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A CONTRIBUTION TO THE LIMNOLOGY OF SHUSWAP LAKE, BRITISH COLUMBIA.

BY

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During two weeks in July in each of the years 1931 and 1932 the writers conducted courses of instruction at Shuswap Lake for the Dominion Hatchery Officers in British Columbia. The headquarters in both years were at Sorrento, the field-work being carried out on the main arm of Shuswap Lake near its outlet. During the four weeks a considerable amount of information was obtained concerning the limnology of that section of the lake and it has seemed of value to record the data.

DESCRIPTION.

The lake lies at an elevation of 1,150 feet above sea-level and has roughly a shape of a distorted letter "H." The area is somewhat over 100 square miles, but the length and narrowness of the arms are such that the shore-line has a length of approximately 600 miles. The lake is drained by the South Thompson River into the Thompson River and thence into the Fraser. There are several large tributaries, notably, Adams River, Scotch Creek, Seymour River, Eagle River, Shuswap River, and Salmon River. The arm of Shuswap Lake investigated is shown in Fig. 1.

GEOLOGY.

Geologically, the area surrounding Shuswap Lake is very complex, and a full discussion is given in the Canadian Geological Survey Memoir No. 68 (Daly, 1915). Three major events are of interest: (1) The extension of an arm of the ocean into the area in very early geological time; (2) a later uplift to the extent of 2,000 feet; (3) glaciation by an ice-sheet, 6,000 feet in thickness.

SOUNDINGS.

Soundings were taken across the arm at various places and at a few isolated points. The positions were located by means of cross-sights from two known positions on shore. The locations and depths (in feet) are shown in Fig. 1. The five soundings in parentheses are the only ones previously on record, and it will be observed that depths up to 345 feet have been found. Probable positions of the 50-, 100-, and 150-foot contours of the bottom are indicated. The bottom in the deeper parts consists of grey clayey ooze with a brownish surface, while toward the shore opposite Sorrento it is largely gravel which was probably brought down by Scotch Creek through an earlier outlet.

PHYSIOCHEMICAL OBSERVATIONS.

On July 17th, 1931, between 3 to 4 p.m. on a hot, clear day, a vertical series of water samples was taken at a point one-half mile south-west of Copper Island. Observations of temperature were made with a reversing thermometer, dissolved oxygen determinations by the Winkler method, and pH determinations by a La Motte colour-comparison set. On September 5th, 1931, another series of observations was made off Sorrento when a strong north wind was blowing. These two sets of data are given in Table I.

TABLE I.—Temperature, Oxygen, and pH Data, Shuswap Lake, 1931.

	Temperature in Degrees Centigrade.	Oxygen in c.c. per Litre.	pH.
July 17, 1931:			
Surface	19.2°	6.5	7.65
2 m.	18.4	——	7.75
5 m.	17.7	——	7.7
7.5 m.	16.9	——	——
10 m.	15.2	——	7.5
15 m.	11.4	——	——
17.5 m.	9.9	——	——
20 m.	8.0	7.6	7.45
29 m.	6.6	——	——
44 m.	5.8	7.3	——
64 m.	5.4	7.3	7.35

TABLE I.—TEMPERATURE, OXYGEN, AND pH DATA, SHUSWAP LAKE, 1931—*Continued.*

	Temperature in Degrees Centigrade.	Oxygen in c.c. per Litre.	pH.
Sept. 5, 1931:			
Surface	19.2	7.5	7.7
10 m.	19.2	.....	.....
12.5 m.	19.2	.....	.....
15.0 m.	15.1	.....	.....
17.5 m.	10.5	.....	.....
20.0 m.	8.6	.....	.....
30.0 m.	5.8	6.4	7.2

On July 23rd, 1931, a vertical series was taken at a point south-west of Copper Island by the men attending the course. Owing to the number of observers and lack of experience the results may not be absolutely accurate, but they afford a general picture of existing conditions. A second series was taken on July 8th, 1932, at a point 1 mile north-east of Sorrento, by the second group of hatchery officers. These two sets of data are shown graphically in Fig. 2, along with oxygen and pH records obtained at the same time.

It will be noted that on July 17th, 1931, the change in temperature between 8 and 18 metres (8.7 and 19.7 yards) constitutes a thermocline in the strict sense of the term. In spite of this stratification the lower water has more than 7 c.c. per litre of dissolved oxygen and there is no indication of stagnation. Immediately prior to September 5th, 1931, strong winds had brought about a thorough mixing of the upper 12 metres (13 yards) of water so that the thermocline on that date occurs between 13 and 20 metres (14.2 and 21.8 yards). The oxygen content of the hypolimnion was still more than 6 c.c. per litre at 30 metres (32.8 yards). The great volume of the hypolimnion in Shuswap Lake provides a large store of oxygen.

HIGHER AQUATIC VEGETATION.

The shore-line in general is stony and while potamogetons occur to some extent offshore, abundant growths of aquatic plants occur only in the sheltered bays. In some areas *Chara* occurred more or less sparsely. The following forms were collected: *Equisetum variegatum, Isoetes holanderi, Potamogeton epihydrus, P. heterophyllus, P. americanus, P. richardsoni, Triglochin palustris, Sagittaria latifolia, Ranunculus aquatilis* var. *capillaceus, Hippurus vulgaris, Myriophyllum spicatum, Utricularia intermedia.* The various species were abundant in Blind Bay and in a backwater near Scotch Creek landing—the potamogetons and bladderwort particularly so.

PLANKTON.

The plankton in the open waters was relatively small in amount and in number of species, but in sheltered bays it was considerably more abundant. A total vertical haul with a large No. 20 net on July 17th, 1931, gave 2.55 c.c. of plankton and on September 5th, 1931, 1.95 c.c., an average of 2.25 c.c. The average of eight similar hauls in Paul Lake in July and August, 1931, was 4.4 c.c. (Rawson, 1934), and the average of eleven similar hauls in Okanagan Lake in July and August, 1935, was 1.4 c.c. (manuscript). The following forms occurred:—

Algæ: *Gloeothece, Glœacapsa, Anabæna, Melosira, Stephanodiscus, Synedra, Fragillaria, Asterionella, Tabellaria, Desmidium, Staurastrum, Spirogyra, Mougeotia.*

Protozoa: *Ceratium hirundinella, Dinobryon sertularia.*

Rotifera: *Conochilus, Keratella cochlearis* var. *macracantha, Notholca longispina, Polyarthra.*

Copepoda: *Cyclops bicuspidatus, Diaptomus ashlandi, Epischura nevadensis, Canthocamptus minutus.*

Cladocera: *Sida crystallina, Diaphanosoma brachyurum, Holopedium gibberum, Daphnia longispina, Simocephalus vetulus, Scapholeberis mucronata, Ceriodaphnia reticulata, Bosmina longispina, Eurycercus lamellatus, Chydorus sphæricus, Acroperus harpæ, Alona costata, Alona affinis, Pleuroxus denticulatus, Pleuroxus procurvatus, Leptodora kindtii.* Mr. G. M. Neal took the following in Salmon Arm in July, 1935: *Daphnia pulex, Ceriodaphnia megalops, Kurzia latissima.*

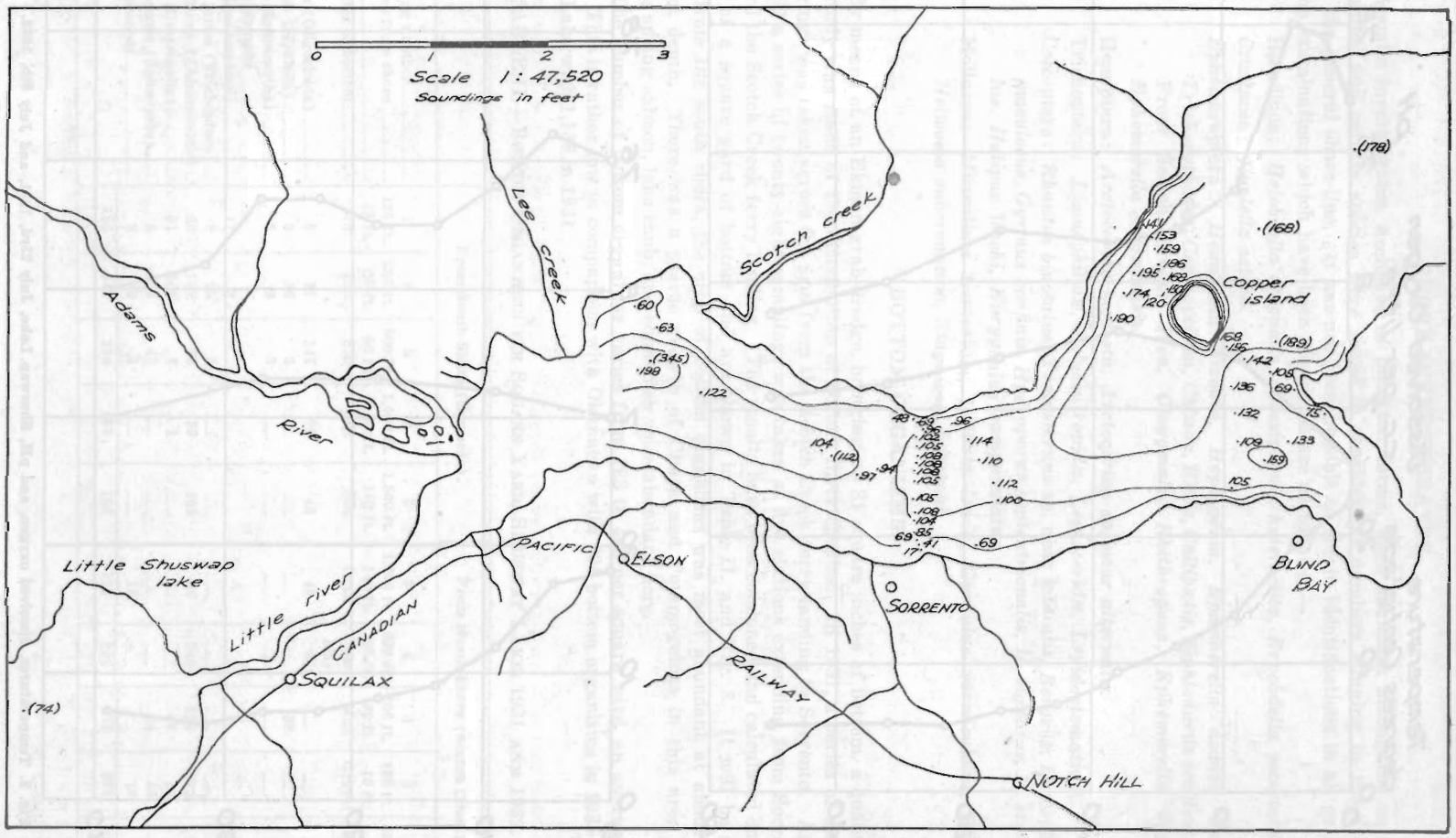

Fig. 1. Sketch-map of the western arm of Shuswap Lake, B.C.

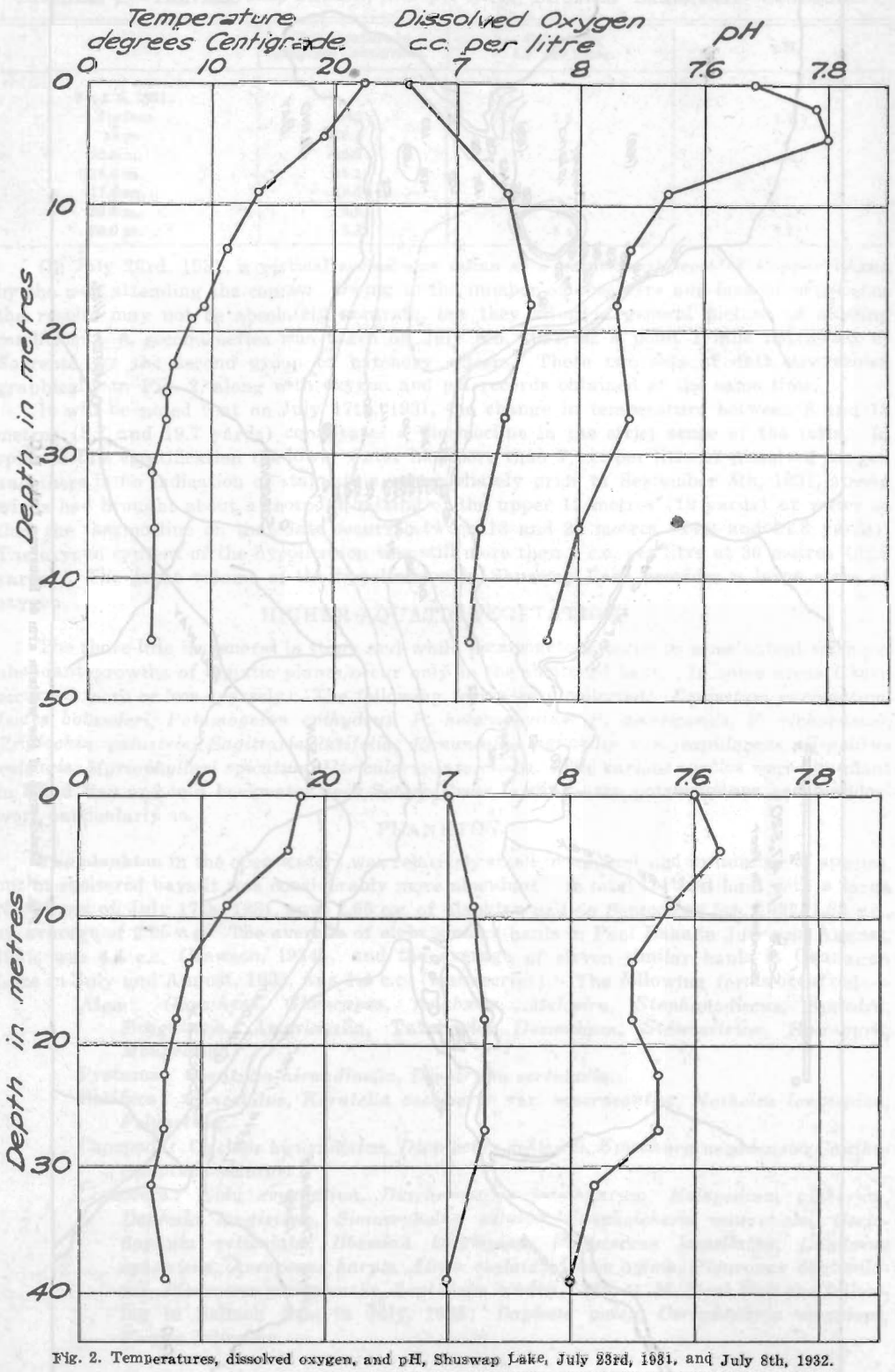

Fig. 2. Temperatures, dissolved oxygen, and pH, Shuswap Lake, July 23rd, 1931, and July 8th, 1932.

SHORE INVERTEBRATES.

Aquatic invertebrates, exclusive of plankton forms, were abundant among the aquatic vegetation, and certain species were found in considerable numbers clinging to the stones along the general shore-line. It has not been possible to obtain identifications in all groups, but the examinations which have been completed are as follows:—

Hirudinea: *Helobdella stagnalis, Glossiphonia heteroclita, Erpobdella punctata.*

Crustacea: *Hyalella azteca.*

Ephemeroptera: *Hexagenia limbata, Heptagenia, Ephemerella doddsi, Cænis, Trichorythodes, Centroptilum, Chlœon, Bætis, Callibætis, Siphlonurus occidentalis.* From Scotch Creek: *Iron, Cinygmula, Rhithrogena, Ephemerella doddsi, Ephemerella coloradensis.*

Hemiptera: *Arctocorixa modesta, Arctocorixa* sp. near *alternata.*

Trichoptera: *Limnephilidæ, Polycentropidæ, Leptoceridæ, Lepidostomatinæ.*

Coleoptera: *Rhantus binotatus, Tropisternus* sp. near *lateralis, Berosus, Laccophilus maculosus, Gyrinus confinis, Hydroporus septentrionalis, H. signatus, H. striatillus, Halipus leechi, Eurygenius campanulatus.*

Mollusca: *Musculium truncatum, Valvata lewisi, Gyraulus vermicularis, Physa, Helisoma subcrenatum, Stagnicola johnsoni.*

BOTTOM ORGANISMS.

By means of an Ekman grab-dredge, bringing up 81 square inches of bottom, a quantitative study was made of the distribution of bottom invertebrates. In 1931, a series of eleven dredgings was taken across the arm from the Scotch Creek ferry landing to Sorrento. Again in 1932 a series of twenty-eight samplings was taken at five stations extending from Sorrento toward the Scotch Creek ferry landing. The results have been combined and calculated on the basis of a square yard of bottom and are shown in Table II. and Fig. 3. It will be seen that from the south shore, the crop of bottom organisms was most abundant at about the 25-foot depth. There was a sparse growth of Chara and Potamogetons in this area and young spring salmon, lake chub, and squawfish were abundant here.

The number of bottom organisms varies from 128 to 449 per square yard, an average of 254. This is rather low in comparison with Okanagan with 304 bottom organisms in 1935 and Paul Lake with 1,136 in 1931.

TABLE II.—Bottom Organisms per Square Yard, Shuswap Lake, 1931 and 1932.

	From South Shore (Sorrento).					From North Shore (Scotch Creek).				
Dredging number	1	2	3	4	5	5	4	3	2	1
Distance from shore	125 ft.	250 ft.	500 ft.	1,000 ft.	1,500 ft.	1,300 ft.	300 ft.	200 ft.	150 ft.	100 ft.
Depth	15 ft.	25 ft.	50 ft.	80 ft.	100 ft.	140 ft.	80 ft.	30 ft.	10 ft.	6 ft.
Character of bottom	Silt	Silt	Silt	Silt	Silt	Ooze	Ooze-clay	Mud	Gravel	Sand
Worms (Oligochæta)	5	21	141	76	43	48	48	----	----	----
Shrimps (Hyalella)	8	36	3	----	----	----	----	32	----	16
Mites (Hydracarina)	5	3	3	----	----	----	----	----	----	16
Mayfly Nymphs (Ephemeroptera)	11	3	----	----	----	----	----	----	----	----
Caddis larvæ (Trichoptera)	8	99	5	----	----	----	----	----	----	----
Midge larvæ (Chironomidæ)	85	103	77	56	123	64	240	128	272	208
Snails (Gastropoda)	51	105	8	1	----	----	----	48	16	16
White clams (Sphæriidæ)	5	36	40	----	----	----	----	64	48	----
Miscellaneous	8	43	3	----	----	16	----	----	16	32
	186	449	280	133	166	128	288	272	352	288

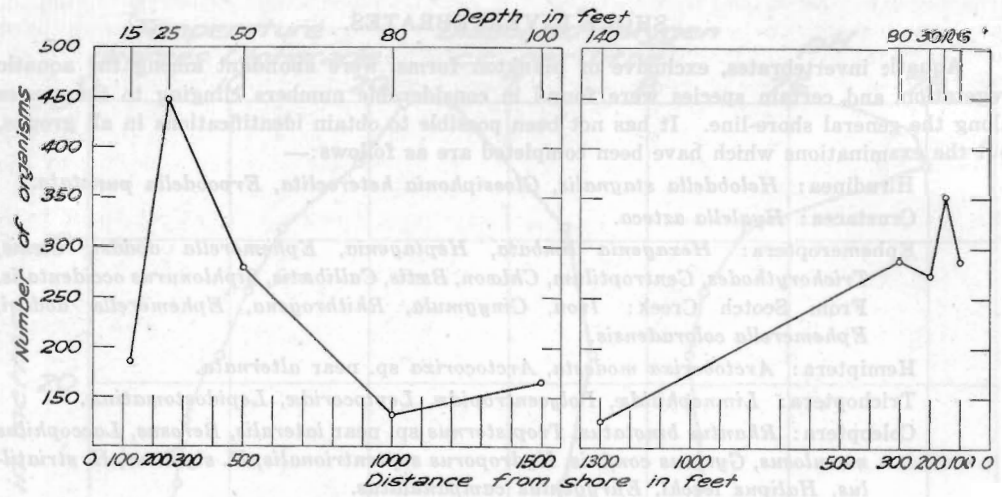

Fig. 3. Distribution of bottom organisms, Shuswap Lake, 1931 and 1932.

FISH.

Collections of fish were made by means of seine hauls and gill-net settings and the following species were obtained:—

Coarse-scaled sucker (*Castostomus macrocheilus*), fine-scaled sucker (*Catostomus catostomus*), lake chub (*Mylocheilus caurinus*), squawfish (*Ptychocheilus oregonensis*), lake shiner (*Richardsonius balteatus*), dace (*Apocope falcata*), carp (*Cyprinus carpio*), Eastern whitefish (*Coregonus clupeaformis*), Rocky Mountain whitefish (*Prosopium williamsoni*), young spring salmon (*Oncorhynchus tschawytscha*), young coho salmon (*O. kisutch*), young sockeye salmon (*O. nerka*), kokanee (*O. nerka kennerlyi*), Kamloops trout (*Salmo gairdneri kamloops*), Dolly Varden char (*Salvelinus malma*), ling (*Lota maculosa*), sculpin (*Cottus asper*).

Shuswap Lake has always been a very important salmon-spawning area. Spring salmon spawn in various tributaries and the young spend several months in the lake before commencing their seaward migration. In both 1931 and 1932, very large numbers of these young fish, about 3¼ inches in length, were feeding along the entire shore length of the portion of the lake under observation, breaking the surface of the water everywhere in the evenings. Examination of stomach contents showed the food to consist largely of midge pupæ, water boatmen, and water fleas, chiefly *Daphnia* (Clemens, 1934). Large numbers of these fish were leaving the lake during July, and Kamloops trout were apparently feeding extensively upon them at the mouth of Little River. Anglers were making good catches of the trout by the use of a silvery lure.

Coho salmon also spawn extensively in the tributaries of the lake, particularly in Eagle River. The young usually spend a year in the streams and lakes before going to sea.

In earlier days, Shuswap Lake was one of the most important sockeye-salmon spawning areas in British Columbia. The adult sockeye in their red spawning livery formed during August and September a continuous procession in the South Thompson River and were referred to as the "long red line." They passed into all the tributary streams in almost incredible numbers. The following account by Mr. D. S. Mitchell is of interest: "Many years ago I rowed in the moonlight up the Salmon River. About a mile from its mouth I tied the bow to a long stake that was driven in the bed of the stream. There was no sign of salmon. I unrolled my blankets in the stern and went to sleep. In the grey of early morning I was aroused by a commotion and found the river full of sockeye salmon running up-stream. I put in an oar and felt that the river was half fish. The increasing light soon showed that it was red from bank to bank. Then a stampede or panic occurred and salmon came surging down but the river was so full of ascending fish that they blockaded and made a great, flat

wriggling dam. So jammed were they that they were crowded out and pushed up the sloping banks out of water. Where the banks steepened these struggling, flapping fish were rolled down on to the backs of the fish in the river, into the mass of which they would again sink. The fish lower down stream, suffocating for oxygen, had turned and were rushing back to the lake to breathe fresh water through their gills. They rushed down-stream creating a great noise like the roar of a storm or the noise of thousands of wild ducks rising from a lake, and followed down-stream by a succession of waves. The river was quiet again, flowing by the stake 14 inches below the wet high-water mark reached a few minutes before. Not a fish was in sight, but in twenty minutes or so they came back filling the river again from bank to bank."

Since the time of the rock-slide in the Fraser River Canyon at Hell's Gate in 1913, the runs to the upper areas of the Fraser River, including Shuswap Lake, have been small. The first large escapement in recent years took place in 1926, when several hundred thousand spawned in Adams River and large numbers have appeared in the succeeding cycle-years, namely, 1930 and 1934.

The young of the sockeye spend a year in the lake and feed largely upon the zoo-plankton. The productive capacity of the lake in plankton must have been enormous to support the hundreds of millions of young fish. Since all the Pacific salmon die after spawning the decomposition of the carcasses may have contributed very much to the fertility of the waters.

Many of the sockeye do not go to sea, but complete their life-cycle in the lake and spawn in the tributary streams as do the sea-run sockeye. These fish are called kokanees and constitute a subspecies of the sockeye under the name *Oncorhynchus nerka kennerlyi*. They are known to spawn in Eagle River, and undoubtedly they make use of many other streams.

The Kamloops trout is abundant in the lake and provides an excellent angling fishery. The Dolly Varden char is also abundant and taken frequently by anglers.

The Rocky Mountain whitefish is common and the young were taken regularly in the seine hauls. A single specimen of the Eastern whitefish, approximately 15 inches in length, was taken in a gill-net. While there is no official record of this species having been introduced into Shuswap Lake, there are rumours to the effect that a planting was made years ago during the period when whitefish eggs were being brought from Manitoba and Ontario. It is probable that the species now occurs in limited numbers as it does in Okanagan Lake.

Suckers, minnows, and sculpins are particularly abundant. The origin of the carp is not known but it has become rather common in the vicinity of Salmon Arm.

The ling is also reported to be abundant in the lake, and considerable numbers appear in Eagle River in the autumn at the time of salmon spawning.

It is hoped that the account of the natural history of a limited portion of Shuswap Lake, incomplete as it is, may form the basis for a more extensive study of this interesting and important body of water.

We wish to gratefully acknowledge the assistance of the following persons in the identification of plants and animals: Dr. F. C. Baker, Dr. C. Betten, Dr. G. C. Carl, Professor J. Davidson, Professor J. R. Dymond, Dr. F. P. Ide, Dr. J. McDunnough, and Dr. J. Percy Moore.

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