A COMPARISON OF INVERTEBRATE BENTHOS POPULATIONS IN FOUR SINK LAKES SIXTEEN YEARS AFTER FERTILIZATION

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

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ABSTRACT

A COMPARISON OF INVERTEBRATE BENTHOS POPULATIONS IN FOUR SINK LAKES SIXTEEN YEARS AFTER FERTILIZATION

by Dell H. Siler

This study was initiated to determine if any of the biological or chemical changes induced by earlier fertilization (Ball, 1950; Tanner, 1952 , 1960) were still evident in four small sink-hole lakes in the northern Lower Peninsula of Michigan. Monthly samples of benthic organisms were taken during the summers of 1966 and 1967. Water chemistry data were also collected during the 1967 sampling period.

The results indicated that oxygen depletion during the summer stagnation period definitely occurred in three of the four lakes.

Winter oxygen depletion also occurred in the two lakes measured, but to a lesser extent than indicated by earlier investigators (Ball, 1950; Tanner, 1952). The average total alkalinity appeared close to prefertilization levels in the fertilized lakes. The averages for the unfertilized lakes showed only slight variation when the 1967 results were compared with those of 1948-1950.

Bottom sampling indicated that considerable variation existed between the standing crop estimates of the two

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sampling periods (1966 and 1967) in three of the four lakes. The presence of the blue-green algae, Aphanothece stignina (Spreng), which apparently was not present during earlier studies, was suggested as one possible explanation for this variation. The organism chiefly responsible for the greater standing crop estimate in 1966 was the midge, Chironomus plumosus (L.), which was concentrated in the 20-30 ft. area of the three lakes in 1966. In both sampling periods, 1966 and 1967, the standing crop estimates were higher than prefertilization levels with the possible exception of South Twin Lake where this level was not known. An analysis of the depth distribution of bottom fauna indicated that South Twin Lake, which received the greatest amount of inorganic fertilizer, had a distribution in 1967 similar to that of 1948, the first year following fertilization. The distribution in the two remaining fertilized lakes most closely resembled that of 1949, the first year of fertilization.

A brief discussion of the taxonomic groups of benthos fauna was also included.

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By

Dell H. Siler

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INTRODUCTION

The cultivation of fish in ponds has been a part of Asian agriculture for nearly 2500 years (Neess, 1949). The growth and development of fish culture in Europe, which began in the fourteenth century, was discussed thoroughly by Neess (1949). The goals of American fish culture differ somewhat from those of the Europeans, namely in reference to the use of the fish and the species preferred. The Americans are, generally speaking, concerned with the sport fishing value of the fish as opposed to the commercial value stressed by the Europeans. As for species, predatory fish are most commonly associated with sport fishing while the fish which lend themselves best to economic production are those feeding closer to the base of the food chain.

Fish culture in the United States increased in stature during the 1930's and early 1940's when fish yields were increased markedly through the application of inorganic fertilizer to ponds. These early investigators, as exemplified by Meehean (1934), Swingle and Smith (1939) and Smith and Swingle (1940) determined that fertilizers increased the basic elements of the food chain, and from their abundance higher levels, including fish, benefited.

The components of fertilizers used in aquatic situations fall into five basic groups: nitrogen, phosphorus, potassium, calcium and organic matter. Maciolek in 1954 completed an extensive summation of work on pond and lake fertilization.

These early studies of pond culture in the United States were centered mainly in the southern states. They were followed by investigations to evaluate the effects of fertilization on lakes, on bodies of water under different climatic conditions, and to determine which elements of fertilizers were the most important. The process of lake fertilization proved much more complex and the results much less predictable than pond fertilization. Maciolek (1954) sites the following characteristics of lakes which differ from ponds as among those partly responsible for the difficulty of lake fertilization; size, depth, thermal stratification, nondrainability and presence of affluents and effluents.

In the past 30 years, fertilization studies have been conducted on many lakes of diverse size and form resulting in varying degrees of success; yet there are very few established guide lines along which one may proceed, with assurance, toward the ultimate goal of increased fish production. The fertilization of limited salt water areas has also been attempted with apparent success (Gross *et al.*, 1944; Raymont, 1950).

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Researchers in the field of lake fertilization have witnessed several undesirable effects, including increase in the numbers of undesirable species of fish, extensive blooms of filamentous algae, dense growths of aquatic plants and oxygen depeltion to the extent of "winterkill" of fish and fish food orgnaisms.

Attempts to increase the productivity of ponds and unproductive lakes were initiated in Michigan by Dr. R. C. Ball (1949, 1950), Patriarch and Ball (1949) and Ball and Tanner (1951). Two of these studies (Ball, 1950; Ball and Tanner, 1951) involved a shallow, warm water lake and a small cold water trout lake both located in the north central area of Michigan's Lower Peninsula. The lakes were fertilized during the summer of 1946 and 1947 using 10-6-4 (nitrogen, phosoporus, potassium) commercial fertilizer. Fertilizer was applied at three week intervals during both summers. The warm water lake supported a heavy bloom of phytoplankton throughout the first summer. During the second summer the shallow areas of the lake were covered with mats of filamentous algae until halfway through the summer when a bloom of phytoplankton again appeared.

No plankton bloom of any significance was produced during either summer in the cold water lake despite increased fertilization. However, a tendency toward eutrophication was shown by a raise in the level of the thermo

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thermocline, depletion of oxygen in the hypolimnion and the appearance of dense mats of filamentous algae.

Both of the fertilized lakes suffered a severe "winterkill" during the winter following the second summer of fertilization. There was no evidence of "winterkill" in either of the control lakes. This made evaluation of fish growth difficult but evidence from fish scales collected during the study seemed to indicate fish growth rate had increased considerably.

In 1948, the year following the completion of the above study, Dr. Howard Tanner initiated a fertilization program under the direction of Dr. R. C. Ball to determine if some fraction of the fertilizer applied to South Twin, the cold water lake, could bring about increased fish production without the undesirable effect of severe oxygen depletion. Five sister lakes in close proximity to South Twin were well suited to this purpose due to their similarity in origin, size and other morphological characteristics. Prefertilization data were gathered during the summer of 1948. During 1949 and 1950, fertilizer similar to that used by Ball (1950) was applied to four of the five lakes with the fifth serving as a control. The lake with the greatest total alkalinity received the largest dosage of fertilizer with the softer lakes receiving lesser amounts. The amounts applied are shown in Table 1. The results were evaluated through temperature and water chemist

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chemistry analysis, bottom sampling, Secchi disk readings, trout stomach content study and a creel census program. This study was reported by Tanner (1952, 1960). Tanner found increased productivity roughly correlated with the rate of fertilization.

TABLE 1.--Rates of fertilizer application.*

Lake	Pounds		Total** ppm	Percent
South Twin	1946 2,000	1947 3,000	28.5	100.
Section-Four	1949 1,700	1950 1,272	15.0	52.6
West Lost	1949 400	1950 300	3.9	13.7
North Twin	1949 0	1950 0	0	0

*Taken from Tanner, 1952.

**For the two summers.

The objective of this study was to determine whether or not there were any residual effects of the increased productivity brought about by the fertilization programs carried out by Ball (1950) and Tanner (1952, 1960). The present study was initiated in July of 1966, sixteen years after the last fertilization by Tanner.

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The literature in the area of lake fertilization is characterized by a general lack of information regarding long term effects of this enrichment process. Tanner (1960) stated, in regard to observations made on South Twin Lake during the three years following fertilization by Ball (1950), ". . . the duration of the increased biological activity and reduction of oxygen may be three years or more." Maciolek (1954) mentioned that "Nutrients are added before or during the growing season and must be renewed at least annually to sustain yields." Garton (1967), in conducting a follow-up study of the liming of an unproductive soft-water bog lake in northern Michigan (Waters, 1956; Waters and Ball, 1957), found after 10 years that hardness alkalinity, conductivity and total phosphorus were still above pre-liming levels. Bottom fauna seemed to have increased greatly and yellow perch (Perca flavescens) appeared to have a faster rate of growth than before liming.

DESCRIPTION OF AREA

The four lakes involved in this study (South Twin, North Twin, West Lost and Section-Four) are located in a special section of the Pigeon River State Forest, including part of Otsego and Cheboygan counties, and designated as the Pigeon River Trout Research Area. This area was placed under the administration of the Institute of Fisheries Research in 1949 and through reorganization is presently administered by the Research and Development Division of the Michigan Conservation Department.

There are six lakes, or "pot-holes" as they are commonly called, in the area; South Twin, North Twin, Lost, West Lost, Hemlock and Section-Four. In addition to approximately a five mile stretch of the Pigeon River in the area there are two other sink-holes that contain water but they are so small that they are not managed and thus not normally considered as members of the Pigeon River Lakes. The four lakes under study lie in sandy soil forested largely with jack pine and aspen typical of the north central part of Michigan's Lower Peninsula. No inlets or outlets were present on any of the four lakes.

These lakes were regarded by early observers (Eschmeyer, 1938) to be of glacial origin corresponding to the pit lakes of Michigan described by Scott (1921). However, as Tanner (1952) later reported, more recent geological evidence strongly supports the theory that the lakes are limestone sinks.

The lakes, with the exception of Hemlock, are very similar in form. They are very nearly circular and range in size from 2.6 to 4.7 acres. They are characterized by having the water surface 30 to 60 feet below the immediate surrounding terrain. They also have in common steep sloping banks, narrow shoal areas, and clear water. Table 2 has been borrowed, in part, from Tanner (1952) to provide more concise information about certain physical and chemical properties of the lakes.

TABLE 2.--Physical and chemical characteristics prior to fertilization (Tanner, 1952).

	Surface areas (acres)	Maximum depth (ft.)	Average depth	Total alkalinity	Per cent shoal*
South Twin	3.9	34	24	74	15.3
North Twin	4.7	44	28	32	13.0
West Lost	3.7	44	29	138	11.0
Section-Four	2.6	72	51	192	4.0

*Shoal and littoral zone are considered synonymous.

MATERIALS AND METHODS

The methods and materials used were largely determined by those used by Tanner (1952), since a comparison with his data was the basis on which this study was organized. Certain changes were made when dictated by availability of materials or when the author felt they would improve the accuracy of the study.

Bottom Sampling

Bottom sampling of the four lakes selected (N. Twin, S. Twin, W. Lost and Section-Four) began in July of 1966 and was continued through September. In 1967, sampling began in June and terminated in September. Bottom samples were taken each summer on a monthly basis at a rate of 10 samples per lake. All samples were taken by means of a 6" x 6" Ekman dredge. A steel sounding cable was used to assure accurate depth measurement of each sample. Samples were brought to the surface and emptied into a plastic bucket. Samples were then taken to the shore and sifted through a wire screen of 30 mesh to concentrate the organisms. The resulting material was placed in a labeled quart jar and removed to the laboratory where it was placed in white enamel pans and examined for organisms. All samples were "picked live" and the organisms were placed in vials containing a preserving solution of six parts water, three parts 95% alcohol, and one part formalin.

Sampling was confined to an area reaching from shore to a depth of 30 feet. This area was determined by Tanner (1952) to contain 95% of the benthos fauna in the lakes. Sampling sites were chosen by placing a grid with numbered squares over the map of the lake and drawing corresponding numbers at random. Five of the monthly samples were chosen from the area 0 to 15 feet and five from the area 16 to 30 feet. Sampling sites were divided into these two groups in order to insure a more uniform sampling of the bottom fauna. The sample sites were located on the lakes by means of a compass and shore markers.

All of the lakes contained numerous submerged logs and related debris which prevented the sampling of certain small areas with the Ekman dredge. The composition of the bottom in certain areas of the lakes often made it necessary to take 10-15 samples before the dredge functioned properly.

Chemical and Thermal Analysis

During the summer of 1967, June 19 to September 11, water chemistry data were collected at approximately 7 to 10 day intervals from 19 June to 11 September.

An electrical resistance thermometer was used to obtain a temperature profile of the lakes so that the position of the thermocline could be determined. After the thermocline was located, water samples were taken by means of a Kemmerer sampler at four vertical stations: surface, mid-epilimnion, upper boundary of the thermocline and mid-hypolimnion. The dissolved oxygen content of the samples was determined at all four stations by means of the Basic Winkler Method. One or two additional samples were taken at each sampling in an attempt to determine the level at which the dissolved oxygen content reached 4 ppm. so that a comparison might be made with similar data collected by Tanner (1952). Samples were fixed in the field and removed to the laboratory for titration. An exception to this was made during the last two sampling dates of 1956 when a Hach Chemical Kit was used. The two methods were checked against each other prior to this time to assure uniformity in readings.

The methyl orange alkalinity was determined at three vertical stations: surface, upper boundary of the thermocline and mid-hypolimnion. Determinations were made using the method outlined in Standard Methods for the Examination of Water and Wastewater.

Although temperature and water chemistry data were not taken by the author during the summer of 1966, monthly data on temperature profile, dissolved oxygen and methyl orange alkalinity were collected by the staff of the Pigeon River Trout Research Station and made available. These data were collected in the same manner as outlined above.

LABORATORY PROCEDURE

Bottom Fauna Samples

In the laboratory the benthos organisms were sorted into the same taxonomic groups used by Tanner (1952). The number of organisms and volume for each group were then determined. The numbers were determined by actual count and the volumes were measured by the displacement method using a modified 1 cc. syringe for the small organisms and a standard graduated centrifuge tube for the larger ones. Both of these volumetric devices were checked for accuracy against a burette. Organisms were removed from the preserving solution, blotted briefly on paper toweling and placed in the volumetric tube which was previously filled to a designated level. The increase in volume was taken to be the volume of the organisms. This method was found by comparison to yield a slightly smaller volume for a given organism than the method used by Tanner (1952). This was probably due to a greater amount of water remaining on the surface of the organisms measured by Tanner since his were not blotted but instead drained for a brief period.

RESULTS AND DISCUSSION

Comparison of Physical and Chemical Properties

Thermocline

The limits of the thermocline were determined during the summer of 1967 by the procedure outlined under methods and materials. Tanner (1952) colllected weekly temperature profiles from the lakes throughout the three summers of his study and compared the results by means of analysis of variance. It was found that, among the four lakes involved in this study, only Section-Four showed a significant difference between the 1948 level and the 1949-1950 level. The difference was an upward shift in the position of the thermocline during the latter period. Section-Four Lake was fertilized at the highest rate under Tanner's program and West Lost at the lowest. The shallower position of the thermocline in Section-Four was attributed to an increased plankton population resulting from fertilization. With greater numbers of plankton present, the heat from the sun was absorbed at a shallower depth (Tanner, 1952). Table 3 shows the average depth of the midpoints of the thermocline for the years 1948-1950 and 1967.

Statistical analysis of these data was not possible because the individual midpoint readings of Tanner's data

TABLE 3.--Average depth in feet of the thermocline mid-points.

Lakes	1948	1949*	1950*	1967
Unfertilized				
South Twin	21.6	24.6	21.2	20.4
North Twin	25.1	28.0	26.7	18.7
Fertilized				
West Lost	25.8	26.0	23.4	24.8
Section-Four	30.1	27.6	21.0	19.0

*Period of fertilization.

were not available. The 1967 averages for South Twin and West Lost Lakes appear to be close to the readings of the earlier period. The Section-Four average for 1967 is nearest to that of 1950, the second year of fertilization, and considerably less than 1948 or 1949. The 1967 average for North Twin seems to present a paradox in that this was the only lake not fertilized by either Tanner (1952) or Ball (1950) and yet the average thermocline depth in 1967 was considerably less than any of the years 1948-1950.

Oxygen Depletion

Oxygen depletion is an important factor to be considered in lake fertilization studies. It may have disastrous effects upon the fauna of a lake as exemplified by the winterkill which followed two summers of fertilization of South Twin Lake (Ball, 1950). Oxygen depletion may also occur during the summer stagnation period and may limit the area of the lake occupied by the fish. Tanner (1952) determined the level at which the dissolved oxygen fell below 4 ppm. and used this as a basis of comparison between the fertilized and unfertilized lakes. The results showed that ". . . the amount of oxygenated water present during the summer period was reduced in the fertilized lakes while little or no reduction occurred in the unfertilized lakes" (Tanner, 1952). There was also a statistically significant difference between pre- and post-fertilization levels of oxygen depletion in the fertilized lakes, the post fertilization levels being significantly less. This oxygen reduction was concluded to be a result of fertilization. Tanner (1952) sites Kusnetzow's (1938) findings regarding bacterial respiration as the chief agent responsible for oxygen depletion in the hypolimnion.

Although the author attempted to determine the extent of oxygen depletion in the lakes during the summer of 1956, sufficient readings were not taken to graphically define the 4 ppm. level in the hypolimnion. North Twin, South Twin and West Lost Lakes exhibited oxygen depletion below the 4 ppm. level in the lower hypolimnion during the summer stagnation period (June 16-September 10). In South

Twin (maximum depth 34 feet) the upper limit of the 4 ppm. dissolved oxygen level was estimated to vary between 24 and 30 feet. This estimate appears to be supported by monthly oxygen determinations taken by the staff of the Pigeon River Station during the summer of 1966. These limits were nearly the same as those shown by Tanner for 1950, three years after fertilization by Ball (1950). For North Twin (maximum depth 44 feet) the same 4 ppm. level was estimated to vary between 25 and 30 feet. This was slightly shallower than any of the levels recorded during 1948-1950. Again, the 1966 results indicate conditions similar to 1967. West Lost Lake (maximum depth 44 feet) displayed a 4 ppm. level at a depth greater than 35 feet. Its upper levels appear to have been 6 to 8 feet shallower than this depth during 1966. In Section-Four Lake, the greatest depth at which a dissolved oxygen determination was made was 55 feet on September 10, 1967. The amount of oxygen present was 5.5 ppm. Other readings of 9.2 and 9.0 ppm. were recorded at 50 feet. The 4 ppm. level was determined by Tanner (1952) to vary between 45 and 53 feet during 1948, the prefertilization year. After fertilization, the level fluctuated between 25 and 35 feet.

Winter oxygen depletion was evaluated by Tanner (1952) from the results of a single series of oxygen determinations taken during each of the three winters, 1948-1950. The samples were taken at a time thought to be most critical with regard to depth of ice and snow on the lakes. One of these trips was made during the last week in February and it was assumed by the author that the others were made at approximately the same time of year. On February 26, 1968, dissolved oxygen determinations were made on North and South Twin Lakes to compare with the results obtained by Tanner. The depth at which the dissolved oxygen reached 2 ppm. during the winter of 1950 and 1951 in North Twin was 27 feet. In 1968, this concentration was reached at 35 feet. For South Twin the 2 ppm. depth for 1948, 1949 and 1950 were 12, 8 and 23 feet respectively. In February of 1968, the depth of this strata was 30 feet. The 1968 winter measurements were made using a portable oxygen meter.

Total Alkalinity

The results of weekly water chemistry data collected by Tanner indicated that there was some reduction in the total alkalinity in all six lakes during each of the years 1948-1950, but among the four lakes involved in this study, only Section-Four Lake was shown by statistical analysis to decrease significantly in total alkalinity during the fertilization years of 1949 and 1950 (Tanner, 1952). The decrease was attributed to fertilization acting to increase the plankton population which in turn required greater amounts of carbon. After the primary source of carbon, carbon dioxide, became depleted, the half bound carbon in the form of calcium bicarbonate was utilized and thus decreased the total alkalinity (Tanner, 1952). Table 4 presents the average total alkalinity for the three periods 1948, 1949-1950 and 1967.

It is interesting to note that West Lost and Section-Four Lakes, which decreased considerably during the fertilization period, both seem to have returned to their pre-fertilization level of alkalinity. The reduction in total alkalinity in the fertilized lakes was indicated by Tanner (1952) to be a function of the rate of fertilization.

TABLE 4.--A comparison of average total alkalinity.

Lake	Average total alkalinity 1948	Average total alkalinity 1949-1950	Average total alkalinity 1967
South Twin	74.0	67.8	70.7
North Twin	31.7	29.5	33.3
West Lost	137.1	120.3	135.1
Section-Four	191.9	153.0	194.8

Barrett (1953) studied the relationship between alkalinity and the absorption of phosphorus resulting from Tanner's fertilization. One of his findings was that "the lakes with the lowest alkalinities had the highest concentration of absorbed phosphates." The importance of this lies in the belief that the absorbed phosphorus may be recirculated in the phosphorus cycle of the lake.

The concept of alkalitrophy was also explored by Barrett (1953). Naumann (1932) suggested that lakes with a methyl orange alkalinity equivalent to 179 ppm. or more were subject to excessive immobilization of phosphorus by calcium and thus should be classified as alkalitrophic. Barrett found this immobilization to be pronounced at alkalinities greater than 120 ppm. methyl orange alkalinity.

Bottom Sampling

The concept of productivity is complex and often misinterpreted. In bottom sampling, it is the standing crop of the organisms that is estimated. Odum (1959), in discussing productivity, states that "standing biomass or standing crop present at any given time should not be confused with productivity." Just to estimate the productivity of the consumers in a small lake would be a tremendous task. Such factors as rate of turnover and respiration would have to be included. The accuracy of estimating the standing crop by bottom sampling becomes questionable when the limitations of the sampling device, species distribution and other factors are considered. Because standing crop is one factor of productivity, it is assumed in such studies as this, that a change in the actual productivity will result in a similar change in the standing crop. If this can be accepted, it seems plausible that bottom sampling as an estimate of productivity can be justified on a comparison basis within the same lake.

As described in the section on methods and materials, sampling sites were selected at random throughout the lake in the area from shore to 30 feet. This differed somewhat from the sampling procedure used by Tanner (1952). Tanner (personal communications) found from preliminary sampling that the distribution of bottom fauna was uniform at any given depth around the lake. Considering this he confined his sampling to a single area on each lake extending from shore to 30 feet and measuring approximately 20 feet in width. The validity of the following comparison depends on the assumption that there is no appreciable change in the concentration of bottom fauna at any given depth throughout the lake.

In order to compare the results of the bottom sampling program carried out by Tanner (1952) with those obtained from the present study, two sets of tables and two sets of figures were prepared. Tables 5, 6, 7 and 8 compare the results of the 1967 sampling with those of 1948, 1949 and 1950. Due to the fact that sampling during the summer of 1966 was only carried out during the three months July-September instead of the usual June-September, a separate set of Tables, 9, 10, 11 and 12 were compiled to compare this three month period with the same period of

TABLE 5.--Invertebrate fauna collected by bottom sampling South Twin Lake 1948, 1949, 1950 and 1967 (fertilized 1946-1947).

Collection dates		1948		1949		1950		1967	
Number of samples		40		42		53		40	
Per cent of samples empty		20		4.8		11.3		2.5	
Area of samples (sq. ft.)		10		10.5		13.2		10	
Total number of organisms		612		987		1363		909	
Number per sq. ft.		61		94		103		90.9	
Total volume of organisms (ml.)		24.11		37.66		34.85		6.07	
Volume per sq. ft.		2.41		3.59		2.64		.61	
Chironomidae*	A	393	64.2	227	23.0	968	71.0	663	72.9
	B	3.16	13.1	1.10	2.9	4.08	11.7	2.04	33.6
Anisoptera	A	10	1.7	38	3.8	23	1.7	24	2.6
	B	1.45	6.0	10.65	28.3	5.63	16.2	1.42	23.4
Clams	A	40	6.5	56	5.7	47	3.4	9	1.0
	B	18.05	74.9	17.80	47.3	22.05	63.3	1.64	27.0
Snails	A	28	4.6	413	41.8	3	.2	1	.10
	B	.58	2.4	6.00	15.9	.01	...	.01	.2
<u>Chaoborus</u>	A	94	15.4	2	.2	1	.1	7	.8
	B	.37	1.6	T	...	T	...	.01	.1
<u>Hyallela</u>	A	...	...	116	11.8	28	2.0	140	15.4
	B	...	...	.62	1.6	1.15	3.3	.70	11.5
Ephemerida	A	27	4.4	18	1.8	29	2.1	32	3.5
	B	.14	.6	.11	.3	.16	.5	.13	2.1
Zygoptera	A	3	.5	31	3.1	22	1.6	1	.1
	B	.02	.1	.10	.3	.50	1.4	.02	.3
Trichoptera	A	6	1.0	56	5.7	38	2.8	3	.3
	B	.28	1.1	.88	2.3	.81	2.3	.02	.3
Annelida	A	...	...	5	.5	5	.4	26	2.9
	B	...	...	.02	.1	.02	...	.05	.8
Coleoptera	A	7	1.2	16	1.6	...	...	2	.2
	B	.02	.1	.21	.6	...	...	.02	.3
All others**	A	4	.7	9	.9	9	.7	1	.1
	B	.05	.2	.18	.5	.51	1.5	.01	.2

*Chironomidae includes the family Heleidae.

**All others includes Leeches, Lepidoptera, Stratomyiidae, Notonectidae, and Tabanidae.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 6.--Invertebrate fauna collected by bottom sampling North Twin Lake, 1948, 1949, 1950 and 1967 (unfertilized).

		1948		1949		1950		1967	
Collection dates		1948		1949		1950		1967	
Number of samples		41		41		52		40	
Per cent of samples empty		34.2		34.2		32.7		12.5	
Area of samples (sq. ft.)		10.2		10.2		13.0		10	
Total number of organisms		180		132		243		449	
Number per sq. ft.		17.6		12.9		18.7		44.0	
Total volume of organisms (ml.)		3.06		2.06		1.48		2.53	
Volume per sq. ft.		.30		.20		.11		.25	
Chironomidae*	A	127	70.6	99	75.0	122	50.2	382	85.1
	B	.56	18.2	.11	5.3	.19	12.8	1.48	58.5
Ephemerida	A	19	10.5	8	6.1	60	24.7	17	3.8
	B	.10	3.1	.04	1.9	.32	21.6	.03	1.2
Anisoptera	A	7	4.4	9	6.8	15	6.2	8	1.8
	B	.88	29.7	1.42	68.7	.70	47.3	.86	34.0
Clams	A	19	10.6	4	3.0	5	2.0	2	.4
	B	1.41	46.1	.01	.5	.09	6.1	.03	1.2
<u>Hyallela</u>	A	1	.5	5	3.8	16	6.6	2	.4
	B	.01	.2	.03	1.3	.08	5.4	.01	.4
Tabanidae	A	2	1.1	1	.8	...	...	...	...
	B	.10	3.3	.24	11.6	...	...	...	...
Hemptera	A	...	...	3	2.3	7	2.9	8	1.8
	B	...	...	.21	10.2	T	...	.04	1.6
All others **	A	5	2.7	2	1.5	17	7.0	30	6.7
	B	.01	.3	T	...	.09	6.1	.09	3.6

*Chironomidae includes the family Heleidae.

**All others includes snails, <u>Chaoborus</u>, Trichoptera, Zygoptera, Coleoptera, Annelida and Leeches.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 7.--Invertebrate fauna collected by bottom sampling West Lost Lake, 1948, 1949, 1950 and 1967 (fertilized 1949-1950).

Collection dates		1948		1949		1950		1967	
Number of samples		42		60		50		40	
Per cent of samples empty		23.8		1.7		10		5.0	
Area of samples (sq. ft.)		10.5		15		12.5		10	
Total number of organisms		117		226		480		665	
Number per sq. ft.		11.1		15.1		38.4		66.5	
Total volume of organisms (ml.)		.63		2.99		5.91		8.96	
Volume per sq. ft.		.06		.20		.47		.90	
Chironomidae*	A	64	53.9	88	38.9	328	68.2	445	66.9
	B	.40	63.5	1.45	48.5	3.63	61.4	1.09	12.2
Anisoptera	A	1	.9	7	3.1	3	.6	1	.2
	B	.01	1.3	.88	29.4	1.54	26.1	.13	1.4
Chaoborus	A	45	38.5	85	37.6	88	18.3	1	.2
	B	.20	31.3	.38	12.7	.40	6.8	T	...
Ephemerida	A	2	1.7	12	5.3	41	8.5	22	3.3
	B	.01	1.6	.06	2.0	.22	3.7	.22	2.5
Hyallela	A	2	1.7	14	6.2	12	2.5	77	11.6
	B	.01	1.0	.07	2.3	.06	1.0	.38	4.2
All others**	A	3	2.7	20	8.8	8	1.7	119	17.9
	B	.01	1.4	.15	5.0	.05	.8	7.13	79.6

*Chironomidae includes the family Heleidae.

**All others includes Snails, Clams, Corixidae, Annelida, Zygoptera, Trichoptera, Notonectidae and Spiders.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 8.--Invertebrate fauna collected by bottom sampling Section-Four Lake 1948, 1949, 1950 and 1967 (fertilized 1949-1950).

Collection dates	1948	1949	1950	1967
Number of samples	32	53	51	40
Per cent of samples empty	28.1	7.6	3.9	0
Area of samples (sq. ft.)	8	13.2	12.8	10
Total number of organisms	63	451	1974	1178
Number per sq. ft.	7.9	34.2	154.5	117.8
Total volume of organisms (ml.)	.29	4.86	12.65	4.97
Volume per sq. ft.	.04	.37	.99	.50

Chironomidae*	A	47	74.6	232	51.4	1934	98.0	780	66.2
	B	.08	26.8	.89	18.3	9.42	74.5	1.48	29.8
Anisoptera	A	3	4.8	9	2.0	7	.4	13	1.1
	B	.16	56.4	1.56	32.1	3.05	24.1	1.41	28.4
Ephemerida	A	3	4.8	65	14.4	11	.6	34	2.9
	B	.02	5.2	.34	7.0	.08	.6	.14	2.8
Hyallela	A	1	1.6	33	7.3	14	.7	303	25.7
	B	.01	1.7	.18	3.7	.07	.5	1.52	30.6
Chaoborus	A	1	1.6	5	1.1	...	...	...	...
	B	.01	3.1	.02	.4	...	...	...	...
Trichoptera	A	...	...	6	1.3	...	...	6	.5
	B	...	...	.02	.4	...	...	.04	.8
Zygoptera	A	2	3.2	...	...	...	...	4	.3
	B	.01	2.7	...	...	...	...	.04	.8
Clam	A	...	...	21	4.6	5	.2	11	.9
	B	...	...	.76	15.6	.01	.1	.21	4.2
Snail	A	...	...	63	14.0	...	...	1	.1
	B	...	...	.56	11.5	...	...	.01	.2
Annelida	A	3	4.8	8	1.8	3	.2	.23	2.0
	B	.01	3.4	.32	6.6	T	...	.07	1.4
All others**	A	3	2.8	9	2.0	1	.0	4	.3
	B	.01	1.7	.21	4.3	.01	.1	.05	1.0

*Chironomidae includes the family Heleidae.

**All others includes Corixidae, *Hydracarnia*, Coleoptera and Tabanidae.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 9.--Invertebrate fauna collected by bottom sampling South Twin Lake July-September 1966 and 1967 (fertilized 1946-1947).

Collection dates		1966		1967	
Number of samples		30		30	
Per cent of samples empty		0		3.3	
Area of samples (sq. ft.)		7.5		7.5	
Total number of organisms		757		720	
Number per sq. ft.		100.9		100.1	
Total volume of organisms (ml.)		10.09		4.91	
Volume per sq. ft.		1.34		.65	
Chironomidae*	A	615	81.2	497	69.0
	B	3.78	37.5	1.30	26.6
Anisoptera	A	2	.3	14	1.9
	B	.02	.2	1.06	21.6
Clams	A	13	1.7	8	1.1
	B	5.9	58.4	1.62	33.0
Snails	A	...	...	1	.1
	B	...	...	.01	.2
Chaoborus	A	51	6.7	6	.8
	B	.07	.6	.01	.2
Hyallela	A	53	7.0	135	18.8
	B	.26	2.6	.68	13.7
Ephemerida	A	4	.5	29	4.0
	B	.01	.1	.12	2.5
Zygoptera	A	...	...	1	.1
	B	...	...	.02	.4
Trichoptera	A	3	.4	3	.4
	B	.02	.2	.02	...
Annelida	A	16	2.1	23	3.2
	B	.03	.3	.04	.9
Coleoptera	A	...	...	2	.3
	B	...	...	.02	...
All others**	A	...	...	1	.1
	B	...	...	.01	..2

*Family Heleidae is included under the heading Chironomidae.

**All others includes Notonectidae.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 10.--Invertebrate fauna collected by bottom sampling North Twin Lake July-September 1966 and 1967.

Collection dates	1966	1967
Number of samples	30	30
Per cent of samples empty	0	12.5
Area of samples (sq. ft.)	7.5	7.5
Total number of organisms	1183	312
Number per sq. ft.	157.7	41.3
Total volume of organisms (ml.)	11.58	1.94
Volume per sq. ft.	1.54	.26

Chironomidae*	A	1048	88.6	252	80.8
	B	10.09	87.2	.93	47.9
Ephemerida	A	4	.3	17	5.4
	B	.01	.1	.03	1.5
Anisoptera	A	2	.2	8	2.6
	B	.66	5.7	.86	44.3
Clams	A	1	.1	1	.3
	B	.02	.2	.01	.5
<u>Hyallela</u>	A	1	.1	2	.6
	B	.01	...	.01	.5
Tabanidae	A	...	...	...	...
	B	...	...	...	...
Hemiptera	A	...	...	8	2.6
	B	...	...	.04	2.1
All others**	A	127	10.7	24	7.7
	B	.79	6.9	.06	3.1

*Family Heleidae is included under the heading Chironomidae.

**All others includes Chaoborus, Annelida, Coleoptera and Leeches.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 11.--Invertebrate fauna collected by bottom sampling West Lost Lake July-September 1966-1967 (fertilized 1949-1950).

Collection dates		1966		1967	
Number of samples		30		30	
Per cent of samples empty		0		3.3	
Area of samples (sq. ft.)		7.5		7.5	
Total number of organisms		579		523	
Number per sq. ft.		77.2		69.7	
Total volume of organisms (ml.)		9.29		7.57	
Volume per sq. ft.		1.24		1.01	
Chironomidae*	A	422	72.9	326	62.3
	B	1.74	18.7	.74	9.7
Anisoptera	A	4	.7	1	.2
	B	.03	.3	.13	1.7
<u>Chaoborus</u>	A	2	.3	1	.2
	B	T	...	T	...
Ephemerida	A	3	.5	17	3.2
	B	.02	.3	.20	2.7
<u>Hyallela</u>	A	6	1.0	68	13.0
	B	.03	.3	.34	4.5
All others**	A	142	24.5	103	19.7
	B	7.37	80.4	6.16	81.3

*Family Heleidae is included under the heading Chironomidae.

**All others includes Annelida, Notonectidae, Clams, Trichoptera and Spiders.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

TABLE 12.--Invertebrate fauna collected by bottom sampling Section-Four Lake July-September 1966 and 1967 (fertilized 1949-1950).

Collection dates		1966		1967	
Number of samples		30		30	
Per cent of samples empty		0		0	
Area of samples (sq. ft.)		7.5		7.5	
Total number of organisms		886		857	
Number per sq. ft.		118.1		114.3	
Total volume of organisms (ml.)		3.27		3.90	
Volume per sq. ft.		.44		.52	
Chironomidae*	A	656	74.0	540	63.0
	B	1.05	32.1	1.00	25.8
Anisoptera	A	10	1.1	10	1.2
	B	.62	19.0	1.30	33.3
Ephemerida	A	7	.8	27	3.2
	B	.02	.6	.12	3.0
<u>Hyallela</u>	A	183	20.6	248	28.9
	B	.92	28.1	1.24	31.8
<u>Chaoborus</u>	A	...	...	...	...
	B	...	...	...	...
Trichoptera	A	6	.7	3	.4
	B	.06	1.7	.02	.6
Zygoptera	A	3	.3	3	.4
	B	.02	.6	.02	.4
Clam	A	3	.3	5	.6
	B	.38	11.6	.11	2.8
Snail	A	1	.1	...	...
	B	.15	4.6	...	...
Annelida	A	15	1.7	17	2.0
	B	.03	.9	.03	.8
All others**	A	2	.2	4	.5
	B	.02	.8	.05	1.3

*Family Heleidae is included under the heading Chironomidae.

**All others includes Tabanidae.

A--Number and per cent of total number.

B--Volume (ml.) and per cent of total volume.

Figure 1.--South Twin Lake (Fertilized 1946-1947).

Composition of bottom fauna from sampling by per cent of total volume.

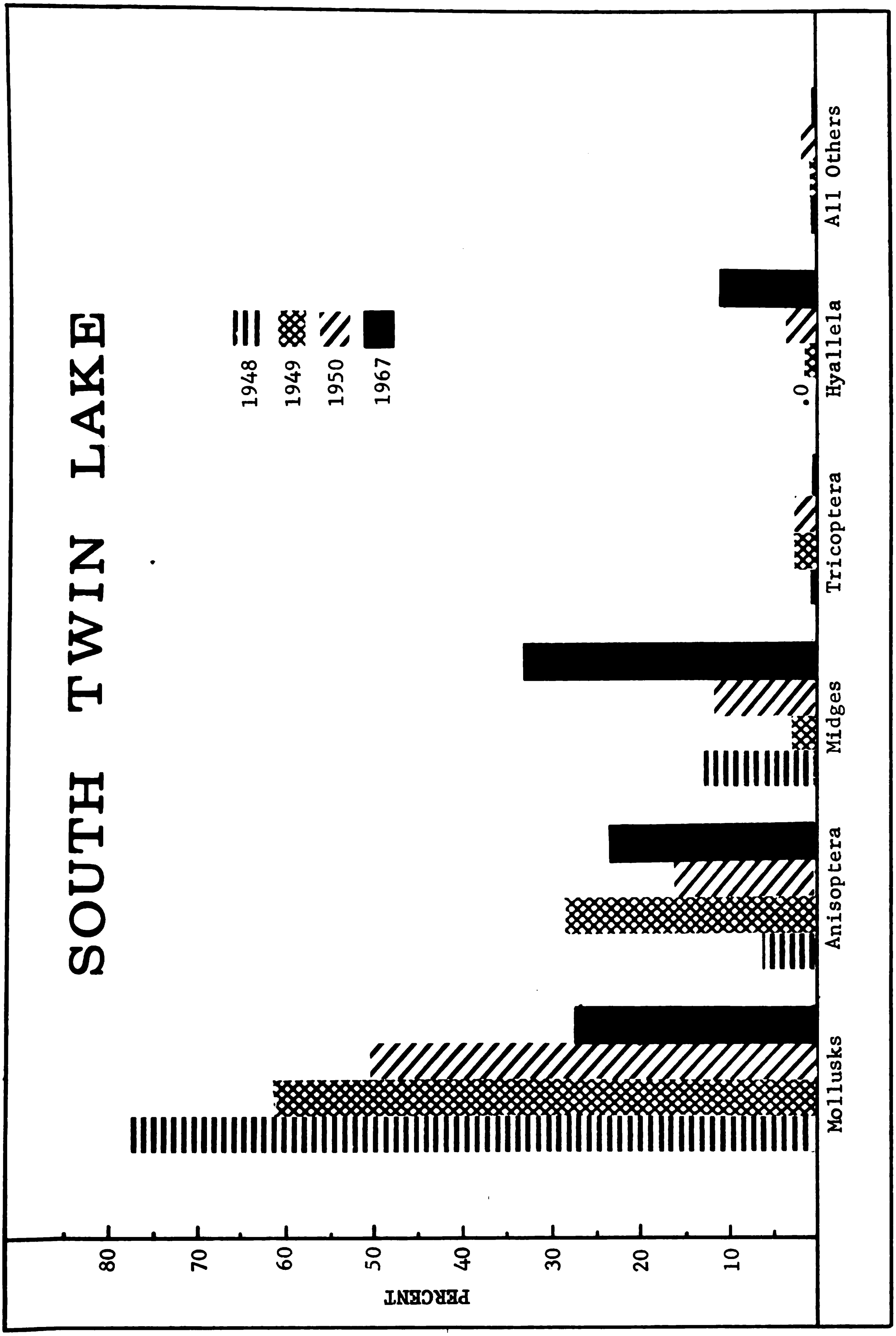

SOUTH TWIN LAKE
1948
1949
1950
1967
Mollusks
Anisoptera
Midges
Tricoptera
.0
Hyallela
All Others
PERCENT
80
70
60
50
40
30
20
10

Figure 2.--North Twin Lake (not fertilized).

Composition of bottom fauna from sampling by per cent of total volume.

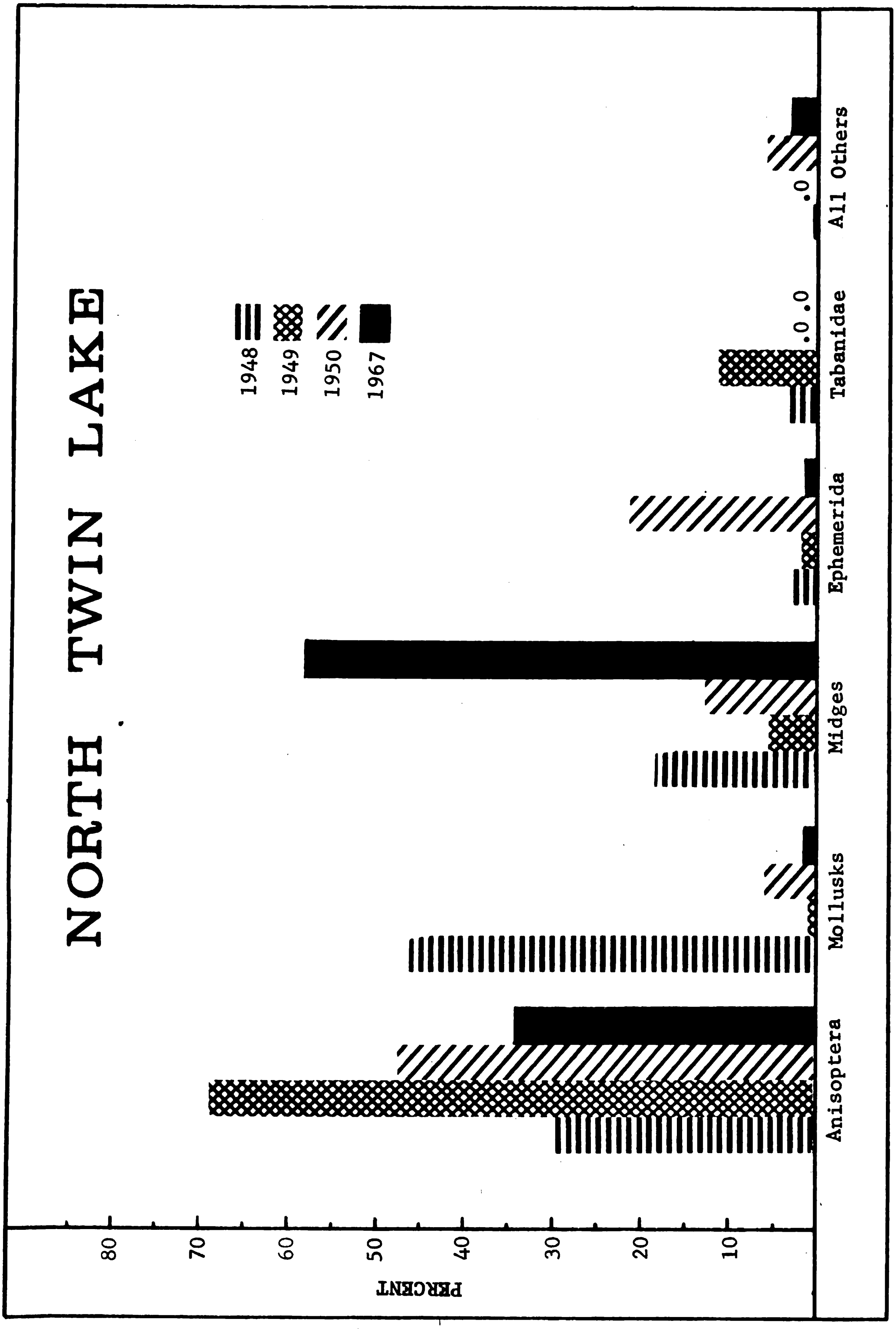

NORTH TWIN LAKE
1948
1949
1950
1967
PERCENT
10
20
30
40
50
60
70
80
Anisoptera
Mollusks
Midges
Ephemerida
Tabanidae
All Others
.0
.0
.0

Figure 3.--West Lost Lake (Fertilized 1949-1950).

Composition of bottom fauna from sampling by per cent of total volume.

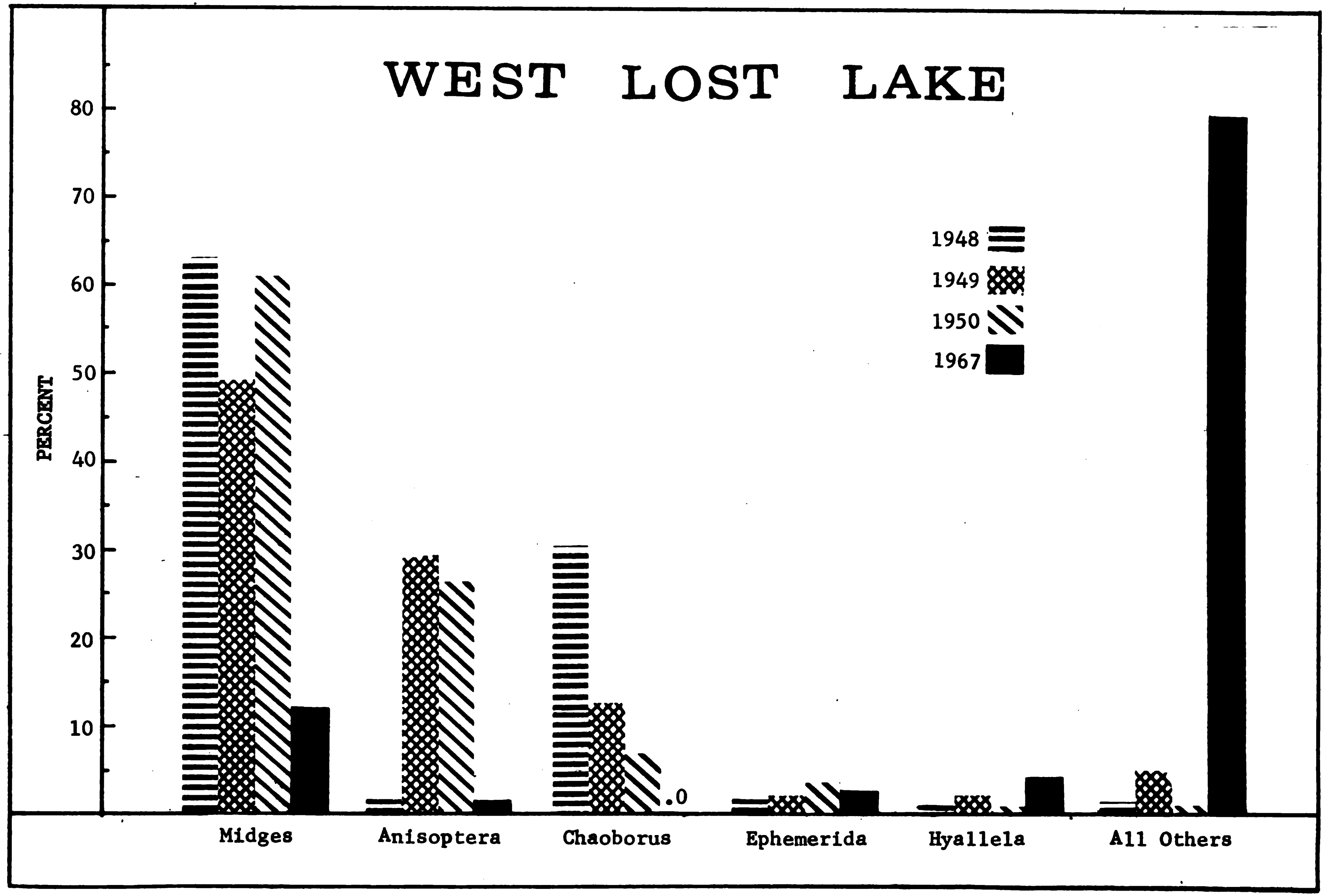

WEST LOST LAKE
PERCENT
80
70
60
50
40
30
20
10
1948
1949
1950
1967
.0
Midges
Anisoptera
Chaoborus
Ephemerida
Hyallela
All Others

Figure 4.--Section-Four Lake (Fertilized 1949-1950).

Composition of bottom fauna from sampling by per cent of total volume.

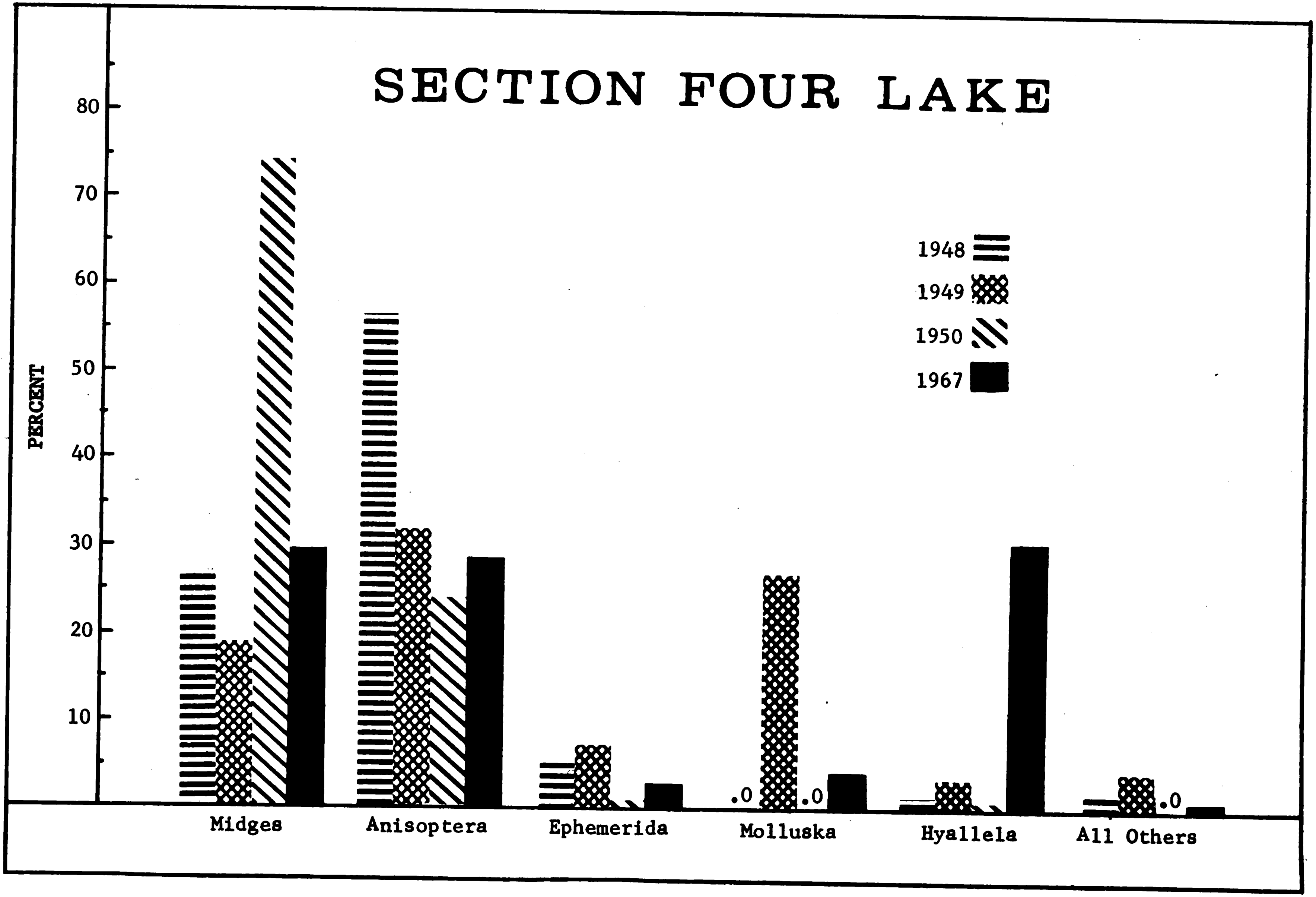

SECTION FOUR LAKE
PERCENT
80
70
60
50
40
30
20
10
1948
1949
1950
1967
.0
.0
.0
Midges
Anisoptera
Ephemerida
Molluska
Hyallela
All Others

Figure 5.--South Twin Lake
(Fertilized 1946-1947).

Depth distribution of selected bottom fauna organisms during the summers of 1948, 1949, 1949 and 1967.

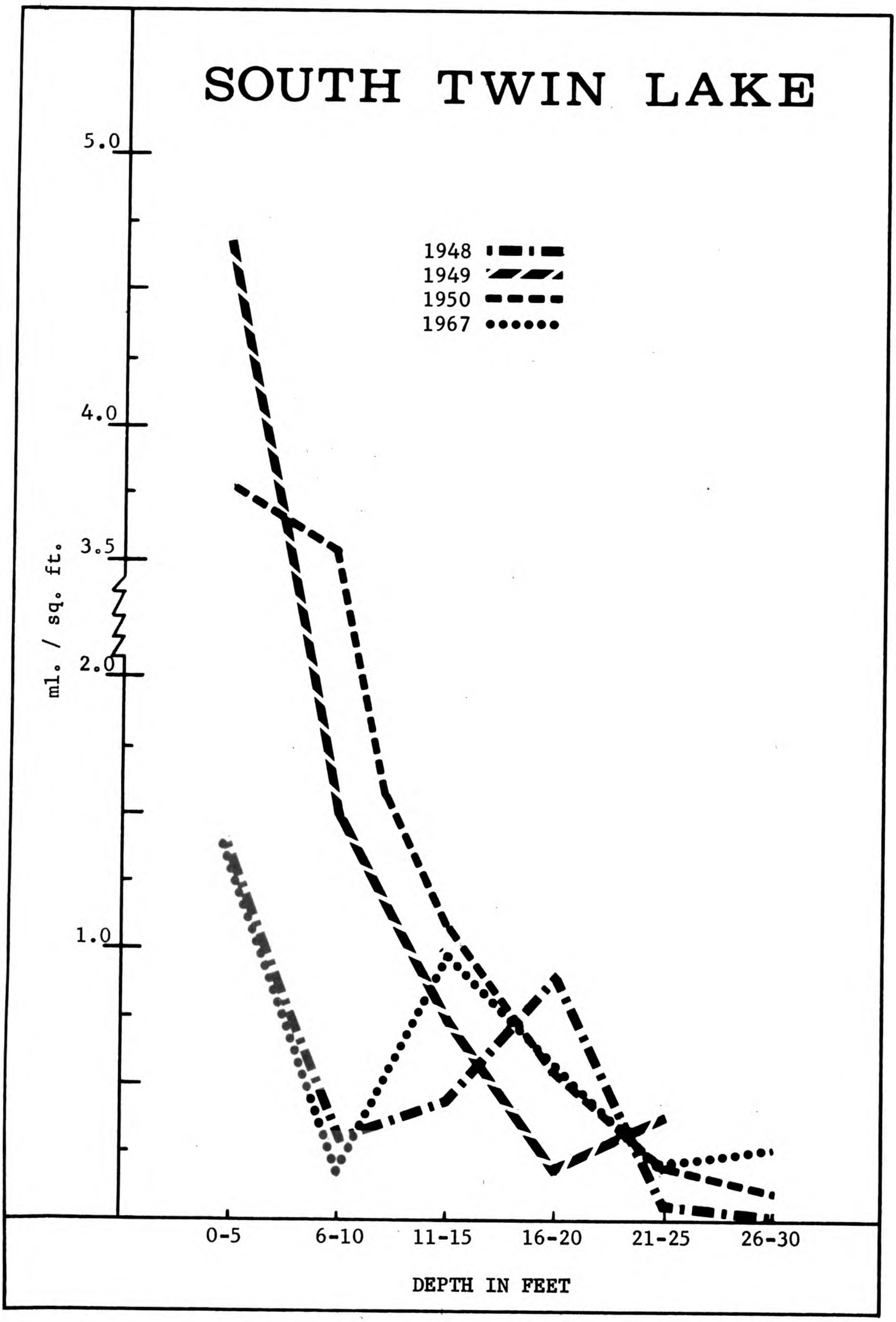

SOUTH TWIN LAKE
1948
1949
1950
1967
5.0
4.0
3.5
2.0
1.0
ml. / sq. ft.
0-5
6-10
11-15
16-20
21-25
26-30
DEPTH IN FEET

Figure 6.--North Twin Lake (Not fertilized).

Depth distribution of selected bottom fauna organisms during the summers of 1948, 1949, 1950 and 1967.

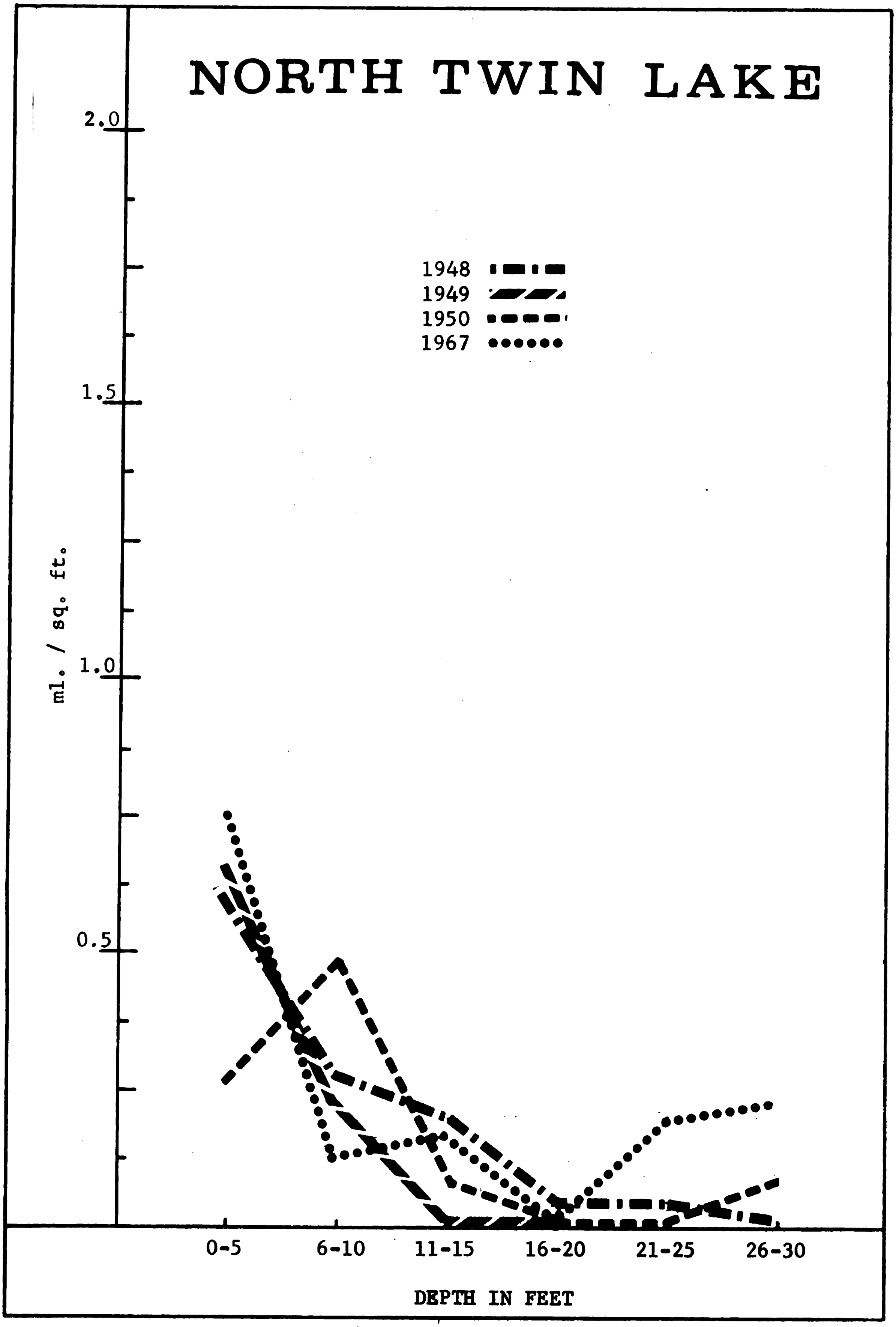

NORTH TWIN LAKE
2.0
1.5
1.0
0.5
ml. / sq. ft.
1948
1949
1950
1967
0-5
6-10
11-15
16-20
21-25
26-30
DEPTH IN FEET

Figure 7.--West Lost Lake (Fertilized 1949-1950).

Depth distribution of selected bottom fauna organisms during the summers of 1948, 1949, 1950 and 1967.

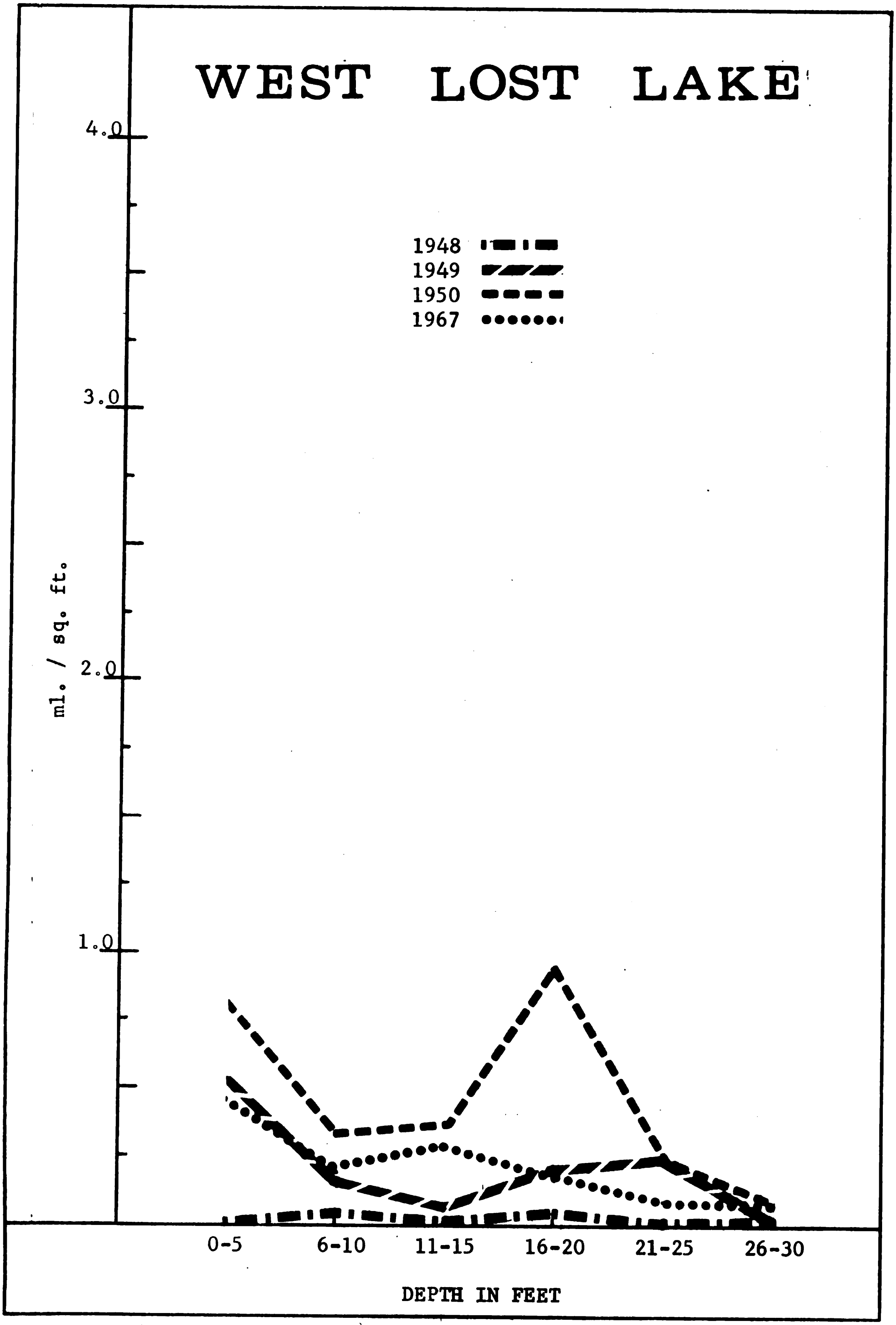
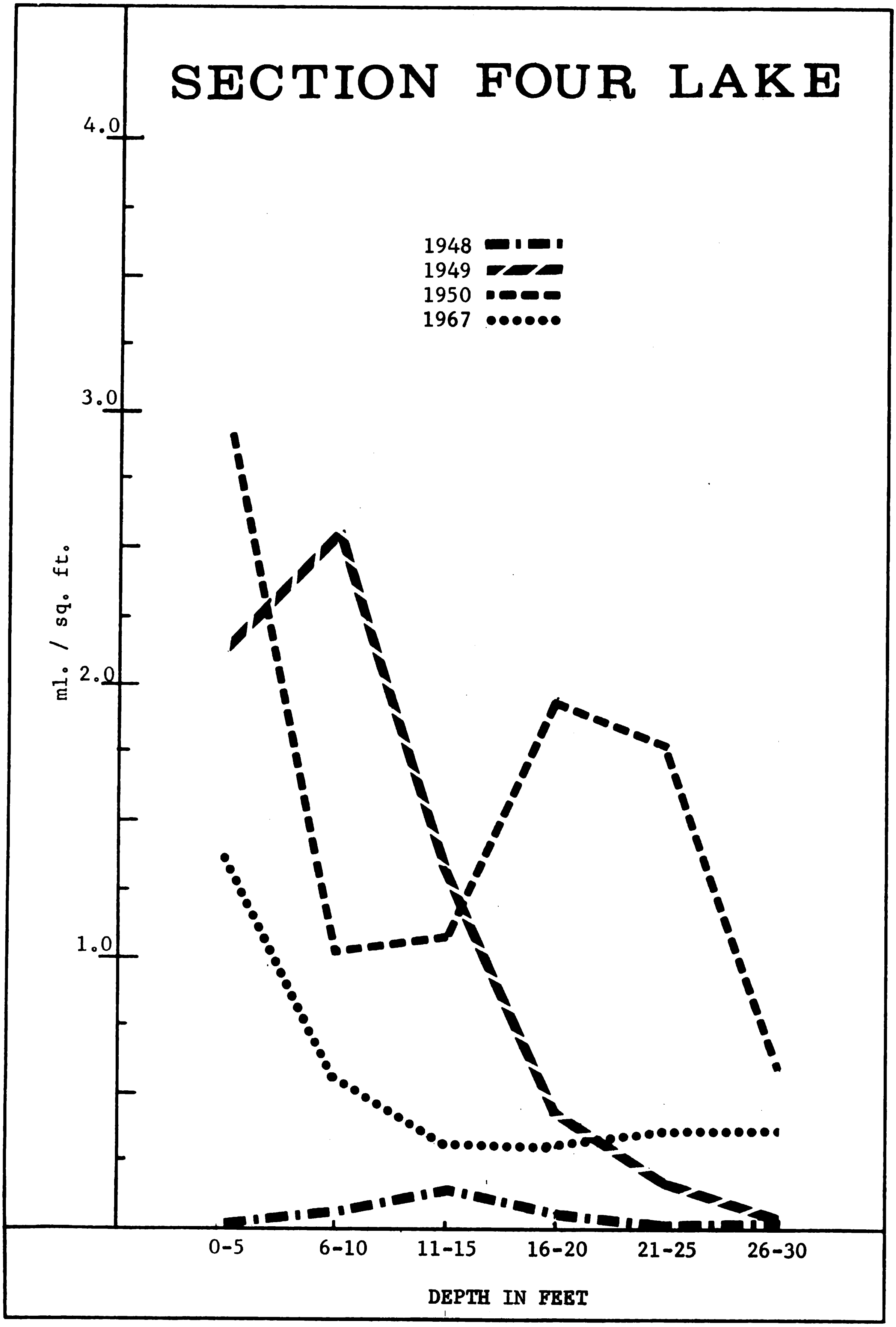

WEST LOST LAKE
1948
1949
1950
1967
4.0
3.0
2.0
1.0
ml. / sq. ft.
0-5
6-10
11-15
16-20
21-25
26-30
DEPTH IN FEET

Figure 8.--Section-Four Lake (Fertilized 1949-1950).

Depth distribution of selected bottom fauna organisms during the summers of 1948, 1949, 1950 and 1967.


SECTION FOUR LAKE
1948
1949
1950
1967
ml. / sq. ft.
4.0
3.0
2.0
1.0
0-5
6-10
11-15
16-20
21-25
26-30
DEPTH IN FEET

1967. Figures 1, 2, 3, and 4 show in the form of a histogram the relative importance by per cent of total volume of the various bottom fauna groups for each of the years 1948, 1949, 1950 and 1967. Figures 5, 6, 7, and 8 show the depth distribution of bottom fauna in volume per sq. foot for the years 1948, 1949, 1950 and 1967.

The first lake presented in each series is South Twin Lake (Table 5), which, as mentioned earlier, was fertilized by Ball (1950) at a rate concluded to be excessive. Unfortunately no estimate was made of the standing crop of South Twin before it was fertilized and thus caution should be exercised in drawing any conclusions from the resulting data. However, if it is assumed that the prefertilization level of the standing crop was approximately equal to those of the neighboring lakes it would then follow that the present level of standing crop is considerably higher than before fertilization. The clams and snails showed a great decrease from the extremely high level in 1948-1950 to that exhibited in 1967. This is probably due to their feeding habits being linked to the abundance of plankton algae and aquatic plants during the fertilization period and immediately after. The relatively high level of abundance maintained by the midges in 1967 compared favorably with levels immediately following fertilization. Table 9 indicates that the 1966 sampling yielded an even larger number and volume of midges equaling nearly twice that of the four month sampling period of 1967. One possible explanation for this large population might be found in the presence of the blue-green alga Aphanothece stignina (Spreng) which occurs in the form of gelatinous balls ranging in size from less than ½ cm. to over 1½ cm. in diameter. The "algae balls" were extremely abundant in the deeper areas of South Twin. Their presence was not noted by either Ball (1950) or Tanner (1952). It is very unlikely that their presence could have been overlooked due to their conspicuous nature. It is possible that this alga was to some extent a result of the earlier fertilization programs. Prescott (1962) in describing this species of algae states " . . . often forming almost continuous gelatinous expanses in the bottoms of favorable eutrophic habitats." This species of algae also occurs in West Lost Lake and the control lake North Twin, however, it was not nearly as extensive in North Twin as in the other two lakes. It was not found in Section-Four but it may exist below the 30 ft. depth to which bottom samples were taken. It is possible that this alga provided the chironomids with browse. This was substantiated somewhat by the occurrence of large numbers of midge cases and often large plumosus-type midges among the alga colonies.

A comparison of the 1966 results with those of 1967 in South Twin as presented in Table 9, shows some interesting differences. The volume per sq. ft. of organisms in 1966 is more than twice that of 1967. Some of this difference can be attributed to the few extra large clams collected in 1966. A substantial part was due to a larger population of chironomids in 1966 which, upon examination of the localities of individual samples, resulted more specifically from a greater population of the large Chironomus plumosus (L.) midges at a depth of 20 to 30 feet. Why this population was not present or was not detected in 1967 is not known. This area between the 20 and 30 ft. depths roughly corresponds to the expanse of the blue-green alga *Aphanothece stagnina* mentioned earlier.

In 1966, the composition of each bottom sample was noted after it had been passed through the 30 mesh wire. The shallowest occurrence of this alga in South Twin during that summer was 23 ft. The composition of the bottom samples was not noted during the summer of 1967 so it is not known how extensive the alga was, only that it did occur in the same three lakes. A change in the abundance or distribution of the algae could be responsible for the vastly different midge population either because of its food value or possibly as a result of toxic by-products. According to Dr. G. W. Prescott (personal communication) this particular species has never been evaluated to determine if it possesses any such toxic by-products. It is known that other blue-greens, largely the filamentous forms, do excrete toxic by-products sometimes harmful to aquatic life (Prescott, 1948; Ingram and Prescott, 1952). Also, in South Twin the specimens of Anisoptera showed a considerable increase in 1967 (Table 9). One explanation might be the rise in the water level of 8-10 inches which occurred in all the lakes in 1967. This new water level submerged a small area around the edge of the lake containing thick grasses which seemeed to provide increased cover and feeding area for the dragonflies. This might have brought about increased survival. Relatively large numbers of dragonfly naiads and crayfish were observed in this area of the lake. The volume of Anisoptera increased in all lakes in 1967 but due to the relatively low numbers collected it was possible that the difference was due merely to chance.

North Twin Lake (Table 6) served as the control lake in the studies conducted by Ball (1950) and Tanner (1952). However, it too was fertilized to a small extent by Eschmeyer (1938) who suspended "several hundred pounds" of fertilizer from a raft in the center of the lake in 1934. He then attributed increased growth and survival of brook trout and perch to the fertilization but admitted that the relationship was not proven. Although these "several hundred pounds" probably did not approach the magnitude of the fertilization applied to the other lakes by Ball (1950) or Tanner (1960), it is possible that they could have had some eutrophying effects. The volume of organisms per sq.

ft. from Table 6 is about the same in 1967 as during Tanner's study. Again the midge seems to be much more abundant in 1967 than earlier. The percent of empty samples from North Twin was noticeably less in 1967, possibly because of the increased midge population.

In North Twin Lake between 1966 and 1967, there was a more pronounced difference in the midge populations than in South Twin. The 1966 samples contained 10 times the volume of midges as did the 1967. The same pattern was followed in North Twin as in South Twin. The midges responsible for most of the increase are the large Chironomus plumosus and the population was centered in the same locality at depths of 20-30 ft. The shallowest recorded occurrence of Aphanothece stagnina in 1966 in North Twin was 29 ft. The area covered by the alga in the three lakes was very erratic and spotty. There are several other possible explanations for this fluctuation in midge population . . . for example, dissolved oxygen levels. The dissolved oxygen levels in the lake were determined at about 10 day intervals during the summer of 1967. During the summer of 1966, monthly oxygen determinations were made by the staff of the Pigeon River Trout Research Station. When the two were compared, there did not seem to be any noteworthy difference in the level of depletion of dissolved oxygen in either of the Twin Lakes.

Hilsenhoff (1967), in his discussion of the ecology and population dynamics of Chrionomus plumosus in lake Winnebago, found that the ". . . C. plumosus population fluctuated greatly, both yearly and seasonally, and often differed markedly from one area of the lake to another." He also states that "some of the most important, yet least studied, factors influencing C. plumosus populations in Lake Winnebago are the diseases and parasites." It may be that one or more of these factors contributed to the fluctuating midge population in West Lost and the Twin Lakes.

West Lost Lake (Table 7) received the least amount of fertilization under the Tanner study. When the results of the 1967 bottom sampling were compared with those of Tanner, the volume of organisms per sq. foot is nearly twice the level reached in 1950, the second summer of fertilization. An examination of the volumes contributed by the individual groups of organisms in 1967 (Figure 3) shows that the clams are responsible for about 80 per cent of the total volume where as in Tanner's study they were not present in benthos samples. The 1966 results (Table 11) show an even larger volume contributed by the clams under the "all others" category. The amphipod, Hyallela, also increased considerably in numbers in 1967 as compared to the 1948, 1949 and 1950. However, this increase was not supported by the 1966 samples. The number and volume of midges was much larger in the 1967 samples than in 1948 (prefertilization). This increased chironomid volume was surpassed in the results of the 1966 sampling. The clams and chironomids, due to their feeding habits, would logically be expected to increase in numbers if the lake had moved toward a eutrophic condition. It also would seem that Chaoborus would be likely to reflect any increase in the primary production due to their plankton feeding habits (Pennak, 1953). Just the opposite occurred; Chaoborus, which was formerly abundant in the lakes, was barely detected in 1966 and 1967.

Section-Four, the lake fertilized at the highest rate by Tanner, displays a substantially greater standing crop in 1966 and 1967 than in either the prefertilization year or in the first year of fertilization (Tables 8 and 12). The two groups which were largely responsible for this increase were the chironomids and the amphipod, Hyallela. Section-Four showed less variation for the 1966-1967 comparison than any of the other three lakes. The volume per sq. ft. of organisms was slightly higher in 1967 but the number and volume of chironomids was again greater for 1966.

Although the blue-green alga mentioned earlier was not detected in Section-Four the green alga Dichotomosiphon was found in a bottom sample at a depth of 22 ft.

Although crayfish were important members of the benthic community in all the lakes they are not included in the above tables. It was felt that their numbers were not sufficiently great to allow an accurate estimate of the population by the sampling program employed. Also it seems likely that they might be able to avoid the dredge as it is lowered to the bottom. Crayfish were originally included in the data taken by Tanner (1952). Although very few crayfish were taken during any of the sampling periods of this study, when they did occur their relatively large volume often tended to mask trends exhibited by the smaller organisms. Patriarche and Ball (1949) excluded crayfish from the results of their bottom fauna sampling for basically the same reasons.

A study of the population dynamics and the productivity of the crayfish population in West Lost Lake, one of the lakes in this study, has been conducted by Dr. W. T. Momot (1965, 1967).

In order to obtain a more accurate estimate of the volumes of the smaller organisms, it was necessary to accumulate considerable numbers of each group so that an average volume of the organisms for each of the groups could be calculated. This method was also used by Tanner (1952). The organisms, size groups, numbers and volume are presented in Table 13 along with the results obtained by Tanner. Two additional groups, annelid and *Chaoborus*, were calculated in addition to the groups used by Tanner (1952). Tanner's method of volume determination was followed as closely as possible for all groups listed. The resulting volumes are quite close to those calculated

TABLE 13.--A comparison of calculated average volumes of small invertebrates.

Millimeters	Volume (ml.)	Number of organisms	Volume (ml.)	Number of organisms
	Tanner		Siler	
Midges				
0 - 4	.0005	200	.0006	200
5 - 6	.0014	150	.0012	150
7 - 8	.0032	200	.0033	200
9 - 10	.0046	200	.0048	200
11 - 12	.0070	100	.0063	100
13 - 14	.0120	50	.0112	40
15 - 16	.0178	45	.0168	35
Hyallela	.0053	250	.0050	250
Annelid			.0019	200
Caenis	.0050	140	.0030	80
Chaoborus			.0013	100

by Tanner except for the larger size groups. One possible reason for the author's volumes being lower for these groups is that the larger groups contained a high percentage of Heleidae (Ceratopogonidae) larvae which appeared to have a lower condition factor than the chironomid midges.

Bottom Fauna Distribution

The vertical distribution and type of bottom fauna in lakes has been used by past investigators to categorize the productive capacities of lakes (Deevey, 1941; Eggleton, 1931). Tanner (1952) mentioned that the pattern of bottom fauna distribution changed in certain of his fertilized lakes after fertilization from a pattern considered to be characteristic of unproductive oligotrophic lakes to that commonly exhibited by more productive eutrophic lakes.

The comparisons shown in Figures 5, 6, 7 and 8 represent the bottom fauna populations including the crayfish but excluding the mollusks. These adjustments were made to conform with the manner of tabulation used by Tanner (1952) who excluded the mollusks to get a more accurate view of important trout food organisms. The mollusks were found to have only a very slight effect on the pattern of distribution for the 1967 samples. The 1966 results were not included in these comparisons because it was felt that the smaller number of samples left certain depth areas with too few samples as a result of the random method of selection. Also, with the exclusion of June from the 1966 sampling, the same span of time could not be compared.

In 1948, South Twin (Figure 5) which had been fertilized by Ball (1950) the two previous summers, exhibited a pattern of distribution similar to some of the "mesotrophic chironomus" and "Chironomous" lakes mentioned by Deevey (1949). These lakes were characterized by having a maximum population in the sublittoral or profundal zones. This pattern of distribution which was not evident in any of the other lakes before fertilization was concluded by Tanner

(1952) to be a result of the earlier fertilization. The sublittoral peak, characteristic of this pattern, was believed caused by increased survival of "Chironomus type" midges in the area due to the profuse shower of expended plankton organisms from above (Tanner, 1952). Chironomus-type midges were found to be the chief component in this area of the lake in 1948 (Tanner, 1952). In the two years following, 1949 and 1950, although the standing crop remained high the sublittoral peak was no longer evident. The 1967 sampling (Figure 5) showed a pattern very similar to that of 1948 except that the sublittoral peak was located in a slightly shallower area.

North Twin, the unfertilized lake (Figure 6), showed very little difference in the vertical distribution of bottom fauna in the four years under consideration. The 1967 sampling indicated a slightly higher standing crop in the 20-30 ft. area of the lake. The contrasting results of the 1966 sampling (Table 10) present the possibility that a large amount of variation may exist from year to year within the lake. If this were the case, it would be difficult to make any generalizations as to the level of the standing crop on the basis of only two years of sampling.

West Lost Lake (Figure 7), fertilized in 1949 and 1950, was noted by Tanner (1952) as having a pattern of distribution in the second summer of fertilization similar to that of South Twin in 1948 and to Deevey's (1941) more productive lakes.

As mentioned earlier, West Lost Lake showed a large increase in the standing crop during 1966 and 1967 over the earlier sampling by Tanner (Tables 7 and 11). This was found to be due largely to the high populations of clams (Figure 3). However, when the clams were excluded the pattern of distribution was quite similar to that of 1949, the first year of fertilization (Figure 7).

The fourth lake, Section-Four, displayed the same sort of distribution in 1950, the second year of fertilization, as South Twin in 1948 and West Lost in 1950. The 1967 depth distribution curve (Figure 8) resembles the 1949 curve more closely than either of the other two years. This type of population was said by Deevey (1941) to be characteristic of lakes where the total quantity of bottom fauna was low. However, it appears considerably higher than the prefertilization, 1948, curve (Figure 8).

Species Composition

A detailed analysis of the species composition of the various taxonomic groupings was not attempted since this procedure was not followed by earlier investigators (Ball, 1950; Tanner, 1952) and, therefore, a comparison would not be possible. A brief analysis, however, is presented.

The most prominent group on all lakes in numbers was the family Chironomidae. As mentioned earlier, the family Heleidae was included under this heading. Specimens of this family were widely distributed in all lakes but never important volumetrically. Mature midge larvae of the species *Chironomus plumosus* (L.) were identified from all four lakes but were not common in Section-Four Lake. A large majority of the remaining midges were probably earlier instars of this species. This species was believed also to be predominant during Tanner's study (Tanner, 1952).

The Anisopterns were important volumetrically due to their relatively large size but were never very numerous. The family Gomphidae, genus *Gomphus*, was the most common genus found in all four lakes and the only anisoptern taken from Section-Four Lake. Members of the families Libellulidae and Aeschnidae were also present. Among the latter, the genera *Anax* and *Boyeria* were predominant. Zygopterns were rarely found in the bottom samples. Those present were members of the family Coenagrionidae.

Among the Ephemeroptera, the genus *Caenis* (Family Caenidae) was common and found in all four of the lakes, but due to its minute size they were never important contributors to the total biomass. *Stenonema*, a member of the family Heptageniidae, was also encountered in all of the lakes but was much less numerous. A similar status of these two genera was noted by Tanner (1952). A few members of the family Baetidae and one of the family Ephemeridae were found in Section-Four Lake.

The amphipod, Hyallela, was also common to all four of the lakes and was especially abundant in Section-Four Lake (Table 8).

The phantom midge larvae Chaoborus (family Culicidae), although found in all of the lakes was seldom encountered in the bottom samples. Chaoborus larvae are predatory on small crustaceans and make pronounced daily vertical migrations in the lakes where they are found (Pennak, 1953). Because of this behavior, the larvae are nearly pelagic and thus their occurrence in bottom samples could not be taken as a true index of their abundance.

Representatives of the order Trichoptera were found in each of the lakes, the most common family being Molannidae, genus Molanna. Tanner (1952) stated that the Limnophilidae were the most numerous of the Trichoptera, however, this statement takes into consideration the two lakes, Hemlock and Lost, not included in the present study. The limnophilids were second in abundance in 1966 and 1967. Tanner found the genus Molanna only in North and South Twin Lakes. Phryganeidae was the third and least abundant of the caddis larvae present. The micro-caddis, family Hydroptilidae, which were mentioned by Tanner as occurring occasionally in the algae mats of South Twin Lake were no longer present, obviously due to the lack of such algae.

The only clams present belonged to the genus Musculium. Snails were very uncommon in all of the lakes. According to Table 5, the snails appear to have progressively declined in South Twin following the early fertilization by Ball (1950). Although they appeared in Section-Four during the first summer (1949) of fertilization (Table 8), they were unexplainably absent from the 1950 sampling.

Small oligochaetes were present throughout the four lakes in moderate numbers.

The crayfish, *Orconectes virilis*, as mentioned earlier, were important members of the benthos fauna but were not included in the results of this study.

Predation

One other factor that must be taken into consideration in making this comparison is the possible differential effects of fish predation upon the benthos organisms. Species composition and abundance of fish are the factors which could cause a difference in the level of predation. Hayne and Ball (1956) concluded from their study of a group of Michigan fish hatching ponds that in the absence of fish the standing crop is relatively high and production is low while with fish present the standing crop decreases and production increases. These results decrease the validity of a productivity comparison on the basis of standing crop when two different fish populations are involved. Table 14 gives a comparison of the number of fish stocked in 1948 during Tanner's study and those planted in the same lakes prior to the 1966-1967 sampling. The interpretation of these data is complicated by the fact that the 1948 planting occurred in the fall of that year after the prefertilization bottom sampling period. During the summer of 1948, up until the time of poisoning (August 1 and 2), large populations of yellow perch (*Perca flavescens*) and common suckers (*Catostomus commersoni commersoni*) were present in North Twin, South Twin, West Lost and Section-Four. Pumpkinseed sunfish (*Lepomis gibbosus*) were also present in West Lost Lake. As Table 14 shows, many more trout were planted during the 1949-1950 period in North and South Twin than during the 1964-1965 period. Tanner (1952) compared the feeding habits of brook and brown trout from the lakes by means of stomach analysis. It was found that brook trout appeared to feed on bottom fauna organisms to a slightly greater extent than brown trout, while brown trout were observed to feed more on terrestrial insects which alighted on the lake surface. The probability of erroneous results being produced by the stocking of different species and varying numbers is somewhat diminished by the bottom sampling results of North Twin Lake. It is evident from Table 6 that these

TABLE 14.--A comparison of planting records for the years 1948, 1949, 1964 and 1965.

	South Twin Lake				North Twin Lake			
Year	1948†	1949	1964	1965	1948	1949	1964	1965
Species*	Brown	Brown	Brook	Brook	Brown	Brown	Brook	Brook
Number	2,150	1,075	430	390	2,850	1,425	550	240
Size**	SL	L	SL	SL	SL	L	SL	SL
	West Lost Lake				Section-Four Lake			
Year	1948	1949	1964	1965	1948	1949	1964	1965
Species	Brown	Brown	Brook	Brook	Brown	Brown	Bows	Bows
Number	2,000	1,000	400	1,750	1,650	825	3,000	3,000
Size	SL	L	SL	SL	SL	L	F	F

†An equal number of brook trout fingerlings were also planted by mistake in North Twin, South Twin and West Lost in 1948.

*Brook--Salvelinus fontinalis; Brown--Salmo trutta; Bows--Salmo gairdneri

**SL = sublegal, about 6"; F = fingerling, about 3.5"; L = legal, average 7" fluctuating fish planting levels have not made themselves evident unless of course some other phenomenum is masking their effects. The aforementioned unexplainable high level of standing crop shown by the 1966 bottom samples (Table 10) can hardly be attributed to the fewer fish in 1966 than 1967 since there were no fish planted after 1965, and monthly samples were removed from the lake during 1966 and 1967 by the staff of the Pigeon River Research Station.

If there were indeed a substantial suppression of the benthos organisms by the large numbers of fish present during the 1949-1950 period, the standing crop of these two years would be underestimating the productivity when compared with other years influenced by fewer fish.

SUMMARY

1. A comparison of thermocline data from the years 1948, 1949, 1950 and 1967 seemed to indicate that the thermocline of the fertilized lake, Section-Four, and the unfertilized lake, North Twin, occupied a shallower position in 1967.
2. Oxygen depletion during the summer stagnation period occurred below the 4 ppm. level in South Twin, North Twin and West Lost Lakes. Oxygen depletion under the winter ice and snow cover appeared to be less in the lakes measured (North Twin and South Twin) than shown by Tanner for the 1948-1950 period.
3. The total alkalinity, which was decreased considerably by fertilization in West Lost and Section-Four, appeared to have regained its prefertilization level.
4. A blue-green alga, Aphanothece stignina, characteristic of eutrophic lakes, was found to occur in the deeper waters of South Twin, North Twin and West Lost Lakes.
5. There was a considerable difference in the estimates of the standing crop between 1966 and 1967 in South Twin, North Twin and West Lost. The 1966 samples showed a higher level in each of these lakes.

6. The bottom sampling results of 1967 indicated the standing crop of benthos organisms was as follows: South Twin was much lower in 1967 than any of the three years following fertilization; North Twin seemed to conform to the 1948-1950 estimates; West Lost was higher than either of the pre- or post-fertilization levels, but this was largely due to the increased number of clams; Section-Four was closest to the results of the first year of fertilization and considerably above the prefertilization level.
7. The vertical distribution of bottom fauna in 1967, as indicated by bottom sampling, was as follows: South Twin's pattern of distribution resembled that of 1948, the first year following fertilization, which is a pattern characteristic of some productive lakes; North Twin was similar to the years 1948-1950; the pattern shown by West Lost appeared most like that of 1949, the first year of fertilization; Section-Four was also similar to the first year of fertilization.
8. The standing crop estimates for both of the sampling periods were considerably above the prefertilization levels in West Lost and Section-Four Lakes. The perfertilization level was not known for the third fertilized lake, South Twin.

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