A STUDY OF THE PRODUCTION OF KAMLOOPS TROUT

(*Salmo gairdnerii kamloops* Jordan)

in

PAUL LAKE, BRITISH COLUMBIA

by

George Cameron Anderson

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ABSTRACT

An investigation of the limnology and the Kamloops trout population of Paul Lake, British Columbia, from the summer of 1947 to the end of the summer of 1949, is presented. Comparisons of the conditions found by the writer are made with those conditions reported by Drs. C.McC. Mottley, D.S. Rawson and D.C.G. MacKay in previous investigations of Paul Lake. Analysis of the environmental conditions indicated extreme annual variations in the summer heat income, an abundance of oxygen at all depths, minor annual fluctuations in the quantity of plantkon, a significant decrease in the quantity of bottom fauna which was believed due to the depletion of the Gammarus population, and a fairly large supply of available food. Another species of fish, the redside shiner, has made its entry into Paul Lake. The statistics of the trout population has shown a decrease in the average size of the age classes of trout since 1931, a large proportion of the younger age classes of trout in the anglers' catch and in the spawning run and a decrease in the size of eggs and number of eggs per female. A large year class resulting from 1945 has been followed through the fishery. The main effects of this year class appear to have been a greater survival of trout and a restoration of older age classes in the anglers' catch and in the spawning run. A comparison of the 1949 creel census data with that for 1936 has indicated a two-fold increase in fishing intensity, a slight decrease in the total catch and a decrease of two-thirds in the catch per unit effort. A revised stocking policy, patterned after the 1945 year class, is outlined.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS.

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INTRODUCTION

This report deals with an investigation of the limnology and the Kamloops trout population of Paul Lake, British Columbia, from the summer of 1947 to the end of the summer of 1949. The purpose has been to provide a contribution to the solution of the problem concerning the propagation and conservation of Kamloops trout, particularly in Paul Lake, but also in other lakes of the province.

Originally, Paul Lake was barren of fish, but it was stocked in 1909 by the Dominion Department of Fisheries. The species of fish selected for stocking was the Kamloops trout, *Salmo gairdnerii kamloops* Jordan. The lake was suitable for investigation because Kamloops trout was the only species present, the spawning run could be controlled, and a creel census was practical. Earlier investigations of this lake have provided a valuable background. In the period from 1931 to 1936, a major study was carried out by the Fisheries Research Board of Canada. Dr. C.McC. Mottley investigated the life history, population and culture of the trout. Dr. D.S. Rawson, in 1931, made a special study of the limnological conditions. In 1946, Dr. D.C.G. MacKay conducted a general survey involving plankton collections, temperature, oxygen and pH determinations and samplings of fish from the anglers' catch.

The material for the present report consists of data obtained in the summer of 1947 by Dr. W.A. Clemens and that obtained by the writer in the summer of 1948 and 1949 including the addition of bottom samples, assessments of the spawning runs and a creel census in 1949. Further, winter samples of plankton, temperatures and trout were taken in December, 1948.

Comparisons of the physical and chemical conditions, the food supply and the statistics of the trout population, as found by the writer, are made with those conditions reported by Drs. Mottley, Rawson and MacKay. On this basis, recommendations are advanced for the future scientific management and continued investigation of Paul Lake. It is hoped that the findings may find some application to the problems in other lakes.

LOCATION AND MORPHOMETRY

Paul Lake lies in a narrow rocky valley at an altitude of 777 m. (2542 ft.), 19.2 km. (12 mi.) north east of Kamloops. It has a length of 6.1 km. (3.8 mi.) and an average width of 0.48 km. (0.3 mi.). The area is approximately 3.9 sq. km. (1.5 sq.mi.) while the maximum depth observed was 55.5 m. (182 ft.). The lake has one major inlet, Paul Creek, which drains Pinantan Lake. There are also a few mountain streams entering the lake which become dry in the summer months. There is only one outlet, Paul Creek. An outline map of Paul Lake is shown in figure 1.

Figure 1.

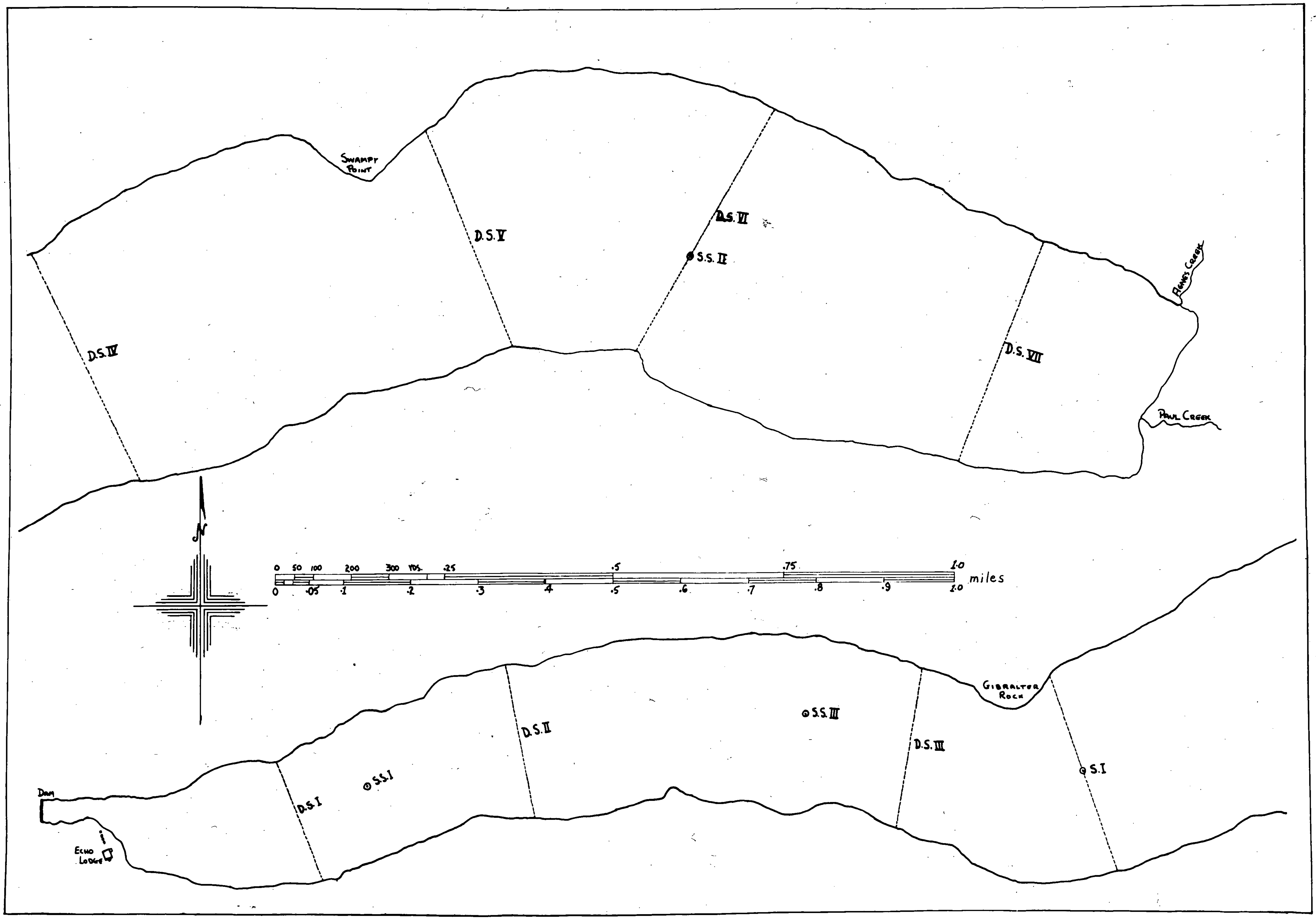
Outline map of Paul Lake

(from Rawson, 1934).

S - station

S.S. - sub station

D.S. - dredging series.


SWAMPY POINT
D.S.V
D.S.VI
S.S.II
D.S.IV
D.S.VII
PAUL CREEK
N
0 50 100 200 300 YDS. .25 .5 .75 1.0
0 .05 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
miles
GIBRALTER ROCK
D.S.II
S.S.III
D.S.III
S.I
D.S.I
S.S.I
DAM
ECHO LODGE

PHYSICAL AND CHEMICAL CONDITIONS

TEMPERATURE.

Series of temperatures were taken at various stations during the summers of the investigation. Tabulated results are shown in Appendix A. The locations of the stations are shown in figure 1.

Rawson (1934) has described the thermal stratification of Paul Lake. After the spring turnover, the upper 10 m. gradually warms up to midsummer conditions. The thermocline is located in the 4.5 to 15 m. region, varying with the annual climatic conditions. The average depth of the upper limit of the thermocline is approximately 5 m. There is very little mixing of water below the thermocline at any time during the summer. The surface temperature may reach a high of 21.5 deg. C. during the summer while the bottom temperature may reach a high of 4.8 deg. C. approximately at the same time. Typical midsummer thermal conditions in Paul Lake are shown in figure 2.

The following figures show the summer heat income* for 1931, 1946, 1947, 1948 and 1949. These have been calculated according to the method of Birge and Juday (1914), and are expressed in gram calories per square centimetre of lake surface.

1931 - 19,562 gm. cal.

1946 - 16,142 gm. cal.

1947 - 15,937 gm. cal.

* The summer heat income is the amount of heat necessary to raise the water from 4 deg. C. to the maximum summer temperature. The formula used to calculate the heat income was as follows:

Dm (Tm - 4 deg.C.) = gm. cal/sq. cm. of lake surface.

Dm - mean depth in cms.
Tm - mean temperature.

1948 - 11,423 gm. cal.

1949 - 13,612 gm. cal.

The summer heat income for Paul Lake shows definite annual fluctuations. The greatest variation can be noted in a comparison of the heat incomes for 1931 and 1948. The difference was in the order of 8,000 gm. cal. The summer heat income in Paul Lake in 1931 is similar to that found in Cultus Lake by Ricker (1937), who stated that the heat budget of Cultus Lake was a direct reflection of the generally equable climate of the region. However, the summer heat income for Paul Lake in 1948 was similar to that of Maligne Lake (Rawson 1942) which is described as an extreme "mountain type".

Annual fluctuations of this magnitude in the summer heat income of a lake might be expected to have definite ecological effects. However, no direct relation could be found between the summer heat income and the growth rates of the trout. Possibly some other aspect of temperature conditions might show a correlation to the growth rate of trout.

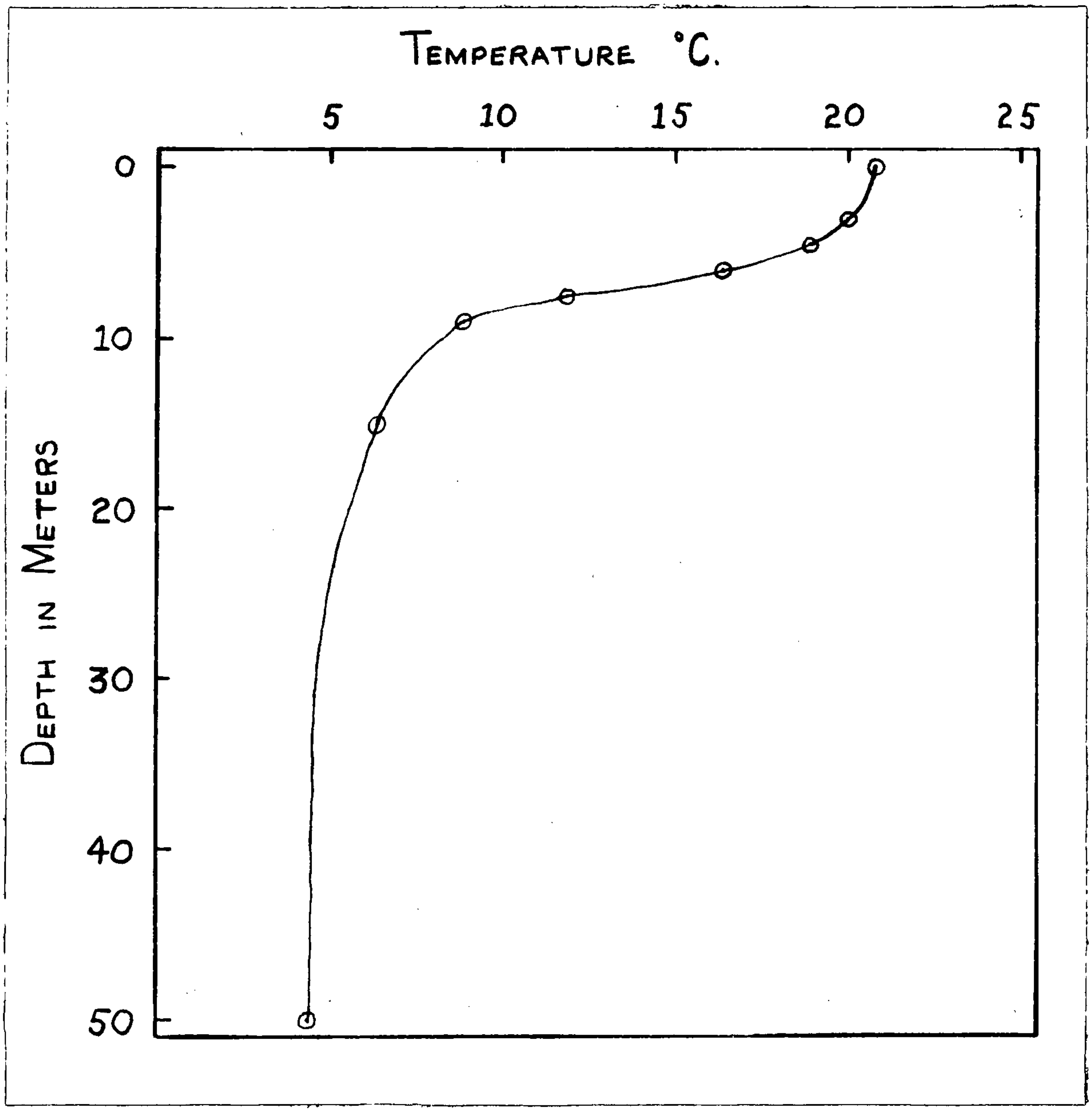


Figure 2.

Midsummer thermal conditions in Paul Lake, August 3, 1949.

OXYGEN CONCENTRATION.

Oxygen determinations using the Winkler method were made at intervals throughout the summer of 1947 and one determination was made in the summer of 1948. Midsummer oxygen conditions are shown in Table I.

Table I.

Midsummer oxygen determinations in Paul Lake, 1931, 1946-1948.

(p.p.m.)

Depth (m).	1931 Aug. 22.	1946 Aug 17.	1947 Aug 21.	1948 Aug. 18.
0	6.3	8.3	9.2	8.4
12	-	9.4	-	-
15	6.3	-	9.2	9.3
50	4.4	7.0	5.6	4.7

There does not appear to be any appreciable difference in dissolved oxygen among the records of the last three years. The oxygen content for 1931 is lower probably because of the higher water temperatures prevailing in 1931 and possibly the results of the determinations are somewhat low due to the use of Miller's method which apparently under certain conditions may give low results. Rawson (1934), has stated that the oxygen supply is always abundant and thus does not act as a limiting factor for the life in the deep waters.

FAUNA OF THE LAKE

PLANKTON.

Plankton hauls were taken periodically throughout the summers of the investigation. Figure 1 shows the locations of the plankton stations. The plankton nets used were modified closing nets of the Wisconsin type (Juday 1916). The net had an aperture of 23 cm., inside diameter, and a filtering area of approximately 3,000 sq. cm. Nets were made up of number twenty bolting silk, 77 meshes to the centimetre, and number ten bolting silk, 44.5 meshes to the centimetre. The method used in obtaining all of the plankton samples was a total vertical haul taken at a speed of half a metre per second. The samples were then preserved in weak formalin. Volumes of plankton were obtained by allowing the sample to settle for twenty-four hours in a graduated centrifuge tube. Centrifuged volumes were obtained by centrifuging each sample for ten minutes at a rate of approximately 1,800 revolutions per minute.

Table II shows the settled and centrifuged volumes of the total vertical hauls of plankton. Ricker (1937) has shown that a net of number twenty silk strains a volume of water which varies with a number of conditions, and hence is of little use quantitatively unless frequently standardized. He has also shown that a net of number ten silk appears to be "unusually constant", even over long periods, and makes an excellent sampling apparatus for adult Entomostraca. In the series in Table II, the efficiency of the number twenty net has been calculated, using the number ten net as a standard. The relative efficiency of the number twenty net ranges from 13 per cent to 71 per cent.

TABIE II.

Volumetric plankton analyses, Paul Iake, 1947-1949.

Year	Date	Station	#10 net		#20 net		
			Settled volume (c.c.)	Centri-fuged vol (cc)	Settled volume (c.c.)	Centri-fuged vol (cc)	Efficiency (%)
1947	Jul 22	S.S.III	9.2	4.8	3.5	1.7	35.4
	Jul 26		5.7	3.1	2.5	1.5	48.4
	Aug 21		5.2	2.7	1.8	1.2	44.4
	Sep 2		4.6	2.9	3.3.	1.0	34.5
	Jul 23	S.S. II	12.1	7.2	7.4	3.6	50.0
	Jul 28		16.9	10.2	4.5	3.0	29.4
	Aug 21		5.9	3.0	1.3	0.9	30.0
	Aug 29		6.5	3.6	2.7	0.9	25.0
	Sep 2		5.0	2.4	3.3	1.1	45.8
1948	Jul 24	S. I	19.1	13.1	2.7	1.75	13.4
	Jul 29		15.1	9.7	3.0	1.8	18.6
	Aug 9		5.3	3.5	3.1	1.85	52.9
	Aug 18		3.9	2.6	1.1	0.75	28.8
	Sep 10		5.3	3.5	1.55	1.0	28.6
	Dec 17	S.S. I	0.9	0.7	0.8	0.5	71.4
1949	May 10	S. I	1.25	0.8			
	Jun 25		3.1	2.1			
	Aug 3		3.1	1.9			
	May 10	S.S. I	0.4	0.25			
	Jun 25		2.3	1.7			
	Aug 4		3.1	2.1			

It is interesting to note that the efficiency was lowest when plankton was abundant (July 24-29) and was highest when plankton was scarce (December).

The peak of plankton production appeared in late July in 1947 and 1948. In 1949 the peak of production was missed. It is probable that it occurred earlier in July and the plankton was on a downward trend when the sample was taken on August 3. The winter sample (0.7 c.c.), taken in December 1948, indicates a fairly large quantity of plankton for this season in comparison with the sample (o.25 c.c.) obtained in May 1949 at the same location.

The mean quantities of plankton taken in July and August in 1931, 1946, 1947 and 1948 are given in Table III. Figures for 1931 have been taken from Clemens, Rawson and McHugh (1939) and figures for 1946 have been taken from MacKay (unpub.).

TABLE III.

Mean volumes of total vertical plankton hauls taken in July and August, Paul Lake, 1931, 1946-1948.

Size Net.

	#10		#20	
Year	Settled Volume (c.c.)	Centrifuged Volume (C.C.)	Settled Volume (c.c.)	Centrifuged Volume (c.c.)
1931	-	-	4.4	-
1946	-	2.15	-	0.6
1947	10.35	6.0	4.0	2.1
1948	10.85	7.2	2.5	1.5

The average amount of plankton recorded for 1946 was low in comparison with that of the other years. Figures for 1947 and 1948 indicate a definite increase in the plankton population over that shown for 1946. Rawson (1934), states that the plankton is only moderate in quantity but that it might indicate efficiency of utilization in the rapid "turn over" and non-accumulation of nutrient materials.

BOTTOM FAUNA.

Series of bottom dredgings were taken in 1948 and 1949 with a 523 sq. cm. Ekman dredge. A total of 68 dredgings were made, 15 collected in 1948 and 53 collected in 1949. Locations of the dredging series are shown in figure 1. In order to make the dredgings comparable with those taken by Rawson in 1931, the samples collected in 1949 were taken in approximately the same locations that Rawson used in 1931. The samples were washed through a coarse and a fine mesh screen (225 meshes per sq. cm.) and the visible organisms preserved in alcohol. Reference has been made to Ward and Whipple (1918) and Needham and Needham (1941) for the identification of organisms.

Numerical Analysis

Each group of organisms was counted and the results are recorded numerically in table IV, according to the different depth zones. The total number of each group of organisms and the total number of organisms have been calculated for the entire area of the lake. These totals have been weighted for the areas of the depth zones. Figures for 1931 have been taken from Rawson (1934).

Several variations in the abundance of groups of organisms can be noted in 1949 when compared with those numbers recorded in 1931. The Chiromonidae were almost twice as abundant in 1949, and made up 75 per cent of the total number of organisms. There was also a larger number of

Planorbis, Zygoptera and Anisoptera, Ephemeroptera, and Oligochaetes in 1949. The *Gammarus* and *Hyalella* populations have been reduced considerably, especially the *Gammarus*. The numbers of Sphaeriidae and Hirudinea have also decreased. The total number of organisms per sq. m. in the lake as a whole was larger than that recorded in 1931.

Figure 3 represents the average number of organisms for the various depth zones in 1931 and 1949. The greatest number of organisms for both years occurred in the 0 to 5 m. zone. There was a sharp drop in numbers in the 5 to 10 m. zone in both cases. In 1931 there was an increase in numbers in the 10 to 20 m. zone, almost equaling that of the 0 to 5 m. zone. This was followed by a steady decline in numbers down to 55 m. In 1949 the numbers of organisms levelled off at the 10 to 40 m. zone and then dropped sharply down to 55 m.

The numerical analysis shows fluctuations in the populations of the different groups of organisms but gives no indication of the quantitative nature of the food supply.

Gravimetric Analysis

Each sample was weighed individually after carefully blotting the excess moisture. In this manner the wet weight of the sample was obtained. The weight of Mollusc shells was deducted according to Rawson (1934). Twenty per cent of the total wet weight of *Physa* and thirty-two per cent of the total wet weight of other Molluscs is the amount contributed by the shell.

The number of dredging samples taken in 1948 is small and therefore a comparison with the quantity of bottom fauna in 1931 gives somewhat doubtful results. The mean wet weight of organisms of eight dredgings in the 0 to 10 m. zone in 1948 is 1.35 gms. in comparison

TABLE IV

Numerical analysis of bottom dredgings, Paul Lake, 1949 as compared to 1931.

Organisms	Depth Zone (m.)								
	1949								1931
	0 - 5	5 - 10	10 - 20	20-30	30-40	40-50	50-55	*0-55	*0-55
Chironomidae	2,110	1,651	1,343	1,767	1,545	595	-	1,121	672
Hyalella	969	7	-	-	-	-	-	101	198
Gammarus	8	22	1	-	3	-	-	4	166
Physa	14	57	3	-	-	-	-	8	7
Limnea	6	100	1	-	-	-	-	11	4
Planorbis	253	342	1	-	-	-	-	62	-
Sphaeriidae	67	40	259	-	95	-	-	70	247
Zygoptera	113	62	-	-	-	-	-	18	3
Anisoptera	84	19	-	-	-	-	-	11	2
Trichoptera	21	7	-	-	-	-	-	3	3
Ephemeroptera	71	2	-	-	-	-	-	8	-
Hirudinea	12	9	-	-	-	-	-	2	19
Planaria	14	28	51	57	41	57	-	34	30
Oligochaeta	-	-	7	47	70	89	38	41	10
Miscellaneous	6	-	4	-	-	-	-	1	2
Totals	3,748	2,346	1,670	1,871	1.754	741	38	1,495	1,363

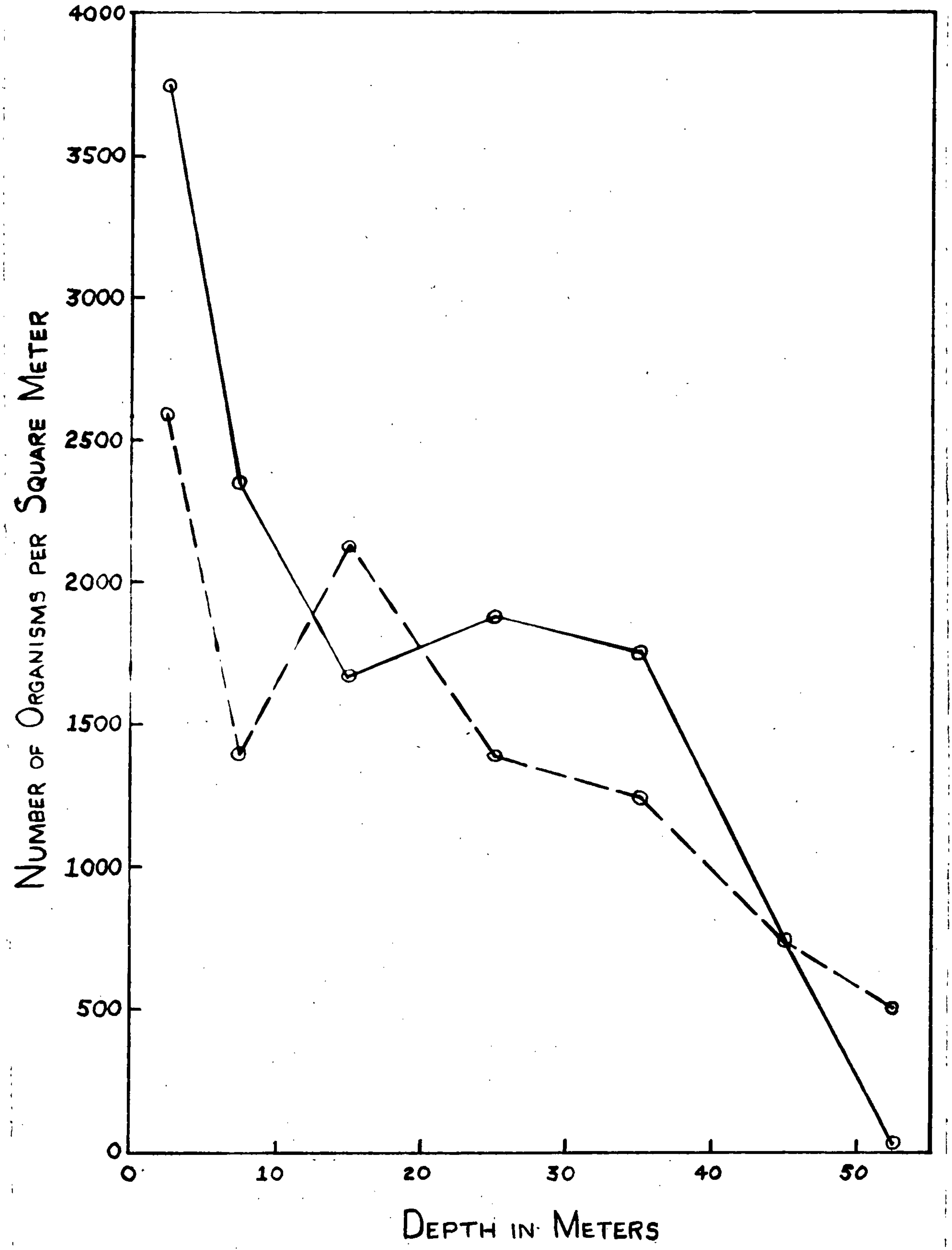
* weighted average.

Figure 3.

Average number of bottom organisms at various depths in Paul Lake, 1931, 1949.

1931 —— ——

1949 ————



4000
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
Number of Organisms per Square Meter
Depth in Meters

with 2.39 gms. in 1931. This suggests a decrease in the quantity of bottom fauna in the lake. In 1949, a thorough investigation of the bottom fauna was made. The results are tabulated in Table V along with results from 1931 which have been taken from Rawson (1934). Detailed results of the gravimetric analysis for 1948 and 1949 are shown in Appendix A.

From an examination of the mean wet weights, there appears to be a decrease, in all depth zones, in the wet weight of bottom organisms in 1949 as compared with 1931. The data were subjected to an analysis of variance modified for a weighting procedure as described by Snedecor (1946, pp. 462, 463). A Summary of the analysis is as follows:

Year	Mean (gm.)	$S\bar{x}$	Variance	"t" value in comparison
1931	0.955	0.151	0.022796	3.85
1949	0.399	0.054	0.002919	

The size of the subsamples (number of dredgings in each depth zone) is small, varying from 4 to 28, so that the significance of a "t" value is difficult to assess, particularly with the complication of the weighting procedure. Assuming that "t" is distributed normally in this type of calculation, the value of 3.85 has a probability of $<$ .001 which is highly significant. It is probably safe to conclude that the total quantity of bottom fauna in Paul Lake in 1949 is significantly less than that in 1931.

Discussion.

A numerical and a gravimetric comparison of the bottom fauna in Paul Lake in 1931 and 1949 has been made. The numbers of organisms have increased while the amount of bottom fauna has decreased. The

TABLE V

Gravimetric analysis of the bottom fauna.

Depth Zones (m.)	Area of Depth Zone (%)	1949				1931			
		No. of Samples	Mean Wet weight (gm.)	S^2	Weighted mean (gm.)	No. of Samples	Mean Wet weight (gm.)	S^2	Weighted mean (gm.)
0-10	10.4	28	1.765	1.851	.184	20	2.514	3.891	.261
10-20	17.9	13	.289	.358	.052	9	1.710	4.088	.306
20-40	24.5	8	.262	.027	.064	11	.852	.849	.209
40-55	47.3	4	.083	.020	.039	11	.378	.074	.179

Weighted mean - .339 gm.
(all depths)

Weighted mean - .955 gm.
(all depths)

increase in numbers has been mainly due to one group of organisms, the Chironomidae. These are small organisms which require large numbers to contribute significantly to the total weight. The group of organisms that have shown a definite decrease in numbers are the Gammarus. Gammarus are usually relatively large organisms which contribute a large proportion to the total weight.of a sample if found in moderate numbers, so that the decrease in quantity of bottom fauna appears to be mainly due to the decrease in the population of Gammarus.

The decrease in the Gammarus population might possibly be due to overgrazing by the trout since 1931, as in that year the stock of trout was depleted (Mottley 1932). If this is the case, it would appear that the bottom fauna was being more efficiently utilized in 1949 than in 1931, as there did not appear to be a significant decrease in the available food of the trout which is shown in a later section of the paper. The phenomenon of complete removal of Gammarus populations ~~have~~ has been reported in other small lakes in British Columbia (Larkin, unpub. verbal information). Another possible explanation for the reduction in the Gammarus population is that of natural annual variation. A poor spawning season or some detrimental ecological effect might be the cause of the variation observed in Paul Lake. Lundbeck (1926) and Alm (1922), cited by Rawson (1930), have observed two-fold annual variations in the total quantity of bottom fauna in some localities. It was not specified whether the variation was due to fluctuations in one group or all groups of bottom organisms.

FISH FAUNA.

The redside shiner, Richardsonius balteatus (Richardson), is the only species of fish other than Kamloops trout which occurs in Paul Lake. This species, in 1948, made its way down from the upper lakes in the same chain as Paul Lake, where it had been introduced by anglers. The shiners in Paul Lake are best treated as a potential source of food rather than available food, particularly since observations made in other lakes would suggest that the trout may eventually feed upon the shiners.

In two small lakes in the same chain as Paul Lake, Hyas and Pinantan lakes, the trout do feed upon shiners. In these lakes, it is alleged that after the appearance of shiners, fishing was poor. After three or four years, the trout "obtained the habit" of eating shiners and fishing gradually returned to its previous standard.

Mr. C.C. Lindsey (unpub. verbal information) has made interesting observations on shiners and eastern brook trout, Salvelinus fontinalis (Mitchell), in Rosebud Lake in the West Kootenay. Shiners are extremely abundant in this small lake; seine hauls of 500 to 1,000 individuals are readily taken. They are a major item in the diet of the brook trout and it would seem that with such a high density of shiners, the trout would exhibit a relatively fast rate of growth and the shiners population would be depleted. However, Mr. Lindsey has observed that the brook trout have great difficulty in catching the shiners. He records the observation that a brook trout may make many attempts to catch one of a large school of shiners, but will usually be unsuccessful. If dead shiners are thrown in the water, the brook trout show no hesitation in taking them.

It might be surmised from these observations that it is only when shiners are extremely abundant that they are sufficiently available for trout to utilize as an item of their diet. In the first few years following their introduction into a lake, the shiners would be at a low density and their occurrence in trout stomachs would be rare. At a higher density, shiners would be more readily available to trout and their occurrence in trout stomachs would be more common. It might also be supposed that in the first few years after their introduction into a lake, the increase in the numbers of shiners would be exponential. Consequently, the availability and the occurrence of shiners in trout stomachs would also increase exponentially and would give the impression that trout had suddenly "obtained the habit" of eating shiners.

It would be expected then, that in Paul Lake, records of shiners in the stomachs of trout will be occasional in the first few years following the entry of shiners into the lake. In three or four years time the shiners may attain a sufficiently high density that they will be commonly taken by trout, as is now apparently the case in Hyas and Pinantan lakes.

The question of the effect the shiners will have upon the fishing at Paul Lake can only be answered by future observations. Their beneficial effects may be (1) to increase the available food supply for the larger trout and thus increase their rate of growth, (2) to utilize food organisms in the lake that are not commonly taken by trout, e.g., Copepoda, and thus increase the efficiency with which the primary fish food organisms (plankton and bottom fauna) are converted into trout flesh.

Their main detrimental effect appears to be that of competition for food with the trout. In an analysis of seventeen shiner stomach contents, Copepoda, Cladocera, Ephemeroptera and Chironomidae predominate in the order named. Carl and Clemens (1948) state that the shiners of Okanagan Lake fed mainly upon Copepoda, Cladocera, and Chironomidae. The ultimate effect of the presence of a large shiner population in Paul Lake is worthy of study.

FOOD SUPPLY OF THE TROUT

In this section, only the food organisms found in the trout stomachs will be dealt with. All other organisms found in the lake, exclusive of those found in the trout stomachs, may be classified as indirect or potential food for the trout.

Stomach contents were preserved from approximately one third of the trout sampled from the angler's catch from 1947 to 1949. Samples were taken from various sizes of fish which were caught either by fly fishing or trolling. Collections were made from spring through to fall so that variations in the available food supply during the fishing season could be observed. Winter samples were obtained in December, 1948, by means of gill netting.

VOLUME OF STOMACH CONTENTS.

Individual stomach contents were placed on paper towels to absorbtthe excess moisture. The volume in c.c. of each stomach content was then obtained by placing the contents in a graduated centrifuge tube along with a known amount of water. Results for July and August of 1947 and July, August, and December of 1948 along with figures taken from Mottley and Mottley (unpub.) for 1932 to 1935 are shown in Table VI.

The factor, mean length of the trout divided by the mean volumes of the stomach contents is meant to show the condition of the available food supply. That is, a high value for the factor indicates a low available food supply while a low value for the factor indicates a relatively large available food supply. A linear relation between the length of the fish and the volume of the stomach was assumed.

TABLE VI.

Volumetric analysis of trout stomach contents, Paul Lake, 1932-1935, 1947, 1948.

Year	Month	Number of Stomachs	Number of Empty Stomachs	Mean Length of fish (c.m.)	Mean Volume of Stomach contents (c.c.)	Factor Mean length / Mean volume
1932	Jul. and Aug.	157	13	35.2	2.96	11.9
1933	Jul. and Aug.	51	10	35.9	1.81	19.8
1934	Jul. and Aug.	33	6	36.2	2.49	14.5
1935	Jul. and Aug.	55	18	31.0	0.91	34.1
1947	Jul. and Aug.	37	7	32.6	1.73	18.8
1948	Jul. and Aug.	69	4	37.1	1.74	21.3
	December	29	1	28.8	0.99	29.1

Mottley and Mottley (unpub.) have inferred that the change in amount of food eaten from 1932 to 1935 directly reflects a decrease in the availability of food of the trout, which might indicate corresponding changes in the food supply of the lake. They have also observed a significant downward trend in the available food supply from spring to fall of each year.

The volumes for July and August of 1947 and 1948 show what would appear to be a significant increase in available food over that of 1935. The low summer heat income in Paul Lake in 1948 could possibly be a contributing factor in the relatively lower supply of available food in comparison with 1947. The winter samples taken in 1948 show a relatively large supply of available food for this season.

Evidence to support the fact that the mean volumes of stomach contents is a fair estimate of the available food supply can be seen in the percentage of empty stomachs noted during the different years. The samples for 1948 should be deleted owing to the extreme environmental changes. When the available food supply is high, the percentage of empty stomachs is low. Conversely, the percentage of empty stomachs increases when the available food supply decreases. A Chi square analysis comparing the ratio of empty stomachs to full stomachs gave the following results:

1932 vs. 1935	$p. < .01$	significant
1948 vs. 1935	$p. < .01$	significant
1932 vs. 1948	$p. > .7$	non significant

ANALYSIS OF STOMACH CONTENTS.

A microscopic examination of each stomach sample was made and the groups of organisms identified. An estimate of the percentage volume of each group of organisms was made for each sample. The percentage volume was converted into c.c. as a function of the total volume of the stomach sample. Total percentage volumes for each group of organisms were then calculated, taking into account the volume in c.c. each group of organisms contributed to the total volume of all the stomach samples in one season. This method of representation is not meant to show the feeding habits of the trout, but is devised to show the quantitative importance of each group of organisms in regard to the total volume of stomach contents for any one season. The results are shown in Table VII.

Daphnia pulex, Odonata, Gastropoda, and *Hyalella* were the most abundant food organisms in the diet of the trout and predominated in the order named. *Daphnia pulex* was the dominant item of food in all seasons except May, 1949, when it was surpassed by Anisoptera and Hymenoptera. In all seasons sampled in 1947, 1948 and 1949, *Gammarus* made up a very small percentage of the stomach contents with the exception of December, 1948, when it contributed 18.8 per cent to the total volume. These data would bear out Rawson's observation that the trout ate large quantities of insects in May and June while the water was sufficiently cool to allow feeding at or near the surface. In this investigation, the trout were found to eat large quantities of bottom and surface insects in May and June and large quantities of bottom insects in December.

Discussion.

It is apparent that there are conspicuous seasonal and annual differences in the diet of trout which presumably reflect seasonal and annual variations in the availability and abundance of the different food organisms. Rawson (1934) observed that *Gammarus* was the main food item of trout in Paul Lake in 1931 and *Daphnia pulex* was next in order. In the period from 1947 to 1949, it was found that *Gammarus* made up only

TABLE VII.

Percentage volume of food organisms in Paul Lake trout stomachs, 1947 - 1949.

Date		Number of Stomachs	Groups of Organisms															
Year	Month		*Daphnia pulex*	*Gammarus*	*Hyalella*	Anisoptera	Zygoptera	Trichoptera	Ephemeroptera	Coleoptera	Chironomidae	Hymenoptera	*Physa*	*Limnea*	*Planorbis*	Sphaeriidae	Hirudinea	Miscellaneous
1947	Jul	20	77.3	0.2	-	5.1	-	6.8	-	-	1.6	-	3.1	0.8	0.2	-	4.5	4.6
	Aug	10	77.1	-	1.6	0.6	-	-	-	-	1.2	-	17.6	-	-	-	-	1.9
1948	Jun	27	29.1	3.7	28.7	10.3	7.7	8.9	1.9	0.4	1.7	-	0.8	1.9	0.9	0.1	1.3	2.7
	Jul	,10	68.0	1.6	11.2	-	-	1.3	-	0.3	0.5	-	13.8	2.0	0.3	-	-	0.9
	Aug	39	61.7	7.9	1.9	3.6	2.1	2.2	0.1	0.4	0.4	1.8	4.3	8.9	-	0.1	-	2.8
	Sep	6	77.8	1.3	3.1	5.6	-	0.4	1.1	0.7	0.4	-	7.0	1.2	1.8	-	-	-
	Dec	14	41.6	18.8	2.0	11.4	12.8	11.8	1.1	0.1	-	-	-	-	-	-	-	-
1949	May	14	18.3	3.6	1.3	27.0	3.8	4.3	0.3	9.9	2.2	21.3	-	3.9	-	-	-	4.0

a minor item of the diet of the trout which reflects a decrease in the *Gammarus* population which was indicated by the analysis of the bottom fauna.

It might also be said that annual and seasonal climatic conditions may act as limiting factors in the availability of trout food. The temperature of the upper layer of water appears to govern, to a large extent, the feeding habits of the trout. It has been shown in an analysis of the trout stomachs and also by Rawson (1934) that the trout in Paul Lake do not generally feed in the shallow shoal area where food is abundant, after the temperature of the water has reached summer conditions. A long warm season would apparently cause the trout to feed mainly in deeper water where the bottom fauna is not as abundant either in species or in quantity, whereas a long cool season would be conducive to feeding at or near the surface where there is an abundance of both species and numbers of organisms. Mottley and Mottley (unpub) observed that for the years 1932 to 1935, the volume of food eaten by trout in the spring was high and dropped progressively until fall. This was probably due to the fact that the trout were forced to feed in deeper water during the summer months.

The restriction of feeding areas by unfavorable temperature conditions (and possibly by other factors; for example, oxygen depletion, pH, light intensity), would indicate that the relation between the quantity of bottom organisms and plankton and their availability is complex and variable. For example, bottom organisms may be extremely abundant in the shoal area, but will not be available to the trout at those times when the water temperature in this area is high enough to force them into deeper water to feed. It might be concluded that because Kamloops trout feed on such a variety of organisms in all ecological zones within a lake, and because variations in environmental factors may exclude them from time to time from some of these zones, that is is difficult to assess the relation between the quantity and quality of food organisms and their availability to trout.

STATISTICS OF THE TROUT POPULATION

HISTORY OF THE STOCKING POLICY.

A record of the plantings of eggs and fry in Paul Lake is given in Table VIII.

TABLE VIII.

Distribution of fry and eggs in Paul Lake.

Year	Number
1909	5,000 fry
1922	42,500 eggs
1923	139,250 eggs
1925	107,000 eggs
1927	100,000 eggs
1928	165,000 eggs
1929	200,000 fry
1930	378,000 eggs
1931	185,000 fry
1932	200,000 fry
1933	200,000 fry
1934	200,000 fry
1935	200,000 fry
1936	200,000 fry
1937	175,000 fry
1938	150,000 fry
1939	150,000 fry
1940	200,000 fry
1941	200,000 fry
1942	200,000 fry
1943	250,000 fry
1944	250,000 fry
1945	100,000 fry
1946	200,000 fry
1947	200,000 fry
1948	nil
1949	300,000 fry

In 1909, Paul Lake was stocked with 5,000 Kamloops trout fry from Adams Lake. The lake had been "barren" previous to this period. The initial stocking was successful and a relatively high rate of growth was realized (Mottley, 1932). In 1922, Paul Creek was planted with 42,500 eggs obtained from an egg collecting hatchery which was built near the lake in that year. Surplus eggs collected were used to stock other "barren" lakes in the province. Following this, the plantings in Paul Lake were irregular until 1931.

An investigation into the propagation and conservation of Kamloops trout was begun in 1931 by the Biological Board of Canada. Rawson (1934) in his study of the productivity of the lake found that the "nutritive" condition of the lake was distinctly oligotrophic. He concluded that the bottom fauna was efficiently utilized by the trout and that Paul Lake appeared to be capable of supporting a relatively large population of Kamloops trout.

Mottley (1932) made a study of the trout population of Paul Lake and found that depletion had occurred. The causes of depletion were believed to be the increased fishing intensity since 1921 and drying up of Paul Creek in August of certain years, with a consequent trapping of the fry and the destroyal of the eggs. To remedy the latter situation he recommended the planting of fry in the lake.

Mottley (1932) outlined a stocking policy for Paul Lake which he believed would (1) efficiently utilize the food supply of the lake, (2) counteract the depletion of trout that he had observed and (3) satisfy the intensity of the fishing at that time. He assumed that the shoreline of the lake was equally as productive as the best type of stream and that the potential feeding ground around the shore was seven miles long and thirty feet wide. Calculations of the fish carrying capacity of this area were made according to Embody (1927), cited by Mottley (1932). On the basis, Mottley calculated that the fish carrying capacity of the lake was probably not less than 200,000 fry annually. In later studies, Mottley (1940) observed that the lake was producing approximately ten pounds of trout per acre per year, 10,000 pounds in all, and he believed that this figure might be taken as the lake's productivity.

In 1937, the stocking was reduced to 175,000 fry and was reduced further in 1938 and 1939 to 150,000 fry per year. This reduction in the number of fry planted was recommended by Mottley due to the decrease in average size of the trout (Clemens, 1937). The stocking was again increased to 200,000 fry in 1940, and was continued until 1942. A further increase to 250,000 fry per year was made in 1943 and 1944.

High waters in 1945 damaged the fish trap and fence. As a result, most of the spawning run escaped to spawn naturally. Therefore, the stocking in this year was reduced to 100,000 fry, as it was believed that the natural spawning would make up the balance. In 1946 and 1947 the stocking was 200,000 fry per year. The water in Paul Creek reached flood conditions in 1948 and again resulted in the escape of most of the spawning run. Artificial planting was not carried out in this year. In 1949, a further experiment was begun on the lake and a planting of 300,000 fry was made. This experiment is discussed in a later section of the paper.

ANGLERS' CATCH.

Trout were sampled from the anglers' catch at Echo Lodge as time and opportunity permitted, during the summers of the investigation. These fish were sampled as soon after being caught as was possible in order to minimize error from loss of weight in storage. The sex, weight, standard and fork lengths, and state of maturity were recorded for each fish. A scale sample was taken below the insertion of the dorsal fin, immediately above the lateral line. Stomach contents were preserved from approximately one third of the fish sampled.

Average measurements.

The average measurements of the trout sampled are shown in Table IX. Average weights of trout from 1932 to 1936 have been taken from Mottley (1940) and were converted from pounds to grams. Unfortunately, figures are lacking for the standard and fork lengths of trout from 1932 to 1936.

TABLE IX

Average measurements of trout in the anglers' catch from Paul Lake, 1932-1936, 1946-1949.

Year	Weight (gm.)	Standard Length (cm.)	Fork Length (cm.)
1932	675.8	-	-
1933	693.0	-	-
1934	530.7	-	-
1935	426.4	-	-
1936	453.6	-	-
1946	324.4	26.7	28.6
1947	399.9	28.4	32.2
1948	594.4	32.8	36.5
1949	469.4	30.2	33.5

Mottley (1941) has shown that there was a significant decrease from 1932 to 1935, in both length and weight of the immature yearling and two-year-old female trout of Paul Lake. He believed that these changes were related to the increase in the stock of trout in the lake.

Figures from 1946 to 1948 show a steady increase in both length and weight. The 1949 measurements show a slight decrease from those in 1948.

Age composition.

The scale samples taken were mounted in glycerine jelly and were viewed under a Promar scale projector. The data were then grouped into age classes. A discussion of scale reading and the criteria used by the writer in interpreting the scales is given in Appendix B.

The percentages of age classes in the anglers' catch are given in Table X.

Table X.

Percentage age composition of the anglers' catch from Paul Lake, 1946-1949.

Year	Age Classes				
	I	II	III	IV	V
1946	63.0	19.7	12.3	4.9	-
1947	24.4	36.7	34.4	3.3	1.1
1948	10.6	50.2	36.2	3.0	-
1949	28.3	35.0	26.7	10.0	-

A large year class can be followed through the fishery beginning with the one-year-old fish in 1946. In this year, they were the dominant age class and made up 63 per cent of the anglers' catch. In 1947 the two-year-old fish were dominant and made up 37 per cent of the catch. The three-year-old fish made up 36 per cent of the catch in 1948. The four-year-old fish contributed 10 per cent of the catch in 1949. This is a high percentage when compared with percentages of four-year-old fish in other years.

The large year class can probably be attributed to the floods in 1945 which allowed natural spawning. The natural spawn coupled with the 100,000 fry planted in 1945 likely resulted in a great influx of fry into the lake and thus produced a dominant one-year-old class in 1946. The number of fry that reached the lake was probably greater than the usual stocking of 200,000 fry annually. The anglers, therefore, caught a much greater percentage of one-year-old fish in 1946 and this brought about the low average size for trout in this year. In 1948 there was still an abundance of the large year class that had not been fished out in the previous two years. This would account for the high average size of fish caught in 1948. The large year class had decreased considerably in numbers in 1949, due to the extensive fishing it had undergone in the previous three years. As a result, the average size of fish in this year was reduced somewhat, as the younger age groups were contributing a larger percentage to the total catch.

The proportions of age classes making up the total catch in different years is instrumental in explaining the fluctuations in average size of fish from 1946 to 1949. That is, the average size of fish caught in these years would be approximately equal, if the percentages of each year class in the catch were similar. Therefore, the reason for the fluctuation in average size of trout from 1946 to 1949 was mainly due to the age composition of the catch rather than to large variations in the growth of the trout. Variations in the growth of the trout are discussed in a later section of the paper.

<u>Catch curve analysis</u>.

The anglers' catches are represented graphically in figure 4.

The method chosen has been to plot catch curves. Loge of the frequency of occurrence was plotted directly against the age classes. The resulting figure shows the trends of the trout population over a period of four years and also shows the survival of the older age groups.

Ricker (1948) described a catch curve as having a steeply ascending left limb, a dome shaped portion and a long descending right limb. Deviations from the theoretical may arise from violent fluctuations in reproduction and therefore recruitment to the fishery. The ascending left limb and the dome of a catch curve represent age classes which are incompletely captured by the gear used to take the sample: that is, they are taken less frequently in relation to their abundance than are older fish. In the case of the trout fishery in British Columbia, there is a legal size limit of eight inches which must be observed and would therefore result in an inadequate sampling of the one-year-old fish.

The catch curve for 1946 deviates from the theoretical in that it lacks a left limb and a dome shaped portion. This would bear out the statement made previously that the stocking was great enough in 1945 to produce a dominant one-year-old class. The one one-year-old class was large enough to dominate the catch, although it was not as subject to heavy fishing as the older age classes.

The 1947 catch curve is characteristic in that it has the essential parts described above. The large age class is now shown by the two-year-old fish. The one-year-old class was due to the usual stocking of 200,000 fry in 1946.

The 1948 and 1949 catch curves are somewhat similar to each other and to the 1947 curve. It can be seen that the large year class originating in 1945 has been surpassed by the two-year-old fish in 1948

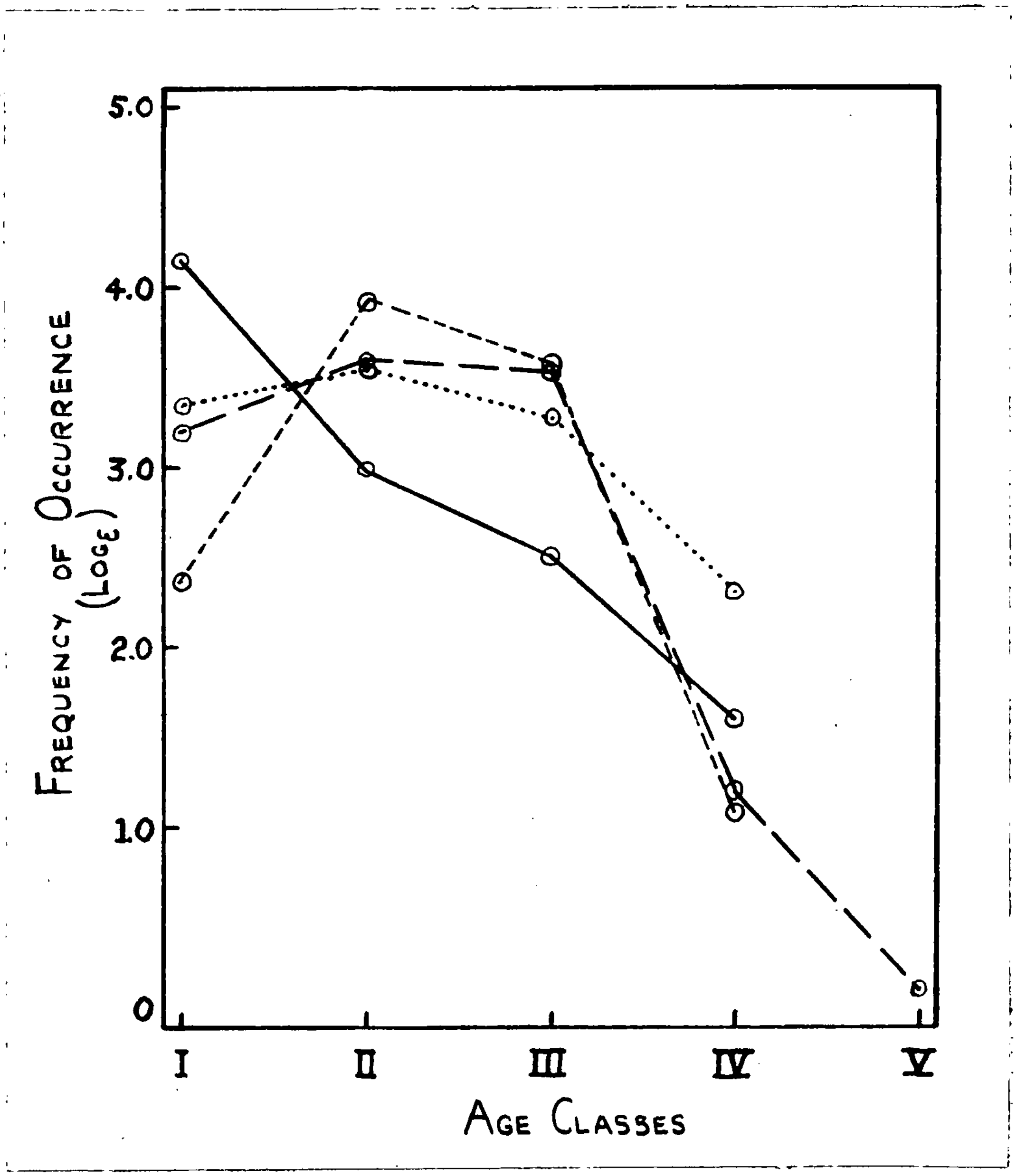


Figure 4.

Catch curves of the anglers' catch, Paul Lake, 1946-1949.

Legend: 1946 ———————
1947 — — — —
1948 - - - - -
1949 ....

and by all age groups in 1949. A high survival of the four-year-old fish can be noted in 1949 in comparison with the previous years. A high percentage of one-year-old fish in the catch in 1949 serves to indicate a successful natural spawning in 1948 as no artificial stocking was carried out in that year.

Length frequency distribution.

Figure 5 represents a method of graphically illustrating the anglers' catch, where the standard lengths rather than the ages of the fish are taken into consideration. Length classes of 3.0 cms. were arbitrarily chosen and the frequency of occurrence of trout were calculated for the different classes. The frequency of occurrence was plotted directly against the length classes.

The large year class resulting from 1945 can be readily followed through the fishery by noting the peak of the curve in each year illustrated. In 1946, the peak occurred at the 20.5 to 23.4 cms. length class. In 1947, the peak had moved over to the 29.5 to 32.4 cms. length class. The large year class had been reduced considerably by 1949 and, in this year, did not form the major peak in the curve. However, the frequency of occurrence of trout in the 35.5 to 41.4 cms. length class was high in comparison with the previous years.

Growth of the trout.

Figure 6 represents the growth, in centimetres, of trout ranging in age from one to four years. The average fork lengths have been plotted against the age classes for five different years. The figures for 1931 have been taken from Mottley (1932) and were converted from inches to centimetres. This method of illustration is not meant to show an accurate rate of growth of the trout.

The growth shown for 1931 was high in comparison with the other

Figure 5.

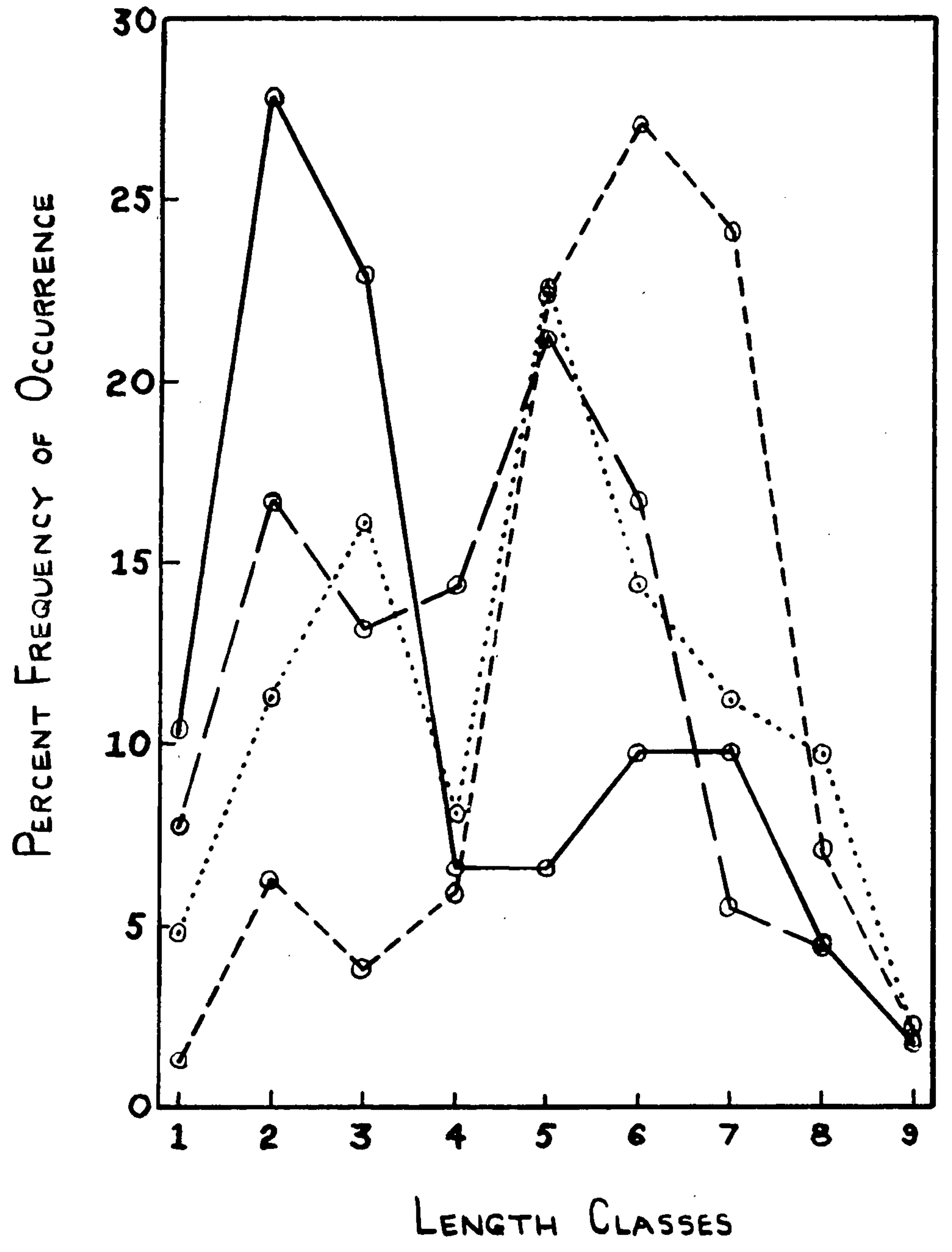
Length frequency curve of the anglers' catch,

Paul Lake, 1946-1949.

Length classes: *1. 17.5 - 20.4 cm.
2. 20.5 - 23.4 cm.
3. 23.5 - 26.4 cm.
4. 26.5 - 29.4 cm.
5. 29.5 - 32.4 cm.
6. 32.5 - 35.4 cm.
7. 35.5 - 38.4 cm.
8. 38.5 - 41.4 cm.
9. 41.5 - 44.4 cm.

*Trout are illegal below 20.3 cm.

Legend: 1946 ————
1947 —— ——
1948 - - - - -
1949 ....



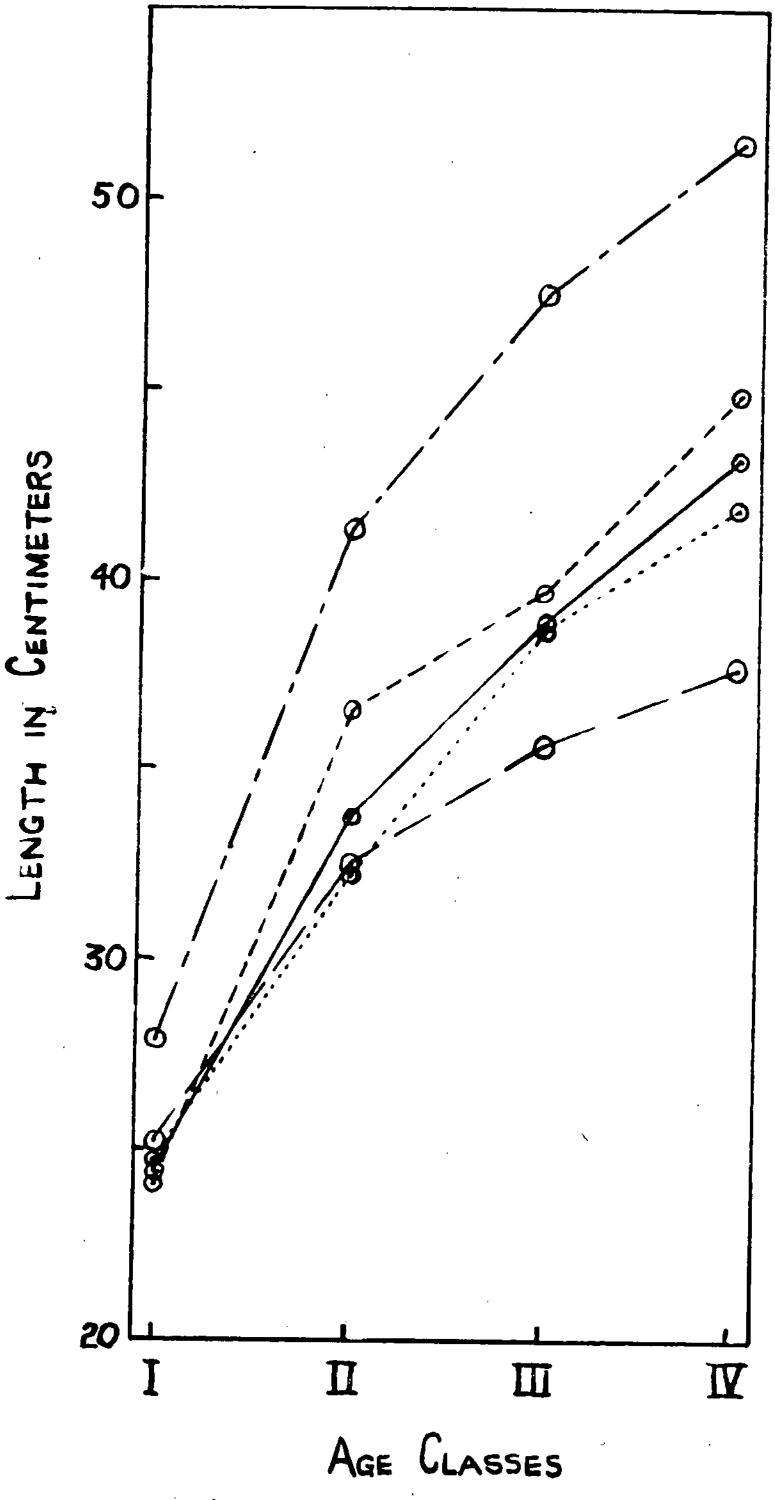
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
PERCENT FREQUENCY OF OCCURRENCE
LENGTH CLASSES

Figure 6.

Growth of trout in the anglers' catch,

Paul Lake, 1931, 1946-1949.

Legend: 1931 —— - ——
1946 ————————
1947 ——— ———
1948 - - - - -
1949 ....



50
40
30
20
Length in Centimeters
I
II
III
IV
Age Classes

years illustrated. In this period, the lake was showing signs of depletion of trout and would account for a relatively rapid rate of growth. There was little difference in the growth from 1946 to 1949 with the exception that 1947 showed a slightly smaller growth.

The mean standard lengths of age classes of trout from 1946 to 1949 are shown in Table XI. The standard deviation and the standard error were calculated for each mean.

TABLE XI.

Mean standard lengths (cm.) and standard errors of age classes of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	1946	1947	1948	1949
I	22.77 ± .183	22.17 ± .318	21.78 ± .734	22.29 ± .507
II	31.73 ± .465	28.87 ± .884	32.94 ± .267	29.08 ± .746
III	35.97 ± .472	31.52 ± .721	35.35 ± .281	34.63 ± .737
IV	39.33 ± .85	33.63 ± 1.415	40.1 ± .964	37.39 ± 1.041

A statistical comparison, using values of "t", was made between the age classes of trout to determine significant variations in length. The results of the comparisons are shown in Table XII.

TABLE XII.

Results of the "t" value comparisons of the standard lengths of age classes of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	Years compared					
	1946,1947	1946,1948	1946,1949	1947,1948	1947,1949	1948,1949
I	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
II	S.	S.	S.	S.	N.S.	S.
III	S.	N.S.	N.S.	S.	S.	N.S.
IV	S.	N.S.	N.S.	S.	N.S.	N.S.

S - significant
N.S. - non significant
Five percent level.

There was no significant difference between the lengths of one-year-old fish in any of the years compared. The outstanding feature of this comparison is in the 1947 catch. In the majority of cases, the average length of each age class in this year, excluding the one-year-old fish, was significantly smaller than corresponding age classes in the other three years.

In 1946, due to the large 1945 year class, the population of trout probably exceeded the optimism capacity for the lake. The food supply appeared to decrease as was indicated by the plankton samples taken in 1946. As a result, there was a reduction of the growth of trout in the period 1946 to 1947, which could be attributed to increased competition as an effect of the decrease in available food, so that a lower average length of trout was observed in 1947. A large proportion of the dominant year class was fished out in 1946 and 1947, and the growth of trout increased in the period 1947 to 1948. An explanation for the fact that the one-year-old fish in 1947 were not found to be smaller is that this age class was not representatively sampled; that is, the smaller one-year-old fish are not of legal size.

Values for the standard deviationsare shown in the following table.

TABLE XIII.

Standard deviations of the mean standard lengths of age classes of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	1946	1947	1948	1949
I	2.448	1.492	3.672	2.211
II	3.478	5.081	2.896	4.477
III	2.793	4.016	2.589	3.458
IV	3.182	2.451	2.55	3.447

"z" values were calculated according to Fisher (1948). Significance was determined by comparing calculated values of "z" with tabled values of "z" at the 5% level of probability. Results of the comparisons are shown in the following table.

TABLE XIVa.

Results of the "z" value comparisons of the standard deviations of age classes of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	Years compared					
	1946-1947	1946,1948	1946,1949	1947,1948	1947,1949	1948,1949
I	S.	S.	N.S.	S.	S.	S.
II	S.	N.S.	S.	S.	N.S.	S.
III	S.	N.S.	N.S.	S.	N.S.	S.
IV	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

TABLE XIVb.

Results of the "z" value comparisons of the standard deviations of age classes of trout in the anglers' catch, Paul Lake, 1946-1949.

Year	Age classes compared		
	I,II	II,III	III,IV
1946	S.	N.S.	N.S.
1947	S.	N.S.	N.S.
1948	N.S.	N.S.	N.S.
1949	S.	N.S.	N.S.

S. - significant
N.S. - non significant
Five per cent level.

The best comparisons may be noted in the two-year-old and three-year-old age classes. Age classes for one-year-old fish are poor for comparison as they are not adequately represented in the anglers' catch, with the result that only the larger one-year-old fish were taken. This would tend to reduce the values of the standard deviations. The sample sizes for four-year-old fish were very small and little confidence can be placed in the results.

Comparisons of the two-year-old fish show that the standard deviations for 1947 and 1949 were significantly higher than for 1946 and 1948. There was no significant difference between the standard deviations for 1946 and 1948 and between those for 1947 and 1949. A repetition of the above is found in three-year-old class, with the exception that there is no significant difference between 1946 and 1949.

In three out of four cases, 1946,1947 and 1949, there were significant differences in the standard deviations between the one- and two-year-old age classes, the two-year-old fish having the higher standard deviations. There were no significant differences in the standard deviations between the two- and three- and between the three- and four-year-old age classes for each year represented.

Two factors might account for the high standard deviation of the two-year-old fish in 1947. These are competition for food and length of time spent as a stream dwelling fish. It was suggested in a previous section of this paper that a more acute competition for food probably resulted from the large stock of fry introduced in 1945. This increased competition apparently resulted in a decrease in the rate of growth, increased individual variation in growth rate and thus a higher value for the standard deviation.

There were probably a large number of fry, from the natural spawning in 1945, that remained in the stream for one year. In an analysis of the 1948 spawning run, which is discussed in a later section of the paper, it was found that approximately 42 per cent of the three-year-old fish of the spawning run had apparently spent a part or all of their first year in the stream. The criterion used in determining "stream type" fish is given in Appendix B. Mottley (1932) has observed that trout "prefer" the stream in their first year at least, and that these "stream type" fish usually do not reach the legal size limit until their second year. Therefore, a large proportion of these "stream type" fish from the 1945 spawning run did not enter the fishery until 1947. The "stream type" fish coupled with the lake dwelling fish for the two-year-old age class in 1947 would give a greater dispersion in size range than usual and would therefore tend to increase the value of the standard deviation. The factor of competition for food would help to explain the high standard deviation for the three-year-old fish in 1947.

Sex ratio.

Chi square values were calculated to determine significant variations from the theoretical 1:1 sex ratio for the different age classes of the anglers' catch. The results are shown in Table XVa. In 1946 and 1947, there were no significant departures from the 1:1 ratio, although the females predominated in the majority of cases. In 1948 and 1949, there were significant variations, and in all cases, female trout dominated the catch.

Table XVb. shows the four years of data grouped together. In all cases, except the one-year-old fish, the anglers were selecting female trout.

The data were then analysed in the following manner. Year classes were followed through the fishery, were grouped and sex ratio comparisons were made. It was again found, in most cases, that the females dominated the fishery.

A possible explanation for the fact that the anglers catch a significantly greater number of female trout than male trout involves the length of time for each sex to attain sexual maturity. Male trout generally spawn earlier in life than female trout (Mottley, 1940). Observations made during scale reading showed that both males and females usually spawn each year after their first spawning. Therefore, female trout might be said to spend a longer period of life as non spawners than do male trout. This would possibly produce a preponderance of male spawners in the lake as compared with female spawners. After a trout has spawned, it is in "poor condition" insofar as the angler is concerned, so that a larger number of male fish would be discarded by the anglers and would give the impression that the anglers were selecting female fish. This does not appear significantly in the one-year-old class as few fish tend to spawn this early in life.

TABLE XVa.

Sex ratio comparisons of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	Male			Female
		1946		
I	93	N.S.	$p > .3$	81
II	22	N.S.	$p > .2$	31
III	14	N.S.	$p > .2$	21
IV	3	N.S.	$p > .05$	10
Total.	132	N.S.	$p > .5$	143
		1947		
I	10	N.S.	$p > .3$	6
II	11	N.S.	$p > .2$	17
III	11	N.S.	$p > .1$	19
IV	2	N.S.	$p > .5$	1
Total.	34	N.S.	$p > .3$	43
		1948		
I	3	S.	$p < .01$	22
II	41	S.	$p < .01$	76
III	35	N.S.	$p > .1$	49
IV	3	N.S.	$p > .2$	7
Total.	82	S.	$p < .01$	154
		1949		
I	6	N.S.	$p > .1$	13
II	12	S.	$p < .05$	24
III	9	N.S.	$p > .3$	13
IV	2	S.	$p < .05$	9
Total.	29	S.	$p < .01$	59

S. - significant
N.S. - non significant
P. - probability
Five per cent level.

TABLE XVb.

Sex ratio comparisons of trout in the anglers' catch, Paul Lake, 1946-1949.

Age Class	Male			Female
I	112	N.S.	p > .5	122
II	86	S.	p < .01	148
III	69	S.	p < .02	102
IV	10	S.	p < .01	27
Total.	399	S.	p < .01	277

S. - significant
N.S. - non significant
p. - probability
Five per cent level.

CREEL CENSUS.

A voluntary creel census was taken at Paul Lake during the fishing season of 1949. Creel census cards were printed and were distributed to Echo Lodge and to the cottages. A creel census sign and box was erected at the outlet of the lake. In this location, it was clearly visible to all those leaving the lake. Publicity was given by the Kamloops Sentinel newspaper and by a radio sports broadcast. Letters urging co-operation from the anglers were distributed to the cottages and whenever possible, the writer personally talked with the anglers. An estimated 90 per cent efficiency of returns was obtained by Mr. J.R. Morrill of Echo Lodge. Unfortunately, very little co-operation was received from the cottages.

The unit chosen for representing the fishing effort is the "boat-day". One "boat-day" is equal to two anglers fishing for five hours. This was the unit chosen by Mottley (1934). The catch per "boat-day" for the three months of data available is as follows:

May - 3.0 fish

June - 2.0 fish

July - 4.5 fish.

May, June and July - 3.2 fish.

An attempt has been made to estimate the total catch for the 1949 fishing season as it might be useful for comparison with previous years. The estimate is based on the returns from Echo Lodge. It was assumed that a 90 per cent efficiency of returns was obtained from the lodge, that May, June and July was one half of the total fishing season and that the cottagers' boats were used one third as much as the lodge boats. The following data have been used in the calculations. The total number of fish recorded at the lodge during May, June and July was 1,870 while the total number of "boat-days" recorded was 588.4. The lodge had 27 boats im operation while the cottagers had a total of 70 boats. With these facts and assumptions, the estimated total catch in Paul Lake in 1949 is 7,743 trout and the estimated total number of "boat-days" is 2,436. This estimate is only approximate and at best can be used only for a rough comparison with previous years.

Table XVI shows a comparison of these estimated totals with previous data obtained by Mottley (1940).

TABLE XVI.

Production of trout in Paul Lake, 1932-1936, 1949.

Year	Total catch of trout	"Boat-days"	Number of fish per "boat-day"	Total weight of fish (lbs)
1932	3,000	750	4	4,500
1933	6,000	1,000	6	9,200
1934	8,000	1,000	8	9,300
1935	12,000	1,200	10	11,300
1936	10,000	1,100	9	10,000
1949	7,743	2,436	3.2	8,050

The estimated total number and weight of fish produced in 1949 is equal to approximately four fifths of the total produced in 1936. It may be noted also, that the fishing intensity has more than doubled, while the catch per unit effort has decreased by two thirds in comparison with 1936.

From these comparisons, it would appear that the total stock of trout in the lake in 1949 has been reduced considerably since 1936. The

1949 production figures compare most closely with those figures for 1932 when the lake was in the process of recovering from a state of depletion. A fishing intensity twice as great as previously, and a reduced total catch should immediately suggest that the lake is once again tending towards depletion.

SPAWNING RUN.

The spawning run at Paul Lake takes place during May and the first half of June of each year in Paul and Agnes Creeks. The majority of the run enters Paul Creek. Mottley (1933) has indicated that the difference between the number of fish entering Paul and Agnes creeks was proportional to the volume of water leaving each stream. In 1933, approximately one fiftieth of the spawning run entered Agnes creek. There is likely a high mortality of eggs and fry in Agnes creek as only the lower reaches, approximately 100 yards, of the creek continue to flow during the summer.

A fish fence and traps are situated on Paul creek, approximately one half a mile from the lake. The spawning trout are counted and stripped and the eggs are then transported to Lloyd's creek hatchery. An effort is made to handle all of the fish in the spawning run, although this has usually not been possible as there are a few "stragglers" that enter the creek after the fence has been removed.

The spawning run at Paul creek was sampled during the spring of 1948 and 1949. In 1948, sampling was carried out in June, shortly after the high waters from the flood had receded. The total number of trout sampled in this year was 90. In May and June of 1949, 195 spawning trout were sampled. These totals were comprised of 27 males and 63 females in 1948, and 92 males and 103 females in 1949. An analysis of the data showed the spawning trout to have average fork lengths of 36.5 cm. in 1948 and 39.5 cm. in 1949.

The scale samples were mounted and read, and arranged into age classes. The results are shown in the following table.

TABLE XVII

Percentage age composition of the spawning run, Paul Lake, 1948, 1949.

Year	Sex	Age classes			
		II	III	IV	V
1948	Male	22.2	59.3	14.8	3.7
	Female	20.6	54.0	25.4	-
1949	Male	4.5	36.4	47.7	11.4
	Female	2.0	24.5	60.2	13.3

The large year class resulting from 1945 can be detected again in analysis of the data. In this case, the large year class dominates the spawning run as three year old fish in 1948 and as four year old fish in 1949. There was a greater percentage of males in the younger age classes, while the females were dominant in the older age classes. This would indicate that male Kamloops trout tend to spawn earlier in life than female trout (Mottley 1940).

Records of the spawning run at Paul creek have been kept by the hatchery officials. These data are shown in the following table.

TABIE XVIII.

Statistics of the spawning run, Paul Lake, 1932 - 1949.

Year	Number of Spawners		Number of Eggs	number of eggs per female	Number of Eggs per fluid ounce.
	Male	Female			
1932	-	-	265,000	-	250
1933	-	-	841,000	-	250
1934	-	-	837,000	-	250
1935	-	-	388,000	-	250
1936	1,022	1,011	1,419,500	1,404	250
1937	802	1,019	1,530,000	1,501	250
1938	452	504	806,000	1,599	250
1939	566	543	1,103,000	2,031	250
1940	743	759	1,680,000	2,213	250
1941	366	373	850,000	2,279	250
1942	822	900	1,800,000	2,000	240
1943	771	819	1,870,000	2,283	250
1944	620	675	1,155,000	1,711	250
1945	286	317	485,000	1,530	250
1946	2,077	1,784	2,135,000	1,197	330
1947	1,255	1,155	1,350,000	1,169	375
1948	237	258	352,500	1,366	380
1949	975	1,095	1,853,000	1,692	300

A comparison is shown of the numbers of male and female spawners, the number of eggs obtained, the number of eggs per female, and the number of eggs per fluid ounce. Data for 1945 and 1948 were biased due to flood conditions and therefore, total numbers cannot be compared with other years.

Chi-square values were calculated for the numbers of male and female trout in each year, in order that significant variations from the theoretical 1:1 sex ratio might be determined. Significant variations were found in 1937, 1946, and 1947. In 1937, the females dominated the run, while in 1946 and 1947, the males dominated the run. An analysis of the anglers' catch showed the fishermen to be significantly selecting female trout. This would tend to explain the preponderance of males in the spawning run in 1946 and 1947. Another reason for the preponderance of males in these years is that the males from the large year class resulting in 1945, would make up a large proportion of these runs. The females would make up only a small percentage of these runs as they tend to spawn mainly in their fourth year. In 1949, the females dominated the run, although the numbers were not significantly larger.

The number of eggs per fluid ounce remained fairly constant, 250 eggs per fluid ounce, from 1932 to 1945. The only deviation noted was in 1942, when the size increased to 240 eggs per fluid ounce. The period 1946 to 1948 showed a decrease in the size of eggs which corresponded to a low point in the number of eggs per female. This would seem to indicate a decrease in the average size of trout in the spawning run during this period. The size of eggs, eggs per female and average size of trout had begun to increase in 1949, which was probably due to a relatively high proportion of the large 1945 year class that reached maturity.

An examination of the figures for the number of eggs per female shows the high point to occur in the period 1939 to 1944. This period corresponds very closely to the war years when the fishing intensity was likely reduced significantly. If this is the case, there was likely a larger proportion of the older age classes that were not fished out and were given the chance to reach maturity. Generally speaking, the older fish are larger in size and have a greater number and size of eggs than the younger fish. This would account for the large number of eggs per female in these years. Since the war years, fishing intensity has likely increased rapidly. Consequently, the numbers of older fish spawning were reduced, and the number of eggs per female and average size of eggs decreased.

The total number of eggs obtained in each year from 1932 to 1944 appears to show a periodic cyclical fluctuation. If the spawning run is divided into three year periods, beginning with 1932 to 1934, a regular recurring low point in egg production in the first year of each period may be observed. The egg production is a direct reflection of the number of females in the spawning run and the number of eggs per female. Figures from 1945 to 1949 are biased due to flood conditions in 1945 and 1948. No explanation can be offered for this cyclical fluctuation because of the absence of pertinent data but there is a possibility that it is a natural phenomenon in the trout population and might warrant investigation in other lakes.

DISCUSSION.

The preceding sections of this paper have dealt with two fundamental aspects of the problem of the productive capacity of lakes. These are the study of the environment of the fish population and the study of the vital statistics of the fish population. Either aspect of the problem may be used as an index of the productivity of a lake.

The study of the environmental conditions in a lake serves to indicate the general suitability of the physical and chemical conditions for the bottom fauna and flora, the plankton and the fish population. Also, a knowledge of the fauna and the available food supply in relation to the area of the lake is obtained which provides an index to the productive capacity of the lake in terms of fish. However, because Kamloops trout feed on a variety of organisms in all ecological zones within a lake and because variations in environmental factors may exclude them from time to time from some of these zones, it is difficult to assess the relation between the quantity and quality of food organisms and their availability for the production of trout. It is for this reason that our knowledge of the relation of the environment to the production of trout is empirical. In the absence of comparable data from other lakes, the statistics of the trout population affords a better direct index of the degree to which the resources of the lake are being utilized. That is, a knowledge of the fish population provides a stronger basis for the formulation of ~~the~~ a suitable management policy.

A combination of both indices is more valuable in that the pros and cons arising from each index can be weighted according to their relative importance. Environmental conditions that would appear detrimental to the fish population might be disregarded, within limits, if it was found that the trout population did not show the effects. For example, the quantity of bottom fauna in Paul Lake has decreased, but an analysis of the fish population did not appear to show a corresponding decrease in available food. A selection of the most promising line of attack can then be made.

Drs. Mottley and Rawson have outlined the conditions that existed in Paul Lake during a previous investigation. A summary of the conditions in 1949 and variations from the previous investigation is outlined below.

The environmental conditions differ somewhat since 1931. The summer heat incomes have shown extreme downward fluctuations since 1931 although other physical and chemical conditions have remained relatively constant. The plankton is moderate in quantity. Fluctuations have occurred, especially in 1946 when a downward fluctuation was observed, but no permanent quantitative change has been observed. The bottom fauna was described as of average richness in 1931 but has decreased in quantity by two-thirds since then. The available food supply of the trout as indicated by the volumes of the stomach contents has shown a decrease in amount from 1932 to 1935, an increase in amount from 1935 to 1949 and a slight decrease in amount from 1932 to 1949. Another species of fish, the redside shiner, has made its entry into Paul Lake.

The statistics of the trout population have also indicated significant variations since 1931. The average size of the age classes of trout has decreased slightly since 1931. The anglers have recently been catching a large proportion of the younger age classes of trout. These younger age groups of trout have also constituted a major portion of the recent spawning runs, causing a reduction in the size of eggs and numbers of eggs per female. A large year class resulting from 1945 has been followed through the fishery. The main effects of this year class appear to have been a greater survival of trout and a restoration of older age classes in the anglers' catch in 1948 and 1949 and in the spawning run in 1949. A comparison of the 1936 records with those from 1949 has indicated a two-fold increase in fishing intensity, ~~and~~ a slight decrease in the total catch and a large decrease in the catch per unit effort.

From an examination of these conditions, it would seem that the previous stocking policy of 200,000 fry per year has been a fair average and has gradually adjusted to the resources of the lake. Conditions in 1949, such as a large increase in the fishing intensity and a large decrease in the catch per unit effort would suggest that the previous management policy might be revised. The problem appears to be a matter of too small a stock of fish to satisfy the increasing fishing intensity. This condition might be improved in two ways; by decreasing the catch limit per person or by increasing the stock of trout in the lake either by increasing the annual planting or possibly by initiating a cyclical fluctuating stocking policy patterned after the 1945 year class.

A reduction in the catch limit alone would have to be drastic. It was found in an analysis of the creel census in 1949 that a reduction to five fish per person per day eliminated only six per cent of the total catch. A reduction in the catch limit would possibly result in a more even distribution of fish to the anglers and would probably not decrease the total catch to any extent. In order for this method to function efficiently, it would be necessary to reduce the catch limit even further.

The result of the 1945 year class was observed with both its detrimental and beneficial effects. The main beneficial effect was the change in the quality of fish as evidenced by the increase in numbers of older and larger fish in the anglers' catch and in the spawning run. This was due to a high survival of fry and thus a high survival of the older age groups of the year class even though they were intensively fished in the years between. The increase in numbers of older and larger fish in the spawning run produced corresponding larger and greater numbers of eggs. The detrimental effects appeared to be that of a decrease of plankton in the year following the origin of the year class and a slight decrease in the growth of trout during the period of low plankton production.

Therefore, for purposes of fish culture and for experiment, it is suggested that the future stocking policy be patterned after the 1945 year class. This could be initiated by the following procedure.

Year I. Introduce a stock of 300,000 fry and produce a dominant year class. This has been carried out in the 1949 stocking.

Year II. Introduce a stock of 100,000 fry as conditions for survival and for growth may be poor in this year due to the large stock preceding it.

Year III. Introduce a stock of 200,000 fry as conditions for survival and for growth should be improving.

Year IV. Repeat the process.

It is also suggested that the catch limit be reduced to five fish per person per day. The cyclical fluctuating stocking policy should result in an improvement in the quality of fish in the anglers' catch and in the spawning run, and if it also results in an increase of the stock in the lake by virtue of a more efficient utilization of the food resources, the reduction to five fish per person per day might decrease the total catch by a greater percentage than it would in 1949, thus leaving a larger food stock in the lake. If the suggested management policy does not increase the stock, the reduced catch limit may act as a safeguard against overfishing.

At the end of three years, the effects of the revised stocking policy on the fish~~ing~~ery should be observed. If it is found that the total yield and the catch per unit effort of trout have not increased, the total stocking could then be increased in multiples of the ratio 3:1:2 provided that the food resources of the lake would warrant an increase in the stock.

Effects of the stocking could be observed by the collection and analysis of the following data; data of the trout in the spawning run, including age composition, total numbers and average size of fish, number of eggs per female and number of eggs per fluid ounce, and data of the trout in the anglers' catch, including age composition, average size and catch per unit effort.

SUMMARY AND CONCLUSIONS

1. A definite summer thermal stratification was observed in Paul Lake. The summer heat incomes have shown extreme annual fluctuations.
2. Oxygen was abundant at all depths.
3. The plankton was moderate in quantity and has shown minor annual fluctuations. There was a reduction in quantity of plankton during the winter but appeared to indicate a fairly large supply for the winter season.
4. There was a relatively large supply of bottom fauna. However, there was a significant reduction in the quantity of bottom fauna since 1931. This reduction in amount appeared to be due to the depletion of the *Gammarus* population.
5. The redside shiner, *Richardsonius balteatus*, has made its entry into Paul Lake. Analysis of the stomach contents showed the shiners to be directly competing with the trout for food.
6. The available food supply for the trout appeared to have increased slightly since 1935. The winter sample indicated a large supply of available food in view of low temperature conditions.
7. A large year class was found to have resulted from the floods in 1945. This year class probably exceeded a stocking of 200,000 fry as it could be traced throughout the fishery. The beneficial effects appeared to outweigh the detrimental effects.

8. The anglers selected significantly more female than male trout, which was possibly due to a preponderance of male spawners in the lake.

9. The fishing intensity has doubled, the total catch has decreased by one fifth and the catch per unit effort has decreased by two thirds. The stock of the trout in the lake is tending towards depletion under the present fishing intensity.

10. The large year class from 1945 has increased the numbers of older fish in the spawning run. Also the number of eggs per female and the size of eggs were increased due to this large year class. A cyclical fluctuation in egg production was noted.

11. A revised stocking policy, patterned after the 1945 year class, has been outlined.

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APPENDIX A.

TABLE XIXa.

Temperature series, Paul Lake, 1947. ° C.

Depth (m.)	Sub station III.				Sub station II.		
	Jul 25.	Aug 21.	Aug 28.	Aug 29.	Jul 28.	Aug 29.	Sep 2.
0	20.0	17.6	19.0	19.2	19.0	19.1	19.4
3	19.5	-	18.5	-	-	18.5	18.4
6	18.6	-	17.6	-	17.6	17.9	17.8
7.5	15.2	17.3	-	17.4	16.1	17.0	17.1
9	12.9	14.6	11.9	-	12.5	11.9	14.5
15	-	6.6	5.8	6.4	6.2.	6.7	6.6
30.5	4.7	4.7	-	4.7	-	4.7	4.7
Bottom	4.5	4.5	4.7	4.7	4.5	4.7	4.6

TABLE XIXb.

Temperature series, Paul Lake, 1948. ° C.

Depth (m.)	Station I.						
	Jul 23.	Jul 24.	Jul 29.	Aug 5.	Aug. 9.	Aug 18.	Sep 10.
0	20.4	19.5	19.0	19.8	20.1	19.0	18.1
3	19.9	19.4	18.4	19.2	19.1	18.7	16.6
4.5	19.6	17.1	16.2	18.2	18.5	18.6	16.2
5.5	14.7	14.2	12.9	16.0	17.4	16.0	-
6	12.0	10.5	11.4	14.0	14.7	14.9	15.2
7.5	7.6	8.8	7.8	8.7	9.8	8.8	11.0
9	-	-	-	7.0	7.4	6.9	8.1
15	5.2	5.3	5.2	5.1	5.2	5.1	5.4
30.5	4.6	4.6	4.6	4.6	4.6	4.6	4.7
53.5	4.4	4.4	4.6	4.4	4.4	4.4	4.5

TABLE XIXc.

Temperature series, Paul Lake, 1948. ° C.

Depth (m.)	Sub station I.					Sub station II.		
	Jul 31	Aug 5	Aug 16	Sep 6	Dec 17	Aug 1	Aug 5	Sep 6
0	19.7	19.3	19.8	16.3	1.2	21.5	19.1	16.3
3	18.4	19.2	18.8	15.8	2.4	19.2	19.1	16.2
4.5	17.2	19.2	18.6	15.7	-	17.9	19.0	15.8
5.5	10.9	18.4	18.6	-	-	16.9	15.0	-
6	9.6	13.6	17.4	12.3	2.8	14.8	12.2	15.4
7.5	7.4	8.5	12.6	8.9	-	8.0	7.8	12.4
9	-	6.5	9.5	7.1	2.9	6.8	6.6	8.2
15	5.2	5.1	5.3	5.2	-	5.2	5.1	5.1
24.5	4.7	4.8	4.9	4.8	3.1	-	-	-
30.5						4.6	4.5	4.5
48						4.4	4.4	4.4

TABLE XIXd.

Temperature series, Paul Lake, 1949. ° C.

Depth (m.)	Station I.		
	May 15	Jun 23	Aug 3
0	15.3	16.1	20.8
3	11.4	16.1	20.0
4.5	10.0	15.3	18.9
6	6.7	13.3	16.4
7.5	6.4	9.2	11.9
9	5.5	6.7	8.9
15	-	4.4	6.4
53.5	4.4	3.9	4.4

TABLE XX.

Dredging Samples, Paul Lake, 1948.

Date	Dredging Series	Depth (m.)	*Wet Weight
Aug 19	S.S. I.	2.0	.4497
		11.5	.1621
		25.0	.0498
		26.0	.0856
		14.5	.2384
		1.5	.8449
Aug 20	S. I.	9.0	.5889
		55.0	.0075
		25.5	.1091
		5.5	3.1530
		1.5	1.5392
Aug 27	S.S. II	2.0	2.2527
		8.0	.5276
		13.0	.0668
		2.0	1.4146

*Weight of Mollusc shells has been deducted.

TABLE XXI.

Dredging Samples, Paul Lake, June 18-25, 1949.

Dredging Series	Depth (m.)	*Wet Weight (gm.)	Dredging Series	Depth (m.)	*Wet Weight (gm.)
D.S. I.	2.5	1.949	D.S. V.	1	2.121
	10.5	2.259		2	3.909
	25.5	.107		17.5	.066
	16.5	.062		45	.005
	9	.591		19	.278
	2	3.073		7	.826
				0.5	2.952
D.S. II.	2.5	1.600	D.S. VI.	2.5	.883
	2.5	.507		9	1.395
	6.5	1.178		11	.076
	14.5	.226		13	.030
	30	.367		13.5	.226
	10.5	.084		33	.267
	5	1.438		41	.293
	2	1.032		49.5	.031
				7	.437
				1.5	.173
D.S. III.	1.5	1.361	D.S. VII.	1	3.688
	4	5.961		5	3.745
	9	.730		21	.441
	39	.359		35	.032
	11	.034		19.5	.224
	2.5	.349		7	.951
	1.5	.698			
	30	.433			
D.S. IV.	2.5	2.814			
	10.5	.123			
	55	.002			
	31.5	.093			
	7.5	1.241			
	7.5	2.338			
	1.5	1.495			
	19.5	.066			

*Weight of Mollusc shells has been deducted.

APPENDIX B.

SCALE READING.

Scale reading is a highly subjective undertaking and requires a good deal of experience. Thus, significant variations in results are not uncommon when a comparison is made with results from other scale readers. The writer has spent a large proportion of time in familiarizing himself with Kamloops trout scales and has devised a fairly objective interpretation of them. Mottley (unpub.) gave an outline of scale reading from which constant reference was made.

A trout scale is composed of an anterior embedded portion which is made up of concentric rings or circuli. The posterior or exposed portion is heavily pigmented and usually lacks circuli. A small area in the centre of the scale is called the nucleus.

The winter check or annulus was the feature used to determine the age of a fish from its scales. Winter checks are due to a sudden decrease in the rate of growth and make their appearance among the circuli in the latero-posterior radius of the scale. A count of the winter cheks indicated the age. Scales that presented much difficulty in reading were not used in the results.

The following criteria were used in determining a winter check.

1. A notch or wedge among the circuli.
2. Cutting over.

   The first summer ring may cross sharply over the winter rings and give the impression that the winter rings have been cut off.

3. Circuli spaced closely together.

Confusion in identifying winter checks might possibly occur due to the following factors.

1. Summer check.

   Available food may become scarce, growth is retarded, and a check occurs. Summer cheks are usually not as well defined as a winter check. (Mottley, unpub.)

2. Injury to fish.

   Growth rate may be retarded and a check may occur.

3. Absence of winter check.

   Growth rate may not slow down significantly during the winter and therefore, a check may not occur in the scale.

4. Spawning scar.

   The resorption of the scale during spawning may be great enough to eliminate previous annuli.

5. Regenerated scale.

   Annuli are not present in regenerated portions of scales.

A Kamloops trout scale from Paul Lake, indicating some of the above features is shown in figure 7.

It has been suggested by Mottley (1932) that stream dwelling fish can be differentiated from lake dwelling fish. He has indicated that scales from stream dwelling fish are characterized by eight or less circuli in one year's growth. However, there are a great deal of "border line" cases when making this separation. Therefore, for the purposes of this investigation, there has been little attempt to make the separation.

Figure 7.

Kamloops trout scale, Paul lake.

1. Nucleus
2. Winter check
3. Summer check
4. Latero-posterior radius

Figure 7.

Kamloops trout scale, Paul Lake.