ECOLOGY OF THE YELLOWSTONE CUTTHROAT TROUT (*SALMO CLARKII LEWISI* GIRARD) IN KIAKHO LAKE, BRITISH COLUMBIA

by

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B. A. University of British Columbia, 1957

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in the Department

of

ZOOLOGY

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

April, 1960

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ABSTRACT

A knowledge of the basic biology of any fish is a primary requirement for the practical management of that stock of fish. This investigation was directed at a pure culture population of Yellowstone cutthroat trout, to describe the basic biology and provide a basis for management and further research.

Kiakho Lake has a surface area of 67.42 acres, a maximum depth of 32 feet and a mean depth of 16.5 feet. Due to the rocky substrate, lack of littoral development and low total dissolved solids, the production of plankton and bottom fauna was small and characteristic of oligotrophic conditions.

The food of cutthroat trout in Kiakho Lake in May was comprised of 83.9 percent by volume and 81.3 percent by occurrence of chironomid pupae. In June the food was 46.7 percent by volume and 45.8 and 35.5 percent by occurrence of chironomid larvae and Gammarus respectively. In July the Gammarus were 57.8 percent by volume and 60.3 percent by occurrence. In Lumberton Reservoir and Monroe Lake the Gammarus comprised 51.0 and 55.6 percent by volume and 34.4 and 78.2 percent by occurrence respectively of the food. In Garcia Lake, Chaoborus was 32.9 percent by volume and 36.0 percent by occurrence and the redside shiner, Richardsonius balteatus, was 27.8 percent by volume and 31.8 percent by occurrence. The fish appeared to be second in preference to Chaoborus.

The body-scale relationship is described by a straight line having a slope of 1. A graph of instantaneous growth rate plotted against length, revealed that faster growing fish have a faster decrease in growth rate. Due to the absence of certain characteristics e.g. a concavity in the upper limit of the graph, the growth of Kiakho Lake cutthroat appeared to support the view that faster growing fish are selected by the fishery, and that it can be demonstrated in this type of graph. The data, fitted to a Parker and Larkin (1959) growth equation gave a z value of 0.71.

The absence of "Lee's Phenomenon" gave support to the premise that the phenomenon can result from selection by a fishery, and invalidated the other ideas concerning the causes as far as this population was concerned.

The spawning run in Kiakho Lake was estimated at 3,000 fish. A tagging program revealed that the fish spent on the average of 13 days to spawn, and that there was approximately a 54 percent mortality. The male fish appeared on the spawning grounds first. The female fish showed a decrease in size, later in the run, which was not shown by the males.

The eggs hatched sometime in mid June and the young fish apparently spend one year in the outlet stream.

The female fish mature between the ages of 2--4 and the males between 1--3. The mean number of eggs per female, plus or minus two standard deviations was 944 ± 393.29. A multiple regression analysis revealed that body length affected the number of eggs produced, 2.5 times as much as egg diameter.

Recommendations were made, due to the probable effects of competition, that cutthroat trout be kept in pure culture populations. It was further suggested that cutthroat trout numbers be maintained in view of the severe reduction and almost extinction of the species in other areas.

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ACKNOWLEDGEMENTS

This study was financially supported by the British Columbia Fish and Game Branch and the Institute of Fisheries, University of British Columbia.

The author would like to gratefully acknowledge J. Boone, M. Y. Ali, R. E. Johannes and J. Varty for their valuable assistance in the field work. Special thanks to T. Miura for assistance in data analysis, F. P. Maher for suggesting Kiakho Lake as a study area and I.L. Withler for contributing data from Garcia Lake.

The author wishes to express his gratitude to Dr. P. A. Larkin for suggesting the problem and his valuable criticism.

INTRODUCTION

In the management of any fishery, it is essential to have an understanding of the biology of the fish or fishes concerned. During the summer of 1958, a study of the life history and ecology of the Yellowstone cutthroat trout (Salmo clarkii lewisi Girard) was initiated. The study was directed at description of all phases of the life history, with particular reference to food habits. Many of the lakes in British Columbia have natural or accidently planted stocks of "coarse fish", predominantly the redside shiner (Richardsonius balteatus), the squawfish (Ptychocheilus oregonense) and various species of suckers and minnows. Larkin and Smith (1954) described the effect of redside shiners on the rainbow trout (Salmo gairdneri) population in Paul Lake, British Columbia. Their work indicated that the trout were adversely affected by the shiners, because rainbow trout will not feed on shiners until they (the trout) attain a length of 10 to 12 inches. At the same time, young trout suffer from competition with shiners and have a reduced growth rate. The present study was initiated to determine whether the cutthroat trout, being more piscivorous would make better use of coarse fish stocks and suffer less from competition.

Within the province of British Columbia, there exist two subspecies of cutthroat trout, the Coastal cutthroat trout (Salmo clarkii clarkii Richardson) and the Yellowstone cutthroat trout (Salmo clarkii lewisi Girard). Qadri (1959) gave a brief review of the distribution of these subspecies within the province. The Coastal cutthroat trout is found in most of the coastal lakes and streams and on the majority of the coastal islands. Fish culture activities have resulted in the Coastal cutthroat being planted east of the coast mountains, in Garcia Lake (1954) near Merritt and in the Shuswap and Similkameen Rivers. The Yellowstone cutthroat is found in the southeastern part of the province. It occurs in the Flathead River, the upper Columbia and Kootenay Rivers, as far west as the Arrow Lakes and north to the Revelstoke area. Fish culture activities have distributed the Yellowstone cutthroat across much of the southern part of the province.

There have been no major studies of the biology of the cutthroat trout in British Columbia. As a result the majority of this study was concerned with the pure culture of Yellowstone cutthroat trout in Kiakho Lake. This information should provide a basis for comparison with later work on mixed populations of cutthroat trout and other species.

Kiakho Lake near Cranbrook, British Columbia, was chosen as a pure culture stock of Yellowstone cutthroat trout. This lake was suitable for several reasons; it is easily accessible, it has had no fishery on it for more than fifteen years, there is a large spawning run in the outlet stream and trap facilities were already installed. Kiakho Lake has been an egg taking station for more than twenty years and has supplied several million eggs for stocking in other lakes. British Columbia Fish and Game Branch records show Kiakho Lake was stocked thirteen times between 1938 and 1952. The stocking was done mostly with eggs, but some cutthroat fry were also used.

To supplement the food habit data, samples of cutthroat were taken from other lakes, some of which had other species of fish in them. These lakes were Monroe Lake and Lumberton Reservoir near Cranbrook and Garcia Lake near Merritt.

All the data collected is filed at the Institute of Fisheries, University of British Columbia.

LAKES

A. PHYSICAL AND CHEMICAL LIMNOLOGY OF KIAKHO LAKE

1. Location, Size and Drainage

Kiakho Lake is situated in southeastern British Columbia, approximately 6 miles due west of Cranbrook, (115° 57' west, 49° 30' north). The lake lies in a small valley at an altitude of 3,600 feet (1,098 m.) and the geology of the drainage area consists of argillites and quartzites (Chapman and Turner, 1956). The lake basin has been formed by a rock slide obstructing the valley and is of type 20a as described by Hutchinson (1957). The average annual precipitation is 40—50 inches per year with 50—70 percent of this in the form of snow (Chapman and Turner, 1956). The total drainage area coming into the lake covers approximately 3 square miles. The lake is frozen about 5 months of the year, from late November to late April. The ice left the lake in 1958 on April 28.

Kiakho Lake has an area of 67.42 acres (27.30 ha.), is 1.1 miles long and averages 550 feet wide. The maximum depth is 32 feet (9.8 m.) and the mean depth is 16.5 feet (5.0 m.). The lake consists of two basins, the large south basin and the small north basin (Fig. 1). These basins are joined by a narrows in the lake, which is 200 feet wide and 5 feet deep. Table 1 summarizes the morphometry of the lake. The lake is bordered on the east and west by precipitous rock slides, which drop

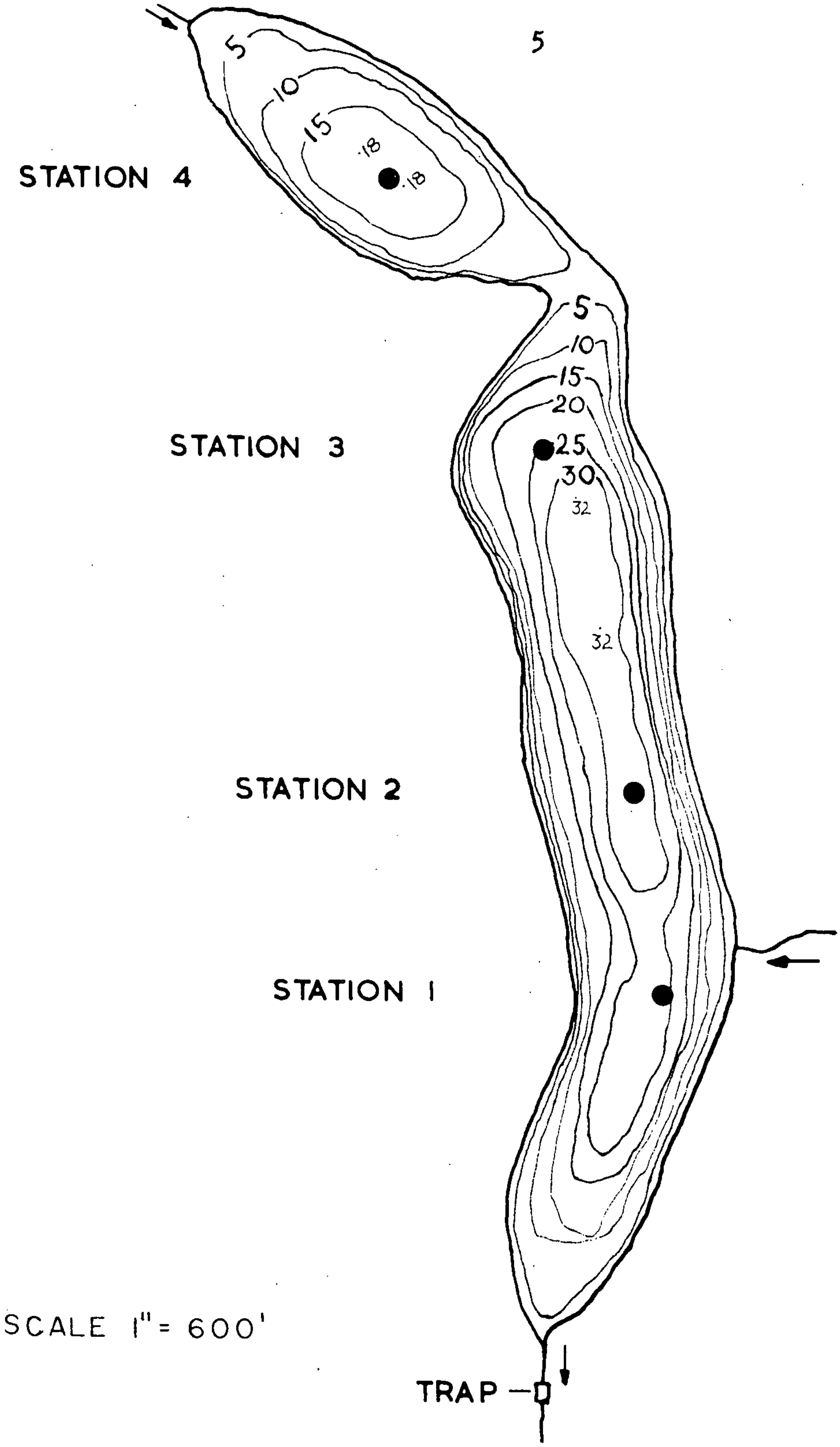

Figure 1. Depth contour map of Kiakho Lake, showing the position of the limnological stations.

TABLE 1. MORPHOMETRY OF KIAKHO LAKE

Surface Area	Maximum Depth	Mean Depth	Volume	Secchi Disc	Shore-line Factor	Shore-line Devel-opment	Volume Develop-ment
67.42 acres	32.0 ft.	16.5 ft.	1,112.8 acre-ft.	17.0 ft.	.0043	2.11	1.55
27.30 ha.	9.8 m.	5.0 m.		5.2 m.			

into the lake. The sides of the lake basin, down to a depth of approximately 12 feet consist of steep slopes of broken rock, ranging in size from fine gravel to pieces 10 feet across. The remainder of the lake bottom consists of organic ooze mixed with very fine sand. The total dissolved solids content is 100 parts per million.

There are two inlets, one at the north end and one about half way along the east side of the south basin. Both inlets are small and each had a flow of approximately 0.25 cubic feet per second in 1958. The inlet at the north end arises from another small lake, but is probably not indicative of the water movement between the lakes. The area between the lakes is swampy and considerable undetected ground water movement could be involved. The inlet on the east side arises from a spring approximately 150 yards up the hillside above the lake.

The outlet at the south end of the lake is small with a flow of approximately 3—4 cubic feet per second during the spring, and nearly dry by midsummer. The lake fluctuation controls the size of the outlet stream flow. The fluctuation was about 8 inches in 1958 as measured from the high water mark on the lake shore. A small spring enters the stream about 25 yards below the lake, and this holds the stream flow at about 0.25 c.f.s. The first 75 yards of the stream consists of rapids over large boulders and gravel bars. The remaining part of the stream that was surveyed, approximately 2,000 yards, consisted of a slow flowing meandering stream with a mud bottom. Approximately 200 yards below the lake a small pool was formed by a beaver dam. In this 200 yards, 2 small springs entered the stream and brought the flow up to approximately 0.50 c.f.s. For 25 yards below the beaver dam the stream flowed through many diverse channels. These channels met and formed a single channel. In the remaining surveyed portion of the stream, the bottom was composed of mud interspaced with 4 small patches of gravel. The gravel patches were approximately 40 feet in length.

2. Temperature

All temperatures were taken with a standard maximum-minimum thermometer. Figure 2 shows the temperature curves for the four stations over the summer period. Stations 1, 2, and 3 were in the south basin, are comparable in depth and show great similarity in the shape of the curves. Station 4 was in the north basin which is only half as deep as the other stations and relatively isolated, as a result, showed much different curves.

In late May and early June the epilimnion extended down to 6 feet, as shown at all four stations. By mid August the epilimnion descended down to 18 feet at stations 1, 2 and 3. Station 4 was isothermal by mid August and was virtually all epilimnion.

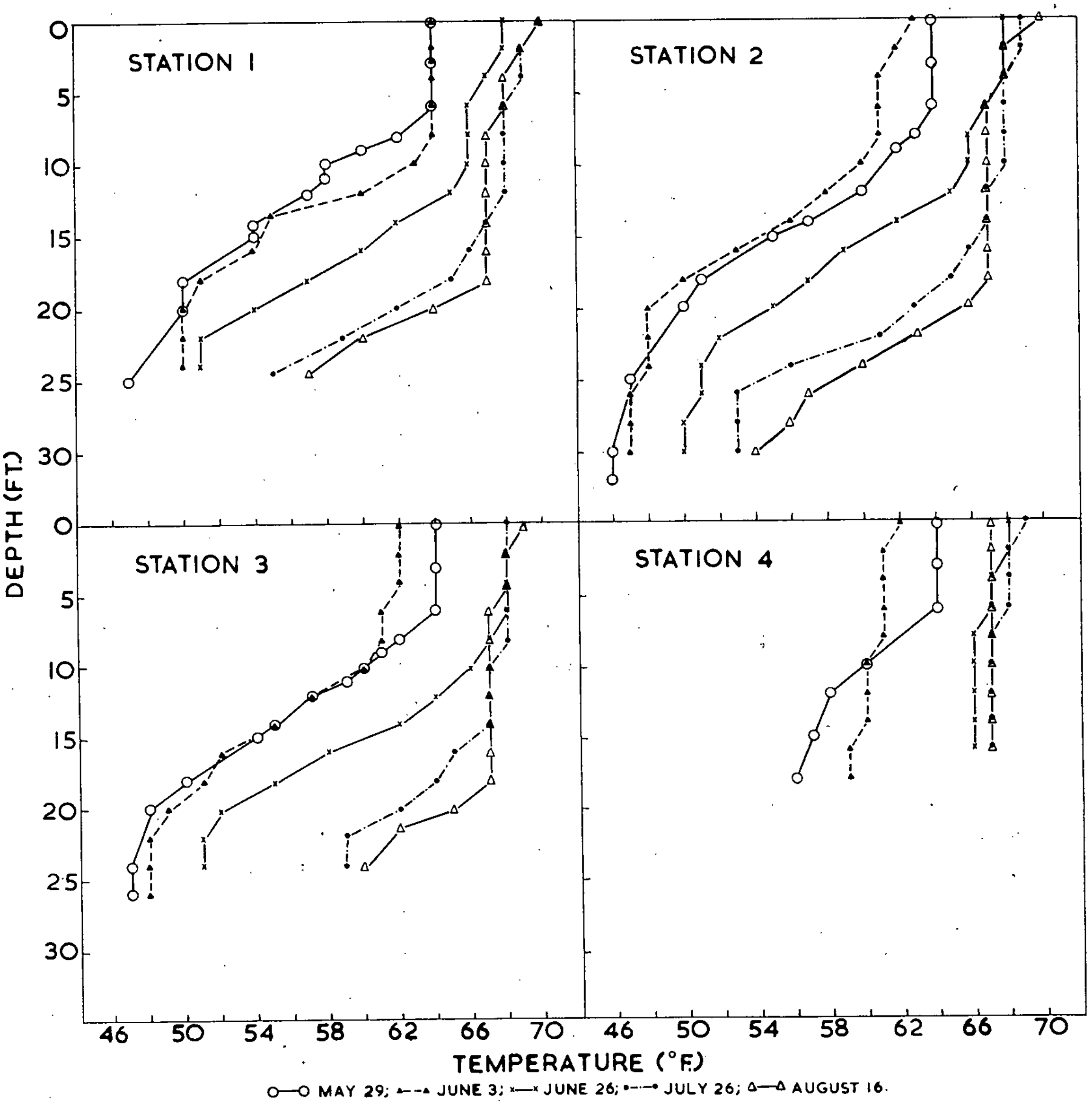

Figure 2. Temperature series for the summer months at four stations.

The thermocline existed throughout the summer at stations 1, 2, and 3. In late May the thermocline extended from 6 to 20 feet, and by mid August it had been displaced down to 18 to 25 feet, which is the bottom at stations 1 and 3. By late July and early August the thermocline was probably effective in sealing off the area below 20 feet from any wind induced circulation.

3. Oxygen Content

Water samples were taken with a Kemmerer bottle and oxygen determinations were done by the Winkler method. Figure 3 shows the oxygen saturation curves, corrected for altitude and temperature for the four stations over the summer period. The curves for May and early June show that a clinograde distribution, as described by Hutchinson (1957) was formed: i.e. total saturation at the surface with a reduction of oxygen with depth. In late June at stations 1 and 2 a positive heterograde distribution formed, with supersaturations up to 120--125 percent, occurring at the 15 foot level. In late July the curves were again clinograde, with a weak positive heterograde distribution formed at station 3. This change from heterograde to clinograde distribution was probably the result of severe wind action. Positive heterograde distributions formed again in mid August at stations 1 and 2, and this time at the 20 foot level. By mid July there was severe stagnation in the area below 25 feet. Station 4 had two periods during the summer in which there was uniform saturation from the surface to the bottom. These two periods corresponded with the formation of the heterograde distributions at station 1 and 2. Ricker (1934) pointed out that supersaturations at depths such as those shown

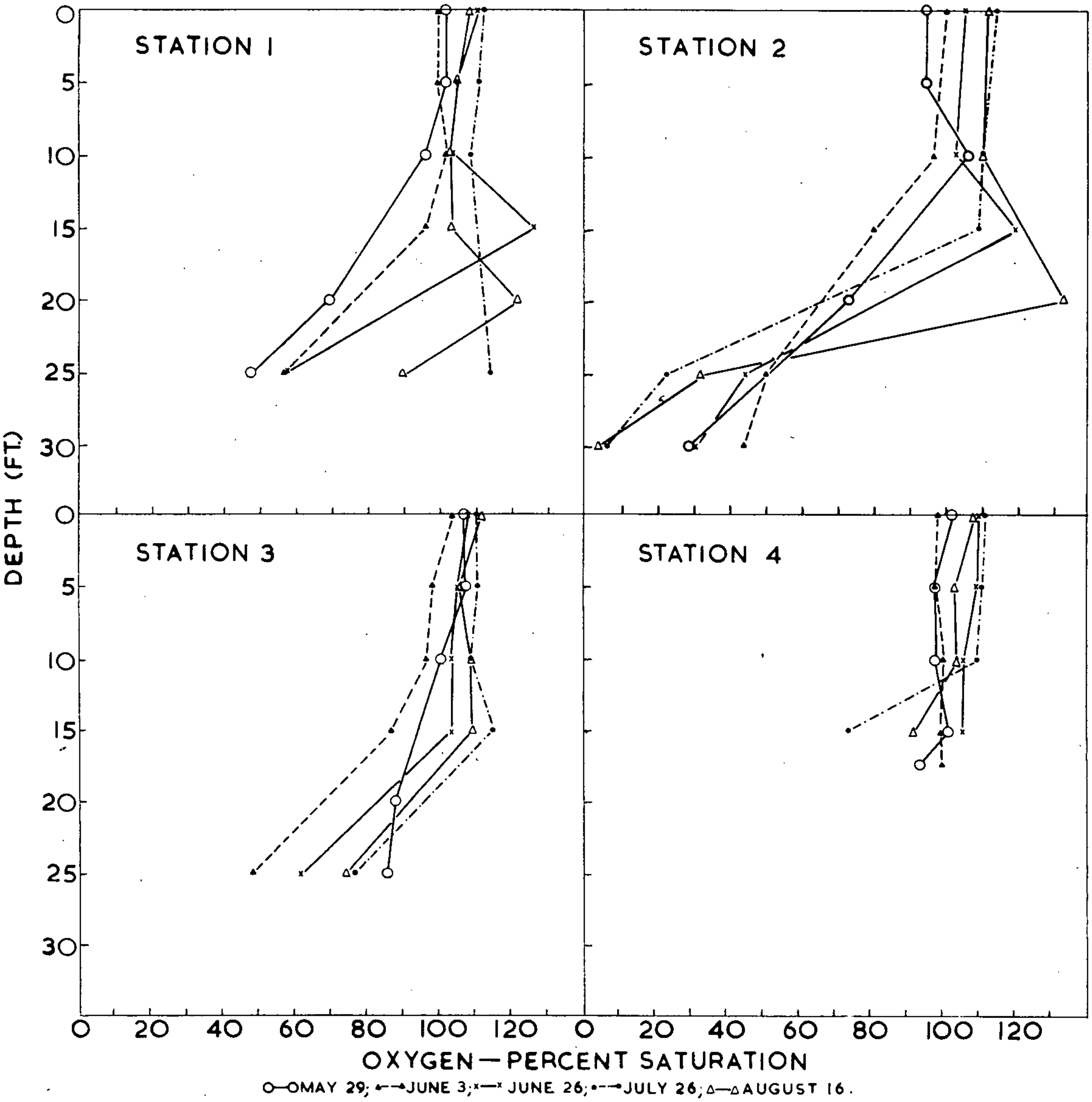

Figure 3. Oxygen series for the summer months at four stations.

in Figure 3, are not absolute supersaturations but apparent supersaturations. Water under the increased hydrostatic pressure, results in increasing the saturation value of that water. In order to have this higher oxygen value at this depth, there must be a source. The small creek, entering the lake from the east side, flowed down a steep rocky hillside for approximately 150 yards. The stream water is probably saturated with oxygen by the time it reaches the lake. The temperature of this stream in mid August was 52°F. This water would probably sink on reaching the lake. As it sinks it would mix with lake water and become warmer, eventually stopping at some intermediate level. The increase in the temperature of this water would result in a supersaturation of oxygen. Since, however the hydrostatic pressure at that depth increases the saturation level of the water, the supersaturation is only apparent and not absolute.

At all stations, by late July and early August there was a small supersaturation in the surface waters. This is probably the result of cooling of the surface waters at night, which allows more oxygen to be dissolved, then a warming of the water in the morning, with no loss of oxygen. This would only be a temporary situation and the first wind action would release the excess oxygen.

B. BIOLOGICAL LIMNOLOGY OF KIAKHO LAKE

1. Flora

There are two common species of plants on the lake bottom—the rooted aquatic, Potamogeton praelongus and the alga Cladophora sp. The distribution of these plants was limited, the Cladophora was found in depths from 12--18 feet in the north basin and 10--25 feet in the northwest corner of the south basin. The Potamogeton was found in depths from 5--12 feet in the north basin and 5--12 feet at the south end of the lake.

2. Bottom Fauna

The bottom samples were taken with a 6 inch Ekman dredge and the material was separated through a screen having 24 meshes to the inch. The species were separated and their volume measured in graduated centrifuge tubes, to the nearest one hundredth of a cubic centimeter. The total number of samples taken was 110.

Figure 4 shows graphically the results of the bottom fauna analysis, of the lake taken as a whole, for the arbitrarily chosen depth zones of 10, 20 and 30 feet, and for the two basins. The graph for the 0--20 foot depth zone of the south basin was included for comparison with the north basin which is 18 feet deep.

The chironomid larvae were scarce in the 0--10 foot zone, were common in the 10--20 foot zone and very abundant in the 20--30 foot depth zone. Gammarus showed the opposite distribution, abundant in shallow waters and rare in the deep waters. Leeches occurred in greatest

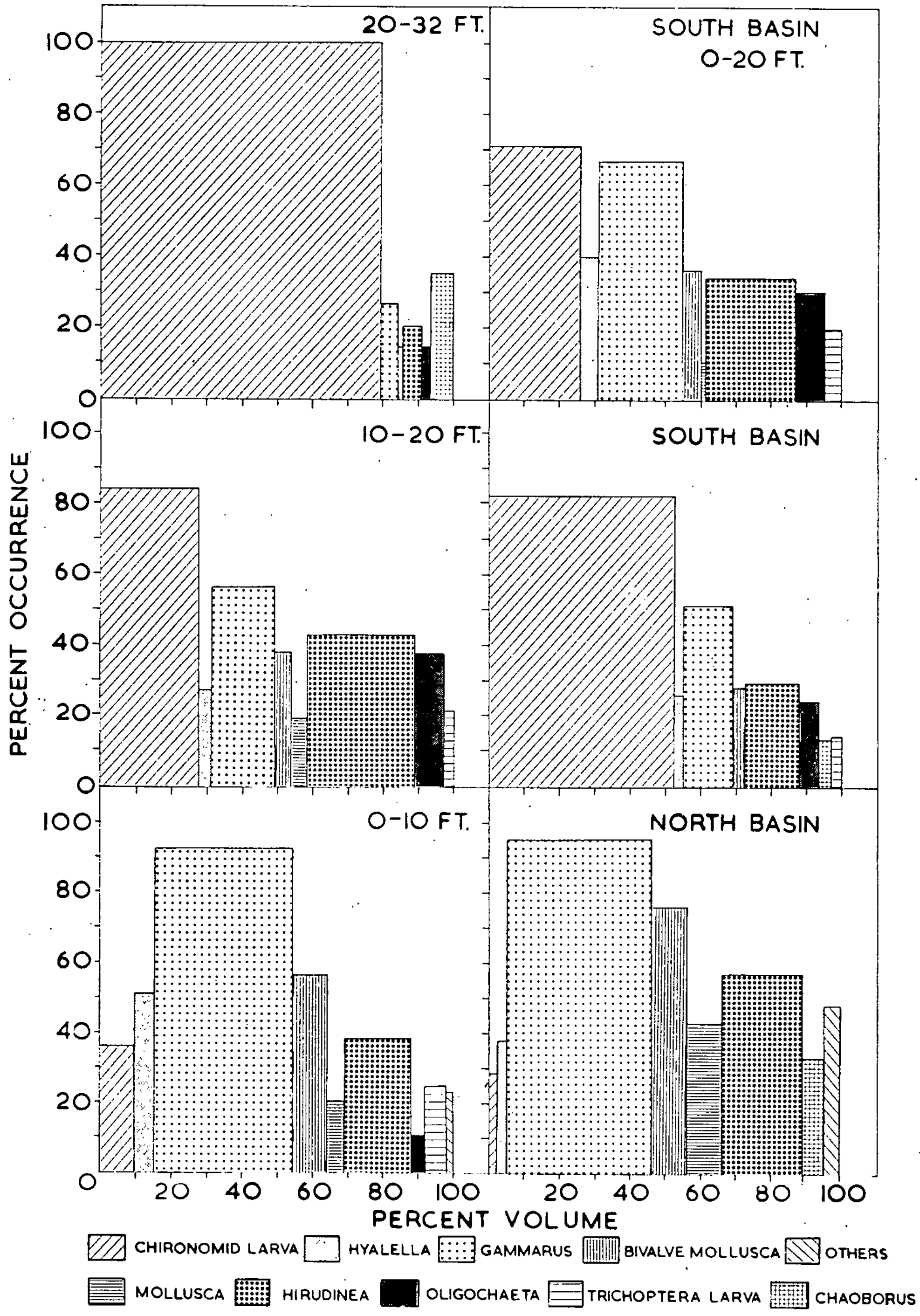

Figure 4. Graphical analysis by percent volume and percent occurrence in total number of dredgings, of the bottom fauna of Kiakho Lake.

numbers in the 10--20 foot zone and were small in numbers in the shallow and deep waters. Figure 4 also shows a comparison of fauna of the north and south basins. The north basin fauna was predominantly Gammarus and leeches, while the south basin fauna was predominantly chironomid larvae. A comparison of the 0--20 foot depth zone of the south basin and the whole north basin, showed that the north basin produced a greater amount of bottom fauna.

Table 2 shows the numerical analysis of the bottom fauna. The fauna of the 0-10 foot zone was made up predominantly of Chironomidae, Hyalella, Gammarus and Mollusca. These organisms accounted for 90.3 percent of the total fauna. The 10--20 foot zone had the same organisms present and the same forms in predominance. The total number of organisms per square meter had shown a considerable decrease. This would appear to be the sublittoral minimum often found in eutrophic lakes (Rawson, 1930). The 20--32 foot depth zone can be considered as the profundal zone, due to the sudden and characteristic faunal change. The dominant forms found here were chironomid larvae (83.6%) and Chaoborus (10.3%) with the other organisms being virtually absent.

Table 3 is the numerical analysis of the bottom fauna of Paul Lake taken from Rawson (1934). Comparing Kiakho Lake bottom fauna with that of Paul Lake shows that the abundant organisms are the same and are of the same general magnitude. The comparison of two different size lakes must proceed cautiously, since many factors affect small lakes, which do not affect large lakes. However, the fact that there is great similarity in the type and amount of bottom fauna, would indicate that the trophic nature of the lakes might be similar, although probably resulting from

TABLE 2. NUMERICAL ANALYSIS OF THE BOTTOM FAUNA OF KIAKHO LAKE

Organisms	Average Number per Square Meter			Percent of Total		
	0-10' (0-3m)	10-20' (3-6m)	20-30' 6-9.8m	0-10'	10-20'	20-30'
Chironomidae	305	606	2,206	16.2	49.3	83.6
Hyalella	464	142	13	24.7	11.5	0.5
Gammarus	559	120	34	29.7	9.8	1.3
Mollusca	370	194	56	19.7	15.8	2.1
Hirundinea	22	22	13	1.2	1.8	0.5
Oligochaeta	112	99	39	6.0	8.0	1.5
Chaoborus	9	11	271	0.5	0.9	10.3
Trichoptera Larva	17	13	3	0.9	1.1	0.1
Nematoda	3	0	1	0.2	0	0.04
Zygoptera Larva	3	9	0	0.2	0.7	0
Ephemeroptera L.	13	9	3	0.7	0.7	0.1
Hydracarina	2	5	1	0.1	0.4	0.04
Megaloptera L.	2	0	0	0.1	0	0
Total	1,881	1,230	2,640	100	100	100

TABLE 3. NUMERICAL ANALYSIS OF PAUL LAKE DREDGING DATA (FROM RAWSON, 1934)

Organisms	Average No. per sq. m. in Depth Zones							#0-20 meters		# whole lake	
	0-5m.	5-10	10-20	20-30	30-40	40-50	50-55	No. per Sq. m.	% of Total	No.per Sq. m.	% of Total
Chironomidae	100	69	945	360	940	560	410	679	28.5	672	49.5
Ampnipoda -											
<u>Hyalella</u>	2149	834	40	+	-	-	-	752	31.7	198	14.6
<u>Gammarus</u>	66	51	510	39	-	40	58	372	15.6	166	12.2
Mollusca -											
<u>Physa</u>	32	180	2	-	-	-	-	28	1.2	7	0.5
<u>Lymnaea</u>	7	42	13	-	-	-	-	15	0.6	4	0.3
<u>Planorbis</u>	5	-	-	-	-	-	-	1	0.0	-	-
Sphaeriidae	40	4	482	990	195	105	17	340	14.7	247	18.1
Odonata -											
Zygoptera	19	67	-	-	-	-	-	12	0.5	3	0.2
Anisoptera	19	-	-	-	-	-	-	6	0.2	2	0.1
Trichoptera	20	44	2	-	-	-	-	12	0.5	3	0.2
Ephemeroptera	4	-	-	-	-	-	-	1	0.0	-	-
Hirundinea	54	49	80	-	-	-	-	75	3.2	19	1.4
Planaria	19	59	45	3	108	10	10	42	1.8	30	2.2
Oligochaeta	29	-	7	5	-	24	10	13	0.5	10	0.7
Miscellaneous	28	+	+	-	-	-	-	8	0.3	2	0.1
All Organisms	2,591	1,399	2,126	1,397	1,243	739	505	2,356	100	1,363	100

two different causes.

Kiakho Lake, being small and shallow, it was anticipated that there would be a high production of bottom fauna. The data had shown that the quantity of bottom fauna is small, and that there is a higher production in the north basin than in the south basin. To explain the paucity of bottom organisms, one must look at the structure and physical nature of the lake basin. The north basin is shallow and the greater part of the bottom is a gentle slope covered with mud, and overgrown with Potamogeton. This basin is virtually isothermal all summer and there is no stagnation. With the rich zone of rooted aquatic plants and the higher production of bottom organisms, this was the only part of the lake which showed signs of littoral development.

In contrast to the north basin, the south basin, has very steep sides and a rocky substrate. There is very little area of shallow mud covered bottom where rooted aquatic plants could grow. The south basin had only the deep water area in which bottom organisms were produced, resulting in the appearance of being the profundal zone of a much larger lake. The low production of bottom fauna in the south basin is probably attributable to the lack of any littoral development. The south basin, in respect to bottom fauna production showed an extreme degree of oligotrophy, while the north basin bordered on mesotrophy.

3. Plankton

Plankton samples were taken in total vertical hauls, with a No. 20 silk Wisconsin type plankton net. Table 4 shows the composition and relative abundance of various organisms. In June the plankton was

TABLE 4. SPECIES COMPOSITION OF THE PLANKTON OF KIAKHO LAKE, AND THEIR RELATIVE ABUNDANCE

June 6		August 16	
Diatoms--*Asterionella*	+++	Desmids--*Staurastrum*	++
Navicula	+		
Fragilaria	++	Diatoms--*Asterionella*	++
Synedra	+	*Navicula*	+
		Fragilaria	+
Blue-Green Algae--		Blue-Green Algae--	
Anabaena	+	*Anabaena*	++
		Aphanocapsa	+
Protozoa--		*Gloeotrichia*	+
Dinobryon	+		
		Green Algae--	
Rotifera--		*Pleurococcus*	+
Anuraea	+	*Tetraspora*	+
Triarthra	+	*Ankistrodesmis*	+
Conochilus	+	Protozoa--	
Asplanchna	+	*Ceratium*	+
Copepoda--		Rotifera--	
Cyclops	++	*Asplanchna*	+++
Diaptomus	+	*Conochilus*	+
Nauplii	+++	*Triarthra*	++
		Notholca	+
Cladocera--			
Daphnia	+	Copepoda--	
		Cyclops	++
		Diaptomus	++
		Cladocera--	
		Daphnia	+++

+++ Very abundant,

++ Common,

\+ Present in small numbers.

dominated by diatoms, rotifers and copepod nauplii. In August the diatoms, desmids, blue-green algae, rotifers, copepods, and cladocerans were abundant. There was a progression from the diatoms and rotifers in the early summer to a rotifer, copepod, cladoceran dominance by late summer.

Table 5 shows the settled volume of plankton from stations 2 and 4. The plankton of the south basin (station 2) reached a peak in volume in late June and then dropped to a constant level in July and August. The plankton of the north basin (station 4) had a smaller settled

TABLE 5. VOLUME OF PLANKTON AT TWO STATIONS, OVER THE SUMMER

Date	Station 2	Station 4
	Vol. in c.c.'s	Vol. in c.c.'s
June 6	0.65	0.55
June 26	1.40	0.70
July 26	1.20	0.55
Aug. 16	1.25	1.90

volume than the south basin, but showed a sudden increase in volume in August. The smaller settled volume found in the north basin is probably due to the depth of water sampled. In the north basin only 18 feet of water was sampled, where as in the south basin, 32 feet of water was sampled.

A comparison of the mean settled volume of plankton on the total dissolved solids from Kiakho Lake, with that found by Northcote and Larkin (1956) for 100 British Columbia lakes, showed a very poor production of plankton. The values of 1.13 c.c. in June and 0.93 c.c. in August for Kiakho Lake, fell below the calculated average of 2.25 c.c. for lakes with 100 p.p.m. total dissolved solids as described by Northcote and Larkin (1956).

An examination of the species composition of the plankton can give an indication of the trophic status of a lake. Rawson (1956) has reviewed and summarized the subject of algal indicators of trophic lake types. Rawson points out that oligotrophic lakes have been characterized by a poor quantity of plankton, many species present in the plankton, and a rarity of water-blooms. Table 6 is a list of the approximate trophic distribution of algae in lakes of Western Canada, according to Rawson (1956).

Kiakho Lake would be considered oligotrophic due to poor production of plankton, the presence of many species in the plankton, and the rarity of water-blooms. A further analysis of the plankton revealed that Asterionella, Fragilaria, and Staurastrum were abundant and Dinobryon was present. All these forms are listed by Rawson as oligotrophic indicators. The blue-green and green algae were represented in the plankton, with Anabaena the most abundant. Ceratium was present, but not abundant. The blue-green algae Anabaena and the protozoan Ceratium are listed as mesotrophic indicators. However, since the oligotrophic indicators were more abundant, the plankton would indicate

TABLE 6. APPROXIMATE TROPHIC DISTRIBUTION OF DOMINANT LIMNETIC ALGAE IN LAKES OF WESTERN CANADA (FROM RAWSON, 1956)

Oligotrophic	Asterionella formosa
	Melosira islandica
	Tabellaria fenestrata
	Tabellaria flocculosa
	Dinobryon divergens
	Fragilaria capucina
	Stephanodiscus niagarae
	Staurastrum spp.
	Melosira granulata
Mesotrophic	Fragilaria crotonensis
	Ceratium hirundinella
	Pediastrum boryanum
	Pediastrum duplex
	Coelosphaerium naegelianum
	Anabaena spp.
	Aphanizomenon flos-aquae
	Microcystis aeruginosa
	Microcystis flos-aquae

that Kiakho Lake was oligotrophic. Rawson (1956) remarks that the use of algal indicators of lake types is still in its infancy and that more investigations are necessary to substantiate their use. It is unfortunate that no such work has been done in British Columbia, where there exists a great diversity of limnological conditions, as pointed out by Northcote and Larkin (1956).

C. TROPHIC DEVELOPMENT OF KIAKHO LAKE

Rawson (1939) indicates that there are probably three major factors affecting the productivity of lakes. These are morphometric, edaphic and climatic factors. Thienemann (1927) and more recently Rawson (1952) support the view that mean depth is a significant index of trophic development of lakes. Thienemann (1927) established the criterion that lakes with a mean depth greater than 10 meters were oligotrophic and those with a mean depth less than 10 meters were eutrophic. According to this criterion, Kiakho Lake with a mean depth of 5 meters would be eutrophic. It has been shown that the low production of bottom fauna and plankton, the lack of littoral development, and the presence of indicator organisms in the plankton indicate that Kiakho Lake is oligotrophic. It is apparent that the oligotrophic state is a result of the limitation by some factor or factors other than morphometry.

The total dissolved solids content of Kiakho Lake is low compared with the average of 285 p.p.m. for the area as calculated by Northcote and Larkin (1956). This low total dissolved solids content is probably due to the very small drainage area, the high precipitation and the general geological composition of the area. It has been indicated previously, that the steep sloped sides of the lake basin with the rocky substrate was not suitable for the production of plant and animal life. This has resulted in little or no littoral development.

It now appears that the factors limiting production in Kiakho Lake are, low total dissolved solids and an unsuitable substrate. Both of these factors would come under the classification of edaphic factors as suggested by Rawson (1939). This indicates that the limitation by certain edaphic factors has resulted in an oligotrophic condition being expressed over a eutrophic morphometry.

D. DESCRIPTION OF OTHER LAKES SAMPLED

1. Monroe Lake

Monroe Lake is situated approximately 12 miles south of Cranbrook, British Columbia. It has a surface area of 230 acres and a maximum depth of 108 feet. The fish species present were, cutthroat trout, rainbow trout, and the cutthroat-rainbow hybrid.

2. Lumberton Reservoir

Lumberton Reservoir is an artificial lake created by a water storage dam, and is located approximately 14 miles south west of Cranbrook. It has a surface area of 59.4 acres and a maximum depth of 6 feet. Cutthroat trout were the only fish present.

3. Garcia Lake

Garcia Lake is situated approximately 8 miles south of Merritt, British Columbia. It has a surface area of 51.4 acres and a maximum depth of 57 feet. Cutthroat trout (*Salmo clarkii clarkii*) and the red-side shiner (*Richardsonius balteatus*) were the only fish present.

FISH

A. FOOD HABITS

Stomach samples of cutthroat trout were collected from Kiakho, Garcia, Monroe and Lumberton Lakes, during the summer of 1958. Kiakho Lake was sampled regularly during May, June and July. The other lakes were sampled in late June and late July. Additional food data on fish from Garcia Lake were taken from the British Columbia Fish and Game Branch files. This material had been collected in June and August of 1957. All the sampling of fish was done with monofilament nylon experimental gill nets with mesh sizes of 1, 1 1/2, 2, 2 1/2, 3, 3 1/2, and 4 inch stretched mesh.

The stomachs collected were placed in cloth sacks, labelled and preserved in 5 percent formalin. The analysis of the stomach contents was done by washing them from the stomach, separating the various constituents and measuring their volume by water displacement in a graduated centrifuge tube.

B. FOODS TAKEN

1. Kiakho Lake

Table 7 and Figure 5 summarize the results of the stomach contents from all of the lakes. Figure 5 shows the monthly change in the diet of Kiakho Lake fish. The food in May in Kiakho Lake was almost entirely chironomid pupae, with *Chaoborus* larvae the next largest item. A change occurred in June to the *Gammarus*-chironomid larvae diet, and by late July the amphipods, *Gammarus* and *Hyalella* were the major food items. This change was probably a reflection of the change in the insect larvae and other aquatic invertebrate populations. The chironomid pupae resulting from larvae which had wintered over one or two years, would be very vulnerable during their emergence. According to Miller (1941) the pupae emerge soon after the ice leaves a lake. When the numbers of emerging chironomid pupae dwindled the fish began utilizing other food sources. The *Gammarus* population would probably be increasing in numbers due to the warming of the water. A population of chironomid larvae were still present and would not emerge until late summer or the following spring (Miller, 1941). This situation could account for the change to a *Gammarus*-chironomid larvae diet. The chironomid larvae show a considerable reduction from the diet between June and July. This is probably due to the stagnation of the 25--32 foot depth area, which Figure 4 shows produces the majority of the chironomid larvae. It has been shown that there is a seasonal variation in the food habits of Kiakho Lake cutthroat trout. This variation appears to be a result of the change in the availability of food organisms.

TABLE 7. STOMACH CONTENTS ANALYSIS FROM KIAKHO, GARCIA, LUMBERTON AND MONROE LAKES

Kiakho Lake								
	May		June		July		August	
	% Occ.	% Vol.	% Occ.	% Vol.	% Occ.	% Vol.	% Occ.	% Vol.
Fish			1.3	0.14	1.4	0.3		
Gammarus	37.5	4.7	46.7	45.8	57.8	60.3		
Hyalella	5.4	Tr.	9.3	2.6	26.8	13.5	50.0	11.0
Chironomid Larvae	10.7	0.16	46.7	35.5	11.3	13.3		
Chironomid Pupae	83.9	81.3	4.0	1.1	9.9	3.3		
Chaoborus	53.6	10.4	16.0	3.8	7.0	1.7	100.0	89.0
Ephemeroptera Larvae			8.0	0.16	16.9	6.4		
Zygoptera Larvae	5.4	Tr.						
Trichoptera Larvae	3.6	0.16	8.0	3.8				
Mollusca	3.6	Tr.	14.7	0.53	19.7	0.6		
Terrestrial Insects	8.9	3.1	2.7	Tr.	4.2	Tr.		
Zygoptera (Adult)			4.0	0.8				
Diptera (Adult)			2.7	0.9	1.4	Tr.		
Hirudinea			4.0	3.7	2.8	0.2		
Dyticidae Larvae	1.8	Tr.						
Notonectidae					4.2	Tr.		
Daphnia			5.3	0.7	1.4	Tr.		
Hydrachnids	1.8	Tr.						
Algae					1.4	0.3		
Wood	1.8	Tr.	4.0	0.5	1.4	Tr.		
Rock	1.8	Tr.			1.4	0.3		
Total Sample Size	62		89		163		5	
Total Volume	193.1 cc.		70.2 cc.		75.4 cc.		0.9 cc.	
Average Volume	3.5 cc.		0.98 cc.		1.1 cc.		0.5 cc.	
No. Empty	6—9.7%		14—15.7%		92—56.4%		3—60.0%	

TABLE 7 (Cont). STOMACH CONTENTS ANALYSIS FROM KIAKHO, GARCIA, LUMBERTON AND MONROE LAKES

	Garcia Lake		Lumberton		Monroe Lake	
	% Occ.	% Vol.	% Occ.	% Vol.	% Occ.	% Vol.
Neuroptera Larvae					3.7	4.0
Fish	27.8	31.9				
Gammarus			51.0	34.4	55.6	78.2
Chironomid Larvae			55.2	13.5	3.7	Tr.
Chironomid Pupae			34.4	7.3	7.4	0.7
Chaoborus	32.9	36.0				
Anisoptera Larvae	5.1	8.4	13.5	11.6	1.9	1.7
Zygoptera Larvae	1.3	0.9	2.1	0.9		
Trichoptera Larvae			11.5	2.1	27.8	13.6
Plecoptera Larvae			2.1	Tr.		
Mollusca			10.8	6.7	7.4	Tr.
Corixidae			28.1	5.1		
Terrestrial Insects	25.3	13.7	14.6	4.4		
Zygoptera (Adult)	1.3	Tr.				
Diptera (Adult)	1.3	Tr.	3.1	0.7		
Dyticidae Larvae			1.0	0.1		
Notonectidae	12.6	0.9	10.4	1.3		
Daphnia	1.3	0.6	1.0	Tr.	3.7	1.1
Chydorinidae			12.5	5.3		
Algae			11.8	6.3		
Wood					3.7	0.4
Anisoptera (Adult)	1.3	0.9				
Copepoda	1.3	1.6				
Total Sample Size	79		102		64	
Total Volume	202.3 cc.		57.6 cc.		30.1 cc.	
No empty			6		10	

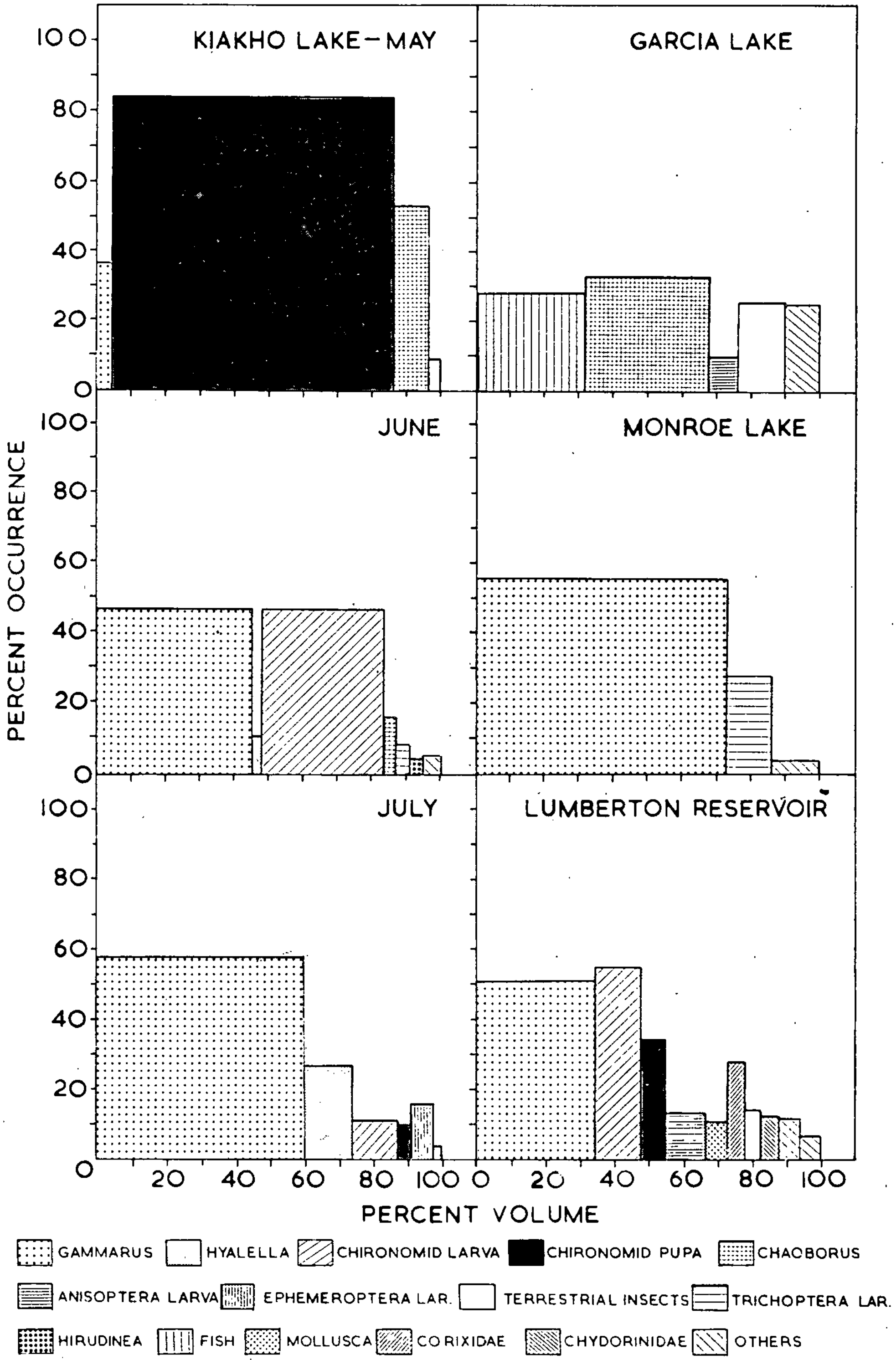

Figure 5. Graphical analysis of the stomach contents of cutthroat trout for May, June, and July in Kiakho Lake and for Monroe, Lumberton and Garcia Lakes.

Only two cases of cannibalism were recorded from 319 stomachs analysed. They occurred in June and July, after the young fish had migrated into the lake from the stream.

There was no apparent difference in the food of different sized fish. The range of size of fish sampled was 15--35 cm. fork length. It was not anticipated there would be a difference in food of different sized fish, since there was a limited number and type of food organisms available.

2. Monroe, Lumberton and Garcia Lakes

The food of the cutthroat trout from Lumberton and Monroe Lakes consisted of *Gammarus* and immature aquatic insects. *Gammarus* was the largest single contributor to the food of the fish from Lumberton Lake, but was only 34 percent by volume, the remaining 66 percent was mostly immature aquatic insects (see Figure 5). There appeared to be no difference in the food of different sized fish. The range of size sampled was 11--38 cm. fork length. Monroe Lake fish fed mostly on *Gammarus* (78 percent by volume), the remaining items were immature aquatic insects, with trichoptera larvae the major element (see Figure 5). The size of fish sampled from Monroe Lake were 19--42 cm. fork length. The fish in Garcia Lake fed mostly on *Chaoborus* larvae and fish (Redside Shiner), with small amounts of immature aquatic insects and terrestrial insects being present (see Figure 5). There appeared to be a definite preference for insect larvae and insects over the Redside Shiner, since the combined results for the insect larvae and insects would be much greater than that of the Redside Shiner.

Dimick and Mote (1934) and Griffiths and Yoeman (1940), working on coastal cutthroat found the majority of their food consisted of terrestrial insects and immature aquatic insects, of which the majority were dipteran larvae and pupae. They found that fish were an insignificant element of the diet.

Echo (1955); Hazzard and Madsen (1933); Hildebrand and Towers (1927); Irving (1954) and Robertson (1947), working on Yellowstone cutthroat trout, all found that the food was predominantly immature aquatic insects (mostly dipterans), amphipods and terrestrial insects. Hildebrand and Towers (1927) and Calhoun (1944b) found cutthroat trout using substantial amounts of microcrustaceans in mid and late summer.

Calhoun (1944b) working with the cutthroat trout (Salmo-clarkii henshawi) found the majority of the food was chironomid pupae and larvae. He also noted that the trout failed to use the minnow Rhinichthys oscula, which was very abundant in the lake. Hazzard and Madsen (1933) reported that from one lake, fish contributed 67 percent, by volume to the diet of the cutthroat. Echo (1955) found 40 percent of the cutthroat stomachs contained fish.

To generalize, the food of the cutthroat trout is predominantly immature aquatic insects, terrestrial insects and amphipods. Gammarus and dipteran larvae and pupae are the greatest contributors to the food. Fish occur in the diet, but appear to be a second choice to the insects. Dimick and Mote (1934) studied rainbow trout along with cutthroat and found their diets were virtually the same. In comparing the results of this investigation with those found by Larkin and Smith (1954) on rainbow trout for 1946--49, there is no difference between the diet of rainbow and cutthroat trout as shown by these studies. It now appears that Yellowstone cutthroat trout at least in the lakes studied in British Columbia, is no more piscivorous than the rainbow trout, but in fact has virtually the same diet. For this reason it would be doubtful that the cutthroat would make better use of coarse fish as a food than rainbow trout.

Larkin and Smith (1954) described the effect of redside shiner on rainbow trout, pointing out that the shiner was a severe competitor of the trout. Calhoun (1944b) noted that the minnow *Rhinichthys oscula* utilized the same food as the young cutthroat, but itself was not part of the cutthroat diet. He advised against the use of it as a forage fish, due to the possible competition with the young trout. The results indicate that cutthroat trout would react to coarse fish populations the same as the rainbow trout as described by Larkin and Smith (1954).

C. CHANGES IN STOMACH CONTENTS VOLUME

Figure 6 shows the change in average stomach volume and number of empty stomachs over the summer for fish from Kiakho Lake. There was a sudden drop in the average volume when the diet changed from chironomid pupae to *Gammarus* and chironomid larvae. This decrease may be a reflection of the availability in numbers of the particular organisms. Another drop occurs in the volume on the change to an almost complete amphipod diet. Calhoun (1944b) found a similar drop in average volume when the fish changed their diet. The number of empty stomachs increased rapidly between June and July and then levelled off in August.

The lower average stomach volume and increased number of empty

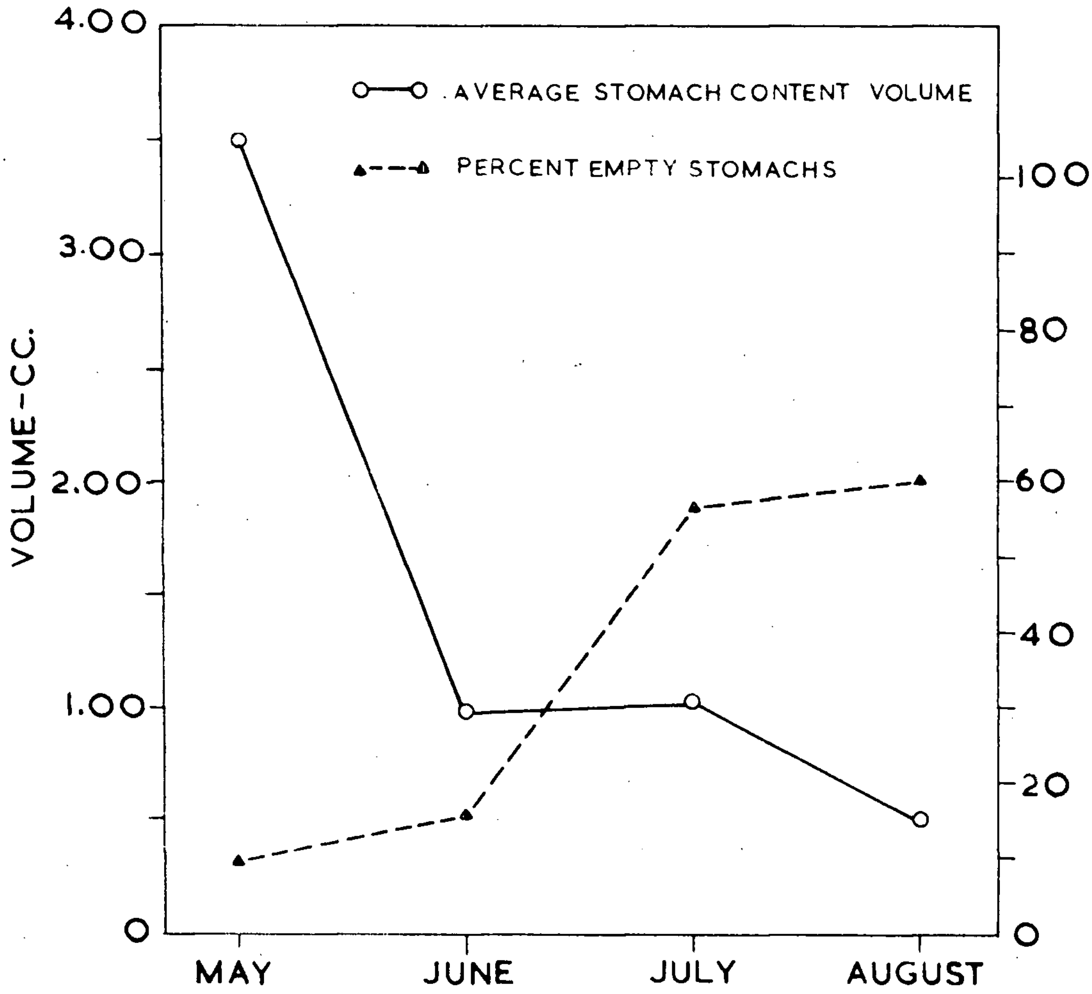

Figure 6. Change in average stomach volume and number of empty stomachs over the summer period, in Kiakho Lake.

stomachs may be in part a result of the water temperature and the method of sampling. All of the samples were taken with gill nets, in which fish will live for varying lengths of time after being caught. The water temperature is at the summer maximum in July and early August. With the increased water temperature, the fish (being poikilothermic) would have an increased physiological activity. Maltzan (1935) found that young carp, passed food through the alimentary canal much quicker at higher water temperatures. This would indicate that fish caught in a gill net could empty their digestive tract more quickly in midsummer, thus appearing that the feeding activity had been reduced. Other factors such as the decrease in availability of food, and a decrease in feeding activity at higher water temperatures may contribute to the phenomena. A study of short term growth e.g. weekly growth, could conceivably reveal whether fish have a reduced feeding activity. With the water temperature high, the physiological activity would be high, and a reduction in feeding should be reflected in a reduction of weight. With the higher physiological activity and the reduced feeding, a utilization of body fat would be required to maintain the energy supply.

D. AGE AND GROWTH

Scale samples used for age and growth determinations were taken from fish caught in the lake, and from fingerlings taken in the outlet stream. The scales were sampled from a standard area on the fish, from the left side between the insertion of the dorsal fin and the lateral line. Determinations of age and growth were made from reading scale impressions made on cellulose acetate strips by use of a jeweller's press.

1. Size at Scale Formation

The smallest fish that had scales was 3.5 cm. fork length and the largest fish without scales was 4.3 cm. fork length. Brown and Bailey (1952) found young cutthroat trout form their scales at approximately 4 cm. fork length. The first annulus was difficult to determine, and an examination of the yearling upstream migrant scales revealed that there were 5--8 circuli contained within the first annulus. Brown and Bailey (1952) found young fish wintering over only partially scaled or without scales and as a result some fish had scales showing none or one annulus, and some fish were a year old before the scales formed. This was not found in Kiakho Lake fish.

2. Body-Scale Relationship

The relationship between fork length and scale diameter was worked out to form a basis for back calculating lengths. Figure 7 shows the results of the body-scale relation. The line shows an inflection at 5 cm. fork length, suggesting the initiation of isometric growth between scale and body dimensions. Smith (1955) found a similar inflection at 4.5 cm. fork length in the coastal cutthroat trout. The line above 6 cm. fork length is described by the formula;

$$\log Y = 1.284 + 1.033 \log X$$

The slope, 1.033 was tested by a "t" test to determine if it was significantly different from a slope of 1. The value fell on the line between significant and nonsignificant. For convenience of calculation the line

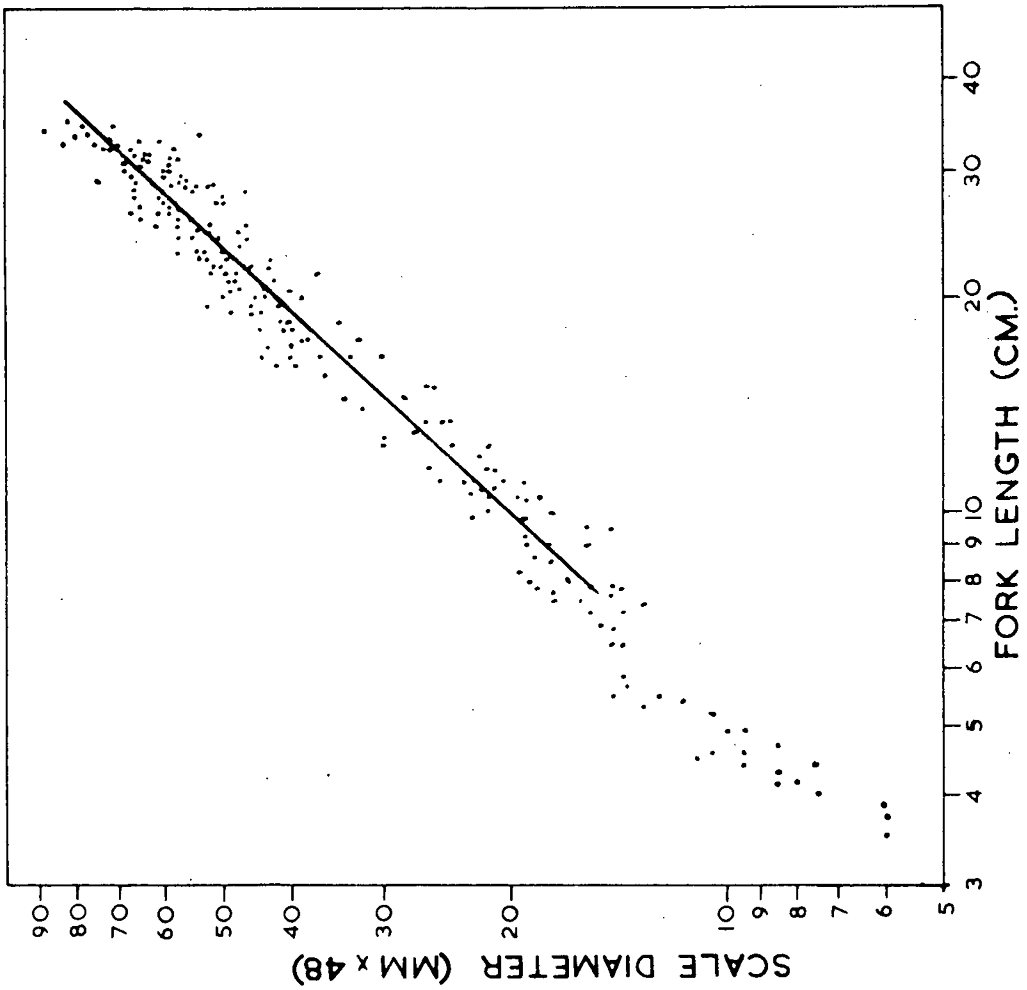

Figure 7. Body-scale relationship.

was assumed to have a slope of 1. With this slope, back calculations were done by direct proportion as described by Smith (1955).

Irving (1954) described the body-scale relation of cutthroat trout as a parabola. The data presented in his paper could have been adequately described with a straight line. Fleener (1952) also described the body-scale relation of cutthroat trout as a parabola. His data showed an apparent curvature and his calculated parabola was almost a straight line. A straight line would appear to describe his data as well as a parabola. Smith (1955) found a straight line relationship for coastal cutthroat trout.

3. Growth Rate

The instantaneous growth rate ($\log_{10}$ of length at age n + 1 minus $\log_{10}$ of length at age n) was calculated for all year classes and plotted against length at the beginning of the growing season. Figure 8 shows the resulting graph plotted on arithmetic axes. To analyse the percent variation in growth rate between small and large fish, the points were plotted on a graph with the ordinate (growth rate) in a logarithmic scale. This transformed the data into a straight line regression which indicated that the percent increase in a unit measurement of length was much greater in small fish than in large fish. To correct for body size, both axes of the graph were made logarithmic. Figure 9 shows this graph. This made it possible to make direct comparisons of growth rate between large and small fish. Despite the correction for body size, there was still a greater variation in the growth rate of smaller fish. It was evident that the variation in growth rate became less as the fish increased in length. The negative slope of the scatter of points is an expression of the decrease

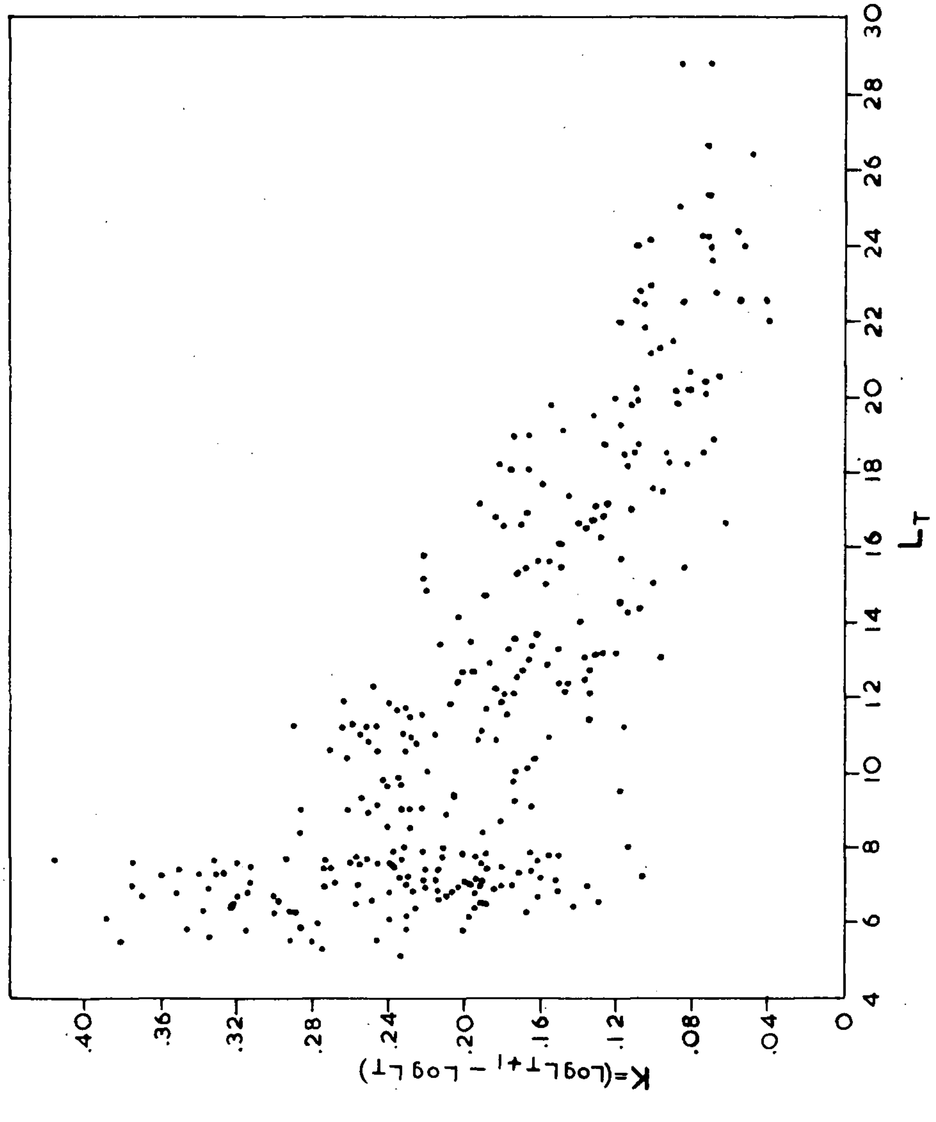

Figure 8. Instantaneous growth rate ($\log_{10}$ fork length at age $n+1$ minus $\log_{10}$ fork length at age n) in relation to fork length at the beginning of the year for cutthroat trout in Kiakho Lake.

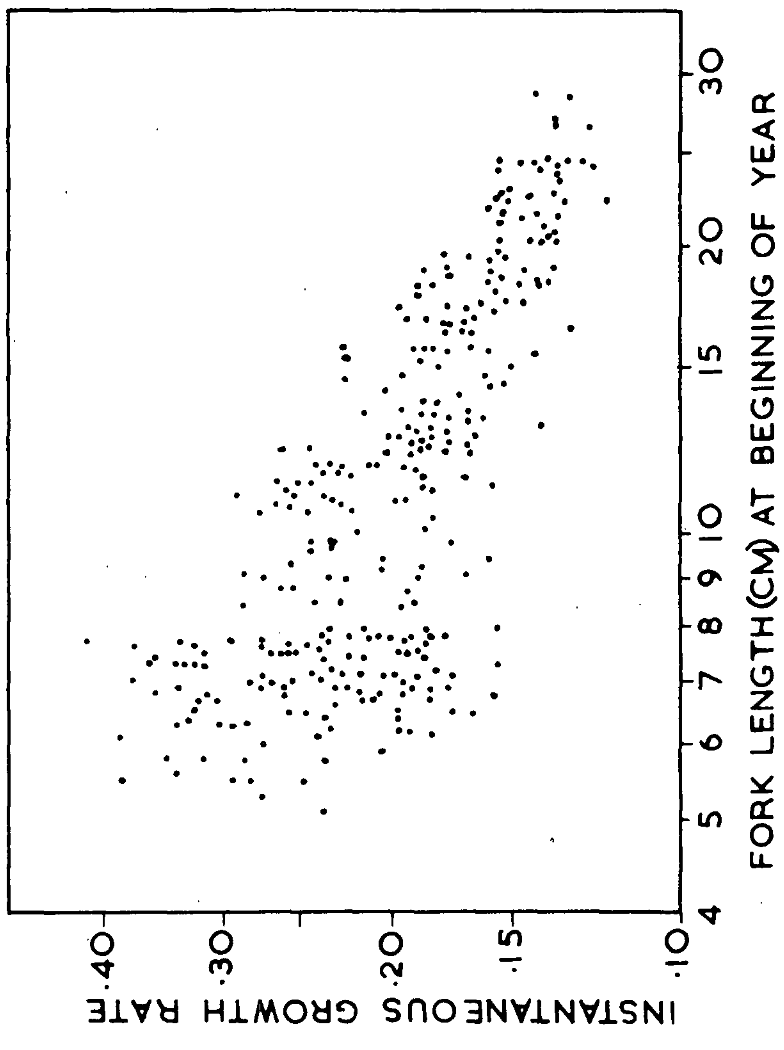

Figure 9. Log_{10} instantaneous growth rate in relation to log_{10} fork length of cutthroat trout in Kiakho Lake.

in growth rate with an increase in length.

The point or body length to which the graph converges, or the size at which there is least variation, might be considered the ultimate size attainable in the particular ecological situation and relative population density. This size is not the maximum size of the fish sampled, it is smaller, and results from the method of analysis. Since growth is a measure of gain in size (e.g., length) between two different sizes, it is referred to the smaller size or the size at the beginning of the rapid growth period.

An examination of the graph shows that the slope of the upper limit of the scatter of points is much steeper than that of the lower limit. This would indicate that the rate of decrease of growth rate is faster in fast growing fish than it is in slow growing fish. If the rate of decrease of growth rate were constant for both slow and fast growing fish, then it would be expected that the slope of the upper limit of points would be parallel to the slope of the lower limit. However, it appears that the ecological situation and relative population density can impose an "ultimate size" on fish, which results in a great reduction in growth rate. It follows then that fast growing fish would reach this ultimate size much more quickly than the slow growing fish and subsequently have a faster decrease in growth rate.

The decrease in growth rate of the faster growing fish in Kiakho Lake had the general form of a straight line, having a negative slope. MacLeod (1958) represented the growth of rainbow trout in a similar fashion, but there was one notable difference. The decrease in growth rate of the faster growing fish was represented in his graph by a concave curve.

Figure 10 shows MacLeod's graph. He explained this concavity as a reflection of the selection of the faster growing fish, by the fishery. The results found from the Kiakho Lake fish appear to support MacLeod's premise. There has been no fishery on Kiakho Lake for a long time, and the rate of decrease of growth rate showed no concavity as found by MacLeod.

The back calculated length of the four year old fish were fitted with a parabolic growth equation (Parker and Larkin, 1959). The exponent z was found to have a value of 0.71 for the cutthroat trout. Parker and Larkin found z equal to 0.60 for the freshwater growth of steelhead trout (Salmo gairdneri). Figure 11 shows a Walford plot of the four year old fish, and the transformed Walford plot with the axes adjusted to the exponential 0.71 according to Parker and Larkin. The transformed plot has adjusted the data so it is parallel to the 45 degree line, but an inflection is suggested at approximately 7 cm. fork length. Parker and Larkin (1959) take the view that changes in z, or rate of change of slope of the curve are reflections of physiological changes. Martin (1949) found inflections in relative growth curves and related them to ossification and maturity. The inflection at 7 cm. fork length in cutthroat trout growth would seem too small for maturity and possibly too large for ossification. The 7 cm. fork length corresponds to the size of the fish when they migrate from the stream into the lake. This change in environment may involve a change in some physiological activity. The inflection may be related to a size at which some physiological change occurs. Parker and Larkin (1959) indicated that a study of size specific metabolic rates to measure the exponent x could be a new

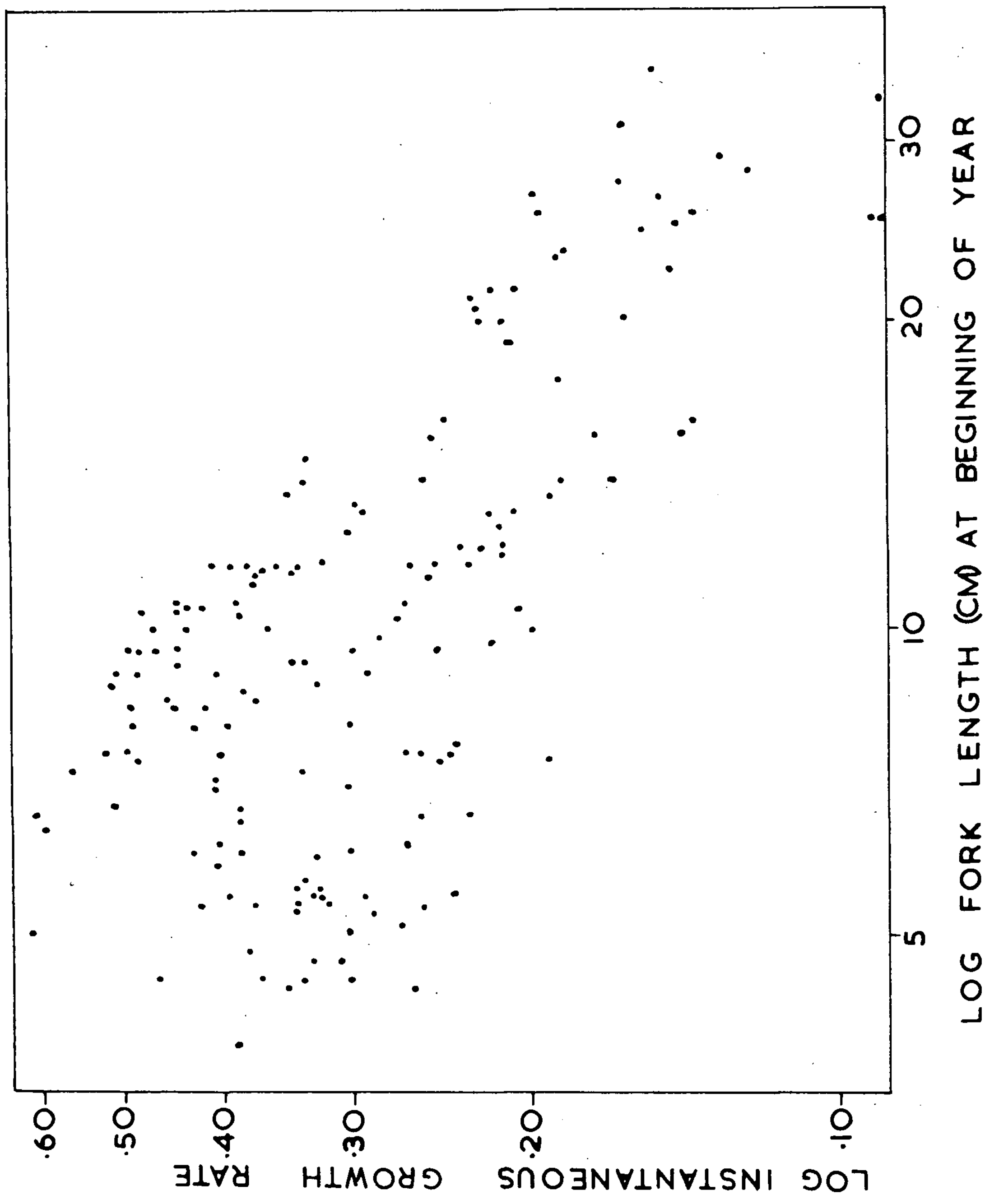

Figure 10. $\log_{10}$ instantaneous growth rate plotted against $\log_{10}$ of fork lengths for rainbow trout in Pinantan Lake (MacLeod, 1958).

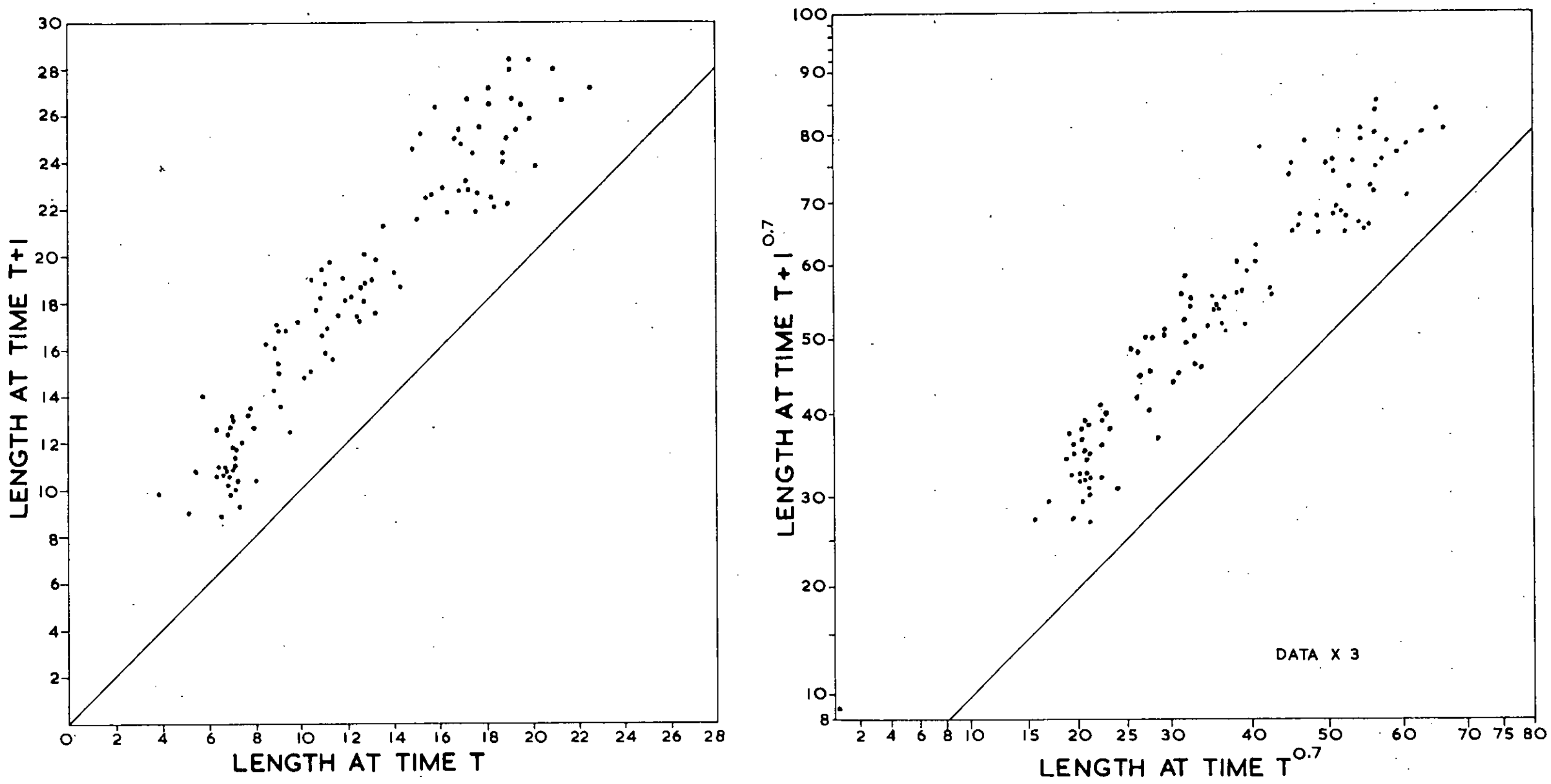

Figure 11. Walford plot of fork length at time T + 1 against fork length at time T and a Parker and Larkin transformed Walford plot with exponent 0.7, for four year old cutthroat trout from Kiakho Lake.

avenue of research. This inflection may be related to some change in the standard metabolic rate.

4. Lee's Phenomenon

When the determination of growth of fish has been done by back calculations from scale measurements, there often appears to be a change in growth rate, especially in the older fish. This change in growth rate was thoroughly studied by Lee (1912) and has subsequently been known as "Lee's Phenomenon". The phenomenon can be described simply as; the older fish appear to have grown more slowly in their younger years than the present young fish.

The average lengths at various ages were calculated for different age classes of fish from Kiakho Lake. Table 8 and Figure 12 show the results.

TABLE 8. AVERAGE LENGTHS IN CENTIMETERS, AT DIFFERENT AGES IN VARIOUS AGE CLASSES

Age	AGE CLASSES					
	I	II	III	IV	V	VI
I	6.8	6.9	7.4	7.2	7.1	6.4
II		13.7	13.0	11.7	11.6	14.4
III			19.0	18.1	18.8	17.5
IV				25.0	24.0	23.6
V					29.3	27.7
VI						33.2

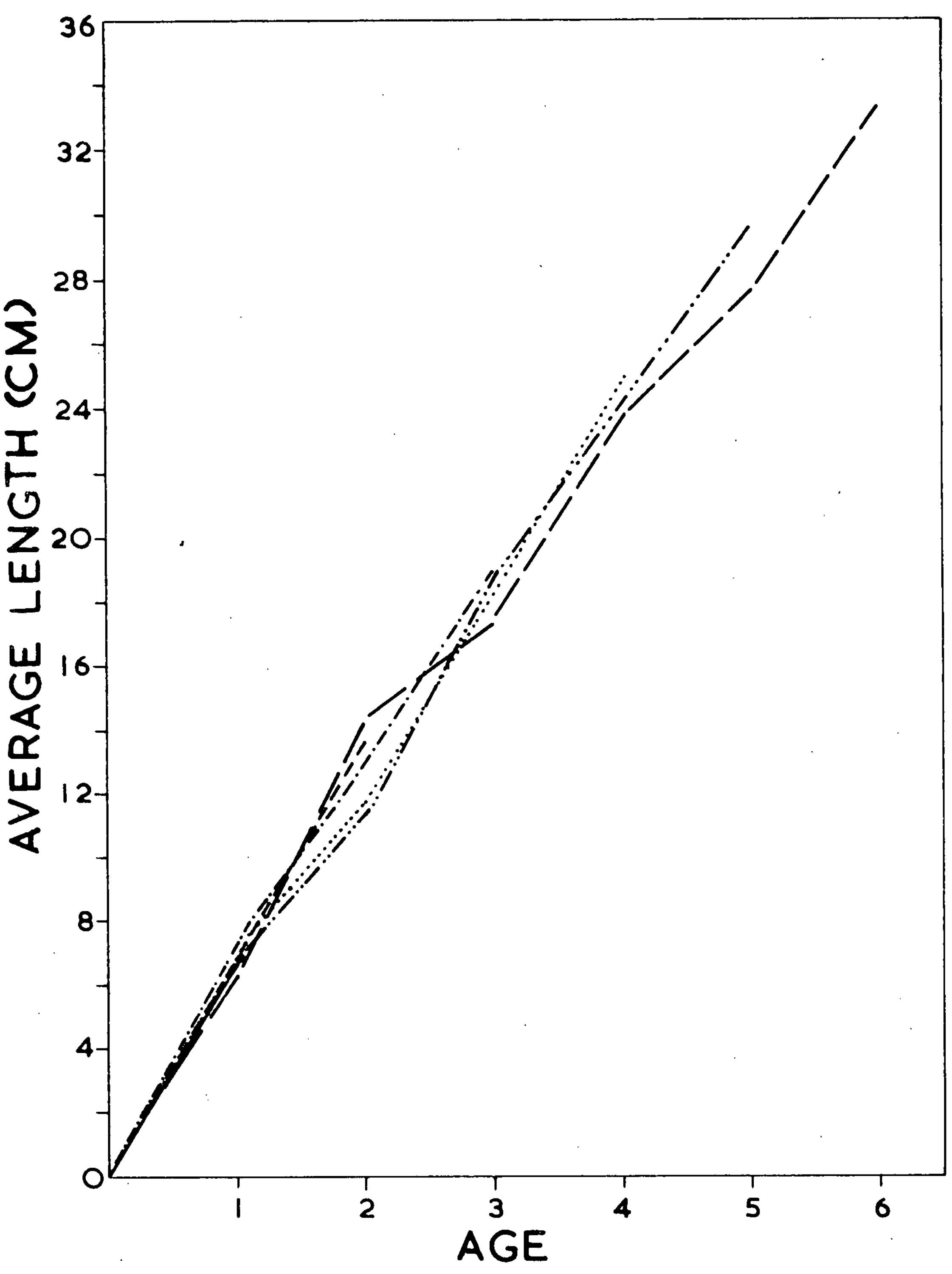

Figure 12. Relation of average fork length of age classes to age.

It is obvious from Table 8 and Figure 12 that Lee's Phenomenon did not exist in Kiakho Lake fish. The six year old fish showed a slight indication of slower growth, but not enough to be considered indicative of Lee's Phenomenon.

Van Oosten (1929) listed seven possible explanations purposed by Lee (1912) for the phenomenon. They are:

1. The sample of fish are not representative of a year group; that is, the youngest year groups are represented only by their biggest individuals, and as we proceed toward the older groups there appears more and more of those that had been smaller individuals in their earliest years, so that the average sizes of the older groups tend to show a less increment of growth and a levelling in values is attained. This Lee termed the "selective effect of size".

2. The nets are selective, retaining only the largest fish of the youngest year group and excluded the largest fish of the oldest year group.

3. Conditions of growth are improving and the fish actually are growing more rapidly at present.

4. Females and males that have different growth rates are present in varying proportions.

5. The scales, especially the flexible newest part, contract when new increments are added.

6. A part of the scale is absorbed in the maturation of sex organs during the spawning period, as, for example in the salmon.

7. Occasionally more than one ring forms per year.

Lee (1920) pointed out that scales do not form until the fish has attained a certain size. This, she indicated, does introduce some error into the calculations, and suggested that it should be corrected, by subtracting this length from the length of the fish before back calculations are made. Hile (1936) advanced more ideas about the cause of Lee's Phenomenon. In summary they are:

1. Selection by gear. This is the same as Lee's (1912) suggestion that only the largest members of the youngest age group are sampled.

2. Selection due to dissimilar distribution. This proposal was based on the idea that fish at different states of maturity or of different size had different spatial distributions and were subsequently not equally represented in the sample.

3. Selection due to differential mortality. Hile suggested that faster growing fish matured sooner and died sooner, thus the older fish were the slow growing element of the population.

Jones (1958) expanded on Hile's idea of differential mortality and pointed out that a fishery could be a major factor in producing it. His idea was that faster growing fish became available to the fishery sooner and were selected out of the population.

The fact that Lee's Phenomenon did not exist in the growth of Kiakho Lake fish would indicate that the reasons given by Lee (1912) and Hile (1936) were not valid for this particular population. Since no fishery existed on Kiakho Lake, Jone's (1958) proposal that a fishery could be a factor in producing the phenomenon cannot be rejected. Larkin and Smith (1954) found the phenomenon in rainbow trout in Paul Lake. This population of fish had been subject to a fishery for a considerable length of time. It would be desirable to study a similar population of cutthroat trout in order to determine if a fishery could cause Lee's Phenomenon.

E. SPAWNING RUN

1. Time and Place

Cutthroat trout, like many salmonids require running water for spawning. Smith (1941) has described the spawning behaviour of cutthroat trout. The spawning run of Kiakho Lake cutthroat trout occurred in the outlet, being the only suitable stream in the system. The run began in late April and continued almost the whole month of May. The first fish were observed to move into the outlet on April 27. This time corresponded with the break up of the ice cover on the lake, which occurred on April 28. Calhoun (1944a) and Irving (1954) observed that cutthroat spawning runs began within a few days of the ice cover break up.

A trap had been installed about 20 feet downstream from the lake, and was used as an egg taking station. The first eggs were taken on May 1 and Table 9 is a summary of the eggs taken in 1958.

TABLE 9. NUMBERS OF EGGS TAKEN IN 1958 AT KIAKHO LAKE

May 1	95,000
May 3	115,000
May 5	143,000
May 10	155,000
May 12	79,000
Total	668,000

The male fish were held from the beginning of the run, to insure having enough for later fertilization. "Green" females were released downstream and ripe females were "stripped" and also released downstream. Egg taking was stopped on May 12 when approximately 700,000 eggs had been taken.

Spawning took place in approximately the first mile and one half of the stream. A reconnaisance was made down stream for about two miles, and the last fish were seen about a mile and one half from the lake. The section of the stream which was used for spawning consisted of erratically spaced patches of fine gravel, interspaced with a fine mid bottom. The hatchery workers had put a picket barrier across the stream about 200 yards below the lake, to stop fish from going down into old placer mining pits. Previously, fish had been observed trapped in these pits, where they eventually died (Varty, pers. com.). The barrier was no longer effective, since the stream had undermined it.

2. Movement and Mortality

A tagging program was initiated to evaluate the movement of the spawners, the population size and the mortality of the spawners. The tagging began on May 12 with 199 Petersen disc tags being put on and the fish released downstream. An additional 99 disc tags were put on, on May 13. All marking from this time on was done by fin clipping. Fish which were put downstream had their right pelvic fin clipped off and fish put upstream had their adipose fin removed. The tagged and marked fish were not representative of sex ratio, since many of them were males which had been held for egg fertilization.

The trap (Fig. 13) was changed on May 13, to accommodate both downstream and upstream migrants. Fine wire screen was installed to stop

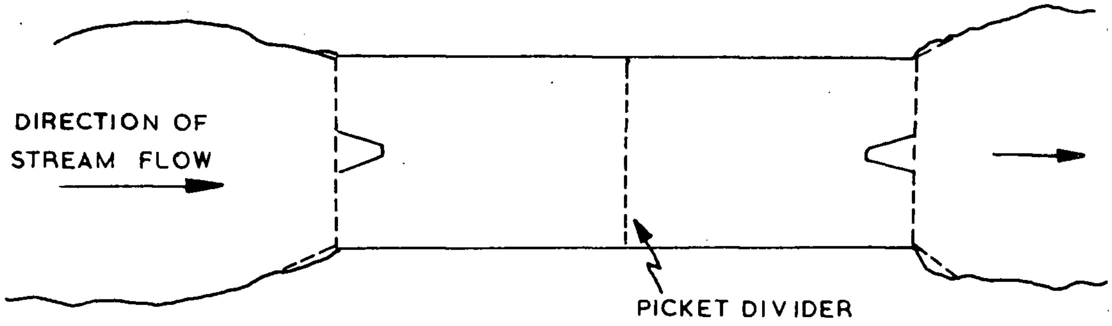

Figure 13. Diagram of trap facilities.

small fish from passing through it. The first fish returned on May 13 and continued to do so until May 26, when the run abruptly stopped. This abrupt stop may have resulted from a barrier caused by dropping water level or by a temperature barrier.

The total size of the spawning run can only be estimated, since many fish had been released downstream before the study began. Table 10 and 11 show the number of fish tagged and fin clipped and the number which returned. From this it can be calculated by direct proportion the number of unmarked fish that went downstream by the number which returned. Using this figure plus the known number of marked fish, the size of the run was estimated at 3,000 fish.

Table 10 and 11 and Figure 14 show that the fish spent from

TABLE 10. DATE AND NUMBERS OF PETERSEN DISC TAGGED FISH PUT UPSTREAM ON COMPLETION OF SPAWNING

Date	With Tags	Lost Tags	Total
May 13	5		5
14	3		3
15	5		5
16	6		6
17	3		3
18	7		7
19			
20	13		13
21			
22	19	9	28
23	12	11	23
24	21	7	28
25			
26	19	8	27
27			
28			
29			
30			
1			
Total	113	35	148

Total disc tags released down stream = 298

TABLE 11. RESULTS OF FIN CLIP MARKING PROGRAM

Date	R.V.C.*	A.C.*	R.V.C. and A.C.
May 13	36	27	
14	69	4	
15	59	91	
16	28	84	
17	33	81	8
18			
19	37	76	9
20	36	92	6
21			
22	37	93	26
23	8	193	46
24	16	87	27
25			
26	13	91	22
27		15	
28			
29			
30		3	
June 1			
2	10	3	
Total	382	940	144

*R.V.C.--Right Ventral Fin clipped--Fish moved downstream.

**A.C.--Adipose Fin Clipped--Fish moved upstream.

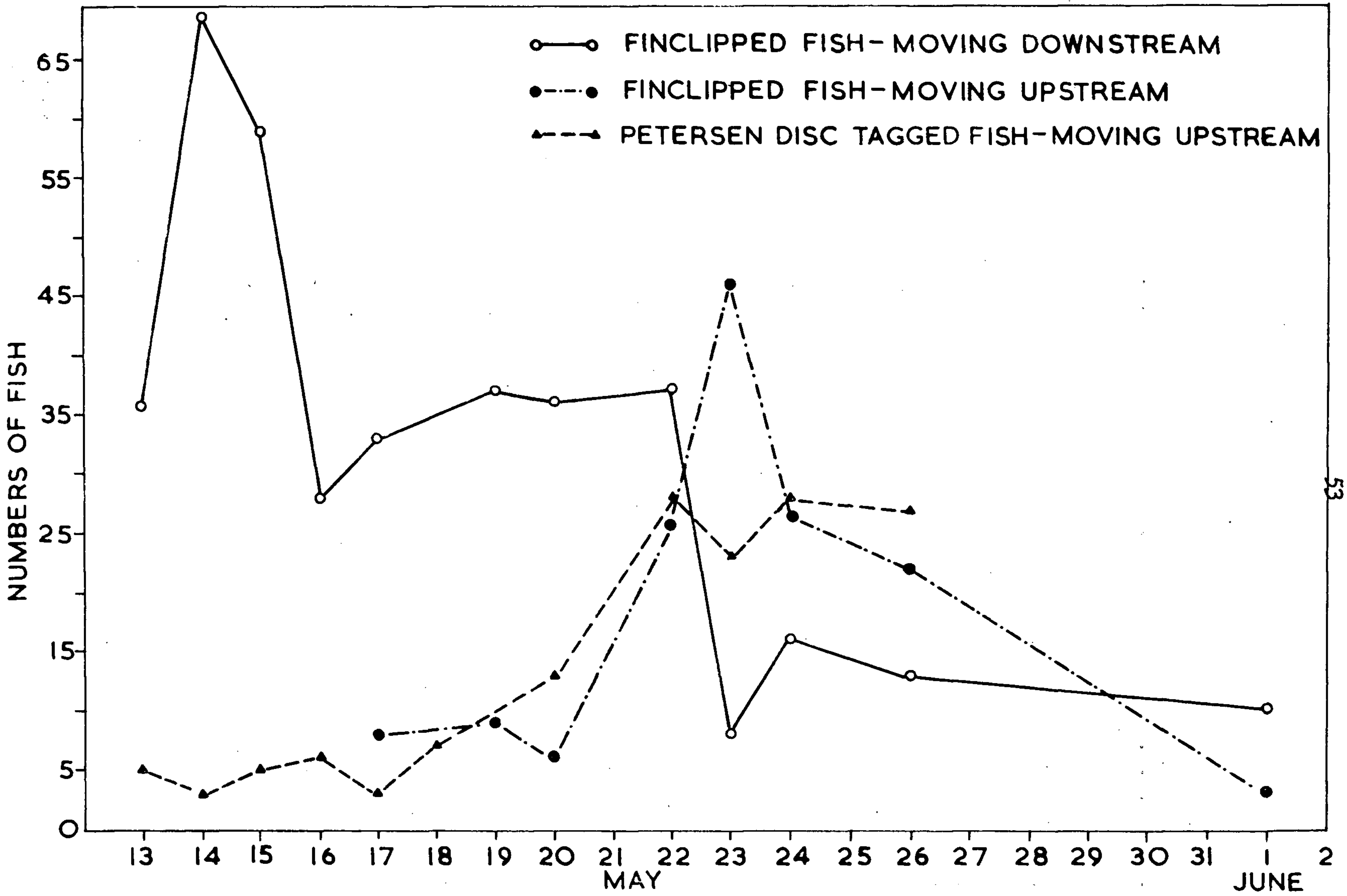

Figure 14. Daily numbers of fin clipped marked fish and disc tagged fish moved through the trap.

10--13 days downstream before returning. There are two estimates of mortality for the fish during this time. One estimate from the Petersen disc tagged fish and one from the fin clipped fish. There was a 50.40 percent mortality in the disc tagged fish and a 62.31 percent mortality in the fin clipped fish. An examination of the time of release of the fin clipped fish showed it was later than that of the disc tagged fish. With the sudden stop of upstream migrants on May 26, it meant that the probability of the return of fish released near the 26th would be lower. To compare the mortalities of the two tagging methods, the fin clipped fish data must be adjusted for the lower probability of return. To adjust this data, the disc tag data was used as a basis. An accumulated percentage return for each day was calculated. Any fish released 13 days before the last day fin clipped fish were released, were considered to have a 100 percent chance of returning. The figure of 13 days was chosen, as it appeared to be the average maximum time spent by fish in spawning. The probability of return of fish released less than 13 days before the final day was calculated by using the accumulated percentages for days after release as calculated from the disc tag data. This calculation gave an answer of expected fish available for return and was 318 fish instead of 382 as might have been supposed if the correction had not been used. Using this corrected value, the mortality of fin clipped fish was 54.8 percent. This value is not significantly different to the disc tagged fish mortality (50.44%) as shown by a chi square test.

Mortality as used in this text, is a collective term embodying actual death of fish and fish which were not accounted for and were not necessarily dead. Of the 298 disc tagged fish released, 113 with tags and 35 which lost tags were returned to the lake. There were 26 tagged fish known dead, leaving 124 fish unaccounted for. Explanations for these unaccounted fish may be: (1) they died and were not found and recorded, (2) lost tags and were not recorded and, or (3) went downstream and moved out of the system.

3. Size Composition and Sex Ratio

Figure 15 shows the size composition of sexes in the run on various dates. The females are definitely smaller later in the run, and the males show a slight trend to being smaller later in the run. The mean sizes indicate that the males are slightly larger than the females. The number of males show a rapid decrease early in the run, but the females continue to go down in relatively large numbers. Irving (1954) found that the majority of the males migrated slightly earlier than the females.

The sex ratio was calculated from the fish sampled by gill nets. It was assumed that there was no selection for either sex by the nets, and positive identification of sexes was possible. The sex ratio came out as 230 females for every 100 males. This would appear that there is a heavy mortality on males, and it is probably during spawning time.

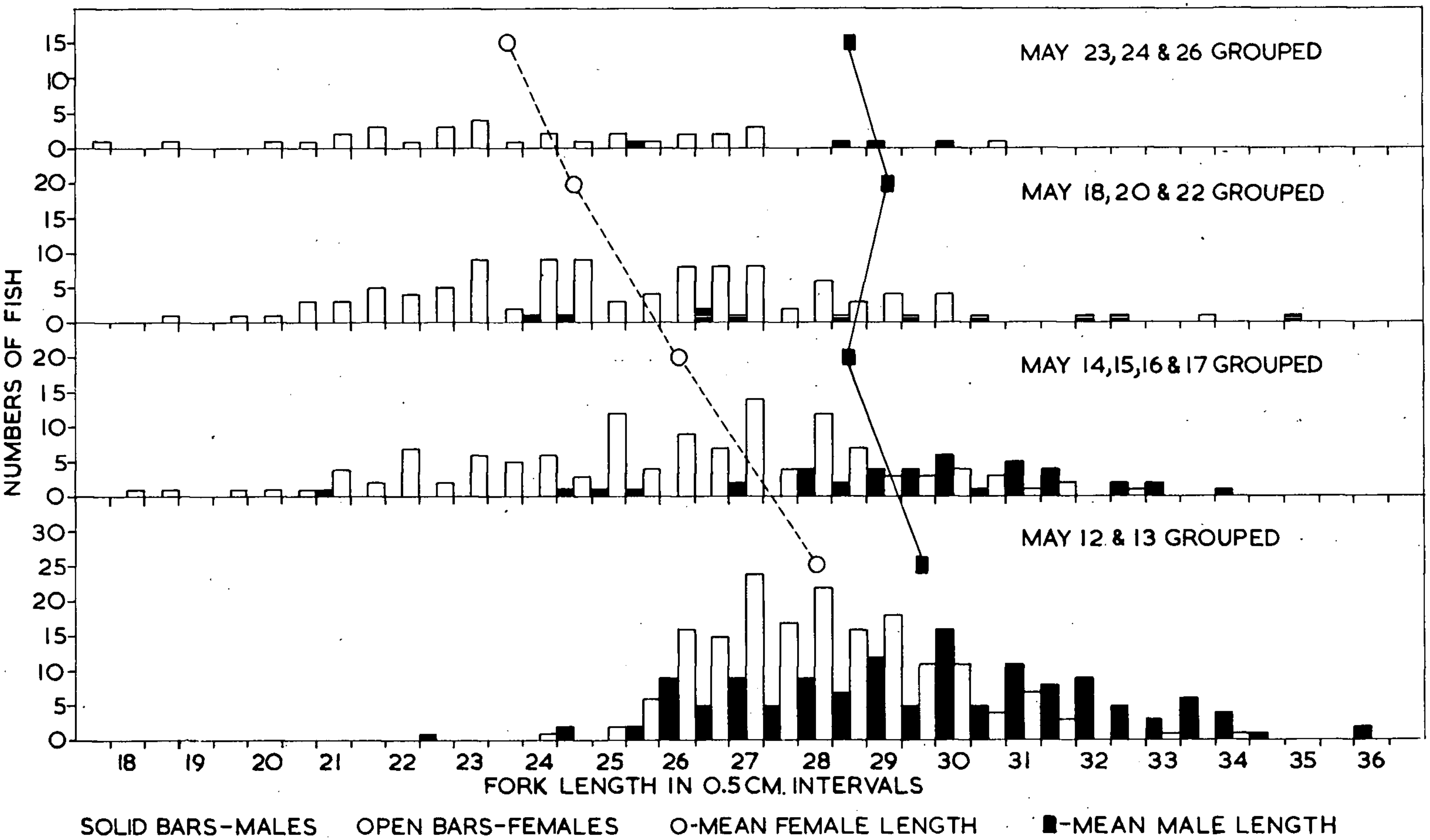

Figure 15. Length frequency of male and female fish moving downstream in the spawning run.

F. UPSTREAM MIGRATION OF FINGERLINGS

The young of the year fish at Kiakho Lake apparently remain in the outlet stream until the following spring, at which time they migrate up to the lake. The young fish emerge from the gravel sometime in June. No information on the exact date of emergence is available, however, small fish approximately 2.5 cm. fork length were taken in the stream on July 1.

The water level of the stream was very low by July, and several barriers had formed. The barriers consisted of places where the stream percolated through the gravel. These barriers apparently force the young of the year fish to remain in the stream until the following spring.

Figure 16 shows the numbers of year old fish moving upstream on various dates. The first fish to move through the trap were on May 22, and the peak of the run occurred on May 27 and 28. The work was stopped on June 7, but the run still continued, although the numbers of fish were small. The total number of fish passed through the trap was 751. A sample of 70 was taken, thus 681 were released into the lake. Every fish put through the trap was measured and the left pectoral fin clipped off as an identifying mark. The marking was done to evaluate the numbers that would return in subsequent spawning runs.

Figure 17 shows the size composition of the young fish migrating upstream. The majority of these fish were one year old but a small sample indicated that some were two years old.

The sudden increase in the number of fish taken in the trap on May 27 and 28 indicates that possibly some environmental factor such as

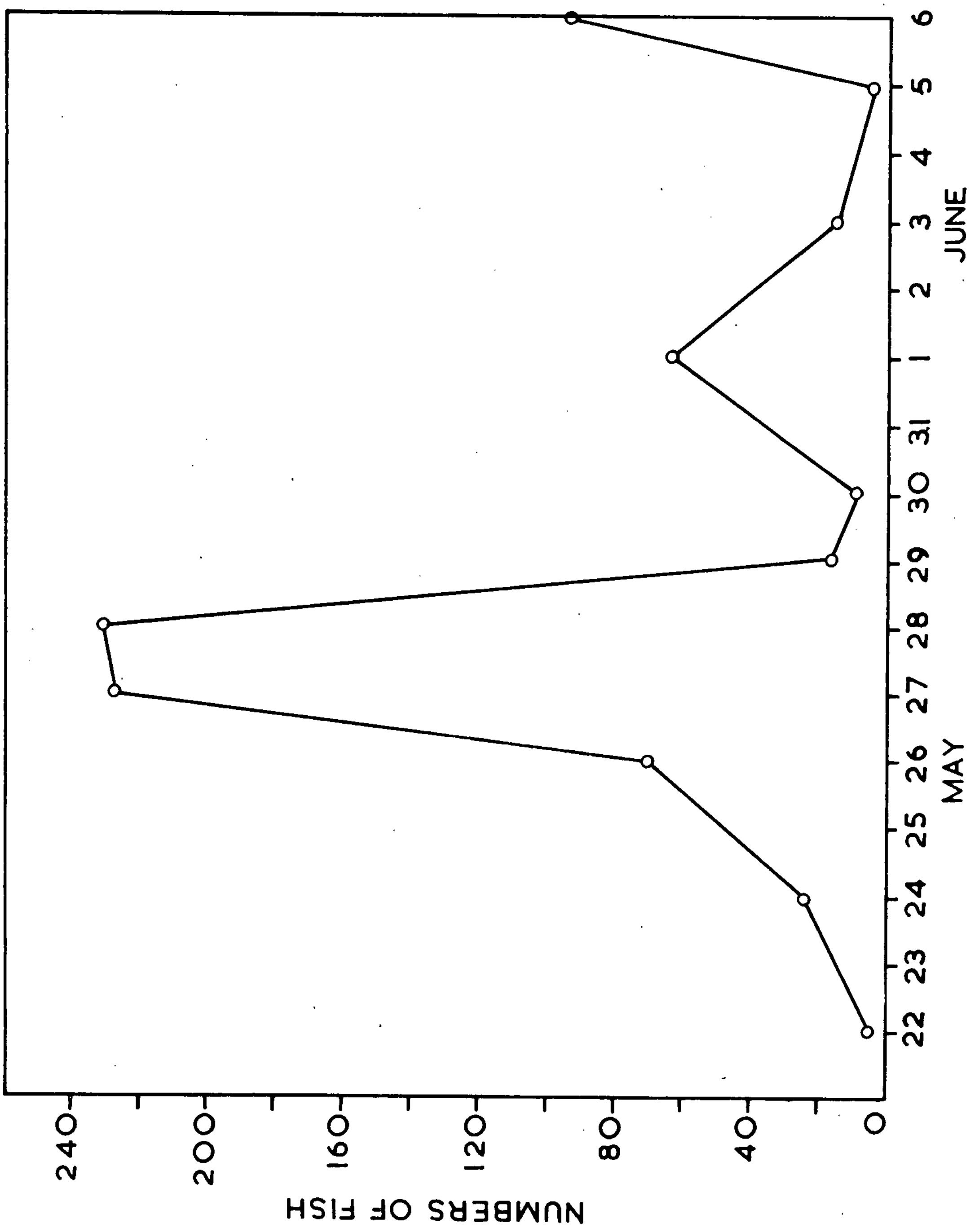

Figure 16. Daily numbers of year old fingerlings moving upstream into Kiakho Lake.

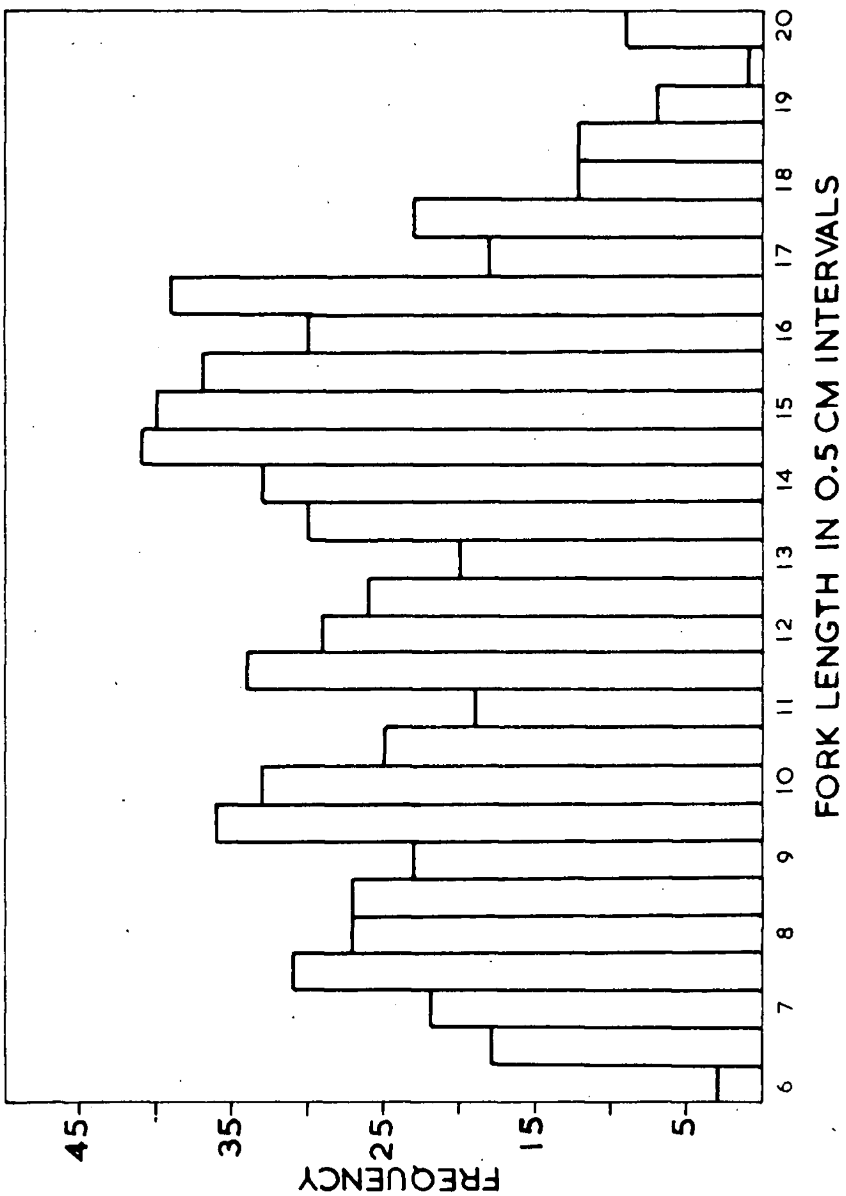

Figure 17. Length frequency of year old fingerling fish moving upstream into Kiakho Lake.

temperature may be controlling the time of migration. The maximum temperature of the stream at the trap on these dates was 62° F. The temperature changes with the length of the stream. On May 14 the temperature of the trap was 51° F., at approximately 150 yards below the trap it was 56° F. and one half mile below the trap it was 60° F. The fish possibly follow some temperature gradient up the stream.

Calhoun (1944 a), Robertson (1947), Cope (1953) and Laakso and Cope (1956) working with Yellowstone cutthroat trout were concerned with inlet spawning runs. In none of the literature was there any record of outlet spawning cutthroat. The fry in inlet streams usually move or are carried by the current into the lake soon after emergence from the gravel (Lindsey, Northcote and Hartman, 1959). The fish at Kiakho Lake are forced to stay in the outlet stream for one year, apparently because of barriers caused by low water conditions. This year spent in the stream is probably very significant in determining the number of fish which will eventually migrate into the lake. Assuming that the size of the previous year's spawning run was comparable in size to 1958, and the fact that only 751 fish returned to the lake, would indicate that severe mortality must have taken place during the year in the stream. This is based on the assumption that the fish can only move into the lake in the spring. There may be a high water flow period in the fall in which the fish could move into the lake. In years when the water flow stays high, the young of the year fish may move into the lake in late summer. Shapley (pers. com.) reports young of the year fish moving into the lake in late July, 1959. The annual local weather conditions are probably very significant in determining the survival of fingerlings. In wet years the size of the year class may be large and in dry years, when the fish are apparently forced to stay in the outlet stream over winter, the numbers may be severely reduced. It would appear that if there was severe mortality in the stream, the lake could be considered a large rearing pond where members of an already severely regulated population were growing. In this study, no attempt was made to evaluate the stream life of the cutthroat trout. It would be desirable to study this phase of its life, as a basis of understanding the dynamics of this particular population.

G. MATURITY AND FECUNDITY

Samples of fish for maturity and fecundity analysis were taken at the trap during the spawning run. Green females were preserved whole, and the egg size and number were determined later. Upstream migrating fingerlings were sampled and the gonads were examined.

1. Age of Maturity

The age of maturity has not been conclusively established in Kiakho Lake cutthroat trout. An examination of the gonads and scales of the fish taken in the lake and spawning run would place the males as maturing at ages 2 and 3 and the females at 3 and 4. Irving (1954) found male cutthroat mature at age 2 and 3 and females at ages 3 and 4. Carl and Clemens (1948) note that Yellowstone cutthroat trout males mature at 8 inches in length and females at 10.5 inches in length.

These lengths correspond to ages 2 and 3 for males and ages 3 and 4 for females in Kiakho Lake. Bilton and Shepard (1955) working on coastal cutthroat trout found that the spawning run was composed of 4—6 years old although some 3 year olds were present.

An examination of the gonads of the upstream migrating fingerlings showed that many of them had well developed testes and ovaries. One female, 17 cm. fork length and 2 years old had several fully developed eggs in the oviduct and appeared to have spawned in the current year. The males which had well developed testes were as small as 10 cm. fork length and one year old. It is not known whether the small fish had come from the lake or were resident in the stream. The number of precocious fish is not known and further collection and study is needed to determine whether they come from the lake or stream. It now appears that male cutthroat trout mature from ages 1—3 and females from ages 2—4.

It is difficult to determine from scales whether there is a high proportion of repeat spawners. Shapley (pers. com.) working at Kiakho Lake in the summer of 1959 reports that there were 139 previously tagged fish released downstream between May 1 and 9, 1959. It would appear that repeat spawning is common in cutthroat trout.

2. <u>Fecundity</u>

The determination of egg number was done by direct count. The numbers of eggs from the left and right ovaries were counted separately. Egg diameter was calculated by taking the mean value of the diameter of 20 preserved eggs. Eggs for diameter measurement were sampled from the anterior, middle and posterior section of each ovary.

The mean number of eggs, plus or minus two standard deviations, per female, was 944 ± 393.29. This gives a range of 500—1,300 eggs and is comparable to the range of 745—1,495 found by Welch (1952). Irving (1954) found a range of 1,500—3,000 eggs. Rounsefell (1957) lists the average number of eggs for cutthroat trout as 1,130. A "t" test showed that there was no difference in the number of eggs in the left and right ovaries ($p = 0.35$). The means plus or minus two standard deviations of 32 samples were, left 473 ± 227.26 and right 471 ± 216.48 eggs.

The mean egg diameter plus or minus two standard deviations was 3.8 0.23 millimeters. Irving (1954) found that the mean diameter of cutthroat trout eggs was 0.188 inches (4.7 mm.). A "t" test showed that there was no significant difference in the size of the eggs in the posterior and anterior sections of the ovaries nor in the left and right ovaries.

3. Factors Affecting Egg Number

A multiple regression analysis was set up to determine the effect of fork length and egg diameter on the number of eggs in the fish. The egg diameter was expressed as the total diameter of 20 eggs for ease of calculation. The resulting formula in standard units is:

$$Y = 0.934\, x'_1 \ (-0.384\, x'_2)$$

and in ordinary units:

$$Y = 200.06 - 103.20\, X_1 - 258.29\, X_2$$

where Y is the number of eggs, X_1 is the fork length and X_2 is the egg diameter expressed as a total diameter of 20 eggs. When the partial regression coefficients are in standard units, their magnitude give the relative importance of X_1 and X_2 as affecting Y. In this particular case the coefficients show that fork length is approximately 2.5 times as important in determining egg number, as is egg diameter. The negative slope of egg diameter indicates that the eggs are smaller where there is a greater number of them. The total regression (R) (Snedecor, 1948) is highly significant at the 1 percent level, and the partial regression coefficients are both significant at the 5 percent level. Cartwright (1959) found an increase in egg number with an increase in fork length in rainbow trout. Rounsefell (1957) found an increase in egg number with increase in fork length in several salmonids.

H. DISTRIBUTION OF FISH WITHIN THE LAKE

The general distribution of fish within the lake was taken from the mean numbers of fish caught in gill net sets at various depths. The majority of the net sets were made on the bottom, but some were made at various depths in the deeper water, by floating the net. Table 12 shows the results for the north and south basins, for floating nets and bottom set nets. It is obvious that the floating net sets at 0--8 feet, 8--16 feet and 15--23 feet caught insignificant numbers of fish. The bottom sets in the south basin showed that the greatest mean number of fish per net set were taken in the 15--23 foot depth zone. The fact that smaller numbers of fish were taken in the shallower zones was probably due to the lack of bottom organisms (food) resulting from

TABLE 12. MEAN CATCH PER NET SET OF FISH AT VARIOUS DEPTHS IN THE NORTH AND SOUTH BASINS AT KIAKHO LAKE

Depth in Feet	Floating Sets		Bottom Sets	
	South Basin	North Basin	South Basin	North Basin
0-- 8	3 (3)*	-	13 (1)	59 (1)
8--16	4 (3)	-	-	48 (2)
15--23	8 (2)	-	25 (4)	
23--31	-	-	12 (4)	

*Figures in parenthesis are the number of net sets upon which the mean catch was based.

the rocky substrate. The stagnation in the area below 25 feet was probably the reason for the low mean catches in the 23--31 foot zone. There is a twofold difference between the mean catches of the north and south basins. This is probably due to the greater abundance of bottom organisms (food) and considerable growth of Potamogeton in the north basin.

Table 12 shows that the greatest mean catches of fish were taken in net sets on the bottom. This would indicate that the fish tend to stay relatively close to the bottom. The food habits would also bear this out, as the food is composed almost entirely of bottom organisms.

DISCUSSION

This study has underlined many of the basic similarities which exist between Yellowstone cutthroat and rainbow trout. Throughout the previous sections comparisons have been made between the cutthroat and the rainbow trout and some are worthy of further mention. These comparisons have indicated that a practical management program for cutthroat trout would be in essence the same program used for rainbow trout.

The general habitat types in which cutthroat and rainbow trout are found show great similarity. The Yellowstone cutthroat trout are, in general, found in clear, cool and relatively unproductive lakes of south eastern British Columbia. The rainbow trout are found in similarly unproductive lakes of the interior plateau of British Columbia as indicated by Rawson (1954) and Larkin and Smith (1954).

It was previously shown that the food utilized by the two species was virtually the same. Comparisons have indicated that cutthroat trout were not more piscivorous than the rainbow trout, but in fact appeared to utilize fish for food in about the same proportion as rainbow trout as described by Rawson (1934), Dimick and Mote (1934), Larkin, Anderson, Clemens, and Mackay (1950) and Larkin and Smith (1954). It can be presupposed, on the basis of the findings of Larkin and Smith (1954), that cutthroat trout would probably show a reduction of growth rate and a decrease in numbers when subjected to competition from other species of fish. Calhoun (1944b) pointed out that minnows (Rhinichthys osculа) were competitors with small cutthroat trout and were not utilized by large cutthroat trout. In forming a management policy for maintaining cutthroat trout populations, it would appear necessary to keep the populations in a pure culture state.

The comparison of growth between cutthroat and rainbow trout showed that the growth characteristics were very similar. The "z" value, for cutthroat, from the Parker and Larkin (1959) growth equation was almost the same as that for the freshwater growth of steelhead trout. The cutthroat trout population of Kiakho Lake has presented an excellent opportunity to examine fish growth where selection by a fishery has had no effect. A comparison was made with McLeod's (1958) work on the growth of rainbow trout in which certain features were attributed to the effects of a fishery. The growth of Kiakho Lake cutthroat trout did not show the features found by McLeod and would appear to support the view that the effects of the fishery were responsible for the differences. Lee's Phenomenon was absent and as a result the ideas set forth by Lee (1912) and Hile (1936) for the causes of the phenomenon, are not valid for this population. Since the phenomenon was absent, it lends support to the view that selection of the faster growing fish by the fishery is a major factor causing Lee's Phenomenon.

The timing, age composition and sex composition of the spawning run were very similar to those of rainbow trout as described by Mottley (1933, 1938) and Lindsey, Northcote and Hartman (1959). It was found that the male cutthroat precede the females in the spawning run. Mottley (1933) found the same situation in the rainbow trout.

The young of the year cutthroat trout remain in the outlet stream at Kiakho Lake for one year before migrating to the lake. Lindsey et. al. (1959) remarked that young rainbow trout remain in the outlet stream before moving up to the lake.

The fecundity of the cutthroat trout was found to be approximately 1,000 eggs per female. A multiple regression analysis showed that body length was a major factor affecting the numbers of eggs per female. Rounsefell (1957) and Cartwright (1959) found the rainbow trout had the same magnitude in numbers of eggs and Cartwright (1959) indicated that body length affected the numbers of eggs in rainbow trout.

Comparison has shown that the basic biology and ecology of the cutthroat and rainbow trout are very similar. It is known that the two species will hybridize. Casual observations by the author and Larkin (pers. com.) indicate that in lakes where the two species exist together, the rainbow trout appear to be more successful with the eventual subordination of the cutthroat trout through hybridization and competition. Due to this, it is not advisable to put the two species together in a lake.

Calhoun (1944a) remarked that the cutthroat trout in California has shown considerable reduction in numbers and now exists only in the alpine lakes and streams. Weisel (1957) states that "Cutthroat trout are on the way out". Weisel remarking on cutthroat trout indicates that due to hybridization, and generally poor management and poor utilization of water resource, the cutthroat stocks in Montana have been depleted. He goes on to say that in only the unfrequented primitive areas are the cutthroat found in any numbers. If for no other reason than aesthetic values, the cutthroat trout should be preserved in British Columbia lakes and not allowed to become a member of the list of now extinct animals. There are still substantial stocks of cutthroat trout in British Columbia and through careful management they could remain as they are.

To investigate and describe the life history and ecology of any species of fish, it is desirable to study a population which is affected by a minimum number of factors. The Kiakho Lake cutthroat trout population fell into such a category. There were no other species of fish present to complicate the picture with competition and there was no fishery operating to add its complications. The study of cutthroat trout under these conditions has given a basis on which evaluations of competition, selection by a fishery, and other aspects of cutthroat biology can be compared.

SUMMARY

1. Kiakho Lake, located 6 miles west of Cranbrook British Columbia, at an altitude of 3,600 feet, has a surface area of 67.42 acres, a maximum depth of 16.5 feet and is composed of two basins. The lake has resulted from a land slide and is situated in a geological area composed of argillites and quartzites and has a total dissolved solids content of 100 parts per million.
2. The temperature characteristics of the lake show thermal stratification with the lower limit of the thermocline on the bottom.
3. The dissolved oxygen content of the lake waters showed reduction (stagnation) below 25 feet during the summer, and apparent supersaturations up to 130 p.p.m. at the 15 and 20 foot levels.
4. Two species of aquatic plants were present in the lake; the rooted aquatic _Potamogeton praelongus_ and the alga _Cladophora_.
5. The bottom fauna was predominated by _Gammarus_, _Hyalella_, chironomid larvae and leeches, with molluscs, oligochaeta and insect larvae being represented. The production of bottom fauna was poor and was attributed to the rocky substrate and lack of littoral development.
6. The plankton production was small in relation to total dissolved solids and was composed of many oligotrophic indicator species.
7. The lake has a eutrophic morphometry but has an oligotrophic productivity, which was attributed to the low total dissolved solids content and a rocky substrate.

8. The food utilized by the fish in Kiakho Lake was wholly derived from the bottom fauna. Considerable changes in the major food items were found over the summer period. In May chironomid pupae was the dominant food, in June the major food was chironomid larvae and Gammarus and in July, Gammarus was the dominant food.
9. The food of the cutthroat trout in Monroe and Lumberton Lakes was composed mainly of bottom organisms, with Gammarus being the most important. In Garcia Lake the food was mainly Chaoborus and redside shiner (Richardsonius balteatus) with Chaoborus being the most important.
10. It was concluded that cutthroat trout would utilize fish for food, but showed a preference for bottom dwelling organisms.
11. The number of empty stomachs increased and the average stomach volume decreased in the Kiakho Lake cutthroat, as the summer progressed. It was proposed that this was related to a higher physiological activity resulting in the digestion of the food before the fish were retrieved, and giving the appearance that feeding activity had been reduced.
12. The body-scale relationship was described by a straight line having a slope of 1.
13. The graph of instantaneous growth rate against length at the beginning of the rapid growth period, revealed that the effect of selection by a fishery possibly could be demonstrated. A comparison with a similar graph of rainbow trout which had been subjected to a fishery, seemed to support the view that the selection of the faster growing fish was apparent as a concavity in the upper limit of the graph.

14. The growth data was fitted to a Parker and Larkin (1959) parabolic growth equation. The exponent z was found to have a value of 0.71 for cutthroat trout.

15. Lee's Phenomenon was not present and gave support to the view that selection by a fishery could be a major factor causing Lee's Phenomenon.

16. The spawning run at Kiakho Lake was in the outlet stream and coincided with the breakup of the ice cover on the lake.

17. A tagging program on the spawning fish, revealed that approximately 3,000 fish went down stream, that they spent approximately 13 days spawning, and that the mortality was approximately 54 percent.

18. The male fish appeared on the spawning grounds before the female fish. The female fish were smaller later in the run and the male fish remained relatively constant in size over the run.

19. The eggs hatch sometime in mid June, and the young fish apparently remain in the outlet stream until the following spring, at which time they migrate into the lake. The year spent in the outlet stream is probably a very significant factor in the dynamics of this population.

20. The female fish mature between the ages of 2 and 4 and the male fish between 1 and 3.

21. The mean number of eggs per female fish, plus or minus two standard deviations was 944   393.29. This gives a range of 500--1,300 eggs.

22. A multiple regression analysis indicated that body size (length) affected egg number 2.5 times as much as egg diameter.

23. The cutthroat trout in Kiakho Lake were distributed in close proximity to the bottom.

24. It was recommended that due to the probable effects of competition, the cutthroat trout be kept in pure culture populations. A further recommendation was, the numbers of cutthroat trout be maintained. It has been found in other areas, that through poor management, the cutthroat trout is becoming nonexistant.

LITERATURE CITED

Bilton, T. H. and M. P. Shepard. 1955. The sports fishery for cutthroat trout at Lakelse, British Columbia. Prog. Rept. Pacific Station. Fish. Res. Bd. Can., 104:38-42.

Brown, C. J. D. and J. E. Bailey. 1952. Time and pattern of scale formation in Yellowstone cutthroat trout, Salmo clarkii lewisi. Trans. Am. Micros. Soc., 71(2):120-124.

Calhoun, A. J. 1944(a). Black-Spotted trout in Blue Lake, California. Calif. Fish and Game, 30(1)22-42.

Calhoun, A. J. 1944(b). The food of the Black-Spotted trout (Salmo clarkii henshawi) in two Sierra Nevada lakes. Calif. Fish and Game, 30(2):80-85.

Carl, G. C. and W. A. Clemens. 1948. The freshwater fishes of British Columbia. British Columbia Provincial Museum, Handbook No. 5.

Cartwright, J. W. 1959. Egg size and egg number in some species of British Columbia freshwater fish. M. Sc. Thesis, University of British Columbia.

Chapman, J. D. and D. B. Turner. 1956. British Columbia, Atlas of Resources. British Columbia Natural Resources Conference, 1956.

Cope, O. B. 1953. Length measurements of Yellowstone trout. U. S. Fish and Wildlife Serv., Special Sci. Rept.--Fish, No. 103.

Dimick, R. E. and D. C. Mote. 1934. A preliminary survey of the food of Oregon trout. Oregon St. Agr. Exp. Sta. Bull., 323, 23 pp.

Echo, J. B. 1955. Some ecological relationships between yellow perch and cutthroat trout in Thompson Lakes, Montana. Trans. Am. Fish Soc., 84:239-248.

Fleener, G. C. 1952. Life history of the cutthroat trout, Salmo clarkii Richardson, in the Logan River, Utah. Trans. Am. Fish. Soc., 81:235-248.

Griffiths, F. P. and E. D. Yoemans. 1940. A comparative study of Oregon coastal lakes from a fish management standpoint. Proc. Sixth Pacific Sci. Cong., 3:323-333.

Hazzard, A. S. and M. J. Madsen. 1933. Studies of the food of the cutthroat trout. Trans. Am. Fish. Soc., 63:198-207.

Hildebrand, S. F. and I. L. Towers. 1927. Food of the trout in Fish Lake, Utah. Ecol. 8(4):389-399.

Hile, Ralph. 1936. Age and growth of the cisco Leucichthys artedi (LeSueur) in the lakes of the northeastern highlands, Wisconsin. Bull. U. S. Bur. Fish., 48(19):211-317.

Hutchinson, G. E. 1957. A treatise on limnology. volume I, geography, physics and chemistry. John Wiley and Sons, Inc. New York.

Irving, R. B. 1954. Ecology of the cutthroat trout in Henrys Lake, Idaho. Trans. Am. Fish Soc., 84:275-296.

Jones, R. 1958. Lee's phenomenon of "apparent change in growth-rate" with particular reference to haddock and plaice. Inter. Comm. Northwest Atlantic Fish. Spec. Pub. No. 1. Some problems for biological fishery surveys and techniques for their solution.

Laakso, M. and O. B. Cope. 1956. Age determinations in Yellowstone cutthroat trout by the scale method. Jour. Wildl. Mgmt., 20(2):138-153.

Larkin, P. A., G. C. Anderson, W. A. Clemens, and D. C. G. Mackay. 1950. The production of Kamloops trout (Salmo gairdneri kamloops, Jordan) in Paul Lake, British Columbia. University of British Columbia Game Department.

Larkin, P. A. and S. B. Smith. 1954. Some effects of introduction of redside shiner on the Kamloops trout in Paul Lake, British Columbia. Trans. Am. Fish. Soc., 83:160-175.

Lee, R. M. 1912. An investigation into the methods of growth determination in fishes. Publ. Circ. Cons. Explor. Mer., No. 63.

Lee, R. M. 1920. A review of the methods of age determination in fishes by means of scales. Fish Invest. Ser. II, Vol. 4(2). Min. Agric. and Fish., London.

Lindsey, C. C., T. G. Northcote, and G. F. Hartman. 1959. Homing of rainbow trout to inlet and outlet spawning streams at Loon Lake, British Columbia. J. Fish. Res. Bd. Can., 16(5):695-719.

MacLeod, J. C. 1958. Growth rate of rainbow trout in Pinantan Lake, British Columbia. B. A. Thesis, University of British Columbia.

Maltzan, Grafin Von M. 1935. Zur Ernahrungsbiologie und physiology des Karpfens. Zool. Zentr. Abt. 3(55):191-218. From, Brown, M. E. 1957. Physiology of fishes. volume I.—metabolism. Academic Press Inc. New York.

Martin, W. R. 1949. The mechanics of environmental control of body form in fishes. Univ. Toronto Stud., Biol. Ser. No. 58. Pub. Ontario Fish Res. Lab. No. 70, pp 1-72.

Miller, R. B. 1941. A contribution to the ecology of the chironomidae of Costello Lake, Algonquin Park, Ontario. Univ. Toronto Stud. Biol. Ser. No. 49. Pub. Ontario Fish Res. Lab. LX.

Mottley, C. McC. 1933. The spawning migration of rainbow trout. Trans. Am. Fish. Soc., 63:80-84.

Mottley, C. McC. 1938. Fluctuations in the intensity of the spawning runs of rainbow trout at Paul Lake. J. Fish. Res. Bd. Can., 4(2):69-87.

Northcote, T. G. and P. A. Larkin. 1956. Indices of Productivity in British Columbia Lakes. J. Fish. Res. Bd. Can., 13(4):515-540.

Parker, R. R. and P. A. Larkin. 1959. A concept of growth in fishes. J. Fish. Res. Bd. Can., 16(5):721-745.

Qadri, S. U. 1959. Some morphological differences between the subspecies of cutthroat trout, Salmo clarkii clarkii and Salmo clarkii lewisi. J. Fish. Res. Bd. Can., 16(6):903-922.

Rawson, D. S. 1930. The bottom fauna of Lake Simcoe and its role in the ecology of the lake. Pub. Ontario Fish. Res. Lab. No. 40.

1934. Productivity studies in lakes of the Kamloops region, British Columbia. Bull. Biol. Bd. Can., No. XLII.

1939. Some physical and chemical factors in the metabolism of lakes. in Problems of lake biology. Pub. Am. Adv. Sci. No.10.

1952. Mean depth and the fish production of large lakes. Ecol. 33(4):513-521.

1956. Algal indicators of trophic lake types. Limnol. and Ocean., 1(1):18-25.

Ricker, W. E. 1934. A critical discussion of various measures of oxygen saturation in lakes. Ecol. 15:348-363.

Rounsefell, G. A. 1957. Fecundity of North American Salmonidae. U. S. Fish and Wildlife Serv. Fish. Bull., No. 122, vol. 57, pp. 451-468.

Robertson, O. H. 1947. An ecological study of two high mountain trout lakes in the Wind River Range, Wyoming. Ecol. 28(2):87-112.

Shapley, P. 1959. Personal communication.

Smith, O. R. 1941. The spawning habits of cutthroat and eastern brook trouts. J. Wildl. Mgmt., 5(4):461-471.

Smith, S. B. 1955. The relation between scale diameter and body length of Kamloops trout, _Salmo gairdneri kamloops_. J. Fish. Res. Bd. Can., 12(5):742-753.

Snedecor, G. W. 1948. Statistical methods, applied to experiments in agriculture and biology. Fourth ed. Iowa State College Press, Ames Iowa.

Thienemann, A. 1927. Der Bau des Seebeckens in seiner Bedeutung für den Ablauf des Lebens in See. Verh. Zool. Bot. Ges., 77. (Translated by T. G. Northcote.)

Van Oosten, J. 1929. Life history of the lake herring (_Leucichthys artedi_ LeSueur) of Lake Huron, as revealed by its scales, with a critique of the scale method. Bull. U. S. Bur. Fish., 44:265-448.

Varty, J. 1958. Personal communication.

Weisel, G. F. 1957. Fish guide for intermountain Montana. Montana State Univ. Press, Missoula Montana.

Welch, J. P. 1952. A population study of Yellowstone Black-Spotted trout (_Salmo clarkii lewisi_ Girard) Ph.D. dissertation, Leland Stanford Jr. Univ., pp. 1-180.