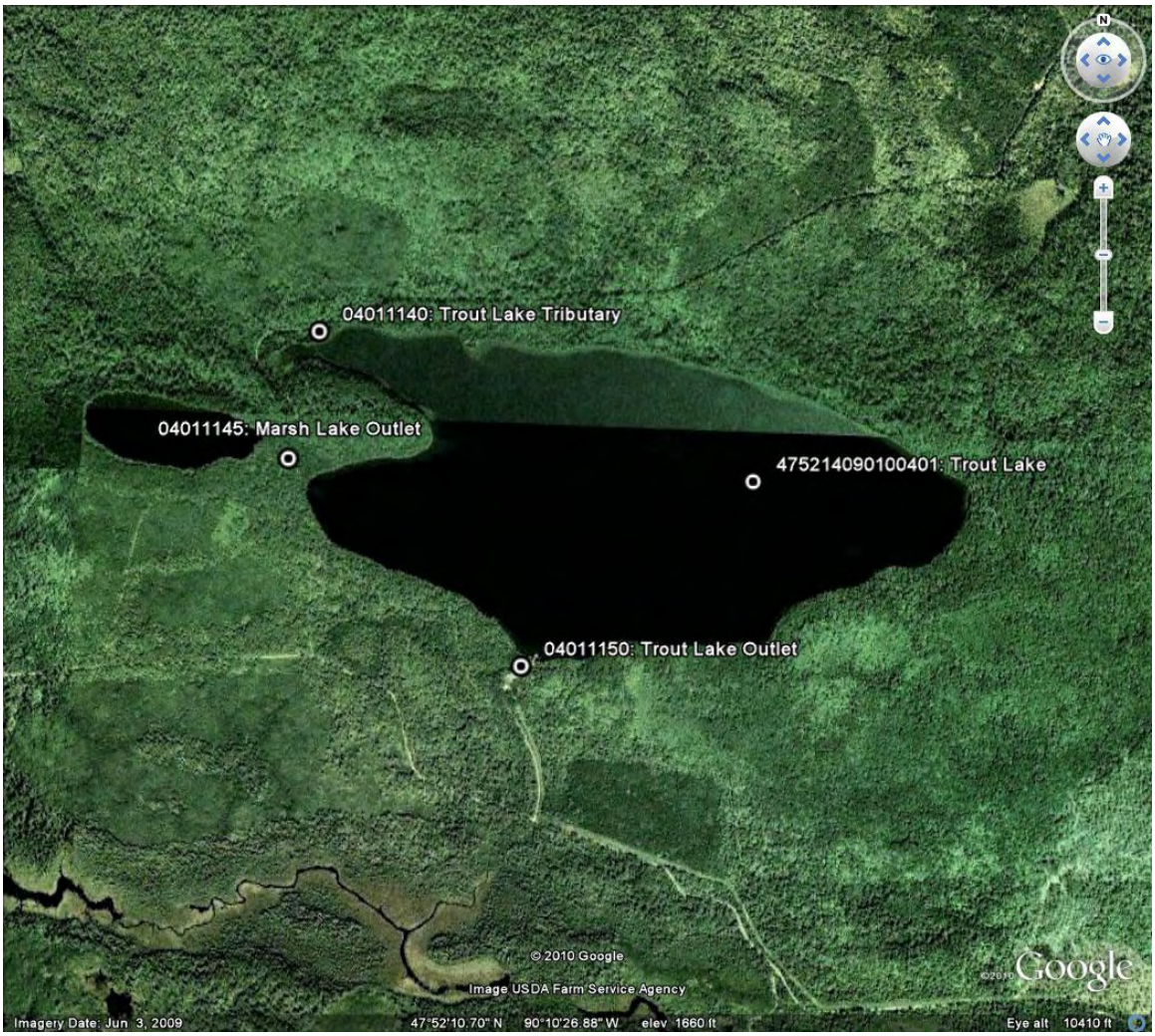
Most recent fisheries surveys follow guidelines outlined by MDNR Special Publication 147 (1993; Manual of Instructions for Lake Survey). Nearshore non-game fish surveys were also completed on each Sentinel lake following methods described by Drake and Pereira (2002).

Water quality

In 2008-2010 water quality data on Trout Lake were collected by the MPCA. MPCA staff sampled Trout monthly from May through October. Samples were collected at the lake's maximum depth, in the northeast portion of the lake (MPCA site # 101; Figure 2). Additionally, in 2010 the USGS collected samples at site 101, the Marsh Lake outlet, a small tributary in the northwest part of the lake, and at the Trout Lake outlet (Figure 10). MPCA lake surface samples were collected with an integrated sampler, a poly vinyl chloride (PVC) tube two meters (6.6 feet) in length, with an inside diameter of 3.2 cm (1.24 inches). Zooplankton samples were collected with an 80 micrometer (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. Temperature and dissolved oxygen (DO) profiles and Secchi disk transparency measurements were also taken by MPCA, MDNR, and USGS staff. 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 laboratories of the Minnesota Department of Health, or USGS 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.

Figure 10. USGS monitoring locations in the Trout Lake watershed. In-lake site is located with MPCA site 101.



Zooplankton

Zooplankton samples were collected monthly from ice-out (May) through October 2008-2010. Two replicate vertical tows were taken at each sampling event. The net was lowered to within 0.5 m 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 percent reagent alcohol. Analysis was conducted by MDNR personnel.

Each zooplankton sample was adjusted to a known volume by filtering through 80 micrograms per liter (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

A fish species list was compiled from data available from standard gill netting, small-mesh gill netting, 3/4-inch-mesh trap netting, 1/4-inch-mesh trap netting, and creel surveys. Trophic guild and tolerance were taken from information provided by Drake and Valley (2005) and from various United States Environmental Protection Agency and MPCA sources. Thermal guilds were assigned according to Lyons et al. (2009).

The fish species community of Trout Lake is naturally low in diversity due to its low productivity. However, a large number of species that are present in the lake are intolerant to increases in nutrients and temperature. With future increases in either productivity and/or lake temperature due to climate warming or other watershed impacts (e.g., development), many of the lake's intolerant species may be displaced by extant species more tolerant of higher nutrient levels and warmer water temperatures. Even though higher water temperatures and nutrients in nutrient-poor lakes like Trout could potentially support greater fish species diversity, the isolated nature of Trout Lake's watershed limits new species introductions. The potential tradeoffs between assisted migration or translocation of species as a climate change adaptation response must be weighed with lessons of the past regarding potential unintended consequences of new species introductions. Prudent approaches will likely occur on a case-by-case, species-by-species basis.

Trout Lake is a native lake trout (*Salvelinus namaycush*) lake, and lake trout are the only game fish species native to the lake. Other major native fish species include cisco (*Coregonus artedi*), white sucker (*Catostomus commersoni*), and yellow perch (*Perca flavescens*) (Figure 11). Splake (*Salvelinus fontinalis* X *S. namaycush*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss)* have been present when stocked, while rainbow smelt (*Osmerus mordax*) were probably introduced when smelt buckets were cleaned in the lake in the 1970s. Remnant brook trout (*Salvelinus fontinalis*) are probably migrants from the Kadunce River, a designated trout stream that is the outlet of Trout Lake. Brook trout were not native to the upper reaches of the Kadunce, and were probably introduced sometime early in the 1900s. The Kadunce River may also support a small brown trout population, with an occasional fish migrating to Trout Lake. Since the smelt introduction, cisco has declined to undetectable levels presumably due to competition and/or predation by rainbow smelt. Ongoing monitoring will be needed to determine the viability of any remnant cisco population.

Minimal temperature-oxygen profile and water chemistry data were collected by a U.S. Forest Service crew in 1937. Lake trout and rainbow trout were listed as the most abundant fish species, but no fish collecting was done. An initial lake survey was completed by a MDNR crew in July 1951. Six gill net sets were used to collect cisco, rainbow trout, brown trout, lake trout, white sucker, and yellow perch. Re-surveys were done in 1981, 1984, and 1987 as part of an acid precipitation intensive monitoring study, and another re-survey was completed in 1999. Fish population assessments were done in 1980, 1990, 1993, 1996, 2007, and 2009. Timing varied from late July to early September, but since 1981 all netting has been done in July or August. Eight gill net sets were used in 2009, six were used in 1980, 1993, 1996, and 2007 and four were used in every other year. Net sets in the 1993 and 1996 assessments, the 1999 re-survey, and the 2007 and 2009 assessments were stratified by depth, with four set deep and two set shallow (five deep and three shallow in 2009). All references to catches in gill nets in the following text will be to the combined catch in deep and shallow standard gill nets or to the catch in all standard nets when sets were not stratified, unless otherwise noted. Trap nets (3/4 and 1/4-inch mesh) and small-mesh gill nets (3/8 and 1/2-inch mesh) have also been routinely used to sample this lake. A special assessment done in July 2008 used only 3/4-inch and 1/4-inch trap nets.

Trout Lake was the subject of several studies between 1951 and 1980. Data from assessments and other sampling done by MDNR Fisheries Research during that period are not available for this report. Studies involving Trout Lake continued after 1980. Close, Colvin, and Hassinger (1985) evaluated the performance of three strains of rainbow trout in Trout Lake. Eiler and Sak (1993) included the lake in a study of potential interactions between lake trout and smallmouth bass (Trout Lake was one of a "no bass" group of lakes). The lake was included in a study comparing lake trout index netting methods (Siesennop 1998a) and in a related study comparing lake trout growth rates in Northeastern Minnesota lakes (Siesennop 1998b). Yule, Siesennop, and Bergquist (2002) tested hydroacoustic methods for assessing fish population in Trout Lake.

Trout Lake has been managed to provide a stream trout fishery since the 1930s, although it is not a designated stream trout lake. Rainbow trout were stocked frequently in the 1930's, 1940's and 1950's and have been stocked almost every year since 1960. From 1977 through 1997, most stocking consisted of at least two strains. An annual quota of about 10,000 yearlings was used (with some variations) from 1988 through 1998. The annual quota was reduced to 7,500 yearlings beginning in 1999. Since 1998 most stocking has consisted of Arlee-strain fish.

Lake trout were stocked frequently from the 1930's through the 1960's, but have been stocked only once since 1967 (6,700 fingerlings in 1984). “Loch Leven” trout were stocked at some time between 1935 and 1945. Brown trout were stocked about three times in the 1930's and 1940's, and splake were stocked once, in 1967.

White sucker were removed by trap netting in 1959-1961 and about 250 lb, of yellow perch were removed in 1980. The removal was apparently part of a study of white sucker-lake trout interactions, and may have resulted in the virtual elimination of the species in Trout Lake - an unusual outcome for this type of activity. The yellow perch removal apparently resulted in decreased catches of yellow perch in gill nets and trap nets in 1981 and 1984; however, the population had fully recovered by 1987. Even this could be considered to have been a fairly large effect for such a minimal removal effort.

A gabion-and-rock filter barrier was constructed across Kadunce Creek just below Trout Lake in 1964. The barrier was intended to block the downstream movement of kokanee salmon from Trout Lake, although there are no records of any kokanee salmon being stocked in the lake at that time. The barrier remained in place until the 1990s, when it was partially washed out. In 1997 it was removed, in a cooperative effort between Trout Lake Resort, Trout Unlimited, and MDNR Fisheries.

Lake trout natural reproduction has been sufficient to maintain a strong population despite substantial fishing pressure and harvest. Lake trout average size has been small; however, this has been the case since at least the 1950's. Lake trout growth was judged to be good in the 1984 survey, but was found to be fairly slow in later surveys and assessments. Since their introduction, rainbow smelt have provided good forage for lake trout; however, they may also compete with or directly prey on juvenile lake trout and cisco (Hassinger and Close 1984).

The current (2009) long range goal for lake trout in Trout Lake is to maintain a population with a minimum gill net catch of 3.0 fish/set. Lake trout gill net catches have ranged from 1.5 to 7.3 fish/set since 1980, with no apparent trends in catch or size (Table 5). The lake trout catch had dropped to 1.5 fish/set by 1996, but rebounded to 5.0 fish/set in 2007. Catches have met or exceeded the long range goal for the lake in every year but 1996. Lake trout collected in 2007 ranged in length from 7.6 to 19.6 inches, with most in the 10-16-inch length range. Seven year classes, all naturally produced, were represented in the catch, including relatively strong year classes produced in 2003 and 2002. Lake trout growth rates (based on otolith-determined ages) had been slow among age-three-to-age fish. Age-five lake trout averaged just 11.2 inches at last annulus formation. The 2009 assessment yielded a similar size distribution.

Trout Lake has been managed to provide a rainbow trout fishery offering anglers fairly high summer catch rates for spring-stocked fish. Survival of stocked rainbow trout beyond their first season in the lake was generally good through the 1980s and early 1990s; however, the rainbow trout fishery has since become mostly "put-and-take." The 1990 assessment showed substantial survival to age two, but similar survival was not observed in any subsequent assessments.

The long range goal for rainbow trout is also to maintain a minimum gill net catch of 3.0 fish/set. That catch value is close to the median (2.5 rainbow trout/set) for summer gill net catches in stream trout lakes in the Grand Marais area. Rainbow trout gill net catches in Trout Lake have ranged from zero to 10.5 fish/set since 1980 (Table 5). Prior to 2009, there had been a distinct trend towards lower catches; however, that was reversed in 2009 when gill netting yielded a catch of 2.75 rainbow trout/set. The long-range goal for rainbow trout has not been met in any assessment of this lake since 1990, although it was nearly met in 2009. Rainbow trout collected in gill nets in 2009 ranged in length from 10.6 to 12.5 inches. Despite low gill net catches recently, anglers have continued to report good fishing for rainbow trout over the open-water season.

Cisco gill net catches have ranged from zero to 4.25 fish/set since 1980 (Table 5). Cisco catches since 1993 have been very low, and none were taken in 2007 and 2009. It is possible that cisco have been extirpated in this lake; however, the cisco catch was also very low in 1951, so low catches recently may just be an

expression of a longer-term fluctuation in their abundance. When present in significant numbers, cisco size distributions in Trout Lake have generally included only large fish from 15 to 24 inches. Cisco collected in this lake have generally been too large to provide forage for lake trout, and may have been competing with lake trout for invertebrate forage. The population appeared to have been unexploited and senile with little or no recruitment. The presence of rainbow smelt may have resulted in recruitment being reduced below levels needed to sustain the population.

Yellow perch gill net catches have ranged from zero to 9.3 fish/set since 1980, with no apparent trend (Table 5). Only three yellow perch were taken in standard gill net sets in 2007, and none were taken in 2009; however, catches in trap nets in both years were similar to catches observed in this lake in all previous assessments (Table 6). Yellow perch trap net catches have always exceeded the median, and have often exceeded the third quartile for lakes of this class. Yellow perch collected in 3/4-inch trap nets in 2009 ranged in length from 4.9 to 9.2, with most between six and eight inches. Yellow perch catches in this lake have generally consisted of smaller fish, and angler interest in the species has been minimal.

Rainbow smelt were first collected in 1981 and were probably accidently introduced by the public. Prior to 1993 little could be said about their relative abundance because they were not very vulnerable to standard survey and assessment netting gear. In inland lakes in this area, smelt numbers have typically been high and their average size has been large in years just following their introduction. In subsequent years, while their numbers may stay high, their average size has tended to drop, to the point where only 3/8-inch mesh gill nets or 1/4-inch trap nets can effectively sample them. Rainbow smelt catches in small-mesh gill nets appeared to peak in Trout Lake in 1996, and had declined to 0.5 fish/set by 2009 (Table 7). Most of the rainbow smelt taken in 1996 were age-one fish caught in the 3/8-inch mesh of small-mesh gill nets; however, smelt as old as age three were present in fairly high numbers.

Yule, Siesennop, and Bergquist (2002) estimated smelt biomass to have been 5.7 lb/acre in September 2001, and 2.4 lb/acre in October 2001. The difference in those estimates was believed to have been due to differences in moon phase during sampling, which can affect whether or not fish move into pelagic areas sampled by hydroacoustic gear. The hydroacoustic gear they used appeared to have been an effective tool for assessing pelagic species (rainbow smelt and rainbow trout, in this case), but much less effective for assessing bottom-oriented fish (lake trout) in a lake like Trout Lake.

Brook trout have been taken in small numbers in most assessments. The 2007 assessment collected one brook trout (13.5 inches) in a standard gill net set and one (11.1 inch) in a small-mesh gill net set. No brook trout were taken in gill nets in 2009, but 13 were collected in 3/4-inch trap nets, the highest catch seen to date in that gear in Trout Lake (Table 6). Brook trout collected in 3/4-inch trap nets in 2009 ranged in length from 6.1 to 11.1 inches, with most in the six-to-seven-inch length range.

Trout Lake has been one of the most heavily-fished lakes in Cook County, in terms of angler-hours/acre, for over 60 years. Many creel surveys have been done over the years by MDNR Fisheries Research and Fisheries Management to monitor use of the lake. Creel surveys were done in the summer of 1952, in summer and winter annually from 1953 through 1960 (unpublished data, Grand Marais lake files), in summer 1961 (Micklus and Johnson 1962; aerial survey only), in the winter of 1965 (Schumacher, Wroblewski, and Burrows 1966; aerial survey only), in summer and winter annually from 1968 through 1970 (Hassinger 1970 and 1971), and in winter 1999 (Persons 2000).

Creel survey estimates from 1968-1970 showed higher fishing pressure, lower lake trout harvest rates, and similar lake trout harvests compared to estimates from 1952-1960 (Table 8). Rainbow trout dominated the summer harvest and lake trout dominated the winter harvest in 1968-1970. Estimates of annual lake trout yield ranged from 1.9 to 8.2 lb/acre in 1968-1970 and averaged 5.1 lb/acre (Hassinger 1970 and 1971). The average estimated annual yield for lake trout from creel surveys done in 1953-1960 was 2.5 lb/acre.

Estimated winter fishing pressure in 1999 was similar to estimates made in 1953-1960, but estimates of lake trout harvest rate and harvest were lower (Table 8). Lake trout were harvested at a mean length of 14.0 inches. Estimated yield for the 1999 winter lake trout fishery was 1.0 lb/acre (Persons 2000). Estimated rainbow trout harvest, harvest rate, and mean length at harvest in winter 1999 were 50 fish, 0.03 fish/angler-h, and 13.0 inches, respectively.

By some measures, estimated lake trout annual yields for Trout Lake in 1968-1970 (an average of 5.1 lb/acre) were not sustainable. Potential lake trout yields can be estimated by measuring available thermal habitat volume (THV) in July. Thermal habitat volume is the volume of lake water where temperatures and dissolved oxygen concentrations are optimal for lake trout. Optimal conditions for lake trout are considered to be water temperatures of 46.4° F (8° C) to 53.6° F (12° C), with oxygen concentrations equal to or greater than 6.0 mg/L. Siesennop (2000) estimated THV in Trout Lake to have been 1.36 hm^3, indicating that the lake was capable of supporting an annual lake trout harvest of 174.2 kg (383.7 lb), or a yield of 1.7 kg/ha (1.5 lb/acre). High harvest and yield observed on Trout Lake in 1968-1970 may have been a factor in the decision to reduce the length of the winter lake trout season, beginning in 1972, from about four months (January-April) to two (January-February).

Cold water habitat assessment

Trout Lake is a deep lake that strongly stratifies (Figure 12). Oxygen concentrations usually remain sufficient in the metalimnion and into the hypolimnion during the period of greatest oxythermal stress (July 28 through August 27 for stratified lakes). Metalimnetic oxygen maxima occurred several times in 2008 and 2009. Metalimnetic oxygen maxima occur when photic depth exceeds thermocline depth, and photosynthesis allows oxygen concentrations to remain high in the cool waters of the metalimnion. Metalimnetic oxygen maxima are usually associated with lakes with good water quality (high Secchi depths).

The benchmark measure of coldwater habitat (temperature at 3 mg O_2 - TDO_3; Jacobson et al. 2010) suggests that coldwater resources in Trout are excellent (Table 10). The mean TDO_3 was 6.6°C during the period of greatest oxythermal stress. On a scale of 0 to 100 (with 0 being worst and 100 best), Trout Lake has a Cisco Habitat Suitability Index of 100 and a Lake Trout Habitat Suitability Index of 27. Profile data replotted as temperature vs. oxygen (Figure 12-c) illustrate how close oxythermal habitat approached lethal conditions (Jacobson et al. 2008). All profiles contained conditions where cisco could survive and were well away from the lethal niche boundary.

Several other coldwater species are present in the lake. Maintaining the good water quality that exists in Trout Lake will be critical for maintaining suitable habitat for these species.

Table 4. Historical fisheries assessment results for Trout Lake

Common name	Species name	Trophic guild	Thermal guild	Environmental tolerance	First documented
Brook stickleback	*Culaea inconstans*	Insectivore	Cool-cold	Neutral	1999
Brook trout	*Salvelinus fontinalis*	Predator	Cold	Intolerant	1981
Brown trout	*Salmo trutta*	Predator	Cold	Intolerant	1951
Splake	*Salvelinus fontinalis X S. namaycush*	Predator	Cold	Intolerant	1969
Central mudminnow	*Umbra limi*	Insectivore	Cool-warm	Neutral	1999
Common shiner	*Luxilus cornutus*	Insectivore	Warm	Neutral	1980
Creek chub	*Semotilus atromaculatus*	Insectivore	Cool-warm	Tolerant	1980
Fathead minnow	*Pimephales promelas*	Omnivore	Warm	Tolerant	1984
Finescale dace	*Phoxinus neogaeus*	Insectivore	Cold-cool	Neutral	1984
Golden shiner	*Notemigonus crysoleucas*	Insectivore	Warm	Neutral	1981

Iowa darter	*Etheostoma exile*	Insectivore	Warm	Intolerant	1984
Lake trout	*Salvelinus namaycush*	Predator	Cold	Intolerant	1951
Mottled sculpin	*Cottus bairdii*	Insectivore	Cold	Intolerant	1980
Northern redbelly dace	*Phoxinus eos*	Herbivore	Cold-cool	Neutral	1984
Pearl dace	*Margariscus margarita*	Insectivore	Cold-cool	Neutral	1980
Longnose dace	*Rhinichthys cataractae*	Insectivore	Cold-cool	Intolerant	2008
Cisco	*Coregonus artedi*	Filter	Cold	Intolerant	1951
Rainbow smelt	*Osmerus mordax*	Invertivore	Cold	Intolerant	1981
Rainbow trout	*Oncorhynchus mykiss*	Predator	Cold	Neutral	1951
Slimy sculpin	*Cottus cognatus*	Insectivore	Cold	Intolerant	1999
White sucker	*Catostomus commersoni*	Omnivore	Cool-warm	Tolerant	1951
Yellow perch	*Perca flavescens*	Insectivore	Cool-warm	Neutral	1951

No white sucker have been collected since removal netting in 1959-1961. No brown trout have been collected since 1951, but they have been reported on rare occasions by anglers. No splake have been collected or reported since 1970. No northern cisco have been collected since 1999.

Table 5. Catch (fish/set) and mean weight (lb/fish) of lake trout, rainbow trout, northern cisco, and yellow perch in gill nets (deep and shallow sets combined) set in Trout Lake, Cook County, Minnesota 1951-2009.

Median and first-third quartile (1st Q-3rdQ) values for Class 1 lakes in Minnesota (lake trout, northern cisco, and yellow perch), or for summer assessments of stream trout lakes in the Grand Marais and Finland areas also noted (rainbow trout, 1950-2005).

		Lake trout		Rainbow trout		Northern cisco		Yellow perch	
Survey date	**Number of nets**	**Catch**	**Mean weight**	**Catch**	**Mean weight**	**Catch**	**Mean weight**	**Catch**	**Mean weight**
7/17/1951	6	4.17	0.76	0.17		0.17		2.33	0.13
9/2/1980	6	6.00	0.66	3.17	0.88	4.00	2.15	7.33	0.12
8/11/1981	4	4.25	1.25	1.50	0.63	4.25	2.12	0.0	
8/22/1984	4	7.25	1.04	2.50	0.37	4.00	2.42	0.0	
8/26/1987	4	5.25	0.70	10.50	0.54	1.75	2.03	9.25	0.14
8/13/1990	4	4.50	1.22	6.50	0.90	2.50	2.44	2.00	0.17
8/2/1993	6	4.33	1.31	0.0		0.50	2.37	2.33	0.30
8/5/1996	6	1.50	3.71	1.83	0.61	0.50	2.22	6.83	0.19
8/5/1999	6	3.00	2.10	0.33	0.68	0.50	2.32	4.17	0.25
8/5/2007	6	5.00	0.75	0.33	1.17	0.0		0.50	0.31
7/20/2009	8	3.00	1.15	2.75	0.53	0.0		0.0	
Median		2.08	1.79	2.50	0.85	7.65	0.42	1.50	0.16
1stQ - 3rdQ		0.85-4.25	1.22-3.06	1.00-6.50	0.47-1.46	1.40-17.38	0.14-0.72	0.28-2.83	0.12-0.20

Table 6. Catch (fish/set) and mean weight (lb/fish) of brook trout, rainbow trout, and yellow perch in 3/4-inch-mesh trap nets set in Trout Lake, Cook County, Minnesota, 1980-2009.

Median and first-third quartile (1stQ - 3rdQ) values for Class 1 lakes in Minnesota (yellow perch), or for summer assessments of stream trout lakes in the Grand Marais and Finland areas also noted (brook trout and rainbow trout; 1950-2005).

		Brook trout		Rainbow trout		Yellow perch	
Survey date	Number of nets	Catch	Mean weight	Catch	Mean weight	Catch	Mean weight
9/2/1980	6	0.0		5.33	0.51	1.00	0.12
8/11/1981	4	0.75	0.25	0.50		2.00	0.13
8/22/1984	4	0.0		1.75	0.11	3.50	0.15
8/26/1987	8	0.25		1.25	0.73	3.25	0.15
8/13/1990	10	0.20		0.70	0.59	3.90	0.16
8/2/1993	10	0.40	0.20	0.60	0.49	2.50	0.16
8/5/1996	12	0.33	0.10	0.25	0.59	6.17	0.13
8/5/2007	12	0.0		0.0		2.00	0.10
7/28/2008	12	0.08		0.0		3.92	0.11
7/20/2009	12	1.08	0.16	0.08		2.17	0.13
Median		1.00	0.38	0.50	0.50	0.50	0.21
1stQ - 3rdQ		0.50-2.50	0.19-0.67	0.25-1.25	0.30-0.86	0.25-2.33	0.14-0.36

Table 7. Rainbow smelt catch (fish/set) in standard graduated –mesh gill nets, 0.5-inch-mesh gill nets, and small mesh (0.38 and 0.5 inch-mesh) gill nets set in Trout Lake, Cook County, Minnesota, 1980-2009.

Survey date	Standard gill nets	0.5-inch gill nets	Small-mesh gill nets
9/2/1980	0.0		
8/11/1981	0.0	0.0	
8/22/1984	1.5		
8/26/1987	1.0	10.5	
8/13/1990	0.0	4.0	
8/2/1993	0.2		54.0
8/5/1996	0.3		186.3
8/5/1999	0.5		26.3
8/5/2007	0.0		10.8
7/20/2009	0.0		0.5

Table 8. Average estimates of fishing pressure (angler-hours/acre) and lake trout and rainbow trout harvest rate (fish/angler-hour) and harvest (number of fish) from creel surveys done on Trout Lake, Cook County, Minnesota, 1952-1960, 1961, 1965, 1968-1970, and 1999.

Years and Seasons	Fishing Pressure	Lake trout		Rainbow trout	
		Harvest rate	Harvest	Harvest rate	Harvest
1952-1960					
Summer	7.7	0.15	293	ND	ND
Winter	9.0	0.36	844	ND	ND
Combined	16.7	0.26	1,137	ND	ND
1961 Summer	6.9	ND	ND	ND	ND
1965 Winter	9.1	ND	ND	ND	ND
1968-1970					
Summer	13.8	0.08	296	0.31	1,101
Winter	13.7	0.23	797	0.02	59
Combined	27.5	0.15	1,093	0.16	1,160
1999 Winter	7.6	0.13	245	0.03	50

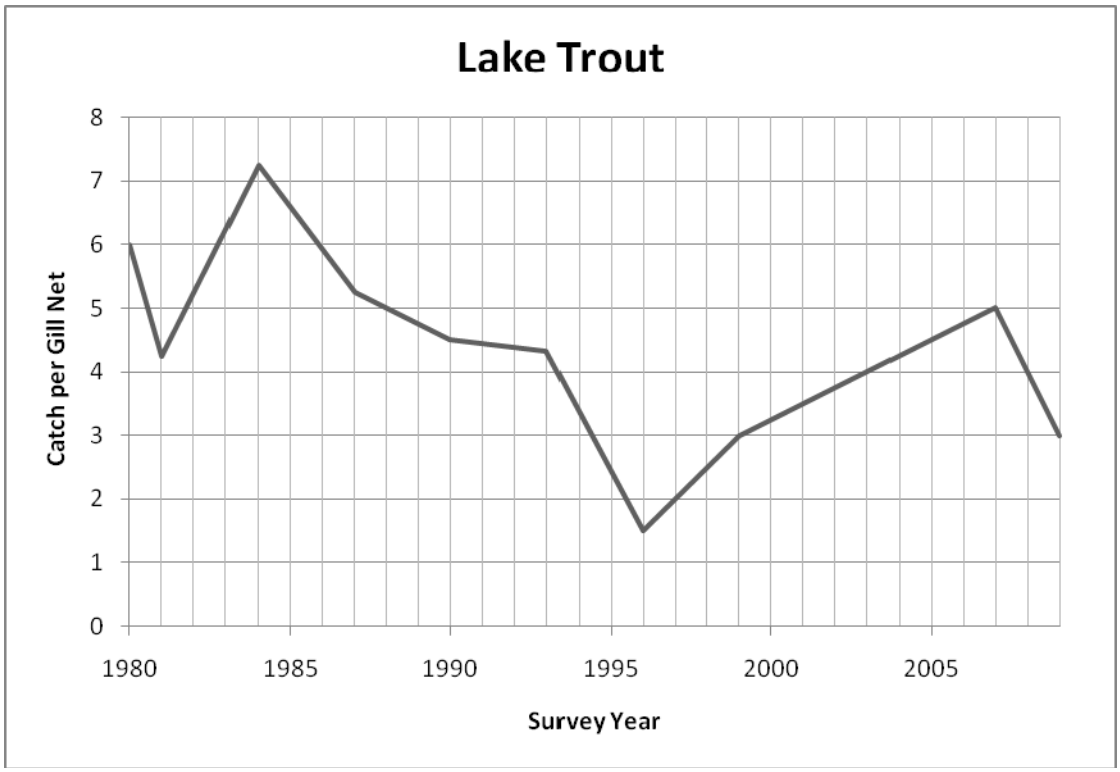
Table 9. Recent survey focal species catch rates compared to similar lake classes

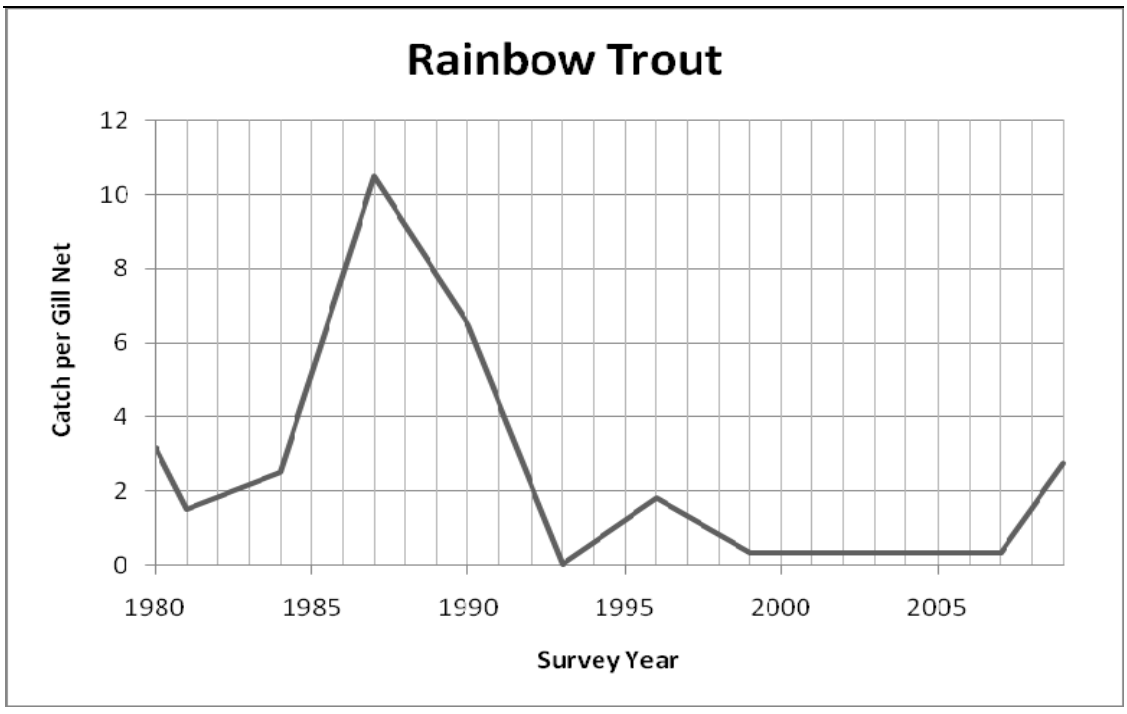
Species	Stocked	Abundance	Size	Trend
Lake trout*	No	High	Small	Stable
Rainbow trout*	Yes	Low	Average	Declining
Brook trout	No	Low	Small	Stable
Rainbow smelt	No	High	Average	Declining
Cisco	No	Very low	Large	Possibly extirpated
Yellow perch	No	High	Small	Fluctuating

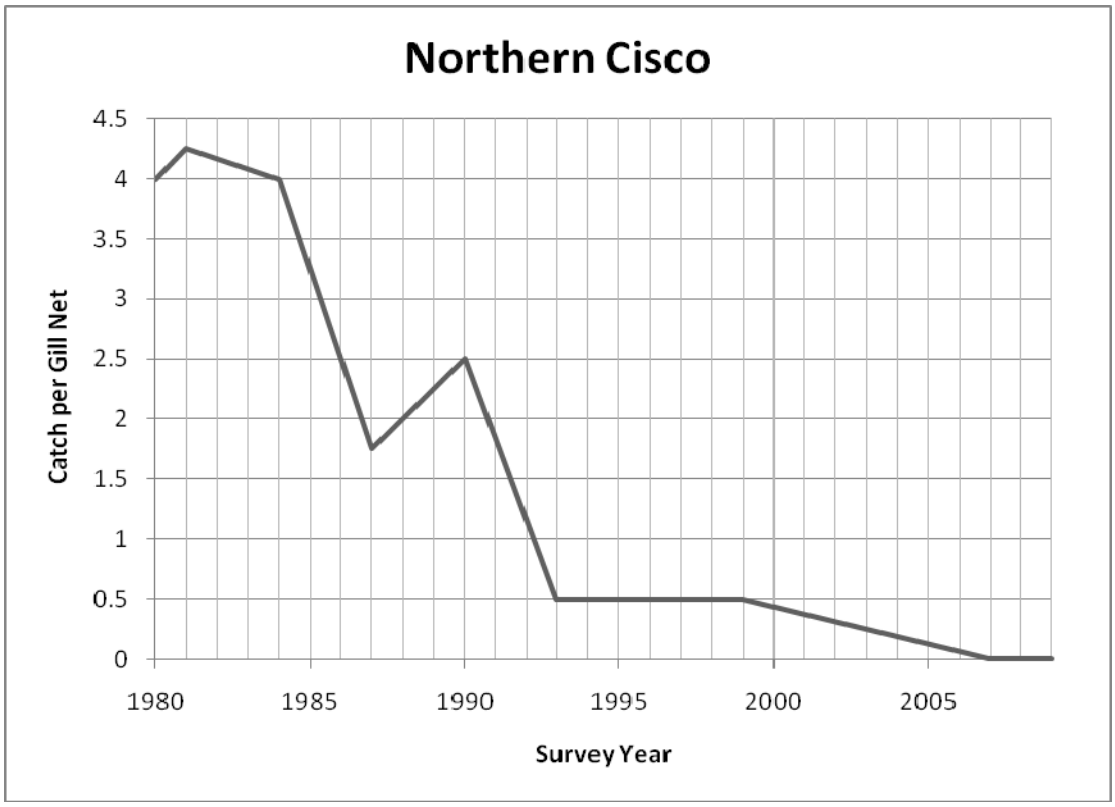
Table 10. Temperatures at three mg O_2 interpolated from the profiles taken by MPCA and MDNR during the period of greatest oxythermal stress (July 28 through August 27) from Trout Lake.

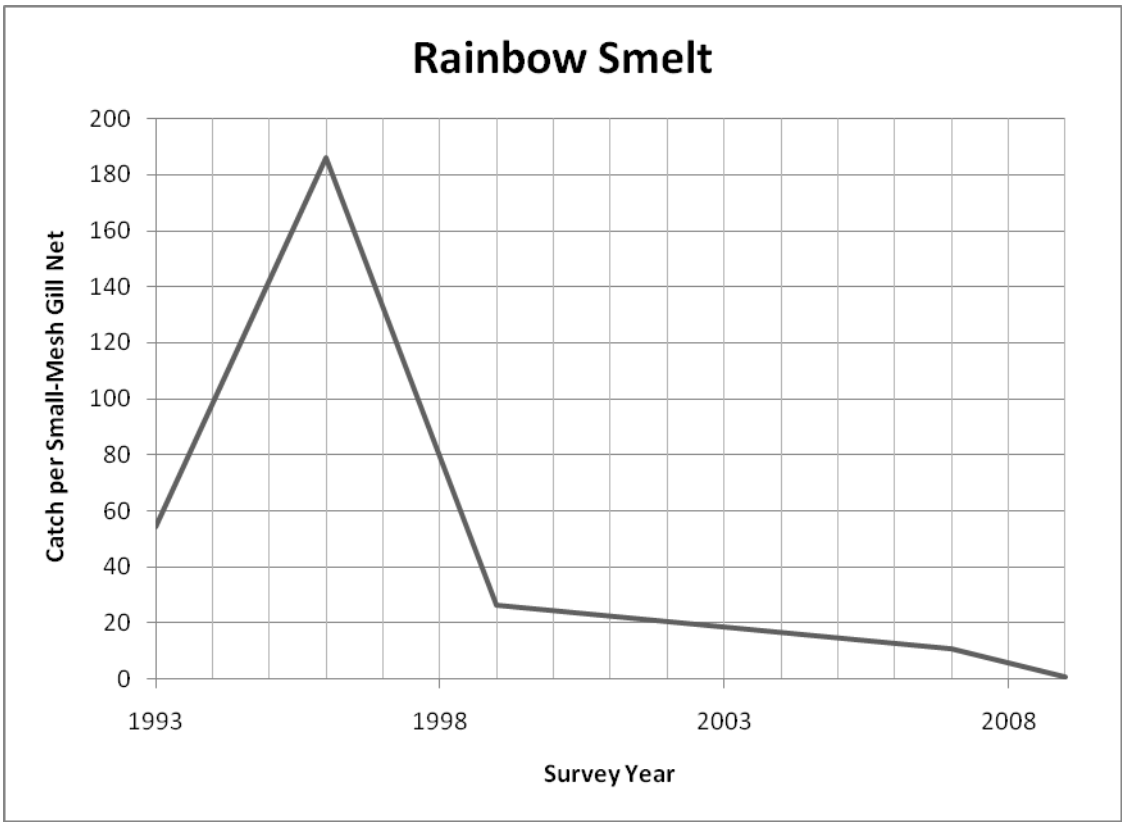
Date	TDO_3
7/3/2008	5.9
8/1/2008	6.8
8/14/2008	6.0
9/4/2008	7.3
8/4/2009	7.1
8/10/2009	6.7
Mean	6.7

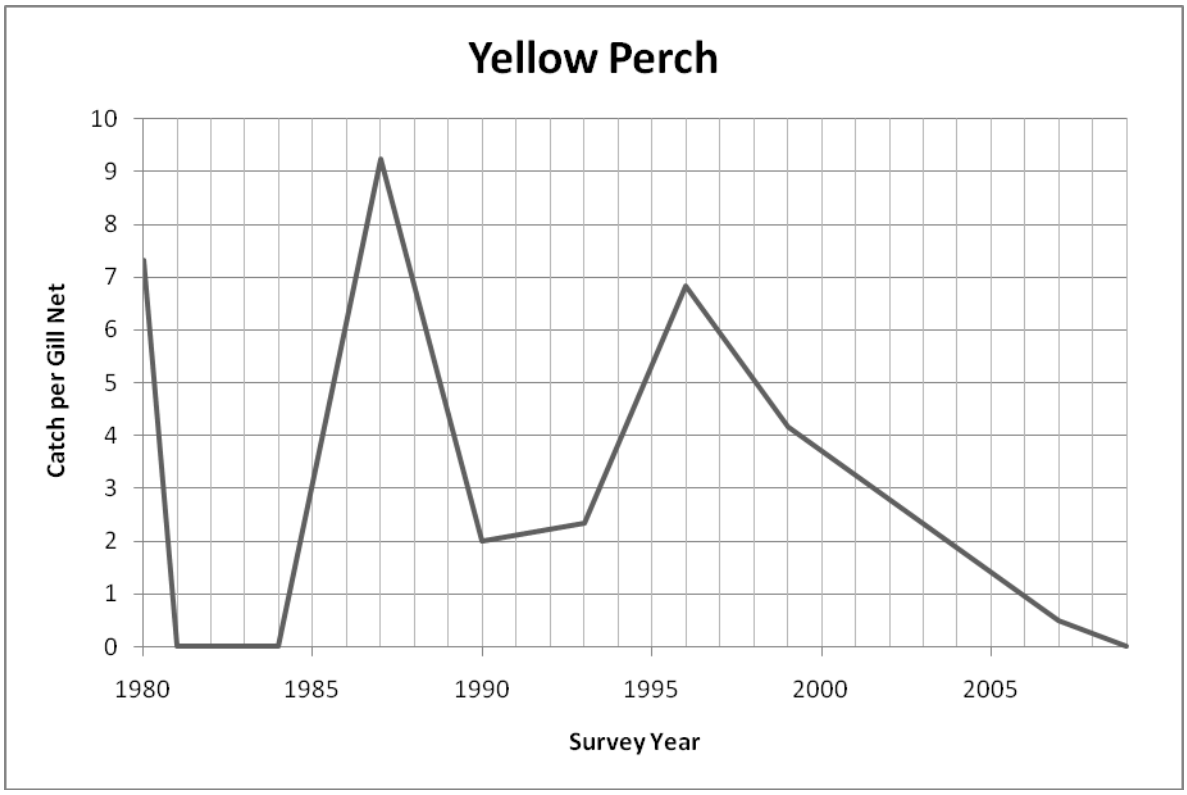
Figure 11. Historical net catches by species for Trout Lake

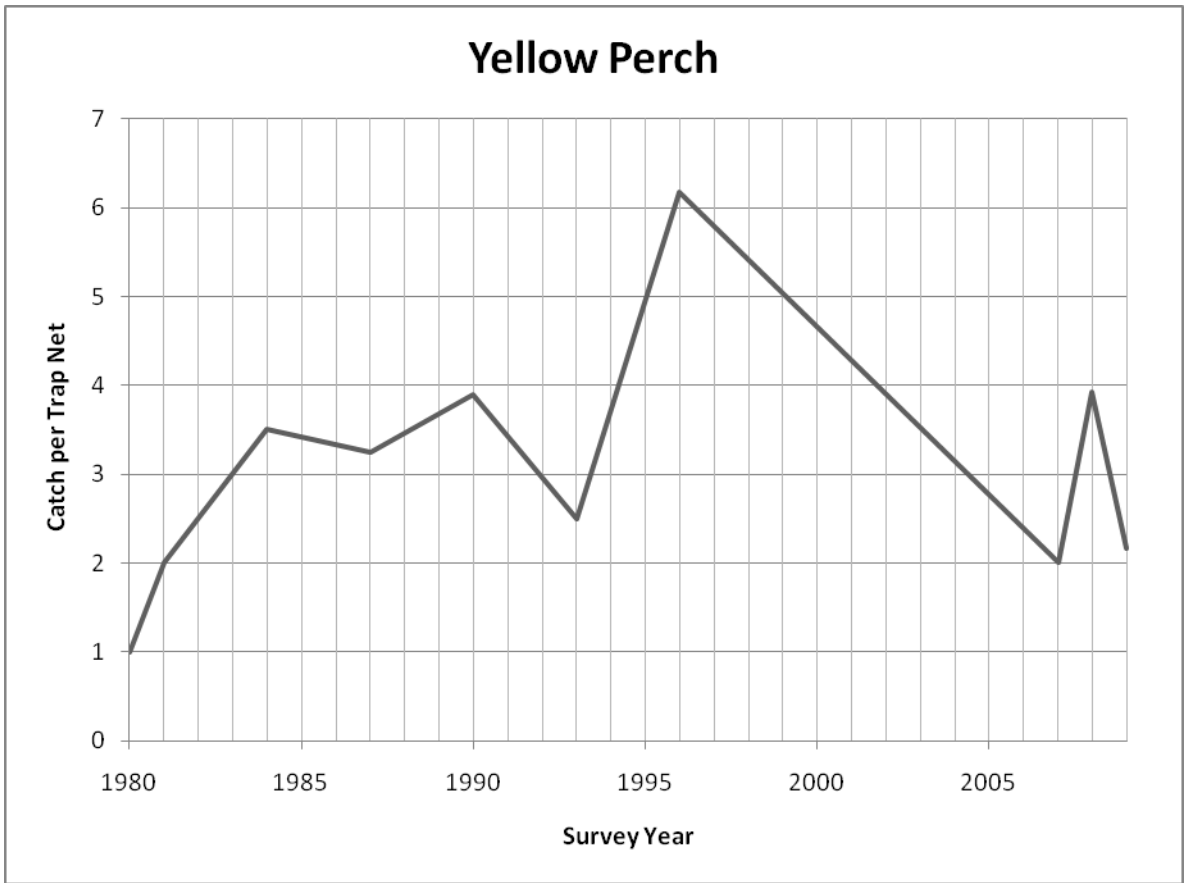





Northern Cisco
Catch per Gill Net
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
Survey Year


Rainbow Smelt
Catch per Small-Mesh Gill Net
200
180
160
140
120
100
80
60
40
20
0
1993
1998
2003
2008
Survey Year


Yellow Perch
Catch per Gill Net
10
9
8
7
6
5
4
3
2
1
0
1980
1985
1990
1995
2000
2005
Survey Year


Yellow Perch
Catch per Trap Net
7
6
5
4
3
2
1
0
1980
1985
1990
1995
2000
2005
Survey Year

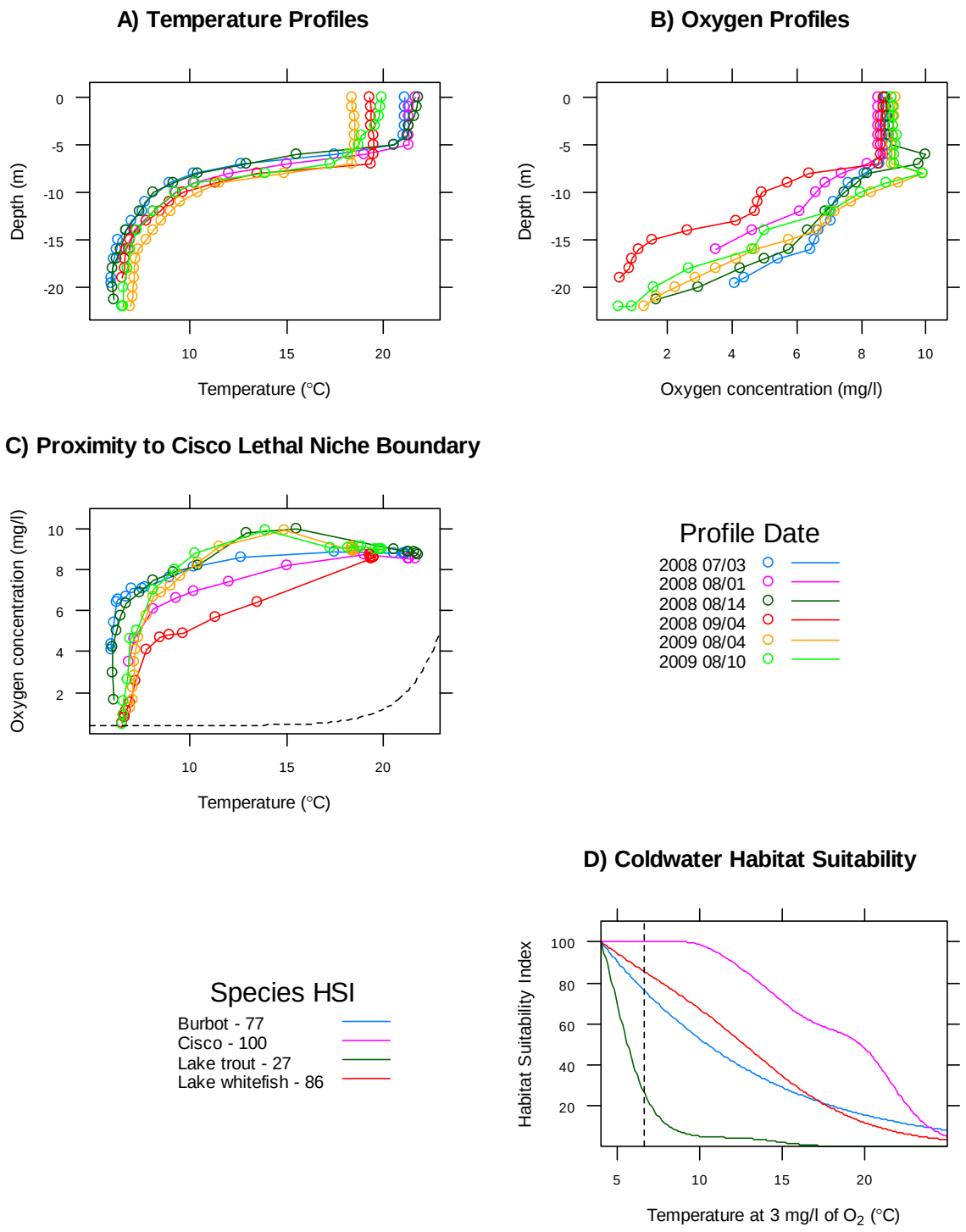


Figure 243. Temperature-dissolved oxygen profiles proximity to lethal boundaries for cisco, and habitat suitability for select cold-water species (Jacobson et al. 2010).

Aquatic plant assessment

Due to its low nutrient productivity and rocky substrates, aquatic plants (especially submersed ones) in Trout Lake are naturally sparse (Figure 13). One to a few different emergent and submersed species have commonly occurred over the surveyed history of the lake (Tables 11 and 12). Plant cover, even in an undisturbed lake like Trout, may still be variable from year to year (Table 12). Warmer water temperatures due to climate change or increases in lake productivity may lead to increased aquatic plant abundance and species diversity thereby affecting associated fish communities.

Table 11. Common species sampled during past lake vegetation surveys. Species were deemed common if they were either noted as "common" or "abundant" or if they were encountered greater than 10 percent of the sample stations or transects surveyed.

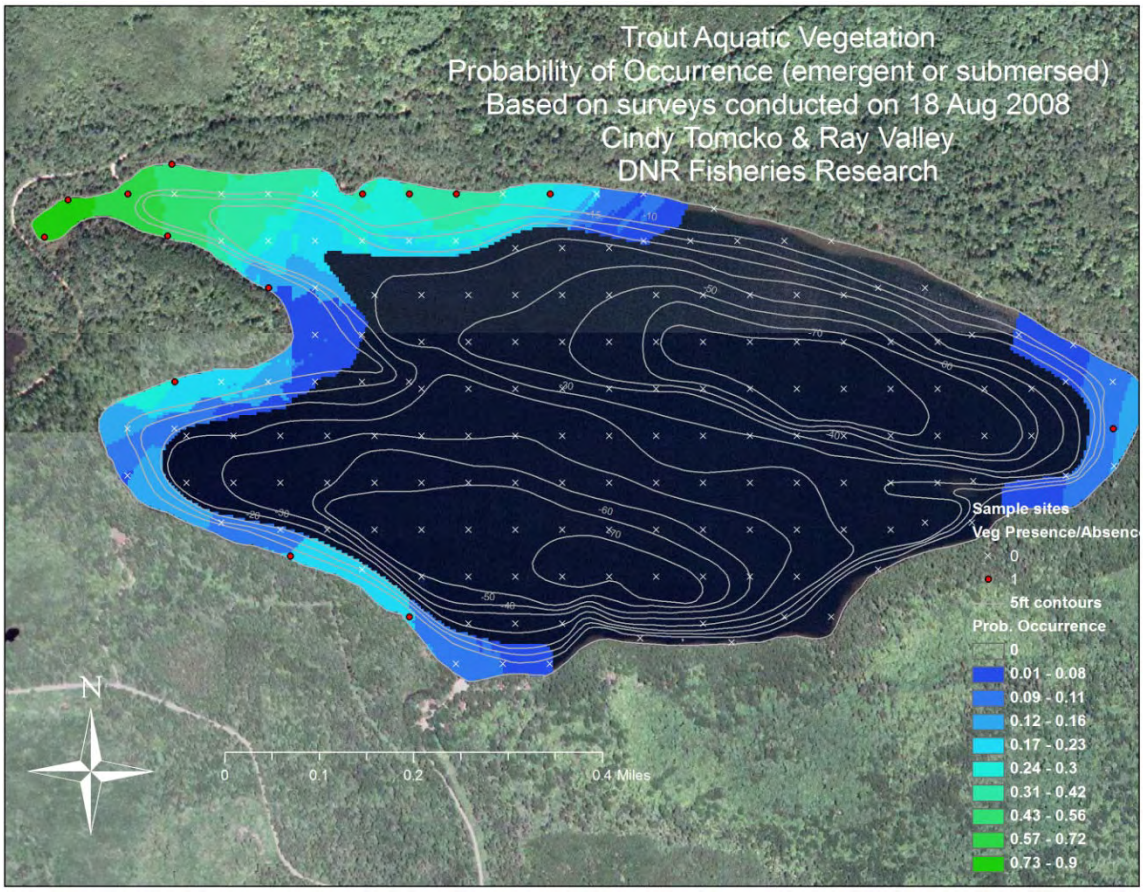
Survey Year	Common Name	Species Name	Growth Form
1951	Bluntleaf pondweed	*Potamogeton obtusifolius*	Submersed
1981	None "common"		
1984	Horsetail	*Equisetum fluviatile*	Emergent
	Leafy pondweed	*Potamogeton foliosus*	Submersed
1987	Small watermilfoil	*Myriophyllum alterniflorum*	Submersed
	Clasping-leaf pondweed	*P. richardsonii*	Submersed
1999	Waterwillow	*Decodon verticillatus*	Emergent
	Horsetail	*Equisetum fluviatile*	Emergent
	Yellow water lily	*Nuphar variegata*	Floating-leaf
	Robbins pondweed	*P. robbinsii*	Submersed

Table 12. Percent frequency of occurrence of aquatic plant species at depths ≤ 15 feet sampled during point-intercept surveys on August 18 2008 and July 13 2009, at Trout Lake, Cook County, MN.

Common Name	Species Name	Growth Form	Frequency (%) 2008	2009
All rooted plants			40.0	25.0
Horsetail	*Equisetum sp.*	Emergent	28.6	25.0
Sedge	*Carex sp.*	Emergent	5.7	0
Large-leaf pondweed	*Potamogeton amplifolius*	Submersed	5.7	0
Filamentous algae			2.9	0
Bladderwort	*Utricularia sp.*	Submersed	2.9	3.8
Robbins pondweed	*Potamogeton robbinsii*	Submersed	2.9	7.7
Three-way sedge	*Dulichium arundinaceum*	Emergent	2.9	0
Blue flag iris	*Iris versicolor*	Emergent	2.9	0
Swamp candle	*Lysimachia terrestris*	Emergent	2.9	0
Buckbean	*Menyanthes trifoliata*	Emergent	2.9	0
Smartweed group	*Polygonum sp.*	Floating-leaf	2.9	0
Ribbon-leaf pondweed	*Potamogeton epihydrus*	Submersed	2.9	0
Max depth of veg growth (ft) [a]			10.2ft	2.0ft

[a] Depth of 95 percent of all plant occurrences

Figure 13. Cover of aquatic plants in August 2008 estimated from point-intercept sampling and indicator kriging interpolation.



Water quality

Standard summer-mean water quality data for 2008, 2009, and 2010 are presented in Table 13, and raw data results are provided in Appendix A. In addition, major cations, anions, and total organic carbon (TOC) were analyzed on three sample dates, and those values and typical ranges as derived from the National Lakes Assessment (NLA) database for Minnesota are summarized in Table 14. 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 Table 14 is based on 64 Minnesota lakes that were included in that NLA study and is intended to provide a state-wide perspective.

Table 13. Trout Lake 2008-2010 summer- mean water quality data. Typical range based on 32 NLF ecoregion reference lakes (Heiskary and Wilson 2008) noted for comparison. A value of half the detection limit was substituted for those values reported as less than the detection limit.

Parameter	Trout Lake 2008 Site 101	Trout Lake 2009 Site 101	Trout Lake 2010 Site 101	NLF
Total phosphorus (µg/L)	7.7	8.0	6.2	14 - 27
Chlorophyll mean (µg/L)	1.4	1.2	1.1	4 - 10
Chlorophyll max (µg/L)	4.3	2.2	1.7	<15
Secchi disk (feet)	15	18	19	8 – 15
(meters)	4.6	5.7	5.9	2.4 – 4.6
Total Kjeldahl Nitrogen (mg/L)	0.3	0.4	0.4	<0.4 – 0.75
Alkalinity (mg/L)	14	14	16	40 - 140
Color (Pt-Co Units)	5	5	5	10 - 35
pH (SU)	6.7	6.5	7.5	7.2 – 8.3
Chloride (mg/L)	<1	1	<1	0.6 – 1.2
Total suspended solids (mg/L)	<1	4.8	2.6	<1 - 2
Total suspended inorganic solids (mg/L)	<1	1.6	1.4	<1 - 2
Conductivity (umhos/cm)	36	34	39	50 - 250
Total nitrogen: Total phosphorus ratio	39:1	50:1	64:1	25:1 - 35:1

Table 14. Trout Lake cation, anion, and total 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.

Parameter	Trout Lake 2008 Site 101	Trout Lake 2009 Site 101	Trout Lake 2010 Site 101	NLF
Total phosphorus (µg/L)	7.7	8.0	6.2	14 - 27
Chlorophyll mean (µg/L)	1.4	1.2	1.1	4 - 10
Chlorophyll max (µg/L)	4.3	2.2	1.7	<15
Secchi disk (feet)	15	18	19	8 – 15
(meters)	4.6	5.7	5.9	2.4 – 4.6
Total Kjeldahl Nitrogen (mg/L)	0.3	0.4	0.4	<0.4 – 0.75
Alkalinity (mg/L)	14	14	16	40 - 140
Color (Pt-Co Units)	5	5	5	10 - 35
pH (SU)	6.7	6.5	7.5	7.2 – 8.3
Chloride (mg/L)	<1	1	<1	0.6 – 1.2
Total suspended solids (mg/L)	<1	4.8	2.6	<1 - 2
Total suspended inorganic solids (mg/L)	<1	1.6	1.4	<1 - 2
Conductivity (umhos/cm)	36	34	39	50 - 250
Total nitrogen: Total phosphorus ratio	39:1	50:1	64:1	25:1 - 35:1

Dissolved oxygen and temperature profiles

MPCA, MDNR, and USGS data were combined to produce dissolved oxygen (DO) and temperature profiles for 2008-10 (Figures 14 and 15). Biweekly profiles were collected by MPCA and MDNR in 2008-10; additional data were collected in 2010 by the USGS. Trout was stratified by late May each year, and stratification remained until October. Maximum surface temperatures peaked at 22.8 degrees in July 2010, the warmest summer (Table 3).Summer 2009 was the coolest and as such, had the lowest epilimnetic temperatures. Overall, water temperatures peaked in late July or early August each year. Optimal lake trout temperatures (8-12 C) were confined to the hypolimnion (depths > 10 m) by mid-summer. Cold temperatures (< 10 C) were maintained at depths greater than approximately 14 m (45 feet) throughout the open water season.

As discussed previously, DO concentrations peaked in the metalimnion and recent monitoring and modeling indicate Trout has excellent cold water habitat. These characteristics are due to the lake's morphology and good water quality. Trends in metalimentic DO are most evident in the 2010 data, the year with the greatest amount of measurements. A gradual decline in well-oxygenated water (concentrations greater than 10 mg/L) is evident as the summer progresses, corresponding with increasing water temperatures in the epilimnion. Epilimnion and metalimnion DO concentrations exceeded six milligrams per liter (mg/L) on all measurements (minimum levels needed to sustain the lake's cold water fishery). DO concentrations only fell below four mg/L deep in the hypolimnion (depths < 14 m; Figure 15). High 2010 epilimnetic temperatures (~ mid August) preceded minimum DO concentrations in the hypolimnion (late September) by a few weeks. In all three years, low oxygenated water (0-2 mg/L) was found deep in the hypolimnion (from the lake bottom upwards to a depth of about 14 m) by late summer. These conditions continued until mid-October (Figure 15). The persistence of low hypolimnetic oxygen into October was due to the time required for complete mixing as the epilimnion began to cool in response to the change in seasons (Figure 14). It is important for temperature and oxygen monitoring to continue. A warming climate may diminish midsummer cold water habitat by increasing the depth and temperature of the epilimnion, and reducing oxygen levels in the hypolimnion by extending the period of summer stratification. Only the metalimnion might then provide conditions suitable for lake trout. There trout find an optimal habitat refuge in a smaller area (i.e. depth range) between the warm waters of the epilimnion and the low-oxygenated deep hypolimnion. More detailed DO data and modeling done by MDNR were included in the preceding section on cold water fisheries habitat.

A comparison of historical temperature profiles (collected in August 1984 and August 1986) to recent data (2008-2010) indicated that mid-summer conditions were similar. Specifically, surface temperatures ranged from 20 to 21 degrees C, the thermocline consistently developed near eight-nine meters, and hypolimnetic temperatures were consistently near 7 C.

Figure 14. 2008-2010 Trout Lake temperature profiles (MPCA, MDNR, and USGS data)

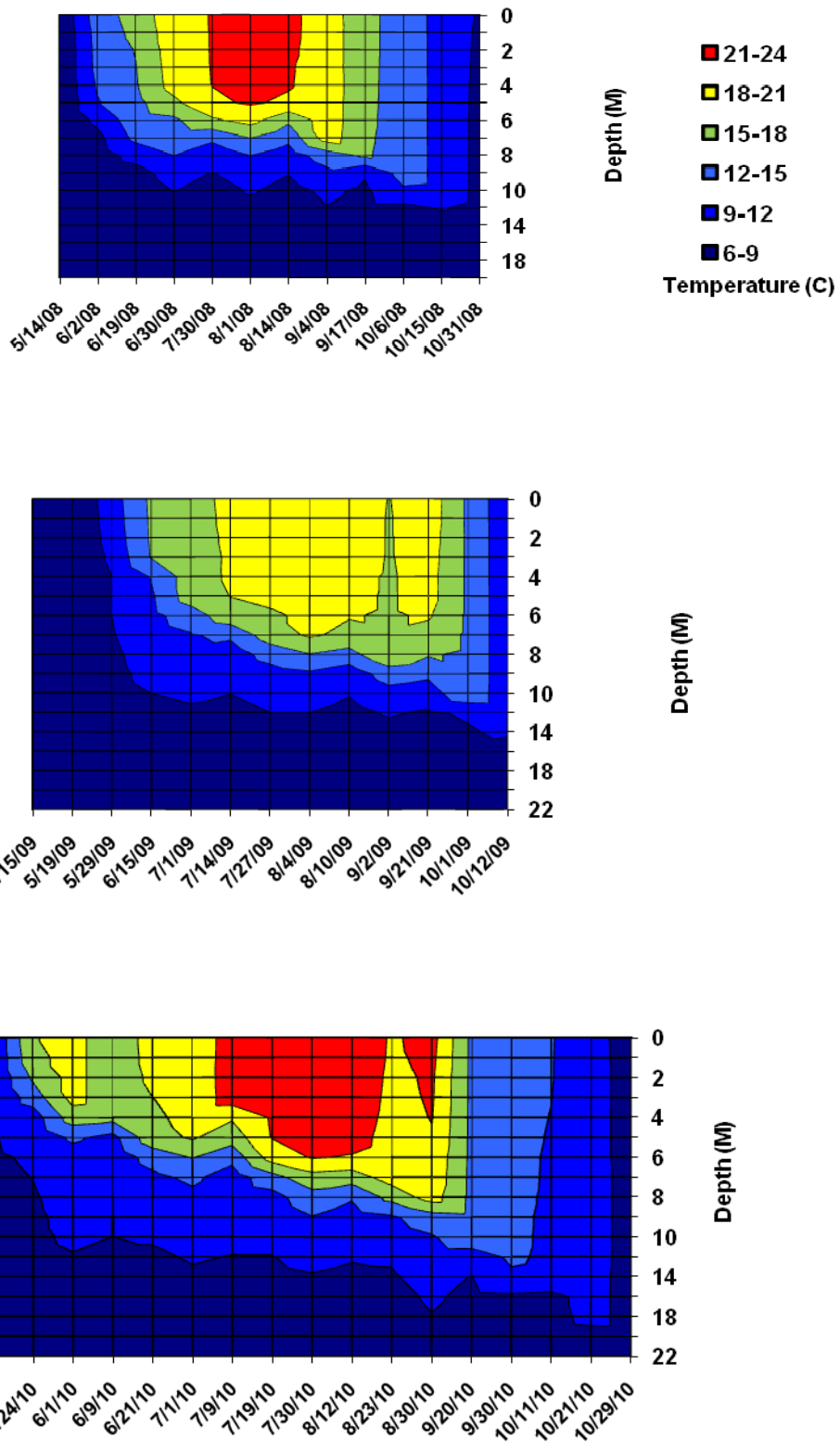
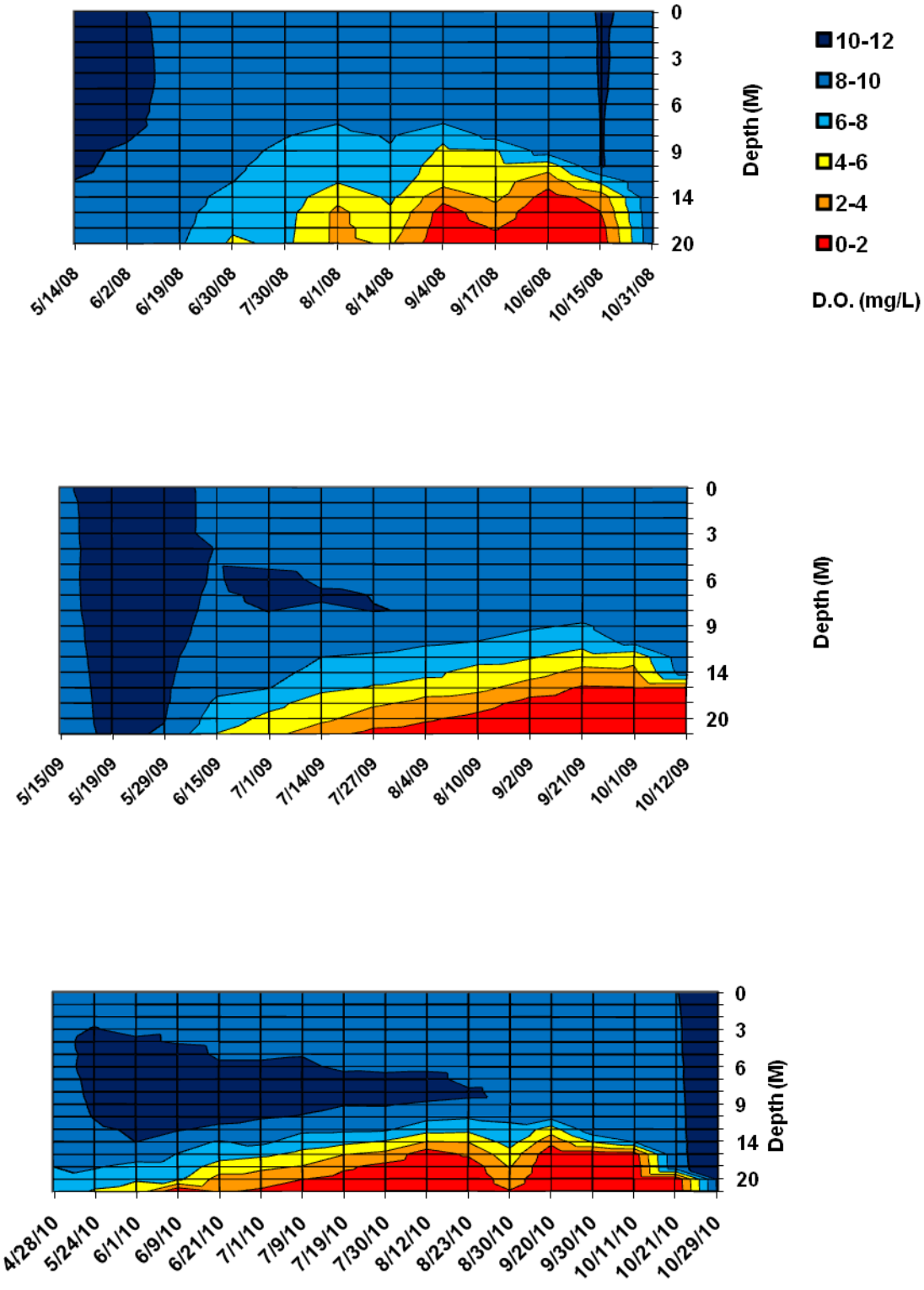


Figure 15. 2008-10 Trout Lake dissolved oxygen profiles



Total phosphorus (TP) concentrations did not change significantly between years, averaging seven µg/L in 2008, eight µg/L in 2009, and six µg/L in 2010. Similarly, concentrations did not vary greatly about the annual mean on a monthly basis, (Figure 16). Spring and fall 2010 concentrations were slightly elevated compared to summer values. Stable TP concentrations are likely due to the lake's undeveloped forested watershed. For most deep, oligotrophic to mesotrophic (low to moderate nutrient) lakes, it is common to observe stable to slightly declining TP from May through September, accompanied by slight increases in chl-*a* and slight decreases in Secchi transparency. This is primarily the result of sedimentation of sediment-attached TP early in the summer along with algal uptake of P and sedimentation as algae grow and die over the summer. Annual average near-bottom (hypolimnion) TP concentrations were slightly higher than the surface values in Trout, which is normal for deep stratified lakes (Figure 17). Hypolimentic TP was typically highest in mid-summer during peak stratification (Figure 18). Additional TP monitoring by the USGS in 2010 allows comparisons within the Trout Lake watershed. Samples collected in various small inlets, the main-lake (site 101), and the outlet are shown in Figure 19. The two tributaries had slightly higher TP concentrations than the lake or its outlet; however these concentrations are low relative to the typical range for NLF streams (McCollor and Heiskary 1993). Marsh Lake is naturally more productive that Trout and the higher TP concentrations were expected. TP data collected separately by the MPCA and USGS at site 101 yielded very similar concentrations (eight µg/L); similar concentrations were also found at the lake outlet (Figure 19), further indicting oligotrophic conditions in Trout Lake.

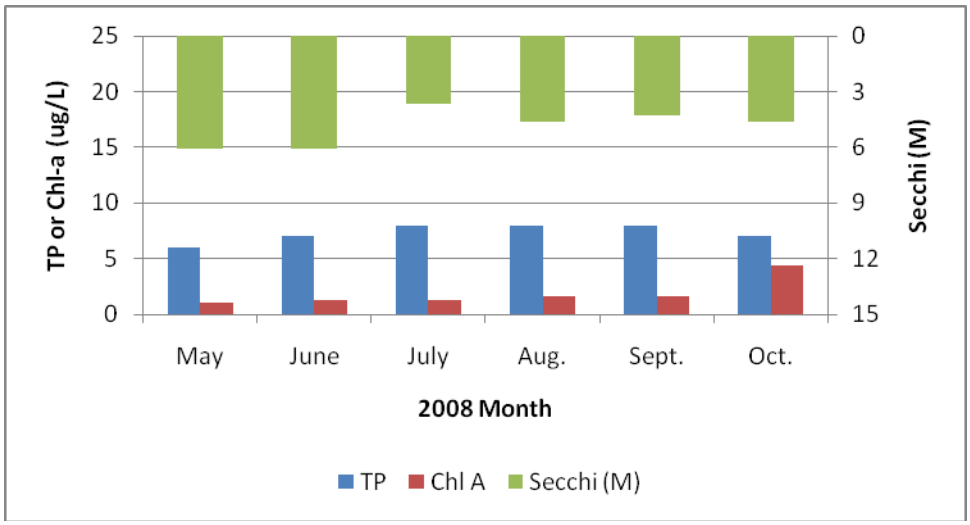
Chlorophyll-*a* (chl-*a*) concentrations provide an estimate of the amount of algal production in a lake. During 2008-10, chl-*a* levels were low in Trout and indicated oligotrophic conditions. Concentrations ranged from 0.8 µg/L to 4.3 µg/L, with an average of 1.2 µg/L (Figure 16). Concentrations greater than 20 µg/L will typically be perceived as a nuisance bloom in northern Minnesota lakes (Heiskary and Walker, 1988). Nuisance blooms were not observed on Trout, and during most sampling events, algae levels in the epilimnion were sparse. Algal growth is limited to some degree by the lake's low TP concentrations and cool temperatures.

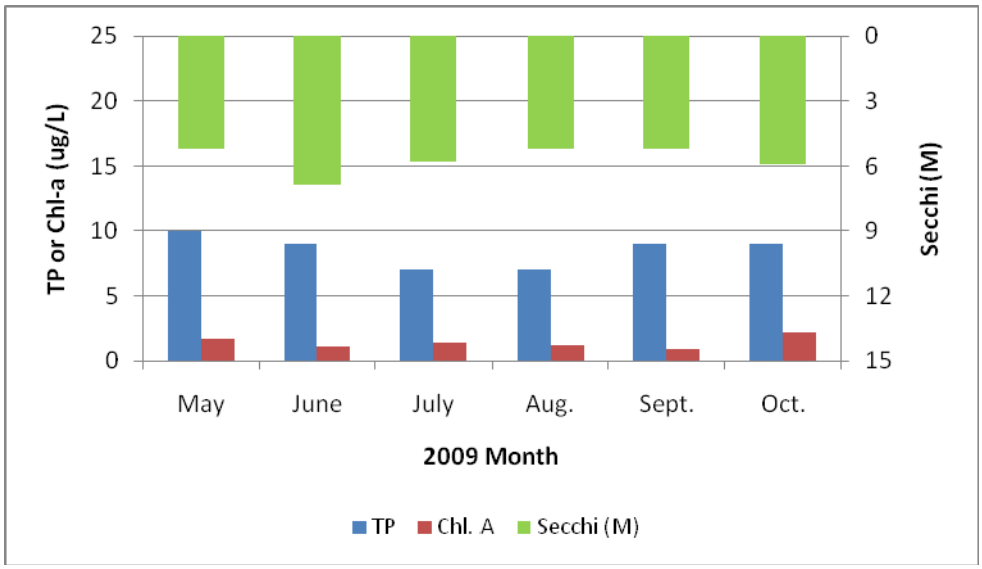
Secchi disk transparency averaged 5.4 m from 2008-10, and slightly increased during the three years. These values are above the NLF ecoregion range. Trout is one of the clearer lakes in the area, and transparency is in approximately the 95th percentile of the MPCA's 1,640 monitoring lakes in the NLF ecoregion. Secchi transparency is influenced by the lake's low nutrients and low color (color averaged only five Pt-Co units (Table 13). Clarity did not vary significantly among months (Figure 16).

Additional water quality parameters were measured, as part of the long-term monitoring of Trout and other Sentinel lakes. This includes some of the standard MPCA lake monitoring measures of total suspended solids (TSS), alkalinity, conductivity and color (Table 13), as well as major cations, anions, and total organic carbon (Table 14). While several of these parameters have "typical" ecoregion-based concentrations, some do not. For parameters without ecoregion–based comparisons, data from the 2007 NLA study were used to provide perspective on reported concentrations. Since the NLA lakes were selected randomly, they provide a reasonable basis for describing typical ranges and distributions at the statewide level.

For the conventional lake monitoring parameters listed in Table 13, most on Trout were outside (commonly lower than) the typical NLF range, because few of the NLF ecoregion reference lakes were oligotrophic trout lakes. The low alkalinity, cation, and anion concentrations indicate soft water, typical of other area trout lakes (Table 14). Chloride is an excellent tracer of human impacts to water resources, and is typically found in low concentrations in NE MN lakes, absent man-induced inputs from road salting or wastewater discharges. Examination of historical chloride data from 1981-2010 indicated that nearly all values were below one mg/L, with most below detection limits (0.5 – 1.0 mg/L). Collectively, these data further indicate that Trout has excellent water quality.

Figure 16. Trout Lake 2008-10 total phosphorus, chlorophyll-a and Secchi depth





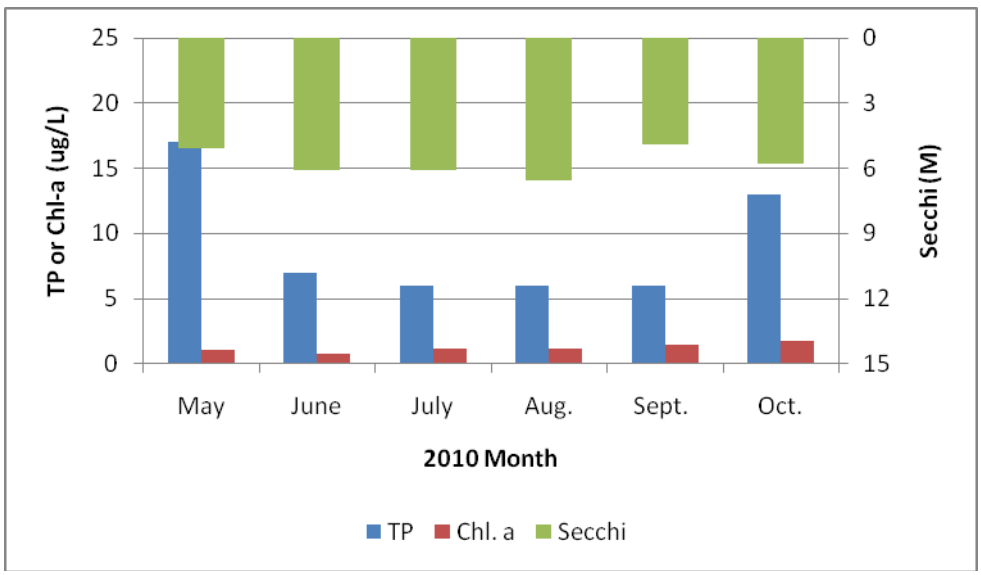


Figure 17. 2008-10 average Trout Lake TP concentrations in the epilimnion and hypolimnion

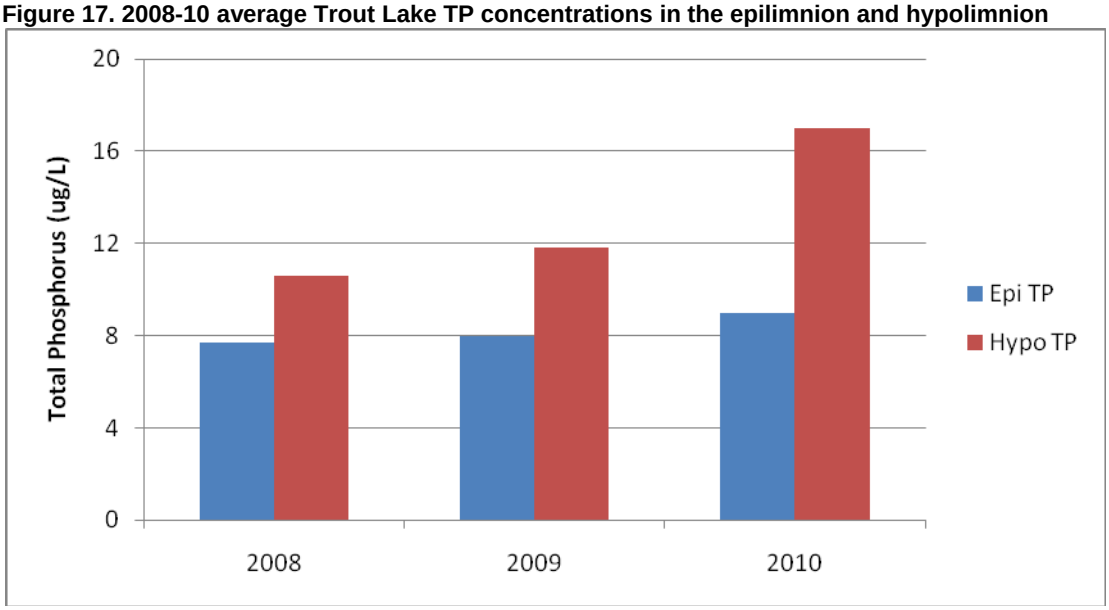


Figure18. 2008-2010 monthly comparisions of TP concentrations in the epilimnion and hypolimnion

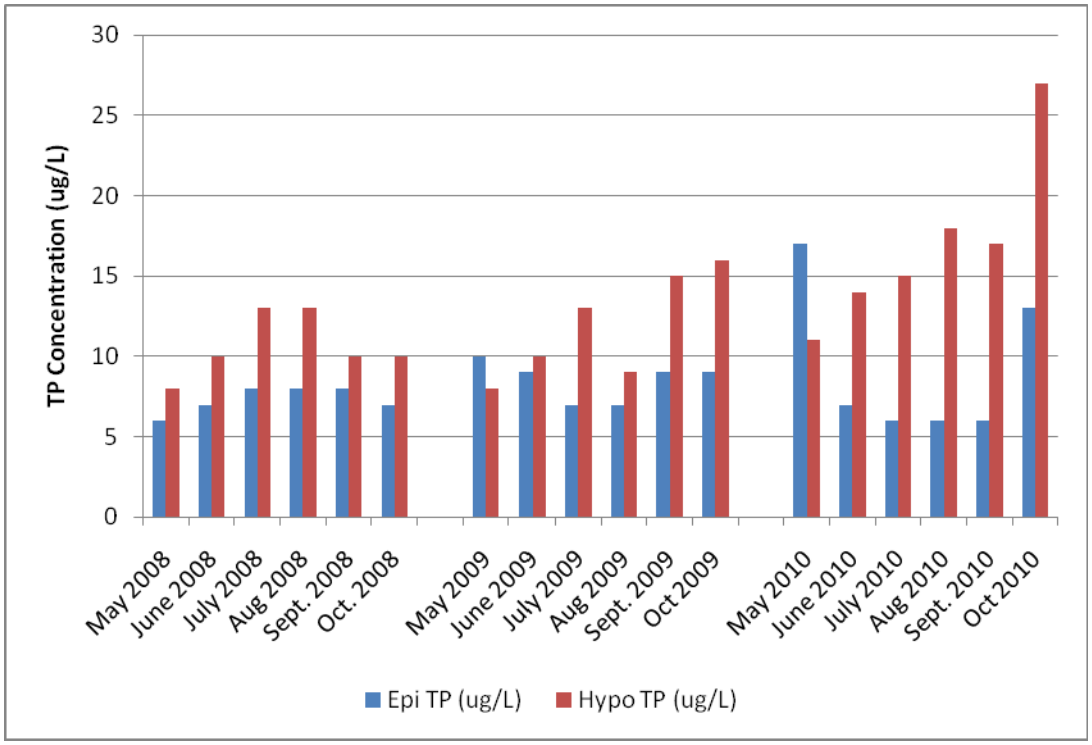
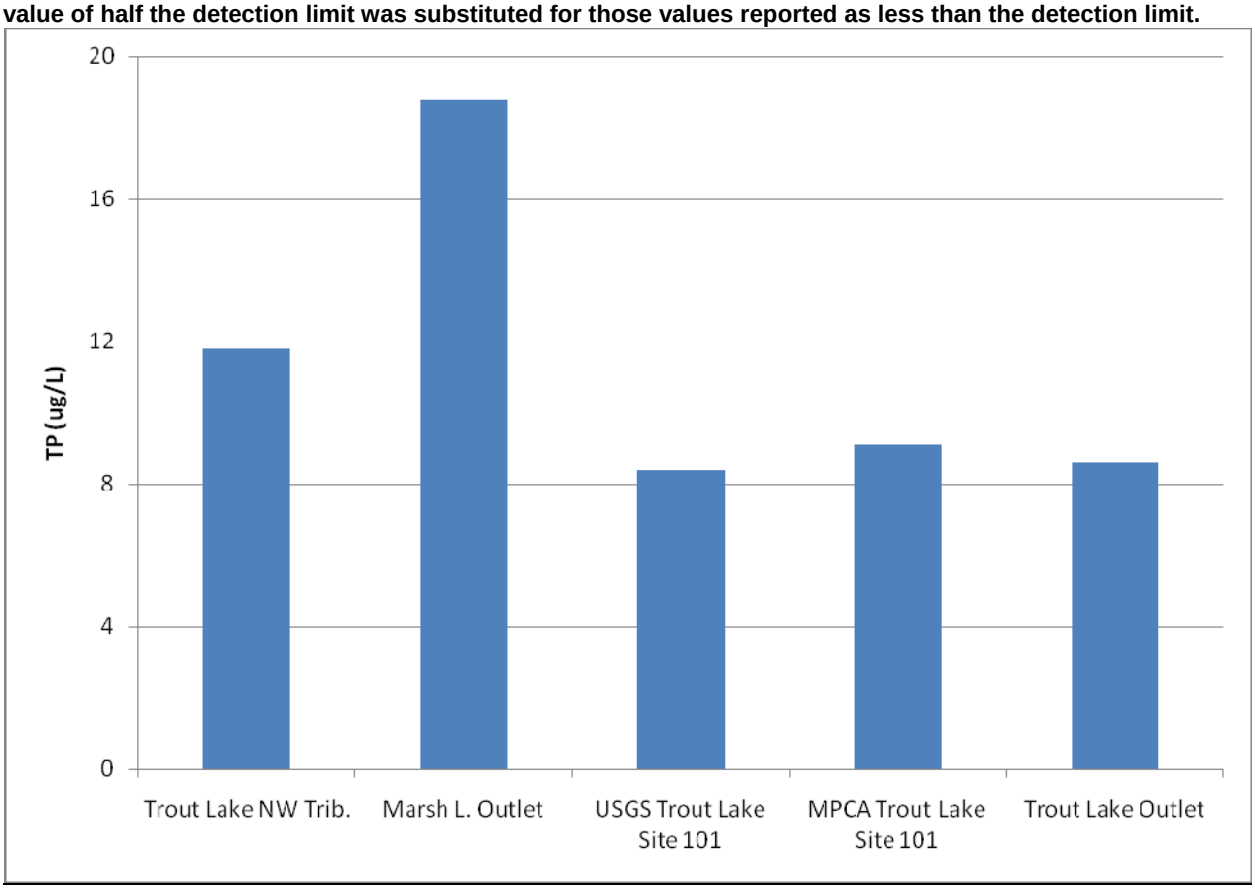


Figure 19. 2010 average TP concentrations within the Trout Lake watershed. USGS data unless noted; a value of half the detection limit was substituted for those values reported as less than the detection limit.



Phytoplankton (algae) for Trout Lake in 2008 and 2009 are presented in terms of algal type (Figures 20 and 21). Samples from May and September 2009 were lost or damaged, so direct comparisons among years are limited. Diatoms and blue-greens tended to be the dominant forms, respectively, while dinoflagellates, yellow-browns, and green algae were sparse. The seasonal dynamics did vary between years. Diatoms, which often prefer cooler water were dominant in the spring and fall in 2009, while they were dominate in mid-summer in 2008. This may be a function of climate or natural variability in algae species.

A seasonal transition in algal types from diatoms to green to blue-green algae is rather typical for mesotrophic and eutrophic lakes in Minnesota. In practice, greens are seldom abundant in Minnesota lakes, and there is often a transition from diatom to blue-green dominance. For oligotrophic lakes like Trout, algal abundance (as reflected by low chlorophyll-a) is very low and numerous species are represented. Though blue-greens may be dominant in mid-summer, they are typically present in very low concentrations and do not attain "nuisance bloom" levels.

Figure 20. Algal composition for Trout Lake in 2008

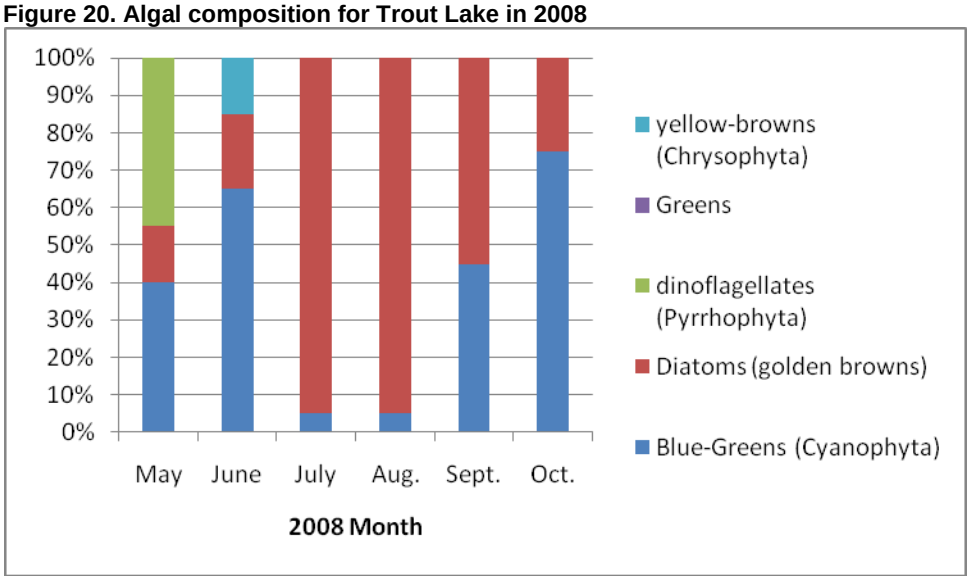
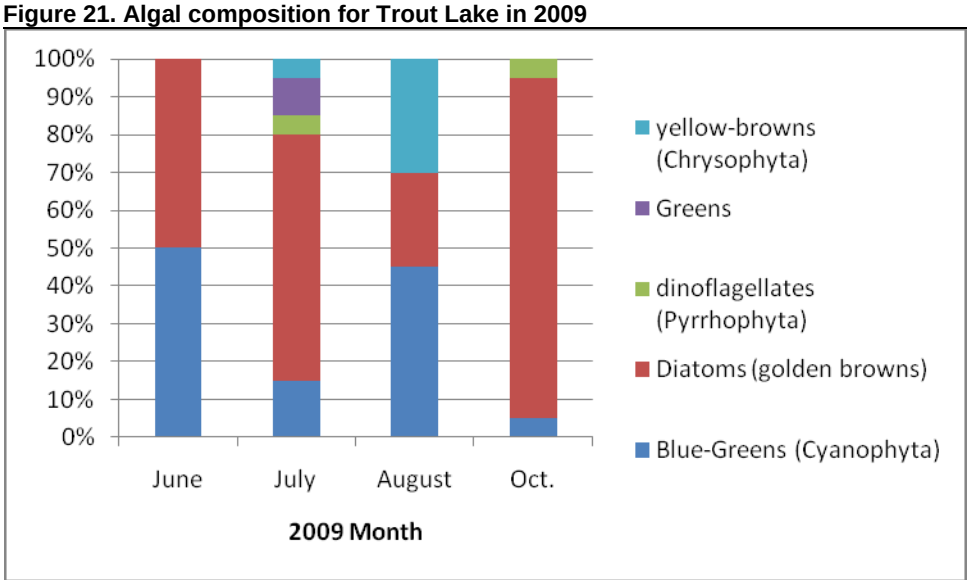


Figure 21. Algal composition for Trout Lake in 2009



Zooplankton

Zooplankton samples were analyzed by Jodie Hirsch at the MDNR. A summary report was prepared that included information for all the Sentinel lakes, and that report is the basis for the following comments on Trout Lake (Hirsch 2009). Mean 2008 zooplankton densities in Trout were below average when compared to the five other Border region Sentinel lakes (Table 15). 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 Trout, being the lone oligotrophic Sentinel Lake (Figure 22). Northern Light Lake had the lowest density and biomass, and has since been replaced in the Sentinel lake network by Tait Lake. Densities and biomass in Trout tended to be highest in spring and lower later in the season (Figure 22). Other observations on Trout's zooplankton community were provided by Hirsch (personal communication, December 2010):

- Trout has one of the lowest total zooplankton densities and biomass of Sentinel lakes (Bearhead's was very similar)
- Trout has a high percentage of calanoid copepods, which may be useful as an indicator of oligotrophic conditionLarge *Daphnia pulex* were present in Trout, which are very efficient grazers of algaeTrout is the only Sentinel lake with the calanoid *Onychodiaptomus sanguineus*
- Other interesting taxa include *Holopedium gibberum* (found in very soft water lakes) and *Leptodiaptomus minutus* (found in lakes in northern MN)

Zooplankton biomass and density from 2008-2010 in Trout Lake are shown in Figure 23. Figure 24 shows the relative composition of cladocerans and copepods. Daphnia were often low in number and biomass (Figure 23). The zooplankton community over the three-year period of record tended to be dominated by copepods (Figure 24). Zooplankton density tended to be highest in the spring, and slowly declined throughout the season. The highest density in May 2008 is likely related to that sample being collected while part of the lake was still ice-covered.

Figure 22. Mean monthly zooplankton densities and biomass for Border Sentinel lakes

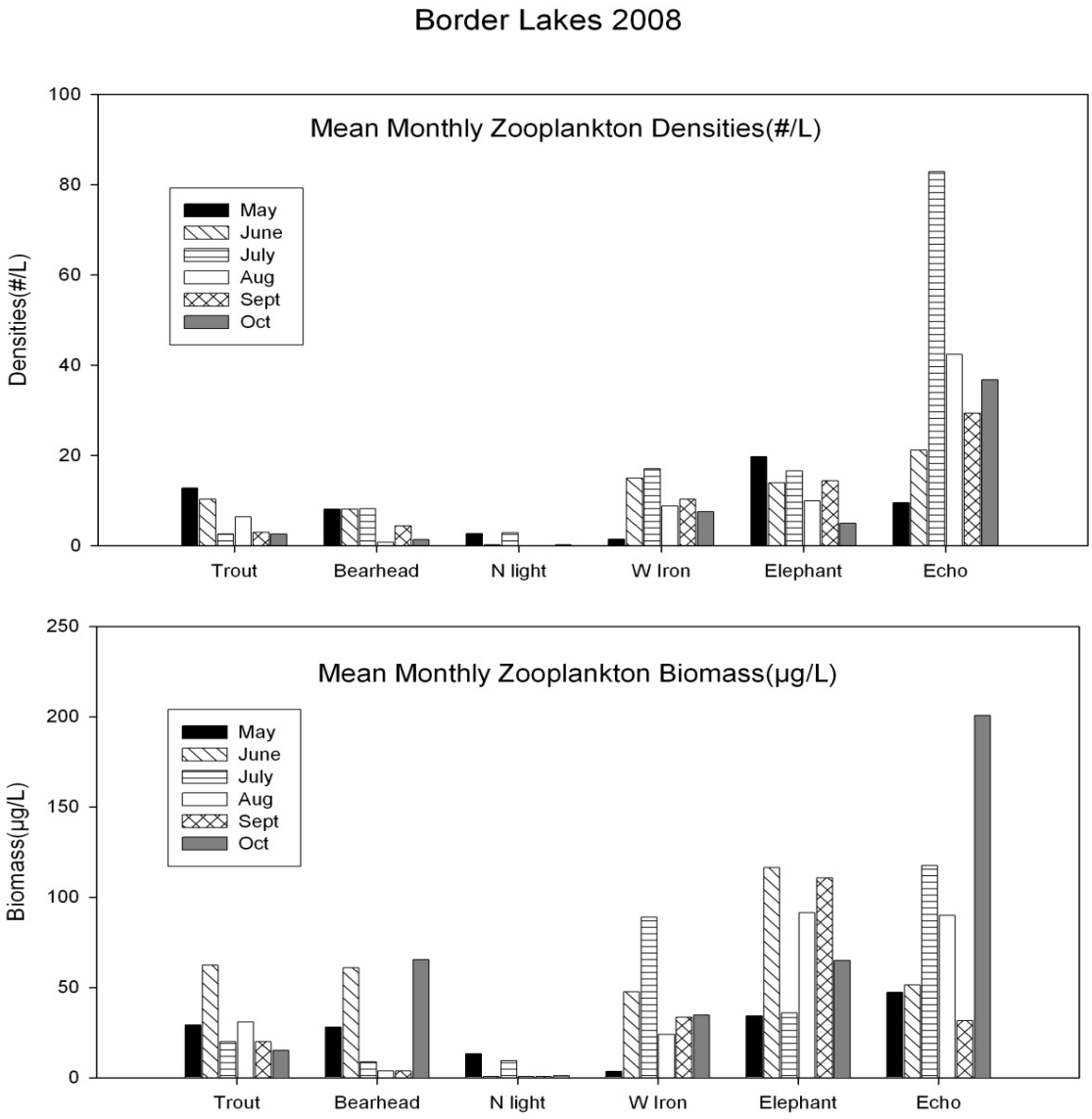
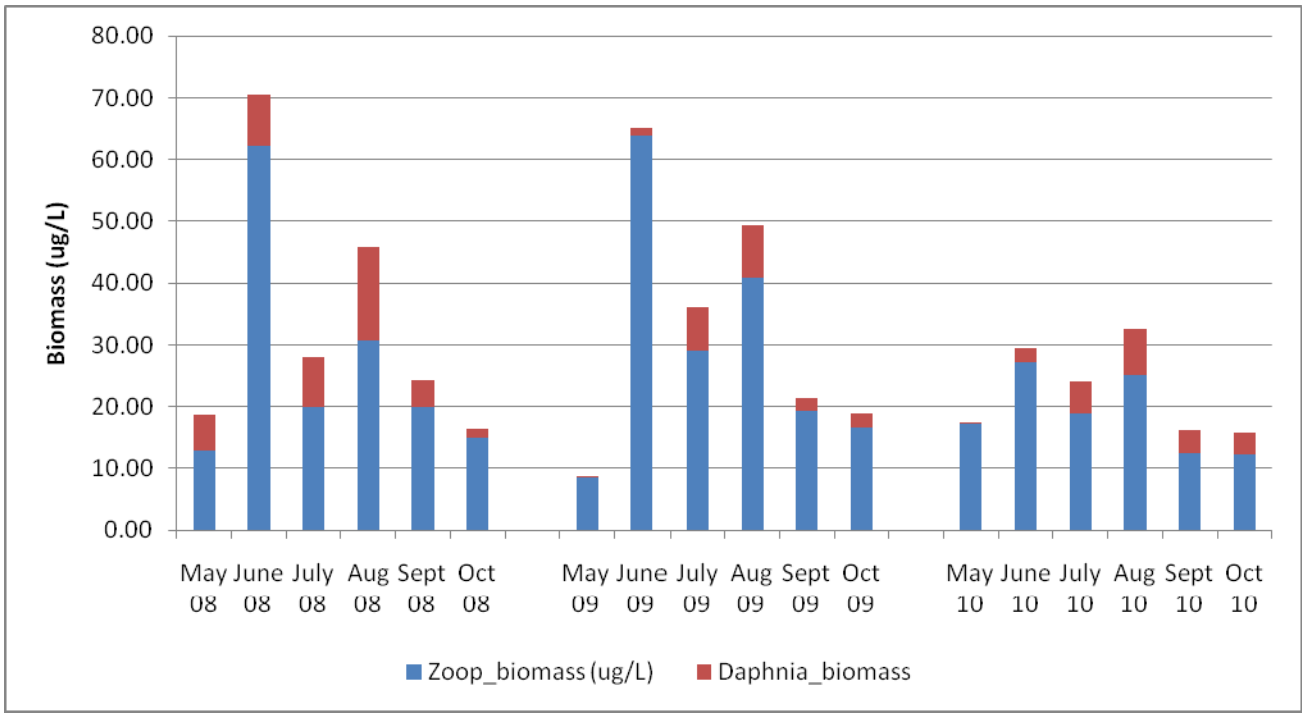


Table 15. 2008 zooplankton data from all Sentinel Lakes

Sentinel Lakes zooplankton 2008	Mean annual densities (#/L)	Mean annual biomass (µg/L)	Total# taxa
Western Cornbelt Plains (WCBP & NGP)			
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 (NCHF)			
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 (NLF)			
Portage	100.10	277.38	10
Red Sand	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 (NLF)			
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

Figure 23. Zooplankton biomass and density in Trout Lake, 2008-2010



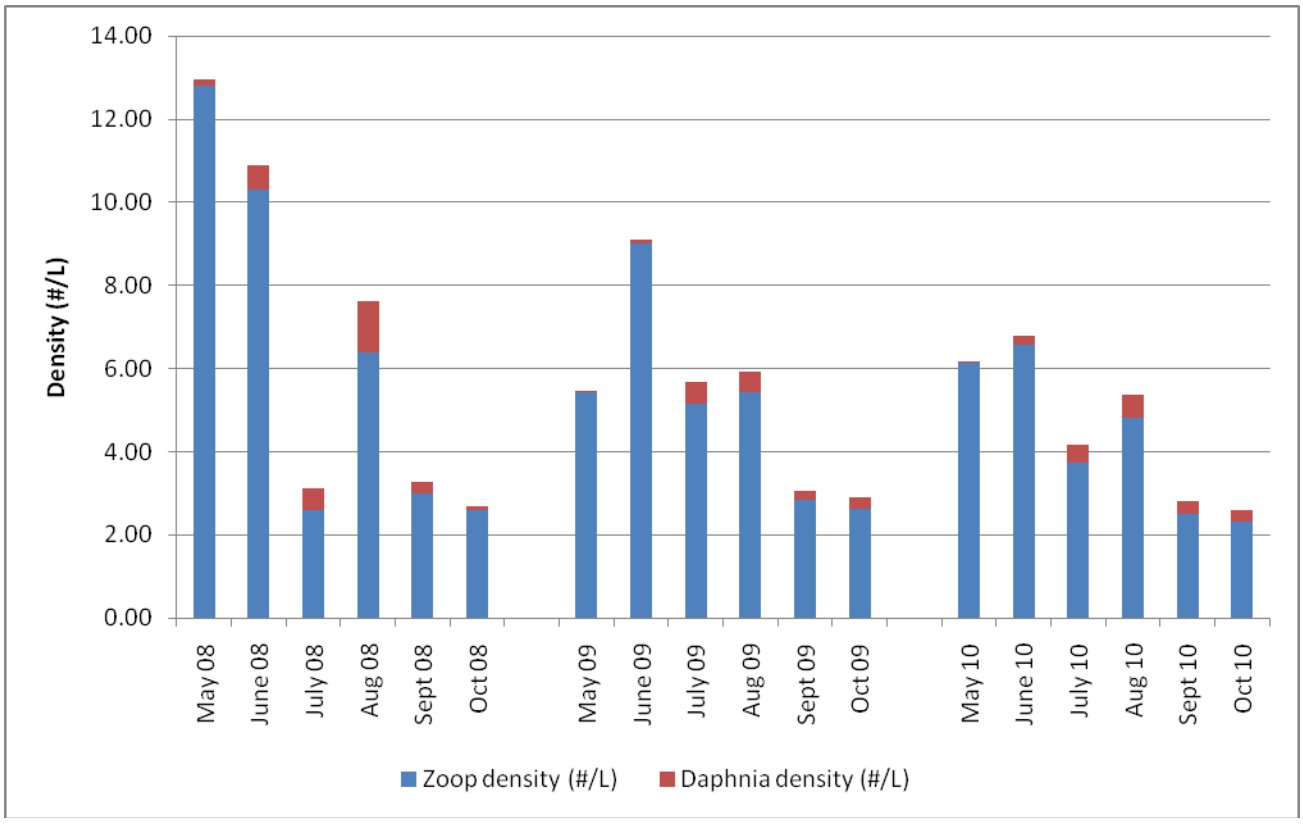
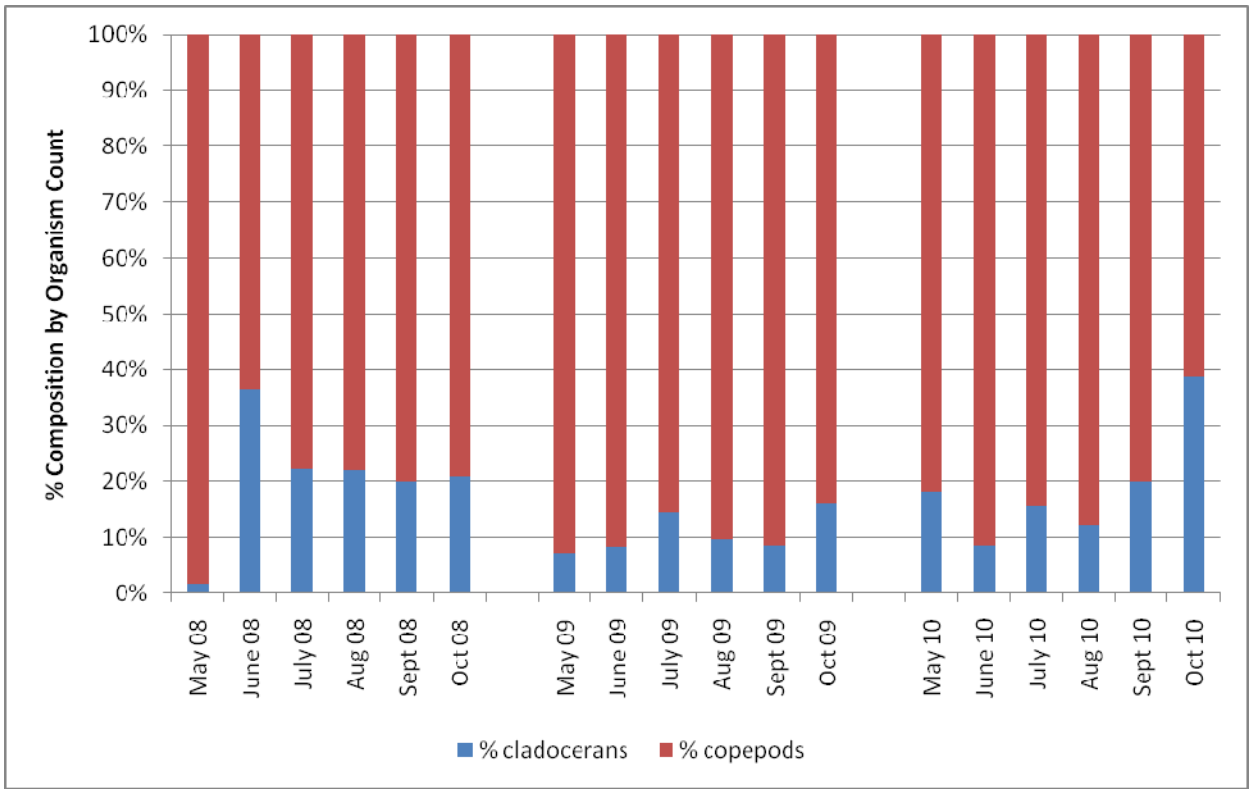


Figure 24. Cladoceran and copepod counts in Trout Lake, 2008-2010



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:

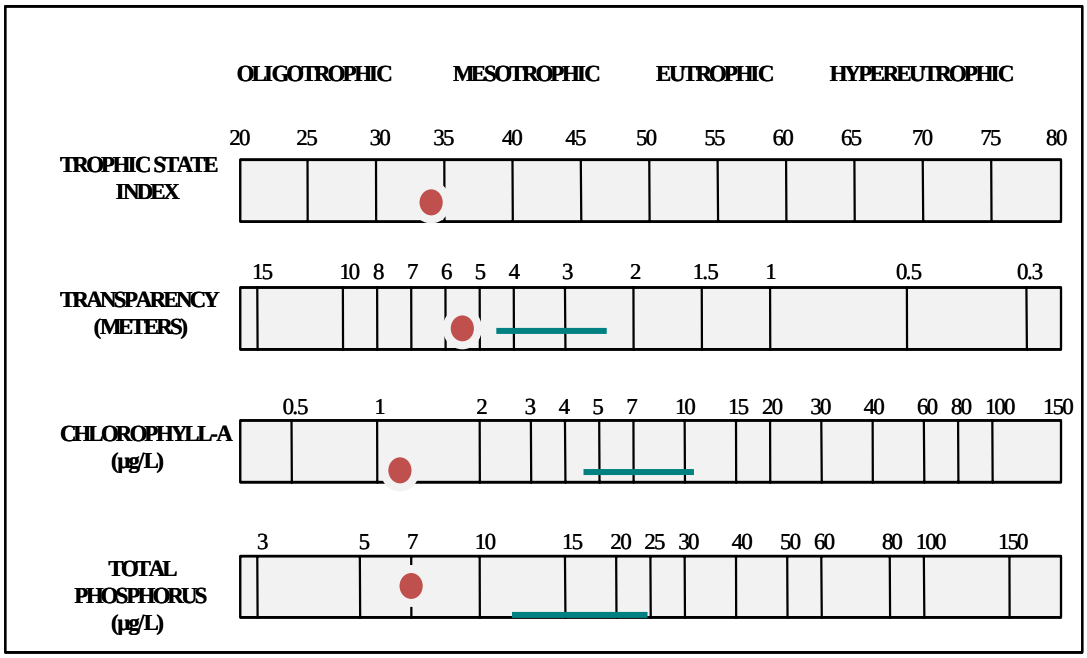
Total Phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

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 25). In general, the phosphorus, chlorophyll, and Secchi TSI values for Trout Lake are in fairly close correspondence with each other (though Secchi is slightly low relative to TP). The TSI values are shown based on MPCA data for 2008-2010 (Figure 25). Based on an average TSI score of 34 Trout Lake would be characterized as oligotrophic.

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.



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

NLF Ecoregion Range — Trout Lake 2008-2010

Figure 25 Trout Lake TSI values from 2008-2010 MPCA Sentinel Lake monitoring data

Trophic Status Trends

One aspect of lake monitoring is to assess trends in the condition of the lakes, where possible, based on data gathered through the MPCA's Citizen Lake Monitoring Program or other available data in STORET. A review of EQuiS data indicates there is abundant data for Trout Lake to describe annual variability and to assess trends. This includes data that was collected in the mid 1980s when Trout was used as an ecoregion reference lake (Heiskary and Wilson 2005). In general, for trend assessment we seek a minimum of eight years of consistent data. Formal trends cannot be determined on Trout because the water quality record is not consecutive. Based on yearly TSI averages calculated for the 1980's through 2010, Trout Lake has historically been classified as oligotrophic, with averages near 30 (Figure 26). Secchi derived TSI values have averaged about 32, with some annual variability. Intensive water quality monitoring (TP and chl-*a* sampling) occurred in the late 1980's, 2003, 2006, and 2008-2010. These data show stable concentrations of TP and chl-*a* within the last decade, with perhaps a decline in TP since the 1980's (Figure 27). Annual average TP and chl-*a* concentrations are consistently near seven and one µg/L respectively, indicating excellent water quality, and standard errors are low.

A formal non-parametric statistical analysis of historical Secchi transparency data on Trout Lake was not performed since the historical record is not consecutive; however, a review of the data indicate that clarity has declined since the late 1980's. The long-term mean transparency is 6.9 m (Figure 28). Transparency averaged eight m from 1986-1990, versus 5.8 m from the last decade (2003, 2006, and 2008-2010); a decline of 2.2 m (seven feet). The cause of this decline is unknown, given the stability of land use in the lake's forest-dominated watershed. Possible explanations may include shifts in zooplankton composition over time, or predator-prey interactions between rainbow smelt and zooplankton. Continued long-term monitoring of water quality and biota is essential to determine if this trend is due to natural variability, climate change, biotic interactions, or other causes.

Figure 26. Trout Lake trophic status trend

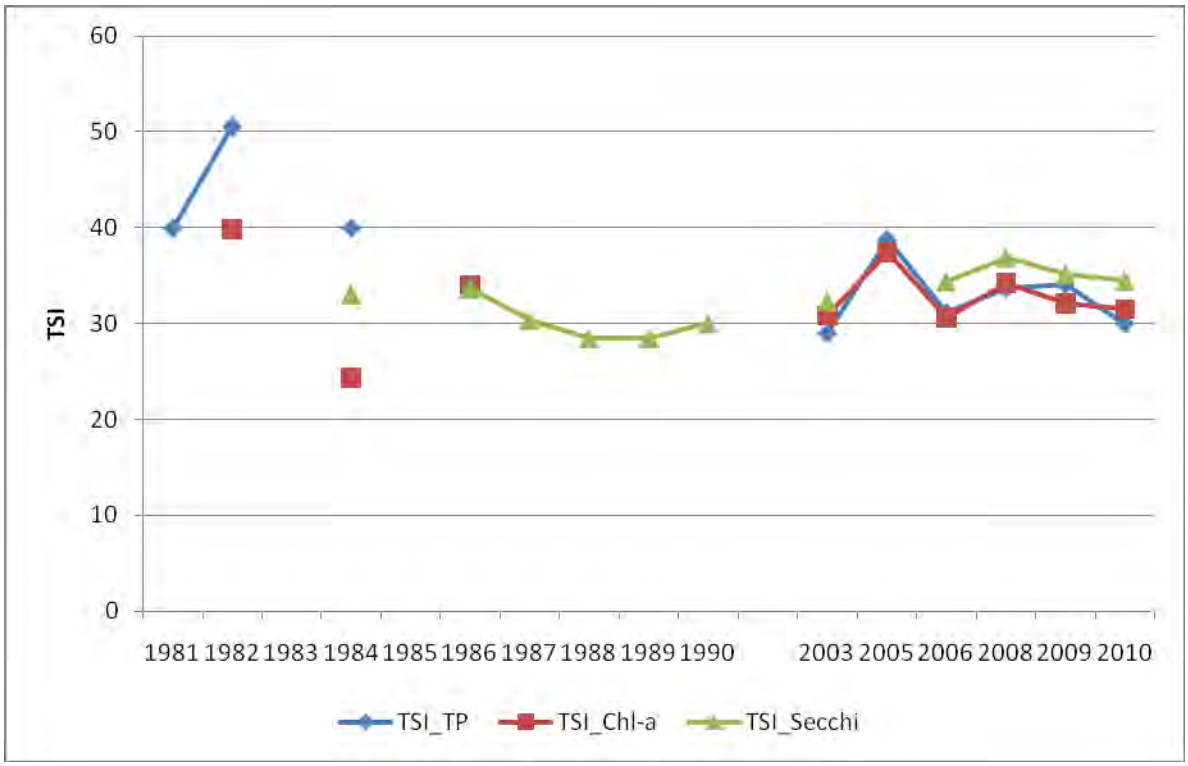


Figure 27. Trout Lake long-term summer-mean total phosphorus and chlorophyll-a concentrations. Standard error of the mean noted for each year.

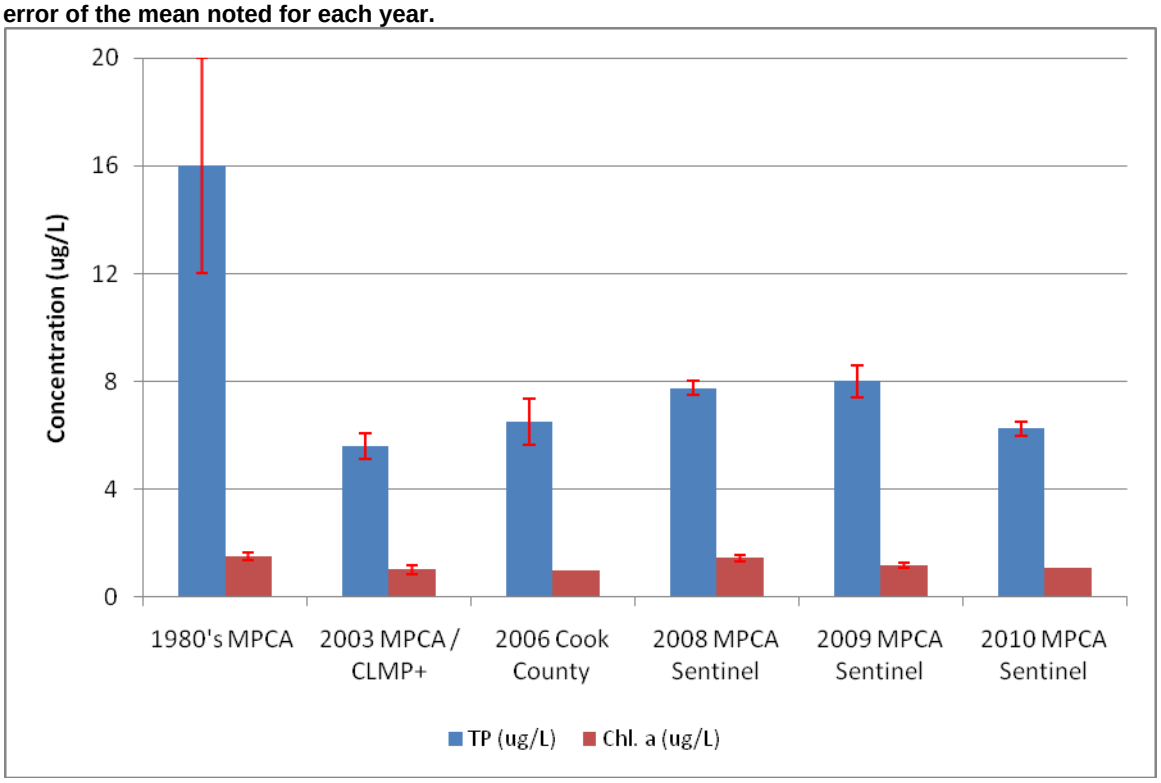
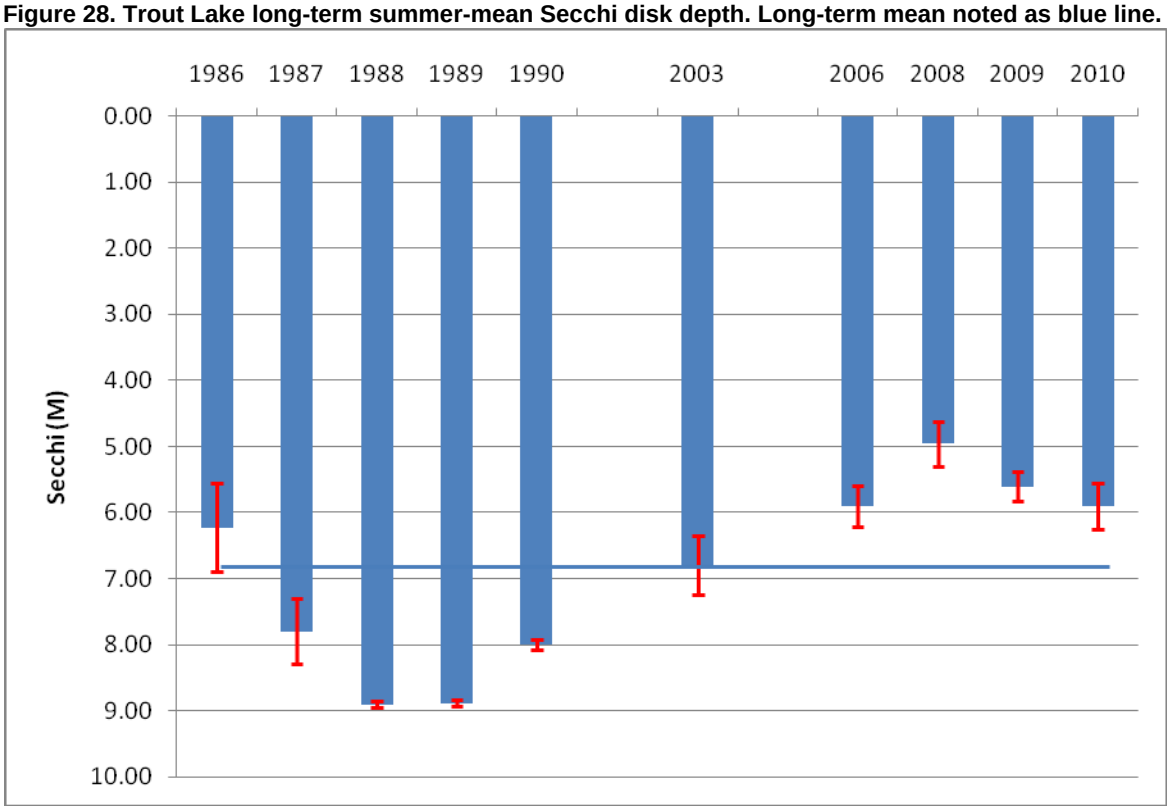


Figure 28. Trout Lake long-term summer-mean Secchi disk depth. Long-term mean noted as blue line.



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 2008-10 water quality of Trout 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 16.

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. Chl-*a* and Secchi predictions are derived from Minnesota-based regression equations. For analysis of Trout Lake, MINLEAP was applied as a basis for comparing the observed (2008-10 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.

Trout Lake is located in the NLF ecoregion and the model was run using NLF-based inputs. To improve model predictions, inflow TP concentration was calibrated to match the 2010 average monitored inflow concentration (16 µg/L). The observed and predicted TP and chl-*a* values for Trout Lake are nearly identical. Observed Secchi is lower than predicted, but not statistically different. MINLEAP predicts a P loading rate of about 30 kilograms per year entering Trout Lake from its small, forested watershed. The model predicts approximately 74 percent of the TP will be retained in the lake, a reasonable estimate given the lake's small watershed, and relatively long residence time (estimated at 10-11 years). 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 Trout Lake, this value is estimated to be 8.6 µg/L, close to the observed concentration (Table 16).

Table 16. MINLEAP model results for Trout Lake

Parameter	2008- 2010 Trout Lake Observed	MINLEAP Predicted NLF Ecoregion
TP (µg/L)	7	8
Chl-*a* (µg /L)	1.2	1.3
Secchi (m)	5.4	6.5
P loading rate (kg/yr)	-	29
P retention (%)	-	74
P inflow conc. (µg/L)	-	16
Water Load (m/yr)	-	0.9
Outflow volume (hm^3/yr)	-	0.9
Residence time (yrs)		10.7
Vighi & Chiaudani		8.6

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 for which we 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.

Trout Lake was assessed relative to the NLF Class 2A ecoregion standards (Table 17). The 2008, 2009, 2010, and long-term summer TP mean for Trout Lake are below this value. Likewise, chl-*a* is below the standard for the NLF ecoregion. Based on these results, Trout Lake is meeting eutrophication criteria for NLF 2A waters (i.e. those waters that support a lake trout fishery).

Table 17. Eutrophication standards by ecoregion and lake type (Heiskary and Wilson, 2005). Trout Lake 2008-2010 summer means; long-term means provided for comparison.

Ecoregion	TP µg/L	Chl-*a* µg/L	Secchi 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
Trout Lake 2008	**7.7**	**1.4**	**4.6**
Trout Lake 2009	**8.0**	**1.2**	**5.7**
Trout Lake 2010	**6.2**	**1.1**	**5.9**
Trout Lake long-term mean	**10.0**	**1.3**	**6.9**

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Appendix A

Lake Surface Water Quality Data for Trout Lake for 2008-2010 (MPCA Data)

All water quality data can be accessed at: http://www.pca.state.mn.us/data/eda ; blank cells = no data

Lake Name	Lake ID	Sample Date	Site ID	Secchi	TP	Chl-*a*	Alkalinity	Chloride	TKN	Color, Apparent	TSS
				Meters	µg/L	µg/L	mg/L	mg/L	mg/L	PCU	mg/L
Trout	16-0049	5/14/08	101	6.1	6	1.0	15	1	0.2	20	<1
Trout	16-0049	6/19/08	101	6.1	7	1.3	14	<1	0.4	5	<1
Trout	16-0049	7/30/08	101	3.6	8	1.3	14	<1	0.3	5	<1
Trout	16-0049	8/14/08	101	4.6	8	1.6	14	<1	0.3	5	2
Trout	16-0049	9/17/08	101	4.3	8	1.7					
Trout	16-0049	10/15/08	101	4.6	7	4.3	16	<1	0.3	5	1.2
Trout	16-0049	5/19/09	101	5.2	10	1.7	14	<1	0.3	5	1.2
Trout	16-0049	6/15/09	101	6.8	9	1.1			0.3		
Trout	16-0049	7/14/09	101	5.8	7	1.4	14	<1	0.3	5	4.8
Trout	16-0049	8/10/09	101	5.2	7	1.2			0.3		
Trout	16-0049	9/21/09	101	5.2	9	1.0			0.6		
Trout	16-0049	10/12/09	101	5.9	9	2.2	13	<1	0.3	10	2.8
Trout	16-0049	5/24/10	101	5.1	17	1.1	15	0.75	0.2	10	1.2
Trout	16-0049	6/21/10	101	6.1	7	0.8	13	<0.5	0.3	5	3.6
Trout	16-0049	7/19/10	101	6.1	6	1.1	21	<1	0.5	5	1.2
Trout	16-0049	8/23/10	101	6.5	6	1.2	13	<0.5	0.3	5	2
Trout	16-0049	9/20/10	101	4.9	6	1.4	17	0.37	0.3	5	3.6
Trout	16-0049	10/11/10	101	5.8	13	1.7	15	<0.5	0.2	10	9.2