Fish management.

1. Fish populations are low because of the basic character of Runyan Lake. Hypolimnetic aeration would make habitable a large area of the bottom water strata of the lake, but this is costly and not a strong recommendation.

2. Brush shelters would attract fish and increase their susceptibility to fishermen.

3. Smallmouth bass, if available, could be stocked in the lake. This would not increase the production or abundance of fish in the lake, but would add another sport fish to those available to fishermen.

4. Northern pike spawning and population levels in the lake require additional investigation. There are a few large adults present from our collections and fishermen reports. However, status of the young-of-the-year is unknown.

Maintenance of access to the shallow embayment.

Control of plants and eventually the sediments in the station L area will have to be done to provide residents there with access to Runyan Lake. Plants are recommended to be controlled by harvesting, perhaps by renting a harvester once or twice per summer to cut down these plants. Chemical control is discouraged, but certainly allowable as a last resort. The sediments in this area are very thick and can only be controlled by dredging, mudcatting or a drawdown and drying at some future date. Thought should be given to how this problem will be addressed. Either option is very, and possibly prohibitively, expensive.

APPENDICES

1. Chloride data
2. Eurasian milfoil
3. White and yellow grub cycle
4. Swimmer's itch life cycle
5. MDNR notes on Runyan Lake
6. MDNR publication on Aquatic Plants
7. 1970 water quality study on Runyan Lake
8. SEMCOG inland lake data
9. NPDES permit for sewage lagoon
10. Stage 1 analysis for sewers
11. Preliminary recommendations 15 November 1979

FRESH WATER PHYSICIANS INC.

PROFESSIONAL
BIOLOGISTS
FOR
COMPLETE
AQUATIC
STUDIES

7/8/76

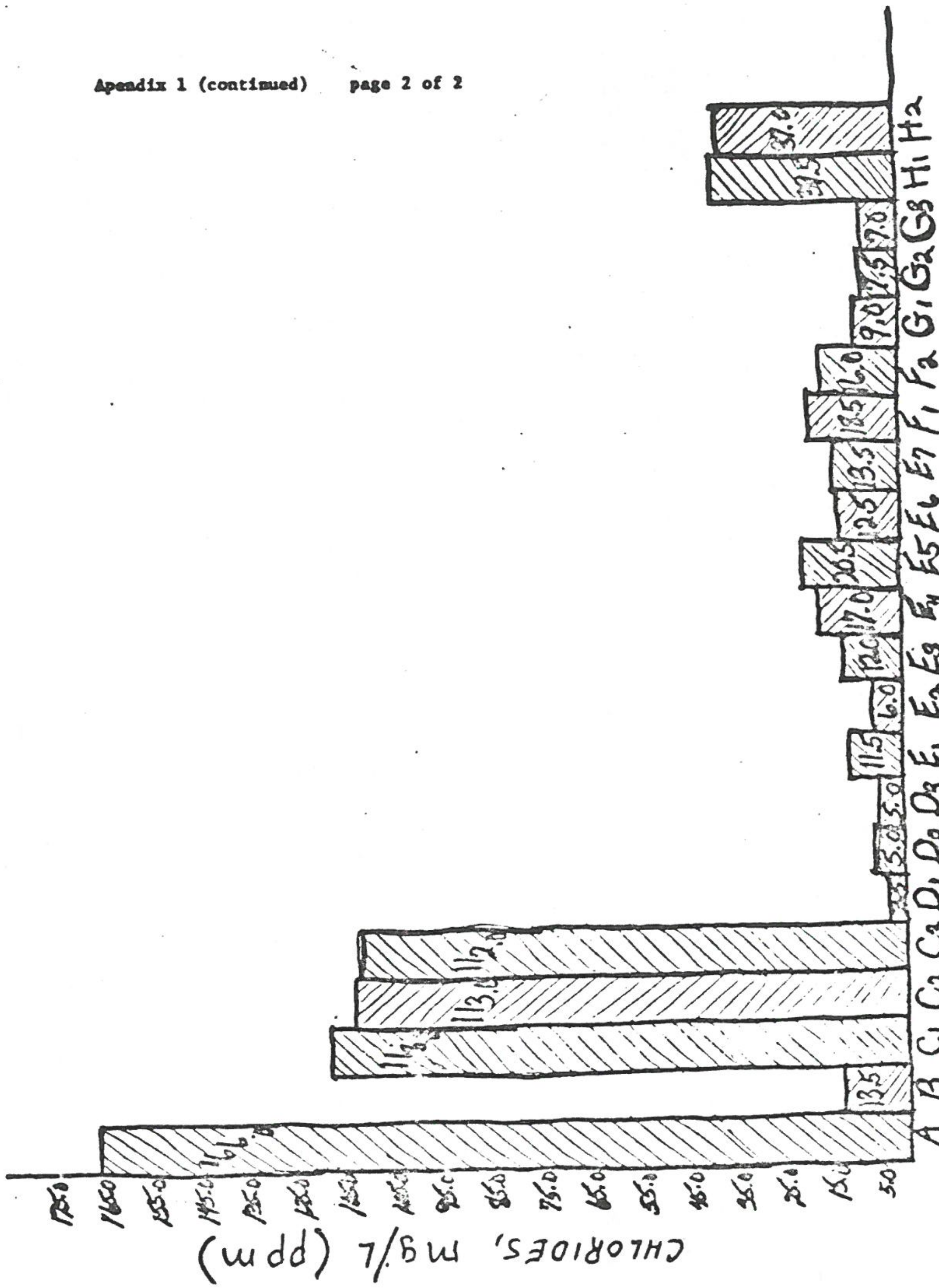
Enclosed is a graphic presentation of chloride data from 8 lakes in Livingston County, Michigan. The samples were taken in the spring of 1976 by property owners. We analyzed the samples and compiled the enclosed graph to give further information on lakes of this region. Your lake is identified and the others presented by code number only for comparison purposes. Please remember that one or two samples are sufficient to give an indication only. Broad generalizations cannot be derived from a limited number of samples.

Ground water ranges from 10 to 20 mg/l (ppm) chlorides. Higher concentrations indicate possible contamination. The two most likely sources are septic tanks and road salt. Each of these inputs is likely to carry nutrients (phosphorus and/or nitrogen) into the lake. Chloride is not a problem in itself normally, but serves as an indicator of possible contamination. Of the lakes in this study, "A" and "C" both warrant further study due to the very high values. "H" also is a bit high. It should be pointed out that nutrient inputs can occur without the presence of chlorides, so lakes can have enrichment problems with low chloride concentrations.

Call or write us if you have further questions.

2180 AUBURN
HOLT, MICHIGAN
517 694 0713

IMPACT STUDIES LAKE MANAGEMENT


CHLORIDES, mg/L (ppm)
LAKE
A B C1 C2 C3 D1 D2 D3 E1 E2 E3 E4 E5 E6 E7 F1 F2 G1 G2 G3 H1 H2

FRESH WATER PHYSICIANS INC.

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To: Chloride Study Lakes

From: Joe Ervin

Re: Chloride Analyses

Attached is a graphic representation of the chloride concentrations of several lakes in Michigan. We analyzed samples sent to us to gain further information about chlorides in area lakes. The chloride ion enters our lakes primarily from septic tank effluents and storm water/urban run-off. Natural groundwater ranges from 10-20 mg/l (parts per million). Concentration above this level indicates inputs from one or both of these sources.

We are not concerned with the chloride concentration itself, but rather what enters your lake with the chlordes. Nutrients, primarily nitrogen and phosphorus are high in both chloride sources named above. The chloride ion is inert and not taken up by sediments or vegetation and so can act as a "tag" on the nutrients. The analysis is relatively inexpensive and easy so we use it widely to determine possible nutrient inputs.

We caution that a lake can have enrichment problems without elevated chloride levels. It is one analysis of the many we make that helps us identify current or potential problems in our study lakes.

If you have any questions concerning these analyses, please call or write me. Thank you for your cooperation in this study.

Sincerely,

Joseph L. Ervin

JLE:sh

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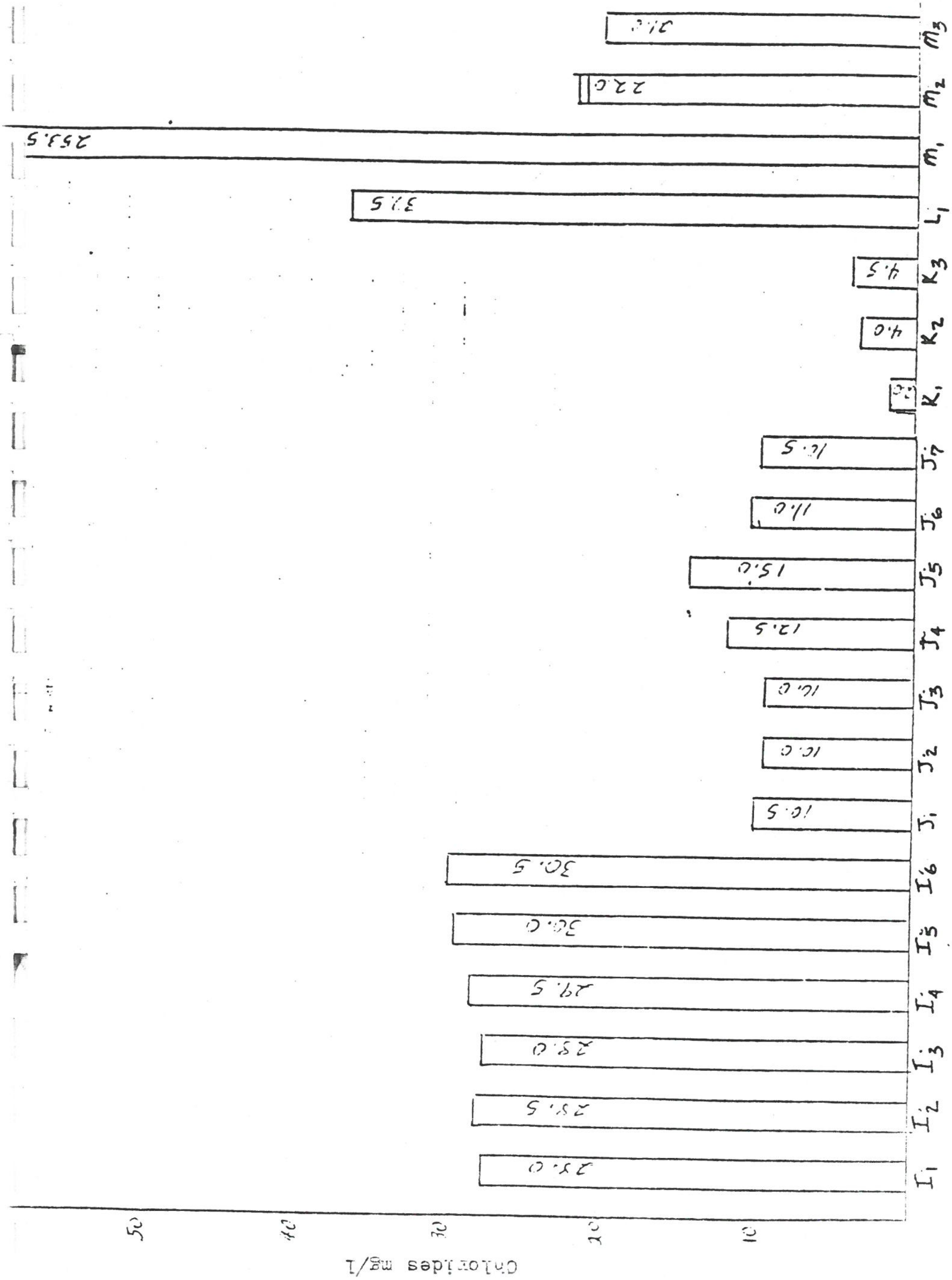
Chlorides mg/l
10
20
30
40
50
I1
I2
I3
I4
I5
I6
J1
J2
J3
J4
J5
J6
J7
K1
K2
K3
L1
M1
M2
M3
29.5
30.0
30.5
10.5
10.0
10.0
12.5
15.0
11.0
10.5
4.0
4.5
37.5
253.5
22.0

FRESH WATER PHYSICIANS INC.

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Eurasian milfoil in Michigan

This aquatic plant is a severe pest in many Michigan lakes. You should learn to recognize it and treat it immediately if it begins to grow in your lake. It is one species that should be eliminated if possible. It can spread very rapidly and grow in depths up to 18'. We do not support the total eradication of aquatic vegetation. However this particular species should not be allowed to get a foothold in any lake. Treatment with 2,4-D is the best approach. We recommend qualified licensed applicators be contacted to treat this weed, which shows up in small clumps. 2, 4-D will exert long term control in many cases because of its systemic activity. Harvesting will cause further spreading. Enclosed are some sketches of the plant. Note that the feather-like leaves are divided into 12-16 sections. Other species of milfoil exist but are not the problem that eurasian milfoil (*Myriophyllum spicatum*) is.

If you would like a survey to determine if this plant is in your lake, we can arrange an inspection at very low cost. Please contact us at your convenience. Please note that we are consultants and do not chemically treat or harvest vegetation. We are only concerned with the proper management of our lakes.

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HOLT, MICHIGAN

MPACT STUDIES LAKE MANAGEMENT

FRESH WATER PHYSICIANS INC.

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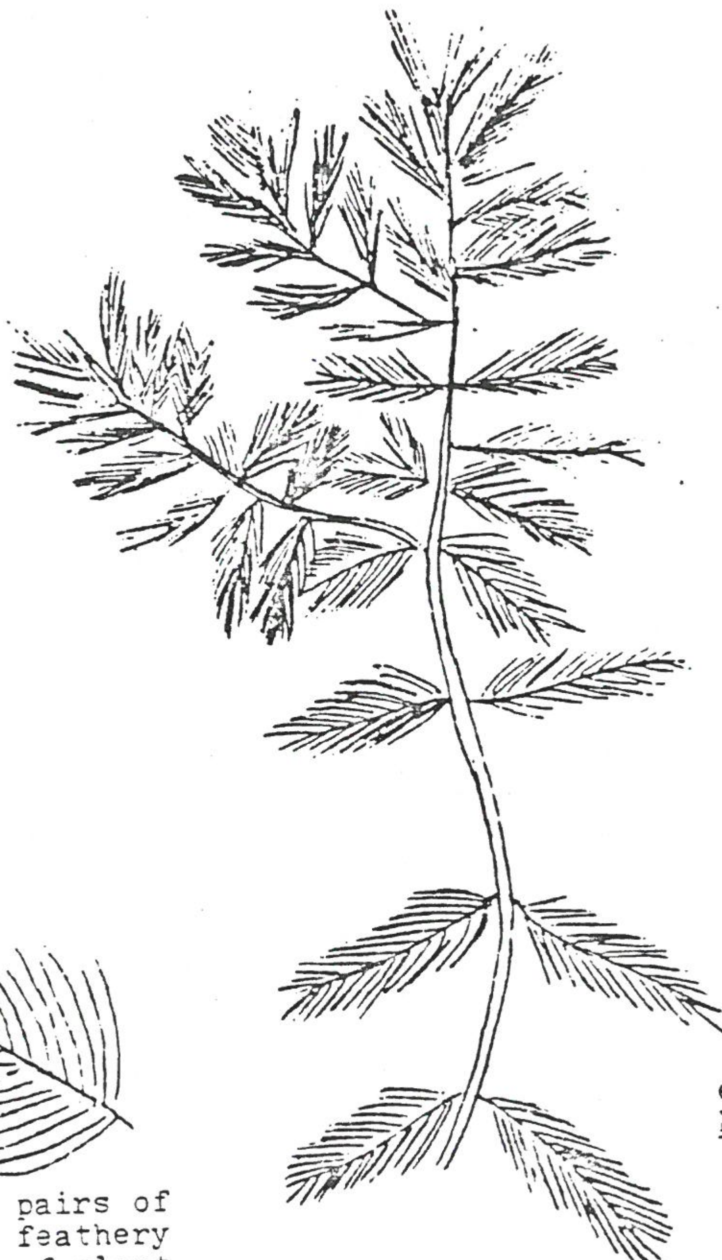

eurasian milfoil
Myriophyllum spicatum

Note 12-16 pairs of
leaves and feathery
appearance of plant

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517 694 0713

MPACT STUDIES LAKE MANAGEMENT

surrounded by two protective walls, the thinner one on the inside being laid down by the worm and the thicker one on the outside being deposited by the fish. The black appearance of the cyst is due to black pigment deposited around the cyst by the fish. The black spots are found mainly in or just beneath the skin.

The life cycle of these forms is quite interesting (Fig. 2). A fish-eating bird, usually a kingfisher, eats the infected fish, thus bringing the black grubs into the intestine of the former where they reach sexual maturity. The adult worms lay eggs which pass out

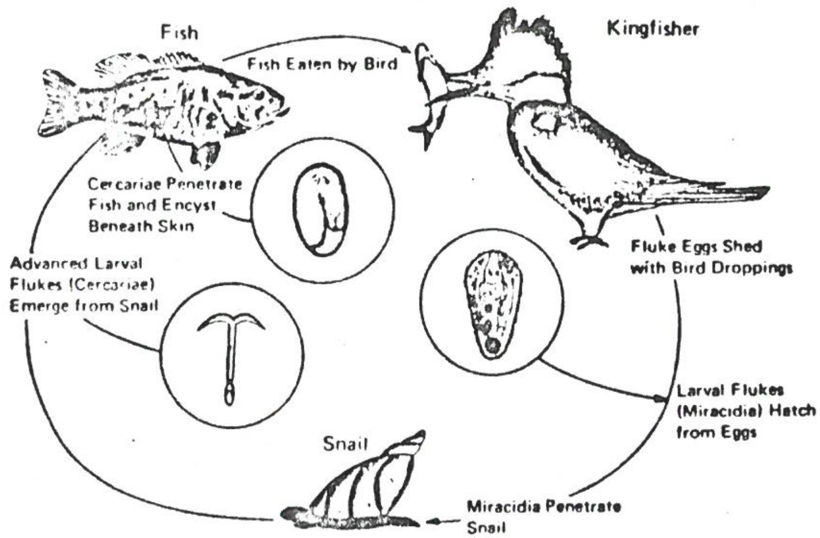


FIGURE 2. Black Spot Life Cycle

with the droppings of the bird. If these eggs reach water (which is absolutely necessary for continuance of the life cycle), they hatch after a proper developmental period into free-swimming organisms called miracidia. These miracidia then find and penetrate the body of a snail. Several generations are produced within the body of the snail, culminating in a free-swimming, fork-tail organism called a cercaria. This form penetrates and comes to rest beneath the scales or in the deeper layers of the muscles of a fish. If the fish is now eaten by a fish-eating bird, the grub develops into an adult worm, and the cycle can repeat itself.

Little information is known about harm done to fish by the black grub. It has been found that bass fry usually die in three days after being exposed to large numbers of the free-living, fork-tail organisms (cercariae) that cause black spot. However, larger

-4-

fish could withstand heavier infections especially when the infection is built up over a period of time. However, heavy infections will most likely have some unfavorable effect on the growth and vitality of the fish. Heavy experimental infections with the black grub of bass (up to 708 grubs per fish) caused a statistically significant loss of weight in a group of four-inch smallmouth bass.

Regarding the edibility of black-spotted fish, it is recognized that the grubs are very specific for the animal in which they become adult worms, and the possibility of their infecting man is very remote. Skinning infected fish will remove most grubs as practically all the cysts occur in the skin. Normal cooking will destroy all the grubs present. It may be safely stated that fish infected with black grubs are quite edible.

White Grub of Liver

The white grub of liver, like the black spot, is a larval fluke belonging to the larval genus *Neascus*. However, unlike the black spot parasite which is usually found beneath the skin of fish, the white grub of liver is restricted to the viscera. Although it is most commonly found encysted in the liver, it can also be found in the kidney, spleen, and

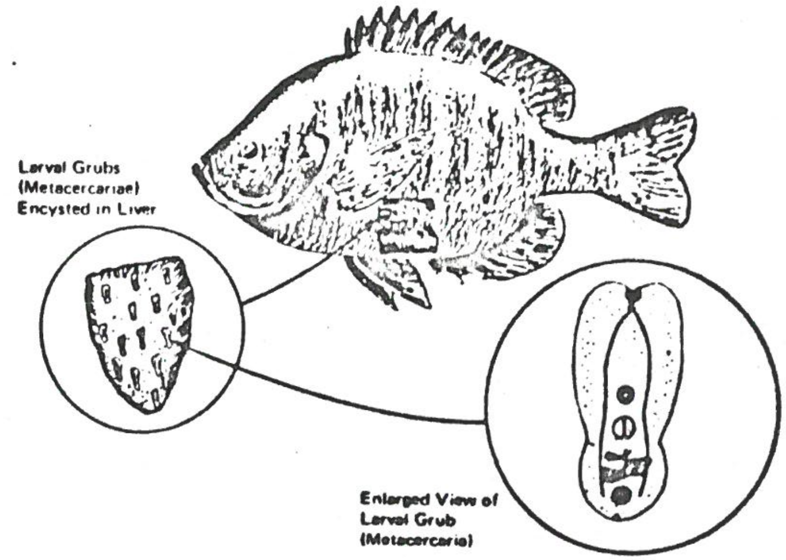


FIGURE 3. Position and Appearance of White Grub of Liver in Fish

-5-

From: Common parasites of freshwater fish. Department of Natural Resources Madison, Wisconsin, 1975. Pub. 10-3600(75). Compiled by Betty L~s; Graphics by Dennis LEvewue.

INTERNAL PARASITES

Internal parasites most often encountered by anglers are worm-like in appearance 1 at first glance may all look quite similar. However, most of them can be divided o four distinct groups: flukes (Trematodes), tapeworms (Cestodes), spiny-headed rms (Acanthocephala), and roundworms (Nematodes).

Flukes (Trematodes)

Flukes are usually found in fish during the parasite's larval stages. They may be ognized by their flattened worm-like body and the presence of oral and ventral kers which are used by the larvae to attach themselves to fish. Because of their earance and the fact that they often produce wart-like cysts on the surface f fish, y are commonly called grubs by anglers. Grubs are most often found encysted in flesh or under the skin of fish but are also found in the eyes and internal organs. ur kinds of grubs will be discussed here: white or yellow grub, black grub or black ot, white grub of liver, and eye grub.

ite or Yellow Grub

The white or yellow grub is the larval stage of the fluke known scientifically as *nostomum marginatum.* They are found as small whitish or yellowish cy in the sh and near or just beneath the skin of fish, especially at the base of the fins and l. In heavy infections, they may be abundant in other locations such as in the walls the body cavity, in the membranes of the head, throat, and gills, and in the gill ments. The living worms are very active when squeezed from the cysts and are proximately a quarter of an inch long by a twentieth of an inch wide. They have a ular opaque, brilliant white or yellow color.

The yellow grub is one of the most common North American parasites. It has been orted from so many species of freshwater fish that it is generally assumed capable infecting any North American species. In Wisconsin, yellow perch and bluegill are me targets although northern pike, minnows, darters, and sunfish are commonly fected.

The yellow grub has a complex life cycle (Fig. 1). The adult worms are fo in the outh, under the tongue, and in the throat and esophagus of fish-eating birds. The gs are shed into the water from the adult worm as the bird feeds in the water. In the e of a few hours the eggs hatch into small free-swimming organisms called racidia which actively seek and penetrate snails. Development of several generations llow in the snail, terminating in the production of small free-swimming, cigar shaped ganisms called cercariae which emerge from the snail during the spring and summer. e cercariae swim freely in the water until they find a fish into whose flesh they netrate and become the white or yellow grubs called metacercariae. If the fish is w eaten by a heron, the grubs develop into adult forms within the bird. The cycle is w ready to repeat itself as just described.

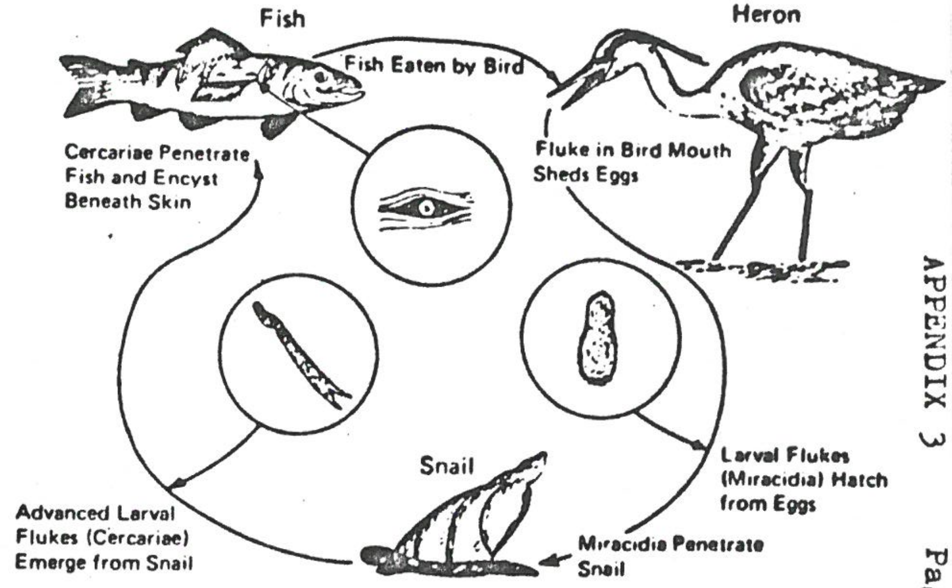


FIGURE 1. Yellow Grub Life Cycle

In light infections, the yellow grub has little apparent detrimental effect upon fis However, it has been observed through activity studies on heavily infected and norm fish that the former swim more slowly so that they are more readily caught by th fish-eating bird in which the grub becomes an adult worm. Also a heavy infectio would undoubtedly have an unfavorable effect on the growth of the fish.

There is little danger of the yellow grub infecting man. A related Asian species o the same genus has been found to infect the upper respiratory tract of man. Such cas are rare and none have been reported in North America. Any parasites of this typ would be killed by thorough cooking.

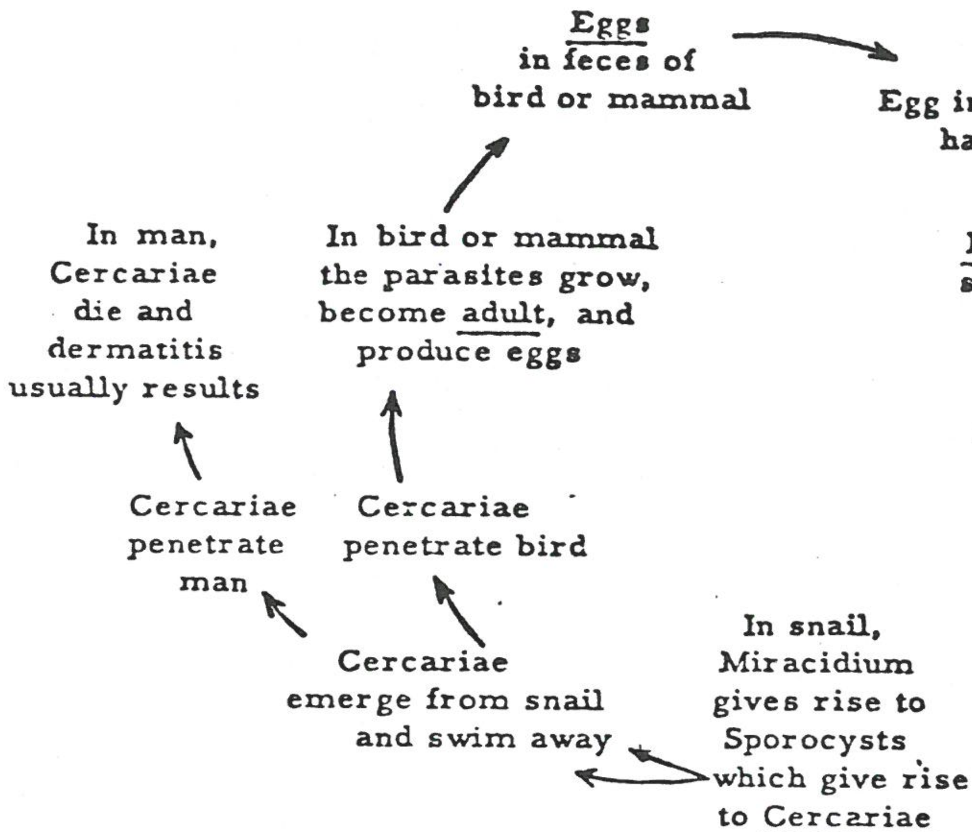
Black Grub or Black Spot

The black spot parasite can belong to any of several families of larval flukes and ha been reported from a wide variety of fish. The most common parasite of this group *Uvulifer ambloplitis* (family Diplostomatidae) which has been recorded from th sunfish, minnow, and pike families of fish. Similar parasites from this family have bee reported from perch, darters, topminnows and mudminnows. Trout are sometime infected by black grubs of a related family, Heterophyidae.

The parasite appears as a small black spot in the skin about a twenty-fifth of an inc in diameter. The encysted larva, called a metacercaria, consists of the small worm

 From: STERKIANA 62-63, SEPTEMBER 1976

THE LIFE CYCLE OF A DERMATITIS-PRODUCING SCHISTOSOME



LIFE CYCLE OF THE PARASITES

The life cycle of a typical dermatitis producing schistosome begins when eggs (Plate I, fig. 1) containing fully developed miracidia (Plate I, fig. 2) leave the infected bird or mammal host in the feces. If these feces happen to be deposited in water, the miracidia hatch out in about ten minutes and begin swimming about. The miracidia probably remain in the vicinity of where they hatched and must encounter an intermediate host snail within about twelve hours or they die (Oliver and Short, 1956: 238-249). If the miracidia happen to encounter a snail, special glands secrete a histolytic substance and they penetrate the snail's body. If the snail happens to be of the proper species, the miracidia develop into sporocysts which in five weeks or less give rise to hundreds of fork-tailed, tadpole-shaped cercariae (Plate I, fig. 3). Under conditions of proper light intensity and temperature the cercariae leave the snail and begin swimming about actively. To complete their life cycle certain avian or mammalian hosts, according to the species of schistosome, must be encountered within twelve to twenty-four hours (Miller and Edney, 1958: 55-60). The cercariae then penetrate the skin of the definitive host by secretion of certain histolytic substances and migrate through the circulatory system to the mesenteric and hepatic blood vessels where they grow and mature (Plate I, fig. 4). The adult worms mate and the females produce hundreds of eggs, many of which find their way to the lumen of the intestine and are voided with the host's feces to start the cycle anew. Many of the eggs also lodge in the host's tissue and cysts form, especially in the liver and intestinal walls, doing considerable damage to these organs (Cort, 1950: 277-302).

The occurrence of schistosome dermatitis in a particular area depends upon the presence of certain birds or mammals infected with schistosome parasites, suitable intermediate host gastropods, ecological conditions favorable for the survival of both hosts and the parasites, and the presence of human beings engaged in an activity which exposes them to the parasites. In many parts of the world these four basic factors are present and as a result the distribution of schistosome dermatitis is worldwide (Cort, 1950: 268-277).

HOW MAN BECOMES INVOLVED WITH THE PARASITES AND A DESCRIPTION OF THE DISEASE

If instead of the normal host, the cercariae penetrate the skin of an abnormal host, like man, they seldom go further than the epidermis. However, the foreign protein substance (the cercariae) causes an allergic response in sensitized humans in ten to fifteen hours which results in intense itching accompanied by erythema and papular eruptions at the points where the cercariae entered the skin. Experiments done by L. Oliver during 1947 and 1948 resulted in 78 percent of people not previously exposed to dermatitis-causing cercariae becoming sensitized after two to eight exposures to dermatitis-causing cercariae. These eruptions are often mistaken, even by dermatologists, for those caused by mosquito bites, poison ivy, or chiggers. The eruptions usually persist for two or three days before vesicules form on them. These vesicules are often ruptured when the infected person rubs and/or scratches them; bacteria may enter and a secondary infection result. The eruptions usually disappear about a week to ten days after infection leaving small scars on the skin (Cort, 1950: 277). Failure of some people to develop an allergic reaction to cercariae has been attributed to a lack of sensitivity to this foreign protein. Such sensitivity may not be acquired until after several exposures to infested waters and apparently some people never develop a sensitivity. However, other people become extremely sensitized and develop urticarial wheals and edematous swellings where the cercariae entered their skin (Olivier, 1949: 290-301). During July of 1967, the investigator talked with a family vacationing on the north shore of Houghton Lake and was told that their eight year old daughter, who had become severely infected with schistosome dermatitis, developed a fever and nausea as a result of the infection. Resort owners on the west shore of the same lake also spoke of guests, especially young children, developing a fever and nausea after becoming infected with schistosome dermatitis. From their reports it appears that children are generally more severely affected than adults. Parents reported that their children who were infected with schistosome dermatitis were extremely uncomfortable at night, tossing and turning, unable to sleep.

Prevention of penetration. Though many different lotions and ointments have been marketed as preventatives against the penetration of the cercariae, none has proved effective. Many people believe that cercariae will not penetrate the skin while it is submerged in the water and that as the skin dries after the person leaves the water that the cercariae are 'stimulated' to penetrate. Therefore, many people contacted in this study stated, that to prevent becoming infected people should shower and/or dry off immediately upon leaving water suspected of being infested with cercariae. These people apparently believe that showering will wash the cercariae off their skin before they have a chance to penetrate and that if the person rubs down briskly with a dry, rough towel, the cercariae will be either wiped off or crushed before they have time to penetrate. Experiments by Oliver have largely disproved this theory as 100 exposures involving thirty persons showed, in almost every instance, that the cercariae could penetrate successfully even while the part of the body exposed was fully submerged (Olivier, 1948: 134-139).

Treatment of eruptions. After the cercariae have penetrated the skin there is little that can be done in the way of treatment. Calamine or caladryl lotion applied to the eruptions may help stop the itching for short periods of time. In severe cases it may be necessary to give antihistamine injections to minimize the reaction. Some people require hospitalization and must be given sedatives to quiet them and permit them to sleep (Hunter, Frye, and Swartzwelder, 1961: 513-515).

SOME COMMON SPECIES OF DERMATITIS-CAUSING SCHISTOSOMES, THEIR INTERMEDIATE AND DEFINITIVE HOSTS

Though more than a dozen species of dermatitis-causing schistosomes have been described in the Great Lakes region since 1928, probably the following are the most important *Trichobilharzia ocellata*, which utilizes the snails *Lymnaea stagnalis* and *L. palustris elodes* as intermediate hosts, with certain species of ducks serving as definitive hosts; *T. stagnicolae*, found in *Lymnaea emarginata*, the final hosts being passerine birds, for example, goldfinches and *T. physellae* found in various species of *Physa*, especially *P. parkeri*, utilizing certain ducks and goldfinches as final hosts (Cort, 1950: 251-307).

Two other common schistosomes which probably are responsible for dermatitis contracted in ditches, woods pools, etc., are *Gigantobilharzia huronensis*, which develops cercariae in *Physa gyrina*, utilizing goldfinches and probably other species of birds as final hosts (Najim, 1956: 443-469), and the mammalian schistosome, *Schistosomatium douthitti*, found in *Lymnaea emarginata canadensis* and *L. stagnalis*, utilizing mice, voles, and muskrats as final hosts (Price, 1931: 665-727).

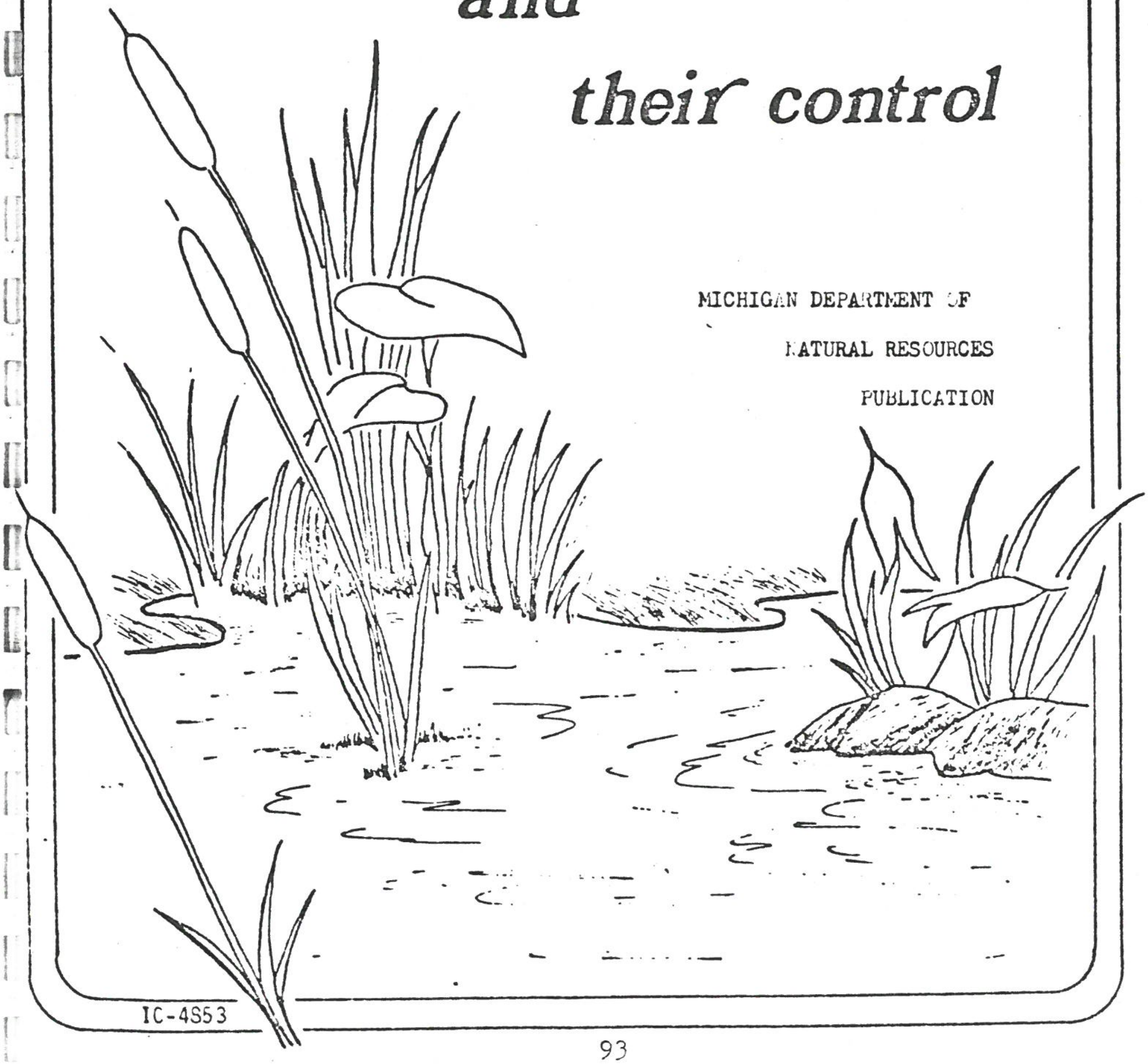
In the above discussion of the species of human dermatitis-causing schistosomes and their snail intermediate and vertebrate definitive hosts, the frequent use of the word 'probably' and general terms such as 'passerine birds and certain ducks' indicates the gaps in knowledge that presently exist in this area. At the present time it is not known how serious the invasion of the cercariae of the mammalian schistosome, *Schistosomatium douthitti* is to humans. Penner (1941) found schistosomules of this parasite in the lung tissue of Rhesus monkeys 5.5 days after exposure to the cercariae (Cort, 1950: 264). Very little is known regarding the bionomics of the avian and lower mammalian schistosomes. Such knowledge is imperative to the development of more adequate control methods. Though beyond the scope of this study, it is only logical to assume that a more thorough and complete knowledge of the parasites causing human dermatitis, the snails acting as intermediate hosts and the vertebrate animals serving as definitive hosts is vital to improving present control techniques and any new control techniques of the future. Knowing more about the ecology and life histories of the carrier snails and which animals serve as final hosts for the various dermatitis-causing schistosomes would greatly improve the precision and efficiency of the currently utilized control program and would appear to be absolutely essential to any future improvement of the control program.

Runyun Lake - Livingston County, Tyrone Township, near U.S. 23, Southwest of Fenton; 200 acres; large mouth bass, blue-gills; T. 4N, R. 6E, Sec. 9, 10

Letter to Mr. Lewis A. Proper of Detroit by Milton P. Adams, Executive Secretary, Water Resources Commission, on June 4, 1954: (In summary): An investigation by members of the Water Resources Commission of Runyun Lake concluded: "(1) There is no unnatural pollution in the lake. (2) There does not appear to be any reason why the lake is not safe for swimming. (3) A portion of the mud puppy population has died off, probably due to a disease peculiar to certain types of amphibious animals. (4) This mortality has had little or no effect upon the fish population and it is believed that it has now run its course as far as the mud puppies are concerned." No further problems were expected from the above observation (apparently mud puppies had a sizeable die-off and caused a letter by Mr. Lewis to be written reporting the incident on May 25, 1954).

Summary Examination sheet on Runyun Lake -- July 31, 1890 -- Tributary to (give immediate and main drainage): Shiawassee system; Depth: 15 feet; Species of fish and present abundance, etc.: None taken; marshy.

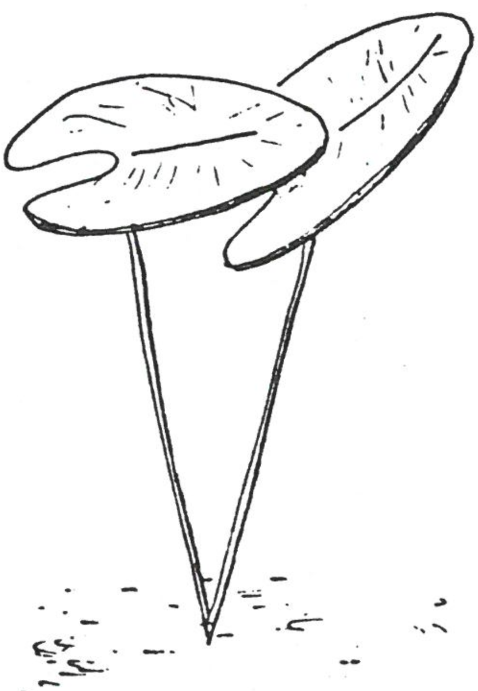
Aquatic Plants and their control



MICHIGAN DEPARTMENT OF
NATURAL RESOURCES
PUBLICATION

IC-4553

Aquatic Plants and their Control

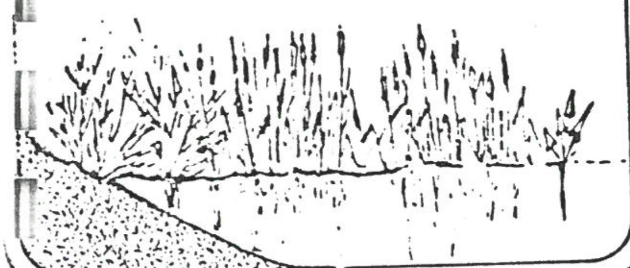


INTRODUCTION

Aquatic plants are a vital part of any lake or pond. They convert by the process of photosynthesis, with the aid of sunlight, chemical elements into living plant tissue. Then they themselves are utilized by bacteria and animal life (zooplankton, fish, waterfowl, insects, and water mammals) as food for energy. The process of photosynthesis also replenishes the aquatic environment with oxygen, which is essential to aquatic animals. Additionally, rooted plants create a varied aquatic environment in which fish-food organisms reside. They are also associated with the reproductive activities of certain fish, and furnish protection for young animals and fish.

Although they are important to the aquatic environment, plants frequently conflict with man's recreational and economic interests. A need, therefore, exists for proper aquatic plant management to insure that the natural environment and man's interests are mutually protected. The Department of Natural Resources, Inland Lake Management Unit, which administers the state laws regulating the application of herbicides to aquatic environments, has developed this bulletin as a primer for those seeking information on aquatic plant management.

Aquatic Plant Types



The proper management of aquatic vegetation requires a knowledge of the various plants that grow in lakes [and] ponds. Although aquatic plants may be divided [in]to many categories, a simple classification according to life forms and growth patterns divides them into two divisions: the algae and the [ma]crophytes.

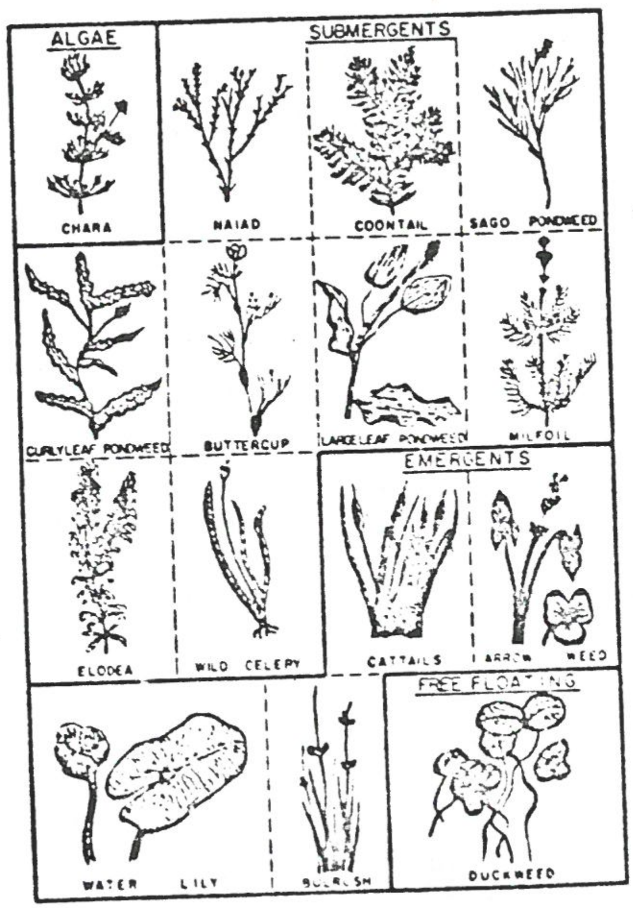
[Al]gae

[Al]gae are divided basically into planktonic, fila[men]tous and macro-algae forms. Planktonic forms are [mi]croscopic, free floating plants often referred to as "water bloom". In large numbers, these algae can [ca]use water to appear green, brown, yellow or even [re]d, depending upon the species present. Fila[me]ntous algae, commonly called "pond scum", can form raft-like masses over the water surface, but since they are vulnerable to winds and currents, they are [ge]nerally restricted to bays, bayous and sheltered [sh]orelines. Filamentous algae can also grow attached to the lake bottom, the macrophytes, or piers and docks. Many attached filamentous algae will [f]requently detach from the substrate and form [f]loating mats. The macro-algae include the two [ty]pes referred to as Chara and Nitella which are large and resemble macrophytes.

[Ma]crophytes

[Th]e macrophytes may also be divided into three basic [for]ms: submergent, emergent, and free-floating. [Su]bmergent macrophytes usually grow rooted to the [bo]ttom with stems and leaves below the water surface, [ex]cept for some plants which may produce a few small [f]loating or aerial leaves. These plants are often [re]ferred to as seaweed, lake grass or moss. Emergent [mac]rophytes (including large floating leaf plants [wi]th attached roots) grow in shallow areas along the shoreline, with most of the plant extending out of the water (e.g. water lilies, cattails). Because of their restricted habitat (shallow water areas) these plants usually cause only localized problems. The only free-floating macrophytes which may be a problem in Michigan waters are the duckweeds. These tiny plants are not attached to any substrate, but float freely within or upon the water. They are subject to current and wind action which will concentrate them in certain portions of a lake where they can be a localized problem.

Identification of the aquatic plants present in a lake is important for proper plant management, since control measures that are effective against one plant type may not be effective against another. Schematic drawings of a few plants which are commonly found in Michigan are presented in Figure 1. Additional help in identification of aquatic plants is available from: (1) county extension agents, (2) chemical companies dealing in aquatic herbicides, (3) universities, (4) Department of Natural Resources' district offices, and (5) licensed aquatic pesticide applicators.



COMMON AQUATIC PLANTS OF MICHIGAN LAKES
(PLANTS NOT DRAWN TO SCALE)

Figure 1

Why Aquatic Plants Grow

The distribution and abundance of aquatic plants in a lake is dependent upon the lake's chemical and physical properties including:

1) the quality and quantity of light available,

2) water levels,

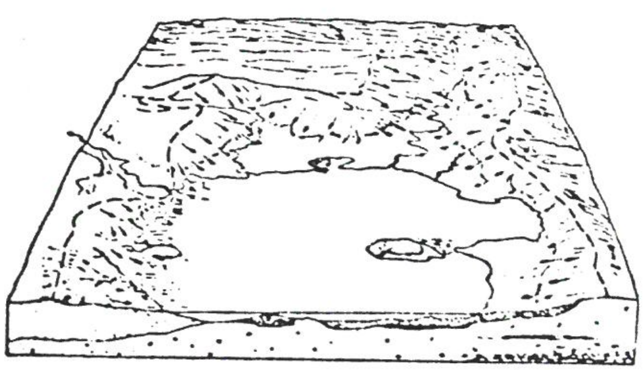
3) water temperatures,

4) particle size of lake bottom sediments,

5) current or wave action, and

6) the concentration of dissolved gasses and nutrients.

In lakes, nutrients and light availability are most often the requirements which limit plant growth. Nutrients are the chemicals such as nitrogen, phosphorus, carbon, potassium, etc., which plants require for their growth. These nutrients originate in the rocks and soils surrounding the lake. Natural processes at work within the lake's watershed continually carry some of these nutrients into the lake. A lake's watershed is the land around the lake from which water drains to the lake (Figure 2). Lake watersheds vary greatly in size, topographic relief and the means by which water moves through the watershed (stream flow, groundwater movement, surface runoff, etc.). The natural movement of nutrients to lakes is therefore dependent upon the characteristics of the watershed.



DIAGRAMATIC REPRESENTATION OF A LAKE AND ITS WATERSHED THE BROKEN LINE REPRESENTS THE DRAINAGE DIVIDE OF THE WATERSHED THE ARROWS DEPICT THE PATTERN OF OVERLAND FLOW

Figure 2

As nutrients move from the watershed, lakes naturally develop an ability to produce aquatic plants. Limnologists (lake scientists) have for many years grouped lakes by a classification system based upon their productivity or ability to produce plants. Lakes that are low in productivity are called oligotrophic, while lakes high in productivity are called eutrophic. Oligotrophic lakes usually:

1) are deep,

2) have high oxygen concentrations in the deeper water,

3) are very clear,

4) have sparse populations of aquatic plants, and

5) are populated with cold water fishes such as trout and whitefish.

Eutrophic lakes usually:

1) are shallow,

2) have little oxygen in waters deeper than 30 feet,

3) have murky water,

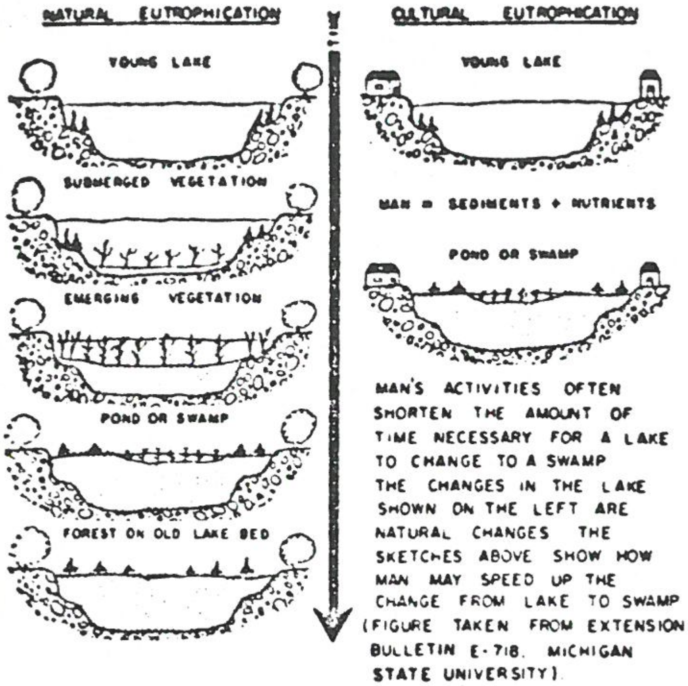
4) have substantial growths of aquatic plants, and

5) are populated with warm water fishes such as bass, pike, and bluegills.

The term mesotrophic is often used to describe a lake with characteristics between oligotrophic and eutrophic.

Over geological time (thousands of years) oligotrophic lakes may very slowly age into mesotrophic and eutrophic lakes. This aging process of lakes is referred to as eutrophication. The rate at which eutrophication (aging) proceeds in any given lake is primarily based upon the quantity of nutrients and sediments washed into the lake from its watershed.

Without the presence of man, lake aging is usually a very slow process requiring many thousands of years. However, the presence of man in a lake watershed can greatly accelerate aging. This greatly accelerated rate of aging is often referred to as "cultural eutrophication" and is caused by the increased amount of nutrients and sediments put into lakes as man changes (development) their watersheds (Figure 3). Consequently, what man does to the land within a lake's watershed can greatly influence the growth of aquatic plants in the lake.



Eutrophication

Figure 3

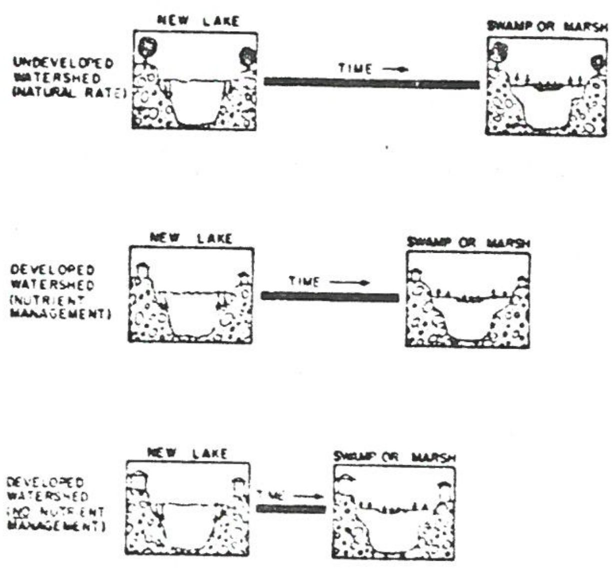
Aquatic Plant Management Program

The goal of aquatic plant management is not to "kill weeds" but to maintain a proper balance of plants within a lake and still retain the lake's recreational and economic importance. Ideally, every aquatic plant management program will have two phases: (1) long-term management (nutrient control) and (2) short-term management (direct manipulation of macrophyte and algae populations). Short-term management is relatively easy to implement, but long-term management is more complicated. It requires considerable community involvement and cooperation, and results take years rather than days to develop.

The remainder of this bulletin will consider the principles and techniques of long-term and short-term aquatic plant management. Not every principle or technique presented will be applicable to every lake and even those that are should be evaluated carefully before using them. While economics must, of course, be considered, ecological values should receive prime consideration before employing any management technique. Attention to ecological values may result in a program that is less costly over the period of a decade or two.

Long-Term Management (Nutrient Control)

Aquatic plants require many nutrients for growth and reproduction. The nutrients most often considered to be in the shortest supply and therefore limiting plant growth are phosphorus and nitrogen. Since aquatic plant populations are directly dependent upon the amount of nutrients available, nuisance growths of plants are only symptoms of high nutrient levels. This is important because all too often aquatic plant control programs are directed only at the aquatic plants, and not at what causes the plants to grow (nutrients). An effective aquatic plant management program must give proper consideration to the amount of nutrients entering the lake. Aquatic plant management techniques designed only to "kill weeds" must be considered only temporary cosmetic measures to reduce the symptoms of high nutrient levels. It is wiser to control the movement of nutrients on the watershed, whenever possible, then to attempt remedial action after nutrients have entered the lake. Although the management of nutrient sources cannot, over the long run, prevent the lake from becoming a marsh, it can reduce the rate of lake aging (Figure 4).



EUTROPHICATION (AGING) OF LAKES WITH DIFFERENT LEVELS OF NUTRIENT LOADING

Figure 4

Limiting the movement of nutrients off the watershed and into lakes will require the management of nutrient sources. Some sources of nutrients both natural and man-made are listed in Table 1. Natural sources of nutrients are those which would contribute nutrients to a lake even if man were not present. Most natural sources contain only very small amounts of nutrients. However, man-made sources of nutrients usually have large volumes and high concentrations of nutrients which can greatly accelerate the rate of lake eutrophication.

All nutrient sources will have different levels of manageability. Some may be uncontrollable, while others may be controlled with little effort or cost. Ideally, it is desirable to know which sources are contributing nutrients to a lake and in what quantities. It is then possible to adjust funds and activities to control nutrient sources to most effectively reduce the amount of nutrients entering the lake. However, this approach in most situations will require an extensive study by a trained limnologist.

The best time to begin a nutrient control program is before aquatic plants have attained nuisance levels, for proper management of a lake requires considerable long-range planning. The management of nutrient sources is an on-going responsibility, which must be intensified as man continues to develop the watershed. Methods of nutrient source management include:

1) proper land use,
2) wise consumer use of commercial products,
3) treatment of inflowing waters high in nutrients,
4) diversion of waters high in nutrients, and
5) municipal and industrial wastewater treatment.

Proper Land Use

The importance of proper land use and watershed planning is beginning to stimulate many units of government, at all levels, to enact ordinances and laws to regulate land use. In Michigan, the State Legislature enacted the Soil Erosion and Sedimentation Control Act of 1972 (Act No. 347 of the Public Acts of 1972) to limit the movement of sediments and associated nutrients into surface waters during earth moving activities (except agricultural tillage).

Minnesota, Wisconsin and Maine now require local government units to establish zoning ordinances for lake and stream front properties to protect the quality of these aquatic environments. Table 2 presents land use practices that should be considered in a nutrient control program.

Wise Consumer Use of Commercial Products

There are several commercial products, such as detergents and fertilizers, used for domestic and commercial purposes which can contribute significant amounts of nitrogen and phosphorus to natural waters. Curtailing or restricting the use of these products or substituting similar products of low nitrogen and phosphorus content would substantially reduce the loading of nutrients to natural waters.

Waterfront property owners should take special care in the use of detergents and fertilizers. Owners with individual septic systems should minimize the use of high phosphate detergents to prevent leaching of phosphorus into the lake by way of the groundwater. Additionally, waterfront property owners should avoid the use of lawn fertilizers. If fertilizers must be used, the soil should be tested to determine which chemical nutrients are needed. If the soil does not require phosphorus, a fertilizer containing little or no phosphorus should be used. County cooperative extension agents can provide information on soil testing procedures and the best dates for applying fertilizers.

Treatment of Inflowing Waters High in Nutrients

In certain situations it may be possible or necessary to treat inflowing waters to reduce nutrient levels before they enter a lake. An inflowing stream or drain may carry substantial amounts of nutrients collected from many sources, such as agricultural drainage or urban stormwater drainage. In certain situations it may be more feasible to chemically or physically treat the inflowing water to reduce nutrients than to control the many diffuse nutrient sources draining into it.

Diversion of Waters High in Nutrients

Diversion is the rerouting of water high in nutrients around or away from a lake. The principle of diversion is applicable to most nutrient sources that can be physically contained or rerouted. The application of this nutrient control technique has been most frequently applied to the diversion of municipal wastewater, but the concept can apply to waters containing high nutrient levels derived from other sources as well.

In many cases where nutrient rich water has been diverted away from a lake, there has been a marked increase in water quality. It must be emphasized, however, that diversion is not a substitute for treatment or proper land management. The diversion of non-treated nutrient rich waters is only a transfer of nutrient control problems to downstream communities.

Municipal and Industrial Wastewater Treatment

Few Michigan inland lakes receive municipal wastewater discharge, but when present, it can be a major source of nutrients for aquatic plant growth. Several methods are now available to reduce the level of plant nutrients in wastewater. But even when these methods are used, a wastewater treatment plant discharging to a lake or its tributaries will contribute greatly to the loading of nutrients to a lake. Diversion of wastewater around lakes or land disposal are possible alternatives for eliminating completely the impact of this nutrient source upon lakes.

Industrial wastewater is highly variable in quality. Those that contain substantial amounts of plant nutrients or toxic materials must be considered in any lake management program.

Table 1. Natural and man-made sources of plant nutrients (chemical elements) to the aquatic environment.

Natural	Man-Made
wetland runoff	domestic and industrial wastewater
meadow land runoff	agricultural runoff (cropland & pasture)
forest runoff	agricultural wetland drainage
precipitation on the lake surface	managed forest runoff
soil erosion	urban stormwater runoff
aquatic bird and animal wastes	septic tank discharges
leaf, pollen and dust deposition	landfill drainage
groundwater influxes	construction activities
nitrogen fixation by plants	lake shore lawn runoff
sediment recycling	atmospheric fall-out of wind borne fertilizers from land and industry

(Modified from Shannon and Brezonik, 1972. Relationship between lake trophic state and nitrogen and phosphorus loading rates. Environ. Sci. Tech. 6:719-725).

Table 2. Examples of wise land use practices which can reduce the movement of nutrients from the watershed into lakes.

a. Advocate sediment control from logging, agricultural activities and urban construction.

b. Preserve wetlands as no development areas.

c. Require or encourage greenbelting to preserve native vegetation along lake and stream banks.

d. Promote proper collection and disposal of or treatment of farm and feedlot animal wastes.

e. Encourage sound farm fertilization practices.

f. Urge community collection and disposal of leaves in urban areas adjacent to large recreational water systems.

g. Require routine inspection and maintenance of catch basins in city storm drains.

h. Limit or restrict the use of fertilizers on lawns adjacent to lakes and streams.

i. Prevent urban stormwater drainage, with its high nutrients, from directly entering a lake, rather encourage subdivision designs which maximize infiltration and groundwater recharge.

j. Regulate the size and use of lake and stream front lots and back lots to prevent overdevelopment of the environment and its associated high nutrient loading.

k. Stipulate a minimum distance of at least 100 feet between the shoreline and installation of private septic systems and tile fields.

l. Prevent development in areas where the groundwater is high or soils are poor nutrient traps for private sewage-disposal systems.

m. Require an environmental impact statement for all development which could significantly degrade environmental quality.

Short-Term Management of Aquatic Plants

Although the initial and continuing phase of aquatic plant management should be the control of nutrient sources, many lakes have such serious plant problems that short-term management techniques may be needed to protect the recreational and economic interests in the lake. Also in cases where nutrient control is impractical, such as shallow reservoirs on major, agricultural or urbanized river systems, short-term management practices may have to be conducted annually. Even in such cases, however, under no circumstances should the complete eradication of aquatic plants be considered. This practice is environmentally unsound and could have very undesirable consequences. In some lakes it may be necessary to alter recreational activities somewhat to suit the lake's state of eutrophication, rather than attempt to change the lake to meet recreational demands. In situations where nutrient control is possible, short-term management techniques should be considered only as temporary measures, designed to replace nuisance plant species with plant species that conflict less with man's recreational and economic interest.

The short-term methods for managing aquatic plants include:

1) biological control,
2) mechanical harvesting,
3) environmental manipulation, and
4) use of herbicides.

These methods are directed primarily at the results (aquatic plants) of nutrients entering the lake and not at reducing the flow of nutrients. In some cases, however, nutrient levels within the water system may be reduced incidently with certain techniques.

Biological Control

Biological control of aquatic vegetation is presently the least understood and utilized of the four short-term management techniques. Biological control normally includes the introduction of an organism that competes with, preys upon, inhibits the growth of, causes disease in or parasitizes a plant species which has created a problem.

The use of biological agents has many potential hazards. Therefore, the use of this control technique in either the terrestrial or the aquatic environment will always be under the direct supervision of state agencies. The introduction and release of exotic, foreign or non-native insects, fish or other animals into Michigan without specific authorization is strictly forbidden by state laws (Act No. 286 of the Public Acts of 1929; Act No. 196 of the Public Acts of 1958). At the present time, there are no specific biological control techniques being applied in Michigan waters.

Mechanical Harvesting

Mechanical harvesting involves the pulling or cutting and removal of macrophytes from selected areas of a lake. It may employ hand tools or highly sophisticated motorized cutting or uprooting devices. The harvesting of algae from lakes appears presently to be economically infeasible primarily due to very high energy costs to remove the microscopic plants from water.

The removal of cut macrophyte material has advantages over allowing the material to decompose in the lake. Removal prevents dissolved oxygen loss and reduces the buildup of organic material on the lake bottom. Additionally, since macrophytes contain nutrients within their tissue, removal of cut material may somewhat reduce the level of nutrients present in the lake. However, in lakes that are annually receiving large amounts of nutrients from the watershed, nutrient removal by harvesting will have no or only a minimal influence in reducing the quantity of nutrients available for plant growth. But, in lakes that have had nutrient loading reduced, harvesting may remove enough nutrients to improve water quality.

Mechanical harvesting also has drawbacks which must be considered. It has a high initial investment if one of the specially manufactured harvesters are purchased. Many of these machines are large, heavy and can be damaged by obstructions (logs, boulders and debris) hidden below the lake surface. Additionally, harvesting could aid the spread of a plant problem, since cut plants may drift into unaffected areas, take root and grow.

Environmental Manipulation

The objective of environmental manipulation is to alter one or more physical or chemical factors (listed in "Why Aquatic Plants Grow") critical to plant reproduction and growth thus making the environment less suitable to the plant. Several techniques have been used with varying degrees of success to manipulate the environment to achieve this goal. None of these methods are always economically and/or environmentally practical in every lake and even in practical situations should be employed only after careful consideration of the plant problem and social, economic factors. Environmental manipulation can provide some control of aquatic plants but without reduction of nutrient inputs, any results achieved will be only temporary. Since most of these methods are somewhat technical, only a brief discussion of each is given below.

Dredging reduces nuisance aquatic macrophytes by deepening the lake bottom below the depth of light penetration. Reduction of the size of the well lighted zone around the shore will reduce the total amount of germination and growth of macrophytes. The disadvantages of dredging include a temporary increase in silt suspended in the water, which on settling in non-dredged areas can smother bottom living animals. Additionally, land must be available for the disposal of dredge spoils. Dredging also may not reduce the level of nutrients available for plant production, therefore, algal populations may increase as macrophyte populations decrease.

Aeration is the introduction of air into the deeper waters of a lake for the purpose of increasing the dissolved oxygen concentration of the water and promoting oxidation of sediments. Aeration is most effective in lakes which are devoid of oxygen in the deep water. Keeping oxygen in the bottom waters will prevent the release of nutrients from sediments. As long as nutrients remain chemically bound to the sediments in the deeper parts of the lake, they are less available for aquatic plant growth. Decreases in nuisance algal populations and a shift to more favorable species have been reported following aeration, but this result is not always observed. A possible disadvantage of aeration is that it can be detrimental to cold water fishes (trout) if warm surface waters are mixed with cool bottom waters making the total lake environment unsuitable for these fish species. There are methods of aerating only the deeper waters, however. The use of an aerator may also cause the resuspension of bottom muds which may increase turbidity.

Nutrient Inactivation is the application of a chemical to a lake that binds with and otherwise immobilizes nutrients necessary for plant growth. Once immobilized, the nutrients settle to the lake bottom. The chemical substance used to immobilize and settle out the nutrients is usually a metal ion (iron, aluminum, calcium) though ion exchange resins, clay, mud, and fly ash have been used experimentally. The settling process may also reduce suspended solids and decrease turbidity and color, in addition to inactivating nutrients. This technique is expensive and may adversely affect the lake biology by covering the bottom sediments and fish-food animals with settling material.

Drawdown or water level manipulation is a potential mechanism for controlling certain types of aquatic vegetation. In this technique, water levels are lowered for a period of time to expose shallow water areas to air. This dries out the exposed plants and kills them. Many submergent macrophytes are susceptible to this procedure, but certain emergent macrophytes actually benefit from it. A drawdown period of approximately two months is necessary for drying and freezing to be effective during winter drawdown.

Dilution or Displacement of low quality water with water of higher quality may lessen aquatic plant problems. However, a supply of higher quality replacement water must be available as well as an acceptable means of disposing of lower quality lake water.

Shading for prolonged periods (4 weeks or greater) has been effective in reducing certain submergent macrophytes by light limitation. Light reduction through the use of water dyes has been tried, though this technique is still in the experimental stage. Black plastic sheeting has been used as a floating shade. Its success on small areas (swimming beaches) is good for certain submergent macrophytes and of limited control value for emergent vegetation. However, problems with wave action and currents limits the usefulness of a floating plastic shade primarily to small ponds.

Covering of Bottom Sediments with sheeting material (black plastic) and/or particulate material (sand, clay, fly ash) can perform two functions in controlling aquatic plants. It can prevent the exchange of nutrients from the sediments to the overlying water and it can retard the establishment of rooted aquatic macrophytes. Disadvantages of this technique are that bottom dwelling animals are usually killed when the sediment is covered and often gas is produced in the covered sediments, rupturing the bottom seal or causing it to float to the surface. Experience with this technique so far has resulted in only temporary control, since macrophytes will gradually recolonize the area.

Intensive Use and Periodic Manual Cleaning of shoreline areas will in many instances prove to be an effective means of aquatic plant control in small beach areas. The rooted plants must produce sufficient food in their leaves to maintain their root systems. Frequent cutting of the leaves or their destruction by wading and swimming will eventually lead to death of the root system by which the plants frequently spread. This technique is particularly effective with emergent vegetation and water lilies. Like weeding the garden, it is necessary to watch for the early development of potential problems and attack the plants as they become established and before they spread over large areas.

Use of Herbicides

Chemical control has, for many years, been the primary means of temporarily controlling aquatic plants. There are a number of chemicals available which offer varying degrees of action time, persistence, cost, selectivity and safety to humans, other mammals and aquatic animal life.

The best time to apply herbicides is during a calm sunny day after water temperatures have reached 50 degrees Fahrenheit, or when plants first show signs of growth. For lakes where a large segment of the surface area is involved in the treatment, the lake should be treated in sections over several days to avoid oxygen loss and consequently the loss of aquatic animal life as the plants decompose. Report immediately any environmental damage or death of large numbers of non-target aquatic animals (fish, frogs, crayfish, etc.) to the Department of Natural Resources, Division of Land Resource Programs, Inland Lake Management Unit, P.O. Box 30028, Lansing Michigan, 48909.

It is important that herbicides be used with extreme care. Those chemicals that are highly toxic to man require special handling such as protective clothing for application and posting of treated water so that innocent swimmers or fishermen are not exposed to potentially harmful chemicals. Before applying any chemical always read the product label completely and follow all instructions. Take special note of all warnings on the label to avoid any personal injury and dispose of all empty chemical containers as directed.

A list of commercial applicators licensed by the Michigan Department of Agriculture to apply herbicides and other pesticides to the aquatic environment is available from the Department of Natural Resources, Inland Lake Management Unit. Additionally, the Inland Lake Management Unit is available to answer questions which may arise concerning chemical control of aquatic plants or other aspects of inland lake management.

When herbicides are part of an aquatic plant management program, special care must be taken to protect both the environment and individuals involved, since herbicides are potentially dangerous to both. To promote the proper use of aquatic herbicides Act No. 86 of the Public Acts of 1977, has granted regulating authority over the application of these compounds to the Department of Natural Resources. A permit is required from the Department of Natural Resources prior to any chemical treatment of waters within multiple ownership or private waters which discharge to waters within multiple ownership. Application forms for a permit may be obtained from the Department of Natural Resources, Division of Land Resource Programs, Inland Lake Management Unit, P.O. Box 30028, Lansing, Michigan 48909.

It is important to point out that the use of herbicides to control aquatic plants has certain drawbacks which should be mentioned. Most herbicides control all forms of plant life to some extent. Desirable aquatic plants may be killed along with the undesirable plants. It is also difficult to control the drift of herbicides under certain conditions, consequently plants may be killed over a much wider area than intended. Additionally, herbicides give only annual control. For continual control, the treatments will have to be repeated for as many years as control is desired. In lakes where herbicides are used repeatedly on a large scale, dramatic shifts in plant populations can occur which may seriously alter the lake's ecology.

At the time of this publication, the chemicals presented in Table 3 are permitted for treatment of aquatic plants in the State of Michigan. Chemicals on the list may have many trade names.

Table 3. Herbicides permitted for aquatic plant control in Michigan and the plant species for which they may serve as potential control agents.

Plant species	Copper Sulfate	Chelated Copper	di(N,N-dimethyl-alkylamine) Salt of Endothall (liquid)	di(N,N-dimethyl-alkylamine) Salt of Endothall (granular)	Endothall	Diquat *	2,4-D	Simazine (used in ponds only)
Algae								
Planktonic	●	●	●					●
Filamentous	●	●	●	●		●		●
Macro-algae	●	●	●	●				●
Macrophytes								
Submergents								
Curly leaf pondweed				●		●		●
Sago pondweed				●		●		●
Large leaf pondweed				●	●	●		●
Naiad				●	●	●	●	●
Buttercup						●		
Coontail				●	●	●	●	●
Milfoil				●	●	●	●	●
Elodea				●		●		
Wild celery				●				
Emergents								
Water lily							●	
Arrow weed							●	
Cattails						●	●	
Bulrush							●	
Free floating								
Duckweed						●		

* Diquat products are restricted for all aquatic uses, except in small ponds such as farm ponds that have no outflow and are under the control of the user. This means that you must be licensed by the Michigan Department of Agriculture as a certified aquatic pest control applicator to purchase and use this material in all water bodies except small ponds under the control of the user.

In calculating the proper amount of herbicide to use, the first step is always to determine the surface area to be treated. In the case of small bodies of water, this can be done by direct measurement with a tape. For waterbodies of unusual shape, divide the surface into distinct areas, each of which is a shape with which you can deal. The surface area of each section can be calculated, and the areas added together to give the total area of the waterbody. In the case of man-made ponds, the engineer or surveyor who designed the pond may already have the surface area calculated.

Depending on the type of herbicide being used and the type of plant being treated, the amount to be used is sometimes calculated on the basis of surface area and sometimes on the volume of water. Follow the directions on the herbicide container. If the herbicide directions specify treatment on the basis of parts per million (ppm), not only the surface area but also the average depth must be determined in order to calculate the volume to be treated. If a contour map of the lake or pond is available, the average depth can be calculated from it. If not, the average depth will have to be measured through the use of a pole or sounding line.

Once the surface area and depth has been determined, it is a simple matter to calculate the volume. For purposes of aquatic plant control, volume is usually calculated in acre-feet. One acre-foot is that volume of water which will cover one acre to a depth of one foot. It is equal to 43,560 cubic feet or approximately 326,000 gallons. To calculate the volume of a waterbody in acre-feet, multiply the surface area (in acres) by the average depth (in feet).

Application Based on Surface Area

When herbicides are applied on the basis of surface area, calculations and recommendations are usually expressed in pounds per acre of water (lb/A). Most commercially available herbicides are not 100 percent active ingredient. The commercial formulation contains various extenders, binders, carriers, surfactants, and solvents in addition to the herbicide. The label should be read carefully to determine how much active ingredient is contained in each gallon or pound of commercial formulation.

Application Based on Volume

The concentration of herbicides used for aquatic weed control are so low that they are most conveniently expressed as parts per million (ppm). If the effective level of a given chemical is 2 ppm, it means that for every million pounds of lake water, 2 pounds of active ingredient are needed. Since an acre-foot of water weighs 2.7 million pounds, dissolving 2.7 pounds of any material in 1 acre-foot of water will result in a concentration of 1 ppm (1 pound of material for every million pounds of water). In Tables 4 and 5, these calculations have already been computed and the amount of chemical necessary to treat one acre-foot of water can be read directly from the table. Table 4 is used where the amount of active ingredient is expressed as a percentage of the product, whereas Table 5 is used where the amount of active ingredient is expressed as pounds per gallon.

Table 4. Pounds of Herbicide Required to Treat One Acre-Foot of Water Based on Concentrations of 1 to 5 Parts Per Million.

Percent Active Ingredient (A.I.)	Parts Per Million (ppm)				
	1	2	3	4	5
1	272	544	815	1,087	1,359
2	136	272	408	544	680
3	91	181	272	362	453
4	68	136	204	272	340
5	54	109	163	217	272
10	27	54	81.5	109	136
25	11	22	33	43.5	54
50	5.4	10.9	16.3	21.7	27.2
100	2.7	5.4	8.2	10.9	13.6

Example: Aquathol granular is 10 percent active ingredient. A treatment of 1 acre-foot at a concentration of 2 ppm requires 54 pounds of chemical.

Table 5. Gallons of Herbicide Required to Treat One Acre-Foot of Water Based on Concentrations of 1 to 5 Parts Per Million.

Pounds Active Ingredient (A.I.) Per Gallon	Parts Per Million (ppm)				
	1	2	3	4	5
1	2.72	5.44	8.15	10.87	13.59
2	1.36	2.72	4.08	5.44	6.80
3	0.91	1.81	2.72	3.62	4.53
4	0.68	1.36	2.04	2.72	3.40
5	0.54	1.09	1.63	2.17	2.72
10	0.27	0.54	0.82	1.09	1.36

Example: Aquathol liquid has 2 pounds of active ingredient per gallon. A treatment of 1 acre-foot at a concentration of 2 ppm requires 2.72 gallons of chemical.

1 acre-foot contains 43,560 cubic feet of water.
1 part per million = 8.345 pounds per million gallons of water.
1 part per million = 2.72 pounds per acre-foot of water.

 Copy for Records

ANALYST: S. M. Usman
DATE SAMPLED: September 14, 1970
TIME: 10:00 - 3:00
LOCATION: Tyrone Township
NAME OF LAKE: Runyon Lake
DATE OF ANALYSIS: September 16, 17, 18, 1970
METHOD OF ANALYSIS: 1. Hach Method (Quick Method)
2. Standard Method
i, Chloride - Mercuric Nitrate Method
Standard Methods for Examination of Water and Waste Water
12th Edition, 87-89.
ii, Phosphate - Chlorostanuous Reduced Molybdophosphoric
Blue Color Method, in Sulfuric Acid System Method I.
Soil Chem. Analysis (Jackson, M. L.); 141-144 (1964).
iii, Rapid Method for Nitrate Determination
(Agr. Food Chem. 15:359-61)

SITE OF SAMPLING	HACH METHOD			STANDARD METHOD		
	Cl^- ppm	$PO_4^=$ ppm	NO_3^- ppm	Cl^- ppm	$PO_4^=$ ppm	NO_3^- ppm
R_1 = Inlet (small creek) wooded area	22.88	0-2	0-.1	8.42	0.017	0.194
R_2 = Ditch - cottages in vicinity	22.88	0-2	0-.1	19.00	0.072	0.194
R_3 = Inlet (small creek)	22.88	0-2	0-.1	8.42	0.066	0.350
R_4 = Outlet - sample taken from other side of the road	22.88	0-2	0-.1	14.59	0.045	0.156
R_5 = Steepy slope - many cottages	22.88	0-2	0-.1	14.59	0.111	0.168
R_6 = Inlet (small creek) wooded area and cottages in vicinity	22.88	0-2	0-.1	10.42	0.094	0.271
R_7 = Lagoon - just at its mouth - cottages in vicinity	22.88	0-2	0-.1	19.80	0.048	0.168
R_8 = Inlet (small creek) wooded area and cottages in vicinity	22.88	0-2	0-.1	5.21	0.033	0.245
R_9 = Inlet (small creek) wooded area and cottages in vicinity	22.88	0-2	0-.1	12.50	0.063	0.297
R_{10} = Inlet (small creek) - a few cottages in vicinity	22.88	0-2	0-.1	16.67	0.409	1.000

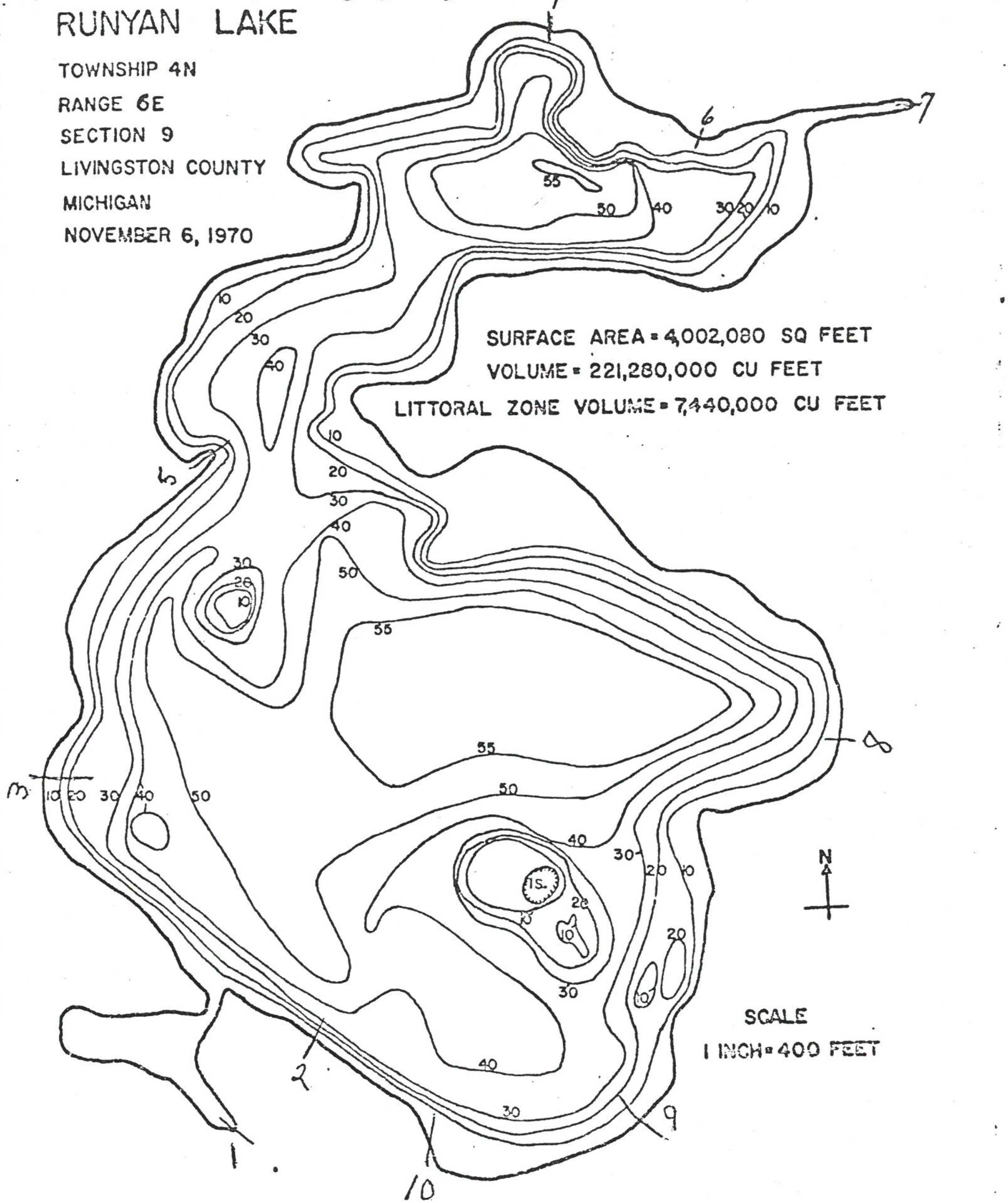
RESEARCHER: S. M. Usman
LAKE: Runyon

Presumptive Test for E. Coli Bacteria

Multiple Tube Fermentation Technique
Standard Methods for the Examination of Water and Waste Water, 12th Edition, 594-609.

SAMPLED DATE: September 14, 1970 TIME: 10:00 - 3:00
RUN DATE: September 15, 1970 TIME: 8:00
READ DATE: September 17, 1970 TIME: 8:00

	DILUTION				
SITE OF SAMPLING	10^{0}	10^{-1}	10^{-2}	10^{-3}	MPN/100 ML
R_1 = Inlet (small creek)wooded	3	1	0	0	43 x 10 = 430
R_2 = Ditch - cottages in vicinity	3	3	1	0	460 x 10 = 4,600
R_3 = Inlet (small creek)	1	0	0	0	4 x 10 = 40
R_4 = Outlet - sample taken from the other side of the road	3	2	0	0	93 x 10 = 930
R_5 = Steepy Slope - many cottages	2	1	0	0	
R_6 = Inlet (small creek) wooded area and cottages in vicinity	3	3	2	0	1,100 x 10 = 11,000
R_7 = Lagoon - just at its mouth - cottages in vicinity	3	3	1	1	460 x 10 = 4,600
R_8 = Inlet (small creek) wooded area and cottages in vicinity	3	3	1	0	460 x 10 = 4,600
R_9 = Inlet (small creek) wooded area and cottages in vicinity	3	3	2	1	150 x 10^2 = 15,000
R_{10} = Inlet (small creek) a few cottages in vicinity	3	3	3	3	1,100 x10^3 = 1100,000 over


RUNYAN LAKE
TOWNSHIP 4N
RANGE 6E
SECTION 9
LIVINGSTON COUNTY
MICHIGAN
NOVEMBER 6, 1970
SURFACE AREA = 4,002,080 SQ FEET
VOLUME = 221,280,000 CU FEET
LITTORAL ZONE VOLUME = 7,440,000 CU FEET
N
SCALE
1 INCH = 400 FEET
1
2
3
4
5
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IS.

ABSTRACT

TITLE:	Inland Lakes Water Quality Sampling Program
AUTHOR:	Anatech Services, Inc.
SUBJECT:	Water Quality Sampling of 78 Inland Lakes in Southeast Michigan
DATE:	December, 1977
LOCAL PLANNING AGENCY:	Southeast Michigan Council of Governments
SOURCES OF COPIES:	Southeast Michigan Council of Governments 800 Book Building 1249 Washington Boulevard Detroit, Michigan 48226
NUMBER OF PAGES:	77
ABSTRACT:	This document presents and initially discusses the data derived from the sampling of 78 inland lakes in Washtenaw, Livingston and Oakland Counties in Southeast Michigan during the spring turnover and the summer period of maximum thermal stratification. The data are useful in assessing the trophic condition of these lakes as well as in initiating the development of a program for water quality improvement for these lakes

CHAPTER I: INTRODUCTION

Anatech Services, Inc. carried out a sampling program on 78 lakes in a three county area for the Southeast Michigan Council of Governments (SEMCOG) as part of SEMCOG's 208 Water Quality Management Plan. This sampling program has three basic objectives which are significant to the final 208 planning program:

1) To define the trophic state and baseline water quality of relatively large lakes greater than 40 hectares (100 acres) in a tri-county area whose environments range from urban to rural.

2) To develop a data base on these lakes, such data being crucial to local water quality management, planning efforts, identification of factors that influence water quality and future undertakings such as the development of computer modeling of the water quality of lakes in Southeast Michigan.

3) To assist, via the data and interpretation thereof, in establishing a basic program of self help for local lake associations in Southeast Michigan.

The data base for this report was derived from two sampling periods. The first period occurred in late March, 1977 during the spring turnover in these lakes. The spring turnover occurs at the point when the ice has just melted and winds have thoroughly mixed the waters to the point of homogeneous oxygen saturation and water temperature throughout the lake. No stratification has taken place and algae blooms, if normally present, have not developed.

The second period occurred in late August, 1977 during the period of maximum thermal stratification when, in lakes of reasonable depth, three strata occur: a) Epilimnion, b) Metalimnion and c) Hypolimnion.

During the sampling periods climatalogical and visual data such as wind speed and direction and wave height were measured and recorded. A number of field measurements were taken at each sampling site on each lake including dissolved oxygen and temperature at 1 meter (3.3 feet) intervals from the top to the bottom as well as a secchi disk depth.

Samples for analysis of numerous nutrient and biological parameters were taken at each site on each lake. The samples in most cases were collected at one meter from the top, one meter from the bottom, at the midpoint during the spring turnover and in the center of the thermocline in August.

Samples were immediately iced and preserved as specified by the United States Environmental Protection Agency. All sample sets were returned to Anatech's facilities or mobile laboratory within 6 hours thereby insuring that labile analyses were initiated before decomposition or sample adulteration occurred. During the August survey, due to the long sampling days, intermediate runners were used to collect the samples during the midday.

In the field, quality control was carried out by duplicating all field measurements and samples for approximately ten percent of the sampling sites. The duplicate samples were analyzed in the lab and were subjected to the same lab quality control standards as the rest of the samples.

In the laboratory Anatech carried out a rigid quality control program including ten percent spike analyses, ten percent duplicate analyses and five percent of the samples were analyzed seven times each for a measurement of analytical precision. All procedures, including quality control were as specified by the United States Environmental Protection Agency.

This report contains sections which describe the location of lakes sampled, sampling procedures, analytical and quality control methodology. A preliminary discussion of the data and suggestions for future studies are presented in Chapter II.

The data collected during both surveys are available from Information Services of the Southeast Michigan Council of Governments and are partially summarized in this report. A detailed statistical analysis of the quality control data is included in Appendices A, B and C. Additional field and laboratory comments are presented in Appendix D.

This is the third paper in a series of four papers that address various aspects of inland lake water quality in Southeast Michigan. The other three papers are entitled: Inland Lake Management Concerns for Southeast Michigan; Water Quality of Southeast Michigan: Inland Lakes and Inland Lake Watershed Management: A Self-Help Approach.

These and other background papers that relate to water quality management can be obtained from the SEMCOG Information Services.

CHAPTER II: COMMENTS AND CONCLUSIONS

The data collected during both surveys present a wide variation in water quality characteristics. Lake Brighton, an example of a hypereutrophic situation, was consistently high in nitrogen and phosphorus as shown in Figures 1 through 6. The dominance of the reduced form of nitrogen, ammonia, is especially indicative of contamination by sewage. Point source pollution maintains this lake in high algal productivity as illustrated by Chlorophyll a in Figures 7 and 8 and results in considerable nuisance algal growth. Maceday, on the opposite end of the spectrum, was the nearest to an oligotrophic situation of all the lakes examined. It was low in nutrients and had oxygenated conditions throughout the water column (Figure 9). This lake is protected to a certain extent by the large volume and thus is able to absorb small nutrient inputs by dilution. A relatively high fecal coliform count encountered during the summer survey, however, suggests considerable septic and/or storm water drainage enter the system. This could override dilution effects in future years and cause premature eutrophication.

During the spring survey, the lakes were in a homogeneous state with respect to chemical and physical parameters. The absence of thermal stratification permits the wind to mix the water column and effectively recycle all the nitrogen and phosphorus accumulated over winter in the hypolimnion. In addition, the ground water table is highest during this period due to rain and melting snow, which increase run off inputs to the lakes. These factors, coupled with the correlation between spring nutrients and summer algal blooms, make the spring overturn a good period to approximate general water quality. Caution must be exercised in any judgments, however, as inputs from recreational activities and agricultural runoff are not present at this time.

The summer survey found most of the lakes to be devoid of oxygen below six to eight meters and no formation of a hypolimnion at sites less that ten meters deep, as shown in Figure 9. Clinograde dissolved oxygen profiles were exhibited in these lakes with a maximum in the epilimnion from wind mixing and algal photosynthesis and a minimum in the hypolimnion due to bacterial metabolism. Of interest are the effects of deep algal lenses found in lakes such as Lower Long. The presence of algal growth produces an abrupt increase in dissolved oxygen amidst an otherwise falling profile. Dissolved oxygen is essential for the survival of fish, but more important, however, is its relation to nutrient concentration. In the presence of oxygen and the ferric form of iron, phosphorus is insoluble in most lakes due to the formation of ferric phosphate. The anoxic, reducing environment of the hypolimnion, however, will solubilize phosphorus and stimulate microbial decomposition to reduced forms of nitrogen such as ammonia. High levels of nutrients accumulate under these conditions and may recycle back through the water column during overturn.

While point sources can be readily identified as the reasons for poor water quality in lakes such as Brighton, Inchwagh, and Ore, it is difficult to assess problem non-point sources for the remainder of the lakes. Examining the conservative ion, chloride, which was found to be high in a majority of the lakes, it is evident that street and septic tank runoff present a problem to almost every lake. Chloride was high during the spring due to winter road salting activities and its associated runoff during the spring thaw and rains. Summer samples revealed a drastic reduction in chloride in certain lakes indicating a flushing of the system. While the exact composition of runoff is unknown, other studies have shown it to be high in nutrients and, therefore, a cause of eutrophication. Land use studies which have been funded under this same grant will also be helpful in assessing non-point sources of pollution (see Figures 10 and 11).

Another trend present in the data was reduction in concentration of the non-conservative ions phosphorus, nitrate and ammonia occurring from spring to summer. Algal metabolism of these nutrients reduces their concentration in the water and may create a limiting situation for further growth. Thus, the addition of nutrients from point or non-point sources could override limiting circumstances and increase the eutrophication potential. The lakes previously reported as having point sources shall have this limiting situation continuously interrupted until more efficient non-polluting treatment facilities are developed. To evaluate lakes with non-point sources, as previously discussed, there is not enough data to precisely evaluate the effect of runoff versus septic systems. However, septic systems as close as 15 feet from lake shores were observed and new construction of such systems was observed in lakes such as West Lake in Washtenaw County.

Considering presence of well developed summer anoxic conditions and high levels of dissolved orthophosphorus during the spring (greater than 20 ppb), most of the lakes studied lie on the eutrophic end of the trophic spectrum. If most of these lakes are phosphorus and/or nitrogen limiting, water quality will probably not worsen, but improve with proper management measures. Water quality could ultimately deteriorate, however, if increased urbanization brings more runoff and/or drainage of low water quality into the system.

The initial data base created by this study is useful in assessing the trophic status of the lakes. There is, however, much information lacking on the internal dynamics of the lakes and source contribution, which are beyond the scope of this study. Further surveys need to be undertaken in these areas.

Sampling programs should include additional sites near shore and at influent drains to define potential areas of nutrient input. Previous studies by this organization have demonstrated unacceptable septic systems and hidden sanitary drains flowing directly into the study waters. Land use studies and field inspection will best define these problem areas.

Once problem areas are determined, control programs can be established. In addition, investigations as to the dynamics of the phosphorus cycle and nutrient limitation need to be considered. Visual observation of many anoxic samples reveals large quantities of ferrous iron which could precipitate much of the phosphorus as ferric phosphate during overturn. This would make the excess phosphorus present in the hypolimnion less available to algae. The analysis of soluble and colloidal iron would, therefore, provide information as to the significance of high levels of phosphorus in the hypolimnion and its potential to influence the lake toward eutrophic states.

TABLE 1

LAKES SAMPLED DURING THE WATER QUALITY PROGRAM. LAKES ARE SEPARATED BY COUNTY AND IDENTIFIED NUMERICALLY FOR REFERENCE ON FIGURES 1 THROUGH 3.

LIVINGSTON COUNTY TOTAL: 22 Lakes, 28 Sites

Lake #	Lake Name	Township	Range	Number of Sampling Sites
10	Bass	1 N	5 E	1
11	Bennett	4 N	5 E	1
12	Bishop	1 N	5 E	2
13	Brighton	2 N	5 E	1
14	Cedar	2 N	4 E	1
15	Chemung	2 N	5 E	2
16	Coon	2 N	4 E	1
17	Crooked (Big)	2 N	5 E	1
18	Crooked (Little)	2 N	5 E	2
19	Hoisington	4 N	5 E	1
20	Inchwagh	1 N	6 E	1
21	Island	1 N	6 E	1
22	Ore	1 N	5 E	1
23	Patterson	1 N	3 E	1
24	Portage	1 N	4 E	2
25	Rush	1 N	5 E	1
26	Silver (Green Oak)	1 N	6 E	1
27	Strawberry	1 N	5 E	1
28	Thompson	3 N	4 E	2
29	Winans	1 N	5 E	1
30	Woodland	2 N	6 E	2
31	Zukey	1 N	5 E	1

TABLE 1 (Continued)

OAKLAND COUNTY TOTAL: 38 Lakes, 57 Sites

Lake #	Lake Name	Township	Range	Number of Sampling Sites
32	Angelus	3 N	9 E	2
33	Bald Eagle	5 N	9 E	1
34	Big	4 N	8 E	1
35	Cass	2 N	9 E	2
36	Cedar Island	3 N	8 E	2
37	Commerce	2 N	8 E	2
38	Deer	4 N	9 E	1
39	Duck	3 N	7 E	2
40	Elizabeth	3 N	9 E	1
41	Green	2 N	9 E	1
42	Greens	4 N	9 E	1
43	Island	2 N	10 E	1
44	Lakeville	5 N	11 E	1
45	Long	2 N	8 E	2
46	Long (Lower)	2 N	10 E	1
47	Loon	3 N	9 E	2
48	Lotus	3 N	9 E	2
49	Louise	5 N	9 E	2
50	Maceday	3 N	9 E	1
51	Oakland	3 N	9 E	1
52	Orchard	2 N	9 E	2
53	Orion	4 N	10 E	2
54	Oxbow	3 N	8 E	2

TABLE 1 (Continued)

OAKLAND COUNTY (Continued)

Lake #	Lake Name	Township	Range	Number of Sampling Sites
55	Pine	2 N	9 E	2
56	Pontiac	3 N	8 E	2
57	Silver (Big)	3 N	9 E	1
58	Straits (Lower)	2 N	8 E	1
59	Straits (Middle)	2 N	8 E	1
60	Straits (Upper)	2 N	9 E	2
61	Tipsico	4 N	7 E	1
62	Union	2 N	8 E	1
63	Walled	1 N	8 E	1
64	Watkins	3 N	9 E	2
65	White	3 N	7 E	2
66	Williams	3 N	9 E	2
67	Wing	2 N	10 E	1
68	Wolverine	2 N	8 E	2
69	Woodhull	3 N	9 E	1