Water Quality-Chlorophyll A Correlations Across Five Lakes

By Taylor Forrest and Dan Klarr

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Abstract

Water samples and water clarity measurements were collected from five lakes of differing trophic status located in northern Michigan (Douglas, Burt, Mullet, Black, and Crooked Lakes) during peak algae production to test the hypothesis that chlorophyll a concentrations will correlate with water clarity depth. Water clarity was measured using a secchi disk; the depth reported was the mean of three separate trials per lake in one location. A photometer (Li-Core photometer Li-192sa) was used to measure light penetration at each sample site to a depth of approximately 1 meter below secchi disk visibility. Water samples were taken at meter intervals to the depth previously established by the Secchi disk.

Only one lake, Burt Lake, was found to have a significant correlation between light penetration and chl a concentration; no other lakes had a significant correlation. We recommend that further investigation be conducted on the relationship between algal biomass and zebra mussels due to their possible influence on water clarity.

Introduction:

Correctly evaluating trophic status of lakes is important to understanding the health and water quality of our lake ecosystems. Trophic status can be artificially influenced by anthropogenic causes such as increased nutrient loading. Excess of nutrients, particularly nitrogen and phosphorous, can cause premature eutrophication of lakes resulting in significant increases in algal biomass (Smith et al. 1999). Eutrophic lakes are characterized by high nutrients, high algae biomass and productivity, and shallow photic zones (Dodds 2002). These differ greatly from oligatrophic lakes which are defined by low nutrients, low algae biomass and productivity, as well as deep photic zones (Dodds 2002). Due to these characteristics, water clarity is greatly influenced by phytoplankton abundance and should differ greatly between oligotrophic and eutrophic lake systems due to their differences in algal biomass.

Chlorophyll a (chl a) is a photosynthetic pigment found in all photosynthetic organisms including all algae making it an excellent proxy for determining algal biomass (Wetzel 2001). Many studies have shown that an increase in algae substantially influences water depth clarity. Swift et al. (2006) found that increased algal biomass contributes greatly to reduction in water clarity.

Our study predicts that chl a concentrations will correlate with water clarity depth. This relationship will vary among the trophic status of lakes. Oligotrophic lakes should have higher clarity with lower chl a concentrations and Eutrophic lakes should show a decreased clarity and high chl a concentrations leading to lower water clarity.

Methods

Water samples and water clarity measurements were collected from five lakes of differing trophic status located in northern Michigan (Douglas, Burt, Mullet, Black, and Crooked Lakes) (see figure 1) during peak algae production, that is during 10 a.m. to 2 p.m. daily. Water clarity was measured using a secchi disk; the depth reported was the mean of three separate trials per lake in one location. A photometer (Li-Core photometer Li-192sa) was used to measure light penetration at each sample site to a depth of approximately 1 meter below secchi disk visibility. Using a Van Dorn water sampler, water samples were taken at meter intervals to the depth previously established by the Secchi disk. These samples were placed in 250 mL plastic sample bottles that were pre-rinsed with lake water and stored on ice in a cooler then transported back to the lab. At the lab, samples were refrigerated until time of analysis. Chl a concentrations were determined.

Analysis of chl a consisted of filtering 60 mL (or more) of each water sample. Filter paper used that collect algae were placed in glass viles with 10mL of 90% acetone and placed in an ice bath for approximately 15 minutes. Samples were then placed in a freezer for a minimum of

24 hours before fluoresced in a Fluorometer TD-700. Before acid was added, measurements were taken; and then measurements were taken again after 3 drops of 1M hydrochloric acid was added to the acetone viles.

Statistical Analysis

The data gathered from all five lakes were then statistically analyzed and chloraphyll A concentrations were compared to degree of water depth clarity and light penetration measurements. This was done using a linear regression.

Results

After running linear regressions on data from all lakes, using log transformed light concentrations as the independent variable and chlorophyll A concentrations as the dependent variable, we found only one significant correlation. This was at Burt Lake ($p = 0.04$, $R^2 = 0.533$). All other lakes did not show significant results or high repeatability ($p > 0.3$ $R^2 < 0.15$) However, Crooked Lake, though insignificant, showed a very high R^2(0.957).

Discussion:

Only one lake, Burt, was found to have a significant correlation between light penetration and chl a concentration. No other lakes had a significant correlation, though it should be noted that Crooked had a very high R^2 value. We also expected the highest chl a concentration to be at the surface of the water and then decrease with light visibility. In some lakes we found this to be true, but two lakes (Douglas and Burt) did not show this pattern. Mullet, Crooked, and Black Lakes all had peak chl a concentrations at the surface.

We attempted to visit a variety of lakes in Northern Michigan with diverse characteristics like nutrient value, beach development, and size. However, due to time constraints we were limited to a sample size of five, which limits the significance of our data, as well as possible inferences we can make about lake systems as a whole. Also, the practice of taking secchi disk depth in each lake and then sampling water at meter intervals down to secchi depth proved ineffective. While the secchi disk provided an insight into water clarity, only measuring chl a and light concentration to the secchi depth did not provide many data points and therefore our regression analyses may not have the same level of significance if we had probed deeper into the lake.

We speculate that some of our results were insignificant due to the presence of zebra mussels in the majority of the lakes sampled. Because they are filter feeders, zebra mussels reduce the amount of chl a in lake ecosystems and can affect trophic status (Qualls et al. 2007). Peak algal biomass is expected to be near the surface of the water due to light availability for photosynthesis. However, we did not often find this pattern in our data and we speculate it is due to the presence of zebra mussels. Lowe and Pillsbury (1995) found that with increases in zebra mussel density, water clarity increased as well as benthic algal blooms. Presence of zebra mussels in many of our study lakes may be responsible for unexpected peak in algae at some depth and explain the patterns we observed in our study. In Burt Lake where the regression analysis proved significant, light and chlorophyll a were correlated; however, in oligotrophic lakes where zebra mussles had altered the nutrient structure of the lake, the correlation between light penetration and chl a concentration was absent or insignificant.

While this study provides insight into the strong effects of zebra mussel populations on the trophic status and nutrient composition of lakes, we recommend that further investigation be conducted on the relationship between algal biomass and zebra mussels due to their influence on water clarity. The influence of zebra mussels on water clarity and trophic statuses of lakes provides further support of the importance of evaluating the water quality of our lake ecosystems.

Literature Cited

Dodds, WK. 2002. Freshwater Ecology. San Diego, California.

Espeland EM, Francoeur SN, Wetzel RG. 2001. Influence of algal photosynthesis on biofilm bacterial production and associated glucosidase and xylosidase activities. *Microbial Ecology.* 42: 524-530.

Lowe, RL. Pillsbury, RW. 1995. Shifts in benthic algal community structure and function following the appearance of zebra mussels (Dreissena polymorpha) in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*. 21: 558-566.

Qualls Theresa M, Dolan David M, Reed Tara, et al. 2007. Analysis of the impacts of zebra mussel, Dreissena polymorpha, on nutrients, water clarity, and the chlorophyllphosphorus relationship in lower Green Bay. *Journal of Great Lakes Research*. 33: 617-626.

Smith VH, Tilman GD, Nekola JC. 1998. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution.* 100: 179-196.

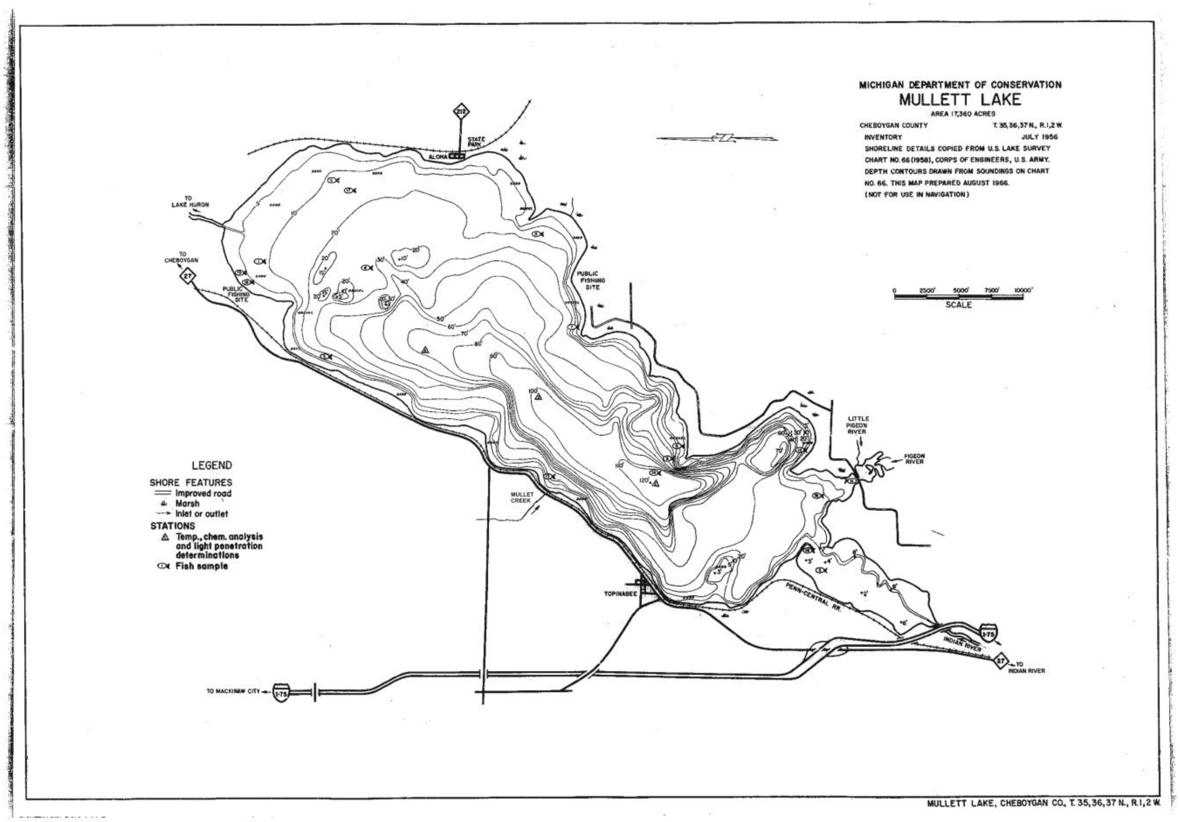
Lake	p value	R^2
Burt Lake	**0.040**	**0.533**
Black Lake	**0.677**	**0.104**
Crooked Lake	**0.133**	**0.957**
Mullet Lake	**0.666**	**0.111**
Douglas Lake	**0.391**	**0.124**

Figure Legend:

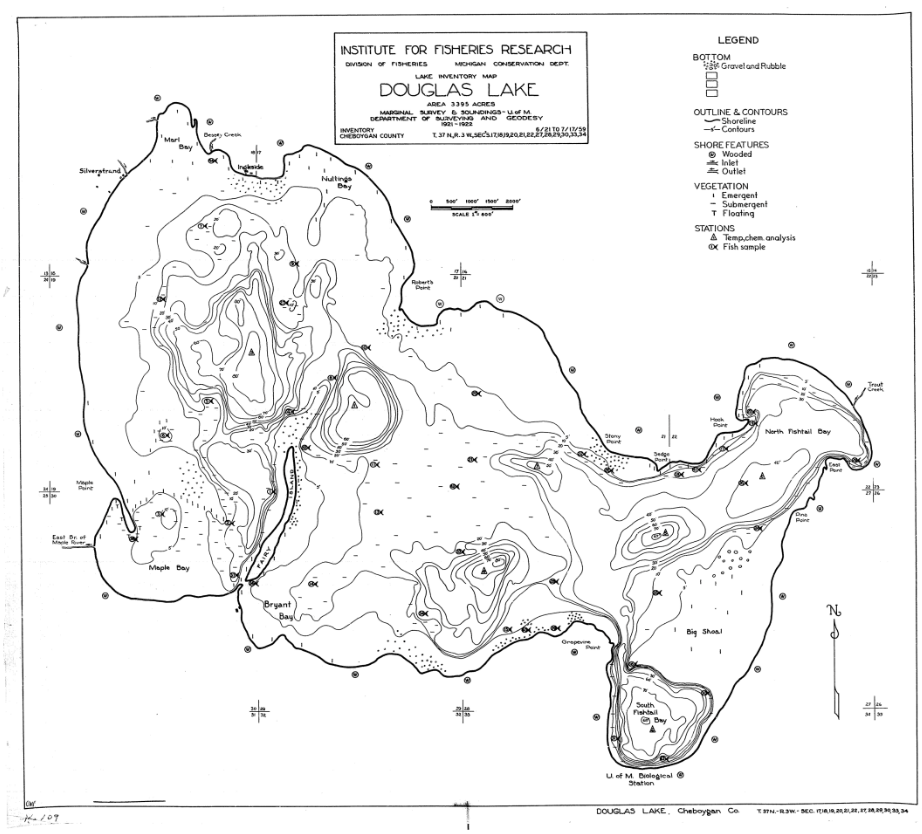
Table 1: Results

Figures 1-5: Benthic maps of lakes visited

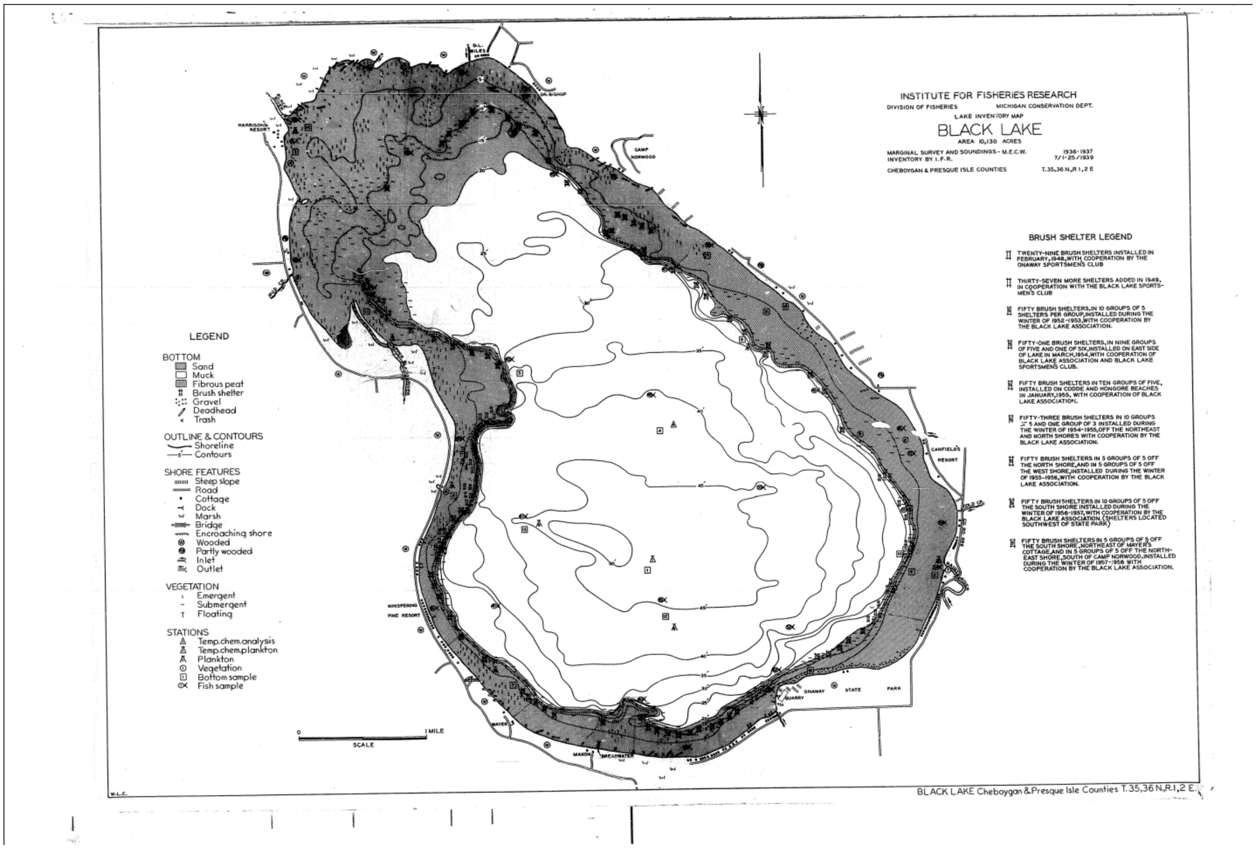
Figures 6-11: correlations between chl a and light intensity (log transformed) in our lakes

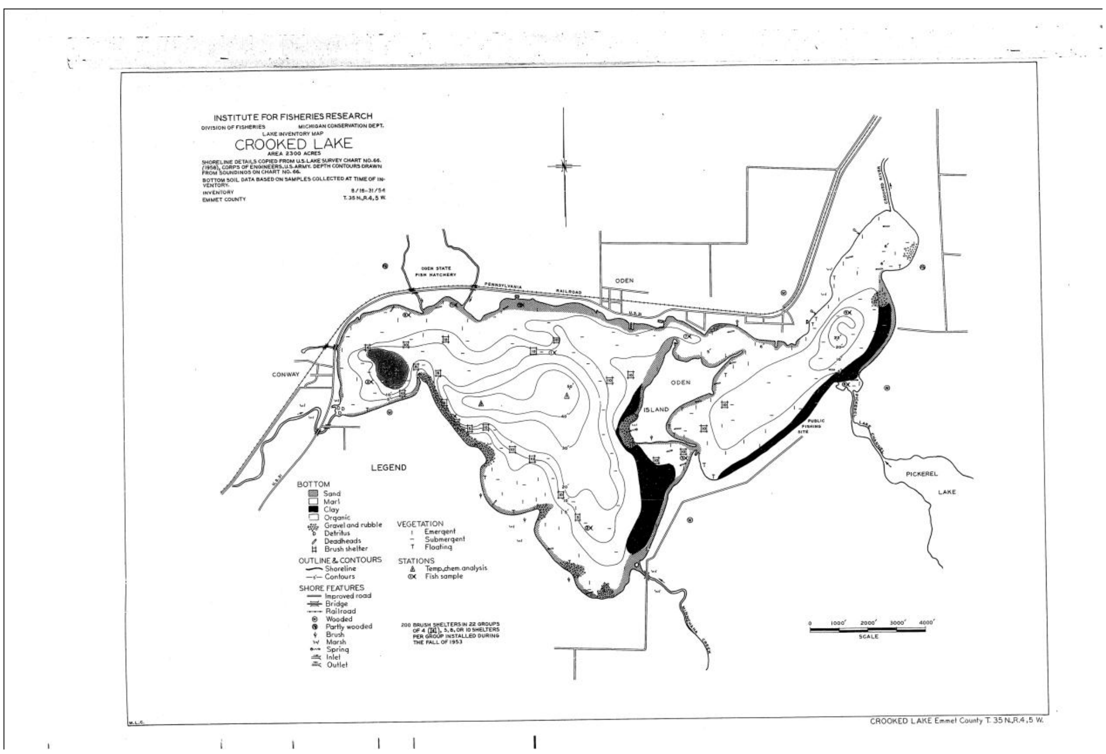


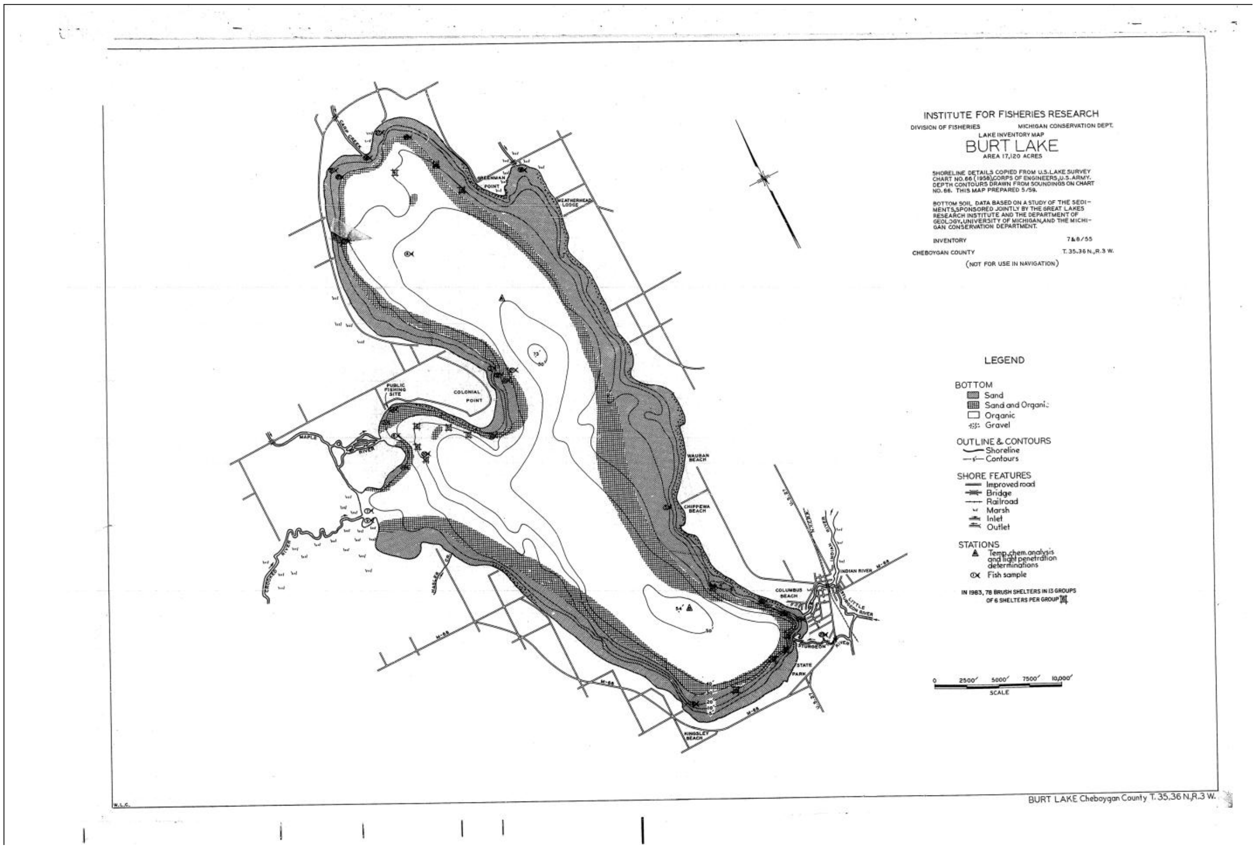
MICHIGAN DEPARTMENT OF CONSERVATION
MULLETT LAKE
AREA 17,360 ACRES
CHEBOYGAN COUNTY T. 35,36,37 N., R.1,2 W.
INVENTORY JULY 1956
SHORELINE DETAILS COPIED FROM U.S. LAKE SURVEY CHART NO. 66 (1958), CORPS OF ENGINEERS, U.S. ARMY.
DEPTH CONTOURS DRAWN FROM SOUNDINGS ON CHART NO. 66. THIS MAP PREPARED AUGUST 1966.
(NOT FOR USE IN NAVIGATION)
SCALE
LEGEND
SHORE FEATURES
Improved road
Marsh
Inlet or outlet
STATIONS
Temp., chem. analysis and light penetration determinations
Fish sample
TO LAKE HURON
TO CHEBOYGAN
PUBLIC FISHING SITE
ALOHA
STATE PARK
LITTLE PIGEON RIVER
PIGEON RIVER
MULLET CREEK
TOPINABEE
PENN-CENTRAL RR.
INDIAN RIVER
TO INDIAN RIVER
TO MACKINAW CITY
MULLETT LAKE, CHEBOYGAN CO., T. 35,36,37 N., R.1,2 W.

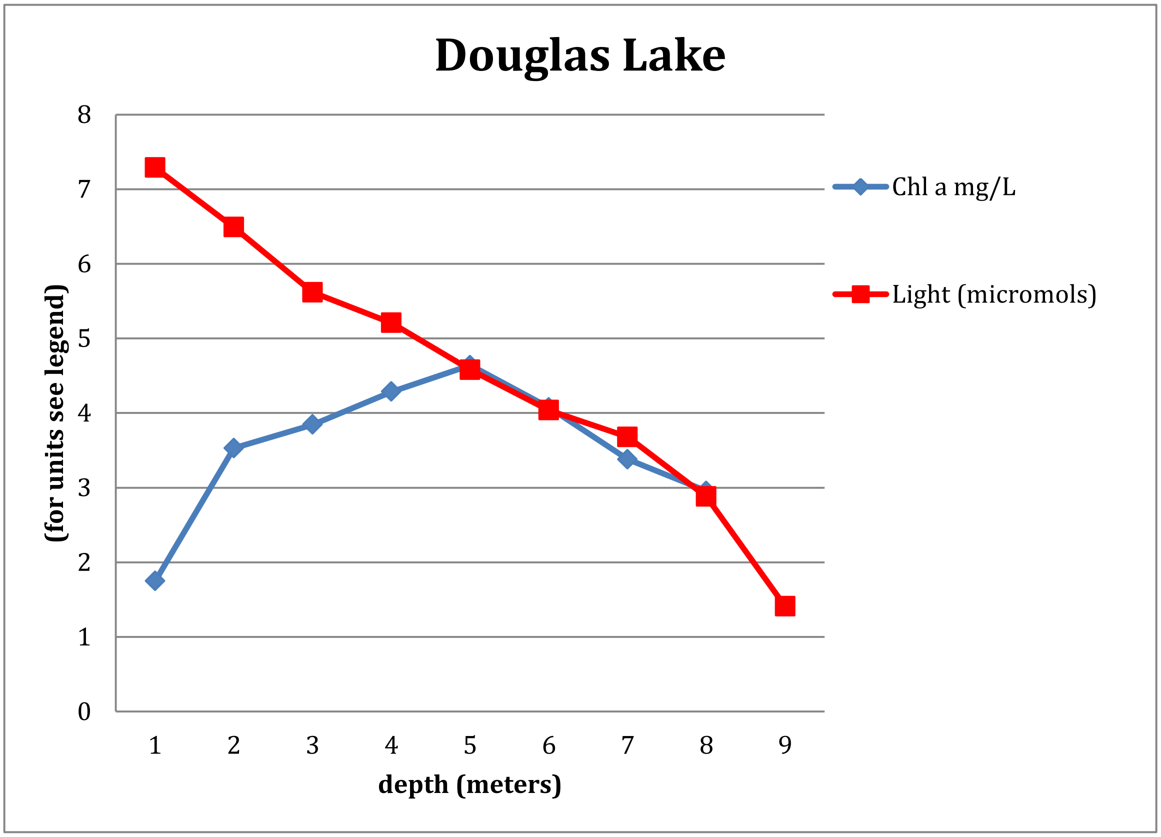


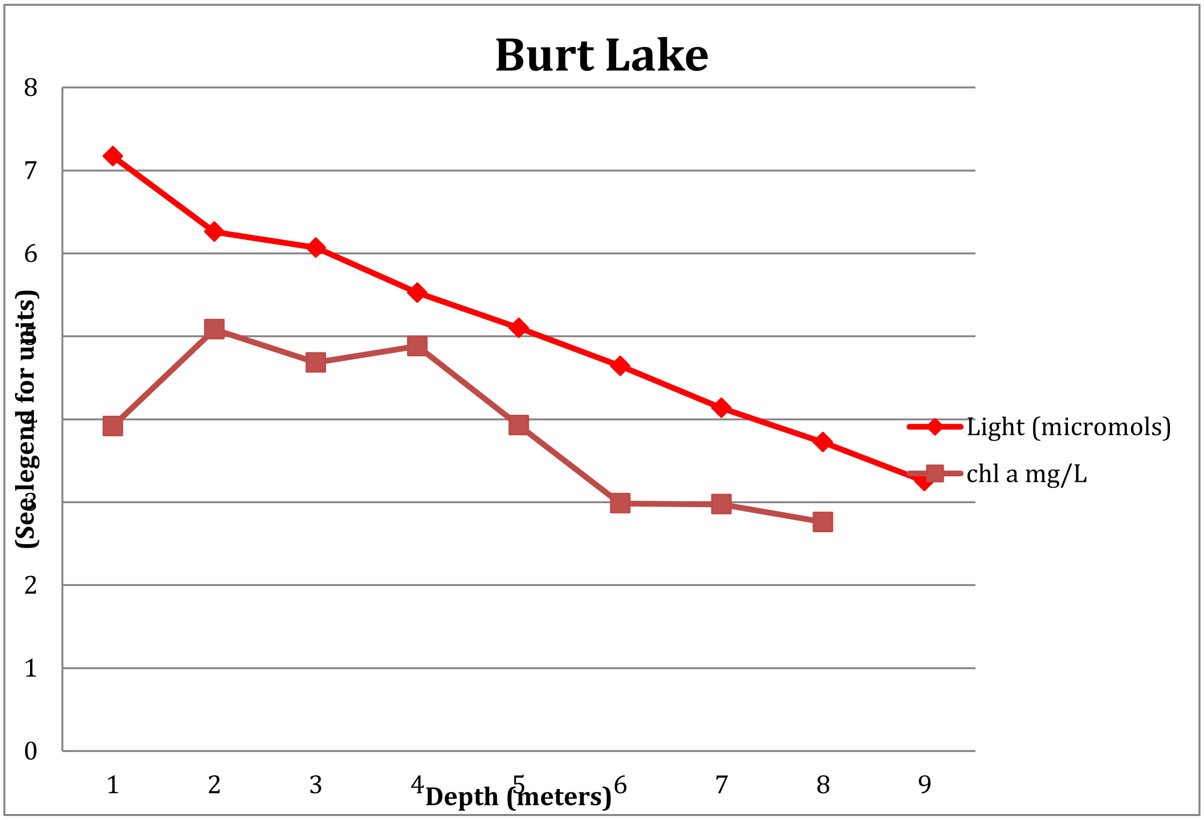
INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
DOUGLAS LAKE
AREA 3395 ACRES
MARGINAL SURVEY & SOUNDINGS - U. of M. DEPARTMENT OF SURVEYING AND GEODESY
1921-1922
INVENTORY CHEBOYGAN COUNTY
LEGEND
BOTTOM
Gravel and Rubble
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Wooded
Inlet
Outlet
VEGETATION
Emergent
Submergent
Floating
STATIONS
Temp, chem. analysis
Fish sample
Marl Bay
Silverstrand
Nuttings Bay
Maple Bay
Bryant Bay
North Fishtail Bay
South Fishtail Bay
Big Shoal
U. of M. Biological Station
DOUGLAS LAKE, Cheboygan Co.

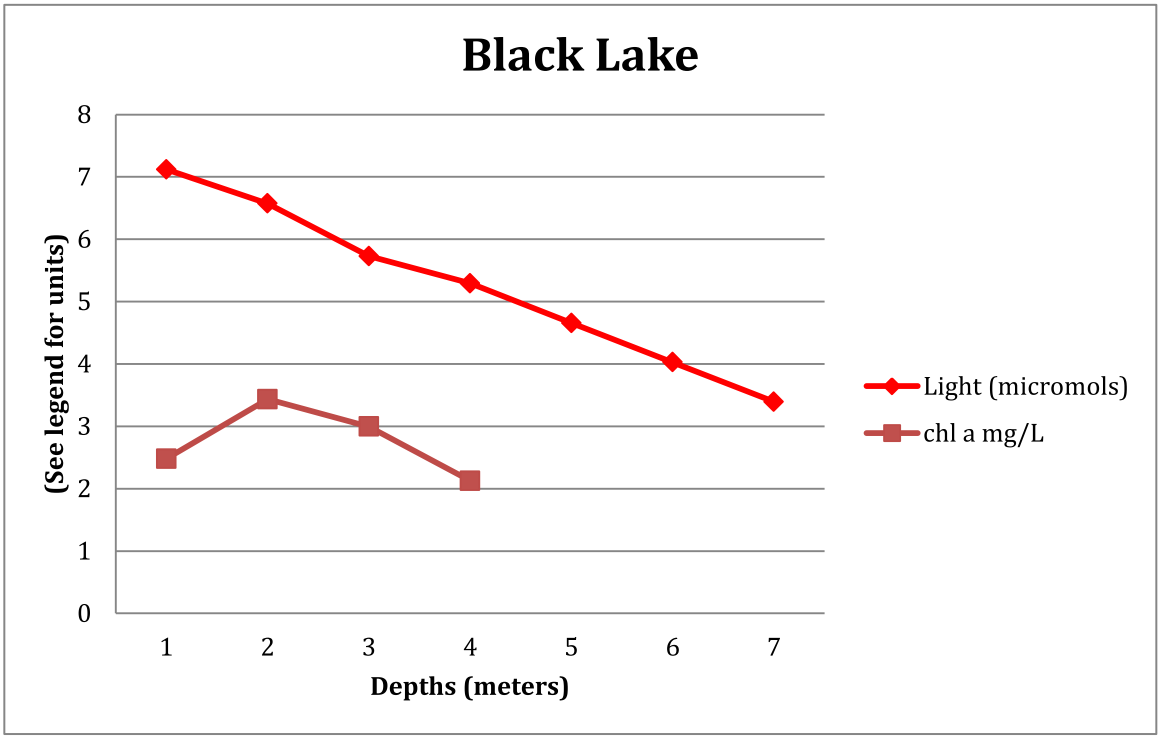

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
BLACK LAKE
AREA 10,130 ACRES
MARGINAL SURVEY AND SOUNDINGS - M.E.C.W. 1936-1937
INVENTORY BY I.F.R. 7/1-25/1939
CHEBOYGAN & PRESQUE ISLE COUNTIES T.35,36 N.,R 1,2 E
BRUSH SHELTER LEGEND
TWENTY-NINE BRUSH SHELTERS INSTALLED IN FEBRUARY, 1948, WITH COOPERATION BY THE ONAWAY SPORTSMEN'S CLUB
THIRTY-SEVEN MORE SHELTERS ADDED IN 1949, IN COOPERATION WITH THE BLACK LAKE SPORTSMEN'S CLUB
FIFTY BRUSH SHELTERS, IN 10 GROUPS OF 5 SHELTERS PER GROUP, INSTALLED DURING THE WINTER OF 1952-1953, WITH COOPERATION BY THE BLACK LAKE ASSOCIATION.
FIFTY-ONE BRUSH SHELTERS, IN NINE GROUPS OF FIVE AND ONE OF SIX, INSTALLED ON EAST SIDE OF LAKE IN MARCH, 1954, WITH COOPERATION OF BLACK LAKE ASSOCIATION AND BLACK LAKE SPORTSMEN'S CLUB.
FIFTY BRUSH SHELTERS IN TEN GROUPS OF FIVE, INSTALLED ON CODDE AND HONGORE BEACHES IN JANUARY, 1955, WITH COOPERATION OF BLACK LAKE ASSOCIATION.
FIFTY-THREE BRUSH SHELTERS IN 10 GROUPS [...] 5 AND ONE GROUP OF 3 INSTALLED DURING THE WINTER OF 1954-1955, OFF THE NORTHEAST AND NORTH SHORES WITH COOPERATION BY THE BLACK LAKE ASSOCIATION.
FIFTY BRUSH SHELTERS IN 5 GROUPS OF 5 OFF THE NORTH SHORE, AND IN 5 GROUPS OF 5 OFF THE WEST SHORE, INSTALLED DURING THE WINTER OF 1955-1956, WITH COOPERATION BY THE BLACK LAKE ASSOCIATION.
FIFTY BRUSH SHELTERS IN 10 GROUPS OF 5 OFF THE SOUTH SHORE INSTALLED DURING THE WINTER OF 1956-1957, WITH COOPERATION BY THE BLACK LAKE ASSOCIATION. (SHELTERS LOCATED SOUTHWEST OF STATE PARK)
FIFTY BRUSH SHELTERS IN 5 GROUPS OF 5 OFF THE SOUTH SHORE, NORTHEAST OF MAYER'S COTTAGE, AND IN 5 GROUPS OF 5 OFF THE NORTH-EAST SHORE, SOUTH OF CAMP NORWOOD, INSTALLED DURING THE WINTER OF 1957-1958 WITH COOPERATION BY THE BLACK LAKE ASSOCIATION.
LEGEND
BOTTOM
Sand
Muck
Fibrous peat
Brush shelter
Gravel
Deadhead
Trash
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Steep slope
Road
Cottage
Dock
Marsh
Bridge
Encroaching shore
Wooded
Partly wooded
Inlet
Outlet
VEGETATION
Emergent
Submergent
Floating
STATIONS
Temp.chem.analysis
Temp.chem.plankton
Plankton
Vegetation
Bottom sample
Fish sample
HARRISON'S RESORT
CAMP NORWOOD
CANFIELD'S RESORT
WHISPERING PINE RESORT
ONAWAY STATE PARK
QUARRY
1 MILE
SCALE
W.L.C.
BLACK LAKE Cheboygan & Presque Isle Counties T.35,36 N.,R.1,2 E.

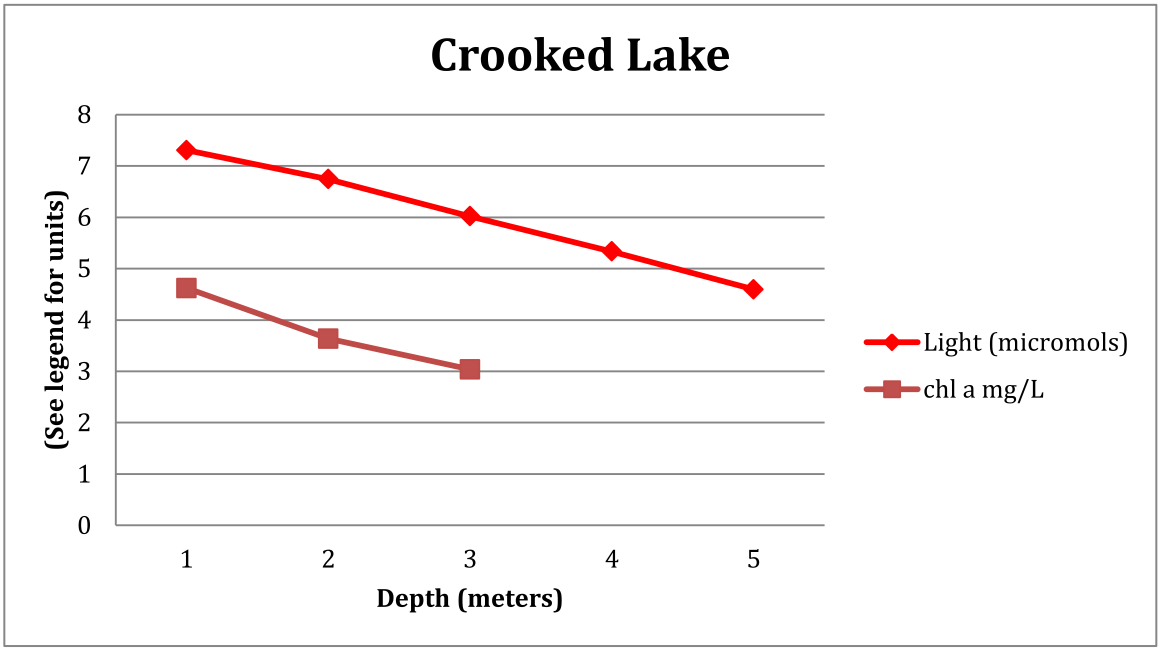

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
CROOKED LAKE
AREA 2300 ACRES
SHORELINE DETAILS COPIED FROM U.S. LAKE SURVEY CHART NO. 66. (1958), CORPS OF ENGINEERS, U.S. ARMY. DEPTH CONTOURS DRAWN FROM SOUNDINGS ON CHART NO. 66.
BOTTOM SOIL DATA BASED ON SAMPLES COLLECTED AT TIME OF INVENTORY.
INVENTORY 8/16-31/54
EMMET COUNTY T. 35 N., R. 4, 5 W.
ODEN STATE FISH HATCHERY
PENNSYLVANIA RAILROAD
ODEN
CONWAY
ISLAND
PUBLIC FISHING SITE
PICKEREL LAKE
LEGEND
BOTTOM
Sand
Marl
Clay
Organic
Gravel and rubble
Detritus
Deadheads
Brush shelter
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Improved road
Bridge
Railroad
Wooded
Partly wooded
Brush
Marsh
Spring
Inlet
Outlet
VEGETATION
Emergent
Submergent
Floating
STATIONS
Temp.chem.analysis
Fish sample
200 BRUSH SHELTERS IN 22 GROUPS OF 4 (...), 5, 8, OR 10 SHELTERS PER GROUP INSTALLED DURING THE FALL OF 1953
0 1000' 2000' 3000' 4000'
SCALE
W.L.C.
CROOKED LAKE Emmet County T. 35 N., R. 4, 5 W.


INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
BURT LAKE
AREA 17,120 ACRES
SHORELINE DETAILS COPIED FROM U.S. LAKE SURVEY CHART NO. 66 (1958), CORPS OF ENGINEERS, U.S. ARMY. DEPTH CONTOURS DRAWN FROM SOUNDINGS ON CHART NO. 66. THIS MAP PREPARED 5/59.
BOTTOM SOIL DATA BASED ON A STUDY OF THE SEDIMENTS, SPONSORED JOINTLY BY THE GREAT LAKES RESEARCH INSTITUTE AND THE DEPARTMENT OF GEOLOGY, UNIVERSITY OF MICHIGAN, AND THE MICHIGAN CONSERVATION DEPARTMENT.
INVENTORY 7&8/55
CHEBOYGAN COUNTY T. 35,36 N., R. 3 W.
(NOT FOR USE IN NAVIGATION)
LEGEND
BOTTOM
Sand
Sand and Organi:
Organic
Gravel
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Improved road
Bridge
Railroad
Marsh
Inlet
Outlet
STATIONS
Temp. chem. analysis and light penetration determinations
Fish sample
IN 1983, 78 BRUSH SHELTERS IN 13 GROUPS OF 6 SHELTERS PER GROUP
0 2500′ 5000′ 7500′ 10,000′
SCALE
BURT LAKE Cheboygan County T. 35,36 N., R. 3 W.

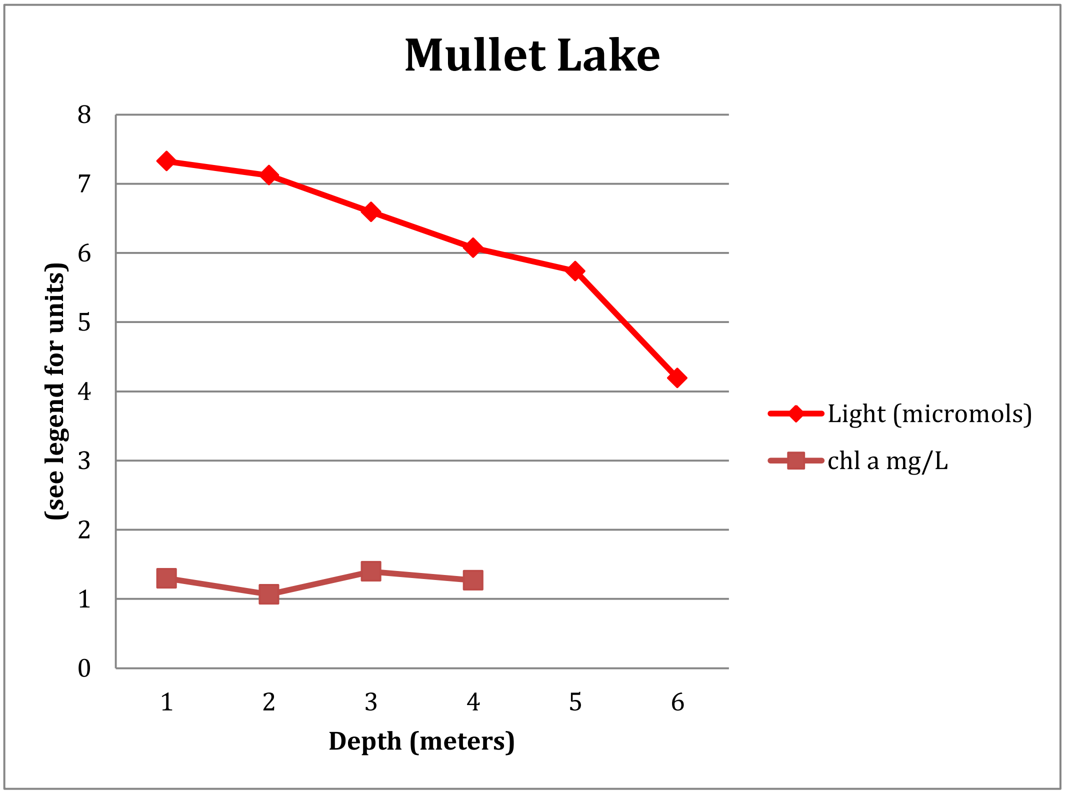

Douglas Lake
8
7
6
5
4
3
2
1
0
(for units see legend)
1 2 3 4 5 6 7 8 9
depth (meters)
Chl a mg/L
Light (micromols)


Burt Lake
8
7
6
5
4
3
2
1
0
(See legend for units)
1
2
3
4
5
6
7
8
9
Depth (meters)
Light (micromols)
chl a mg/L


Black Lake
(See legend for units)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
Depths (meters)
Light (micromols)
chl a mg/L



Crooked Lake
(See legend for units)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Depth (meters)
Light (micromols)
chl a mg/L


Mullet Lake
(see legend for units)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
Depth (meters)
Light (micromols)
chl a mg/L