AN ASSESSMENT OF EXISTING WATER QUALITY
FOR
THREE LAKES, ANTRIM COUNTY, MICHIGAN

PREPARED FOR THE THREE LAKES ASSOCIATION

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Last, but certainly not least, I wish to express my most sincere gratitude to Clark Reed. Clark volunteered his time and efforts in tabulating data and providing his share of typing prowess.

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ABSTRACT

Water quality assessment for lentic systems is difficult to measure by one or two methods when considered in terms of complex biological and chemical interactions, physical variations, and constant alteration of environmental conditions. Twenty years of research data have been accumulated for Three Lakes Association with emphasis directed at water quality changes of lake systems under juristiction of the aforementioned organization.

Compilation of this data is expressed on comparative associations in several sections of this report. These include chemical and limnological data, algal associations, bacterial associations, and benthic associations where applicable. Results are tabulated and graphed when possible to show variations of lentic conditions versus time. Careful examination of results will provide insight toward possible regeneration, degeneration, or similarities in water quality.

INTRODUCTION

Consideration of water quality assessment among scientists leads to many varied theories of limnology, ecology, and methodology. Only in the past twenty years have testing procedures reached a point of sophistication to yield vast quantities of results. However, use of several of these techniques provide only general overviews of an aquatic system: specific answers demand consideration and assessment of all possible interactions within each trophic level of a given ecosystem.

Before answers can be gained by various laboratory analyses, it is necessary to consider 1) geological history, 2) lake ontogeny, 3) chemistry, 4) biology, and 5) environmental variations. Any lake ecosystem is an extremely fragile complex of many interacting variables which provide each body of water with a distinctive character. The following sub-headings will provide some introduction to each of the five aforementioned areas.

Geological History

To gain a full understanding of Antrim County's Chain of Lakes, it is necessary to examine geological events of the past 20,000 years. Antrim's bedrock is composed of Devonian and Mississippian formations of 250-600,000 years ago. Aeranaceous tills of northwestern Lower Michigan are resultant of Wisconsinian glacial retreat during the Pleistocene Epoch, a period when the entire state was covered by one thousand metres of ice (Dorr and Eschman, 1970). Two glacial substage advances, the Port Huron and the Valders Stadial, are responsible for moraine and drumlin development which affect flow direction and basin areas of local waterways. Page 1 of Appendix A illustrates moraine development of the Pleistocene.

The Wisconsinian and its various substages had varied affects on the Laurentian Great Lakes and shoreline regions which include the Chain of Lakes. Though discrepancies occur among Hutchinson (1957), Dorr, et.al. (1970), and Scott (1921) regarding chronological dates, sequential events are similar and illustrated with elevation information on page 2, Appendix A.

Due to retreat of the Valders substage, Lake Algonquin filled to an elevation of 206 metres and included Torch and Elk lake basins, connected by channels in the Elk Rapids and Eastport areas. Lake Bellaire and Clam Lake are outwashes formed by meltwater trapped between an inner and outer moraine of the Valders retreat. A post-glacial thermal maximum occurred, lowering lake elevations below 90 metres and resultant bar and dune formation separated Torch from the main lake at Eastport. Isostatic rebound within the earth's crust refilled the basin and formed Lake Nipissing. Nipissing wave action cut into the Algonquin terrace, forming steep cliffs at water's edge. Currents became much more important during this period, forming bars and points as known now (Scott, 1921). Current elevation levels of the lakes are due to a shift in drainage from the Mississippi River system to the St. Lawrence River via the Niagara escarpment.

Results of glacial events can easily be traced in Antrim County. East Torch Lake Drive runs along the berm of the Nipissing beach while the Algonquin beach is located farther to the east, approximately 7.5 metres higher in elevation. The bases of these beaches are often marked by the presence of large boulders, exposed by years of erosion of the glacial till. Lake Algonquin also included Thayer Lake, thus the absence of the Algonquin beach along East Torch Lake Drive for several miles south of Clam River. Two glacial moraines referred to in a previous paragraph can be observed as one ridge follows U.S. 131 north of Mancelona while Schuss Mountain resort is atop another moraine.

Lake Ontogeny

Lake ontogeny as defined is tracing the entire course of development throughout a lake's life history. As with any life form, a lake progressively ages which is expressed in terms of productive capacity. Oligotrophy and eutrophy are two terms located at opposite ends of the aging spectrum. Naumann (1931) defines oligotrophy as poor production capacity for organic matter and eutrophy as high production within a given system. Mesotrophy falls in between these two endpoints. Simplified flowcharts have been illustrated on pages 3 and 4 of Appendix A.

Ontogeny is dependent on many outside influences. Morphometry or basin structure is extremely important as lakes located in deep, rock basins will not age as rapidly as those in muds or outwash areas. Another consideration is typology of bedrock underlying the lake, such as in marl lakes, as shown on page 5 of Appendix A. Reactions with water, such as in limestone regions, will yield a constant inflow of dissolved ions such as calcium and magnesium. Creek inflows and drainage basin relief will definately influence silt and chemical loading into a lentic system, thus altering rates of productivity.

Human influence, unchecked, is the greatest detriment to any freshwater system. People accept responsibilities for drainage basin alterations, channelization, urbanization, defoliation, and direct pollution through lake use and septic leaching - all of which increase productivity. It has been estimated the human presence on a lentic system can increase eutrophication rates by 1000 times.

Chemistry

Chemical analyses of water are extremely well defined in methodology such as in Standard Methods (A.P.H.A., 1975). There are basic components and elements present in natural waters though at varied concentrations, depending on surrounding land use, morphometry, and ontogeny. These include calcium, magnesium, inorganic and organic carbon, heavy metals, oxygen, nitrogen, phosphorus, carbonate, bicarbonate, and various organic acids.

Examination of these factors can provide an accurate account of water quality at the specific sample site at the time of sampling. In combination, these chemical constituencies are responsible for hardness, alkalinity or acidity, and buffering capacities in a system. Nutrients, or nitrogenous and phosphoric complexes, are of principle concern as both are required for increased productivity.

Environmental and Physical Variation

Consideration of any freshwater system would be worthless without inclusion of physical and environmental interactions. Weather conditions may alter one chemical constituent such as oxygen and results may "snowball." Phosphate nutrient loading will simply occur from atmospheric fall-out and precipitation. Brylinsky and Mann (1973) illustrate effects of environmental variables on nutrient and element availabilities in two figures on page 6 of Appendix A.

Biology

There are several methods for assessing collected biota for an aquatic system, but most commonly used is the Saprobien-system. Originally devised for lotic pollutional studies in 1908 by Kolkwitz and Marsson, it has been redefined and evaluated for lakes. Much of this reclassification is written up by Fjerdingstad (1963). This method of categorization emphasizes spectral placement of different biotic communities by tolerance to various pollutants of aquatic environments. Saprobic placement also illustrates the importance of species identification when possible as species of the same genus may be resistant to differing water types (Resh and Unzicker, 1975). Examples of saprobic classification and explanations are offered on page 7 of Appendix A.

As community and species identification has been stressed, interaction of various trophic levels must be examined to develop an understanding for the ecosystem as a whole.

> "There is a relation between the concept of trophic levels and that of food chains but the two concepts are not identical, the first being a simplified assumption while the second is purely descriptive. If a diagram of the passage of high energy molecules through an ecological community is made, it will be found that the potential energy of any given molecule will either have dissipated in heat in or near the body of some organism or been transferred to some other organism."
>
> (Lindeman, 1942)

Lindeman devised a simplistic model, shown on page 8 of Appendix A which demonstrates interactions among trophic levels, all of which will occur within a lake.

MATERIALS AND METHODS

Water quality assessment collections for Three Lakes Association are procured using two research vessels owned by Central Michigan University. A 6.1 meter Penn Yan, the Katy M., is equipped with an 85 horsepower Evinrude outboard and used on Lake Bellaire, Clam Lake, and the inflowing rivers. The Fish Hawk is an 8.3 meter Broadwater and is used on Torch Lake during inclement or windy weather. Sample analyses are performed in the Water Quality Laboratory, located on Park Street in Bellaire, Michigan.

Biological Analyses

Algal, plankton, and macrophyte samples are collected qualitatively in an effort to study transient and seasonal communities at each sample location. Phyto- and zooplankton are collected and concentrated using a modified Wisconsin net for vertical and horizontal tows. Whole plankton samples are collected in a two liter Kemmerer water sampler and filtered. Samples are fixed in magnesium carbonate and preserved in a 4% formalyn solution. Filamentous algae and macrophytes are collected by Petersen dredge or by hand and preserved. Preserved samples are permanently mounted in glycerin jelly and identified with a Bausch and Lomb phase contrast microscope. Taxonomic keys used in the laboratory include Smith (1950), Prescott(1961), Prescott (1970), and Fassett (1957). Confirmations, when necessary, are made by Dr. Matthew Hohn of Central Michigan University.

Benthic organisms are collected qualitatively by Petersen dredge grab samples. Each sample is rinsed through a #30 mesh screen three times to remove sediments and remains are stored in gallon jugs filled with 4% formalyn solution. In the laboratory, contents are placed in enamel pans and organisms are hand-picked from the sample. Approximately twenty aliquots of a each grab sample are "picked" further with aid of Swift Stereo 90 Dissecting Microscopes. Most benthic organisms are identified grossly, with taxonomic keys of Eddy and Hodson (1950), Pennak (1953), and Usinger (1956). Smaller aquatic organisms are mounted according to procedures of Pennak and Curry (1962) and subsequently identified with keys of Townes (1952), Johannsen (1933), Dow and Turner (1976), Mason (1973), Pennak, Usinger, and Curry. Aquatic dipterans and zooplankton are confirmed by Dr. LaVerne L. Curry, retired Chairman of Biology, Central Michigan University.

Bacterial analyses are run bimonthly at all sample sites. Specific types analysed include total coliform, faecal coliform, and faecal streptococci. Ten milliliters of water sample are filtered with a sterilized phosphate buffer. The resultant filter pad is placed in the proper medium container and incubated for a specific number of hours. The number of bacterial colonies is tabulated and compared with previous work. Equipment used includes two cabinet-type incubation chambers and a manifold-vacuum system. Specific procedures for analysis are published by the Millipore Corporation (1974).

Chemical Analyses

Before all chemical tests, weather data, water temperature, and secchi transparencies are recorded. As noted in the Environmental Variation section of the Introduction, many outside influences may alter chemistry results. Chemical testing is run on a bimonthly basis. Specific tests run for all locations include dissolved oxygen, pH, ortho-phosphate phosphorus, nitrate-nitrogen, calcium hardness, total hardness, total alkalinity, and specific conductivity. Biochemical oxygen demand, nitrite-nitrogen, grease and oil, and chlorides are run for specific sites. All tests are run according to A.P.H.A. (1975).

The laboratory has several instruments which speed analyses once standardized. These include a Bausch and Lomb Spectronic 20, a Beckman Model G pH meter, a Galvanic Cell Oxygen Analyser, and a Conductivity Bridge. Hach Kit is used for bacterial-chemical studies on stream inflows in the area after standardization.

Other

The Inland Lakes Management Unit of the Michigan Department of Natural Resources instituted a Self-Help program for lake associations around the state of Michigan. For the third year, Three Lakes Association is participating in this program. A secchi transparency and weather data is recorded before a vertical tow is taken. Samples are frozen and later analysed by the D.N.R. for chlorophyll a content.

RESULTS

Results of chemical, bacteriological, biological, and physical investigations have been tabulated for comparison. Page 1 of Appendix B is an annotated bibliography for data contributions of each researcher, chronologically listed. All results are expressed as maximum and minimum unless otherwise noted. Torch Lake results will be found on pages 2 through 5 of Appendix B, Clam Lake results on pages 6 to 9, and Lake Bellaire results on pages 10 through 13. Pages 14 and 15 show graphic results of last year's participation in the Inland Lake Self-Help Program sponsored by the Michigan Department of Natural Resources.

Torch Lake

Chemically, Torch Lake has changed little if at all in the past seventeen years except in pH and alkalinity. Dissolved oxygen remains quite high throughout the water column, dependent on sampling procedure and location. Biologically, the lake is dominated by saproxenous organisms, though Rhizosolenia sp. and Attheya sp. may occupy a saprophobous level of the saprobiensystem. Cladophora (glomerata ?) sp. develops on some shoreline rocks, undoubtedly due to nutrient leaching or natural decomposition in sheltered areas. Spencer Creek at Alden and Torch River show a history of causing elevated bacteria plate counts. Secchi transparency (abbreviated as "trans") fluctuates with available incident light and wave action, but constantly is among the highest in the State of Michigan.

Clam Lake

Clam Lake chemistry fluctuates greatly from station to station, but if samples are taken from the same location it is relatively comparable. Biological data is plentiful and diversity is quite high if considering the entire lake. Most species are saproxenous, though in some problem areas saprophilic forms such as Oscillatoria sp. develop. Bacterial data is scattered and not comparable. Secchi transparencies have remained similar over eight years.

Lake Bellaire

Lake Bellaire chemistry has remained quite stable for eight years and biological organisms, primarily saproxenous with exception of several blue-green algae, have remained constant in regard to a basic mesotrophic community. Intermediate River and Wilson's Creek are bacterial and nutrient sources, though lower in 1977 and 1978 for nitrogen and phosphorus loading. Physical data results were comparable with exception of one secchi transparency taken in 1972.

Inland Lake Self-Help Program

Three Lakes Association joined the Self-Help Program in 1976. First year results only included Torch and Clam Lakes. In 1977, Torch Lake was determined to be an oligotrophic basin while Clam was mesotrophic and Lake Bellaire was in a transitional mesotrophic state. Only Lake Bellaire is being analysed for chlorophyll a in 1978.

DISCUSSION

Water Quality Assessment for the Three Lakes

For the past fifty years, limnologists have attempted to devise methods and sampling procedures for an overall assessment of water quality. Unfortunately for science, finances and manpower shortages seem to place their own "limiting factors" on this type of research. Bits and pieces of work on various organisms and water types have been well documented, but as yet, no person has been able to conceive a workable model for the problem at hand; that is, incorporating every trophic level and function with physical and chemical water parameters to permit and accurate and total overview of a lentic system.

Though much presented data may have appeared very similar, there was not enough similar work done by the same methods to permit a point versus point comparison. Techniques, especially in chemistry, have changed very drastically since scientists first started to study these lakes. There is an extraordinary number of variables which come into play when considering a lentic ecosystem, and difficulties arise when trying to predict a certain cause-effect situation which is not constantly present.

Placement of a "trophic" status on any lake demands careful analysis of the entire situation. Evaluation of data and results would lead one to consider all of Torch Lake as oligotrophic. Chemical and biological analyses at the Alden public dock display mesotrophy at best. Secchi transparencies have never extended beyond six (6) metres off of the Clam River breakwater, yet visibility was nearly 15 metres near Christian Point.

Sample locations on Clam Lake and Lake Bellaire appear as different lakes below the surface. Bottom typology, macrophytic growth, and biotic communities contrast though chemistry tests may be very comparable from point to point. Page 1 of Appendix C illustrates current sample sites for the water quality program. Interested individuals should take time to examine several of these locations and mentally note the differences.

Considering the lakes as entire entities, Torch Lake is indeed oligotrophic. Lake Bellaire is mesotrophic according to organism communities and chemical data. Certain shallow areas, such as the northeast corner, may take on more eutrophic character during certain environmental stresses. Clam Lake is a mesotrophic system in the central channel, but tends toward eutrophy in the southeast corner.

Some Unexpected Water Quality Problems and Subsequent Evaluations

During June of 1977, several riparians voiced concern over fish mortality in Lake Bellaire. The species involved, rainbow smelt (Osmerus mordax), was dying off and proving to be a nuisance for lakefront property owners. Research by the Michigan Department of Natural Resources and the Water Quality Laboratory showed probable cause of death to be temperature stress. Smelt are extremely temperature-sensitive and an abnormally warm spring caught them in shallow water during their spawning run. Elevated water temperature was the only abnormality noted as water chemistry readings were as would be expected and there was no sediment build-up in gill filaments.

A heat wave during Memorial Day weekend of 1978 perpetuated a minor algae pulse in the northeast corner of Lake Bellaire. The genus involved was Cladophora (glomerata ?) sp. and a nutrient release from the bottom sediments was held responsible. Nutrient movement through and out of lake muds is governed by dissolved oxygen content in waters overlying the sediments. High temperatures and no wind for circulation will deplete oxygen concentration in shallow water, sometimes creating an anoxic condition. Redox (oxidation-reduction) potential, which normally keeps nutrients bound to the muds, decreased which allows nutrient migration through muds into overlying water (Hynes and Greib, 1970). Chemical analysis on Lake Bellaire showed supportive evidence for this phenomenon as no heavy nutrient loads were entering the lake from Intermediate River or through inflowing creeks. Nitrates and phosphates which were available to the algae are already present in muds from a combination of natural plant decomposition, run-off, atmosheric fall-out and precipitation, and careless riparian practices.

Pollen has caused much concern among Torch Lake riparians during 1978. As in algal problems on Lake Bellaire, heavy pollen concentrations were due to shifting weather conditions which literally promoted "explosions" of blossoming shoreline vegetation, releasing massive concentrations of pine, cedar, alder, poplar, and willow pollen. These masses appear as a yellow-green conglomeration resembling chicken broth. The odor of "dead fish" is simply from the natural decomposition of these pollen grains during hot days when wind is non-existant. Riparian owners may notice a thin, green film on shoreline rocks at the waterline. This slime is the alga Cladophora though a different species than that of Lake Bellaire. Pollen decomposition releases several nitrogenous and phosphoric compounds which permit a slight perpetuation of algal growth. More dense concentrations may indicate more serious problems and riparians should contact the laboratory.

A final "problem" which has been questioned repeatedly is marl formation. Marl is actually calcium carbonate ($CaCO_3$) and precipitation of this compound occurs quite frequently in hardwater lakes of glaciated regions. In natural hardwaters, there exists a balance, or buffering capacity among compounds of inorganic carbon origin. These include calcium bicarbonate, calcium carbonate, carbon dioxide, and natural alkalinity and hardness. Loss of carbon dioxide due to high atmospheric temperature causes heavy marl precipitation (Wetzel, 1975). Calcium carbonate is also primarily responsible for thick encrustations on rocks in Torch Lake and on the algal form, Chara sp., in Clam River. Please refer to Page 5 of Appendix A.

SUMMARY

As may be noted in previous sections of this report, any year to year comparisons of data for the three lakes are subject to difference. These alterations may be due to environment, weather, different analysis techniques, or changes in sampling stations. A year's data, if complete, can be compared with another year and certain assumptions and observations toward water quality can be made with some confidence. It is important to realize that a lentic ecosystem is subject to constant fluctuation if certain pressures are exerted.

Though it is extremely difficult to base a lake's trophic status on one variable such as dissolved oxygen profiles or chlorophyll a, the theory behind such studies is extremely sound. Data is substantial and dependable because samples are standardized and results are collected, tabulated, and applied similarly each year. Accuracy and precision are necessary for an effective water quality assessment - these accomplishments depend on a standard sampling program which will be stringently adhered to and followed in future years.

LITERATURE CITED:

Alden, Jon, 1968. Estimate of the Water Quality of Intermediate River, Lake Bellaire, and Clam Lake by Appraisal of Bottom Fauna as Related to the Saprobic System. Central Michigan University, Xerox.

Ameriacan Public Health Association, 1975. Standard Methods for the Examination of Water and Wastewater, 14th Edition. Washington, D.C., A.P.H.A., 923 pp.

Barber, Bruce, 1970. Water Quality Study of Chain O' Lakes. Central Michigan University, Xerox.

Benjamin, Daniel et.al., 1970. A Base-Line Study of the Upper Chain O' Lakes with Reference to Several Stations in the Lower Chain and Grand Traverse Bay in Antrim, Kalkaska, and Grand Traverse Counties. Central Michigan University, Xerox.

Boyd, Larry, 1975. Field notations.

Boyd, Larry, 1976. Field notations.

Brylinsky and Mann, 1973. Analysis of factors governing production in lakes and reservoirs. Limnology and Oceanography 18(1): 13-22.

Curry, LaVerne L., 1962. A Study of the Ecology and Taxonomy of Freshwater Midges (Diptera:Tendipedidae) of Michigan with Special Reference to their Role in the "Turnover" of Radioactive Substances in the Hydrosol. Report 2. Mt. Pleasant, MI., Central Michigan University, 149 pp.

Dorr and Eschman, 1970. Geology of Michigan. Ann Arbor, MI., University of Michigan Press, 476 pp.

Dow and Turner, 1976. A Taxonomic Revision of the Nearctic Species of the Genus BEZZIA (Diptera:Ceratopogonidae). Research Division Bulletin 103. Blacksburg, VA., Virginia Polytechnical Institute and State University, 162 pp.

Eddy and Hodson, 1950. Taxonomic Keys to the Common Animals of the North Central States. Minneapolis, MN., Burgess Publishing Company, 162 pp.

Everhart, Lloyd et.al., 1971. A Study Based on the Saprobiontic System of the Chain of Lakes, Antrim, Charlevoix, Kalkaska, and Grand Traverse Counties, September and October, 1970. Central Michigan University, Xerox.

Fassett, Norman C., 1957. A Manual of Aquatic Plants. Madison, WS., University of Wisconsin Press, 405 pp.

Fjerdingstad, E., 1963. Limnological Estimation of Water Pollution Levels. Geneva, WHO/EBL/10, 21 June 1963, 29 pp.

Fultz, Roger, 1970. Report of Aquatic Insects and Chemical Analysis of the Chain O' Lakes. Central Michigan University, Xerox.

Garcia, Dudley, 1968. A Survey of Fecal Streptococcus on the Chain O' Lakes. Central Michigan University, Xerox.

Geers and Sundberg, 1973-1975. Chain O' Lakes Survey. Field Notations.

Gryska, Bernard, 1964. A Probe into the Waters at Torch Lake. Central Michigan University, Xerox.

Hamilton, et.al., 1972. Bottom Fauna Analysis of Lake Bellaire. Central Michigan University, Xerox.

Hutchinson, G.E., 1957. A Treatise on Limnology. I. Geography, Physics, and Chemistry. New York, NY., John Wiley and Sons, Inc., 1025 pp.

Hynes and Greib, 1970. Movement of phosphate and other ions from and through lake muds. Journal of Fisheries Research Board 27:653-672.

Johannsen, O.A., 1934. Aquatic Diptera. Ithaca, NY., Cornell University Press, 269 pp.

King, Robert H., 1965. Quantitative Plankton Study on Torch Lake, Michigan. Central Michigan University, Xerox.

King, Robert H., 1966. Limnological Investigation of the Chain O' Lakes, Grand Traverse, Kalkaska, and Antrim Counties. Central Michigan University, Xerox.

Lawrenz, Ronald, 1970. Plankton Samples from Torch Lake, Clam Lake, and Lake Bellaire. Report No. 2. Central Michigan University, Xerox

Lawrenz, Ronald, 1970. Bottom Organism Study of Chain O' Lakes. Central Michigan University, Xerox.

Lawrenz, Ronald, 1971. Shoreline Algal Survey on Lake Bellaire, Clam, and Torch Lakes. Central Michigan University, Xerox.

Lindeman, 1942. The trophic-dynamic aspect of ecology. Ecology 23:399-

Mason, William T., 1973. An Introduction to the Identification of Chironomid Larvae. Cincinnati, OH., United States Environmental Protection Agency, 90 pp.

Geological Survey Division, 1967. Morainic Systems of Michigan. Lansing, MI., Michigan Department of Natural Resources, Map.

Inland Lakes Management Unit, 1976. Inland Lakes Self-Help Program Annual Report. Lansing, MI., Michigan Department of Natural Resources, 31 pp.

Inland Lakes Management Unit, 1977. Inland Lakes Self-Help Program Annual Report. Lansing, MI., Michigan Department of Natural Resources, 34 pp.

Millipore Corporation, 1974. Fecal Coliform Analysis, Total Coliform Analysis. Bedford, MA., Millipore Corporation, AB311 and AB313.

Morgan, Dennis, 1970., Indicators of Organic Pollution in the Chain O' Lakes. Central Michigan University, Xerox.

Naumann, E., 1931. Limnologische Terminologie. Handbuch der biologische Arbeitsmethoden, Abt. IX, Teil 8. Berlin, Urban and Schwartzenberg, 776 pp.

Pennak, Robert, 1953. Fresh-Water Invertebrates of the United States. New York, NY., Ronald Press Company, 769 pp.

Prescott, G.W., 1962. Algae of the Western Great Lakes Area. Dubuque, IA William C. Brown Company Publishers, 977 pp.

Prescott, G.W., 1970. How to Know the Freshwater Algae. Dubuque, IA., William C. Brown Company Publishers, 348 pp.

Resh and Unzicker, 1975. Water quality monitoring and aquatic organisms: the importance of species identification. Journal of Water Pollution Control 47(1): 9-17.

Scott, I.D., 1921. Inland Lakes of Michigan. Lansing, MI., Wynkoop Hallenbeck Crawford Company, 383 pp.

Smith, Gilbert, 1950. Freshwater Algae of the United States. New York, NY., McGraw-Hill Book Company, 719 pp.

Smith, Robert, 1968. Plankton Report for the Chain O' Lakes. Central Michigan University, Xerox.

Sundberg, Jerry, 1972. Bacteriological, Biological, and Physical Results from 1972 Surveys of the Chain O' Lakes. Central Michigan University, Xerox.

Usinger, Robert L., ed., 1956. Aquatic Insects of California. Berkeley, CA., University of California Press, 508 pp.

Townes, Henry K., 1952. Guide to the Insects of Connecticut, Part VI., Fifth Fascicle: Midges and Gnats. Hartford, CT., United Printing Services, Inc., 255 pp.

Wetzel, Robert G., 1972. The role of carbon in hard-water marl lakes. In G.E. Likens, ed., Nutrients and Eutrophication: The Limiting-Nutrient Controversy. Special Symposium, American Society of Limnology and Oceanography 1: 84-91.

Wetzel, Robert G., 1975. Limnology. Philadelphia, PA., W.B. Saunders Company, 743 pp.

Witzerman, Robert A., 1978. Methods for Determination of Community Structure and Function of a Lentic Ecosystem. Central Michigan University, xerox.

Witzerman, Robert A., 1978. A Supplemental Report: An Overview of Current Water Quality for the Lower Chain of Lakes. Central Michigan University, xerox.

GLOSSARY

ACCURACY--An indication of the proximity of a set of data to the true value of the thing being measured, whether by accident or design. See PRECISION

ALIQUOT--A portion of a given sample.

ALGAE--Simple plants, many microscopic; contain chlorophyll.

AMPHIPODA--Macroscopic aquatic crustaceans that are laterally compressed; Dense populations are associated with aquatic vegetation.

AUTECOLOGY--Ecology of an individual organism.

BENTHIC REGION--The substrate underlying water which is usually inhabited by immature insects.

BIOCHEMICAL OXYGEN DEMAND (B.O.D.)--Determination of relative oxygen requirements of wastewater, effluents, and polluted water.

BOTTOM TYPE--type of materials composing the substrate.

CALCIUM HARDNESS--Amount of calcium in water supplies from passage through or over deposits of limestone, dolomite, gypsum, or gypsimiferous earth.

CONDUCTIVITY--Yields a measure of water's capacity to convey an electric current; the more dissolved substances in the watercourse, the lower the electrical capacitance.

DISSOLVED OXYGEN (D.O.)--Indicates amount of oxygen concentrated in a given volume of water; associated with corrosivity of water, photosynthetic activity, and septicity.

ECOLOGY--The science of interrelationships between living organisms and their environment.

ECOSYSTEM--The interaction of all living and non-living paramenters within a given environment.

EUTROPHICATION--The intentional or unintentional enrichment of water, leading to more rapid aging.

FAUNA--Reference to animal life found within a given system.

FLORA--Reference to plant life found within a given system.

LENTIC--Reference to a lake system.

LIMNOLOGY--The study of the physical, chemical, and biological aspects of inland waters.

LOTIC--Reference to a stream system.

MESOTROPHIC--Adjective describing moderate productivity in a lake.

NITRATE-NITROGEN--Represents the most oxidized phase in the nitrogen cycle and normally reaches important concentration in the final steps of biologic oxidation; important as nutrient-nitrogen source for plants.

OLIGOTROPHIC--Adjective describing a lake with low productivity.

ONTOGENY--The science of tracing an entire life history.

ORTHO-PHOSPHATES--A highly oxidized form of phosphorus which is limiting to growth of organisms; an increase of phosphorus from run-off or decomposition will often stimulate the growth of organisms, thus lowering dissolved oxygen and raising biochemical oxygen demand.

GLOSSARY (CONT'D)

pH--A scale based from 1 to 14 where a value less than 7.0 indicates acidity and above 7.0 is basic; most natural waters are basic due to carbonate and bicarbonate; pH is actually defined as the logarithm of the reciprocal of hydrogen ion concentration or activity in moles per liter.

PHYTOPLANKTON--Microscopic, non-attached algae forms. Locomotion powers are weak or non-existent and cells drift with waves or current.

PRECISION--An indication of the standard deviation in a set of data, but not necessarily an indication of the proximity to the true value of the thing being measured. See ACCURACY.

SAPROBIONTIC--Adjective describing organisms which inhabit aquatic environments generally devoid of oxygen; hydrogen sulfide and ammonia are the predominent chemical complexes.

SAPROPHILOUS--Adjective describing organisms which generally occur in polluted waters, but may occassionally occur in other communities.

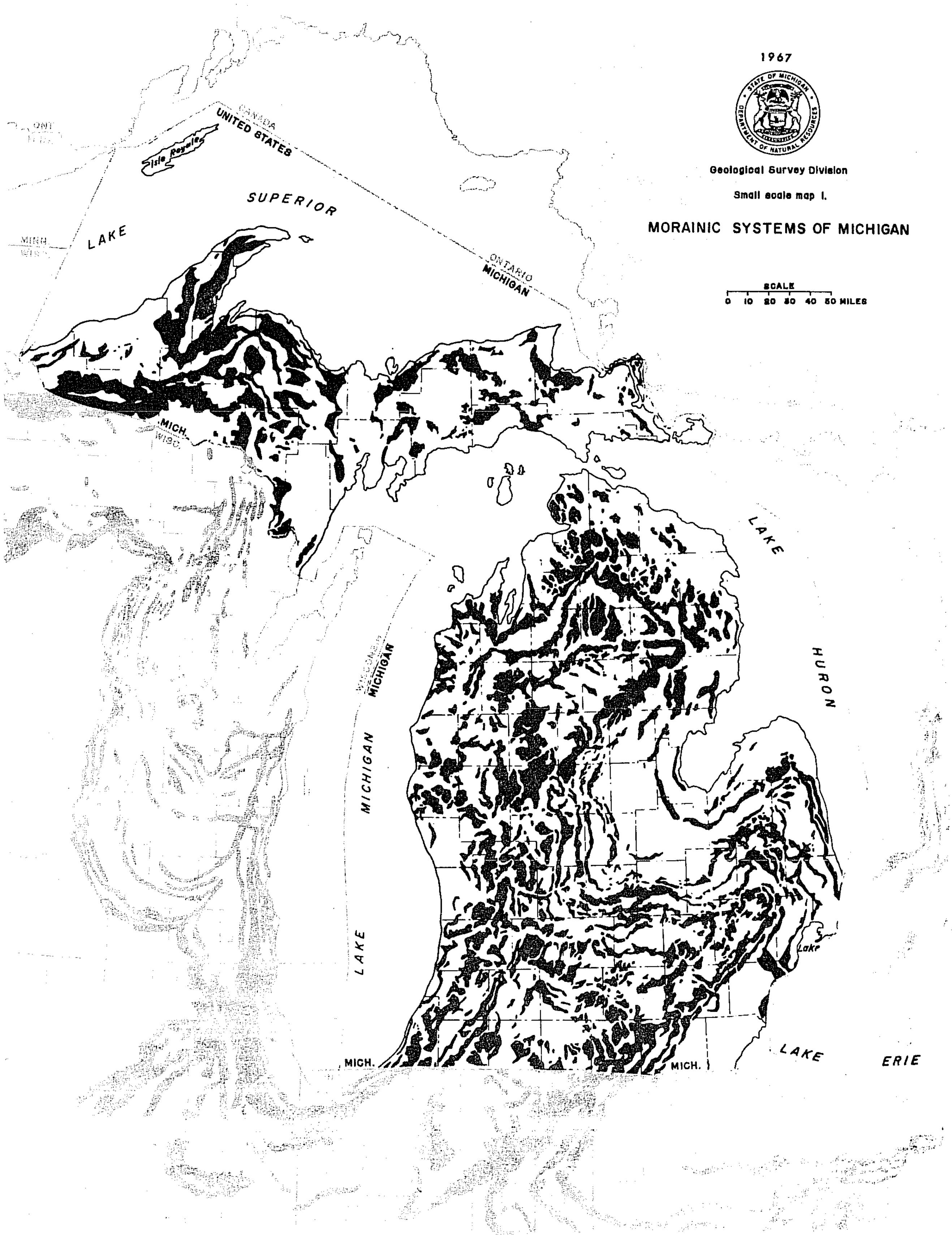
SAPROPHOBOUS--Adjective describing organisms unable to tolerate pollution

SAPROXENOUS--Adjective describing organisms which generally inhabit unpolluted waters, but are tolerant of mild pollution.

SECCHI DISC--A devise used to measure visibility depths in water. The upper surface of a circular metal plate, 20 cm. in diameter, is divided into four quadrants and so painted that two quadrants opposi either are black and the intervening ones are white. When suspended at various depths of water by means of a graduated line, its point of disappearence indicates the limit of visibility into the water.

TOTAL ALKALINITY--The capacity of water to accept protons, usually imparted by carbonate, bicarbonate, or hydroxide components.

TOTAL HARDNESS--A characteristic of water which represents the total concentration of calcium, magnesium, aluminum, and other assorted polyvalent metal ions.



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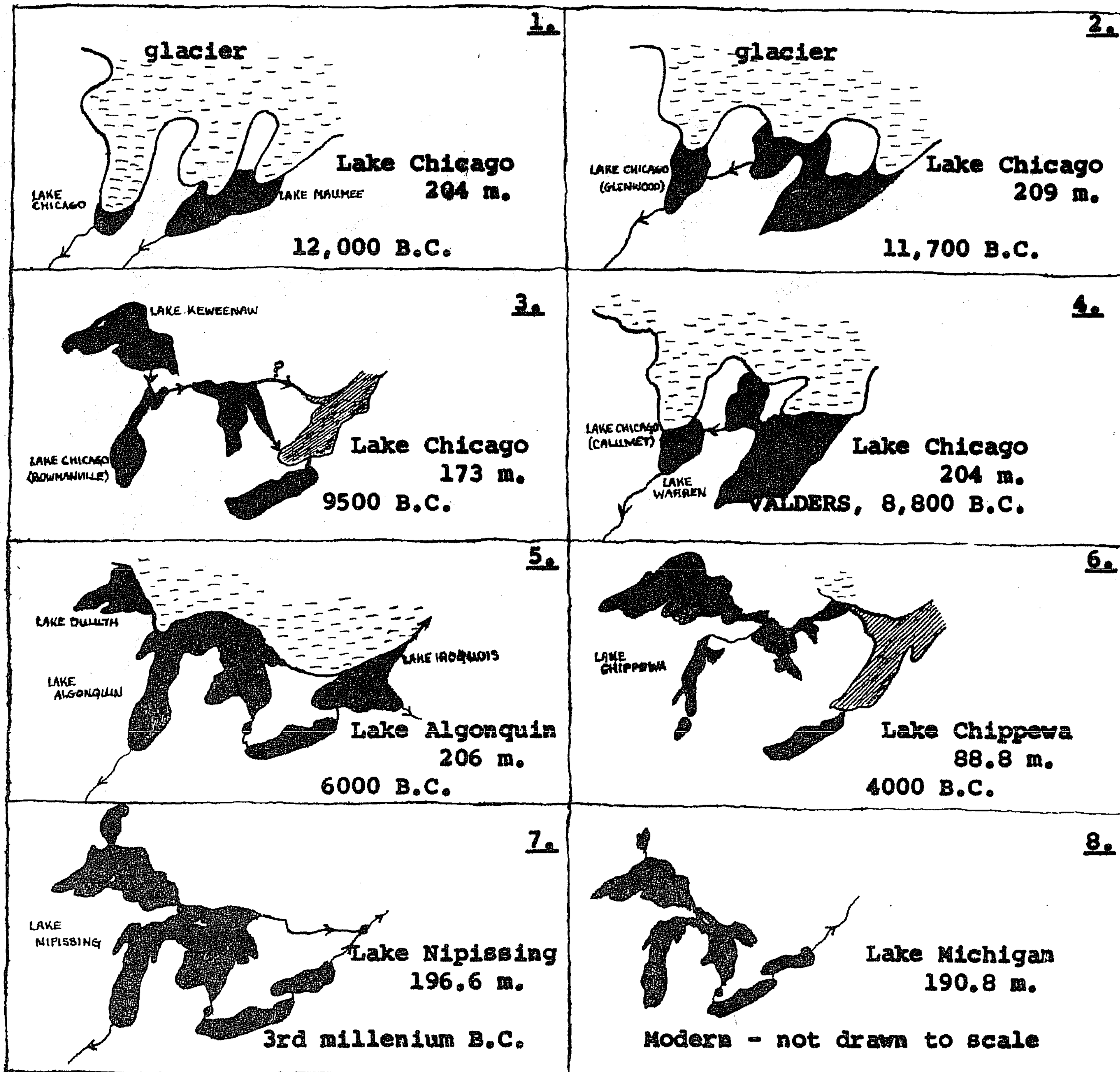
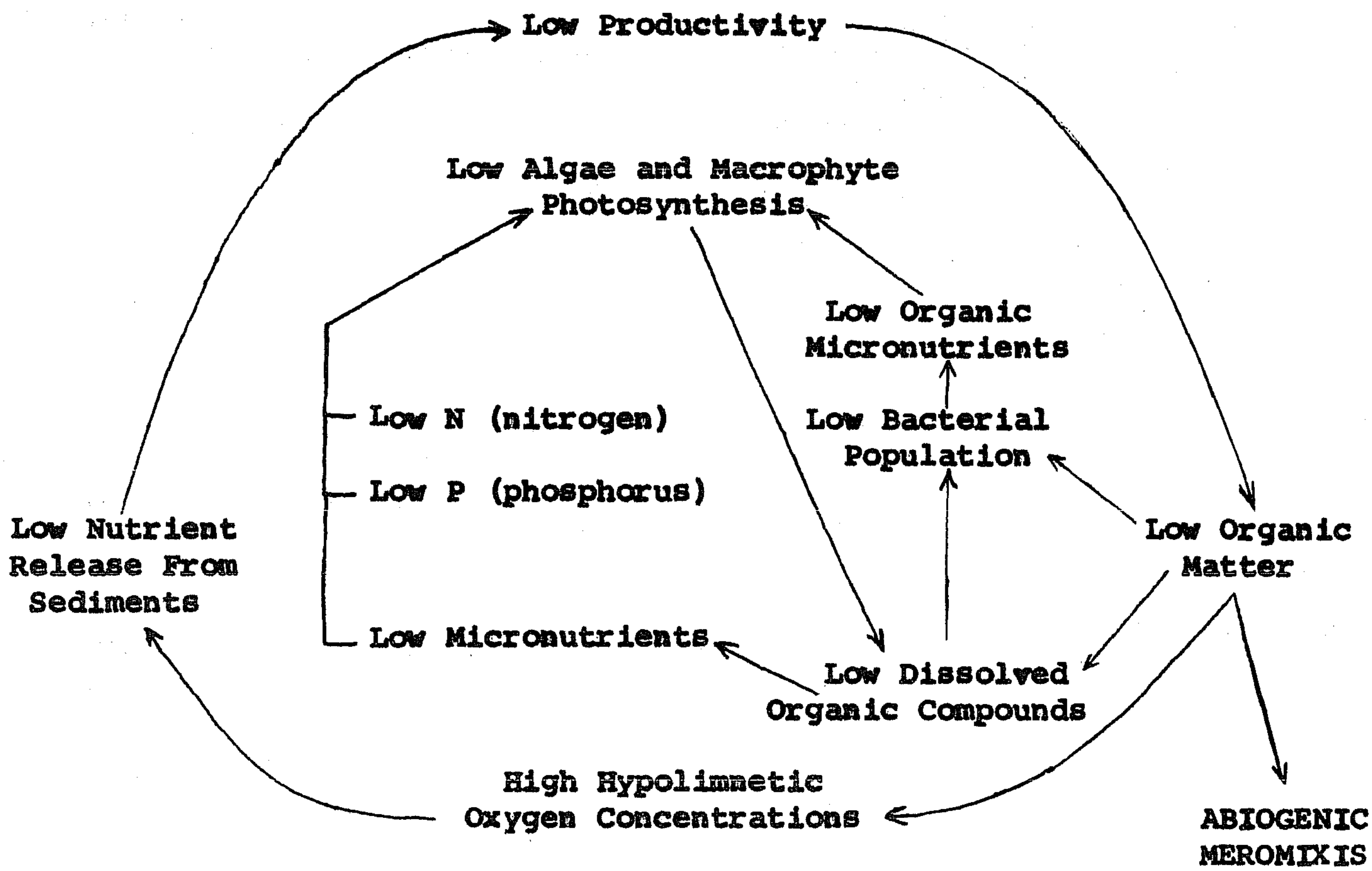
Geomorphology of Laurentian Great Lakes



flow direction
glacier
lake
marine embayment

(Hutchinson, 1957)

Oligotrophic Lake

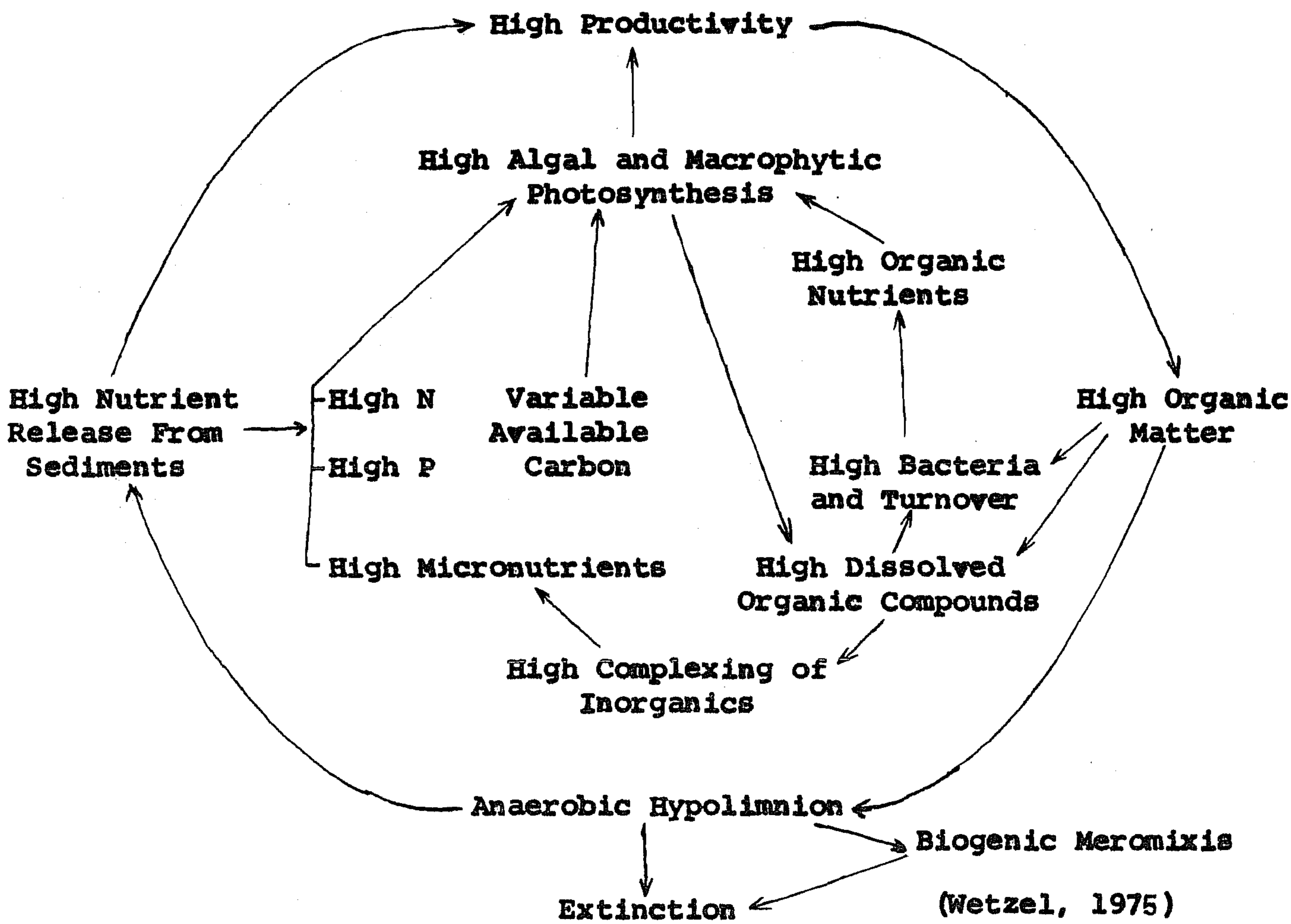


(Wetzel, 1975)

The classical example of an oligotrophic system in this area is Torch Lake. Nutrient input is quite low and there are very few emergent plants.

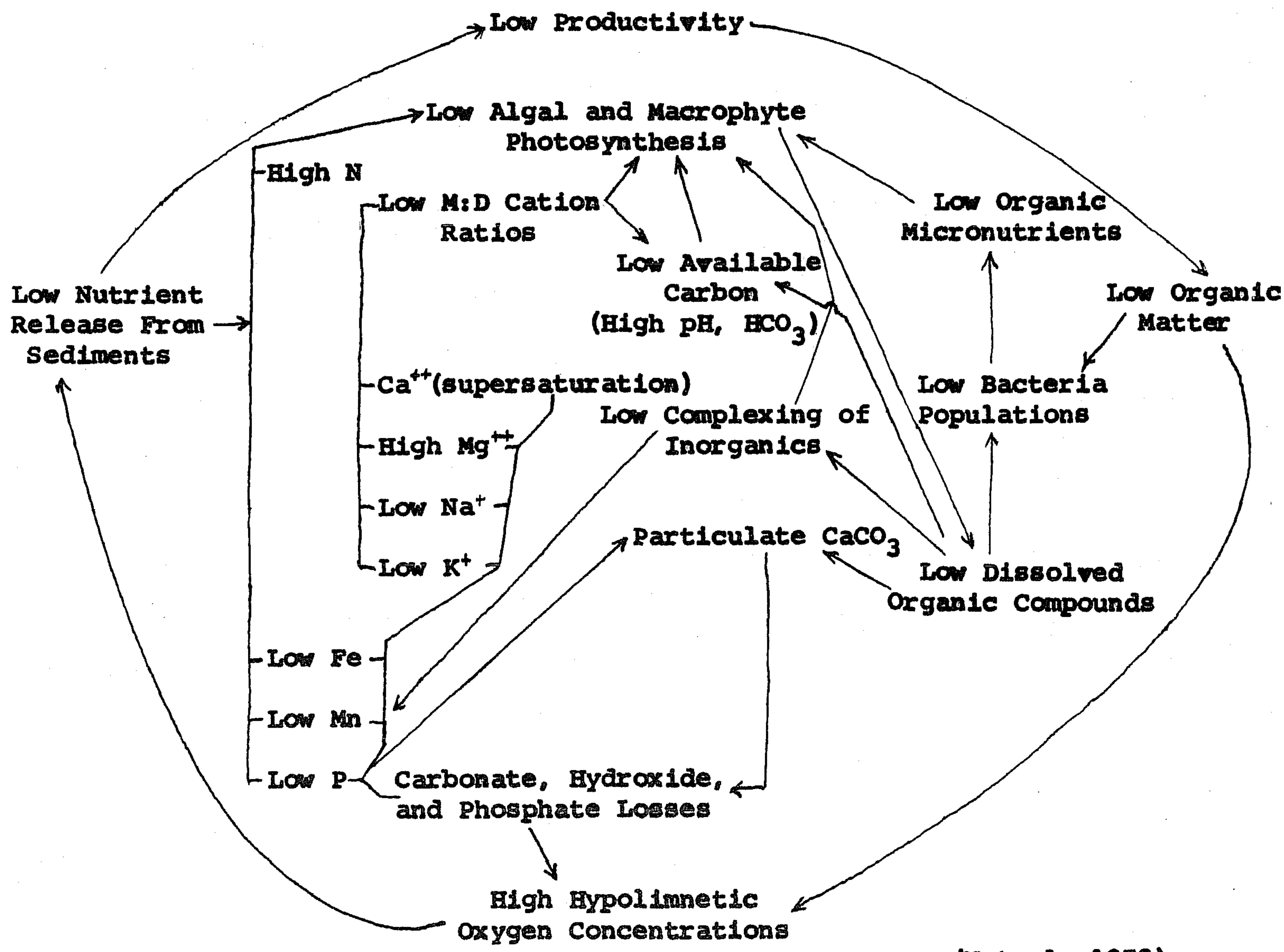
This illustration provides a basic flow chart of what actually occurs in an oligotrophic lake and shows some of the complex inter-relationships.

Eutrophic Lake



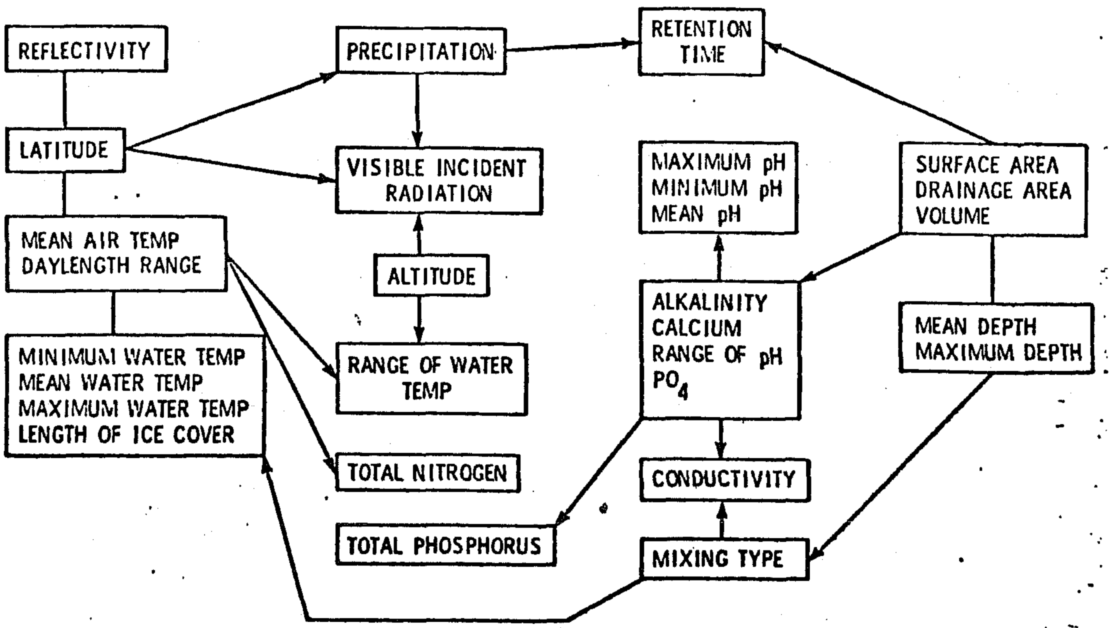
Though Clam Lake does not have an anoxic hypolimnion or high bacterial counts, chemically and biologically, it is approaching a eutrophic lake status.

Marl Lake



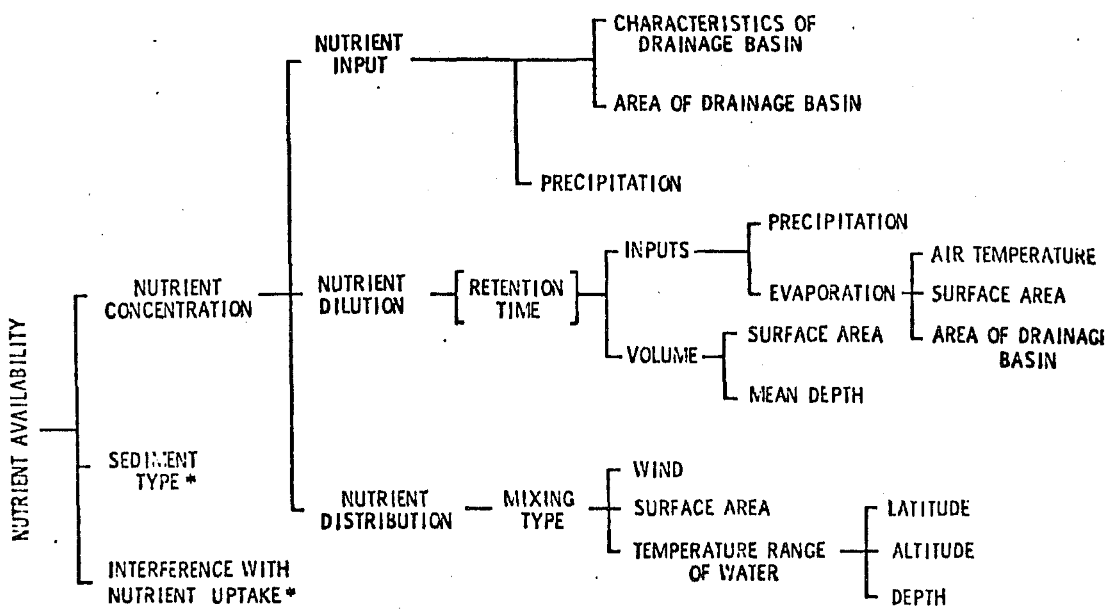
(Wetzel, 1972)

Although Torch Lake and Lake Bellaire are not true marl lakes, high calcareous inputs give them many of the characteristics, including marl formation and an encrustation of calcium carbonate ($CaCO_3$) on rocks, plants, and the bottom substrate.



(Brylinsky and Mann, 1973

Figure 1. Interrelations between non-biological variables



(Brylinsky and Mann, 1973

Figure 2. Various factors affecting nutrient availability

APPENDIX A

The Saprobiensystem

Saprobiontic species - aquatic environment essentially devoid of oxygen; ammonium and hydrogen sulfide are predominent chemical complexes.

Bacteria	Algae	Protozoans
Beggiatoa alba	*Chlorella sp.*	*Bodo caudatus*
Spirillum sp.	*Oscillatoria brevis*	*Bodo putrinis*
Thiothrix nivea	*Anabaena constricta*	*Clamydomonas debaryana*
Thiocystis sp.	*Ulothrix zonata* var.A	*Euglena viridis*
Sphaerotilis natans		

Saprophilous species - organisms generally occur in polluted waters but occassionally occur in other communities.

Algae	Invertebrates
Anabaena cylindrica	*Chironomus plumosus*
Cladophora fracta	*Tubifex tubifex*
Diatoma vulgare	
Stigeoclonium tenue	
Spirogyra decimina	
Ulothrix tenerrima	

Saproxenous species - organisms generally inhabit unpolluted waters but are tolerant of mild pollution situations.

Algae	Invertebrates
Cladophora crispata	*Polypedilum sp.*
Cladophora glomerata	*Hexagenia sp.*
Hydrodictyon reticulatum	
Spirogyra tenuissima	
Ulothrix zonata var.B	

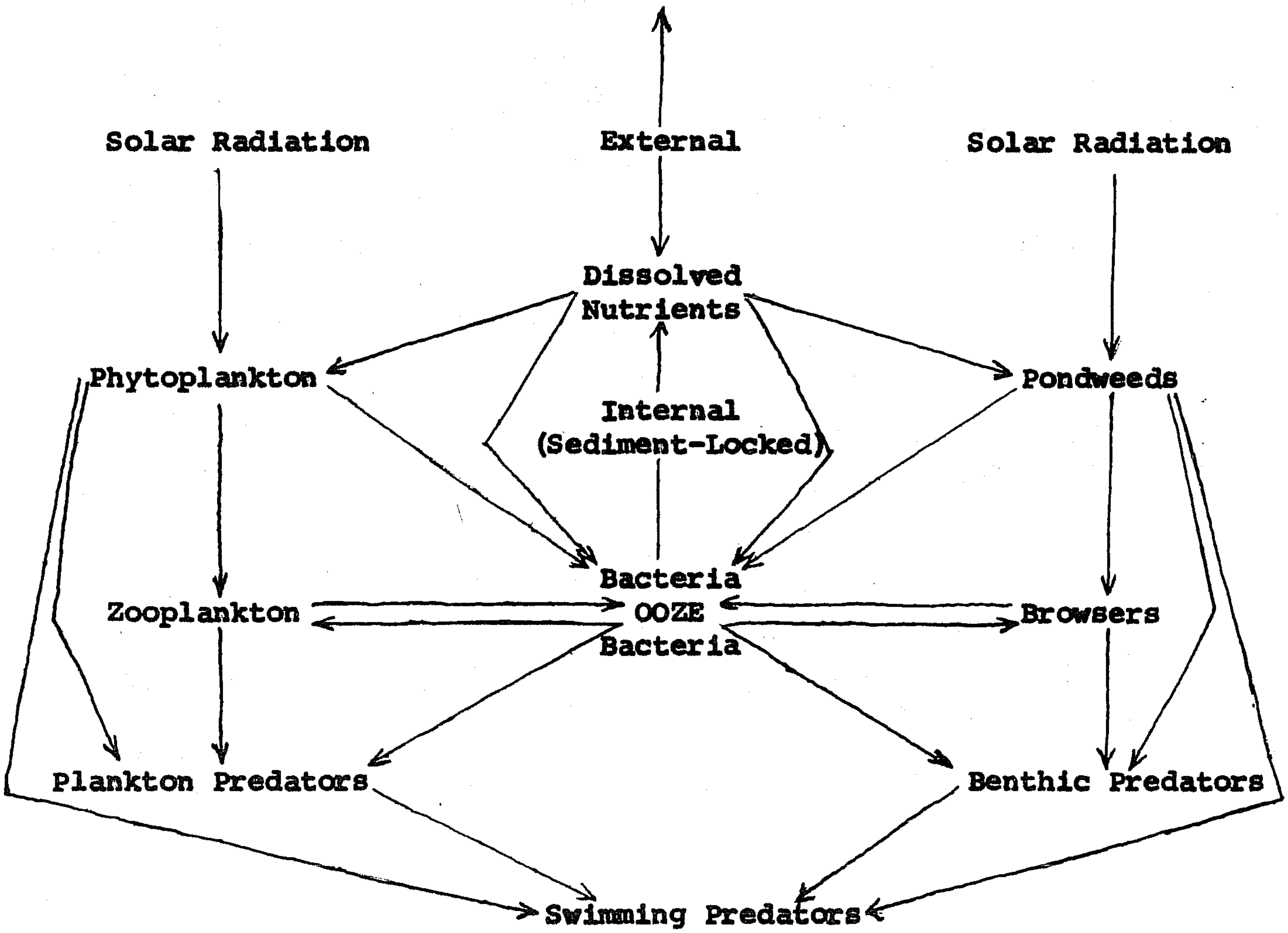
Saprophobous species - organisms unable to tolerate pollution.

Algae	Invertebrates
Rhizosolenia sp.	*Ephemera sp.*
Attheya sp.	
Mastogloia smithii	
Denticula sp.	

(Fjerdingstad, 1963)*

* Algae, bacteria, and protozoa

Model Lentic Food Chain



(Lindeman, 1942)

This model is an idealized illustration as no situation in the "real world" is so straight forward. However, consideration of Lindeman's work, coupled with previous pages of this Appendix should provide a reader with some respect for complex interactions occuring in lakes.

APPENDIX B

* Annotated Bibliography for Data Contribution

Chronological by Year

Research Year	Investigator	Lakes Worked On			Biology	Chemistry	Bacteria
		Bellaire	Torch	Clam			
1964	Gryska		X		X		
1965	King		X		X	X	
1966	King	X		X	X	X	
1967	Alden	X	X	X	X	X	X
1968	Alden	X		X	X		X
	Garcia	X	X	X			X
	Smith	X	X	X	X		
1970	Barber	X	X	X			X
	Fultz	X	X	X	X	X	X
	Morgan	X	X	X			X
	Lawrenz	X	X	X	X		
1971	Lawrenz	X	X	X	X		
1972	Hamilton	X			X	X	
	Sundberg	X	X	X	X	X	X
1973-75	Geers & Sundberg	X	X	X		some	X
1975	Boyd	X	X		X		X
1976	Boyd	X	X		X		X
1977-78	Witzerman	X	X	X	X	X	X

* For complete reference, see Literature Cited section under investigator's name.

APPENDIX B

TORCH LAKE: PHYSIO-CHEMICAL DATA

$\frac{max}{min}$ max/min chemical data in mg/l

Year	Temp. (°C) Air	Temp. (°C) Water	Trans. (meters)	D.O.	CO_2	Hard. $CaCO_3$	pH	N NO_2	N NO_3	PO_4	Alk. (HCO_3^-)	Turb. (SO_2)	Date
1978	26	9	14.7	9.1	0/0	210	8.3	--	.10	--	180	--	5/23
	34	18	9.9	--	--	--	--	--	--	--	--	--	5/31
	28	15.5	12.7	9.8	0/0	210	8.6	.02	.12	.05	190	--	6/18
1977	--	--	14.1 6.8	9.2 6.8	0	220 210	8.8 8.4	.01 .00	.10 .00	trace 0.0	210 190	--	?
1975-76	--	--	--	--	--	--	--	--	--	--	--	--	--
1974	--	--	--	8.2/6.8	--	--	--	--	--	--	--	--	8/14
1973	--	--	--	10.5 9.5	28 2.5	97.5 85.3	8.1	--	--	--	145	--	7/7 8/8
1972	--	--	--	--	--	--	--	--	--	--	--	--	--
1971	--	--	--	--	--	--	--	--	--	--	--	--	--
1970	30 26	20 14.5	bottom 5.0	4.4 4.2	0 0	230 210	8.8 7.6	.020 .017	.12 .10	.21 .05	200 180	--	9/20
1967-69	--	--	--	--	--	--	--	--	--	--	--	--	--
1966	--	--	--	12.1/11.5	--	--	8.3/8.05	--	--	--	137/133	--	4/1-5/31
1965	--	--	--	11.3	--	--	7.2	--	--	--	278	--	--
1962-64	--	--	--	--	--	--	--	--	--	--	--	--	--
1961	--	--	--	7.6	--	--	8.8	--	--	--	138	--	?

APPENDIX B

TORCH LAKE: BACTERIOLOGICAL DATA

Year	Location, Date	Total Coliform	faecal colif.	faecal stre
1978	--	--	--	--
1977	Bonnie Brook, 5/1-12/31	400/100	20 /0	10 /0
	Spencer Cr., 5/1-12/31	1100/600	40 /20	20 /10
1976	Mouth, Clam R., 7/11	3200*	--	12*
	Mid-lake, 7/11	200*	--	0*
	French Pt., 7/11	300*	--	0*
1975	Spencer Cr., 7/1	10	<10*	--
	Bonnie Brook, 7/1	270	<10*	--
	Mid-lake, 7/1	0	--	--
	Brownwood culvert, 7/1	50	--	--
1974	Spencer Cr., 5/20-7/28	1100/23	--	--
	Bonnie Brook, 5/21-7/9	93/23	--	--
	Mid-lake, 7/28	0	--	--
1973	Spencer Cr., 9/22-12/18	1100/9	--	--
	Bonnie Brook, 12/17-12/18	96/4	--	--
	Torch River, 5/29-12/18	93/0	--	--
1972	Spencer Cr., 7/29	400/<400	--	--
	Spencer Cr., 10/7	460	--	--
	Other Points, 7/10	43/9	--	--
1971	--	--	--	--
1970	Spencer Cr., 10/17	2000	--	--
1969	--	--	--	--
1968	Spencer Cr., 6-7/68	908/74	--	--
	South end, 6-7/68	18/0	--	--

* Samples run by Michigan Dept. Public Health (presumably higher values due to shipping time).

APPENDIX B

Torch Lake: Biological Data

YEAR	SPECIES IDENTIFIED	
	Flora	
1972	-------------------------	
1971	Cladophora sp. Gomphonema sp. Rhizosolenia sp.	
1970	Fragilaria sp. Synedra sp. Asterionella sp.	
1969	-------------------------	
1968	Asterionella sp. Fragilaria sp. Ceratium sp.	Synedra sp. Dinobyron sp.
1967	-------------------------	
1966	-------------------------	
1965	Synedra sp. Diatoma sp.	
1964	Asterionella sp. Cyclotella sp. Cymbella sp.	Diatoma sp. Fragilaria sp.

Fauna

Amphipoda
Ephemera varia
Pelecypoda

Haegenia gillineata
Keratella sp.

APPENDIX B

Torch Lake: Biological Data

YEAR	SPECIES IDENTIFIED — Flora		Fauna
1978	*Cladophora sp.*	*Melosira sp.*	*Ephemera* (varia ?) *sp.*
	Asterionella sp.	*Rhizosolenia sp.*	*Polypedilum sp.*
	Fragilaria sp.	*Navicula sp.*	*Procladius sp.*
	Dinobyron sp.	*Synedra sp.*	*Haemopsis grandis*
	Ceratium sp.		
1977	*Cladophora sp.*	*Cymbella sp.*	*Keratella sp.*
	Asterionella (formosa ?) *sp.*		Copepoda
	Ceratium sp.	*Dinobyron sp.*	
	Attheya sp.	*Diatoma sp.*	
	Gomphonema sp.	*Rhizosolenia sp.*	
1976	*Synedra filiformis*	*Cymbella sp.*	
	Amphora ovalis	*Navicula sp.*	
	Acnanthes flexula	*Gomphonema dichotomum*	
	Denticula tenuis	*Fragilaria sp.*	
1975	*Navicula sp.*	*Synedra sp.*	
	Mastogloia smithii	*Cymbella cymbiformis*	
	Denticula sp.	*Cocconeis sp.*	
	Amphora sp.	*Cyclotella* (ocellata ?) *sp.*	
	Eunotia sp.		
1974	---		---
1973	---		---

APPENDIX B

CLAM LAKE: PHYSIO-CHEMICAL DATA

Year	Temp. (°C) Air	Water	Trans. (meters)	D.O.	CO_2
1978	32.0 25.0	19.5 20.0	2.0 2.3	4.8 4.8	0/0 0/0
1977	--	--	2.2 1.0	5.0 2.8	0
1976	--	--	--	--	--
1975	--	--	--	--	--
1974	--	--	--	8.4/8.1	--
1973	--	--	--	--	--
1972	31.2 25.6	25.0 20.3	--	13.2 10.0	60 16
1971	--	--	--	--	--
1970	--	--	2.4	4.4 3.8	6 0
1966-69	--	--	--	--	--
1965	--	--	--	11.2	--
1962-64	--	--	--	--	--
1961	--	--	--	7.07	--

max/min Hard. $CaCO_3$	max/min pH	N NO_2	N NO_3	PO_4	Alk (HCO_3^-)	Turb. (SO_2)	Date
180	8.8	.02	.25	.04	160	--	5/31
180	8.6	.01	.15	trace	150	--	6/15
180/170	9.4/8.7	.02/.01	.35/.20	1.6/0.1	150/140	--	6/1-10/
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	8/14
--	--	--	--	--	--	--	--
340/140	9.1/6.5	--	--	--	--	--	7/8
--	--	--	--	--	--	--	--
--	9.6/8.05	.01	2.0/.12	6.0/0	160/150	--	9/19
--	--	--	--	--	--	--	--
--	7.2	--	--	--	288	--	?
--	--	--	--	--	--	--	--
--	8.2	--	--	--	160	--	?

chemical data in mg/l

APPENDIX B

CLAM LAKE: BACTERIOLOGICAL DATA max/min

Year	Location, Date	Total Coliform	faecal colif.	faecal strep.
1978	Dewitt's Marina area, 5/31	800	<50	<10
	Grass River, 5/31	200	--	--
1977	Finch Creek, (?)	200/0	--	--
	Grass River, (?)	100/0	10 /0	--
1976	Redfern Marina (now Dewitt's), 7/11	2400*		
1975	--	--	--	--
1974	(?), 6/30-7/7	93/0	--	--
1973	(?), 5/29	23	--	--
1972	(?), 10/7	240/23	--	--
1971	--	--	--	--
1970	Clam River Bridge, 10/17	333/0	--	--
1969	--	--	--	--
1968	Redfern Marina, 6,7/68	3/.5	--	--
	Watomie Pines, 6,7/68	18.5/0	--	--
	Mouth, Grass River	189/.5	--	--
1967	(?), 10/14	43/9	--	--

* Samples run by Michigan Dept. Public Health (presumably higher values due to shipping time).

APPENDIX B

Clam Lake: Biological Data

YEAR	SPECIES IDENTIFIED
	Flora
1972	*Anabaena* sp. *Dinobyron* sp. *Synura* sp.
1971	*Cladophora* sp. *Gomphonema* sp. *Synedra* sp. *Cymbella* sp.
1970	
1969	------------------------
1968	*Asterionella* sp. *Fragilaria* sp. *Ceratium* sp. *Synedra* sp. *Dinobyron* sp.
1967	
1966	
1965	*Cladophora* sp.

Fauna

Amphipoda
Isopoda
Ephemeroptera
Procladius sp.
Polypedilum sp.

Ephemera sp.
Ephemera varia
Isopoda
Amphipoda
Pelecypoda

Gammarus fasciatus
Ascellus militaris
Calopsectra sp.2
Ascellus intermedius
Hyalella azteca
Helobdella sp.

Hyalella azteca *Polypedilum sp.* *Procladius sp.*
Placobdella parasitica *Pisidium sp.*
Glyptotendipes sp. *Ascellus intermedius*
Cryptochironomus sp.

Keratella sp. Ephemeroptera

Clam Lake: Biological Data

YEAR	SPECIES IDENTIFICATION Flora		Fauna	
1978	Cladophora sp. Potomegeton sp. Ceratium sp. Dinobyron sp.	Melosira ambigua Tabellaria sp. Asterionella formosa	Hyalella azteca Ascellus intermedius Keratella cochlearis Paralauterborniella sp. Tanytarsus (pallicicornis ?) sp. Clinotanypus sp. Stempillina sp.	Tanypus sp. Polypedilum sp. Procladius sp.
1977	Cladophora sp. Melosira ambigua Ceratium sp. Oscillatoria sp. Tabellaria sp. Synura sp.	Asterionella sp. Microcystis flosaquae Dinobyron sp. Mallamonas sp. Navicula sp.	Kellicottia longispina Ascellus intermedius Bosmina longirostris Daphnia sp. Polypedilum sp. Procladius sp.	Cyclops sp.
1976	-------------------------		-------------------------	
1975	-------------------------		-------------------------	
1974	-------------------------		-------------------------	
1973	-------------------------		-------------------------	

LAKE BELLAIRE: PHYSIO-CHEMICAL DATA

Year	Temp. (°C) Air	Water	Trans. (meters)	D.O.	CO_2
1978	34 23	21.0 19.5	3.4 4.7	5.2 5.6	0/0 0/0
1977	29.5 15.5	22.6 12.0	4.5 2.6	5.0 3.8	0 0
1976	--	--	--	--	--
1975	--	--	--	--	--
1974	--	--	--	8.8 8.1	--
1973	--	--	--	--	--
1972	13.0 11.0	16.0 16.0	3.35 1.5	9.6 4.2	8.5 1.0
1971	--	--	--	--	--
1970	--	--	--	5.0 4.0	0 0

max/min   max/min   chemical data in mg/l

Hard. $CaCO_3$	pH	N NO_2	NO_3	PO_4	Alk. (HCO_3^-)	Turb. (SO_2)	Date
180	8.0	.010	.20	.10	160	--	5/30
180	8.2	--	.10	trace	170	--	6/16
190/180	8.8/8.2	.020/.000	.15/.00	.30/.10	160/140	--	6/1-10/
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	8/14
--	--	--	--	--	--	--	--
168/130	8.4/7.3	--	--	--	168/130	8.9/3.0	9/30
--	--	--	--	--	--	--	--
235/180	8.5/7.1	.02	.13/.12	.38/.05	200/150	--	9/19

APPENDIX B

LAKE BELLAIRE: BACTERIOLOGICAL DATA max/min

Year	Location, Date	Total coliform	faecal colif.	faecal strep.
1978	Wilson's Cr., (?)	300	<20	0
	Intermediate R., (?)	500	<40	<10
1977	Wilson's Cr., 5/1-12/31	900/200	30/10	30/0
	Intermediate R., 5/1-12/31	1100/300	60/20	40/20
1976	Wilson's Cr., 6/30	2400*	20*	--
	Wilson's Cr., 7/12	400*	50*	--
	Wilson's Cr., 7/11	1000*	0*	228*
1975	--	--	--	--
1974	Mid-lake, 7/28	0	--	--
1973	--	--	--	--
1972	Intermediate R., 7/29	200/<100	--	--
	Intermediate R., 7/29	1600/<100	--	--
	Other stations, 7/10	240/7	--	--
1969-71	--	--	--	--
1968	Intermediate R., 6-7/68	145/6	--	--
	Middle, 6-7/68	9/4	--	--
	Grass R. outlet, 6-7/68	37/11	--	--
1967	? , 10/14	93/3	--	--

* Samples run by Michigan Dept. Public Health (presumably higher values, due to shipping time).

APPENDIX B

Lake Bellaire; Biological Data

YEAR	SPECIES IDENTIFIED	
		Flora
1972 (9/30)		
1971	*Cladophora sp.*	*Cymbella sp.*
	Gomphonema sp.	*Acnanthes sp.*
	Synedra sp.	*Diatoma sp.*
1970		
1969	------------------------	
1968	*Fragilaria sp.*	*Dinobyron sp.*
	Ceratium sp.	*Synedra sp.*
	Asterionella sp.	
1967		
1966	------------------------	
1965	*Anabaena sp.*	
	Cladophora sp.	

Fauna

Hyalella azteca
Ascellus militaris
Oligochaeta sp.
Ephemera simulans

Hexagenia sp. Amphipoda
Gastropoda Annelida
Pelecypoda

Campeloma decisium
Ascellus militaris
Gammarus fasciatus

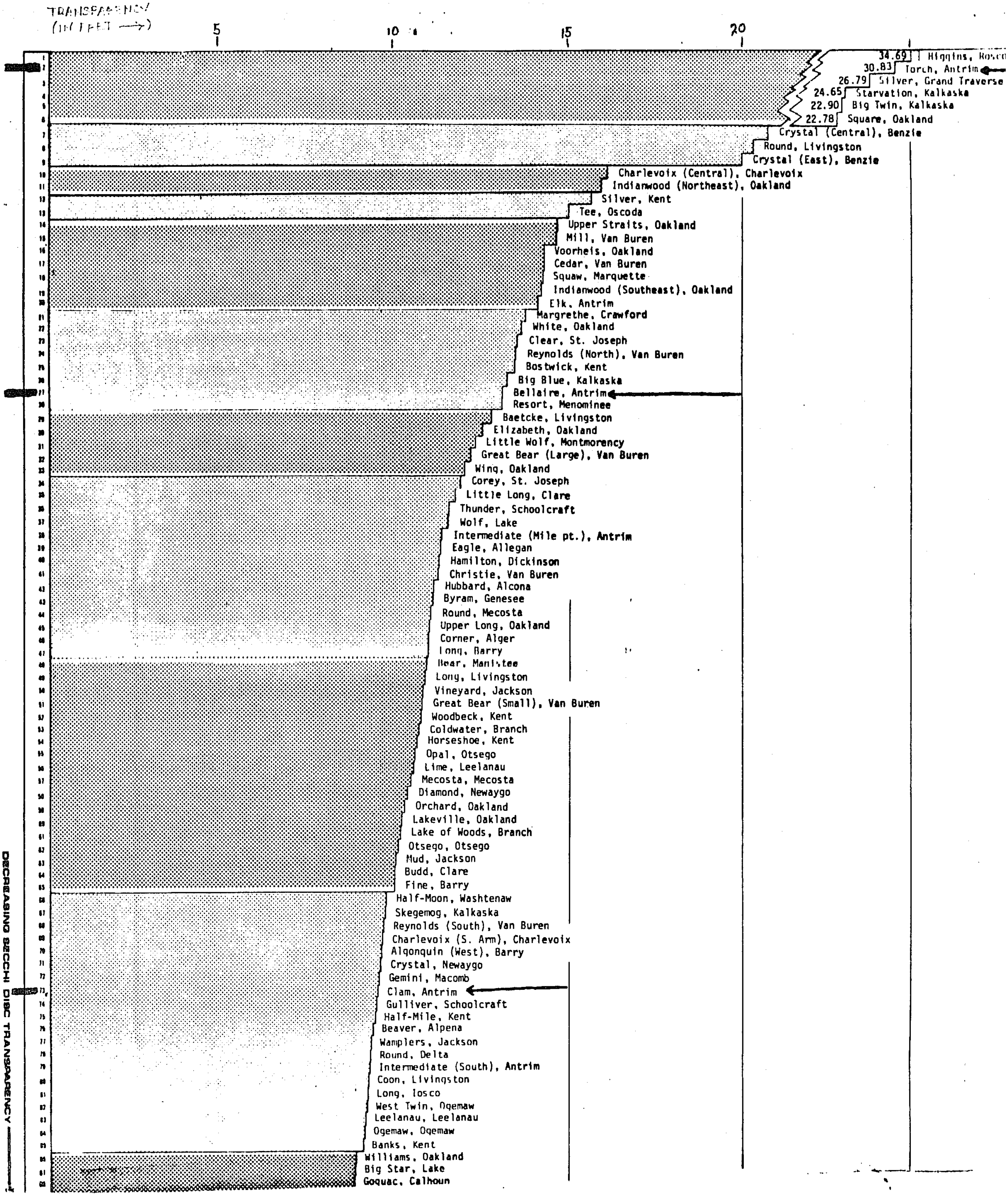
Pelecypoda

Lake Bellaire: Biological Data

YEAR	SPECIES IDENTIFIED: Flora	SPECIES IDENTIFIED: Fauna
1978	*Cladophora* (glomerata ?) *sp.* *Spirogyra sp.* *Anabaena cylindrica* *Microcystis sp.* *Melosira ambiqua* *Melosira sp.*B *Ceratium sp.* *Fragilaria capucina* *Asterionella formosa* *Cocconeis sp.* *Tabellaria sp.*	*Keratella sp.* *Tubifex tubifex* *Endochironomus sp.* *Polypedilum sp.* *Procladius sp.* Cycloptidae *Chironomus sp.*
1977	*Cladophora sp.* *Spirogyra sp.* *Ceratium sp.* *Fragilaria sp.* *Melosira ambiqua* *Tabellaria sp.*	*Kellicottia longispina* *Keratella sp.* *Hyalella azteca* *Daphnia sp.* *Bosmina sp.* *Endochironomus sp.* *Procladius sp.* Tanytarsini tribe
1976	*Cyclotella ocellata* *Melosira ambiqua* *Fragilaria capucina* *Synura ulna* *Cymbella tumida* *Asterionella formosa*	
1975	*Melosira ambiqua* *Hydrodictyon reticulatum* *Cladophora sp.* *Asterionella formosa* *Fragilaria capucina* *Tabellaria flustrata*	
1974	-------------------------	-------------------------
1973	-------------------------	-------------------------

APPENDIX B

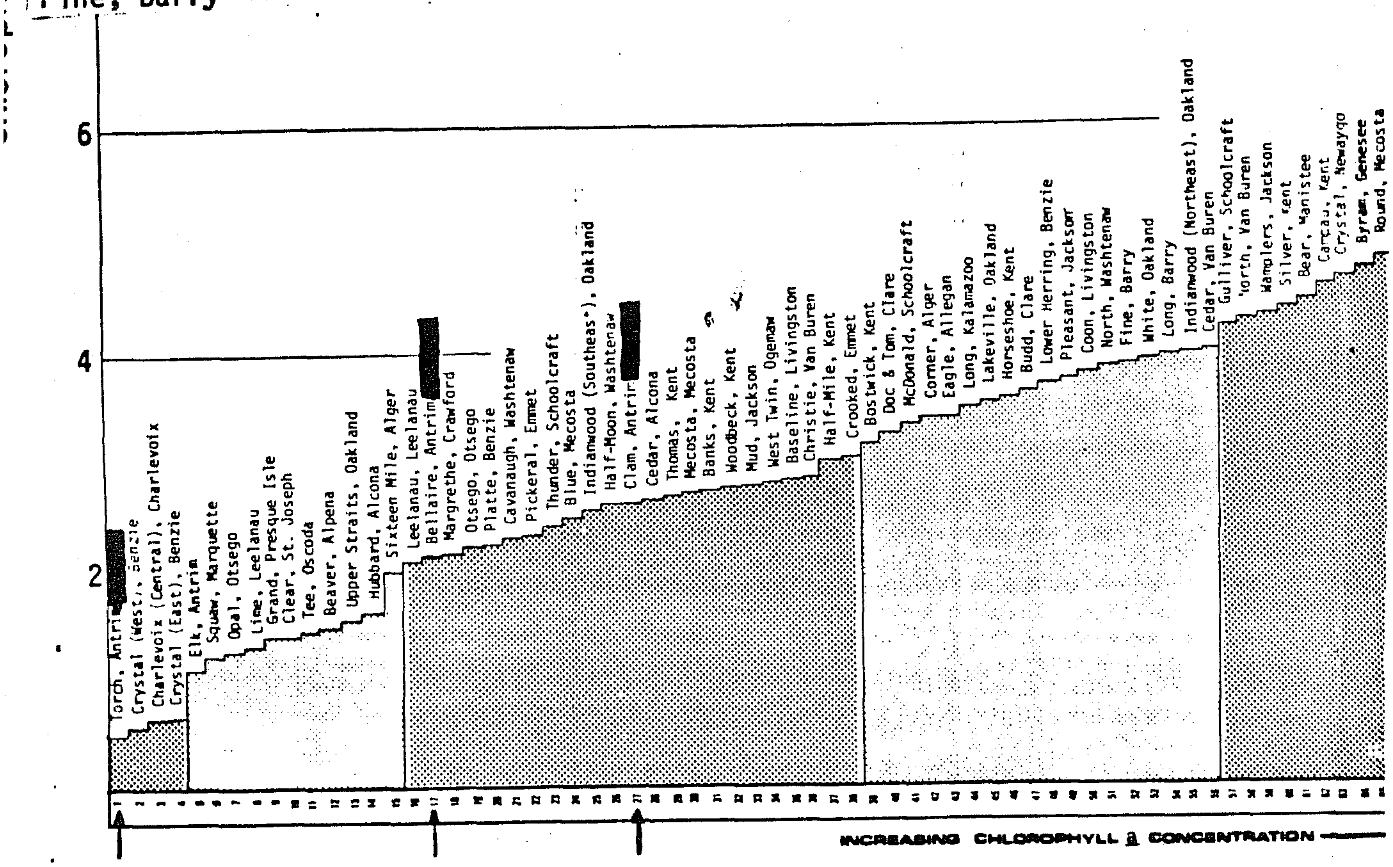
Self-Help Program Secchi Transparency Graph



APPENDIX B

Self-Help Program Chlorophyll a Graph

Lake Name, County	No. on Figure 5	Secchi Transparency Mean (ft.)	Secchi Transparency No. of Samples	Chlorophyll a Mean (µg/l)	Chlorophyll a No. of Samples	Trophic Status[a]
Cedar, Alcona	1	5.24	21	2.67	10	Eutrophic
Hubbard, Alcona	2	11.21	19	1.75	7	Mesotrophic
Vaughn, Alcona	--	5.45	13	----	--	Eutrophic
AuTrain, Alger	3	8.33	3	14.00	3	Eutrophic
Cook, Alger	4	4.00	10	5.57	10	Eutrophic
Corner, Alger	5	11.00	4	3.23	3	Mesotrophic
Sixteen Mile, Alger	6	6.93	3	1.95	2	Mesotrophic
Eagle, Allegan	7	11.34	18	3.25	10	Mesotrophic
Hutchins, Allegan	--	7.82	14	----	--	Mesotrophic
Beaver, Alpena	8	9.53	17	1.51	10	Mesotrophic
Bellaire, Antrim	9	13.08	6	2.02	6	Mesotrophic
Clam, Antrim	10	9.60	5	2.64	5	Mesotrophic
Elk, Antrim	11	14.14	18	1.17	10	Mesotrophic
Intermediate, Antrim	--					
Mile Point	--	11.39	17	----	--	Mesotrophic
South Basin	--	9.16	15	----	--	Mesotrophic
Torch, Antrim	12	30.83	6	0.54	6	Oligotrophic
Algonquin, Barry	--					
East Basin	13	8.38	17	5.89	10	Mesotrophic
West Basin	14	9.76	17	5.64	10	Mesotrophic
Fine, Barry	15	10.03	19	3.65	11	Mesotrophic



... Michigan Lakes (93 Basins) in 1977 Self Help Monitoring Ranked on Basis of Inc

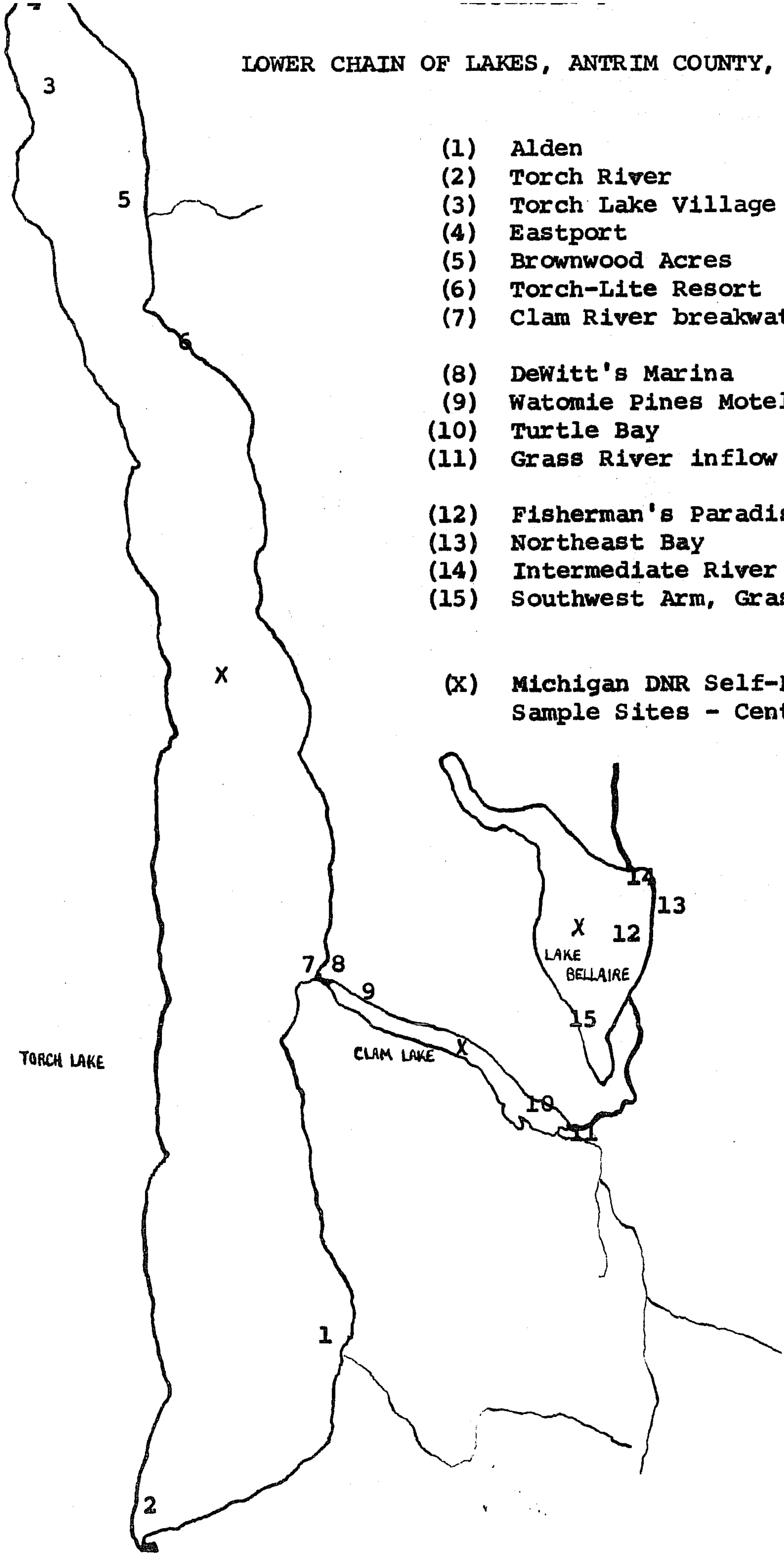
LOWER CHAIN OF LAKES, ANTRIM COUNTY, MI.

(1) Alden
(2) Torch River
(3) Torch Lake Village
(4) Eastport
(5) Brownwood Acres
(6) Torch-Lite Resort
(7) Clam River breakwater

(8) DeWitt's Marina
(9) Watomie Pines Motel
(10) Turtle Bay
(11) Grass River inflow

(12) Fisherman's Paradise Access
(13) Northeast Bay
(14) Intermediate River inflow
(15) Southwest Arm, Grass River outflow

(X) Michigan DNR Self-Help Program
Sample Sites - Central Lake Basins



APPENDIX C

Morphometry of the Three Lakes

Torch Lake, Antrim County, Michigan

Maximum Length	30.080 kilometers
Maximum Effective Length	28.014 kilometers
Maximum Width	3.864 kilometers
Maximum Effective Width	3.864 kilometers
Maximum Depth	94.450 meters
Area	7636.689 hectares
Mean Width	2.576 kilometers
Length of Shoreline	66.493 kilometers
Direction of Major Axis	N-S

Clam Lake, Antrim County, Michigan

Maximum Length	5.635 kilometers
Maximum Effective Length	2.898 kilometers
Maximum Width	.483 kilometers
Maximum Effective Width	.483 kilometers
Maximum Depth	6.080 meters
Area	194.256 hectares
Mean Width	.161 kilometers
Length of Shoreline	12.075 kilometers
Direction of Major Axis	NW-SE

Lake Bellaire, Antrim County, Michigan

Maximum Length	7.245 kilometers
Maximum Effective Length	5.152 kilometers
Maximum Width	2.254 kilometers
Maximum Effective Width	2.254 kilometers
Maximum Depth	31.380 meters
Area	718.343 hectares
Mean Width	.966 kilometers
Length of Shoreline	16.744 kilometers
Direction of Major Axis	NNW-SSE

(Benjamin, 1970)