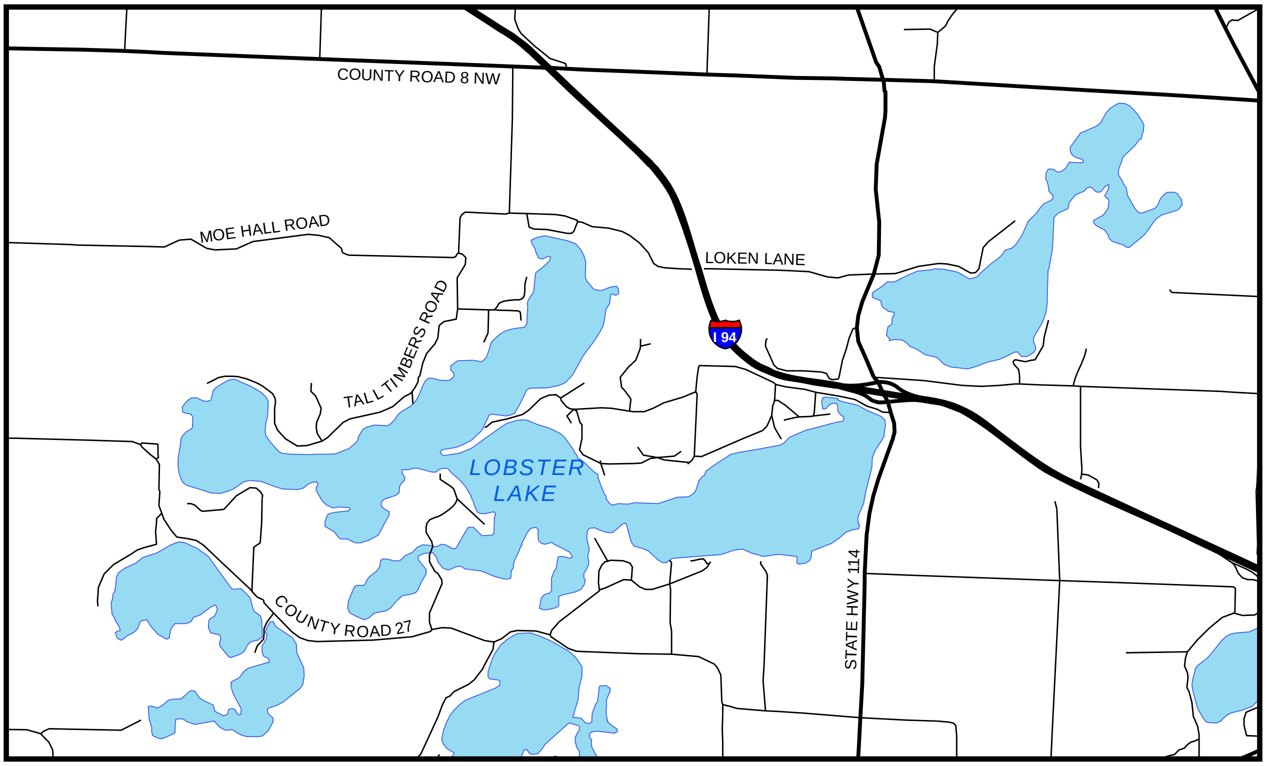
Lobster Lake Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+):

Advanced Volunteer Lake Monitoring

Douglas County



Minnesota Pollution Control Agency

December 2005

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Lobster Lake Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+):
Advanced Volunteer Lake Monitoring
Douglas County

Lobster Lake (East Bay)	**(21-0144-01)**
Lobster Lake (West Bay)	**(21-0144-02)**

Minnesota Pollution Control Agency

Environmental Analysis and Outcomes Division
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Lobster Lake Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring Douglas County

Part 1: Program History and Background Information on Minnesota Lakes

Minnesota's Citizen Lake-Monitoring Program (CLMP) is the largest and oldest volunteer lake-monitoring program in the country. Volunteers in the CLMP currently use a Secchi disk to measure the clarity on hundreds of Minnesota's lakes. The expanded program, including the collection of water chemistry samples for analysis along with Secchi transparency collection, was conducted in several counties. A total of sixteen lakes were selected for monitoring in 2005 by volunteer lake monitors. These lakes were: Latoka, Lobster and Mary Lakes (Douglas County); Big Kandiyohi, Diamond, Long, and Wakanda Lakes (Kandiyohi County); Blueberry, Duck, Jim-Cook, Lower Twin, Morgan, Upper Twin Lakes (Hubbard/Wadena Counties); Bass, Howard, and Pleasant Lakes (Wright County). Spirit and Stocking Lakes (Wadena County) were also sampled by volunteer lake monitors through the County. The data from these two additional lakes was incorporated in the 2005 Wadena County CLMP+ report. All equipment and analytical costs for the samples were provided for and paid by the Minnesota Pollution Control Agency (MPCA). *Note: Only data from Lobster Lake will be discussed in this update report.*

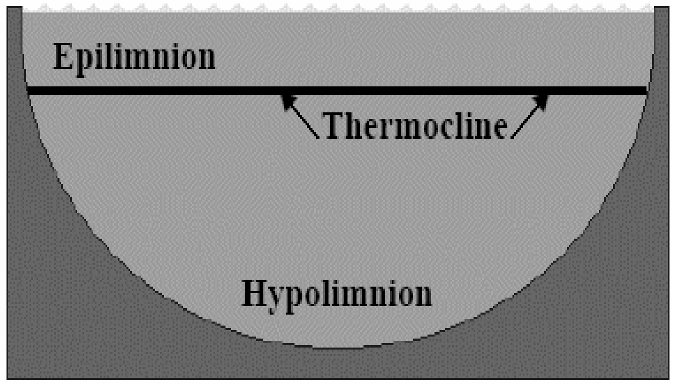
Volunteers on these lakes collected water chemistry samples and temperature profiles twice per month along with their weekly Secchi transparency readings. After sampling, the volunteers dropped off their samples at a predetermined location within their county. Jerry Haggenmiller and Kory Kosek, Douglas County Soil and Water Conservation District (SWCD), helped plan and coordinate the sample drop-off/pick up schedule for the samples in Douglas County. Special thanks to the volunteers on Lobster Lake who helped make this project a success: Pete Onstad, Richard Knutson, Ron Hofstedt and Hardy Huettl. MPCA staff and volunteer monitors collected quality assurance and quality control (QA/QC) samples for this project.

The MPCA core lake-monitoring programs include the CLMP, the Lake Assessment Program (LAP), and the Clean Water Partnership (CWP) Program. In addition to these programs, the MPCA annually monitors numerous lakes to provide baseline water quality data, provide data for potential LAP and CWP lakes, and characterize lake conditions in different regions of the state. MPCA also examines year-to-year variability in ecoregion reference lakes and provides additional trophic status data for lakes exhibiting trends in Secchi transparency. Lobster Lake was included in the MPCA's LAP program in 1990 with the help of the Lobster Lake Association.

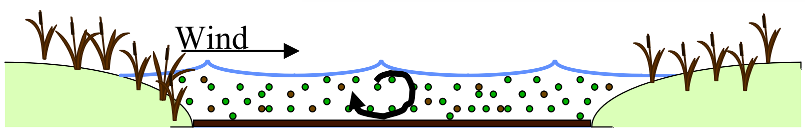
The state of Minnesota is divided into seven ecoregions (Figure 1), based on soils, landform, potential natural vegetation, and land use. Lobster Lake is located within the North Central Hardwood Forest (NCHF) ecoregion. Comparing a lake's water quality to that of reference lakes in the same ecoregion provided one basis for characterizing the condition of the lake.

Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 30 - 40 feet or more) often stratify (form layers) during the summer months and are referred to as *dimictic*. These lakes full-mix or turn-over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 20 feet or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Some lakes, intermediate between these two, may stratify intermittently during calm periods. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth interval). In general, the upper, well-mixed layer (epilimnion) is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. Most of the fish in the lake will be found in the epilimnion or near the thermocline. The combined effect of depth and stratification can influence overall water quality.

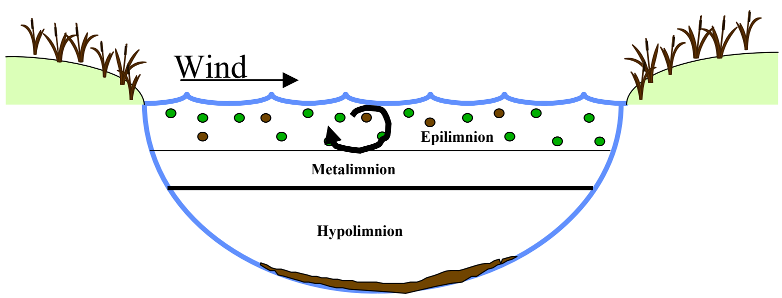
Diagram of Lake Layers for Deep and Shallow Lakes



Polymictic Lake
Shallow, No Layers,
Mixes Continuously
Spring, Summer & Fall



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Summer



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Spring/Fall

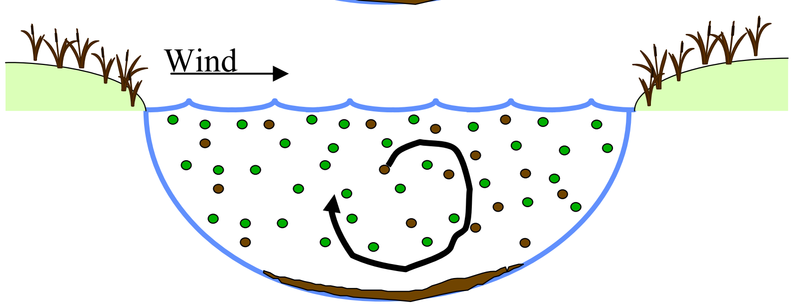
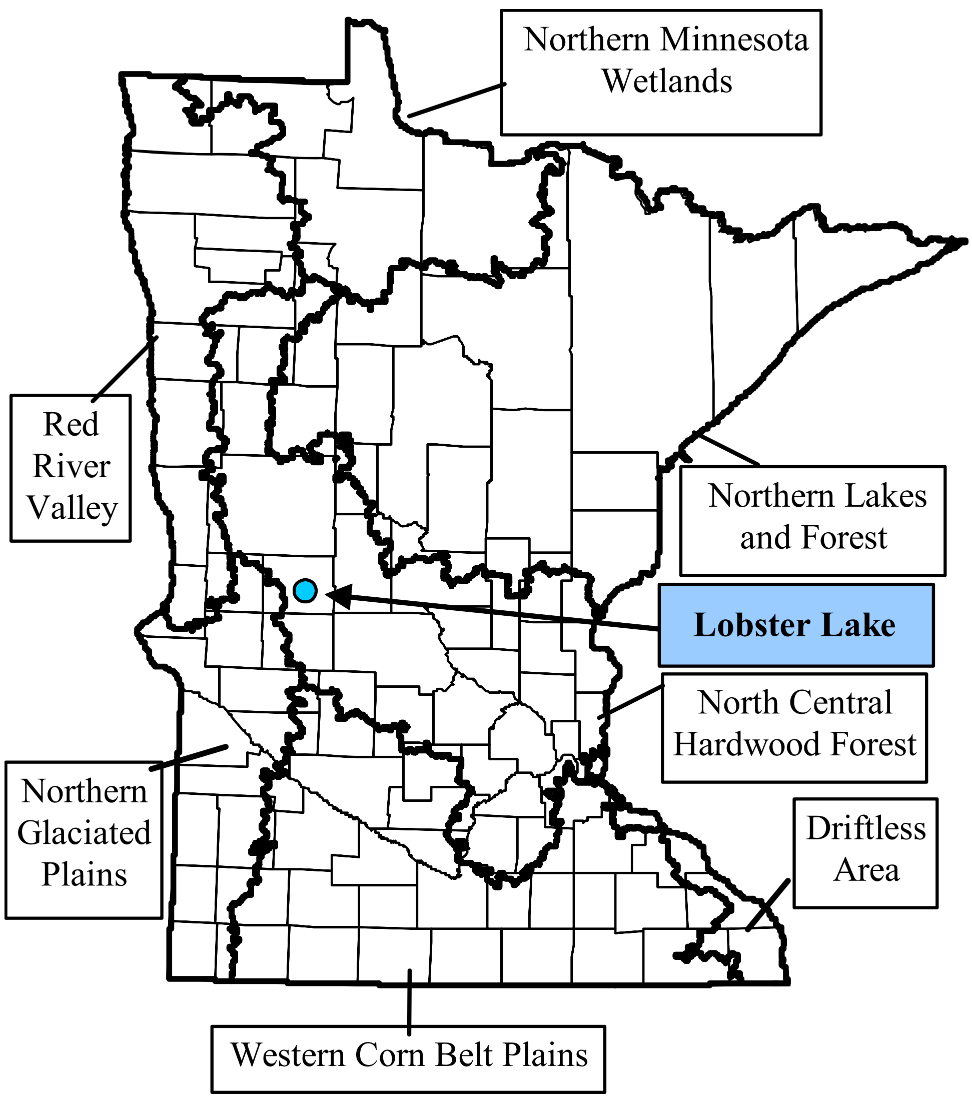


Figure 1. Minnesota's Ecoregions and Counties



Part 2: 2005 Lake Surveys

Methods

This report includes data from 2005 as well as previously collected data available in STORET, U.S. Environmental Protection Agency's (EPA) national water quality data bank (Appendix). The following discussion assumes familiarity with basic limnology terms as used in a "Citizens Guide to Lake Protection" and as commonly used in LAP reports. A glossary of terms is included in the appendix and can also be accessed at http://www.pca.state.mn.us/water/lakeacro.html.

One site in each bay of the lake was monitored twice per month, from June through September. Lake surface samples were collected with an integrated sampler, constructed from a PVC tube

6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Lake-bottom samples were collected 1 meter off the bottom of the lake by MPCA staff using a Kemmerer sampler. Seasonal averages were calculated using June – September data. Sampling procedures were employed as described in the MPCA Quality Control Manual and Citizen Lake-Monitoring Program "Plus" Manual. Laboratory analyses were performed at the Minnesota Department of Health using EPA-approved methods. Surface samples from volunteers were analyzed for: total phosphorus (TP), chlorophyll-*a*, and pheophytin. Secchi disk transparency and user perception information was recorded at all sites. Volunteers also collected temperature profiles for each site using a FishHawk Model 520 digital depth and temperature meter. Algae samples were collected from the chlorophyll-*a* sample bottles and preserved with Lugol's solution.

MPCA staff collected surface samples and bottom samples for each site on three occasions. These data serve to augment the volunteer collection and provide an opportunity for comparison of results. MPCA collected surface samples were analyzed for the following parameters: TP, chlorophyll-*a*, pheophytin, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), suspended volatile solids (SVS), total chloride, alkalinity and color. Conductivity, pH, and dissolved oxygen and temperature profiles were collected using a Hydrolab multi-probe unit. Lake-bottom samples were analyzed for TP. Secchi disk transparency and user perception information was recorded for each site. Qualitative analysis of zooplankton collected using a zooplankton net was also recorded for each site.

Additional information, such as bathymetric (contour) and location maps, was obtained from the DNR's lakefinder Web site (http://www.dnr.state.mn.us/lakefind/index.html) and the MPCA Web site (http://www.pca.state.mn.us) and from U.S. Geological Survey quad maps. Watershed area information for the lake was provided from the 1990 LAP report.

Data Analysis

A series of graphs are presented for each bay including: TP, chlorophyll-*a*, Secchi disk transparency, and temperature profiles. Sample dates with a single asterisk indicate data collected by the MPCA. Dates with no asterisk were collected by CLMP volunteer lake monitors. All raw data for each lake and site are available in the appendix.

The Quality Assurance/Quality Control (QA/QC) samples were taken routinely throughout the sampling season. Thirteen field duplicate TP samples were taken. A field duplicate is a second sample taken right after an initial sample in the exact same location. Field duplicates assess sampler and laboratory precision (reproducibility). Duplicate sample are collected in the exact same manner as the first sample, including the normal sampling equipment cleaning procedures. Of these 13 samples, the percent difference ranged from 0 – 33 percent of the original sample, with the majority (77 %) falling within the 0 – 15 percent range. Of the 12 paired chlorophyll-*a* samples, the percent difference range was 2 – 16 percent, with the majority (83 %) falling within the 0 – 15 percent range. These results are very good considering the difference in quality of the participating lakes and varying concentration levels of these parameters. Four TP sample results from the following lakes were omitted due to sample contamination from adding Lugol's solution instead of sulfuric acid preservative: Duck Lake (Hubbard County), Upper Twin Lake (Hubbard County), Lower Twin Lake (Wadena County), and Pleasant Lake (Wright County).

One chlorophyll-*a* sample from Duck Lake (Hubbard County) was also omitted due to sample contamination from Lugol's.

Several TP samples from early June, for the CLMP+ lakes, were held for one week longer than the recommended holding time due to the 2005 government shutdown. However, given that the samples were properly preserved with acid, kept cool and in a dark place, we do not feel these samples were compromised. Several color results were also held over the recommended holding time by one day. As with the TP samples, the integrity of these samples should also still be acceptable.

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration, chlorophyll-*a* concentration, and Secchi disk transparency of the lake based on the lake area, lake depth, and the area of the lake's watershed. Additional information about this model can be found in the modeling section of this report or a complete explanation of this model may be found in Wilson and Walker (1989).

Table 1. Lobster Lake Morphometric and Watershed Characteristics

Morphometry	21-0144-01 East Bay	21-0144-02 West Bay	Whole Lake
Area[1]	**724 acres 293 ha 1.1 mi^2**	**513 acres 208 ha 0.8 mi^2**	**1,237 acres 501 ha 1.9 mi^2**
Mean Depth[1]	**16 feet 4.9 meters**	**14 feet 4.3 meters**	**15.2 feet 4.6 meters**
Maximum Depth[1]	**65 feet 19.8 meters**	**35 feet 10.7 meters**	**65 feet 19.8 meters**
Volume[1]	**11,584 acre-feet 14.3 hm^3**	**7,182 acre-feet 8.9 hm^3**	**18,766 acre-feet 23.2 hm^3**
Littoral Area[2]			**~ 51 %**
Watershed area[1] *(excludes the lake)*			**31,360 acres 12,696 ha 49 mi^2**
Watershed:Lake[1]	**-**	**-**	**25:1**

Table 2: Lobster Lake 1990 and 2005 Average Summer Water Quality
(Based on 1990 and 2005 epilimnetic data.)

Parameters	East Lobster 1990	West Lobster 1990	East Lobster 2005	West Lobster 2005	Typical Range for NCHF Ecoregion[3]
Total Phosphorus (µg/L)	21.0	35.0	22.2	25.3	23 – 50
Chlorophyll-*a* (µg/L)[4] **Mean**	10.8	14.9	6.6	9.3	5 – 22
Chlorophyll-*a*(µg/L)[4] **Maximum**	18.2	20.8	11.4	18.0	7 – 37
Secchi disk (m)	2.2	1.8	2.6	2.3	1.5 – 3.2
Secchi disk (feet)	7.1	6.1	8.6	7.6	4.9 – 10.5
Total Kjeldahl Nitrogen (mg/L)	1.4	1.6	0.9	1.0	0.62 – 1.2
Alkalinity (mg/L)	193	187	187	177	75 – 150
Color (Pt-Co Units)	10	13	12	13	10 – 20
pH (SU)	--	--	7.9	8.0	8.6 – 8.8
Chloride (mg/L)	12.3	12.3	17	16	4 – 10
Total Suspended Solids (mg/L)	4.4	5.3	3.8	3.2	2 – 6
Total Suspended Inorganic Solids	1.8	2.2	2.0	2.7	1 – 2
Conductivity (µmhos/cm)	415	417	357	349	300 – 400
TN:TP Ratio	67:1	46:1	41:1	40:1	25:1 – 35:1

Table 3. Lobster Lake Trophic Status Indicators: 1990 and 2005

TSI Parameter	East Lobster 1990	West Lobster 1990	East Lobster 2005	West Lobster 2005
TP TSIP =	**47**	**54**	**49**	**51**
Chl-*a* TSIC =	**53**	**56**	**49**	**52**
Secchi TSIS =	**50**	**53**	**46**	**48**
Mean (All) TSI =	**50**	**53**	**48**	**50**

[1]MPCA Lake Assessment Report (Heiskary, 1991)
[2]DNR Web Site (www.dnr.state.mn.us)
[3] Based on approximately 700 assessed lakes in the North Central Hardwood Forests Ecoregion
[4] Chlorophyll-*a* measurements have been corrected for pheophytin.

Figure 2. Carlson's Trophic State Index, based on a scale of 0 – 100. (Carlson 1977)

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.

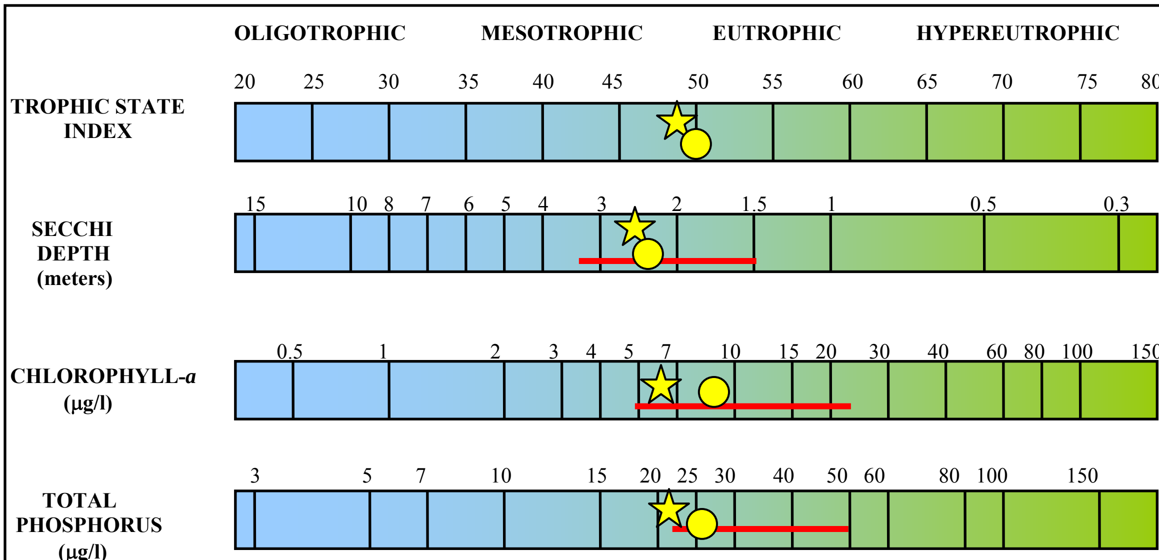
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

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 bluegreen 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.

NCHF Ecoregion Range, 25th – 75th percentile: 2005 East Lobster:

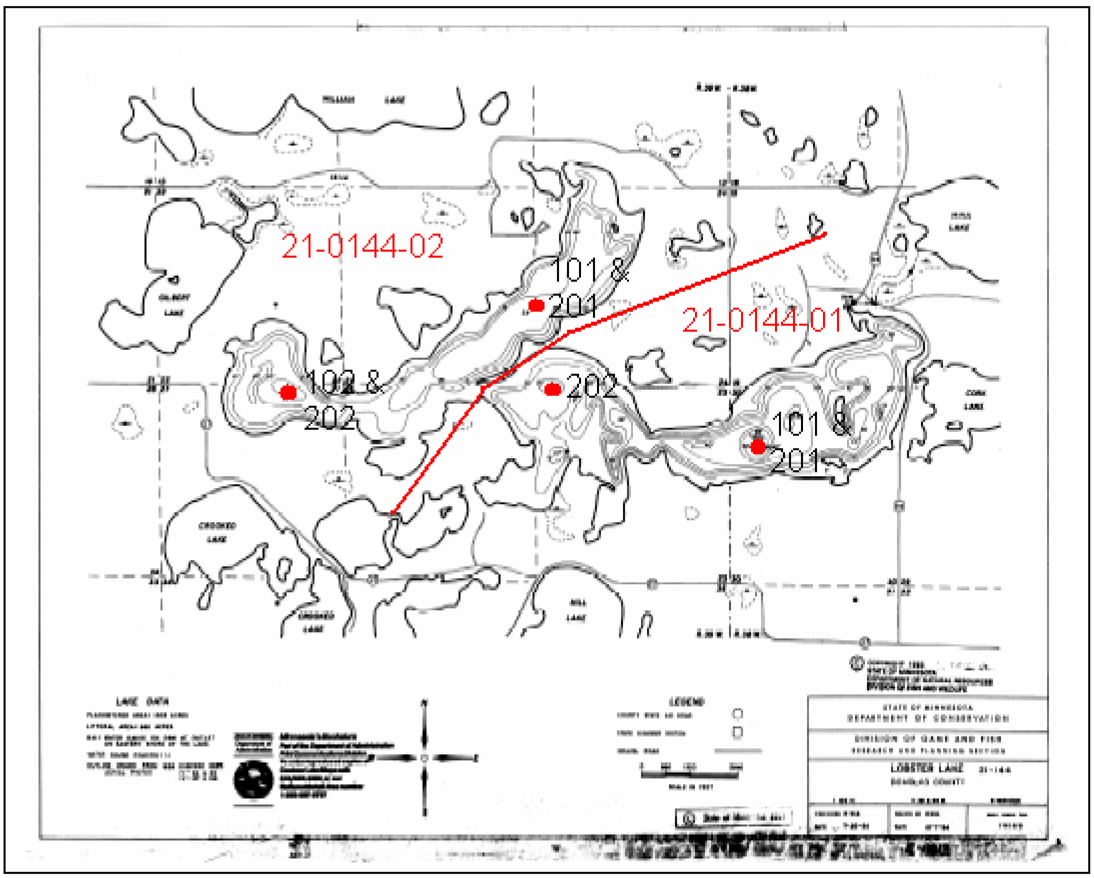
2005 West Lobster:

Lobster Lake (21-0144-01 and 21-0144-02)

Lobster Lake is located approximately six miles south of Garfield, Minnesota. It is a large lake with two distinct basins that lie in an east-west orientation. The whole lake covers 1,237 acres with maximum depth of 65 feet (west basin) and mean depth of 15.2 feet. It is in the upper five percent of lakes in terms of its size. Approximately 51 percent of the lake is littoral and there is one public access for the lake. It has a very large watershed, 49 mi^2; and as such, the watershed to lake ratio is also large at 25:1 (Table 2). The majority of the watershed flows into the eastern basin before flowing out to Lake Mina. Its water residence time is on the order of one to two years.

Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitors: Pete Onstad, Richard Knutson, Ron Hofsted and Hardy Huetl. Two sites were used on Lobster Lake: Site 101– located in the east basin (21-0144-01) of the lake and Site 101 – located in the west basin (21-0144-02) (Figure 3).

Figure 3. Lobster Lake Bathymetric Map and Monitoring Location



Temperature data indicated that the lake was well-mixed at the May and late September sampling events in the east basin. In contrast, the west basin, which is shallower, was well-mixed on most sampling occasions. Surface temperatures ranged from 11.4 °C in May to 27 °C in early-September for the east basin (Figure 4). Temperatures ranged from 11.9 °C in May to 28 °C early-July for the west basin. Profile data for the east basin indicates that the lake was thermally stratified from 5 – 8 meters.

Figure 4. Lobster Lake Temperature Profiles for 2005

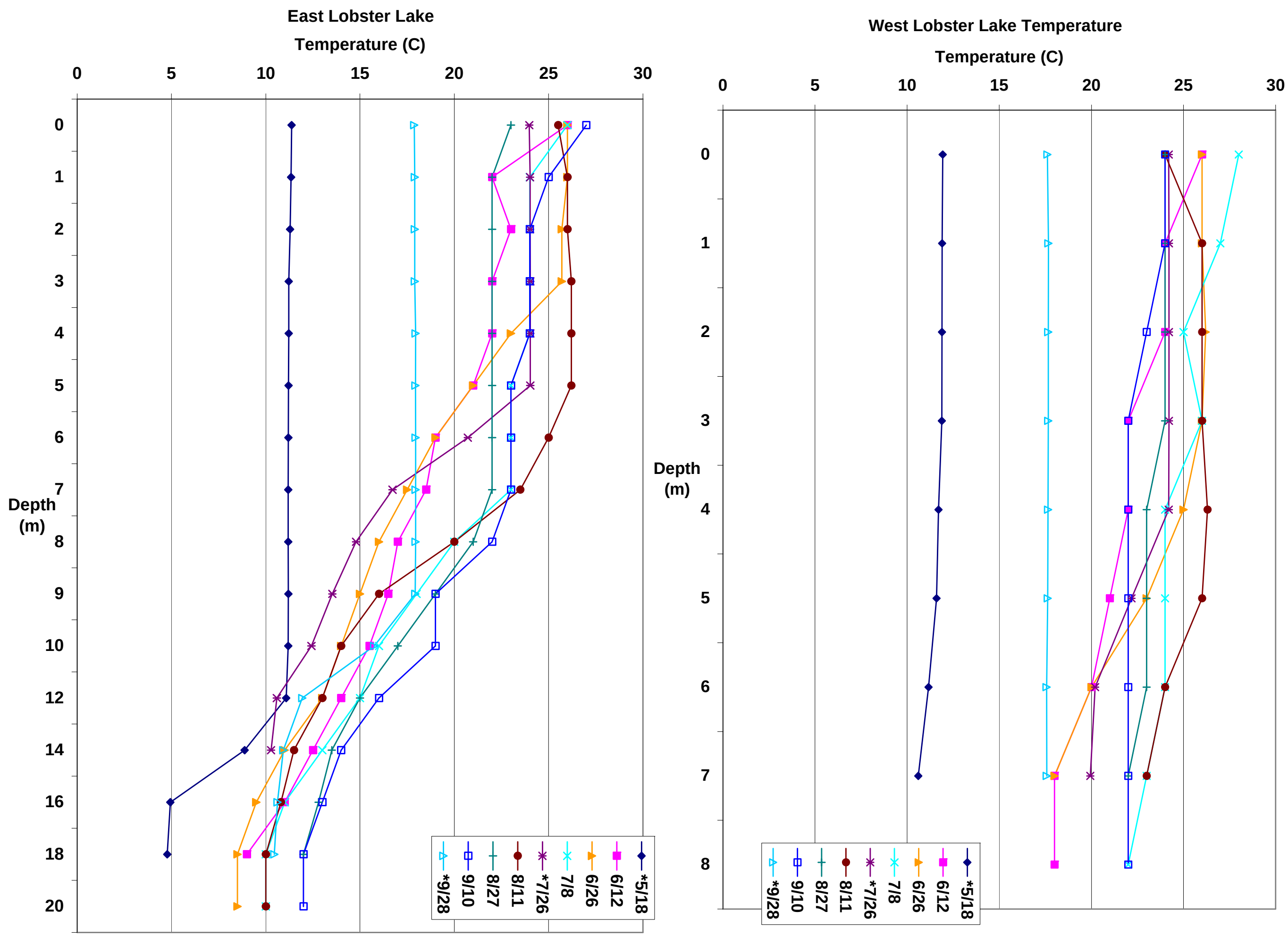
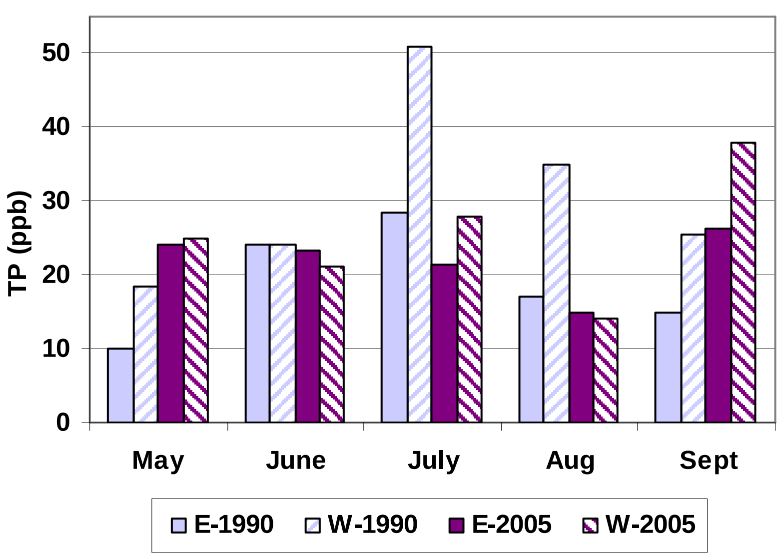
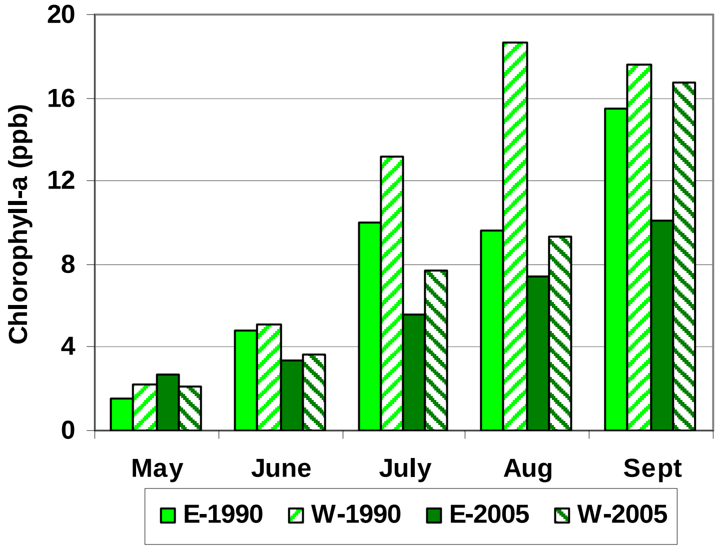


Figure 5. Lobster Lake Total Phosphorus Results



Total phosphorus (TP) concentrations averaged 22.2 and 25.3 µg/L (micrograms per liter or parts per billion) in East and West Lobster Lakes, respectively, during the summer of 2005. These values are better than or well within the typical range of concentrations for reference lakes in this ecoregion (Table 2). TP concentrations observed in 2005 ranged from 15 – 28 µg/L for East Lobster and from 13 – 42 µg/L for West Lobster (Appendix). With the exceptions of May and September, TP concentrations in 1990 were higher than in 2005. Although TP was higher in the east basin in June 2005 and August 2005 (by less than 2 µg/L), overall the concentrations in the west basin were higher than the east basin in both 1990 and 2005.

Figure 6. Lobster Lake Chlorophyll-*a* Results



Chlorophyll-*a* concentrations averaged 6.6 and 9.3 µg/L, respectively, for East and West Lobster Lakes in 2005 and were well within the ecoregion range (Table 2). Concentrations in the east basin ranged from 3.2 – 11.4 µg/L; while concentrations in the west basin ranged from 3.1 – 18 µg/L for 2005 (Appendix). Overall, chlorophyll-*a* values in 2005 were lower than those observed in 1990, with the exception of May (Figure 6). Also, chlorophyll-*a* concentrations were consistently lower in the east basin, with the exception of May 2005**.**

Figure 7a. East Lobster Lake Algal Populations for 2005

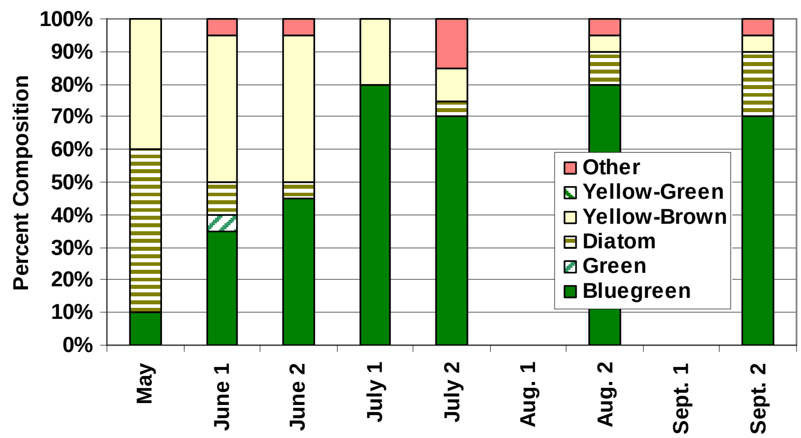
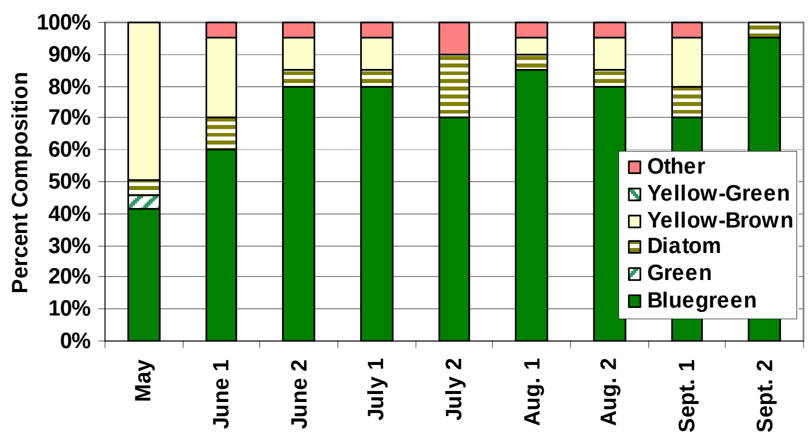


Figure 7b. West Lobster Lake Algal Populations for 2005



The composition of the phytoplankton (algae) populations of East and West Lobster Lakes are presented in Figures 7a and 7b. Data are presented in terms of algal type. Samples were collected at Site 101 for each basin. The yellow-browns and blue-greens were well represented throughout the summer, with blue-green algae dominating the algae population beginning in July for East Lobster and June for West Lobster. Bloom conditions (>10 µg/L chlorophyll-*a*) were evident during the August and September 2005 sampling events for West Lobster and were near bloom conditions during the September 2005 sampling event for East Lobster (Figure 6). No nuisance blooms (>20 µg/L chlorophyll-*a*) were noted for East or West Lobster Lake for 2005. A seasonal transition in algal types from diatoms to greens to blue-greens is typical for mesotrophic and eutrophic lakes in Minnesota.

Secchi disk transparency on East Lobster Lake ranged from 6.5 feet in early-August to 13.5 feet in late-June and averaged 8.6 feet for 2005 (Appendix). Transparency on West Lobster Lake ranged from 4.9 feet in late-September to 18 feet in May and averaged 7.6 feet for 2005 (Appendix). These transparency measures are well within the typical range for ecoregion reference lakes (Table 2). Transparency in the east basin was better than the west basin in 1990. With the exception of May and July, the same was true for 2005 transparency. Overall, Secchi transparency was better in 2005 in both basins as compared to 1990 (Figure 8).

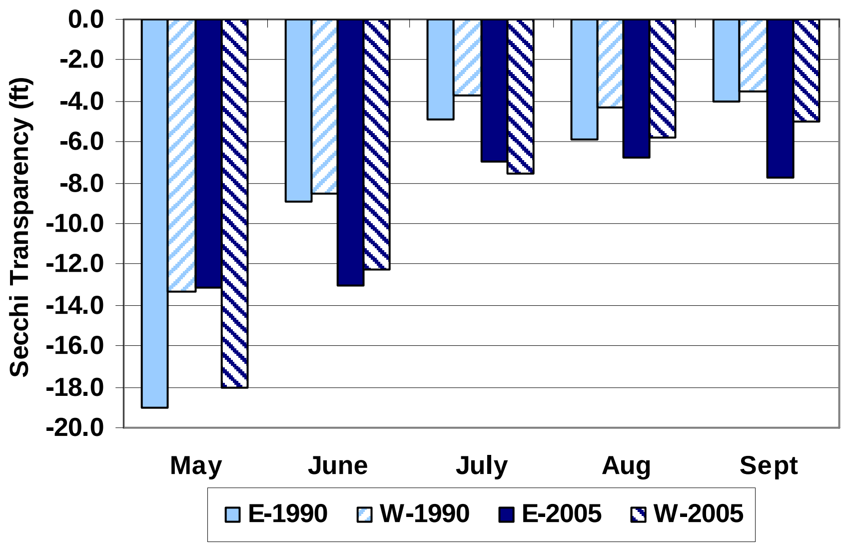


Figure 8. Lobster Lake Secchi Transparency Results

Along with transparency measurements, subjective measures of Lobster Lake's "physical appearance" and "recreational suitability" were made. Physical condition in 2005 was generally characterized as "not quite crystal clear" (Class 2) in both basins; while recreational suitability was primarily characterized as "beautiful" and "minor problems" (Classes 1 and 2) for both basins (Appendix).

Other parameters, such as total Kjeldahl nitrogen, color, total suspended solids and conductivity, analyzed for Lobster Lake were all near or well within the typical range of values for ecoregion reference lakes (Table 2) for both basins. The pH was slightly below the ecoregion reference range; while alkalinity and chloride were slightly above the ecoregion reference range for both basins. An increase in chloride was noted for both basins between the 1990 and 2005 studies. The primary source of chloride is most likely road salt usage. This is not unexpected given development in the area and that the lakes have an extensive road network around them and within their watershed.

Trophic State Index (TSI) values for each basin of Lobster Lake compare very favorably to each other (Table 3); indicating *mesotrophic* to *eutrophic* conditions for both basins. Based on TSI values, it appears that overall water quality in the east basin in 2005 (Mean TSI = 48) was slightly improved over 1990 water quality (Mean TSI = 50). TSI values for the west basin were also improved in 2005 (Mean TSI = 50) as compared to the 1990 values (Mean TSI = 53). Therefore, Secchi transparency should continue to be a good estimator for TP and chlorophyll-*a* values as well as an indicator of overall water quality for both basins of Lobster Lake.

Part 3. Water Quality Trends

All available Secchi transparency data from STORET (U.S. EPA's national water quality database) were used for these assessments. The majority of the data collected is from volunteer lake monitors in the MPCA's Citizen Lake-Monitoring Program and the Lake Association. For our trend analysis, we ran Kendall statistical test using WQ Stat Plus™ software on the CLMP+ lakes with four or more transparency readings per summer (June – September) and eight or more years of data. We used a probability (p) level of $p \leq 0.1$ as the basis for identifying significant trends. At this p-level, there is a 10 percent chance of identifying a trend when it does not exist. Simply stated, the smaller the p-value, the stronger the trend (i.e. more likely a trend occurred). Summer-mean transparency in a lake varies from year to year due to climatic changes (precipitation, runoff, and temperature), nutrient and sediment loading, and biological factors. Understanding and quantifying the relative magnitude of this variability is essential to assessing trends. Based on a previous study (Heiskary and Lindbloom 1993), typical year-to-year Secchi transparency variability was found to be on the order of 1 – 2 feet. In general, annual transparency in Minnesota lakes fluctuates within about 20 percent of the long-term mean. Lakes with larger fluctuations or non-random fluctuations, relative to the long-term mean, often exhibit a trend. Both basins of Lobster Lake were included for Secchi transparency trend analysis; while only the east basin had enough TP and chlorophyll-*a* data for trend analysis. The figures of this section (Figures 9 – 11) contain a factor called standard error (Std. Error). Standard error is defined as the standard deviation of a dataset divided by the square root of the number of samples from that dataset. Standard error is a measure of variability within a dataset and provides a simple basis for comparing means. The closer the values are to each other, the smaller this line will be in following figures. Small standard error means minimal variability in the measurements during a given summer, whereas a large standard error implies a high degree of variability.

East Lobster Lake (21-0144-01)

Based on 19 years of Secchi data, there has been some fluctuation in transparency, but no statistically significant trend is noted ($p>0.2$) at this time. Secchi transparency has ranged from a low of 5.9 feet in 1985 to a maximum of 10.7 feet in 1989 with a long-term average of 8.4 feet (Figure 9). Standard error was typically less than 1 foot, indicating very little variability within the dataset. This is a very extensive and complete dataset (no significant breaks in the records).

Lobster Lake was sampled as part of the MPCA's Lake Assessment Program (LAP) in 1990. East Lobster has also been monitored in more recent years by the lake association. A comparison of historical TP and chlorophyll-*a* data are presented in Figure 10 and Figure 11, respectively. Based on 8 years of data, there is no statistically significant trend ($p>0.2$) in TP or chlorophyll-*a* for East Lobster Lake. TP concentrations ranged from a low of 20.3 µg/L in 1998 to a high of 43.3 µg/L in 1985 (Figure 10); while chlorophyll-*a* ranged from a low of 5.6 µg/L in 2002 to a high of 11.4 µg/L in 1985 (Figure 11). Standard error for TP ranged from 1.5 – 6.4 µg/L; indicating some variability within the dataset; particularly in 1985 and 1999. Chlorophyll-*a* standard error ranged from 0.4 – 2.4 µg/L; indicating little variability within the dataset.

It should be noted, however, that there is a small break in the dataset from 1987 – 1989 and 1991 – 1996 for both parameters. Data from these time periods would have helped strengthen our trend analysis for TP and chlorophyll-*a* in East Lobster Lake.

Figure 9. Lobster Lake Summer-Mean Secchi Transparency

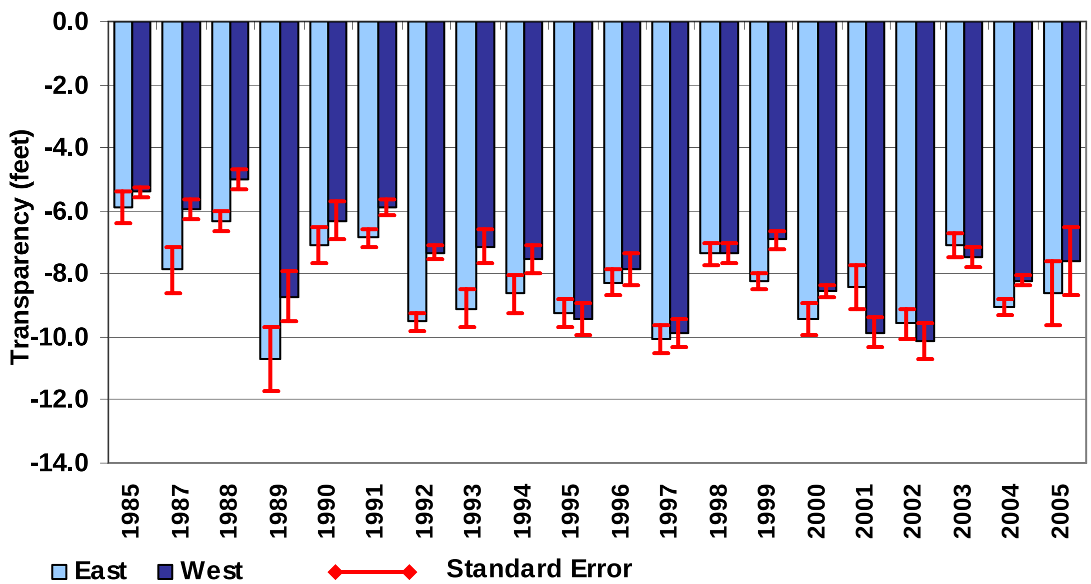


Figure 10. Lobster Lake Summer-Mean Total Phosphorus

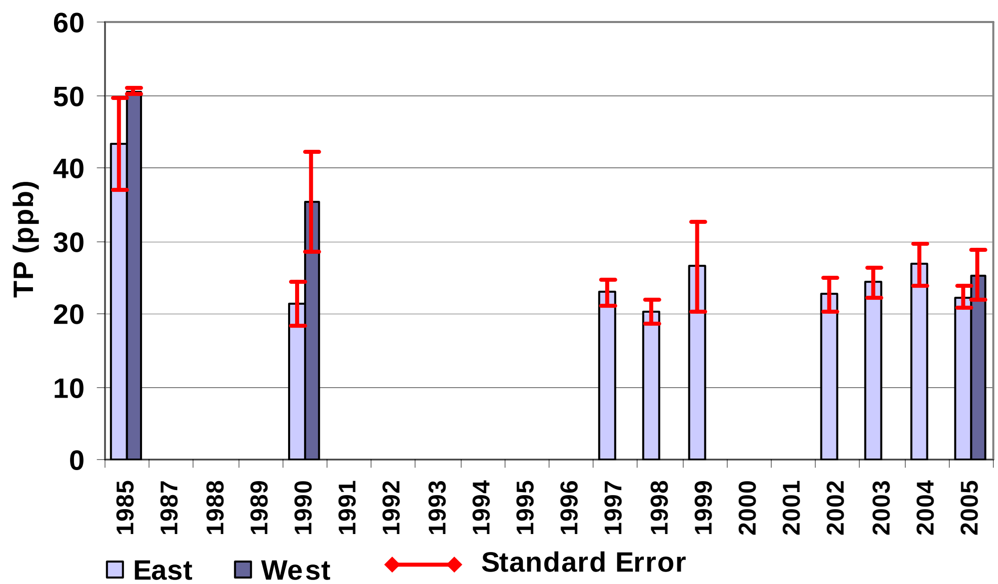
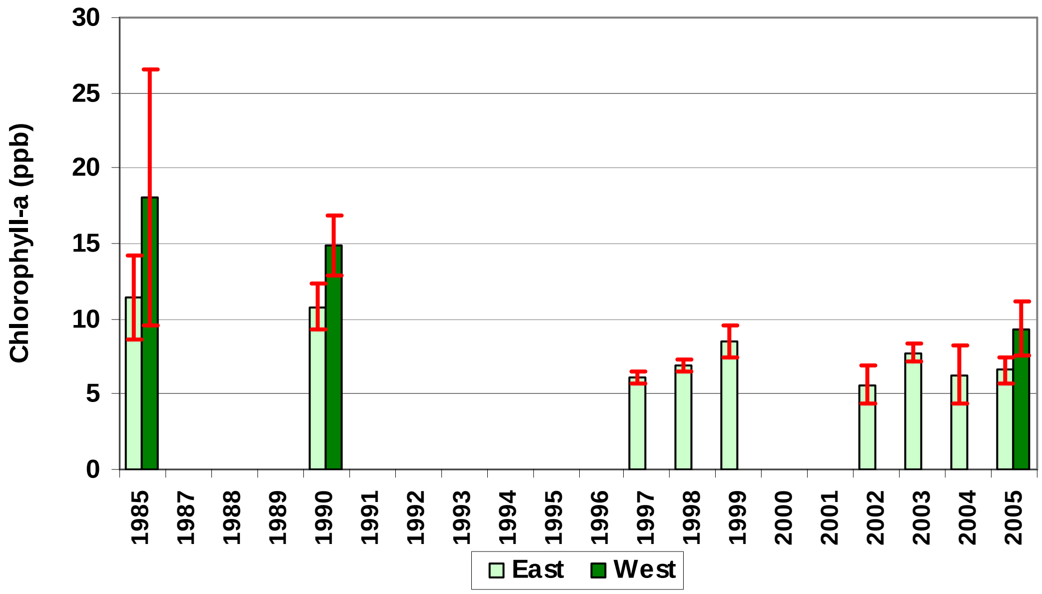


Figure 11. Lobster Lake Summer-Mean Chlorophyll-*a*



<u>West Lobster Lake (21-0144-02)</u>

Based on 19 years of data, there has been a statistically significant improvement in Secchi transparency ($p<0.05$). Secchi transparency has ranged from a low of 5.0 feet in 1988 to a maximum of 10.1 feet in 2002, with a long-term average of 7.6 feet (Figure 9). This is a very extensive and complete dataset (no significant breaks in the records). Standard error was typically less than 1.1 foot, indicating very little variability within the dataset.

There was not enough data for trend analysis of TP and chlorophyll-*a* in West Lobster Lake. Based on the available data, it does appear that there has been a reduction in the TP and chlorophyll-*a* concentrations in this basin (Figure 10 and 11, Appendix). It would be interesting to review changes in land use in the West Lobster Lake watershed to determine if changes may have contributed to a reduction in TP. Continued monitoring of these two parameters in the west basin will add to the current database and strengthen our ability to do trend analysis on this basin.

Part 4. Water Quality Modeling

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration of the lake. These predictions are based on: lake area, mean depth, watershed area, and ecoregion in which the lake is located. Known information such as lake and watershed areas, and mean depth are inputs to the model; which in turn, computes a "predicted" TP value. The predicted TP value is used to predict a chlorophyll value, which in turn, is used to predict a Secchi value. The predicted values can then compared to the observed values (summer means) for each lake to determine if the lake's condition is what would be expected – based on its size, depth and watershed area. The model has some limitations in that it cannot take into account groundwater influence and cannot account for TP-trapping or settling in large lakes that may be upstream of the lake being modeled.

A subroutine in the MINLEAP model provides an estimate of background TP concentration for each lake based on its mean depth and alkalinity. This estimate was derived from an equation developed by Vighi and Chiaudani (1985) and is based on the morphoedaphic index commonly used in fisheries science. This equation assumes that most of the phosphorus entering the lake arises from soil erosion in the watershed, and that phosphorus and other minerals, which contribute to alkalinity, are delivered in relatively constant proportions. In turn, the mean depth of the lake will moderate the in-lake phosphorus concentration (e.g. deep lakes settle material readily, which contributes to low phosphorus concentrations). This estimated "background" concentration helps place modern-day results and goal setting in perspective. Mean depth, watershed area and volumes were known for the lake from previous studies and reports.

Lobster Lake

Modeling for the lake used "whole lake" information from Table 1. In addition, East and West Lobster Lake data were averaged for a "whole lake" concentration for TP, chlorophyll-*a* and Secchi transparency for both 1990 and 2005. The 2005 calculated observed values for TP, chlorophyll-*a* and Secchi transparency were slightly better than the 1990 calculated observed values (Table 4).

Table 4. MINLEAP Model Outputs & Predictions

LAKE	TP (µg/L) Observed[1]	TP (µg/L) Predicted[2]	TP (µg/L) Vighi-Chiaudani	Chl-a (µg/L) Observed[1]	Chl-a (µg/L) Predicted[2]	Secchi (m) Observed[1]	Secchi (m) Predicted[2]
[3]Lobster 1990	28	52 ± 17	25	12.9	21 ± 13	2.0	1.3 ± 0.5
Lobster 2005	24	53 ± 17	25	7.9	22 ± 13	2.5	1.3 ± 0.5
[4]Lobster 2005	24	32 ± 10	25	7.9	10.6 ± 6	2.5	1.9 ± 0.7

[1]Observed Values reported as an average of East and West Lobster Lake data.
[2]Predicted Values based on the Total watershed.
[3]From 1990 LAP report.
[4]Calibrated Model Run.

MINLEAP predicted a significantly higher TP concentration than the 1990 and 2005 calculated values for the lake (Table 4). The Vighi-Chiaudani model predicted a similar TP concentration for the lake as compared to the 1990 and 2005 calculated-observed values (Table 4). A second model run where the stream inflow TP concentrations were reduced to 70 µg/L yielded more comparable results. TP-loading, based on the calibrated model run, for the lake was estimated to be about 1,300 kg P/yr. *(Note: there are 2.2 pounds of phosphorus per kilogram.)* The TP-retention coefficient was estimated to be 0.59. This means that roughly 59 percent of the TP that enters Lobster Lake stays in the lake. Because the predicted TP was slightly higher than the calculated-observed value, the predicted chlorophyll-*a* concentration is also significantly higher. As well, the predicted Secchi transparency is slightly poorer than the 1990 and 2005 calculated values for Lobster Lake. Overall, the calibrated model predictions compare more favorably with the calculated-observed results. MINLEAP cannot take into account upstream wetlands in the watershed, and therefore the model may be overestimating P exports from the various land uses in the watershed. A more precise determination of TP loading would require a more complex water quality model, such as BATHTUB; which is a good tool for modeling reservoirs, chains of lakes, lakes with multiple inlets or situations where more detailed nutrient and water budgets are required. More information on the model, BATHTUB, is available at the MPCA web site (http://www.pca.state.mn.us/water/charting.html).

Part 5. Goal Setting

For East and West Lobster Lakes, it would be desirable to maintain the currently low in-lake TP concentrations. The summer-mean P-concentration for the lakes was within the predicted P-value and near the Vighi and Chiaudani "background" estimate. Based on Tables 5 and 6, the lakes should be fully supporting for all specified uses. Continued efforts to protect these waters from any degradation are strongly recommended. Some important considerations for improving and protecting the water quality of the lakes include implementation of BMP's in the shoreland areas and ultimately through the watershed with a particular emphasis on the direct drainage area. A more comprehensive review of land use practices in the watershed may reveal opportunities for implementing BMPs in the watershed and reducing P-loading to the lakes. Proper maintenance of buffers areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of P-loading (e.g., stormwater from near-shore development activities in the watershed), will serve to minimize loading to the lakes. These and other considerations will be important if the water quality of these Douglas County lakes is to be maintained over the long term.

Table 5. Nutrient and Trophic Status Thresholds for Determination of Use Support for Lakes.

Ecoregion (TSI)	TP (ppb)	Chl (ppb)	Secchi (m)	TP Range (ppb)	TP (ppb)	Chl (ppb)	Secchi (m)
305(b):	**Full Support**			*Partial Support*	*Non-Support*		
303(d):	**Not Listed**			**Review**	**Listed**		
NCHF	**< 40**	**< 15**	**≥ 1.2**	**40 – 45**	**> 45**	**> 18**	**< 1.1**
(TSI)	(< 57)	(< 57)	(< 57)	(57 – 59)	(> 59)	(> 59)	(> 59)

Derived from MPCA Guidance Manual for Assessing Minnesota Surface Waters for Determination of Impairment (MPCA 2003). *TSI* = Carlson's Trophic State Index; *Chl-a* = Chlorophyll-*a*, includes both pheophytin-corrected and non-pheophytin-corrected values; *ppb* = parts per billion or µg/L; *m* = meters

Table 6. Draft Eutrophication Criteria by Ecoregion and Lake Type & 2005 Observed Summer-means for Comparison (Heiskary and Wilson, 2005)

Ecoregion	TP (ppb)	Chl-*a* (ppb)	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
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

Douglas County Lakes: 2005 Observed (Ecoregion)	TP (ppb)	Chl-*a* (ppb)	Secchi (m)
East Lobster (NCHF)	22.2	6.6	2.6
West Lobster (NCHF)	25.3	9.3	2.3

Part 6. Summary & Recommendations

During the summer of 2005, Lobster Lake was sampled by CLMP volunteers as a part of a monitoring program, CLMP "Plus". This lake was selected because it is a priority in the county and was exhibiting a trend in Secchi transparency.

Following are a few general observations and recommendations based on our monitoring and data analysis:

A. Secchi transparency monitoring: Monitoring Secchi transparency provides a good basis for estimating trophic status and detecting trends. Routine participation is essential to allow for trend analysis. Continued CLMP monitoring on both basins of the lake will contribute to the database, which already exists and allow for future trend assessments.

B. Water quality and tropic status: Based on data collected in 2005, both East and West Lobster Lakes exhibited TP concentrations comparable to the typical range for minimally-impacted lakes in the NCHF ecoregion. The two lakes also exhibited chlorophyll-*a* concentrations comparable to the typical range for reference lakes. Both East and West Lobster Lakes would be considered *mesotrophic – eutrophic* in condition.

C. Water quality trends: Both East and West Lobster Lakes had sufficient number of previous years of Secchi data for trend analysis; while only East Lobster Lake had sufficient data for TP and chlorophyll-*a* trend analysis. No statistical trends in transparency, TP or chlorophyll-*a* were found for East Lobster Lake; but West Lobster Lake did show a statistical improvement in transparency over time. Continued monitoring of these lakes will strengthen the database and enhance our ability to assess trends for these lakes.

D. Model predictions: In general, a calibrated MINLEAP model predicted TP slightly higher for Lobster Lake as compared to the calculated-observed value. In return, the predicted chlorophyll-*a* and Secchi values were also slightly different than their calculated-observed corresponding values. Model limitations were most likely the largest factor in these differences.

E. This lake has very good water quality and every effort to protect it from degradation should be taken. Further development or land use change in the watershed should occur in a manner that minimizes water quality impacts on the lake. In the shoreland areas, setback provisions should be strictly followed. MDNR and County shoreland regulations will be important in this regard.

- Stormwater regulations should be adhered to during and following any major construction/development activities in the watershed. This is particularly important as development increases around the lake. Limiting the amount of impervious surfaces can have beneficial affects as well, in terms of reduced runoff and P-loading. Properly designed sedimentation ponds should be included in any development to minimize P-loading to the lakes. A "no-net-increase" in TP is recommended.

- Activities in the watershed that change drainage patterns, such as wetland removal or major alterations in lake use, should be discouraged unless they are carefully planned and adequately controlled. Restoring or improving wetlands in the watershed may also be beneficial for reducing the amount of nutrients or sediments that reach the lake. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.
- The lake association should continue to seek representation on boards or commissions that address land management activities so that their impact can be minimized. The booklet, <u>Protecting Minnesota's Waters: The Land-Use Connection</u>, may be a useful educational tool in this area.
- Macrophyte population and distribution maps for the lake may be beneficial to the association. Exotic species such as *Eurasian water milfoil* and *curly-leaf pondweed* can dramatically impact quality resources such as Lobster Lake. Tracking the population and distribution of rooted aquatic plants can be helpful in determining if changes within the system are occurring and be a possible warning signs for those changes.

F. On-site septic systems are a *potential* source of nutrients to lakes that are not sewered. While their influence may not be express in terms of dramatic increases in algae in the lake, they may be expressed by increased near-shore weed growth or excessive attached algae on docks and plants. A house-to-house septic system survey may help the individual lake association and Douglas County determine if homeowners are somewhat familiar with the age and maintenance (pumping) of their systems and if further education is needed on proper maintenance of their systems. This may also help them encourage all homeowners with non-code systems to bring their systems up to code. The lake association may want to facilitate a lake-wide schedule for pumping systems.

G. An examination of land use practices or changes in land use in the watershed may be of interest for the association and Douglas County – particularly for the west basin of the lake. In addition, identification of possible nutrient sources such as lawn fertilizer, the effects of ditching and draining of wetlands, and development practices etc., may aid the lake association in determining areas where best management practices may be needed. For example, recent studies indicated that a majority of lawns in the Twin Cities metro area do not need additional phosphorus – this may be true for lawns in Douglas County as well. In April 2004, a new law came into effect restricting the use of phosphorus fertilizers in Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties and set a three percent (by weight) limit outside the metro area. In 2005 this law was extended statewide. The lake associations, together with Douglas County, <u>should encourage the use of P-free fertilizers</u> on lawns in the watershed. There may be other opportunities to implement/promote Best Management Practices (BMP's) that may reduce nutrient loading from other sources in the watershed as well.

Appendix

1. **Lobster Lake 2005 CLMP+ and Historic Data**

2. **Watershed Maps for Lobster Lake**

3. **Lake Level Data for Lobster Lake**

4. **Status of the Fishery for Lobster Lake**

Appendix 1. Lobster Lake CLMP+ Data

East Lobster (21-0144-01)

Source	Site	Date	Time	Depth	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	101	05/18/2005	8:15	0	24.0	2.67	< 0.33	4.7	1.3	10.0	200.0	16.0	0.83	13.18	7.13	358	1	1
MPCA	101	05/18/2005	8:15	17	124.0													
Volunteer	101	06/12/2005	13:20	0	20 Q	3.45	0.47							12.50			2	2
Volunteer	101	06/26/2005	13:15	0	23.0	3.15	0.38							13.50			2	2
Volunteer-FD	101	06/26/2005	13:15	0	27.0	3.47	1.15											
Volunteer	101	07/08/2005	13:10	0	21.0	4.69	0.47							7.50			2	2
MPCA	101	07/26/2005	8:00	0	22.0	6.47	1.42	2.8	2.4	5.0	180.0	18.0	0.93	6.56	8.60	324	2	1
MPCA	101	07/26/2005	8:00	15	256.0													
Volunteer	101	08/11/2005	13:10	0	15.0	6.92	0.64							6.50			2	2
Volunteer	101	08/27/2005	13:10	0	15.0	7.94	0.90							7.00			2	2
Volunteer	101	09/10/2005	13:22	0	24.0	9.13	0.95							7.50			2	2
Volunteer-FD	101	09/10/2005	13:22	0	27.0	9.67	1.36											
MPCA	101	09/28/2005	8:00	0	28.0	11.40	1.65	4.0	2.4	20.0	180.0	18.0	0.99	7.87	8.05	388	3	2
MPCA	101	09/28/2005	8:00	17	237.0													

West Lobster (21-0144-02)

Source	Site	Date	Time	Depth	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	101	05/18/2005	8:45	0	25.0	2.12	< 0.33	1.6	1.2	20.0	190.0	15.0	0.86	18.04	7.24	347	1	1
MPCA	101	05/18/2005	8:45	6	31.0													
Volunteer	101	06/12/2005	14:00	0	19 Q	3.07	0.46							13.50			2	2
Volunteer	101	06/26/2005	14:10	0	23.0	4.25	1.06							11.00			2	2
Volunteer	101	07/08/2005	14:10	0	27.0	7.51	0.79							9.00			2	2
MPCA	101	07/26/2005	8:30	0	29.0	7.95	1.99	3.2	2.8	10.0	170.0	17.0	1.04	5.91	8.61	316	2	1
MPCA	101	07/26/2005	8:30	7	57.0													
Volunteer	101	08/11/2005	13:55	0	15.0	7.12	0.83							6.00			2	2
Volunteer	101	08/27/2005	13:40	0	13.0	11.40	0.87							5.50			2	2
Volunteer	101	09/10/2005	13:45	0	34.0	18.00	1.82							5.00			2	2
MPCA	101	09/28/2005	8:30	0	42.0	15.40	2.08	4.8	4.0	10.0	170.0	17.0	1.13	4.92	8.14	384	3	2
MPCA	101	09/28/2005	8:30	6	52.0													

TP = Total Phosphorus (ppb or µg/L)
Chla = Chlorophyll-*a* (ppb or µg/L)
Pheo = Pheophytin (ppb or µg/L)
TSS = Total Suspended Solids (mg/L)
TSV = Total Suspended Volatile Solids (mg/L)
COL = Color (Pt-Co Units)
Alk = Alkalinity (mg/L)
CL = Chloride (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
SDF = Secchi Transparency (ft)
pH = pH of Sample (SU)
Cond = Conductivity of sample (umhos/cm)
PC = Physical Condition
RS = Recreational Suitability
FD, Q, K = Remark codes for parameters *(FD = field duplicate sample; Q=held past holding time; K=less than the detection limit)*

2005 Temperature & Dissolve Oxygen Data for Lobster Lake

East Lobster (21-0144-01) Temperature (°C)

Depth (m)	*5/18	6/12	6/26	7/8	*7/26	8/11	8/27	9/10	*9/28
0	11.37	26	26	26	23.97	25.5	23	27	17.87
1	11.34	22	26	24	24.02	26	22	25	17.9
2	11.29	23	25.7	24	24.02	26	22	24	17.9
3	11.22	22	25.7	24	24.03	26.2	22	24	17.9
4	11.22	22	23	24	24.03	26.2	22	24	17.95
5	11.21	21	21	23	24.03	26.2	22	23	17.94
6	11.2	19	19	23	20.72	25	22	23	17.95
7	11.19	18.5	17.5	23	16.72	23.5	22	23	17.95
8	11.19	17	16	20	14.79	20	21	22	17.95
9	11.2	16.5	15	18	13.53	16	19	19	17.93
10	11.19	15.5	14	16	12.42	14	17	19	15.75
12	11.08	14	13	15	10.59	13	15	16	11.94
14	8.88	12.5	11	13	10.28	11.5	13.5	14	10.93
16	4.94	11	9.5	11		10.8	12.8	13	10.62
18	4.78	9	8.5	10		10	12	12	10.45
20			8.5	10		10		12	

West Lobster (21-0144-02) Temperature (°C)

Depth (m)	*5/18	6/12	6/26	7/8	*7/26	8/11	8/27	9/10	*9/28
0	11.93	26	26	28	24.2	24	24	24	17.61
1	11.9	24	26	27	24.21	26	24	24	17.67
2	11.89	24	26.2	25	24.21	26	24	23	17.66
3	11.88	22	26	26	24.21	26	24	22	17.66
4	11.7	22	25	24	24.2	26.3	23	22	17.65
5	11.59	21	23	24	22.18	26	23	22	17.63
6	11.16	20	20	24	20.2	24	23	22	17.57
7	10.6	18	18	23	19.94	23	22	22	17.58
8		18		22				22	

East Lobster (21-0144-01)	Depth (m)	5/18	7/26	9/28
Dissolved Oxygen (mg/L)	0	12.31	7.3	7.89
	1	10.18	7.26	7.56
	2	9.98	7.13	7.41
	3	9.94	7.15	7.32
	4	9.85	7.19	7.28
	5	9.82	7.16	7.27
	6	9.77	5.64	7.14
	7	9.68	0.74	7.18
	8	9.64	0.51	7.14
	9	9.62	0.36	7.01
	10	9.58	0.3	2.95
	12	9.57	0.3	0.85
	14	7.73	0.29	0.48
	16	3.86		0.38
	18	0.74		0.35

West Lobster (21-0144-02)	Depth (m)	5/18	7/26	9/28
Dissolved Oxygen (mg/L)	0	**13.37**	**6.88**	**7.01**
	1	10.41	6.86	6.82
	2	10.06	6.85	6.75
	3	9.97	6.83	6.74
	4	9.83	6.82	6.73
	5	9.5	4.11	6.82
	6	9.55	1.51	6.82
	7	8.54	0.93	6.52

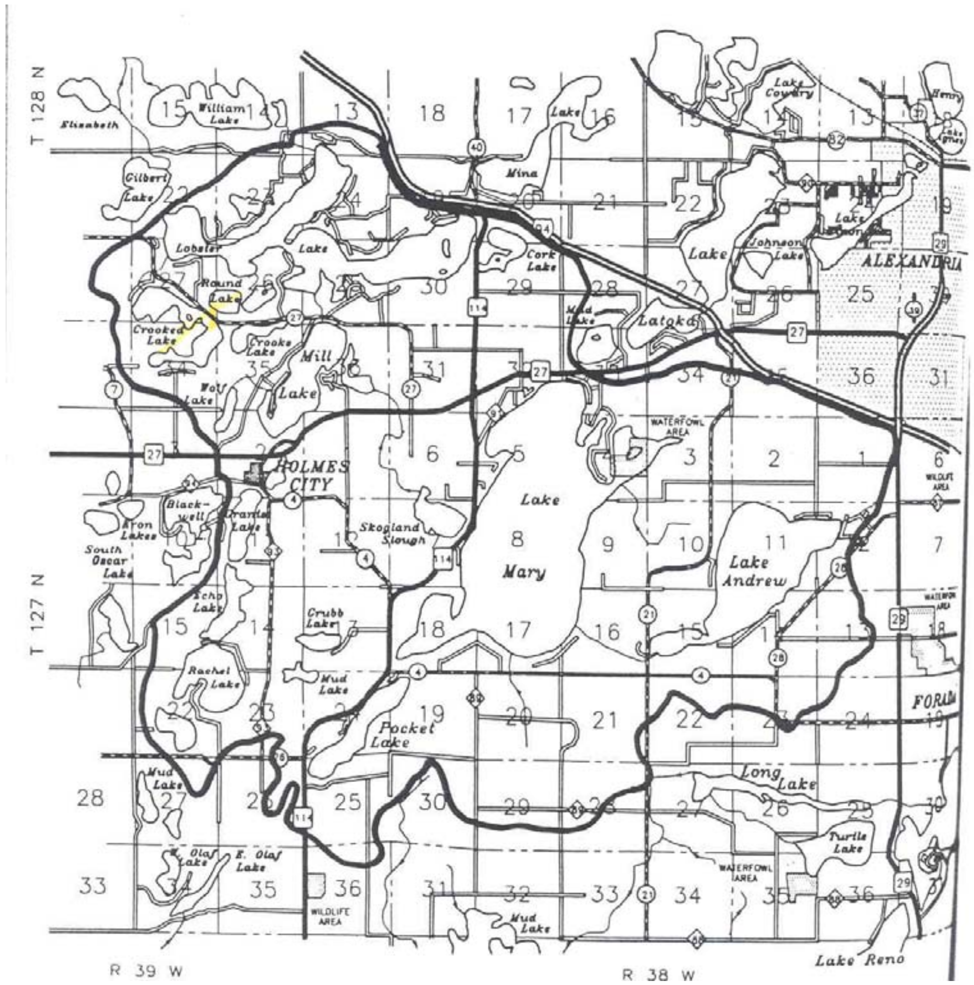
Historic Data

	East Lobster Lake (21-0144-01)									West Lobster Lake (21-0144-02)								
Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1985	5.9	0.5	3	43.3	6.4	3	11.4	2.4	3	5.4	0.2	2	50.5	0.5	2	18.1	8.5	2
1987	7.9	0.7	23							5.9	0.3	24						
1988	6.3	0.3	16							5.0	0.3	16						
1989	10.7	1.0	30							8.7	0.8	30						
1990	7.1	0.6	33	21.3	3.0	6	10.8	1.5	7	6.3	0.6	36	35.3	6.8	7	14.9	2.0	7
1991	6.9	0.3	26							5.9	0.2	26						
1992	9.5	0.3	22							7.3	0.2	22						
1993	9.1	0.6	18							7.1	0.5	18						
1994	8.6	0.6	24							7.5	0.4	24						
1995	9.2	0.4	26							9.4	0.5	26						
1996	8.3	0.4	22							7.8	0.5	22						
1997	10.1	0.4	48	22.9	1.7	12	6.1	0.4	12	9.9	0.5	36						
1998	7.4	0.3	36	20.3	1.7	8	6.9	0.4	8	7.3	0.3	29						
1999	8.2	0.3	34	26.5	6.1	4	8.5	1.0	4	6.9	0.3	22						
2000	9.4	0.5	24							8.6	0.2	14						
2001	8.4	0.7	24							9.9	0.5	16						
2002	9.6	0.5	32	22.6	2.3	8	5.6	1.3	8	10.1	0.6	22						
2003	7.1	0.4	26	24.3	2.0	4	7.8	0.6	4	7.5	0.3	20						
2004	9.1	0.3	28	26.8	2.9	4	6.3	1.9	4	8.2	0.2	34						
2005	8.6	1.0	8	22.2	1.5	10	6.6	0.9	10	7.6	1.1	8	25.3	3.5	8	9.3	1.8	8

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
TP = Total Phosphorus (ppb or µg/L)
SEP = Standard Error for TP
NP = # TP samples/yr
CHLa = Chlorophyll-*a* (ppb or µg/L)
SEC = Standard Error for CHLa
NC = # CHLa samples/yr

Appendix 2. Watershed Maps for Lobster Lake

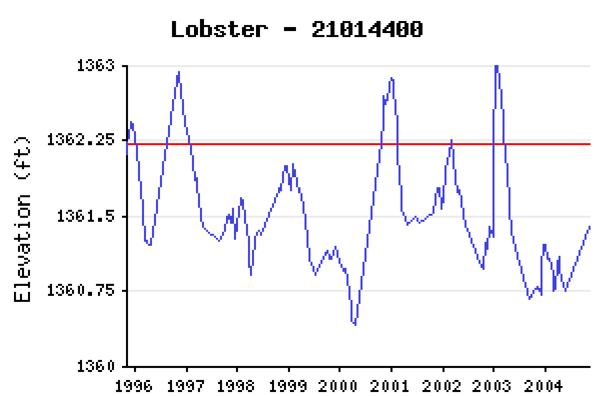
(from 1990 LAP Report)



Appendix 3. Lake Level Information for Lobster Lake

(From MN DNR Web site: www.dnr.state.mn.us)

Period of record: 10/23/1936 to 04/28/2005
# of readings: 1226
Highest recorded: 1362.98 ft (07/19/2003)
Highest known: 1364.2 ft
Lowest recorded: 1351.73 ft (10/23/1936)
Recorded range: 11.25 ft
Average water level: 1357.37 ft
Last reading: 1361.38 ft (04/28/2005)
OHW elevation: 1362.2 ft
Datum: 1929 (ft)



Appendix 4. Status of the Fishery for Lobster Lake

Excerpts from DNR web site www.dnr.state.mn.us

For a complete report, please visit the MDNR web site

Lobster Lake Status of the Fishery (as of 07/23/2001): Lobster Lake supports an abundant and diverse aquatic plant community. These aquatic plants provide critical fish habitat and compete with nuisance algae for the available nutrients in the lake. Northern pike catch rates averaged 11.3 fish per gillnet, with the largest fish measuring just under 33.0 inches. Bluegill size structure is not favorable. Only 23 percent of the sampled fish exceeded six inches and no fish measured more than eight inches. These fish continue to grow slowly. Walleye catches averaged 2.0 fish per gillnet as compared to 3.2 and 4.6 fish per gillnet in the 1996 and 1989 surveys, respectively. The mean length of the sampled fish was 18.4 inches with the largest fish measuring over 24 inches. Largemouth bass remain abundant with a spring electrofishing survey resulting in a catch of 62.4 fish per hour. Black crappie are not sampled effectively during the summer; however, gillnet catches averaged 5.6 fish per net which is relatively high. A spring ice-out muskellunge survey was conducted in 2001. This survey resulted in the capture of 53 fish, with the largest fish measuring 51.5 inches.

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GLOSSARY

Alkalinity: Capacity of a lake to neutralize acid.

Chloride: Common anionic form of chlorine which carries one net negative charge. A common anion in many waters.

Chlorophyll a: The main pigment in algae. It is used to measure aquatic productivity.

Ecoregion: Areas of relative homogeneity based on land use, soils, topography and potential natural vegetation.

Epilimnion: Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

Eutrophic: Describes a lake of high photosynthetic productivity. Nutrient rich.

Hypolimnion: The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Littoral Area: The shallow areas around a lake's shoreline, dominated by aquatic plants.

Mesotrophic: Describes a lake of moderate photosynthetic productivity.

Metalimnion: The middle layer of lake water during the summer months.

Nitrite/Nitrate Nitrogen: The weight of concentration of the nitrogen in the nitrate ion.

Oligotrophic: Describes a lake of low photosynthetic productivity.

Phosphate: An essential nutrient containing phosphorus and oxygen. Phosphate is often a critical nutrient in lake eutrophication management.

Phosphorus: Phosphorus is an element that can be found in commercial products such as foods, detergents, and fertilizers as well as in larger amounts naturally in organic materials, soils, and rocks. Phosphorus is one of many essential plant nutrients. Phosphorus forms are continually recycling throughout the aquatic environment. All forms are measured under the term "Total Phosphorus" in parts per billion (ppb).

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Secchi Disk: A metal plate used for measuring the depth of light penetration in water.

Suspended Solids: Small particles that hang in the water column and create turbid, or cloudy conditions.

Total Maximum Daily Load (TMDL): This process determines why waters are impaired, the amount by which pollution must be reduced to meet water-quality standards and determines allocations (limits) for all contributing sources plus future growth.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth. Zone of maximum change in temperature over the depth interval.

Trophic Status: The level of growth or productivity of a lake as measured by phosphorus content, algae abundance, and depth of light penetration.

Turnover (Overturn): Warming or cooling surface waters, activated by wind action, mix with lower, deeper layers of water.

Watershed: Geographical area that supplies water to a stream, lake, or river.

Zooplankton: Microscopic animals.