APPENDIX NO. 7a.

PHYSICAL AND CHEMICAL STUDIES
in the
SOCKEYE PRODUCING LAKES
of the
SKEENA RIVER.

CONTENTS

A. INTRODUCTION - A general survey of the Skeena river and its lakes with some pertinent figures on drainage area, lakes and geology.

B. LAKE STUDIES - Physical studies and records of certain lakes commencing with Lakelse as a reference lake and considering the remainder so far as possible under the headings of Physiography and Morphometry, Temperature, Transparency, Dissolved Oxygen and Hydrogen-ion Concentration.

The lakes considered are :-

I LAKELSE LAKE
II JOHNSTON LAKE
III ALASTAIR LAKE
IV KITSUMGALLUM LAKE
V KITWANGA LAKE
VI KISPIOX LAKES
VII MORICE LAKE
VIII BABINE LAKE
IX NILKITKWA LAKE
X MORRISON LAKE
XI MOTASE LAKE
XII BEAR LAKE
XIII AZUKLOTZ LAKE
XIV SUSTUT AND ASITKA LAKES
VX JOHANSON LAKE
XVI DAMSHILGWIT AND SLAMGEESH LAKES
XVII KLUATANTAN LAKES

C. TABLE - A composite table of these lakes including areas, avg. depths, turbidity etc.

D. DISCUSSION - The relation of physical conditions to sockeye production.

E. RECOMMENDATIONS.

INTRODUCTION

The Skeena river drains into the Pacific ocean just south of the city of Prince Rupert and is located geographically by the points 54° 10' N. Lat., 130° 10' W. Long. Its eastern limit extends some 200 miles inland, embracing an area of drainage of 19,300 sq. miles, equivalent to twice the area of Lake Erie or just slightly less than the area of the Province of Nova Scotia. It reaches through the Coast range mountains to find its major source of supply from the eastern slopes of this range, the Babine range, and, in its extreme northern source, from the very western slopes of the Rockies.

Geologically the lower, more coastal region of drainage is of Mesozoic vintage and composed mainly of igneous extrusions of granite and diorite. Further inland, about 150 miles, the exposures are of a Cretaceous and Jurassic time (particularly from the lower Cretaceous) and made up of sedimentary rocks. A number of coal deposits are known with certain of these being actively exploited (Telkwa river coal field). Silver, lead and copper constitute the other main mineral resources in this area.

With the exception of the main valley basin, the vast majority of this watershed is between 2,000 and 5,000 feet high, with the balance over 5,000 feet. Its southern drainage is just bordered by the northern limits of the Douglas fir. On the average it is densely wooded, particularly the coastal section up to 150 miles inland which is characterized in its lower altitudes by spruce, cedar, hemlock and larch. Poplar and aspen appear in greater abundance beyond this zone which is coincident with a change in soil type and reduction in average precipitation.

There are over fifty charted lakes of an area exceeding 1,000 acres involving twenty-seven lakes which are utilized by salmon. These in turn can be further reduced to twenty-one of distinct importance from the aspect of salmon production. They may be listed as (1) Johnston (2) Alastair (3) Kitsumgallum (4) Lakelse (5) Kitwanga (6) Swan (7) Club (8) Stephens (9) Morice (10) Babine (11) Nilkitkwa (12) Morrison (13) Bear (14) Azuklotz (15) Asitka (17) Johanson (18) Damshilgwit (19) Slamgeesh (20) Kluayaz (21) Kluatantan.

During the course of the investigation certain of these lakes have received considerably more attention than others. It has been a balance between abundance of sockeye frequenting the lake, suitability for study and accessibility. Since there is but one highway and one railroad, and each of these subject to temporary blockage through floods or snow drifts, this latter consideration has been of paramount importance. The lake singled out for most intensive study was Lakelse lake, a small, shallow lake, twelve miles from the town of Terrace on the main Skeena river road and rail communication.

The other, to which much consideration has been given, was Babine lake, the major sockeye spawning area for the whole river system.

Each of these lakes is considered below, mainly in its physical aspects commencing with Lakelse lake to form the "reference lake" for the remainder. These latter have been dealt with as they occur from west to east.

I THE LIMNOGRAPHY OF LAKELSE LAKE, BRITISH COLUMBIA.

CONTENTS

INTRODUCTION

During the past five years (1944 - 1948) physical and chemical studies have been conducted on Lakelse lake, B.C., as part of the programme of salmon research on the Skeena River (Pritchard 1947). It has been the express purpose of "The Skeena River Salmon Investigation" to examine the conditions for all species of salmon with particular interest in the sockeye salmon, *Oncorhynchus nerka*. Primarily the investigation has been designed to establish conservation measures.

The life cycle of sockeye usually involves at least one year of lake residence. It is during this lacustrine stage that the greatest mortality befalls the young sockeye (Foerster 1938; Brett 1947). In recognition of the ~~consequent~~ significance of lake studies in this investigation general surveys of the more important bodies of water in the Skeena River drainage have been conducted. Lakelse lake was singled out for particular attention in an effort to elucidate the more limited findings in other areas by a critical study of one area.

In setting forth these data, although strictly a record and study of the physical structure of the lake, an effort has been made to demonstrate what relation these have to sockeye survival, both young and old, and what limitations are imposed by this particular environment. The investigation was initiated for biological reasons, consequently it is the biological significance which is of paramount interest.

The term "limnography"[x], although not in common usage, has been introduced by reason of its particular applicability to such a study as this. The keynote is that of the physical structure of the lake. No account of the orientation or distribution of animal life within the lake is presented.

---

[x] Defined as "a study of the physical structure of a lake". This eliminates the biological consideration implied in the work "Limnology".

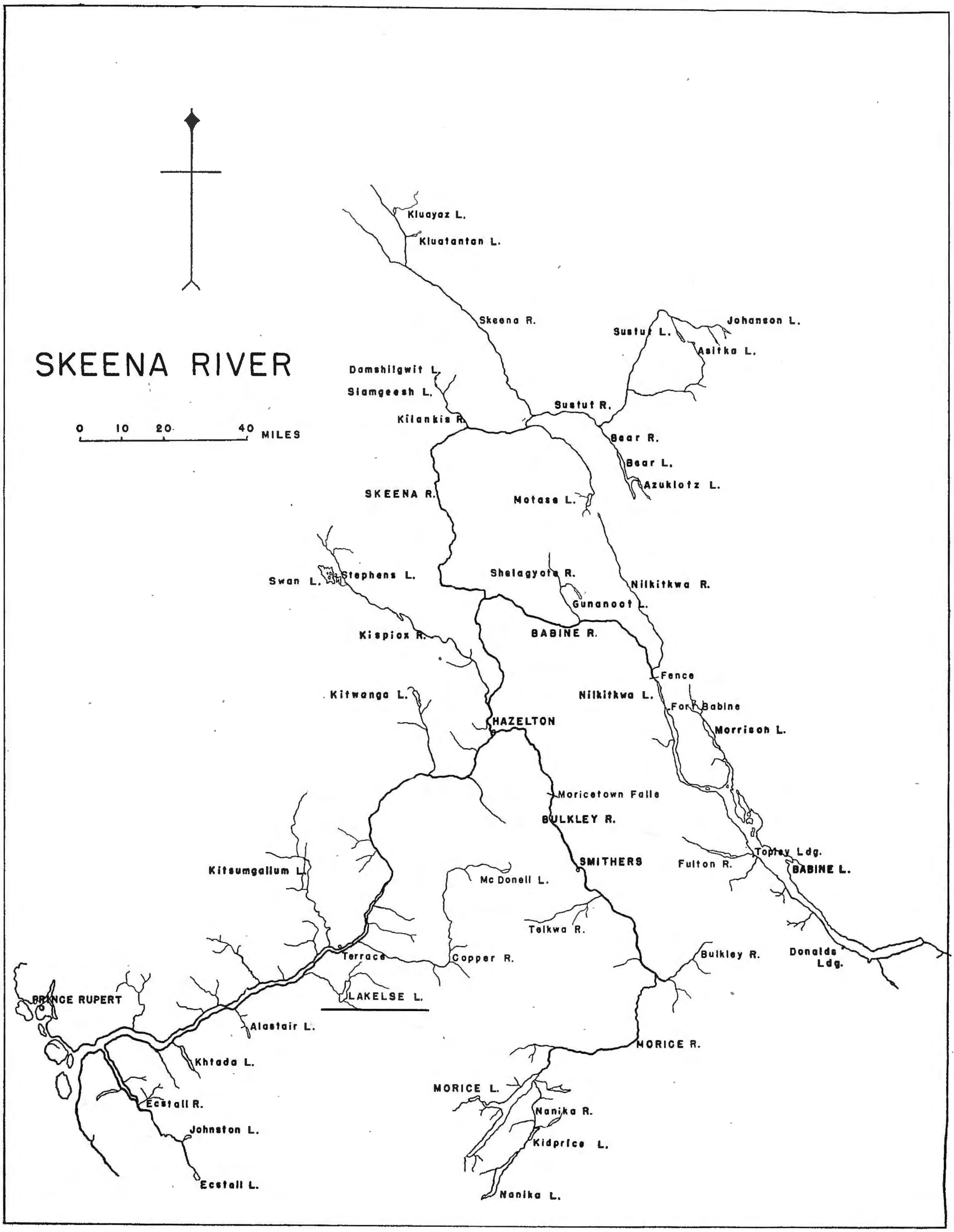


Figure 1. Map of the Skeena River, British Columbia, showing position of Lakelse lake in relation to the complete drainage.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

Lakelse lake, Lat. 54°30' N., 128°40' W., is situated seventy miles directly east of the coastal city of Prince Rupert and about ten miles south of the Skeena river (figure 1). To the west and east of the lake, mountains rise to 5,000 feet (1,500 meters) and more, forming a basin two to seven miles wide which crosses the Skeena valley at Terrace and extends south to the Kitimat arm of the Pacific. A low flat-topped rise of 300 feet (92 m.) in the valley basin just south of the lake forms the division of drainage between the lake and the Kitimat arm. The geological structure and fossil remains indicate that the area was once continuous with the ocean, a possibility which is readily conceived by studying the land elevations. The height of the lake itself is reported at 220 feet (67 m.), about 30 feet (9.2 m.) above the level of the Skeena river at the point of outlet of the Lakelse river into the former.

The mountains of this area constitute a portion of the eastern margin of the Coast Range which was lifted up from pre-existing rocks during the Jurassic period by enormous upwellings of igneous magmas of an acidic nature. These rocks in the form of multiple batholiths consist mainly of granite, diorite and quartz porphyry. The exposure of the basin itself is of more recent Pleistocene time and is mainly alluvium and glacial silt (Marshall 1926).

During the evolution of the Glacial age much of this whole coastal region was depressed 500 to 600 feet by an immense thickness of ice. With its recession and the uplifting of the land masses, some 20,000 years ago, the connection and drainage to the Kitmat arm was severed and dammed up to form the present lake (Hanson 1923).

Climate

The climate of the Lakelse lake area can be judged from the records taken at the meteorological station at Terrace, just ten miles due

Figure 2. Aerial view of Lakelse lake taken from 17,000 feet showing the north end of the lake and Williams creek. (By the courtesy of the British Columbia Government).

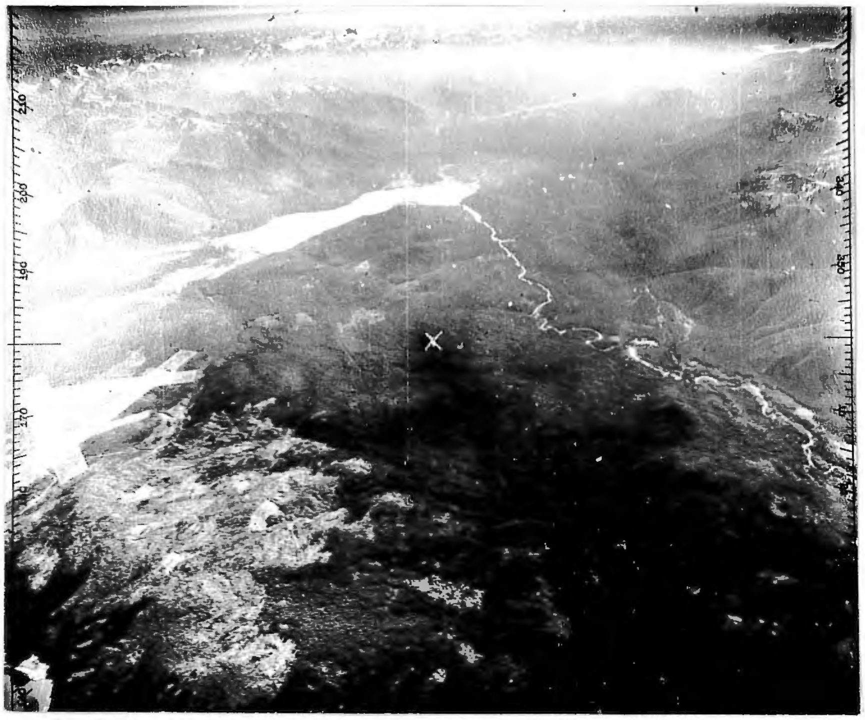


Figure 3. Oblique aerial view of Lakelse lake taken from 17,000 feet. The lakelse river, draining from the south end is clearly visible. In the upper right-hand corner, the inland tip of the Kitimat arm is included. (By the courtesy of the British Columbia Government).

north of the lake, and from recent records taken during the spring and summer months at the lake itself. These latter indicate a slightly greater precipitation and a somewhat more moderate temperature at the lake when compared with those from Terrace (May to September), although very similar weekly means exist. The body of water and the criss-crossing mountain ranges of the Lakelse and Skeena river valleys would account for such local differences.

The annual mean temperature for Terrace during the past 33 years (B.C. Climate 1945) was 44°F. (6.7°C.). Although the temperature rarely rises above 90°F. (38°C.) nor falls below 0°F. (-18°C.) and is therefore of a fairly moderate nature, the winters are somewhat more extreme in their frequent heavy snowfalls and continued frost which may prolong the winter well into April in the heavily wooded country surrounding the lake. In this manner a considerable reservoir of water is retained in the form of snow and ice particularly on the mountain sides.

The spring may well be a time of floods, gouging out river beds and cutting new courses to leave portions of the old water ways neglected in later reduced flow. This is a characteristic of a great deal of the Skeena river country and in both the spring and the late fall constitutes a potential and unpredictable threat to the survival of salmon eggs from a given spawning.

The average precipitation for the same 33-year period is recorded (B.C. Climate 1945) as 46.85 inches (119.0 cm.). The months of May to August present the minimum period of rainfall, with an average of just under 2 inches (5.1 cm.) per month, following which there is a rapid rise of rain and later snow to a peak in November of 7.48 inches (19.0 cm.).

In the spring, lake and stream levels have been found to rise more in accordance with hours of sunlight (melting snow) than with precipitation, a relation which is gradually supplanted by the effect of precipitation alone with the progress of the seasons into the summer months. By August and September when the adult sockeye are entering the streams, rainfall appears

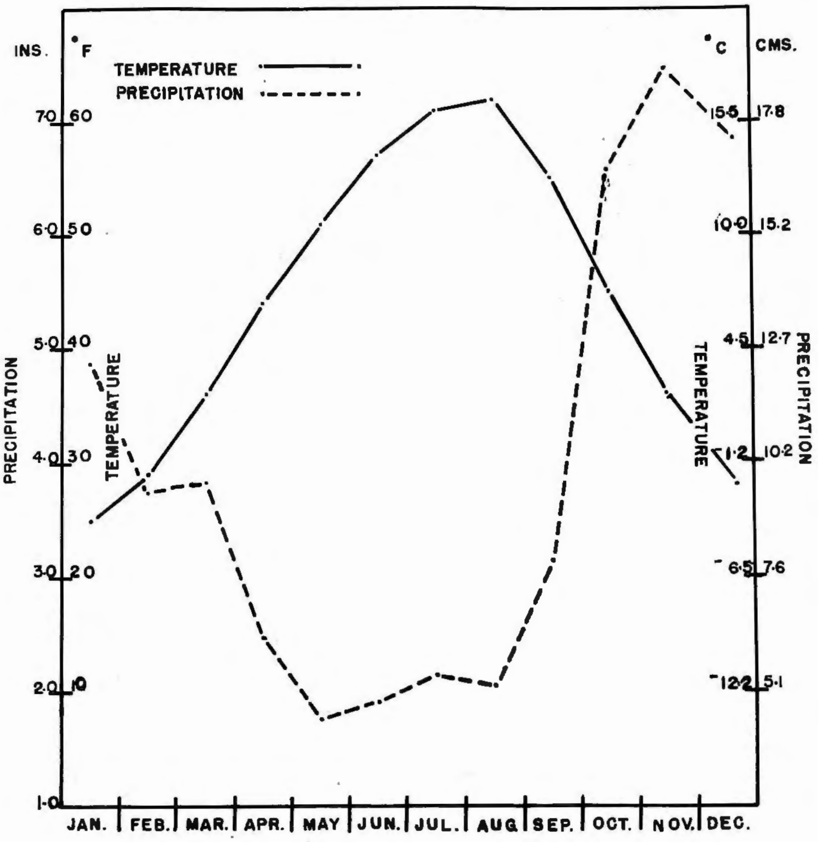


Figure 4. Average temperature and precipitation at Terrace, B.C.

to be all important in maintaining the height of the rivers and consequent covering of the spawning beds, with the exception of a few spring-fed tributaries (e.g. Scully creek). An all-over reduction in the precipitation during those months in the Skeena river drainage appears to result in a possible reduction in the subsequent commercial catches of adult sockeye (cf. Hagman 1938).

In figure 4 (table I) have been depicted the mean monthly variations in temperature and rainfall as recorded at Terrace, B.C., for the years 1913 to 1945 inclusive. The location of the lake is such that it is just on the border between coastal weather conditions and the drier inland state. As a result, it experiences considerable variation in weather, but can be considered as characterized by a moderate climate with fairly heavy rain and snowfall.

TABLE I

Thirty-three year average of temperature (°F) and rainfall (inches) at Terrace, B.C.

Month	Temp.	Rainfall	Month	Temp.	Rainfall
Jan.	25	4.89	July	61	2.14
Feb.	29	3.73	Aug.	62	2.06
Mar.	36	3.82	Sept.	55	3.16
April	44	2.48	Oct.	45	6.58
May	51	1.76	Nov.	36	7.48
June	57	1.90	Dec.	28	6.85

Size, Shoreline and Bottom Configuration

The lake is approximately 5.4 miles in length along a N.E. - S.W. axis and varies from 0.7 to 1.5 miles in width, covering an area of some 5.47 square miles, or 3,500 acres (14.2 km^2). With a regular shoreline the

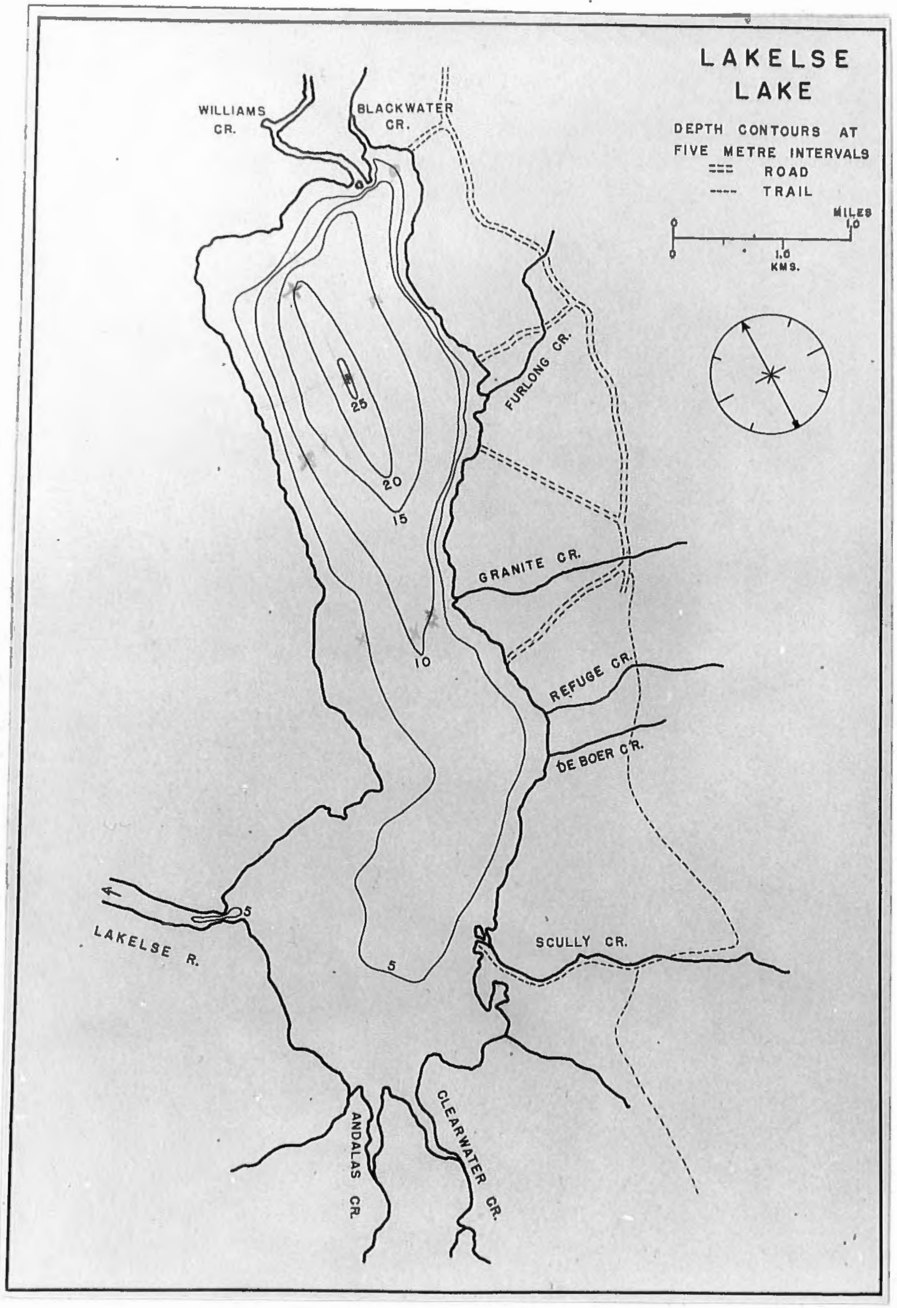


Figure 5. Map of Lakelse lake, British Columbia, showing bottom configuration.

shore development[x] is not great, being just short of twice the minimum and equal to 1.83. It is characterized by many reed beds and very little rock with gradual sloping beaches.

Figure 5 illustrates the shape and the bottom configuration, the latter plotted to five metre intervals. The southern end is particularly shallow and reflects the general condition throughout, in which the mean depth is only 7.8 metres (24 feet). The areas and volumes for each 5 metre interval have been recorded in table II.

The shape and general configuration of a lake in all its particular characteristics are so profound in their biological significance that to deal in any way with the manner in which these apply to sockeye survival would be to deal with many of the major problems of lake biology. Rawson (1939) has brought together many of the physical features of a lake and illustrated how they might be represented by "A chart suggesting the interrelation of factors affecting the metabolism of a lake". These factors are drawn together in one final co-ordinating end-point of "productivity".

The particular feature of Lakelse lake which defines so much of its nature is its mean depth of 7.8 metres. Young sockeye are considered to be limnetic rather than littoral in habit during the summer months (Ricker 1937). Being so shallow the limnetic zone is correspondingly reduced and the average littoral temperatures tend to rise to considerable heights, adding to the limitations imposed. On the other hand this promotes growth of aquatic plants and animals resulting in a greater unit abundance of food, and a lake capable of supporting larger populations of young fish. The net balance is one of favourable conditions of growth and survival for sockeye if only the feature of productivity is considered (McMahon 1948).

---

[x] The shore development is the ratio of the actual shoreline length to the circumference of a circle with an area equal to that of the lake.

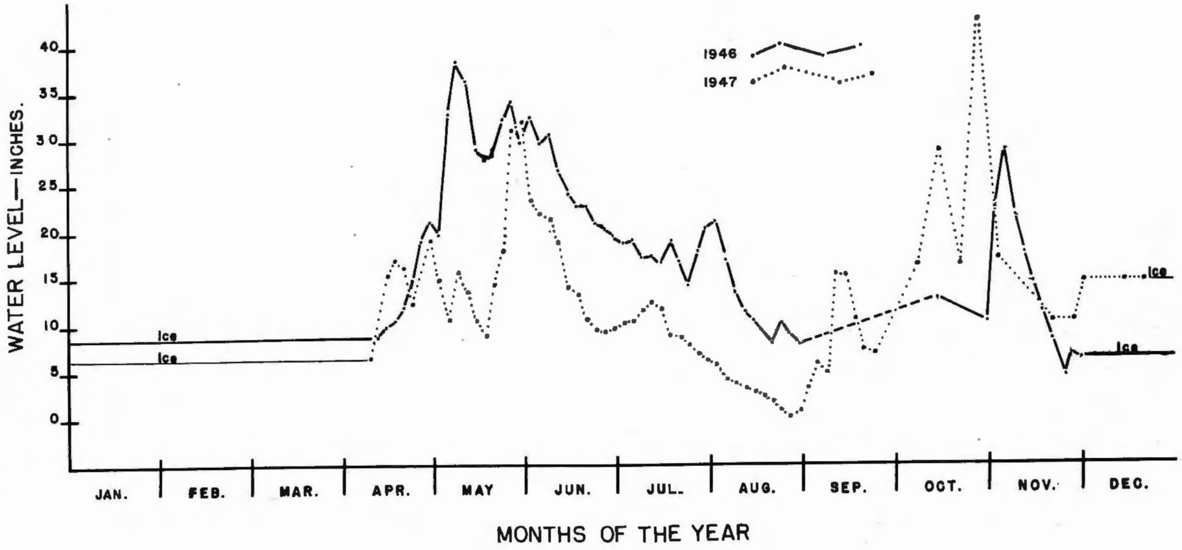


Figure 6. Annual variation in water level for 1946 and 1947 at Lakelse lake.

Morphometrical Tables

The morphometrical data have been brought together in table II.

TABLE II

The morphometry of Lakelse lake

Area	14.17 sq.kms.	(5.47 sq. miles)
Maximum length	8.7 kms.	(5.4 miles)
Maximum width	2.4 kms.	(1.5 miles)
Maximum depth	32.2 m.	(98 feet)
Mean depth	7.9 m.	(24 feet)
Volume	108.0 x 10^6 cu.m.	(141.3 x 10^6 cu.yd.)
Shore development	1.83	
Elevation	72.2 m.	(220 feet)

Depth	Area in Hectares	Percent. Total Surface Area	Strata.	Volume in cu.m. x 10^6	Percent Total Volume
0 m.	1420	100.0 %	0 - 5 m.	55.7	51.6 %
5	808	77.0	5 - 10	30.4	28.1
10	412	29.1	10 - 15	15.4	14.3
15	205	14.4	15 - 20	4.9	4.5
20	52	3.7	20 - 25	1.4	1.3
25	3	0.2	25 - 32.2	0.2	0.2
			Total	108.0	

Drainage and Water Level

The main stream drainage into the lake is that from Williams creek at the northern end, supplemented by the lesser streams of Granite and Scully creeks from the east, and Clearwater and Andalas creeks from the south, the only outlet being the Lakelse river. This latter flows fairly directly northwest from the southwestern portion of the lake out to the Skeena twelve miles distant and, with the exception of the first mile, is characterized by an even, rapid flow over coarse gravel and boulders. The mouth is narrow and deep, expanding into a wide, shallow arm (800 feet) with little noticeable current and in many ways simulating a small adjacent lake preceding the more turbulent portion of the river further downstream.

The general characteristics of these rivers (figure 5) have been outlined in table III.

TABLE III

Physical characteristics of the main streams entering Lakelse lake

River	Summer Temp.	pH		Clarity	At Outlet		Gradient	Bottom.
		Red	Blue		Width	Depth		
William Cr.	8-12°C.	7.3	7.1	Fairly opaque	1. 60'* 2. 60' 3. 15'	4'	1/160	Gravel & Sand.
Blackwater Cr.	17-20°C.	---	6.5	Fairly clear	60'	5'	1/800	Mud, Silt and Sand.
Granite Cr.	8-10°C.	7.2	7.0	Clear	25'	2'	1/25	Boulders, Gravel & Sand.
De Boer Cr.	9-11°C.	7.3	6.9	Clear	25'	1'	1/25	Sand & Gravel.
Scully Cr.	8-10°C.	7.3	7.2	Clear	25'	3'	1/80	Sand & Gravel.
Clearwater Cr.	10-13°C.	7.9	7.7	Clear	200 '	2'	1/300	Sand & Silt.
Andalas Cr.	7-10°C	7.9	7.6	Opaque	200 '	2'	1/300	Silt.

* Three separate outlets.

For the past five years approximately eighty per cent of the total adult sockeye run has entered Williams creek. While spawning they distribute themselves over its many suitable gravel beds for a distance of four to four and one-half miles (Pritchard and Cameron 1940). The major supply of water to the lake comes from this source which is mainly glacial in origin. Williams creek in providing the spawning beds, constitutes one of the main physical features of importance in a salmon producing body of water.

The fluctuations in volume discharge of Williams creek are reflected in fluctuations of water level within the lake and in the Lakelse river. A continuous record of the lake water-level changes consequently provides a picture of the variations in river heights, in the case of Williams creek to a lesser degree, while in Lakelse river to a slightly greater degree.

Peaks of high water usually occur in May following melting of snow under intense sunlight and in late October or early November as a result of heavy precipitation. The low levels occur between the end of August and the beginning of September, and just prior to ice formation (figure 6).

The late summer minimum coincides with the major spawning period. If there is a particular drought at this time, a reduction in the amount of spawning bed present may seriously reduce the efficiency of egg deposition. However, if abnormally high water exists then many beds may be left exposed in a subsequent drop of level. It would appear that an average level somewhere near that of the final freeze-up level would be most suitable for successful production of young fish from a given seeding.

TEMPERATURE

Procedure

The temperature variation has been recorded for Lakelse lake at a single station in the vicinity of the greatest depth, Station 1, during the months of July to September of 1944, April to September 1945, and continuously throughout all months of the year from April, 1946, to the present time. It is expected that these records will continue on the present basis which provides for regular vertical readings taken twice per month (first and middle of each month) with the possible exception of periods during the winter when travelling on the ice surface of the lake is not safe. Throughout this study a standardized Negretti-Zambra deep-sea reversing thermometer, graduated to fifths of a degree Centigrade, has been used (Kemmerer et. al. 1923). In addition, a bathythermograph (Spilhaus 1937, 1940) was used in 1946 and operated for more extensive recordings in the early part of each season's work. Its use was directed toward determining the thermal structure of the whole lake rather then of one column, thus testing the degree of representation afforded by the single station. Since the lake is characterized by one main depression the complications of thermal structure introduced by submerged depressions (Welch and Eggleton 1932) are not present. The most representative position for complete temperature readings automatically becomes the deepest point in the lake.

line of 0°

dotted line for [illegible]

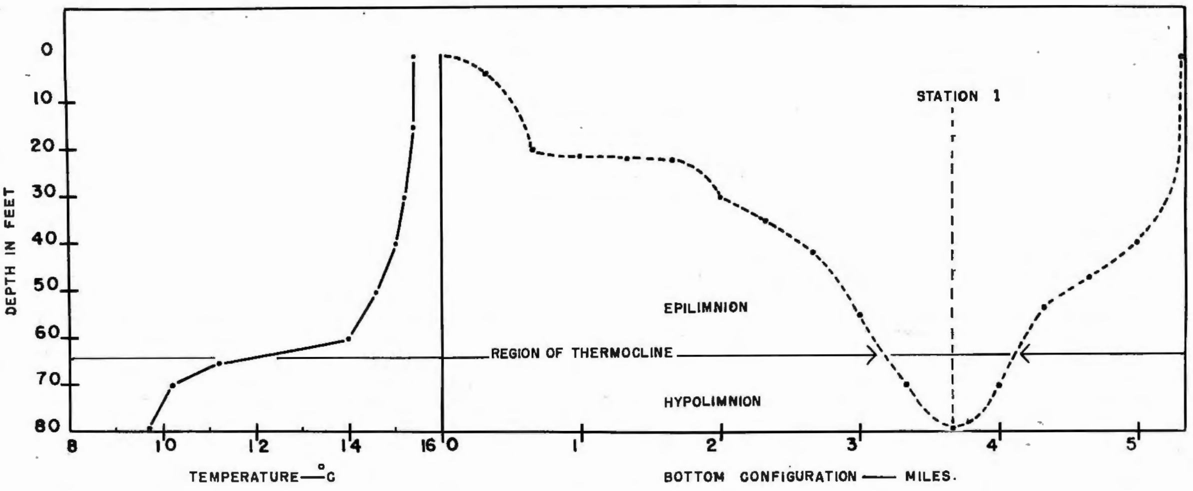


Figure 7. Thermal stratification at Station 1, Lakelse lake, Sept. 14, 1945, and bottom configuration of Lakelse lake in longitudinal cross-section.

Seasonal Changes

1. Spring Overturn. With the fairly moderate climatic conditions in winter, the ice coverage is not excessive, amounting to a maximum of twenty-four inches of porous snow-ice intermingled with layers of hard ice. Toward the end of March in an average year, sunshine and warm winds constantly melt the surface and reduce the thickness. The break-up varies from abrupt upheaval to gradual displacement depending entirely on the meteorological phenomena which precede it. Once the ice has been reduced to a few inches and shows definite cracks and breaking points a heavy wind can be disruptive, the actual break-up being followed in quick succession ? by the spring overturn (Welch, 1945) and a rapid rise in surface temperature.

For the years 1945, 46 and 47 the overturn has occurred within one day of April 4th, while in 1948, which was has gone down on record as an ~~most~~ exceptional year, the overturn did not occur until April 24th. The average and usual state is a break-up and overturn in the first week of April.

2. Thermocline Formation and period of summer Stagnation. The presence of a true thermocline[*] rarely becomes apparent in the first month of heat interchange but thermal stratification is present from the very first days and an upper circulation of water of different depths occurs to varying degrees in proportion to the intensity and duration of the wind. This is in direct contrast to the period leading up to ice formation in the fall of the year.

The significance of a true thermocline must come in the fact that once a thermal stratification of greater than 1°C. per meter has been established then some degree of permanency exists in the presence of definite strata bodies of water within the lake itself. These are of entirely different thermal and flow characteristics and distinguished as the epilimnion, the thermocline

metre above ?

---

[*] Defined as equal to or greater than a change of 1°C. per meter (Welch 1935) + not much used now!

?

and the hypolimnion, all well established and accepted zones within any thermally stratified lake above 4°C. (Birge and Juday 1914).

Intense winds, sweeping up the open Kitimat Arm of the coast and through the Lakelse lake valley, often constantly disrupt and convert the thermal layering of the lake resulting in marked flustuations in the presence, absence or position of one or more true thermoclines, yet the very deepest portion of the lake appears to remain at least partially out of circulation. Lakelse lake, then, is becomes a very poor example of the classical concept of a thermally stratified lake in midsummer. It might best be described as a lake which undergoes thermal stratification of varying degrees, sometimes exceeding 1°C. per meter, with an upper zone of water which tends to circulate as a separate body within itself and which becomes more apparent as the max a peak in water temperature is approached. This body of water usually varies from 35 to 50 feet in its lower level of circulation and yet may be completely dispersed within a few hours by wind effect.

?

elementary

epilim.

– metres

no

An rare example of a true thermocline is depicted in figure 7 illustrating the presence at this time of a very deep large epilimnion developed late in the year. The point of greatest temperature difference at 65 metres feet, and therefore close to the centre of the thermocline, has been horizontally transposed to indicate on the diagram of the lake the relation of the epilimnion, thermocline and hypolimnion. That the volume major portion of the lake is taken over by an unstable epilimnion in the later stages of summer stagnation is evident.

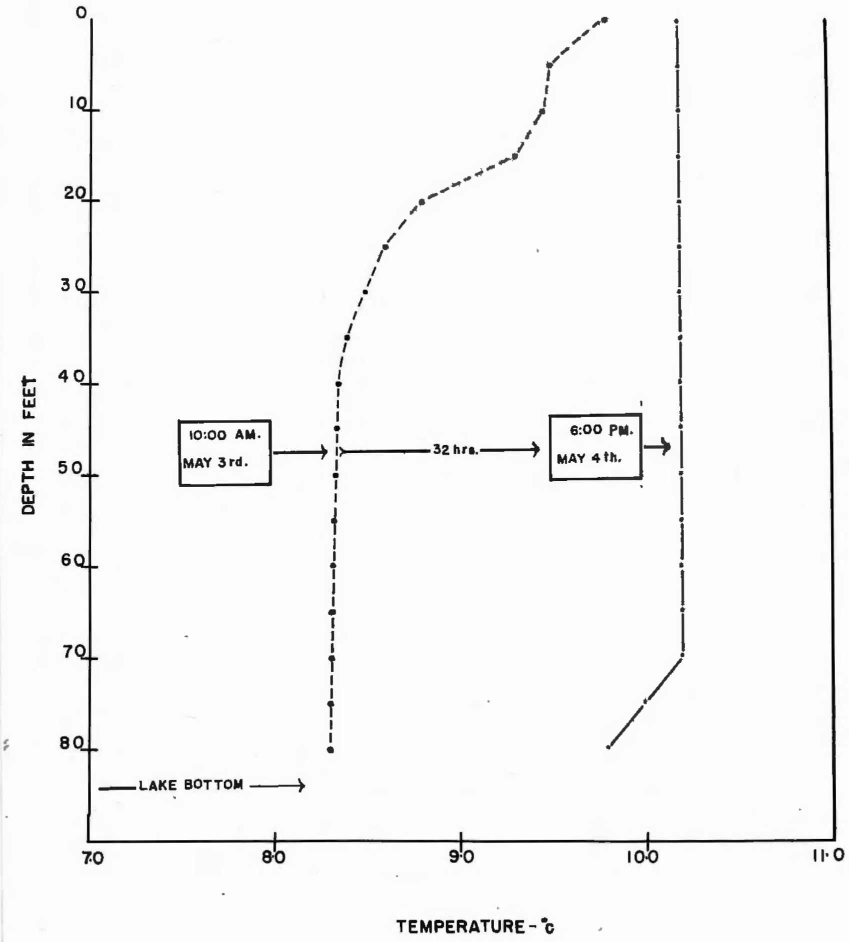
??

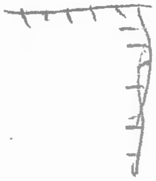
?

The depth of a lake can be sufficiently great to preclude the effect of disturbances on the surface becoming manifest in any particular manner below 300 feet (Alsterberg 1930; Halbfass 1931; Krogh and Lange 1932; Wright 1931). In general for lakes of the Skeena River Drainage (See Prog. Rep., Pac. Biol. Stn., Nos. 66 to 70, 72 & 74) the thermal status of any zone of water below this depth is virtually constant within one degree centigrade.

effect heating & wind currents only to 100 m±

all summer?
all year?





delete .0.

unbelievable amount of heating in one day.

Figure 8. Change in thermal stratification from May 3rd to May 4th at Station 1, Lakelse lake, following a heavy wind.

This is true, no matter what the surface area or lake configuration may be. For lakes such as Lakelse of 100 feet or less in depth, wind can have a dramatic effect. A very striking example of this was obtained in the first week of May, 1946. A bathythermograph recording was made at 10:00 a.m. on May 3rd, following a number of days of calm, warm weather. By noon of May 4th one of the heaviest blows of the year had churned the lake into a comparative maelstrom (Beaufort rating of 6). It was possible to obtain a second recording 32 hours after the first (see figure 8). The whole lake had been put into circulation sweeping the warmer waters of the south section to intermingle with those of the north central portion and the bottom temperature (at 80') was raised from 8.3°C. to 9.8°C., resulting in a complete overturn. highest mean temps

The maximum overall temperature states for each year from which the annual heat budgets have been calculated appear in table IV. The average peak condition (1944-47) has come some time in the month of August when the whole lake became warmed to an extent which resulted in temperatures averaging 19.1± 0.9°C. to 10.9± 1.4°C. from top to bottom.

TABLE IV

Surface and bottom temperatures at the time of maximum thermal state, Station I, Lakelse lake.

Year	Date	Surface	Bottom
1944	Aug. 8	19.4°C.	13.0°C.
1945	" 8	20.2	9.2
1946	" 29	18.8	10.3
1947	" 15	17.8	11.1
Average	Aug. 15	19.1 ± 0.9°C.	10.9 ± 1.4°C.

3. Fall Overturn. By September all strata of the lake with the exception of the greatest depths have commenced to cool. A month later there is complete temperature decline, the upper strata losing heat units more rapidly than the lower strata, resulting in final uniformity of temperatures throughout. This state occurs at a temperature distinctly above 4°C. at which the density of water is maximal. In 1946 it occurred by approximately October 31st with a uniform temperature of 7.0°C., while in 1947 a consistent and almost parallel decline of temperature for all strata commenced in early October and finally merged just prior to the overturn. This marks the start of the overturn which continues until a new stratification in reverse occurs when the surface cools below 4°C. The average duration of the overturn may extend over many days, rapid~~ly~~ cooling being effected by nightly drops in air temperature well below freezing (Climate of British Columbia 1945). By the end of November ice has usually closed the lake to further wind produced currents. Table V contains a summation ? or of the data for duration of overturn and commencement of surface freezing.

TABLE V

Fall overturn and winter data, Lakelse lake

	Fall Overturn			Winter Stagnation		
Year	Date Commenced	Temp.	Date 4°C. reached	Date of Freeze-up	Min. Bottom Temp.	Date of Break-up
1946 - 7	Oct. 31	7.0°C.	Nov. 8	Nov. 24	3.7°C.	April 15
1947 - 8	Oct. 15	11.0°C.	Dec. 8	Dec. 20	3.2°C.	April 23

4. Winter Stagnation. The sharp drop in temperature ceases for the lake as a whole when a temperature of 4°C has been reached. Only the surface waters continue to cool at an accelerated rate, no longer passing into circulation by increased depth, but remaining at the surface and giving rise to the usual inverse thermal stratification. The extent of the upper stratification at first exceeds 1°C. per meter of depth. As further ?

or re

rapid gradient is reduced?

cooling takes place and the ice surface is established this steeply inclined thermal state is gradually dispensed, reducing the temperatures at each depth progressively until the more stable bottom temperatures are involved. A reduction of temperature at 80 feet has been apparent in both 1947 and 1948.

by conduction ?

With the elimination of wind effect by an ice blanket the thermal changes conform more readily to the state described for most ice covered lakes (Welch 1935; Greenbank 1945). The term "stagnation" however is somewhat misleading here in that it would imply a marked stability to the water of greatest depth and the absence of any circulation within its bounds. That there may be some exchange as a result of river water displacement would appear possible through inference from the high oxygen content recorded throughout the winters of 1946-47 and 1947-48. The complete thermal variation at 20 foot intervals of depth from April 1946 to April 1948 has been depicted in figure 9, table VI.

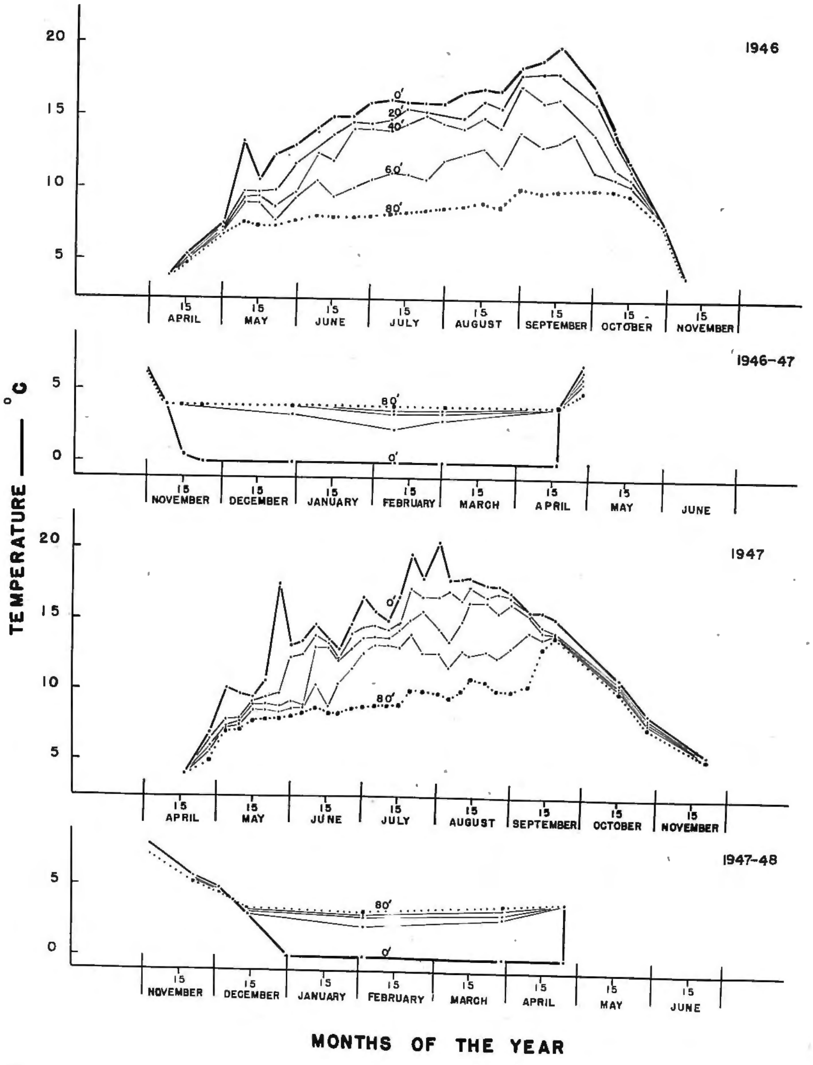


Figure 9. Thermal variation at depths of 20 foot intervals at Station 1, Lakelse lake, from April 1946 to April 1948.

TABLE VI

Temperature variations at 20 foot depths, Lakelse lake, Station 1.

	Depth in feet				
Date	0'	20'	40'	60'	80'
1946					
April 8	4.0°	4.0°	4.0°	4.0°	4.0°
15	5.5	5.3	5.2	5.0	5.0
30	7.7	7.3	7.2	7.1	7.0
May 9	13.4	9.7	9.4	9.1	7.8
15	10.7	9.7	9.5	9.0	7.5
22	12.5	9.9	8.8	7.8	7.5
30	13.1	11.7	9.8	9.4	7.8
June 8	14.4	14.0	12.5	10.6	8.2
15	15.1	13.8	12.0	9.5	8.1
22	15.2	14.6	14.2	10.1	8.2
30	16.1	14.6	14.2	10.7	8.3
July 8	16.3	14.9	14.1	11.2	8.4
15	16.2	15.6	14.5	11.0	8.5
22	16.2	15.4	15.1	10.7	8.6
30	16.2	16.0	14.5	12.0	8.8
Aug. 8	16.8	16.0	14.3	12.5	8.9
15	17.1	16.2	15.0	12.8	9.2
22	17.0	15.6	14.3	11.6	8.8
30	18.6	18.0	17.2	14.0	10.2
Sept. 8	19.2	18.0	16.0	13.0	9.8
15	20.0	18.1	16.3	13.3	10.0
30	17.0	16.1	13.9	11.2	10.1
Oct. 8	14.2	13.3	11.5	10.7	10.0
15	12.0	11.3	10.8	10.4	9.9
30	7.0	7.0	7.0	7.0	7.0
Nov. 8	4.0	4.0	4.0	4.0	4.0
15	0.5	4.0	4.0	4.0	4.0
23	0.0	4.0	4.0	4.0	4.0
Dec. 29	0.0	3.5	4.0	4.0	4.0
1947					
Feb. 9	0.0	2.4	3.6	3.6	3.7
Mar. 1	0.0	3.0	3.5	3.6	3.8

TABLE VI (Continued)

Temperature variations at 20 foot depths, Lakelse lake, Station 1.

	Depth in feet				
Date	0'	20'	40'	60'	80'
1947					
April 17	4.0°	4.0°	4.0°	4.0°	4.0°
27	6.9	6.5	6.0	5.7	5.0
May 5	10.1	7.8	7.5	7.3	7.1
10	9.7	7.9	7.7	7.4	7.2
15	9.5	9.3	9.1	8.6	7.8
20	10.7	9.5	9.0	8.5	7.9
25	17.6	9.8	8.8	8.4	8.0
31	13.2	12.3	9.3	8.6	8.1
June 5	13.5	12.6	9.0	8.6	8.4
10	14.7	13.8	13.0	10.4	8.8
15	13.6	13.4	13.1	8.9	8.5
20	12.9	12.3	12.4	10.5	8.4
25	14.7	14.0	12.9	11.6	8.7
July 1	16.5	14.5	13.7	12.6	8.8
5	15.5	14.6	13.8	13.2	8.9
10	14.9	14.4	13.8	13.2	9.0
15	16.6	14.8	14.3	13.0	9.0
20	19.6	17.3	15.0	14.0	10.1
25	17.9	16.6	15.6	12.7	10.0
Aug. 1	20.5	16.6	14.4	12.7	9.8
5	17.8	17.0	13.5	11.7	9.5
10	17.9	16.4	14.9	12.8	10.1
13	18.0	17.4	16.3	12.6	11.0
20	17.5	16.6	16.2	12.8	10.7
25	17.5	16.9	15.5	12.4	10.0
30	16.9	16.6	16.2	13.1	10.0
Sept. 6	15.7	15.7	15.4	14.2	10.5
15	15.7	14.6	14.2	13.7	13.0
21	15.2	14.2	14.1	14.0	13.8
Oct. 15	11.0	11.0	11.0	10.9	10.5
28	8.5	8.5	8.2	7.9	7.6
Nov. 21	5.7	5.7	5.7	5.7	5.4
Dec. 1	4.9	4.9	4.9	4.9	4.5
7	4.0	4.0	4.0	4.0	4.0
14	3.0	3.0	3.3	3.4	3.4
1948					
Feb. 2	0.0	2.2	2.8	3.2	3.2
Mar. 29	0.0	2.8	3.1	3.5	3.8
April 25	4.0	4.0	4.0	4.0	4.0

The pitfalls of depicting a dynamic state in static phases are many. The usual four major states have been used to distinguish the main cyclic periods of changing thermal gradient in the lake. The inadequacies in this particular instance are apparent, yet, for clarity in presentation and concept it is convenient to depict the relation in this manner. Yoshimura (1935) has sub-divided the stagnation periods of fresh water lakes into eight distinguishable phases in an attempt to elucidate further the thermal evolution within a lake. Since it is dynamic in nature, division into different categories is in part arbitrary relying on the aspects of importance attached to the study by some particular investigator. In the case of Lakelse lake, being in a north temperate zone, the two physical features which result in major differences in thermal stratification are that it is reduced in temperature through 4°C. and that it becomes ice covered. Any classification of the lake should depend on these phenomena.

rep.

Complete & partial phase cf Ricker!

Heat Budgets

The amount of solar energy incident on any lake surface must determine the final production of animal life in that lake. It is the unit of activation, without which, any amount of basic productive constituents would lie dormant. Attempts to set a measure of the manifestation of this energy in terms of heat units and provide a means of comparing different lakes was advanced through the work of Forel (1901) and Halbfass (1905, 1913), and later developed by Birge (1915) and Birge and Juday (1914, 1921, 1929). The annual heat budget may be defined as the amount of heat necessary to raise the temperature of a lake from its minimum (winter) to its maximum (summer) state. Where winter data do not exist Birge and Juday (1914) have introduced the term "summer heat income" which they have defined as the amount of heat necessary to raise the temperature of a lake from 4°C. to its summer maximum (applicable to temperate lakes only).

Fry says No!!

not limiting

Heat budgets are highest in the most oligotrophic deep lakes!

[illegible] explain - just refs

The significance of heat-budgets has been questioned by each of the above investigators and the conclusions are conflicting. In particular Birge and Juday (1914) have defended and developed its use as a comparative index. Birge (191~~6~~5) states, "No doubt more complete study will show that the heat budgets of the several lakes are influenced by elevation, surroundings, size of affluents and effluents, climate, cloudiness, latitude and other conditions as well, but at present a direct and unmistakable effect of any one of these conditions can be pointed out only in a very few cases, and it is best to consider the budgets in gross and without too much attention to particular circumstances" (p.167). "It allows us to determine the influence of such factors as the area and depth on the amount of heat taken in by them" (p.176). Ricker (1937) in his study of Cultus lake, B.C., comments that "The small heat budget of Cultus lake is a direct reflection of the generally equable climate of the region" (p.376). The relation of heat budgets to productivity in lakes has not been widely considered, yet it would appear that if the energy relations are reflected by heat budgets then this unit should be an index of potential productivity. ND

Whatever the significance may be it is interesting to compare the annual heat budgets of Lakelse lake with those from two other sockeye producing lakes on the Pacific coast, Karluk lake, Alaska (Juday et al. 1932) and Cultus lake, B.C. (Ricker 1937). The immensity of the sockeye populations (Gilbert and Rich 1927) which migrate both into (adult) and out of (young migrant) Karluk lake necessitate a colossal conversion and production of food. Cultus lake, classified as oligotrophic by Ricker (1937), is nearly one-sixth the area of Karluk lake, but only produces by comparison about one one-hundreth as many sockeye (Foerster 1937). Lakelse by proportion in unit area averages less sockeye than Cultus, particularly in peak years (over twice the area of Cultus yet just half the number of sockeye). If considered in gross aspect and neglecting the influence of competing population, the controlling factor would appear to be one of productivity, which, if basically related to the calorific exchange, should be reflected by the heat budgets. Compared with the European and American lakes studies by Birge (1915), Lakelse is the lowest with an annual heat budget of 16,000 gm. cal. per cm^2. Karluk lake is twice this amount and Cultus lies in an intermediate position. Lakelse lake, then would appear to be limited in its production, at least in part, by a low heat budget. no!

Significance of what Temperature

Different periods of growth and different states of temperature acclimation will undoubtedly result in marked variations in temperature responses amongst sockeye. As stated previously the fry and yearlings appear to frequent the limnetic zone, avoiding the littoral region, perhaps because of a temperature intolerance or purely from thermal preference. The latter view is supported by the work of Donaldson and Foster (1940) who state, "From the experimental evidence and field observations, it would appear that the young sockeye salmon are very selective in their choice of water of uniform temperature, choosing that water near the thermocline in preference to warmer surface water or colder waters in the depths of the lakes." They also conclude that "the temperature of the surface layer of water in the lake (Skaha lake, B.C.) was too high for optimum growth, survival, and efficient utilization of food." Ricker (1937) has stated that "the summer feeding of fingerlings appears to be chiefly confined to the region between 5 and 15 metres depth, which includes the thermocline and adjacent narrow strips of the epilminion and hypolimnion. Foraging is limited upward by scarcity of food, and downward by poor illumination or low temperature". The latter conclusion is one made more by inference than direct observation. The same can be said for Lakelse lake, for, with the exception of one single observation, fry have not never been caught or observed

mean temp of trophogenic zone 0-10 m

during the summer in the littoral zone which is the only area where suitable fishing gear has been employed.

Temperature as a direct lethal factor (cf. Fry 1947) and temperature as an indirect factor promoting death through disease have distinctly different operative levels. The effect of the myobacterium <u>Chrondrococcus columnaris</u> as an extreme threat to the survival of salmon under given temperatures has been demonstated by Fish (1948) and Fish and Rucker (1943). The former states (1948) that, "Below 60°F., columnaris disease is of little consequence, but between 60° and 70°F., <u>C. columnaris</u> invades the inevitable cuts and abraisons on fish, quickly establishing a secondary infection that may prove lethal. Above 70°F., <u>C. columnaris</u> becomes a pathogen in its own right and needs no mechanical injuries to open a door through the protecting mucous coating of the skin and gills".

No significant examples of either direct or indirect effects of temperature causing high mortality in sockeye have ever been observed at Lakelse lake. Its all-embracing effect appears to be one of promoting food growth and activity while limiting the scope of foraging mainly to the limmetic and thermoclinal zones. ?

fundamental

not measured!

TRANSPARENCY AND COLOUR

Procedure

As a measure of transparency a standard Secchi disc (Welch 1935) was used and operated at the time of making bi-weekly observations recordings in the centre of the lake at Station 1. By observing the usual methods of operating this instrument, and recording the accompanying weather conditions, a broad classific. categorizing of the Skeena river lakes has been accomplished.

Variation and Average Transparency

A peak in transparency has repeated itself in July and again in September in every year case of continuous observation on Lakelse lake, while the end of May and the middle of October have been characterised by heights of ?

turbidity (figure 10, table VIII). These latter two coincide with periods of flood and may be compared with the graph of water level fluctuation, figure 6. The lake, however, cannot be considered as a typical glacially silted lake for its average transparency from the records of 1945-48 is 10.0 feet (approx. 3 m.) and a record of 17.5 feet (5.3 m.) exists for August 30th 1947.

glac. source ?

Although the main stream discharge into the lake stems from mountain sides of the surrounding terrain and consequently results in a partial silting of the waters, the obstruction to light penetration on an average day must come as much from microscopic organisms and organic matter as from inorganic suspended particles. The temperature relations are probably as responsible for this phenomenon as any other factor. In the summer season, the temperature of the epilimnion is almost invariably higher than the temperature of the cold river waters, thus the silt tends to be carried down to the hypolimnion zone, leaving the upper waters comparatively clear. The exact reverse of this has been found to be true for other lakes in the same drainage.

authority?

TABLE VIII

Mean depths in feet of disappearance and reappearance of a Secchi disc, Lakelse lake, 1945 - 1948

1945		1946		1947		1948	
		April 11	6.4	April 17	10.8		
		" 25	7.6			April 30	11.2
		May 10	7.0			May 15	10.2
		" 25	7.6	May 31	6.5	June 1	3.7
		June 10	8.7	June 15	9.4	" 20	5.7
		" 25	11.3			" 30	7.2
July 23	8.7	July 10	14.8	July 1	12.7		
" 31	9.0	" 25	11.5	" 16	16.5	July 15	14.5
Aug. 6	11.4	Aug. 10	11.4	Aug. 18	14.7	Aug. 2	16.5
" 21	12.8	" 25	7.2	" 30	17.5	" 16	11.2
Sept. 14	13.8	Sept. 10	14.7	Sept. 15	4.0	" 30	5.7
				" 21	3.7		
		Oct. 14	3.6				

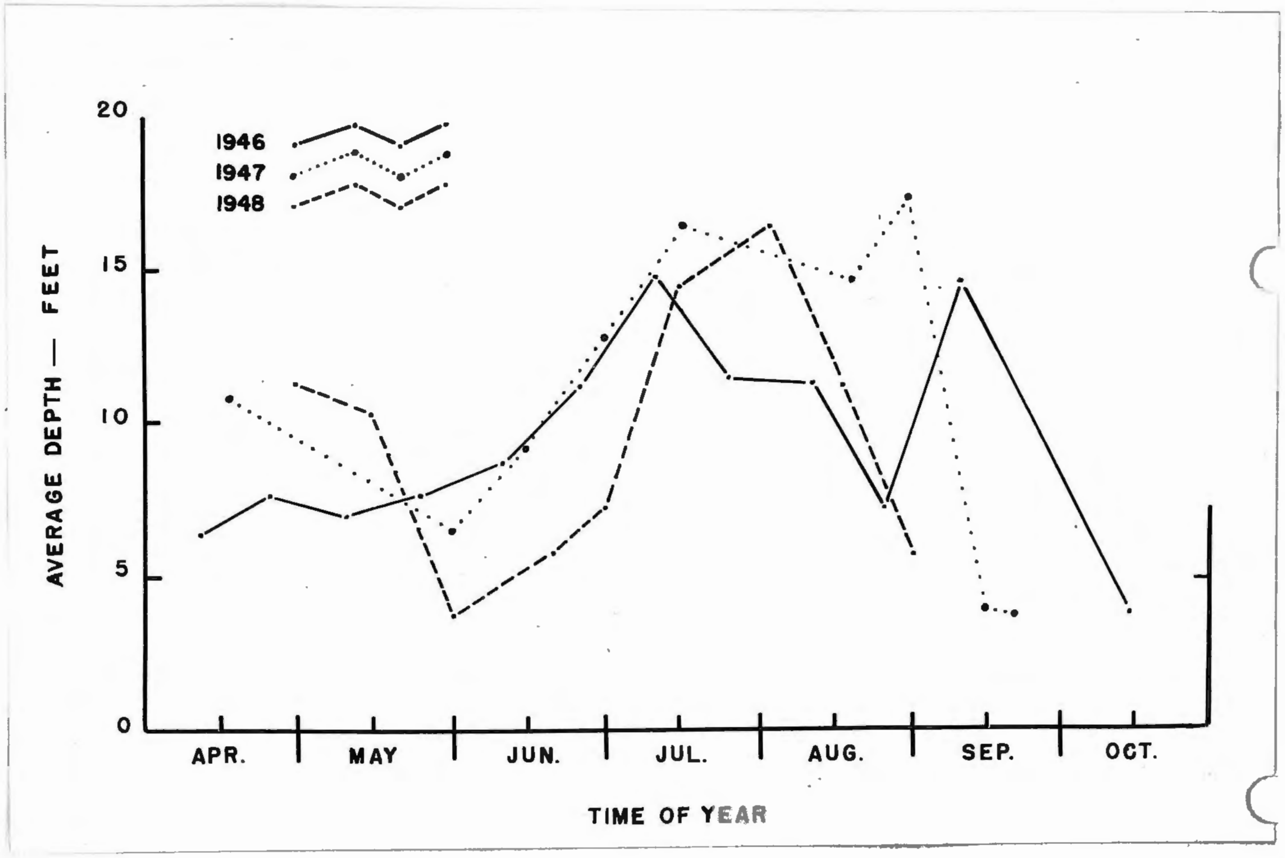


Figure 10. Secchi disc recordings at Station 1, Lakelse lake, 1946 - 1948.

The colour, if any, might be described best as a deep blue although it is not distinctive. At times it does become a brown-grey following wind and flood, but the main fact is that most of the light is absorbed and that no particular visible wave length is reflected.

Significance

The factor of light penetration, absorption and reflection is of inestimable importance in its affect on the basic foundations of food relations within a lake and may influence the productivity directly or indirectly as much as any other physical factor. In particular the phytoplankton, abundance and distribution, is directly dependent upon the light penetration. ? In this respect, for Lakelse lake there is no marked diminution at the lowest depths of 60 to 80 feet in the abundance of algae, 98 while higher plant life, particularly certain sedges, flourishes down out to depths of 30 feet. ? The problems involved in the measurement and interpretation of light penetration have been critically considered by Utterback (1941), ? and Clarke (1939) concludes that "the biological significance of ultraviolet in natural waters is in doubt, but the visible component of light is important in the regulation of the activity of many animals, in the vision of fish, and especially in the photosynthesis of the plants. Since the utilization of light is very low even under the most favourable circumstances, it is understandable that light is so frequently a limiting factor in the aquatic environment." not very pertinent ?

Its application to the survival of sockeye is consequently an indirect one in so far as the degree of productivity will limit the populations supported. It becomes a question of competition between species, and habitat selection. antec.

The lower limits of sight and of food abundance are very reduced in certain of the Skeena river lakes, considerably more so than in Lakelse. A preliminary survey would suggest indicate that the suitability of a lake for sockeye production may be is closely linked with transparency.

DISSOLVED OXYGEN

Procedure

With a view to recording oxygen concentrations, samples of the water at various levels, always including the surface, usually the thermocline region, and one sample within a few feet of the bottom, were taken with a Kemmerer water bottle as routine procedure while determining temperature gradients at Station No. 1. These samples were analysed for total oxygen by the Winkler method of determining dissolved gas (Theriault 1931).

Seasonal Changes

The variation in oxygen content of any lake is mainly a product of organic decay, animal metabolism and physical dynamics. During the spring and fall overturns no distinct deficit can readily occur for purely physical reasons. The periods of major concern, biologically, are during the summer and winter stagnation periods (Birge and Juday 1911; Greenbank 1945). The variation in oxygen saturation at depths of 0, 40 and 80 feet have been plotted in figure 11 (table IX) which is a typical example of the conditions for that portion of the year. No record has been taken of an oxygen saturation below 45% (5.2 p. p. m., 9.7°C., 80 ft., Sept. 14, 1945) and since this degree of reduction is restricted to the hypolimnion very little dimimution of the total oxygen content occurs. It might be expected that winter stagnation would result in a more pronounced deficit, but all attempts to measure this have indicated a consistently high level of oxygen saturation (e.g., April 6, 1945, 10.5 p.p.m., 80 feet, 3.8°C., 78 per cent. saturation).

It will be noted (figure 11) that at times the surface oxygen rises above 100 per cent. saturation, although only slightly. Each of these occasions was marked by rising surface temperatures and calm water conditions. Since the solubility of oxygen in water decreases with rising temperature the above facts would readily explain the observed phenomena.

also photosynthesis ?

Undoubtedly an active wind circulation and unstable thermocline during the summer, with a submarine flow pattern during the winter, play an important yet undefined roles in the oxygen saturation at all levels in the lake.

TABLE IX

Oxygen concentrations at Station 1, 1946

Date	Depth	Temp.	Oxygen	Saturation
April 25	0 feet	6.7°C.	11.7 p.p.m.	95%
	80	6.0	11.4	91
May 10	0	12.2	10.6	98
	40	9.5	11.3	98
	80	7.8	11.0	93
25	0	12.2	11.5	105
	40	9.1	11.3	98
	80	7.6	11.6	96
June 10	0	13.2	10.9	104
	40	11.4	11.3	103
	80	8.1	10.8	91
25	0	14.6	10.6	104
	40	14.1	12.7	104
	80	8.5	11.0	94
July 10	0	16.5	10.0	102
	40	14.1	9.9	96
	80	9.4	9.2	78
25	0	16.4	10.0	102
	40	14.8	13.0	101
	80	9.0	9.9	85
Aug. 10	0	18.4	9.5	100
	40	15.0	9.4	93
	80	9.5	8.5	71
25	0	18.4	9.5	100
	40	16.0	9.4	95
	80	9.3	7.0	61
Sept. 10	0	18.9	9.8	104
	40	15.9	9.3	93
	80	10.2	6.9	61
Oct. 14	0	12.2	10.8	100
	80	10.4	11.3	100

<u>Significance</u>

While working on stream pollution Ellis (1937) made numerous oxygen determinations from many fresh-water streams and rivers of the United States and concluded that in all of the 5,809 cases, mixed fish faunae were not found in waters carrying less than 4 p.p.m. dissolved

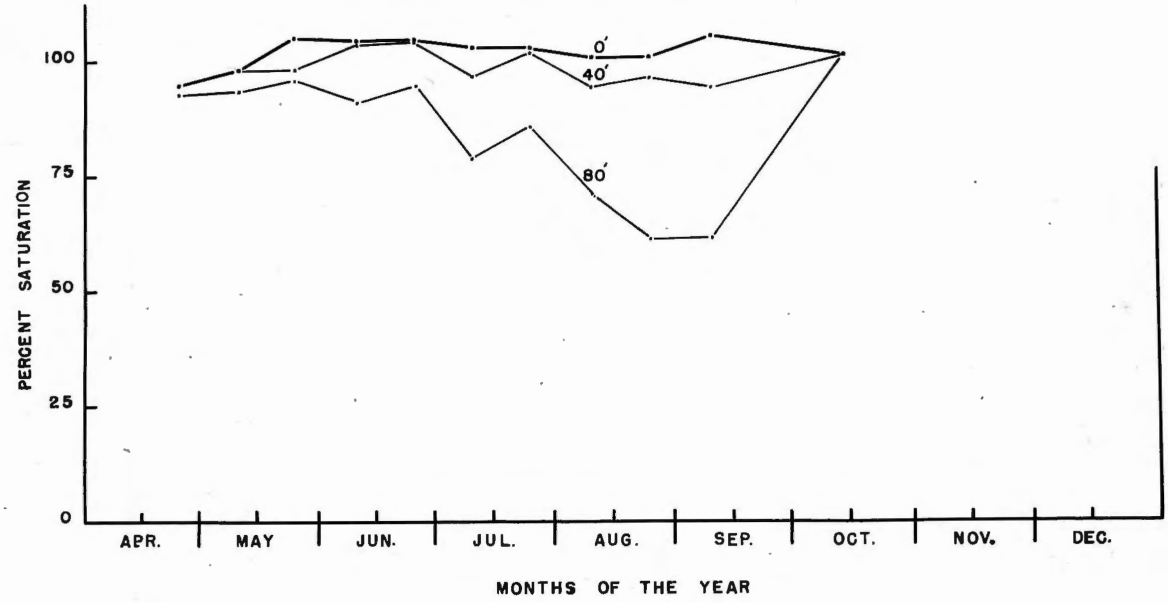


Figure 11. Variation in oxygen saturation at 0, 40 and 80 feet, Station 1, Lakelse lake, 1946.

oxygen." At 10°C., 4 p.p.m. dissolved oxygen is eqivalent to 35 per cent. saturation. Embody (1927) states that the oxygen content should not be less than 3 c.c. per litre for brook trout, i.e., 27 per cent. saturation at 10°C. Both lake trout and whitefish were obtained from the bottom gill-net sets in certain lakes of Wisconsin when the oxygen was found to be strikingly low (Birge and Juday 1911). At the time when the nets (containing six trout) were raised the bottom oxygen concentration was 0.9 c.c. per litre, with a concentration of 2.1 c.c. per litre, two meters higher. A record of six specimens of whitefish taken at 67 meters in Green lake is also included, at which depth the water contained little less than 1 c.c. of oxygen per litre (less than 10 per cent. at 5°C.).

Gardner and Leetham (1914) have shown experimentally that the amount of oxygen required by fish varies with the temperature of the water. Asphyxial points for brown trout vary from 1.13 p.p.m. at 43.5°F. (6.4°C.) to 3.4 p.p.m. at 77.0°F. (25°C.). This is also essentially true for brook trout and rainbow trout (Gutsell 1929). Townsend (Townsend and Earnest 1940; Townsend and Cheyne 1944) has reviewed various minimum oxygen tolerances of salmonoid fishes and points out that these minima differ by nearly eight times the lowest value observed and that the highest is that reported by Gardner and Leetham, cited above.

Not very pert. when so far from dangerous low O_2 ?

With this information and taking into account that no consideration has been given to many possible complicating factors such as increased carbon dioxide (see Creaser 1930; Shaw 1946), a general statement that, unless oxygen concentrations of 30 per cent. (i.e. about 3.5 p.p.m. or 2.5 c.c. per litre at 10°C.), or less, are discovered in some region of the water body of a lake, then it is most likely that oxygen is in no way a limiting factor to either the distribution or existence of any species of fish within the water system. This has been shown to be essentially true for sockeye by Chapman (1939) who found that distress from low oxygen could be demonstrated experimentally at or below 3.5 p.p.m. with accompanying high temperatures (up to 19.2°C) and with an above normal concentration of carbon dioxide (up to 2.3 p.p.m.).

The immediate application of this conclusion for Lakelse lake would be that sockeye are in no possible particular way limited by oxygen deficits and that, in any consideration of their high lacustrine mortality, the problem of oxygen deficiency can, at least for the present, be set aside (cf. Ricker 1937, p. 393).

HYDROGEN ION CONCENTRATION OR pH.

Procedure

It is routine procedure in lake studies to make systematic recordings of the extent of acidity or alkalinity of the water, particularly in the deeper sections where experience has taught that the extremes are most likely to be met. The significance of the pH, especially when no determinations of carbon dioxide concentrations are made, may be most useful as an index of certain environmental conditions (Rawson, 1939). At Station 1, pH recordings were made at various levels including the surface and bottom (not closer than 2 feet from the actual bottom) using a Taylor pH Slide Comparator, Model T-0, with a Bromthymol Blue Slide (pH 6.0-7.6) and a Cresol Red Slide (pH 7.2-8.8), manufactured by W.A. Taylor and Co., Baltimore, Md. Wherever possible, duplicate readings were made on the same samples of water with the two slides. From the discrepancies recorded and further checks on the reliability of such colorimetric field determinations, it became apparent that many inaccuracies may and do occur with this system.

Also in same paper pH not much use in [illegible] applic

Results

Using the bromthymol blue slide the average summer readings with their standard deviations were:

Average surface pH = 7.1 ± 0.2
Average bottom pH = 6.6 ± 0.2
Difference = 0.5 ± 0.28

The difference is slight. Throughout the epilimnion the pH was quite constant, usually with a slight drop through the zone of thermal stratification, and a somewhat greater drop in the hypolimnion. Being close to the neutral point (pH 7.0) and exhibiting so little divergence from this state it might be inferred that water circulation and gaseous exchange are quite unimpeded, that no excess of CO_2 accumulates, and that the products of bottom decay are well dispersed. In addition the pH of the inflowing rivers is 7.0 _ 0.7 (table III) from which it can be concluded that the surrounding area of drainage is not balanced to any excess towards acidic or alkaline deposits.

Significance

Lakelse lake typifies a body of water with very little variation ? in pH, and which is practically neutral only slightly acidic. Investigations to date indicate that even more sensitive fish like trout can withstand wide variations in pH (Needlam 1940) and that it is of little importance in affecting their distribution. Creaser (1930) states that the "range of tolerance by brook trout varies at least from 4.1 to 9.5, and furthermore the hydrogen-ion concentration throughout this range does not seem to shift the voluntary toleration limits either of temperature or of dissolved oxygen content." Even sudden changes of fair magnitude, 2.0 above and below the neutral point, can be tolerated by certain species of Centrarchidae (Wiebe 1931). Thus, with the exception of possible microstratification of the bottom, further consideration of pH in Lakelse lake would seem needless with respect to its influence on, or limitation of, animal life within the lake.

CLASSIFICATION

Lakes have been classified on various bases, mainly from separate and collective considerations of mean depth, oxygen content, temperature, bound carbon-dioxide, dissolved nutritive material, plankton communities and bottom fauna. Welch (1935; 1941) and Rawson (1939) have reviewed and critisised these classifications pointing out their useful aspects and short-comings. (Arbitrary divisions in dynamic and intergrated lake types make these attempts very inapplicable in certain cases.) Biologically, if they constitute an index of productivity then their usefulness and application should come in large measure from this aspect. ✓ ? ?

In such a lake as Lakelse the epilimnion constitutes nearly ninety per cent. of the water volume by mid-summer and might well be expected to have an amount of oxygen far exceeding that of the hypolimnion, regardless of any discrepancy in the amount of oxygen per unit volume in the two strata. From oxygen relations it automatically becomes an eutrophic lake. Its mean depth is such as to support this classification, yet its relative production of sockeye when compared with the oligotrophic Cultus lake is less and its plankton population is not particularly abundant. slightly ?

Unquestionably it may be placed among the Temperate lakes, Order 2 (Whipple 1927), i.e., surface temperatures vary above and below 4°C.; temperature of bottom water varies only slightly from 4°C.; it has two circulation periods.

During the course of study on the Skeena river it was convenient to classify the different lakes into two distinct groups, adding a third class called "Intermediate" merely to place those which actually were intermediate, in a convenient corner. The two major categories were: (1) Deep, cold bodies of water distinctly opaque and grey from glacial silt, and (2) Rather shallow bodies of water, clear, of moderate temperature, and abundant in plant life. Lakelse lake is an example of the second type. = mesotrophic No 3rd group

SUMMARY

1. Lakelse lake, in the Skeena river drainage, is a small (3,500 acres), shallow (24 feet mean depth) lake, situated in the eastern extremity of the Coast range mountains. The district is of moderate climate with relatively heavy snow fall providing glacial sources for stream drainage.

bulk.

2. Heavy winds tend to keep the majority of the lake in circulation during the summer resulting in an unstable thermal stratification, and bottom temperatures which rise to 10°C and 11°C. Ice coverage usually lasts from December to early April.

3. Although the transparency varies considerable it is usually over 10 feet (Secchi's disc) and considered as average by comparison with other lakes in the same drainage.

4. The dissolved oxygen remains high all year round, being only reduced in a very restricted hypolimnial zone. The minimum on record was 45% (5.2 p.p.m., 9.7°C.).

Dyett & Tison

5. The pH was very stable throughout.

6. The lake may be classified as eutrophic and temperate (second order).

7. A discussion of the application of these findings to the limitation of sockeye production has been included.

REFERENCES

Alsterberg, G. 1930. Die thermischen und chemischen Ausgleiche in den Seen zwischen Boden- und Wasserkontakt sowie ihre biologische Bedentung. Int. Rev. Hydrobio., 24, 290-327.

Birge, E.A. 1915. The heat budgets of American and European lakes. Trans. Wisc. Acad. Sci., Arts and Lett., 28; 166-213.

" 1932. Solar radiation and inland lakes. Fourth report observations of 1931, also second report on solar radiation and inland lakes. Trans. Wisc. Acad. Sci., Arts and Lett., 27; 523-563.

Birge, E.A. and C. Juday. 1911. The inland lakes of Wisconsin. The dissolved gases of the water and their biological significance. Bull. Wisc. Geol. Nat. Hist. Surv., 22, Sci. Ser. 7: 1-259.

" 1914. A limnological study of the Finger lakes of New York. Bull. U.S. Bur. Fish., 32: 527-609, Doc. No. 791.

" 1921. Further limnological observations on the Finger lakes of New York. Bull. U.S. Bur. Fish., 37: 211-252, Doc. No. 905.

" 1929. Transmission of solar radiation by the waters of inland lakes. Trans. Wisc. Acad. Sci. Arts and Lett., 25: 285-335.

Brehm, V. and F. Ruttner. 1926. Die Biocönsen der Lunzer Gewässer. Int. Rev. Hydrobiol., 16: 281-391.

Brett, J. R. 1948. The design and operation of a trap for the capture of migrating young sockeye salmon. Trans. Am. Fish. Soc., 75 (1945): 97-104.

Chandler, D.C. 1942. Limnological studies of western Lake Erie. II Light penetration and its relation to turbidity. Ecology, 23: 41-52.

Chapman, W.M. 1939. Effects of a decreased oxygen supply on sockeye and chinook salmon. Trans. Am. Fish. Soc., 69: 197-204.

Clarke, G.L. 1939. The utilisation of solar energy by aquatic organisms. Prob. Lake Biol., A.A.A.S. Publ. 10: 27-38.

Clemens, W.A., D.S. Rawson and J.L. McHugh. 1939. A biological study of Okanagan lake, British Columbia. Bull. Fish. Res. Bd. Can., 56: 1-70.

Creaser, C.W. 1930. Relative importance of hydrogen ion concentration, temperature, dissolved oxygen, and carbon dioxide tension on habitat selection by brook-trout. Ecology, 11: 246-262.

Dakin, W.J. and C.M.G. Dakin. 1925. The oxygen requirements of certain aquatic animals and its bearing upon the source of food supply. B. Jour. Exp. Biol., 2: 293-322.

Department of Agriculture. 1945. Climate of British Columbia. Table of Temperature precipitation and sunshine. Report for 1945, Victoria, B.C. 1-27.

Donaldson, L.R. and F.J. Foster. 1941. Experimental study of the effect of various water temperatures on the growth, food utilization, and mortality rates of fingerling sockeye salmon. Trans. Am. Fish. Soc., 70: 339-346. (1940)

Eggleton, F.E. 1931. A limnological study of the profundal bottom fauna of certain fresh-water lakes. Ecol. Monog., 1: 231-331.

Ellis, M.M. 1935. Water purity standards for fresh-water fishes. U.S. Bur. Fish., Special Rep., Mimeographed: 1-14.

" 1937. Detection and measurement of stream pollution. U.S. Bur. Fish. Bull., No. 22.

Embody, G.C. 1927. An outline of stream study and the development of a stocking policy. Contrib. Agricult. Lab., Cornell Univ., 1-21.

" 1936. Water suitable for trout culture. Fish Culture, 2 (1), Mimeographed, N.Y. State Consev.Dept., 1-5.

Fish, F.F. 1948. The return of blueback salmon to the Columbia river. The Sci. Monthly, 66 (4): 283-292.

Fish, F.F. and R.R. Rucker. 1943. Columnaris as a disease of cold-water fishes. Trans. Am. Fish Soc., 73: 32-36.

Foerster, R.E. 1938. An investigation of the relative efficiencies of natural and artificial propagation of sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia. J. Fish. Res. Bd. Can. 4 (3) 151-161.

Forel, F.A. 1901. Etude thermique des Lacs du Nord de l' Europe. Arch. Sci. Phys. et Nat., T. 12, No. 7, Geneva.

Fry, F.E.J. 1947. Effects of the environment on animal activity. Pub. Ont. Fish. Res. Lab., 68: 1-62.

Gardner, J.A. and C. Leetham. 1914. On the respiratory exchange in fresh-water fish. Part I. On brown trout. Biochem. 8: 374-390.

Gilbert, C.H. and W.H. Rich. 1927. Investigations concerning the red-salmon runs to the Karluk river, Alaska. Bull. Bur. Fish., 43 (2): 1-69.

Greenbank, J. 1945. Limnological conditions in ice-covered lakes, especially as related to winter-kill of fish. Ecol. Itonog, 15: 343-392.

Gutsell, J.S. 1929. Influence of certain water conditions, especially dissolved gases, on trout. Ecology, 10 (1): 77-96.

Hagman, N. 1938. The variations in the catch of salmon and the water levels of the rivers. ~~Helsinki, 1938~~. Ann. Zool. Soc. zool.-bot. Fenn. Vanamo, Helsinki, 5(6): 1-43

Halbfass, W. 1905. Die Thermik der Binner-seen und des Kleina. Petermanns Mitt., 51: 219 - .

" 1913a. Einfluss der geographischen Lage auf die Warmeverhaltnisse von seen. Petermanns Mitt., 59: 312- .

Halbfass, W. 1931. Wie geschieht die Anreicherung tie ferer Wasserschichten von seen und Meeren mit atmosphärischen Sauerstoff? Verh. int. Verein. Limnol. 5: 284-297.

Hanson, G. 1923. Reconnaissance between Skeena river and Stewart, B.C. Geol. Surv. Sum. Rep., Part A.

Juday, C., W.H. Rich, G.I. Kemmerer and A. Mann. 1932. Limnological studies of Karlük lake, Alaska 1926 - 1930. Bull. U.S. Bur. Fish., 12: 407 - 436.

Kemmerer, G.I, J.B. Barard and W.R. Boorman. 1923. Northwestern lakes of the United States. Biological and Chemical studies with reference to possibilities in production of fish. Bull. U.S. Bur. Fish., 39: 51-140, Doc. No. 944.

Krogh, A. and E. Lange. 1932. Quantitative Uterouchungen über Plankton Kolloide and gadöste organische und anorganische Substanzen in dem Furesse. Int. Rev. Hydrobiol., 26: 20-53.

Marshall, J.R. 1926. Lakelse lake map-area, Coast District, B.C. Geol. Sur. Sum. Rep., Part A: 35-45.

Moore, W.G. 1942. Field studies of the oxygen requirements of certain fresh-water fishes. Ecology, 23: 319-329.

McMahon, V.H. 1948. A comparative limnological study of Lakelse and Morrison lakes, B.C., with a view to assessing the suitability of Morrison lake for the propagation of sockeye salmon. Ms. Report, Pac. Biol. Sta., Nanaimo, B.C., 1-45.

Needham, P.R. 1940. Trout Streams. Comstock Pub. Co. Inc., Ithaca, N.Y.: 1-233.

Pritchard, A.L. 1947. Fish cultural problems involved in the conservation of anadromous fish, with particular reference to Skeena river salmon. Can. Fish Culturist, 1 (2): 8-13.

Pritchard, A.L. and W.M. Cameron. 1940. Observations on the sockeye salmon run at Lakelse lake (Skeena river) in the year 1939. Prog. Rep., Pac. Biol. Stn., 43: 14-16.

Progress reports. 1946 - 1948. Lakes of the Skeena river drainage.

No. 66. I Lakelse lake. J.R. Brett and A.L. Pritchard.
No. 67. II Morice lake. J.R. Brett and A.L. Pritchard.
No. 68. III Kitwanga lake. J.A. McConnell and J.R. Brett.
No. 69. IV Kitsumgallum lake. J.R. Brett.
No. 70. V Bear lake. D.R. Foskett.
No. 72. VI The lakes of the upper Sustut river. D.R. Foskett.
No. 74. VII Morrison lake. V.H. McMahon.
No. 75. VIII Lakes of the Lac-da-dah basin. F.C. Withler.

Fish. Res. Bd. Can., Prog. Rep. Pac.

Rawson, D.S. 1936. Physical and chemical studies in lakes of the Prince Albert park, Saskatchewan. J. Biol. Bd. Can., 2 (3): 227-284.

✓ Rawson, D.S. 1939. Some physical and chemical factors in the metabolism of lakes. Am. Ass. Adv. Sci., 10: 9-26.

Ricker, W.E. 1934. A critical discussion of various measures of oxygen saturation in lakes. Ecology 25, 4: 348-363.

✓ " 1937a. Physical and chemical characteristics of Cultus lake, British Columbia. J. Biol. Bd. Can., 3 (4): 363-402.

✓ " 1937b. The food and food supply of sockeye salmon (*Oncorhynchus nerka* Walbaum) in Cultus lake, British Columbia. J. Biol. Bd. Can., 3 (5): 450-468.

Rholer, E. 1926. Temperaturbeobachtungen an einem 1914 bei Rudersdorf estanden See mit starker Dichothermie. Archiv. Hydrobiol., 17: 395-403.

✓ Shaw, P.S. 1946. Oxygen consumption of trout and salmon. Calif. Fish and Game, 32 (1): 3-12.

✓ Spilhaus, A.F. 1937. A bathythermograph. Sears Found. Jour. Mar. Res., 1, 1: New Haven.

" 1940. A detailed study of the surface layers of the ocean in the neighborhood of the Gulf Stream with aid of rapid measuring hydrographic instruments. *ibid*., 3, 1.

✓ Theriault, E.J. 1931. Detailed instructions for the performance of the dissolved oxygen and biochemical oxygen demand tests. U.S. Treas. Dept., Public Health Service, Suppl. No. 90 to the Public Health Reports.

Thienemann, A. 1928. Der Sauerstoff imm eutrophen und oligotrophen see. Rie Binnengeuiasser, 4, Stuttgart.

✓ Townsend, L.D. and H. Cheyne. 1944. The influence of hydrogen ion concentration on the minimum dissolved oxygen toleration of the silver salmon, *Oncorhynchus kisutch* (Walbaum) Ecology, 25 (4): 461-466.

✓ Townsend, L.P. and D. Earnest. 1940. The effects of low oxygen and other extreme conditions on salmonoid fish. Proc. Sixth Pac. Sci. Cong., Oceanog. and Marine Biol. 3: 345-351.

Utterback, C.L. 1941. The penetration and scattering of solar and sky radiation in natural water bodies of the Pacific Northwest. Symp. on Hydrobiol., Univ. Wisconsin Press, 45-59.

✓ Welch, P.S. 1935. Limnology. McGraw-Hill Book Co., New York, N.Y. 1-471.

✓ " 1941. Dissolved oxygen in relation~~s~~ to lake types. Symp. on Hydrob., Univ. Wisconsin Press, 60-90.

Welch, P.S. and F.E. Eggleton. 1932. Limnological investigations on northern Michigan lakes. II. A further study of depression individuality in Douglas lake. Mich. Acad. Sci., 15.

✓ Whipple, G.C. 1927. The microscopy of drinking water. John Wiley and Sons. Inc., 4th ed. 1-409.

Wiebe, A.H. 1931. Notes on the exposure of several species of fish to sudden changes in the Hydrogen-ion concentration of the water and to an atmosphere of pure oxygen. Trans. Am. Fish Soc., 61: 216-222.

Wilding, J.L. 1939. The oxygen threshold for three species of fish. Ecology, 20: 253-263.

Winkler, L.W. 1889. Die Löslichkeit des Sauerstoff in Wasser. Berichie Chem. Gesellschaft, 22: 1764-1774.

Wright, S. 1931. Bottom temperatures of deep lakes. Science, 74: 413.

Yoshimura, S. 1935. A subdivision of the stagnation periods of freshwater lakes. Archiv. Hydrobiol., 28: 236-239.

II JOHNSTON LAKE

INTRODUCTION

In the years prior to 1936, commercial fishing was permitted in lower reaches of the Ecstahl river and it is considered by some that overfishing may have resulted in a reduced escapement to the spawning streams. Preliminary work was started on this area in 1946 in order to ascertain its productive capacities. This consisted of a basic survey on August 26 of one of the tributaries of the Ecstahl river, Johnston creek and lake.

PHYSIOGRAPHY and MORPHOMETRY

The Ecstahl river enters the south side of the Skeena, 8 miles from its mouth through a deep cleft in the Coast mountains and stretches south-eastward for nearly 40 miles. It flows through very rugged terrain, the mountains on each side in the lower area dropping steeply into the river bed. Tidal influence extends up the Ecstahl about thirty miles to the "forks" where Johnston lake enters from the east through Johnston creek.

Johnston lake, about two miles long and three quarters of a mile in width, has steeply inclined shores dropping off rapidly into a deep basin exceeding 165 feet in depth (figure 1). The water contains a slight glacial silt suspension rendering it opaque at a depth of about 15 feet.

No further physical data have been obtained for this lake.

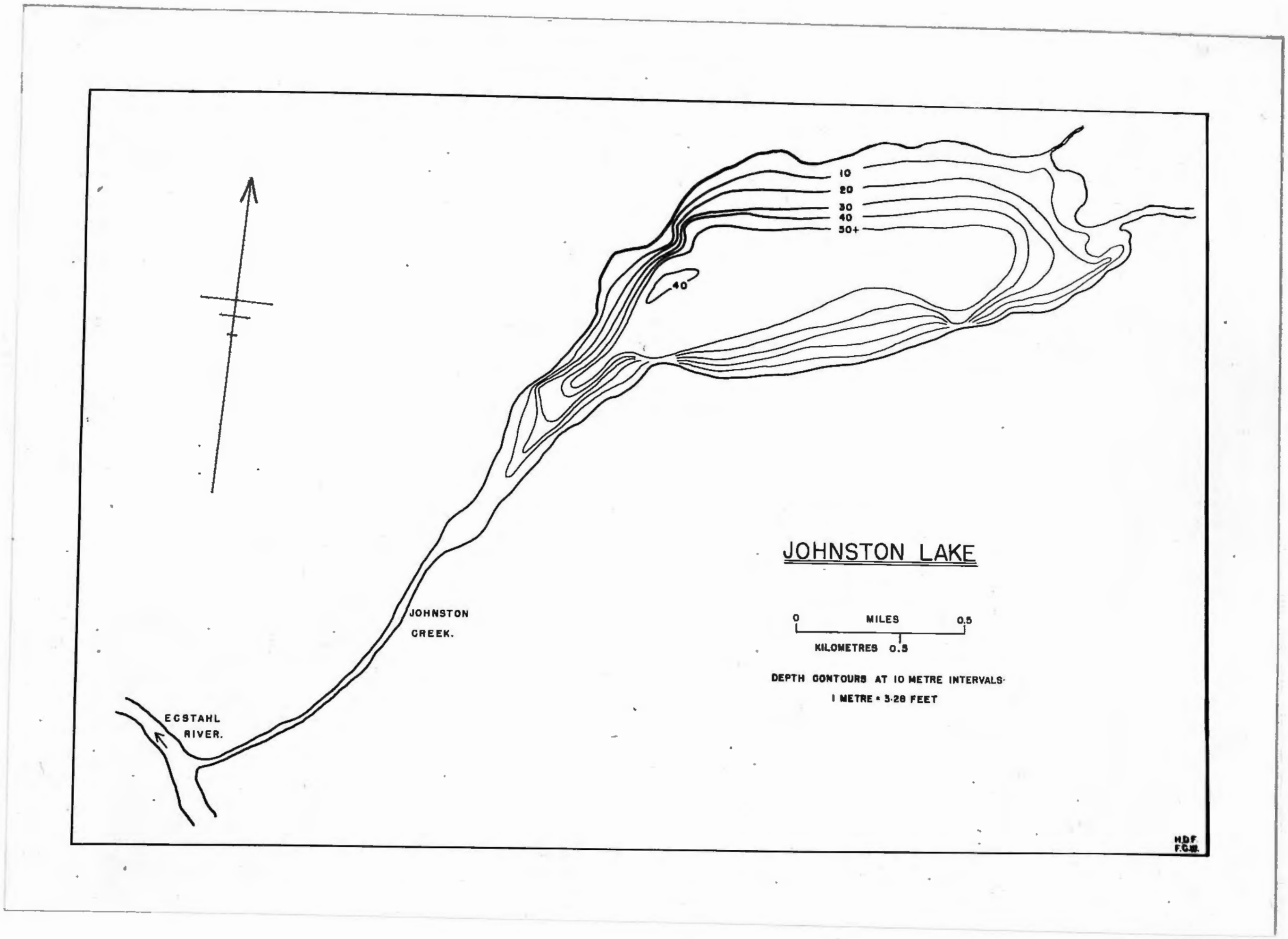


Figure 1. Johnston lake with bottom contours indicated. (Depths greater than 50 m. are not shown).

III ALASTAIR LAKE

INTRODUCTION

The only reports on file credited The Alastair lake-Gitnadoix river district with having all species of salmon present in its streams, but no records of abundance or distribution were available. Such scanty information was more than likely obtained through unauthenticated reports from trappers who were known to have been operating in the area about 1915. Prior to this date it is on record that an Indian settlement existed at the junction of the Gitnadoix and Skeena rivers and undoubtedly obtained salmon from the Gitnadoix river for food.

A first attempt to land on this lake by plane was made in 1944 in the hope of adding to the limited amount of information concerning spawning bed facilities and extent of utilization. This was unsuccessful by reason of low overcast obliterating the lake and making landing too hazardous. No further attempt was made until 1946 when arrangements to investigate this area were upset at the last minute and the pressure of other work did not permit a re-organization. In 1947, however, supplies, equipment and a boat were transported by truck to a point on the north side of the Skeena river almost opposite the outlet of the Gitnadoix river on the opposite side. Between the dates of August 21 and 28 the loaded boat was pulled, pushed and dragged up the river and into the lake, a preliminary survey completed and the party returned to Terrace.

PHYSIOGRAPHY and MORPHOMETRY

Location

On the south side of the Skeena river and slightly over 40 miles from the coast there enters a rather blue-green and partially glaciated river, the Gitnadoix, which flows in a comparatively direct

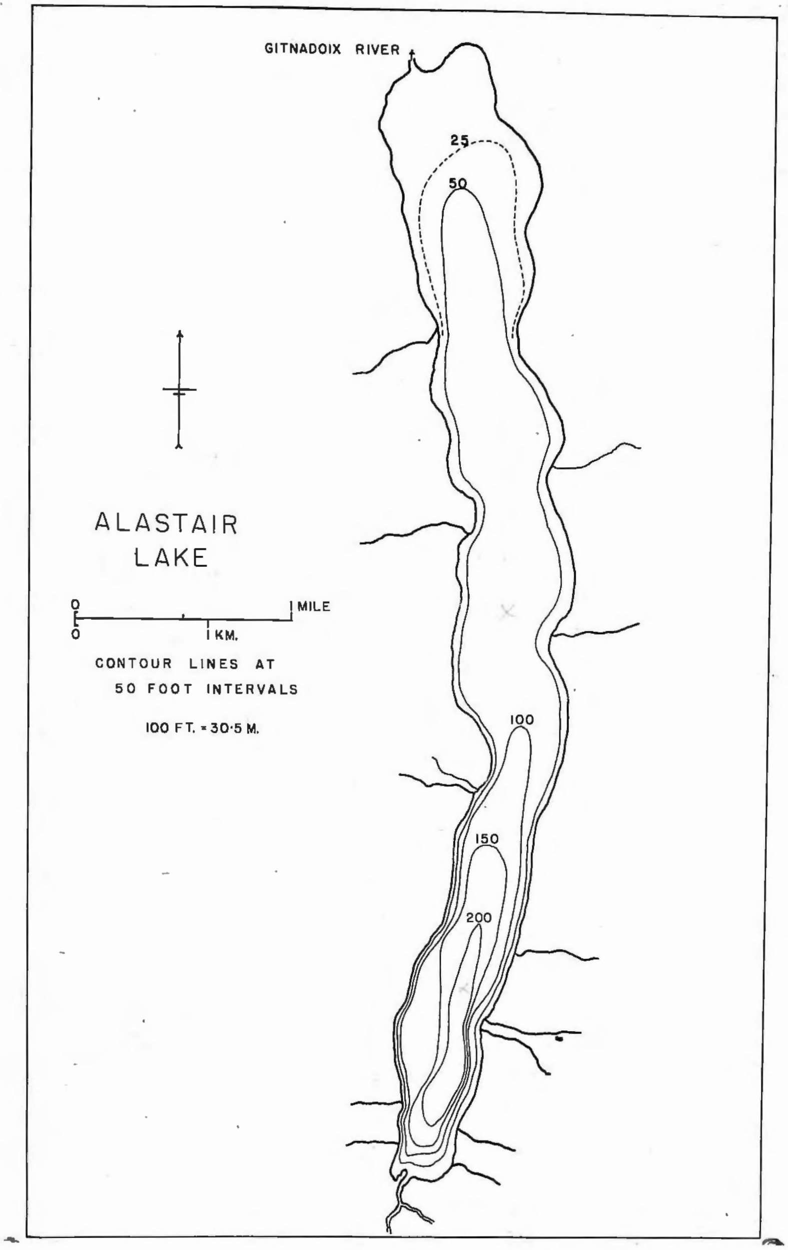


Figure 1. Map of Alastair lake showing bottom configuration.

course N. by N.W. from Alastair lake. The location of this lake, Lat. 54° 9' N., Long. 129° 15' W., places it almost centrally in the ridge of the Coast Range mountains which vary from 3 to 7,000 feet in height and in this particular niche average 4,500'. The lake itself is probably 500 feet above sea level, but no accurate recordings of this exists.

Drainage and Climate

Particularly heavy snow fields and glaciation are present in the valleys of the mountains encircling the south end and give rise to two main streams which merge one third of a mile above the lake resulting in a common outlet. Other than these two the remaining drainage into the lake is by way of numerous small creeks which tumble down as long narrow waterfalls forming small deltas at the edge of the lake.

The outlet to the lake is at the north end where the Gitnadoix river flows through the flats of a narrow valley emptying into the Skeena some twenty miles from the lake. From its appearance and the shoreline of the lake it might be concluded that a relatively stable water level exists. At the same time of the survey, when the lake levels of other areas in the lower Skeena were approaching a minimal state, that in Alastair lake was not much lower than the average high water line. It is possible that when rain water is not maintaining the water flow into the lake that sunlight and average summer temperatures maintain the supply through melting snow and ice.

From its geographical position, 40 miles due east of the coast, and interpolating from the gradient of changing meteorological conditions recorded from west to east across the Skeena drainage, the average rainfall is between 50 and 60 inches and the average January temperature fall just below 30°F. Since the lake is very well protected from wind action it is possible that for part of the winter months it is ice covered. If such is the case it is likely that this coverage would be neither solid nor heavy.

Size, shape and bottom configuration

The lake is 5¼ miles long with an average and fairly constant width of ½ mile, tapering slightly to the south (figure 1). Despite the steeply inclined mountains which border the very edge of the lake and usually characterize deep bodies of water, soundings revealed a flat and relatively shallow bottom at the north end which gradually dropped off toward the upper extremity reaching a maximum depth of 236 feet one-half mile from the southern shore, and an average of slightly less than 75 feet in overall depth. Its area is approximately 1,500 acres which places it amongst the smallest lakes receiving particular study on the Skeena.

Very few rooted aquatic plants are present other than at the north end where the gradual and continuous upward slope of the bottom results in an area which is slowly becoming an extensive marsh and beaver swampland. The remaining restricted very shallow portions of the lake are the product of active erosion caused by small creeks which cascade down the mountain sides into the lake depositing gravel, sand and silt, not suited to plant growth. There is consequently little in the way of shoreline which characterize productive lakes. By far the greatest majority is rugged, steep and strewn with trees and old debris, mostly water logged and under the surface. Perhaps 10% of the shoreline is of sand and gravel.

TEMPERATURE

Wind force and direction play an integral part in the temperature gradients of any lake. Additional proof of limited wave action was obtained by determining the vertical temperature conditions in the deepest portion of the lake (Station 1). The temperature relations showed a high thermocline extending from 15.7°C. at 15 feet to 8.0°C. at 40 feet, followed by a steady drop to 4.4°C. at 200 feet. The protection afforded by the surrounding mountains undoubtedly accounts for such a high and very shallow epilimnion which did not even reach the proportions of that for such a small lake as Kitwanga (Number V). A second station set up more centrally in the lake showed essentially the same thermal gradient. From comparison with continuous recording of temperatures at Lakelse lake the period at the end of August usually coincides with the peak of maximum thermal state. Those recordings for Alastair lake are thus close to maximum for the year, an important fact for determining heat incomes.

TRANSPARENCY

For a lake with its water source at times essentially of a glacial origin, the clarity of the water was considerably greater than might be expected. The average of disappearance and reappearance of a Secchi disc was 25.7 feet which is among the deepest points of disappearance on record for Lakes of the Skeena river. Considering a fair abundance of plankton, then the amount of glacial silt in suspension might be exceedingly low and limitations from this source in phytoplankton production correspondingly low. The lack of disturbance of the water from wind action, and rainwater contributing mainly to the creek discharge at the time of inspection, probably resulted in maximum clarity.

DISSOLVED OXYGEN

No oxygen determinations were made. It would seem most likely, however, from the nature of the lake with a large hypolimnion and subject to complete circulation twice a year (fall and spring overturn) that there is very little possibility of a deficiency of oxygen at any level.

IV KITSUMGALLUM LAKE

INTRODUCTION

Kitsumgallum, or more commonly Kalum lake, although situated in the same district as Lakelse lake and of the same climatic conditions, contrasts greatly in its physical and chemical characteristics with those of Lakelse lake, being an example of a lake with conditions of a nature completely opposite to those at Lakelse and consequently of particular interest in the effect of these on the biological phenomena. Thus, the run of adult sockeye up the spawning streams at Lakelse is usually at its peak by the third week in August and is virtually over by the middle of September, whereas this is the peak time for Kalum lake. Lakelse is classified as having an early run, while Kalum can be grouped with those lakes having a late run.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

In Upper Cretaceous times it appears that certain of the territory drained by the present Nass and upper Skeena rivers was actually then of common drainage passing through an old eroded Kitsumgallum - Lakelse valley to empty into the Pacific in the territory now occupied by the Kitimat Arm. This relation carried through the Jurassic Age but was completely disrupted and reformed during the Glacial Age and its termination. With the uplifting of the Coast region the two lakes, Lakelse and Kitsumgallum, were formed, the former draining north to the new Skeena and the latter south to the same river. In addition, a very low height of land, just dividing the relative drainage area of the Kitsumgallum - Skeena linkage and the new Nass drainage was formed. The uplifting of the rock masses, although of similar structure, was considerably greater in the Kitsumgallum territory resulting in mountain heights nearly 2,000 feet above those for Lakelse and producing a geological

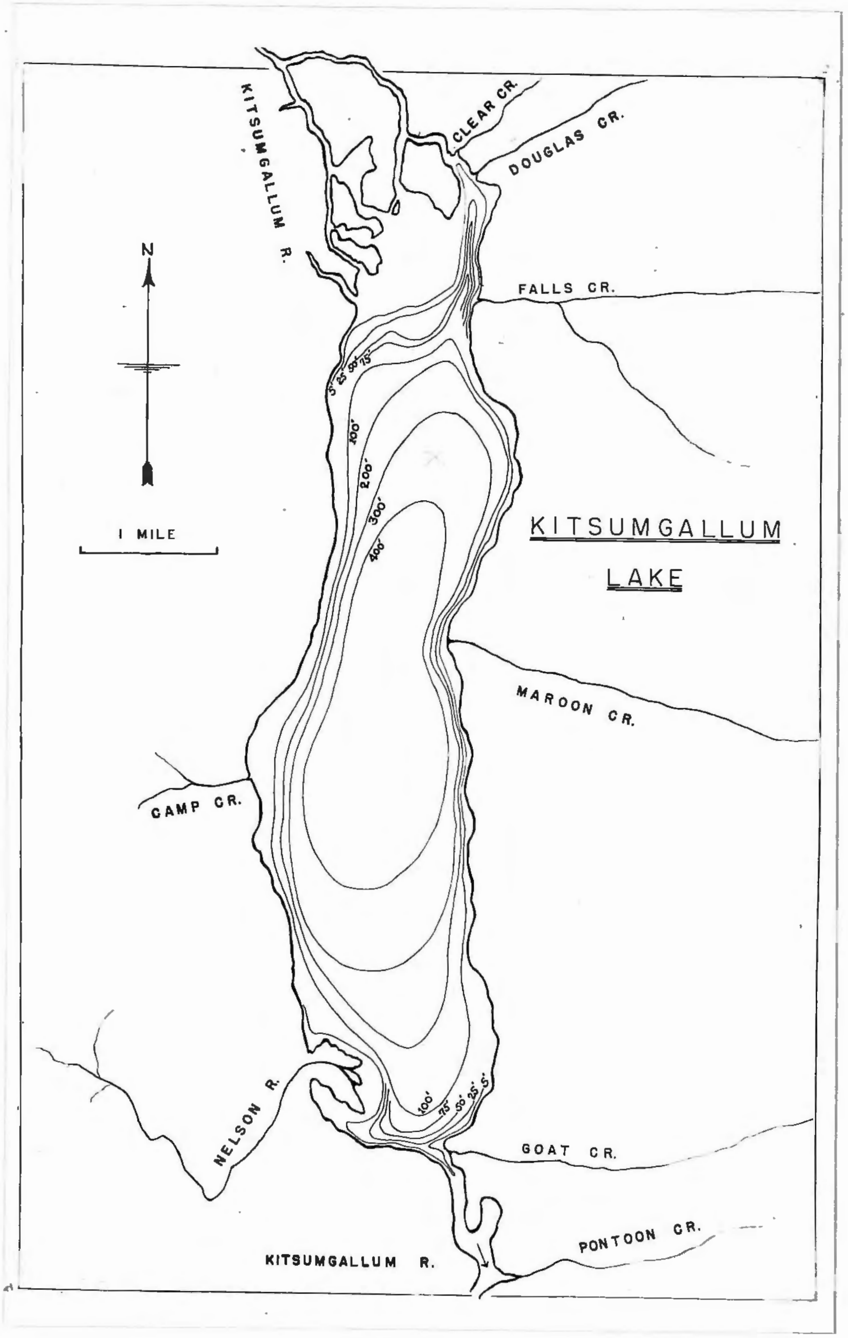


Figure 1. Map of Kitsumgallum lake showing bottom contour lines and tributary streams. (5,25,50 and 75-foot contour lines are shown for both ends and 100, 200, 300 and 400-foot lines for the whole lake. The shallow contours have been left partially completed to avoid confusion along the shores in the central portion of the lake.)

more "youthful" type of terrain. The altitude of the lake itself is reported as 468 feet.

Drainage and Climate

Nine main creeks each pour cold glacial water into the lake from the surrounding mountains. Six of these are rocky, fast flowing creeks while the remaining three, Kalum, Cedar and Nelson rivers, are more sluggish with a heavier silt content deposited at their outlets in the north and south ends. From the southern extreme, running southward and continuous with the long axis of the lake, is the Kitsumgallum river which joins the Skeena river near Terrace. This latter is not to be confused with the Kitsumgallum river emptying into the lake at the northern extremity which is known locally as the Beaver river, although not recorded as such on geographical maps.

To the above characteristics may be added the following data in tabular form for each river as recorded in the second week of July, 1944, and found to be typical from subsequent visits each year.

dense ?

River	Temperature	Clarity
Kalum (Beaver) R.	7.2°C.	Quite opaque
Cedar river	7.2°C	Quite opaque
Clear creek	8.5°C.	Clear
Dry creek	8.0°C.	Clear
Falls creek	11.2°C.	Medium opaque
Douglas creek	8.2°C.	Clear to cloudy
Maroon creek	12.0°C.	Clear
Nelson river	8.5°C.	Very opaque
Camp creek	10.5°C.	Fairly clear

The climate is best represented by that recorded for Terrace (refer to Lakelse lake) but undoubtedly has local characteristics as a result of its particular mountain profile.

Size, Shape and Bottom Configuration

In area Kitsumgallum lake covers 6.8 sq. miles being approximately 6.8 miles long and averaging 1 to 1.6 miles wide.

Routine soundings revealed a lake with sharply-inclined and precipitous shores dropping off steeply on the eastern and western sides from the base of nearby mountains to depths of over 400 feet, rising more gradually at the narrow north and south ends to shallow glacial silt flats formed by the Kalum and Nelson rivers. The whole lake is virtually one large basin of 300 to 400 feet in depth as represented in the map, (figure 1) which shows the contour lines at either end for 5, 25, 50 and 75 feet with those for 100, 200, 300 and 400 feet completed for the whole lake.

Although this lake is over seventy miles inland from the coast, and situated in the heart of the mountains forming the eastern side of the Coast range, parts of its bottom are actually below sea level. The fact is interesting in any consideration of the geological origin of the region and of the fish populations therein.

TEMPERATURE

Since Kitsumgallum is frequently subject to heavy wind action and so uniformly deep, it possesses a sufficiently large volume of well circulated water to be relatively inflexible in its temperature changes. The effects of the sun's radiation over the comparatively small surface area are distributed downward through convection, conduction, and wind agitation. Heat dissipated through the action of these prevailing winds and consequent wave motion is soon lost to recognition in the great capacity of the lake to absorb heat and yet show little manifest change in temperature. It was not practical to maintain a party in the area throughout the year, but visits were made at selected times when the temperatures in Lakelse were almost at, or had reached their summer maximum. With the exception of very localized shallow strata, which sometimes occur for brief periods after windless sunny days, the surface temperatures did not rise above 13°C. (55.4°F.). The temperature at a depth of 150 feet varies just over two Centigrade degrees throughout the year (4° to 6°), while the bottom remains unchanged at 4°C. (39.2°F.).

Although it is true that certain forms of life thrive in such low temperatures, it is not the general rule for fresh-water plant and animal life. In Kitsumgallum there exists the lowest number of small food organisms (plankton) per unit volume of any of the Skeena lakes thus far investigated. It is also well known that growth rates are almost invariably reduced by low temperatures.

TRANSPARENCY

In any lake small plant forms are the basic item in the food cycle and on these depend the small microscopic animals which are in turn the food of young sockeye. For these minute plant forms sunlight is a necessary prerequisite. In Kitsumgallum lake penetration of light to any appreciable depth is greatly reduced by the prodigious quantity of glacial silt in suspension. This is constantly poured down from the mountain sides, particularly in the spring and summer, by the larger streams. So great is the concentration of this silt that a Secchi disc (an 8-inch white circle on an 11-inch black square) has been visible during the summers of the past three years to a depth of only one or two feet below the surface. Samples of water taken from the surface show a distinct grey mist. Surprisingly enough, samples brought up from 100 feet or lower are quite clear. This deep zone, the hypolimnion or area of water below the region of sudden temperature change (the thermocline), is known to be subject to circulation only twice a year. Through this relatively stagnant hypolimnion, settling of silt particles must occur as is well proven by bottom samples of fine grey mud throughout the lake. Such a bottom could hardly be expected to support bottom organisms to any great degree.

DISSOLVED OXYGEN

The oxygen concentrations, even in the middle of the summer stagnation period, have been found to be exceedingly high, rarely being reduced below 80 per cent. saturation. Since it is reported that some winters pass without ice coverage, in all likelyhood oxygen saturations remain at a high level throughout the complete year.

HYDROGEN-ION CONCENTRATION

The pH or hydrogen-ion concentration is equally as stable as that recorded for Lakelse lake and very close to the neutral point (7.0).

V KITWANGA LAKE

INTRODUCTION

Kitwanga lake is one of the smaller sockeye nursery areas on the lower Skeena. A four week study was made of the area in August, 1945 and the findings checked in the following two summers during short trips made to estimate the spawning escapements.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

Kitwanga lake lies in a broad mountain bordered valley which opens northward from the main Skeena valley at a point 150 miles east of Prince Rupert and 20 miles south-west of Hazelton. The lake is located 20 miles up the valley from the Skeena river. North of the lake the valley opens out, joining the Cranberry river on Nass drainage which in turn is separated from the Lac-da-dah basin of the Kispiox system by a ridge of hills.

Located at 55° 30' N., 128° 00' W. the lake is on the western margin of the Interior Plateau area of British Columbia at an altitude of approximately 600 feet. The lake was formed by glacial action toward the end of the Pleistocene period and has a bed-rock of sediments probably of early Cretaceious age consisting mainly of argillite with some interbedded sandstone.

Drainage and Climate

The largest tributary of Kitwanga lake enters at the north-eastern corner from an extensive muskeg and willow area which stretches north of the lake to the Cranberry. It is a small, slow-flowing creek as yet unnamed which in its lower reaches averages 30 feet in width and 5 feet in depth. Two miles from the lake it commences to break up into small channels. The

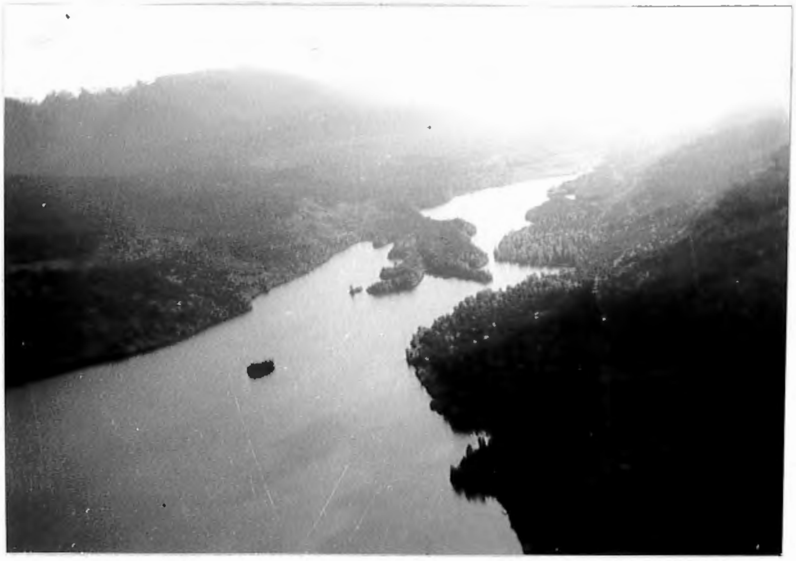


Figure 1. Aerial view of Kitwanga lake looking south towards the Skeena river.

Figure 2. Northern section of Kitwanga lake from the north-eastern corner. The mountains in the centre background are on the south bank of the Skeena.

creek is evidently of little importance as a salmon spawning stream. The conifer forested slopes to the east and west of the lake are drained by 12 small clear streamlets and lake spawning must occur around their mouths or in other seepage areas.

The climate, typical of the area around Hazelton, is characterized by mean air temperatures of 15°F. in January increasing to 60°F. in July and an annual precipitation of about 18 inches.

Size, shape and Bottom Configuration

Kitwanga lake, totalling 4.5 miles in length, is really two lakes, the large northern portion with an area of 2.4 square miles being separated from the small southern section, area 0.4 square miles, by a channel 25 to 50 feet in width. The photograph, Figure 1, and map, Figure 3, illustrate this relationship.

The shoreline is comparatively long, 13.8 miles, with several islands and bays. The actual shore, as illustrated in Figure 2, consists of small stones and pebbles with little vegetation. Shallow shelves show at the northern and southern ends and in several bays. Here, extensive areas of reeds and horsetails appear.

In Figure 3 are submitted the depth contours of the lake which illustrate the distinct shallowness of the water. Soundings in the northern portion did not exceed 32 feet and the greatest depth observed, 44 feet (13.4 metres), was in the southern portion. Each section of the lake maintains a fairly uniform depth, the northern, 25 to 30 feet and the southern, 30 to 40 feet.

TEMPERATURE

The thermal conditions are dissimilar in the two sections of the lake. Wind action maintains considerable circulation in the shallow northern section during the summer months. In the middle of July, 1940 there was a

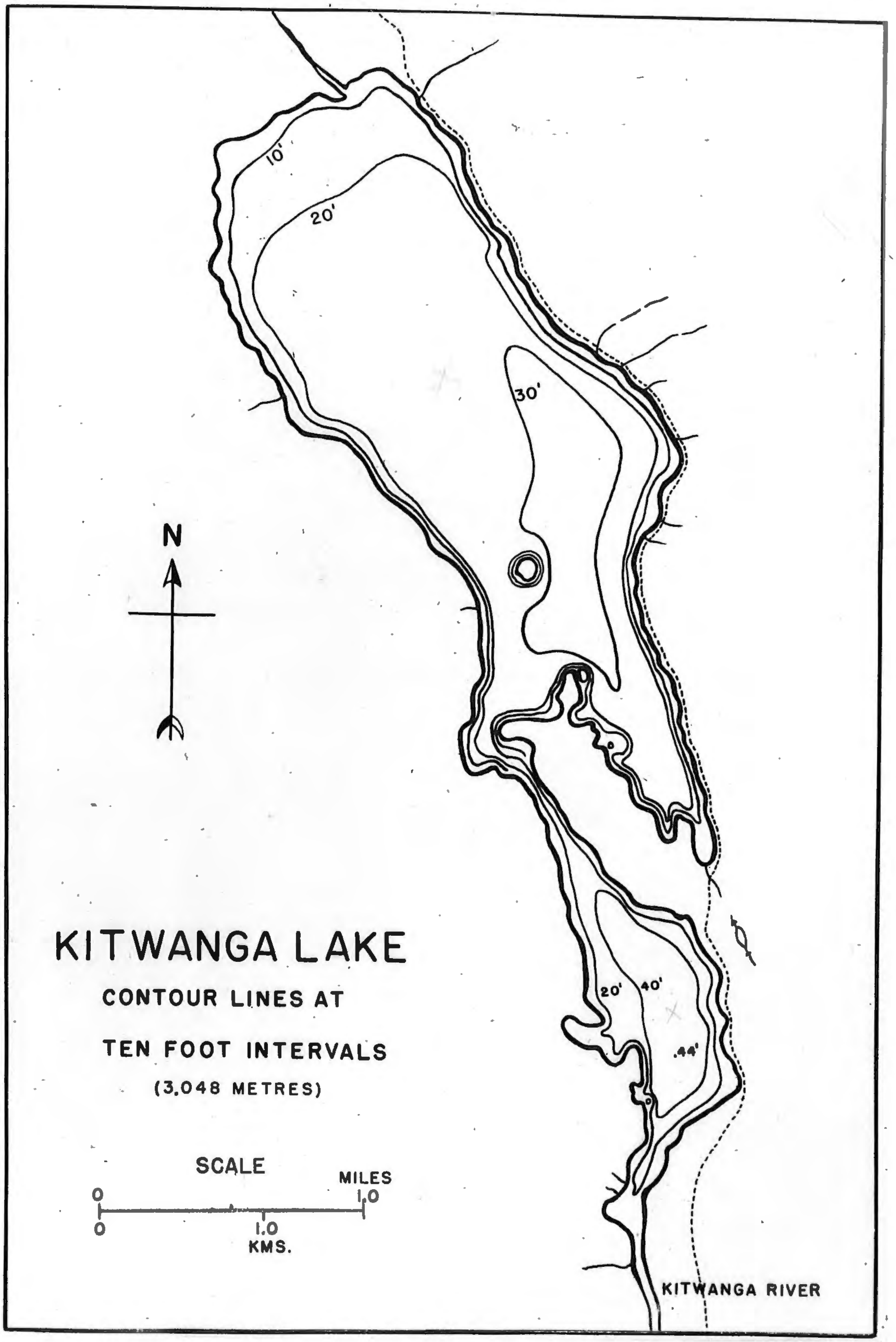


Figure 3. Contour map of Kitwanga lake.

difference of 5.3°C. (9.5°F) between surface and bottom (27 feet) temperatures, which decrease later in the summer. On August 14, 1946 the surface temperature was 16.2°C. (61.2°F.) and the bottom 13.3°C. (55.9°F.), giving a difference of only 2.9°C. (5.2°F). On the other hand, the southern section of the lake is thermally stratified, having a moderately well defined thermocline between 15 and 25 feet early in the summer, extending down to 30 feet by mid-September. Wind action produces uniform temperatures as high as 15.7°C. (50.3°F.) in the upper 15 feet but the temperature at the bottom (41 feet) does not exceed 7.0°C. (44.6°F). The lake is probably covered with ice for about four months during the winter.

TRANSPARENCY

The water of Kitwanga lake is clear in midsummer. The average depth of disappearance and reappearance of a Secchi disc for readings from July to September are 16.2 feet in the northern part and 21.0 feet in the southern. Variations from 27.1 feet to 13.3 feet have been recorded, as a result of variations in abundance of the phytoplankton which at times is very abundant.

DISSOLVED OXYGEN

During the summer months, the waters of Kitwanga lake are sufficiently well circulated to provide adequate oxygen supplies to the upper 20 feet of the northern lake and the upper 30 feet of the southern. Distinct oxygen depletion does occur in the lower 10 feet of the northern section in spite of the high temperatures that indicate considerable circulation. As presented in Table I, saturations as low as 11 per cent. have been recorded at 27 feet. Again in the southern lake, reduction of oxygen to practically zero takes place in the lower 13 or 14 feet as the summer stagnation progresses. This lack of oxygen, the result apparently of a high rate of organic decay, animal metabolism and the static nature

? of conduction?

of the lower levels is the only record in the Skeena lakes investigated to date. It is not considered to be a serious limiting factor to production in this lake because it affects a minor part of the total volume of the lake.

TABLE I

Oxygen concentrations in Kitwanga lake, 1945 and 1946

Date	Depth	Temp.	Oxygen	Saturation
A. Northern Section				
Aug. 31, 1945	0'	17.3°C.	9.0 p.p.m.	96%
	13'	16.8	8.6	91
	26'	15.4	3.2	33
Jul. 14, 1946	0'	17.8	9.9	104
	15'	15.8	8.6	86
	27'	12.5	3.4	11
Aug. 14, 1946	0'	16.2	9.9	100
	15'	15.9	9.5	95
	20'	14.4	7.8	75
	25'	13.3	3.0	28
B. Southern Section				
Aug. 7, 1945	0'	19.1	8.3	91
	20'	13.0	10.2	107
	40'	5.4	12.4	24
Aug. 30, 1945	0'	17.6	9.0	96
	20'	13.1	9.9	97
	40'	5.7	0.0	0
Jul. 15, 1946	0'	17.2	9.7	100
	20'	13.3	8.9	87
	40'	6.6	1.0	7
Aug. 14, 1946	0'	16.8	10.1	103
	20'	14.6	8.4	82
	30'	7.6	4.5	37
	35'	6.6	0.14	2
	40'	5.95	0.14	2

HYDROGEN ION CONCENTRATION

Samples of surface, middle and bottom waters of the lake have been tested with a Taylor pH Slide Comparator, No variation greater than 0.5 from neutral was recorded with the bottom waters tending to be nearest the neutral point.

VI LAKES OF THE KISPOIX SYSTEM

INTRODUCTION

The chain of three lakes comprising what is called locally the Lac-da-dah drains into the Kispoix river through Stephens creek. A five-week survey of the area conducted in 1945 demonstrated that the spawning ground area in the system appeared to be the immediate limiting factor for sockeye production. Subsequent surveys in 1946 and 1947 were made for spawning escapement counts solely.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

The Lac-da-dah lies 55° 41' N and 128° 40' W, 40 miles NNW of Hazelton and 70 miles east of the Portland canal. The basin containing the lakes lies on the eastern side of the coast mountains, on the border of the Interior Plateau which is composed of volcanic and sedimentary rocks of Mesozoic formation. Since no maps of the area are yet available, the altitude is estimated at 1500 feet.

The drainage boundaries are marked by low mountains which separate the area from the Cranberry drainage to the west and the Nass drainage to the north. Between the lakes and the Kispoix river are small hills whose lower portions run into marshland.

Drainage and Climate

Falls creek is the only notable stream flowing into any of the three lakes. Compared to other Skeena streams, it is relatively small. Since it arises in turn from a small lake at its headwaters, it is clear, but is so restricted in size that the spawning facilities are very definitely restricted.

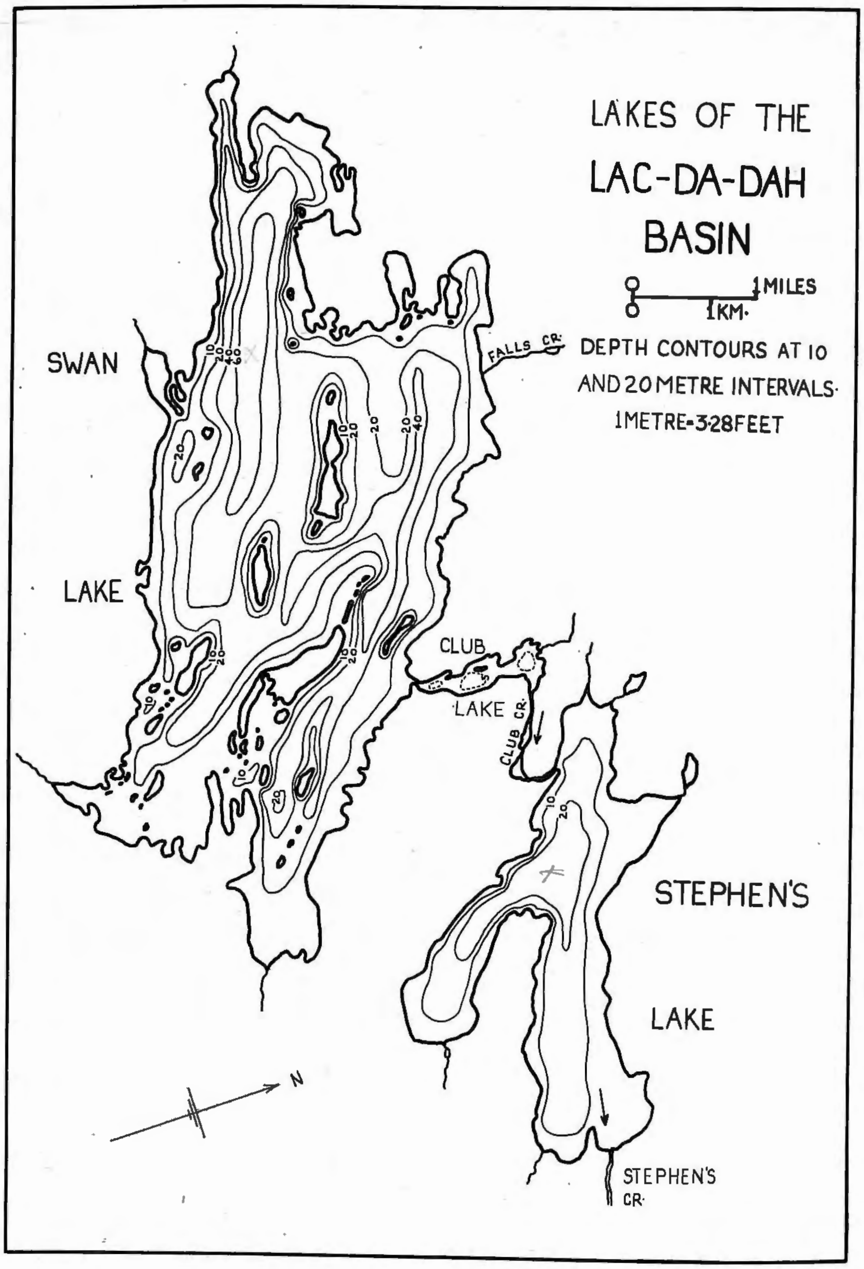


Figure 1. Map of the Kispoix (Lac-da-dah) lakes showing tributary streams and bottom contours at 10, 20, 40 and 60-metre depths.

Fish do not enter the stream until the advent of fall rains, which are characteristic of the area and reflected in the thick growth of spruce under which the ground is deeply carpeted with moss. The summer months are hot and dry in most years.

In contrast with the erratic water levels of Falls creek, Club creek is quite stable as a result of the reservoir action of Swan lake. This intermediate water course (see Fig. 1) provides the usable spawning gravel for the area. Drainage of the restricted basin is effected largely by seepage and numerous very small creeks which individually deserve little notice.

Size, Shape and Bottom Configuration

Swan lake, the largest and uppermost of the three lakes, exhibits the most irregular shoreline and bottom configuration of the three. Though approximately only seven miles long and two miles wide it contains forty-nine islands of varying size, which contributes greatly to an already extensive shore development. The maximum depth, in spite of the numerous islands, is 64 meters (210 feet).

Club lake is a shallow enlargement of Club creek approximately one mile long. The bottom, which is almost devoid of plant life, is muddy and seldom more than 5 m. (16 feet) deep.

Stephens lake, in contrast with Swan lake, has less shore development and is only three and one-half miles long by one mile wide at its greatest width. The deepest area is found at the entrance to the large bay to the south, where the depth is about one-third the maximum of Swan lake, or 26 m. (85 feet). The lack of islands indicates the gently sloping, evenly contoured bottom configuration. The shallow shoreline is given over to plant growth more extensively than either Swan or Club lakes.

TEMPERATURE

During the summer months, Swan and Stephens lakes exhibits marked thermal stratification with well-defined thermoclines. Although the bottom waters of Swan lake because of greater depth are as cold as 4.3°C. (40°F.), the lake waters show a greater depth of heat distribution than Stephens lake whose 20 m. waters are 5.0°C. (41°F). This is due chiefly to the greater surface exposed to wind action in Swan lake. Higher surface temperatures (20.3°C. or 60°F) are also characteristic of Stephens lake. With such conditions prevailing there should be no restriction in the production of food organisms in either lake.

TRANSPARENCY

Although no Secchi disc readings were taken on the Kispoix lakes, they may be considered as relatively clear. As might be expected from the rolling nature of the surrounding country and lack of glaciers, there is no indication of glacial silt. The slightly greater turbidity apparent in Stephens lake is attributable to a stronger growth of phyto-and zooplankton in the surface waters, thought to be brought on by the more typically eutrophic character of the waters.

OXYGEN

Oxygen determinations made during the period of maximum heat content in both Stephens and Swan lakes showed high concentrations at all depths. Since Swan lake is reported locally to be free of ice in some winters, there is little likelihood of winter stagnation in this lake. Stephens lake is known to freeze every winter, but there is no reason to suppose that it would suffer oxygen depletion during the winter.

VII MORICE LAKE

INTRODUCTION

For salmon which have migrated up the Skeena river as far as Hazelton, a division in the water course is presented. They may either swing north and continue along the Skeena, or proceed in a south-easterly direction up the Bulkley. Most of those which follow the latter route fight their way through the gorge at Hagwilget and continue their journey through the 20 to 25 miles of the Bulkley canyon to Moricetown falls. Here the pink salmon, Oncorhynchus gorbuscha, the weakest of the four species involved, is apparently stopped by the force of water pouring over the 25-foot cascades. About 80 miles inland from Moricetown just below the village of Houston, another choice in route is offered to those fish which remain. By far the largest number, in fact almost all, continue in and up through the cold, fastflowing, grayish glacial waters of the Morice river even to Morice lake and its tributary streams lying 60 to 70 miles to the south-west. There is as yet no known definite reason why only very few move up the warm, slower-flowing, clear Upper Bulkley which winds through the relatively flat farm lands of the district to Bulkley lake about 40 miles eastward.

In all the long journey to the headwaters, the two most difficult natural obstacles to the migration of salmon are undoubtedly the turbulent waters at Hagwilget and the falls at Moricetown. No such serious hazards occur in the Morice river above its junction with the Upper Bulkley, but there is no denying the fact that the salmon which traverse it must expend considerable effort to navigate the fast white water, the many rapids, log jams, and canyons which characterise its entire length of 60 or 70 miles to the lake. In Morice lake an opportunity is afforded for a temporary halt in the flight to reach the spawning grounds. Some salmon, however, particularly the coho, O. Kisutch, may already have branched off to enter streams tributary

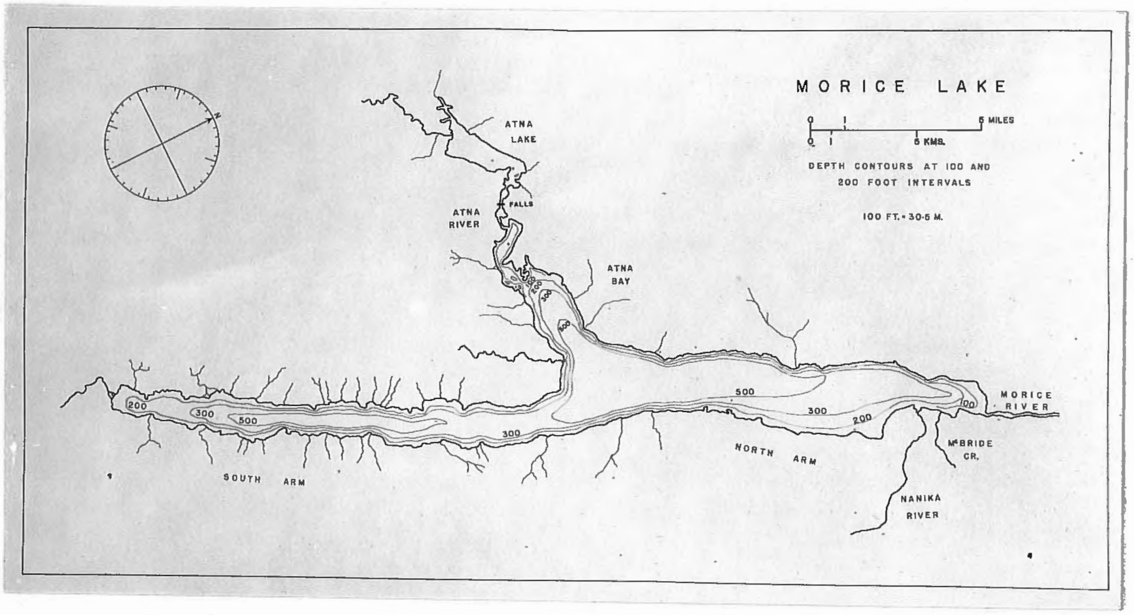


Figure 1. Map of Morice lake showing bottom contour lines and tributary streams.

to the river itself. Others may have stopped to spawn in the upper reaches of the main Morice river. Still others, like the spring salmon, O. <u>tshawy-tscha</u>, may have entered the lake, and, when mature, have dropped back to utilize the deep gravel beds in the last few miles of the Morice river.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

In the extreme southern sector of drainage in the Skeena river system lies a comparatively large lake, Morice lake, Lat. 54° o" N., Long. 127° 40" W., elevation 2,614 feet, situated in a basin between two mountain ridges of 5,000 feet and over which almost completely encircle it, only the north-east shore, in the region of McBride lake and the entrance of the Nanika river, being relatively flat. From the north-east extremity where it is drained by a single large river, the Morice river, it extends south-west for a distance of nearly 30 miles. With the exception of a large bay, Atna bay, which stretches westward for four miles near the centre of the lake, it is only from one to two miles in width.

In general the lake lies in an exposure of coast range intrusives from the Jurassic and, or, Cretaceous periods consisting mainly of granites and quartz with feldspar deposits. Glaciation has modified the topography of the entire district and is still active in the many alpine glaciers abreast of the lake. Rocks are well exposed only in some burned areas, on the steeper slopes and above timberline at about 4,500 feet while the lowlands are heavily timbered. In most places the rocks possess marked fractures that result in the production of heavy talus slopes on many of the higher mountains. Land slides are not uncommon, bringing with them many trees from the mountain sides which may be seen lining the edge of the shore, particularly at the north-eastern end where they have drifted under the influence of prevailing south-westerly winds.

Drainage and Climate

In the high deep valleys between the mountains, immense snow fields and ice beds provide a reservoir from which the numerous cascading rivulets and waterfalls tumble down pouring cold silted water into the lake at many points.

There are only two tributary streams of any volume or importance, the Nanika and the Atna. The Nanika river, arising in Kidprice lake and flowing in a northerly direction, actually provides the final outlet for two other moderately large bodies of water, Stepp and Nanika lakes. This chain in which Kidprice is centrally located, lies in a valley on the other side of a mountain ridge from Morice lake about 8 miles to the south-east. On the Nanika immediately below its point of outflow from Kidprice lake, is a falls 40 feet or more in height which completely blocks the movement of the salmon upstream. The Atna river draining the mountainous area to the west, expands into a small lake a few miles before it enters Atna bay. Three-quarters of a mile from its outlet are two falls, one just above the other, respectively 13 and 10 feet in height. These certainly could not be considered a complete barrier to salmon, but they constitute a definite hazard to further upstream migration.

No climatological station has ever been established in this region. However, from its position, altitude and physical appearance it must border on the eastern extremity of the Coast type conditions and be not unlike Lakelse lake in general precipitation. The altitude would lower the average temperature considerably and provide increased snow and ice fields. In the spring flood of 1948 the Bulkley river was as torrential as any. Its volume of flow is mainly a product of the Morice lake drainage and it was apparent that the conditions were very similar at Morice lake when compared with Lakelse rather than with Babine.

Size, Shape and Bottom Configuration

As might be expected from the topography of the area, the lake is very deep. In most of the area, the water reaches depths of at least 200 feet, while in the southern arm and central portion there are large basins over 500 feet in depth. The maximum depth has not yet been recorded. It is at least 775 feet and may possibly reach 1,000 (figure 1).

The shore line is irregular and rocky with little gravel or sand except in the regions of the outlet of the Nanika river and the outlet of Morice lake. Shallow waters are completely lacking with the exception of one small bay, Nanika bay, near the mouth of the stream of the same name. No humus or mud bottoms were discovered, only silt, sand and gravel. Conditions such as these have apparently resulted in a complete lack of rooted aquatic vegitation. In consequence, practically no ducks and geese frequent the area. With the exception of scattered mergansers and loons, the lake is singularly deficient in bird like.

TEMPERATURE

By use of a bathythermograph records were made mainly in the centre of the lake, up to 300 feet, opposite the outlet of the Nanika river where a station was established for repetition of determinations and for plankton sampling. Other recordings up to 400 feet were made centrally in the lake. From these it was apparent that by far the largest volume of the lake water, below 200 feet, never varied more than 1°C. No temperature above 5°C. was obtained at a depth of 200 feet while by 350, 4°C. was reached and consequently the minimum for that time of year. Fed by glaciers and deep as it is, it is not surprising that even in mid-summer the surface temperature of the lake does not rise above 14°C.

Conditions such as these should certainly induce a body of water of low productivity. This is evidenced by the relative scarcity of both food organisms (plankton, bottom fauna, etc.) and fish.

TRANSPARENCY

Despite the heavy glacial silt which makes visibility restricted to a matter of inches in the streams, water transparency within the lake, determined by a standard Secchi disc, was recorded at 15 feet in early September of 1944 while in August of 1945 it was just over 9 feet, changing to 7½ feet by September of that year following a period of clear warm weather. It is probable that later in the year when the ice fields remain frozen and are not melted by warm suns that the water transparency increases progressively.

OXYGEN

No oxygen determinations were made. It would seem most likely, however, from the nature of the lake and the heavy winds that circulate the water that there is little possibility of a deficiency of oxygen at any level.

VIII BABINE LAKE

INTRODUCTION

The size of Babine lake (172 sq. mi.) alone is enough to make the surveying of its physical features a formidable task from the very outset. During the first two summers of investigation only very generalised recordings of an exploratory nature were made and some soundings were commenced. In 1946 the lake was sub-divided into three divisions (figure 1) and each of these considered as separate "lakes" with separate parties responsible for all research in each division. By integrating these findings a composite picture of this rather diverse lake could be established. This subdivision of operations was maintained in 1947 and to some degree in 1948. Winter observations have been conducted almost entirely at the extreme north-western end, with one short visit in February of 1945 to the central section of the lake.

In the overall sockeye salmon economy of the Skeena River, Babine lake is the major controlling unit. Over half the total sockeye escapement moves into this body of water and spawns in its tributaries. Variation in physical or biological conditions affecting salmon here in Babine could play a major part in increasing or decreasing the commercial catch.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

Lake Babine lies between the 125th and 137th parallels of Longitude with its drainage area extending beyond these limits. It sweeps from approximately 54° 30' to 55° 20' N. Lat. (figure 1) in a northwesterly direction almost parallel to the Bulkley river 15 to 30 miles southwest of it. Between this river and the lakes lies the Babine Mountain Range, an extensive range between 5,000 and 10,000 feet high, the eastern slopes of which drain into Babine lake. To the east lies a more open, lower, rolling

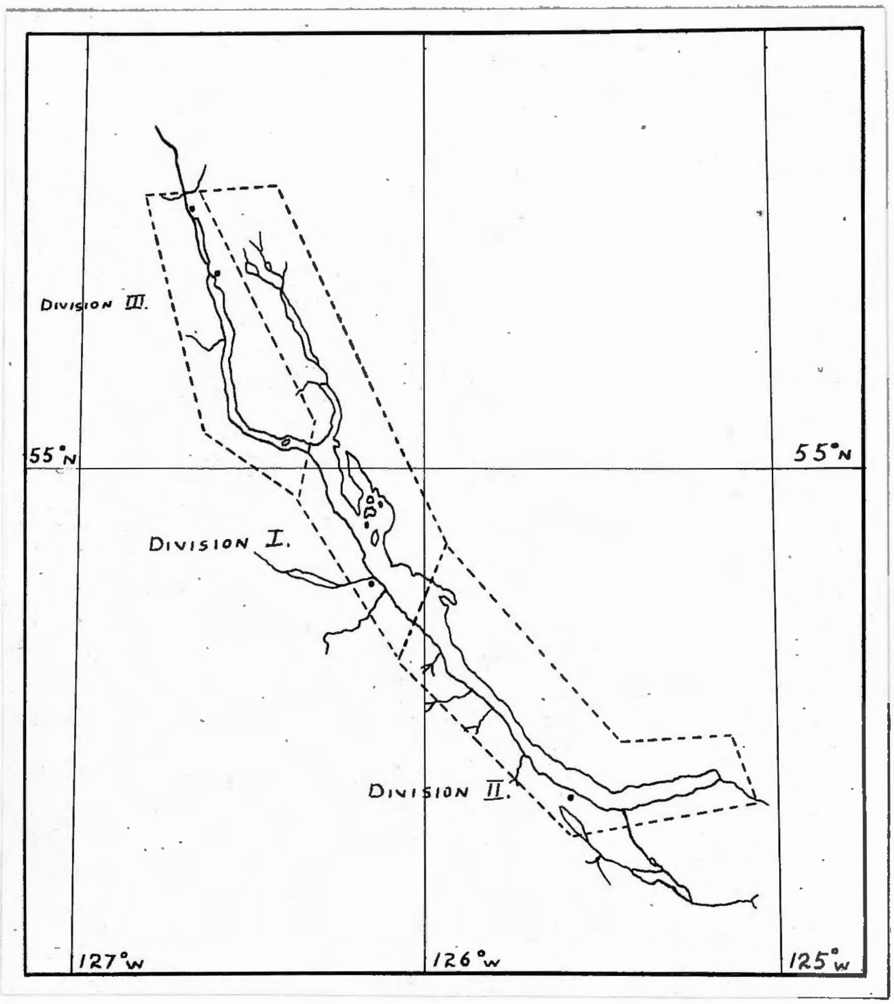


Figure 1. Babine lake arbitrarily subdivided into three Divisions.

country stretching to the foothills of the Rockies and never reaching altitudes as high as 5,000 feet. This is not much higher than the lake itself which is recorded as 2,332 feet in altitude.

The northern half of the lake lies in an exposure of rocks and glacial talus chiefly from Lower Cretaceous time (Mesozoic) while the southern half (slightly more than Division II) is embedded in a basin of Cenozoic sedimentary and volcanic rocks. A portion of eroded rock, chiefly of Palaeozoic origin, skirts about twenty-five miles of the mid eastern and western shores.

Drainage and Climate

Through the relative disposition of the mountain ranges and general topography the vast majority of the rivers flowing into this lake stem from the glaciers and snow fields to the southwest with the eastern boundary almost barren. The outlet is at the tip of the north-western arm via the upper Babine river through Nilkitkwa lake and thence by the lower Babine river to join the Skeena river 45 miles due west. The main inflowing rivers are listed below with some pertinent characteristics.

River	Summer Temp.	Clarity	Outlet Diam.	Bottom	Presence of falls
Grizzly creek	11.5°C	Clear	30'	Gravel	¾ mile
Sutherland river	-	"	150'	Mud and Sand	—
Six mile creek	17.0	"	20'	Small boulders	¾ mile
Four mile "	10.0	"	30'	Small boulders, gravel	" "
Fifteen mile cr.	15.0	"	60'	" " "	½ "
Pendleton creek	11.5	"	10'	Boulders, gravel	2 "
Twin creek	12.0	"	50'	Coarse gravel	4 "
Pierre creek	11.0	"	50'	Gravel	4
Sockeye creek	11.0	"	10'	"	—
Tachek creek	11.5	"	45'	"	4½ "
Fulton river	13.0	"	150 & 100'	Boulders, gravel	3½ "
Nine mile creek	-	"	30'	Gravel, small bould-	2 "
Five mile creek	-	"	10'	" " " ers	—
Morrison river	-	"	60'	" " "	—

On the average they are good, coarse and fine gravel spawning streams which have apparently not changed their courses frequently or radically in many years.

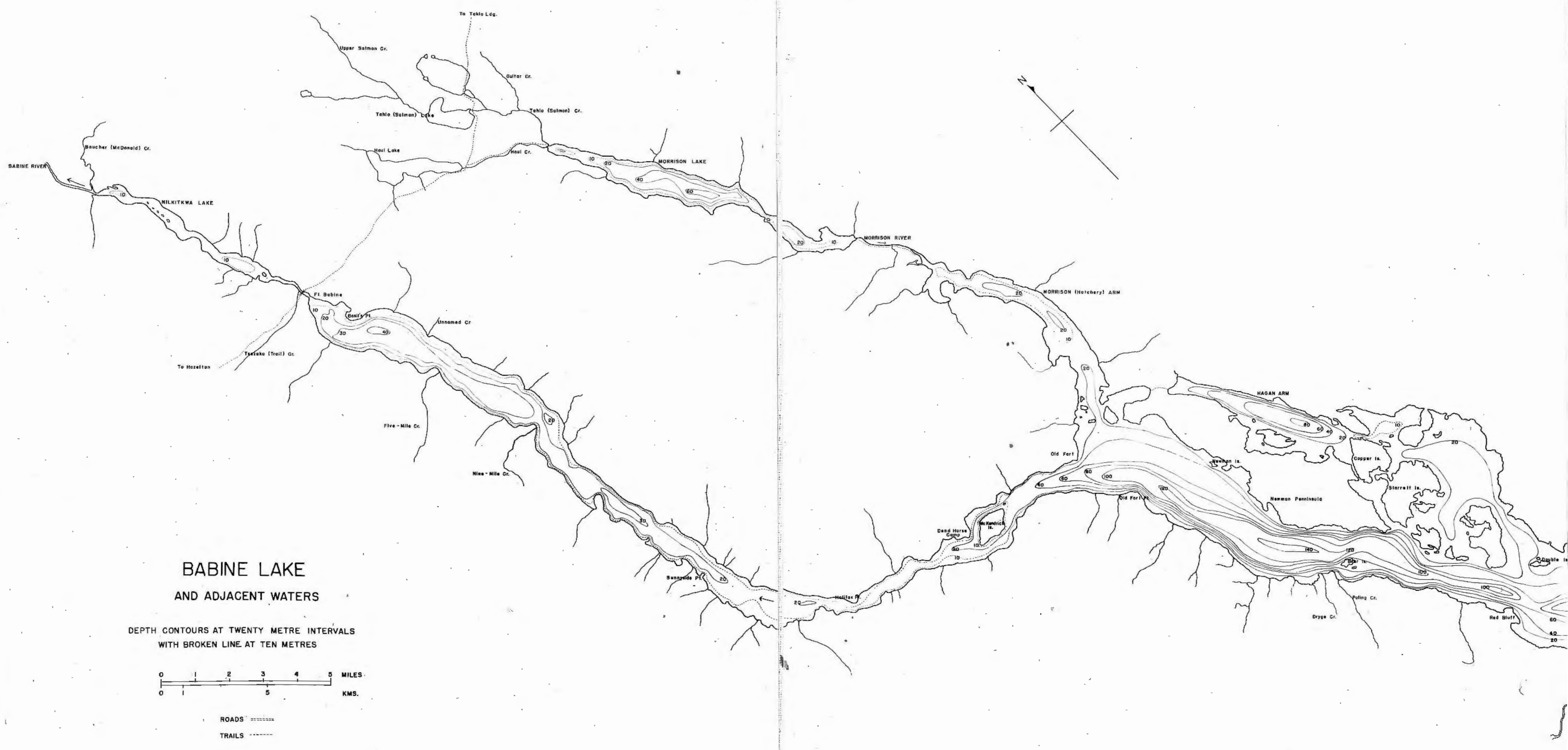
From June 17 to September 20 in 1947 the lake level dropped 33 inches at an average rate of .35" per day. This is typical of most years on record in that the peak of water height usually occurs about the third week of June while the lowest levels are recorded during the spawning month of September.

The climate of the Babine area is characterized by moderately warm summers (average August temperature 56°F) and extreme winters (average January temperature 10°F) with the low annual rainfall of about 19 inches typical of the area east of the Coast range.

Size, Shape and Bottom Configuration

The area of Babine lake has already been stated as approximately 172 sq. miles. It is distinguished by being the largest lake completely within the boundaries of British Columbia but is actually not as large as Lake Atlin which just punctures the British Columbia - Yukon boundary. Its area is obtained mainly by its great length which is 92.5 miles, the width varying from less than a mile to 5.8 miles in the central region (Wright's Bay). This results in the considerable shore development of 6.59 on the latest maps. The photographs, figures 2, 3 and 4, are presented to show the nature of the Babine area.

The bottom configuration, illustrated in figure 5, reveals a central depression extending throughout the main body of the lake and varying from 80 to 140 meters (260 ft. to 460 ft.). The deepest portion is located in the central southern sector which exceeds 180 meters and has a maximum depth recorded as 207 meters (680 feet). This contrasts with the two northern arms which are quite shallow and only exceed 30 meters (100 feet) in portions of the larger western arm.



BABINE LAKE

AND ADJACENT WATERS

DEPTH CONTOURS AT TWENTY METRE INTERVALS
WITH BROKEN LINE AT TEN METRES

N
Sutherland (Beaver) River
20
40
60
80
100
120
140
Chick Isp
Gullwing Is.
160
Gullwing (Six-mile) Cr.
Four-Mile Cr.
Silver Is.
Silver Is. Ldg.
20
40
20
Pinkut (12-mile) Cr.
160
160
160
140
120
100
80
Donald Ldg.
Cross (Pendleton) Cr.
Pendleton Bay
To Burn's Lake
Wright Cr.
10
Long Is.
Wright Bay
10
20
Wright Is.
40
60
40
60
80
100
120
140
120
100
80
80
Tachek Is.
Pt. Arthur Harbour
Sand Spit
Tachek Cr.
Sockeye Cr.
Forks Cr.
Driscol Cr.
Pierre Cr.
Griffin Cr.
Twin Cr.

Figure 5. Map of Babine lake showing bottom configuration.

Figure 2. Aerial view of north central Babine lake (Division I) with the north arm in the centre background and the Babine range in the extreme background.

Figure 3. View of northern part of Division I, Babine lake, looking north towards Old Fort Point.

Figure 4. Aerial view of central Babine lake showing Starrett island and the entrance to Hogan arm in the foreground.

The southern division can be described as having a narrow shoreline which drops off sharply into deep water, and consists of six confluent types: 1 - gently sloping sand and mud shore (20%); 2 - gently sloping fine gravel (19%); 3 - gently sloping broken rock and boulder (4%); 4 - more steeply inclined shore with fine gravel soon replaced with course gravel (42%); 5 - broken rocks on a precipitious slope (8%); and no shoreline, bluffs (4%). This gives a very concise description of this major Division and is fairly well applicable to the whole lake with the exception of the two shallow arms which have less rock, not steeply inclined shores, and scattered reed beds.

TEMPERATURE

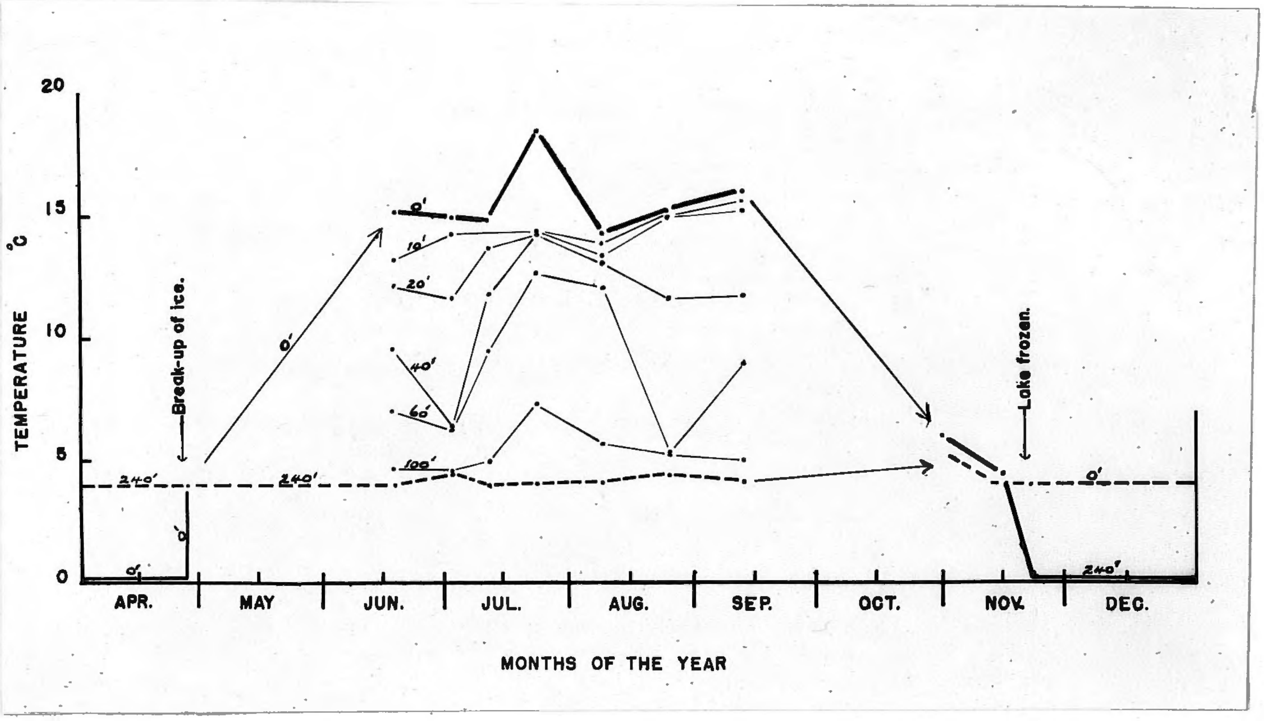
The temperature at Babine lake has been measured by means of both Negretti-Zambra deep-sea reversing thermometers and a deep Bathythermograph at separate stations located in each of the three Divisions. Winter records exist for 1946 and 1947 for the Station establish~~ment~~ed near Fort Babine at the north-western tip.

Seasonal Changes

An average air temperature of 10°F. (-12.2°C.) in January has been recorded for Fort St. James which is the most representative meteorological station in the immediate Babine lake district. The July and August means (52 years) are both 56°F. (13.3°C.) so moderately extreme bursts of cold and warm weather separate the seasons quite markedly and result in fairly heavy ice coverage in winter and temperatures of 17° and 18°C. in the surface waters of the open lake in summer.

1. Spring Overturn. The ice break-up usually commences by the last week in April in the main body of the lake but does not occur until a week to ten days later in the shallow more protected arms. In 1947 the major ice dispersal was recorded as of April 27th while that for Fort Babine was May 7th. The overturn follows almost immediately with rapid ascent of surface temperatures as the hours of sunlight have a maximum possible of 16 to 17

Division II



Division III

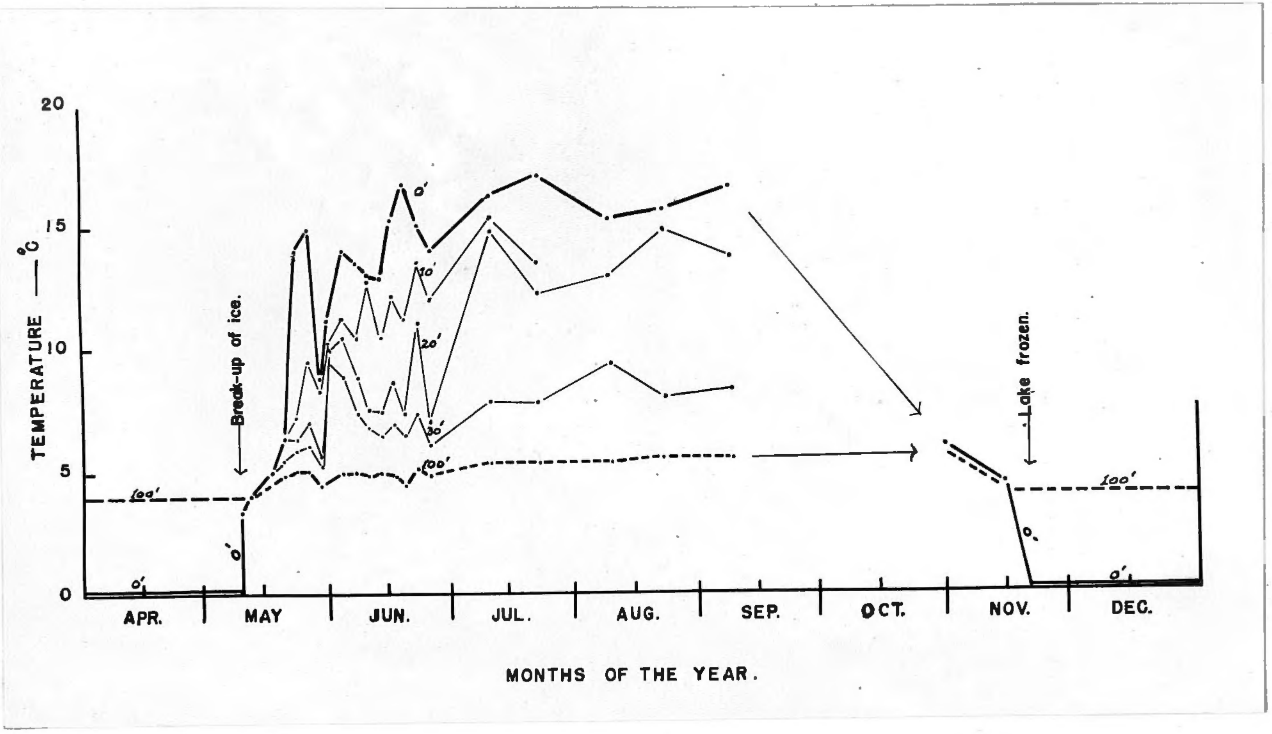


Figure 6. Annual.

hours at this latitude in May. This whole phenomenon takes place on the average almost exactly one month after that for Lakelse lake.

2. Thermocline Formation and period of Summer Stagnation. Being so diverse in nature the different portions of the lake may take on different aspects of thermal stratification, a fact which has been found to be quite true of the three Stations, particularly that at Fort Babine. Thermal stratification in the major portion of the lake and to a lesser degree in the side arms is very unstable, moving in and out of the defined thermocline state (1°C. per meter or more) in relation to sunny calm days and effective wind action. In the southern portion, months have passed without a record of a thermal stratification reaching as much as 1°C. per meter. Considerable fluctuation results in the temperature at any given level up to 100 feet for Division II and the southern section of Division I, while greater stability occurs in Division III below 50 feet. The net result~~s~~ is one of considerable circulation constantly changing in effective depth and never producing a distinctly stagnant hypolimnion as in more sheltered southern lakes. Table 1, presents the surface and bottom temperatures at the time of maximal thermal state for Division II and III. (Division I is very similar to Division II):

Table 1. Surface and bottom temperatures at time of maximum thermal state

Year	Date		Surface		Bottom		Depth	
	Div. II	Div. III	Div.II	Div.III	Div.II	Div.III	Div.II	Div.III
1946	Jul. 23	Aug. 9	18.3°C.	15.2°C.	4.1°C.	5.0°C.	240'	120'
1947	Jul. 25	Aug. 22	14.1°C.	17.5°C.	4.0°C.	7.5°C.	240'	120'

3. Fall Overturn. Late in the month of October and on to about the middle of November the surface and bottom temperatures progressively approach the same thermal level, those in depths of 200 feet or more varying but little throughout the year. Once 4°C. has been reached the period of actual overturn is most effective. In more shallow zones it must occur over a greater period of time as these levels become equal in temperature to that of the surface

above 4°C. (cf. Lakelse).

The following table records pertinent data for the fall overturn and freeze-up:

Table 2. Fall Overturn and winter data

Year	Date Commenced		Temp		Date 4°C. reached		Date of Freeze-up	
	Div.II	Div.III	Div.II	Div.III	Div.II	Div.III	Div.II	Div.III
1946	Nov. 9	Nov. 1	4.1[x]	6.0[x]	Nov. 9	Nov. 18	Nov. 20	Nov. 21
1947	Dec. 6	Nov. 3	4.1[x]	7.3[x]	Dec. 6	Dec. 9	Dec. 14	Dec. 15

x Estimated.

4. Winter Stagnation. Ice coverage usually extends from sometime in late November or early December and lasts about five months forming a very solid layer by February. Very heavy winds may prolong the open water season or may even break up a light ice coverage in the main portion of the lake, as apparently occurred in the winter of 1947-8. Portions of Babine lake were still open in January 1948. Temperatures of 30°F. below zero brought about refreezing in February. The minimum thermal state probably occurs in March.

Figure 6 has been presented to illustrate the thermal changes throughout one complete year for Division II and III, so far as records have been obtained. Arrows indicate the linking path of probable thermal change.

TRANSPARENCY

Secchi disc recordings have varied from 2.2 m. (7.2 feet) to 6.6 m. (21.7 feet) at different points of time and place throughout the lake. The overall average is 5.42 m. (17.8 feet) which places it among the more transparent lakes of the Skeena drainage.

DISSOLVED OXYGEN

All oxygen determinations point to a very high and consistent oxygen concentration rarely below 80% at any depth for the major portion of the year. The winter months have only been determined through samples which were delayed in their final titration (Winkler method) and therefore subject to error, however these all indicated high oxygen content at low levels throughout the winter also.

HYDROGEN-ION CONCENTRATION

The usual consistent stability close to or slightly above the neutral point of 7.0 in pH exists throughout the lake.

IX NILKITKWA LAKE

INTRODUCTION

Nilkitkwa lake might be regarded as a widening of the Babine river. The large salmon producing Babine lake empties into Nilkitkwa from the one mile long Upper Babine river. After passing through, the flow continues in an arc northwestward down the Lower Babine river to join the North Skeena 45 miles to the west.

It is on the migration route of the adult salmon that spawn in the Upper Babine river and in tributaries to Babine lake, of the yearling salmon migrating to the ocean and is also a nursery area for sockeye and coho, progeny of spawnings in the Upper and Lower Babine rivers. Studied by the party covering the northern division of Babine lake, it received greatest attention in 1946 and 1947.

PHYSIOGRAPHY and MORPHOMETRY

The lake, totalling 6.5 miles in length, and not exceeding .5 miles in width has a constriction in the centre, where, especially during high water, a slow current may be observed. The lake is shallow, having a mean depth of 6.3 metres (19.2 feet) and the shoreline, gently sloped, has a high proportion of reeds (56%). In the reed and horsetail areas the shoreline tends to be swampy while along the remainder are low poplar and spruce bluffs. There are no sizeable tributaries entering the sides of the lake, the main inflow coming from the upper Babine river.

TEMPERATURE

Nilkitkwa lake, being open and shallow, is circulated to a considerable extent in summer and no thermocline is developed. The average bottom temperature in 1946 was 8.0°C. (46.4°F.) and the average surface temperature 14.8°C. (58.6°F.). Ice cover lasts as in Babine, for approximately five months of the year.

TRANSPARENCY

Secchi disc records have varied from 1.8 metres (5.9 feet) to 6.0 metres (19.7 feet) with an average of 4.8 metres (15.7 feet) slightly less than that for Babine lake.

DISSOLVED OXYGEN

Oxygen saturation has been high at all times in Nilkitkwa lake, little difference being recorded between surface and bottom concentrations.

X MORRISON LAKE

INTRODUCTION

Since the Morrison lake system constitutes one of the larger tributaries to Babine lake a preliminary investigation of the biological features of Morrison lake was made in the summer of 1945. At this time a record of some of the more salient points was kept and in subsequent years more extensive observations and studies were made of the conditions therein.

PHYSIOGRAPHY and MORPHOMETRY

Location and Geology

At approximately 55° 15' N. and 126° 20' W. Morrison lake lies in a valley which runs parallel to the northern arm of Babine lake. It is separated from the latter by a series of high hills 5 to 10 miles in width and is bounded on the east by a similar height of land. The lake lies at about 2,400 feet above sea-level.

The geological development here is very similar to that of the northern Babine area.

Coarse rocks and boulders are to be found lining the shore of Morrison lake while from a depth of 3 metres (10 feet) out the bottom of the lake is almost entirely composed of a thick grey adhesive mud.

Drainage

Unlike most of the lakes of the system which are situated at the heads of their respective drainage areas and are fed only by small tributary streams, Morrison lake lies between a system of small lakes and streams to the north and the larger Babine lake to the south.

The two streams entering the lake at the north end, Haul and Salmon creeks, carry almost the entire volume of inflowing water, and Salmon creek alone is utilized by salmon spawners. To the south Morrison lake empties into the Morrison arm of Babine lake by way of the Morrison river.

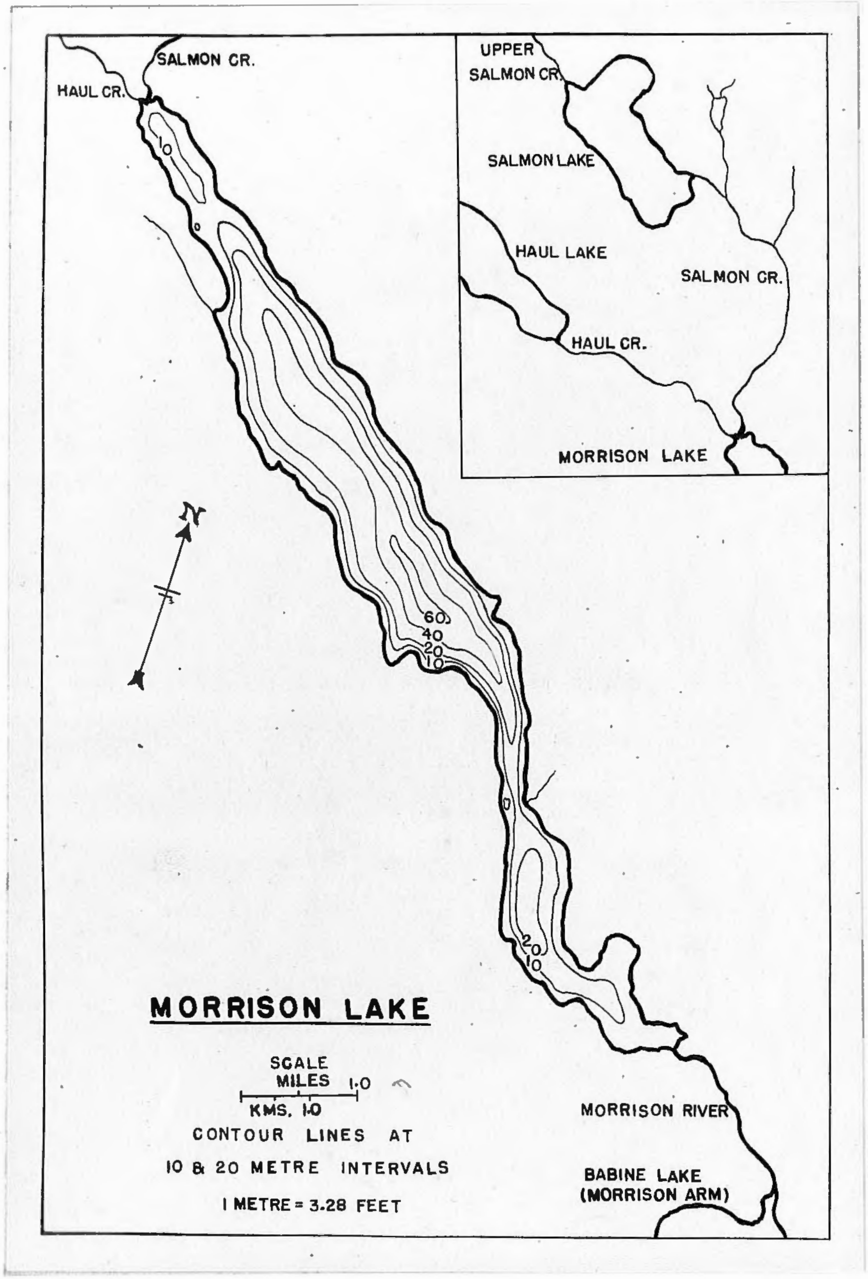


Figure 1. Map of Morrison lake showing tributary streams and bottom contours.

Although the gravel of this river accommodates a large number of salmon spawners, it has not been determined what percentage of the hatching fry migrate upstream into Morrison lake. In any case it may be said that the spawning facilities on this system constitute a limiting factor to greater salmon production.

Size, Shape and Bottom Configuration

The lake is approximately 10 miles long with an average width of .5 miles and covers an area of 5.55 square miles. Depths of over 60 metres (183 feet) may be found in the central portion of the lake while the northern and southern sections are relatively shallow - 20 metres (61 feet) and less. Because of the long, narrow shape of the lake the shore development ratio is fairly high.

TEMPERATURE

For the whole period of investigation, a thermocline between the 5 and 10 metre water levels has existed during the greater part of each summer. Although the lake is quite open to and is often frequented by strong winds from the northwest, the protective shape of the northern and southern portions and the deep waters of the central area tend to resist mixing by wind action. During the early part of August, 1947, there were temperature differences of 6.1°C., 6.55°C. and 7.7°C. between the 5 and 10 metre levels at the 3 stations set up in the northern, central and southern regions respectively.

TRANSPARENCY

In the summer of 1947 the average level of disappearance of a Secchi disc was approximately 11 feet. Morrison lake, then, has what may be called average clarity in comparison with other lakes on the system.

DISSOLVED OXYGEN

From the analyses of samples of water collected during the summers, and by a comparison of the physical features with other lakes, there is no reason to believe that the oxygen supply in Morrison lake should at any time or at any depth be a limiting factor to fish production. The lowest recorded summer concentration was approximately 60% saturation near the bottom of the lake.

HYDROGEN ION CONCENTRATION

Water samples from Morrison lake consistently range between pH readings of 6.8 and 7.2, indicating a very stable condition in this regard.

XI MOTASE LAKE

Physiography and Morphometry

Motase lake, at the head of the Squingula river, is located at an altitude of 3,350 feet about ten miles west of the south end of Bear lake. It is four miles long by one mile wide and is constricted in the centre so that it has roughly the shape of an hour glass. While soundings have not been numerous enough to give a complete picture it is not an extremely deep lake though it does exceed 100 feet. Its main tributaries being of glacial origin the lake is heavily silted.

Temperatures

The temperature of the lake on September 25, 1946 was 6.67°C., (44°F) at the surface and 6.12°C. (43°F.) at a depth of 80 feet indicating that the lake was already well advanced toward freeze up.

Transparency

Secchi's disc reading in this lake was eight inches.

Classification

The heavy silting alone in this lake produces ecological conditions which place it in the first class of lakes as outlined for the system.

XII BEAR LAKE

Physiography and Morphometry

Bear lake is situated in the area bounded by 56° and 56° 15' N.L. and 126° 45' and 127° 00' W.L. at an altitude of 2,640 feet. It is 160 miles NW of Fort St. James, the nearest supply point. The lake lies in a valley 4 to 5 miles wide which is bounded on the west by the volcanic rocks of the Tsaytut spur and on the east by the thin-sediments of the Connelly range of the Omineca mountains.

The area has seen much volcanic activity in the past and was at one time covered by the shallow inland sea which flooded much of the province. The lake bed itself was formed by a southerly moving glacier 15,000 years ago. Both the terrain and the streams present a youthful appearance, the latter in some instances fluctuating between two or more channels.

The lake, 12 miles long with a maximum width of 3 miles, has a surface area of 7.2 square miles. It is divided by a shallow narrows into two basins, the northern one having a maximum depth of 135 feet and the southern a depth of 240 feet. A large shallow area, Tsaytut bay, lies to the southeast of the narrows and thus is close to both basins, though it is more intimately connected with the southern part of the lake. This bay and the narrows have extensive beds of submerged and emergent vegetation near the shores, extending in some cases as far as the ten-foot depth contour. Lacking a complete hydrographic survey the mean depth of the lake has been estimated as 42 feet and the volume of the lake as 314 million cubic yards. The shore development of the lake is 3.2. The lake forms the headwaters of the Bear river and is approximately 300 miles by water from the mouth of the Skeena river.

Climatic conditions while normal for the more mountainous regions

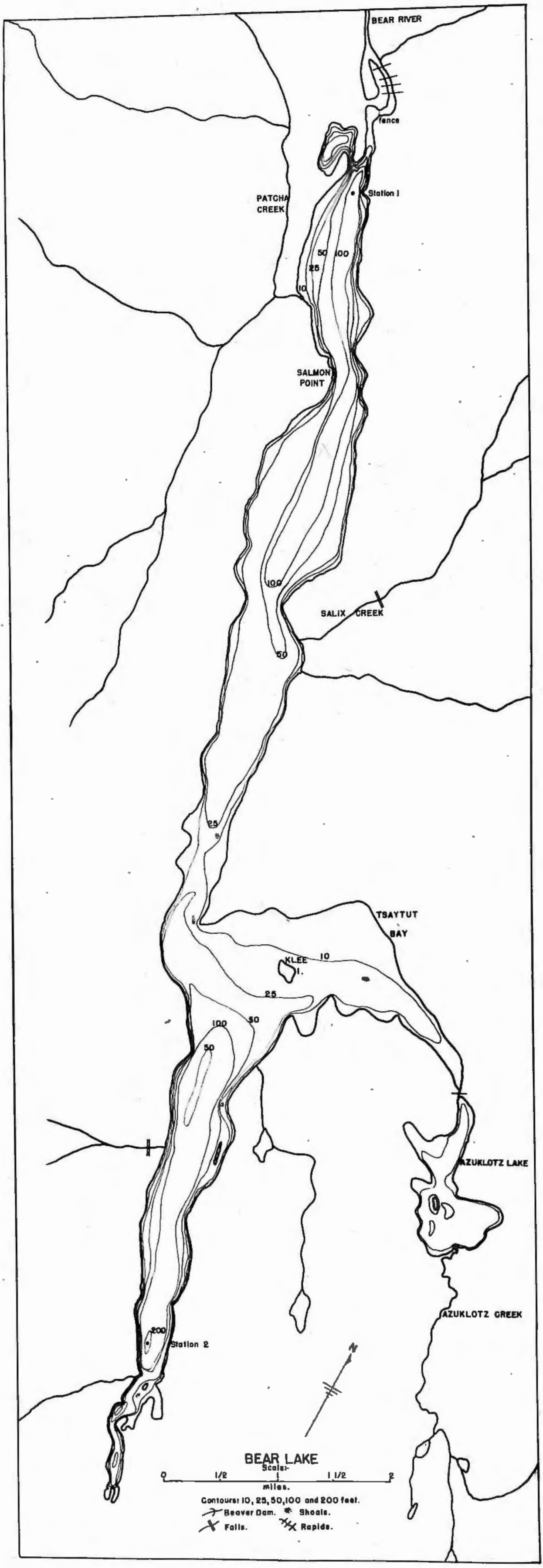


Figure 1. Map of Bear lake showing bottom contours.

of the upper Skeena are more severe than those of Lakelse and Babine. The precipitation is, from all indications, much heavier than at Babine lake. Certain data support the theory that the southern part of the lake has during the summer a warmer climate than the northern basin. This is undoubtedly due to gaps in the bordering mountain ranges just south of the lake.

Temperature

The highest temperature recorded for the open surface waters of Bear lake was 19.25°C. (66.65°F) at Station I on July 31, 1948. The highest surface temperature recorded for Station II was 18°C. (64.4°F.) on August 10, 1948. Peak temperatures for the bottom water at the two stations have been 6°C. (42.8°F) at Station I on September 25 and October 5 in 1947 and 5.3°C (41.54°F) at Station II on September 23, 1948. Bear lake has shown a peculiar thermal condition in both 1947 and 1948 in the form of a layer of water at some depth which was warmer than the waters immediately above and below it. The condition is temporary and has only been found once in each year though on each occasion it has been present in both basins though not at the same depth in each basin in 1948. It is possible that similar conditions may be present under the ice since the only reasonable explanation of the phenomenon is that such layers are caused by mineral springs and calm weather would be necessary for their establishment. Recent volcanic deposits occur in the area so the presence of hot springs is not impossible.

A rough estimate of the summer heat income for Bear lake has been obtained from temperature series taken from 1945 to 1948. Since, however, the yearly visits have not always included the time of optimum lake temperatures the figures are probably minimal. For Station I the summer heat income was found to be 17,700 gm. cal. per $cm.^2$ and for Station II, 23,500 gm. cal. per $cm.^2$. For comparison the Lakelse lake summer heat income, 16,000 gm. cal. per $cm.^2$, is approximately the same as that for the northern part, Station I, and considerably less than that of the southern basin of Bear lake.

Transparency

The transparency of Bear lake is such that Secchi's disc can be seen on the average to depths of 14 to 15 feet during the summer and fall.

An analysis of a sample of Bear lake surface water showed a pH of 7.3 and a total dissolved solids content of 44 parts per million. The report of this analysis is shown below in Table I.

Table I. Chemical analysis of water sample from Bear lake, taken on October 3, 1948.

REACTION.........	pH 7.30	
Following Results in Parts per Million:		
Suspended Matter		TRACE (less than 1)
ALKALINITY:		
Carbonates	(CO_3)	NONE
Bicarbonates	(HCO_3)	28.6
TOTAL DISSOLVED SOLIDS:		44
Fixed Solids	26	
Volatile Soilds	18	
ANALYSIS OF FIXED SOLIDS:		
Silica	(SiO_2)	5.0
Iron Oxide & Alumina	$(Fe_2O_3, Al_2O_3$	1.0
Calcium Oxide	(CaO)	10.6
Magnesium Oxide	(MgO)	2.6
Undetermined (alkalies etc.) by difference		6.5
Sulphates	(SO_3)	4.5
Chlorides	(Cl)	NONE

The most notable factor here is the extremely low total dissolved solids.

Dissolved Oxygen

No determinations have been made of the O_2 content of the lake waters, but also there has been, however, no indication that the lake ever suffers from insufficient oxygen and lakes of this type very seldom have deficiencies of sufficient intensity to affect the fish in them.

Hydrogen Ion Concentration

The record of the pH, 7.30, is given in the analysis of Bear lake water, Table I, is the only one available for this lake.

Classification

The lake classification arbitrarily set up for the sake of uniformity and simplicity does not precisely fit Bear lake as it is a moderately deep, cold, clear lake. Thus it is placed in the intermediate class provided.

XIII AZUKLOTZ LAKE

Physiography and Morphometry

Azuklotz lake, located to the east of the southern part of Bear lake is tributary to it through a short stream with a four-foot drop. It is 1¾ miles long by ¾ of a mile wide and has a maximum depth of 35 feet. It is characterized by large shallow areas with beds of submerged vegetation. It has one main tributary, Azuklotz creek, though in some years it enters the lake through two channels.

Temperatures and Transparency

The highest surface temperature recorded for this lake was 19.75°C (67.55°F.) on August 11, 1948 and the highest bottom temperature was 16.2°C. (61.18°F.) on the same date. Its summer heat income has averaged 9,500 gm. cal. per cm.^{2} during the past three years. The water has the same degree of clarity as that of Bear lake, Secchi's disc being visible on the average to a depth of 14 to 15 feet.

Classification

Azuklotz lake belongs in the second category in the lakes of the Skeena drainage as previously outlined.

XIV SUSTUT AND ASITKA LAKES

Physiography and Morphometry

Sustut lake, at the headwaters of the Sustut river, and Asitka lake at the headwaters of the Asitka river, are located 1½ miles from each other at an altitude of 4,500 feet approximately 30 miles northeast of Bear lake. The lakes are over 300 miles from the sea by river.

Sustut, the largest of the two lakes, is 3½ miles long by one-half mile wide and has a maximum depth of 61 feet. The shoreline is fairly regular and gently shelving, with one large, shallow rock-strewn area at the north end. Asitka is a smaller lake 3/5 mile long and ½ mile wide with a maximum depth of 26 feet. The shoreline is marked by several bays only a few inches deep. Sustut lake has only one large bed of rooted aquatic plants. Asitka lake has scattered rooted aquatic plants in all shallow areas but no thick beds.

The streams tributary to both lakes are small and the water entering the lakes is to a large extent seepage. The upper Sustut river carries varying amounts of glacial silt but its small size prevents it having more than a local effect on the lake.

Temperatures

Temperatures have been recorded only twice in Sustut lake and once in Asitka lake. Due to the lateness in the season they cannot be expected to show the maximum temperatures reached by these lakes. On neither occasion, August 22, 1945 and September 9, 1946 was there a hypolimnion at Sustut lake as the thermocline reached the bottom of the lake where the temperature was 8.9°C. (48°F) on both occasions. The highest surface temperature - 14.7°C. (58.5°F.) was recorded in 1946. The summer heat income on the basis of the above figures was 15,250 gm. cal. per cm^2. in 1946.

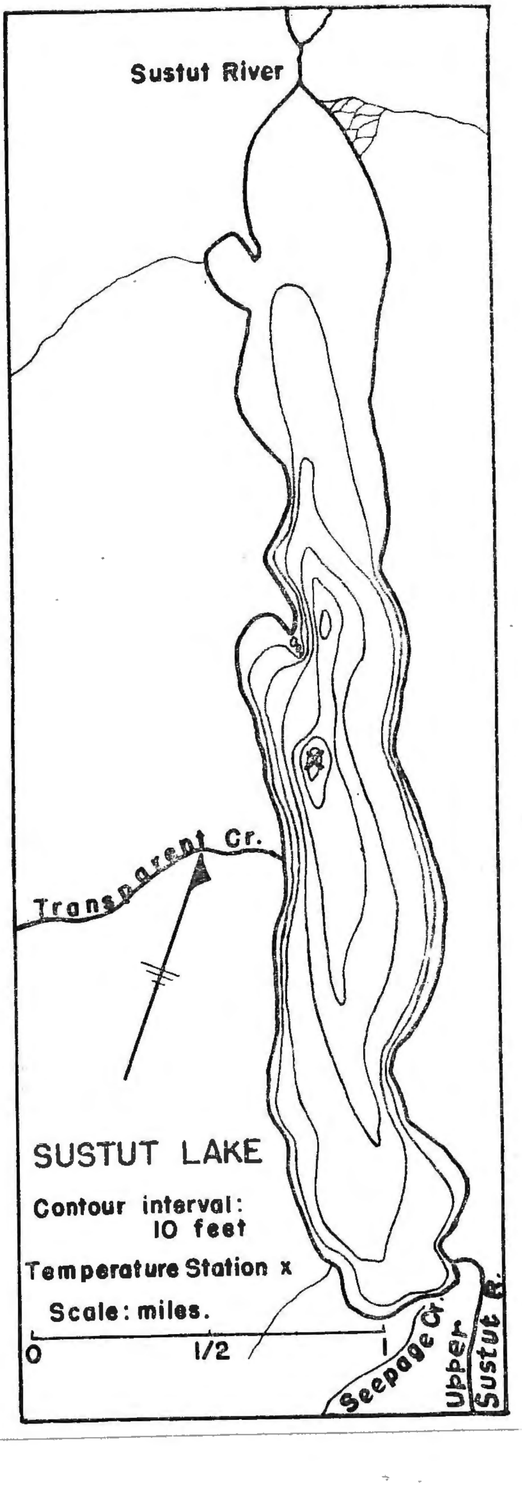
Asitka lake in the same year had a surface temperature of 13.9°C. (57°F.) and a bottom temperature of 11.7°C. (53°F.) with a summer heat income of 6,950 gm. cal. per cm.^{2}.

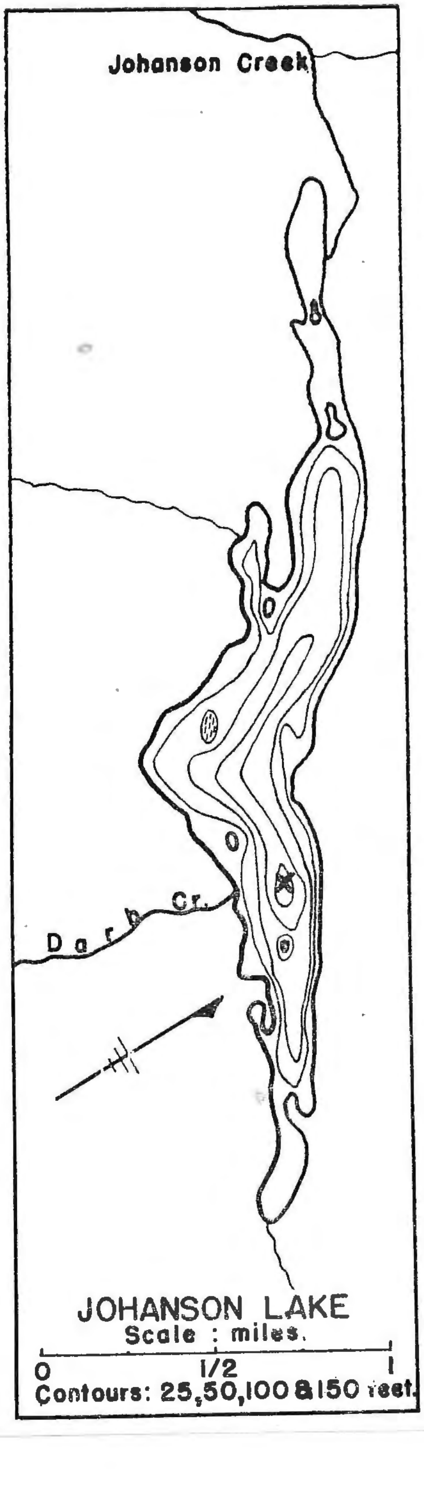
Transparency

Despite a definite indication of silt in Sustut lake Secchi's disc could be seen to a depth of 30 feet. Asitka lake, however, has no silt and the lower reading, 18 feet, for Secchi's disc is probably an indication of a greater plankton population.

Classification

Though the high altitude makes these lakes less productive than would be normal at ordinary levels they fit best in the second class of lakes as outlined for the Skeena.


Sustut River
Transparent Cr.
SUSTUT LAKE
Contour interval: 10 feet
Temperature Station x
Scale: miles.
0
1/2
1
Seepage Cr.
Upper Sustut R.


Johanson Creek
Darb Cr.
JOHANSON LAKE
Scale : miles.
0
1/2
1
Contours: 25,50,100 & 150 feet.

XV JOHANSON LAKE

Physiography and Morphometry

Johanson lake, on the headwaters of Johanson creek, a tributary of the Sustut river, has the greatest altitude, 4,730 feet, of any of the sockeye lakes of the Skeena river watershed. In addition it is also one of the farthest from the sea, being approximately 350 miles from the mouth of the river.

The lake is 2¾ miles long by ½ mile wide and has a depth of 160 feet. It is characterized by a lack of shallow areas around both the shore and the islands. Rooted aquatic vegetation is confined to a very small area at the east end and even here it was extremely sparse.

It has two tributaries, Darb creek, the outlet from the silted Darb lake and a small unnamed creek carrying glacial water.

Temperature

The surface temperature on September 16, 1946 was 11.5°C. (52.7°F.) and a typical thermocline was present between the 35 and 50 foot levels. At this time both the epilimnion and hypolimnion w~~h~~ere characterized by very uniform temperatures.

Transparency

The water is fairly clear, Secchi's disc having been visible to a depth of 30 feet on a cloudy day.

Classification

Though Johanson lake has the characteristics in the main of Group I lakes the abundance of silting alone necessitates placing it in the intermediate Group III.

XVI DAMSHILGWIT AND SLAMGEESH LAKES

Physiography and Morphometry

The Slamgeesh river, a tributary of the Kilankis river 80 miles north of Hazelton, has two small lakes located on it. The larger and more northerly of these is Damshilgwit or Cabin lake and the other is Slamgeesh lake. Though exact figures for the altitude of these lakes could not be obtained they are between the 2,000 and 2,500 foot contours on maps of the area.

Cabin lake, one-half mile by one-quarter mile, has a maximum depth of 40 feet and Slamgeesh lake, smaller and shallower, is one-quarter mile by one-quarter mile with a maximum depth of 26 feet. Weed beds were not extensive in Cabin lake which had a muddy to oozy bottom from which marsh gas exuded in many places. Slamgeesh lake did not appear to have the same exudation of gas though the bottom appeared to be much the same as that of Cabin lake. There are extensive beds of both submerged and emergent vegetation in Slamgeesh lake which appears to be much more productive than Cabin lake.

Temperatures

A temperature series taken at Cabin lake on July 24 showed a surface temperature of 13.8°C. (56.8°F.) and a bottom temperature of 7.8°C. (46°F.) giving a summer heat income to that date of 7,150 gm. cal. per cm.^{2}. On July 27 a temperature series at Slamgeesh lake revealed a surface temperature of 12.2°C. (54°F.) and a bottom temperature of 11.1°C. (52°F), showing a heat income of 6,180 gm. cal. per cm^2. The lower heat income for Slamgeesh lake is probably a direct reflection on the greater replacement of water by the river in proportion to the volume of the lake than is the case in Cabin lake.

Transparency

The transparency of both these lakes was of the same order, Secchi's disc having been visible to a depth of 12 feet in both cases.

Classification

Both these lakes unboubtedly fit in the second category of lakes as outlined.

XVII KLUATANTAN LAKES

Physiography and Morphometry

The watershed of the Klustantan river is on the northern edge of the Groundhog coal field 120 miles north and slightly west of Hazelton. Two creeks, Kluayas, a heavily silted stream and Klustantan, a small clear stream, have lakes on them to which salmon ascend. Kluayas lake, the largest, is located close to the mouth of Kluayas creek just north of the 57th parallel North Latitude and west of the 128th meridian West Longitude. The two Klustantan lakes are located on Klustantan creek about seven miles southeast of Kluayas lake. Though the exact altitude of these lakes has not been determined it is believed to be about 3,500 to 3,800 feet for Kluayas, and the Klustantan lakes somewhat lower.

Kluayas lake is irregular in outline, 2 miles long by 1 mile wide, with a large part of the northern end quite shallow and a large shallow bay at the southwest corner. It has a maximum depth of 64 feet. The two Klustantan lakes, seperated by a quarter-mile of creek, do not appear to be deep though no soundings were made. They are each approximately one-half by one-quarter mile and the edges gradually grade off into swamp.

Temperatures

The maximum temperature recorded at Kluayas lake was on August 21, 1946 when 11.4°C. (52.5°F.) was recorded at the surface and 7.8°C. (46°F.) at the bottom. On the basis of these temperatures the summer heat income is 7,600 gm. cal. per cm^2. No temperatures were obtained from the Klustantan lakes.

Transparency

Kluayas lake, with the main inlet a glacial stream, had a Secchi's disc reading of six inches. The Klustantan lakes have no glacial inlets and thus the water is clear.

<u>Classification</u>

Because of its silt content Kluayaz lake must be placed in the first category of Skeena lakes and the Kluatantan lakes could be expected to fit in the second category.

c

TABLE

The following composite table has been drawn up to bring together pertinent figures on the physical features of these twenty lakes.

mean temp?

	Area - Square Miles.	Max. length - miles.	Max. Width - miles.	Max. Depth - feet.	Mean Depth - feet.	Volume - cubic yards x 10^6	Shoreline Development	Elevation - Feet.	Surface Peak Temperature - °C	Bottom Peak Temperature - °C	Mean Transparency - feet.	Minimum summer bottom O_2 per cent. concentration.
Lakelse	5.47	5.4	1.5	98	24.0	141.3	1.83	220	20.2	13.8	10.0	45
Johnston	0.87	2.0	0.6	-	-	-	-	-	-	-	-	-
Alastair	2.3	5.2	0.5	236	74.0	179.	2.21	500	17.1	4.4	25.7	-
Kitsumgallum	6.8	6.8	1.6	435	232.5	1632.	2.03	468	13.0	4.0	1.5	80
Kitwanga	2.8	4.5	1.0	44	23.8	68.	2.33	600	19.1	7.0	18.9	0
Swan	10.8	7.0	2.0	210	74.7	832.	3.47	1500	16.8	4.3	-	90
Stephens	3.1	3.5	1.0	85	34.0	112.	2.10	1500	20.3	5.0	-	72
Morice	40.0	25.4	2.8	775-	327.0	13507.	3.18	2614	14.0	4.0	9.8	-
Babine	171.8	92.5	5.8	680	160.8	34726.	6.59	2332	18.3	7.5	17.8	52
Nilkitkwa	2.0	6.5	0.5	62	19.2	39.	2.79	2310	16.4	8.6	15.7	63
Morrison	5.6	9.5	1.1	200	68.5	400.	2.60	2400	19.4	5.4	11.0	62
Motase	-	3.5	1.0	105	-	-	-	3350	6.75	6.3	0.5	-
Bear	7.2	12.4	3.0	240	42.0	314.	3.2	2640	19.25	6.0	14.5	-
Azuklotz	0	1.75	0.75	35	-	-	-	2648	19.75	16.2	14.5	-
Sustut	1.3	3.5	0.5	61	21.4	28.	2.06	4250	-	-	30.0	-
Asitka	-	0.75	0.5	26	-	-	-	4250	13.5	11.7	18.0	-
Johanson	0.6	2.75	0.5	162	48.3	30.	2.90	4730	11.5	5.3	30.0	-
Damshilgwit	-	0.5	0.25	40	-	-	-	-	13.8	8.9	12.0	-
Slamgeesha	-	0.25	0.25	26	-	-	-	-	12.3	11.4	12.0	-
Kluayaz	-	2.0	1.0	64	-	-	-	3800	11.25	7.8	0.5	-

On the basis of classification which has been described in the section on Lakelse lake, namely, (1) Deep, cold bodies of water distinctly opaque and grey from glacial silt, (2) Rather shallow bodies of water, clear, of moderate temperature, and abundant in plant life, and (3) Intermediate between (1) and (2), the above lakes may be grouped thus :

Group 1.	Group 2.	Group 3.
Johnston	Lakelse	Alastair
Kitsumgallum	Kitwanga	Swan
Morice	Stephens	Babine
Motase	Nilkitkwa	Bear
Kluayaz	Morrison	Johanson
	Azuklotz	
	Sustut	
	Asitka	
	Damshilgwit	
	Slamgeesh	
	Kluatantan	

The importance of the lakes in the general sockeye production can be assessed by their relative spawning escapements which, for the present, may be assigned as :-

Group 1. (total) - 15 - 15% of escapement

Group 2. " - 20 - 20% " "

Group 3. " - 55 - 65% " "

D. DISCUSSION

In the first section, dealing with Lakelse lake, the biological implication of each of the main physical features has been considered and may be applied in general aspect to each of the subsequent lakes modified by the particular characteristics of that lake. The streams have been described more in relation to their direct effect on the lake rather than with respect to spawning facilities (see Appendix 5).

Certain broad generalizations can be made relative to conditions in the "nursery" lakes from the point of view of sockeye production.

1. No direct limiting factor of a physical nature, with one minor exception, has been discovered (Exception - Mid-summer oxygen concentration in Kitwanga hypolimnion).

2. No indication of any particular change in the physical features during the present century can be demonstrated by this study or past records. No particular flood or fire has left a demonstrable modification.

3. Production in lakes is the product of many subtle and interacting forces which may be found to unite or disunite for particular patterns of fish survival.

4. The presence of high turbidity appears directly related with low production, and in this respect, delineates the lakes in Group 1 as of poor production and of little feasible improvement possibilities.

5. Low temperature is also directly related to low production. It may be that the whole area is limited by a low heat income.

6. The lack of stable thermoclines appears to be an asset in that it does not result in stagnant hypolimnions.

7. A water level in the lake in September equal to that of the freeze-up may result in better production.

8. Lakes of Group 2 hold the greatest promise for improvement from fertilization if that were attempted as a possible means of increasing production.

E. RECOMMENDATIONS

1. That a study of the amount of basic elements be made, with particular interest in Nitrogen, Phosphorous and Silicon.

2. That one lake be selected for particular study.

3. That experiments with fertilization be considered.