SPATIAL DISTRIBUTION OF FISH IN SUMMER IN NICOLA LAKE, BRITISH COLUMBIA

by

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ABSTRACT

Diurnal and seasonal variation in spatial distribution of fifteen species of fish were studied in Nicola Lake during summer. Maximum depth at which fish were taken was 110 ft. where only Kokanee were found. Peamouth Chub, Largescale Sucker and Prickly Sculpin were found in depths up to 80 ft. Chiselmouth were restricted to the shallow southwest basin all throughout summer. Carp fingerlings were also restricted to shallow weedy areas. All other species were available in all major regions of the lake.

Young-of-the-year of Peamouth Chub, Largescale Sucker, Squawfish, Redside Shiner and Prickly Sculpin stayed very close to shore during daylight. Fry of Kokanee, Rainbow Trout, Mountain Whitefish and Chinook Salmon appeared in areas close to stream inlets and outlets during day. Smaller size groups of fish available on the shore in daylight moved offshore at night, when larger fry and adults appeared in the shore. Young of Mountain Whitefish were dispersed in different regions of the shore at night.

Variation was observed between daylight and dark distribution of different species. Adult Peamouth Chub and Redside Shiners stayed on the bottom during daylight but they invaded surface and shallow shore areas at night. Squawfish also tended to leave the bottom at night.

Factors determining migration and summer distribution of fishes were investigated. Thermal stratification was unstable and had no apparent effect on vertical migration of most species. Only Squawfish avoided the hypolimnion.

Dissolved oxygen was plentiful up to a depth of 96 ft. and its effect, therefore, could not be assessed.

Light apparently played an important role in determining movements of fish in daylight and dark. Diurnal variation in distribution is attributed to effect of light.

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I. INTRODUCTION

The spatial distribution of fish in a lake is a dynamic equilibrium between the biology of the fish species and the physical, chemical and biotic environment. The distribution is constantly changing with time. The comprehension of these movements, their causes and their effets would involve an understanding of the mechanics of the ecosystem of the lake itself.

Various factors are constantly at work, but to what extent each factor is responsible is rather difficult to appreciate in nature.

Possibly, each causative factor might show its individual influence on fish distribution. On the other hand, distribution may be the resultant of the interactions of two or more factors. When one factor in the environment is constant, it has been assumed that the other varying factors determine the distribution. Similarly, 'modifier' factors are known to alter the influence of some dominant physical factors.

The purposes of the present study are (1) to observe the gross effects of biotic, chemical and physical environment on the distribution of a fish in a lake, and (2) to try to understand, where possible, the mechanisms which determine this distribution during the summer.

Nicola Lake was chosen as the working site because of two considerations - (1) the lake provides a wide variety of fish species and different habitats; and (2) facilities for field study were available through the Fish and Game Branch of the British Columbia Department of Recreation and Conservation.

II. MATERIALS AND METHODS

Description of the lake:

Nicola Lake is situated along the highway approximately 40 miles south of Kamloops and 10 miles northeast of Merritt, B. C. in 50° 120° SW at an altitude of 2056 ft. above sea level, in the southern interior plateau of the province of British Columbia.

The area in which the lake is situated is known as Nicola basin, a part in the Princeton-Nicola-Kamloops depression formed and developed as a trough of some definiteness during the tertiary times (Brink and Farstad, 1949). In this and two other basins, a series of lakes formed in late Pleistocene times - as the melting ice dammed one or the other narrow basin outlets (Mathews, 1944).

The area is characterized by sedimentary and volcanic rocks extensively glaciated and with a mantle of lucustrine silts (Northcote and Larkin, 1956).

Climatically, the region is dry. The whole southern interior plateau, of which the Nicola valley is a part, has a low annual precipitation and extreme temperature conditions (Northcote and Larkin, 1956). During the summer of 1958, precipitation in and around the lake was extremely low. The maximum rainfall on any single day in the whole season occurred on 2 September when it was recorded as .095 inches. Precipitation in the summer was very occasional and sparse. Air temperature in the middle of summer ranged between 90° and 100°F during the day while at night there was a rapid drop. The maximum daylight temperature of 100°F was recorded on 24 August, 1958. Northcote and Larkin (1956) discussed the effect of climatic factors upon lake productivity. According to them in dry areas with low precipitation and hot summer, the T.D.S. of lakes should be relatively high. The T.D.S.

of Nicola Lake is found to agree with the above observation.

Morphometry of the lake

Maximum length of Nicola Lake is 12.7 miles, while its maximum width does not exceed 1.53 miles. In two places, about 1.3 miles southeast of and again about 493 yards southwest of Quilchena, width of the lake is maximum. In the remaining parts, its width does not exceed one mile. The total length of shore line is 27.8 miles while the shore development is only 2.5. It has a total surface area of 6041 acres with a maximum and mean depth of 181 ft. and 77 ft. respectively. Total volume, as calculated, is about 2,000,000,000 cubic ft. Depth contours of the lake are presented in Figure 1.

Proportion of the total area under different depth zones are summarized below.

Table I. - Total area in different depth contours.

Depth Zone	% of total area
0' - 25'	27.3
25' - 50'	22.6
50' - 75'	20.1
75' - 100'	16.7
100' - 125'	8.4
125' - 150'	4.3
150' - 175'	0.5
175' - Above	0.1

The lake basin can be divided into two broad ecological regions, the deeper and larger portion from point 'N' (shown in Fig. 1) northwards up to the north end, and a shallow southwestern portion, from 'N' in Figure 1

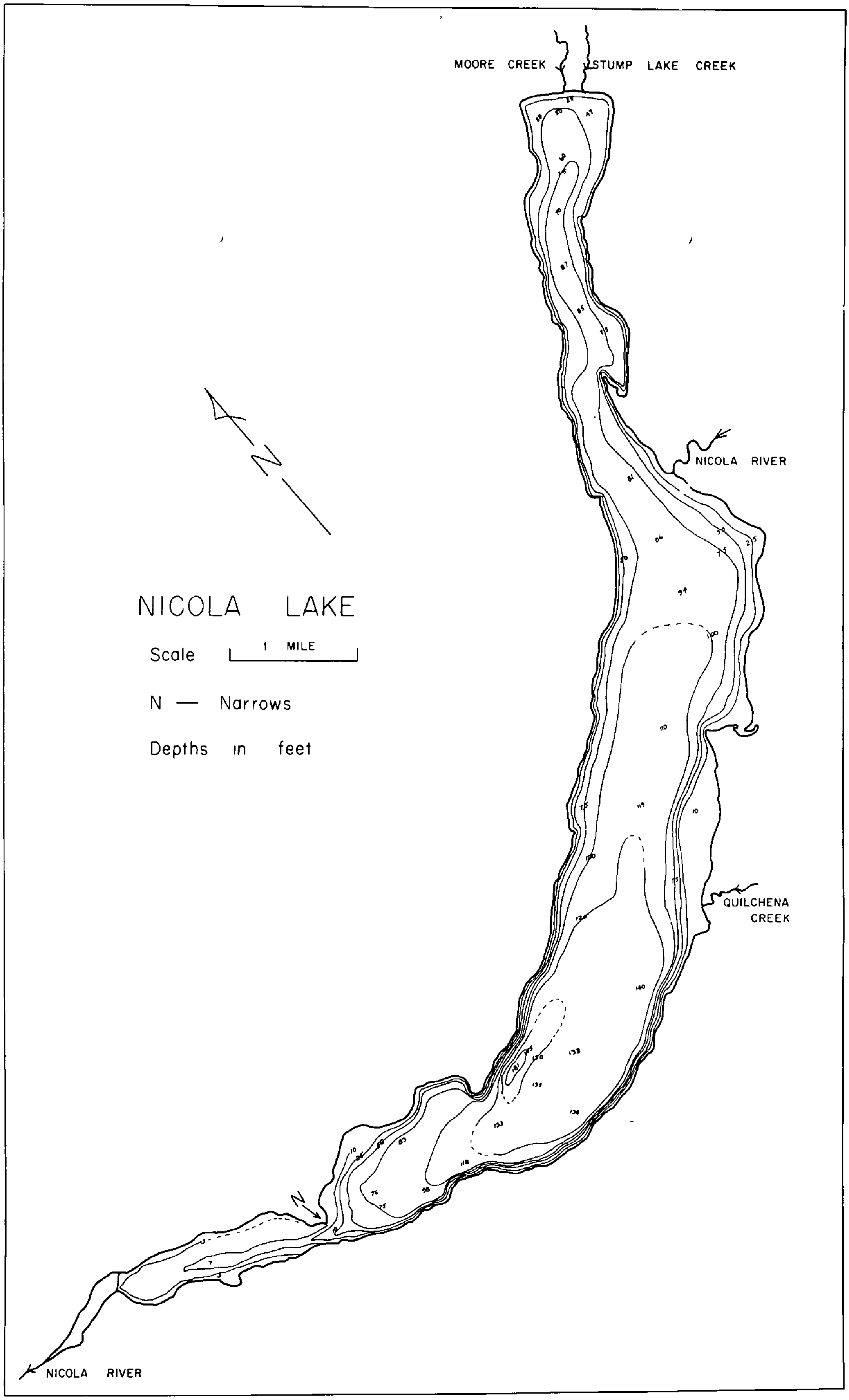

Figure 1. Map of Nicola Lake showing contour line.

southwards down to Nicola River outlet. Maximum depth in the shallow basin does not exceed 10 ft.

The shores are predominantly rocky and precipitous in the deeper portion, while in the shallow southwest portion, the shores are not as rocky and slope into water very gradually. A steep chain of mountains rise from the water along the west shore of the deeper portion of the lake, with the exception of some areas opposite Quilchena where sandy beaches occur. The eastern shore, though for the most part rocky, is not as steep as the western shore. More sandy beaches are present along the eastern shore. A lagoon and some swampy areas are found along the southeast shore between Nicola River inlet and Quilchena Creek. The eastern shore is shallow for about 500 yards commencing at the north tip of the lake, and the slope of the bottom is gradual. The north shore has a continuous sandy beach from one end to the other. As against the rocky and steep shore in the deeper portion of the lake, shores of the shallow southwest part are composed of stone free till. Here the shore has a very small declivity.

In the main body of the lake, the bottom is mainly mud, and the mud bottom appears from below a depth of about 10 ft. In shallower zones along shore, the bottom is either gravel, sand or a mixture of sand, gravel and mud. In the lagoon and swamps along the eastern and southeastern shore, the bottom is mud. The shallow southwest portion of the lake has also a thick deposit of mud mixed with decaying vegetation on the bottom.

Inlets and Outlets:

There are four inlets that flow into the lake, two in the north shore and two on its southeast side. Inlets on the north shore are Moore Creek and Stump Lake Creek (Fig. 1). Both of the inlets retain water during summer.

The latter (Stump Lake Creek) connects this lake with Stump Lake situated at a distance of about 10 miles east. Nicola River enters the lake on its eastern side at a distance of about 4 miles from the northeast tip and flows through the lake. The other inlet in the southeast side is Quilchena Creek which dries up during summer. One very small inlet joins the lake at its northwest end (Fig. 1), but for most of the summer it remains dry. The only outlet of the lake is Nicola River which is wider than any of the inlets and flows into the Fraser River system through the Thompson River.

Physical and Chemical characteristics:

Temperature and other limnological data were collected chiefly at stations VI and IX (Fig. 6). Temperature and water samples were also collected from stations II and VIII (Fig. 6) during early and mid summer respectively.

Temperatures were recorded with a maximum-minimum thermometer, and a Thermistor.

Figures 2, 3 and 4 summarize temperature recordings made in different periods of the summer.

These figures show that in 1958 the lake became thermally stratified during summer, but the stratification tended to disappear from time to time (Table II). Thermal stratification, though not very sharp, commenced as early as June (10-11 June) when the thermocline was seen at a depth of 35-40 ft. With the progress of the season, the sharpness of stratification increased, and the thermocline rose to 15-17 ft. (22 July). Three days later, on 25 July, the thermocline had descended to 21 ft., while on 28 July, no thermal stratification was noticed. For the remaining period of the summer, fluctuation in the position of the thermocline can be seen, with complete disappearance once again on 25 August (Table II and Fig. 3). It is suspected

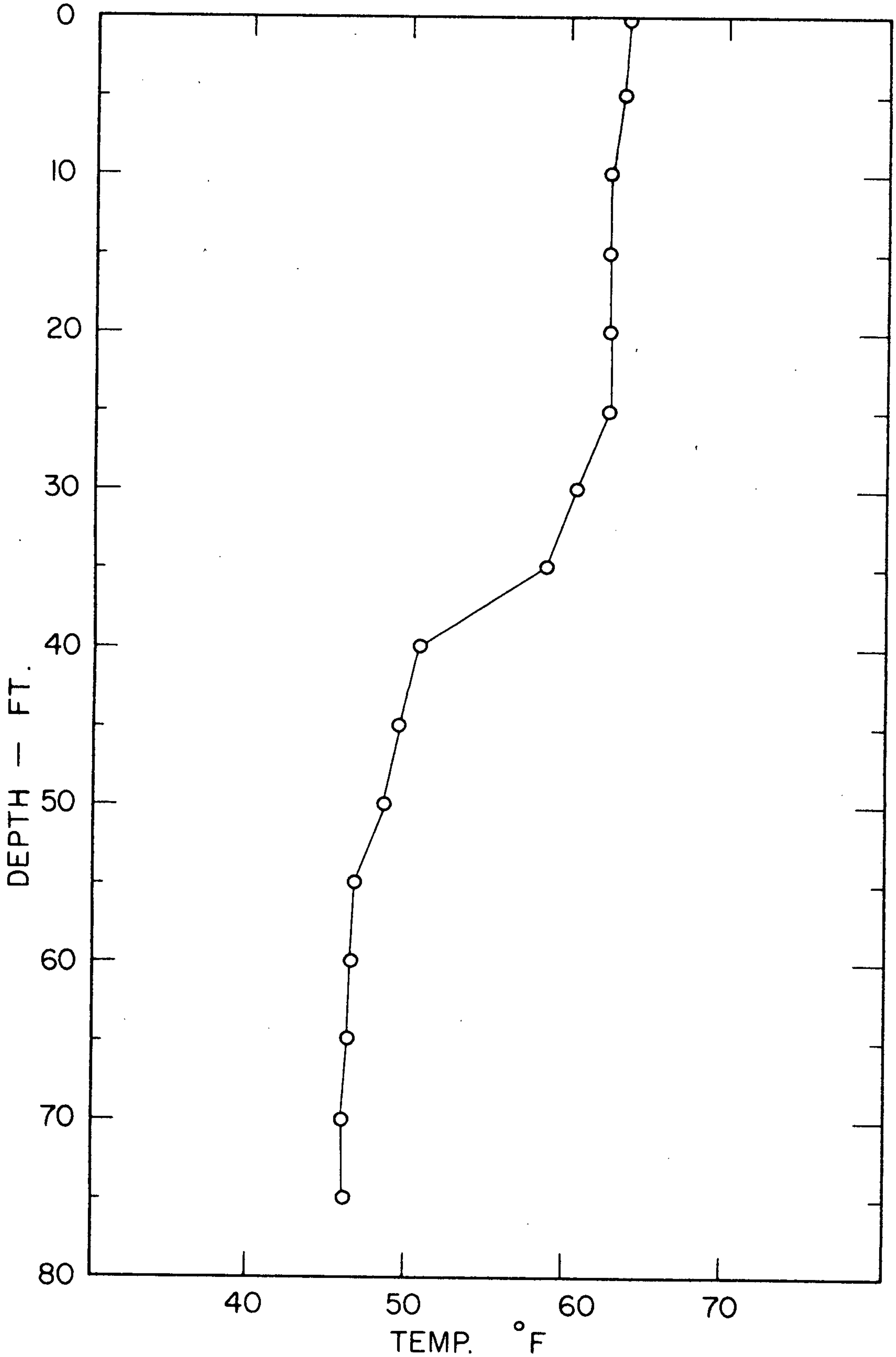

Figure 2. Temperature curves from 80 ft. station, Nicola Lake.

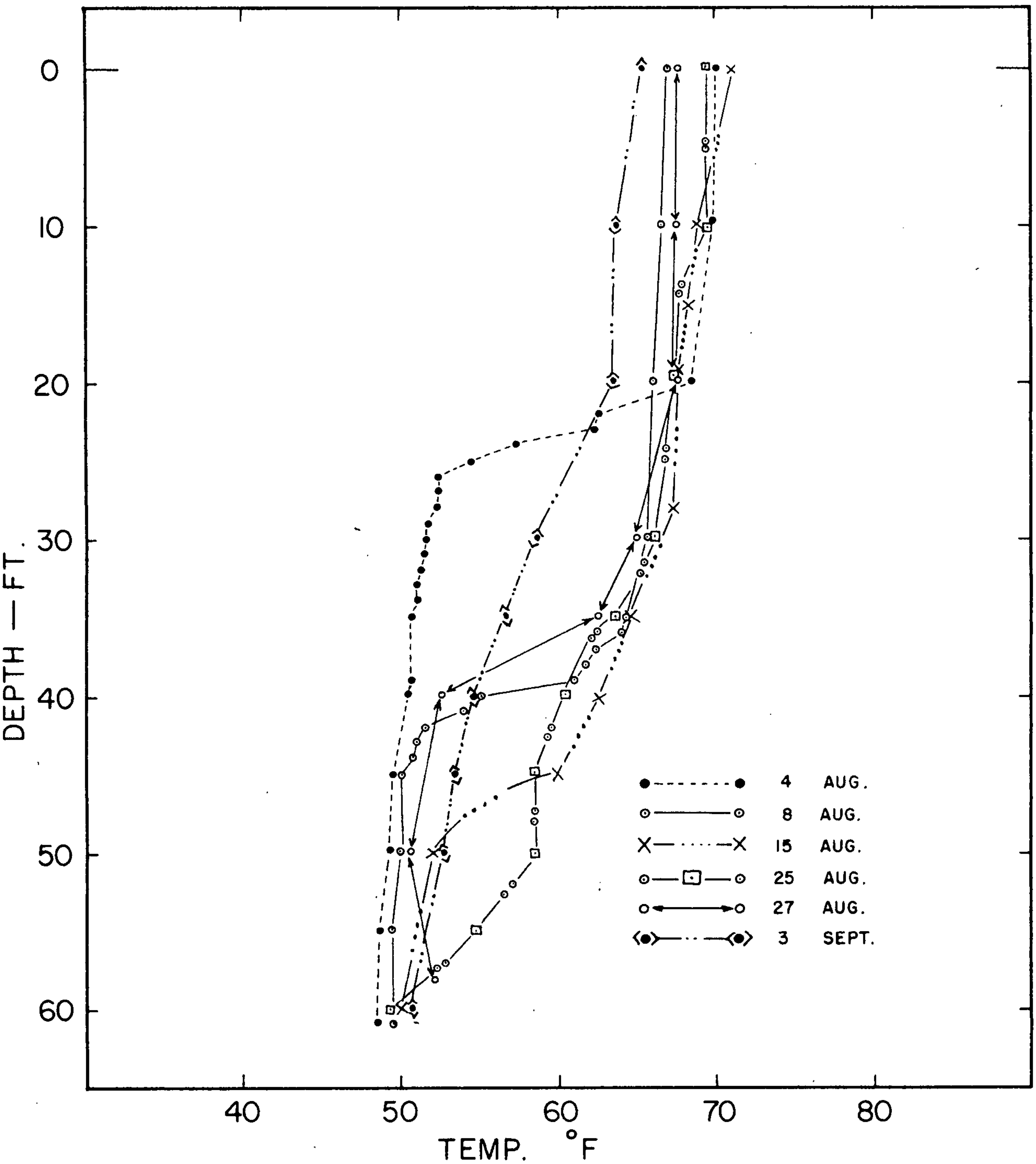

Figure 3. Temperature curves from 60 ft. station, Nicola Lake.

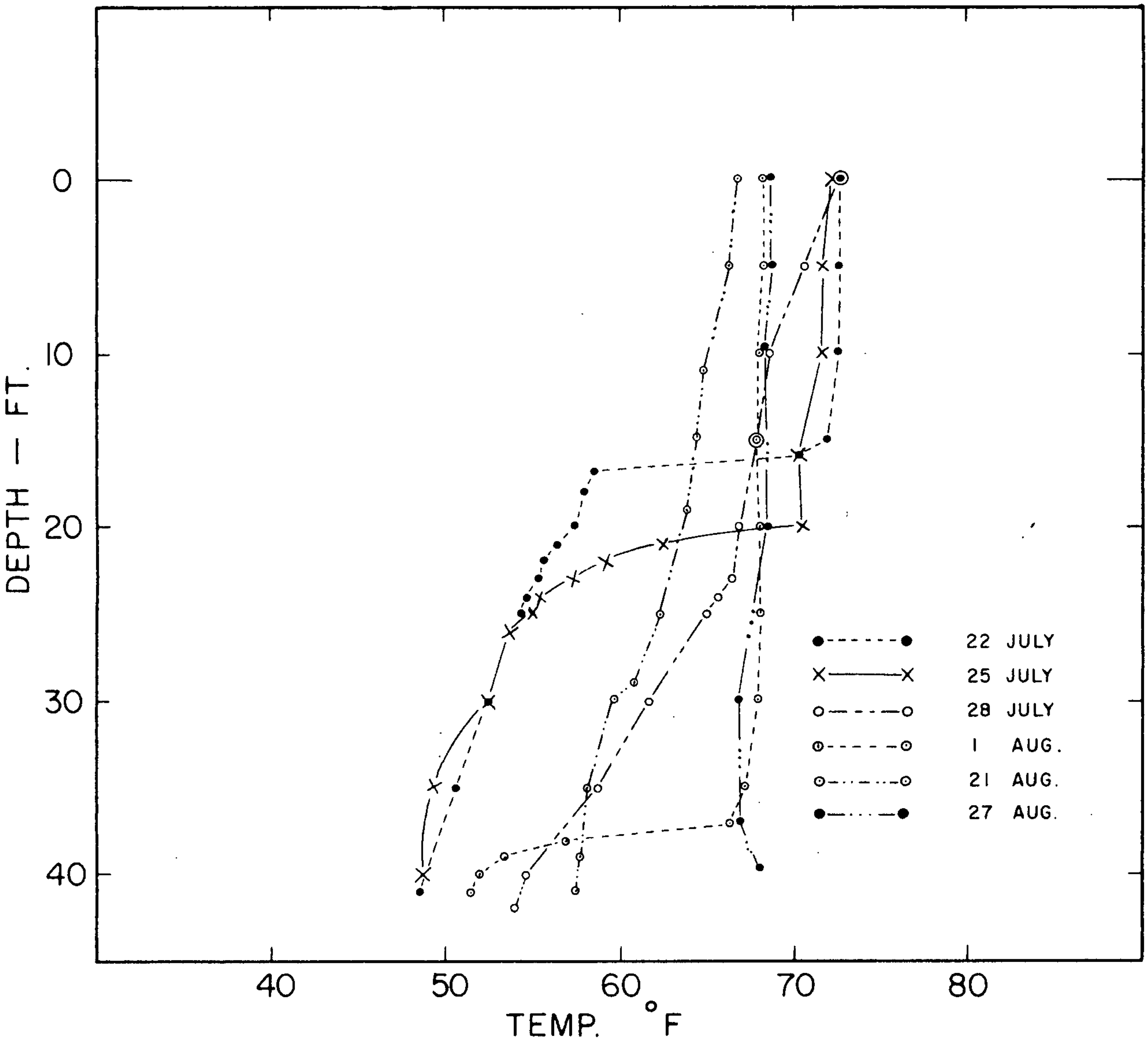

Figure 4. Temperature curves from 40 ft. station, Nicola Lake.

TABLE II. Position of thermocline in Nicola Lake during summer, 1958.

Date	Depth of thermocline Upper limit (in ft.)	Lower limit (in ft.)	Remarks
12 June	35	40	Temperature recorded from station II.
22 July	15	17	Temperature recorded from station VI.
25 July	21	23	Temperature recorded from station VI.
28 July	-	-	No thermocline. Temperature recorded from station VI.
1 August	37	40	Temperature recorded from station VI.
4 August	21	26	Temperature recorded from station IX.
8 August	39	42	Temperature recorded from station IX.
15 August	45	50	Temperature recorded from station IX.
25 August	-	-	No thermocline. Temperature recorded from station IX.
27 August	35	40	Temperature recorded from station IX.

that these alterations are the result of strong and almost continuous wind action to which the lake was exposed throughout the summer. Wind blew from the west and southwest direction and as a result, piling up of the epilimnioitic water occurred in the north and northeast end of the lake. Occurrence of temperature seiches in Skaha Lake is reported by Ferguson (1949). Complete disappearance of stratification cannot perhaps be explained as the result of wind action. Occasional disappearance of the thermocline, however, indicates that thermal stratification is very unstable. Rawson (1934) found no thermal stratification in Nicola Lake when temperatures were recorded on 8 July and 30 August in 1931.

For determining the dissolved oxygen content in water, water samples were collected with a "Kemmerer" water sampler and analysed by Winkler's method. Results of the analysis are presented in Figure 5 and Table III. In water up to the depth of 96 ft., dissolved oxygen content can be considered rather high (3.4 p.p.m.). The quantity of dissolved oxygen at a depth of 175 ft. was found to be 1.8 p.p.m. This indicates that the lake is oligotrophic in nature and does not have much organic decomposition in the hypolimnion during summer. The oxygen curves presented in Figure 5 appear to be rather of clinograde type, characteristic of the eutrophic type of lakes (Hutchinson, 1956). But since the oxygen depletion in the deeper water is more or less gradual, the situation may be said to be somewhat intermediate between the orthograde and clinograde type of curves. Rawson (1934) found heavy depletion of oxygen (0.4 p.p.m.) in the bottom regions when water samples were examined on 20 August, 1931, showing that marked differences may occur in different years.

Secchi disc readings taken are summarized in Table IV. The readings indicate that water remains fairly clear throughout the summer.

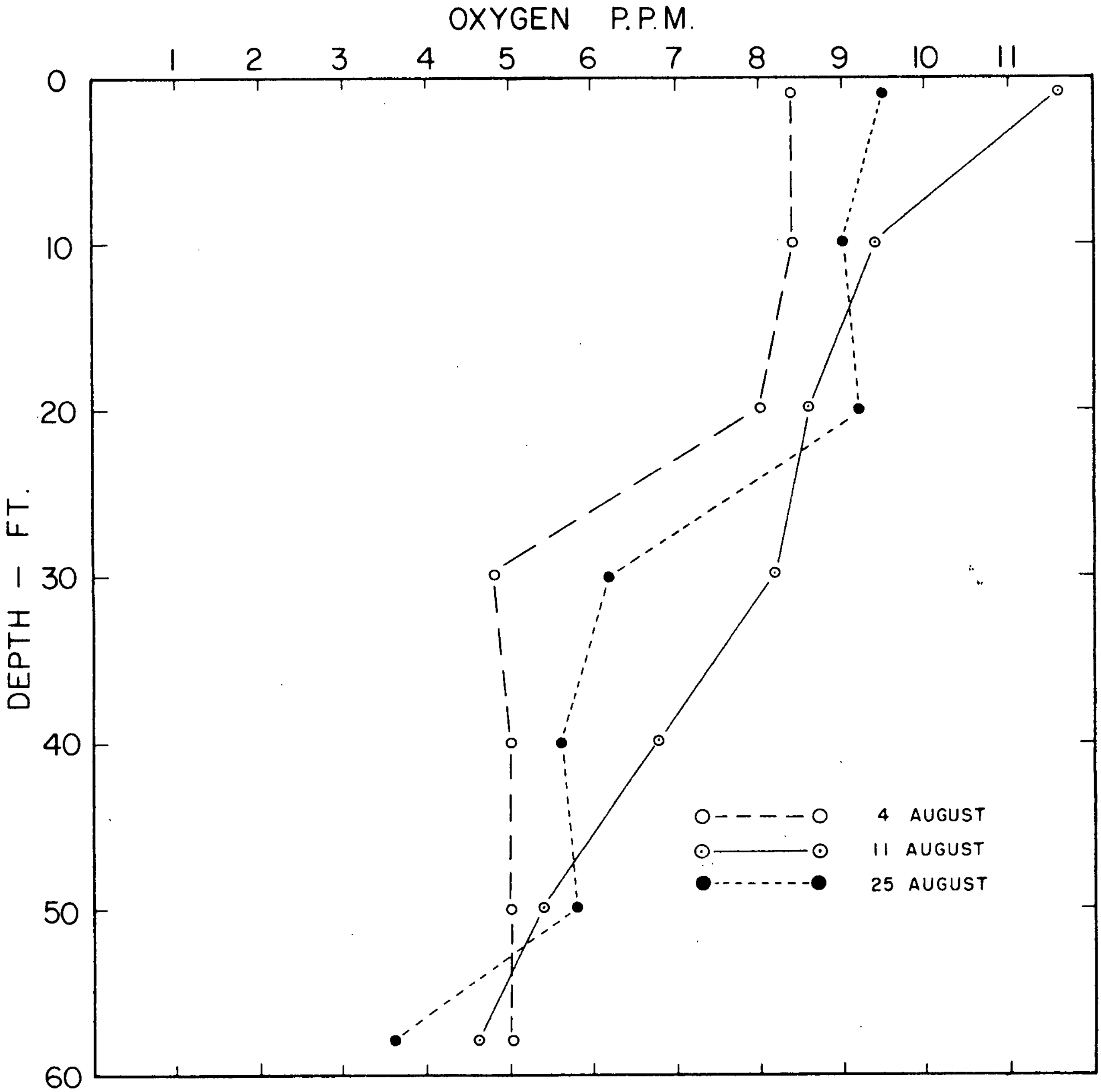

Figure 5. Availability of dissolved oxygen in Nicola Lake during the summer of 1958.

TABLE III (a). Dissolved oxygen in p.p.m. recorded from station IX.

Date	Depth (ft.)	Temperature in °F	Oxygen p.p.m.
4 August	1	70.0	8.4
	10	69.7	8.4
	20	68.1	8.0
	30	51.8	4.8
	40	50.3	5.0
	50	49.1	5.0
	58	48.6	5.0
11 August	1	67.0	11.6
	10	67.0	9.4
	20	66.5	8.6
	30	66.0	8.2
	40	60.0	6.8
	50	55.0	5.4
	58	50.8	4.6
25 August	1	69.8	9.5
	10	69.3	9.0
	20	67.3	9.2
	30	66.0	6.2
	40	60.3	5.6
	50	58.5	5.8
	58	-	3.6

TABLE III(b). Dissolved Oxygen in p.p.m. recorded from stations VI and VIII.

(a) Station VI

Date	Depth (ft.)	Temperature °F	Oxygen p.p.m.	Remarks
19 August	1		9.2	
	10		8.2	
	20		7.6	
	39.5		3.8	
27 August	1	68.5	9.2	
	10	68.4	9.2	
	20	68.1	9.2	
	30	66.8	9.1	
	37.5	66.8	6.6	
(b) Station VIII.				
22 August	96	-	3.4	
	107	45.8	2.4	
	175	-	1.8	

TABLE IV. Secchi disc readings taken from station IX.

Date	Limit of visibility (ft.)	Light condition and air temperature
8 August	4.5	Overcast 0/10
11 "	6	Overcast 10/10
15 "	5.5	Air temperature 70°F
20 "	6.5	Air temperature 68°F
25 "	6.9	Overcast 7/10
27 "	5	Overcast 9/10 air temperature 64°F
7 September	5.4	Overcast 0/10 air temperature 60°F

Total dissolved solid content of water was found to range between 151 and 200 p.p.m., which is high compared to the lakes in coastal regions of British Columbia.

Biological characteristics:

(a) Vegetation: Aquatic vegetation is sparse except in the shallow southwest portion of the lake. *Najas* sp., *Chara* sp., and *Callotricha* sp. grow in the shallow shore areas, specially in the north shore of the main body of lake up to a depth of about 6 ft. No vegetation grows in areas of the shore where the bottom is exclusively sandy. In the shallow shore areas of the east and southeast side, particularly in the swamps and lagoons, *Scirpus* sp. and *Typha* sp. grow abundantly. In the shallow southwest region, dominant species are *Potamogeton richardsonii*(?), *P. panormitanus* (?), *Zannichellia palustris* and *Myriophyllum* sp. *Scirpus* sp. and *Typha* sp. are also seen on either side of this shallow portion.

(b) Plankton: Plankton samples were taken in different periods of the season, and were found to be composed chiefly of *Ceratium* sp. (Dinoflagellata), *Nothoca* sp. (Rotifera), *Diaptomus* sp., *Bosmina* sp. and *Daphnia* sp. (Cladocera), *Cyclops* (Copepoda), *Anabaena* and *Aphanizomenon* (Blue green algae). Rawson (1934) mentions the same type of plankton organisms which were poor in quantity.

(c) Bottom fauna: Bottom fauna was not studied in the course of the present investigation. Rawson (1934) found a very scanty population of bottom fauna composed of Chironomid larvae, *Pisidium*, Oligochaeta and Nematoda.

(d) Fish fauna: The lake contains several species of fish which are listed below. All but the carp are native species.

(1) Rainbow Trout, _Salmo gairdnerii_ Jordan.

(2) Chinook Salmon, _Oncorhynchus tshawytscha_ (Walbaum).

Both young and sexually mature adults are seen.

(3) Kokanee, _Oncorhynchus nerka_ (Walbaum).

(4) Dolly Varden, _Salvelinus malma_ (Walbaum).

(5) Mountain Whitefish, _Prosopium williamsonii_ (Girard).

(6) Largescale Sucker, _Catostomus macrocheilus_ Girard.

(7) Bridgelip Sucker, _Catostomus columbianus_ (Eigenmann and Eigenmann).

This species is recorded from this lake for the first time.

(8) Squawfish, _Ptychocheilus oregonense_ Richardson.

(9) Peamouth Chub, _Mylocheilus caurinum_, (Richardson).

(10) Redside Shiner, _Richardsonius balteatus_, (Richardson).

(11) Chiselmouth, _Acrocheilus alutaceus_, Agassiz and Pickering.

This species is a new record from the lake as well as from the Thompson River drainage system to which the lake is connected.

(12) Carp, _Cyprinus carpio_, Linnaeus.

An introduced species.

(13) Longnose Dace, _Rhinichthys cataractae_ (Cuvier and Valenciennes).

Presence of this species is also recorded for the first time.

(14) Burbot, _Lota lota_ (Linnaeus).

(15) Prickly Sculpin, _Cottus asper_ Richardson.

Sampling

Stations:- To obtain a picture of the availability of different species of fish in different parts of the lake, three stations were selected in distant areas. Particulars of the location of the stations are given below, and are also shown in Figures 6 and 7.

I - Station in front of Moore Creek inlet along the 10 ft. contour line of lake bottom.

II - Station in 80 ft. of water, approximately one mile from the north shore.

III - Station in the shallow southwest portion of the lake in 5-8 ft. contour.

Three other stations were also set up along the northwest shore at a distance of about 800 yards from north shore in different depths as detailed below. These stations will, henceforward, be referred to as stations IV, V and VI in the following order (Fig. 3).

IV. Station in 10 ft. of water closest to shore.

V. Station in 20 ft. of water next to but a little south of station IV.

VI. Station in 40 ft. of water in line with but at a distance of about 100 ft. from the 10 ft. station (IV).

Owing to close proximity of 10 and 20 ft. contour line, station V was fixed about 200 ft. south of station IV. These three stations were set up primarily to study inshore and offshore movement pattern of fish in different periods of the day.

In addition to the stations mentioned, gill net sets were also made in front of Nicola River outlet once during the season and in the deepest zone of the lake. These are shown in Figure 3 as station VII and station VIII.

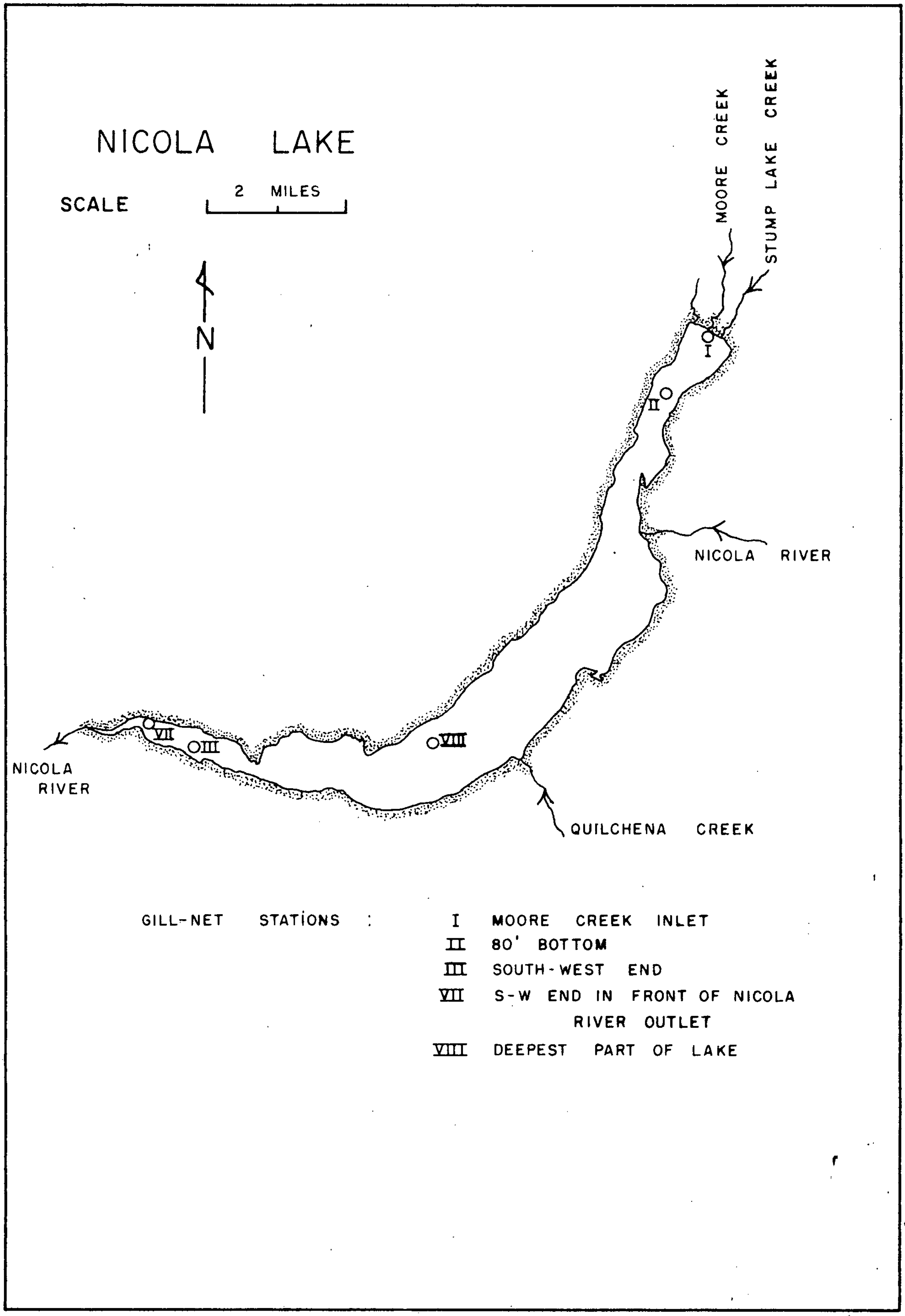

Figure 6. Map showing gill net stations in different parts of the lake.

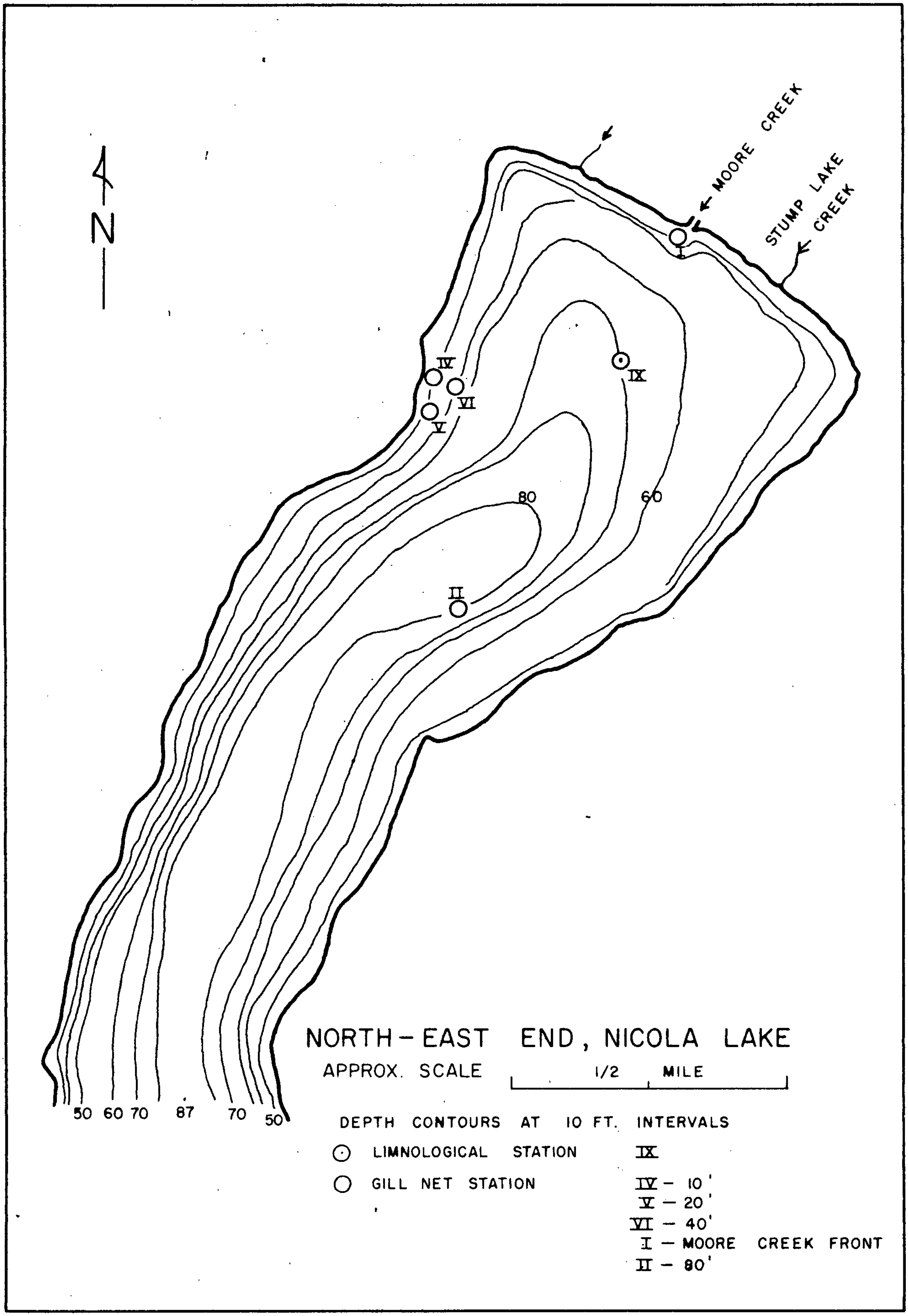

Figure 7. Map showing gill net stations in northwest end of the lake.

Sampling equipments and technique

Three gangs of nylon experimental gill net were used for obtaining samples from the stations referred to in different periods of the season. Each gang of net was composed of six pieces of different mesh size, each piece being 25 ft. long and 12 ft. deep. Total length of a gang of net was, therefore, 150 ft. The sizes of mesh used were 1", 3", 2", 3.5", 1.5" and 2.5" (when stretched) and the pieces in the gangs were joined together in the same order. Selective fishing by any one particular mesh size of net is well known but in the present case probability of selective fishing was greatly reduced by the use of wide range of mesh sizes in each gang.

Each gang of gill net was divided into two equal halves, upper and lower by painting a line across the middle of its entire length. Floats in each section of the gang were marked by letters and the mesh size was also inscribed on each float. These marks were used to note the exact position of a fish in the net. In determining the position of fish, each horizontal half of net was again divided into upper and lower halves. Thus a fish in the net could be located in relation to mesh size, part of the net between two particular floats and the region i.e., top, second, third or bottom quarter of net.

In addition to the three gangs of experimental nylon net, another gang of monofilament nylon net was used. This gang was composed of seven equal sections, each 40 ft. long. The gang was made up of 1", 4", 2.5", 3", 2", 1.5" and 3.5" inch mesh sizes, joined together in the order given. Total length of this gang was 280 ft. This gang was used only once during the summer.

Sampling methods

For convenience, the whole period of summer was arbitrarily divided into three parts. The early summer included the period from the middle of June to the last week of July while the first two weeks of August were termed as mid summer. Late summer included the period between the third week of August and first week of September.

As it was intended to observe and study the variation of movement and abundance of fish in different periods of day, net sets in stations IV, V and VI were made on a six-hourly basis to cover the period of daylight, evening and early night, and late hours of night including early morning. Net sets for evening and night covered the period of transition from light to darkness in the evening and darkness to light during early morning. The fishing hours followed are tabulated below and the different periods will, henceforward, be referred to as day, evening and night.

TABLE V. Fishing hours in stations IV-VI.

Period of day	Time covered
1. Daylight	10.00 - 16.00 hours
2. Evening	18.30 - 00.30 "
3. Night	02.00 - 00.80 "

During each period in the summer, three gangs of nylon nets were set on the bottom at each of the stations IV, V and VI simultaneously. Each net set was made parallel to the closest shore i.e., northwest shore. In each station, both ends of the gang of net covered the same depth of water. In every part of the season, bottom net sets at these stations were repeated for each period of the day, i.e., daylight, evening and night.

Similarly, for each period of summer, another series of net sets were made in three different layers of water in the vertical plane at station VI. One gang of net was floated on the surface with the help of five large buoys. The second set was suspended in the midwater with the floats at the depth of 20 ft. The third gang was set on the bottom at station VI. These sets were also made parallel to the northwest shore. This vertical series of net sets were repeated for every part of the day in each period of the summer. Thus it can be seen that on the bottom at station VI, nets were set twice for every part of the day during each period of summer, once in relation to the bottom sets in different stations (IV to VI) and again in relation to the vertical series of net sets at station VI.

In station I, nets were set in a manner to encircle the area in front of the Moore Creek inlet. Usually two gangs of nets were set together along the 10 ft contour line to block off the inlet mouth. These sets were made in the evening and taken out in the next morning. These sets too fished the same depth of lake all along its length except once in spring (1 May). Results of the sampling effort from the station are summarized in Table VI. These sets were always made parallel to the north shore and perpendicular to the northwest shore.

In station II, two net sets were made during each period of summer. One gang of net was set on the lake bottom while the other gang was kept floated in surface layer almost above the bottom set. Both the sets were made parallel to the northwest shore. Different mesh sizes in each gang fished the same depth and level of water for the given period of time. These two sets were made usually in the evening and taken out the next morning. Table VII summarizes sampling at this station.

Sampling in station III in the southwest basin was repeated once for every period of the summer. One gang of net was set in this station perpendicular to southeast shore. These nets were set overnight. Net was put in water in the late afternoon and taken out the next morning. In this case, different mesh sizes fished different depths, the shore end and outer end being in depths of about 5 and 8 ft. respectively. Since the difference in depth is very small, it can be ignored for all practical purposes. Besides

TABLE VI. Particulars of gill net catches in front of Moore Creek inlet, Nicola Lake during the summer, 1958.

Net on the 10 ft. contour line.

Date	Depth and position of net	Relation to north shore	Species caught												total	Remarks
			KT	KK	DV	SS	SQ	LSS	BLS	MW	PM	RSS	BT	SC		
30 April-1 May	10 ft. bottom	parallel	6	-	-	-	8	7	-	1	24	9	-	1	56	Two nets set together
10-11 June	"	"	5	-	1	-	35	14	4	13	21	60	1	-	154	One net set
28-29 July	"	"	1	6	-	4	18	12	1	6	47	77	-	-	172	Two nets set together
4- 5 August	"	"	4	5	-	-	24	7	-	17	51	110	1	4	223	Two nets set together
11-12 August	"	"	6	10	-	-	16	6	-	10	34	138	2	1	223	Two nets set together
18-19 August	"	"	4	14	-	-	46	14	1	9	18	117	-	6	229	Two nets set together
25-26 August	"	"	6	50	-	3	6	13	3	3	29	141	1	5	260	Two nets set together

Legend:-

KT - Rainbow Trout
KK - Kokanee
DV - Dolly Varden
SS - Chinook Salmon
SQ - Squawfish
LSS - Largescale Sucker
BLS - Bridgelip Sucker
MW - Mountain Whitefish
RSS - Redside Shiner
BT - Burbot
SC - Prickly Sculpin
PM - Peamouth Chub
CP - Carp
CM - Chisel Mouth

TABLE VII. Particulars of gill net catches at 80 ft. station, Nicola Lake during summer, 1958.

Period of summer	Date	Depth and position of net	Relation to shore	Species of fish obtained									Total	Remarks
				KT	KK	DV	LSS	SQ	PM	RSS	BT	SC		
Early summer	11-12 June	Bottom at 80 ft.	Parallel	-	2	-	1	-	3	-	1	1	8	Both ends of net in 80 ft. of water
Mid summer	29-30 July	"	"	-	6	-	-	-	-	-	-	-	6	"
Late summer	3-4 Sept.	"	"	-	20	-	-	-	3	-	-	-	23	"
Early summer	11-12 June	Surface at 80 ft. depth	Parallel	1	1	-	-	1	27	11	-	-	41	Both ends of net in surface
Mid summer	29-30 July	"	"	2	-	-	-	-	11	2	-	-	15	"
Late summer	3-4 Sept.	"	"	5	-	-	-	-	10	15	-	-	30	"

the sampling in station III, sampling in the southwest basin was done in front of the Nicola River outlet (station VII in Fig. 6) once during mid summer. Particulars of catch, time of net set and depth fishes in stations III and VII are presented in Table VIII.

The other sampling done in the northwest shore was with the 280 ft. long gang of monofilament nylon net. This set was made perpendicular to shore across stations IV and VI. The net set was made in the evening and taken out on the next morning. This is the only net set each component mesh-size of which fished at different depths at the same time. The inshore end of this gang was in about 8 ft. of water, while its offshore end fished at a depth of about 50 ft. Table IX summarizes the catch of this net set while particulars on species combinations that appeared in different mesh sizes of this set are presented in Table X.

In the deepest region of the lake, three sets with experimental nylon net were made in three different depth zones. The first was on the bottom at a depth of 173 ft., but no fish appeared. The second effort fished a depth of 80-120 ft. Two gangs of nets joined together were set perpendicular to shore in this case. The third set, comprised of two gangs joined together, and placed at right angle to shore, fished the bottom at depths from 110 to 140 ft. Results of the sampling are summarized in Table XI.

Efficiency and reliability of gill net catches

Table XII summarizes the catch each mesh size had made in 54 net sets made in stations IV, V and VI on the bottom as well as in different levels of water. It can be seen from this table that different size groups of Peamouth Chub, Squawfish, Rainbow Trout and Mountain Whitefish were fairly sampled by the gangs of nets. Redside Shiners appeared consistently in the 1" mesh size indicating that any other mesh size for this small sized fish is ineffective.

TABLE VIII. Particulars of gill net catches in southwest end of Nicola Lake during summer, 1958.

Date	Depth and position of net	Relation to shore	Depth at two ends of net		Species caught														Total
			Inshore	Offshore	KT	KK	DV	SS	MW	SQ	LSS	BLS	PM	RSS	CM	CP	BT	SC	
10-11 June	Bottom at 5-8 ft.	Perpen-dicular	5'	8'	1	-	1	-	8	9	8	2	24	16	1	-	-	-	70
9-10 Aug.	"	"	4'	6'	1	-	-	1	15	9	10	-	84	25	-	1	-	1	147
9-10 Aug.	Bottom at 3-7 ft. nearer to Nicola River outlet	At 60° angle to west shore	3'	7'	-	-	-	-	12	28	6	1	16	13	2	2	-	1	81
5- 6 Sept.	Bottom at 5-8 ft. as on 10-11 June '58	Perpen-dicular			2	2	-	2	28	19	17	3	49	63	18	3	-	10	216

TABLE IX. Number of fish obtained in the monofilament nylon experimental gill net set at right angle to shore across 10 and 40 feet station.

Date 9-10 Aug. 1958	Time 21.00-07.00 hours	Species	Total number of fish	Number of fish moving to north shore	Number of fish moving away from north shore	Loose fish
		Peamouth Chub	99	53	39	7
		Redside Shiner	23	14	8	1
		Squawfish	39	26	8	5
		Largescale Sucker	28	17	6	5
		Burbot	5	0	4	1
		Kokanee	2	1	1	0
		Rainbow Trout	4	2	0	2
		Mountain Whitefish	5	5	0	0

TABLE X. Species combination and mean length of each species of fish caught in different mesh sizes of monofilament net set.

Species	Mesh Sizes: 1" No. of fish	1" Mean length (in mm)	4" No. of fish	4" Mean length (in mm)	$2\frac{1}{2}$" No. of fish	$2\frac{1}{2}$" Mean length (in mm)	3" No. of fish	3" Mean length (in mm)	2" No. of fish	2" Mean length (in mm)	$3\frac{1}{2}$" No. of fish	$3\frac{1}{2}$" Mean length (in mm)	$1\frac{1}{2}$" No. of fish	$1\frac{1}{2}$" Mean length (in mm)
Rainbow Trout									1	307	1	480	2	451.5
Mountain Whitefish					3	321.3					2	272.5		
Kokanee							1	185	1	231				
Largescale Sucker			2	444	1	332	1	370	5	212.5	8	292.6	11	149.9
Burbot			2	481			3	488.3						
Squawfish					10	326.8					4	328	25	176.3
Peamouth Chub	24				2	217.5			34	231.8			39	187.5
Redside Shiner	23													

TABLE XI. Particulars of gill net catches at depths beyond 80 ft. in Nicola Lake during summer, 1958.

Date	Depth and position of net	Relation to shore	Depth of lake at two end of net (in ft.)		Species caught	Remarks
			Inshore end	Offshore end	Kokanee	
10-11 August	Bottom at 173 ft.	Perpen-dicular	173'	173'		No fish caught
21-22 August	Bottom at 120 ft.	"	80'	120'	5	Fish obtained from the part of net lying between 90-96 ft. bottom. Average length of fish: 234 mm.
22-23 August	Bottom at 140 ft.	"	110'	140'	1	Fish obtained from the part of net lying at approx. 110 ft. bottom. Length of fish: 242 mm.

TABLE XII. Species combination in different mesh sizes in 54 net sets in stations IV, V and VI.

Species of fish	1" mesh	1½" mesh	2" mesh	2½" mesh	3" mesh	3½" mesh
Peamouth Chub	394 fish	386	212	9	1	-
Redside Shiner	454 "					
Squawfish	7 "	34	16	27	27	9
Carp						1
Largescale Sucker		2	7	12	8	17
Kokanee	6	7	43	5	4	2
Rainbow Trout	2	13	6	2	6	4
Dolly Varden					2	1
Spring Salmon						1
Mountain Whitefish			3	8	7	4
Burbot				2	1	8
Sculpin	8					

Cartwright (1956) suggested that nets set perpendicular to shore catch more fish than nets set parallel to shore. Results of the only set made perpendicular to shore (Table IX) tend to agree with the above suggestion.

Withler (1948) found that nets set on the bottom are more effective and take larger numbers and more variety of fish than sets made in midwater or in surface water. Results of the net sets made in the present case do not agree with Withler's observation. Surface sets made in station II always yielded a larger catch and more variety of species than the sets made on the bottom in the same station for identical periods of time. This result tends to show that effectiveness of net sets for capturing wider variety and larger number of specimens depends on the abundance and movement of fish in the vicinity of the net rather than on the position of net sets. A comparison of the catches made in surface, midwater and bottom net sets in the evening of 16-17 August tend to support this view. Catches of these net sets are summarized below.

TABLE XIII. Catch composition and the total number of fish captured in the surface, midwater and bottom net sets in station VI on 16-17 August.

Species	Number of fish captured		
	Surface set	Midwater set	Bottom set
Peamouth Chub	27	23	22
Redside Shiner	29	14	6
Squawfish	2	-	-
Rainbow Trout	3	4	-
Mountain Whitefish	-	1	-
Largescale Sucker	-	-	1
Prickly Sculpin	-	-	1
Kokanee	-	-	1
Total	61	42	31

Cartwright (1956) suggested that the hours of darkness are the most effective period for sampling by gill nets. In the present case, catches by the gill nets set on the bottom at 40 ft. depth were always greater in the daylight than those at night. A summary of the total number of fish captured on the bottom at 40 ft. depth is presented below.

TABLE XIV. Number of fish caught by gill net in daylight, evening and night on the bottom in station VI.

Season	Daylight	Evening	Night
Early summer	34	23	4
Mid summer	74	31	54
Late summer	84	27	52

From the above it can be inferred that efficacy of gill net for capturing fish does not depend on the period of day in so far as sampling in deeper bottom regions is concerned. In shallow waters, however, more fish may appear at night as at that time fish would not see the net and avoid it. On the other hand, appearance of fish in gill nets is probably determined by the concentration of fish in and around the area where nets are set at a given period of time. A sample of one or more species of fish appearing in a gill net can, therefore, be said to represent the groups of fish that remain distributed in a given area for a given period of time. Much of the subsequent argument is based on this assumption that there is a positive correlation between the number of fish taken by a gill net and the concentration of fish in a given locality where the net was set. Fry (1937) suggests that there is a strong positive correlation between the number of fish appearing in a gill net and the concentration of fish in a given locality. He further mentions of a consistency in the number of fish taken from a given locality:

"However, the surface catches, where a net left out for long periods was cleared daily, show that in one locality there is a definite trend in the number taken, which is consistent with the belief that the numbers taken are not due to erratic movements of large schools".

Sampling by beach seine net

In the study of spatial distribution of fish, it is necessary to look into the habits and habitats of each species of fish in different stages of its life history. Habits and preferences of fry and young-of-the-year of fish species are known to differ from their adult stage. To complete the picture of distribution, an attempt was made to find out the habits of young-of-the-year and fry in the lake. As the young fish are known to inhabit very shallow water along the shore, sampling was done along the shore with a beach seine net. The net used was of nylon material with $\frac{1}{4}$ inch mesh size. It was 30 ft. long and 8 ft. deep with proper lead line and floats.

Sampling by seine net fall under two categories,- (1) sampling at beaches in different regions of the lake to observe variability, if any, in the composition of the shore population and (2) sampling at the beaches on the north shore during different periods of the day to record variation in the presence of different species of fish and their size composition in the daylight and at night.

Seine haul stations are shown in Figure 8. Seine hauls in different shores usually were taken from a depth of 3-4 ft. of water where bottom conditions permitted such an operation. Fish appearing in these hauls were chiefly composed of young-of-the year of various species. Depending on the bottom conditions, different species of fish appeared in different regions of the lake.

The second category of sampling was carried on in the north shore in the region lying west of Moore Creek inlet, at a distance of about 100 ft.

from the inlet. The selected zone on the shore was divided into nine equal sections, each section measuring 22 ft. in length. The sections were marked off with wooden pegs. The substrate in all these sections up to the depth of 4 ft. was similar. At the water edge the bottom was sandy but mud and gravel replaced sand with increasing distance from the shore.

Seine hauls were taken from 1, 2, 3 and 4 ft. deep water during a single operation. The sections netted were selected in a random manner but two adjoining sections were never used for taking hauls in any single operation. Seine hauls were made chiefly in daylight and at night when light conditions were completely different. Some hauls were, however, made during the periods of transition e.g., dusk and dawn. For the purpose of the present analysis and discussion, samples obtained from 4 ft. of water have only been taken into consideration. Species composition in seine hauls in 1, 2, and 3 ft. of water was similar to that in the hauls from 4 ft. of water but differred only in quantity. As such, these hauls were not taken into account.

Sampling by dip net

Along the west shore, where seine netting was not possible, sampling was done several times during the period between the third week of July and second week of August with a dip net. The dip net was used in collecting fish that were moving in about 2 ft. deep water over the rocky bottom close to shore.

Treatment of samples

All gill net sets made between July 17 and first week of September were brought to shore with fish therein. On shore, each string of net was spread on a piece of tarpaulin and the position of each fish was recorded in relation to the depth of net, mesh size and direction it was headed at

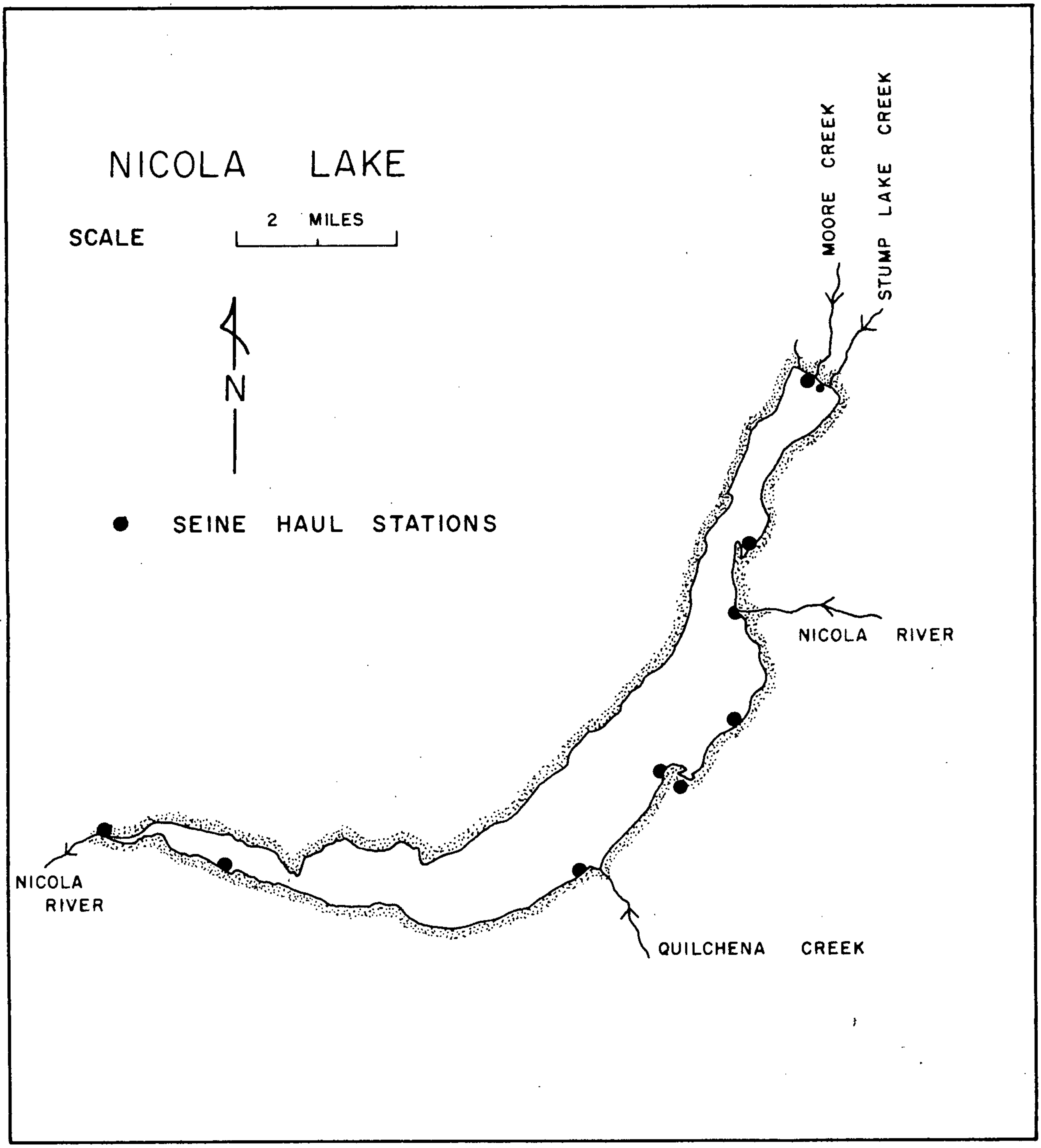

Figure 8. Map showing seine haul stations.

the time of capture.

The standard length of each fish was measured on a wooden board fitted with a measuring scale in millimeter. Thereafter, specimens from each net were preserved separately in containers containing 10 % fromalin.

In case of the seine hauls, each catch was preserved immediately after making the haul separately in containers. Subsequently, catch in each container was sorted into different species and length of each individual fish was measured and recorded.

III. RESULTS

Peamouth Chub

Movement of Peamouth Chub in both vertical and lateral planes during summer was studied and results thereon are presented in Table XV (a-d) and Figure 9.

Over the entire summer, Peamouth Chub, in general, tend to stay close to the bottom in deeper waters during the hours of daylight. An exception to this general trend is noticeable once in early summer (28 July) when five fish appeared in the surface set. This exception can be related to the fact that on this day intensity of light was very low which might have induced the fish to explore the surface region of water. Occurrence of fish in midwater during daylight is indicated by the samples obtained in mid and late summer, but no generalization can be made as, on both occasions, number of fish sampled was small.

Peamouth Chub sampled in the bottom net sets during daylight hours display a significant tendency of staying closer to the lake floor. This is seen to be a consistent feature all through the summer except once in mid summer (1 August) when a tendency of vertical spreading is indicated by the sample in the bottom net set at station VI.

In early and mid summer, congregation of Peamouth Chub in and around the 20 ft. contour line is indicated, but in late summer more fish appear in the deeper bottom zone during daylight.

In the evening during different periods of summer, Peamouth Chub show a significant tendency to spread in all levels of water. During this part of the day, fish appear consistently in the surface and midwater net sets. Moreover, from the position of fish in all bottom sets in the evening, the tendency of remaining spread in the vertical plane is clearly visible.

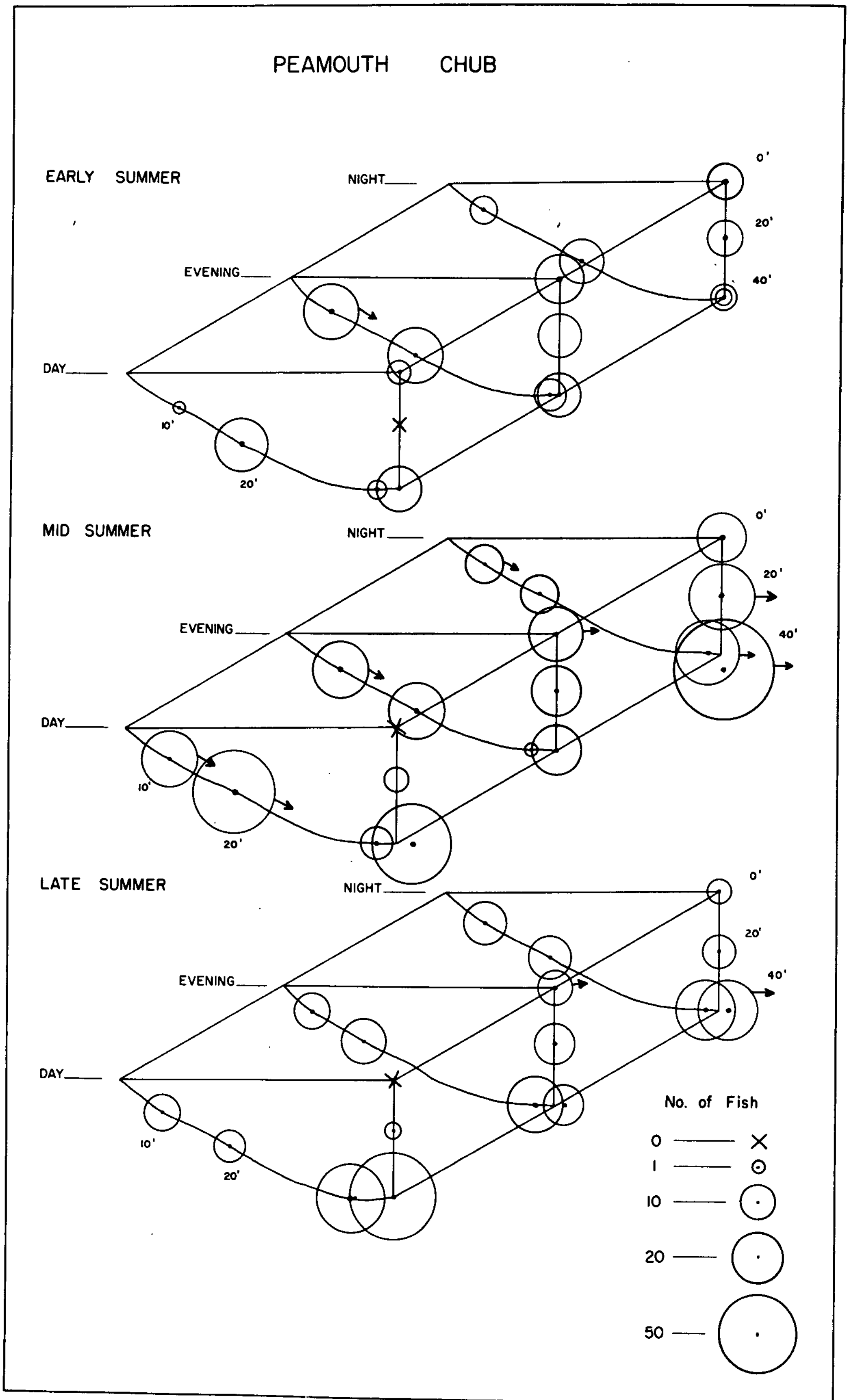

Fig. 9. Occurrence of Peamouth Chub in the gill net sets in stations IV to VI in different periods of summer. Area of circle represents total number of fish. Arrow indicates direction of fish.

TABLE XV (a). Number of Peamouth Chub obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake.

Early Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
20 July	10' Bottom	Daylight	1	1	0	0		0	1	
17-18 "	" "	Evening	31	6	22	3	moving offshore $X^2 = 9.14$	11	19	
23 July	" "	Night	6	2	4	0		5	1	
20 July	20' Bottom	Daylight	22	10	9	3		4	16	Fish stay at bottom $X^2 = 7.2$
17-18 "	" "	Evening	26	10	16	0		13	13	
23 July	" "	Night	16	6	8	2		4	10	
20 July	40' Bottom	Daylight	3	2	1	0		1	2	
17-18 "	" "	Evening	9	4	5	0		1	8	Fish stay at bottom $X^2 = 7.0$
23 July	" "	Night	6	2	2	2		2	4	
28 July	Surface	Daylight	5	2	2	1		2	2	
24-25 "	"	Evening	20	8	11	1		6	13	$X^2 = 2.58$
26 July	"	Night	9	4	5	0		6	3	
28 July	Suspended	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	15	7	7	1		9	5	
26 July	"	Night	9	3	4	2		4	3	
28 July	40' Bottom	Daylight	19	7	8	4		2	13	Fish in Bottom $X^2 = 4.03$
24-25 "	" "	Evening	17	10	6	1		5	11	
26 July	" "	Night	2	1	1	0		1	1	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XV (b). Number of Peamouth Chub obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake.

Mid Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10' Bottom	Daylight	23	5	16	2	Moving offshore $X^2 = 5.76$	4	17	Fish stay at bottom $X^2 = 8.04$
6-7 "	" "	Evening	25	5	20	0	$X^2 = 9.0$ "	14	11	$X^2 = .36$
4 Aug.	" "	Night	15	1	13	1	$X^2 = 10.2$ "	1	13	$X^2 = 10.2$ "
1 Aug.	20' Bottom	Daylight	57	9	32	16	$X^2 = 12.9$ "	14	28	$X^2 = 4.66$ "
6-7 "	" "	Evening	28	12	16	0	$X^2 = .56$	9	19	$X^2 = 3.56$
4 Aug.	" "	Night	16	9	7	0	$X^2 = .25$	5	11	$X^2 = 2.25$
1 Aug.	40' Bottom	Daylight	10	5	5	0		7	3	$X^2 = 1.6$
6-7 "	" "	Evening	1	0	1	0		0	1	
4 Aug.	" "	Night	80	22	52	6	$X^2 = 12.16$ "	12	63	$X^2 = 34.6$ "
15 Aug.	Surface	Daylight	0	0	0	0		0	0	
16-17"	"	Evening	27	5	19	3	$X^2 = 8.16$ "	4	20	$X^2 = 10.6$ "
16 Aug.	"	Night	21	8	10	3		6	12	
15 Aug.	Suspended	Daylight	5	2	2	1		1	3	
16-17"	"	Evening	23	9	13	1		14	8	
16 Aug.	"	Night	39	13	26	0	$X^2 = 4.32$ "	21	18	
15 Aug.	40' Bottom	Daylight	46	18	28	0		8	38	$X^2 = 23.8$ "
16-17"	" "	Evening	22	11	9	2		3	18	$X^2 = 10.7$ "
16 Aug.	" "	Night	37	12	22	3	$X^2 = 4.16$ "	8	27	$X^2 = 10.2$ "

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XV (c). Number of Peamouth Chub obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake

Late Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including χ^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including χ^2 value)
29 Aug.	10' Bottom	Daylight	10	5	3	2		0	8	Stay at bottom
26-27"	" "	Evening	9	3	5	1		3	5	
28 Aug.	" "	Night	14	5	8	1		4	10	
29 Aug.	20' Bottom	Daylight	6	1	5	0		0	6	Stay at bottom
26-27"	" "	Evening	17	7	5	5		8	4	
28 Aug.	" "	Night	15	5	9	1		4	11	
29 Aug.	40' Bottom	Daylight	41	15	21	5		9	29	Stay at bottom; $\chi^2 = 10.4$
26-27"	" "	Evening	27	14	12	1		10	16	
28 Aug.	" "	Night	33	13	14	6		19	8	Do not stay at bott. $\chi^2 = 4.48$
31 Aug.	Surface	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	9	0	9	0	Moving offshore	4	5	
2 Sept.	"	Night	5	1	4	0		2	3	
31 Aug.	Suspended	Daylight	1	0	1	0		1	0	
2-3 Sept.	"	Evening	15	5	9	1		6	8	
2 Sept.	"	Night	11	3	7	1		3	7	
31 Aug.	40' Bottom	Daylight	59	26	25	8		12	39	Stay at bottom; $\chi^2 = 14.28$
2-3 Sept.	" "	Evening	14	6	7	1		4	9	
2 Sept.	" "	Night	32	9	21	2	Moving offshore $\chi^2 = 6.12$	4	26	Stay at bottom $\chi^2 = 16.5$

Note - Chi-square is not calculated where sample size is small and no conclusion noted.

TABLE XV (d). Number of Peamouth Chub caught in the net sets in front of Moore Creek inlet, (East end of lake) in 80 ft. station in mid lake and in front of Nicola River outlet (west end of lake).

	Station	Date 1958	Time (hours)	Total No. of fish	Direction of movement		
					to shore	off shore	loose
A. Early Summer	East end Moore Cr.inlet	30 Apr. 1 May	22.00- 10.15	24	-	-	-
	" " "	10-11 June	19.30- 12.25	21	-	-	-
	" " "	28-29	31.30-	47	20	24	3
	West end Nicola R.outl.	10-11 June	16.15- 09.25	24	-	-	-
	80' station at bottom	11-12 June	22.00- 09.00	3	-	-	-
	80' station at surface	11-12 June	21.30- 10.00	27	-	-	-
B. Mid Summer	East end Moore Cr.inlet	4-5 Aug.	21.00- 08.30	51	18	31	2
	" " "	11-12 Aug.	20.45- 08.00	34	11	21	2
	West end Nicola R.outl.	9-10 Aug.	15.00- 11.30	84	57	20	7
	" " "	9-10 Aug.	15.45- 11.00	16	11	2	3
	80' station at bottom	29-30 July	20.30- 07.00	0	0	0	0
	80' station at surface	29-30 July	21.00- 07.30	11	3	8	0
C. Late Summer	East end Moore Cr.inlet	18-19 Aug.	20.00- 08.00	18	5	10	3
	" " "	25-26 Aug.	20.30- 08.30	29	6	21	2
	West end Nicola R.outl.	5-6 Sept.	16.45- 09.45	49	28	20	1
	80' station at bottom	3-4 Sept.	19.45- 10.30	3	1	2	0
	80' station at surface	3-4 Sept.	20.10- 10.40	10	2	8	0

Toward late night and early morning, a trend of returning back from the upper layers toward bottom is noticed in mid and late summer. At the same time, in a lateral plane, fish tend to leave the shallower regions of the lake for the deeper bottom away from shore, during this part of the day, in both mid and late summer. In early summer, on the other hand, samples do not indicate any movement back to deeper water from midwater, but fish from shallower bottom regions close to shore show the tendency of moving into the deeper offshore regions when light conditions change from night to day.

The maximum depth at which Peamouth Chub are seen in summer is 80 ft. where the species was sampled on the bottom both in early (10-11 June) and late (3-4 September) summer. In mid summer (28-29 July), no fish were, however, caught at this depth. Non appearance of fish during the peak of summer, and very small sample size in late summer, may be interpreted to indicate that 80 ft. bottom region is not preferred by this species.

Thermal stratification does not seem to affect the vertical migration of Peamouth Chub. During different periods of summer, Peamouth Chub are seen moving freely from epilimnion to hypolimnion and vice versa in different periods of the day.

The fish was available in all major regions of the lake. Its abundance in north and southwest ends was almost the same in early summer, but with the progress of summer, particularly in the middle of August, sampling indicated more fish in the southwest end. This pattern of relative abundance continued for the remaining period of summer. This shift in relative abundance was probably due to the fact that in August (peak period of the summer), vegetation grow more abundantly in the shallow southwest basin than in any other part of the lake.

Fish sampled in net sets parallel to the northwest shore do not display any significant offshore or inshore direction of movement in every case.

In early summer, the evening sample in 10 ft. bottom showed a significant offshore direction of movement. In mid summer, the following samples showed a significant direction of movement, and in every case, fish were headed offshore.

(a) Sample in 10 ft. bottom set in the daylight.

(b) " " 10 ft. " " " " evening.

(c) " " 10 ft. " " at night.

(d) " " 20 ft. " " in the daylight.

(e) " " 40 ft. " " at night.

(f) " " surface set in the evening.

(g) " " suspended set at night.

(h) " " 40 ft. bottom set at night.

From the above it appears that changes in light conditions do not cause a change in the direction of movement of Peamouth Chub. In late summer, the night sample from the bottom in 40 ft. water shows a significant offshore direction of movement. Change in season does not, therefore, appear to influence the direction of movement. From the data, it can be concluded that mid summer conditions produce offshore pattern of movement in a pronounced manner, whereas in early and late summer, no such effect is apparent and fish tend to show randomness in movement.

The above interpretations would be made more clear, if information were available on the lateral movement pattern of Peamouth Chub along shore. In the net set made perpendicular to shore across stations IV and VI, 99 Peamouth Chub appeared (Table IX). Of these, 53 were headed towards the north shore and the balance in the opposite direction. This points to the fact that Peamouth Chub also move laterally along shore at night.

Sizes of fish do not appear to influence their direction of movement, but depth distribution seems to be influenced by size. With the increase in depth of water, the average size of fish was seen to increase.

Literature on Peamouth Chub

In Skaha Lake, Ferguson (1949) found that Peamouth Chub live in shallow water and he described this fish as a shallow water species. Godfrey (1955) noted that the peak abundance of Peamouth Chub in summer occurs in the 0-5 meter (0-16 ft.) zone. Carl and Clemens (1953) describe Peamouth Chub as a species inhabiting shallow weedy zones of a lake.

Absence of Peamouth Chub in 80 ft. deep water during the peak of summer may be related to its preference for shallow waters as suggested by the authors quoted above. Appearance of more fish at night in the weedy shallow southwest end in the mid summer seems to be in agreement with the findings of Carl and Clemens (1953). There is, however, no evidence that during the daylight hours a similar abundance of Peamouth Chub persists in the weedy areas.

Inferences drawn by both Godfrey (1955) and Ferguson (1949) seem to be based on sampling done at night. Samples from the night net sets of the present study agree with the above inferences. However, the situation in the daylight appears to be different when Peamouth Chub showed a preference for staying closer to the bottom in deeper water.

As for size stratification in the depth distribution of Peamouth Chub, no reference is seen in earlier literature, but a similar feature is mentioned by Lindsey (1953) and Crossman (1957) in the case of Redside Shiner.

Schultz (1935) observed that schools of Peamouth Chub gathering near shore in very shallow waters in the daylight for breeding purposes are scared away by the appearance of Squawfish. Consistent absence of Peamouth Chub in shallow water and on the surface during daylight might probably be associated with some instinctive response of the fish to avoid lighted areas and thereby avoid the attention of the predators. The tendency of getting spread in all levels of water at night, on the other hand, was probably due to increased feeding activity of the species.

Redside Shiner

Results on the movement pattern are summarized in Table XVI (a-d) and Figure 10.

All through the summer, in daylight, Redside Shiners tend to stay close to the lake bottom. This consistency in behaviour during daylight hours is not seen in fish sampled at 40 ft. bottom during late summer (29 and 31 August) when a tendency of spreading up vertically is noticeable. On both these days light intensity was extremely low which probably simulated a condition of night at deeper waters. Low light intensities may, therefore, be associated with the vertical spreading of fish in late summer.

In daylight during early summer, Redside Shiners appear to remain uniformly distributed all over from shore to the 40 ft. depth zone but in mid summer a tendency of congregation around the 20 ft. contour line is noticed. In late summer in daylight, the mid summer feature is lost again. A variation in the size of sample is seen in 40 ft. station during mid as well as late summer. In mid summer, there was a time lapse of 14 days between the two samplings (1 and 15 August) but in late summer, the samples were obtained within a day of each other. The variation in midsummer is probably due to changes in physical conditions that took place over a period of two weeks. On 1 August, the thermocline is seen in 37-40 ft. of water when only 1 fish appeared in the net set. On the other hand, on 15 August, when 16 fish appeared in the net set, there was no thermocline at this depth.

In the evening Redside Shiners display a trend of spreading into midwater and into the surface over both shallow and deep water. This tendency of scattering is consistent in all parts of the summer. Fish sampled in bottom sets in the evening also show the spreading in vertical plane in all

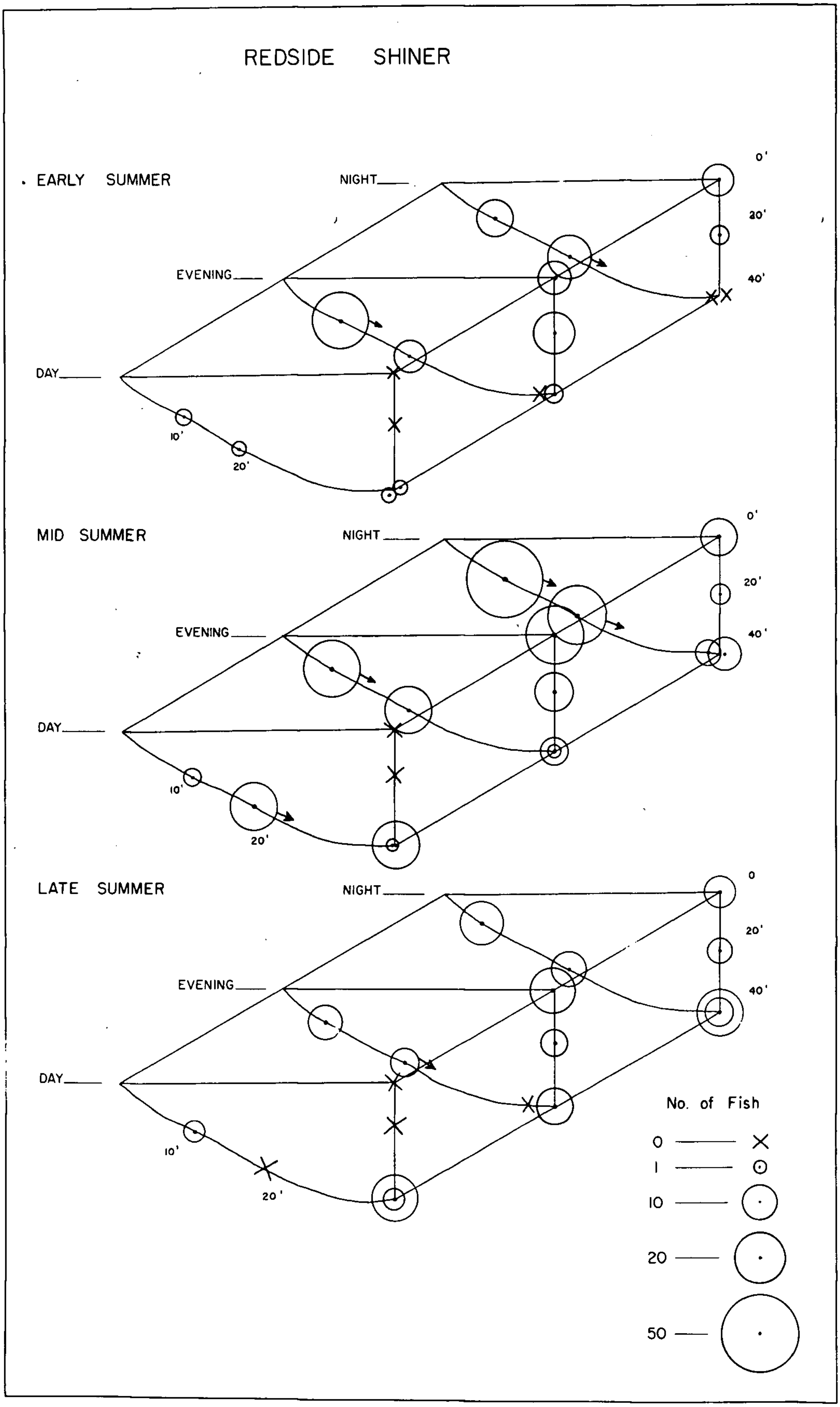

Fig. 10. Occurrence of Redside Shiner in gill net sets in stations IV-VI in different periods of summer. Area of circle represents total number of fish. Arrow indicates direction of fish.

TABLE XVI (a). Number of Shiners obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake.

A. Early Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
20 July	10 ft. bottom	daylight	2	1	0	1		1	0	
17-18 "		evening	21	6	15	0	Moving off-shore X^2 = 7.52	5	16	Stay at bottom X^2 = 11
23 July	"	night	11	5	6	0		4	7	
20 July	20 ft. bottom	daylight	1	0	1	0		0	1	
17-18 "		evening	7	1	6	0		3	4	
23 July	"	night	17	4	13	0	moving off shore X^2 = 4.26	4	13	Back to bottom
20 July	40 ft. bottom	daylight	1	0	1	0		0	1	
17-18 "		evening	0	0	0	0		0	0	
23 July	"	night	0	0	0	0		0	0	
28 July	Surface	daylight	0	0	0	0		0	0	
24-25 "	" set	evening	8	4	4	0		3	5	
26 July	" "	night	8	2	6	0		7	1	Not on bottom. X^2 = 3.81
28 July	Suspend.	daylight	0	0	0	0		0	0	
24-25 "	" set	evening	14	5	9	0		7	7	
26 July	" "	night	2	2	0	0		0	2	
28 July	Bottom set 40 ft.	daylight	1	0	1	0		0	1	
24-25 "		evening	2	1	1	0		2	0	
26 July		night	0	0	0	0		0	0	

Note - Chi-square is not calculated where sample-size is small and no conclusion is noted.

TABLE XVI (b). Number os Shiners obtained in net sets (vertical and lateral) along northwest shore, Nicola Lake.

B. Mid Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (Including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10 ft. bottom	Daylight	2	1	1	0		0	2	
6-7 "		Evening	26	6	20	0	Moving off shore X^2= 7.52	11	15	Fish not on bottom X^2 = .614
4 Aug.	"	Night	47	10	37	0	Moving off shore X^2 = 15.4	26	21	Fish not on bottom X^2 = .52
1 Aug.	20 ft. bottom	Daylight	18	4	13	0	Moving off shore X^2= 4.5	5	13	Fish on bottom X^2 = 3.54
6-7 "	"	Evening	17	5	12	0		2	15	Fish on bottom X^2 = 9.8
4 Aug.	"	Night	26	8	18	0	Moving off shore X^2= 3.8	10	16	Fish not on bottom X^2 = 1.38
1 Aug.	40 ft. bottom	Daylight	1	1	0	0		1	0	
6-7 "		Evening	1	1	0	0		1	0	
4 Aug.	"	Night	5	2	3	0		5	0	
15 Aug.	Surface set	Daylight	0	0	0	0		0	0	
16-17"		Evening	29	13	16	0		14	15	Fish not on bottom X^2 = .034
16 Aug.	"	Night	11	5	4	2		5	4	
15 Aug.	Suspend. set	Daylight	0	0	0	0		0	0	
16-17 "		Evening	14	6	7	1		8	5	
16 Aug.	"	Night	3	0	3	0		2	1	
15 Aug.	40 ft. bottom	Daylight	16	9	6	1		2	13	Fish on bottom X^2= 8.06
16-17 "		Evening	6	3	3	0		3	3	
16 Aug.	"	Night	9	3	6	0		6	3	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XVI (c). Number of Shiners obtained in stations (vertical and lateral) along northwest shore, Nicola Lake.

C. Late Summer

Date 1958	Depth and position of net	Period of day	Total No. of fish	No. of fish moving		Loose fish	Conclusion (including X^2 value)	No. of fish		Conclusion (including X^2 value)
				to shore	off shore			in top half of net	in bottom half of net	
29 Aug.	10 ft.	Daylight	4	3	0	1		o	4	
26-27"	bottom	Evening	11	8	3	0		5	6	
28 Aug.	"	Night	14	6	8	0		2	12	Fish back on bottom
29 Aug.	20 ft.	Daylight	0	0	0	0		0	0	
26-27"	bottom	Evening	6	0	5	1	Moving offshore $X^2 = 4.1$	3	2	
28 Aug.	"	Night	9	5	3	1		3	5	
29 Aug.	40 ft.	Daylight	3	0	3	0		2	1	
26-27"	bottom	Evening	10	3	7	0		5	5	
28 Aug.	"	Night	7	3	4	0		5	2	
31 Aug.	Surface	Daylight	0	0	0	0		0	0	
2-3 Sept.	set	Evening	18	9	6	3		9	6	
2 Sept.	"	Night	8	2	5	1		4	3	
31 Aug.	Suspend.	Daylight	0	0	0	0		0	0	
2-3 Sept.	set	Evening	6	4	2	0		3	3	
2 Sept.	"	Night	5	1	4	0		4	1	
31 Aug.	40 ft.	Daylight	17	5	11	1		11	5	
2-3 Sept.	bottom	Evening	0	0	0	0		0	0	
2 Sept.	"	Night	17	5	8	4		1	12	Fish back on bottom

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XVI (d). Redside Shiner sampled in net sets in different parts of Nicola Lake.

	Stations	Date 1958	Time (hours)	Total fish	Direction of movement to shore	Direction of movement off shore	Loose fish	Remarks
A. Early Summer	NE end (in front of Moore Cr. inlet)	30 Apr. 1 May	22.00-10.15	9				Direction not noted. 2 net set continually across inlet mouth.
	" "	10-11 June	19.30-12.25	21				Direction not noted. 1 net set in same position as above
	" "	28-29 July	21.30-08.30	77	26	48	3	2 net set continually across inlet in 10' contour.
	SW end (close to Nicola R. outlet)	10-11 June	16.15-09.25	16				
	80 ft. station bottom set	11-12 June	22.00-09.00	0				No fish.
	80 ft. station surface set	11-12 June	22.00-09.00	11				Direction not noted.
B. Mid Summer	NE end (Moore Cr. inlet)	4-5 Aug.	21.00-08.30	110	35	74	1	
	" "	11-12 Aug.	20.45-08.00	138	66	69	3	
	SW end (close to Nicola R. outlet)	9-10 Aug.	15.00-11.30	25	18	6	1	
	SW end(in front of Nicola R. outlet)	9-10 Aug.	15.45 11.00	13	9	4	0	
	80 ft. station bottom set	29-30 July	20.30-07.00	0				No fish.
	80 ft. station surface set	29-30 July	21.00-07.30	1				Direction not noted.
C. Late Summer	NE end (Moore Cr. inlet)	18-19 Aug.	20.00-08.00	117	50	56	11	
	" "	25-26 Aug.	20.30-08.30	141	33	100	8	
	SW end(in front of Nicola R. outlet)	5-6 Sept.	16.45 09.45	63	31	32	0	
	80 ft. station on the bottom	3-4 Sept.	19.45 10.30	0				No fish.
	80 ft. station surface set	3-4 Sept.	20.10-10.40	15	5	10	0	

cases, except those from 20 ft. bottom set in mid summer. It can thus be inferred that changes in light conditions after nightfall induce Shiners to spread out in shallow and surface water. During this period, this species goes into open water along the surface levels as is indicated by the sampling of surface net sets in station II during different periods of summer.

In early summer, more fish appear to stay in midwater in the evening but in mid and late summer, they appear to congregate in the surface region. A large variation in the number of fish sampled in station VI on the bottom is seen in mid as well as late summer. These variations in the number of fish sampled in mid summer is attributable to causes mentioned in case of daylight sets. In late summer, the net set made on 26-27 August yielded 10 fish, but the other set made on 2-3 September yielded none, inspite of the fact that a thermocline was in 40 ft. of water on the former occasion but on 2-3 September, the thermocline had disappeared. This variation was probably caused by some other factor.

Towards late night and dawn in early summer Redside Shiners do not exhibit any tendency of returning to deeper regions (towards the bottom in 40 ft. depth) but seem to congregate around the 20 ft. contour line. In mid summer, some fish show the tendency to return to the bottom region in 40 ft. though most fish seem to hold on to their position in surface and midwater. In late summer, during the same period of the day, more fish show the tendency to return to deeper water. The overall tendency of Shiners appear to be to head back into the lake bottom from surface and midwater towards late night and dawn, but instead of making a straight vertical descent, they probably move in an oblique manner from the surface region in open water to the shallower bottom zone. In late summer, more fish appear in the bottom around 40 ft. depth zone.

Like Peamouth Chub, some of the samples of Redside Shiner show a significant direction of movement and in all such cases most fish were headed offshore (Table XVI a-c). In case of this species, neither different periods of day, nor the changes in condition in different periods of summer, seem to have any influence in determining the direction of movement. The sample of Redside Shiners obtained in net sets perpendicular to shore in the northwest end indicate that the fish move parallel to shore at night.

In the bottom net set in station II, Redside Shiners never appear in any part of the summer. Moreover, sample size obtained in bottom net sets in station VI are consistently small. Evidently Redside Shiners prefer to live in shallow areas close to shore during summer.

The species is available in all regions of the lake, but the sampling results indicate that it is more abundant in the northeast end.

Effect of thermal stratification on this fish does not appear to be very clear. During different periods of summer, it was seen within the thermocline, though not in significant numbers. It is known, however, to prefer to live in the epilimnion and the appearance of large number of fish in the epilimnion in the evening and at night tend to agree to the above belief. Occurrence of the fish in the hypolimnion during the daylight is probably induced by its tendency to avoid light.

Literature on Redside Shiner

Crossman (1957), Ferguson (1949) and Lindsey (1953) mentioned that Redside Shiners prefer to stay in shallow waters close to shore. The present findings also agree with this observation of the above authors. Crossman (1957) and Lindsey (1953) also observed that at night, Redside Shiners become scattered in distribution. Crossman suggested that fish either come up from deeper water at the centre or move into open water from shore during the hours of darkness. Lindsey (1950) considered that Redside Shiners come to surface at night as a result of their increased activity. The present information tend to be in agreement with the above findings.

Lindsey (1950) and Crossman (1957) further observed a horizontal size stratification of Redside Shiner in early July immediately after the newly hatched out fry become abundant in shore regions. Crossman also mentioned that in mid July, Redside Shiner fry move offshore making the species less abundant in the shore region but they return to shore in schools by the end of the first week of August. Seine hauls in the present case showed a similarity in the movement of newly hatched fry of Redside Shiner.

A vertical stratification in size groups of the Redside Shiners was observed by Lindsey (1953). He mentioned that different size groups of fish inhabit different depth zones, smaller fish occupying shallower water. In the present study, no such phenomena are detectable from the daylight samples in any period of summer. But the samples obtained after nightfall in all depths in early summer and those from surface and midwater in mid and late summer show size stratification. No general conclusion can, however, be drawn from the present study, because of the variable and small sample size obtained. Larkin and Smith (1953) pointed out that Redside Shiner fry show a tendency of staying in the inshore areas during daylight while the adults remain in the littoral zone in mid summer. Results of seine hauls and gill nettings agree in general with the above observation.

Ferguson (1949) observed that Redside Shiners prefer to live in the epilimnion. This observation was apparently based on the catches made at night with gill nets. Situation at night in the present case was found similar but during daylight, fish appeared to keep away from the epilimnion.

Northern Squawfish

Results are presented in Table XVII (a-d) and Figure 11. In early summer, during different periods of day, Squawfish display a preference to remain on the bottom in the littoral zone, but with the progress of summer, they appear in deeper water.

During the daylight hours, in early summer the tendency to stay close to shore is pronounced. In mid and late summer, all the daylight samplings indicate a spreading in the depth distribution when fish appeared in all the samples of 40 ft. depth zone.

During evening, in early summer, fish tend to invade very shallow shore areas as well as the surface and mid water. In mid summer, the trend of early summer is maintained, but in late summer in the evening, more fish appear in the bottom around the 20 and 40 ft. contour lines. In late summer, no fish seem to invade the surface or midwater in the evening.

At night, fish tend to leave different levels of water (surface and midwater) invaded in the evening and return to the bottom in the littoral zone. In mid summer at night, though more fish appear on the littoral zone, some of them appear to stay on in the surface and midwater. In late summer, fish tend to return to deeper bottom waters rather than to the littoral zone. The tendency of remaining spread in surface and midwater, detected in mid summer, is also maintained.

All through the summer, a general trend of staying close to the bottom is noticeable during the daylight hours. In the evening, fish tend to get spread vertically. At night again, they appear to come back close to the bottom.

The fish sampled do not show any significant direction of movement away from or toward the shore in any period of summer. But the sample from the net set made perpendicular to the northwest shore indicates that the species moves parallel to shore at night. In this set, 39 Squawfish appeared of which 29 are found headed north.

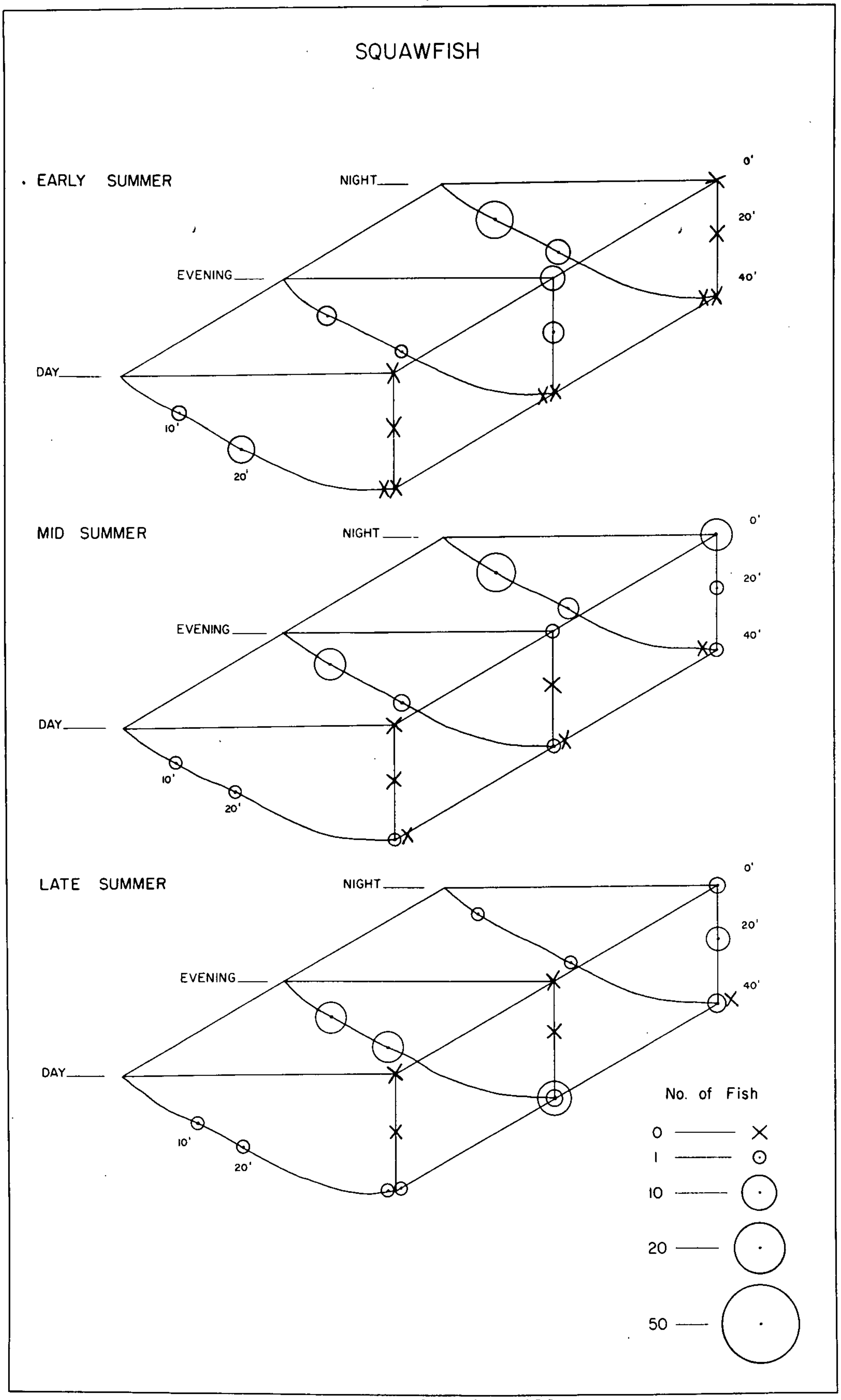

Fig. 11. Occurrence of Northern Squawfish in gill net sets in stations IV-VI in different periods of summer. Area of circle represents total number of fish.

TABLE XVII (a). Number of Squawfish obtained in net sets (Vertical and Lateral) in the stations along Northwest shore, Nicola Lake

Early Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (Including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (Including X^2 value)
20 July	10' Bottom	Daylight	2	1	1	0		1	1	
17-18"	" "	Evening	3	2	0	1		2	1	
23 July	" "	Night	13	5	8	0	X^2 = .68	3	10	X^2 = 3.76
20 July	20' Bottom	Daylight	6	1	5	0	X^2 = 2.66	1	5	X^2 = 2.66
17-18 "	" "	Evening	1	1	0	0		0	1	
23 July	" "	Night	5	1	4	0	X^2 = 1.8	0	5	
20 July	40' Bottom	Daylight)								
17-18 "	" "	Evening)	0	0	0	0		0	0	
23 July	" "	Night)								
20 July	Surface	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	5	3	2	0		2	3	
26 July	"	Night	0	0	0	0		0	0	
28 July	Suspended	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	3	1	2	0		2	1	
26 July	"	Night	0	0	0	0		0	0	
28 July	40' Bottom	Daylight)								
24-25 "	" "	Evening)	0	0	0	0		0	0	
26 July	" "	Night)								

Note - (1) Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XVII (b). Number of Squawfish obtained in net sets (vertical and lateral) in the stations along Northwest shore, Nicola Lake

Mid Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusions (Including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusions (Including X^2 value)
1 Aug.	10' Bottom	Daylight	2	1	1	0		0	2	
6-7 "	" "	Evening	8	1	7	0		3	5	
4 Aug.	" "	Night	12	4	8	0	$X^2 = 2.$	3	9	$X^2 = 3.0$
1 Aug.	20' Bottom	Daylight	1	0	1	0		0	1	
6-7 "	" "	Evening	2	1	1	0		2	0	
4 Aug.	" "	Night	4	2	2	0		3	1	
1 Aug.	40' Bottom	Daylight	1	0	1	0		1	0	
6-7 "	" "	Evening	1	1	0	0		1	0	
4 Aug.	" "	Night	0	0	0	0		0	0	
15 Aug.	Surface	Daylight	0	0	0	0		0	0	
16-17"	"	Evening	2	1	1	0		2	0	
16 Aug.	"	Night	7	4	3	0		2	5	
15 Aug.	Suspended	Daylight	0	0	0	0		0	0	
16-17"	"	Evening	0	0	0	0		0	0	
16 Aug.	"	Night	1	1	0	0		1	0	
15 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
16-17"	" "	Evening	0	0	0	0		0	0	
16 Aug.	" "	Night	1	0	1	0		1	0	

Note - Chi-square is not calculated where sample is small and no conclusion is noted.

TABLE XVII (c). Number of Squawfish obtained in net sets (vertical and lateral) in the stations along Northwest shore, Nicola Lake.
<u>Late Summer</u>

Date 1958	Depth and position of net set	Period of day	Total No.of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusions (Including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusions (Including X^2 value
29 Aug.	10' Bottom	Daylight	1	0	0	1				
26-27"	" "	Evening	7	3	4	0		1	6	$X^2 = 3.4$
28 Aug.	" "	Night	1	1	0	0		0	1	
29 Aug.	20' Bottom	Daylight	1	1	0	0		0	1	
26-27"	" "	Evening	10	5	3	2		4	4	
28 Aug.	" "	Night	1	0	1	0		0	1	
29 Aug.	40' Bottom	Daylight	1	1	0	0		0	1	
26-27"	" "	Evening	10	5	4	1		1	8	
28 Aug.	" "	Night	3	1	2	0		2	1	
31 Aug.	Surface	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	0	0	0	0		0	0	
2 Sept.	"	Night	2	0	2	0		2	0	
31 Aug.	Suspended	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	0	0	0	0		0	0	
2 Sept.	"	Night	4	2	2	0		1	3	
31 Aug.	40' Bottom	Daylight	1	0	0	1		1	0	
2-3 Sept.	" "	Evening	1	1	0	0		1	0	
2 Sept.	" "	Night	0	0	0	0		0	0	

Note: Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XVII (d). Number of Squawfish obtained in net sets made in different parts of Nicola Lake in 1958.

	Stations	Date	Time (hours)	Total fish	Direction of movement to shore	Direction of movement off shore	Loose fish	Remarks
A. Early Summer	NE End (in front of Moore Cr.inlet)	30 Apr 1 May	22.00- 10.15	8				Direction not noted. Two nets set together.
	" "	10-11 June	19.30- 12.25	35				Direction not noted. One net set.
	" "	28-29 July	21.30- 08.30	18	8	8	2	Two nets set together.
	SW End (close to Nicola R. outlet)	10-11 June	16.15- 09.25	9				Direction not noted.
	80 ft. Station Bottom set	11-12 June	22.00- 09.00	0				No fish.
	80 ft. Station Surface set	11-12 June	22.00- 09.00	1				Direction not noted.
B. Mid Summer	NE End (in front of Moore Cr.inlet)	4-5 Aug.	21.00- 08.30	24	10	11	3	Two nets set together
	" "	11-12 Aug.	20.45- 08.00	16	10	5	1	Two nets set together
	SW End (close to Nicola R. outlet)	9-10 Aug.	15.00- 11.30	9	7	1	1	
	SW End(in front of Nicola R. outlet)	9-10 Aug.	15.45- 11.00	28	15	8	5	
	80 ft. Station Bottom set	29-30 July	20.30- 07.00	0				
	80 ft. Station Surface set	29-30 July	21.00- 07.30	0				
C. Late Summer	NE End(in front of Moore Cr. inlet)	18-19 Aug.	20.00- 08.00	46	15	24	7	
	" "	25-26 Aug.	20.30- 08.30	6	1	5	0	
	SW End (close to Nicola R. outlet)	5-6 Sept.	16.45- 09.45	19	13	5	1	
	80 ft. Station Bottom set	3-4 Sept.	19.45- 10.30	0				
	80 ft. Station Surface set	3-4 Sept.	20.10- 10.40	0				

Vertical distribution of Squawfish in summer appears to be influenced by the position of the thermocline. They did not appear below the thermocline during any period of the summer. Some fish appeared within the thermocline once in early and again in late summer.

Literature on Squawfish

Cartwright (1956) mentioned that in summer months Squawfish inhabit the littoral zone. In his sampling effort, Cartwright captured more than 90% of Squawfish from above the 30 ft. contour line of the lake. In Cultus Lake, during the months of April to early July, Squawfish appear in larger numbers in net sets made close to shore where 90% of the total catch come from sets made within the 30 ft. contour line (Ricker, 1941; Foerster and Ricker, 1941). This greater abundance of Squawfish in shallow water in Cultus Lake continues until mid September. Results of the present study are in agreement with the findings both in Shumway and Cultus Lake, except for the tendency of spreading into the deeper water in late August. This exception may be induced by feeding as is seen for fish in Skaha Lake (Ferguson, 1949).

In Okanagan Lake, smaller fish of the size range of 6-8" were consistently found in the shore region, while larger fish appeared to dominate the region of the "drop off"(Cartwright, 1956). No such size stratification of Squawfish is detectable in the present case. In early summer, the average size of fish near shore was larger than those offshore, particularly during daylight and evening. In mid summer, at night only, size stratification similar to that in Okanagan Lake was seen. Variation in the size composition of fish in different periods of the day is, however, noticeable in mid summer. In the daylight hours, average size of the fish seemed to be less than that of evening and night. In late summer, during the daylight hours smaller fish appeared in areas close to shore while in offshore waters, only larger fish were seen. But with nightfall, larger sized fish invade the shore region replacing the smaller fish seen in this zone during day.

Average size of fish sampled in surface as well as midwater was consistently found greater than those on the bottom. According to Ricker (1941), Squawfish prefer to feed upon Redside Shiners in summer and the appearance of larger Squawfish in surface and midwater may be ascribed to their feeding activity.

Carp

Tables VIII, XVIII and XXVIII summarize the catch of Carp.

Fry and fingerlings remained confined to the south and southwest region of the lake near shore. The area extends from the Lagoon near Quilchena up to the southwest shallow basin. Carps appear to prefer areas with mud bottom covered with vegetation. Fingerlings were taken in gill nets in the southwest basin only after the appearance of vegetation in that region.

Only one adult Carp appeared in the gill net sets in the deeper main body of the lake. From this sampling, no general conclusion on the movement and distribution of Carp is possible.

Literature on Carp

Richardson (1913) observed that Carp fingerlings prefer areas with mud bottom with vegetation. Richardson suggested that fingerlings abound in weed covered areas, not only to feed upon the vegetation but also to take smaller organisms that inhabit the weedy zone. He observed that in the Ceratophyllum zone in the west shore of Illinois River, fingerlings feed upon Hyalella Knickerbockeri living on the vegetation.

According to Cahn (1929), Carp feed upon aquatic vegetation so intensively that they change the ecology of their habitat by completely eradicating plants.

TABLE XVIII. Number of Carp obtained from the net sets in the stations along the northwest shore of Nicola Lake during the summer, 1958.

Date	Depth and position of net	Period of day	Total No. of fish	No. of fish moving		Loose fish	Conclusion on direction of movement of fish	No. of fish in		Conclusions on position held by fish	Remarks
				to shore	off shore			top half of net	bottom half of net		
28 Aug.	20 ft. bottom	night	1	1	0	0		0	1		Late summer

Note: No Carp was caught in any other net sets in these stations during the whole period of summer.

Cady (1943) observed that Carp have a wide range of depth distribution. In Norris reservoir, Carp were taken from the upper 60 ft. of water but occasionally they were netted from depths of 85 and 95 ft. as well. Cady (1943) concluded that this species tends to remain distributed evenly from surface to a depth of 50 ft. during the period from the middle of March to late October. Haslbauer (1945) suggested that Carp remain associated with the bottom but occasionally 'jump' over deep water far from shore. According to Pearse (1921), Carp do not go below the 5 meter (18 ft.) depth zone. From the above findings, it appears that Carp probably have different ranges of depth distribution in different water systems. In the case of Perch, Birge and Juday (1941) reported similar difference in depth distribution.

The experimental work of Pitt, et al (1950) showed that Carp have a final temperature preferendum of 32°C (89.6°F). Richardson (1913) reported a temperature tolerance of 92°F by Carp fingerlings. In the context of the above findings, it can be assumed that in lakes, distribution of the species would remain confined to the epilimnion.

<u>Longnose Dace</u>

Longnose Dace have not been previously recorded from Nicola Lake. Seine hauls made in shores close to Quilchena Creek show that this fish live in shallow water along shore. In addition, it also was seen in the trap in the Moore Creek inlet several times during the summer. Seine hauls in Nicola River outlet at a distance of about eight miles from the lake show an abundance of this species in the river.

Literature on Longnose Dace

This species is known to live in shallow shore areas of lakes and in cool streams (Carl and Clemens, 1953).

It is known to have a preference for insect larvae as food. In addition, it also feeds upon Copepods, Nematodes, Algae and fragments of higher plants (Johannes, 1957). Since mud bottoms along shore support more insect larvae and plants (Pearse,1921), the presence of Longnose Dace can be associated with its food and feeding habits.

Chiselmouth

Data on Chiselmouth are presented in Table VIII. This is also a new record from Nicola Lake and the Thompson River drainage system to which the lake is connected.

It was found in the shallow southwest basin of the lake only in all parts of summer. In early summer, only one fish appeared in the net set in station III but in mid and late summer, more fish were sampled.

Analysis of stomach contents of the fish sampled reveal that it feeds chiefly on fragments of Potamogeton and Myriophyllum sp. But these plants are available in abundance in the southwest basin during the summer. Distribution of Chiselmouth may be ascribed to their food and feeding habits.

Seine hauls in the Nicola River outlet at distances of about 1 mile, 8 miles and 12 miles away from the lake revealed the presence of young Chiselmouth in good numbers in the river. No young Chiselmouth were taken in seine hauls made in the lake.

Bridgelip Sucker

Particulars of the sampling of Bridgelip Suckers appear in Tables VI and VIII. This is a new record from this locality.

This species was sampled in different regions of the lake in shallow water. In early summer, larger sized specimens were found but in mid and late summer, only small sized specimen were found in the net sets.

Young-of-the-year of this fish were seen in large numbers in Nicola River outlet.

The sample sizes are too small to make any conclusion on the distribution and movement of this fish.

According to Lindsey (personal communication) Bridgelip Suckers are primarily stream dwelling fish with the habit of scraping rocks for collection of food.

Largescale Sucker

Results are summarized in Table XIX (a-c) and Figure 12.

During the daylight hours, this fish apparently stays close to the ground in different periods of summer. In early summer it tends to avoid areas close to shore in daylight, but with the progress of summer, spreading on the bottom occurs. No fish on the bottom around 20 ft. depth zone were, however seen in late summer.

It does not display any tendency of spreading into the mid or surface water at nightfall during any part of the summer. This is contrary to what is observed in Peamouth Chub, Redside Shiner and Squawfish.

In early summer during evening, fish are seen on the bottom in 10 ft. depth zone but in mid summer, for the same period of day, these are found in the bottom away from shore (Fig. 12). In late summer again, the distribution on the bottom appears somewhat different, when samples of the fish appear in the net sets on the bottom at 10 and 40 ft.

At night, fish are seen on the bottom in all depths in early summer. During mid summer, fish appear to remain congregated on the bottom close to shore at night though the tendency of remaining spread in depths of 40 ft. still persists. In late summer, at night, they tend to avoid the shallow water near shore.

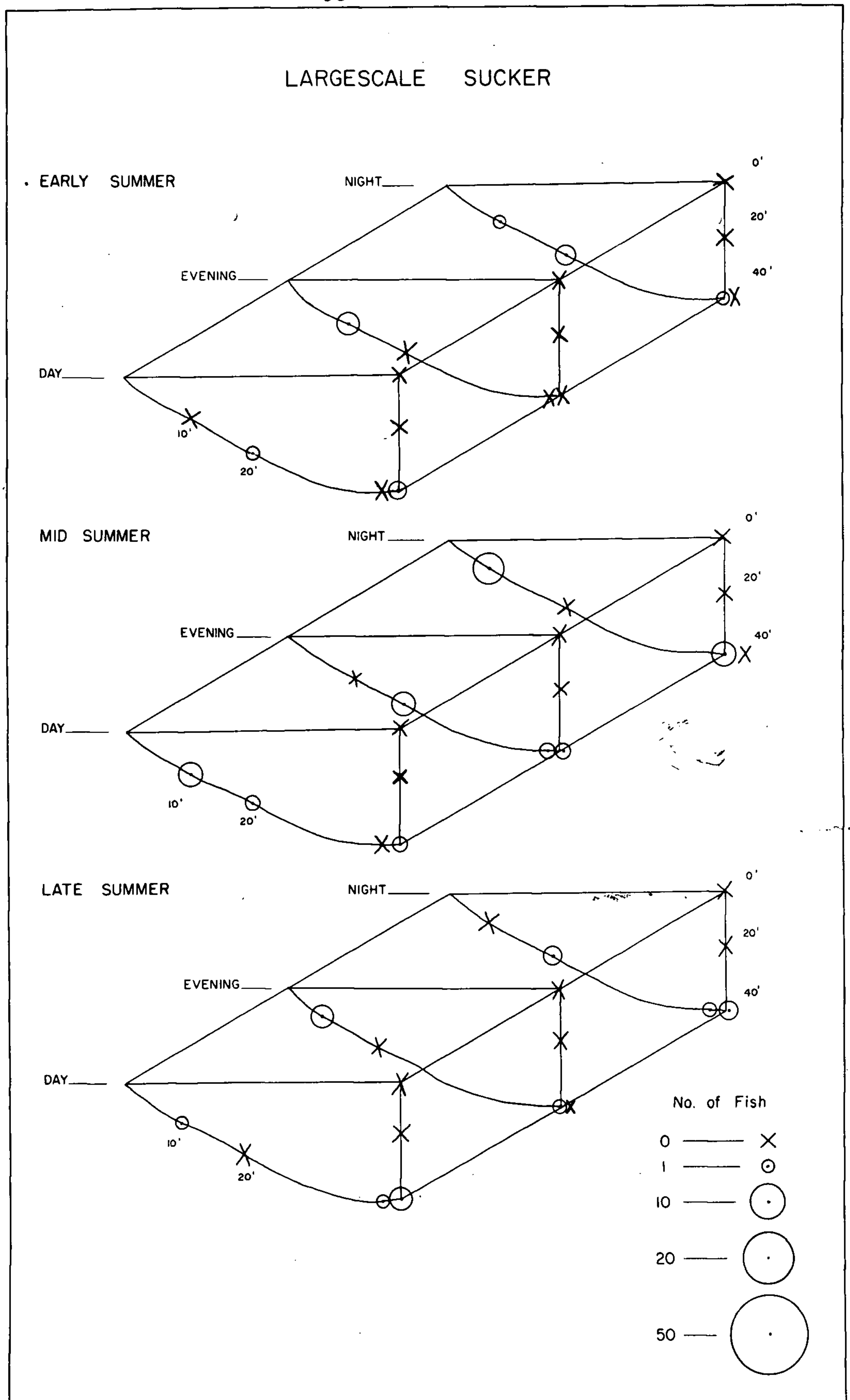

Fig. 12. Occurrence of Largescale Sucker in gill net sets in stations IV-VI in different periods of summer. Area of circle represents total number of fish.

TABLE XIX (a). Number of Largescale Sucker obtained in net sets (vertical and lateral) in the stations along Northwest shore, Nicola Lake.

Early Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
20 July	10' Bottom	Daylight	0	0	0	0		0	0	
17-18 "	" "	Evening	3	2	1	0		2	1	
23 July	" "	Night	1	0	0	1		0	0	
20 July	20' Bottom	Daylight	1	1	0	0		0	1	
17-18 "	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	2	1	1	0		0	2	
20 July	40' Bottom	Daylight	0	0	0	0		0	0	
17-18 "	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	1	0	1	0		1	0	
28 July	Surface	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	0	0	0	0		0	0	
26 July	"	Night	0	0	0	0		0	0	
28 July 24-25 " 26 July	Suspended " "	Daylight) Evening) Night)	0	0	0	0		0	0	
28 July	40' Bottom	Daylight	2	1	1	0		2	0	
24-25 "	" "	Evening	0	0	0	0		0	0	
26 July	" "	Night	0	0	0	0		0	0	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XIX (b). Number of Largescale Sucker obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake.

Mid Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10' Bottom	Daylight	3	0	2	1		0	3	
6-7 "	" "	Evening	0	0	0	0		0	0	
4 Aug.	" "	Night	7	2	3	2		1	5	
1 Aug.	20' Bottom	Daylight	1	1	0	0		0	1	
6-7 "	" "	Evening	5	3	2	0		1	4	
4 Aug.	" "	Night	0	0	0	0		0	0	
1 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
6-7 "	" "	Evening	1	0	1	0		0	1	
2 Aug.	" "	Night	3	1	2	0		0	3	
15 Aug. 16-17 " 16 Aug.	Surface " "	Daylight Evening Night	0	0	0	0		0	0	
15 Aug. 16-17 " 16 Aug.	Suspended " "	Daylight Evening Night	0	0	0	0		0	0	
15 Aug.	40' Bottom	Daylight	2	1	1	0		0	2	
16-17"	" "	Evening	1	1	0	0		1	0	
16 Aug.	" "	Night	0	0	0	0		0	0	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XIX (c). Number of Largescale Sucker obtained in net sets (vertical and lateral) in the stations along northwest shore, Nicola Lake.

Late Summer

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving		Loose fish	Conclusion (including X^2 value)	No. of fish		Conclusion (including X^2 value)
				to shore	off shore			in top half of net	in bottom half of net	
29 Aug.	10' Bottom	Daylight	1	0	1	0		0	1	
26-27 "	" "	Evening	3	1	2	0		1	2	
28 Aug.	" "	Night	0	0	0	0		0	0	
29 Aug.	20' Bottom	Daylight	0	0	0	0		0	0	
26-27 "	" "	Evening	0	0	0	0		0	0	
28 Aug.	" "	Night	2	1	0	1		0	2	
29 Aug.	40' Bottom	Daylight	1	1	0	0		0	1	
26-27 "	" "	Evening	2	0	2	0		1	1	
28 Aug.	" "	Night	1	1	0	0		1	0	
31 Aug.	Surface	Daylight)								
2-3 Sept.	"	Evening)	0	0	0	0		0	0	
2 Sept.	"	Night)								
31 Aug.	Suspended	Daylight)								
2-3 Sept.	"	Evening)	0	0	0	0		0	0	
2 Sept.	"	Night)								
31 Aug.	40' Bottom	Daylight	3	1	2	0		2	1	
2-3 Sept.	" "	Evening	0	0	0	0		0	0	
2 Sept.	" "	Night	2	1	1	0		1	1	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

Sampling on the bottom at station II indicates that the Largescale Sucker has a depth distribution up to 80 ft. in early summer only (June).

Movement of this fish in the vertical plane does not seem to be inhibited by thermal stratification. In early summer, it was found on either side of the thermocline. Similarly in mid summer (4 August) it was sampled in both the epilimnion and hypolimnion.

Largescale Suckers remain distributed in all the major regions of the lake during the summer, but more of them appear to stay in the deeper portion.

The samples from stations IV-VI do not show any significant direction of movement offshore or inshore. On the other hand, sample in the net set perpendicular to northwest shore indicated that Largescale Sucker move parallel to shore at night and remain on the bottom up to a depth of about 50 ft. from shore.

In contrast to adult fish, young ones seemed to be influenced by light in their movement towards or away from the shore. Seine hauls indicated that during the daylight hours, fry of Largescale Suckers remain very close to the shore, but at night they move away and in their place bigger young fish come to the shore.

Literature on Largescale Sucker

Ferguson (1949) mentioned Largescale Suckers as bottom dwelling fish. Clemens (1939) also noted them as bottom dwellers in Okanagan Lake.

Spoor and Schloemer (1938) observed that the White Sucker, <u>Catostomus commersoni</u> in Muskellunge Lake move inshore at night and offshore in the morning. In the case of Largescale Sucker, a similar trend can be clearly detected if only the seine haul collections are analysed.

<u>Burbot</u>

Burbot

Summary of sampling results is presented in Tables VI, VII, IX, and XX from which it would be apparent that this fish do not show any consistency in their appearance in areas sampled.

In daylight, it was seen on the bottom in 10 ft. during early summer but in mid and late summer, no fish were seen in this region. In late summer, fish were found on the bottom in 40 ft. depth during the daylight hours.

In the evening, fish appeared on the bottom in 20 ft. depth zone in early summer while in mid summer, fish were seen on the bottom at station VI. In late summer only, the samples indicate a complete spreading of Burbot on the bottom from shore to deeper water up to 40 ft.

At night, none of the sampling efforts in early and late summer caught any fish. In mid summer only, fish were seen on the bottom in 40 ft. depth zone.

Thermal stratification does not appear to limit the vertical migration of this species. They were found moving into shallow water very close to shore while following schools of Kokanee. In mid summer when the thermocline was at a depth of 20 ft. Burbot were seen in 10 as well as 40 ft. depth zone. Burbot appeared in the trap set in the mouth of Moore Creek inlet quite frequently during the summer. They were found in increased number in front of Moore Creek inlet in late summer, when spawning run of Kokanee had commenced.

Literature on Burbot

According to Ferguson (1949) and Godfrey (1955), Burbots inhabit the deeper bottom zones of lake. Absence of Burbot in any net set in the shallow southwest basin and their appearance in the net set in 80 ft. bottom in early summer are in agreement with the above obsrvations.

TABLE XX. Number of Burbot obtained in net sets in the station slong northwest shore of Nicola Lake During summer, 1958.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)	Remarks
28 July	40' Bottom	Daylight	1	1	0	0		0	1		Early summer. No fish in other sets
17-18 "	20' Bottom	Evening	1	0	1	0		0	1		" "
6-7 Aug.	40' Bottom	Evening	2	1	1	0		0	2		Mid Summer
4 Aug.	10' "	Night	1	1	0	0		0	1		" "
16 "	40' "	Night	1	1	0	0		1	0		" " No fish in any other sets.
31 Aug.	40' Bottom	Daylight	1	1	0	0		0	1		Late Summer
26-27"	10' "	Evening	1	0	1	0		0	1		" "
26-27"	20' "	Evening	1	1	0	0		1	0		" "
2-3 Sept.	40' "	Evening	2	1	1	0		0	2		" " No fish in any other sets.

Clemens (1950) suggested that larger Burbot prefer to eat large sized food. Ferguson (1949) commented that Burbot have a preference for feeding upon Kokanee. Godfrey (1955) pointed out that Burbots appear in very shallow water in the Skeena River system when the spring migration of Salmon smolts commences. He associated this with the preference of Burbot for Salmon smolts as food.

Prickly Sculpin

Results are presented in Tables VI, VII, VIII, IX and XXI.

According to Ricker (1941), Prickly Sculpin is a bottom dwelling species and inhabits principally the regions close to shore. Results in the present study agree in general with Ricker. Appearance of stray Sculpins on the bottom at 80 ft. and 40 ft. in different periods of the summer is probably an indication that adult and large Prickly Sculpins tend to explore deeper parts of the lake. But since the samples are extremely poor, this phenomenon cannot be considered as significant.

During the daylight hours, young fish are seen to move in small schools all along the shore including the rocky west shore. In north shore, seine haul samplings showed that with nightfall, young and small fish seen in the daylight move offshore and in their place, larger fish appear in 2-3 ft. water on the shore.

Prickly Sculpins are known to live in the epilimnion only (Ferguson, 1949) but the appearance of single individuals on either side of the thermocline in the present study shows that thermal stratification does not act as a strong barrier for the species.

Kokanee

Data on Kokanee are presented in Table XXII (a-c) and Figure 13. Only

TABLE XXI. Number of Sculpins obtained in net sets in the stations along the northwest shore of Nicola Lake during the summer, 1958.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)	Remarks
17-18 July	10' Bottom	Evening	1	1	0	0		0	1		Early Summer No [illegible] fish in any other sets.
" "	20' Bottom	"	1	0	1	0		1	0		
16-17 Aug.	40' Bottom	Evening	1	0	0	1		0	1		Mid Summer no fish in any other set.
26-27 Aug.	10' Bottom	Evening	1	0	1	0		0	1		Late Summer
	20' "	Evening	3	2	1	0		0	3		" "
31 Aug.	40' "	Daylight	1	0	0	1		0	1		" " No fish in any other set.

large Kokanee were taken by gill netting and the discussion relates to only fish in their ultimate year.

All through the summer, Kokanee tend to stay on the bottom in deeper regions of the lake during the hours of daylight.

In the evening, movement of fish towards the shore and upward into midwater was noticeable in early summer. In mid summer, movement towards shallower water was indicated by the appearance of fish in net sets on 10 ft. bottom zone in the evening. In late summer, Kokanee tended to get distributed in surface, midwater and in the bottom regions along shore. This departure from their normal tendency of staying in deeper water was probably spurred by the sexual maturity of the fish.

At night in early summer, fish stayed in the deeper bottom zone, and the same trend persisted in mid summer. But in late summer fish were seen in the surface level as well as in midwater at night. This is evidently the result of sexual ripening of fish. During this period, schools of Kokanee were found near the Moore Creek inlet mouth even after dawn.

Literature on Kokanee

Kokanee are known to live in deeper water in the hypolimnion during summer. With the rise of temperature in summer they go into deeper water (Curtis and Fraser 1948). According to Ferguson (1949), in Skaha Lake Kokanee were sampled in greatest numbers from 60 ft. of water, but they also appeared in depths up to 131 ft. In the present study, Kokanee is the only species that was found to live in depths of 110 ft. in the summer (Table XI). Further, it was sampled from a depth of 80 ft. all through the season. Thus it may be concluded that it is a deep water species. Clemens, et al (1939) noted that Kokanee live in intermediate depths in Okanagan Lake.

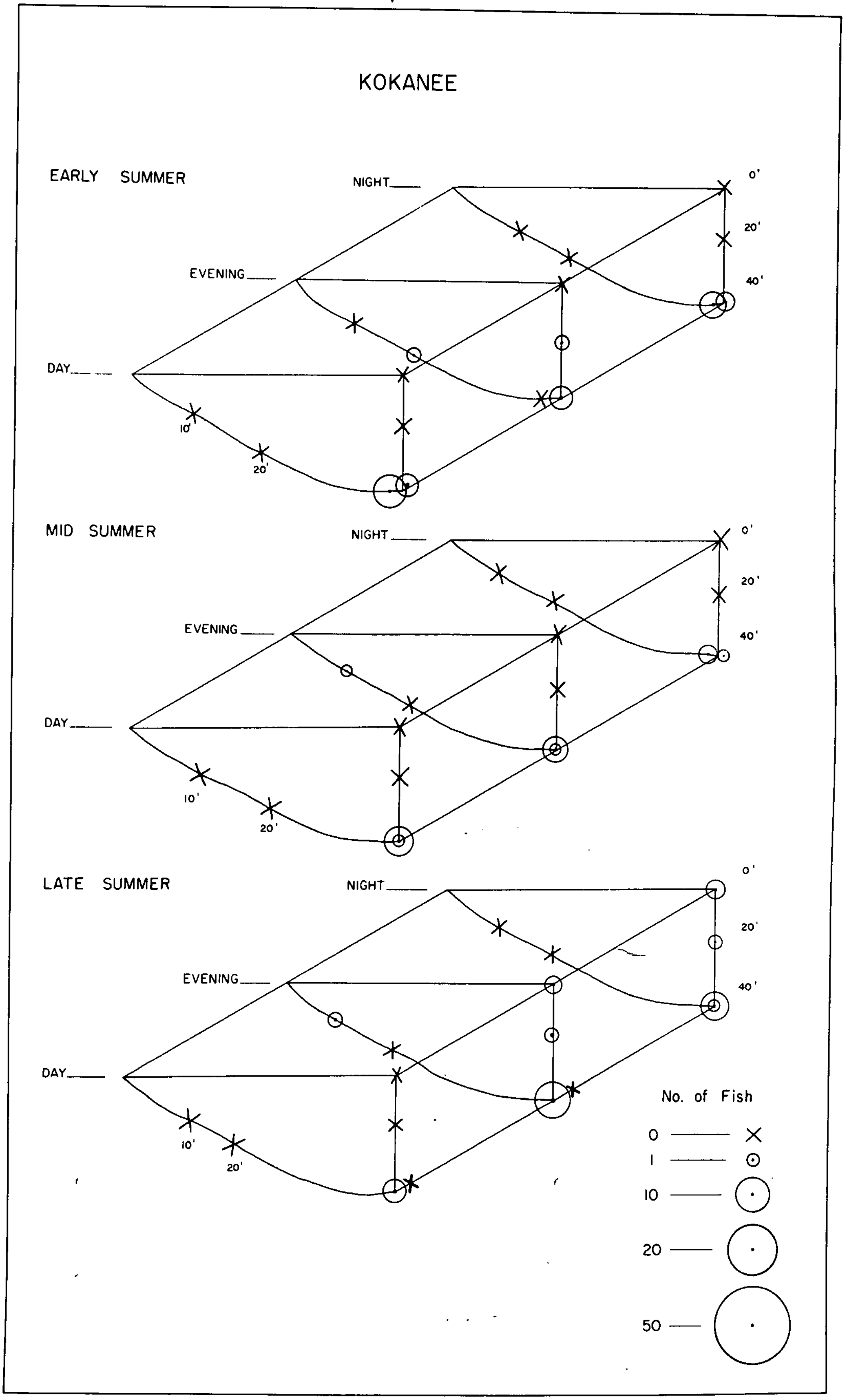

Fig. 13. Occurrence of Kokanee in gill net sets in stations IV-VI in different periods of summer. Area of circle represents total number of fish.

TABLE XXII (a). Number of Kokanee obtained in net sets in the stations along northwest shore of Nicola Lake during Early Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
20 July	10' Bottom	Daylight	0	0	0	0		0	0	
17-18 "	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	0	0	0	0		0	0	
20 July	20' Bottom	Daylight	0	0	0	0		0	0	
17-18 "	" "	Evaning	1	1	0	0		1	0	
23 July	" "	Night	0	0	0	0		0	0	
20 July	40' Bottom	Daylight	7	5	2	0		0	7	
17-18 "	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	4	3	1	0		2	2	
28 July	Surface	Daylight)								
24-25 "	"	Evening)	0	0	0	0		0	0	
26 July	"	Night)								
28 July	Suspended	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	1	0	1	0		0	1	
26 July	"	Night	0	0	0	0		0	0	
28 July	40' Bottom	Daylight	4	1	2	1		2	2	
24-25 "	" "	Evening	3	0	3	0		1	2	
26 July	" "	Night	2	0	1	1		0	2	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XXII(b). Number of Kokanee obtained in net sets in the stations along northwest shore of Nicola Lake during Mid Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10' Bottom	Daylight	0	0	0	0		0	0	
6-7 "	" "	Evening	1	1	0	0		0	1	
4 Aug.	" "	Night	0	0	0	0		0	0	
1 Aug.	20' Bottom	Daylight)								
6-7 "	" "	Evening)	0	0	0	0		0	0	
4 Aug.	" "	Night)								
1 Aug.	40' Bottom	Daylight	6	3	3	0		2	4	
6-7 "	" "	Evening	4	2	2	0		2	2	
4 Aug.	" "	Night	2	1	1	0		1	1	
15 Aug.	Surface	Daylight)								
16-17"	"	Evening)	0	0	0	0		0	0	
16 Aug.	"	Night)								
15 Aug.	Suspended	Daylight)								
16-17"	"	Evening)	0	0	0	0		0	0	
16 Aug.	"	Night)								
15 Aug.	40' Bottom	Daylight	1	1	0	0		0	1	
16-17"	" "	Evening	1	1	0	0		1	0	
16 Aug.	" "	Night	1	0	1	0		0	1	

Note - Chi-square is not calculated where sample size is small and no conclusion noted.

TABLE XXII(c). Number of Kokanee obtained in net sets in the stations along northwest shore of Nicola Lake during Late Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (Including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
29 Aug.	10' Bottom	Daylight	0	0	0	0		0	0	
26-27"	" "	Evening	1	0	1	0		1	0	
28 Aug.	" "	Night	0	0	0	0		0	0	
29 Aug.	20' Bottom	Daylight)								
26-27"	" "	Evening)	0	0	0	0		0	0	
28 Aug.	" "	Night)								
29 Aug.	40' Bottom	Daylight	4	3	1	0		2	2	
26-27"	" "	Evening	0	0	0	0		0	0	
28 Aug.	" "	Night	7	6	1	0		1	6	
31 Aug.	Surface	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	2	0	2	0		1	1	
2 Sept.	"	Night	2	0	2	0		2	0	
31 Aug.	Suspended	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	1	1	0	0		1	0	
2 Sept.	"	Night	1	0	1	0		1	0	
31 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
2-3 Sept.	" "	Evening	10	2	8	0		3	7	
2 Sept.	" "	Night	1	1	0	0		1	0	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

Rainbow Trout

Results are summarized in Table XXIII (a-c).

No Raibow Trout were seen in the daylight and evening in 10 or 20 ft. depth zone in any period of the season. At night, however, it appeared in 10 and 20 ft. depths on the bottom but this was not consistent in different periods of the summer.

On the bottom in the 40 ft. depth zone, it was found in all periods of day in mid as well as late summer.

In the vertical plane, no fish were seen in the surface waters during the daylight hours all through the summer. In late summer only, fish were seen in the surface level at night.

In midwater, fish appeared in the daylight, evening and at night during the mid summer. In early summer, fish were seen in midwater at night.

The irregular appearance of Rainbow Trout in different levels and depths of water shows that it is an open water species and remains distributed in different depths. No fish were, however, sampled from depths of 80 ft. or more during any part of the summer.

Observations in the present case indicate that thermal stratification does not act as a barrier in the vertical movement of this fish.

The samples obtained also do not indicate the existence of any off-shore or inshore direction of movement in Rainbow Trout during different periods of the day.

Literature on Rainbow Trout

Clemens (1939) described Rainbow Trout as an open water species. Findings of Ferguson (1949) in Skaha Lake showed that Rainbow Trout live in different depths in the open water during summer.

TABLE XXIII (a). Number of Rainbow Trout obtained in net sets in the stations along the northwest shore of Nicola Lake during Early Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including χ^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including χ^2 value)
20 July	10' Bottom	Daylight	0	0	0	0		0	0	
17-18"	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	1	0	1	0		1	0	
20 July	20' Bottom	Daylight)								
17-18 "	" "	Evening)	0	0	0	0		0	0	
23 July	" "	Night)								
20 July	40' Bottom	Daylight)								
17-18 "	" "	Evening)	0	0	0	0		0	0	
23 July	" "	Night)								
28 July	Surface	Daylight)								
24-25 "	"	Evening)	0	0	0	0		0	0	
26 July	"	Night)								
28 July	Suspended	Daylight	0	0	0	0		0	0	
24-25 "	"	Evening	0	0	0	0		0	0	
26 July	"	Night	2	0	2	0		2	0	
28 July	40' Bottom	Daylight)								
24-25 "	" "	Evening)	0	0	0	0		0	0	
26 July	" "	Night)								

XXIII (b). Number of Rainbow Trout obtained in net sets in the stations along the northwest shore of Nicola Lake during <u>Mid Summer.</u>

Date 1958	Depth and position of net set	Period of day	Total No. of Fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10' Bottom	Daylight	0	0	0	0		0	0	
6-7 "	" "	Evening	0	0	0	0		0	0	
4 Aug.	" "	Night	3	2	1	0		2	1	
1 Aug.	20' Bottom	Daylight	0	0	0	0		0	0	
6-7 "	" "	Evening	0	0	0	0		0	0	
4 Aug.	" "	Night	2	2	0	0		1	1	
1 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
6-7 "	" "	Evening	1	0	1	0		1	0	
4 Aug.	" "	Night	1	0	1	0		0	1	
15 Aug.	Surface	Daylight	0	0	0	0		0	0	
16-17"	"	Evening	3	2	1	0		1	2	
16 Aug.	"	Night	2	0	2	0		0	2	
15 Aug.	Suspended	Daylight	1	1	0	0		1	0	
16-17"	"	Evening	4	1	3	0		3	1	
16 Aug.	"	Night	4	3	0	1		2	1	
15 Aug.	40' Bottom	Daylight	1	0	0	1				
16-17"	" "	Evening	0	0	0	0		0	0	
16 Aug.	" "	Night	4	3	0	1		3	0	

TABLE XXIII (c). Number of Rainbow Trout obtained in net sets in the stations along the northwest shore of Nicola Lake during <u>Late Summer.</u>

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
29 Aug.	10' Bottom	Daylight)								
26-27"	" "	Evening)	0	0	0	0		0	0	
28 Aug.	" "	Night)								
29 Aug.	20' Bottom	Daylight)	0	0	0	0		0	0	
26-27"	" "	Evening)	0	0	0	0		0	0	
28 Aug.	" "	Night	1	0	1	0		1	0	
29 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
26-27"	" "	Evening	1	1	0	0		1	0	
28 Aug.	" "	Night	0	0	0	0		0	0	
31 Aug.	Surface	Daylight	0	0	0	0		0	0	
2-3 Sept.	"	Evening	0	0	0	0		0	0	
2 Sept.	"	Night	2	2	0	0		1	1	
31 Aug.	Suspended	Daylight)								
2-3 Sept.	"	Evening)	0	0	0	0		0	0	
2 Sept.	"	Night)								
31 Aug.	40' Bottom	Daylight	2	2	0	0		0	2	
2-3 Sept.	" "	Evening	0	0	0	0		0	0	
2 Sept.	" "	Night	0	0	0	0		0	0	

Dolly Varden

Data on Dolly Varden are presented in Table XXIV.

Information obtained are not adequate to give a clear picture of the distribution of the species.

In the whole summer, it was sampled once in the daylight in early summer and twice during late summer - in the daylight and at night. Every time, it was found in the nets set on the 40 ft. bottom.

Ricker (1941) states that Dolly Varden live on the bottom. In Cultus Lake, this species was captured in gill nets set in deeper waters only (Foerster and Ricker, 1941). The present data appear similar to the findings referred to above.

Though a bottom dwelling species, it never appeared in net sets made on the bottom at 80 ft. or at 100 ft. This indicates that Dolly Vardens do not probably frequent deep water in the summer.

In early summer, one Dolly Varden was sampled in the southwest basin. From this stray fish, it is difficult to infer that in summer Dolly Vardens come into shallow shore areas.

Chinook Salmon

Particulars of Chinook Salmon are presented in Tables VI, VIII and XXV.

The adult Chinook Salmon appeared in the nets set at night only. In net sets in front of Moore Creek inlet, Chinook Salmon appeared in early as well as late summer. From the southwest end net set, it was obtained in mid and late summer, while in late summer, only one fish was found on the northwest shore. All fish sampled were found sexually mature and the movements at night particularly near the streams may be related to their reproductive activity.

TABLE XXIV. Number of Dolly Varden obtained in net sets in the stations along northwest shore of Nicola Lake during summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving		Loose fish	Conclusion (including X^2 value)	No. of fish		Conclusion (including X^2 value)	Remarks
				to shore	off shore			in top half of net	in bottom half of net		
28 July	40' Bottom	Daylight	1	0	1	0		0	1		Early Summer
29 Aug.	40' Bottom	Daylight	1	1	0	0		0	1		Late Summer
28 "	" "	Night	1	0	0	1		1	0		" "

Note: No other net sets in these stations yielded any more Dolly Varden, during the whole summer.

TABLE XXV. Number of Chinook Salmon obtained in the net sets in the stations along northwest shore of Nicola Lake during Summer, 1958.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving		Loose fish	Conclusion (including X^2 value)	No. of fish		Conclusion (including X^2 value)	Remarks
				to shore	off shore			in top half of net	in bottom half of net		
26-27 Aug.	10' Bottom	Evening	1	1	0	0		0	1		

Note: No Chinook Salmon was caught in any other net sets made in these stations during the whole summer.

Young of Chinook Salmon also were found in seine hauls made close to the Moore Creek inlet and in the Nicola River outlet. Once during the whole period of summer, one small young Chinook Salmon was taken in the net set in station III. Presence of large number of young fish in Nicola River outlet seemed to indicate that the young fish commence their seaward journey during summer months. From Shuswap Lake, commencement of seaward journey of young Chinook Salmon in July was recorded by Clemens (1934).

Mountain Whitefish

Results are presented in Table XXVI (a-c) and Figure 14.

In the daylight hours of early summer, fish were found on the bottom in deeper waters but in mid summer, fish tended to remain spread all over the bottom from shore to the depth of 40 ft. In late summer, on the other hand, no fish were seen on the bottom during daylight hours.

In the evening, fish were seen on the bottom at 40 ft. in early summer but in mid summer, fish appeared on the bottom near shore as well as in mid-water. In late summer, fish appeared only on the bottom in station IV (10 ft.).

In the nets set at night, fish were seen in 40 ft. bottom in early summer but in mid summer, fish appeared on the bottom both in stations IV and VI. In late summer, no fish were seen in the northwest region of the lake.

The general disappearance of fish in the northwest shore in late summer coincided with a relatively large catch of the species in station III. Examination of gonads of these fish from station III revealed that they were sexually ripe. Their disappearance from the main body of the lake and congregation in front of Nicola River outlet can be related to the spawning activity of the species in the later part of summer.

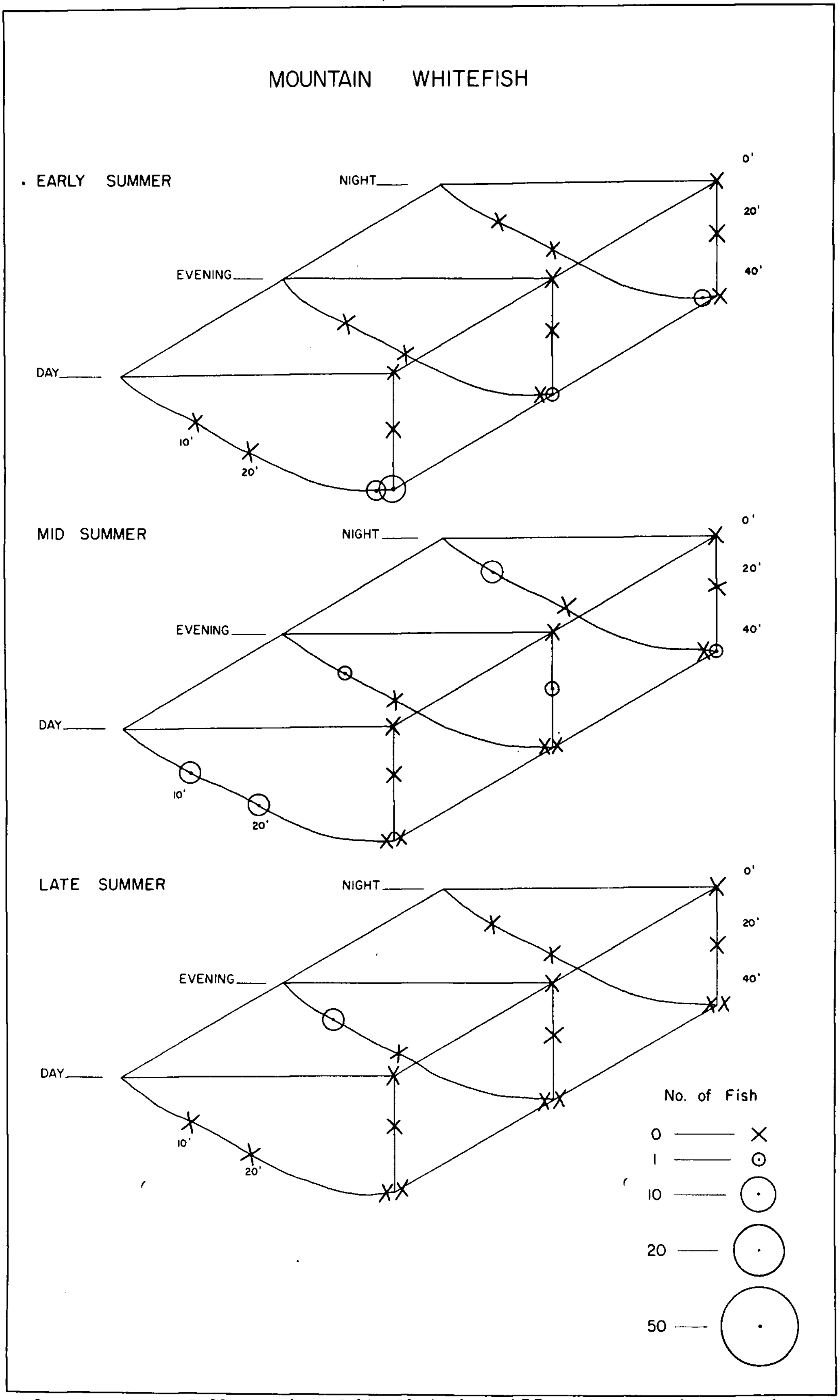

Fig. 14. Occurrence of Mountain Whitefish in gill net sets in stations IV-VI in different periods of summer. Area of circle represents total number of fish.

TABLE XXVI (a). Number of Mountain Whitefish obtained in net sets (vertical and lateral) in stations along northwest shore of Nicola Lake during Early Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	off shore	Loose fish	Conclusion (includind X^2 value)	No. of Fish in top half of net	in bottom half of net	Conclusion (including X^2 value)
20 July	10' Bottom	Daylight)								
17-18 "	" "	Evening)	0	0	0	0		0	0	
23 July	" "	Night)								
20 July	20' Bottom	Daylight)								
17-18 "	" "	Evening)	0	0	0	0		0	0	
23 July	" "	Night)								
20 July	40' Bottom	Daylight	2	0	2	0		0	2	
17-18 "	" "	Evening	0	0	0	0		0	0	
23 July	" "	Night	2	0	1	1		1	1	
28 July	Surface	Daylight)								
24-25 "	"	Evening)	0	0	0	0		0	0	
26 July	"	Night)								
28 July	Suspended	Daylight)								
24-25 "	"	Evening)	0	0	0	0		0	0	
26 July	"	Night)								
28 July	40' Bottom	Daylight	5	2	3	0		0	5	
24-25 "	" "	Evening	1	0	1	0		0	1	
26 July	" "	Night	0	0	0	0		0	0	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XXVI (b). Number of Mountain Whitefish obtained in net sets (vertical and lateral) in stations along northwest shore of Nicola Lake during Mid Summer.

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
1 Aug.	10' Bottom	Daylight	2	1	1	0		0	2	
6-7 "	" "	Evening	1	0	0	1		0	1	
4 Aug.	" "	Night	3	1	1	1		0	3	
1 Aug.	20' Bottom	Daylight	2	0	2	0		1	1	
6-7 "	" "	Evening	0	0	0	0		0	0	
4 Aug.	" "	Night	0	0	0	0		0	0	
1 Aug.	40' Bottom	Daylight)								
6-7 "	" "	Evening)	0	0	0	0		0	0	
4 Aug.	" "	Night)								
15 Aug.	Surface	Daylight)								
16-17"	"	Evening)	0	0	0	0		0	0	
16 Aug.	"	Night)								
15 Aug.	Suspended	Daylight	0	0	0	0		0	0	
16-17"	"	Evening	1	1	0	0		0	1	
16 Aug.	"	Night	0	0	0	0		0	0	
15 Aug.	40' Bottom	Daylight	0	0	0	0		0	0	
16-17"	" "	Evening	0	0	0	0		0	0	
16 Aug.	" "	Night	1	0	1	0		0	1	

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

TABLE XXVI (c). Number of Mountain Whitefish obtained in net sets (vertical and lateral) in stations along northwest shore of Nicola Lake during <u>Late Summer.</u>

Date 1958	Depth and position of net set	Period of day	Total No. of fish	No. of fish moving to shore	No. of fish moving off shore	Loose fish	Conclusion (including X^2 value)	No. of fish in top half of net	No. of fish in bottom half of net	Conclusion (including X^2 value)
29 Aug.	10' Bottom	Daylight	0	0	0	0		0	0	
26-27 "	" "	Evening	2	0	2	0		2	0	
28 Aug.	" "	Night	0	0	0	0		0	0	
29 Aug.	20' Bottom	Daylight)								
26-27"	" "	Evening)	0	0	0	0		0	0	
28 Aug.	" "	Night)								
29 Aug.	40' Bottom	Daylight)								
26-27"	" "	Evening)	0	0	0	0		0	0	
28 Aug.	" "	Night)								
31 Aug.	Surface	Daylight)								
2-3 Sept.	"	Evening)	0	0	0	0		0	0	
2 Sept.	"	Night)								
31 Aug.	Suspended	Daylight)								
2-3 Sept.	"	Evening)	0	0	0	0		0	0	
2 Sept.	"	Night)								
31 Aug.	40' Bottom	Daylight)								
2-3 Sept.	" "	Evening)	0	0	0	0		0	0	
2 Sept.	" "	Night)								

Note - Chi-square is not calculated where sample size is small and no conclusion is noted.

Literature on Mountain Whitefish

In his study of the ecology of Skeena River System Whitefish, Godfrey (1955) reported that Mountain Whitefish are more abundant on the bottom in 16-32' depth zone. Present data are in agreement. According to Ferguson (1949), position of Mountain Whitefish is intermediate between shallow water and deep water fishes in Skaha Lake where it was seen to come to shore zone for feeding on the bottom. Appearance of the species in shallow shore areas in the present case appears to be similar to the situation in Skaha Lake.

Non-availability of Mountain Whitefish in net sets made on the bottom in 80 ft. and deeper waters all through the summer agrees completely with the results of Godfrey (1955) in Babine and Lakelse lakes.

McHugh (1940) mentioned that with the increase in their size, Mountain Whitefish modify their feeding habits to include larger plankton and other bigger organisms including fish. Ferguson (1949) observed that in areas with sparse bottom fauna, this fish moves into different areas to look for food. Appearance of the species in midwater during mid summer may be related to its feeding activity as suggested above.

Influence of thermal stratification on this species is not clear. In early summer it is never found above the thermocline but in late summer, it was never seen in the hypolimnion. In Skaha Lake, it is found to occupy a position intermediate between epilimnion and hypolimnion (Ferguson 1949).

Seine hauls in north shore

Results of seine hauls made in the north shore in different periods of the day are presented in Table XXVII (a-c).

In the early summer, young-of-the-year of Largescale Sucker, Squawfish, Peamouth Chub and Prickly Sculpin of sizes ranging from 16 to 33 mm. inhabited the sandy beaches along north shore during the daylight hours. At dusk, larger size groups of Peamouth Chub, Largescale Sucker, Squawfish invaded the shore. Redside Shiners of the size range of 43-91 mm. also appeared on the shore at this time. In the case of Prickly Sculpins, the same size group of fry as seen in the daylight were found to continue to live on the shore. The young-of-the year class of fry of all species except Prickly Sculpin appeared to move off-shore with change in light condition.

At night, this offshore movement of smaller fry and inshore movement of bigger specimens appeared to become complete. In addition, fry of Mountain Whitefish also were observed to come into the beach. Proportion of different species in the shore population also appeared to undergo changes with variation in light conditions.

In mid summer, the same phenomena of the variation in the size group and species composition in daylight and at night were found to continue. During this period, larger size groups of Prickly Sculpin came into shore at night.

In late summer, the same pattern in the inshore and offshore movement of the different size groups of young fish as seen in the preceding periods of summer continued. During this period, a seine haul made in the predawn period showed that very few fish stay near the beach at this part of the day.

Towards the middle of August, young-of-the-year of Redside Shiner, Peamouth Chub and Largescale Sucker were found to move about in 2-3 ft. deep

TABLE XXVII (a). Particulars of seine hauls in the north shore, Nicola Lake in Early Summer, 1958.

Date	Time (hrs.)	Period of day	Weather conditions	Bottom conditions	Species	Range of size (mm.)	Total of each size group and each species	Percent total catch
17 July	16.30	Daylight	Bright and clear day, little wind	Sandy and muddy	(I) Largescale Sucker	16-28	435	36.5
					(II) Squawfish	16-23	322	27.0
					(III) PM Chub	21-33	392	32.9
					(IV) Sculpin	16-29	43	3.6
						Total	1192	100
17 July	23.30	Night	Clear sky; little wind	Sandy and muddy	(I) Largescale Sucker (a)	68-251	30)	34.0
					(b)	21-25	85)	
					(II) Squawfish	16-27	27	8.0
					(III) PM Chub (a)	66-225	11)	4.4
					(b)	17-33	4)	
					(IV) Redside Shiner	52-100	125	37.0
					(V) Sculpin	16-31	52	15.4
					(VI) Mount.Whitef.	57-71	4	11.2
						Total	338	100
17 July	21.00	Dusk	Clear sky wind-nil	Sandy and muddy	(I) Largesc.Sucker (a)	17-26	816)	77.0
					(b)	63-200	4)	
					(II) Squawfish (a)	16-25	64)	6.38
					(b)	133-215	4)	
					(III) PM Chub (a)	15-29	100)	10.14
					(b)	62-185	8)	
					(IV) Reds.Shiner	43-91	9	0.85
					(v) Sculpin	18-33	60	5.63
						Total	1065	100

TABLE XXVII (b). Particulars of seine hauls in the north shore, Nicola Lake, in Mid Summer, 1958.

Date	Time (hrs.)	Period of day	Weather conditions	Bottom conditions	Species	Range of size (mm.)	Total of each size group and each species	Percent total catch
6 Aug.	12.20	Daylight	Complete	Sandy and	(I) Largescale (a)	21-43	153)	17.5
			overcast	muddy	Sucker (b)	65-131	2)	
			wind 15-18		(II) Squawfish (a)	18-38	225)	25.5
			M.P.H.		(b)	86	1)	
			S.SW		(III) PM Chub (a)	17-51	70)	8.1
					(b)	114	1)	
					(IV) Redside (a)	17-51	344)	44.2
					Shiner (b)	57-102	47)	
					(V) Sculpin	15-31	41	4.6
					(VI) M.Whitefish	76	1	0.1
						Total	885	100.0
6 Aug.	23.00	Night	Complete	Sandy and	(I) Largescale (a)	21-45	88)	10.8
			overcast	muddy	Sucker (b)	73-215	21)	
			wind 3-4		(II) Squawfish (a)	20-31	11)	1.2
			M.P.H.		(b)	100	1)	
					(III) PM Chub (a)	16-38	67)	7.1
					(b)	117-240	4)	
					(IV) Redside (a)	18-31	119)	32.1
					Shiner (b)	52-116	203)	
					(V) Sculpin	16-76	486	48.4
					(VI) M.Whitefish	81-217	4	0.4
						Total	1004	100.0

TABLE XXVII (c). Particulars of seine hauls in north shore, Nicola Lake, in Late Summer, 1958.

Date	Time (hrs.)	Period of day	Weather Conditions	Bottom Conditions	Species	Range of size (mm.)	Total of each size group and each species	Percent total catch
26 Aug.	04.15	Pre-dawn	Cloudy.	Sandy and	(I) Largescale (a)	31-62	7)	7.3
			Overcast	muddy	Sucker (b)	254	1)	
			5/10		(II) Squawfish	23-45	18	16.4
			Wind 12-16		(III) PM Chub (a)	21-43	8)	9.1
			M.P.H. S.-		(b)	215-253	2)	
			SW.		(IV)Redside (a)	17-40	6)	32.7
					Shiner (b)	60-114	30)	
					(V) Sculpin	16-68	38	34.5
						Total	110	100.0
26 Aug.	14.30	Daylight	Overcast	Sandy and	(I) Largescale (a)	22-67	183)	5.7
			8/10 almost	muddy	Sucker (b)	95-108	2)	
			complete		(II) Squawfish (a)	25-49	1153)	35.9
			Wind 12-14		(b)	50-130	20)	
			M.P.H. SW.		(III) PM Chub (a)	22-57	266)	8.3
					(b)	90-135	6)	
					(IV) Redside Shin.	22-106	1630	49.9
					(V) Sculpin (a)	17-33	5)	0.2
					(b)	57	1)	
						Total	3266	100.0
26 Aug.	22.30	Night	Overcast	Sandy and	(I) Largescale (a)	40-57	55)	26.0
			complete	muddy	Sucker (b)	78-400	8)	
			Wind-very		(II) Squawfish (a)	28-45	63)	26.7
			light to		(b)	129-105	2)	
			nil.		(III) Redside (a)	21-42	19)	45.7
					Shiner (b)	57-116	92)	
					(IV) M. Whitefish	88-260	4	1.6
						Total	243	100.0

water in moderate sized schools. In late summer, the schooling appeared to become pronounced with more individuals in each school.

Predominance of different species in the shore population also tended to vary in different periods of summer and also over day and night in the same period of the season. In early summer, during the daylight hours, Largescale Sucker fry were seen as the dominant group but at night, Prickly Sculpins became the major species. But from mid summer on, Redside Shiner fry became the dominant group in the daylight hours. At night, dominance of Prickly Sculpin continued. In late summer, a reversed picture of the mid summer situation was found to develop with Prickly Sculpin dominating during the day, but yielding their position to Redside Shiner at night.

Presence of newly hatched Redside Shiner fry along the shore in different periods of the season show a similarity to conditions in Paul Lake where Shiner fry were not found in the middle of July but reappeared in early August (Crossman 1957).

Seine hauls in other regions of shore

Results are summarized in Table XXVIII.

Peamouth Chub were found on all shores irrespective of the nature of bottom. But one seine haul made in front of Moore Creek inlet did not yield any Peamouth Chub. Largescale Suckers also appeared in all parts except in Nicola River inlet. In the lagoon on the southeast shore, Carp appeared in seine hauls together with Peamouth Chub, Largescale Sucker, Redside Shiner and Prickly Sculpin.

Inlet and outlet streams seemed to influence the composition of shore populations of young fish. Seine hauls made in front of Moore Creek inlet and Nicola River inlet tended to bear out the above observation. The haul

TABLE XXVIII. Particulars of seine hauls in different parts of Nicola lake, taken in the daylight hours.

Date 1958	Location of haul	Bottom conditions	Species caught																					
			PM mm	Total	RSS mm	Total	SQ mm	Total	LND mm	Total	CP mm	Total	KT mm	Total	SS mm	Total	KK mm	Total	MW mm	Total	SC mm	Total	LSS mm	Total
18 July	SE shore south of Quilchena Cr. inlet	Sandy beach	16-32	122	14-49	4	20-24	2													20-31	43	17-	483
"	Lagoon in SE shore	Muddy bottom &murky	21-60	24	44-48 76	4	61-66	6			51-70	25									22-77	87	23-61	13
"	"	"	18-67	32	53-78	2	63	1													20-107	85	21-95	23
"	SE shore south of Quilchena Cr.	Sandy	30-75	11	41-78	6	51-73	10	30-33	2													27-104	25
1 Aug.	N. shore in front of Moore Cr. inlet	"											120	1	61-115	38	140	1	62-225	19	24-36	18	230	1
8 Aug.	Magi Moore's bay SE shore	Sandy with gravel upto4'	16-32	318	19-37	246	17-26	17													12-35	140	15-27	155
"	Nicola R. inlet SE shore		20	1																	15-50	261		
"	NE Quilchena Point	Rocky	15-40	33	16-33	39	18-26	15													29	1	22-39	31
"	E. of Quilchena SE side of lake	Stagn. murky stinky Ooze bottom	20-35	12	18-80	65	21-85	44			56-96	8									30-32	2	23-36	62

Cont.......

TABLE XXVIII - Cont'd.

Date 1958	Location of haul	Bottom conditions	Species caught																					
			PM mm	Total	RSS mm	Total	SQ mm	Total	LND mm	Total	CP mm	Total	KT mm	Total	SS mm	Total	KK mm	Total	MW mm	Total	SC mm	Total	LSS mm	Total
8 Aug.	SW End 1 mile from Nicola R. outlet	Muddy with decayed veget.	30-48	305	30-32	5	20-36	39													38-65	6	27-50	497
8 Aug.	Nicola R. outlet	Rocky, silt, weed beds; slow currt.	43-123	8	31-105	124	25-92	11			81-98	4			90-	1					28-130	79	30-95	40

Note: LND = Longnose Dace.

For other abbreviations, Table VI may be seen.

in front of Moore Creek inlet showed young Kokanee, Chinook Salmon, and Rainbow Trout as the dominant group of fish. The haul in front of Nicola River inlet showed only Peamouth Chub and Prickly Sculpins. Sampling in the Nicola River outlet about a mile down from the lake produced Redside Shiner, Peamouth Chub, Carp fingerlings and young of Chinook Salmon.

Seine hauls along the southeast shore a little south of Quilchena Creek, showed Longnose Dace in the beach in addition to other usual species whereas the haul made in the lagoon in early summer revealed the presence of Carp fingerlings in that locality.

Fry of different species seen to inhabit the shores are believed to have a common food habit (Larkin 1956). Occurrence of these species together in the lake can, therefore, be related to their food and feeding habits.

Dip net sampling

In the steep rocky shore, along the western side, fry of Peamouth Chub, Prickly Sculpin, Redside Shiner and Squawfish were found moving in schools in 2-3 ft. of depth during the period from the third week of July to middle of August. Largescale Sucker fry was conspicuous by their absence along the rocky shore regions and this is probably due to the different substrate over which they could not feed effectively.

IV. FISH ASSOCIATIONS

Assemblage of different species in certain habitat zones is the outcome of their response to seasonal or daily changes in the physical, chemical or biological conditions. Assemblage may also be induced by the urge of reproductive activity or by social attractions as in the higher animals (Odum, 1954). In the case of fish, intraspecific social attractions may exist, but interspecific association can be considered as the result of their identical response to certain physical or chemical changes in the environment or the result of their tendency to share a common source of food supply. Factors of food and feeding may bring about the association of predator and prey species. Associations of fish in different habitats are, therefore, the outcome of the interactions of various factors - physical, chemical and biological.

The season, e.g. summer, during which the present study was made, is known to bring about certain physiological barriers for fish over which little migration takes place (Ferguson, 1949). Ferguson defines Peamouth Chub, Redside Shiner, Prickly Sculpin, Squawfish, Carp and Largescale Sucker as shore species living above the epilimnion. The present study also showed a similar association of shore dwelling species. All throughout the season, Peamouth Chub, Redside Shiner, Largescale Sucker and Squawfish are seen to occupy the bottom of the lake in the shore regions, during daylight hours. During night, this bottom association of fish is strengthened by Prickly Sculpins. In the shallow southwest end, Chiselmouth, Longnose Dace, Carp and Bridgelip Sucker come into this association of fish occupying shallow shore regions of the lake. Figures 15, 16 and 17 summarize the association of fish as seen in the net sets on the northwest shore during the summer.

This basic association of shore zone fishes can be further subdivided into two groups according to their food habits. Carp, Prickly Sculpin,

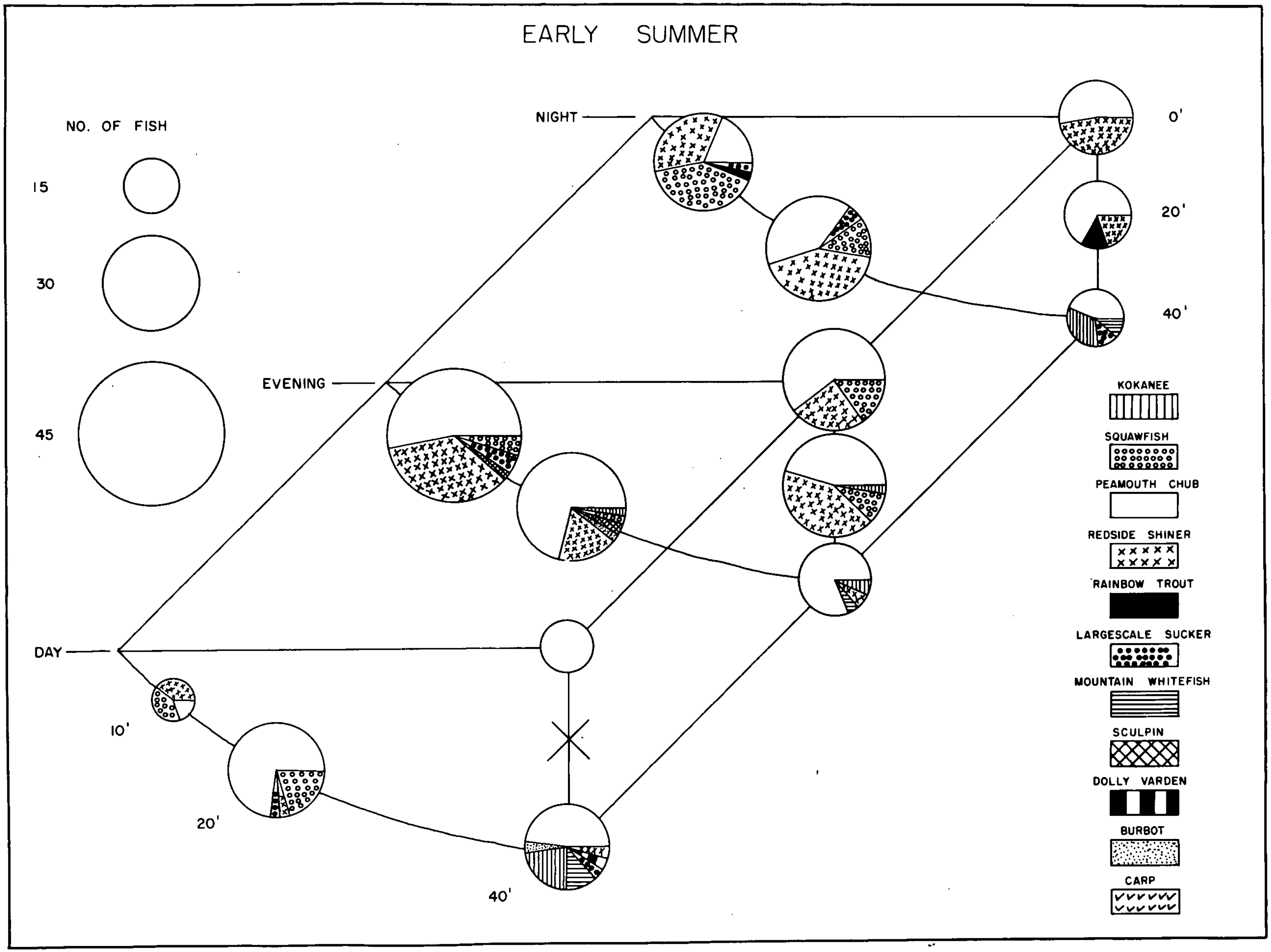

Fig. 15. Occurrence of fish in gill net sets in northwest shore in early summer.

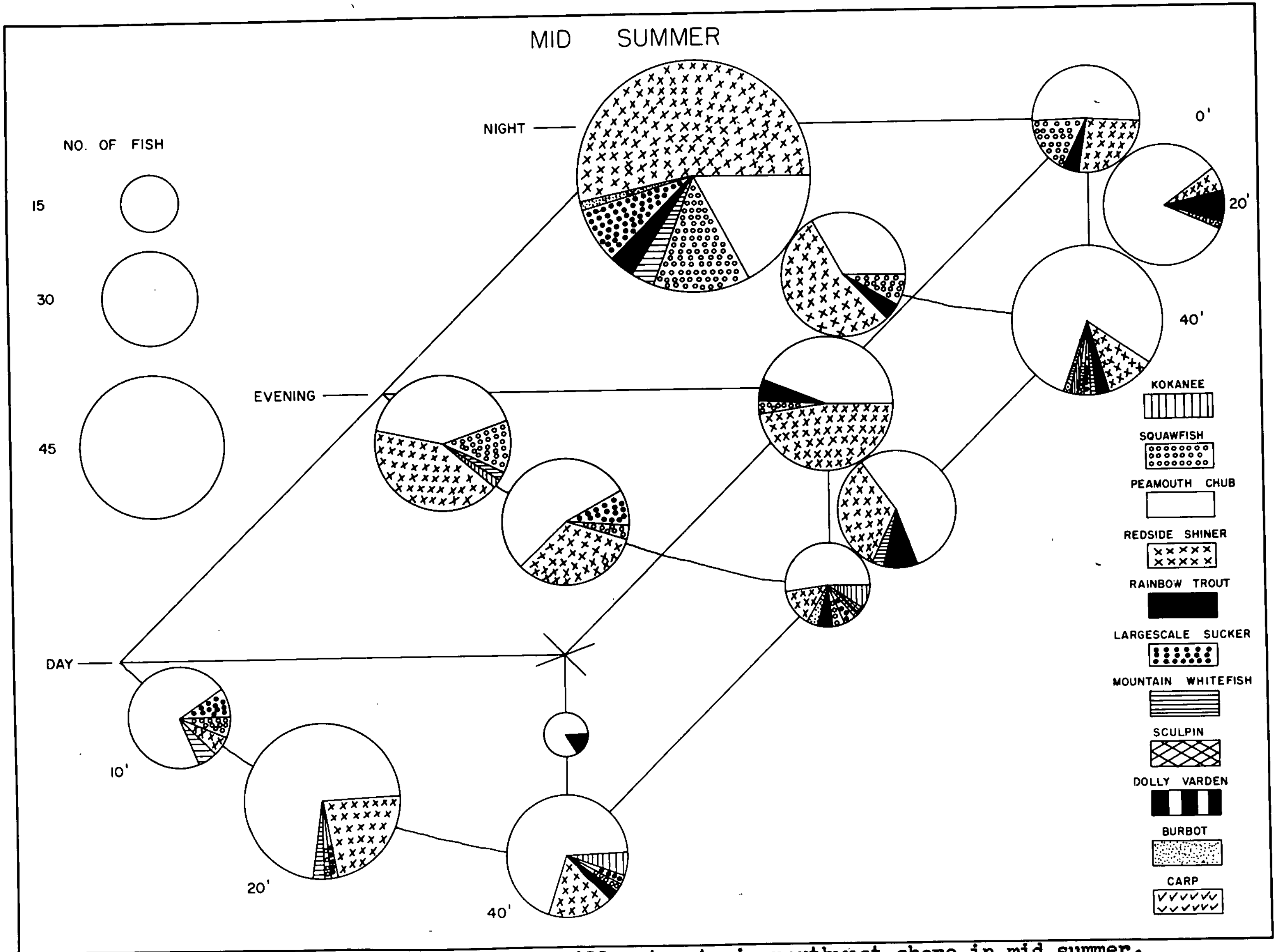

Fig. 16. Occurrence of fish in gill net sets in northwest shore in mid summer.

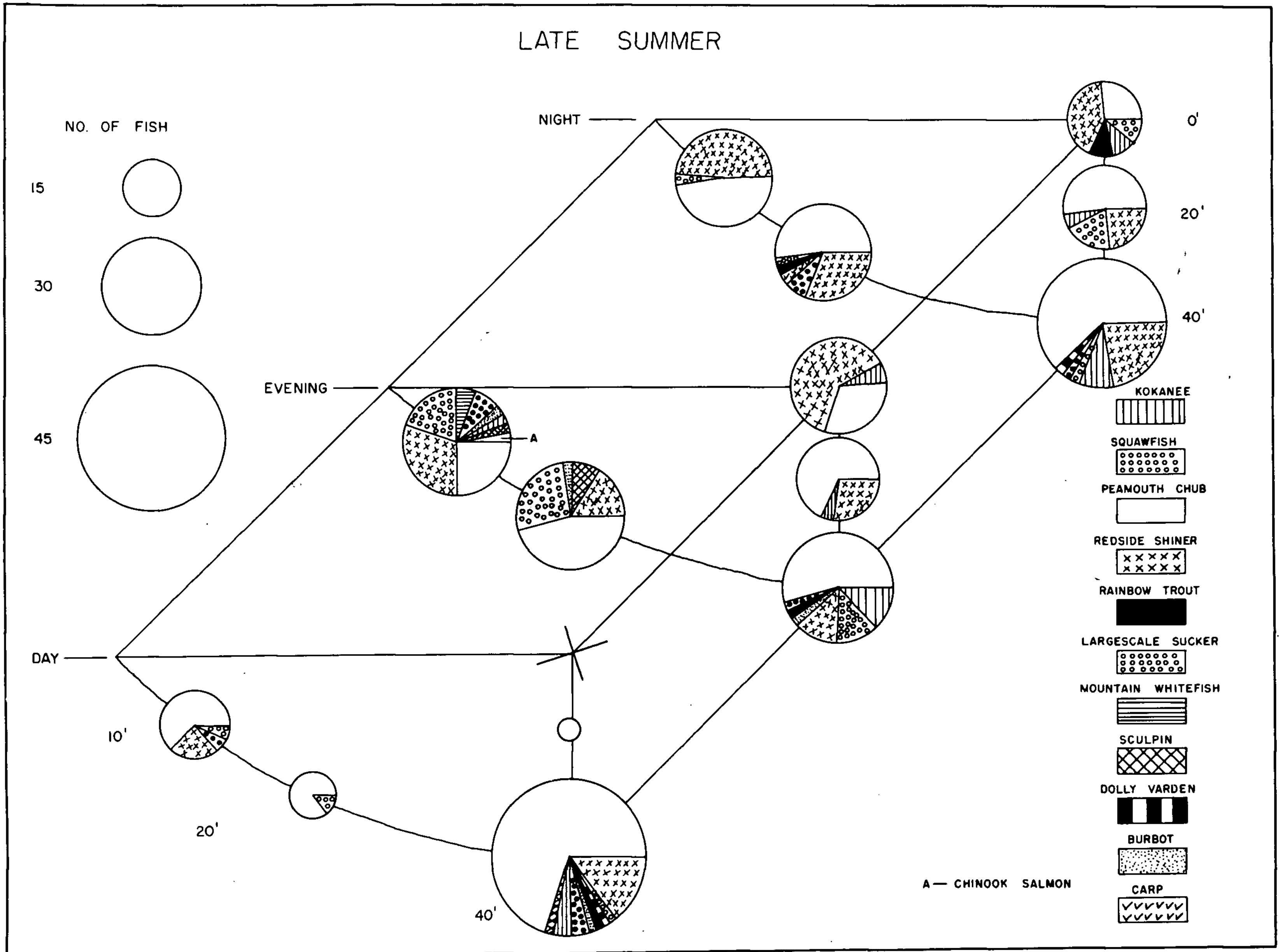

Fig. 17. Occurrence of fish in gill net sets in northwest shore in late summer.

Largescale Sucker, and Chiselmouth can be said to represent the bottom dwelling association while the association of Peamouth Chub and Redside Shiner which consistently show the tendency to form an association in surface and midwater at nightfall, may be termed as the intermediate group. But this association of Peamouth Chub and Redside Shiner as seen in upper layers of water during night is transient as they basically rely on bottom food (Ferguson 1949). The appearance of Squawfish in the shore zone is probably due to the fact that it preys upon all the shore zone fishes, particularly Redside Shiner, young of Peamouth Chub and Prickly Sculpin (Ferguson 1949). Its occasional presence at night in the association of Peamouth Chub and Redside Shiners is probably due to its tendency to actively hunt for the prey fish, particularly Redside Shiners.

The other major association can be termed as the open water association which includes Rainbow Trout, Dolly Varden, Mountain Whitefish, Kokanee and Burbot. Dolly Varden, Mountain Whitefish, Kokanee and Burbot are known to live in deeper waters below the thermocline and therefore, this association including Rainbow Trout can also be defined as deep water association. In the deep water, the association is however not as intense as in the case of shore zone association. Larger Rainbow Trout and Burbot are primarily fish eaters, mainly feeding upon Kokanee (Ferguson, 1949), while Kokanee and Mountain Whitefish share the plankton food available. Data obtained in the present study tend to agree, in general, to this pattern of fish associations which was also observed in Okanagan Lake (Clemens, 1939) and Skaha Lake (Ferguson, 1949).

In different periods of summer, certain exceptions to the general habitat pattern are noticeable. One or more species belonging to one particular association are seen to invade the other zone for some period of time. Such exceptions to the general rule are displayed by Mountain Whitefish, Rainbow Trout, Kokanee and Burbot on the one hand and Peamouth Chub, Largescale Sucker and Prickly Sculpin on the other. Mountain Whitefish were seen in the shore zone twice during the summer in the northwest end of lake while in the southwest basin, these were present consistently all throughout the summer. This is however, in agreement with the findings of Godfrey (1955) and Ferguson (1949). Ferguson considers the position of Mountain Whitefish as intermediate between shore zone association and deep water association, but Clemens (1953) describes this species as belonging to offshore population. Though primarily a bottom feeding species, larger Mountain Whitefish invade other habitats to obtain additional food (Ferguson, 1949). Nicola Lake is poor in bottom fauna, particularly in the deeper regions, and as such the appearance of Mountain Whitefish in shore zones seems logical in the light of the findings in Skaha Lake (Ferguson, 1949) and Babine Lake (Godfrey, 1955). In Skaha Lake, Burbot and Rainbow Trout were observed to venture into shallow zones of water for short periods of time. These two species in the present case show similarity in behaviour with that of Skaha Lake fish generally. Burbot, apparently, come inshore in search of prey fish which are available in the shore association, or for Kokanee moving into the shallow water during different periods of the season. Numbers of Peamouth Chub, Largescale Sucker, and Prickly Sculpin seen in 80 ft. depth zone are not significant and these can be termed as 'stragglers'(Allee, et al.(1950)), which move into zones other than their own as a result of some secondary influence.

The third association of fish that is of importance in Nicola Lake is that of the fry and young-of-the-year of different species. In the case of young-of-the-year, the association is seen to be composed of Redside Shiner, Peamouth Chub, Squawfish, Largescale Sucker, Prickly Sculpins. During daylight, this composition of the association of young is noticeable in shores with sandy beach conditions. In shores with muddy substrates, Carp fingerlings become a part of the association. In rocky shores along the western side of the lake, the young-of-the-year of Largescale Sucker drop out of this association of Peamouth Chub, Squawfish and Prickly Sculpin seen on other parts of the shore. Fingerlings and fry of Chinook Salmon, Kokanee, Rainbow Trout and Mountain Whitefish appear in the general association of the young fish only in areas where stream water mingle with lake water and in the outlet stream. This preference shown by the Salmonid and Coregonid young for areas close to stream mouths cannot be attributed to food preferences as can be done in the case of other species.

This association of fry and young-of-the-year shows a slight modification in so far as their size is concerned. Smaller fry seem to move away from the shore at night giving place to comparatively larger specimen of their own kind. In addition, fingerlings of Mountain Whitefish also appear in the association at night.

V. FOOD AND FEEDING HABITS OF FISH AND RELATION THEREOF TO THEIR SPATIAL DISTRIBUTION

In order of importance, feeding activity is next to breeding activity in modifying habits and habitats of fish. Breeding activity, although dominant, is temporary in nature, but feeding governs the activity all the year round. From this point of view, analysis of the food and feeding habits may throw more light on the problem and clear the picture of the summer distribution of fish.

Food and feeding habits of almost all the species of fish found in Nicola Lake have been dealt with adequately in the literature, a summary of which is presented in Table XXIX.

Fry (1937) and Godfrey (1955) discuss the influence of feeding activity on the summer distribution of different fish species. In Lake Nipissing, Fry found that Ciscoes remain in the epilimnion in summer for some time to feed upon emerging Mayfly even if the temperature conditions become unfavourable to the fish. Poor bottom fauna can force a bottom feeding fish to re-orient its feeding habits and distribution. Common Whitefish in Morrison Lake are found to feed upon plankton crustaceans though normally they depend on bottom organisms in other lakes (Godfrey, 1955). Increase in body size sometimes forces a fish to look for additional diet in areas other than its former feeding zone. In the case of Mountain Whitefish, both McHugh (1940) and Ferguson (1949) note the existence of such a phenomenon. In Nicola Lake also, appearance of the Mountain Whitefish in midwater is probably induced by the fishes' requirements of larger food organisms and plankton.

The opposite of what is discussed above is sometimes found to occur. The influence of physical environment becomes so great at times that fish are forced to modify or restrict their feeding activity under such conditions.

TABLE XXIX. Food of the species of fishes discussed. * Asterisk indicates major item of food.

Species	Food				Miscellaneous	Authority	Remarks
	Fish	Bottom fauna	Surface insects	Plankton			
Peamouth Chub		Chironomidae, Mayfly Nymph Mollusc, Caddis larvae	Moths, Beetle, Flies, Hymenoptera	*Copepods, *Cladocera Algae	Plant material	Clemens et al (1939) Ferguson (1949) (Godfrey (1955)	
Redside Shiner		Chironomid, larvae, Mayfly nymphs and aquat. insects		*Copepods, Cladocera	Plant material	Clemens et al (1939) Ferguson (1949)	
Squawfish	Kokanee, Mountain Whitefish, *Chub, *Shiner and Sculpin	Snail, clams, Insect larvae, Mayfly nymph, Caddis larvae, water-mite and *Crayfish	Water boatman	Algae and other plankton in small quantity	Other plant materials	Cartwright (1956) Clemens (1939 Clemens and Munro (1937) Ferguson (1949) Godfrey (1955) Ricker (1941)	
Carp		Oligochaeta, Ostracoda, Mayfly nymphs, Caddis larvae, Chironomid larvae, Hyallela, Hydracarina.		Copepods, Rotifers, Cladocera, Algae and shrimp	Fragments of higher plants.	Clemens et al (1939) Ferguson (1949 Haslbauer (1945) Richardson (1913)	
Longnose Dace		*Insect larvae and Nematodes		Copepods, *Algae	Fragm. of higher plants.	Breder and Crawford (1922) Johannes (1957) Hubbs and Cooper (1936)	
Chiselmouth					Algae and fragments of Myriophyllum and Potamogeton	Result of stomach analysis.	

Cont.'d......

TABLE XXIX. Cont'd.

Spesies	Food: Fish	Bottom fauna	Surface insects	Plankton	Miscellaneous	Authority	Remarks
Mountain Whitefish	Sculpin, Kokanee, Mountain Whitefish	*Chironomid larvae, Caddis, larvae & pupae, other insect larvae and mollusc		Cladocera and other plankton		Ferguson (1949) Godfrey (1955) McHugh (1940)	
Kokanee	Young of Kokanee			Cladocera		Clemens (1939) Ferguson (1949) Ricker (1941)	
Chinook Salmon (fry only)		Chironomid larvae & pupae, Hydracarina, Chaoborus	*Diptera, *Hymenoptera, Homoptera, Heteroptera Aphid	*Daphnia, *Bosmina, Eurycerus & Copepods		Clemens (1934)	
Rainbow Trout	*Shiner, Chub, Squawfish, Kokanee, Whitefish	Chironomid larvae, Mayfly larvae & nymph, Snails, Amphipods, Crayfish, Watermite	*Trichoptera, Coleoptera	Cladocera	Spiders	Clarence (1942) Crossman (1957) Larkin & Smith (1954) Leonard & Leonard (1949)	
Dolly Varden	Shiners, Stickleback, Squawfish, Sucker, Sculpin, Sockeye fry	Bottom insect materials of the orders of Odonata, Coleoptera, Trichoptera, Leeches and Snails.			Salmon eggs	Delacy & Morton (1942) Godfrey (1955) Ricker (1941)	
Largescale Sucker		Mayfly nymph, *Caddis larvae, *Chironomid larvae, Molluscs, Amphipods.		Cladocera, Copepods, Ostracods, *Diatom	Detritus & algae other than Diatom	Carl (1936) Clemens (1939) Ferguson (1949)	

Cont'd......

TABLE XXIX. Cont'd.

Species	Food					Authority	Remarks
	Fish	Bottom fauna	Surface insects	Plankton	Miscellaneous		
Burbot	Rainbow Trout, Dace, Cottids, Coregonids, *Kokanees, *Shiners, Perches	Amphipods, Mayfly nymph, Diptera larvae Mollusca, Caddis larvae Crayfish		Copepods Cladocera		Beeton (1956) Bjorn (1937) Clemens (1950) Ferguson (1949) Van Oosten (1937)	
Prickly Sculpin	Sculpin	*Chironomid larvae, *Gastropods, *Amphipods, *Caddis larvae		Copepods, Cladocera		Clemens (1939) Ferguson (1949) Koster (1937)	

Ferguson (1949) points out the existence of such influence in the case of Rainbow Trout, Kokanee and Mountain Whitefish in Skaha Lake. He ascribes the erratic growth of these species to poor feeding caused by high temperature. Light condition probably modifies the feeding activity of fish directly by restricting their movement and indirectly by regulating distribution of organisms upon which fish feed. Spreading of Peamouth Chub and Redside Shiner in different levels of water after nightfall is probably a reflection of their increased feeding activity under the cover of darkness. Redside Shiners appearing in the seine hauls at night were almost always found to have their stomachs gorged with food. This feeding tends to support the speculation made above.

Common food and food preferences are known to bring about the association of fishes in different habitats. Ferguson (1949) classifies different fish associations on the basis of their common food preferences. Prickly Sculpin, Largescale Sucker and Burbot are shown as members of the shore association of fish in Skaha Lake. All the three species share insect larvae, Copepods, Ostracods, Algae and Diatoms, although emphasis for one or the other item of food differ for different fish. Godfrey (1955) describes Peamouth Chub as the most important competitor of Mountain Whitefish in Lakelse Lake. Both species consume mostly bottom organisms and show similarity in their depth distribution. Table XXIX shows the common food habits of Largescale Sucker, Peamouth Chub, Prickly Sculpin, and Redside Shiner and these four species are found to be in association all through the summer in Nicola Lake. Similarly, young-of-the-year of the freshwater fish often share a common diet of plankton food (Larkin, 1956). These appear together in a compact association in the shore areas during different periods of summer.

Larkin (1956) mentions that various species of fish though showing a preference for some common food, collect the same from different regions of the lake and thus remain distributed differentially. Non-appearance of smaller size group of Burbot in the shore region of Nicola Lake can probably be explained in terms of the observation mentioned above.

In Okanagan Lake, fish remain distributed in space in two distinct groups - one in shallow shoreward association and the other in open water association (Clemens, 1939). The two associations are fundamentally based on their distinctive food habits. The shore association included Largescale Sucker, Carp, Redside Shiner, Squawfish, Peamouth Chub, Longnose Dace, Leopard Dace and Prickly Sculpin. The open water association, on the other hand, is composed of Kokanee, Rainbow Trout, Mountain Whitefish, Eastern Whitefish, Burbot and Longnose Sucker.

In Nicola Lake, distribution of the available species appears to be similar to that of Okanagan Lake. Redside Shiner, Peamouth Chub, Squawfish, Prickly Sculpin, Largescale Sucker, Bridgelip Sucker, Carp, Longnose Dace and Chiselmouth appear in the shoreward shallow region although all the species do not occur together all around the lake. Chiselmouth, Carp (fingerlings) and Bridgelip Sucker occur together in the shallow weedy south west basin and food habits of these species agree with the type of their habitat. Peamouth Chub and Redside Shiner show a striking similarity in their selection of food and feeding habit in summer (Ferguson, 1949). Occurence of these two species in surface or midwater can easily be ascribed to their common food habits.

Ferguson suggests that the open water association of Kokanee, Dolly Varden, Rainbow Trout and Mountain Whitefish is the result of their common feeding on plankton. Dolly Varden take insect larvae on the bottom and thus compete for the food of Mountain Whitefish (Godfrey, 1955). The diet of Mountain Whitefish again overlaps that of the Carp-Sucker combination (Ferguson, 1949). Feeding habits of Mountain Whitefish are also known to overlap those of Peamouth Chub, Squawfish and Suckers and competition between these species for food is suggested by Godfrey (1955). Overlap in food habits of Mountain Whitefish helps in interpreting its presence in shallow shore areas and in the midwater.

Any discussion of food and feeding habits of fish remains incomplete if the relationship and distribution of predator and prey species of fish are not analysed. The principal predators in Nicola Lake are Rainbow Trout, Dolly Varden, Kokanee, Burbot and Squawfish.

Squawfish are known to confine their predatory activity in the shallow and surface regions of lake during summer, but occasionally go into the thermocline in search for prey fish (Ferguson, 1949). Appearance of Squawfish in surface and midwater in the evening, as well as in the thermocline, may be ascribed to its predation on different prey species that are available in those zones. Its food for summer is tabulated in Table XXIX.

Burbot, a deepwater species, have a tendency to take Kokanee and Redside Shiners in summer (Ferguson, 1949). Appearance of Burbot in the shallow region in early and mid summer is probably associated with the presence of Redside Shiners. In late summer, it shows a distinct tendency to prey upon Kokanee. Twice in the summer, large Burbot with Kokanee stuck in their gullet were seen floating on the lake surface.

Dolly Varden feed upon Redside Shiners, Sticklebacks, Squawfish and Prickly Sculpins (Ricker, 1941). Dolly Varden appear in shallow water in the summer probably to prey upon these species, particularly because of poor bottom fauna in Nicola Lake.

Rainbow Trout are reported to depend on chance contact with the prey species for feeding upon them (Crossman, 1957). Conditions in summer offer this contact by bringing them together in surface and midwater. Lack of Rainbow Trout in large numbers with the prey species in the shore regions tend to support the conclusion of Crossman.

Kokanee is known to be cannibalistic in habit and feed upon young Kokanees (Ricker, 1941). Findings of Ferguson in Skaha Lake appear to support the views of Ricker.

Though food and feeding habits are considered one of the major factors in fish distribution, their effects become complicated due to the overlap in food habits displayed by different species. Larkin (1956) concludes that fish are not typically confined to a particular zone as a whole at any time or as sub-groups distributed in the same way at different time. This conclusion seems to be very much applicable to the fish association of Nicola Lake.

VI. DISCUSSION

Temperature

The role of temperature in shaping and regulating the summer distribution of fish has been discussed in a comprehensive manner by Fry (1937). Fry observed that Ciscoes in Lake Nipissing leave the shallow waters and head for the bottom in late spring and early summer when temperature in the upper strata of water starts to rise. He also observed that the commencement of downward migration was correlated with the temperature in upper 30 ft. of water attaining a certain threshold. A temperature of 20°C was found to trigger off the downward movement. In early as well as in mid summer, Ciscoes tended to keep within the hypolimnion by moving downward with the descending thermocline. In late summer, oxygen depletion and excess of carbon dioxide forced Ciscoes to leave the bottom, and during this period, fish were seen to live in the region just below the thermocline. The concentration of fish immediately below the thermocline was considered to be the result of the ascending populations' avoidance of the warm water of the epilimnion when suddenly subjected to it after experiencing the cool and even temperatured waters of the hypolimnion. The final evacuation of the hypolimnion by Ciscoes was ascribed to the destruction of the balance between the opposing effects of the warm water above and the unfavourable concentrations of dissolved gases below. The downward movement was found to be orderly with the largest males moving down first, followed by large males and largest females. The youngest age groups of the two sexes were the last to move down. This association in the downward movement was related to the lowest upper temperature threshold of the different size groups of the Ciscoes.

Odell (1932) believes that the principal factor that regulates the distribution of deepwater fish is their requirement for low temperature, while the shallow water species are obliged to stay in their habitat because of the requirements of warm water and abundant food supply. According to Odell, Smelt, Cisco, Whitefish, Lake Trout, Finescaled Sucker and Burbot are deep-water forms.

Dendy (1945, 1946, 1948) has also studied the relationship between temperature and distribution of fish in the Tennessee Valley reservoirs. According to this author, a very close correlation between temperature and fish distribution cannot be expected, as some individuals of a particular species are always found above and below the preferred temperature zone. In the case of Sauger, Walleye, Largemouth Bass, Spotted Bass, Drum and Shad, a definite correlation was found to exist between the temperature and distribution of the middle fifty percent of each of the species. Sauger showed a preference to live in the temperature range of 60°-70°F, but Walleye displayed preference for temperature ranging between 70° and 80°F. Largemouth Bass showed preference to live in the warm epilimnion while Drum tended to live in the cooler water only. Drum occupied the thermocline but when stagnant water moved into that layer, they moved downwards in cooler water instead of coming up into well aerated but warm water above. Spotted Bass and Shad showed the same temperature preference as Walleye. The wide spread of Carp and Redhorse was, according to Dendy, an indication of the wide temperature tolerance of these species.

Another instance of temperature affecting the distribution of fish can be seen in the work of Martin and Baldwin (1958: in Ferguson, 1958). In two lakes of Algonquin Park, Ontario, the hybrid of Salvelinus (fontinalis x namaycush) was found to occupy three different depth zones in three different years and this apparently resulted from the change in depth and position of the thermocline over the years.

Hile and Juday (1941) also mentioned the importance of temperature as a factor regulating the spatial distribution of fish but they believed that temperature does not work alone. They further mentioned that the same species of fish might display preference for different temperature zones in different lakes. Perch were found to inhabit the shallow and warm water in 3-5 meter zone in Nebish, Trout and Silver lakes, but the same fish displayed a marked preference for the deeper and cooler areas in Muskellunge Lake. A similar variability in temperature preference of a single species in different lakes was recorded by Pearse (1921) in the case of Rock Bass. Bryan and Howell (1946) suggested that in uniform temperature, depth distribution of fish is regulated by other factors.

In two interconnected lakes in Algonquin Park, Ontario, Whitefish (genus Coregonus), Lake Trout and Burbot were found to exhibit a definite migration from the warmer lake to the cooler one when temperature in the warmer lake reach 12°C in summer (Kennedy, 1941).

Effect of a thermocline on fish distribution has been discussed by various authors. The thermocline is looked upon as a natural boundary within the lake that limits the distribution of fish. Fry (1939: in Ferguson, 1958) pointed out that the sharpness of the thermocline in early summer in Lake Opeongo determines the availability of Perch to Lake Trout. Bardach (1955: in Ferguson, 1958) related oxygen conditions to Perch distribution when he considered the effects of shallow and deep thermoclines in lake West Okoboji. From the work of Dendy in Norris reservoir, it appears that fish can overcome the barrier of the thermocline for at least a temporary period when confronted with other unfavourable environmental factors. In Lake Nipissing, Ciscoes were found to pierce the thermocline in late summer and early fall when conditions of dissolved gases in the hypolimnion became intolerable. Ferguson (1958) indicated that the evidence at hand is not sufficient to reach a firm conclusion on the thermocline as a barrier to fish distribution.

Temperature influence in Nicola Lake

The findings discussed above related to fish species that are not available in Nicola Lake, and an exact comparison of the conditions is, therefore, not possible. Temperature preferences of the various species in Nicola Lake are not very clear. The picture becomes all the more complicated by the appearance of the same species in different thermal zones in the daylight and at night. Availability of Peamouth Chub in all temperature zones probably indicates that the species can tolerate a wide range of temperature conditions in case of necessity. Redside Shiners are known to have a preference for the eplilimnion but here they showed a tolerance for the environment in the hypolimnion during daylight hours. A general conclusion cannot be drawn as the samples obtained are not of significant size. Squawfish tend to remain above the thermocline with occasional exceptions when they were taken within a short distance below the upper limit of the thermocline. This occasional penetration of the thermocline was probably induced by some other factors. Burbot, knowm as deep and cool water dwelling species, appeared in the shallow water zones, particularly at night. Kokanee, a cold water species, were also found in shallow warm water in summer. This migration of Kokanee was apparently stimulated by their spawning activity. Thus it may be inferred that to meet other necessities of life, fish can temporarily live in zones with temperature conditions that are not in the preferred limit but are within the limit of their tolerance.

The thermocline in Nicola Lake appeared very unstable. Twice during the summer of 1958, once on 28 July and again on 25 August, no thermocline was seen. In other periods of summer, the thermocline was found to shift position frequently. How far this shift in the thermocline affected fish distribution is difficult to estimate from the available data. Observations of Fry (1937) in the case of Cisco and movement pattern of Peamouth Chub, Redside Shiners, Burbot and Rainbow Trout tend to show that for these species, the thermocline does not act as a strong barrier.

Ferguson (1958) points out that temperature, acting alone, can determine the distribution of fish in laboratory conditions. In nature, however, this is not possible as other factors such as light, oxygen availability, conditioned response related to feeding routines and social behaviour can interfere with the expression of response to temperature.

Oxygen

The second important factor that regulates the distribution pattern of fish or modifies the response of fish to temperature is the amount of dissolved oxygen available in different depths.

According to Pearse (1921), maximum depth distribution of Perch depended upon the oxygen availability in different levels of water. In Norris reservoir, during the period from mid-April to mid-July, when oxygen was abundant up to a depth of 100 ft., many fish showed a wide range of distribution extending both above and below the thermocline (Dendy, 1945). But in the presence of a stagnant density layer in the thermocline, Sauger moved up into layers with sufficient oxygen. Black Crappie also tended to move upwards when oxygen content in the original habitat dropped to less than 1.5 p.p.m. Most of the fish in Norris reservoir stayed below the stagnant layer as long as oxygen condition permitted and then passed through the stagnant layer to the well aerated water above, but remained within the coldest possible part of the upper layers. Dendy further suggests that in an environment having adequate dissolved oxygen, depth distribution of fish is determined by thermal stratification.

Instances are also on record where fish were seen to surmount the difficulties of oxygen supply for short periods of time in order to meet certain other needs. Pearse and Achtenburg (1920) found that Perch in Lake Mentoda would go into oxygen deficient water, stay there for about two hours for feeding and come back to the original habitat. That fish cannot stay in oxygenless water for a longer period of time was also demonstrated by the above authors. Fish were kept in layers of water with .07 p.p.m. of oxygen and at the end of three hours, none of the fish were found alive.

Hile and Juday (1941) consider that distribution is influenced not only by the abundance of oxygen but also by the concentration of free carbon dioxide in water. Fry (1937) suggests that upward movement of Ciscoe in late summer occurs due to depletion of oxygen in the hypolimnion coupled with a rise in carbon dioxide concentration in that layer. According to Powers (1938), fish can live in water having a higher quantity of free carbon dioxide provided the rise in carbon dioxide content is gradual.

Oxygen influence in Nicola Lake

In Nicola Lake, during the summer oxygen was available in abundance even in deeper regions. Dissolved oxygen at a depth of 96 ft. was 3.4 p.p.m. during the peak of summer. Accordingly, distribution of fish in water of that depth and above was probably not determined by oxygen. Absence of any fish in depths beyond 110 ft. might be due to low temperature and low dissolved oxygen in that region. Dissolved oxygen at a depth of 175 ft. was found to be 1.8 p.p.m. Presence of Kokanee in depths of 100-110 ft. might be interpreted as an indication that this species can tolerate both low temperature and low oxygen availability in water.

Bottom conditions

Condition of the bottom and configuration of the slope of the basin are known to exert some influence in determining fish distribution (Hile and Juday, 1941). Bryan and Howell (1946) compared the availability of fish on the bottom in Norris reservoir and Wheeler reservoir. In the former, certain species of fish were always found on the bottom but in the latter reservoir, the same fishes were found to keep away from the bottom. This difference was suggested to be due to the fact that in Wheeler reservoir, no such accumulation occurs (Dendy, 1948). Haslbauer (1945) discussed the relationship of fish distribution to bottom conditions with reference to the feeding habits of fish. He related the relatively higher abundance of Sauger, Walleye, Drum, Shad and Carp near the bottom to the feeding behaviour of these species.

Fry (1937) believed that presence of fish in any particular stratum of water depends on the relation of that stratum to the bottom.

In Nicola Lake, the distribution of fish can be related to the bottom only as far as feeding was concerned. Chiselmouth were found in an area with bottom conditions that favour growth of the food for the species. Appearance of Mountain Whitefish in midwater may be ascribed to the poor bottom conditions of the lake.

Light.

Role of light as a determinant of fish distribution, particularly in deeper water, is not clearly understood. Dendy (1945) pointed out that game fish in Norris reservoir showed no tendency to be related to light intensities. Discussion by Dendy does not contain any information on the changes of distribution that might occur in daylight and at night. The statement of Dendy, therefore, is difficult to accept so far as variation in the movement of fish over 24-hour period is concerned.

References to 24-hour variation in fish movement are not numerous. Russel (1926 and 1928) reported variation in vertical distribution of the pelagic young of various Teleostean fish in Plymouth area during different periods of a day. In Lake Nipigon, Coregonid fish were taken in greater numbers in nets set at night (Hart, 1931). Yellow Perch were found to migrate upwards at night (Pearse and Achtenburg, 1920). Hickling (1927) indicated that Hake migrate upwards at night. Bryan and Howell (1946) considered that distribution of fish in Wheeler reservoir is regulated by light conditions when temperature is uniform. Carlander and Cleary (1949) observed that Catostomus commersonii show a striking degree of change in habitat in different periods of the day. In daylight, this fish was taken in nets set in deeper water, but at night, fish appeared only in nets set in shallow water.

Light is believed to exert influence on movement by regulating the activity pattern of fish. Some fish are found to remain inactive in higher light intensities as in the day. According to Hickling (1927), Hake remain idle and inactive during the hours of daylight. Some fish, on the other hand, remain active during daylight but become quiescent in the hours of darkness. In an experimental study on 24-hour change in the feeding activity of young Salmon and Trout, Hoar (1942) observed that at night a quiescence overcame the fish leading to a complete cessation of their feeding activity. This phenomenon was interpreted by the author as a sleep condition in the hours of darkness when food is less likely to be available.

Hasler and Villemonte (1952) observed quiescence and sleep condition at night in Perch in Lake Mendota. In daylight, Perch were found moving in compact schools in water levels far above the bottom. In the presundown period, these schools were found to move inshore on to a shelf but kept above the bottom. The maximum concentration of Perch in the inshore region occurred just before evening. When light intensity drops off sharply during the twilight hours, fish settled down on the bottom as isolated individuals. It was postulated by the authors that with approaching twilight the Perch, accustomed to seeing one another, lose their tendency to school, settle to the bottom and maintain contact with sand. It was also considered possible that this nocturnal quiescent behaviour could have survival value in escaping natural enemies like Northern Pike which hunt for food at night and can perceive the prey principally by vibrations resulting from the latter's swimming movement.

In contrast to the above, various fish are known to become active at night. The reasons why some fish become more active is not clear. Probably light affects movement directly as well as indirectly through its influence on the behaviour of food organisms (Hasler and Bardach, 1949). The scattering of Redside Shiners at night was suggested to be in response to increased activity (Lindsey, 1953).

Light influence in Nicola Lake

In the present study, Redside Shiners and Peamouth Chub were found to move into the surface and midwater at night all throughout the summer. Besides, they were also found to come into very shallow regions close to shore. During the hours of daylight, they seldom appeared in the areas mentioned above. The spawning movement of Kokanee also was found to commence after nightfall, reaching its peak in the hours of maximum darkness. Similarly, Burbot were found in the shallower waters at night only. Mountain Whitefish and Largescale Suckers also showed a tendency of coming close to shore at night. Squawfish also appeared in areas other than on the bottom at night.

This changed pattern in distribution may be associated with the increased feeding activity of Redside Shiners and Peamouth Chub. Redside Shiners obtained in seine hauls at night were found to have their stomachs gorged with food. In the case of Rainbow Trout, more specimens were taken at night, suggesting that this fish does not become quiescent at night under natural conditions.

Offshore and inshore movement

Evermann and Clark (1920) observed that in Lake Maxincucke, Suckers and Rock Bass move inshore on still nights. Spoor and Schloemer (1938) pointed out that Suckers in Muskellunge Lake move inshore in the evening and offshore in the morning. The findings of Carlander and Cleary (1949) mentioned earlier can also be treated as another evidence of the existence of inshore movement of fish at night.

In the present study, an attempt was made to detect the existence of inshore and offshore movement of different species of fish. Results obtained were not clear in the case of most species, as the number in each sample was very small. In the case of Peamouth Chub and Redside Shiners only, a significant pattern of movement away from shore was detected. No variation in the offshore direction of movement in different periods of day or in different periods of the summer could be detected from the samples. This, however, does not appear reasonable. If fish had moved offshore, they should come back to the shore region sometime to show up in the net sets in offshore direction the next time. The net sets from which samples were analysed for detecting movement pattern (net sets in stations IV, V and VI) were within about 150 ft. from shore. Within this short distance from shore, fish probably move about in a rather circular fashion instead of making a movement perpendicular to shore, and in the process of their oblique movement, some schools of fish hit the nets from one side only. Existence of a lateral movement along shore could be detected from the net that was set perpendicular to shore across stations IV and VI.

On the other hand, if only the seine haul results are viewed, the existence of an inshore movement in the evening and offshore movement in the morning can be noticed in the case of Redside Shiners, Peamouth Chub, Mountain Whitefish and Largescale Suckers.

The factors believed to induce movement and regulate spatial distribution of fish seem to act independently. Although the principal factors tend to dominate, some local factors may act as modifiers. Thus fish are obliged to reorient their distribution, to a certain extent keeping within the general framework set up by the major factors of temperature and oxygen.

VII. SUMMARY AND CONCLUSION

The spatial distribution of fish species in Nicola Lake, their movement in day and at night and variation thereof in different periods of the summer have been studied. The pattern as observed in each fish species are summarized below.

1. Peamouth Chub - This fish generally stays on the bottom in the daylight all through the summer. In the evening, a spreading of the fish occurs from bottom towards the surface. Intensity of this spreading varies in different periods of summer. In early and mid summer, they remain almost uniformly distributed in all levels from surface to the bottom but in late summer more fish are seen on the bottom and in midwater than on the surface. Towards late night and early morning, they leave the surface and midwater for the bottom. This trend is noticeable only in mid and late summer whereas in early summer, no such trend is detectable from the fish sampled. Existence of a significant offshore direction of movement is revealed by some of the samples. But no variation in the direction of movement with change of light conditions or with changes in the season is revealed by the samples. During the hours of darkness, they appear to move about parallel to shore. The fish live in water up to 80 ft. deep during summer. Thermal stratification does not appear to hinder the vertical movement of the fish.

Young-of-the-year of Peamouth Chub live in schools in very shallow areas along shore all around the lake in the daylight in association with the young of other Cyprinid fish and Suckers. At night, these young fish move offshore when young and adult of bigger size come to live on the shore.

2. Redside Shiner - Redside Shiners live in the bottom in the daylight in different periods of summer. This is a shallow water species and is never seen on the bottom in deeper waters. It is never found in depths beyond 40

ft. In the evening, they spread into surface, midwater and shallower bottom zone near shore. Fish in surface water move into the open water far away from shore. During this period, more fish come to live in the surface water and on the bottom close to shore. This pattern of distribution in the evening is consistent all through the summer. Except in late summer, no tendency of returning to the deeper bottom from the surface level is displayed by Redside Shiners towards late night and early morning. Existence of a significant off-shore direction of movement is revealed by some of the samples of fish. This direction of movement does not appear to change with changes in the periods of day or with changes in conditions of the season. At night, Redside Shiner, like Peamouth Chub, appear to move about parallel to shore. Newly hatched fry of Redside Shiner live in the shallow shore regions in the daylight in association with the young of other species. At night, these young fry move offshore and in their place, larger Redside Shiner appear on the shore. Movement of this species does not appear to be affected by thermal stratification.

3. Squawfish - In the daylight, Squawfish remain on the bottom. In early summer they appear to remain in depths up to 20 ft. but in mid and late summer, the range extends out to the bottom at about 40 ft.

In the evening, Squawfish also show a tendency to become spread up in surface and midwater during early summer. Laterally they become spread on the bottom in deeper waters. In mid summer, they appear in the surface water in addition to becoming spread along the bottom. In late summer, spreading along the bottom is maintained but the tendency of going up into surface and mid-water is not detectable from the sampling. Towards late night and early morning, they remain spread in different water levels from surface to the bottom in mid and late summer. In early summer, they are seen on the bottom close to shore only during late night period.

Samples obtained do not show any significant offshore or inshore direction of movement. At night, they also appear to move about parallel to shore. Young-of-the-year remain in association with Peamouth Chub and Redside Shiner fry in the shore areas in the daylight. With nightfall, an offshore movement of smaller fry and inshore movement of larger fry and young occur in the same manner as seen in the case of Peamouth Chub and Redside Shiner. Vertical distribution of Squawfish is influenced by thermal stratification. They are never seen in the hypolimnion.

4. Carp - Fingerlings live in southeast shore regions and the southwest basin where the bottom is muddy and contains weed beds.

5. Chiselmouth - This species is a new record from Nicola Lake and the Thompson River drainage system. They live exclusively in the warm and shallow southwest basin which, as a habitat, is different from the deep portion of the lake. Young of the fish are available in the Nicola River outlet in numbers.

6. Longnose Dace - Dace live all around the lake in shallow waters close to shore. Specimens are seen to ascend Moore Creek inlet in summer. In Nicola River outlet, they are also available.

7. Largescale Sucker - Largescale Sucker live on the bottom in the daylight during the entire period of summer. In the early summer, no Sucker are seen on the bottom in 10 ft. depth zone while in late summer, none are found around 20 ft. depth zone.

In the evening, they remain in the bottom but get spread in all depths from shore to 40 ft. depth zone and congregation in different depths changes slightly. Towards late night and early morning, distribution remains more or less the same as seen in the evening. Its distribution indicates that it is a bottom dwelling species and prefers to live in areas close to shore.

Vertically, it remains distributed up to 80 ft. bottom in early summer only but, subsequently, moves into the shore zone. Young-of-the-year live in the daytime very close to shore all around the lake except in the rocky margins. In the shores of southwest basin, young are seen in larger schools. At night, young fish move offshore while larger size group of fish come inshore. Thermal stratification does not act as a complete barrier in its movement.

8. Bridgelip Sucker - This species is available in all major regions of the lake but is not as abundant as the Largescale Sucker. Relatively more of this fish are available in the southwest basin. Seine hauls in the Nicola River outlet show that young of this fish frequent the stream in large numbers.

9. Kokanee - This is the only species of fish that lives in depths up to 110 ft. during summer.

In daylight, they live on the bottom of the lake in deeper regions during the whole summer. In the evening they tend to come near shore and into the upper levels of water during early summer. In mid summer, they also are seen on the bottom in shallow zones in the evening. In late summer, spreading in all levels of water is marked. This phenomenon is related to the spawning activity of the fish. They ascend the Moore Creek inlet for spawning during late summer.

Towards late night and morning, fish go back into deeper regions in early and mid summer but in late summer, they are found to remain spread even after dawn.

No significant offshore or inshore direction of movement is detectable in this case. Thermal stratification does not appear to stand as a barrier for this fish in its vertical migration.

10. Chinook Salmon - Adults of this species move into the shallow waters in the evening. The adults sampled are found to be almost ripe sexually. Young

of the species are found to move into the inlet stream at night and stay close to the streams. Seine hauls in the Nicola River outlet show large numbers of young descending the stream.

11. Rainbow Trout - Rainbow Trout live in open water during the summer. They never live close to the bottom. All through the season, they are mostly found in areas away from the shore. At night, they show a tendency to come closer to shore, as indicated by their appearance in 10 and 20 ft. bottom zones several times during the season. In mid summer, they remain distributed from midwater and downwards in the daylight but in the evening and night, get spread into the surface levels of water. In late summer, they appear in the surface water at night only. They live in intermediate depths during summer and are never found in depths of 80 ft. or more. Sample sizes are too small for the purpose of studying direction of movement. Thermal stratification does not appear to hinder the movement of this fish in the vertical plane.

12. Dolly Varden - This is also a bottom dwelling form and is found to live on the bottom away from shore. In this lake, they are never found in 80 ft. or deeper water. They also come into shallow waters at night presumably for the purpose of feeding. Invasion of shallow water appears to occur in early summer only. This fish seems to have a preference for living in the hypolimnion.

13. Mountain Whitefish - This is a bottom dwelling species and lives in the open water area. In early summer, they remain on the bottom in deeper waters during the periods of daylight, evening and night. In mid summer, they come to live in the shallow shoreward region and are seen on the 10 ft. bottom in the daylight, evening and at night. In the evening in mid summer, spreading occurs into midwater from where they come back to the bottom in the morning. Disappearance of the fish from the deep portion of the lake in late summer is associated with their sexual maturity. During this period, they appear in

large numbers in the southwest basin in front of the Nicola River outlet. Young Whitefish come into different regions of shore during night only.

14. Burbot - It is also a bottom dwelling fish and occupies the bottom areas in depths ranging from 20 to 80 ft. in early summer. In mid and late summer no fish are seen in 80 ft. of water. At night only, they come into the shallow areas close to shore presumably to feed upon other fishes. While following the school of Kokanee, they come into Moore Creek inlet mouth. They are never found in the southwest basin during the whole period of summer.

15. Prickly Sculpin - This fish usually remains on the bottom up to a depth of 20 ft. during the daylight and at night. Once in early summer, one fish was found on the bottom in 80 ft. Young Sculpins are found to move about along the shore all around the lake in the daylight in association with the young of Cyprinid and Catostomid fishes. At night, bigger individuals come into the shore region.

16. Fish Association: Two broad associations of fish are noticeable during summer. One association can be defined as the shore zone association which includes Peamouth Chub, Redside Shiner, Squawfish, Chiselmouth, Longnose Dace, Carp, Bridgelip Sucker, Largescale Sucker and Prickly Sculpin. The other, open water association, includes Rainbow Trout, Kokanee, Mountain Whitefish and Burbot. In the shore zone association, the constituent fishes vary in different region of the lake. In the deeper portion of the lake, it consists chiefly of all the fish described above except Chiselmouth and Bridgelip Sucker. In the southwest basin, Chiselmouth and Bridgelip Sucker come into the shore zone association. Several times during the summer, fishes belonging to one association are found to frequent the habitat zone of the other.

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