Province of
British Columbia

Ministry of
Environment

OI
SOUTHE

by— W.A. CLEMENS
D.S. RAWSON
J.L. McHUGH

Technical Report—

A BIOLOGICAL SURVEY OF OKANAGAN LAKE,
BRITISH COLUMBIA (1939)

1N

FISHERIES
RESEARCH
BOARD
OF
CANADA

BULLETIN

1934-39

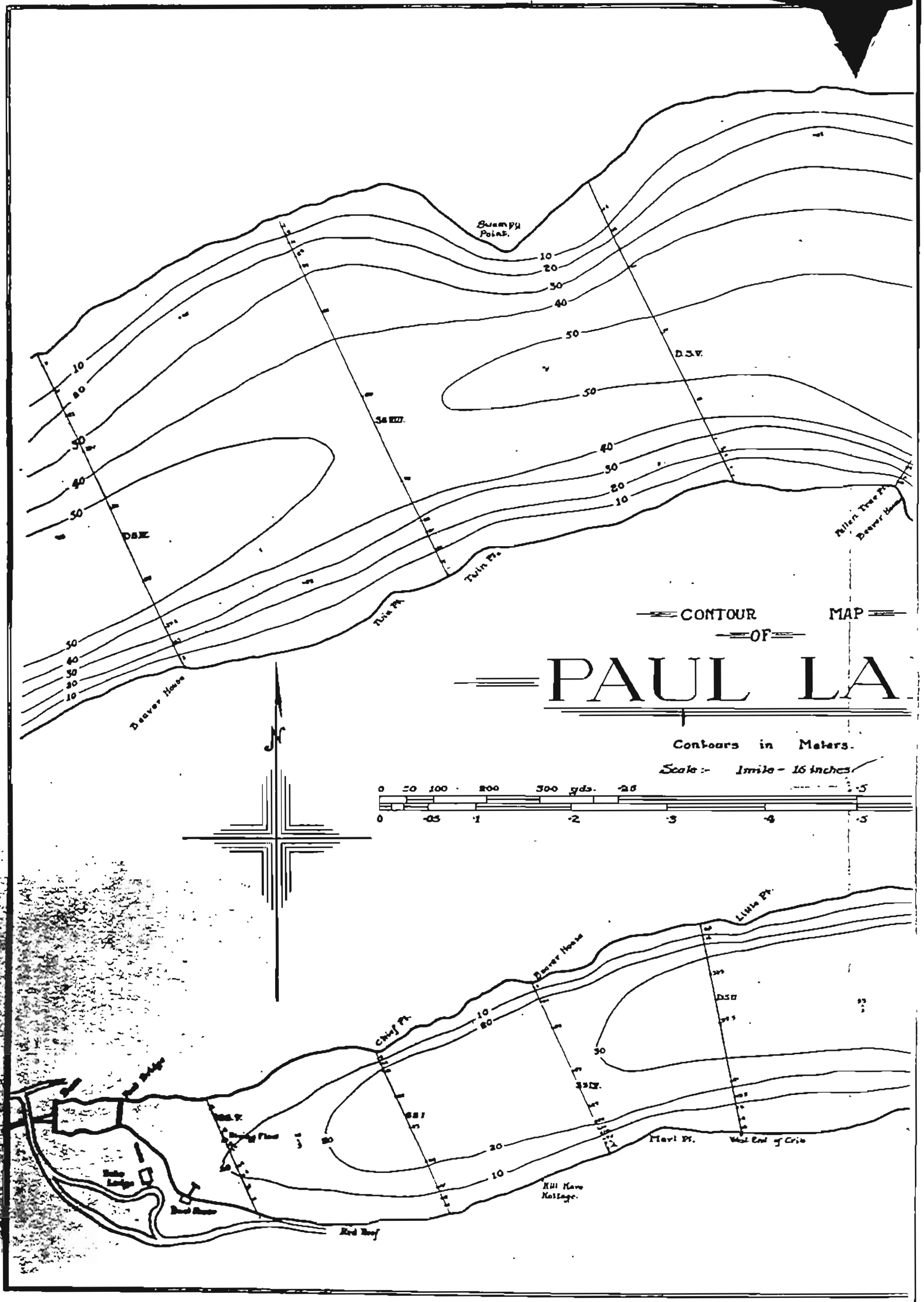
No. 41-58

TABLE OF CONTENTS

57. Salmon for angling in the Margaree river. By A.G. Huntsman, pp. 1-75, 1939.

58. Bird control to increase the Margaree river salmon By H.C. White, pp. 1-30, 1939.

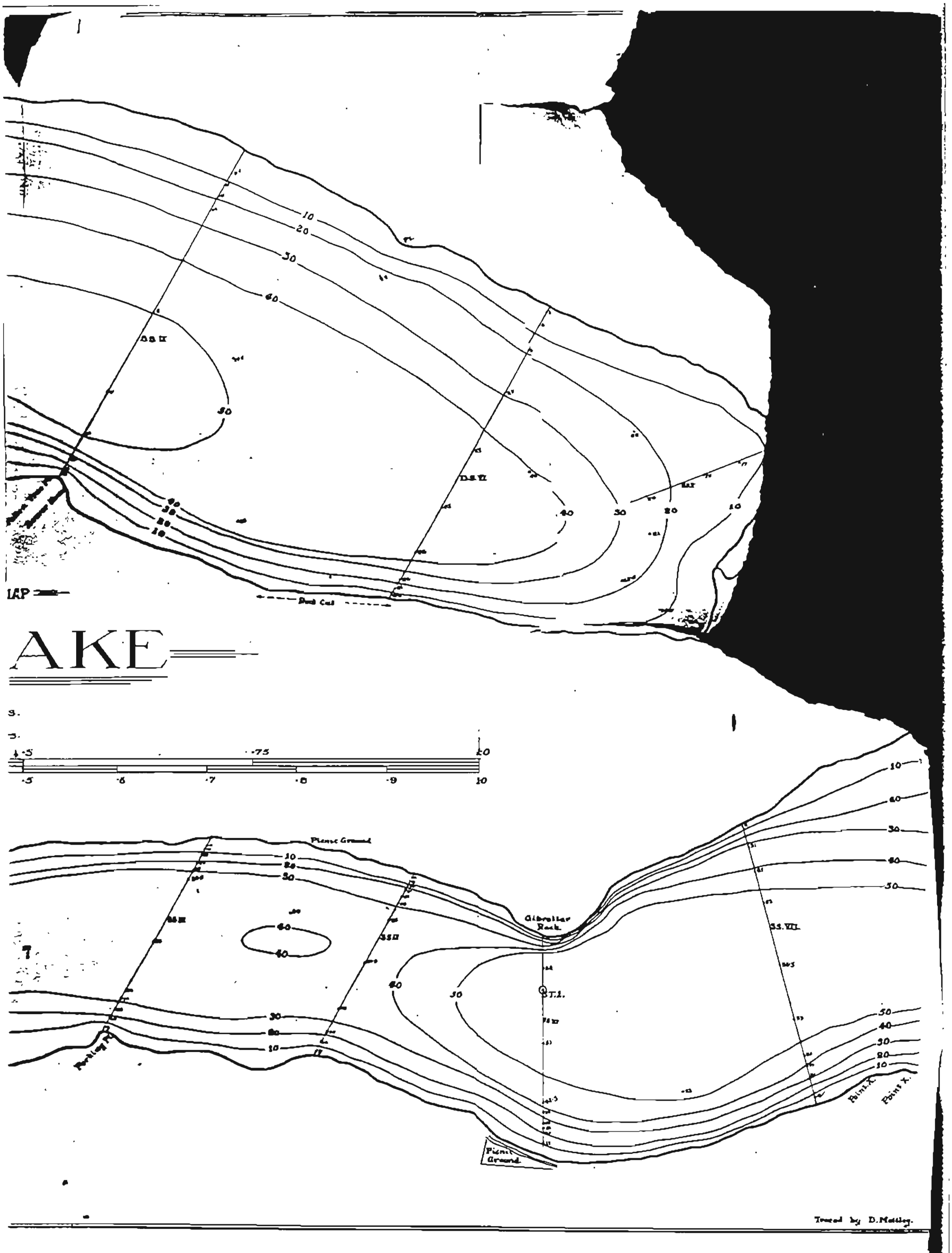
59. The chemistry and technology of marine animal oils with particular reference to those of Canada. Edited by H.N. Brocklesby, pp. 1-442, 1941. (Bound separately).



CONTOUR MAP OF PAUL LA

Contours in Meters.

Scale:- 1mile - 16 inches



IAP
AKE
·5
·75
1·0
·5
·6
·7
·8
·9
1·0
10
20
30
40
S.S.II
50
D.S.VI
40
30
20
10
40
30
20
10
Dud Cut
Picnic Ground
10
20
30
40
40
S.S.III
S.S.II
Gibraltar Rock
S.S.VII
40
30
S.T.1.
30
20
10
Point X
Point X
50
40
30
20
10
10
20
30
40
50
Picnic Ground
Traced by D. Motley.

A BIOLOGICAL SURVEY OF OKANAGAN LAKE, BRITISH COLUMBIA

By W. A. Clemens
Director, Pacific Biological Station
D. S. Rawson
University of Saskatchewan
and
J. L. McHugh
Pacific Biological Station

INTRODUCTION

By W. A. Clemens

During July and August, 1935, a study of the physical, chemical and biological features of Okanagan lake, British Columbia, was carried out by the writer in association with Dr. D. S. Rawson of the University of Saskatchewan and Mr. J. L. McHugh of the University of British Columbia, assisted by Mr. A. Clemens and Mr. C. Child. The investigation centred about the Kamloops trout, *Salmo gairdneri kamloops*, which is at present the only important "sport" fish in the lake.

At the time white settlers entered the Okanagan valley, about 1860, and during the years immediately following, trout are said to have been very abundant. In recent years, however, anglers have maintained that the stock of trout has been seriously diminishing and have pressed for more extensive fish-cultural operations as a means of improving the fishing. The investigation had for its object, therefore, the determination of the conditions existing in the lake as a scientific basis for the possible development of a comprehensive fish-cultural program.

In view of the fact that the field work was confined to but two months in the summer, the survey cannot be said to be complete. A study of spring and autumn conditions is especially desirable, particularly in relation to the spawning and abundance of the trout and the kokanee, *Oncorhynchus nerka kennerlyi*. However, sufficient data have been obtained from the present investigation and from enquiry to permit of the presentation of certain facts, conclusions and recommendations.

Headquarters were established at Okanagan Mission on the east shore, and from there excursions were made to all parts of the lake. In addition, it was found desirable to examine three lakes in the immediate drainage basin, namely, Kalamalka, Woods and Duck lakes, as well as two small mountain lakes connected with the system, namely, Beaver and Chute lakes.

The investigation was carried out as part of the program of the Pacific Biological Station of the Fisheries Research Board of Canada. Some financial aid was given by the Fish Cultural Branch of the Department of Fisheries, Ottawa, for which grateful acknowledgment is made. Our sincere thanks are tendered to many residents of the region who gave assistance in many ways, in particular to various members of the local fish and game associations and to Mr. G. N. Gartrell, Fisheries Inspector, Summerland. We are also indebted to Major J. A. Motherwell for information concerning the stocking of the various lakes and the removal of carp.

The following reports are included:

1. Physical and chemical studies, plankton and bottom fauna of Okanagan lake, B.C., with appended data from adjacent smaller lakes, by D. S. Rawson, pp. 3-26.
2. The fishes of Okanagan lake and nearby waters, by W. A. Clemens, pp. 27-38.
3. The whitefishes, *Coregonus clupeaformis* (Mitchill) and *Prospium williamsoni* (Girard) of the lakes of the Okanagan valley, British Columbia, by J. L. McHugh, pp. 39-50.
4. Fish cultural problems in the Okanagan area, by W. A. Clemens, pp. 51-57.
   Appendix. Tables XVII-XX, pp. 58-70.

PHYSICAL AND CHEMICAL STUDIES, PLANKTON AND BOTTOM FAUNA OF OKANAGAN LAKE, B.C., IN 1935 WITH APPENDED DATA FROM ADJACENT SMALLER LAKES

By D. S. Rawson

ACKNOWLEDGMENT

Grateful thanks are extended to the Dominion Water Power and Hydrometric Bureau which supplied useful hydrometric data, to Mr. C. C. Kelly of the Provincial Soil Survey Branch for data with respect to the geology of the Okanagan valley and to the following persons for identifications of organisms: Dr. E. G. Berry (Gastropoda), Dr. S. T. Brooks (Pelecypoda), Dr. G. C. Carl (Cladocera and Copepoda), Dr. W. J. Clench (Physa), Miss J. Fraser (Trichoptera), Dr. F. P. Ide (Ephemeroptera), Prof. C. W. Lowe (Algae), Dr. Ruth Marshall (Hydracarina), Dr. J. P. Moore (Hirudinea), Dr. F. J. Myers (Rotatoria), Prof. F. Neave (Plecoptera), Dr. J. G. Rempel (Chironomidae), Dr. E. M. Walker (Odonata).

PHYSIOGRAPHY AND HYDROGRAPHY

Location and Geology

Okanagan lake is one of four large lakes in the southern part of the interior plateau of British Columbia. From east to west they are Kootenay, Arrow and Okanagan with Shuswap lying just north of Okanagan. All are narrow and lie in deep valleys which extend generally in a north and south direction.

Since its formation in the middle of the Tertiary period the Okanagan valley has had a varied and interesting history, certain features of which are of importance in the present study. Glacial activity at one time blocked the valley so that the lake drained northward into the Thompson river system. Thus the lake was at one time connected with the present Shuswap basin. Since the recession of the last ice sheet, about 25,000 years ago, drainage to the south was re-established.

The valley is older and its adjacent mountains show more erosion than those of the Fraser valley to the north. The surroundings are still rugged with the lake lying in a deep narrow basin and mountains in the vicinity rising nearly 6,000 feet above its surface (figure 1). The upper parts of its tributary streams are rapid with frequent falls. Lower in the valley irrigation is carried on to such an extent that some streams fail to reach the lake.

DRAINAGE

The question of drainage is of particular interest in this investigation since the chief fisheries problem in the region involves the Kamloops trout, a stream spawning species.

The watershed drains southward into the Columbia river and that part of it which empties into Okanagan lake measures 2,300 sq. mi. (*Surface water supply of Canada, Pacific Drainage for the climatic year 1929-30, Dept. of the Interior, 1935*). This drainage area is proportionately smaller than that of other large lakes, such as Shuswap and Kootenay. There is also a lower precipitation and lower run off in the Okanagan valley and consequently a greater tendency for the tributary streams to dry up. In the following comparison the outflows of Okanagan, Shuswap and Kootenay lakes are measured at Penticton, Chase and Nelson respectively. The run off is indicated both as discharge in cubic feet per square mile of drainage area and as the equivalent depth in inches over the drainage area.

Lake	Drainage area sq. mi. (approx.)	Mean monthly discharge (10 yr. av.) cu. ft./sec.	Run off cu. ft./sec. per sq. mi.	Run off depth, in. per sq. mi.
Okanagan..	2,340	433	0.17	2.3
Shuswap...	7,000	9,940	1.42	19.2
Kootenay..	17,700	25,400	1.35	19.5

The average monthly discharge from Okanagan lake at Penticton is indicated as 433 cu. ft. per sec., but in the past ten years it has varied from 59 to 1,100. This is in part the result of controlling the outflow at the dam and in part the effect of variation in the annual precipitation. A comparison of the influence of these factors is made in figure 2, where the mean monthly discharge is plotted along with annual precipitation for a period of 10 years. The figure used for precipitation is the average of five stations, Vernon, Okanagan centre, Kelowna, Peachland and Penticton. In some periods the correlation is evident, as in 1927 where exceptionally heavy precipitation is followed by increased discharge in 1928. At other times the effect of storage is evident, as in the period 1932-35 where discharge remained high while precipitation fluctuated considerably.

	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Aver.
Inches of precipitation at Okanagan L., average 5 sta...	12.2	17.4	10.4	11.2	10.5	11.0	14.8	11.4	13.2	12.8	12.5
Mean monthly discharge at Penticton (cu. ft. per sec.)....	212	228	1,100	270	80	59	422	599	695	669	433

The control of the outflow of the lake is of moderate importance as compared with the control exercised over its tributary streams for irrigation purposes. Records of monthly discharge through the period April-September are available for about 15 streams tributary into Okanagan lake. An examination of these records gives little suggestion of the natural flow in the streams but much evidence of the extent to which they are utilized for irrigation. Long lake creek, the outlet from Kalamalka to Vernon creek, had an average flow near its source of 33 ft. per sec. and only 19 ft. per sec. at a station two miles below.

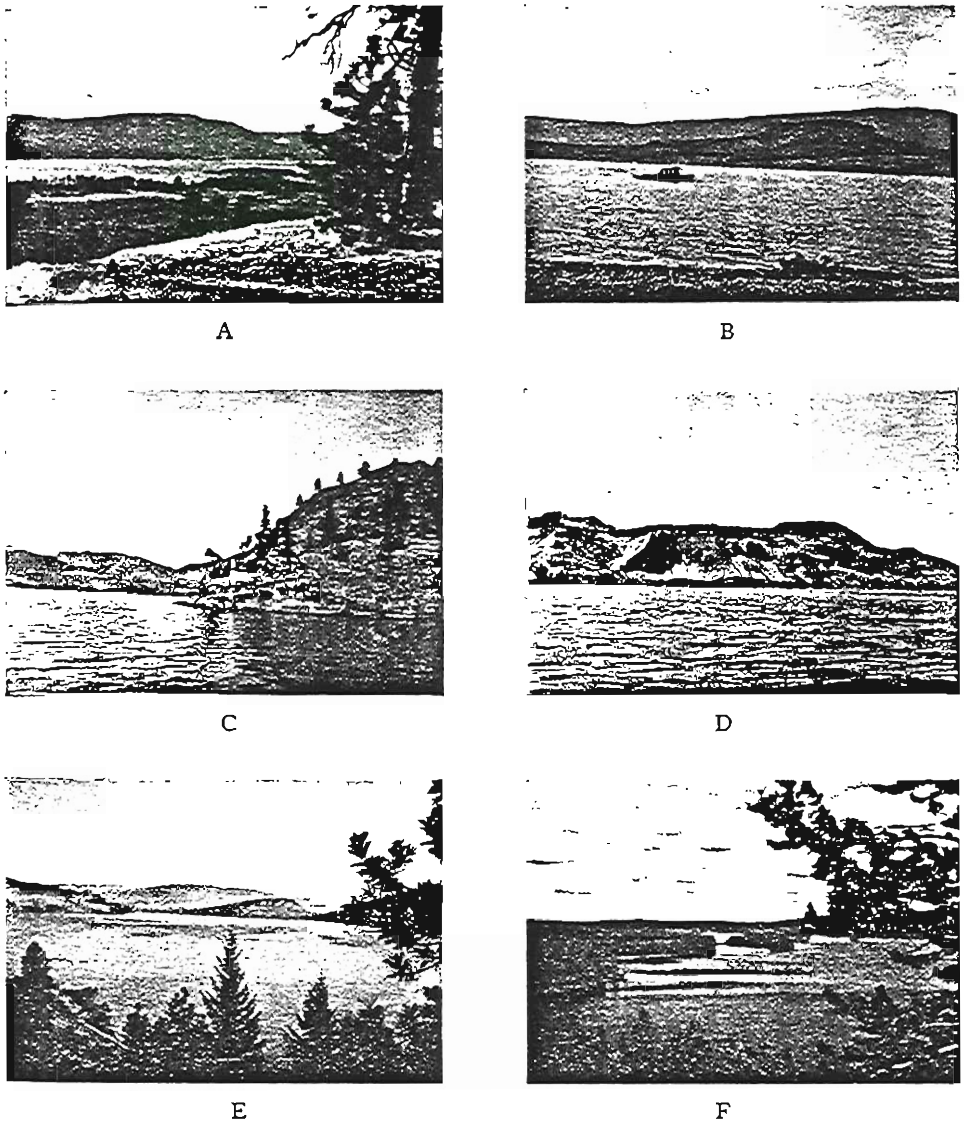


FIGURE 1. Views of lakes, Okanagan area. A. Okanagan lake at Okanagan Mission, with irrigated fruit lands below. B. Okanagan lake at Okanagan Mission. C. Okanagan lake at Squally point. D. Okanagan lake at Summerland. E. Kalamalka lake looking toward north end. F. Beaver lake located in dense forested area at 4,500 feet.

A further complicating factor is found in the irregularity of the natural run off during the season, causing severe flooding at times and shortage at others.

It is apparent that the combined effect of a meagre and variable precipitation, an irregular run off and a still more irregular utilization of the streams for irrigation, creates a situation in which the natural reproduction of stream spawning fish is very uncertain.

SIZE AND SHORELINE

The lake has an area of 143 sq. mi. The length is 67 mi. and the average width about 2 mi. Being so narrow it has a proportionately long shoreline, 165 mi., as measured from a map on the scale of 1 mile to the inch. The shore development (relation of shore length to minimum circumference for the same area) is therefore 3.9, but this figure is somewhat misleading since the shoreline is only moderately irregular and the "protected" type of shore is very scarce. Field notes indicate that of the total shore length about 9 per cent has a rooted aquatic vegetation. This is made up chiefly of bulrush (*Scirpus*) beds and is found in scattered localities mostly along the western shore and in the shallow bay at the north. Of the remaining shore line, 52 per cent is of bare rock or large stones, 26 per cent of fine gravel often with shrubbery and terrestrial plants growing close to the water's edge, and the remaining 13 per cent is of bare sand.

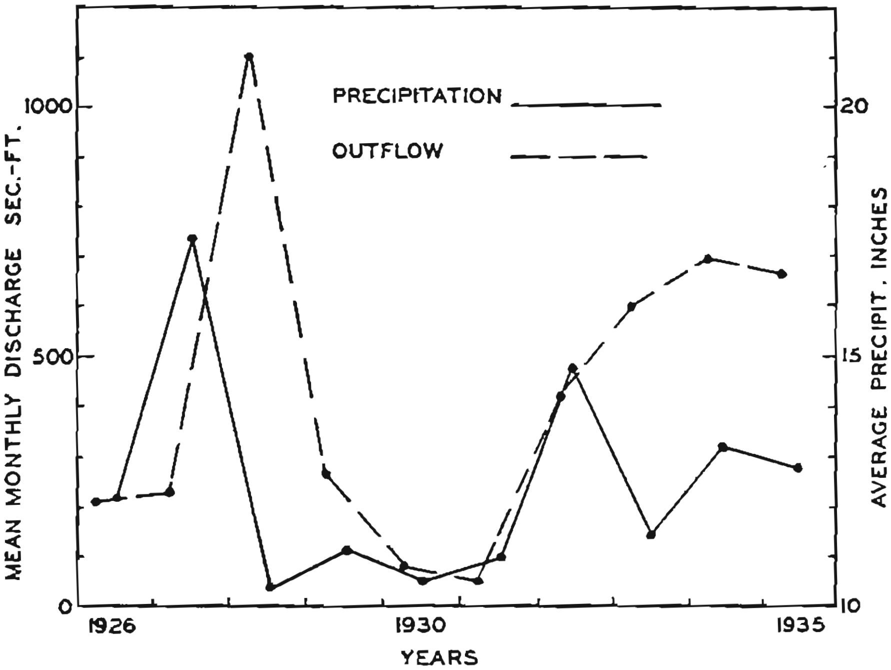


FIGURE 2. Precipitation and lake discharge, 1926-1935, Okanagan lake.

DEPTH

The lake is very deep with an observed maximum of 760 ft. (232 m.) between Carr's landing and Nahun. The mean depth has been determined as 228 ft. (69.5 m.). A total of 250 soundings was used to obtain depth contours, some of which are seen on the accompanying map, figure 3. The greatest depths were found north from the centre of the lake where a 10-mile stretch is more than 655 ft. (200 m.) deep. A second deep region is found off Trepanier where a con-

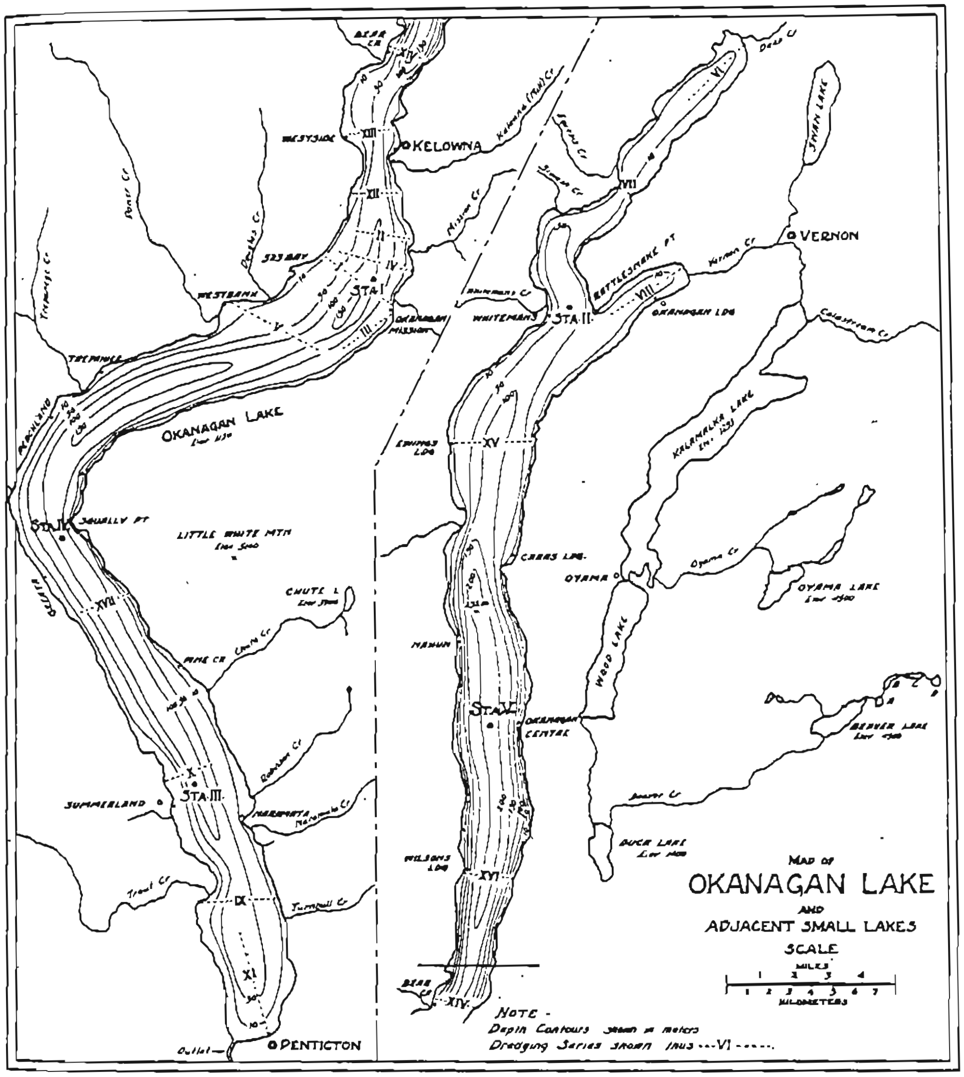


FIGURE 3. Map of Okanagan lake showing depth contours and location of observation stations.

siderable area exceeds 500 ft. in depth. Both ends of the lake are relatively shallow. At the north end, a large bay about 6 miles long is mostly shallow and muddy with beds of bulrushes (*Scirpus*) and low shores quite unlike the remainder of the lake. Only 15 per cent of the lake area is less than 10 m. (33 ft.) deep and most of this shallow water is near the ends of the lake. In the central region of the lake the shores shelve rapidly into deep water.

The volumes of water in the different depth strata are of importance in dealing with the distribution of temperature, of oxygen, and in other connections. The relative volumes of the various strata have therefore been calculated and are shown in table I.

TABLE I. Analyses of depth data for Okanagan lake (1 m. = 3.28 ft.)

Depth zone or stratum	% of total area	% of total volume	Depth zone or stratum	% of total area	% of total volume
0– 10 m.	15.3	13.4	0– 25 m.	26.5	30.9
10– 20	9.4	11.6	25– 50	20.0	21.9
20– 30	7.6	10.2	50– 75	12.2	16.1
30– 40	8.1	9.1	75–100	10.8	12.1
40– 50	8.0	8.0	100–125	11.3	8.4
50– 75	12.2	16.3	125–150	6.8	5.3
75–100	10.7	12.2	150–175	4.6	3.4
100–125	11.3	8.5	175–200	2.5	1.3
125–150	6.8	5.3	200–225	2.0	0.7
150–200	7.1	4.7	225–250	1.5	....
200–250	3.4	0.7			

It will be seen that 70 per cent of the lake volume lies below the 20 m. (66 ft.) level and 50 per cent below the 50 m. (164 ft.) level. Less than 1 per cent of the total volume was found below the 200 m. (656 ft.) level.

In studying the morphometry of lake basins use is made of an index obtained by dividing the volume of the 0-10 m. (0-33 ft.) stratum into the remainder of the volume of the lake. For Okanagan lake this index is 6.7, and this, along with other morphometric data presented above, classifies Okanagan as a typical alpine lake. Seneca lake, New York, and Lake Constance, Switzerland, are well-known examples of this type.

PHYSICAL AND CHEMICAL CONDITIONS

TEMPERATURE

Five stations for the observation of temperature are indicated on the accompanying map. At station I temperature series were taken at approximately weekly intervals throughout July and August. At station II off Rattlesnake point near the north end and III off Summerland in the south, three series were taken; at stations IV and V off Squally point and Okanagan Centre respectively, a single series. Each series included from 10 to 15 temperatures at various depths from surface to bottom. These were taken with a deep sea reversing thermometer attached to apparatus which brought up from the same depth a sample of water for chemical analysis.

The temperature observations at station I are presented in figure 4, which indicates the variation in vertical distribution of temperature over this period. The surface temperature was 17.1°C. (63°F.) on July 4 and rose through the month to 20 or 21° (68 or 70°) about which level it fluctuated during August. The observed maximum surface temperature was 21.3° on August 13. At the bottom (100 m.) the temperature varied less than one-tenth of a degree, remaining between 4.5 and 4.6°C. (40.1 and 40.3°F.).

The vertical temperature change is more readily observed from figure 5. The upper 10 m. (33 ft.), known as the epilimnion, is comparatively warm; from 10-15 m. (33-49 ft.) is a stratum of rapid change in temperature, the thermocline; and below this a large body of relatively cold water, the hypolimnion. On July 4 the vertical distribution of temperatures was such that three regions may be distinguished, a condition described as thermal stratification. On July 13 stratification had been disturbed and a considerable amount of heat forced down to between 15 and 25 metres (49 and 82 ft.) depth. On July 17 stratification had been re-established with the thermocline at a lower level. Figure 5 serves to indicate both the nature of the stratification and the readiness with which it may be altered in Okanagan lake.

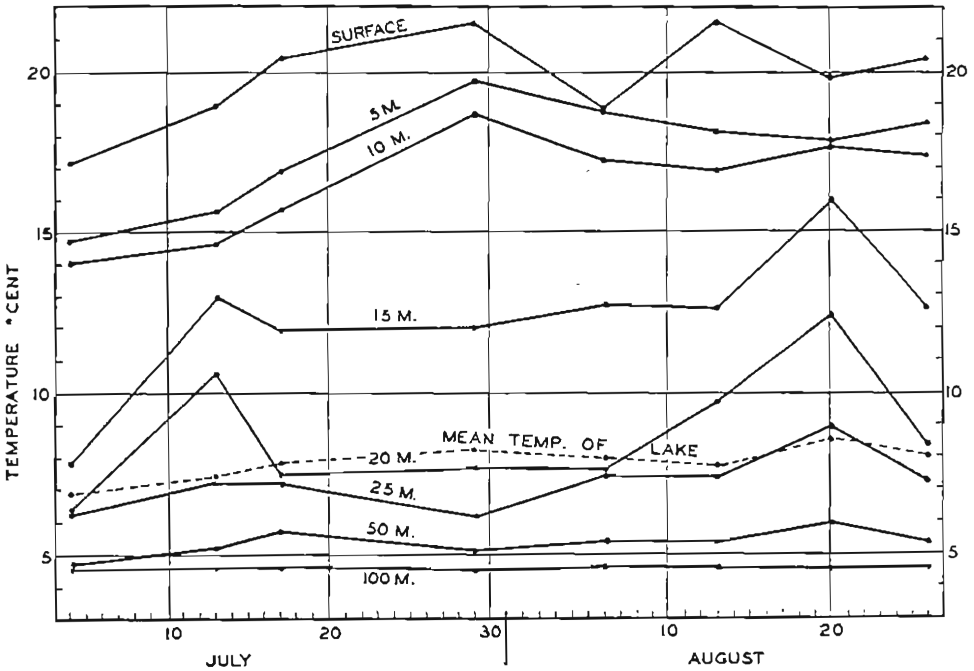


FIGURE 4. Temperature observations, July and August, station I, Okanagan lake.

Temperature series were taken at stations I to V to test the reliability of observations at station I as applied to the lake as a whole. Because of the diffi-

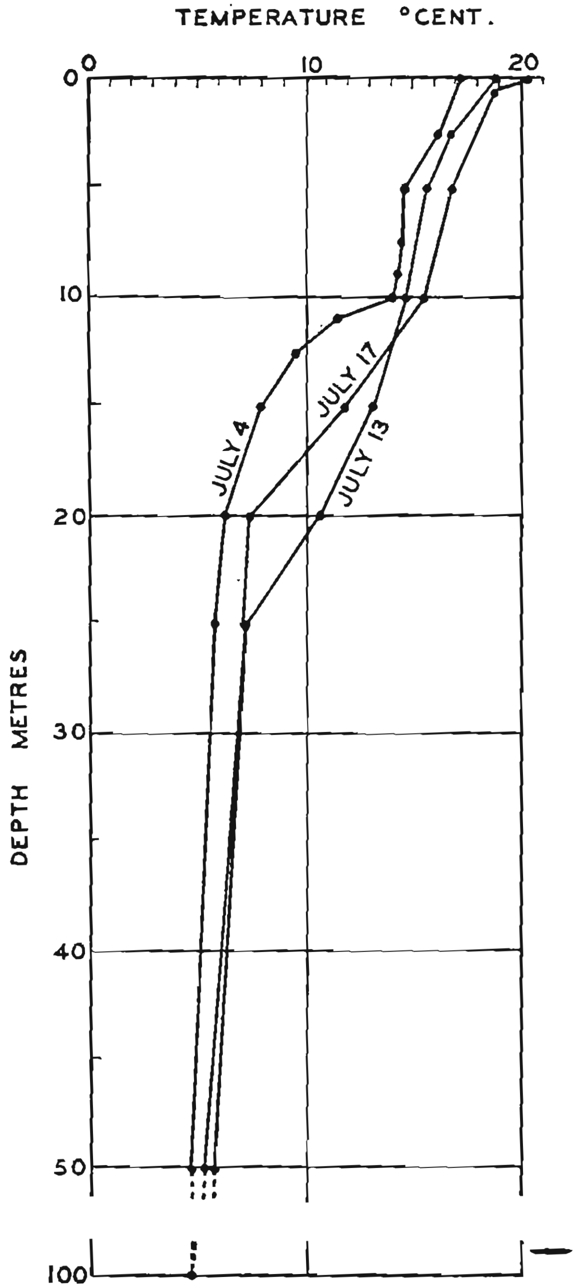


FIGURE 5. Vertical distribution of temperatures, July, station I, Okanagan lake.

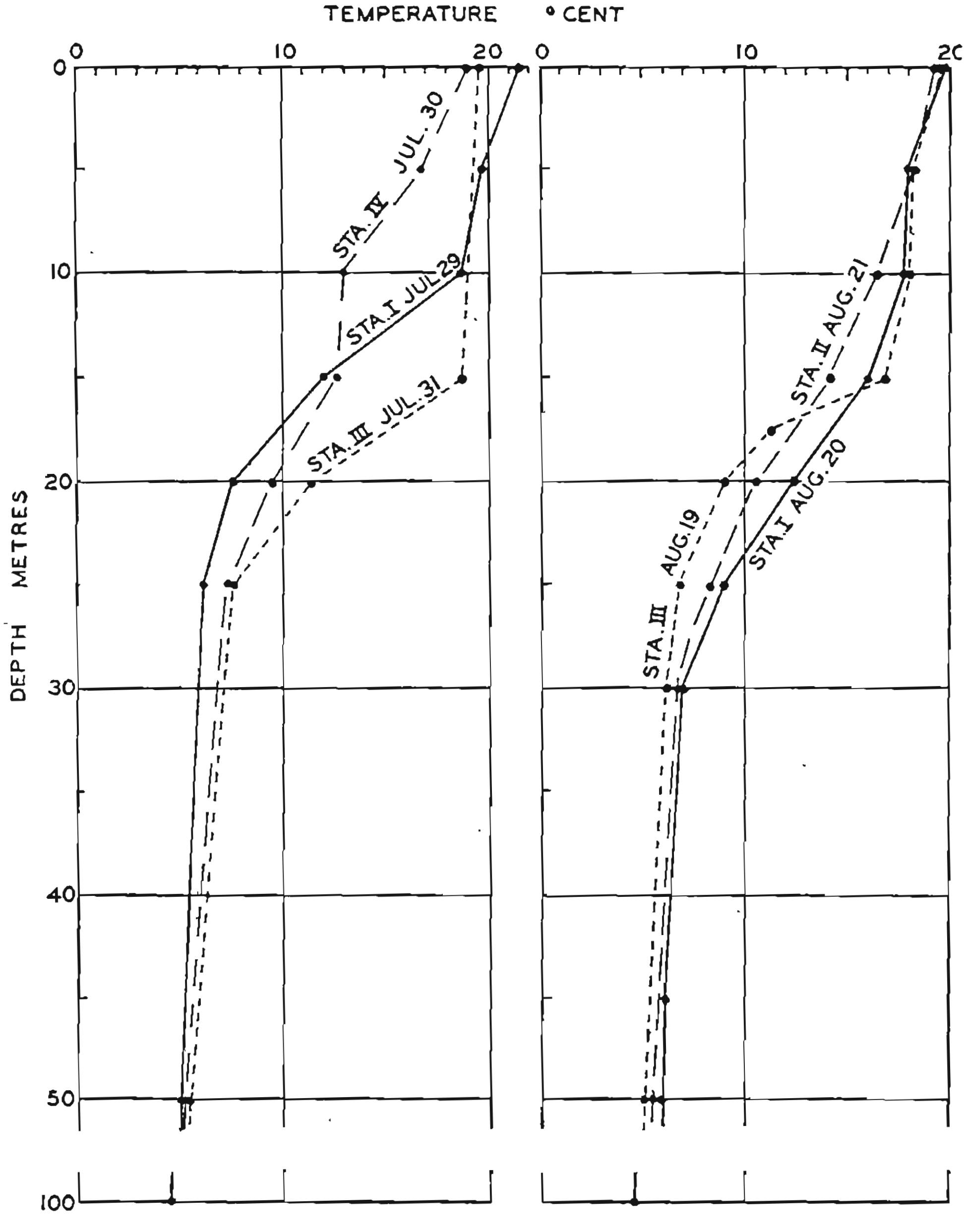


FIGURE 6. Temperature records on successive days at various stations, July and August, Okanagan lake.

culty of the distances separating these stations it was impossible to take simultaneous readings, and the best alternative was to take readings on successive days. Figure 6 shows the results of such series, the former indicating extreme variation on successive days between stations I, II and IV, and the latter less extensive differences between stations I, II and III. The evidence tends to show that these fluctuations are a result of movements in the lake water and not of variations in the temperature of the lake as a whole. For this reason records from station I were used to calculate the mean temperature of the lake inserted in figure 4.

The mean temperature of the lake varied between 7.0°C. (44.6°F.) on July 4 and 8.7° (47.5°) on August 20. Thus the lake water as a whole remains exceedingly cold throughout the summer. The total annual range of mean lake temperature would be less than 5°C. (9°F.). Such a condition might be expected in a lake where 70 per cent of the volume lies below the 25 metre (82 ft.) level, where as figure 4 shows, the temperature changes very little.

The temperature records indicate frequent and complex movements of the water in the upper 25 metres (82 ft.), the description of which would require a much more thorough study than was possible in 1935. The question is of special interest since periodic temperature fluctuations or seiches have been demonstrated in lakes of this morphological type.

TRANSPARENCY

The lake water is very clear as was indicated by the high visibility in the near shore area and by the use of Secchi's disc. This is a white disc 20 cm. (8 inches) in diameter. The depth to which it remains visible provides a measure of the transparency of the water. Readings at station I in Okanagan lake varied from 8 to 10 m. (26 to 33 ft.).

DISSOLVED OXYGEN

The amount of dissolved oxygen was determined on samples taken along with the temperature series, and a summary of these observations appears in table II. The high oxygen content of the hypolimnion is at once evident, and even at the bottom (100 m. or 328 ft.) the lowest dissolved oxygen was 6.8. cc. per litre. In a single determination with a sample from 175 m. (574 ft.) at station

TABLE II. The vertical distribution of oxygen at station I, Okanagan lake, in July and August, 1935

	Oxygen in cc. per litre						
Depth (m.)	July 4	July 13	July 17	July 29	Aug. 6	Aug. 13	Aug. 20
Surface	6.0	5.0	5.2	5.2	5.5	5.3	5.4
15	6.5	5.8	5.9	6.4	6.3	6.2	6.1
25	6.4	6.2	6.7	6.9	6.9	6.8	6.6
50	6.6	6.9	6.8	6.9	...	...	...
100	6.8	6.8	...	6.9	7.3	7.3	7.2

IV on July 17 the dissolved oxygen was 6.3 cc. per litre. Saturation values corrected for altitude ranged between 72 and 92 per cent, which is a further expression of the abundance of dissolved oxygen.

Dissolved oxygen is a useful index to the nutritive condition of a lake and the large quantities mentioned above would indicate a high degree of oligotrophy in Okanagan lake. Oligotrophy, as contrasted with eutrophy, denotes a condition marked by relatively small quantities of plankton, much oxygen and relatively low productive capacity. A useful measure is found in Thienemann's (*Der Sauerstoff im eutrophen und oligotrophen See. Die Binnengewässer, Band IV, Stuttgart, 1928*) relation $\frac{O_2H}{O_2E}$, that is, the ratio of the total oxygen of the hypolimnion to that of the epilimnion, the 10-metre (33 ft.) level being considered as the division between these regions. With this index any value greater than one indicates oligotrophy and only in deep alpine lakes are values of 5 to 10 found. This value for Okanagan lake is 6.4.

HYDROGEN ION CONCENTRATION

The alkalinity was measured by hydrogen ion (pH) determinations made colorimetrically with La Motte standards. At the surface the pH values were from 8.0 to 8.2, at 15 metres (49 ft.) usually 7.9 or 8.0 and at the bottom (100 m.) 7.8. In the deepest water examined (175 m.) the value was 7.6.

MINERAL AND ORGANIC ANALYSES

A sample of the surface water collected on April 28, 1936, has been analysed for mineral and organic constituents (table III). The total solid content was 145 mg. per litre, which is near the average for lakes of this type. The water is of moderate hardness and contains considerable amounts of sulphate and calcium. The very small amounts of nitrogen compounds add to the evidence of extreme oligotrophy.

TABLE III. Analyses of sample surface water, Okanagan lake, collected April 28, 1936, one mile off Okanagan Mission and some distance south of Station I. Analyses by Mr. J. P. Tully, Pacific Biological Station, Nanaimo.

Residue on evaporation	145.0	Aluminum (Al)	12.9
Organic residue	41.1	Calcium (Ca)	28.7
Free ammonia	0.0023	Magnesium (Mg)	0.0
Albuminoid ammonia	0.00051	Carbonate (CO_3)	16.9
Nitrate (NO_3)	0.00	Bicarbonate (HCO_3)	131.0
Nitrite (NO_2)	0.00	Sulphate (SO_4)	48.0
Silica	3.9	Chlorine (Cl)	0.0
Iron (Fe)	0.00		

In its physical and chemical features Okanagan is a typical large alpine lake comparable to Seneca, of the Finger lakes, New York, or to lake Constance in Switzerland. Like them it has a long deep basin, cold water, and exhibits an extreme oligotrophy in its oxygen relations (table IV).

TABLE IV. Comparative data for Okanagan and other large Alpine lakes.

	Okanagan L., B.C., Canada	L. Constance, Switzerland	Seneca L., New York, U.S.A.
Altitude m.	345.	395.	135.
Latitude	50°00′	47°38′	42°30′
Area sq. km.	370.	475.	175.
Length and width km	117x3.2	67x13	57x3.1
Mean depth m.	69.5	100.	88.6
Max. depth m.	232.	252.	188.
Volume cu. m. x 10^6	25,700.	46,700.	15,540.
Vol. E* as % of total	13.4	10.1	10.6
Mean temp. °C., midsummer	8.6	6.5	7.5
Wind distrib. heat gr. cal/cm^2	32,700.	22,400.	31,500.
Ann. heat budgets gr. cal/cm^2	34,000.	23,200.	36,500.
Oxygen of epilimnion cc/l.	5.8	7.0	7.0
Oxygen of hypolimnion cc/l.	6.6	7.4	8.6
$\frac{O_2H}{O_2E}$	6.4	10.4	10.4
O_2 in greatest depth cc/l.	6.3	7.6	8.4
O_2 in greatest depth % sat.	71.	90.	92.

*E is the "hydrographic epilimnion" of Thienemann (1928), i.e. the 0-10 stratum.

PLANKTON

The plankton, which includes the microscopic plants and animals throughout the water of the lake, is a basic source of food for larger animals. In a survey of this kind it is of interest to know both the kinds of organisms and the quantities in which they occur.

The sampling was done by means of silk nets, a method subject to considerable error but the only one practicable in this case. Two nets of number 20 silk bolting cloth were used, a small one with an aperture of about 5 inches and a larger one with a mouth 10 inches wide. They were of the "Wisconsin" type and could be closed at any level, thus making it possible to take a series of hauls to demonstrate vertical distribution of organisms. The larger net was used to obtain samples large enough for the determination of total organic nitrogen.

The composition of the hauls has been studied by a number of specialists interested in the different groups. In the present account only the more abundant and characteristic organisms are mentioned. A full list will be found in table XVII of the appendix.

The phytoplankton or plant members of the plankton include ~~three~~ groups of algae, blue green, green and diatoms. The blue green algae, Myxophyceae, were represented by eight species of which *Anabaena flos-aquae* and *Aphanizo-*

menon dispersus were the most characteristic. The green algae (Chlorophyceae), of which twenty species were identified, were most commonly represented by such forms as *Dictyosphaerium pulchellum*, *Oocystis parva*, *Staurastrum gracile* and *Botryococcus Braunii*.

Of 34 species of diatoms (Bacillarieae) six were most abundant: *Asterionella formosa*, *Cyclotella compta*, *Fragilaria crotonensis*, *Melosira granulata*, *Stephanodiscus niagarae* and *Tabellaria fenestrata*.

The zooplankton or animal forms may be considered in four groups, Protozoa, rotifers, waterfleas and copepods. The Protozoa, unicellular forms, were made up chiefly of *Ceratium hirundinella* and two species of *Dinobryon*.

Seven species of rotifers (Rotatoria) included *Notholca longispina*, very widespread, *Conochilus unicornis* and *Ploesoma truncatum*, common in surface tows, *Collotheca mutabilis* and *Synchaeta sp.* common in deep water.

The water fleas (Cladocera) were represented by eleven species of which two, *Daphnia longispina* and *Bosmina longispina*, were most widespread. Other species were found to be common in certain localities.

Only three species of copepods (Copepoda) were identified but they formed a large fraction of the total plankton. They were *Diaptomus ashlandi*, *Cyclops biscuspidatus* and *Epischura nevadensis*, the first two being abundant throughout the season and at all depths.

Variations in the composition of the plankton during the two-month period were comparatively slight and consisted chiefly of the appearance and disappearance of a few species. The most stable group included *Diaptomus*, *Cyclops*, *Ceratium* and *Tabellaria*. Certain other forms were steadily present but never in large numbers, while a third group, notably *Epischura*, *Scapholeberis*, *Diaphanosoma*, *Anabaena* and *Botryococcus* occurred irregularly and in more variable numbers. This condition of general constancy in the plankton population is in marked contrast to the violent "pulses" common in the smaller lakes of the region.

Examination of the vertical series indicated that on a few occasions there was a concentration of the blue green alga *Anabaena* on the surface constituting a slight water bloom. Certain rotifers mentioned above were more abundant in the deeper water (150 to 300 ft.). The nauplii or larvae of copepods also tended to be more numerous in the deeper water. With these exceptions the vertical distribution consisted in a gradual reduction with depth of the many forms found at the surface.

On two occasions hauls were taken on successive days at stations I, II and III. Comparison of these showed that the species mentioned above as "stable" throughout the season were also uniformly present in widely separated parts of the lake. Differences in the catch at the three stations involved certain less abundant species which had been found variable at a single station. It was also noteworthy that the total quantity of plankton taken at each of the three stations on successive days was practically uniform.

Quantitative analyses have been made of total vertical hauls with the large net taken at approximately weekly intervals at station I and less frequently at stations II and III. As suggested above, the plankton net is not completely satisfactory for sampling because it is difficult to determine the exact volume of water which it strains. Further sampling errors may result from irregularity in the distribution of the plankton organisms. From the available data and from the results of other investigators, we have no reason to suspect that there is any great irregularity in the distribution of organisms in the open water region of Okanagan lake. Undoubtedly some irregularity of distribution does occur in the shallow near shore area. In further justification of the method, it should be noted that the equipment and methods of sampling were similar to those used in other British Columbia lakes with which comparisons are made.

The average volume of eleven total vertical hauls between July 4 and August 26 was 1.40 cc. The dry weight was 28.4 mg. and the total organic nitrogen 1.86 mg. (table V). Of this amount, about 57 per cent was from the upper 10 m., 24 per cent from 10-20 m., 10 per cent from 20-50 m., and 9 per cent from 50-100 m. The deeper water was therefore extremely unproductive with respect to plankton.

TABLE V. Quantity of plankton in total vertical hauls in Okanagan lake.

Station	Date	Volume cc.	Dry weight mg.	Total organic N_2 mg.
Station I	July 4	1.05	17.7	1.4
" "	July 13	1.85	25.0	1.9
" "	July 19	2.35	48.0	3.6
" "	July 29	1.15	21.2	1.5
" "	Aug. 6	1.00	17.4	1.4
" "	Aug. 12	1.35	39.2	2.2
" "	Aug. 20	1.55	37.8	2.1
" "	Aug. 26	0.60	16.6	0.8
Station II	Aug. 21	1.20	23.8	1.4
Station III	July 31	2.05	33.9	1.7
" "	Aug. 19	1.30	32.3	2.4
Average		1.40	28.4	1.86

The average of eight hauls taken in Paul lake near Kamloops, B.C., in July and August, 1934, may be compared with the average hauls in Okanagan lake as follows:

	Volume cc.	Dry wt. mg.	Total org. N_2 mg.
Okanagan lake, 11 hauls, July-Aug. 1935..........	1.4	28.4	1.86
Paul lake, 8 " " " 1931..........	4.4	36.2	2.61

The amounts of nitrogenous material in the total vertical hauls from Paul lake is about one and one-half times as great as that from Okanagan although the latter is a much deeper lake. Paul is a small and highly productive lake (cf. table VII). Shuswap lake, lying north of Okanagan in the Thompson drainage, has a more comparable area and depth. In Shuswap lake total vertical hauls gave, on July 17, 1931, a total volume of 2.55 cc. and on September 5, 1.95, an average of 2.25 cc. It is thus seen that plankton collections from Okanagan lake are very much less than those of small lakes in the region but not much smaller than those from Shuswap which is another deep alpine lake.

BOTTOM FAUNA

The organisms on the lake bottom were investigated by the use of an Ekman dredge which took a sample of 500 sq. cm. (77 sq. inches) in area. The quantitative samples included 115 dredge hauls and 20 collections in the near shore region. These were supplemented by qualitative collections from about 25 locations. All quantitative samples were washed through fine meshed screens from which the macroscopic organisms were recovered.

Composition

As with the plankton, the bottom organisms have been examined and measured. In most cases they have been identified by specialists in the various groups. In the following description only the more significant species are mentioned. A complete list is given in table XVIII of the appendix. The major groups represented were the leeches, crustaceans, insects, water-mites and molluscs.

The leeches (Hirudinea) collected were of four species with *Helobdella stagnalis* and *Placobdella montifera* common near the shore. *Piscicola punctata* was ? found attached to squawfish and other minnows.

The crustaceans were represented by two fresh water shrimps (Amphipoda), *Gammarus limnaeus* present in small numbers near the shore, and *Hyalella azteca* common down to a depth of 10 m. (33 ft.). A crayfish, *Potamobius klamathensis*, was taken in small numbers.

The insects included a number of orders, four of which will be considered here. The mayflies (Ephemeroptera) included more than twelve species. The larger forms, *Hexagenia limbata* and *Ephemera simulans*, were widely distributed in the upper 25 m. (82 ft.). Small species of *Caenis* were also found at these depths, but the remainder of the group were chiefly near shore. The dragonflies (Odonata) were of three species of which the damselfly, *Enallagma cyathigerum*, was the most abundant. The caddis flies (Trichoptera) included fifteen species, the larvae of which were mostly in depths of less than 10 m. (33 ft.). The genera *Hydroptila*, *Polycentropus* and *Limnephilus* were common. The true flies (Diptera) were represented chiefly by the midges (Chironomidae) of which more than twenty-five species were collected. Midge larvae were the most abundant and widespread of all bottom organisms. Large larvae of the genus *Chironomus* and smaller forms belonging to the genera *Cryptochironomus*, *Polypedilum*, *Orthocladius* and *Tanytarsus* were prominent.

Water-mites (Hydracarina) of two species, *Piona rotunda* and *Hygrobates longipalpis*, were collected.

The molluscs were scarce except in a very limited near shore region. Of the snails (Gastropoda) six species were identified. *Lymnaea caperata*, *Gyraulus parvus* and a new species of *Physa* were the most common. The mussels or "clams" (Pelecypoda) included two large species of the genus *Anodonta*, namely, (*oregonensis* and *beringiana*), neither of which were numerous, and many minute forms sometimes known as white clams (Sphaeriidae) of a single species, *Pisidium compressum*, which ranged in depths from approximately 8 to 250 feet.

Other groups not mentioned above but of moderate importance were the aquatic bugs (Hemiptera), beetles (Coleoptera) and the aquatic earthworms (Oligochaeta).

DISTRIBUTION

The availability of the bottom organisms as food for fish is affected both by their distribution and abundance. In table VI the distribution of organisms with respect to depth is readily seen. The midge larvae are most numerous and they are fairly uniform in their distribution down to a depth of 75 m. (246 ft.). White clams and oligochaete worms were the only other forms found in the deepest water, the latter group being numerous even at depths of 400 ft.

TABLE VI. The average numbers of bottom organisms per square metre at various depths in Okanagan lake

Depth (metres)	0–1	1–5	5–10	10–20	20–30	30–50	50–75	75–125	All depths
No. of samples	20	29	22	18	12	14	15	4	135
Midge larvae	113	260	405	356	206	313	300	188	268
Oligochaete worms	20	26	36	40	23	110	68	102	53
Mayfly nymphs	67	8	23	17	5	..	..	..	15
Fresh-water shrimps	32	11	35	21	..	..	..	..	12
Caddis larvae	24	9	7	8	..	..	..	..	6
White clams	0	3	..	1	..	6	5	..	2
Snails	9	1	4	..	..	..	..	..	2
Miscellaneous	22	3	3	13	2	..	3	..	6
All organisms	287	321	513	456	236	429	376	290	364

In the shallower water greater irregularity of distribution was found. Mayfly nymphs were practically confined to the upper 25 m. (82 ft.), and the remaining groups to the upper 20 m. (66 ft.). Since this represents only one-quarter of the lake area, it is evident that most of the lake bottom is populated only by chironomids, oligochaetes and white clams, and these in comparatively small numbers.

An unusual feature of the fauna is the scarcity of molluscs. In the shore area *Physa* and a few planorbids are found. These with the scattered Sphaeriidae comprise almost the whole molluscan fauna of the lake.

Certain organisms showed special distribution with respect to bottom types. In the deeper water, the bottom was frequently light in colour with little organic content and varied from soft ooze to stiff clay. This supported smaller numbers of oligochaetes and midge larvae than the darker muds of shallower portions of the bottom. Such regions were found at depths of 5-20 m. (16-66 ft.) and contained more organic matter. Sand was the usual bottom type from shore to 10 m. (33 ft.), but in a few places rooted vegetation occurred and in these the fresh water shrimp (*Hyalella*) was abundant. Mayfly nymphs of the genus *Hexagenia* were most commonly found in soft clay ooze. Some of the midge larvae appeared to prefer certain types of bottom material, a striking example being that of *Limnochironomus*, which was found only on bare stone or rock bottom near the shore.

QUANTITY

The number of bottom organisms has been indicated in table VII where it is seen that the average for the whole lake is 364 per square metre (305 per square yard). Of this number the midge larvae make up 74 per cent, oligochaetes 15, mayfly nymphs 4, fresh-water shrimps 3, and all other organisms 4 per cent.

TABLE VII. The amount of bottom organisms in various lakes.

Lake	Area		Mean depth		Av. number organisms	Dry weight organisms
	sq. km.	(sq. mi.)	m.	(ft.)	per sq. m.	kg./ha.
Okanagan	143	(370)	69	(226)	364	2.0
Nipigon	1,760	(4,550)	55	(180)	1,056	5.9
Ontario	7,050	(18,200)	91	(299)	.....	4.3
Simcoe	280	(720)	15	(49)	820	11.0
Waskesiu	27	(70)	11	(36)	6,554	13.7
Paul	1.5	(4)	34	(112)	1,363	41.5
Mendota	15	(39)	13	(43)	.....	45.1

In some respects the weight of organisms is more useful as a measure of the amount of fauna than their numbers. The net weight of the organisms from each dredging was determined, using a delicate torsion balance. The deduction for the shell weight of the molluscs was made after determining the average proportion of shell to body weight in different species. The average weight of organisms per dredging was 0.049 grams (0.75 gr.), equivalent to 0.982 grams per square metre. Since the dry weight of these organisms is approximately 20 per cent of the net weight, the average dry weight of bottom organisms in Okanagan lake is 0.196 grams per square metre, mollusc shell deducted. For comparative purposes this may be called 2.0 kg. per hectare, as given in table VII, or 1.8 lb. per acre.

As a basis for evaluating the above data, information as to the amount of bottom fauna found in lakes of various sizes is included in table VII. In Okanagan lake the number of organisms is small and the organisms themselves of small size so that the amount of fauna by weight is exceedingly low. The extent of this paucity is more evident when we note that even very large lakes like Nipigon and Ontario have twice or three times the amount of bottom organisms to be found in Okanagan. It should be recorded that the results from a small number of dredgings taken in Shuswap, another lake of this general type, in July, 1931, suggest a similar paucity of bottom organisms.

PRODUCTIVITY

The quantities of plankton and bottom organisms have been determined to give some suggestion of the productive capacity of the lake with respect to fish.

It should be remembered that we are measuring the "standing crop" of organisms which does not indicate the "annual harvest" or the rate of production. Also the degree of accuracy with which these organisms can be measured, or the efficiency of their utilization estimated, is not high. Nevertheless it seems reasonable that since these organisms are the ultimate source of all fish food, their amounts should indicate in a rough way the possible fish production. With a plankton which may be described as moderate to poor and a very poor bottom fauna, the basic productivity of Okanagan lake must be comparatively low. It is thus not surprising that although the eastern whitefish, *Coregonus clupeaformis*, was introduced into the lake and is now widely distributed, it failed to reach either numbers or size which would provide a profitable fishery.

While food organisms occur in oligotrophic lakes in relatively small quantities, it has been suggested by some authors that in them there is a more efficient utilization than in eutrophic lakes where nutritive materials are abundant. While we have no means of verifying this in Okanagan lake, it should be noted that in spite of the small amounts of plankton taken in the net samples, many of the fish stomachs contained plankton. In fact ten of the fourteen species of fish in the lake had eaten important quantities of plankton.

It has been stated that Okanagan lake is an extreme oligotrophic type and that lakes of this group are marked by a comparative scarcity of organisms. The extreme depth and low temperature are undoubtedly factors in this low productivity but probably not the complete explanation. Further investigation of the amount of organic and inorganic materials both in the water and in the bottom deposits would be of use in an understanding of this problem.

SUMMARY

Okanagan lake is a large and deep alpine lake in the southern portion of the central plateau of British Columbia. Its area is 370 sq. km. (143 sq. mi.), its maximum depth 232 m. (760 ft.) and its mean depth 69.5 m. (228 ft.). The lake basin is long and narrow with a shoreline predominately rocky or stony.

The surface temperature of the lake rose to about 20°C. (68°F.) at midsummer and thermal stratification was usually present with a variable thermocline between 10 and 20 metres (33-65 ft.). The hypolimnion was always cold and so extensive that the mean temperature of the lake did not exceed 8.7°C. (47.5°F.). The dissolved oxygen was plentiful from surface to bottom with never less than 70 per cent saturation.

Morphometry, temperature, oxygen and nitrogen analyses indicate Okanagan lake as an extremely oligotrophic type. In its richness in calcium it resembles the deep oligotrophic lakes of the Alps rather than those of Norway.

The net plankton of the open water was compared with similar samples from other lakes and found to be comparatively poor. The macroscopic bottom organisms were very scanty averaging 364 per square metre and 2.0 kg. dry weight per hectare (304 per sq. yard and 1.8 lb. per acre).

The paucity of minute organisms in the lake suggests that it is capable of a relatively limited fish production.

OTHER LAKES OF THE OKANAGAN VALLEY

In the course of the survey it was found advisable to visit several smaller lakes which were involved in the Kamloops trout problem. Of the five lakes visited two, Beaver and Chute, were at high altitudes and the remaining three, Duck, Woods and Kalamalka, form a chain which drains into Okanagan lake through Vernon creek. The location of these lakes is shown on the accompanying map.

Beaver Lake

Beaver, also known as Swalwell, lake is located about 15 miles north-west of Kelowna, at an altitude of 4,500 ft., in a densely wooded area. It is slightly more than one square mile in area and has a maximum depth of about 24 metres. A chain of smaller lakes known as A, B, C and D drain into its upper (eastern) end. A second stream, Echo (Buckhorn) creek, empties into the lake on the north shore opposite the outlet. This is a cold spring creek and on it is located a rearing station for trout.

WATER CONDITIONS

Temperature series taken on July 11 and August 25 show in both cases comparatively cold water and marked thermal stratification. The temperatures were as follows:

Depth (m.)	July 11 (°C.)	Aug. 25 (°C.)
Surface	13.4	15.6
5.0	12.4	14.3
7.5	9.3	7.8
10.0	7.3	7.6
15.0	6.2	6.7
Bottom, 22.0	5.2	6.1

The thermocline, between 5 and 7.5 metres, shows on July 11 a total temperature drop of 3.1 and on August 25, 6.5°C. This increase in the extent of thermal stratification was accompanied by a corresponding decrease in the dissolved oxygen of the hypolimnion.

Dissolved oxygen

Depth	July 11		August 25	
(m.)	(cc./1.)	(% sat.)	(cc./1.)	(% sat.)
Surface	5.4	87	4.9	83
5.0	5.4	86	5.0	81
7.5	...	..	3.1	44
10.0	5.2	74	0.6	8
15.0	4.5	62	0.5	7
22.0	1.8	24	0.4	5

The water was somewhat acid in reaction, on July 11 a pH of 6.9 at surface and 6.7 at bottom. On August 25 it was 7.3 at surface and less than 6.5 at the bottom. A strong odour of hydrogen sulphide was observed from the bottom water on the latter date.

These data indicate the degree of thermal stratification and of stagnation in the hypolimnion. On August 25 there was only an insignificant amount of oxygen beneath the thermocline.

PLANKTON

Plankton samples were taken on July 11 and on August 25 and at both times the copepods *Diaptomus ashlandi* and *D. arcticus* were predominant. These forms with the rotifer *Conochilus unicornis* made up the bulk of the plankton. (A list of the organisms collected in Beaver, Chute, Kalamalka, Woods and Duck lakes is given in table XX of the appendix.)

The plankton from the total vertical hauls with the large net was measured volumetrically and the amount of organic nitrogen determined.

July 11	Total	vertical	haul	Vol. 1.15 cc.	Total	org.	N_2	2.1 mg.
August 25	"	"	"	" 1.85 cc.	"	"	"	2.7 mg.

The amount of plankton is seen to be larger than that collected in Okanagan lake where the hauls were made in a depth five times as great. This amount is somewhat smaller than that observed in small lakes of the Kamloops region, 1931, but the samples are too few to support final conclusions. Collections from Penask lake, at similar altitude, had approximately twice as much nitrogenous material as those from Beaver lake.

BOTTOM FAUNA

The bottom fauna was sampled with 12 dredgings on July 11. These were taken in two series, one in the long axis of the lake and the other at right angles to the first and crossing the deepest water. Additional collections were made along the shore, at the outlet and in the upper lakes.

Midge larvae were the most numerous organisms occurring in eleven of the twelve dredgings and in average numbers equal to 234 per square metre. White clams, oligochaete worms and caddis larvae were fairly numerous and other organisms rare.

The average net weight of organisms in these dredgings with mollusc shell deducted was 2.06 gm., which is equal to about 8 kilograms dry weight per hectare. In view of the small number of samples no great reliance can be placed on this figure.

THE UPPER LAKES

Observations on A, B, C and D lakes were made on July 12. The maximum observed depths were 17, 18, 14 and 11 metres respectively. Each lake showed marked thermal stratification with the thermocline nearer the surface than in

Beaver lake. The dissolved oxygen of the bottom water was 0.9, 0.3, 1.2 and 0.5 cc. per litre respectively. This indicates a stagnation more severe than that in Beaver lake at the same time.

Plankton samples indicated general similarity to that of Beaver lake, but the water flea *Daphnia pulex* was much more abundant and the blue green alga *Aphanizomenon* was present as a surface bloom, especially in lakes C and D.

The "drowned" shoreline resulting from artificial raising of the water level is obvious in these lakes but the shore fauna appeared to be quite rich. Caddis larvae, dragonfly and mayfly nymphs, leeches and water mites were all observed in considerable numbers on the shores of D lake.

From the brief examination of Beaver and its tributary lakes a few factors would appear to have special significance with reference to the trout problem. The high altitude and resulting low surface temperatures allow the trout to feed at or near the surface and thus provide fly fishing even at midsummer. It is probable also that the lowered oxygen supply of the hypolimnion forces the fish to stay in the upper stratum. The abundance of the large copepods and cladocera in the plankton suggests an ample food supply for the younger fish. Important food organisms of the adult fish such as caddis flies, mayflies and freshwater shrimps are present in the shallow water regions. Several anglers have reported a noticeable decline in the numbers of shrimps (*Gammarus*) and caddis in recent years. The quantity of organisms in this variable shallow water region could not be determined in the brief examination but they were certainly present in considerable variety.

CHUTE LAKE

Chute lake, also known as Lequime, is a small lake of about one-sixth of a square mile in area and situated about eight miles south of Okanagan Mission. It is at the high altitude of 3,900 ft. and its surroundings resemble those of Beaver lake. The maximum depth observed was 14 metres.

Examined on August 26 the temperature and oxygen distribution were as follows:

Depth (m.)	Temperature (°C.)	Oxygen (cc./l.)
Surface	15.7	5.2
4.0	14.3	3.9
5.0	11.5	2.2
5.5	9.4	....
6.0	8.3	1.4
7.5	8.1	0.05
10.0	7.4	0.0
Bottom, 14.0	7.2	0.0

The water was thermally stratified and the oxygen of the deep water depleted to an even greater extent than in Beaver lake on the previous day. The smaller area of Chute lake would lessen the mixing effect of winds and thus favour the progress of stagnation. The deep layer of black organic ooze on the bottom would utilize much oxygen and also contribute to the stagnation. The lake water had a distinct yellowish colour and was somewhat acid in reaction. Secchi's disc was visible only to the depth of 1.0 metre.

The plankton appeared to be fairly rich and was dominated by the copepod *Diaptomus* and the rotifer *Keratella*. The amount in a total vertical haul was 0.95 cc. and 1.0 mg. total nitrogen. This is quite large considering that the haul was in a depth of only 14 metres. The bottom fauna was not sampled by dredging but a small quantity of bottom material was brought up for examination. This proved to be a very black organic ooze and contained a few minute midge larvae.

In a general way Chute lake resembles Beaver but it is smaller and suffers from a more severe summer stagnation.

KALAMALKA LAKE

Kalamalka is the largest of three lakes lying in a valley parallel to Okanagan lake and draining into it through Vernon creek (figure 1). Woods lake drains into Kalamalka by a short canal and the two are sometimes referred to as Long lake. The elevation of these lakes is about 1,300 feet. Kalamalka is about 10 miles long, one mile in width and has an area of 12 square miles. Its shape resembles that of Okanagan lake even to the forking of the northern end. The maximum depth observed was 130 metres. The deepest part was approximately central but the depth exceeds 50 metres for most of its length.

A temperature series was taken on August 14, two miles from the south end, in a depth of 56 metres.

Depth (m.)	Temp. (°C.)	O_2 (cc./1)	pH
Surface	17.5	5.6	8.2
5	17.2		
10	16.7		
15	15.3	6.9	8.2
20	12.2		
25	11.4	6.9	8.2
30	10.0		
35	9.0		
40	5.6	7.4	8.1
Bottom, 55	4.5	7.2	8.0

There was no thermocline present at this time but a drop of 3°C. between 15 and 20 metres. It will be noted that the temperatures, oxygen distribution and pH are decidedly like those in Okanagan lake on August 13. The transparency is high, Secchi's disc being visible at 6 to 7 metres, again like Okanagan.

Plankton samples from the deeper water include large numbers of the copepods *Diaptomus* and *Cyclops* and a few water fleas. At the surface *Dinobryon* and *Ceratium* were abundant and *Notholca* and *Aphanizomenon* common. The amount of plankton in the total vertical haul was 1.55 cc. and 2.0 mg. nitrogen, much the same as that from station I, Okanagan lake, at this time.

Six dredgings were taken at depths of 1 to 56 metres. The bottom material was mostly of grey ooze or clay. Midge larvae were present in all dredgings and made up 95 per cent of the total organisms. At depths down to 30 metres these were abundant, averaging more than 1,000 per square metre. In deeper water they were much less numerous. The average weight of organisms in the six dredgings was 0.16 grams wet weight, the equivalent of about 6.5 kilograms dry weight per hectare. This average is undoubtedly too high to represent the whole lake since only two of the dredgings were taken in the extensive and semi-barren deep water region.

With respect to physical conditions, plankton and bottom fauna, Kalamalka lake is much like Okanagan with its deep cold water, plentiful supply of oxygen and scanty fauna. As might be expected, in the smaller lake the scarcity of organisms is less extreme.

WOODS LAKE

Woods lake is about 4 square miles in area and closely connected to Kalamalka by the above mentioned canal. The depth is almost uniform over a large part of its area, variation being limited to the range of 25 to 32 metres except in the region near shore.

A series of temperatures and oxygen determinations was made on August 13.

Depth (m.)	Temp. (°C.)	O_2 (cc./1)	pH
Surface	18.5	5.7	8.4
5.0	18.7		
10.0	15.0	4.5	8.0
12.5	10.4		
15.0	8.5	4.5	7.8
20.0	6.8		
Bottom, 30.0	5.8	1.7	7.2

The thermocline, located between 10 and 15 metres, was sharply defined and the dissolved oxygen much reduced in the deeper water. Low transparency of the water was indicated by Secchi's disc readings of 2 to 2.5 metres, this being in part the result of an algal bloom.

The plankton samples contained a tremendous quantity of *Aphanizomenon* which was present as a heavy bloom at this time. The other organisms, chiefly the copepod *Diaptomus* and a few rotifers, were obscured by the algae. The quantity of plankton in the vertical haul was 7.0 cc. and the total nitrogen 223 mg. This is the result of a pulse rather than the normal plankton. A similar pulse of *Aphanizomenon* existed in Duck lake at the same time.

Eight dredgings in Woods lake brought up a very black organic ooze from depths of 15 to 30 metres and in it a very dense fauna of oligochaete worms and midge larvae. In most places the oligochaetes numbered more than 1,000 per square metre and in one sample at a depth of 21 metres 23,000 per square metre. Such numbers of oligochaetes are found only in stagnant and richly organic bottom deposits. The average wet weight per dredging was 2.17 grams, equivalent to 87 kilograms dry weight per hectare. This figure is probably too high to represent the lake as a whole and in any case the stagnant bottom condition would largely prevent the utilization of this fauna by fish.

DUCK LAKE

Duck, or Ellison, lake is the third and smallest in the chain and has an area of about 2 square miles. Its maximum depth is only 5 metres. On August 24 surface and bottom water samples were examined.

	Temp. (°C.)	O_2 (cc./1)	pH
Surface	18.9	5.3	8.8
Bottom, 5 m.	17.8	3.2	7.8

The surface sample was distinctly yellow, possibly from the presence of *Ceratium* in large numbers. The reason for the high alkalinity of the surface water is not known.

Plankton samples revealed a great pulse of *Ceratium* which had apparently followed the decomposition of the *Aphanizomenon* a week earlier. Diatoms and a few rotifers were common in the vertical haul. The total nitrogen from a vertical haul was 14.2 mg.

Two dredgings brought up a soft clay deposit with moderate numbers of midge larvae, oligochaete worms and a few *Corethra* larvae.

These three lakes, one draining into the other, are very different among themselves and very different also from Beaver lake. The latter would also drain into Duck lake, but, as has been indicated above, much of its flow is diverted elsewhere for irrigation purposes. The series of lakes varies from extreme eutrophy to extreme oligotrophy and yet is closely connected and with the same water supply. They offer most interesting possibilities for further investigation, both from the purely scientific point of view and to provide fundamental data of use in the Kamloops trout problem in these and in Okanagan lake.

THE FISHES OF OKANAGAN LAKE AND NEARBY WATERS

BY W. A. CLEMENS

In the study of the fishes of the lakes, collections were made by means of a gang of seven gill nets of 1¼, 1½, 2, 2½, 3, 4 and 5-inch stretched mesh, each 50 yards in length. This string was set 40 times in various localities at depths from 9 to 375 feet (3 to 115 metres). Numerous seine hauls were made with a thirty-foot quarter-inch net and a ninety-foot half-inch net. In addition specimens of Kamloops trout were provided by a number of anglers, particularly by Mr. J. C. Child, and of kokanee by Mr. G. N. Gartrell and Mr. R. Leckie-Ewing.

The following fourteen species of fish were obtained:

Rocky Mountain whitefish...	*Prosopium williamsoni* (Girard)
Eastern whitefish...........	*Coregonus clupeaformis* (Mitchill)
Kokanee....................	*Oncorhynchus nerka kennerlyi* (Suckley)
Kamloops trout............	*Salmo gairdneri kamloops* (Jordan)
Fine-scaled sucker..........	*Catostomus catostomus* (Forster)
Coarse-scaled sucker........	*Catostomus macrocheilus* Girard
Carp......................	*Cyprinus carpio* Linnaeus
Lake shiner................	*Richardsonius balteatus* (Richardson)
Squawfish.................	*Ptychocheilus oregonensis* (Richardson)
Chub.....................	*Mylocheilus caurinus* (Richardson)
Long-nosed dace...........	*Rhinichthys cataractae* (Cuvier & Valenciennes)
Silver-grey minnow.........	*Apocope falcata* (Eigenmann and Eigenmann)
Sculpin....................	*Cottus asper* Richardson
Ling......................	*Lota maculosa* (Le Sueur)

Reports of the occurrence of a few additional species were received, namely, a species of lamprey, a species of sturgeon and the Eastern speckled trout, *Salvelinus fontinalis*, which was introduced some years ago into a stream at Kelowna. Three species of Pacific salmon, namely, the sockeye, *Oncorhynchus nerka*, the spring, *O. tschawytscha*, and the coho, *O. kisutch*, are said to have entered the lake in the early days.

ORIGIN OF THE FISH FAUNA

During the last glacial period there could, of course, have been no fish present in what is now the mainland of British Columbia. With the retreat of the ice and the establishment of drainage streams to the south, many species undoubtedly gradually spread northward. In recent years the carp has come by this route and the large-mouthed black bass has at least reached Osoyoos lake, both species having been brought into the state of Washington waters from Eastern United States. It is probable that the ling and the fine-scaled sucker came from the north before the Shuswap lake drainage changed from the Okanagan to the Fraser outlet since these are species common in the Great Lakes region of eastern Canada and also indigenous across northern Canada including northern British Columbia.

Finally two species have been introduced directly, the Eastern whitefish and the Eastern speckled trout. The former has established itself but there seems to be no evidence that the latter has done so.

DISTRIBUTION AND ABUNDANCE IN THE LAKE

The fish tend to form two distinct groups in respect to their distribution in the lake, namely, the shallow-water shoreward species and the open-water species. The former group comprises the coarse-scaled sucker, carp, lake shiner, squawfish, chub, long-nosed dace, silver-gray minnow and sculpin; the latter group, the fine-scaled sucker, Rocky Mountain whitefish, Eastern whitefish, kokanee, Kamloops trout and ling. The two associations are illustrated in figure 7. There is a certain amount of overlapping and there are times when the above segregation is temporaily abandoned, as, for example, in the early autumn when the whitefish, kokanee and ling enter the shallow waters to spawn, and in the spring when the Kamloops trout enter the streams or shore-waters to spawn. The chief food relations of the adult fish are shown by arrows.

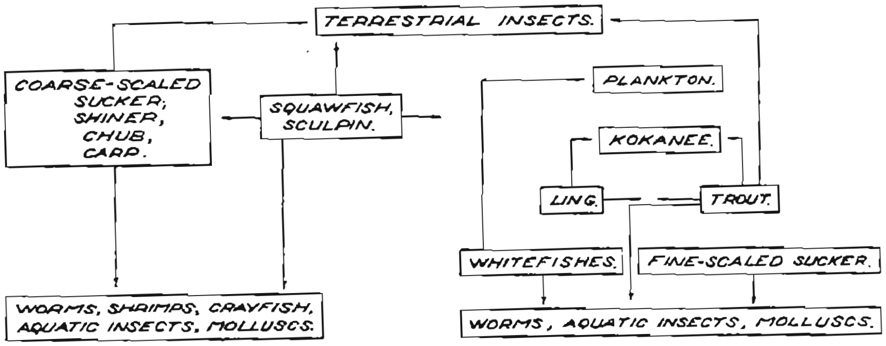


FIGURE 7. Distribution and food relations of fish in Okanagan lake.

Certain species are exceedingly abundant, as, for example, lake shiners, chub, squawfish and coarse-scaled suckers. Large numbers of the young of these fishes inhabit all the shoreward areas where growths of aquatic plants occur.

The kokanee is probably abundant in the open waters. The summer observations were entirely inadequate for the formation of an opinion as to numbers but statements by residents as to spawning individuals would seem to indicate a considerable population.

Carp, Rocky Mountain whitefish, Eastern whitefish, Kamloops trout and sculpins occur abundantly, the fine-scaled sucker and ling much less so, and the long-nosed dace and silver-gray minnow apparently in very limited numbers.

LIFE HISTORIES OF THE SPECIES

Kokanee, *Oncorhynchus nerka kennerlyi* (Suckley)

This lake-locked sockeye salmon occurs in considerable abundance in Okanagan lake. Since it is a fish occupying the open waters at intermediate depths, only a very few specimens were taken in the bottom sets of gill nets. Spawning occurs in the autumn along the shores and in some of the streams. The kokanee mature for the most part at four years and the males develop the red coloration, the hooked snout and the deep body as do the sea-run sockeye. As far as known all individuals die after spawning. The size at maturity varies considerably, ranging for the most part between 8 and 10 inches but in some cases reaching 12 inches or more.

The food consists almost entirely of water-fleas (Cladocera) and copepods of the plankton, with midge larvae and pupae and microscopic diatoms occurring as minor items. The food of 14 individuals taken chiefly in July and October was examined and the occurrences were as follows: copepods 5; water-fleas 14; midge larvae and pupae 2; algae 1.

The chief cladoceran was *Daphnia longispina*, but *Bosmina longispina* occurred in abundance. The gill rakers are relatively fine and numerous (about 34) and make possible the use of these small organisms as food.

The kokanee is a very important fish in the food cycle of the lake because it feeds upon plankton and in turn forms a rich food supply for the Kamloops trout. There is no doubt that the abundance of kokanees determines the production of large trout in Okanagan lake and that a population of considerable size should be maintained. That there has been a considerable decrease in abundance in recent years is the opinion of many residents and two remedial measures have been suggested, namely, the prohibition of the taking of kokanee for food purposes and the introduction of fry from other areas. In 1933 the Department of Fisheries introduced 239,250 and in 1935, 149,200 fry. It may be pointed out that before a sound policy can be developed it is necessary to obtain information concerning: (1) the life-history of the fish, (2) the numbers of kokanee in the lake, and (3) the relation of the numbers of kokanee to the plankton supply on the one hand and to the numbers and size of trout on the other.

Kamloops trout, *Salmo gairdneri kamloops* (Jordan)

This species is native to the Okanagan area. Prior to the extensive development of irrigation systems, it was probably very abundant in Okanagan lake, where satisfactory conditions for growth were afforded and where the numerous tributary streams provided excellent spawning grounds. As the development of orchards extended throughout the valley and as more and more water was taken from the streams for irrigation, the streams became less and less suitable for the reproduction of trout. While the period of the survey did not cover the spawning and fry period, the summer observations together with the statements of residents provided sufficient evidence to indicate that the majority of the streams could not be relied upon in most seasons to maintain sufficient flow to insure the complete passage of fry or fingerlings down to the lake. The extent of the escapement of the young fish undoubtedly varies greatly with the wetness or dryness of the spring and early summer.

To meet this adverse condition, two fish cultural procedures have been followed in recent years. The Dominion Department of Fisheries has brought to its Summerland hatchery considerable numbers of eggs obtained chiefly at Penask lake, and liberated the resulting fry at various points around the lake. At the same time, the members of the Kelowna Fish and Game Protective Association have established several large natural rearing ponds with some financial assistance from the Provincial Game Department. Eggs have been supplied by the Dominion Department of Fisheries from its egg-collecting station at Beaver lake and the resulting young fish held in the ponds until the yearling stage when they have been released in the lower portion of Mission creek and directly in the lake.

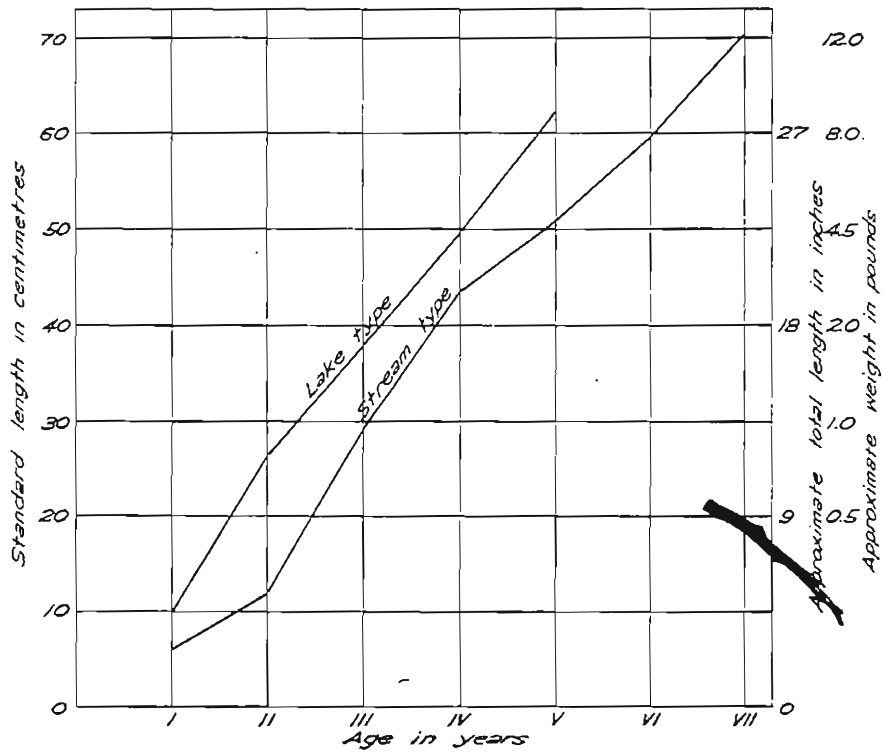


FIGURE 8. Rates of growth of Kamloops trout in Okanagan lake.

The records of liberations in recent years are given in table VIII. Natural propagation and these introductions from other areas have probably served to maintain a considerable stock of trout.

The size of this stock is unknown but that it is considerable is indicated by the annual catches. In view of all the circumstances, there is every reason to believe that the present stock can be maintained, possibly increased by a definite fish cultural policy and the matter will be discussed in a later section of this report.

Only two individuals of Kamloops trout were taken in the gill nets and one fingerling 1.6 inches (3.5 cm.) in a seine haul. Other specimens were supplied through the kind assistance of anglers. The largest specimen measured 31 inches (72.9 cm.) and weighed 14½ pounds. It was caught in November and had apparently completed its eighth summer. Reports of occasional individuals weighing as high as 36 pounds were received.

TABLE VIII. Distribution of eggs and fry

IN OKANAGAN LAKE

Year of stocking	Species	Eggs or fry	Quantity	Source of supply
1919...........	Kamloops trout	Fry	20,000	Gerrard hatchery
1922...........	"	Eggs	90,000	Lloyds creek
1922...........	"	Eggs	30,000	"
1923...........	"	Eggs	200,000	"
1924...........	"	Eyed eggs	75,000	"
1928...........	"	Fry	60,000	Penask lake hatchery
1929...........	"	Fry	75,000	Summerland hatchery
1929...........	"	Fry	10,000	" "
1929...........	"	Fry	10,850	" "
1930...........	"	Fry	45,825	" "
1931...........	"	Fry	145,000	" "
1931...........	"	Fry	34,964	" "
1932...........	"	Fry	5,000	Summerland (ex Penask)
1933...........	Kokanee	Fry	239,250	Summerland
1934...........	Kamloops trout	Fry	58,402	Summerland (ex Penask)
1934...........	Kokanee	Fry	149,200	Summerland
1935...........	Kamloops trout	Fry	234,379	Summerland (ex Penask)

IN OKANAGAN RIVER

Year of stocking	Species	Eggs or fry	Quantity	Source of supply
1923...........	Kamloops trout	Eggs	160,000	Lloyds creek

Twenty-eight individuals contained a variety of food organisms. The majority were taken in October and November, 1935, and they had been feeding on terrestrial insects and kokanee. Two specimens taken in August had fed to some extent upon aquatic insects. The details are as follows.

28 fish, 10 to 27½ in. (22.8 to 66.0 cm.): fresh water shrimps 1; spiders 5; mayfly nymphs 2; caddis larvae 2; midge larvae 5; other aquatic insects 4; terrestrial insects 17; fish 10; fish eggs 1.

In addition, the stomach contents of 11 fish taken from Beaver lake during July and August were examined and the result showed that the chief food of these was caddis larvae. Kamloops trout is the only species of fish present in this lake. The details are as follows.

11 fish, 6 to 23¾ in. (13.2 to 56.5 cm.): mayfly nymphs 2; dragonfly nymphs 2; caddis larvae 10; midge larvae 4; other aquatic insects 1; terrestrial insects 4.

The data on rate of growth are shown in figure 8. Six individuals had spent the first year in streams and the remainder, 34, in the lake. The growth rates of these two groups have been presented separately and they should be considered as only approximate since such a small number of individuals is involved. The assistance of Dr. C. McC. Mottley in the interpretation of these scales is gratefully acknowledged.

Fine-scaled sucker, *Catostomus catostomus* (Forster)

This species is also known as the northern or long-nosed sucker. It usually inhabits water of considerable depth and appears to be an associate of the Eastern whitefish when the two species occur in the same body of water. Only three individuals were obtained in gill net settings, one off Summerland at a depth of 200 feet (60 metres) and two off Westside at a depth of approximately 100 feet (30 metres). A few small specimens were obtained in seine hauls.

The food of two individuals 11⅜ in. (25.7 cm.) and 16½ in. (38.5 cm.) in length taken off Westside consisted chiefly of midge larvae with considerable numbers of ostracods, copepods (*Cyclops*) and water mites in addition.

The material was too limited to attempt to determine the rate of growth of the population of the lake, but the two individuals referred to above appeared to be in their fourth and fifth summers respectively.

The fine-scaled sucker is probably not particularly abundant in Okanagan lake and is probably subject to the same limiting factors that apply to the Eastern whitefish, the chief of which would seem to be a lack of food materials on the lake bottom both in quality and quantity.

Coarse-scaled sucker, *Catostomus macrocheilus* Girard

This is the common sucker of Okanagan and connected lakes, where it inhabits relatively shallow water, no specimen having been taken below 50 feet (15 m.). It is particularly abundant around the weedy margins of the lake, including bays and backwaters, and in the mouths of streams. The young are exceedingly abundant among the reeds where they feed upon the plant and animal growths on the stems and on the lake bottom. A large size is attained. In Okanagan lake a specimen 18⅛ inches (41.6 cm.) was obtained, while lengths of 15 to 17 inches were rather common. In Woods lake a specimen 21¼ inches (49.5 cm.) in length and 3 lb. 4 oz. in weight was taken in a shore seine.

The food of twenty-nine specimens averaging 3½ inches (7.4 cm.) in length consisted chiefly of small midge larvae but with considerable numbers of copepods, water-fleas and caddis larvae. The food of larger specimens averaging 10½ inches (23.5 cm.) was composed of large numbers of crustaceans (ostracods, copepods, water-fleas), midge larvae and other aquatic insects. Molluscs occurred in a few instances. In both small and large individuals, diatoms and other algae occurred in considerable quantities along with detritus (sand, mud, fragments of plants and animals). The following data show the number of stomachs in which each food organism occurred.

21 fish under 5½ in. (12 cm.): ostracods 1; copepods 5; water-fleas 11; water mites 1; mayfly nymphs 1; caddis larvae 11; midge larvae 24; other aquatic insects 2; algae 6.

22 fish over 5½ in. (12 cm.): ostracods 6; copepods 10; water-fleas 9; freshwater shrimps 1; water mites 5; mayfly nymphs 1; caddis larvae 9; midge larvae 19; other aquatic insects 5; terrestrial insects 2; molluscs 4; algae 6.

Some idea of the rate of growth has been obtained from an examination of the scales of forty-nine individuals from Okanagan lake. The determination of the annual growth areas in the scales of these fish was very difficult and the data presented should be regarded as tentative and approximate (figure 9). The rates of growth of specimens from Woods and Duck lakes appeared to be essentially similar. One large individual 21¼ inches in length taken in Woods lake was probably about 15 years of age.

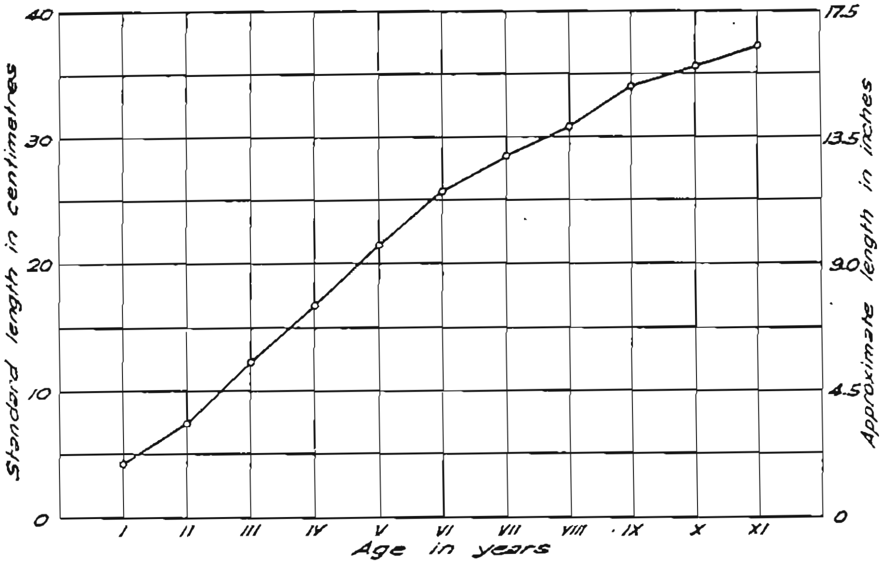


FIGURE 9. Rate of growth of the coarse-scaled sucker in Okanagan lake.

Carp, *Cyprinus carpio* Linnaeus

The exact date when carp appeared in Okanagan lake in unknown, but Mr. G. N. Gartrell, Fisheries Inspector, states that it was probably in 1917. Mr. Gartrell is also of the opinion that they reached their greatest abundance in the year 1934. Extensive observations during the summer of 1935 indicated that they were not exceedingly abundant anywhere in Okanagan lake. For some reason the young could not be located and only two small individuals were obtained, one, 5⅝ inches (13.0 cm.) in length, was taken in the 2″ gill net off Okanagan Mission and another, 1½ inches (3.2 cm.) in length, was picked up dead in the backwater north of the mouth of Mission creek. Neither were young carp seen or taken in Kalamalka, Woods or Duck lakes in spite of intensive search.

It is quite possible that the history of the carp in Okanagan lake is similar to that of introduced species in other areas in which there occurs a more or less rapid increase in numbers followed by a subsidence to a certain level controlled by environmental factors. The decline may have been hastened by removal of considerable numbers in traps at the outlet of Okanagan lake and in the stream connecting Duck and Woods lakes. In 1934, a trap at the outlet of the lake captured approximately seven tons according to Inspector Gartrell. The removal of carp in the Okanagan sub-district by means of traps is given by the Department of Fisheries as follows:

1932, 7,081 fish, 14 tons; 1933, 3,000 fish, 5½ tons.
1934, 1,114 fish, 2 tons; and in addition the 7 tons mentioned above, making a total of 9 tons.
1935, 3,625 fish, 6¾ tons; 1936, 1,002 fish, 2 tons.

In the above calculations of tons an average weight of 3¾ pounds is used, being the average of 13 fish captured by seine in Woods lake in 1935.

Carp averaging 17 inches in length (range 14 to 20¼ in.) were taken by seine in Summerland and Westside areas and in the North arm where considerable numbers occurred, and thirteen individuals obtained from Woods lake averaged 17¾ inches (range 15½ to 21⅛).

The food of fifteen individuals ranging in length from 5⅝ to 21⅛ inches consisted chiefly of bottom organisms such as crustaceans, larvae and nymphs of aquatic insects, worms, small snails, algae and plant fragments. The number of occurrences of the various food organisms was as follows: worms (Oligochaeta) 7; ostracods 15; copepods 10; water-fleas 13; freshwater shrimps 7; water mites 5; mayfly nymphs 7; caddis larvae 7; terrestrial insects 5; midge larvae 12; molluscs 11; fish eggs 1; algae 11; higher plant tissue 14.

In feeding habits and character of food, the carp very closely resembles the coarse-scaled sucker. In one instance a few fish eggs occurred and it is not improbable that at certain times the eggs of whitefish, kokanee and other species may be taken. It is not a fish-eating species and is therefore not a predatory enemy of trout. However, it consumes very large quantities of the basic food materials and like other coarse fishes does not appear to be contributing to the economic productivity of the lake.

Owing to the limited number of specimens examined, the lack of young fish, and the difficulty in interpreting the scales, it is not possible to determine accurately the rate of growth of the carp in Okanagan and nearby lakes. Examination of the scales shows that the fish 5⅝ inches in length was apparently in its third summer. Fish of 16 inches appeared to be in the eighth summer; fish approximately 18 inches in the ninth summer; the larger fish probably in their tenth and eleventh summers. If these interpretations of the scales are correct they indicate a much slower rate of growth than in many other bodies of water, as for example Cayuga lake, New York state.

The reproductive capacity of the carp is very great. A specimen 18½ inches (41.5 cm.) in length contained approximately 300,000 eggs.

Lake Shiner *Richardsonius balteatus* (Richardson)

Of the fishes inhabiting the shallow waters, the lake shiner is probably the most abundant. Large numbers occurred in every area where aquatic plants grew. There was considerable variation in the body form of these minnows, those taken at Summerland being particularly deep and compressed.

The food of individuals less than 2¼ inches (4.5 cm.) in length consisted largely of copepods with considerable numbers of water-fleas and midge larvae; other aquatic insects and diatoms occurred to some extent. Individuals 2½ inches (5 cm.) and over in length fed almost entirely upon insects both aquatic and terrestrial, but slightly more upon the former. Of the aquatic insects, midge larvae, mayfly nymphs and caddis larvae predominated. The terrestrial insects were represented by a variety of beetles, flies, and Hymenoptera, chiefly ants. The number of occurrences were as follows:

17 fish, 1½ to 2¼ in. (3.0 to 4.5 cm.): copepods 11; water-fleas 4; midge larvae 5; other aquatic insects 3; algae 3.

33 fish, 2¼ to 4½ in. (4.5 to 9.5 cm.): water-fleas 5; water mites 2; mayfly nymphs 4; caddis larvae 4; other aquatic insects 10; terrestrial insects 17; midge larvae 9; algae 3.

No information has been obtained as to spawning and no attempt has been made to determine the rate of growth. The largest specimen recorded had a length of 4½ inches (9.5 cm.).

No evidence has been obtained to indicate that this minnow is eaten by trout. It is evident that the distribution of the two species in the lake is such that seldom are they brought together. Were the situation otherwise the shiner would constitute an excellent "forage" fish for the trout, but as it is, only the squawfish would appear to be in a position to benefit particularly from the presence of this abundant food supply.

Squawfish, *Ptychocheilus oregonensis* (Richardson)

The squawfish is a minnow which reaches a large size and is abundant in Okanagan, Woods and Duck lakes. It inhabits the shoreward waters for the most part and probably for this reason it appeared in the gill nets only occasionally. Only five specimens were taken in this gear in Okanagan lake, as compared with 89 of the chub. A set in Woods lake in water thick with the alga *Aphanizomenon* yielded 17 squawfish as compared with 62 chub.

Its food consists largely of various species of fish and it is the chief predator of the shallow water association. During the summer of 1935 sculpins and Rocky Mountain whitefish were the chief fishes eaten but other data from the lake (*Munro and Clemens, "The American merganser in British Columbia and its relation to the fish population", Biol. Bd. Can. Bull. No. LV, 1937*) show kokanee, Kamloops trout and minnows as additional food items.

While the squawfish is essentially a fish eater it also feeds to a large extent upon aquatic invertebrates such as freshwater shrimps, crayfish and insects, as well as upon terrestrial insects falling upon the surface of the water. The young up to about 4½ inches feed upon small crustaceans and insects. The following are the data on times of occurrence of the food items.

15 fish less than 4½ inches: water-fleas 6; mayfly nymphs 3; caddis larvae 3; midge larvae 8; other aquatic insects 3.

23 fish over 4½ inches: water-fleas 2; freshwater shrimps 1; crayfish 2; water mites 1; mayfly nymphs 7; midge larvae 7; terrestrial insects 6; fish 13.

In figure 10 are presented the rates of growth of Okanagan and Woods lake squawfish. It would appear that the fish of the latter lake grow somewhat more rapidly and attain a much greater age and size. One individual was obtained in Woods lake which was 18 inches in length (42.5 cm.) and was apparently in its 12th summer. The majority of the larger squawfish taken in Okanagan lake were from 10 to 12 inches in length and in their seventh summer.

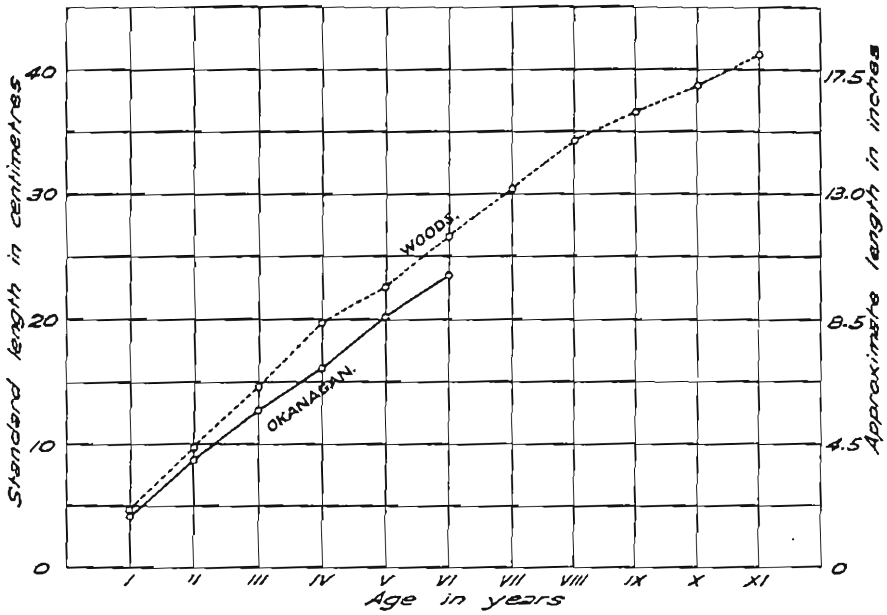


FIGURE 10. Rates of growth of the squawfish in Okanagan and Woods lakes.

Chub, *Mylocheilus caurinus* (Richardson)

The shallow shoreward waters, particularly where aquatic vegetation is abundant, are thickly populated with chub. Only the lake shiner would appear to exceed this species in numbers. It was taken more frequently in the gill nets than any other species, which fact may also indicate that it is a very active fish. The latter supposition is supported by the food data which show that larger chub feed to a considerable extent upon terrestrial insects.

The food of the very young fish consists chiefly of water-fleas, but also of copepods, water mites, small midge larvae, small aquatic and terrestrial insects.

The food of the larger fish is made up largely of insects both aquatic and terrestrial, including mayfly nymphs, caddis larvae, midge larvae on the one hand and various moths, beetles, flies and Hymenoptera on the other. Water-fleas occur frequently and molluscs occasionally. Finally remains of small fishes occurred in four out of 46 digestive tracts examined. In a few cases the fragments were those of sculpins and it is probable that the species was represented in all cases. The following are the occurrences of the various food organisms.

6 fish, 1½ to 5 in. (3 to 10.5 cm.): worms 1; copepods 3; water-fleas 6; water mites 2; midge larvae 3; other aquatic insects 2; terrestrial insects 1; molluscs 1; algae 1.

46 fish, 6 to 9¾ in. (13 to 23 cm.): water-fleas 14, water mites 6; mayfly nymphs 26; caddis larvae and pupae 10; midge larvae and pupae 12; terrestrial insects 24; molluscs 7; fish 4.

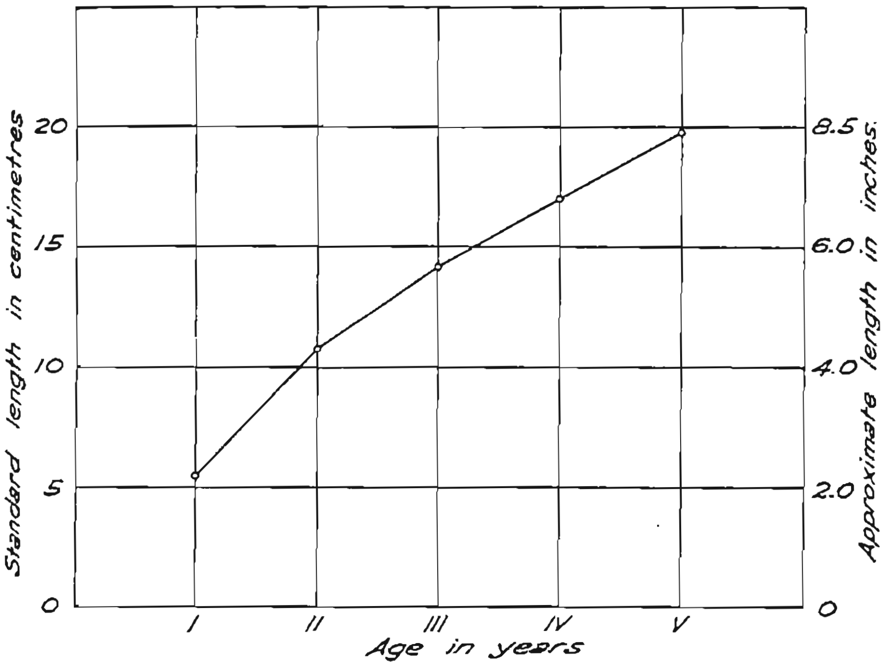


FIGURE 11. Rate of growth of the chub in Okanagan and Woods lakes.

The rate of growth is shown in figure 11. Since the Okanagan and Woods lake specimens did not show any significant differences in growth rate the graph is based upon the combined determinations of 69 fish from Okanagan lake and 13 from Woods lake. The largest individual taken measured 9¾ inches (23.0 cm.) and was in its sixth summer.

Long-nosed dace, *Rhinichthys cataractae* (Cuvier and Valenciennes)

A few small specimens of this minnow were taken in seines, chiefly in the Okanagan Mission area but also at Westside and Okanagan landing. It is readily recognized by the long pointed snout, a narrow black line from the eye to the tip of the snout and the inferior mouth. It was found on the bottom at the mouth of Mission creek and along the more or less exposed shores of the lake. The sizes ranged from approximately 1⅜ to 1⅞ inches (3.0 to 4.2 cm.).

Silver-grey minnow, *Apocope falcata* (Eigenmann and Eigenmann)

This species was similar in size, numbers and distribution to the long-nosed dace. It is silvery-gray in general coloration with black markings over back and sides. One specimen taken at Okanagan Mission was 1½ inches (3.3 cm.) in length. This minnow and the long-nosed dace usually inhabit cold and rather swift mountain streams.

Sculpin, *Cottus asper* Richardson

The sculpin or bullhead seemed to be widely distributed around the shores of Okanagan lake as it was almost invariably taken in the small-meshed shore seine. For the most part the fish were small. The largest in the seine hauls had a length of 3⅝ inches (7.7 cm.). One individual caught in a gill net near Okanagan landing measured 4½ inches in length. It is interesting to note that sculpins occurred in the stomachs of Eastern whitefish, chub and squawfish.

The food of small individuals consisted of copepods, water-fleas and midge larvae, while that of larger individuals showed a preponderance of midge larvae and other aquatic insects. The occurrences of food organisms were as follows.

10 fish, ¾ to 1½ in. (1.4 to 2.4 cm.): ostracods 1; copepods 8; water-fleas 10; midge larvae 7.

11 fish, 1¾ to 3⅝ in. (2.8 to 7.7 cm.): ostracods 1; copepods 2; water-fleas 1; fresh-water shrimps 2; mayfly nymphs 1; water boatmen 1; caddis larvae 2; midge larvae 9; fish 1.

Ling, *Lota maculosa* (Le Sueur)

Little information was obtained as to the abundance of ling in Okanagan lake. Two individuals were obtained in the gill net settings, one approximately 22½ inches (55 cm.) and the other 6¼ inches (15 cm.) in length. A third individual of medium size was picked up dead along the bank of a stream a short distance from the mouth. Several reports were received of catches of large ling by anglers. Three small specimens were taken in seine hauls as follows: two individuals 1⅓ inches (2.8 cm.) and 1 inch (2.5 cm.) near the mouth of Mission creek on July 27, and one individual 1½ inches (4 cm.) in Woods lake on August 14.

Two specimens examined contained kokanee in the stomachs and it is probable that the kokanee is the staple diet of the ling in Okanagan and other lakes in the valley. One individual 22½ in. (55 cm.) in length contained a kokanee 8¼ in. (20 cm.) in length. Munro and Clemens (*loc. cit.*) report the food of a specimen 6½ inches in length as consisting of a mayfly nymph and other aquatic insects.

It may not be generally known that the ling is a member of the cod family and is the only representative of the family in fresh water. Further information concerning its life-history and its place in the economy of the waters is very desirable.

THE WHITEFISHES *COREGONUS CLUPEAFORMIS* (MITCHILL) AND *PROSOPIUM WILLIAMSONI* (GIRARD) OF THE LAKES OF THE OKANAGAN VALLEY, BRITISH COLUMBIA

By J. Laurence McHugh

INTRODUCTION

In conjunction with the investigation of the productivity of Okanagan lake in respect to Kamloops trout, a special study was made of the whitefishes. Two species of the latter occur in the lake, namely, the Rocky Mountain whitefish, *Prosopium williamsoni* (Girard), and the eastern or common whitefish, *Coregonus clupeaformis* (Mitchill). The former is native to the Rocky mountains region and westward and is indigenous to the lakes of the Okanagan region. The latter is distributed across the continent, occurs naturally in northern British Columbia but not in the southern portion of the province; it was introduced into Okanagan and certain nearby lakes from lake Winnipeg. The present paper deals with these two species.

The study divides itself into three main parts ; first, an analysis of the food organisms as revealed by the stomach contents; secondly, age and rate of growth, determined by an examination of the scales; and lastly, a study of the variability and reliability of some of the characters which may be used for purposes of identification. The data collected also give information with regard to depths at which the species are commonly found. Finally the results are compared to show similarities and differences between the two species.

ACKNOWLEDGMENTS

The material on which this paper is based was supplied by Dr. W. A. Clemens, to whom the writer wishes to express thanks for his kindness in suggesting the topic and providing the necessary material, and also for his interest and assistance during the course of the investigation. The examination of the material was carried out at the University of British Columbia under the supervision of Dr. C. McLean Fraser, whose helpful suggestions and guidance have been very much appreciated.

Information concerning whitefish plantings and fishing experiments in lakes of the Okanagan valley has been kindly supplied by Mr. G. N. Gartrell, Fisheries Inspector at Summerland, B.C., and Major J. A. Motherwell, Chief Supervisor of Fisheries, Vancouver.

The assistance of Professor G. J. Spencer and Dr. G. C. Carl has been most valuable in the identification of many of the insects and insect remains present in the stomachs.

GEAR AND METHODS

A gang of 7 gill nets was used. Each net was 50 yards in length and the sizes were as follows: $1\frac{1}{4}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, 4 and 5-inch stretched mesh. The nets were set on the bottom and thus it was possible to determine the relative abundance of fish at various horizontal depths in the bottom four-foot stratum, while the variety of mesh sizes allowed for the capture of a graded series of lengths.

Beach seines of the usual type were used, one having a small mesh to allow for the capture of small fish.

In most cases the stomach contents were removed soon after capture and preserved in four per cent formalin. A few scales were removed from the left side of the fish in the area between the dorsal fin and the lateral line.

Two length measurements were taken, the standard length being considered as the distance from tip of snout to the posterior end of the vertebral column, measured in centimetres, and the total length as the distance from tip of snout to fork of caudal fin, measured in inches.

Stomach contents were examined under the low power of the binocular microscope and the percentage volume of the various organisms present was estimated.

The scales were mounted in glycerine jelly and the age determinations were made with the use of a Promar projector. Each winter band or annulus was considered as representing the completion of one year of life (*Van Oosten, "A study of the scales of whitefishes of known ages", Zoologica, New York Zoological Society, Vol. II, no. 17, 1923*). The positions of the winter bands were marked off on cards for the determination of the growth rate.

The lengths at the end of each winter of life were calculated by the method developed by Van Oosten (*1923, loc. cit.*). Assuming the increase in diameter of the scale from winter to winter to be in the same proportion as the increase in length for the same period, the length increments were calculated from the length of the fish at the time of capture.

Counts were made of scales, fin rays, and other variable characters to permit comparison of the two species of whitefish with each other, and also with races of their own species in other lakes. Except for medial structures the counts were made on the left side of the fish. Counts were made of the bony fin *rays*, all in the pectoral and pelvic fins, but in the dorsal and anal fins the short rays anterior to the longest ray were not counted unless they equalled at least half its length, and the divided ray at the posterior end was counted as one only. *Scales* on and above the lateral line were counted only to the end of the vertebral column, ignoring the small scales in the fleshy portion of the caudal fin. *Rows of scales* above and below lateral line were counted diagonally from the insertion of the dorsal or anal fin to, but not including, the lateral line scale. All *gill rakers* were counted, whether fully developed or not. When one raker occurred exactly in the centre of the fork of the gill arch, it was included with the count for the short arm. All *vertebrae* were counted (including those in the upturned portion at the posterior end) after removing the flesh from one side of the fish.

EASTERN WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL)

As far as can be ascertained, this species was first introduced to the Okanagan valley in the year 1894, eggs being brought from lake Winnipeg, hatched in the New Westminster hatchery, and the fry planted in Okanagan and Kalamalka lakes, to the number of 1,200,000. That the venture was successful to some extent is shown by the fact that, no later plantings being known until 1928, adult whitefish of this species were captured by Professor J. R. Dymond in July, 1928, in Okanagan lake near Kelowna.

In order to determine the possibility of establishing a commercial fishery in Okanagan lake, a permit was issued to a resident of Kelowna, Mr. Straumfjord, in November, 1928. He had gained his fishing experience in Manitoba, and conducted operations regularly until October, 1929, except for a short period in the early part of the year when ice conditions prevented the placing of nets in the water. The results proved financially unsatisfactory, and the results of an investigation of other lakes in the same drainage system proved equally unsatisfactory. Although the Eastern whitefish is known to have been planted in Kalamalka and Okanagan lakes only, the species has been found to exist in other lakes of the system, all downstream from Okanagan lake, which suggests that the fish have migrated down stream during some stage of their existence. That neither during Straumfjord's experiments, nor during the survey of 1935 were any whitefish of the genus *Coregonus* taken in Woods or in Kalamalka lake, seems to indicate that these fish are more scarce in the upper reaches of the river system.

Table IX shows the monthly catch in each of the lakes for the whole period of the experiment. In cases where the number of days' fishing for the month was available, the number of fish caught per day (index of abundance) was obtained

TABLE IX Catch of the Eastern and Rocky Mountain whitefish in the various lakes, for each month in which fishing took place.

			Eastern whitefish			Rocky Mt. whitefish	
Lake	Year	Month	No. of fish	No. of days	Fish per day	No. of fish	Fish per day
Woods	1929	November	0	2		23	11.5
Kalamalka	1929	November	0	1		5	5.0
Okanagan	1928	Nov.-Dec.	330			0	
	1929	Jan.-Mar.	295			0	
		April	139			1	
		May	86			0	
		June	120			44	
		July	91			2	
		August	219			0	
		September	349	28	12.5±1.9	1	
		October	220	20	11.0±1.9	0	
		November	45	3	15.0±8.3	1	0.3
Dog	1929	November	339	12	28.2±6.5	9	0.7
Vaseaux	1929	November	102	2	51.0±39.0	0	
Osoyoos	1929	November	14	1		0	

by dividing the total number of fish by the number of days required to catch them. As the reliability of this figure depends on the number of days, the probable error of each value was calculated.

It is apparent that the balance is in favour of the two lakes (Dog and Vaseaux) immediately to the south of Okanagan lake. In the table, the lakes are listed in order of sequence in the downstream direction, and it can be seen that the values increase from Kalamalka lake at the upper end of the system to Dog and Vaseaux lakes, and decline from there to Osoyoos lake at the south.

Further consideration of the data in table IX suggests the possibility of an inverse relation between the abundance of the introduced and the native species in succeeding lakes of the system. Apparently the native whitefish is the dominant species in the upper lakes of the river, while the introduced form increases in abundance and becomes dominant in a downstream direction.

In 1928 and 1929 eggs from the Waterhen river, lake Winnipegosis, were hatched in the Dominion government hatchery at Summerland on Okanagan lake. From these, 4,780,000 fry were placed in Okanagan lake and its tributaries in 1928, and 4,680,000 in 1929. Conclusive evidence of the success of these plantings is not available, but the rather meagre catches of 1935 would lead one to believe that Okanagan lake in its present state is unsuitable for the profitable rearing of the Eastern whitefish.

Forty-five specimens were taken in 1935 in the gill nets, and one was found dead in the water near the lake shore.

FOOD

The contents of 55 stomachs of fish taken in Okanagan lake were examined and the following organisms were identified: bryozoan statoblasts; four genera of water fleas,—*Daphnia*, *Eurycercus*, *Leptodora* and *Bosmina*; two genera of copepods,—*Cyclops* and *Epischura*; unidentified ostracods; two families of flies (Diptera),—the Chironomidae and Tipulidae; larval and pupal caddis flies; nymphs of mayflies; remains of Hymenoptera and other insects; the water mites or Hydrachnidae; molluscs, represented by both clams and snails; and fish, represented by sculpins (*Cottus asper*). Plant material recognized consisted of algae (*Nostoc*, *Chara*, and a number of filamentous species); pond weeds (*Potamogeton*); unidentified seeds; and other remains of the higher plants. Other substances found were bottom ooze, sand particles, clinkers, and bits of wood, sometimes forming a large portion of the stomach contents.

The food of 37 specimens taken in 1935 is given in table X. In addition to these, the contents of the stomachs of 18 individuals taken by Straumfjord in 1929 were examined. No record of the ages of these fish was available. The results are presented in table XI.

Three individuals in the first year of life had eaten chiefly midge and cranefly larvae (70 to 80%). Additional items included bryozoan statoblasts, ostracods, and filamentous algae.

Table X. Food organisms of 37 Eastern whitefish, July-August, 1935. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Daphnia*	8	8	100
	Eurycercus	4	X	X
	Leptodora	4	4	100
	Bosmina	1	X	X
Copepods :	*Cyclops*	7	X	X
	Epischura	1	X	X
Ostracods :	Ostracoda	18	X	X
Water mites :	Hydracarina	25	X	5
Midge larvae :	Chironomidae	18	6	100
Midge pupae :		14	5	70
Cranefly pupae :	Tipulidae	10	4	15
Caddis larvae :	Trichoptera	4	X	X
Caddis pupae :		4	X	X
Mayfly nymphs :	Ephemeroptera	12	7	90
Ants, etc.:	Hymenoptera	2	X	X
Clams :	Pelecypoda	1	X	X
Snails :	Gastropoda	18	6	75
Sculpins :	*Cottus* sp.	12	18	95
Bryozoa :	Statoblasts	6	X	X
Algae :	Filamentous	16	16	95
	Chara.	14	10	5
	Nostoc	5	3	70
Pond weeds :	*Potamogeton*	2	X	X

Table XI. Food organisms of 18 Eastern whitefish, September-October, 1929. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Eurycercus*	13	21	90
	Leptodora	4	X	5
Ostracods :	Ostracoda	5	X	X
Water mites :	Hydracarina	13	2	20
Midge larvae :	Chironomidae	13	41	95
Midge pupae :		3	X	X
Mayfly nymphs :	Ephemeroptera	2	4	75
Other insect remains :		2	X	X
Clams :	Sphaeridae	14	5	50
Bryozoa :	Statoblasts	2	X	X
Algae :	Filamentous	2	X	10
	Nostoc	2	X	X
Higher plants :	Seeds	4	X	X
	Other spermatophyte	8	X	X
Unidentified :	remains	12	2	25

Three specimens in the second year had taken chiefly filamentous algae (60%) and snails (up to 75%). Other items were water fleas, copepods, ostracods, water mites, midge larvae, and algae, including *Chara*.

Twenty-six individuals in the third year contained a great variety of organisms. The most important materials were water fleas, copepods, aquatic insect larvae, small fish, filamentous algae and *Chara*.

The food of five fish in the fourth year consisted of aquatic insect larvae, small fish and algae for the most part.

AGE, GROWTH, SPAWNING

The scale method of computing the age and the length at the end of each winter of life has been used, practically as described by Van Oosten (*Life history of the lake herring [Leucichthys artedi Le Sueur] of lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fish., vol. XLIV, Doc. no. 1053, 1929*).

The winter check in growth shows itself as a succession of less distinct and much broken, closely applied circuli. The length of an individual at the end of each successive year is calculated according to the following formula:

$$\frac{\text{Length of scale at end of year } X}{\text{Total length of scale}} = \frac{\text{Length of fish at end of year } X}{\text{Length of fish at time of capture}}$$

The length of the scale at any selected time was measured from the centre of the focus anteriorly. The results produced by this method are open to criticism for the reason that they exhibit the effect described by Van Oosten (*1929, loc. cit.*) as "Lee's phenomenon". This shows itself in table XII as a decrease in the average calculated length in the early years of life as the fish increase in age, and an increase in calculated length in the later years with increasing age.

The age of a fish in its first year, the scales of which do not show a winter check, is represented by the numeral I, that of one in the second year by II, and so on.

Table XII shows the average standard length at the end of each year of life for each year class. The last value in each horizontal row represents the actual

TABLE XII. Standard length attained by the various year classes of Eastern whitefish at the end of each year of life.

Year class	Age group	Average calculated standard length in mm. attained at end of each year							
		I	II	III	IV	V	VI	VII	Individuals
1929......	VII	119	205	268	312	347	373	(383)	1
1930......	VI	105	172	238	293	325	(342)		1
1931......	V	113	232	279	308	(321)			1
1932......	IV	114	192	254	(283)				2
1933......	III	132	228	(262)					28
1934......	II	141	(200)						7
1935......	I	(130)							4
Weighted average.		131	224	259	304	336	373		

The figures in brackets represent the length in the year of capture—i.e. only a partial year's growth.

standard length at the time of capture. The year class was determined by reckoning back from the year of capture, according to the number of winter checks. Each vertical column contains the average standard lengths of fish of equal age, while the horizontal rows show the yearly increase in length for each age group. In determining the averages for the whole sample, the individual averages were weighted to the number of individuals represented, so that the last horizontal row contains the true average standard lengths at the end of each year of life.

The data are presented graphically in figure 12. The portion at the end of each curve indicated by a broken line represents the growth from the previous spring to the time of capture, and hence cannot be considered as a full year's growth. Up to the end of the third year of life this curve of average values can be considered as fairly accurate, since up to this point the size of the samples remains relatively large. From here on, however, the significance of each point decreases, due to the small number of fish which were in their fourth year or older. It is evident that the average yearly increment in length of the Eastern whitefish in Okanagan lake decreases as the fish increases in age.

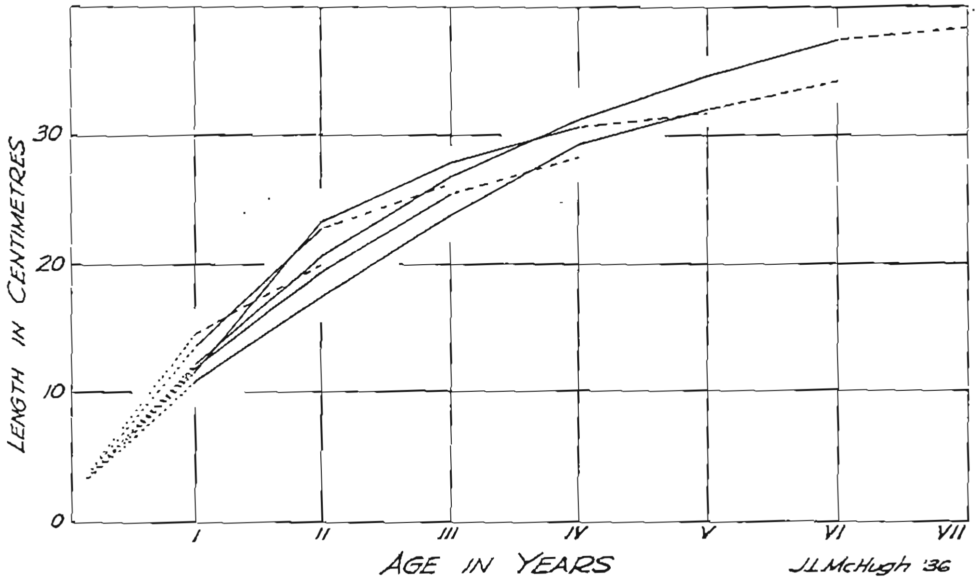


FIGURE 12. Rates of growth of the age classes of the Eastern whitefish in Okanagan lake.

The only record available as to the spawning habits of the Eastern whitefish in Okanagan lake is found in reports of Mr. Gartrell, fisheries inspector. On December 13, 1928, he reported that specimens captured would not have been ready for spawning for approximately two weeks, while on December 31 he stated that most of the fish in recent catches had spawned.

VARIABILITY OF INDIVIDUAL CHARACTERS

The methods of examination have been described. As this work was done on formalin preserved specimens, it was thought advisable to compare only characters which could not be altered by shrinkage or loss of normal shape.

The results of the counts made from the Okanagan specimens are summarized in table XIII. When these are compared with counts made on fish from lakes of Manitoba, Ontario, and the eastern states, it is found that in all cases the results are closely comparable. It must be concluded that the Okanagan population is not significantly modified with respect to any character examined.

TABLE XIII. Variability in individual characters of the Eastern whitefish in Okanagan lake.

	Minimum	Maximum	Most frequent value	No. of individuals
Fin rays				
Dorsal	10	12	11	43
Anal	9	13	11	41
Pectoral	15	17	16	40
Pelvic	10	12	11	41
Scale counts				
In lateral line	70	85	77	40
In row above lateral line	62	84	77	38
Rows above lateral line	10	11	10	41
Rows below lateral line				
—from pelvic	8	9	9	42
—from anal	8	9	8	40
Gill rakers				
Short arm	10	12	11	43
Long arm	15	20	18	43
Total	26	31	29	43
Branchiostegals	8	10	9	37
Vertebrae	56	60	58	42

ROCKY MOUNTAIN WHITEFISH *PROSOPIUM WILLIAMSONI* (GIRARD)

During his experiments, Straumfjord found the 3½-inch stretched mesh to be the most suitable size for the capture of adult Eastern whitefish. Having obtained this information, he used this type of net exclusively until operations ceased. For the entire period, the catch of Rocky Mountain whitefish amounted to only nine fish in Okanagan lake. This might be interpreted in various ways: (1) that these fish inhabit waters of a different depth from those frequented by the Eastern whitefish; (2) that they do not normally feed on the bottom, thus inhabiting waters above the level of the nets; (3) that the numbers of the species present in the lake were relatively small; or (4) that the species seldom reached a size sufficiently large to allow it to become caught in the nets. The last explanation would seem to be the proper one since the results of the 1935 survey seem to show that the habitats of the two species overlap to some degree, that they both feed to a great extent on bottom organisms, and that the numbers of each, taking the total catch as a criterion, are fairly close to being equal, whereas the data show that the Rocky Mountain whitefish does not reach as great a length as the Eastern whitefish. Table IX shows the catches of Rocky Mountain whitefish in each lake as compared with the figures for the eastern species.

The fish taken in 1935 consisted of 35 obtained in the gill nets and 6 in a small-meshed seine.

FOOD

The organisms identified in the contents of 40 stomachs of fish taken in Okanagan and Woods lakes are given in table XIV.

The food of three individuals of the first year taken in the mouth of Trout creek consisted chiefly of aquatic insect larvae, water fleas and copepods, while the food of another individual, also in the first year and captured off the mouth of Mission creek, consisted of the water flea, *Daphnia*, only.

The food of the fourteeen individuals of the second year was comprised chiefly of water fleas, copepods, and aquatic insect larvae, but two individuals had fed largely upon terrestrial beetles.

TABLE XIV. Food organisms of 36 Rocky Mountain whitefish. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Daphnia*	31	63	100
	Scapholeberis	4	X	X
	Alona	2	X	X
	Leptodora	1	X	X
	Diaphanosoma	4	X	20
Water mites :	Hydracarina	2	X	X
Shrimps :	Amphipoda	1	X	X
Midge larvae :	Chironomidae	6	X	5
Midge pupae :		28	5	60
Caddis larvae :	Trichoptera	6	4	90
Caddis pupae :		8	3	25
Cranefly pupae :	Tipulidae	7	3	25
Blackfly larvae :	Simuliidae	5	X	5
Flies :	Empididae	2	X	X
Mayfly nymphs :	Ephemeroptera	12	8	70
Stonefly nymphs :	Plecoptera	3	X	80
Beetles :	Dytiscidae	2	X	45
	Carabidae	2	X	50

Sixteen specimens of the third year had also eaten largely of water fleas and copepods with considerable amounts of aquatic insect larvae in addition.

Two individuals of the fourth year had taken *Daphnia* and aquatic insect larvae.

The older specimens appear to depend upon water fleas and copepods for their main food supply and *Daphnia* is undoubtedly the most important organism, forming approximately two-thirds in volume of all the food taken. The remainder is made up almost exclusively of aquatic insect material obtained from the lake bottom.

AGE, GROWTH AND SPAWNING

The age of each fish was determined by the scale method, and the length at the end of each winter of life by the method described previously. The results are presented in table XV, which corresponds in form to table XII. The data for the two individuals from Woods lake are not included.

The curve in figure 13 represents the weighted averages, and consequently shows the average standard length at the end of each year of life for the whole sample. With it, for purposes of comparison, is given a similar curve for the Eastern whitefish.

The decreasing slope of the curve for the Rocky Mountain whitefish shows

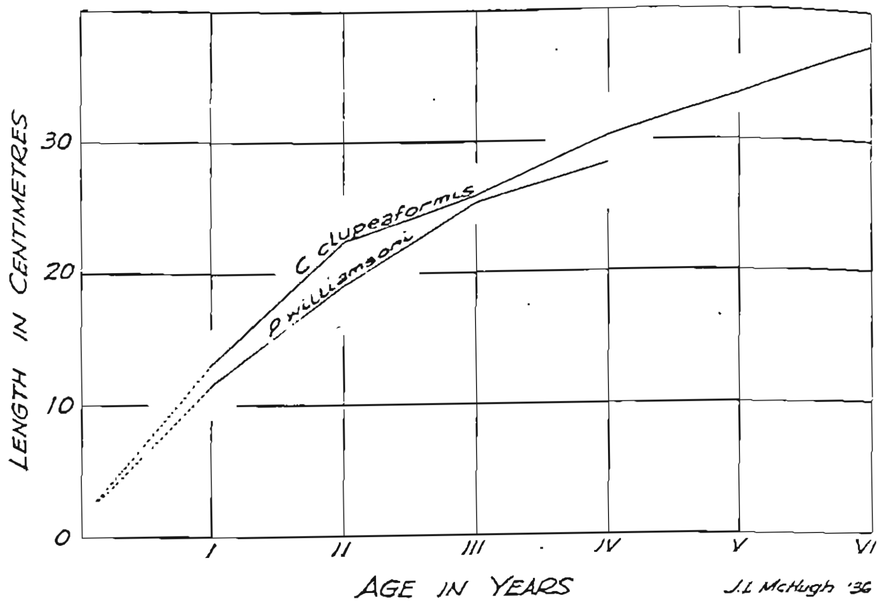


FIGURE 13. Rates of growth of the Eastern and Rocky Mountain whitefishes in Okanagan lake.

TABLE XV. Standard length attained by the various year classes of Rocky Mountain whitefish at the end of each year of life. The figures in brackets represent the length in the year of capture—i.e. only a partial year's growth.

Year class	Age group	Average calculated standard length in mm. attained at the end of year					No. of individuals
		I	II	III	IV	V	
1931	V	113	193	255	282	(294)	1
1932	IV						0
1933	III	114	191	(218)			16
1934	II	119	(166)				16
1935	I	(60)					4
Weighted average		116	191	255	282		

that the average yearly increment in length decreases as the age of the fish increases. The curves for the two species are similar in slope but it can be seen that the eastern species grows more rapidly in its first year and maintains its superiority in length throughout life. It also appears that the Rocky Mountain whitefish has a shorter span of life, although this has not been definitely proved.

Spawning is said to take place in November but no exact information is available.

Variability of Individual Characters

Published morphological records of the Rocky Mountain whitefish indicate a considerable degree of variation in the various meristic characters. Table XVI is a summary of counts made in this investigation. Two of the individuals were taken in Woods lake, and the remainder in Okanagan lake. These results appear to lie within the range covered by the same species in other localities, and thus the Okanagan lake population exhibits no significant differences with respect to the characters examined.

Table XVI. Variability of individual characters of the Rocky Mountain whitefish in Okanagan lake.

	Minimum	Maximum	Most frequent value	No. of individuals
Fin rays				
Dorsal	11	14	12	19
Anal	10	12	11	19
Pectoral	16	19	18	19
Pelvic	10	12	11	18
Scale counts				
In lateral line	75	89	82	19
In row above lateral line	73	89	81	19
Rows above lateral line	9	10	9	19
Rows below lateral line				
—from pelvic	8	9	8	18
—from anal	7	8	8	17
Gill rakers				
Short arm	6	11	9	19
Long arm	11	15	13	19
Total	17	25	22	19
Branchiostegals	7	9	8	19
Vertebrae	56	60	58	19

DEPTH RANGE

All Straumfjord's catches were made in the 3½-inch mesh, and therefore the depths given refer in the main to fish of a certain size range. He gives the average weight of the Eastern whitefish caught in this mesh as one pound. In Okanagan lake during September, October, and November, 1929, all catches were made at depths from 10 to 150 feet (3 to 46 m.). In Dog, Vaseaux, and Osoyoos lakes in November, 1929, the Eastern whitefish were taken from 4 to 40 feet (1 to 12 m.).

Eastern whitefish in Okanagan lake during July and August, 1935, were captured at depths ranging from 20 to 138 feet (6 to 42 m.). A complete series of settings at all depths was made across the lake from Okanagan Mission, the deepest set being greater than 138 feet (42 m.), but at this depth no whitefish were taken.

The depths at which Rocky Mountain whitefish were taken ranged from the shallow waters of Trout and Mission creeks to a depth of 50 feet (15 m.). This last was the greatest depth at which this species was found.

SUMMARY AND CONCLUSION

Two species of whitefish are known to exist in lakes of the Okanagan valley. The Rocky Mountain whitefish, *Prosopium williamsoni*, is the native species, and the Eastern whitefish, *Coregonus clupeaformis*, an introduced species.

Commercial fishing of either of the species is unprofitable.

The food of the Eastern whitefish in Okanagan lake seems to exhibit a considerable seasonal variation. During the period July to August plant material formed the greatest bulk of the stomach contents. Next in order of quantity were small fish, Cladocera and insect material. In September and October insect food predominated, followed by Cladocera and Pelecypoda. The most important food of the Rocky Mountain whitefish for the July-August period was the cladoceran, *Daphnia*, and the remainder consisted of insect material.

The annual increment in the length of each species decreases with increasing age. The Eastern whitefish grow faster than the native whitefish and attain a greater size.

The two species can be distinguished readily from each other by the difference in the number of gill rakers. The Eastern whitefish has consistently a larger number of gill rakers than the Rocky Mountain whitefish. The rays in the pectoral fin and the branchiostegals also differ on the average, but since there is an overlapping of the values in both cases, these characters cannot be used alone to differentiate between the two species.

Both species are found on or near the bottom after the first few months of life. The native whitefish apparently inhabits shallower waters than the Eastern whitefish, although the ranges of the two overlap to some extent.

As far as can be ascertained, the Eastern whitefish spawns in the latter part of December and the Rocky Mountain whitefish in late autumn.

FISH CULTURAL PROBLEMS IN THE OKANAGAN AREA

By W. A. Clemens

OKANAGAN LAKE

Okanagan is a relatively large lake of considerable depth. While its surface waters become quite warm in late summer, its great body of deep water remains at a low temperature throughout the year and the average mean summer temperature for the lake as a whole is low.

The amount of microscopic life (plankton) in the open water is comparatively small as is also the quantity of organisms on the bottom beyond the shoreward area of rooted aquatic vegetation. The production of invertebrate organisms among the areas of vegetation along the shores is fairly abundant but these areas are limited in extent. It has been estimated that of the total shore length only about nine per cent has a rooted aquatic vegetation.

These facts indicate a limited productivity. The low average temperature means relatively slow growth and low rate of reproduction for the aquatic plants and animals, and a slow turnover of organic materials, particularly in the offshore region.

The end result of the productivity of the lake from an economic point of view is fish which are desired for commercial or sport purposes. The quantity of fish produced by a body of water depends largely upon two factors, namely, the food supply and the adequacy of the facilities for reproduction. If the food supply is large and the conditions for spawning and incubation very good, production may be potentially high and a large number of fish may be removed annually. If on the other hand one or both of the above factors operate adversely, production may be on a very low level and various measures may be necessary in order to provide an adequate surplus for the fishery. Each body of water is therefore a problem in which must be determined the productive capacity and the amount of the surplus stock that may be removed by the fishery.

It is evident that in spite of certain limiting factors a considerable number of fish of various species are produced in Okanagan lake. These occur in two more or less distinct groups, namely, an inshore population consisting of the shiners, chub, squawfish, carp, coarse-scaled suckers and sculpins, and an offshore population consisting of the fine-scaled suckers, Rocky Mountain whitefish, Eastern whitefish, kokanee, Kamloops trout and ling.

In the former group all except the squawfish feed chiefly upon small aquatic invertebrates and terrestrial insects while the squawfish is largely a fish eater when adult. In the latter group, the whitefishes are bottom feeders, the kokanee a plankton feeder and the Kamloops trout and ling fish eaters.

Although limited in extent, the shallow areas in which rooted aquatic plants grow appear to be highly productive of fish, but of kinds which are not desired by man. It would seem that a very large amount of the primary food materials is going into the production of fish which are not utilized and there would appear to be little possibility of developing a commercial fishery because of insufficient quantities to provide a sustained yield.

When introductions are considered for the purpose of utilizing the productiveness of the shoreward areas by more desirable species it is apparent that it would be necessary to introduce either a species which fed upon the invertebrates or one which fed upon the coarse fishes. In either case it could not be a commercial fish because the total area available for such production would not sustain a profitable industry any more than will the present population. Among the sport fish there does not appear to be a species which feeds entirely upon aquatic invertebrates. On the other hand there are several species of game fishes which are predaceous upon other fish. An introduction at the present time would be inadvisable because of the lack of knowledge as to the interrelations among fish populations but the matter is of sufficient importance to warrant a very careful investigation.

The question of the reduction in numbers of the coarse fish of the shallow areas and its relation to the production of trout cannot be adequately dealt with at the present time because of lack of experimental or sufficiently extensive observational data. Whether trout would occupy the inshore areas and consume the food materials now taken by the coarse fish, were these largely eliminated, is not known, but it would seem doubtful. While the squawfish takes trout when they are readily available its chief food seems to consist of coarse fish, and as long as these are abundant its feeding activities will not likely seriously menace the trout population. To a great extent the shallow-water association does not involve the trout and would not seem to be a very significant factor in limiting their numbers.

Three species of fish occupy the deeper waters beyond the shoreward areas. These are the Rocky Mountain whitefish, the Eastern whitefish and the fine-scaled sucker. The first two are desirable for commercial exploitation but they do not occur in sufficient numbers to support a profitable fishery. They feed for the most part upon invertebrates living on the bottom of the lake, and since the present investigation has revealed a paucity of bottom organisms it is likely that the food supply is the chief factor limiting their abundance. The total absence of deep water shrimp-like forms such as *Pontoporeia* and *Mysis* may be a significant feature in the food situation, particularly in respect to the Eastern whitefish, since in eastern lakes which support commercial fisheries for this species a large portion of the food consists of these deep water crustaceans. If any further attempt is to be made to develop a commercial fishery for the Eastern whitefish, the possible introduction of *Pontoporeia* and *Mysis* should be considered. They occur in Waterton lake, Alberta, and are said to be present in certain lakes in the state of Washington, and there would seem to be every reason to expect that if introduced into Okanagan lake they would become established. Any such introductions should probably be made in the form of the eggs of these species to avoid the possibility of the introduction of fish parasites.

The fine-scaled sucker is not abundant in the lake at the present time probably because of the limited food supply as in the case of the Eastern whitefish. If the food conditions in the lake were improved it is quite likely that there would be an increase in the numbers of these suckers and it might be necessary to adopt measures to limit their numbers.

Mention has already been made of the importance of kokanee in relation to trout. It has been impossible to form an opinion as to the abundance of this fish in the lake and whether it is far from or near to a maximum population. Undoubtedly the numbers of kokanee are related to the quantity of its food supply, namely, the plankton crustacea which in Okanagan lake are not particularly abundant, although apparently comparable in species and numbers to those of such large lakes as Shuswap. The problem of increasing the plankton production of a large lake has not yet been solved, and at the present time there would appear to be no economical way in which the lake may be fertilized in order to increase the amount of open water plankton and thereby the production of a plankton feeding fish such as the kokanee. If investigation should indicate a meagre population in relation to the food supply, introductions of eggs or fry from other areas would seem to be a reasonable procedure. It is evident that a thorough knowledge of the life-history of the kokanee is essential to a well-rounded fish cultural programme in relation to trout.

The fish most desired in Okanagan lake is the Kamloops trout, because it is an excellent sport fish and is an economic asset to the extent that it attracts non-local fishermen. The difficulty of developing at the present time an exact cultural policy for the trout of Okanagan lake lies in the fact that certain necessary basic data are not yet available. The present stock in the lake, the number of young produced naturally each year, and the number of fish caught annually are unknown. In view of this lack of fundamental information the situation can be dealt with only in very general terms.

Reference may be made to conditions in Paul lake which has an area of approximately 1,000 acres. During the past five years, production has been maintained by the planting annually of 200,000 fry, natural propagation under the present programme being practically negligible. There is now an annual production of 10,000 fish taken by anglers and a spawning run of approximately 2,500 fish in Paul creek. Were conditions exactly similar in Okanagan lake there would be an angler's catch of 900,000 fish and a spawning population of 225,000 on the basis of lake area. However, conditions are not similar and Okanagan lake can not be expected to produce trout on the same scale as Paul lake, largely because the production of basic food materials such as plankton and bottom organisms is one-third to one-fourth that of Paul lake in quantity.

On the basis of a liberation of 200 fry per acre, Okanagan lake would require 18,000,000 fry. However, the food supply may be considered as only a third that of Paul lake so that an annual production of 66 fry per acre or a total of 6,000,000 should approximate the carrying capacity of Okanagan lake. There is a possibility of natural propagation, in certain years at least, supplying a portion of this amount, but at best it cannot be great with perhaps 60 per cent of the tributary streams being utilized more or less completely for irrigation purposes. If natural propagation is contributing 40 per cent of the requirement, then there should be annual introduction of 40 fry per acre, that is, a total of 3,500,000 or the equivalent. No account is taken of predators or the presence of kokanees as a food supply. There is no way in which the influence of these factors in the situation may be calculated and for present purposes they may be considered as neutralizing each other.

In 1935 the Department distributed 234,379 fry in the lake. In addition the Kelowna Rod and Gun Club has been rearing the product of 250,000 eggs in its large natural retaining ponds and liberating the fish as yearlings. No artificial feeding is necessary in these ponds and the cost of production is very small. Since it is estimated that there is a mortality approaching ninety per cent among the young fish during the first year of life in natural bodies of water, the yearlings liberated from the Kelowna ponds may be considered as equivalent to 2,000,000 fry.

If therefore the guesses made above are at all valid, the present stocking policy is approaching the lake's requirement. If the Kelowna ponds could liberate 250,000 to 300,000 yearlings annually and the Summerland hatchery distribute 500,000 to 1,000,000 fry annually, there would seem to be reason to believe that there would be an approach to the productive capacity of trout in the lake under its present conditions and that the trout fishing would be maintained at a reasonably high level.

In summary the situation in regard to the production of fish in Okanagan lake would seem to be as follows. There is a large area of relatively low productivity in the centre of the lake which is occupied by economically valuable species such as the Kamloops trout, kokanee and the whitefishes. There is a smaller area of relatively high productivity around the margin of the lake which is occupied by a number of species of no value economically at the present time. With respect to the Kamloops trout a tentative fish cultural programme has been outlined, designed to meet the existing conditions. Information concerning the kokanee is so meagre that no policy can be presented. The obvious importance of this species to trout production has been pointed out and it is possible that investigation may reveal that the kokanee production may be so managed as to provide a limited supply for human use as well as a food supply for the trout. As for the whitefishes, it seems evident that lack of food supply limits their production. If efforts to remedy the food condition were undertaken and proved successful, there might result a commercial fishery limited in extent by reason of the small size of the lake.

The utilization of the productive capacity of the marginal area of the lake presents quite a different problem. As indicated previously, it would seem that the introduction of a game fish which would feed upon the coarse fish and not destroy the trout would be the proper procedure. Three species suggest themselves, namely, the large-mouthed black bass, the small-mouthed black bass and the maskinonge. The first is now in Osoyoos lake and there is considerable likelihood of it eventually making its way into Okanagan lake. If it does so, there would seem to be no cause for undue alarm provided its numbers are kept within limits by angling and so not allowed to increase to such an extent as to eliminate the food supply in the form of coarse fish. It might be advisable to withhold any restrictive fishing regulations and thereby have a factor tending to restrict the numbers. In the meantime it would seem most desirable to study thoroughly the conditions now existing in Kootenay, Christina and Osoyoos lakes where black bass have become established. Furthermore, the early life history of the Kamloops trout should be studied to see whether the young get into deep water early enough to escape an active predator. Consideration of the environmental conditions in the lake might indicate that an introduction of the small-mouthed black bass would be preferable to that of the large-mouthed species. The maskinonge has a good reputation as a game fish and reaches a size large enough to eat the large coarse fish of the lake.

The first step in the study of Okanagan lake from the point of view of fish production has been a general survey from which certain facts have been recorded, and an attempt has been made to present a picture of the fish cultural problem. The next step should be a series of specific investigations along the lines indicated in this report.

KALAMALKA LAKE

Conditions in Kalamalka lake are essentially similar to those in Okanagan lake and the problems in respect to fish production much the same. Coldstream creek appears to be the tributary which is used chiefly by the trout for spawning purposes, although Oyama creek is used to some extent. From statements made by anglers it appears that this stream is subject to the same deficiencies in respect to trout production as Okanagan lake tributaries. The obvious fish cultural policy for meeting the deficiency in natural production would seem to be the establishment of an egg-collecting station on Coldstream creek, the transfer of the eggs to a hatchery somewhere in the area and the liberation of the fry throughout the lake. Under this policy, in which there would be no allowance for natural reproduction, an annual planting of approximately 500,000 fry or 50,000 yearlings would be required on the same basis of limited productivity as in the case of Okanagan lake.

WOODS LAKE

The conditions prevailing in Woods lake during the summer of 1935 were definitely unsuitable for trout production. The very low oxygen content of the deeper waters, the high surface temperatures and the enormous production of algae constitute an environment in which it would seem impossible for trout to maintain an existence. In addition there are no tributary streams suitable for spawning purposes. The stocking of Woods lake with trout would seem inadvisable under present conditions. The lake contains a very large population of carp, chub, shiners, squawfish and suckers, all of which are able to live in the warm shallow water. In addition the Rocky Mountain whitefish is present in some numbers. In some summers it suffers rather heavy mortalities, presumably as a result of conditions of high temperature and lack of oxygen, or of the development of toxic substances arising from the decomposition of the excessive quantities of algae.

Information has recently come to hand that kokanee have become plentiful and are providing a considerable amount of sport fishing. Individuals between two and three pounds have been taken.

If black bass should appear in Okanagan lake the species might be introduced into Woods lake where it might become successfully established by reason of the abundance of a food supply in the form of minnows and suckers.

The discovery of the causes of excessive algal growths and the development of control measures would seem to be the first essential in any sound fish cultural policy for Woods lake.

DUCK LAKE

This is a shallow body of water, with high temperatures and an excessive production of algae, and it is entirely unsuitable for trout. No constructive recommendations are offered at the present time.

BEAVER LAKE

Beaver lake, as well as the smaller connecting lakes A, B, C and D, was originally barren of fish and was first stocked with Kamloops trout in 1926 with 5,000 eggs from Lloyds creek hatchery at Paul lake. In 1927, 20,000 eggs and in 1928, 10,000 fry were transferred from the same source. Subsequent introductions were as follows: 1931, 3,000 Kamloops trout fry from Fish lake; 1933, 125,000 Kamloops trout fry from Penask lake. As has been the case in other parts of the province, the fish increased very rapidly in numbers by reason of the abundant food supply and the absence of competitors and predators. At the present time there is some indication that the lake is over-populated from an angling point of view in that the average size of the fish caught has been steadily declining. Many of the anglers are of the opinion that the numbers of freshwater shrimps and caddis larvae have decreased.

The time available for study of the lake was too brief to determine the exact condition of affairs, but if it is a case of too many trout the situation can be improved by removing large numbers of eggs for stocking Okanagan and other lakes each year and by taking out more fish by angling. The extent of natural spawning should be determined and then an attempt made to calculate the number of eggs which may be removed, leaving approximately 200 fry per acre. These figures are based on the data obtained at Paul lake, where a distribution of 175 to 200 fry per acre with practically no natural production serves to maintain an excellent fishery. By observation and experiment the annual liberation of fry must be adjusted to the productive capacity of the lake in the matter of food supply for the trout.

CHUTE LAKE

From the data obtained on a single examination, Chute lake would appear to be much less productive than Beaver lake. This lake was originally barren of fish and was stocked as follows: In 1917, 20,000 cutthroat trout fry; 1918, 30,000 cutthroat trout fry; 1919, 7,000 cutthroat trout fry and 15,000 Atlantic salmon fry; 1924, 5,000 Kamloops trout eyed eggs; 1928, 10,000 Kamloops trout eyed eggs. Plantings with Kamloops trout eggs were continued until 1935 with the exception of 1933. Only the Kamloops trout has apparently become established, and it seems likely that the natural reproduction will maintain the stock to the carrying capacity of the lake in spite of the passage of some trout into the outlet stream.

APPENDIX

TABLE XVII. Organisms collected by plankton net in Okanagan lake, 1935.

ALGAE

Identified by Professor C. W. Lowe, University of Manitoba.

MYXOPHYCEAE	
Anabaena flos-aquae (Lyng.) Bréb.	Very common.
Anabaena planktonica Brunn.	
Anabaena spiroides var. crassa Lemm.	
Aphanizomenon dispersus var. minor G. M. Smith	Common.
Chroococcus limneticus Lemm.	Common.
Chroococcus minutus (Kütz.) Näg.	
Chroococcus turgidus (Kütz.) Näg.	Rare.
Coelosphaerium Kutzingianum Näg.	
BACILLARIEAE	
Amphiprora ornata Bail.	
Amphora ovalis Kütz.	
Asterionella formosa Hass.	Abundant.
Campylodiscus hibernicus Ehr.	
Cyclotella compta (Ehr.) Kütz.	Common.
Cymatopleura elliptica var. hibernica W. Smith	
Cymbella cuspidata Kütz.	
Cymbella cymbiformis Kütz.	
Epithemia turgida Ehr.	
Epithemia zebra Ehr.	Rare.
Fragilaria capucina Desm.	
Fragilaria crotonensis Kitt.	Abundant.
Gomphonema geminatum Lyng.	Rare.
Gyrosigma attenuatum Kütz.	
Melosira granulata Ehr.	Abundant.
Melosira undulata (Ehr.) Kütz.	
Navicula gastrum Ehr.	
Navicula legumen Ehr.	Rare.
Navicula pusila W. Smith	Rare.
Navicula sculpta Ehr.	Rare.
Navicula Semen Ehr.	Rare.
Navicula Smithii Bréb.	Rare.
Navicula viridis Ehr.	
Nitzschia linearis (Ag.) W. Smith	Rare.
Rhapalodia gibba Ehr.	Rare.
Stauroneis anceps Ehr.	Rare.
Stephanodiscus niagarae Ehr.	Abundant.
Surirella biseriata Bréb.	

TABLE XVII—*Continued*

Surirella elegans Ehr.	
Surirella splendida (Ehr.) Kütz.	Rare.
Surirella spiralis Kütz.	
Synedra Ulna Ehr.	
Tabellaria fenestrata Kütz.	Abundant.
Tabellaria flocculosa Kütz.	
HETEROKONTAE	
Botryococcus Braunii Kütz.	Abundant
CHLOROPHYCEAE	
Closterium setaceum Ehr.	Rare.
Cosmarium bioculatum Bréb.	
Cosmarium depressum (Näg.) Lund.	
Cosmarium humile (Gay) Nordst.	Rare.
Crucigenia quadrata Morren	Rare.
Dictyosphaerium pulchellum Wood	Abundant.
Golenkinia radiata Chodat	
Gloeocystis gigas (Kütz.) Lagerh.	
Gonium pectorale O. Müller	Rare.
Mougeotia sp.	Fragments.
Oedogonium sp.	Fragments.
Oocystis parva W. & G. West	Common.
Pediastrum Boryanum (Turp.) Menegh.	Rare.
Sphaerocystis Schroeteri Chodat	Rare.
Spirogyra sp.	Fragments.
Spondylosium planum (Wolle) G. S. West	Rare.
Staurastrum dejectum Bréb.	Rare.
Staurastrum gracile Ralfs	Abundant.
Staurastrum paradoxum var. longipes Nordst.	

PROTOZOA

Ceratium hirundinella O. F. Müller	Abundant.
Dinobryon divergens Imhof	Abundant.
Dinobryon stipitatum Stein	Common.
Peridinium sp.	Rare.

ROTATORIA

Identified by Dr. F. J. Myers, American Museum of Natural History.

Conochilus unicornis Rouss.	Sometimes numerous surface tows.
Collotheca mutabilis (Hudson)	Depths of 50 to 100 metres.
Gastropus stylifer Imhof	Rare in surface tows.
Notholca longispina (Kellicott)	Most abundant.
Ploesoma truncatum (Lev.)	Common surface tows especially late August.
Ploesoma hudsoni (Imhof)	Rare in surface tows.
Synchaeta sp. probably oblonga Ehr.	Common 50 to 100 metres.

TABLE XVII—*Continued*

CLADOCERA AND COPEPODA

Identified by Dr. G. C. Carl, Pacific Biological Station

Sida crystallina (Müller)	Rare.
Diaphanosoma brachyurum Lieven	Common surface tows short period late July.
Holopedium gibberum Zaddach	Rare.
Daphnia longispina (Müller)	Most constant of the Cladocera and present at all depths.
Scapholeberis mucronata (Müller)	Common single surface tow on August 6 and rare in others.
Bosmina longispina Leydig	Second to Daphnia in abundance and like it, present in deep water.
Eurycercus lamellatus Müller	Not taken in the net samples but frequently found in dredgings.
Leptodora kindtii (Focke)	Rare in nets but fairly common in fish stomachs.
Alona affinis (Leydig)	This and the two following species not taken in nets but found in the stomach contents of the coarse-scaled sucker and carp.
Acroperus harpae (Baird)	
Chydorus sphaericus (Müller)	
Epischura nevadensis Lillj.	Common but never abundant.
Diaptomus ashlandi Marsh	Abundant or common in every haul and present at all depths. Adults were found in the stomachs of common suckers.
Cyclops bicuspidatus Claus	Common at all times and in all depths.

TABLE XVIII. Organisms collected by dredge in Okanagan lake, 1935.

HIRUDINEA

Identified by Dr. J. P. Moore, University of Pennsylvania.

Helobdella stagnalis (Linn.)	Several collections.
Placobdella montifera Moore	Two collections.
Piscicola punctata Verrill	From squawfish and minnows.
Erpobdella punctata (Leidy)	From stomach of garter snake near the lake.

CRUSTACEA

AMPHIPODA	
Gammarus limnaeus Smith	Present in small numbers at depths of less than 1 metre.
Hyalella azteca Saussure	Common down to 10 metres and a few specimens as deep as 15 metres. Most abundant among Chara and other rooted vegetation.
DECAPODA	
Potamobius klamathensis Stimpson	A few specimens at Okanagan Mission and Chute creek.

Table XVIII—*Continued*

INSECTA

EPHEMEROPTERA

Identified by Dr. F. P. Ide, University of Toronto.

Hexagenia limbata Guerin	One adult male at Summerland August 1 and numerous nymphs from depths of 2 to 30 metres.
Ephemera simulans Walker	One adult female at Okanagan Mission, July 17, and nymphs from shore to depths of 20 metres.
Leptophlebia debilis Walker	A single nymph at shoreline.
Leptophlebia sp. (near bicornuta McDunnough)	Several nymphs at shore and to depths of 1 metre.
Choroterpes sp.	Many nymphs, possibly of two species in shallow water.
Caenis sp.	Common down to depths of 25 metres.
Trichorythodes spp.	One species common in shallow water and a second rare near shore.
Callibaetis sp.	One adult female, Okanagan Mission, July 17.
Centroptilum sp.	Rare at various depths.
Stenonema sp. (rubromaculatum group)	Rare along shore.
Heptagenia sp.	A single nymph at depth of less than 1 metre.

ODONATA

Identified by Dr. E. M. Walker, University of Toronto

Enallagma cyathigerum Charp.	Many adults and nymphs, July 2 to August 12
Enallagma boreale Selys	Adult, August 12.
Gomphus graslinellus Walsh	Full grown nymph, July 2.

PLECOPTERA

Acroneuria pacifica Banks	A single adult taken near the mouth of Mission creek was identified as this species by Prof. F. Neave, University of Manitoba.

TRICHOPTERA

Identified by Miss J. Fraser, University of Toronto.

Ithytrichia sp.	Larvae common near shore.
Hydroptila sp.	Larvae common along shore and to depth of 10 metres. One live specimen from 22 metres.
Polycentropus sp.	Larvae at depths of less than 10 metres.
Oecetis avara Banks	Adults common from July 17 to August 29.
Oecetis incerta Walker	Adults at Okanagan landing, July 17.
Oecetis spp.	Larvae of four species at depths of 0 to 11 metres.
Mystacides spp.	Larvae and pupae of three species in shallow water.
Phryganea cinerea Walker	Adult on August 5.
Limnephilus sp.	Larvae from shallow water.
Colpotaulus sp.	Adults in July and August.

TABLE XVIII—*Continued*

HEMIPTERA	
Notonecta sp.	Common in shallow protected bays.
Corixa sp.	Common along shores.
Gerris sp.	Adult and nymphal individuals from several shore locations.
DIPTERA	

Identified by Dr. J. G. Rempel, Regina College.

Chironomus plumosus L.	Few specimens at 0 to 20 metres depth.
" sp. (near hyperboreus)	Common at 0 to 15 metres depth.
" sp. (like hyperboreus but lacking ventral blood gills)	Common at all depths down to 85 metres.
Endochironomus sp.	Common from shore to 20 metres—rare 20 to 60 metres.
Cryptochironomus sp. a.	Abundant from shore to 20 metres.
" sp. b.	Common from shore to 10 metres.
" sp. c.	Few from shore to 10 metres.
Limnochironomus sp.	Rare and found only along shore, depths 0 to 3 metres.
Allochironomus sp.	Common from shore to 25 metres.
Prochironomus sp.	Common 0 to 10 metres.
Glyptotendipes sp.	Few from shore to 7 metres.
Paratendipes sp.	Common at shore and rare to 40 and 90 metres.
Microtendipes sp.	Rare from shore to 10 metres.
Pentapedilum sp.	In one collection only at depth of 0.5 metres.
Polypedilum sp.	Abundant to 10 metres—rare to 35 metres.
Orthocladiinae sp. a.	Abundant at all depths.
" sp. b.	Common at all depths and abundant from 50 to 90 metres.
" sp. c.	Common from shore to 50 metres.
" sp. d.	Rare, 0 to 10 metres.
" sp. e.	Rare, 0 to 5 metres.
" sp. f.	Rare from shore to 25 metres.
Tanypodinae	Abundant at all depths to 85 metres.
Tanytarsus (gregarius group)	Common from shore to 10 metres.
" (attersee group)	Few from shore to 10 metres.
" (lauterborni group)	Very rare, at shore only.
Tanypus sp.	Few at depths of less than 0.5 metres.
Simulium sp.	Larvae were taken in Mission creek.
Leptidae	Larvae in shallow water dredgings on three occasions.
Tipulidae	Larvae collected near shore and common in fish stomachs.
COLEOPTERA	
Hydroporus sp.	A few larvae in a single dredg~~ing,~~ larvae of an hydrophilid form occurred near shore among scattered vegetation.

TABLE XVIII—*Continued*

HYDRACARINA

Identified by Dr. Ruth Marshall, Rockford, Illinois.

Piona rotunda (Kram.)	One female in shallow water.
Hygrobates longipalpis (Herm.)	Numerous from water's edge to depth of 3 metres.

MOLLUSCA

GASTROPODA

Identified by Dr. E. G. Berry, University of Michigan, with the exception of the genus Physa which was determined by Dr. W. J. Clench, Harvard College, Cambridge, Mass.

Lymnaea caperata Say	Common in the shore areas.
Lymnaea modicella rustica (Lea)	A few individuals of this species collected in depths of less than 5 metres.
Gyraulus parvus (Say)	Most common of the Planorbidae.
Menetus exacuus (Say)	Several specimens at depths to 5 metres.
Physa sp.	Probably a new species but resembling P. johnsoni Clench in some respects; most common of all the gastropods and widely distributed around the lake in exposed rocky regions and in protected bays.
Physa propinqua Tryon	A single specimen.

PELECYPODA

Identified by Dr. S. T. Brooks, Carnegie Museum, Pittsburg.

Anodonta oregonensis Lea	Common on sandy bottom in various parts of the lake; young specimens taken in the dredge at 8 and 9 metres.
Anodonta beringiana Midd.	Less common than the former species.
Pisidium compressum Prime	Small numbers taken in many parts of the lake and in depths ranging from 2.5 to 74 metres.

Table XIX. Record of dredgings in Okanagan lake, 1935.

Dredging Series & Number	Depth Metres	Type of Bottom	Chironomid larvae	Oligochaete worms	Mayfly nymphs	Amphipoda	Caddis larvae	Sphaeriidae	Gastropoda	Miscellaneous	All organisms	Wet weight gm. less mollusc.shell
S I D1	2.5	sand	36	1	1					1	39	.029
2	9.5	sand, chara	17		1	10	1				29	.071
3	15.	clay ooze	10								10	.037
4	19.5	clay	1	1							2	.004
5	48.	clay ooze	21	8				1			30	.037
6	74.	soft ooze	12	2				3			17	.024
7	32.	soft ooze	11	2							13	.030
8	11.	sand, chara	47		7	19	3	1		10	87	.135
9	5.	bare sand	24								24	.008
S II 1	1.	sand	36	4							40	.053
2	2.	sand	6								6	.014
3	19.	mud	32	7							39	.102
4	40.	clay ooze	35	40				3			78	.179
5	57.	clay ooze	12	30							42	.123
S III 1	6.	sand	18	4	5						27	.046
2	6.5	sand	12		1					1	14	.021
3	9.0	mud, chara	25		3	6					34	.073
4	9.5	mud debris	28		4	2	1		1		36	.100
5	10.5	muddy	14	2							16	.152
6	12.5	mud	10								10	.024
S IV 1	2.	sand	45								45	.006
2	2.5	sand, veget.	19	3	1	5	4	3	1	1	37	.114
3	22.	clay ooze	21	2							23	.041
4	33.	ooze	19	3							22	.066
5	44.	ooze	11								11	.012
6	7.0	soft ooze	15	4							19	.040
S V 1	3.	sand	13								13	.030
2	3.5	sand, chara	52	3		2	1				58	.061
3	6.0	clay, chara	12	4	2		1		2		21	.186
4	9.5	clay, chara	33	2	3	12	1				51	.147
5	17.	soft ooze	16								16	.028
6	18.	sand, pebble	9								9	.016
7	25.	mud, crust	9							1	10	.014
8	58	mud	38						1	2	41	.083
9	113.	mud	14								14	.032
S VI 1	2.	mud, debris	19								19	.037
2	5.5	mud, veget.	29	2							31	.173
3	12.5	mud	13	1							14	.132
4	35.	mud	12	16							28	.193

TABLE XIX—*Continued*

Dredging Series & Number	Depth Metres	Type of Bottom	Chironomid larvae	Oligochaete worms	Mayfly nymphs	Amphipods	Caddis larvae	Sphaeriidae	Gastropoda	Miscellaneous	All organisms	Wet weight gm. less mollusc. shell
SVII D1	7.	mud, debris	19		4						23	.289
2	20.	mud	32	3						2	37	.361
3	16.	mud	11	13							24	.098
SVIII 1	2.	clayey mud	1	3							4	.021
2	5.5	mud	80	6							86	.598
3	8.5	mud	47	7							54	.372
4	13.	mud	25	4	1						30	.406
5	19.	mud	24								24	.093
6	25.	mud	27	4							31	.090
S IX 1	1.5	sand										.000
2	3	silt, veget.	6		3	1	1	1		1	13	.042
3	1.5	gravel, clay	3							1	4	.000
4	16.	pebbles, mud	5				3				8	.034
5	56.	mud, debris	14	7							21	.071
6	90.	stiff clay	9	20							29	.071
8	69.	stiff clay	26	2							28	.039
9	40.	stiff clay	27	2							29	.059
10	22.	mud	10								10	.017
11	11.	mud, debris	57	3	6						66	.166
S X 1	1.	black silt	3	1							4	.008
2	3.	sand, veget.	10	1		2					13	.035
3	5.	sand	15	2		4					21	.098
4	9.	chara, mud	15	3		5					23	.060
5	10.	chara	8								8	.015
6	60.	clay	4	1							5	.016
S XI 1	1.	mud, chara	2	1							3	.009
2	5.5	mud, debris	4	1	1						6	.077
3	8.5	mud, debris	10		1			1		1	13	.070
4	59.	clay, mud	14								14	.033
SXII 1	2.	sand, chara	10								10	.011
2	4.5	sand, chara	19	2	1						22	.017
3	9.	grey clay	3	2						1	6	.048
4	53.	mud	11								11	.044
5	67.	mud	15	2							17	.046
6	67.	mud, crust	9	1							10	.017
7	32.	soft ooze	22	2							24	.138
8	3.	ooze, veget.	2	5			2				9	.032
9	2.	sand, chara	13	4							17	.020

TABLE XIX—*Continued*

Dredging Series & Number	Depth Metres	Type of Bottom	Chironomid larvae	Oligochaete worms	Mayfly nymphs	Amphipods	Caddis larvae	Sphaeriidae	Gastropoda	Miscellaneous	All organisms	Wet weight gm. less mollusc.shell
SXIII D1	2.	sand	1								1	.000
2	3.	sand, stones	1				1				2	.000
3	9.	grey clay	34	1	1		1				37	.053
4	15.	grey clay	4		1		1				6	.036
5	54.	grey mud	25								25	.029
6	85.	grey clay	21	2							23	.071
7	72.	mud, crust	17	1							18	.024
8	42.	grey clay	23	1							24	.049
9	26.	clay	18	3	1						22	.068
10	2.5	sand, veget.	1	1	3	2	3				10	.051
S XIV 1	10.	sand, chara	6	2		2					10	.024
2	20.	stones	1	1							2	.000
3	44.	sand		2							2	.002
4	77.	clay, debris	3	4							7	.027
5	46.	clay	8								4	.008
6	27.	sand	8	2							10	.010
7	20.	sand		3	1						4	.007
S XV 1	3.	sand	1								1	.000
2	9.	sand, chara	9				2				11	.013
3	22.	sand, clay	13								13	.015
4	34.	stiff clay	23								23	.058
5	54.	clay	16	3							19	.052
6	58.	clay	6	2							8	.019
7	41.	clay	4	1							5	.012
8	23.	red sand	4								4	.002
9	14.	coarse sand	2	1							3	.006
S XVI 1	5.	sand, gravel	6	1							7	.001
2	20.	stone	4								4	.019
3	28.	sand										.000
4	81	clay										.000
5	60	clay	3								3	.003
6	36	sand, gravel	3								3	.005
7	5.5	gravel	12						1		13	.005
SXVII 1	4	sand, chara	8	6	2						16	.090
2	5	sand, chara	22		1						23	.072
3	14	clay, shells	7								7	.009
4	22	sand, gravel									14	.050
5	55	clay									14	.007

TABLE XX. Plankton and bottom organisms collected in Kalamalka, Woods, Duck, Beaver and Chute lakes, 1935.

Identifications were made by the authorities whose aid has been previously acknowledged

ALGAE

MYXOPHYCEAE	
Anabaena flos-aquae (Lyng.) Bréb.	In all of the five small lakes examined.
Anabaena planktonica Brunn	In Beaver lake.
Anabaena spiroides var. crassa Lemm.	Common in all five lakes.
Aphanizomenon flos-aquae (L.) Ralfs	In Beaver, Kalamalka, Woods and Duck lakes.
Aphanocapsa delicatissima W. & G. West	Chute lake.
Aphanocapsa Grevillei (Hass.) Raben.	Chute lake.
Chroococcus limneticus Lemm.	Beaver and Chute lakes.
Chroococcus minutus (Kütz.) Näg.	Chute lake.
Coelosphaerium Kutzingianum Näg.	Beaver and Chute lakes.
Gloeotrichia echinulata (J. E. Smith) Richter.	Beaver and Kalamalka lakes.
Microcystis aeruginosa (Kütz.) G. S. West	Beaver and Duck lakes.
BACILLARIEAE	
Amphora ovalis Kütz.	Chute lake.
Asterionella formosa Hass.	Beaver, Kalamalka and Chute lakes.
Epithemia Argus Ehr.	Kalamalka lake.
Epithemia turgida Ehr.	Beaver lake.
Eunotia lunaris Ehr.	Kalamalka lake.
Fragilaria crotonensis Kitt.	Kalamalka lake.
Gomphonema geminatum Lyng.	Kalamalka lake.
Gyrosigma attenuatum Kütz.	Kalamalka lake.
Melosira granulata Ehr.	Beaver, Kalamalka, Duck and Chute lakes.
Stephanodiscus niagarae Ehr.	In all five lakes.
Tabellaria fenestrata Kütz.	Beaver lake.
Tabellaria fenestrata var. asterionelloides Grun.	Chute lake.
Tabellaria flocculosa Kütz.	Beaver lake.
HETEROKONTAE	
Botryococcus Braunii Kütz.	Beaver, Kalamalka and Chute lakes.
CHLOROPHYCEAE	
Arthrodesmus Incus (Bréb.) Hass.	Chute lake.
Asterococcus limneticus G. M. Smith	Chute lake.
Cosmarium depressum (Näg.) Lund	Chute lake.
Dictyosphaerium pulchellum Wood	Beaver and Chute lakes.
Eudorina elegans Ehr.	Beaver, Kalamalka, Duck and Chute lakes.
Gloeocystis gigas (Kütz.) Lagerh.	Chute lake.
Oocystis Borgei Snow	Chute lake.
Pandorina morum Bory	Beaver lake.
Pediastrum duplex var. clathratum (A. Br.) Lagerh.	Duck lake.
Quadrigula Pfitzeri (Schrod.) G. M. Smith	Chute lake.
Selenastrum gracile Reinsch	Chute lake.
Spirogyra sp.	Fragments in Kalamalka lake.
Staurastrum Dickiei Ralfs	Chute lake.
Staurastrum paradoxum Meyen	Kalamalka and Chute lakes.

TABLE XX—*Continued*

Staurastrum paradoxum var. longipes Nordst.	Chute lake.
Volvox sp.	Lakes above Beaver.
Xanthidium fasciculatum Ehr.	Chute lake.
Zygnema sp.	Fragments in Beaver lake.

PROTOZOA

Dinobryon divergens Imhof	Kalamalka and Chute lakes.
Ceratium hirundinella O. F. Müller	In all five lakes.

ROTATORIA

Asplanchna priodonta Gosse	Rare in Duck lake.
Conochilus unicornis Rouss.	Abundant in Beaver lake and lakes above it.
Euchlanis dilatata Ehr.	Common in Beaver, rare in Woods lake.
Filinia longiseta (Ehr.)	In Woods and Duck lakes.
Keratella cochlearis Gosse	Rare in Beaver. Frequent in Chute lake.
Keratella cochlearis, new variety	Abundant in Chute lake, frequent in Beaver and lakes above it.
Keratella cochlearis recurvispina Jäger.	Rare in lakes above Beaver.
Keratella quadrata (Müller)	Rare in Woods lake.
Notholca longispina (Kell.)	Common in Beaver and lakes above it, also in Chute and Kalamalka lakes.
Ploesoma hudsoni (Imhof)	Rare in Beaver lake.
Polyarthra trigla Ehr.	Frequent in Chute and Kalamalka lakes.
Trichocerca cylindrica (Imhof)	Abundant in Beaver and frequent in Duck lake.
Trichocerca pusilla (Jennings)	Rare in Beaver lake.
Trichocerca multicrinis (Kell.)	Rare in Duck lake.
Trichotria pocillum (Müller)	Rare in Woods lake.

COELENTERATA

Hydra sp.	Numerous individuals of bright red colour at Beaver lake outlet.

BRYOZOA

Cristatella mucedo var. idae Leidy	From Beaver lake outlet and Woods lake
Plumatella sp.	Statoblasts in Beaver lake.

HIRUDINEA

Identified by Dr. J. P. Moore, University of Pennsylvania.

Glossiphonia complanata (Linn.)	Lakes above Beaver lake.
Helobdella stagnalis (Linn.)	Kalamalka lake.
Placobdella montifera Moore	Pool near Woods lake.
Piscicola punctata Verrill	From squawfish, Kalamalka lake.
Haemopis marmoratis (Say)	Lakes above Beaver lake.
Erpobdella punctata Leidy	Beaver creek and Beaver lake.
Nephelopsis obscura Verrill	Lakes above Beaver lake.

TABLE XX—*Continued*

CRUSTACEA

COPEPODA	
Diaptomus ashlandi Marsh	Abundant in Beaver lake.
Diaptomus tyrelli Poppe	Abundant in Chute lake.
Diaptomus arcticus Marsh	Common in Beaver, few in Chute lake.
Diaptomus sp.	In Woods and Duck lakes.
Cyclops bicuspidatus Claus	Common in Kalamalka.
Cyclops sp.	In Duck lake.
Epischura nevadensis Lillj.	In Kalamalka lake.
CLADOCERA	
Diaphanosoma brachyurum (Lieven)	Frequent in Chute and present in Duck lake.
Holopedium gibberum Zaddach	Rare in Beaver lake.
Daphnia longispina (Müller)	Common in Beaver and Chute lakes, present in Duck, Woods and Kalamalka.
Daphnia pulex (de Geer)	Common in the lakes above Beaver lake.
Ceriodaphnia lacustris Birge	Rare in Woods lake.
Bosmina longirostris O. F. Müller	Frequent in Kalamalka lake.
Polyphemus pediculus (L.)	In Chute lake.
Scapholeberis mucronata (Müller)	Frequent in Kalamalka lake.
AMPHIPODA	
Gammarus limnaeus Smith	Collected in small numbers at Beaver lake.
Hyalella azteca Saussure	Common in Beaver lake.

INSECTA

EPHEMEROPTERA	
Hexagenia limbata Walker	From Kalamalka lake 3 metres depth.
Blasturus cupidus Say	Nymphs and an adult from lakes above Beaver, July 12.
Ephemerella tibialis McD.	Nymphs from outlet of Beaver lake.
Caenis sp.	From shallow water in Kalamalka lake.
Baetis sp. (vagans group)	Outlet of Beaver lake.
Callibaetis sp.	Several adults, male and female, from Beaver and the lakes above it, July 11 and 12.
Trichorythodes sp.	Many nymphs from Kalamalka lake, apparently of a new species.
Siphlonurus sp. (near S. inflatus)	Nymph from outlet near Beaver lake.
PLECOPTERA	
Acroneuria pacifica Banks	Adults at outlet creek Beaver lake.
Nemoura sp.	One nymph from Beaver lake.
ODONATA	
Enallagma boreale Selys	Very numerous at Beaver lake, July 12.
TRICHOPTERA	
Polycentropus sp.	Larvae from Kalamalka lake.
Oecetis sp.	Larvae from Beaver lake.
Mystacides sp.	Larvae from Beaver lake.
Limnephilus spp.	Larvae from Kalamalka, Beaver and the lakes above Beaver.
Hesperophylax designata (Walker)	Adult from lake above Beaver.

TABLE XX—*Continued*

Only l[illegible] have been examined and the determinations are therefore limited to genera in most cases.

Chironomus plumosus L.	Common in Woods lake, a few in Beaver and rare in Kalamalka.
Chironomus sp. (near hyperboreus)	Common in Woods lake, rare in Kalamalka.
Chironomus sp.	Abundant in Woods lake, few in Beaver, rare in Kalamalka.
Endochironomus sp.	Abundant in deeper water of Kalamalka and Beaver lakes, rare in Woods.
Glyptotendipes sp.	Rare in Beaver and Woods lakes.
Polypedilum sp.	One specimen from Woods lake.
Orthocladiinae sp. (a)	As seen in Okanagan lake. In small numbers but widely distributed in Kalamalka and Beaver lakes.
Tanytarsus (gregarius group)	Few in Beaver and Woods lakes.
Tanytarsus (attersee group)	Rare in Woods lake.
Tanytarsus (lauterborni group)	Near shore in Kalamalka lake.
Tanypus sp.	Common at intermediate depths in Kalamalka, Beaver and Woods lakes.
Corethra (Chaoborus) sp.	A few larvae in Duck lake only.

MOLLUSCA

Menetus exacuous (Say)	Common at Beaver lake.
Gyraulus parvus Prime	Kalamalka lake.
Pisidium compressum Prime	Common in Beaver lake.
Pisidium sp. near pugetense	Common in Beaver lake.
Anodonta oregonensis Lea	Kalamalka lake.
Anodonta beringiana Midd.	Woods lake.