limnological conditions in the lake so any future effects can be judged against present conditions.

METHODS AND EXPLANATIONS

Our study involves physical, chemical and biological measurements and observations by professional aquatic biologists. We use specialized samplers and equipment designed to thoroughly examine all areas of an aquatic system. Shallow water, deep water, sediments, animal and plant life as well as inlet and outlet streams are intensively sampled and analyzed at several key stations. Our SCUBA divers assist in some data collection. Some analyses are completed in the field, while the balance are transported to our laboratory for complete examination and/or identification of organisms found in samples.

After the field study, we analyze, summarize and interpret the data. We utilize a comprehensive library of limnological studies, and review all the latest management practices in constructing the management plan. All our methods are standard limnological procedures and most chemical analyses are according to standard methods for the examination of water and wastewater.

Station Location: During any study we choose a number of places (stations) where we do our sampling for each of the desired parameters. We strive to have a station in any unusual or important place, such as inlet and outlet streams, as well as in representative areas in the lake proper. One of these areas is always the deepest part of the lake. Here we check on the degree of thermal and chemical stratification which is extremely important in characterizing the stage of eutrophication, invertebrates present and possible threat to fish. The number and location of these stations for this study are noted in the Results section.

Physical Parameters:

Depth: Depth is measured in several areas with a sonic depth finder or a marked sounding line.

Acreage: Acreage figures, when desired, are derived from maps, by triangulation and/or estimation. The percentage of lake surface area in shallow water (less than 10 feet) is an important factor. This Zone (known as the Littoral Zone) is where light can penetrate with enough intensity to support rooted aquatic plants. Natural lakes usually have Littoral Zones around their perimeters. Man-made lakes and some reservoirs often have extensive areas classed as Littoral.

Sediments: Bottom accumulations give good histories of the lake. The depth, degree of compaction and actual makeup of the sediments reveal much about the past. An Ekman dredge is used to sample bottom sediments for examination. Artificial lakes often fill in more rapidly than natural lakes because disruption of natural drainage systems occurs when these lakes are built. Sediments are either organic (remains of plants and animals produced in the lake or washed in) or inorganic (non-living materials from wave erosion or erosion and run-off from the watershed).

Light Penetration: The clarity of the water in a lake determines how far sunlight can penetrate. This in turn has a basic relationship to the production of living phytoplankton (minute plants) which are basic producers in the lake and the foundation of the food chain. We measure light penetration with a small circular black and white Secchi disc attached to a calibrated line. The depth at which this disc just disappears (amount of water transparency) will vary between lakes and in the same lake during different seasons, depending on degree of water clarity. This reference depth can be checked periodically and can reflect the presence of plankton blooms and turbidity caused by urban run-off, etc.

Temperature: This is a physical parameter but will be discussed in the chemistry section with dissolved oxygen, since a discussion of stratification is closely related to both the temperature and other chemical parameters, especially dissolved oxygen.

Stream Flows on Inlets and Outlets: Estimation of flows in and out of a lake give us information about ground water inputs and amount of water moving through the ecosystem. When tied to the chemical analyses described earlier, nutrient inputs and outputs can be calculated and amount of impact of these inputs evaluated.

CHEMICAL PARAMETERS

Water chemistry parameters are extremely useful measurements and can reveal a considerable amount about the type of lake and how the nutrients are fluxing through the system, they are important in classifying lakes and can give valuable information about the kind of organisms that can be expected to exist under a certain chemical regime. All chemical parameters are a measure of a certain ion or ion complex in water. The most important elements-carbon (C), hydrogen (H), and oxygen (O) are the basic units that comprise all life, so their importance is readily obvious. Other elements like phosphorus (P) and nitrogen (N) are extremely important because they are important links in proteins and RNA/DNA chains. Since the latter two (P & N) are very important plant nutrients, and since P has been shown to be critical and often times a limiting nutrient in some systems, great attention is given to these two variables. Other micro-nutrients such as boron, silicon, sulfur, etc. and vitamins can also be limiting under special circumstances. However, in most cases, phosphorus turns out to be the most important nutrient limnologists are concerned about.

Temperature Stratification: Temperature governs the rate of biological processes. A series of temperature measurements from the surface to the bottom in a lake (temperature profile) is very useful in detecting stratification patterns. Stratification in early summer develops because the warm sun heats the surface layers of a lake. This water becomes less dense, due to its heating and "floats" on the colder more dense waters below. Three layers of water are thus set up. The surface warm waters are called the epilimnion, the middle zone of rapid transition in temperatures is called the thermocline and the cold bottom waters, usually around 39° F., are termed the hypolimnion. As summer progresses the lowest cold layer of water (hypolimnion) becomes more and more isolated from the upper layers because they are colder and more dense than surface waters.

When cooler weather returns the warm upper waters (called epilimnion) cool to about 39° F. and because water this temperature is the most dense (heaviest), it begins to sink to the bottom. This causes the lake to "turnover" or mix and the temperature becomes a uniform 39° F. top to bottom.

Because water is most dense at 39° F., the deep portions of the lake "fill" with this "heavy water". Water colder than this (39° F.) is actually lighter and floats on the more dense water below, until freezing at 32° F. seals the lake. During the winter decomposition on the bottom can warm bottom temperatures slightly.

In the spring when the ice melts and warms from 32 to 39° F., seasonal winds will mix the lake again, thus completing the yearly cycle. This represents a typical cycle, and many variations can exist, depending on the lake shape, size, depth and location. Since summer stratification is usually the most critical period in the cycle because of the possibility the hypolimnion may go anoxic (no oxygen--discussed next), we always try to schedule our sampling during this period of the year. Another critical time exists during late winter as oxygen can be depleted from the entire water column in certain lakes under conditions of prolonged snow cover.

<u>Dissolved Oxygen:</u> This dissolved gas is one of the most significant chemical substances in natural waters. It regulates the activity of the living aquatic community and serves as an indicator of lake conditions. Dissolved oxygen is measured using the Winkler method with the azide modification. Fixed samples are titrated with PAO (phenel arsene oxide) and results are expressed in mg/l (ppm) of oxygen which can range normally from 0 to about 14 mg/l. Water samples for this and all other chemical determinations are collected using a device called a Kemmerer water sampler which can be lowered to any desired depth and tripped using a messenger on a calibrated line. The messenger causes the cylinder to seal and the desired water sample is then removed after the Kemmerer is brought to the surface. Most oxygen in water of course is the result of the photosynthetic activities of plants, the algae and aquatic macrophytes. Some enters water through diffusion from air. Animals use this oxygen while giving off carbon dioxide (CO_2) during respiration. The interrelationships between these two communities determine the amount of productivity that occurs and the degree of eutrophi-

cation (lake aging) that exists.

A series of oxygen determinations can tell us a great deal about a lake, especially in summer. In many lakes in this area, a summer stratification or stagnation period occurs. This layering causes an isolation of layers of water because of temperature--density relationships already discussed. In the spring turnover period dissolved oxygen values are at saturation values from top to bottom. However in these lakes by July or August some or all of the oxygen in the bottom layer is lost (used up by bacteria) to the decomposition process occuring in the bottom sediments. The richer the lake, the more sediment produced and the more oxygen used up. Since there is no way for oxygen to get down to these layers (there is not enough light for algae to photosynthesize there), the hypolimnion becomes devoid of oxygen in rich lakes. In non-fertile lakes (Oligotrophic) there is very little decomposition that occurs and therefore little or no oxygen depletion occurs. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living here and also changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic).

Stratification (layering process) does not occur in all lakes. Shallow lakes are often well mixed throughout the year because of wind action. Some lakes or reservoirs have large flow-throughs so stratification never gets established.

Stratified lakes will mix in the fall because of cooler weather and the oxygen content in the entire water column will be replenished. During winter the oxygen may again be depleted near the bottom by decomposition processes. As noted previously, winterkill of fish results when this condition occurs. Winter dissolved oxygen depletion is caused by early snows and a long period of ice cover when little sunlight can penetrate into the lake water. Thus no oxygen can be produced and if the lake is severely eutrophic, so much decomposition occurs, that all the dissolved oxygen in the lake is depleted.

In the spring, with the melting of ice, oxygen is again injected into the hypolimnion during this mixing or "turnover" period. Summer again repeats the process of stratification and bottom depletion of dissolved oxygen.

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 24 hour cycle. During a day in summer plants photosynthesize and produce oxygen while at night they join the animals in respiring (creating CO_2) and using up oxygen. This creates a diel cycle of high DO levels during the day and low levels at night. These DO sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH: The pH of most lakes in this area range from about 6 to 9. The pH value (measure of the acid or alakaline nature of water) is governed by the concentration of H^+ ions which are affected by the carbonate-bicarbonate buffer system, the dissociation of carbonic acid (H_2CO_3) into H^+ ions and bicarbonate. PH may vary during a daily cycle as actions of aquatic plants and algae utilize CO_2 from the carbonate-bicarbonate system. The pH will rise as a result. During the evening hours, the pH will drop due to respiratory demands. This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO_2 during the day in photosynthesis there is a drop in CO_2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO_2) thus causing a rise in CO_2 concentration and a concomitant decrease in pH toward a more acid condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution which would cause deviations from expected values. pH is measured in the field with color comparators and in the laboratory with a Beckman pH meter.

Alkalinity: The amount of acid (H^+ ion) that needs to be added to a water sample to get a sample to a pH of 4.5 (the endpoint of a methyl-orange indicator) is a measure of the buffering capacity of the water and can be quantitatively determined as ppm as $CaCO_3$. This measurement is termed total alkalinity and serves as an indicator of basic productivity and an estimate of the total carbon source available to plants. Alkalinity is a measure of hydroxides (OH^-), carbonates ($CO_3^=$) and bicarbonates present. Plants utilize carbon dioxide until that is exhausted and then begin to extract CO_2 from the carbonate-bicarbonate buffer system through chemical shifts. As discussed before, this decrease in CO_2 concentrations causes great pH increases during the day and a pH drop during the night. There are two kinds of alkalinity measured, both based on the indicators which are used to detect the end-point of the titration. The first is called phenolphthalein alkalinity (phth) and is that amount of alkalinity obtained when the sample is titrated to a pH of 8.3. This measurement is often 0, but can be found during the conditions previously discussed, that is during summer days and intense photosynthesis. Total alkalinity was noted above and includes phth alkalinity.

Hardness: Like alkalinity, hardness is also a measure of an ion, though these are divalent cations, positive double charged ions like Calcium (Ca^{++}) and Magnesium (Mg^{++}). Again, the units of hardness are mg/l as $CaCO_3$. A sample of water is buffered and then an indicator added. Titration to the indicator endpoint with EDTA completes the analysis. As with all our analyses, for more detail consult Standard Methods. Alkalinity and hardness are complementary, so that comparing the two readings can give information about what ions are present in the system and confirm trends seen in other data. This is true because every Calcium ion must have a bicarbonate ion or other such divalent negative ion and vice versa, each carbonate or hydroxide must have a divalent or monovalent anion associated with it. For example, we might find high chlorides from street run-off in a particular sample. Since chlorides are probably applied as $CaCl_2$, we would confirm our suspicions when hardness (a measure of Ca^{++} ions) was considerably higher than alkalinity. If alkalinity were higher than hardness it would indicate that some positive anion like Potassium (K^{+}) was present in the lake, associated with the bicarbonate and carbonate ions and not measured by hardness. Generally speaking, high alkalinity and hardness values are associated with a greater degree of eutrophication and lakes are classified as soft, medium or hard-water lakes based on these values.

Chlorides: This analysis is important because chlorides (Cl) are transported into lakes from septic tank effluents and urban run-off. Chlorides are detected by titration using mercuric nitrate and an indicator. Results are expressed as mg/l chlorides. The effluent from septic tanks is high in chlorides. Dwellings around a lake having septic tanks contribute to the chloride content of the lake. Depending upon flow-through, chlorides may accumulate in concentrations considerably higher than natural ground water. Likewise, urban run-off can transport chlorides from road salting operations, and also bring in nutrients. The chloride "tag" is a simple way to detect possible nutrient additions and septic tank contamination. Ground water in this area averages 10-20 mg/l. Values above this are indicative of possible pollution.

Phosphorus: This element, as noted, is an important plant nutrient which in most aquatic situations is the limiting factor in plant growth. Thus if this nutrient can be controlled, many of the undesirable side effects of eutrophication (dense macrophyte growth and algae blooms) can be avoided. The addition of small amounts of P can trigger these massive growths. Usually the other necessary elements (carbon, nitrogen, light, trace elements, etc.) are present in quantities sufficient to allow these excessive growths. Phosphorus thus is limiting (occasionally carbon or nitrogen may be limiting). Two forms of phosphorus are usually measured. Total P is the total amount of P in the sample expressed as ppm as P, and soluble P or Ortho P is that phosphorus which is dissolved in the sample and supposedly "available" to plants for uptake and growth. Both are valuable parameters useful in judging eutrophication problems.

Nitrogen: There are various forms of the plant nutrient nitrogen, which are measured in the laboratory, using complicated methods. The most reduced form of Nitrogen, ammonia (NH_3) is usually formed in the absence of dissolved oxygen and from the breakdown of proteins. Thus high concentrations are sometimes found on or near the bottom under stratified anoxic conditions. Ammonia is reported as mg/l as N and is toxic in high concentrations to fish and other sensitive invertebrates. With turnover in the spring most ammonia is converted to nitrates (NO_3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO_2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. It, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about sucession of algae species, the last of which, blue-green algae (an undesirable species), can fix their own nitrogen (some members) and thus out-compete more desirable forms.

BIOLOGICAL PARAMETERS

Bacteria - This group of organisms is extremely important in the biology of lakes in that they are responsible for all the decomposition that occurs in a lake as well as many chemical transformations, such as the manufacture of Hydrogen sulfide by sulfur bacteria, denitrifying bacteria which transform nitrate to ammonia, etc. Another important group is the coliform bacteria which when present can indicate that sewage has somehow entered the body of water. The methods used (Standard Methods) indicate the degree of contamination of the water with wastes from human or animal sources. Since this is a public health aspect, we do not intrepret nor routinely run coliform, unless there is a special reason to do so.

Algae - The algae are a heterogeneous group of plants which possess chlorophyll by which photosynthesis, the production of organic matter and oxygen using sunlight and carbon dioxide, occurs. They are the fundamental part of the food chain leading to fish in most aquatic environments. There are a number of different phyla, including the undesirable blue-green algae, which contain many of the forms which cause serious problems in highly eutrophic lakes. These algae can fix their own nitrogen (a few forms cannot) and they usually have gas-filled vaculoes which allows them to float on the surface of the water. There is usually a seasonal succession of species which occurs depending on the dominant members of the algal population and the environmental changes which occur. The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicelled organisms, which are responsible many times for the green or brownish color of water they are blooming in. The filamentous forms, such as Spirogyra and Cladophora are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type,, Chara, a green alga, looks like an aquatic macrophyte and grows on the bottom in the littoral zone, sometimes in massive beds. Understanding the different forms and how they interact (since plants and algae compete for the nutrients present and can shade one another out depending on which was the competitive advantage) is important in controlling them and formulating sensible management plans. Samples are collected using a No. 20 plankton net, preserved with 10% formalin and examined microscopically in the laboratory.

Macrophytes - The aquatic plants which are common in most aquatic environments are the other type of primary producer in the aquatic ecosystem. They only grow in the euphotic zone, which is usually the inshore littoral zone up to 6 ft, but in some lakes with good water clarity and with the introduced eurasian water-milfoil (Myriophyllum spicatum), growths have been observed in much deeper water. Plants are very important as habitat for insects, zooplankton and fish, as well as their ability to produce oxygen. Plants have a seasonal growth pattern wherein overwintering roots or seeds germinate in the spring. Most growth occurs during early summer. Again plants respond to high levels of nutrients by growing in huge beds. They can extract required nutrients both from the water and the sediment. Again phosphorus is a critical nutrient for them. The aquatic plants and algae are closely related, so that any control of one, must be examined in light of what the other forms will do in response to the freed nutrients and lack of competition. For example killing all macrophytes may then result in massive algae blooms which are even more difficult to control.

Zooplankton - This group of organisms is common in most bodies of water, particularily lakes and ponds. They are very small creatures, usually less than 1/8 inch long, and usually live in the water column where they eat detritus and algae. Some are predaceous on other forms. This group is seldom seen in ponds or lakes by the casual observer of wildlife but are very important links in the food web leading from the algae to fish. They are usually partially transparent organisms which have limited ability to move against a lakes currents and wave action, but are sometimes considered part of the "plankton" because they have such little control over their movements, being dependent on wind-induced or other currents for transport. They are important indicators for biologists for three reasons. First the kind and number present can be used to predict what type of lake they live in as well as information about the stage of eutrophy it is in. Second, they are very important food sources for fish, and third they can be used to detect the effects of pollution or chemical insult, if certain forms expected to be present are not. These data can be added to other such data on a lake and the total picture can then easily lead to the correct conclusions about what has occurred in a body of water.

Zooplankton are collected by towing a no. 10 plankton net through the water and the resulting sample is preserved with 10% formalin then examined microscopically in the lab. Qualitative estimates of abundance are usually given.

Benthos - The group of organisms which is in the bottom sediments or associated with the bottom are termed benthos. These organisms are invertebrates (lacking a backbone) and are composed of such animals as aquatic insect larvae and adults, amphipods (fairy shrimp), oligochaetes (aquatic worms), snails and clams. Again the importance of this group for fish food and as intermediates in the food chain should be realized. Because of the tremendous variety of animals in each group and their respective tolerances for different environmental conditions, this group is a very important indicator of environmental quality. We particularily examine samples from deep water stations for the presence of organisms, as certain types live in low to no dissolved oxygen levels; whereas other kinds can only exist when their high dissolved oxygen needs are satisified. These organisms are collected using a special sampler called an Ekman dredge or Ekman grab sampler. It is lowered to the bottom in the open position, a messenger sent down the line and tripped. This results in about a 1 square foot sample of bottom being sampled. The sample is washed through a series of screens to remove the fine mud and detritus, leaving only the larger organisms and plant material behind. The sample is then picked in the field or lab and the organisms found identified.

Fish - Thetop carnivores in most aquatic ecosystems, excluding man, are the fish. They are integrators of a vast number and variety of ever-changing conditions in a body of water. They, unlike the zooplankton and benthos which can reflect short-term changes, are indigative of the long-range, cumulative influences of the lake or stream on their behavior and growth. Again the kind of fish, salmon or sunfish, can tell us alot about the type of lake, whether oligotrophic or eutrophic, that we are working with. We collect fish with seines, gillnets and from lucky fishermen on the lake. Most fish are weighed, measured, sexed, their stomach contents are removed and identified, they are aged and breeding condition is observed and recorded. The catches from our nets and age information on the fish will tell us how your fish compare with state averages and whether or not fish growth is good. Another problem, "stunting", can be detected using these sources of information. Stomach contents of fish also tell us whether or not good sources of food are present and help confirm age and growth data conclusions. Inbalances in predator-prey relationships are a closely related problem which we can usually ascertain by examining the data and thru talk with local fishermen. From studying the water chemistry data and supportive biological data, we can make recommendations, such as habitat improvement, stocking of more predators, chemical renovation and predict for example the effects of destroying macrophytes through chemical control. All elements of the ecosystem are intimately interrelated and must be examined to predict or solve problems.

RESULTS

Introduction

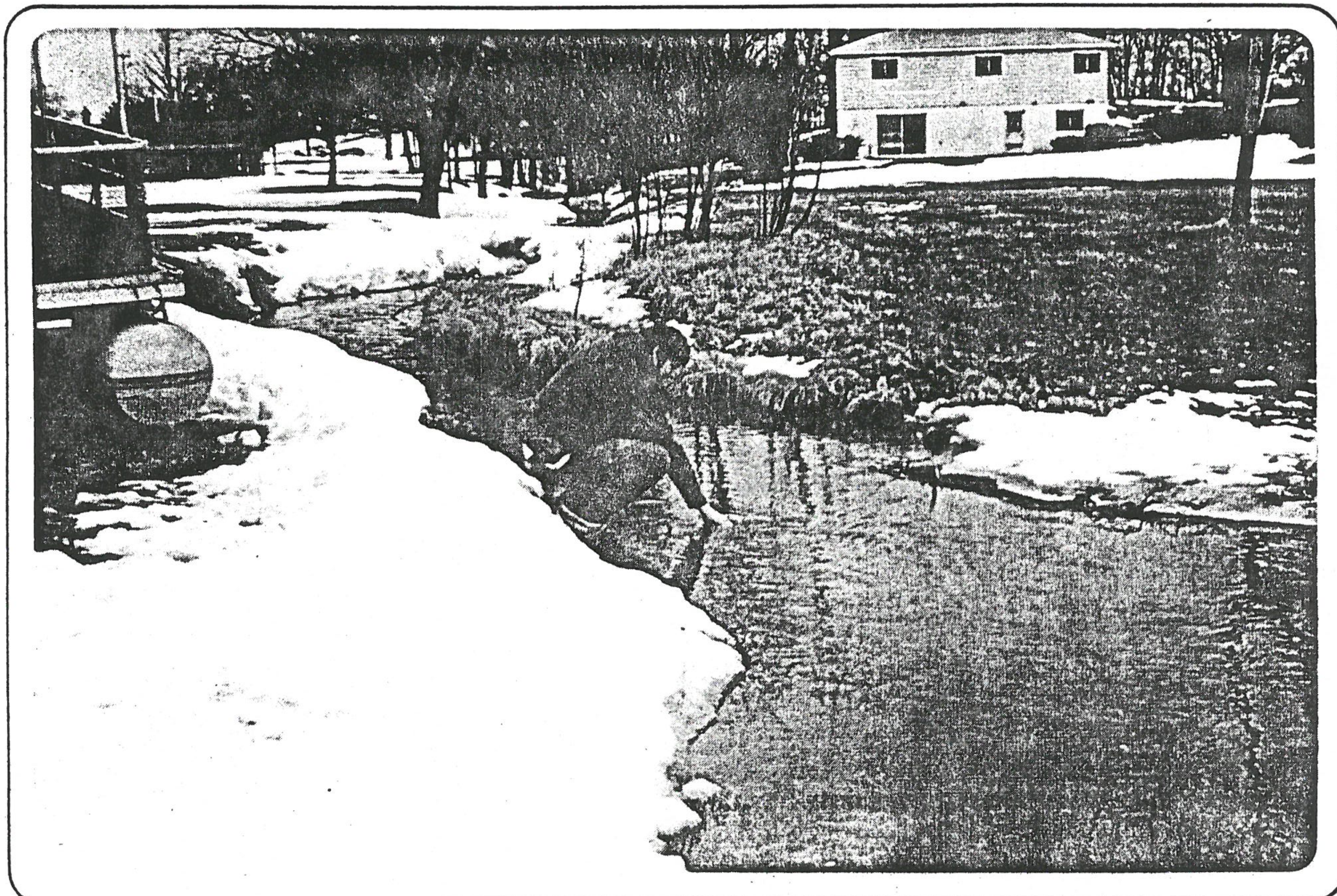
Runyan Lake, a 200-acre lake located in Livingston County near Fenton, Michigan was investigated during the winter and summer of 1979. Samples of the water, sediments, benthos, zooplankton, plants and fish were examined. Inputs of nutrients into the lake from incoming streams were evaluated. Our initital winter sampling was conducted on 3 March 1979 through the ice. Folbwup and more extensive sampling was performed on 11 August.

Watershed Description

The local watershed of Runyan Lake is mostly cottages, wooded areas, some swamps and other wetlands and a few farms (Fig. 1). A number of creeks enter Runyan Lake, the most prominent being Denton Creek on the NNE. Water flows out of Runyan Lake through the outfall into Stearns Lake then into Housington Lake from whence it enters the Shiawassee River (Fig. 2). From the Shiawassee River, water then flows into the Saginaw River and thence into Saginaw Bay, Lake Huron. This puts Runyan Lake in Planning Subarea 3.2 according to Great Lakes Basin Commission Framework studies.

Station Location

To adequately sample the chemical, physical and biological components of Runyan Lake we established 12 stations in the lake and adjacent creeks. We found six creeks entering the



Picture 2. Water sample collection at station B, 3 March 1979.

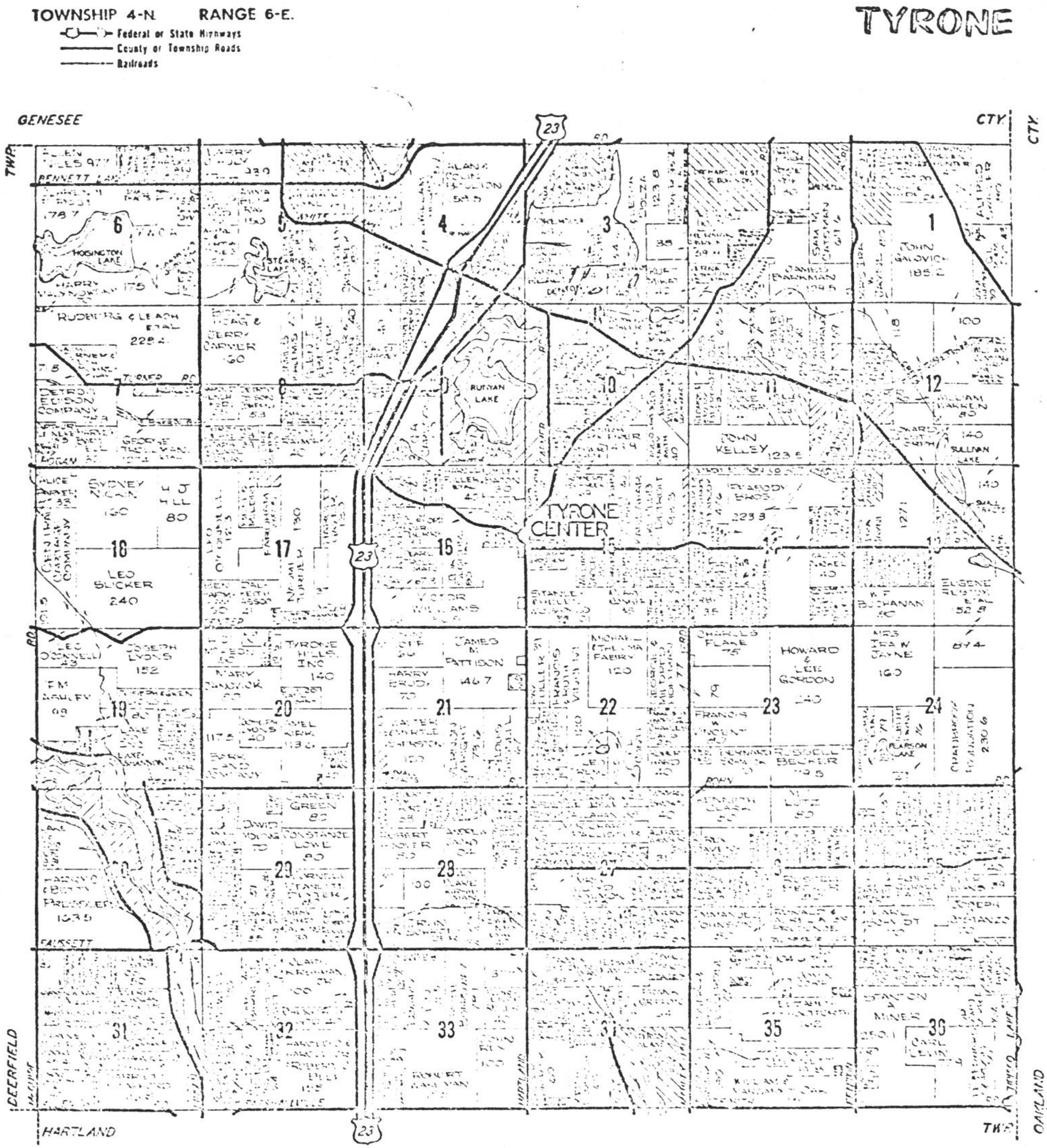


Figure 1. Map of Runyan Lake showing location in the county and general character of the surrounding watershed.

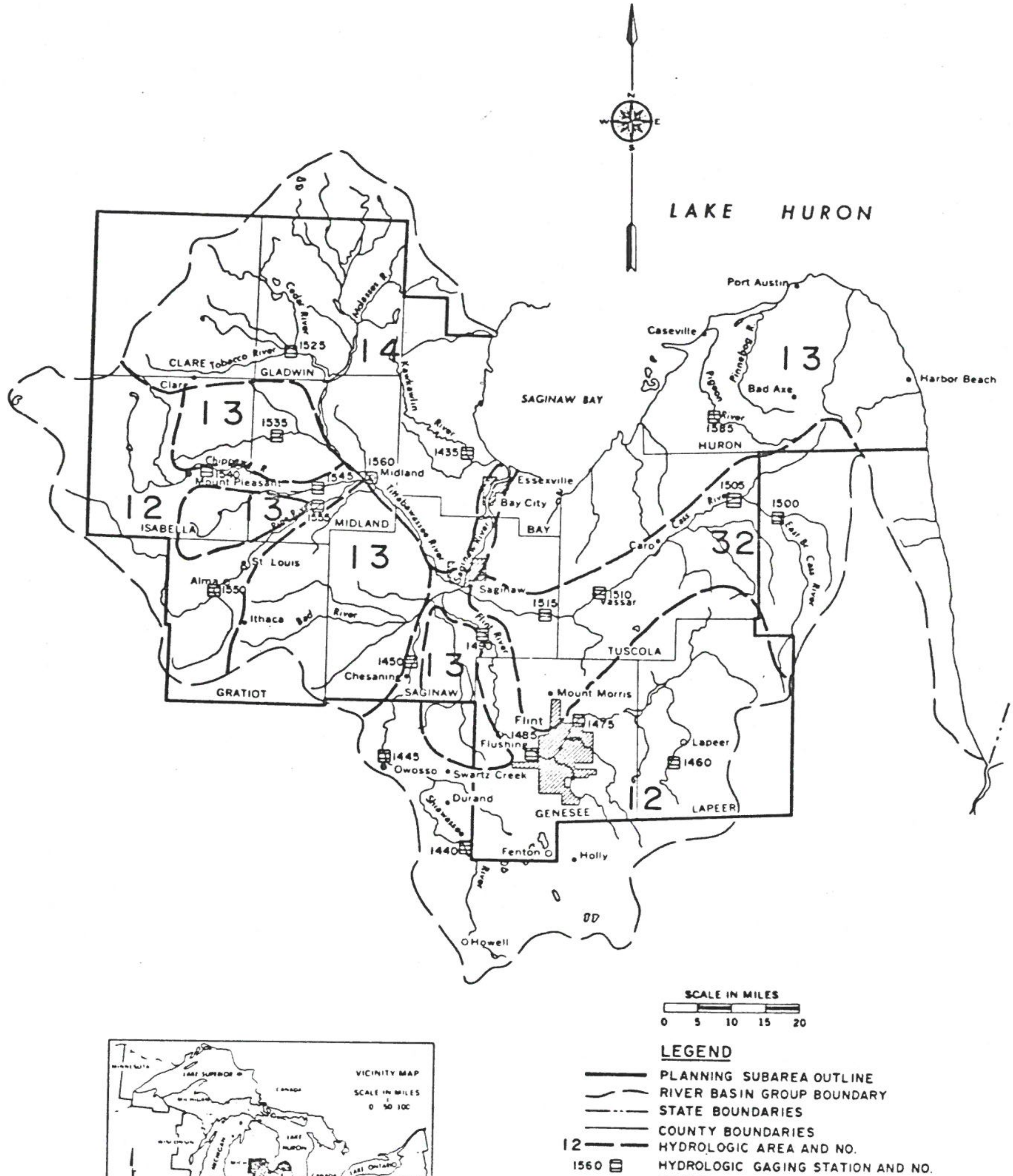


FIGURE 2–8 Hydrologic Gaging Stations, Planning Subarea 3.2

Figure 2. Watershed map showing the location of Runyan Lake and its drainage system. Map taken from Great Lakes Commission Framework Study.

lake (stations D, C, G, F, E and B--see Fig. 1 and Table 1) and collected water samples from them in winter (3 March) and summer (11 August). An additional six stations were established in the lake in the three deep basins (stations A, M and K), in a shallow weedy embayment (station L) on the SSW side of the lake, and two were set up as gill net stations (stations J and H). A large number of stations were utilized to sample the diverse habitats present and because of the large number of lots located on Runyan Lake (Fig. 4). A former study (see Appendix 7) conducted in 1970 measured a number of chemical parameters and bacterial counts. Stations for that study are depicted as large numerals (1 to 10) on the map in Figure 3.

Physical Parameters

Secchi disc. Secchi disc readings in Runyan Lake during 11 August varied from 6 to 8 ft (Table 2). These values were expected to be considerably higher, and since they were not, it indicates that there was a concentration of algae at or below 8 ft, which caused the low secchi disc readings. Evidence for this is the increased dissolved oxygen concentrations observed at about 15 ft at many of the deep basin stations (Table 1). The increased dissolved oxygen peak was undoubtedly caused by the concentration of algae at that depth. Secchi disc data suggest that Runyan Lake is a mesotrophic lake, in between the pristine oligotrophic state and the highly fertilized eutrophic state.

Table 1. List of stations, location and depths where water and biological samples were collected on Runyan Lake during 1979. See Figure 1 for exact station location.

STATION	DESCRIPTION AND LOCATION
Station D	Creek SSW of lake crossing Robin Drive and enters a small, weedy embayment at the SSW end of the lake.
Station C	Creek on W side of the lake, crossing Walnut Rd.
Station G	Denton Creek, located on NE upper tip of lake; crosses Carmar Rd.
Station F	Creek on E side of lake; in mid-lake crosses Carmar Rd.
Station E	Creek on the S end of the lake off Meryl Rd.
Station A	Located in the northern end of the lake in about 55 ft of water.
Station B	Creek located between the outfall and station G (Denton Creek) on the north end of the lake.
Station J	Located in frontof Al Luchenbills (10950 Runyan Lake Rd) on the NW tip of the lake. Also used for gill nets; 27 ft. deep.
Station M	Deepwater station (40 Ft.) located in mid-lake narrows.
Station L	Located in the weedy embayment at the SSW side of the lake. Depth about 7 ft maximum.
Station H	Gill net station in about 10-20 ft of water. Located on the E side of the southern half of the lake.
Station K	Deep basin (55 ft) in the middle of the southern end of the lake.

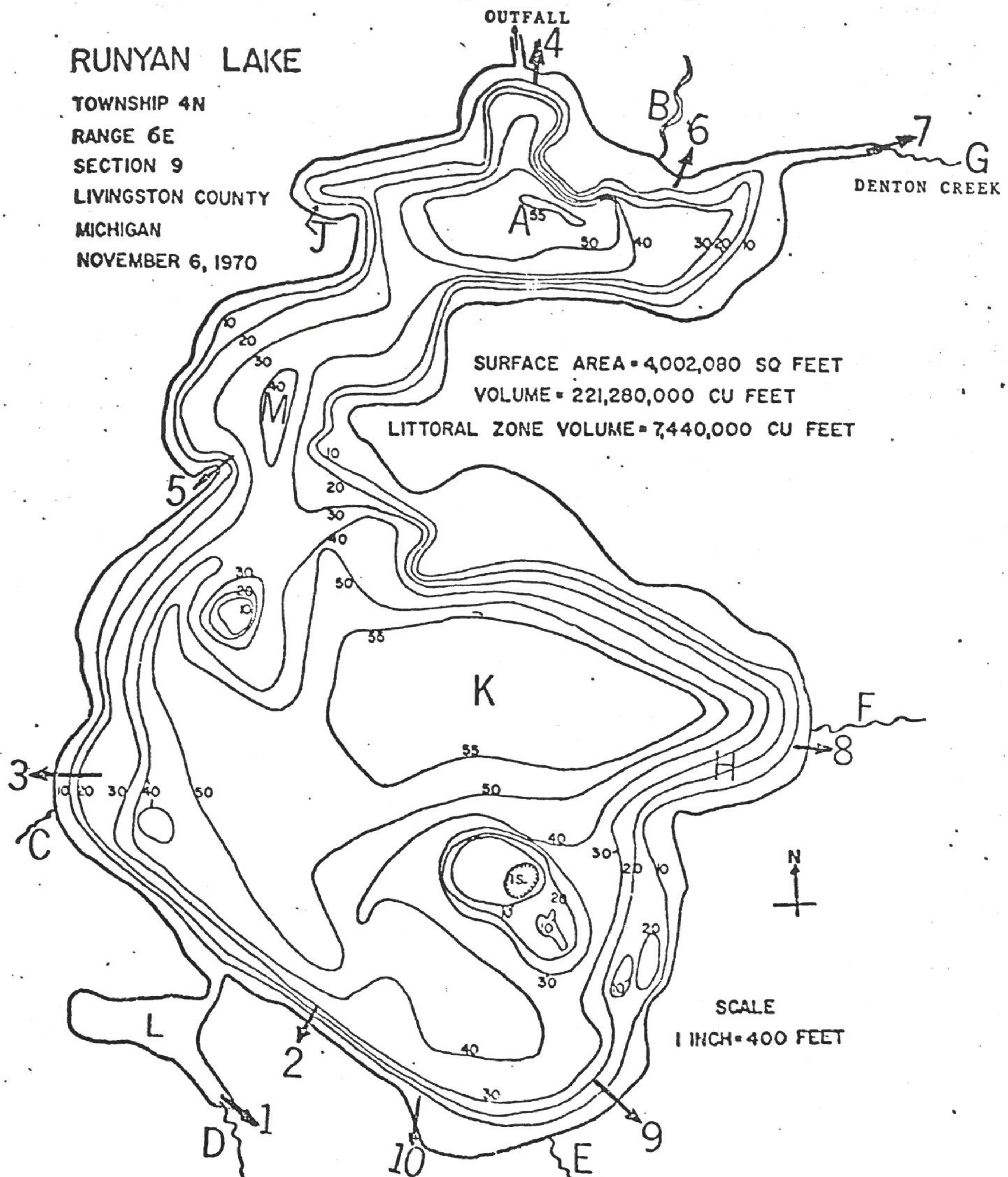


Figure 3. Map of Runyan Lake (T4N R6E S9), Livingston County, near Fenton, Michigan showing stream inlets, the outlet, sampling stations for a former survey (large numerals) and our sampling stations (large letters) during 1977. See Table 1 for a detailed description of each station sampled.

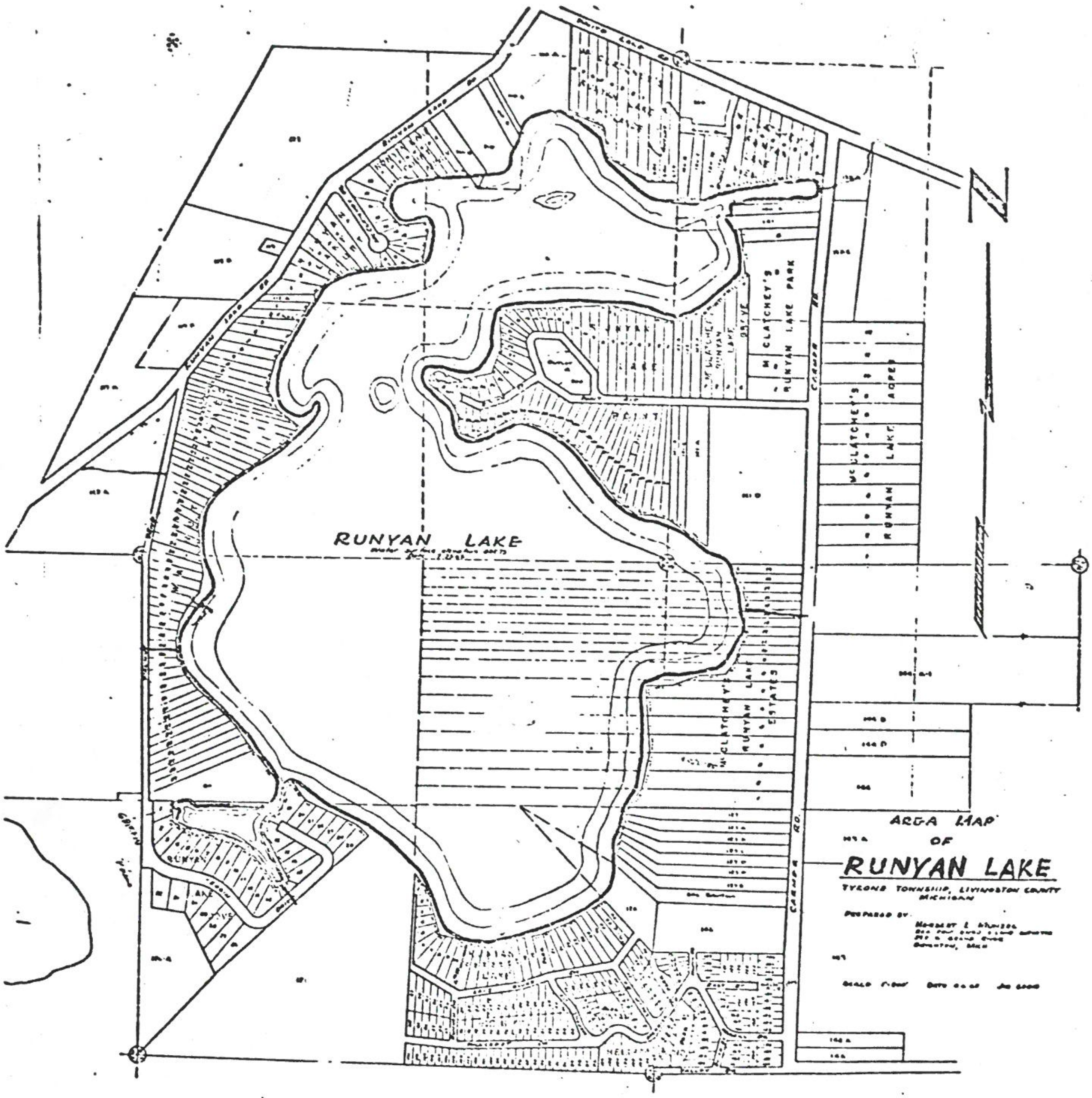


Figure 4. Map of Runyan Lake showing location of lots surrounding the shoreline and adjacent land.

Table 2. Some physical and limnological parameters measured on 3 March and 11 August, 1979 at various stations, outfalls and creeks on and near Runyan Lake, Livingston County, Michigan. mg/l = milligrams per liter or parts per million (ppm); P = phosphorus; NO_3-N = nitrate as mg/l nitrogen; NH_3-N = ammonia as mg/l nitrogen; C = Centigrade; under alkalinity and hardness, units are mg/l as calcium carbonate; total and soluble phosphorus are expressed as mg/l phosphorus. See Fig. 1 for station location.

STATION	Secchi disc (ft.)	Water temp. (C)	Dissolved oxygen (mg/l)	pH	Total alkalinity (mg/l)	Hardness (mg/l)	Chlorides (mg/l)	Silica (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Total Kjeldahl (mg/l)	Soluble Phosphorus (mg/l)	Total Phosphorus (mg/l)	Hydrogen Sulfide (mg/l)
3 March 1979														
A - surface		2.6	12.7		-	-	-		-	-	-	-	-	-
A - 10 ft		4.1	13.5		107	148	16		.04	.05	3.15	.03	.42	
A - 20 ft		4.1	12.8		114	167	28		.02	.02	.18	.01	.01	
A - 30 ft		4.1	11.0		109	159	25		.04	.03	.39	.01	.04	
A - 40 ft		4.1	9.5		143	200	30		.05	.03	.46	.01	.039	
A - 50 ft		4.1	7.7		120	158	16		.05	.02	.44	.01	.072	
C - creek W side					117	151	22		.01	.06	.37	.01	.19	
D - creek SSW side					140	166	7		.28	.26	.95	.02	.14	
F - creek E side					118	154	7		.05	.24	.45	.06	.32	
G - Denton Creek					112	156	35		.02	.17	.85	.03	.20	
Beebe's well sample		9.6			150	178	4		.01	.01	3.15	.01	.15	
11 August 1979														
A - surface	8	22.0	8.9	8.3	110	149	17		.01	.01	.31	.01	.02	
A - 17 ft	-	13.0	12.1	8.0	156	192	15		.02	.01	.46	.01	.10	
A - 33 ft	-	11.2	1.5	7.3	158	197	15		.01	.10	.65	.01	.45	
A - 50 ft	-	11.2	0	7.3	143	170	16		.55	.01	1.22	.01	.065	1.5

Table 2. Continued

STATION	Secchi disc (ft.)	Water temp. (C)	Dissolved oxygen (mg/1)	pH	Total alkalinity (mg/1)	Hardness (mg/1)	Chlorides (mg/1)	Silica (mg/1)	Ammonia (mg/1)	Nitrate (mg/1)	Total Kjeldahl (mg/1)	Soluble Phosphorus (mg/1)	Total Phosphorus (mg/1)	Hydrogen Sulfide (mg/1)
B - creek N side					131	155	16		.01	.01	.70	.02	.66	
C - creek W side					150	190	32		.51	.01	.45	.01	.38	
D - creek SSW side					207	217	6		.01	.01	.45	.01	.05	
E - creek S side					141	179	12		.01	.07	.25	.01	.075	
F - creek E side					115	152	12		.01	.02	.45	.02	.08	
G - Denton Creek					194	208	27		.01	.01	.70	.02	.025	
J - surface	8	22	8.7	8.2	141	177	16		.01	.01	.45	.01	.026	
J - 27 ft	-	14	10.8	8.0	149	183	16		.03	.01	.67	.02	.24	
K - surface	6	22	9.0	8.2										
K - 17 ft		20	12.2	8.2	97	134	16		.01	.01	.40	.01	.12	
K - 33 ft		9	3.6	7.5	122	144	15		.01	.03	.43	.01	.05	
K - 50 ft		7	0	7.3	166	195	16		.24	.01	.81	.02	.004	1
L - surface	7	22	9.5		174	197	11		.01	.01	.46	.01	.88	
M - 0 ft	7	22	7.6	8.3	-	-	-		-	-	-	-	-	
M - 13 ft	-	20	8.6	8.2	98	134	16		.01	.01	.45	.01	.025	
M - 27 ft	-	12.5	10.1	8.0	98	130	13		.01	.01	.45	.01	.12	
M - 40 ft	-	12	0	7.3	159	191	16		.49	.01	1.31	.02	.072	2
Outlet					84	124	16		.01	.01	.43	.01	.08	

Water depth. Examination of the countours of Runyan Lake (Fig. 3) shows three deep basins exist in the lake varying from 40 ft at station M to 55 ft at stations K and A. The general character of the lake is greatly affected by basin shape and contour. Because the lake is so deep, it is better able to assimilate nutrients which enter the basin. In addition, the deep character of the lake also dictates the amount of littoral zone (shallow weedy part of the lake) that the lake will have, which is the usual "trouble" area in eutrophic lakes. Since Runyan Lake has a very narrow and small littoral zone, there are no serious problems with abundant aquatic macrophyte growth in the lake, which is a positive characteristic for maintaining Runyan Lake in its present esthetic state. Unfortunately, the "productivity" of the lake (biomass of organisms and plants produced per unit time) is also related to the overall nutrient state and the amount of littoral zone in the lake. Since Runyan Lake is marginally nutrient-poor, and has low production, the fish, the final step in the food chain, also reflect this. Thus, one must realize that the desirable aspects of low nutrient content and productivity--clear lake and few aquatic plants--have some other associated aspects, few fish, which should be expected as a result of the trophic status of the lake. The shallow, weedy embayment at the SSW end of the lake (station L) is a good example of what the main part of Runyan Lake could become with additional nutrient input. That area (station L) also contains a greater number and density of fish on a unit area basis than does the main part of the lake.

Sediments. The sediment buildup and composition in Runyan Lake's deep basins (stations M, J, K and A--Table 3) were similar--finely divided detritus (leaves, twigs, plants) and black organic muck. This accumulation has resulted in a typical bottom material which because of the anoxic conditions (devoid of dissolved oxygen) on the bottom which occurs during summer stagnation, creates habitat only inhabitable by a few benthic organisms--chironomids and oligochaetes. These sediments, where decomposition by bacteria takes place, have built up sufficiently to cause dissolved oxygen depletions and toxic hydrogen sulfide concentrations near bottom during the summer.

The shallow weedy embayment at the SSW side of the lake (see Fig. 3), has a creek entering it and is protected from the main part of the lake. Because of a combination of factors--creek entry, shallowness of the area, possible septic tank and other nutrient entry from adjacent residents--this area has become weed-choked. In an effort to keep this area passable for navigation, chemical control of the plants has been practiced. This accelerates the sediment deposition problem and we have seen sediments there up to 4 ft thick. Most of this sediment is composed of decomposed aquatic plants which have accumulated over the years.

Chemical Parameters

Water temperature. Water temperature data (Table 2, Fig. 5) were of interest in that they established that during the winter the deep basin (station A) was as expected almost

Table 3. Abundance (no./square foot) of benthic organisms found at selected stations in Runyan Lake, Livingston County, Michigan 11 August 1979. Also given is the occurrence of aquatic macrophytes and sediment composition at each station.

STATION	BENTHIC TAXA FOUND	AQUATIC PLANTS FOUND	COMPOSITION OF SEDIMENTS
A - 55 ft	1 Oligochaeta (aquatic worms)	None	Finely divided, very black organic matter, few leaves and fine detritus
K - 55 ft	3 Chironomidae (midges) 3 <u>Chaoborus</u> (phantom midges)	None - near shore are bullrushes and <u>Potamogeton amplifolius</u>	Finely divided black muck, detritus
J - 27 ft	162 Chironomidae 58 Oligochaeta 2 Pelecypoda (fingenail clams) 2 Gastropoda (snails)	None - onshore are <u>Potamogeton amplifolius</u> <u>Chara</u>, lily pads, bull-rushes, <u>Elodea</u>, <u>Najas</u>, Sago Pondweed, <u>P. foliosus</u>	Black organic muck, fine leaves, twigs, detritus
L - 7 ft (weedy embay-ment)	2 Chironomidae 2 Trichoptera 5 Hirudinea (leeches) 10 Gastropoda 5 Hydracarnia (water mites) 3 Copepoda (zooplankton) 7 Ostracoda 57 Oligochaeta 68 Amphipoda (fairy shrimp) <u>Hyalella azteca</u>	Sago Pondweed, lilies, <u>Chara</u>, bladderwort, Coontail (<u>Cerato-phylum</u>), <u>Elodea</u>, algae, <u>Potamogeton crispus</u>	Thick sediments, much vegetation and detritus
M - 40 ft	13 Chironomidae 1 <u>Chaoborus</u>	None	Finely divided detritus, black organic muck

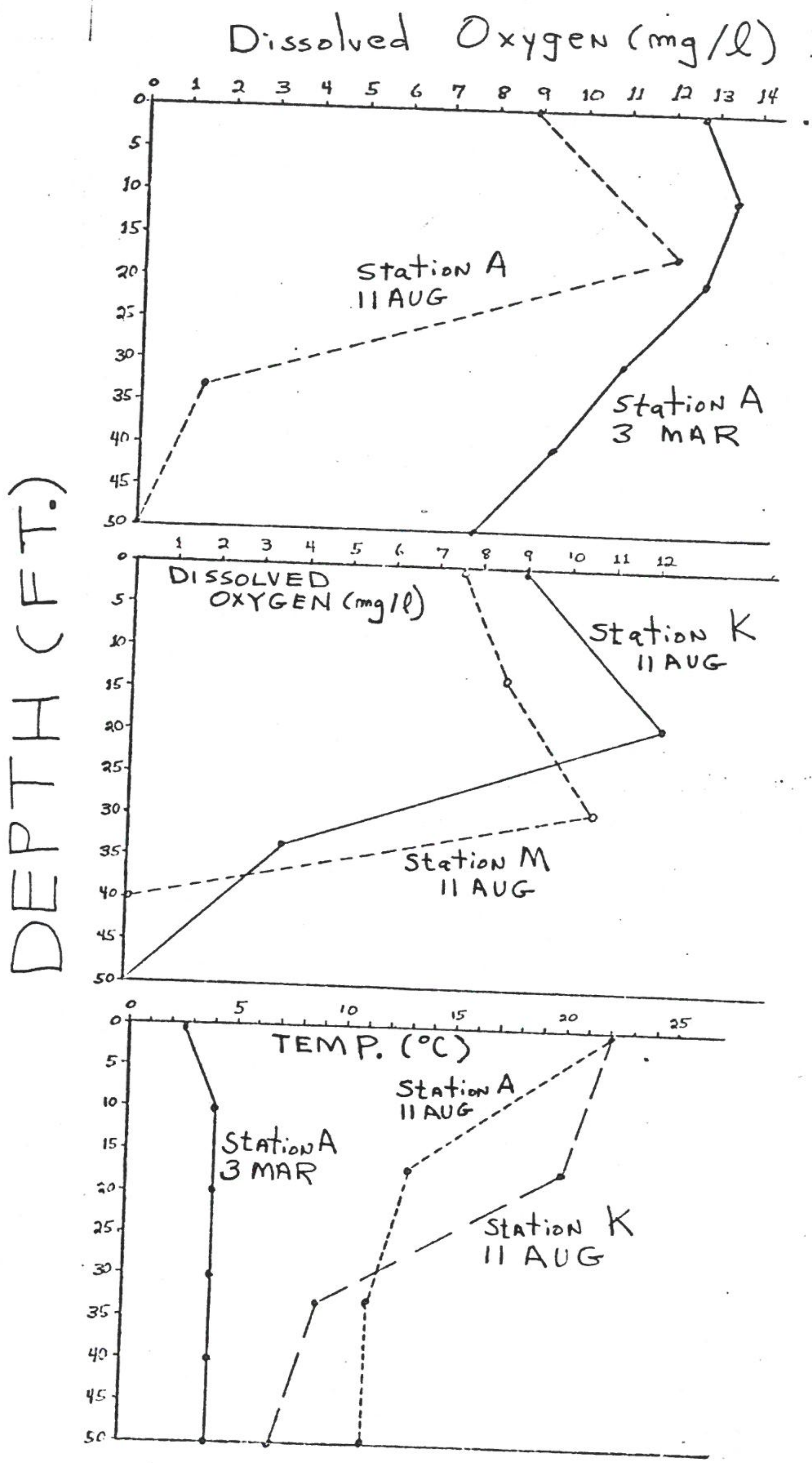


Figure 5. Graphical presentation of water temperature (C) and dissolved oxygen (mg/l) profiles for Runyan Lake deepwater stations A, K and M on 3 March and 11 August 1979.

Picture 3. Winter sampling on Runyan Lake at station A, 3 March 1979.

isothermal at about 4.1 C. Dissolved oxygen levels were also high even on the bottom. In the summer stratification was well established at all deep basin stations. Water was warmest at the surface (epilimnion), being 22 C. The thermocline, depth strata of fastest change in temperature, was around 15-20 ft. Temperatures on the bottom of Runyan Lake ranged from 7 to 14 C, very cool. The shallow embayment as expected was very warm, 22 C, another reason for the higher productivity there.

Dissolved Oxygen. The amount of dissolved oxygen in the various water strata of a lake is very important to the final community that can exist there. No fish can live in an environment totally devoid of oxygen. Fish can only make occasional migrations into such an area. However other organisms, particularly benthos, can live in these areas, although communities that do inhabit such an area are not as rich as one which contains high concentrations of oxygen.

The winter dissolved oxygen profile of Runyan Lake was taken only at station A (55 ft) (Table 2, Fig. 5). The profile showed high levels of dissolved oxygen at all strata, although concentrations were reduced from saturation levels at bottom strata. These high concentrations of dissolved oxygen on the bottom in late winter are unusual and unexpected. First, it allows fish access to the entire water column of the lake. They can feed on many organisms on the bottom not normally accessible to fish. Second, such a profile shows the lake has not built up a large amount of muck and detritus on the bottom, which usually depletes the oxygen on the bottom through decompositional processes. Such a profile (oxygen at all depths) characterizes Runyan Lake as an oligotrophic lake (one with clear water, deep, low in nutrients). However, the summer dissolved oxygen profile (depleted oxygen on the bottom), modestly high nutrient levels in the lake, reduced secchi disc readings and occasional blooms of algae, suggest that the winter profile observed was due to other than normal limnological processes. Additional work in winter 1980 should establish if this commonly occurs in the lake or was an anomalous occurrence either in 1979 or just at station A.

An interesting feature of the summer dissolved oxygen profile (Fig. 5) was peak levels of oxygen below the surface at about 20-30 ft, corresponding with the thermocline. This is somewhat unexpected, as the surface waters usually contain, because of the presence of algae and high light conditions, peak amounts of dissolved oxygen. However, we feel that there is probably a concentration of algae at the lower depths (20 ft strata), which were responsible for the high concentrations of dissolved oxygen observed. Intense light in surface waters can inhibit algal production, particularly in clear waters. We found very few algae in our surface samples and will examine samples from lower depths in 1980 to confirm this hypothesis.

pH. The acid-alkaline nature of water in Runyan Lake was as expected, around 8.3 at the surface, indicating that plant activity, through removal of carbon dioxide, had increased