

WILDLIFE MANAGEMENT BULLETIN



DEPARTMENT OF NORTHERN AFFAIRS
AND NATIONAL RESOURCES
NATIONAL PARKS BRANCH
CANADIAN WILDLIFE SERVICE

SERIES 3

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DEPARTMENT OF NORTHERN AFFAIRS
AND
NATIONAL RESOURCES
NATIONAL PARKS BRANCH
CANADIAN WILDLIFE SERVICE

STUDIES OF LAKE TROUT AND COMMON WHITEFISH
IN WATERTON LAKES, WATERTON LAKES
NATIONAL PARK, ALBERTA.

by

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Wildlife Management Bulletins are produced to make available to wildlife administrators the information contained in reports which are submitted by officers of the Canadian Wildlife Service.

The reports do not, in most cases, cover extensive studies and are not written primarily for publication. Recommendations arising from the studies are not included.

INTRODUCTION

During the summer of 1951, the authors and A. Boudreault, summer assistant, established headquarters at Waterton Lakes National Park and undertook a study of the limnology of Waterton Lakes with particular reference to lake trout and common whitefish. The investigations carried out and the findings obtained are reported and discussed hereunder.

Because part of the Upper Waterton Lake is in Glacier National Park, Montana, authorities of that park were asked to supply permits for collecting in United States waters and were invited to send biologists to participate in the program. Dr. R.B. Brunson, Biologist for Glacier National Park and Professor of Zoology at Montana State University, with two assistants, carried out research on two phases of the program, the study of bottom fauna and the study of feeding habits of common whitefish.

Waterton Lakes National Park (Fig. 1) is located in the southwest corner of the Province of Alberta and is the Canadian part of the Waterton-Glacier International Peace Park. Waterton Park was established in 1895 and now covers an area of 204 square miles along the eastern slope of the Rocky Mountains. Within the park are many streams and lakes located at altitudes ranging from 4,185 feet to 7,100 feet. Several native and introduced game fish including cutthroat trout, rainbow trout, eastern brook trout, lake trout, Dolly Varden, Rocky Mountain whitefish, and pike are found in the waters of the park. Grayling are found occasionally in the Belly River, which flows from Glacier National Park through Waterton National Park.

Few data on Waterton Lakes were available, since they were investigated previously only once, by Dr. D.S. Rawson and his party during the summer of 1937. At that time the plankton, bottom fauna, physical and chemical relations, and fish fauna in the lakes were studied. The report covering Dr. Rawson's investigations and conclusions was submitted in 1938, and in the same year, an examination of the food of the common and Rocky Mountain whitefish, based on specimens collected by Dr. Rawson in 1937, was reported by Dr. J.L. McHugh.

Since 1922, 640,000 cutthroat trout, 460,000 rainbow trout, and 300,000 lake trout fingerlings and yearling fish have been planted in Waterton Lakes.

A creel census project, whereby anglers report their catches from park waters, was begun in the park in 1939

and has continued with increasing success. During 12 years the annual returns of completed creel census cards increased from 6 to 1,370, the latter number reporting 2,456 angling efforts. Reports on creel census data were prepared each year up to 1953.

MORPHOMETRY OF THE LAKES

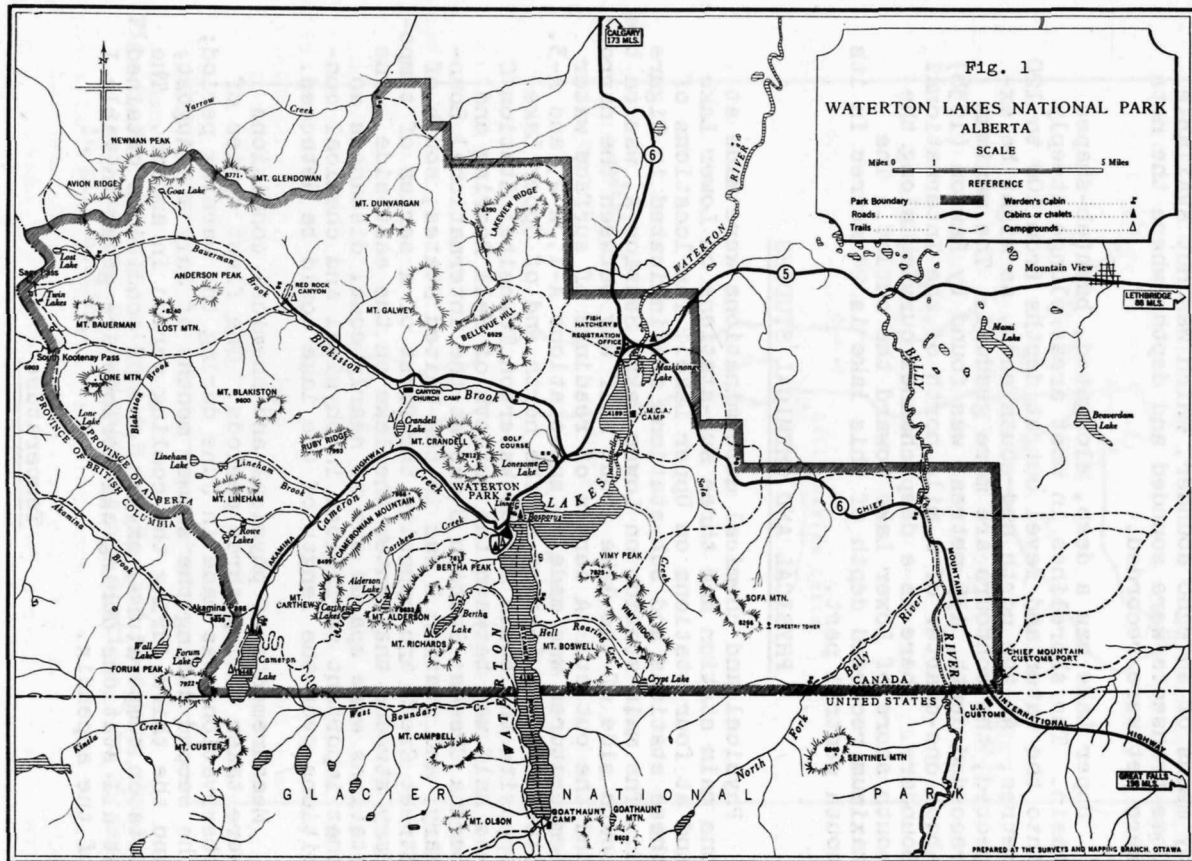
The Waterton Lakes are two bodies of water hereafter referred to as Upper Lake and Lower Lake. Drainage from Glacier National Park is by means of Kootenai Creek and a number of smaller streams emptying into Upper Lake. Upper and Lower Lake are joined by a shallow narrows with a maximum depth of six feet at high water. A stream named Dardanelles drains Lower Lake into a lake locally known as Knight's Lake, from which flows Waterton River. Maskinonge Lake, which is shallow and marshy, drains into Waterton River near the outlet of Knight's Lake.

Upper Lake lies at an altitude of approximately 4,193 feet. It is seven miles long and one-half mile wide and covers an area of 3.7 square miles. The direction of its long axis is almost due north and south. Lower Lake is roughly kidney-shaped. It is $2\frac{1}{2}$ miles long and about three-quarters of a mile wide and covers an area of 1.8 square miles. Its long axis lies nearly east and west.

These lakes lie between high peaks and ridges of the Clarke Range to the west and the Lewis Range to the east. They are known geologically as finger lakes. They occupy basins produced by erosion of alpine glaciers. The rocks in the area are sedimentary deposits of the late Precambrian age--quartzites, metargillites, limestones, and dolomites. The bed of the narrows between the two lakes and underwater ridges in the lakes are composed of resistant strata of massive bedded dolomites of the Altyn formation. Various colours in the rocks and differences in resistance to erosion have created remarkable scenic effects in the area.

The lakes are being filled at present by sand and gravel carried down from the mountains by the streams, which are making small shallow deltas such as those at the mouths of Cameron, Hell Roaring, Bertha, and Boundary Creeks. Two large streams, Blakiston Brook or Pass Creek and Sofa Creek, have deposited a large sand and gravel flat between Knight's Lake and Lower Lake.

Time did not permit a complete sounding of the lakes. It is known that hard rock formations produce underwater



ridges running across the lakes, but details of such irregularities could not be discovered readily except by means of an echo sounder, which was not available. Some transects were sounded and depths where the nets were set were recorded.

Upper Lake has a deep, elongated, bathtub-shaped basin. The shorelines in most areas plunge steeply into the water and level out at depths from 100 to 120 metres. At the north and south ends, as might be expected, the contours are more gradual. The maximum recorded depth, 135 metres, was found by Rawson (1938) about one-quarter of a mile north of the International Boundary. There is a deep channel curving along the south shore of Lower Lake toward the outlet. The maximum recorded depth of this lake is 24 metres in its south central part.

PHYSICAL AND CHEMICAL STUDIES

Physical and chemical determinations were made at one main station and three sub-stations on Lower Lake and at four stations on Upper Lake. The locations of these stations and sub-stations are indicated in Figure 2. The main station on Lower Lake, Station A, was on the south side of the lake about half way between the narrows and the outlet. A series of readings of surface water temperatures was made at sub-stations A-1, A-2, and A-3. Station B was located at the north end of Upper Lake opposite the south end of Waterton Townsite; Station C was half way between the outlets of Hell Roaring and Bertha Creeks; Station D was at the International Boundary; and Station E was in the United States, south of Street Creek and opposite the first of a series of temporary streams that enter the lake on the east side. The stations were spaced out at nearly equal distances so that important variations in physical and chemical conditions over the length of the lake could be detected.

Measurements of physical and chemical conditions were taken during three periods. The first series of observations was made in June during the warming period; the second during the summer months of July and August; and the third during the cooling period in autumn. The data on temperature, oxygen, and pH conditions obtained at all stations during all periods are given in Table I of the appendix.

Temperature

From the graph in Figure 3, prepared from the readings obtained at Station C, it may be noted that heating of the

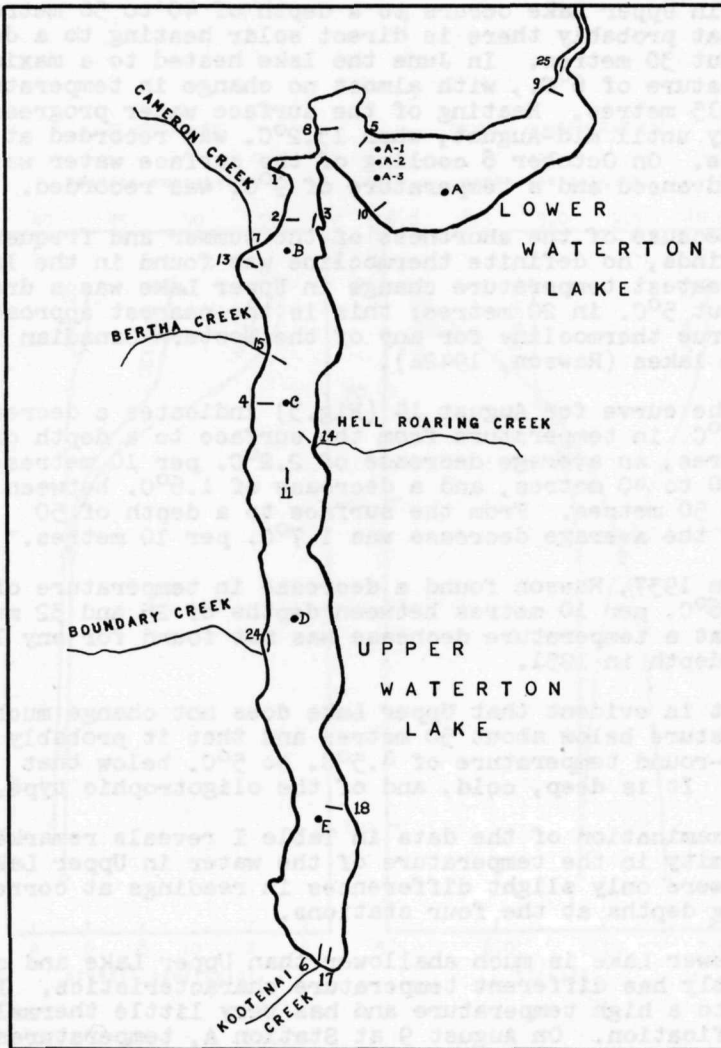


Fig. 2. Map showing Stations A,B,C,D,E, used in making physical and chemical determinations, and Stations 1 to 25 used in gill netting.

water in Upper Lake occurs to a depth of 40 to 50 metres, and that probably there is direct solar heating to a depth of about 30 metres. In June the lake heated to a maximum temperature of $6^{\circ}\text{C}.$, with almost no change in temperature below 15 metres. Heating of the surface water progressed rapidly until mid-August, when $13.2^{\circ}\text{C}.$ was recorded at the surface. On October 6 cooling of the surface water was well advanced and a temperature of $9^{\circ}\text{C}.$ was recorded.

Because of the shortness of the summer and frequent high winds, no definite thermocline was found in the lakes. The greatest temperature change in Upper Lake was a drop of about $5^{\circ}\text{C}.$ in 20 metres; this is the nearest approach to a true thermocline for any of the Western Canadian alpine lakes (Rawson, 1942a).

The curve for August 14 (Fig.3) indicates a decrease of $0.4^{\circ}\text{C}.$ in temperature from the surface to a depth of 10 metres, an average decrease of $2.2^{\circ}\text{C}.$ per 10 metres from 10 to 40 metres, and a decrease of $1.6^{\circ}\text{C}.$ between 40 and 50 metres. From the surface to a depth of 50 metres the average decrease was $1.7^{\circ}\text{C}.$ per 10 metres.

In 1937, Rawson found a decrease in temperature of about $6^{\circ}\text{C}.$ per 10 metres between depths of 25 and 32 metres. So great a temperature decrease was not found for any 10-metre depth in 1951.

It is evident that Upper Lake does not change much in temperature below about 50 metres and that it probably has a year-round temperature of $4.5^{\circ}\text{C}.$ to $5^{\circ}\text{C}.$ below that depth. It is deep, cold, and of the oligotrophic type.

Examination of the data in Table I reveals remarkable uniformity in the temperature of the water in Upper Lake. There were only slight differences in readings at corresponding depths at the four stations.

Lower Lake is much shallower than Upper Lake and consequently has different temperature characteristics. It heats to a high temperature and has very little thermal stratification. On August 9 at Station A, temperatures of $14.4^{\circ}\text{C}.$ at the surface and of $11.2^{\circ}\text{C}.$ at the bottom, were recorded, a difference of $3.2^{\circ}\text{C}.$ in 20 metres. On September 14, the temperature was $12.3^{\circ}\text{C}.$ at the surface and $11.6^{\circ}\text{C}.$ at the bottom, a difference of only $0.7^{\circ}\text{C}.$ Because of the shallowness of the narrows, the flow from Upper Lake to Lower Lake in summer consists largely of warmed surface water. The surface water may be slightly warmer near the shore than in the middle of the lake, as shown on June 29 when comparative surface and bottom temperatures were recorded from 2-, 10-, and 18-metre depths at Sub-stations

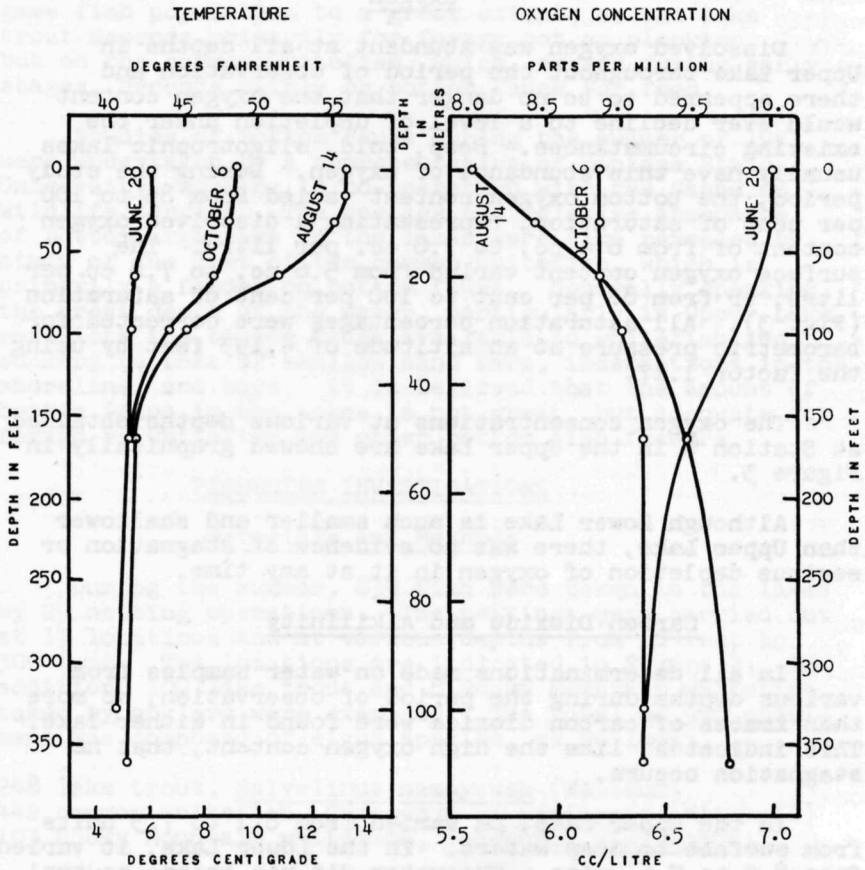


Fig. 3 - Oxygen and temperature determinations from Station C, Upper Lake.

A-1, A-2, and A-3. The surface temperature at Sub-station A-1, near the shore, was 2.3°C. greater than at the other sub-stations.

Oxygen

Dissolved oxygen was abundant at all depths in Upper Lake throughout the period of observation and there appeared to be no danger that the oxygen content would ever decline to a level of depletion under the existing circumstances. Deep, cold, oligotrophic lakes usually have this abundance of oxygen. During the study period, the bottom oxygen content varied from 83 to 100 per cent of saturation, representing a dissolved oxygen content of from 6.4 cc. to 7.8 cc. per litre. The surface oxygen content varied from 5.6 cc. to 7.8 cc. per litre, or from 80 per cent to 100 per cent of saturation (Fig. 3). All saturation percentages were corrected for barometric pressure at an altitude of 4,193 feet by using the factor 1.17.

The oxygen concentrations at various depths obtained at Station C in the Upper Lake are showed graphically in Figure 3.

Although Lower Lake is much smaller and shallower than Upper Lake, there was no evidence of stagnation or serious depletion of oxygen in it at any time.

Carbon Dioxide and Alkalinity

In all determinations made on water samples from various depths during the period of observation, no more than traces of carbon dioxide were found in either lake. This indicates, like the high oxygen content, that no stagnation occurs.

In the Upper Lake, pH varied from 8.1 to 7.3 units from surface to deep waters. In the Lower Lake, it varied from 8.0 to 7.6 units. The water did not become neutral or acidic during any period of observation.

PLANKTON AND BOTTOM FAUNAL STUDIES

The plankton was sampled quantitatively throughout the summer by means of a tow net and a Juday plankton trap. The organisms found were chiefly of the following genera: Diaptomus, Cyclops, Asterionella, Fragillaria, and Diatoma. All these forms were present throughout the summer, except Cyclops which were remarkably rare in all samples.

The plankton in all samples taken, in both lakes, was significantly poor in numbers of organisms. As these lakes are sub-alpine and oligotrophic in nature, the paucity of plankton is to be expected. It is not believed, however, that this condition affects the game fish population to a great extent, as the lake trout depends primarily for forage not on plankton, but on the common whitefish, which, except during early stages, depends mainly on bottom fauna for food.

Studies of bottom fauna during the summer of 1951 were undertaken by a representative of Montana State University, working in co-operation with the Canadian Wildlife Service. The species and relative abundance of bottom organisms in the lakes were also revealed by study of the diet of the common whitefish, which is primarily a feeder on bottom fauna. Generally speaking, the great depth of the water, particularly in Upper Lake, restricts the bottom fauna available to whitefish and suckers to that of shallow sand bars, indentations in the shoreline, and bays. It is believed that the amount of bottom fauna in the lakes is not great, but adequate for forage by whitefish and other bottom fish feeders.

FISHERIES INVESTIGATIONS

Materials and Methods

During the summer, 839 fish were taken in the lakes by 29 netting operations. The nettings were carried out at 17 locations and at various depths from 20 feet to 300 feet. The locations are indicated in Figure 2. In addition, 109 lake trout and 8 Rocky Mountain whitefish taken by anglers were examined. The total of 956 specimens was composed of eight species, as follows:

- 248 lake trout, Salvelinus namaycush (Walbaum)
- 442 common whitefish, Coregonus clupeaformis (Mitchell)
- 103 Rocky Mountain whitefish, Coregonus williamsoni
Girard
- 11 white sucker, Catostomus commersoni (Lacépède)
- 132 longnose sucker, Catostomus catostomus (Forster)
- 18 ling or burbot, Lota lota (Linnaeus)
- 1 cutthroat trout, Salmo clarki (Girard)
- 1 rainbow trout, Salmo gairdneri Richardson

A list of the number of each of the first six species taken by netting, including the date of capture, and the location where the net was set in each case, is presented in Table II of the appendix.

Gill nets of nylon thread were used. On September 7, a 100-yard length of net in the stretched-mesh size of $5\frac{1}{2}$ inches, 20 feet wide, was set at Station C in Upper Lake in such a way that it hung vertically with its top at the surface. For all other nettings six nets each 25 yards long were joined together in a gang, which was set on the bottom, the largest-meshed net farthest from shore. The stretched-mesh sizes of the six nets were $1\frac{1}{2}$, 2, 3, 4, 5, and $5\frac{1}{2}$ inches, respectively, and their widths were 40, 40, 30, 20, 15, and 15 meshes, respectively. Each was about six feet wide. The use of the standard gang of nets described above allowed comparative sampling at various stations on the lake. The nets were set in the evening and raised the following morning; the date shown in each case is that on which the nets were raised and the fish taken from them.

Immediately after capture of the fish, the following information for each specimen was recorded on a scale envelope: serial number; species; location and date of capture; weight in pounds; and length, measured from tip of nose to fork of tail, in inches to the nearest eighth of an inch. Sex and stage of maturity were determined by examination of the gonads; the stages of development were represented by numbers as follows:

Stage - 0 Fish immature, gonads small, sex determinable only under microscope.

Stage - 1)
 Stage - 2) Progressive stages in development
 Stage - 3) between immaturity and spawning.
 Stage - 4)

Stage - 5) Gonads fully mature; fish ready to spawn.

Stage - 6) Spawning recently completed.

Degree of parasitism, amount of fat present, and general condition were also noted.

Stomach contents of lake trout taken by netting were examined in the field immediately after the netting operation was completed; those taken by

angling were examined shortly after capture. Contents of whitefish stomachs were bottled and preserved for future examination.

Length, weight, and age determinations of specimens of common sucker, sturgeon sucker, and ling were taken and the stomach contents of ling were examined. Examination of fresh scales soon after they were taken from the fish was found to be the most successful means of determining age. For this reason the age determinations were made in the field laboratory by means of a portable projector. Age was recorded in completed years: thus a fish with scales showing six checks (annuli) was recorded as six years of age.

Lake Trout Studies

Introduction

The productivity of a body of water is related to the amount of fish food available in it, its physical and chemical characteristics, and the soil and rock of surrounding areas. The degree of productivity is reflected by the number of fish produced and their sizes and growth rates. If there are to be suitable conditions for producing lake trout in a lake there must be sufficient amounts of plankton and bottom fauna, and at least one intermediate species of fish able to utilize these organisms. When lake trout have a good rate of growth, it may be stated that limnological conditions are favourable, that an abundant food supply is available, and that the conditions favour both the utilization of the plankton and bottom fauna by the intermediate species and the utilization of this species by the lake trout.

Circumstances did not permit a complete study of the productivity of Waterton Lakes. However attempts were made to investigate the lake trout population with respect to size composition, growth rate, feeding habits, sexual maturation, and relationship between length and weight, and to compare the data from the Waterton Lakes with published data from other lake trout populations.

In all, 248 lake trout from both lakes, comprising 139 taken by netting and 109 caught by anglers, were examined.

Distribution

Lake trout were found at all depths sampled. Large ones were seen in shallows close to the shore in July. All but one of the netting operations were carried out at depths from 3 to 30 metres, and trout were taken at almost every netting.

On July 11, at a depth of about 100 metres, six trout different in several respects from those taken at lesser depths were netted. They were darker in colour, had different feeding habits, and evidently matured at a smaller size and had a slower rate of growth. They were in poor condition. They were believed to be a "deep water" type of trout, adapted to dim light, high pressure, and constant coldness; however, occasional specimens of this type were found among fish taken at higher levels.

Length, Weight, and Age Frequencies

The length-frequency distribution of lake trout from both lakes was studied separately on specimens netted and on those obtained from anglers. Data are presented on Table III of the appendix. The lengths of fish from the Lower Lake ranged from 15 to 34 inches for those caught by angling and from 13 to 35 inches for those caught by netting. From the Upper Lake, fish caught by angling ranged between 11 and 35 inches in length while those caught by netting ranged from 7 to 36 inches. In the Lower Lake, 85 per cent of the fish caught by angling ranged between 18 and 27 inches in length; 62 per cent ranged between 20 and 25 inches. Netting, however, showed uniform distribution between 16 and 29 inches, with no dominant size ranges.

The weight-frequency distribution of lake trout from each lake according to sampling methods, is presented in Table IV of the appendix. The largest specimen brought for examination by an angler weighed 25.5 pounds. One 25-pounder was also caught by netting. Among fish caught by angling in the Lower Lake, nearly 75 per cent weighed between two and seven pounds, inclusive; the weights of those caught by netting were uniformly distributed between one and twelve pounds. In the Upper Lake, nearly 75 per cent of the fish caught by netting weighed less than three pounds.

The frequency of occurrence of various age groups based on 246 age determinations was tabulated separately

for each lake for fish taken by angling and netting. Data are presented in Table V of the appendix. The ages of all fish examined, from both lakes, were found to range from three to sixteen years. Anglers obtained most of their catches from the five- to eight-year age groups. Most of the netted fish were from the same age groups. From the frequency distribution, it seemed that the abundance of lake trout falls drastically after the ninth year because of larger catches of six- to eight-year-old fish by angling, because of natural mortality of older fish, or, more likely, for both reasons.

The sampling returns from netting and angling were not similar in the two lakes. The data are too few to permit discussion of sampling methods. However, they indicate the relative numbers of fish of the older age groups (nine to sixteen years) in the lakes. With the six-, seven-, and eight-year-old fish representing strong age classes, fishing in Waterton Lakes could be expected to be well maintained or even improved in the next two or three years, with larger fish being taken.

Food Studies

The stomachs of 248 lake trout taken by angling and netting were examined. Of these, 50 stomachs (20 per cent) were found empty and are not included in further calculations. The food items found in the remaining 198 stomachs are listed below in Table 1, which gives the number and percentage of stomachs containing each item.

The principal food item was the common whitefish, found in 88 stomachs (45 per cent). Rocky Mountain whitefish was found in five stomachs and ling in seven stomachs. Sculpins were found in four stomachs, all from a sample of six taken in a net set below 300 feet in the deepest water, where sculpin is believed to be the only species immediately available. The other two stomachs in the sample were empty.

Suckers, reported as a food item of lake trout by Rawson (1938), were not found in stomachs examined in 1951. One stomach contained seven small lake trout about $5\frac{1}{2}$ inches in length which had been marked by the removal of a fin. A planting of yearling lake trout marked in this way had been made several days before. Other food items were various kinds of insects (particularly chironomids), leeches, snails, and organic and inorganic detritus. Many items were found in the

stomachs only during particular periods, because they occurred only, or in large abundance at those times; for example Hymenoptera (chiefly flying ants) were most abundant during late June and the first three weeks of July. It was reported that 17 lake trout were taken by an angler using a black-gnat fly on July 15, at the time when flying ants were most abundant. It was noted that 42 per cent of the stomachs contained diptera, sometimes adults and larvae, but more often pupae. Those items were found most frequently during June and July, and in small fish.

Table 1. Occurrence of Food Items
in 198 Lake Trout Stomachs.

Item	Number of Stomachs	Percentage Frequency
<u>Crustacea</u>		
Amphipods	2	1
Plankton	4	2
Malacostraca (Mysis)	5	2.5
<u>Hirudinea</u>	3	1.5
<u>Mollusca</u>	1	0.5
<u>Insecta</u>		
Diptera - Chironomids		
adults	2	1
pupae	54	27
larvae	27	14
Hymenoptera	8	4
Coleoptera	6	3
Ephemera	2	1
Lepidoptera (pupa)	1	0.5
Hemiptera	4	2
Trichoptera	5	2.5
<u>Pisces</u>		
Sculpin	4	2
Ling	7	3.5
Lake trout, yearlings	1	0.5
Rocky Mountain whitefish	5	2.5
Common whitefish	88	45
Unidentified remains	53	27
<u>Stones and Organic</u>		
Detritus	4	2

Unidentified fish remains, probably common whitefish for the most part, were found in 27 per cent of the stomachs.

Rawson (1938) found that Mysis sp. was an important food item of lake trout taken from deep water.

The food preferences of fish of various lengths, as indicated by stomach contents, are summarized below. Only the two principal food items, fish and chironomids, are considered.

<u>Length Group in Inches</u>	<u>No. of Specimens</u>	<u>Per Cent Occurrence</u>	
		<u>Chironomids</u>	<u>Fish</u>
6 - 9	6	67	33
10 - 14	15	53	53
15 - 20	78	28	81
over 20	99	36	81

It may be noted that chironomids and fish are taken as food by lake trout of all sizes but particularly by those less than 15 inches in length, and that fish is the largest item in the diet of lake trout measuring 15 inches or more. The availability of small fish for young lake trout seems to be a very important factor in the successful development of the population.

Growth

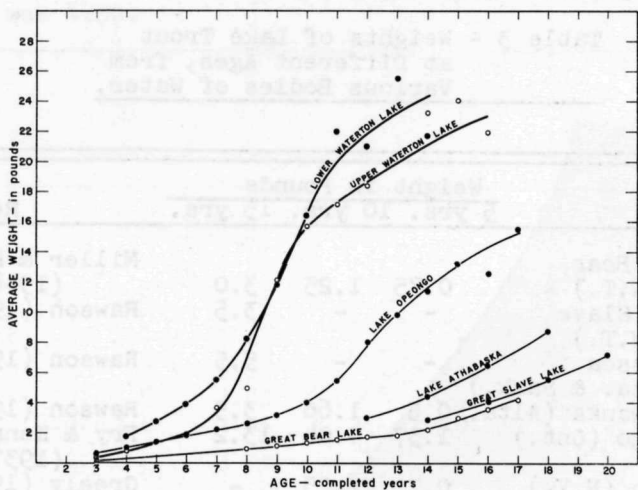
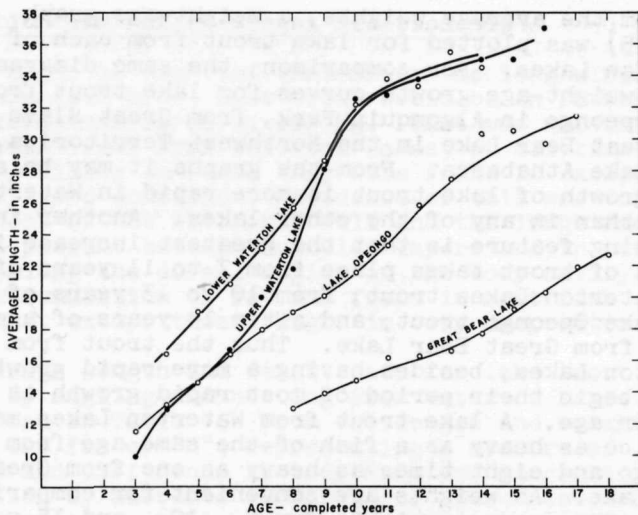
This study is based on 246 specimens. The lengths of all fish taken by angling and by netting were arranged in age groups. The ranges and averages of length and weight, and the number of specimens of each age group, for both sexes, are presented in Table 2, where the data for the two lakes are given separately. A considerable difference between the growth rates of trout from the two lakes is apparent. In Lower Lake, which is warmer and shallower than Upper Lake, the trout have a considerably higher average growth rate, particularly noticeable in the weight records.

From the data on the average lengths of year-classes, length-age curves for both Waterton Lakes were constructed and are presented in Figure 4. Length-age curves for Lake Opeongo and Great Bear Lake are also shown. It appears that at equal ages

trout from Lower Lake are generally longer than trout from Upper Lake and much longer than those from Lake Opeongo and Great Bear Lake.

Table 2 - Length and Weight Ranges and Averages of Lake Trout for Each Year Class.

Age in Years	No. of Specimens	Length in Inches		Weight in Pounds	
		Range	Av.	Range	Av.
<u>UPPER LAKE</u>					
3	15	7.5 -12.3	9.9	0.1 - 0.6	0.3
4	6	10.75-14.75	12.9	0.4 - 1.3	0.8
5	8	12.25-18.0	14.6	0.7 - 2.4	1.2
6	27	13.5 -21.75	16.7	0.9 - 3.6	1.9
7	22	16.25-25.5	20.0	1.7 - 7.9	3.7
8	12	17.5 -27.5	21.8	2.1 -10.0	5.0
9	5	25.75-32.75	28.1	9.25-16.0	11.9
10	2	32.25-32.75	32.5	15.2 -16.3	15.7
11	1	32.75	-	17.1	-
12	1	33.75	-	18.4	-
13	N11	-	-	-	-
14	1	35.0	-	23.3	-
15	1	35.0	-	24.0	-
16	1	36.5	-	21.9	-
<u>LOWER LAKE</u>					
3	N11	-	-	-	-
4	7	15.0 -17.5	16.4	0.8- 2.3	1.8
5	19	13.25-23.0	19.1	0.9- 5.2	2.8
6	34	15.25-25.0	20.8	1.4- 7.0	3.9
7	28	17.25-25.5	23.1	2.0- 9.4	5.5
8	34	19.5 -29.0	25.6	3.5-12.5	8.2
9	11	22.75-34.5	28.6	5.6-16.0	11.8
10	4	29.0 -34.5	32.2	13.8-21.2	16.4
11	3	32.0 -35.0	33.8	18.0-25.0	22.0
12	1	-	33.3	-	21.0
13	1	-	35.5	-	25.5
14	2	34.0 -35.3	34.5	18.1-25.4	21.7
15	N11	-	-	-	-
16	N11	-	-	-	-



Figs. 4 and 5 - Age-length and age-weight relationships of lake trout from various lakes.

From the average weights, a weight-age graph (Fig. 5) was plotted for lake trout from each of the Waterton Lakes. For comparison, the same diagram shows weight-age growth curves for lake trout from Lake Opeongo in Algonquin Park, from Great Slave Lake and Great Bear Lake in the Northwest Territories, and from Lake Athabasca. From the graphs it may be seen that growth of lake trout is more rapid in Waterton Lakes than in any of the other lakes. Another interesting feature is that the greatest increase in weight of trout takes place from 7 to 11 years of age for Waterton Lakes trout, from 10 to 13 years of age for Lake Opeongo trout, and after 14 years of age for trout from Great Bear Lake. Thus the trout from Waterton Lakes, besides having a more rapid growth rate, begin their period of most rapid growth at an earlier age. A lake trout from Waterton Lakes may be twice as heavy as a fish of the same age from Lake Opeongo and eight times as heavy as one from Great Bear Lake. As weights are convenient for comparing sizes, the average weights for 5-, 10-, and 15-year-old lake trout from various waters are summarized in Table 3.

Table 3 - Weights of Lake Trout
at Different Ages, from
Various Bodies of Water.

Lake	Weight in Pounds			Reference
	5 yrs.	10 yrs.	15 yrs.	
Great Bear (N.W.T.)	0.75	1.25	3.0	Miller & Kennedy (1948)
Great Slave (N.W.T.)	-	-	3.5	Rawson (1947b)
Athabasca (Alta. & Sask.)	-	-	5.5	Rawson (1947a)
Minnewanka (Alta.)	0.5	1.66	3.5	Rawson (1942b)
Opeongo (Ont.)	1.37	4.04	13.2	Fry & Kennedy (1937)
Otsego (N.Y.)	0.7	12.25	-	Greely (1936)
Upper Waterton	1.25	15.75	22.0	
Lower Waterton	2.5	16.25	22.5	

Condition and Length-Weight Relationship

It might be expected that after the long winter of a mountain area, lake trout would be in rather poor condition in early spring. That was not the case with trout from Waterton Lakes; at all times, and especially in June, they were found in exceptionally good condition. Evidence of this was the thickness of the abdominal wall and the large amount of fat present between muscular layers and in particular along the dorsal region of the body cavity. This accumulation of fat was found in most fish examined, except those caught in very deep water.

Average length and weight data for lake trout taken by angling and netting from Waterton Lakes are presented in Table 4. From the length and weight data, the factor "K", representing a measure of change and difference in body form and describing condition by absolute numbers, was calculated, and is given in the table. The value of the condition factor varied from 3.16 to 5.60, and generally increased with the size of the fish. The average value was 4.30.

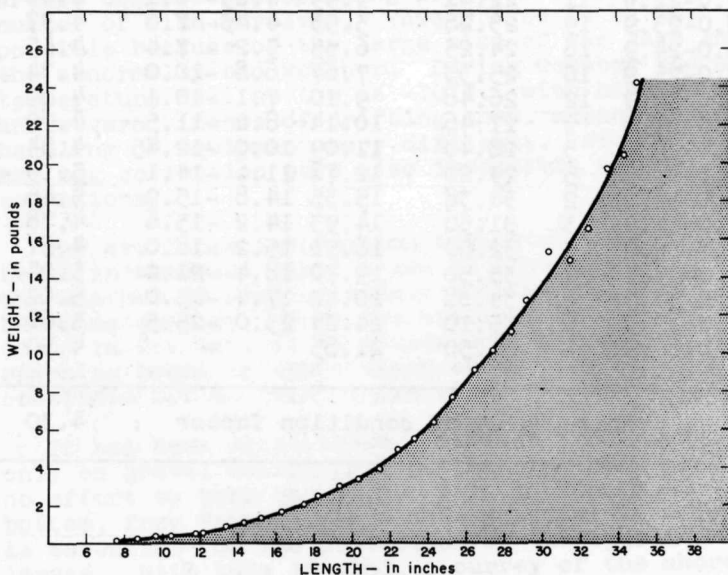


Fig. 6 - Length-weight relationships of lake trout.

Table 4 - Average Lengths and Weights, Weight Ranges, and Condition Factors of Various Length Ranges of Lake Trout.

Length Range (inches)	No. Examined	Average Length (inches)	Average Weight (pounds)	Weight Range (pounds)	Condition Factor "K"
7.0- 7.9	2	7.62	0.14	0.13- 0.15	3.16
8.0- 8.9	1	8.75	0.25	-	3.73
9.0- 9.9	4	9.62	0.32	0.31- 0.34	3.62
10.0-10.9	7	10.43	0.38	0.31- 0.44	3.38
11.0-11.9	2	11.81	0.54	0.50- 0.59	3.28
12.0-12.9	3	12.17	0.61	0.53- 0.69	3.35
13.0-13.9	5	13.40	0.92	0.88- 1.0	3.82
14.0-14.9	6	14.29	1.09	1.0 - 1.25	3.73
15.0-15.9	10	15.20	1.37	0.75- 1.69	3.90
16.0-16.9	13	16.31	1.68	1.44- 2.0	3.88
17.0-17.9	16	17.46	2.06	1.12- 2.85	3.84
18.0-18.9	18	18.21	2.52	1.95- 3.1	4.18
19.0-19.9	12	19.36	3.07	2.8 - 3.5	4.20
20.0-20.0	29	20.33	3.39	3.0 - 4.25	4.05
21.0-21.9	9	21.45	3.95	3.65- 4.55	4.03
22.0-22.9	11	22.41	4.99	4.25- 6.1	4.44
23.0-23.9	19	23.28	5.53	4.45- 7.0	4.37
24.0-24.9	18	24.25	6.35	5.2 - 7.4	4.45
25.0-25.9	10	25.33	7.67	6.8 -10.0	4.74
26.0-26.9	12	26.48	9.10	7.1 -10.1	4.89
27.0-27.9	9	27.46	10.14	8.2 -11.5	4.90
28.0-28.9	5	28.40	11.09	10.0 -12.45	4.84
29.0-29.9	5	29.20	12.78	11.6 -14.1	5.13
30.0-30.9	2	30.38	15.35	14.8 -15.9	5.46
31.0-31.9	3	31.50	14.93	14.2 -15.6	4.78
32.0-32.9	5	32.50	16.51	15.2 -18.0	4.81
33.0-33.9	2	33.50	19.70	18.4 -21.0	5.24
34.0-34.9	4	34.38	20.42	17.4 -25.0	5.02
35.0-35.9	5	35.10	24.24	23.0 -25.5	5.60
36.0-36.9	1	36.50	21.85	-	4.50

Average value of condition factor : 4.30

The relationship between length and weight takes the form of a normal curve (Fig. 6), with weight increasing more rapidly than length after the first four or five years of growth. The curve establishes that the weight of lake trout in Waterton lakes, at the minimum legal length of 15 inches, is somewhat more than one pound, and that a 30-inch-long lake trout weighs about 14 pounds.

Spawning Period and Areas.

An attempt to study the spawning habits of the lake trout in Waterton Lakes was made in the autumn of 1951. The staff of the hatchery assisted in this project.

All lake trout captured during the summer were examined for sex and maturity as described under Materials and Methods. One object was to determine whether they would have spawned in 1951. During October, when the season for spawning was approaching, several nettings were carried out and the fish taken were examined closely for sexual and body characteristics. Attempts were also made to locate spawning areas, observe the spawning act, and estimate the number of fish involved. This proved to be impossible because of the large size of the lake and the abnormally bad weather. During October the air temperature fell as low as -10°F. , with high winds and several inches of drifting snow, making the handling of equipment very difficult. Fish stripping and egg collection were also impossible under such conditions.

The available information indicates that the lake trout in Waterton Lakes spawn in late autumn, when the weather is growing colder and the days are becoming shorter. From the examination of trout taken in October, it is estimated that in 1951 spawning began in these lakes about October 20 and continued for at least three weeks.

It has been established that lake trout spawn only on gravel bottom free of sand and mud, making no effort to bury the eggs. A rough, creviced bottom, free from currents and excessive wave action, is essential for the protection of the eggs and larvae. With this in mind, a survey of the shoreline was made. It was found that many bays and

shallows had clean gravel beds, ideal for spawning trout. On two occasions fish were observed close to shore over gravel areas.

On October 18, taking advantage of a rare calm day, Lower Lake was entirely surveyed for spawning areas. At 4.30 p.m., 75 to 100 lake trout of various sizes were noted in an area where the bottom material varied from large boulders to gravel in 10 to 15 feet of water. No definite pattern of movement could be ascertained although the fish were apparently attracted to the area and did not seem to be disturbed by the boat. These fish were believed to be male lake trout preparing to spawn or competing for spawning rights. The condition of fish netted at that time indicated that spawning would take place about a week later. At another location a group of about 20 fish was noted in poor light at about 5.45 p.m. on the same day. This observation was continued by means of a sealed-beam lamp connected to a 6-volt battery and mounted on a pipe. The fish were over a bottom similar to that of the previous observation. They seemed to be disturbed by the boat and the light and eventually all disappeared.

Sex Ratios and External Characteristics

Twelve of the total of 248 lake trout examined were immature and their sex could not be determined under field conditions. Of the remaining 236, 123 were females and 113 males, giving a sex ratio of nearly one male to one female.

Fish of the salmon family usually assume distinctive coloration and markings at the spawning period, but among lake trout from Waterton Lakes no external characteristics that might distinguish them as mature and ready to spawn are evident on either male or female. Malformation of the lower jaw, known as "kype", commonly observed in mature males of other species of this family, rarely occurs in lake trout from Waterton Lakes and it was found almost impossible to identify mature males from head characteristics alone. Throughout the investigation, males and females were very similar in colour when removed from the water. However, this may not be the case immediately before spawning, as no fish were taken at that time.

Age and Size at Maturity

Each fish was examined to determine whether it was ready to spawn in 1951, and classified accordingly. The results are given in Table VI of the appendix. It may be seen that the gonads of trout from Upper Lake may be mature at five years of age, when the length is about 16.5 inches and the weight less than two pounds. However, the number of five-year-old fish with mature gonads was very small: one out of eleven males, and two out of eight females. The proportion of fish ready to spawn increased irregularly with age up to ten years, at which age all those examined were ready to spawn.

Only one lake trout from Lower Lake less than six years of age--a five-year-old female--was found in near-spawning condition. In this lake a smaller proportion of the trout appears to spawn at six years of age than in Upper Lake.

The questions of spawning frequency and senility were carefully considered, since it has been reported that lake trout in Great Bear Lake do not spawn every year (Miller and Kennedy, 1948) and that lake trout in Lake Opeongo are subject to senility (Fry and Kennedy, 1937).

The numbers of lake trout of both sexes from both lakes, from six to nine years of age, inclusive, classified as spawners or non-spawners for 1951, were as follows:

	Number of		<u>Total</u>
	<u>Males</u>	<u>Females</u>	
Spawners	46	45	91
Non-spawners	33	48	81

It is interesting to note that among males of these ages the number ready to spawn was slightly greater than the number that was not; among females the numbers were about equal. All the 19 trout ten years of age or older were ready to spawn (Table VI). This suggests that the trout probably spawn every other year from the first year of sexual maturity until they are about ten years of age, and annually after that.

Senility in lake trout of small size, as observed at Lake Opeongo by Fry and Kennedy, was not observed at Waterton Lakes.

General Considerations

Parasitism of the lake trout in these lakes is slight; in no fish were cysts found in the flesh and many fish showed no signs of parasitism. The parasites found were of the tapeworm type; they were small in size and they had not harmed the fish to any apparent degree.

Lake trout from Waterton Lakes were very fat as a result of favourable conditions existing in these waters. Apparently they were quite numerous, as netting operations took many specimens in almost every case. In several instances nets were set at locations never considered for angling because, according to local residents, "there are no lake trout there". Usually many specimens were netted at these locations, with the result that anglers began fishing them and making good catches.

Considering the rapid growth rates and generally good condition of these fish it was difficult to understand why anglers were dissatisfied with the angling in previous years.

The 1951 study indicated that the lake trout of Waterton Lakes required no management action. However, considering the abundance of forage fish and the increasing angling demand, it might be possible and desirable to add to the population of lake trout by planting hatchery-raised fish.

Common Whitefish Studies

From the food studies of lake trout, previously discussed, it is evident that the common whitefish (*Coregonus clupeaformis*) is important for lake trout. The netting operations in the Waterton Lakes resulted in the taking of 442 common whitefish. These whitefish were used to study the size frequency, growth, and feeding habits of this important forage species.

The netting results indicated that there was an ample supply of common whitefish in both lakes. They were taken at all twelve netting stations in Upper Lake and all five netting stations in Lower Lake (Fig. 2).

Length and Age Frequencies

The length-frequency distribution of the whitefish from both lakes is presented in Figure 7. From this figure, certain characteristics of the whitefish population are apparent.

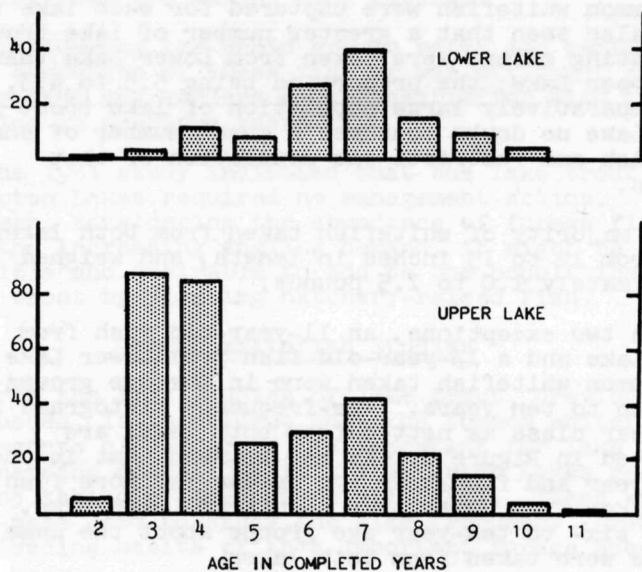
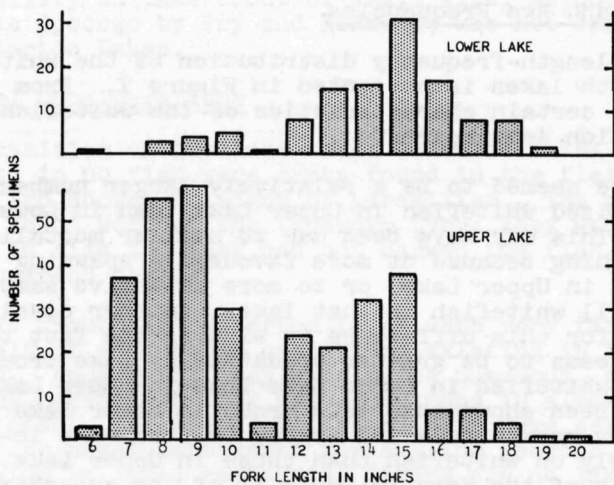
There seemed to be a relatively larger number of small-sized whitefish in Upper Lake than in Lower Lake. This may have been due to smaller mortality in hatching because of more favourable spawning conditions in Upper Lake, or to more selective sampling for small whitefish in that lake. Another possible reason for this difference in size is the fact that there seems to be greater predation by lake trout on common whitefish in Lower Lake than in Upper Lake. It has been shown that lake trout in Lower Lake have a faster growth rate and appear to feed more intensively on whitefish than those in Upper Lake. Analysis of the data in Table II of the appendix reveals that in Lower Lake 2.2 common whitefish were captured for each lake trout, whereas in Upper Lake 3.3 common whitefish were captured for each lake trout. It is also seen that a greater number of lake trout per netting effort were taken from Lower Lake than from Upper Lake, the proportion being 5.5 to 4.3. The comparatively large population of lake trout in Lower Lake no doubt consumes a great number of small whitefish and restricts the population of that species.

The majority of whitefish taken from both lakes were from 12 to 15 inches in length, and weighed approximately 1.0 to 1.5 pounds.

With two exceptions, an 11-year-old fish from Upper Lake and a 13-year-old fish from Lower Lake, all common whitefish taken were in the age groups from two to ten years. Age-frequency histograms for each year class as netted from both lakes are presented in Figure 8. It may be seen that in the three-year and four-year age groups far more fish were taken from Upper Lake than from Lower Lake. In the six- to ten-year age groups about the same numbers were taken from both lakes.

Length-Weight Relationships

The average lengths and weights of common whitefish from both lakes, by one-inch length ranges, appear in Table VII of the appendix. The length-



Figs. 7 and 8 - Length-frequency and age-frequency distribution of common whitefish.

weight relationship is illustrated graphically in Figure 9. The curve of the graph illustrates a normal relationship. The weight increases slowly with increase in length from 7 to 11 inches and more rapidly with greater lengths. Lengths and weights of whitefish from Shakespeare Lake (Hart, 1931a), Great Bear Lake (Kennedy, 1949), and Lake Ontario (Hart, 1931b) are shown in the graph for comparative purposes. The weights of whitefish from the other lakes average about one-quarter pound more than those of whitefish of similar length from Waterton Lakes.

Growth Studies

The records of all whitefish taken were grouped by age and the average lengths and weights were calculated for each age class. These data are presented in Table 5.

Table 5-Average Length and Weight of Common Whitefish for Each Completed Year of Age.

Age (Completed Years)	Number of Specimens	Average Length (Inches)	Average Weight (Pounds)
<u>Upper Lake</u>			
2	6	6.83	0.09
3	88	8.05	0.19
4	85	9.61	0.35
5	26	12.17	0.78
6	30	13.78	1.13
7	42	14.79	1.37
8	22	15.63	1.73
9	14	16.45	2.09
10	4	15.94	2.05
11	1	16.00	2.19
<u>Lower Lake</u>			
2	1	6.25	0.11
3	3	8.50	0.24
4	11	10.35	0.46
5	8	13.25	1.02
6	27	13.87	1.18
7	40	15.33	1.60
8	15	16.35	2.00
9	9	18.08	2.95
10	4	17.94	2.71
11	Nil	-	-
12	"	-	-
13	1	21.50	5.90

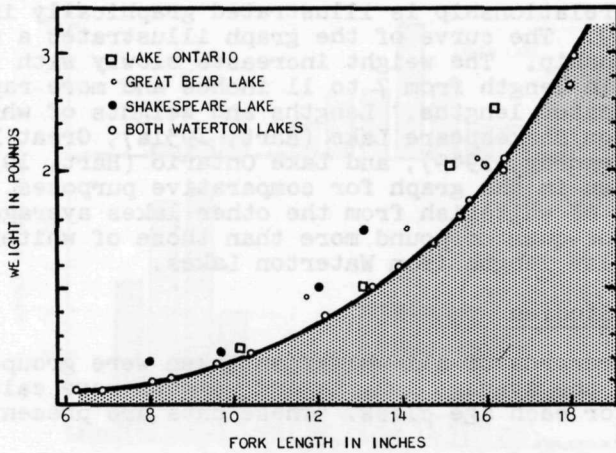


Fig. 9 - Length-weight relationships of common whitefish.

A growth curve plotted from the average lengths of year-classes is presented in Figure 10. Length-age curves for whitefish from Shakespeare Lake, Great Bear Lake, and Lake Ontario are included in the figure for comparative purposes. From this figure it may be seen that fish of the same age from Lower Lake are generally longer than those from Upper Lake. The difference is probably due to the greater depth and colder water in Upper Lake and the scarcity in the latter of shallow areas with abundant bottom fauna. It may also be seen that fish from both the Waterton Lakes are shorter than those of comparative age from Great Bear Lake and Lake Ontario, and have a slower growth rate.

From the average weights for the year-classes, growth curves for the same lakes, and for Lesser Slave Lake (Miller, 1945) were plotted and are presented in Figure 11. It appears that common whitefish grow more rapidly in weight as well as in length in Lower Lake than in Upper Lake, but more slowly in either than in Great Bear Lake, Lake Ontario, and Lesser Slave Lake.

The comparatively slow growth rate and low ratio of weight to length found in Waterton Lakes whitefish seems to be related to the general body shape of these fish, which did not seem to have as great a body depth

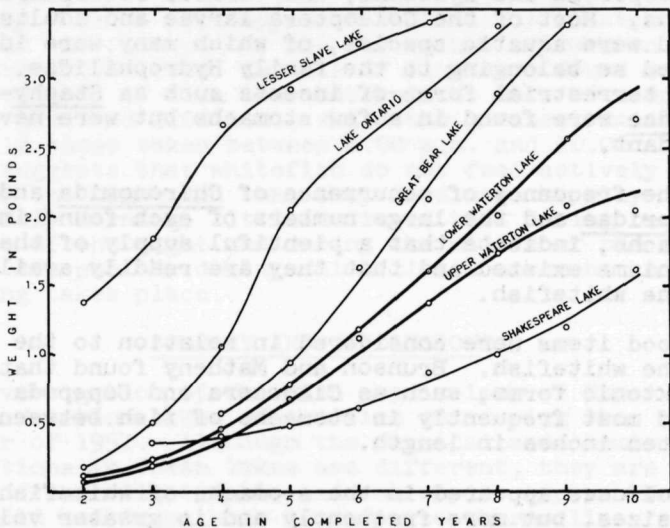
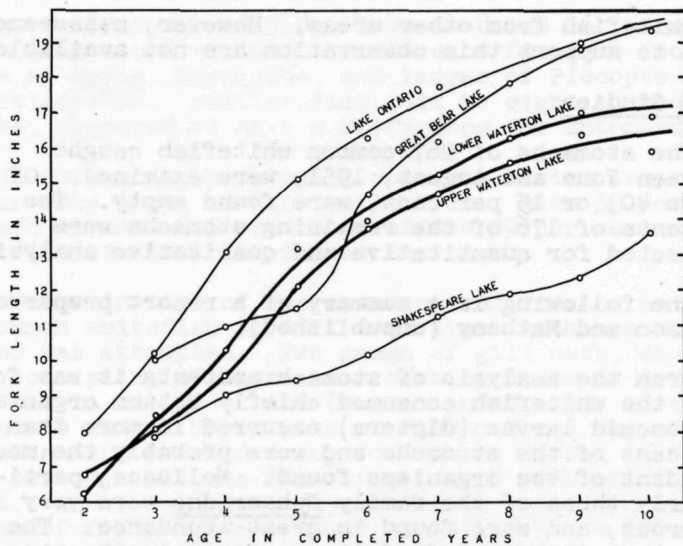


Fig. 10 & 11 - Age-length and age-weight relationships of common whitefish.

as whitefish from other areas. However, measurement data to support this observation are not available.

Food Studies

The stomachs of 267 common whitefish caught between June and August, 1951, were examined. Of these 40, or 15 per cent, were found empty. The contents of 176 of the remaining stomachs were collected for quantitative and qualitative analysis.

The following is a summary of a report prepared by Brunson and Matheny (unpublished).

From the analysis of stomach contents it was found that the whitefish consumed chiefly bottom organisms. Chironomid larvae (diptera) occurred in more than 50 per cent of the stomachs and were probably the most abundant of the organisms found. Molluscs, particularly those of the family Sphaeriidae were very numerous, and were found in great abundance. The next most important food items, found in the stomachs of whitefish of all sizes, were the Amphipods (Pontoporeia and Hyaella) and various Plecoptera nymphs. Most of the Coleoptera larvae and adults found were aquatic species, of which many were identified as belonging to the family Hydrophilidae. Some terrestrial forms of insects such as Staphylinidae were found in a few stomachs but were never abundant.

The frequency of occurrence of Chironomids and Sphaeriidae and the large numbers of each found in the stomachs, indicate that a plentiful supply of these organisms existed and that they are readily available to the whitefish.

Food items were considered in relation to the size of the whitefish. Brunson and Matheny found that planktonic forms, such as Cladocera and Copepoda were found most frequently in stomachs of fish between six and ten inches in length.

Molluscs appeared in the stomachs of whitefish of all sizes, but more frequently and in greater volume in fish of large sizes. This was particularly true of the Sphaeriidae. Some of the molluscs, such as Cyraulius, Valvata, Physa, and Lymnea occurred almost exclusively in whitefish more than 14 inches in length.

Intermediate-sized fish, between 8 and 16 inches in length, appeared to have a preference for such food items as Mysis, Amphipods, and larvae of Plecoptera and Coleoptera. Smaller fish, six to eight inches in length, appeared to have a preference for Entomostraca.

The volume of the stomach contents varied from immeasurable small amounts to 16.1 cc., with 39 per cent between 0.1 and 0.5 cc. Most of the 39 per cent were from fish six to eight inches in length.

A determination of the movement and feeding activity of common whitefish at different times within a 20-hour period was attempted. Two gangs of gill nets, each gang consisting of three nets each 25 yards in length, were set in two locations (Nos. 1 and 2, Fig. 2) near the north end of Upper Lake at 2,00 p.m. on August 2. The nets were checked every four hours during a 20-hour period. All the fish caught were removed at each visit. An attempt was made to compare the kind and amount of food present in the stomachs of the fish taken at the various visits. Brunson and Matheny found that the periods of greatest activity of the whitefish were in the early evening and in the morning. There also appeared to be a correlation between the time of day and the volume of food in the stomachs. The least amounts of food were found in the stomachs of fish that entered the nets between 10.00 p.m. and 2.00 a.m., while the greatest amounts were in those taken between 6.00 a.m. and 10.00 a.m. This suggests that whitefish do not feed actively during the night and that they feed most heavily in the early morning. It is believed that during the middle of the night and during the middle of the day there are periods during which little movement and feeding takes place.

SUMMARY AND CONCLUSIONS

Investigation of the fish populations of Upper and Lower Waterton Lakes was carried out during the summer of 1951. Although the physical and chemical conditions in these lakes are different, they are both of the oligotrophic and sub-alpine type. They are cold and deep, have no definite thermocline, are alkaline in nature, and have abundant oxygen at all depths.

The plankton population of the lakes is poor. Bottom fauna is not abundant, but appears to be sufficient to support the whitefish population.

During the summer, 956 fish from both lakes were examined. These included 248 lake trout obtained by 29 netting operations and from anglers.

Lake trout caught by angling were most numerous at weights of about four pounds and lengths of 15 to 25 inches. Lake trout examined were from three to sixteen years of age, and most of those taken by angling were from five to eight years of age. The six-, seven-, and eight-year age classes appeared to be large, so that angling in the lakes was expected to be well maintained or even improved in the next two or three angling seasons.

The lake trout fed most actively in July and the first two weeks of August. It was found that they did not feed exclusively in deep water but rose to feed at the surface in certain seasons. The principal food item of the lake trout was the common whitefish; other fish found in their stomachs much less frequently were Rocky Mountain whitefish, ling, sculpin.

The lake trout were found to have excellent growth. Few lakes in Canada, and no known lake with such low temperature and short growing season shows as high a growth rate for the species. The lake trout in Lower Lake have a more rapid growth rate than those in Upper Lake. The trout of these lakes increase in weight most rapidly between seven and eleven years of age, in contrast with those at other lakes.

The lake trout were in excellent condition, having few parasites, well-developed muscular layers, and an abundant supply of fat, particularly in the body cavity.

The lake trout spawn in autumn, beginning October 20 to 25 and probably continuing three weeks to a month. The earliest spawning is at five years of age but the majority spawn for the first time at the age of six. There are many suitable spawning areas in both lakes.

Some reasons for the excellent condition and good growth rate of the lake trout, particularly in Lower Lake, are believed to be: (1) the population of lake

trout was adequate but not dense; (2) there was an abundant and readily available supply of common whitefish, the food item most commonly found in lake trout stomachs; (3) there were few other species competing for whitefish; (4) the water was clear and mildly alkaline, contained a fair amount of dissolved minerals, and had ample oxygen at all depths during the ice-free period; and (5) there was no thermocline and the fish could spread out over all areas to obtain food.

Common whitefish examined were from two to thirteen years of age. Most of them were in the three- and four-year age classes. Growth of these fish is less rapid in Waterton Lakes than in other lakes in Canada. According to Brunson and Mathenay, who studied the food habits of this species in the Waterton Lakes, the most important food items of these fish were found to be molluscs and Diptera larvae, particularly of the family Chironomidae. The young of this species from six to ten inches in length showed a preference for a planktonic diet, chiefly Cladocera and copepods. Feeding habits of the whitefish did not seem to vary greatly during the summer period. The most active daily feeding period was between two and six o'clock in the morning, with a secondary peak at ten o'clock in the evening.

ACKNOWLEDGMENTS

During the investigation, Superintendent J.H. Atkinson and the staff of the park supplied equipment and assistance and Park Hatchery Superintendent G.E. Bailey and his assistant supported the research program with voluntary aid.

Dr. R.B. Brunson, Montana State University, and his assistants, representing Glacier National Park and the U.S. National Park Service, conducted the bottom fauna studies and the study of the food of the common whitefish, and courteously granted permission to cite their findings to the preparation of this report.

Anglers in the park expressed their interest in many ways and co-operated by donating fish for examination and by completing creel census cards.

To all of these the authors wish to express sincere thanks and grateful acknowledgment.

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APPENDIX

Table I - Data on Chemical and Physical Determinations.

Date (1951)	Depth (Metres)	Temperature (Degrees C)	Oxygen (cc/litre)	Oxygen (% saturation)	pH
<u>Station A - Lower Lake</u>					
June 15	Nil	8.0	7.0	97	7.7
" 15	22	7.4	6.8	93	7.8
" 29	Nil	12.5(1)	-	-	-
" 29	2	9.0	-	-	-
" 29	Nil	10.2(2)	-	-	-
" 29	10	6.8	-	-	-
" 29	Nil	10.2(3)	-	-	-
" 29	18	6.4	-	-	-
Aug. 9	Nil	14.4	5.5	90	8.0
" 9	18	11.2	5.9	86	7.8
Sept. 14	Nil	12.3	5.5	86	7.6
" 14	5	11.8	5.6	86	7.6
" 14	10	11.7	5.6	86	7.6
" 14	20	11.6	5.7	87	7.6
<u>Station B - Upper Lake</u>					
June 15	Nil	6.0	7.0	93	7.7
" 15	40	5.0	7.0	92	7.7
" 26	Nil	5.0(4)	7.2(4)	93	7.5
" 26	15	5.5	7.0	95	7.7
" 26	20	5.8	7.1	100	7.7
" 26	40	5.2	7.0	98	7.5
July 13	Nil	8.6	6.9	84	7.5
" 13	10	8.6	6.7	82	7.7
" 13	20	7.8	7.0	83	7.7
" 13	30	7.0	7.0	82	7.7
" 13	40	4.6	7.5	83	7.7
Aug. 14	Nil	13.4	5.8	93	8.1
" 14	5	13.2	5.9	93	8.1
" 14	10	12.9	5.8	90	8.1
" 14	20	10.7	6.1	90	7.9
" 14	30	6.4	6.6	88	7.8
" 14	40	5.5	6.7	88	7.8
Sept. 17	Nil	11.6	6.0	92	7.8
" 17	5	11.2	6.1	94	7.8
" 17	10	11.0	6.1	92	7.8
" 17	20	10.8	6.3	94	7.6
" 17	30	8.0	6.5	91	7.4
" 17	40	5.7	6.8	90	7.4

- (1) Close to shore at Sub-station A-1.
- (2) (3) Off shore at Sub-stations A-2 and A-3.
- (4) Observations made after two days of snow and rain in freezing temperatures.

Table I - Data on Chemical and Physical Determinations (cont'd).

Date (1951)	Depth (Metres)	Temperature (Degrees C)	Oxygen (cc/litre)	Oxygen (% saturation)	pH
<u>Station C - Upper Lake</u>					
June 28	N11	6.0	7.0	93	7.7
" 28	10	6.0	7.0	93	7.7
" 28	20	5.4	-	-	-
" 28	50	5.2	6.6	85	7.7
" 28	100	4.7	6.4	85	7.5
Aug. 14	N11	13.2	5.6	90	8.1
" 14	5	13.2	5.8	92	8.1
" 14	10	12.8	5.9	90	8.1
" 14	20	10.7	6.2	90	7.9
" 14	30	7.3	6.4	86	7.9
" 14	50	5.4	6.6	85	7.8
" 14	110	5.0	6.8	87	7.8
Oct. 6	N11	9.1	6.2	90	7.8
" 6	5	9.1	6.3	91	7.8
" 6	10	8.9	6.2	90	7.7
" 6	20	8.4	6.2	88	7.6
" 6	30	6.7	6.3	86	7.4
" 6	50	5.3	6.4	85	7.4
" 6	110	5.0	6.4	85	7.4
<u>Station D - Upper Lake</u>					
June 15	N11	5.0	7.8	100	7.4
" 15	50	4.5	7.7	98	7.6
July 30	N11	12.1	6.1	80	7.5
" 30	50	5.1	7.6	84	7.5
Oct. 6	N11	8.7	6.7	97	7.5
" 6	10	8.6	6.7	96	7.6
" 6	20	7.9	6.8	96	7.5
" 6	30	6.5	6.9	94	7.5
" 6	50	5.2	7.1	94	7.4
" 6	100	4.8	7.1	92	7.4
<u>Station E - Upper Lake</u>					
June 15	N11	5.0	7.5	88	7.9
" 15	50	4.5	7.8	100	7.7
" 30	N11	7.6	7.4	102	7.6
" 30	10	5.8	7.2	96	7.5
" 30	45	5.0	7.2	93	7.5
" 30	90	4.6	7.2	93	7.6
July 30	N11	12.2	6.0	79	7.7
" 30	50	5.2	7.4	83	7.3
Oct. 8	N11	8.6	6.8	98	7.6
" 8	10	8.6	6.7	96	7.6
" 8	30	6.5	6.7	90	7.6
" 8	50	5.4	6.8	90	7.5
" 8	100	4.9	6.8	88	7.6

Table II - Fish Species and Numbers Taken by Netting. (1)

Date (1951)	Netting Station	Lake Trout	Rocky Mountain White- fish	Long- nose Sucker	White Sucker	Ling	Common White- fish	Total
<u>Upper Lake</u>								
June 18	1	1	Nil	2	Nil	Nil	11	14
" 19	1	4	"	2	"	"	46	52
" 20	2	16	"	3	"	2	53	74
" 27	3 & 4	1	5	Nil	"	Nil	4	10
July 1	6	6	47	10	"	3	14	80
" 4	7	2	1	5	"	Nil	23	31
" 11	11	6	Nil	Nil	"	1	Nil	7
" 19	13	2	"	"	"	Nil	7	9
" 21	14	Nil	"	1	"	1	13	15
" 21	15	6	"	6	"	Nil	3	15
" 25	2	3	7	2	"	1	36	49
" 31	17	4	2	Nil	"	1	29	36
" 31	18	5	Nil	"	"	1	13	19
Aug. 2	2	10	1	"	"	Nil	17	28
" 2	1	5	1	"	"	"	36	42
" 28	24	7	1	"	"	2	12	22
Sept. 7	2	Nil	Nil	"	"	Nil	Nil	Nil
Oct. 13	1	6	6	3	2	"	5	22
Sub-total --		84	71	34	2	12	322	525
<u>Lower Lake</u>								
June 29	5	7	1	15	Nil	1	16	40
July 5	8	6	9	4	"	Nil	19	38
" 9	9	5	Nil	3	"	1	6	15
" 9	10	12	"	5	"	3	43	63
Aug. 22	10	4	4	6	Nil	Nil	4	18
" 23	5	3	Nil	35	3	"	3	44
" 25	9	8	"	15	4	1	5	33
Sept. 1	25	1	9	Nil	Nil	Nil	2	12
Oct. 4	10	4	Nil	"	2	"	2	8
" 25	10	5	1	15	Nil	"	20	41
Sub-total --		55	24	98	9	6	120	312
Total --		139	95	132	11	18	442	837

(1) One rainbow and one cutthroat trout caught by netting in the Upper Lake not included in this table.

Table III - Length-Frequency Distribution of Lake Trout Caught
by Angling and Netting from both Waterton Lakes.

Length (Inches)	Upper Lake		Lower Lake	
	Angling	Netting	Angling	Netting
6-7	-	2	-	-
8-9	-	5	-	-
10-11	1	8	-	-
12-13	1	6	-	1
14-15	3	9	1	3
16-17	3	16	3	7
18-19	3	11	11	5
20-21	5	7	20	6
22-23	1	6	18	5
24-25	1	3	17	7
26-27	1	3	10	7
28-29	-	1	3	6
30-31	-	-	3	2
32-33	-	5	-	2
34-35	1	1	3	4
36-37	-	1	-	-
Totals	20	84	89	55

Table IV - Weight-Frequency Distribution of Lake Trout Caught
by Angling and Netting from both Waterton Lakes.

Weight (Pounds)	Upper Lake		Lower Lake	
	Angling	Netting	Angling	Netting
Less than 1	2	20	1	1
1-2	6	19	2	6
2-3	2	15	10	7
3-4	4	9	21	4
4-5	2	3	3	7
5-6	1	3	18	2
6-7	-	2	10	3
7-8	1	1	4	4
8-9	-	-	3	3
9-10	-	2	4	2
10-11	1	2	3	4
11-12	-	-	2	2
12-13	-	-	1	2
13-14	-	-	1	-
14-15	-	1	1	1
15-16	-	1	2	1
16-17	-	2	-	-
17-18	-	1	-	1
18-19	-	1	1	1
19-20	-	-	-	-
More than 20	1	2	2	4
Totals	20	84	89	55

Table V - Age-Frequency Distribution of Lake Trout Caught
by Angling and Netting from both Waterton Lakes.

Age in Completed Years	Upper Lake		Lower Lake	
	Angling	Netting	Angling	Netting
3	2	13	-	-
4	1	5	2	5
5	-	8	11	8
6	4	23	26	8
7	8	14	22	6
8	4	8	18	16
9	-	5	6	5
10	-	2	2	2
11	-	1	1	2
12	-	1	-	1
13	-	-	-	1
14	1	-	1	1
15	-	1	-	-
16	-	1	-	-
Totals	20	82	89	55

Table VI - Spawning Condition of Lake Trout
by Age Groups.

Note: A - No. ready to spawn; B - No. not ready to spawn

Age in Completed Years	Lower Lake				Upper Lake				Total
	Male		Female		Male		Female		
	A	B	A	B	A	B	A	B	
3	0	0	0	0	0	5	0	1	6
4	0	5	0	2	0	2	0	3	12
5	1	10	2	6	0	1	1	6	27
6	6	9	6	12	4	11	4	9	61
7	10	5	8	5	7	3	7	6	51
8	9	4	9	11	7	1	2	3	46
9	3	0	5	2	0	0	4	0	14
10	4	0	1	0	0	0	2	0	7
11	2	0	1	0	0	0	1	0	4
12	0	0	1	0	1	0	0	0	2
13	1	0	0	0	0	0	0	0	1
14	1	0	1	0	0	0	1	0	3
15	0	0	0	0	0	0	1	0	1
16	0	0	0	0	1	0	0	0	1
Total	37	33	34	38	20	23	23	28	236

Table VII - Average Lengths and Average Weights for
One-Inch Length Ranges of Common Whitefish
Taken from both Waterton Lakes.

Length Range (Inches)	Average Length (Inches)	Weight Range (Pounds)	Average Weight (Pounds)	Number of Specimens
<u>Upper Lake</u>				
6- 6.9	6.42	0.06-0.09	0.07	3
7- 7.9	7.47	0.09-0.22	0.14	37
8- 8.9	8.24	0.13-0.34	0.20	55
9- 9.9	9.40	0.22-0.56	0.33	58
10-10.9	10.15	0.31-0.47	0.40	30
11-11.9	11.12	0.44-0.65	0.54	4
12-12.9	12.42	0.69-1.00	0.81	24
13-13.9	13.37	0.81-1.19	1.03	21
14-14.9	14.35	1.06-1.53	1.29	32
15-15.9	15.31	1.06-1.88	1.54	38
16-16.9	16.29	1.56-2.19	1.95	7
17-17.9	17.29	1.75-2.69	2.38	7
18-18.9	18.19	2.75-3.31	3.01	4
<u>Lower Lake</u>				
6- 6.9	6.25	-	0.11	1
7- 7.9	-	-	-	Nil
8- 8.9	8.42	0.22-0.32	0.26	3
9- 9.9	9.44	0.25-0.37	0.32	4
10-10.9	10.48	0.41-0.51	0.45	5
11-11.9	11.38	0.62	0.62	1
12-12.9	12.39	0.72-1.06	0.84	8
13-13.9	13.25	0.81-1.19	0.99	15
14-14.9	14.45	1.13-1.50	1.34	16
15-15.9	15.37	1.37-1.84	1.61	31
16-16.9	16.22	1.59-2.22	1.90	17
17-17.9	17.19	2.06-2.88	2.32	8
18-18.9	18.22	2.78-3.31	3.03	8

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