pH to the alkaline side (Table 2). Another concurrent finding was the lower pH (around 7.3) observed near bottom. This is caused by the bacterial decomposition of bottom detritus which releases carbon dioxide and lowers pH. No values were recorded which would indicate the lake was receiving any toxic pollutants or had any abnormal stratification patterns.

Alkalinity. Alkalinity is a measure of the productive status of the lake, since the ions it is a measure of (carbonates, bicarbonates and hydroxides) are the main carbon source for plants. Data collected in winter (Table 2) showed alkalinity varied from a low of 107 ppm at station A to a high of 150 ppm in the well sample which we analyzed. During August a much wider range of values was observed--207 ppm was found at station D, a creek on the SSW side of the lake and 84 ppm was found at the outlet to Runyan Lake. Most in-lake values were in the 120-150 ppm range. Values in this range establish Runyan Lake as a hardwater lake, which should be moderately productive, given the appropriate morphometric (basin shape) characteristics. It also designates the lake as eutrophic rather than oligotrophic, because of the high values observed.

Hardness. Hardness is a companion variable to alkalinity, since it measures the divalent anions (calcium, magnesium, etc.) present in the water which are usually associated chemically with carbonate and bicarbonate ions (those measured by alkalinity). Hardness values in winter ranged from 148 to 200 ppm, while in summer they varied from 124 ppm (at the outlet--also lowest for alkalinity) to 217 ppm (at station D--also highest for alkalinity) (see Table 2). These high values confirm the hardwater nature of Runyan Lake and again cause a classification more toward eutrophic than oligotrophic. Another point to be made is that, in every case, hardness was higher than alkalinity, indicating that there were many more divalent anions not associated with bicarbonates or carbonates. These negative ions could likely be chlorides which averaged about 16 ppm throughout winter and summer and some others such as sulfates. Reasons for the lowest alkalinity and hardness values being at the outlet are unknown. Clearly some dilution by low-ion water or precipitation and/or plant activity there is decreasing the concentration of anions and cations in the water flowing through the outlet.

Chlorides. Chlorides, as noted, averaged about 16 ppm (see Table 2) with a range from 4 ppm (well sample--very low value) to a high of 32 ppm at station C (creek on the W side of the lake). The highest value, 32 ppm, is not an excessively high value in itself, but when one checks what relatively uncontaminated ground water is (4 ppm) and what the lake probably would contain without any interference from man, one can see that 32 ppm represents an 8-fold increase over ground water levels. Winter chloride data exhibit two interesting data points. The chloride profile shows an uneven and therefore unexpected pattern. Surface and bottom chloride concentrations were 16 ppm, while middle depth strata were much higher (25-30 ppm) at 55 ft station A

(Table 2). Since chloride ions are not involved in major chemical or biological interactions, they tend to distribute themselves evenly throughout a water body, providing a mechanism for this transfer (e.g., winds, currents, overturns) is available. The reason for the anomalous distribution noted above may be related to the creeks that enter the lake in this basin, viz., Denton Creek which is carrying the highest load of chlorides. The water entering the lake from these creeks may, because of thermal gradients in the lake, distribute themselves only at mid-depths. Rain (very low in chlorides) and snow may enter the lake in surface waters and dilute chlorides, while springs or other ground water inflow (low in chlorides) may dilute water near bottom.

The second point is the relatively high concentration of chlorides in two of the four creeks sampled. These creeks (station G--Denton Creek, and station C--creek on the W side) are suspected of carrying not only high chlorides, but also high nutrients, which is confirmed by the nutrient data (Table 2). As noted in Methods, chlorides are used as indicators of nutrient input, both from the watershed and septic tanks (their effluent is high in chlorides). That from the watershed could be from livestock operations and similar sources, but is most likely from road salting activities. In general, levels of chlorides observed during the winter in the creeks at Runyan Lake are relatively low compared with levels we have observed in highly contaminated areas (see Appendix 1 and Appendix 8, Figures 10 and 11). The SEMCOG study (Appendix 8, Figures 10 and 11) showed a range of spring chloride values in lakes in Oakland and Livingston Counties to be from about 2 ppm to 191 ppm. We have measured values up to 400 ppm in some polluted streams entering lakes. The 30 ppm value was about mid-way in the ranking among the 78 lakes they studied.

In summer, Runyan Lake chloride levels were considerably more consistent as would be expected, with values recorded from 13 to 17 ppm. Even the outlet concentrations were similar--16 ppm. Apparently the winter chloride in-lake concentrations are subjected to considerable stratification patterns because of the influence of the creeks in the area. Creeks during the summer contained chloride levels comparable to winter levels, varying from 6 to 32 ppm. The creek on the W side (station C) and Denton Creek (station G) were again very high in chlorides as was found in the winter. These streams undoubtedly have higher inputs of contaminated stormwater than the others we sampled and sources of these chemicals should be investigated further.

Data from a previous study of Runyan Lake (Appendix 7) showed chloride levels from 5.21 ppm (a creek on the E side of the lake, our station F) to 19.8 ppm (Denton Creek, our station G). We found levels similar to these in our study and Denton Creek carried high levels in 1979 as it did in 1970, indicating a consistent high concentration of chlorides from the watershed it drains.

<u>Phosphorus</u>. Nutrients that enter a lake are key elements, since plants require them for growth. The key element for plant (algae and aquatic macrophytes) growth is generally

considered to be phosphorus, because it is usually in very short supply relative to nitrogen (some algae can fix their own) and other minerals and vitamins. Therefore the amount of growth of plants observed and hence the trophic state (whether eutrophic, highly productive or not) is directly dependent on the phosphorus supply. For Runyan Lake during winter 1979 we measured soluble P or ortho-phosphorus (OP) values ranging from .01 to .03 ppm at station A (55 ft) and values of .01 to .06 ppm for the creek samples. Total phosphorus (TP) varied from .01 to .42 ppm at station A and .14 to .32 ppm in the creek samples. The .42 ppm observed at station A is inordinately high and inconsistent with other values in the series. Nitrogen values were also very high at that strata (10 ft). Our only possible explanation is that algae may have accumulated at that depth strata and caused the high TP and total Kjeldahl (total nitrogen) observed at that depth. Interestingly enough a similar situation occurred at station A in the summer at 33 ft where .45 ppm TP was recorded. These values are very high as about .03 ppm available P could cause a massive algal bloom. During fall overturn, these high values of P will become available to aquatic plants in the littoral zone and algae in the surface waters, since overturn (see Methods) causes an equal distribution of all chemical parameters when it occurs in fall and spring. Unfortunately we only collected algae from surface waters so we were unable to confirm the presence of a dense concentration at lower depths. However, the above P data and the prominent peaks in dissolved oxygen levels at lower depths at these deep stations are evidence that supports this view.

Soluble P data are generally low, being even lower in summer as algae and plants take up all available P in their surrounding water. One high value (.06 ppm) was recorded at station F, a creek on the E side of the lake (Table 2, Fig. 3). These high levels of OP will contribute sometimes significant levels of nutrients to Runyan Lake. TP values were also high (.32 ppm) at this creek in the winter, but somewhat lower (.08 ppm) during the summer.

Total P concentrations were very high at some in-lake stations (A--10 ft, A--33 ft, J--27 ft, L--surface) and at many of the streams entering the lake (stations C, D, F, G and B) (Table 2). Unfortunately these data signal high productivity somewhere in the watershed streams and within the lake itself, particularly at the deep strata in the basins of the lake and in surface waters (as expected) in the shallow backwater area of station L. The streams appear to be a major source of nutrients in the winter and spring, but some (stations D, E, F and G) possessed very low levels in summer.

It is thus our conclusion from the P data that Runyan Lake is under stress from modest P inputs and these have not yet begun to cause massive changes (i.e., vast beds of aquatic plants, pervasive algal blooms), but some of these symptoms have been noted. Obviously, effort should be directed toward controlling nutrient input into the lake from nearshore septic tanks (support sewers that include stormwater runoff) and toward determining the source of some of the nutrients entering the lake from the many streams on Runyan Lake. An important point-source may be located like the Paul Sapiano Apartments in Fenton which to date has not discharged to Denton Creek according to MDNR records (see Appendix 9). Sources like this one must be watched, since they represent a significant insult to Runyan Lake, which would act as a sewage treatment plant for the effluent created by the residents of this complex. It may also be that nothing can be specific but that the concentrations of nutrients are the product of a vast number of uncontrollable sources in the watershed (small farms, runoff, faulty septic tanks, etc.).

To compare Runyan Lake OP and TP values with those observed in other lakes in Oakland and Livingston Counties, see Appendix 8, Figs. 1, 2, 3 and 4. A common OP value for Runyan Lake in spring was about .01 mg/l which placed Runyan Lake on the low end of the scale, a desired place since it means the lake is low in nutrients. In summer OP values were also low in Runyan Lake, placing it about in the middle for lakes studied in 1977 in the two counties. For TP Runyan Lake values in spring and summer ranked in the middle and toward the top respectively, indicating that the lake has stored many nutrients in the algae, detritus and biological material in the water column. These data suggest that the lake is strongly eutrophic, but as noted before many of the other supporting characteristics (algae blooms, vast plant beds, good fish production) were not documented for the lake.

We then must conclude that the lake is in a transition period and soon will begin to show these signs of eutrophy unless nutrient entry is curtailed.

Brief mention should be made of another study by S. M. Usman (1970) (see Appendix 7). This study was conducted on 16-18 September 1970 at 10 stations (see numbers on Fig. 3) on Runyan Lake and its associated tributaries. We sampled many of the same areas and so our results are comparable. Usman found values of total phosphorus to vary from .045 ppm at the outlet to .409 ppm near our station E, a creek on the S end of the lake. We found low TP values in our summer 1979 samples from station E. Values of TP from this creek and from a flowage near some cottages in 1970 establish some very high phosphorus at least at two of the ten stations sampled in 1970.

Nitrogen. Another important nutrient, nitrogen (N), which though not usually as critical an element as phosphorus, is still of great interest to limnologists concerned with lake management. High levels in incoming waters or the lake proper can indicate domestic pollution and are required for plant growth. As noted however, some algae, i.e., bluegreens, can like many of the terrestrial plants (legumes) fix their own nitrogen. Thus when there are limiting amounts of nitrogen available, this algal group can dominate. In general, nitrogen is usually depleted from many inland lakes during late summer, allowing these groups to take over.

Examination of the nitrogen data should begin with a brief description of what the three types mean. Nitrates

($NO_3^=$) are the form most readily available to plants and usually are formed from the decomposition of organic matter, when through various biodegradable and other chemical changes, it enters water as nitrates. Ammonia (NH_4^+) is one of the first decomposition products which upon exposure to oxygen is converted to nitrates. Both nitrates and ammonia can be utilized by plants. Total Kjeldahl measures all the nitrogen (organic and inorganic) that is present in a sample.

Runyan Lake winter nitrates were very low--about .02-.05 mg/l. Ammonia values were also very low. Total Kjeldahl (TK) was low for all samples, except at station A (10 ft) where 3.15 mg/l was recorded. We also found high total phosphorus at this depth and speculate that an algae or zooplankton layer or perhaps some effect of the streams layering out at 10 ft caused these anomalous values. The well sample was also high in TK, which is often the case in ground-water samples. Creek samples were low in ammonia concentrations, except for station D (SSW side of lake) where .28 ppm was recorded. This is a very high ammonia value and with proper pH water with this concentration could be toxic to fish. This sample also had high nitrate and TK values.

Ammonia levels observed in winter in Runyan Lake (about .03 mg/l) place it in the lower levels of the rankings among the 78 lakes studied by SEMCOG (Appendix 8, Fig. 3) which shows Runyan Lake at least in this series of samples had very low levels of this nutrient. Nitrates were also low. Nitrates were also studied by Usman (1971) who found values in incoming creeks to range from .168 to 1.0 mg/l in September.

These values are not unexpected and show no really critically high values entering the lake during this time.

Summer nitrogen values exhibited considerably more variation. Ammonia which can act dually as a nutrient and a toxic substance when high levels exist, did exactly that at deep basin stations. Ammonia levels were characteristically low at the surface and mid-depths because of the presence of high dissolved oxygen levels there which quickly convert ammonia to nitrates which in turn are utilized by plants. At the bottom at all three deep basin stations, anoxia (no oxygen) existed and high ammonia levels were observed--from .24 to .55 mg/l (Table 2). These high levels are potentially toxic to any fish and many other organisms which enter this water. The lack of oxygen and high hydrogen sulfide found at these deep stations further dramatizes the toxic environment that exists at these stations. Summer nitrate values in the lake were low probably because they were taken up by plants. TK values indicate that considerable organic material was present as values were high.

Ammonia values for Runyan Lake were comparable to most values observed in the 78 SEMCOG lakes (Appendix 8, Fig. 6), and were low.

Creek nitrogen data for Runyan Lake in the summer (Table 2) showed all forms of nitrogen measured were modestly low. Only station C (creek on the W side) had high ammonia values--.51 mg/l. This is a high value and undoubtedly this creek is contributing high nitrogen loads to the lake. The creek on the W side of the lake (station D) had high ammonia concentrations in spring.

Concern over a lagoon which was built as part of an apartment complex near Runyan Lake to receive and process sewage was clarified when contact with the MDNR was made. A copy of the National Pollution Discharge Elimination System (NPDES) permit and discussion with MDNR officials revealed that this facility is well designed and to date the lagoon contents have not been discharged into Denton Creek. We are against any operations such as this and warn the residents of Runyan Lake to be alert to any such diversions of stormwater, domestic or industrial effluent into the creeks that enter Runyan Lake. The residents should support sewers for the lake and pressure these other "users" to do the same. Runyan Lake is a high water quality lake and should not be acting as a sewage treatment plant for people or industries in the watershed.

Hydrogen sulfide. We measured hydrogen sulfide at a number of deep station locations on the bottom (Table 2). This compound (H_2S) is very toxic and is formed from decomposing organic matter under anaerobic (no dissolved oxygen) conditions. We found high levels (1 to 2 ppm) at all deep water stations. Concentrations this high would be toxic to fish and thus exclude them from this area of the lake bottom.

Biological Parameters

Bacteria. We did not collect any bacteria (coliform) samples, but such data were collected on Runyan Lake in 1970 (Appendix 7). These data show some very high levels of coliform present at some stations. The standard for total coliform counts is about 2000/100 ml; any values greater than that are considered above normal and indicate some input of bacteria into the lake above what normally would be expected to be found there. Coliform and fecal coliform can be indicative of human sewage contamination in the lake, but there are other sources such as warm-blooded animals--ducks, muskrats, etc. Of the 10 samples collected in 1970, six exceeded the 2000/100 ml standard, which indicates considerable contamination from a number of sources. Sample R6 (near our station B creek) had 11,600/100 ml, the second highest recorded and certainly indicative of some high inputs of contaminated water into Runyan Lake. Sample R10 near our station E creek had outrageous concentrations (1,100,000+/100 ml) which again is very serious and clearly points out the health as well as fertilizing threat to the people and the lake from these sources. We have recorded some high levels of nutrients from these creeks. Since these data were collected 10 years ago, we hope conditions have changed. It may be well worth running some more samples for coliforms to check present levels of contamination.

Phytoplankton (algae). Algae are the microscopic green plants that inhabit water and are responsible in part for some of the oxygen that enters water. Man is usually not concerned with these plants unless they interfere with his use of the water. Fortunately, few algae blooms have been observed at Runyan Lake, an indicator that the lake is probably mid-way (mesotrophic) between oligotrophy and eutrophy. We caution lake residents that the lake is pivotal and additional nutrient insults could result in the lake becoming totally eutrophic. Present algae data (Table 4) from openwater stations were uniformly scant; densities were very low. However those that were found were blue-greens, those most likely to cause problems for lake residents. Blue-greens (Anabaena and Microcystis) usually dominate in late summer, when nutrients (particularly nitrogen forms) are scarce. Blue-greens, unlike all other groups, can fix their own nitrogen, and thus out-compete these other, usually more desirable forms, like diatoms and green algae. Blue-greens float on the surface, are often mistaken for green paint when they die, and accumulate along shores. They are also very difficult to control chemically. The best remedy is prevention, or secondly, attempts to keep most of the nutrients tied up in aquatic plant biomass. Again, if the nutrient problems continue in Runyan Lake, you could see increased algae blooms and aquatic plant accumulations until they reach problem levels. We do not feel that present levels of algae densities are a problem.

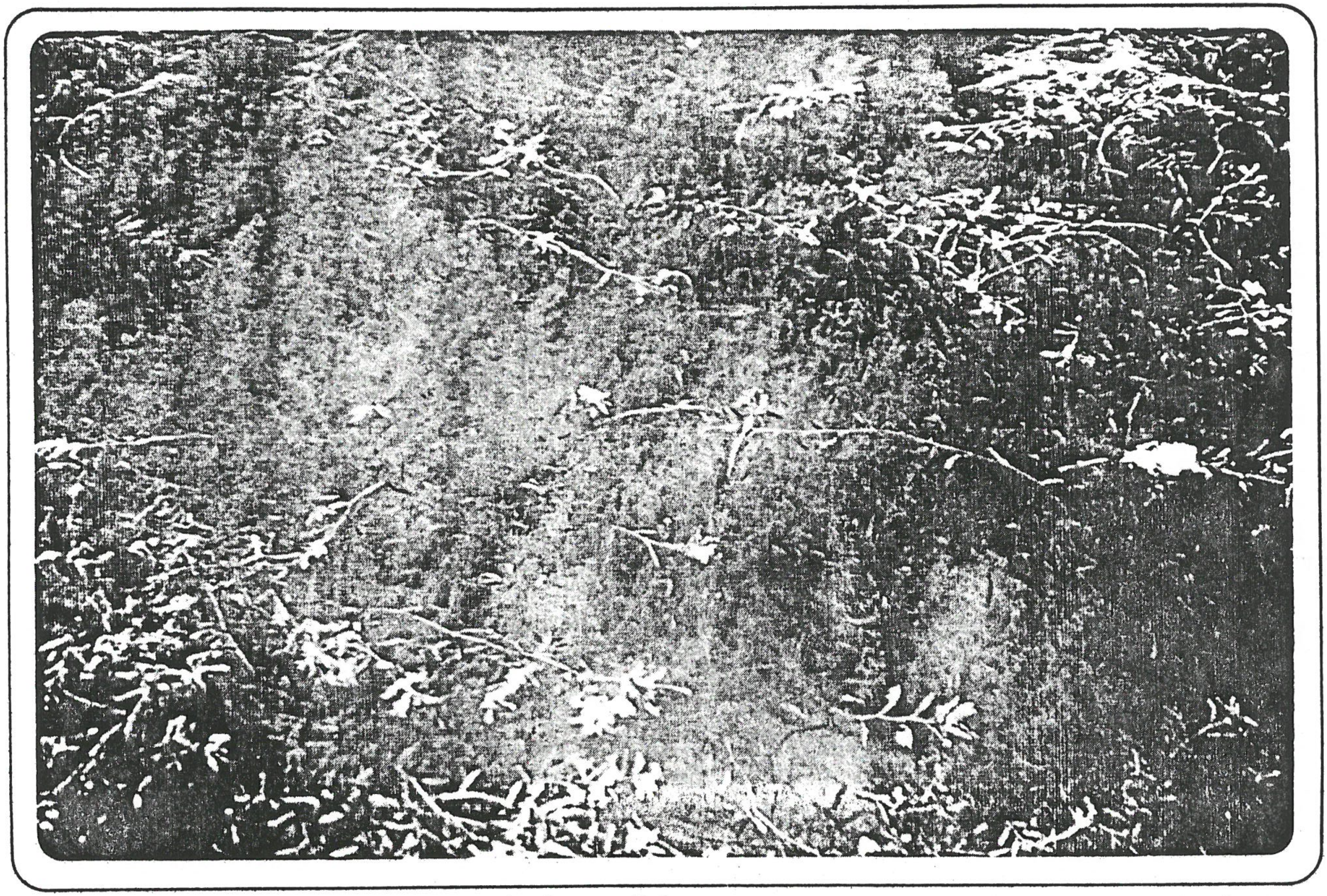
The weedy embayment (station L, Fig. 3) had a much greater variety of algal species (Table 4). Blue-greens, greens, diatoms, and chrysophytes were all present. Dinobryon was the most abundant form. More species and higher densities in the embayment are expected, even though data are probably confounded by the fact that the embayment was treated chemically. Runyan Lake can be expected to show characteristics similar to that of the embayment if nutrient input to the lake is not curtailed.

Table 4. A compilation of the qualitative abundance of algae observed in water samples collected from various stations on Runyan Lake, Livingston County, Michigan 11 August 1979. (See Fig. 1 for station descriptions and locations.)

STATION	GROUP	SPECIES	ABUNDANCE
A - 55 ft	Blue-green	Anabaena sp.	Rare
		Gomphosphaeria lacustris	Rare
		Microcystis aeruginosa	Rare
		Scytonema sp.	Rare
J - 27 ft	Blue-green	Anabaena sp.	Rare
K - 55 ft	Blue-green	Microcystis aeruginosa	Rare
L - 7 ft (weedy embayment)	Blue-green	Anabaena sp.	Rare
	Green	Oedogium sp.	Common
	Chrysophytes	Ceratium hirundinella	Common
		Dinobryon divergens	Abundant
	Diatoms	Cocconeis sp.	Rare
		Cymbella sp. (growing on Oedogonium)	Rare
		Epithemia sp. (growing on Oedogonium)	Rare
		Fragilaria crotonensis	Common
		Synedra ulna	Common
M - 40 ft	Blue-greens	Anabaena sp.	Rare
		Microcystis aeruginosa	Rare

Aquatic Macrophytes. The aquatic plants found in Runyan Lake were very sparse (Table 3); none were observed at openwater stations. Near shore in many areas bullrushes were observed along with some modestly thick beds of Potamogeton amplifolius. These two aquatic plants, one emergent and one submerged, were the dominant aquatic plants in the lake. They also are indicative of oligotrophic conditions. Much of the P. amplifolius was covered with precipitated calcium carbonate. Some Chara, lily pads, Najas and Elodea were also observed.

In the station L embayment, many more species (and in larger quantities) were found compared with Runyan Lake proper. Again this was expected because that area is shallow (receives much sunlight), has deep sediments (allows good root development for aquatic plants) and receives large quantities of nutrients from a creek that enters there. In fact, that embayment is acting as a mini-treatment plant, causing much of the nutrients there to be tied up in the algae and aquatic plants that abound there. Were it not for this area, these nutrients would enter Runyan Lake unaffected and cause increased eutrophication of the lake. Control of the aquatic plants in this embayment will be difficult for the reasons just discussed. Chemical control may be the only alternative, but we would recommend that a harvester be considered for this control. At some time the flocculent, deep sediments must somehow be reduced or this area will revert to a shallow marsh. Since this area is needed for access to the lake, the problem will have to be



Picture 4. Aquatic macrophyte bed in Runyan Lake.

addressed. Dredging or a drawdown of some type would give temporary relief.

Zooplankton. The zooplankton are small, macroscopic invertebrates which inhabit most water bodies. They are excellent food for many species of fish, particularly larval fish. They are also indicative of trophic status. *Daphnia galeata mendotae* was the most abundant species of zooplankton found in Runyan Lake (Table 5). *D. retrocurva* was also common in the lake. *Daphnia* spp. are among the largest of the zooplankton species that inhabit lakes; they are seldom abundant in lakes which have abundant fish populations, since fish eat many of these larger zooplankters, leaving only the smaller species. A good example of this phenomenon is apparent in the data, since at station L (weedy embayment) there were very few *Daphnia* spp., while those which were abundant were smaller species.

Besides these points, we concluded from the zooplankton data that a good species diversity existed and that an adequate supply should be available for the fish. In addition to zooplankton a number of other animals were collected including: flatworms, mayfly naiads, amphipods, ostracods and many other invertebrates. Again good species diversity is indicated.

Benthos. The insect larvae and other small invertebrates which inhabit the bottom sediments and aquatic plants of a lake are important fish-food organisms. The benthos of Runyan Lake deepwater stations (Table 3) was limited to very few groups: Oligochaetes (aquatic worms), Chironomids

Table 5. Abundance of zooplankton (and other taxa) collected with a plankton net at a number of stations in Runyan Lake, Livingston County, Michigan 11 August 1979. (See Fig. 1 for station location.) A = abundant; C = common; R = rare; P = present; 1 = most numerous within a category; 2 = second most numerous; 3 = third most numerous, etc. C_1-C_6 refers to increasing stages of maturity of the zooplankters.

TAXA	ABUNDANCE				
Zooplankton	Station A (55 ft)	Station J (27 ft)	Station K (55 ft)	Station L (7 ft)	Station M (40 ft)
Daphnia galeata mendotae	A-1	A-1	A-3	R	A-3
Daphnia retrocurva	C	C-3	C-1	R	C-1
Epischura (C_1-C_5)	A-2	A-2	A-1	-	A-1
Epischura lacustris (C_6)	C	C-1	C-2	-	C-2
Diaptomus (C_1-C_5)	A-3	A-3	A-2	C-3	A-2
Diaptomus sp. (C_6)	C	C-2	C-3	R	C-3
Cyclops (C_1-C_5)	R	R	R	C-2	R
Cyclops (C_6)	R	R	R	R	R
Diaphanosoma leuchtenbergianum	-	R	-	R	R
Leptodora kindii	-	R	-	-	-
Camptocorcus rectinostris	-	R	-	-	-
Bosmina longirostris	-	R	-	R	-
Ceriodaphnia sp.	-	-	-	C-1	-
Eucyclops sp. (C_6)	-	-	-	R	-
Chydorus sp.	-	-	-	R	-
Eurycercus lamellatus	-	-	-	R	-
Other animals					
Flatworms	-	-	-	P	-
Mayfly larvae	-	-	-	P	-
Asplanchna	-	-	-	P	-
Oligochaetes	-	-	-	P	-
Chironomids	-	-	-	P	-
Amphipods	-	-	-	P	-
Ostracods	P	P	-	P	P
Rotifers	P	P	A	P	P
Ephippia	P	-	-	P	-

(insects like mosquitos), Chaoborus (phantom midges--insects) and some snail and clam shells. The community of benthos present is not diverse because of the anoxic (no oxygen) conditions that develop on the bottom during the summer. In addition, high levels of hydrogen sulfide were also documented during summer. These animals are probably only fed on during spring and fall overturn and maybe during winter if high oxygen levels exist on the bottom allowing fish access to these areas. The dearth of organisms at station A may be a reflection of the toxic conditions which exist on the bottom during most times of the year. Water chemistry conditions at shallower stations J and M apparently were not as toxic, probably because of more wind-generated water exchange, which apparently allowed more benthic organisms to exist there.

At station L, the weedy embayment, a large number of different species of benthic organisms were present (Table 3). Some of these benthic animals are indicators of well-oxygenated clean-water conditions. Caddisflies, amphipods and snails are some of these organisms. Again because of the productive nature of this habitat, a large number of different species were expected. All these benthic organisms are good food for fish as can be seen from examination of the food eaten by fish.

Fish. An astounding number of species (17) of fish were collected in gillnetting and seining efforts in Runyan Lake (Table 6). Predators included: Esocidae (Pike family)--Northern Pike (Esox lucius), Grass pickerel (Esox americanus);

Table 6. Number, length, weight, sex and stomach contents of fishes collected by seine and gillnet from Runyan Lake, Livingston County, Michigan 11 August 1979. M = male, F = female, I = immature, Dev. = developed, Mod. = moderately, U = undetermined, P = poor condition.

SPECIES	LENGTH (INCHES)	WEIGHT (OUNCES)	SEX	BREEDING CONDITION	STOMACH CONTENTS
Northern Pike	25.5	58	F	Spent	1 Lake Herring (5" long)
White Sucker	16.6	30	M	Mod. Dev.	Detritus
Yellow Perch	6.3	1.2	F	Poorly Dev.	Chironomids
Yellow Perch	6.8	1.5	F	Poorly Dev.	Odonata naiad (dragonflies)
Lake Herring	7.4	2.0	F	Poorly Dev.	Zooplankton
Lake Herring	7.8	2.0	F	Poorly Dev.	Zooplankton
Pumpkinseed	6.0	2.6	U	-	Snails, Leptoceridae (caddisflies)
Pumpkinseed	3.2	.3	F	Mod. Dev.	<u>Hyalella</u> (amphipods), dragonfly, mayfly
Bluegill	5.5	1.7	M	Poorly Dev.	2 crayfish
Bluegill	5.2	1.1	M	Poorly Dev.	Empty
Bluegill	5.2	1.3	I	I	<u>Hyalella</u>, Leptoceridae, <u>Daphnia</u>, chironomid
Bluegill	2.5	.1	I	I	Damselfly, mayfly
Green Sunfish	4.5	.9	M	Mod. Dev.	Adult dragonfly
Green Sunfish	4.7	.9	F	Spent	Plant fragments, feathers (small bird ?)
Green Sunfish	3.8	.6	M	Mod. Dev.	2 mayflies
Green Sunfish	1.8	.1	I	I	Chironomid
Hybrid Sunfish (GSxPS)	4.6	1.1	M	Mod. Dev.	Caddisfly, <u>Hyalella</u>, <u>Caenis</u>, snails
Warmouth	4.5	1.0	F	Spent	Terrestrial beetles, snail
Rock Bass	1.3	.02	I	I	Empty
Rock Bass	1.3	.02	I	I	Empty
Largemouth Bass	2.5	.1	I	I	Many <u>Hyalella</u>, fish, siphlonuridae (mayfly)
Largemouth Bass	2.0	.08	I	I	Many <u>Hyalella</u>, fish, chironomid
Largemouth Bass	1.8	.07	I	I	4 mayflies, 4 <u>Hyalella</u>
Largemouth Bass	2.2	.1	I	I	Mayfly, <u>Hyalella</u>, dragonfly

Table 6. Continued

SPECIES	LENGTH (INCHES)	WEIGHT (CUNCES)	SEX	BREEDING CONDITION	STOMACH CONTENTS
Largemouth Bass	2.0	.1	I	I	Fish, mayflies
Largemouth Bass	1.6	.06	I	I	Zooplankton (Daphnia)
Largemouth Bass	2.4	.1	I	I	Many Hyalella, mayfly
Largemouth Bass	1.6	.08	I	I	Hyalella, mayfly
Largemouth Bass	1.8	.07	I	I	Hyalella, mayfly
Yellow Bullhead	1.7	.08	I	I	Hyalella, dragonfly
Grass Pickerel	2.8	.1	I	I	Larval fish
Banded Killifish	2.3	.1	F	Slightly Dev.	Empty
Banded Killifish	.9	.01	P	P	Empty
Banded Killifish	1.3	.01	P	P	Empty
Johnny Darter	1.5	.01	P	P	Empty
Iowa Darter	1.3	.01	-	-	-
Iowa Darter	1.3	.01	-	-	-
Iowa Darter	1.3	.01	-	-	-
Bluntnose Minnow	2.2	.1	-	-	-
Bluntnose Minnow	2.0	.07	-	-	-
Bluntnose Minnow	2.2	.1	-	-	-
Bluntnose Minnow	2.0	.08	-	-	-
Bluntnose Minnow	2.1	.08	-	-	-
Bluntnose Minnow	2.0	.07	-	-	-

and largemouth bass (*Micropterus salmoides*) a member of the sunfish family. Others included: Percidae (perch family)--yellow perch (*Perca flavescens*), johnny darter (*Etheostoma nigrum*), Iowa darter (*Etheostoma exile*); Catostomidae (sucker family)--white sucker (*Catostomus commersoni*); Centrachidae (sunfish family)--besides the largemouth bass, warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Amploplites rupestris*), green sunfish (*Lepomis cyanellus*), hybrid sunfish (*Lepomis*); Ictaluridae (catfish family)--yellow bullhead (*Ictalurus natalis*); Cyprinidae (minnow family)--bluntnose minnow (*Pimephales notatus*), Coregonidae (whitefish family)--lake herring (*Coregonus artedii*); and Cyprinodontidae (killifish family)--banded killifish (*Fundulus diaphanus*). This is an unexpected number of species of fish, but a good indication of good water quality and diverse habitats present in Runyan Lake. We seldom see this much species diversity in southern Michigan lakes--usually only sunfish, crappies, bass and northern pike are present in highly eutrophic lakes. Reports from fishermen and Al Luchenbill state that bowfin (*Amia calva*) and gar (*Lepisosteus* spp.) are also present. We were unable to confirm this finding.

Among the species of fish present, we can break them down into a number of groups: Predators (northern pike, grass pickerel, largemouth bass), forage species (the rest). The predators generally feed on fish when they are older--species like bass and grass pickerel (a small species that seldom reaches a foot in length) feed on benthos and zooplankton when they are young. The large number of species of sunfish ensure efficient utilization of the food supply in the lake. Yellow perch are another aggressive species that feed on or near bottom and add to the diversity in the lake. Two darters were collected. These species live on or near bottom in clear, high water quality lakes. They are a good sign that Runyan Lake still has good water which supports these species. Banded killifish feed at the surface generally and are not common in Michigan lakes. White suckers are also present in the lake. They are bottom feeders of insects and algae and spawn in the spring in creeks. We seined one yellow bullhead from the lake. These species are also bottom feeders on benthos and algae. Lastly, the bluntnose minnows provide another source of forage, their young for the young predators and adults for the older predators. Lake herring are a unique species in that they are found in very few inland lakes in Michigan. Coregonids are cold-water species that require high levels of dissolved oxygen. Therefore, it is apparent that such conditions exist in Runyan Lake. Our limnological data (Table 2) show that during winter, fall and spring, conditions are suitable for lake herring (and should be for trout also); however during summer conditions do appear to be stressful for lake herring. There is only a thin band of water that is cold enough and that contains enough dissolved oxygen to support this species. However, presence of this fish in the lake does indicate that Runyan Lake still retains some of its oligotrophic character. However, as noted, if the present deterioration continues (increased nutrients), the dissolved oxygen depletion that has existed in summer will get worse and lake herring will all die and Runyan Lake will make the shift to a eutrophic lake.

Data in Table 2 showed that the northern pike captured had eaten a 5-inch lake herring. We caught no young-of-the-year (YOY) northern pike in the lake, which leads us to be concerned about the level of spawning in the lake. A number of seemingly suitable creeks exist up which northern pike could run for spawning. The embayment at station L may also serve as a spawning area. At the present time, it appears that the main "fisheries problem" in Runyan Lake is its biggest asset--low productivity. By that we mean that Runyan Lake has a small littoral zone (weedy shallow area) and low amounts of algae and aquatic plants, consistent with our major thesis of Runyan Lake being transitional between an oligotrophic and eutrophic lake. This means that the trophic structure such a system can support is small. The analogy can be made between growing a garden on a rocky gravelly soil and a black fertile soil. Runyan Lake is somewhere between showing characteristics of both types. You must try to preserve the lake in its present condition and even more, try to reverse this aging process. The point of this discussion is then that the lake just cannot support many fish and the fishermen should not be disappointed. The clear water, low abundance of aquatic plants and lack of algae blooms should be enjoyed. To get good production the lake will require fertilization, which we are trying to prevent. However, a few things, which we will discuss later, can be done in the fish management area.

Regarding largemouth bass, another important sport fish, all we were able to capture were YOY, newly hatched in 1979. This indicates that good reproduction of bass has occurred and we feel that no major problems exist with this species. We realize that more large fish present in the lake is desired, but the same constraints already discussed will keep the biomass of all fish species low. Food eaten by these YOY was diverse, including many benthic organisms and fish. Zooplankton were also consumed. The wide range of food eaten indicates the complex nature of the food web in Runyan Lake. The bass are feeding on and depend on invertebrates when they are small and then switch to fish when they grow larger. We feel the bass population is as high as the productivity in the lake will allow at this time. Adequate spawning by this species appears to be occurring regularly.

Yellow perch caught were 6.3-6.8 inches--both were females eating benthic organisms. Perch seem also to be common, but not abundant in the lake.

Lake herring (silvery fish) are known planktivores (feed on zooplankton) and this was confirmed by our data (Table 6). We have already discussed the important status of this fish in your lake. They require cold, well oxygenated water and represent the oligotrophic character of Runyan Lake. These fish are excellent smoked. The specimens we caught

Green sunfish were also collected. They were also eating a large number of different items including benthos and a bird (?). None had empty stomachs, but growth was still poor, as has been the pattern in the lake. The hybrid sunfish was also eating benthos.

Warmouth are a rare species of sunfish which are seldom observed in lower Michigan. They are common farther south. The specimen we collected was eating terrestrial insects. Warmouth have large mouths and their spine complements differ from all other centrachids.

Rock bass are another rarely caught species in Michigan, although they are abundant in certain lakes, rivers and backwater areas. They sometimes abound in oligotrophic lakes. They have red eyes, large mouths, grow to modest sizes (up to one pound) and are voracious feeders. The specimen we caught was eating snails and terrestrial insects.

One yellow bullhead was also seined during our collecting efforts, adding another species to the diverse group present in the lake. Having high diversity insures that habitats and food organisms are efficiently utilized in the lake and is also indicative of high water quality. As eutrophication (aging) increases in a lake many of the species present there can no longer live and reproduce and soon are no longer present.

Grass pickerel have already been discussed, but it should be noted that this species can easily be mistaken for YOY northern pike and therefore give a false picture of the success of northern pike spawning. Pickerel never get very big (8-10 inches is large) and one we caught was eating a larval fish. This species also feeds on benthos.

Banded killifish have never been collected in our studies on Michigan lakes. This species is also uncommon in the state's lakes. They are a member of a family which has a characteristic mouth--wide and close to the top of the head. They are a small fish, attaining lengths of only 2-3 inches. They are surface feeders and act as forage for predatory fishes. We collected several, all of which had empty stomachs.

We also collected two species of darters which are very small members of the perch family. They live strictly on the bottom and are again indicators of high water quality, seldom being found in polluted or eutrophic lakes. They feed on benthos and usually inhabit the inshore zone. The two species we caught were johnny darters and Iowa darters; both had no food in their stomachs.

One species of minnow is also present in Runyan Lake, the bluntnose minnow. This species is an excellent forage fish, since it is available to predators at all lengths. Bluntnose feed on organic bottom material and algae, and reproduce in high numbers. If there had been no minnows present we would have recommended that this or another related species be stocked in the lake to help utilize food resources some of the other common fish do not eat.

In summary, we have made a number of tentative conclusions about the fish populations in Runyan Lake. Please bear in mind that we have only collected one sample, talked to some fishermen and must draw our conclusions based on these limited data. Point one is that Runyan Lake has a relatively small littoral zone (inshore shallow area), a number of deep basins which because of summer anoxia (depleted oxygen in the bottom layers of the lake) are largely off-limits to most fish, and most important the lake is just not a fertile lake, at least not to date. This low fertility limits the amount of the fish crop and little that would be wise or acceptable can be done to change the basic character of the lake. However, as we have repeatedly noted, if nutrients continue to pour into the lake and septic tanks are not eliminated, the lake could cross over and become a eutrophic lake. Then fish production would be higher and there would be complaints of poor water clarity, algae blooms, deep sediments and large aquatic plant beds interfering with recreational use of the lake.

A number of small projects are suggested by the present situation in the lake regarding fish management. An aerator could be installed in the deep basin of the lake in summer to aerate this part of the lake and thus allow fish to inhabit this area. A hypolimnetic (bottom strata of the lake) aerator is the recommended method. However these devices are costly, you may have to have one in each of the basins, and all this just to have rainbow trout in the lake seems cost ineffective. Since lake herring are presently surviving in Runyan Lake, it shows that at least a small amount of the type of habitat a species like trout would require is present in the lake. This strata as noted, though, is small. Also stocking of trout in Runyan Lake would subject them to predation by northern pike which might be a large source of mortality. From discussions with lake residents it was discovered that indeed trout (species unknown) have been stocked in the lake, never to be seen again. Other exotic species that might be considered for stocking are walleye and smallmouth bass. Walleye would not survive the entire year because of the summer anoxia on the bottom. Smallmouth bass, however, are more tolerant of higher temperatures and may indeed be a species worth considering as an addition to the Runyan Lake fish fauna. They may not increase the productivity in the lake, but may channel some of the present forage fish into smallmouth bass biomass which would be desirable to Runyan's anglers.

Another small project that might be attempted is to put down some brush shelters in 10-15 ft of water. These shelters increase the production of fish food organisms (benthos), but more importantly act to concentrate fish in the area where they are placed. Thus anglers would have a greater chance of catching fish in the area of these fish attractors.

PROBLEMS, CAUSES AND SOLUTIONS

Problem: Eutrophication and enrichment of Runyan Lake.

Causes: Nutrient entry into Runyan Lake from creeks, stormwater runoff and septic tank seepage into the lake.

Solutions:

Nutrient reduction. This is the key management strategy for Runyan Lake. The weight of the physical, chemical and biological data indicate that Runyan Lake is in a pivotal state (mesotrophic) between oligotrophy (low productivity) and eutrophy (highly fertilized). Nutrients entering the creeks are seasonally high; in the lake they were generally low. There was hypolimnetic oxygen depletion on the bottom in all the deep basins during summer, but not in winter. Lake herring, a cold-water species, is now in transition in Runyan Lake, living in summer in a narrow band of cold water (the thermocline) which contains sufficient oxygen. Aquatic plant beds are small and algae blooms are sparse and uncommon. These data portend eventual eutrophy for Runyan Lake unless nutrient entry into the lake is controlled. This is accomplished on a watershed-wide basis by the vigilance of lake residents in detecting any development, storm water culvert diversion, wetland destruction or other potential sources of nitrogen or phosphorus. Additional research in this area would also help to pinpoint potential sources and therefore focus on these problem areas to get solutions. If the watershed is heavily farmland, contour farming and other conservation measures can be advocated to the people involved.

A second source of nutrients is the septic tanks on the lake. The only solution is to put in sewers. Some preliminary work has been done on planning a facility for Runyan Lake (Appendix 10). Residents must support this endeavor, because only through nutrient diversion of septic wastes can the high water quality of Runyan Lake be preserved.

In addition, personal habits around each household on the lake must be changed. There are a number of steps that can be taken to curtail nutrient input from homesites on the lakeshore. They are summarized in two lists on the following two pages and include such things as: plant a greenbelt, reduce or eliminate lawn fertilization, burn leaves away from the lake shore, use non-phosphate detergents, do not run any sumps, effluent pipes or eavestroughs into the lake, and discourage geese from residing on the lake by not feeding them.

Problem: Hypolimnetic oxygen depletion.

Causes: Accelerated lake aging caused by excessive nutrients and increased sediment buildup.

Solutions: Curtail nutrient input as above. Hypolimnetic aeration is the cure; however, this technique is excessively costly and is not recommended because it is believed to be cost ineffective.

GUIDELINES FOR LAKE DWELLERS

1. DROP THE USE OF "HIGH PHOSPHATE" DETERGENTS. Use low phosphate detergents or switch back to soft water and soap. Nutrients, including phosphates, are the chief cause of accelerated aging of lakes and result in algae and water weed growth.

2. USE LESS DISHWASHER DETERGENT THAN RECOMMENDED (TRY HALF). Experiment with using less laundry detergent.

3. STOP FERTILIZING, especially near the lake. In other areas use as little as possible liquid fertilizer rather than the granular or pellet inorganic type.

4. STOP USING PERSISTENT PESTICIDES, ESPECIALLY DDT, CHLORDANE, AND LINDANE. Insect spraying near lakes should be applied with caution, giving wind direction and approved pesticides first consideration.

5. PUT IN SEWERS. During heavy rainfall with ground saturated with water, sewage will overflow the surface of the soil and into the lake or into the ground water and then into the lake.

6. MONITOR EXISTING SEPTIC SYSTEMS. Service tanks every other year to collect and remove scum and sludge to prevent clogging of the drain field soil.

7. LEAVE THE SHORELINE IN ITS NATURAL STATE. Do not fertilize lawns down to the water's edge. The natural vegetation will help to prevent erosion, remove some nutrient from runoff, and be less expensive to maintain.

8. CONTROL EROSION. Plant vegetation immediately after construction and guard against any debris from the construction reaching the lake.

9. DO NOT IRRIGATE WITH LAKE WATER WHEN THE WATER LEVEL IS LOW OR IN THE DAYTIME WHEN EVAPORATION IS HIGHEST.

10. STOP LITTER. Litter on ice in winter will end up in the water or on the beach in the spring. Remove debris from your area of the lake.

11. CONSULT THE DEPT. OF NATURAL RESOURCES BEFORE APPLYING CHEMICAL WEED KILLERS OR HERBICIDES (mandatory for public and most private lakes).

12. DO NOT FEED THE GEESE. Goose droppings are rich in nutrients and bacteria.

"An ounce of prevention is worth a pound of cure."

Sources:

"Environmental Guidelines for Inland Lakefront Property Owners", Michigan Water Resources Commission Inland Lake Studies Section

Inland Lakes Reference Handbook, Inland Lakes and Shorelands Project, Huron River Watershed Council

GUIDELINES FOR PROPERTY OWNERS:

CONTROLLING LOCAL NUTRIENT INPUT TO LAKES

It is especially important that the water quality in your lake be protected. Riparians and other users can and should have a positive influence on water quality. If the following steps are taken, definite benefits can result:

1. Eliminate or reduce lawn fertilization. Area wide soil testing should be instituted. Only use fertilizers that are necessary.

2. Establish a greenbelt of thick shrubby evergreens in a strip 10-20' along the lake edge.

3. Draw the lake down in the fall and require property owners to clean beach areas in front of their houses. Dispose of aquatic plants, muck, etc. far away from the lake edge, in gardens or landfills.

4. Require low or no phosphate detergents be used in all cleaning activities--inside and outside the house.

5. Allow no basement sumps or eavestrough drains to drain near or into the lake.

6. Rake all leaves away from the lake and compost them in gardens, etc.

7. Restrict direct inputs of urban runoff or storm water coming from within subdivisions or dwellings on the lake. If possible this water should either be re-routed to wetlands first or be diverted around the lake.

8. Inspection and upkeep of septic tanks is mandatory.

Problem: Deep sediments, dense aquatic plant beds and algae blooms in the station L (weedy embayment) area.

Causes: Shallow nature of the bay and entry of a creek into that bay which contains many nutrients.

Solutions: The source of the nutrients entering the stream should be discovered if possible and attempts made to curtail these inputs. The plants and algae may have to be treated chemically to maintain a path for boat traffic. However we advocate mechanical removal as a far better alternative. There are people who do rent their harvester who may do this for you more cheaply than chemicals. Lastly, the deep sediments that exist there may have to be addressed at some time. Dredging is one alternative and a drawdown is another. In the latter case, some method would have to be devised to divert the creek, block off the entrance of the bay to Runyan Lake and pump out the pond, and either allow the sediments to dry or use machinery to deepen the pond.

Problem: Lack of abundant supply of sport fish in Runyan Lake.

Cause: Basic character (low fertility at present) of Runyan Lake. The numerous deep basins which are devoid of oxygen during the most productive season of the year take a good percentage of the volume and area of the lake out of fish production. Also the littoral zone (shallow, weedy inshore zone) is limited and vegetation is sparse, cutting down on food organisms and habitat for fish.

<u>Solution</u>: Appreciate the fact that having a clean, clear water lake with low plant abundance will have a corresponding low production of fish accompanying it. After you understand that fish production is low and only fertilizing the lake (undesirable) will improve it, we can make a number of suggestions to improve the fishery. Aeration of the hypolimnion (low water strata) is an alternative which would create more habitat, free more area and allow fish access to the fish-food organisms (benthos) on the bottom at these depths. Oxygenated water there would also encourage more benthic organisms to grow there now because of the toxic conditions that exist there. Brush shelters could be installed in a few areas where vegetation is sparse and no problems with boat operation are anticipated. They should be placed in 10-15 ft of water and be marked. These shelters will concentrate and attract fish to aid fishermen in catching them. They will <u>not</u> increase fish production. Another option which could be pursued is to stock smallmouth bass. They, unlike walleyes and trout, should be able to survive the present hypolimnetic deoxygenation which occurs in the summer. Walleyes and trout undoubtedly would die, either from the lack of oxygen in thermal strata required or from pike predation. On the other hand, smallmouth bass should survive both. Keep in mind stocking this species will <u>not</u> increase the production (total biomass of predatory fish in the lake)

but will add another sport fish to the ones already in the lake.

Problem: Lack of Northern Pike

Cause: Unknown. There may not be a lack of pike; they may be at carrying capacity for Runyan Lake. However, spawning habitat in the lake is poorly known; they may have access to adequate marshes and flooded areas or the weedy embayment may act as a suitable site.

Solution: More information should be gathered from residents, examination and identification of spawning grounds and nursery areas must be completed, and a better picture of the pike population in the lake is required before reasonable recommendations can be advanced.

MANAGEMENT RECOMMENDATIONS

A summary of our preliminary recommendations which were presented to Runyan Lake residents in November 1979 is given in Appendix 11. Those presented here are similar to our earlier ones; for a more detailed discussion of alternatives and the problems we discovered see the Problems, Causes and Solutions section. Recommendations given here represent a distillation of solutions examined in the former section and reflect our detailed analysis and interpretation of the data gathered.

Recognition and appreciation of the inherent beauty of Runyan Lake.

The water quality in Runyan Lake is high. There is a diverse group of species of animals and plants in the lake. Water clarity is high and compared with most other lakes in adjacent counties, Runyan Lake is unique. Our first recommendation thus is for lake residents to appreciate the lake as the fine aquatic resource that it represents. Realize also that because of the character of the lake (low productivity, high diversity of species) that fish production will also be low.

Protect the long-term water quality of the lake.

Runyan Lake is in a transitional state between oligotrophy (low production, infertile) and eutrophy (high production, very fertile). At present it is a mesotrophic lake with most characteristics leaning toward those of an oligotrophic lake. However, any serious nutrient input may cause a shift in the water quality of the lake toward eutrophy. Such a shift would result in increased algal blooms, extensive plant beds, more serious deoxygenation in the hypolimnion in summer which would kill all the remaining lake herring, and one positive aspect, increase fish production. To guard against this occurence you must:

1. Support installation of sewers. Septic tanks do not remove nutrients; they eventually end up in the lake and contribute to the acceleration of the lake aging process. Lake residents should realize that the cost of installation of sewers is really a small payment considering the irreplaceable value of high water quality in Runyan Lake.

2. Curtail personal use of nutrients. The most blatant abuse of nutrients occurs with lawn fertilization and lack of greenbelts at the lake shore. Education of lake residents, who are often unaware of the consequences of their actions, will go a long way toward controlling the input of nutrients that originate from lakeshore residents. Other things that should be done include: do not run any effluent from eaves, washing machines, etc., into the lake, do not burn leaves near the lake or allow any to enter the lake, discourage geese from living on the lake, and be sure to use non-phosphate detergents.

3. Fight nutrients and pollution in any stream entering Runyan Lake. Controlling nutrients in the watershed is difficult because point sources are not the usual input. Non-point sources, such as runoff from agricultural lands,

roads and domestic households, are almost impossible to identify. Thus, residents should fight any source of nutrient input or potential source in the watershed as soon as they are identified. These would include stormwater drains, the sewage processing lagoon we discussed that is located on Denton Creek, and any other similar inputs.

4. Discourage any more development on the lake or in the watershed. Any further housing developments along the shores of Runyan Lake should be discouraged for the impact, both through the nutrients contributed and the increased recreational conflict such additions will create. Runyan Lake human populations are already straining the capacity of the lake to absorb all the impacts they cause. Developments on watershed land should also be reviewed, evaluated and opposed as their building will cause serious impact on the water quality of the lake. Stormwater culverts and the sewage lagoon we investigated are examples of the kind of chemical and bacteriological insults to the lake that should be opposed at all cost.

5. Support the preservation of all wetlands. Marshes, swamps and bogs are very important, ecologically sensitive areas. They prevent flooding by acting as a giant sponge, sometimes are spawning grounds for fish, support diverse and abundant furbearing animals and birds, and most important for lakes, they act as purifiers and filters, cleansing polluted and nutrient-rich waters. They are positive aspects of any water body and should be guarded with utmost vigor.