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FEASIBILITY OF SALMON ENHANCEMENT PROGRAMS IN THE INDIAN LAKE SYSTEM, SOUTHEASTERN ALASKA, WITH EMPHASIS ON POPULATION CHARACTERISTICS OF RESIDENT DOLLY VARDEN CHAR, *Salvelinus malma* (Walbaum)

By

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ABSTRACT

The Indian Lake system, a chain of three lakes, is adjacent to the Alaska Department of Fish and Game Snettisham hatchery. Hatchery incubation capacity for coho salmon *(Oncorhynchus kisutch)* far exceeds rearing capacity. For this reason, production of coho can be increased by rearing a portion in nearby natural waters. The possibility of releasing excess fry into the Indian Lake system is being investigated. This lake system is not accessible to anadromous salmon because there is an 11 m falls on the outlet river. This study is an examination of baseline limnological and ichthyological data collected on the Indian Lake system during the summer of 1979. Emphasis is placed on population characteristics of the resident Dolly Varden char *(Salvelinus malma)*. Limited life history information is also given on the other resident species; kokanee *(O. nerka)*, threespined stickleback *(Gasterosteus aculeatus)*, and coastrange sculpin *(Cottis aleuticus)*.

Mark and recapture techniques and catch per effort sampling were used to obtain estimates of the number of char in each lake and stream as well as information on char movement and spatial distribution. The age, growth, sex, maturity, and diet of the char was also evaluated. There was considerable movement of char within and between the lakes and rivers; an estimated 13% of the char which were in a particular lake or stream in June moved to a different lake or stream in August. There was a net movement of char from the littoral to benthic zone in Indian Lake as the summer progressed. In the lakes most char resided near the bottom, but a small pelagic population of char might exist. The largest char sampled was 556 mm in length and the oldest was age XIV. Younger char, age I to III, were found primarily in the rivers or littoral zones of the lakes. Larger, older char were captured at all depths. Most char were mature by age V or VI. The frequency of annual spawning was greater for females than for males. Females grew more slowly than males, probably because of the additional spawning stress. The char consumed a wide variety of food items; Chironomidae were the most frequently found item.

Using the Indian Lake system as a natural rearing area for coho salmon appears feasible. Intense competition for space and food between introduced coho and the resident fish species is likely in the streams and littoral zones. Overall productivity of the Indian Lake system is low, and a large-scale coho salmon stocking program would probably benefit from an accompanying lake fertilization program.

INTRODUCTION

There are numerous lake systems in Southeastern Alaska which are inaccessible to anadromous salmonids due to barrier falls or rapids on the outlet stream. Many of these systems have resident fish populations (Armstrong and Morrow 1980; Blackett 1973; Crone and Koenings 1975; Delacy and Morton 1943). Fisheries biologists from the Alaska Department of Fish and Game (ADF&G), U.S. National Marine Fisheries Service, U.S. Forest Service, and private aquaculture associations are investigating the feasibility of supplemental salmon production in these landlocked lake systems. Currently three possibilities are under consideration: use of the lakes as a natural rearing area for artificially incubated *Oncorhynchus* fry, increasing the productivity of stocked systems by the addition of nutrients, and development of anadromous salmon runs in these systems by construction of fishways around the barrier falls or rapids.

The Indian Lake system (Figure 1) is a connected series of three lakes. The system is being considered as a site for both a lake stocking program, with coho salmon *(Oncorhynchus kisutch)* fry; and a lake fertilization program. A fishway around the outlet falls is not planned because construction costs would be very high. The ADF&G Snettisham salmon hatchery is located close to the Indian Lake system. Coho salmon from Speel Lake (Figure 1), incubated in the hatchery, could be used as brood-stock for fry releases into the Indian Lake system. The ADF&G conducted the investigation on which this report is based to determine the feasibility of using the Indian Lake system as a natural rearing area for coho salmon, and to collect initial lake productivity information before releasing coho fry or fertilizing the lakes. All field data was collected between June and September in 1979.

This study focuses on the abundance, movement, spatial distribution, growth, maturity, and diet of the resident Dolly Varden char *(Salvelinus malma)*, which are the dominant fish species in the Indian Lake system. To determine the advisability of rearing coho salmon in the Indian Lake system, the biology of the resident char must be understood. Little life history information on the resident form of Dolly Varden char has been published (Armstrong and Morrow 1980).

Limited life history information is presented for the other resident fish species; kokanee *Oncorhynchus nerka* (Walbaum), threespine stickleback *Gasterosteus aculeatus* (Linnaeus), and coastrange sculpin *Cottus aleuticus* (Gilbert).

The productivity of the Indian Lake system was evaluated by studying the population characteristics of the resident fish species and relating this information to limnological and morphological data. Information on the abundance, movement, distribution, and diet of the resident fish species was used to predict the interaction between introduced coho and the resident fish populations.

The objectives of this study were:

1) to describe the abundance, spatial distribution, and movement of the resident fish species in the Indian Lake system;

2) to describe the age, growth, sex, maturity, and diet of the resident char and kokanee;

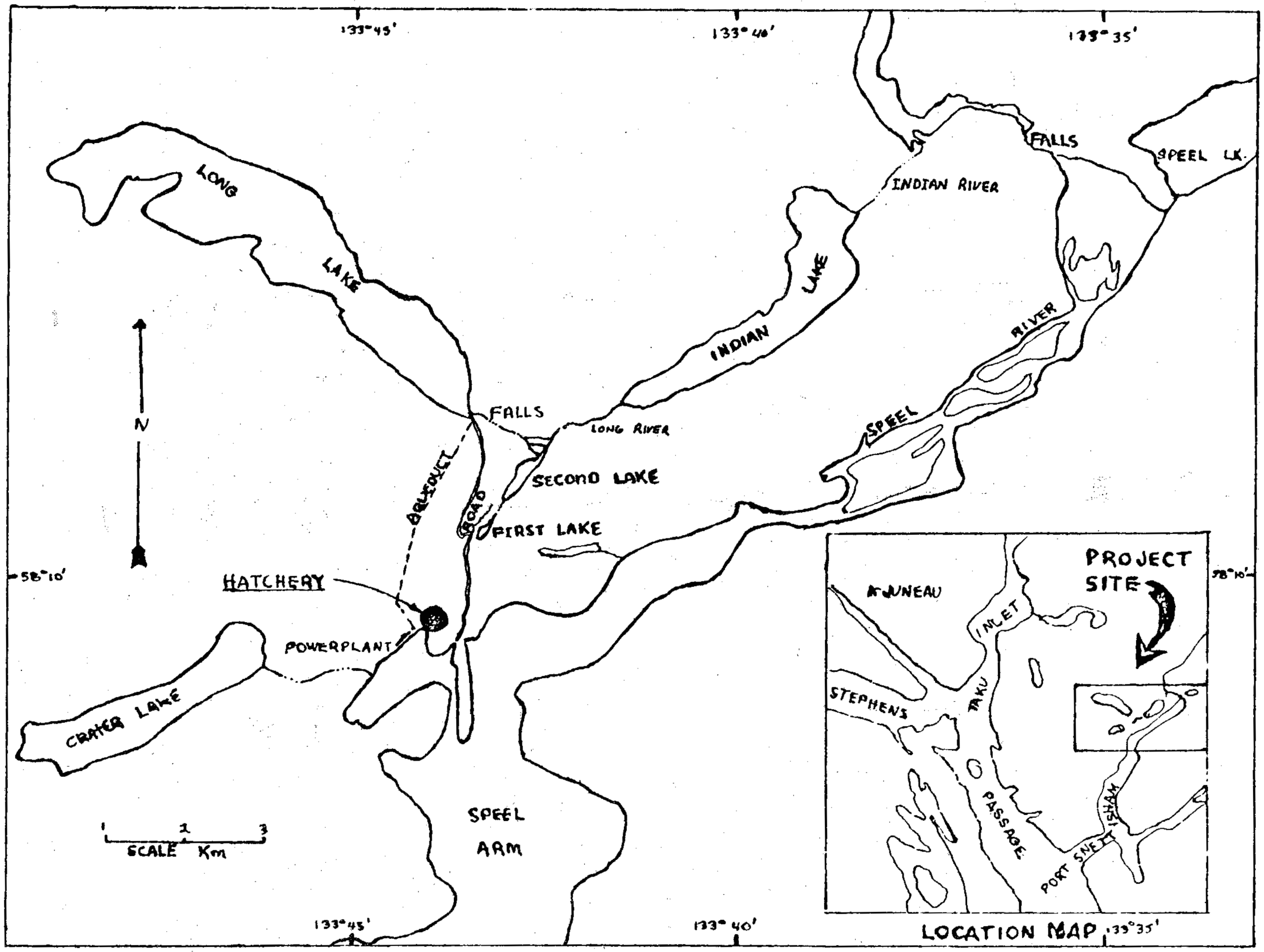


Figure 1. Map of the Indian Lake system and vicinity.

3) to describe morphological and limnological characteristics of the system; and

4) to interpret the above icthyological and limnological information as it relates to lake stocking and lake fertilization programs.

BACKGROUND

Description of the Indian Lake System

The Indian Lake system is located at the head of Speel Inlet, 45 km southeast of Juneau, Alaska (Figure 1). The lakes and rivers included in this study are First Lake, Second Lake, Long River, Indian Lake, and Indian River. First Lake is the upstream lake. Speel Inlet is a fjord, and the Indian Lake valley is a landlocked extension of the fiord. Both Second and Indian Lakes occupy U-shaped valleys typical of glacial erosion. The hillsides bordering Indian Lake rise to over 610 m. Bathymetry of First Lake, Second Lake, and Indian Lake is presented in Figures 2, 3, and 4, respectively. Table 1 summarizes the morphology of each lake.

First Lake has no inlet streams and receives water primarily from surface water runoff. As a result water level and outlet water flow fluctuates widely with rainfall. First Lake is connected to Second Lake by a small cascading stream. This stream is approximately 120 m in length with an average gradient of 10 to 1. Long River arises from Long Lake, elevation 248 m, and braids down to join the lower part of Long River flowing from Second Lake to Indian Lake. A major tributary of the upper Long River also flows into the lower part of Second Lake. The discharge of water from Long Lake is seasonal, occurring from late June to early November in 1979. Second Lake also receives contributions from several small streams, of which the one draining First Lake is the largest. The greatest inflow to Indian Lake comes from Long River; numerous smaller streams also flow into Indian Lake. Flow in these feeder streams is dependent on snowmelt and rainfall. There is an 11 m falls on Speel River below the outlet of Indian River which acts as a barrier to upstream fish movement.

Snettisham Hydroelectric Project

In February 1971 the Alaska Power Authority completed construction of a 70,000 kilowatt hydroelectric power plant at the head of Speel Arm. This power plant provides electric power to Juneau, population 22,000 (1980 census). A 2440 m tunnel taps water from Long Lake, elevation 248 m, and transports it to turbines near sea level at the head of Speel Inlet. A low-head dam was constructed at the outlet of Long Lake to increase the hydraulic head and help prevent seasonal water shortages.

Each summer since 1971 snow and ice-melt in the glacier-fed Long Lake drainage has contributed more water to Long Lake than that tapped for hydroelectric power. At the end of July in 1979, Long Lake water began to spill over the dam and continued to do so until early October. The water level of Second Lake, Long River, Indian Lake, and Indian River rose 2 m or more after Long Lake over-

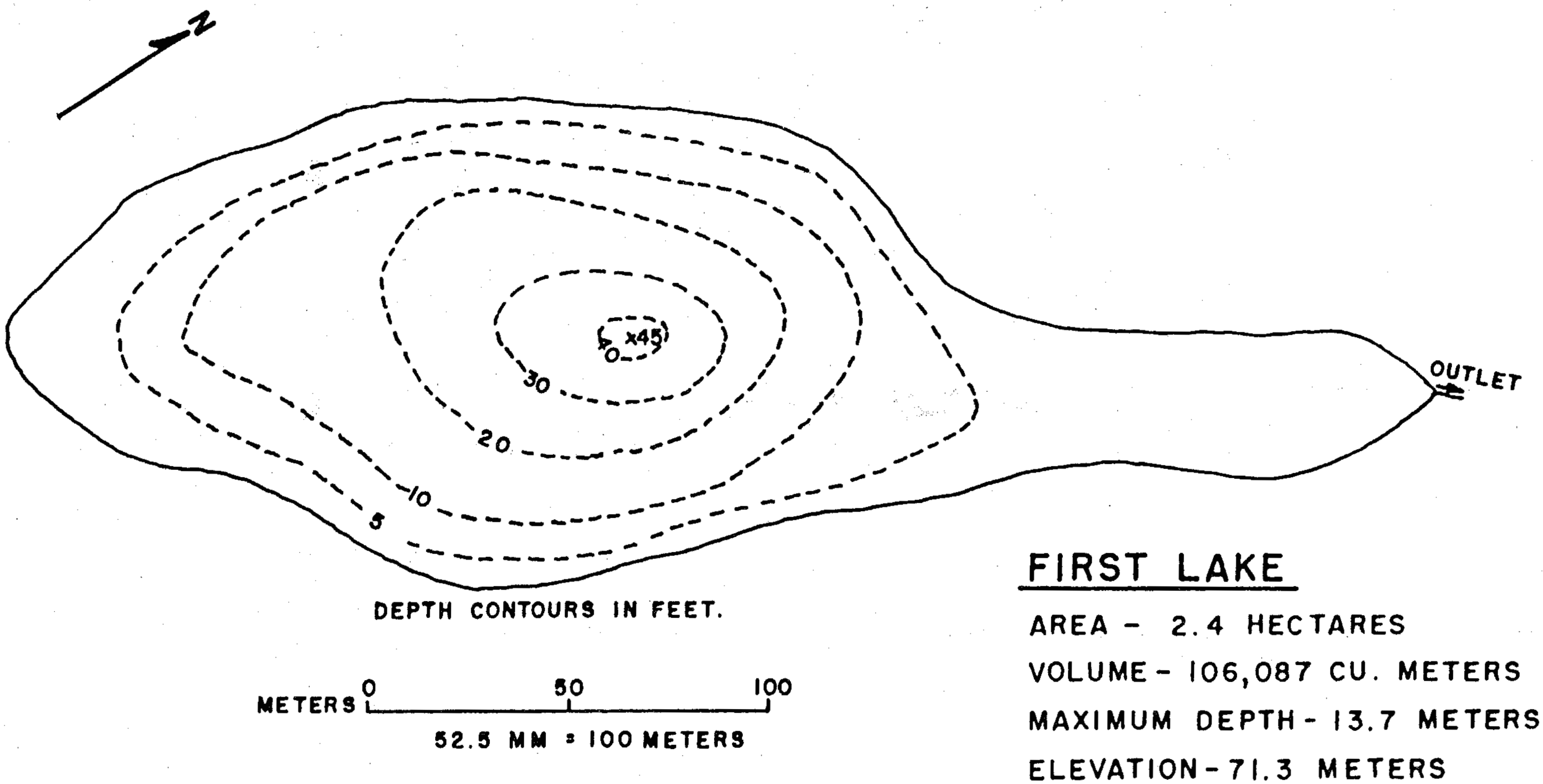


Figure 2. Bathymetric map of First Lake.

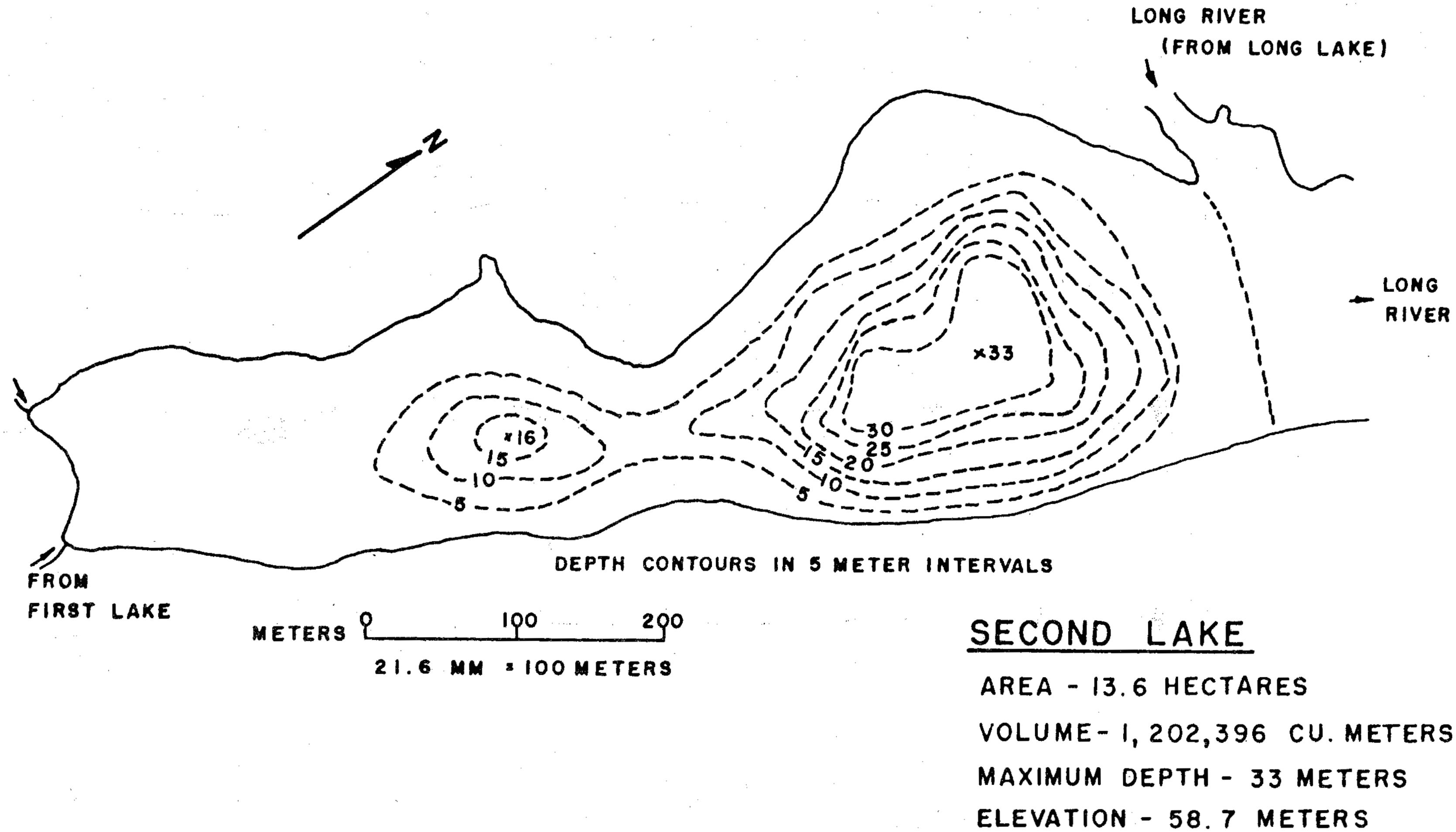
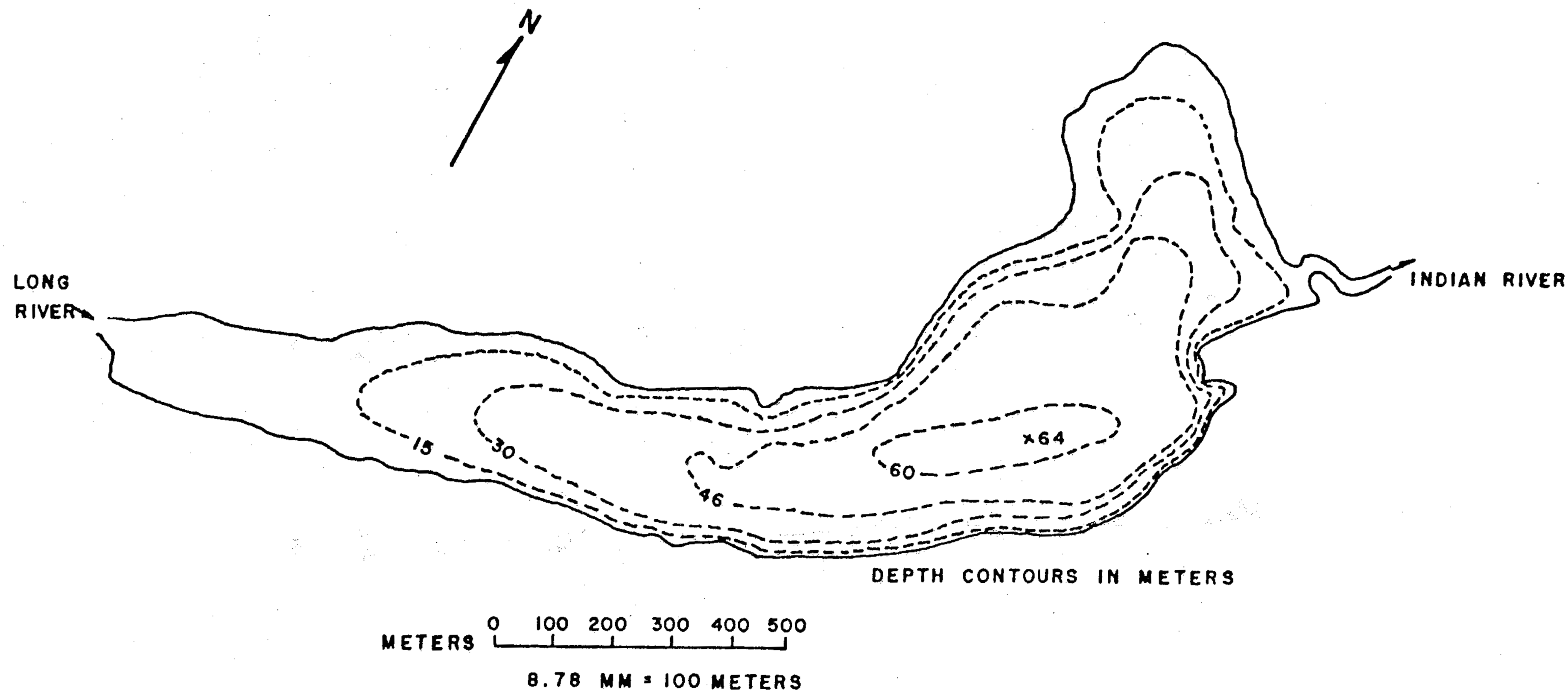


Figure 3. Bathymetric map of Second Lake.



INDIAN LAKE

AREA - 221.6 HECTARES

VOLUME - 68,933,657 CU. METERS

MAXIMUM DEPTH - 64 METERS

ELEVATION - 53.9 METERS

Figure 4. Bathymetric map of Indian Lake.

Table 1. Morphology of First Lake, Second Lake, and Indian Lake.

	First Lake[1]	Second Lake	Indian Lake[2]
Surface Area (hectares)	2.4	13.6	221.6
Volume (cubic meters)	106.087	1,202,396	68,933,657
Mean Depth (meters)	4.4	8.8	31.1
Maximum Depth (meters)	13.7	33.0	64.0
Maximum Length (meters)	350	826	3,808
Maximum Width (meters)	118	281	889

Percent Area of Depth Zones:

First Lake		Second Lake		Indian Lake	
1.5m	48.2	5m	34.6	15m	44.7
4.6m	32.7	10m	24.2	30m	32.4
7.6m	14.6	15m	16.6	46m	18.5
11.0m	4.2	20m	11.4	60m	4.4
13.7m	.4	30m	5.1		

Percent Volumes of Depth Zones:

First Lake		Second Lake		Indian Lake	
0- 1.5m	29.4	0- 5m	39.9	0-15m	41.5
1.5- 4.6m	39.3	5-10m	21.9	15-30m	30.2
4.6- 7.6m	22.5	10-15m	15.1	30-46m	19.7
7.6-11.0m	8.7	15-20m	10.2	46-60m	8.3
11.0-13.7m	1.9	20-25m	7.2	60-64m	.3
		25-30m	4.9		
		30-33m	.8		

1 Bathymetry determined by U.S. Dept. of the Interior Geological Survey. Map: Crater Lake and Long Lake, Alaska. Sheet 2, 1952.

2 Bathymetry determined by U.S. Forest Service personnel (Berg 1974).

flowed the dam. The U.S. Geological Survey estimates that before construction of the dam 93% of Long River discharge came from Long Lake (Berg 1974).

Each year more Long Lake water is used to meet the increasing demand for power in Juneau. By 1985 the discharge from Long Lake into Second and Indian Lakes is expected to be negligible (Gordon Hallum, Alaska Power Authority, Juneau, personal communication 1980). Outflow from Long Lake will occur only during the peak of snow-melt in late July or early August. Thus the hydrology of the Indian Lake system has been significantly altered by the operation of the Snettisham power plant.

Certain limnological characteristics of the Indian Lake system, with the exception of First Lake, can be expected to change with the reduction of discharge from Long Lake. Long Lake receives glacial runoff, and the water is cold and silty. As Long Lake discharge decreases, so does the introduction of glacial silt and cold water, and the transparency and temperature of the Indian Lake system increases. Greater light penetration and warmer water temperatures might result in increased productivity which could benefit resident or introduced fish populations.

U.S. Forest Service biologists are interested in evaluating changes in the productivity of the system resulting from the decreased discharge from Long Lake. They conducted surveys of Indian Lake in August of 1957, 1958, 1959, 1974, and 1978 (Blankenship 1978). Lengths and sex of char and kokanee captured in gill nets were determined. Temperature profile and Secchi disk depth data were also obtained.

Origin of Resident Fish Species

Ricker (1940) described the evolution of a kokanee population resulting from the formation of a barrier to anadromous sockeye. The emigration of smolts is not prevented by a waterfall on the outlet stream. For a self-perpetuating landlocked population of sockeye (kokanee) to form, residual sockeye must be present in the system. These residual sockeye, Ricker states, are the first stage of kokanee population formation. He reasons that in a lake system with free access to the ocean the anadromous sockeye have a survival advantage over the residual sockeye, and this advantage prevents "the permanent survival of the residents' lacustrine progeny" (Ricker 1940). However, if a barrier to upstream fish movement forms which subsequently reduces the anadromous survival rate, evolution of a kokanee population could occur. The evolution of a landlocked population of Dolly Varden char from a previously anadromous population might be similar to that of kokanee (Maekawa 1978).

The establishment of the resident fish species in the Indian Lake system could have occurred in this manner. The falls on Speel River is believed to have formed as a result of glacial erosion during the pleistocene epoch. Before formation of the falls, anadromous (sockeye, Dolly Varden char) and euryhaline (sculpin, stickleback) fishes migrated in and out of or resided in the Indian Lake system. With the gradual formation of Speel River falls, anadromous char and sockeye experienced lower survival. The progeny from anadromous char and sockeye which did not migrate to sea then gained a survival advantage over the anadromous population. When the Speel River falls formed a complete barrier to upstream migration of anadromous fish, distinct landlocked forms of Dolly Varden char and sockeye became established in the Indian Lake system.

Stocking of Coho in First Lake

On 31 July 1979, 9,042 coho fry were planted in First Lake. The principal objective of this lake stocking experiment was to evaluate the feasibility of using the Indian Lake system as a natural rearing area for coho salmon. In particular, the objective was to determine if coho smolts migrating over the falls on Speel River would suffer heavy mortality. If a reasonable number return as adults then it can be reasoned that the Speel River falls did not kill most coho smolts.

The highest survival and growth was desired for the coho released into First Lake. For this reason there was an attempt to remove all resident fish from the lake in order to reduce expected interspecific competition between rearing coho fry and the resident fish species. A trap was installed at the outlet of First Lake to count smolts and to prevent emigration of resident fish. Coho were marked with half-length coded wire tags to allow estimation of the number of adults produced from this stocking experiment.

MATERIALS AND METHODS

Limnology

Limnological data collected in the Indian Lake system is presented in Table 2. Limnological measurements were taken every two weeks; exact dates are given in the sampling schedule in Table 3. Water temperatures at the outlets of First Lake and Indian Lake were monitored throughout the summer with Ryan[1] thermographs. Two thermographs were set in each outlet. The thermographs in First Lake were positioned 0.15 m above the bottom and in Indian Lake 1 m below the surface. The thermographs were calibrated with mercury thermometers every two weeks.

Zooplankton samples were collected every two weeks from First Lake and Indian Lake. Duplicate vertical hauls were taken near the deepest point (13 m in First Lake, 55 m in Indian Lake) of each lake. Zooplankton nets were 0.5 m diameter and 2 m long with No. 10 Nitex mesh having aperatures of 153 microns and 45% open area. Net efficiency was not taken into account in calculations of zooplankton density. Zooplankton samples were preserved in 5% formalin immediately after collection.

The number of each genus of zooplankton in a sample was estimated by multiplying the average number of each plankton present in each of three 1 ml subsamples by the total volume of the sample. Identification and counting of zooplankton was done by ADF&G staff.

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[1] Peabody, Ryan, Model J.

Table 2. Limnological data collected on the Indian Lake system, June through August 1979.

First Lake and Indian Lake continuous outlet water temperatures

Every two weeks at the deepest part of First Lake and Indian Lake:

- duplicate vertical zooplankton tows
- bottom to surface temperatures and dissolved oxygen profile
- surface alkalinity, hardness, and pH
- secchi disk transparency

Every two weeks at the outlet of First Lake and Indian Lake:

- water temperature (1 m)
- dissolved oxygen (1 m)

Table 3. Daily sampling schedule for mark-recapture population estimates, collection of fish for age-growth and diet determination, and limnological sampling in the Indian Lake system, 1979.

Month	Days and activities
June	1, [2] FL, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, (17), (18), [19] FL&IL, 20, (21), 22, 23, 24, 25, 26, 27, 28, 29, 30
	Days 5–9: Second Lake – Mark and Release
	Days 11–20: Long River and inlet half of Indian Lake – Mark and Release
	Days 21–30: Outlet half of Indian Lake and Indian River – Mark and Release
July	(1), [2] FL&IL, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, [15] FL&IL, (16), (17), 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, [31] FL
August	([1]) IL, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, [16] FL&IL, (17), 18, 19, (20), 21, 22, 23, 24, 25, [26] IL, (27), [28] FL, 29, 30, 31
	Days 4–9: inlet half of Indian lower 1/5 Long River; AWL[1] Sampling
	Days 10–15: outlet half of Indian Lake upper 1/3 of Indian River; AWL Sampling
	Days 4–15: Examine for marks
	Days 19–23: Second Lake and upper 4/5 Long River – Examine for marks; AWL Sampling

□ = Limnological data collected, FL = First Lake, IL = Indian Lake.

○ = Dolly Varden char stomach samples collected.

1 AWL sampling refers to days when char and kokanee were killed for age, weight, length, etc. determinations.

Surface-to-bottom temperature and dissolved oxygen were measured in conjunction with plankton sampling. A Weston and Stack temperature and dissolved oxygen meter was used to measure the dissolved oxygen from the surface to 6 m. Below 6 m dissolved oxygen was measured by Winkler titration with the aid of a HACH kit. A Kemmer bottle was used to take water samples. A mercury thermometer affixed inside the Kemmer bottle was used to measure temperature (to the nearest 0.2°C) at all depths. In First Lake, measurements of the temperature and dissolved oxygen profile were taken at 1 m intervals from the surface down to 14 m. In Indian Lake readings were made at 1 m intervals from the surface down to 6 m, and then at 5 or 10 m intervals to the bottom. Alkalinity, hardness, and pH were measured at the surface of each lake with a HACH kit.

The bathymetric map of Second Lake was prepared with a fathometer. Twenty-five transects were laid out across the lake, using an aerial photograph to locate each transect. Depth readings were taken at 5 second intervals (approximately every 4 m) while traversing the lake at a slow constant speed. The bathymetry was then determined by plotting the desired 5 m depth contours at that fraction of the total transect distance.

Sampling Gear

Four types of fishing gear were used in this study: large minnow traps, small minnow traps, shore-based fyke nets, and variable-mesh gill nets. Different gear types were used to insure the capture of a wide size range of char, the target species, as well as sockeye, sticklebacks, and cottids.

Large minnow traps were 90 cm long, 35 cm wide, and the funnels had 5 to 10 cm openings. They were fabricated of 0.6 cm square mesh hardware cloth. A circular aluminum band (1.9 cm wide and 0.3 cm thick) in each end of the trap provided the framework. Fish were removed through an opening in the side of the trap. Small minnow traps were 44 cm long and 23 cm wide, with 4 cm openings, and a mesh size of 0.6 cm. The shore-based fyke nets were manufactured by Sterling Nylon Net Company, Memphis, Tennessee. The fyke net dimensions and method of fishing are shown in Figure 5. The anchor, pully, and float arrangement allowed the cod end of the net to be retrieved without removing the net from the water. Variable mesh gill nets were 38.1 m long, 1.8 m deep, and consisted of five 7.6 m panels of stretched mesh sizes 12.7 mm, 19.1 mm, 25.4 mm, 38.1 mm, and 50.8 mm. The gill nets were always fished with the small mesh near shore.

Salmon eggs were used as bait in the large and small minnow traps. The eggs were disinfected and treated with Borax (Appendix A describes the procedure). The salmon-egg bait was placed in 250 ml plastic containers. The bait containers had 6 mm holes allowing a controlled amount of water to permeate the bait. Bait containers were used to keep the fish from eating the eggs and to prolong the attractive power of the bait. By preventing the entrapped fish from consuming the bait there was no loss of potentially fish-attractive bait and no direct exposure of the resident fish to any undisinfected eggs. Since a controlled amount of water permeated the bait the eggs retained their orange color longer than if they had been loose in the trap, and thus were probably more effective in attracting fish over a longer period of time.

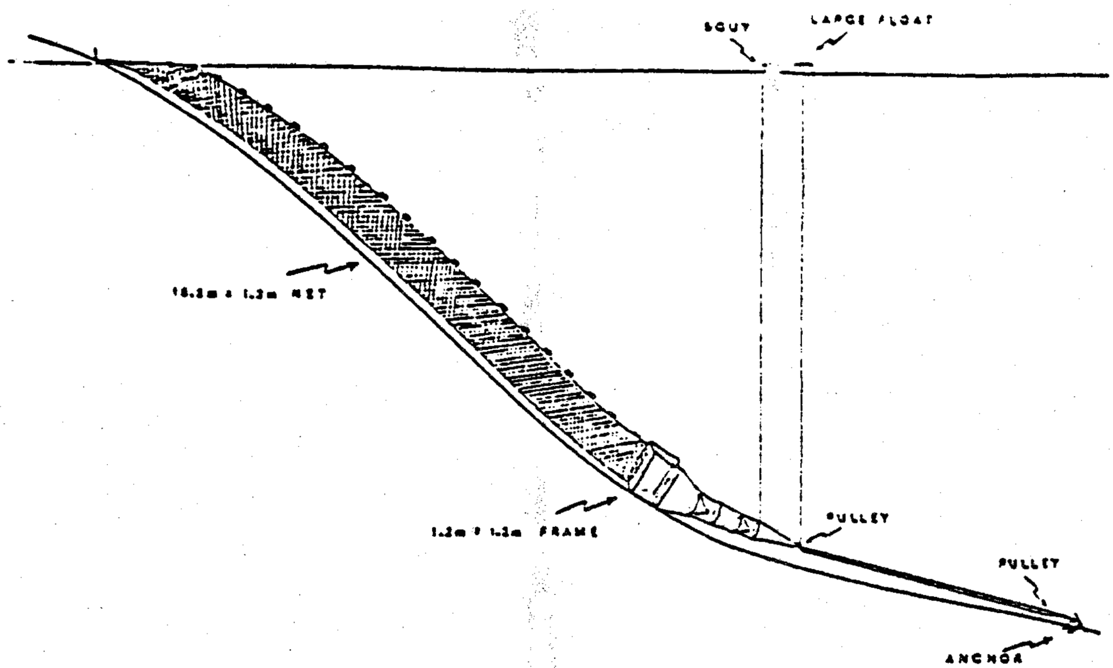

Figure 5. Fyke net dimensions and method of fishing.

Abundance, Movement, and Spatial Distribution

On 2 June a 1.3 cm square-mesh fence was installed at the outlet of First Lake to block any fish movement in or out of the lake. From 1 June to 7 June the following pieces of gear were fished in First Lake: 7 small minnow traps, 13 large minnow traps, 2 floating variable-mesh gill nets, and 2 sinking variable-mesh gill nets. Minnow traps and gill nets were fished systematically throughout the lake so that all areas were sampled. Variable-mesh gill nets were fished for the remainder of the summer; five gill nets from 8 June to 1 July, and four gill nets from 6 July to 17 August. The gill nets were checked at approximately 4-day intervals. Gill nets were set parallel to shore at even intervals around the perimeter of the lake.

All fish captured in First Lake were removed. The catch and fishing effort during each fishing interval was recorded. A Leslie (Ricker 1975, p. 150) population estimate was used in First Lake to estimate the abundance of char. The upper and lower confidence limits were computed using formula 6.4 in Ricker (1975). The data used to compute this estimate is limited to 8 June - 17 August when only gill nets were fished. Since the gear types were not constant throughout the summer there is no straightforward method to equate the effort for the mixed-gear-type fishery (minnow traps and gill nets) with the effort when only gill nets were fished.

The abundance, movement, and spatial distribution of the four resident fish species were investigated using mark and recapture sampling and catch per unit effort information. Second Lake, Long River, the inlet half of Indian Lake, the outlet half of Indian Lake, and Indian River were considered as five separate strata for all abundance and movement estimates. Indian Lake was divided in halves of equal surface area to enable an estimate of the within-lake movement of char and kokanee to be made, and to permit a more intensive sampling effort. By reducing travel time between traps, more traps could be fished each day. In Second Lake and each half of Indian Lake three distinct sampling zones were defined: littoral, benthic, and pelagic (Figure 6). The sampling schedule for marking and examining fish for marks throughout the Indian Lake system is presented in Table 3.

The fish were marked by clipping fins. Different combinations of fin clips were used so recaptured fish could be traced to the stream or lake and zone in which they had been marked. The fin clips used in each lake and stream are detailed in Table 4.

The fish were anesthetized with tricaine methanesulfonate (M.S. 222). Baking soda was added to the M.S. 222 as a buffer. The concentration of M.S. 222 used was approximately 40 ppm (.15 g M.S. 222 + .08 g baking soda per 4 L H_2O).

During mark-recapture sampling the following data was recorded for each piece of gear fished: date, lake or stream, sampling period, zone, gear type, gear location, depth, hour of set, hour of pull, total fishing time, number and species of fish captured, the mark each fish was given or recaptured with, and the fate of each fish. All mark and recapture data was recorded on data forms (Appendix B). The data was coded numerically to facilitate rapid data entry. During mark sampling, data was initially recorded in field notebooks and later

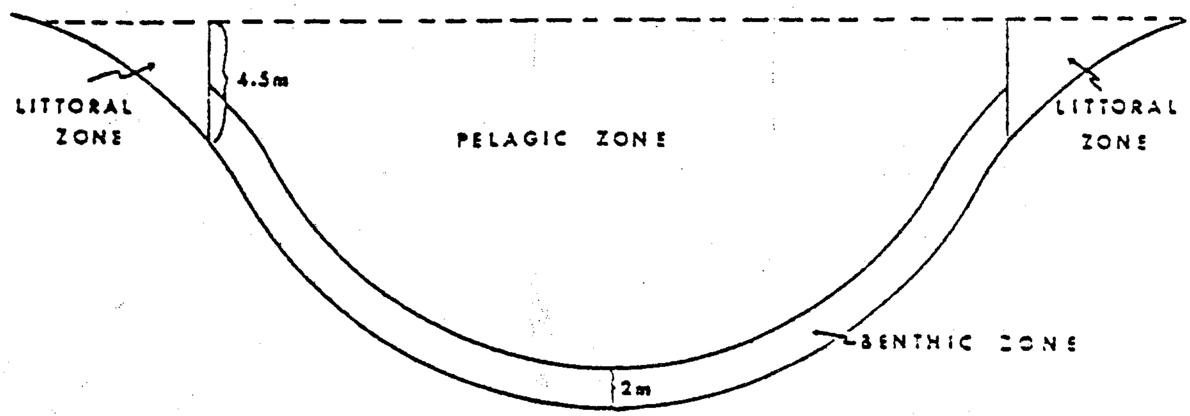

Figure 6. Schematic diagram of the littoral, benthic, and pelagic lake sampling zones.

Table 4. Fin clips used to mark Dolly Varden char, kokanee, stickleback, and sculpin in each lake and river.

	Char and Kokanee	Stickleback	Sculpin
Second Lake:			
littoral -	RV	RV	RV
benthic -	RV LC		
pelagic -	RV UC		
inlet half Indian Lake:			
littoral -	Ad	LV	LV
benthic -	Ad LC		
pelagic -	Ad UC		
outlet half Indian Lake:			
littoral -	LV	LV	LV
benthic -	LV LC		
pelagic -	LV UC		
Long River:	UC	RV	RV
Indian River:	LC	LV	LV

RV = right ventral clip
LV = left ventral clip
Ad = adipose clip
LC = lower caudal clip
UC = upper caudal clip

transferred to the data forms. In recapture sampling field data was recorded directly on the data forms which had been printed on weatherproof paper.

The following gear types were used for mark and recapture sampling: 50 large minnow traps, 35 small minnow traps, and two shore-based fyke nets. During recapture sampling in August three variable-mesh gill nets were fished in Second and Indian Lakes.

Minnow traps were fished systematically in each lake and stream stratum so that all areas were sampled. Figures 7 and 8 show gear placement for the mark and recapture sampling in Second Lake and in each half of Indian Lake. In Second Lake surface and midwater sampling, minnow traps were buoyed above the benthic zone traps. The depths of these surface and midwater traps were 1 m and from 5 to 15 m, respectively. With the exception of one large and one small minnow trap, all traps fished in Indian Lake were set on the bottom.

During mark sampling in Indian Lake there was a limited amount of trap relocation from the littoral zone to the benthic zone because the recapture-to-capture ratios were higher in the littoral zone. Traps were frequently moved a short distance before being reset and therefore the location of each piece of gear in the previous figures is not precise. Traps in the littoral, benthic, and pelagic zones were checked simultaneously to reduce possible variation in trap catches due to diel movement of fish between zones. All fishing gear was checked daily except on 7 June in Second Lake and on the days when age and growth data were collected from char in Indian Lake. During recapture sampling in August all fish were released alive after being examined for marks except the char and kokanee killed for analysis of age and growth.

Both large and small minnow traps (5 or 6 of each) were used to collect fish in the rivers. Traps were set at equal intervals along both shores at locations which looked the most promising for the capture of fish, ideally in shaded, slow-water sites. Traps were systematically moved up or down river in an attempt to sample all areas.

Sampling strategy included steps to insure that the marked fish were randomly distributed among the unmarked members of the population. Marked fish were released at some distance from the trap; and marked and unmarked fish were allowed to intermix for over a month between mark and recapture sampling. A considerable amount of gear was fished and the gear was moved in order to sample fish from all areas of the system.

A Chapman-Junge (1954) stratified population estimate was used to estimate the number of char in each lake and stream. This method also yields estimates of the mixing or migration rate of char between areas. The Chapman-Junge technique is applicable to the Indian Lake system char population which is stratified by area (Second Lake, Long River, Indian Lake, and Indian River), with partial mixing occurring between areas with time.

The computationally-simpler Peterson (Ricker 1975) estimate is not valid because the assumption that the sample is random with respect to the marked members of the population cannot be made. Movement of char between the lakes and streams should be taken into account. There are not barriers to fish movement in the

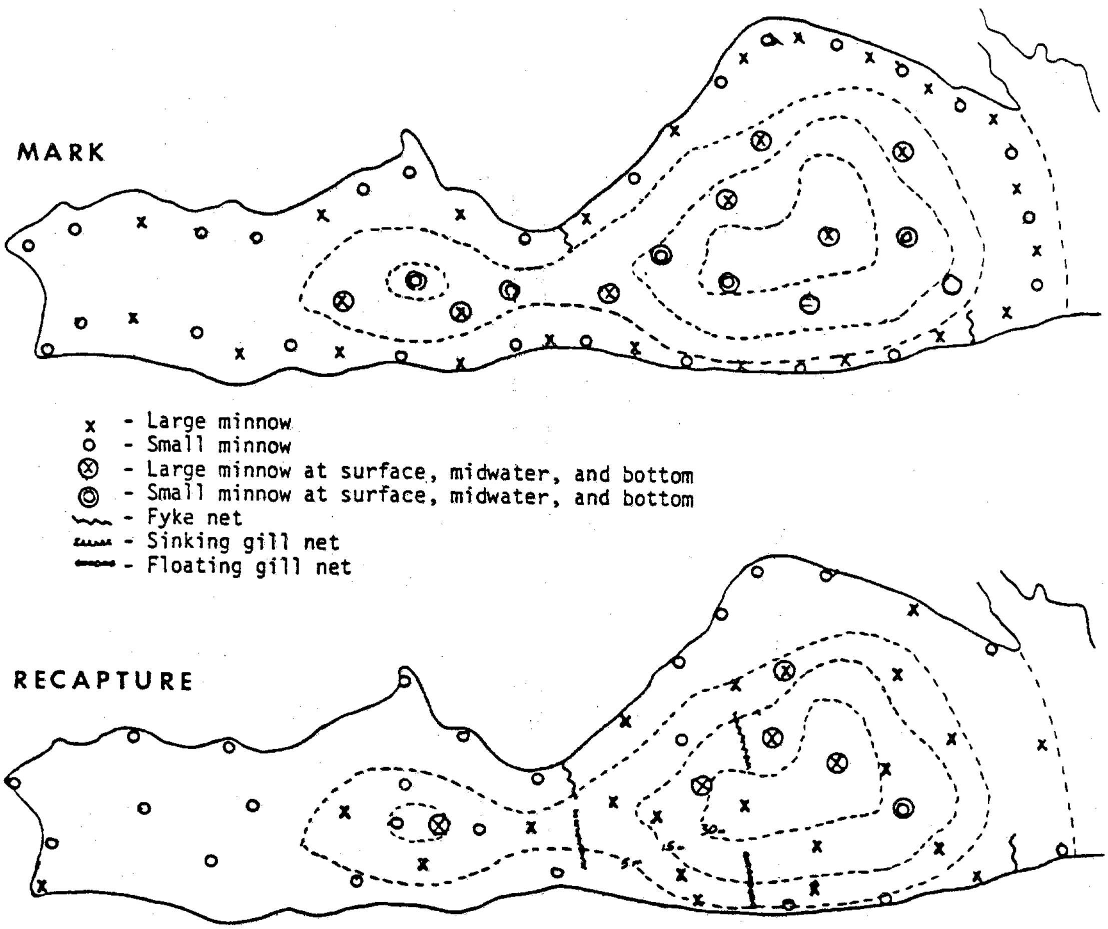

Figure 7. Gear placement for the marking and recapture of fish in Second Lake.

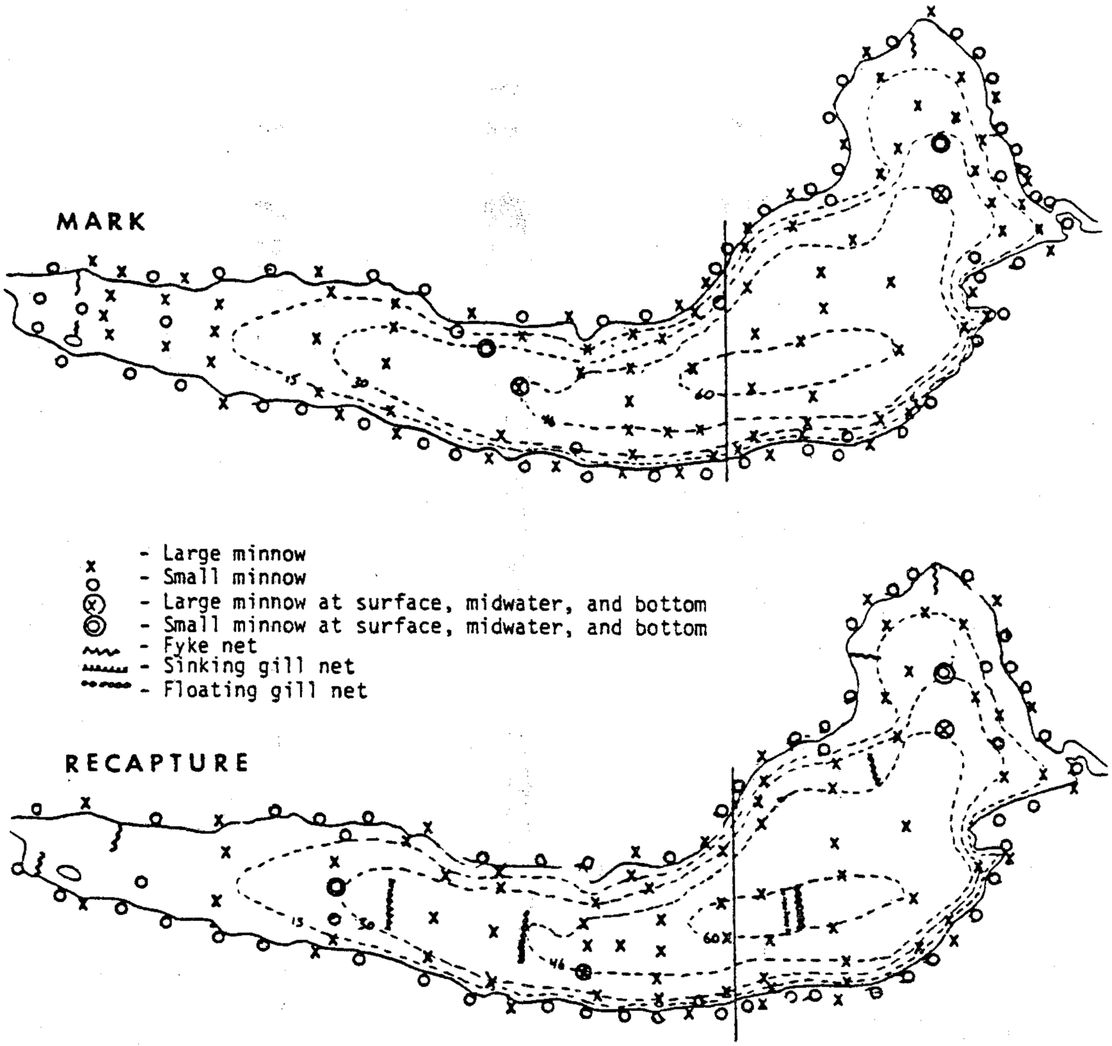

Figure 8. Gear placement for the marking and recapture of fish in Indian Lake.

system between Second Lake and Indian River. If there is movement of marked char out of a particular stratum before recapture then all marked fish will not have an equal probability of being recaptured; the char which have left that stratum will not be susceptible to the sampling gear. Thus a Peterson estimate based on the recapture-to-capture ratio at the time of examining for marks will tend to be too large. Refer to Appendix C for a comparison of different population estimates computed using the mark and recapture data from the Indian Lake system.

The Chapman-Junge population estimate is based on a number of assumptions:

a) that a random sample is taken within each stratum;

b) that the proportion of fish with a particular migratory history are in equal proportion in the release and in the recovery strata;

c) that the proportion of marked types are in equal proportion in the release and in the recovery strata; and

d) that marked fish behave like unmarked fish.

The Chapman-Junge population estimate is actually a series of estimates; the estimate of the total number of fish in the entire area, the estimate of the number of fish in each stratum at time of marking and at time of recapture, and an estimate of the number of fish which were in a particular stratum at time of marking which had either remained or moved to another stratum at time of recapture. If all assumptions hold then an estimate of the number of fish in each stratum can be made. If either assumptions c) or d) are violated only the total population size estimate remains valid.

The Chapman-Junge estimate requires the following notation:

N_{ij} = The number of fish in stratum i at time of release and in stratum j at time of recovery.

M_{ij} = The number of tagged fish in stratum i at time of release and in stratum j at time of recovery.

C_{ij} = The number of fish sampled in stratum j at time of recovery that were in stratum i at time of release.

R_{ij} = The number of fish tagged in stratum i and subsequently recovered in stratum j.

$(i, j = 1, 2..,r;\ r =$ number of strata$)$

The estimate of the number of fish in each recovery stratum requires assumptions a) and b);which can be expressed as

$$\sum_{j=1}^{r} R_{ij} \frac{N_{.j}}{C_{.j}} = M_{i.} \quad (i=1,2,\ldots r)$$

, where a "." substituted for an index indicates summation over that index.

This is expressed in matrix algebra as

$$\underline{R}\,\underline{C_D}^{-1}\,\underline{N_{.j}} = \underline{M_{i.}}\,,$$ where $\underline{C_D} = \underline{C_{.j}}'\,\underline{I}$, and $\underline{I}$ is the identity matrix,

giving,

$$\overset{\underline{R}}{\begin{bmatrix} R_{11} & R_{12} & \cdots & R_{1r} \\ R_{21} & R_{22} & \cdots & R_{2r} \\ \vdots & \vdots & \ddots & \vdots \\ R_{r1} & R_{r2} & \cdots & R_{rr} \end{bmatrix}} \overset{\underline{C_D}^{-1}}{\begin{bmatrix} 1/C_{.1} & & & \\ & 1/C_{.2} & & \\ & & \ddots & \\ & & & 1/C_{.r} \end{bmatrix}} \overset{\underline{N_{.j}}}{\begin{bmatrix} N_{.1} \\ N_{.2} \\ \vdots \\ N_{.r} \end{bmatrix}} = \overset{\underline{M_{i.}}}{\begin{bmatrix} M_{1.} \\ M_{2.} \\ \vdots \\ M_{r.} \end{bmatrix}} .$$

Thus, $\underline{\hat{N}_{.j}} = \underline{C_D}\,\underline{R}^{-1}\,\underline{M_{i.}}$ (the estimated number of fish in each recovery stratum)

and $\hat{N}_{..} = \sum_{j=1}^{r} \hat{N}_{.j}$ (the total population size) .

The estimate of the number of fish in each release stratum requires assumptions a) and c); which can be expressed as:

$$\sum_{i=1}^{r} R_{ij} \frac{N_{i.}}{M_{i.}} = C_{.j} \quad (j=1,2...r) ,$$

which is expressed in matrix algebra as:

$$\underline{N_{i.}}'\,\underline{M_D}^{-1}\,\underline{R} = \underline{C_{.j}}'\,,$$ where $\underline{M_D} = \underline{M_{i.}}\,\underline{I}$,

or,

$$\underline{N'_{i.}} \qquad \underline{M_D^{-1}} \qquad \underline{R} = \underline{C'_{.j}}$$

$$\begin{bmatrix} N_{1.} & N_{2.} & \cdots & N_{r.} \end{bmatrix} \begin{bmatrix} 1/M_{1.} & & & \\ & 1/M_{2.} & & \\ & & \ddots & \\ & & & 1/M_{r.} \end{bmatrix} \begin{bmatrix} R_{11} & R_{12} & \cdots & R_{1r} \\ R_{21} & R_{22} & \cdots & R_{2r} \\ \vdots & \vdots & \ddots & \vdots \\ R_{r1} & R_{r2} & \cdots & R_{r} \end{bmatrix} = \begin{bmatrix} C_{.1} & C_{.2} & \cdots & C_{.r} \end{bmatrix}$$

Thus, $\underline{N_{i.}}' = \underline{C_{.j}}' \, \underline{R}^{-1} \, \underline{M_D}$, (the estimated number of fish in each realease stratum)

and $\hat{N}_{..} = \sum_{i=1}^{r} \hat{N}_{i.}$. (the total population size).

The estimated N_{ij} matrix is

$$\hat{N}_{ij} = \frac{R_{ij} \, \hat{N}_{i.} \, \hat{N}_{j.}}{M_{i.} \, C_{.j}} \quad .$$

(the estimated number of fish in each stratum at time of release and at time of recovery)

The asymptotic variance of $\hat{N}_{..}$ is approximately

$$\sum_{i=1}^{r} \sum_{j=1}^{r} \frac{\hat{N}_{ij} \, \hat{N}_{i.} \, \hat{N}_{.j}}{M_{i.} \, C_{.j}} \quad .$$

A computer program written by Dr. Jeff Fujioka (Fisheries Biologist, National Marine Fisheries Service, Auke Bay Laboratory) in the BASIC language was used to perform the matrix algebra required for the Chapman-Junge estimates.

For Peterson estimates the number of fish which need to be marked and examined for marks at a desired level of accuracy and precision can be determined with the aid of Figures 1-6 in Robson and Regier (1964). Determinations of these mark and recapture sample sizes is based on an initial estimate of the actual population size. Both the Chapman-Junge and Peterson estimates are based on similar mark and recapture sampling methodology. Each estimate is based on the ratio of marked fish in the sample to the number of marks in the population. Therefore, the figures presented by Robson and Regier (1964) were used to determine the number of char to be marked and examined for marks for the Chapman-Junge estimate. A rough estimate of the number of char in each lake was made by using the density of char in Osprey Lake (Schmidt and Robards 1976). During mark sampling, Schnabel (Ricker 1975) estimates were computed to improve this approximation. The desired accuracy of char estimates in each lake and stream was 10% of the actual population size at the 95% confidence level, the level of accuracy and precision Robson and Regier (1964) recommended for research. Thus Figure 6 in Robson and Regier was used as a guide to determine the minimum number of char which needed to be marked and examined for marks in each lake and stream.

To get some insight into the degree of char movement between zones and locations in Second Lake, all char sampled in June larger than 200 mm in length were individually marked with internal-anchor Floy tags. Fifty-three char were so marked. Record was kept of the date, zone, depth, and location of each recaptured char.

The marking and recapture catch per unit effort (CPUE) by depth for char in Second and Indian Lakes was computed for large and small minnow traps.

The numbers of kokanee, stickleback, and sculpin in each lake and river were estimated using mark and recapture methods. The abundance estimate used was the Chapman modification of the Peterson estimate (omitting the -1):

$$N = \frac{(M + 1)(C + 1)}{(R + 1)}$$ where N is the estimated population size,

M is the number marked, C is the number examined for marks, and R is the number recaptured.

Confidence intervals were computed based on direct sampling with replacement using the Poisson distribution frequency table (Ricker 1975, p. 343). When recaptures were larger than the table limit of 50, E.S. Pearson's formula as given by Ricker was used to compute the upper and lower limits for the confidence interval. The spatial distribution and movement of these three species was evaluated using catch information.

A total of 1,829 char were sampled from the Indian Lake system for age, length, weight, sex, and gonad condition. All char captured from First Lake were killed and age, growth, and maturity determined. The majority of First Lake char were captured in gill nets which were allowed to fish for 3 to 5 days. Some char collected were too decomposed for accurate weight measurement. Age, growth, and maturity information from char in Second Lake, Long River, Indian Lake, and Indian River was collected during recapture sampling in August. Table 3 gives the exact dates fish were collected for age, growth, and maturity determination. Seventy kokanee captured from Second Lake and Indian Lake were also killed for age, length, weight, sex, and gonad condition determination. These fish were collected in minnow traps, fyke nets, and variable mesh gill nets set in all areas of each lake and stream.

Fork lengths were measured to the nearest millimeter and weights to the nearest 0.1 g. Sex and gonad condition were determined by dissection. The gonads were classified, according to Nelson (1966), into three maturity groups: "immature", "mature, spawning imminent", and "mature, spawning not imminent". Blackett (1968) termed these three maturity stages as: "completely undeveloped gonad", "undeveloped gonad", and "developing gonad". No measurements of ovary weight or egg diamter were made. All length, weight, sex, and gonad condition determinations were made in the field from freshly-caught fish.

Ovaries from eight mature, spawning-imminent char were dissected and preserved in 10% formalin. The eggs were counted after the field season.

Otoliths (sagitta) were used to age the char and kokanee. After length and weight determinations, the heads of each char and kokanee were severed, individually numbered, and stored in 50% ethanol (ETOH) in a freezer.

The method used to dissect, read, and interpret the otoliths is that described by Heiser (1966) except that the otoliths were not placed in a liquid detergent solution to clear for viewing. Instead the otoliths were never permitted to dry out (which turns them opaque, obscuring the annuli). Otoliths were stored and read in 50% ethanol according to the procedure recommended by LaLanne (1975). LaLanne tried several methods of clearing dried walleye pollock *(Theragra chalcogramma)* otoliths but found that none restored the original translucency. Little difficulty was encountered in making age determinations from the char otoliths. Each hyaline ring (winter check) on a char's otolith was counted as a year of life.

Every two weeks about 30 char were collected for diet determination: 10 from Long River, 10 from the littoral zone of Indian Lake, and 10 from the benthic zone of Indian Lake (refer to Table 3). Stomachs were dissected and preserved in 5% formalin. Age, growth, and maturity data was also collected on these char. Sampling gear consisted of variable-mesh gill nets and large minnow traps. All char were captured between 0900 and 1200 hours. Analysis of stomach contents was done by ADF&G staff.

Statistical tests were performed with two computer packages available on the University of Alaska Computer Network, the Biomedical Computer Programs P-series (BMDP) (Dixon, W.J. 1977) and the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975). The specific BMDP or SPSS program used, its author and revision date, and application in the analysis of age, growth, and maturity data is listed below:

Program	Author, Revision Date	Application
BMDP2D	Engelman, 2/7/75	Proofreading data, data description
BMDP7D	Sampson, 2/7/75	Data description, analysis of variance
BMDP5D	Chasen, 2/7/75	Data description, histograms
BMDP6D	Chasen, 4/30/76	Bivariate scatter plots, computation of linear regression equations and residual mean square
BMDP1R	Jackson and Douglas, 2/7/75	Multiple linear regression
BMDP1V	Engelman and Yamaski, 4/30/76	One-way analysis of variance and covariance
SPSS	Nie et al. 1975	Proofreading, data description
"Crosstabs"		Summing catch data

RESULTS AND DISCUSSION

Limnology

The mean daily water temperature at the outlet of First Lake was 16°C and at the outlet of Indian Lake it was 12°C from 13 June to 25 August 1979. The daily range of First Lake outlet water temperature was greater than that for Indian Lake (Figure 9). Temperature profiles for First Lake show the presence of a shallow thermocline at 2 to 3 m in mid-June (Figure 10). Temperature profiles of Indian Lake show the absence of a thermocline until 26 August, the last day of sampling (Figure 11).

The highest dissolved oxygen level in First Lake occurred at depths between 2 and 3 m (Figure 12). In First Lake the dissolved oxygen near the bottom of

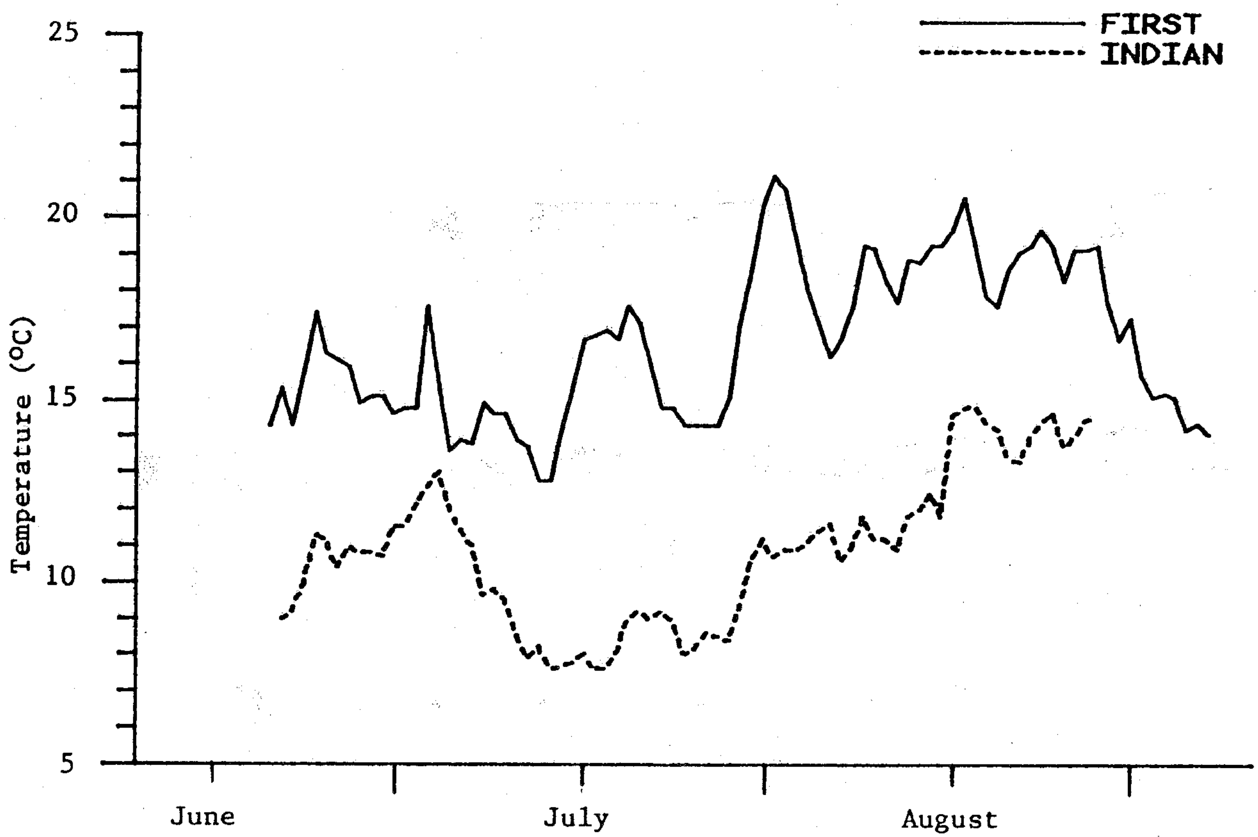

Figure 9. Average daily water temperatures at the outlet of First Lake and at the outlet of Indian Lake.

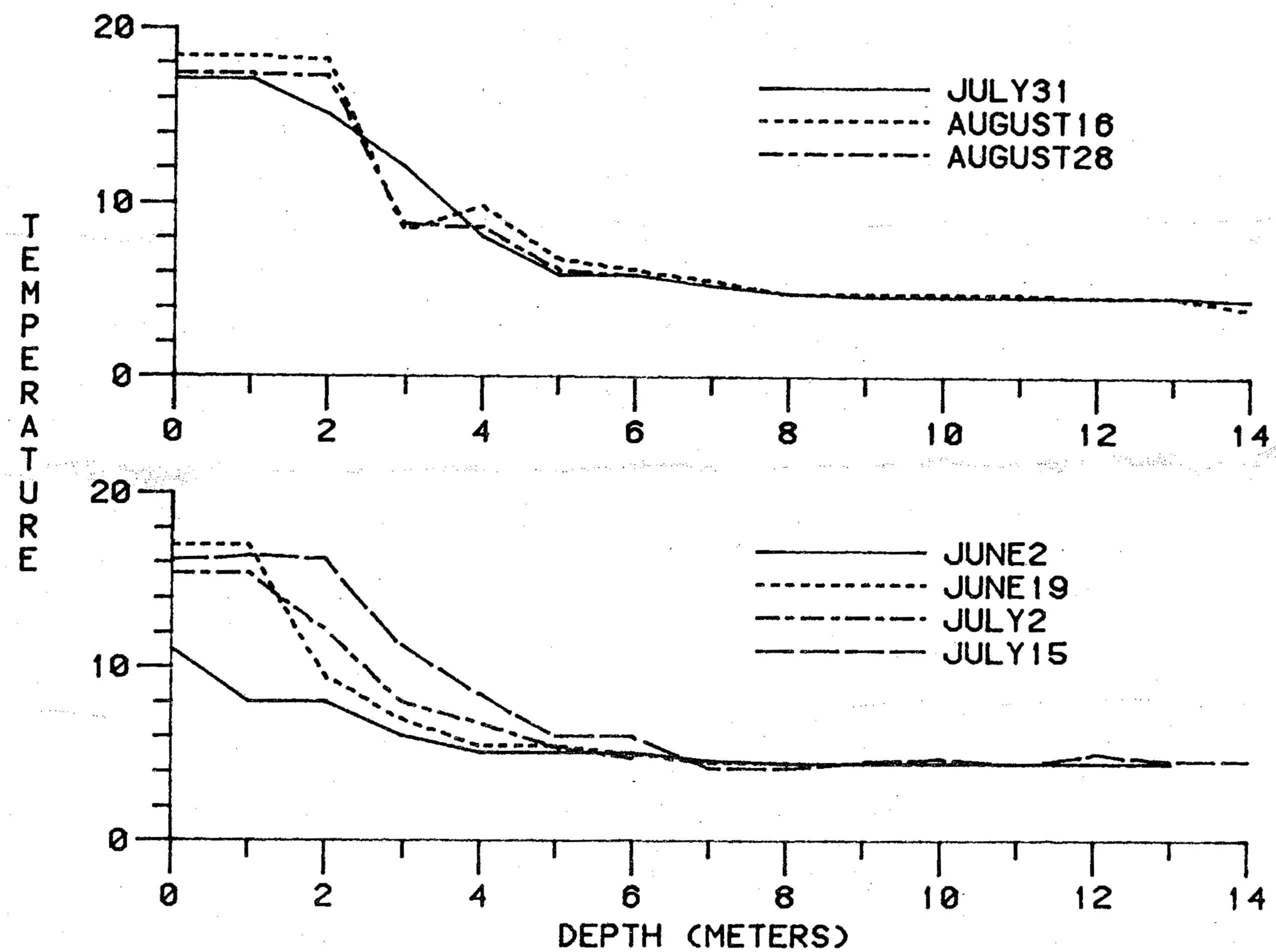

Figure 10. Temperature profile of First Lake, 2 June to 28 August 1979.

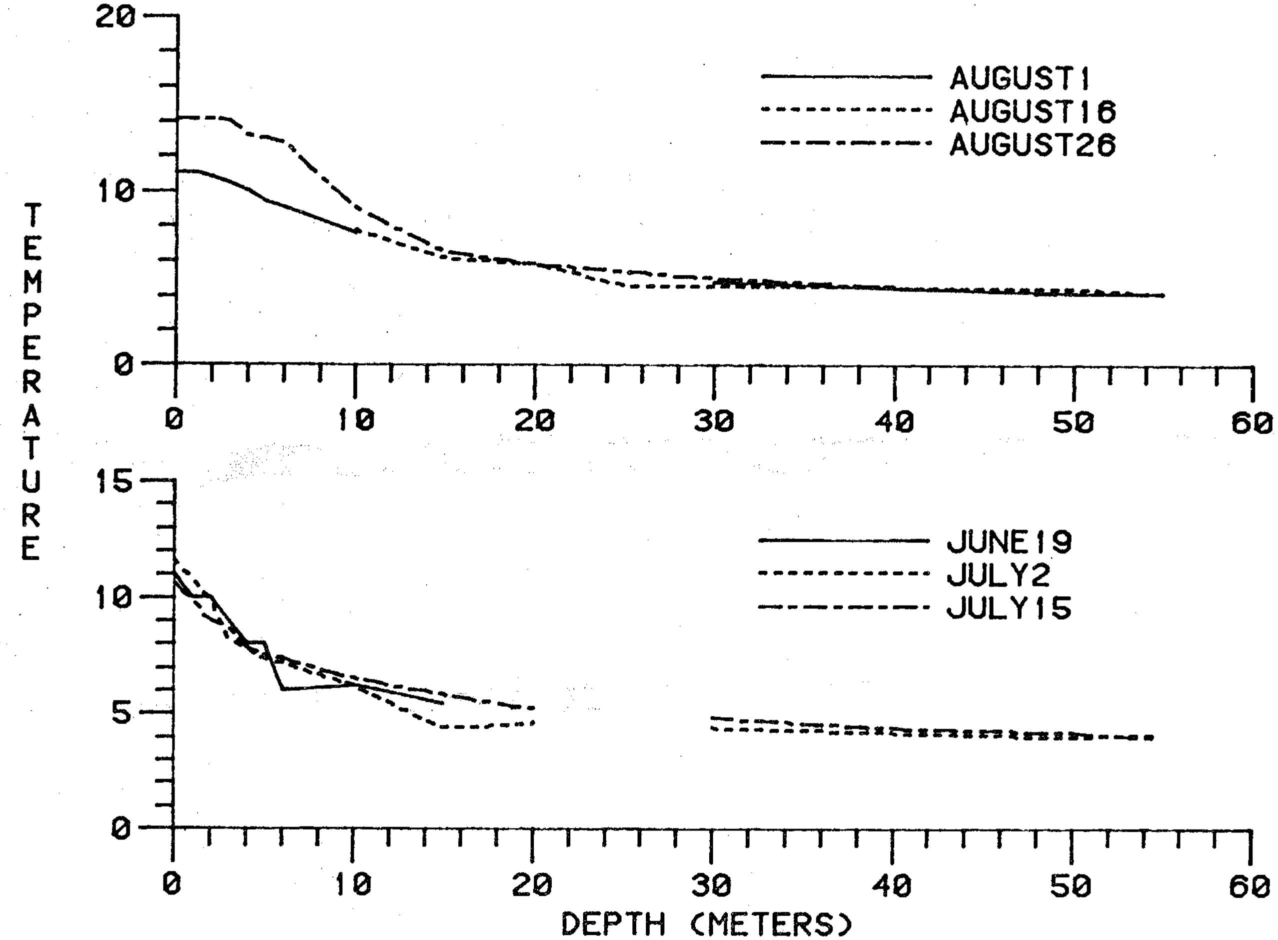

Figure 11. Temperature profile of Indian Lake, 19 June to 26 August 1979.

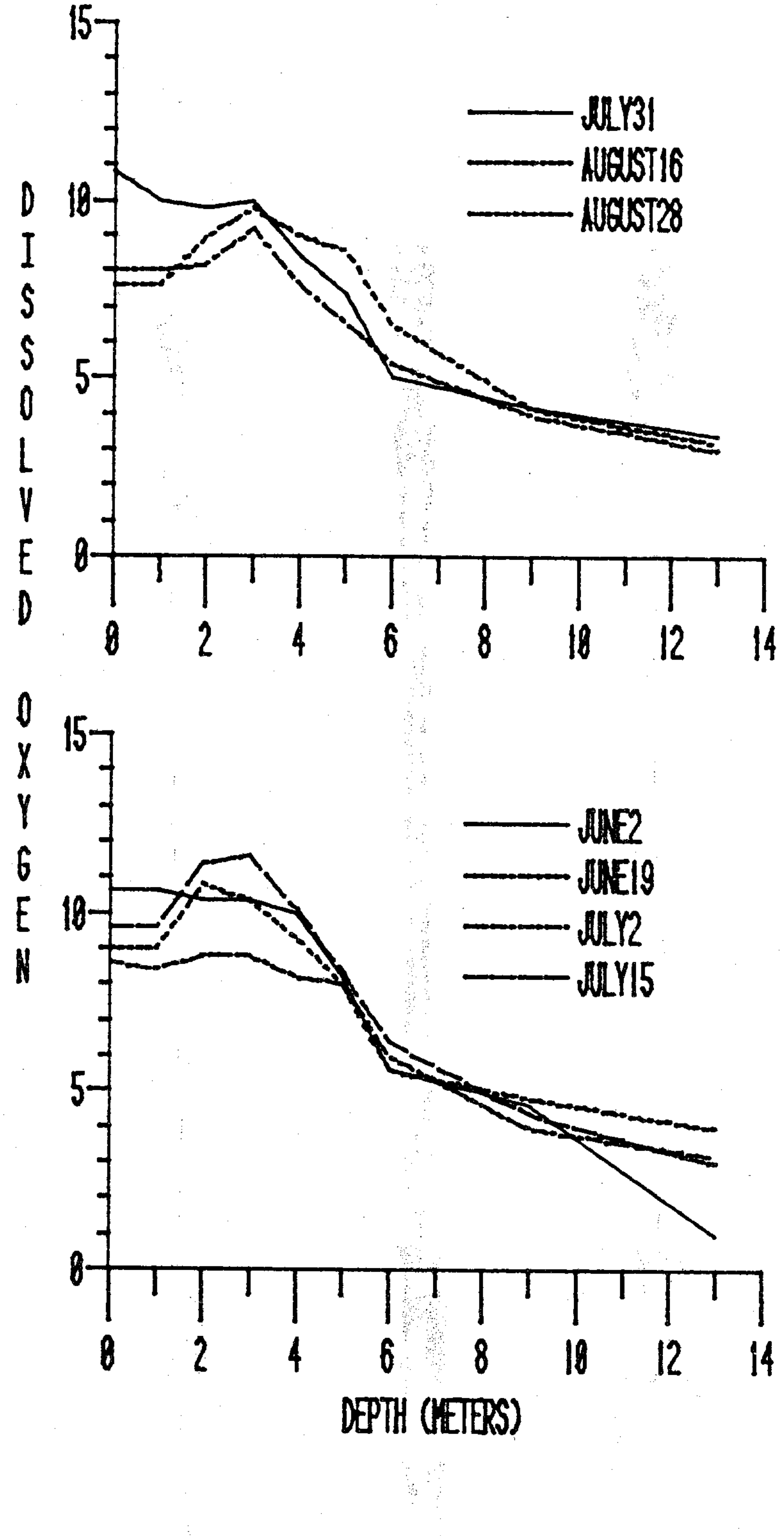

Figure 12. Dissolved oxygen (mg/L) profile of First Lake, 2 June to 28 August 1979.

First Lake ranged between 1.0 to 3.4 mg/L throughout the study period. The dissolved oxygen in Indian Lake was not biologically limiting at any depth. The lowest dissolved oxygen measurement obtained was 9.0 mg near the bottom of the lake on 26 August. Dissolved oxygen in the outlet stream from First Lake ranged from a low of 2.5 mg/L on 2 June to a high of 10.2 mg/L on 15 July (Table 5).

The surface water alkalinity and hardness remained constant in both lakes at 2 mg/L. The surface pH of First Lake averaged 5.6 with a range of 5.5 to 5.8 and the surface pH of Indian Lake averaged 6.7 with a range of 6.6 to 6.8. Secchi disk readings for Indian Lake were greater than for First Lake (Figure 13). The mean Secchi disk reading in First Lake was 3.9 m and in Indian Lake 6.4 m.

Zooplankton hauls in First Lake contained members of the orders *Cladocera*, *Copepoda*, and *Rotifera* (Table 6) while only *Copepoda* were found in Indian Lake (Table 7). In First Lake the most abundant zooplankton for most of the study period were concohiloides and in Indian Lake Cyclopoid copepods were most common.

Age, Growth, Sex, Maturity, and Diet

A total of 1,843 Dolly Varden char were killed in August from throughout the Indian Lake system for age and growth or diet determinations. Of these 1,843 char, age determinations were made on 1,802, weight on 1,736, sex on 1,800, and gonad condition on 1,453. Lengths were measured on all char killed.

The mean length, weight, age, condition factor K, where $K = \frac{\text{weight}}{\text{length}} \times 10^5$) and frequency by sex and condition of gonads for char collected in each lake and stream are presented in Table 8. The oldest char sampled in the Indian Lake system were age XIV and the youngest were age I. The range in length of char sampled was from 58 mm to 556 mm and the range in weight was from 2 to 1,864 g. The mean length, range, standard deviation, and sample size of each age class of char collected from First Lake, Second Lake, Long River, both halves of Indian Lake, and Indian River is presented in Table 9. For the age and growth analysis each half of Indian Lake was considered separately to allow comparisons of char growth between each half and direct comparisons with the population abundance, movement, and spatial distribution estimates.

Char sampled from Long and Indian Rivers were smaller and younger than char from Second and Indian Lakes (Table 8). The age distributions of char sampled from the rivers were skewed toward younger char (Figure 14). Most of the larger, older char were sampled from the lakes.

Char sampled from First Lake were the largest and oldest; there were few age I to III char sampled (Figure 14). The most common age of the char obtained was V. The greater mean age and size of char sampled from First Lake is possibly due to selectivity of the gill nets toward larger char (Figure 15). Variable-mesh gill nets were the dominant gear type fished in First Lake. In addition, it is unlikely that char spawn in First Lake because of the lack of suitable spawning substrate. Possibly the char which emigrated to First Lake needed to grow to a certain size before becoming physically capable of navigating the small cascading creek between Second Lake and First Lake.

Table 5. First Lake and Indian Lake outlet stream temperature and dissolved oxygen (D.O.) measurements, 2 June to 28 August 1979.

Date		FIRST LAKE			INDIAN LAKE		
		Time (h)	Temp(°C)	D.O.(mg/L)	Time (h)	Temp(°C)	D.O.(mg/L)
June	2	1700	12	2.5	[1]	[1]	[1]
	19	1100	16	10.0	1700	10.2	12.2
July	2	1100	15.8	7.6	[1]	[1]	[1]
	10	[1]	[1]	[1]	1200	9.0	10.6
	15	1000	16.2	10.2	1330	10.0	13.8
	31	1530	17.5	9.0	[1]	[1]	[1]
August	1	[1]	[1]	[1]	1600	11.0	11.0
	16	1500	17.6	8.4	1130	13.6	10.6
	26	[1]	[1]	[1]	1230	15.0	10.0
	28	1400	16.6	8.0			

[1] No data was taken.

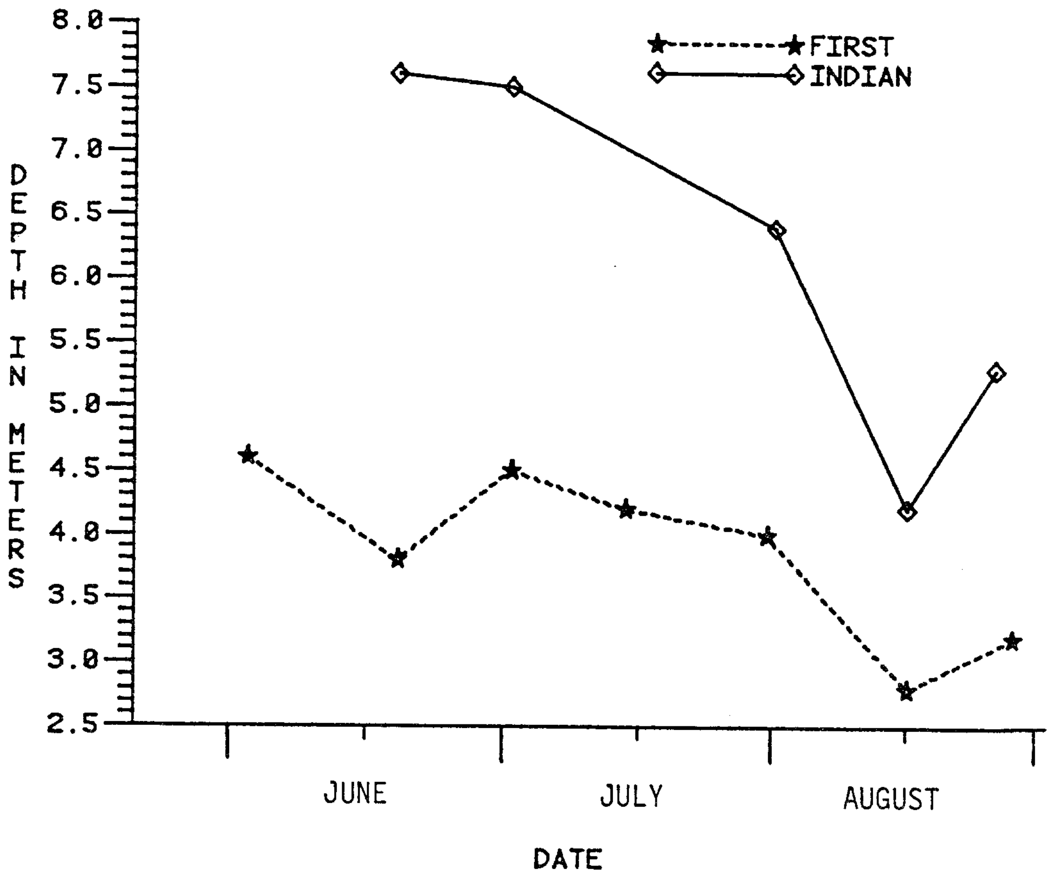

Figure 13. Secchi disk readings in First Lake and Indian Lake, June to August 1979.

Table 6. Zooplankton composition and density (organisms per cubic meter) in First Lake, 2 June to 18 October 1979. Plankton density computations are the average of two vertical plankton tows from a depth of 13 m using a no. 10 Nitex net.

Date	June 2	June 19	July 2	July 15	July 31	August 16	August 28	September 15	October 3	October 18
CLADOCERA										
Bosminidae	10	3								
Daphnidae	20									
Holopedidae	7	291	3,500	1,008	5,586	1,777	1,274	338	25	8
Cladocera eggs	3	26	1,553	58		295	118	63	5	
Chydorinea	16	6							5	
COPEPODA										
Cyclopoid copepod	75	131	137	82	103	96	15		3	
Calinoid copepod	585	777	1,317	868	442	686	798	1,551	258	149
Nauplii	1,195	543	93	21			15	9	85	105
Copepod eggs		7	103				49	319	57	4
ROTIFERA										
Keratella	10	287	656	514	1,049	137	181	20	31	11
Conochilus			45	89	3,878	4,019	34	1,843	260	38
Conochiloides	20	25	3,758	10,595	23,998	11,274	18,369	1,322	390	1,290
Total Density (-eggs)	1,938	2,063	9,626	13,177	35,416	17,989	20,685	5,083	1,057	1,601

Table 7. Zooplankton composition and density (organisms per cubic meter) in Indian Lake, 19 June to 26 August 1979. Plankton density computations are average of two bottom (55 m) to surface vertical plankton tows using a no. 10 Nitex net.

Date	June 19	July 2	July 15	August 1	August 16	August 26
COPEPODA						
Cyclopoid copepod	548	1,033	2,290	1,623	4,459	2,644
Nauplii	1,087	573	421	200	153	93
Copepod eggs			125	182	1,143	147
Total Density (-eggs)	1,635	1,606	2,711	1,823	4,612	2,737

Table 8. Mean length, weight, age, condition factor (K), and frequency by sex and gonad condition of char collected in each lake and stream. The range and standard deviation of the length, weight, age, and K values are listed as are the percentage of each sex and stage of maturity. Sample sizes are in parentheses. See text for gonad condition code definitions.

Lake/Stream	Length	Weight	Sex M	Sex F	Age	K	Condition of gonads 1	2	3
	168.1	65.6	28	26	5.3	1.038			
	91-302	5.1-283.2			2-9	.667-1.299			
First Lake	46.507	58.290	51.9%	48.1%	1.595	.123		———	
	(65)	(54)	(54)		(60)	(52)			
	130.9	30.0	159	168	3.4	.853	263	19	46
	75-437	3.0-830.0	48.6%	51.4%	1-14	.67-1.16	80.1	5.8	14.0
Second Lake	47.128	67.691			1.884	.203			
	(333)	(333)	(327)		(326)	(333)		(328)	
	112.3	16.4	145	134	2.7	.848	211	46	10
	62-283	1.9-170.8	52%	48%.	1-9	.61-1.16	79.0	17.2	3.7
Long River	38.164	23.485			1.575	.078			
	(286)	(263)	(279)		(284)	(263)		(267)	
	149.7	46.0	233	229	4.4	.899	100	76	9
Inlet end of	65-551	2.1-1864.0			1-13	.55-1.33	54.0	41.1	4.9
Indian Lake	55.457	152.248	50.4	49.6	1.708	.095			
	(472)	(401)	(462)		(465)	(401)		(185)	
	143.5	42.3	233	265	4.1	.888	318	147	27
Outlet end of	58-556	2.0-1825.0			1-14	.60-1.22			
Indian Lake	54.745	128.508	46.8	53.2	1.925	.137	64.6	29.9	5.5
	(505)	(503)	(498)		(490)	(503)		(492)	
	112.6	15.7	78	102	2.9	.869	148	27	6
	60-216	2.0-98.8			1-8	.61-1.12			
Indian River	31.959	15.480	43.3	56.7	1.355	.064	81.8	14.9	3.3
	(182)	(182)	(180)		(177)	(182)		(181)	
	135.7	34.8	876	924	3.8	.880	1,040	315	98
Entire Indian	58-556	1.9-1864.0	48.7	51.3	1-14	.55-1.33	71.6	21.7	6.7
Lake System	51.618	106.942			1.885	.135			
	(1843)	(1736)	(1800)		(1802)	(1734)		(1453)	

Table 9. Mean length, standard deviation, range, and sample size for each age class of Dolly Varden char collected from throughout the Indian Lake system.

		AGE													
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
FIRST LAKE	Mean Length		92.0	119.2	135.5	158.5	182.5	194.8	267.5	302.0					
	S.D.		1.414	10.426	24.568	21.673	19.435	20.856	5.802						
			93	129	176	187	225	227	273						
	Range		91	106	102	110	162	168	262						
	N		2	5	13	16	8	11	4	1					
SECOND LAKE	Mean Length	79.7	101.1	116.9	140.8	159.9	181.3	207.8	210.0	252.0	320.5			383.0	437.0
	S.D.	2.872	7.562	10.738	19.920	25.265	32.138	22.085	4.583	25.232	38.891				
		85	119	140	197	246	221	238	215	279	348				
	Range	75	80	94	114	117	104	167	206	218	293				
	N	9	125	75	42	36	17	11	3	4	2			1	1
LONG RIVER	Mean Length	77.5	97.1	115.9	135.9	156.6	195.8	221.4		271.0					
	S.D.	6.965	10.833	10.998	10.935	29.068	22.486	43.690							
		94	127	141	152	208	235	238							
	Range	62	66	94	114	103	161	161							
	N	64	99	52	30	18	12	8		1					
inlet half INDIAN LAKE	Mean Length	69.5	95.4	119.6	134.0	158.8	180.7	199.0	229.2	283.0	324.2	372.5	480.0	551.0	
	S.D.	3.109	8.121	12.046	14.075	18.831	22.824	11.045	38.535	32.146	80.067	118.978	24.576		
		72	115	185	177	246	240	217	284	316	399	456	498		
	Range	65	81	99	106	101	144	183	208	232	203	196	452		
	N	4	28	92	141	126	45	7	4	5	5	4	3	1	
outlet half INDIAN LAKE	Mean Length	71.3	94.6	118.4	140.6	165.0	187.5	193.4	198.8	248.2		427.2			485.5
	S.D.	7.459	11.043	14.140	18.342	17.705	26.987	19.186	12.614	32.505		99.911			54.447
		87	121	166	190	237	265	242	228	305		556			524
	Range	58	67	85	109	131	133	172	183	218		316			447
	N	15	96	99	90	103	45	16	14	6		4			2
INDIAN RIVER	Mean Length	71.7	92.8	115.3	137.8	161.9	185.7	189.0	205.0						
	S.D.	7.447	11.931	11.344	15.961	18.613	33.322	7.071	2.828						
		90	122	140	173	189	216	194	207						
	Range	60	66	77	104	121	150	184	203						
	N	14	72	47	20	17	3	2	2						

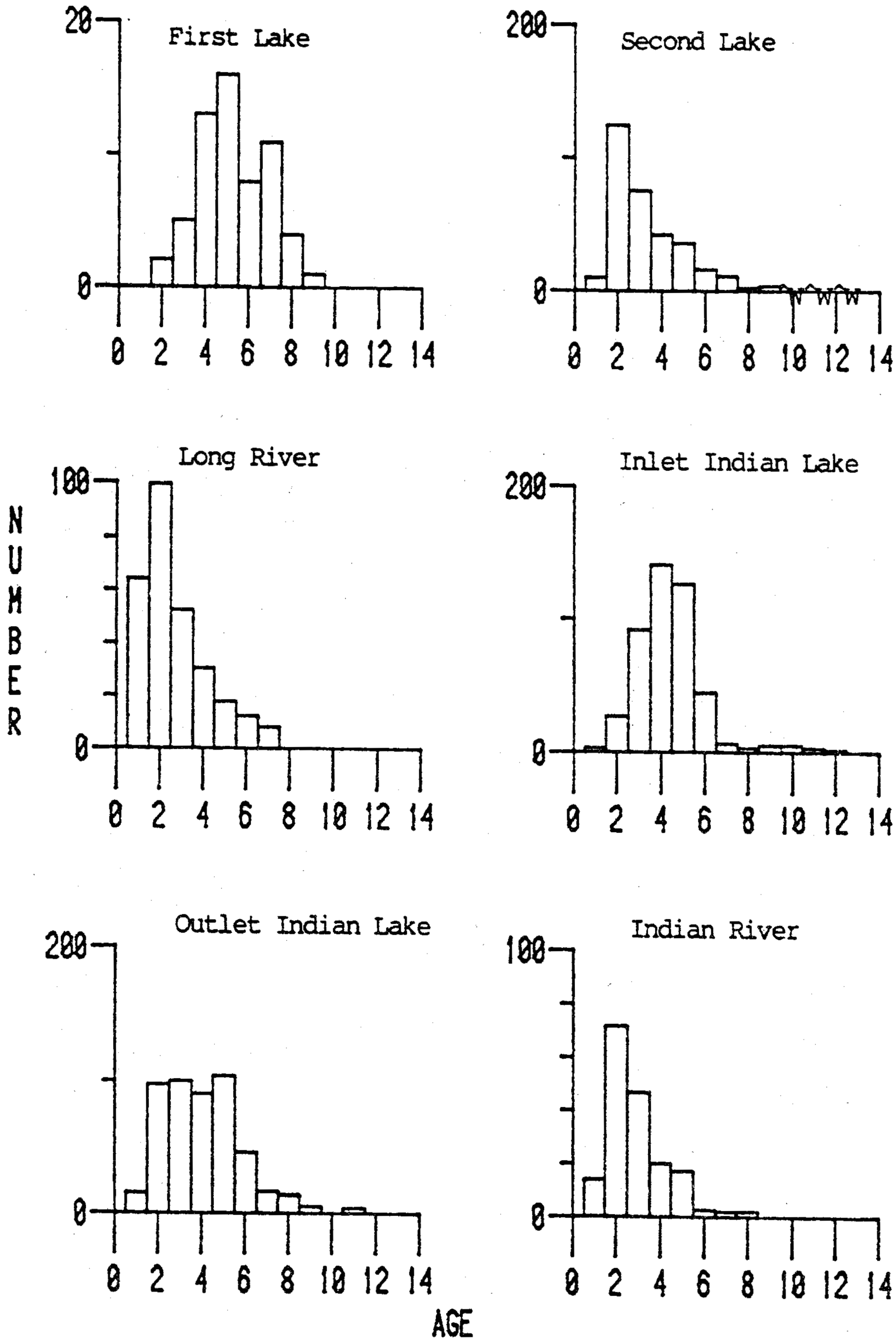

Figure 14. Age frequency of Dolly Varden char in First Lake, Second Lake, Long River, inlet half of Indian Lake, outlet half of Indian Lake, and Indian River.

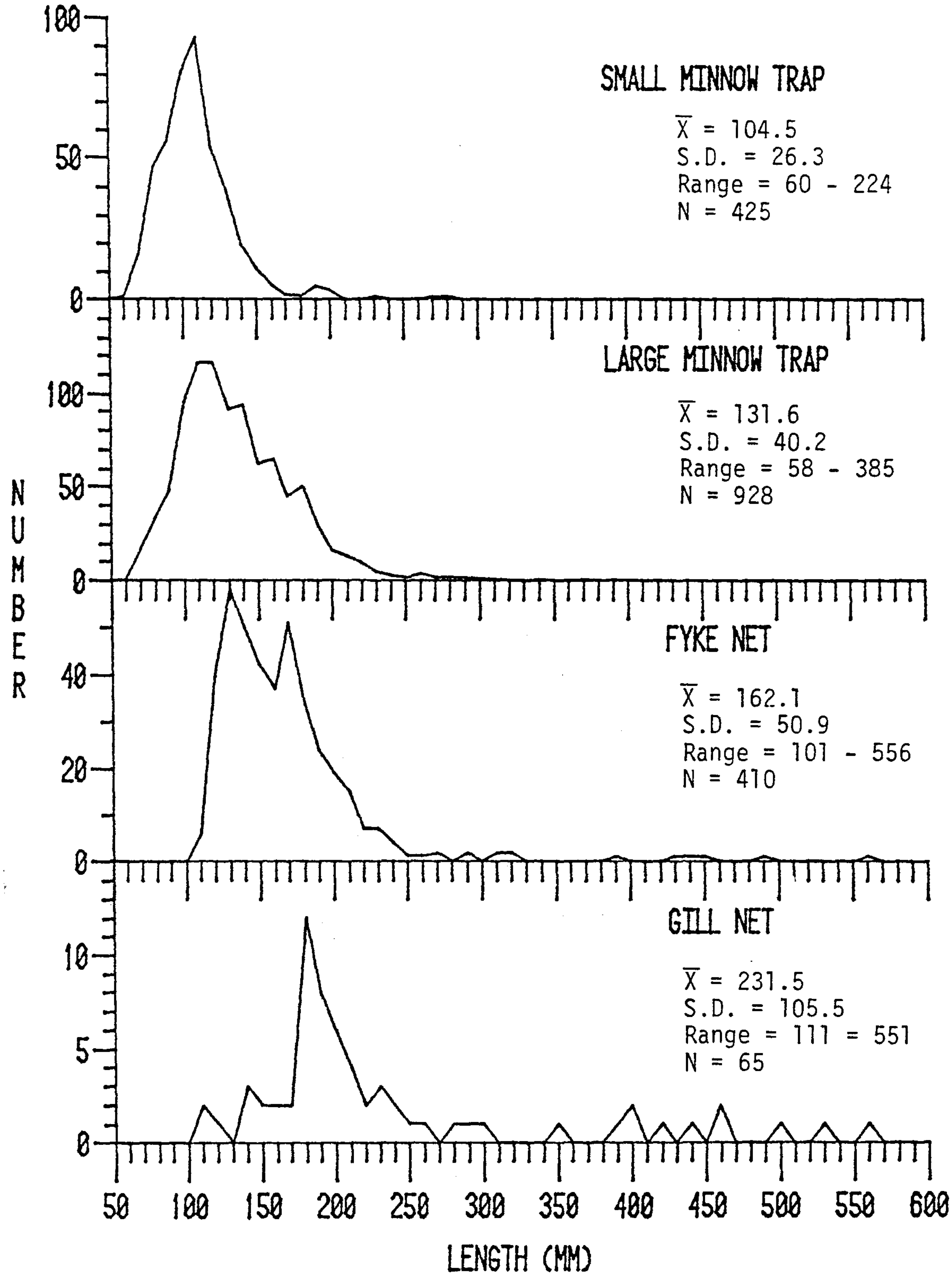

Figure 15. Length frequency for Dolly Varden char captured by each gear type plotted in 10 mm increments. Data from each lake and river are combined.

Growth curves for char collected from each lake and river are presented in Figure 16 using the length-age data in Table 9. No attempt was made to describe the age-length relationship of char with a non-linear equation since the linear equation regression correlations were all .864 or better. Correlations for regression of the logarithm of length on age were not consistently closer to 1.

There is a change in slope in these growth curves at approximately age VIII when the char are approximately 200 mm in length. For ages I to VIII the mean slope is 20.677 and for ages VIII to XIV the slope is 51.053. This change in slope may be related to a change from an insectivorous to a piscivorous diet. At approximately age VIII the char are large enough to prey on sticklebacks, cottids, knokanee, and young char. This piscivorous diet may result in a faster growth rate for the char. Fish are also a year-round food supply. The minimum critical size for the char to effectively prey on fish is approximately 200 mm, based on the inflection point in the growth curve. Small sample sizes and random variability with the larger, older char prohibit drawing any definite conclusions.

Analysis of covariance revealed significant differences in the growth rates (mm/yr) for char collected from each lake and stream (Table 10). A Newman-Keuls multiple range test (Zar 1974, p. 155) was used to group lakes and streams which did not have significantly different slopes for the age-length relationship. Only Indian River and inlet half of Indian Lake did not have significantly different growth rates when all age groups of char were used in the analysis. When the covariance analysis was repeated with the analysis limited to char aged VIII and younger so all groups were represented in each lake and stream, there were again significant differences in the growth rates of char from each lake and stream. A Newman-Keuls multiple range test determined that all lakes and streams are significantly different with the exception of Indian River and First Lake when the analysis was limited to char aged I to VIII. The growth rates for Second Lake and each half of Indian Lake for age VIII to XIV char are not significantly different; however the slopes of 36, 63, and 56 respectively do suggest differences in growth rates. Larger sample sizes of these older, larger char are required to make a definitive statement.

Examination of the age-length relationship by sex of char sampled from each lake and stream revealed that the males have the fastest growth rate (Table 11; Figure 17). A covariance analysis of the age-length relationship between male and female char collected from throughout the Indian Lake system determined that the age-length relationship for males was significantly different from that for females (Table 12). The mean length of the 818 males was 134.4 mm and that of the 858 females was 132.5 mm. The male and female mean ages were 3.687 and 3.718, respectively. The slope of the age-length relationship for males and females was 25.2258 and 22.4097, respectively. Spawning stress might be greater for females than it is for males; egg development might require more energy than teste development. In addition most female char in the Indian Lake system spawn annually between the ages of VI and IX; males, on the other hand, apparently spawn every two years.

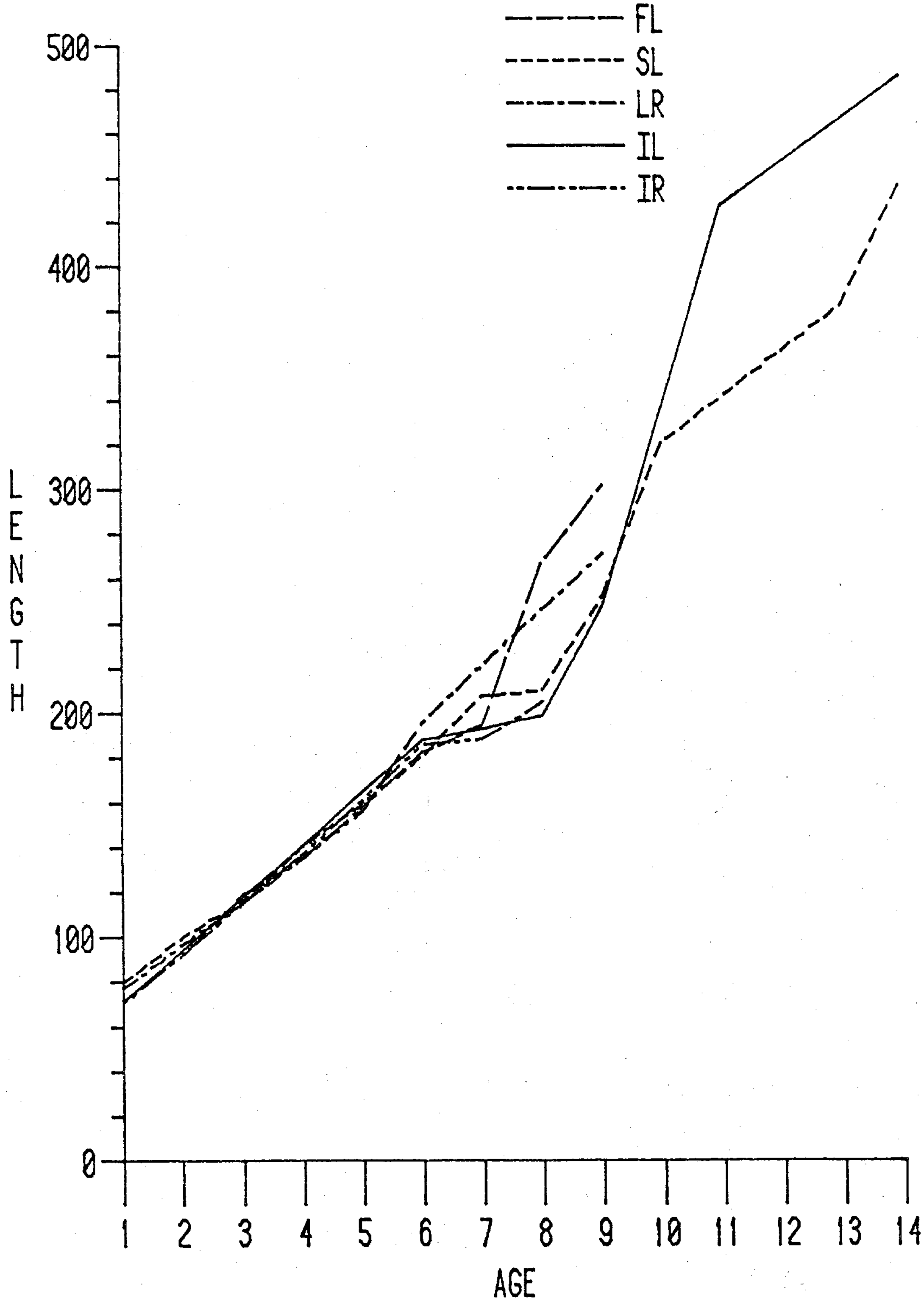

Figure 16. Growth curves for Dolly Varden char captured from First Lake (FL), Second Lake (SL), Long River (LR), Indian Lake (IL), and Indian River (IR).

Table 10. Covariance analysis of the age (independent) vs length (dependent) relationship between char collected from each lake and stream.

Age groups considered in analysis	SAMPLE SIZE					
	FL	SL	LR	TT	OT	TR
All age groups (ages 1-14)	40	326	258	392	536	124
Ages 1-8	39	319	257	381	525	124
Ages 8-14	-	10	-	12	27	-

Age groups considered in analysis	MEAN AGE / LENGTH					
	FL	SL	LR	TT	OT	TR
All age groups (ages 1-14)	5.625 175.900	3.420 129.267	2.647 110.888	4.372 145.962	4.058 141.688	2.371 102.193
Ages 1-8	5.538 172.667	3.266 125.254	2.623 110.265	4.192 139.373	3.920 137.297	2.371 102.193
Ages 8-14	-	9.700 275.100	-	10.417 360.667	9.074 261.370	-

Age groups considered in analysis	SLOPE						F-value for equality of slopes	Significant at (α = .05)
	FL	SL	LR	TT	OT	TR		
All age groups (ages 1-14)	26.0784	22.0980	21.5039	28.4059	24.2923	24.2794	12.2471	Yes
Ages 1-8	25.2602	20.3336	21.2383	19.4063	20.7673	24.2794	3.0721	Yes
Ages 8-14	-	36.2668	-	63.1973	55.6769	-	2.3050	No

Table 11. Age-length relationship for male and female char collected from each lake and stream.

LAKE/STREAM	SEX	SAMPLE SIZE	AGE(Yr)-LENGTH(mm) RELATIONSHIP	R
	M	27	L = 24.283 + 26.749A	.868
FIRST	F	26	L = 40.266 + 24.729A	.870
LAKE	Both	53	L = 32.851 + 25.626A	.867
	M	159	L = 52.718 + 22.664A	.925
SECOND	F	166	L = 55.305 + 21.308A	.929
LAKE	Both	325	L = 53.826 + 22.041A	.926
	M	144	L = 51.766 + 22.832A	.909
LONG	F	134	L - 53.193 + 21.604A	.930
RIVER	Both	278	L = 52.567 + 22.206A	.918
inlet half of	M	231	L = 10.106 + 31.844A	.906
INDIAN	F	225	L = 34.102 + 25.655A	.864
LAKE	Both	456	L = 19.823 + 29.239A	.887
outlet half of	M	226	L = 35.563 + 26.962A	.894
INDIAN	F	259	L = 49.101 + 22.441A	.901
LAKE	Both	485	L = 42.540 + 24.585A	.892
	M	78	L = 50.238 + 21.772A	.928
INDIAN	F	97	L = 52.092 + 20.821A	.894
RIVER	Both	175	L = 51.146 + 21.288A	.911

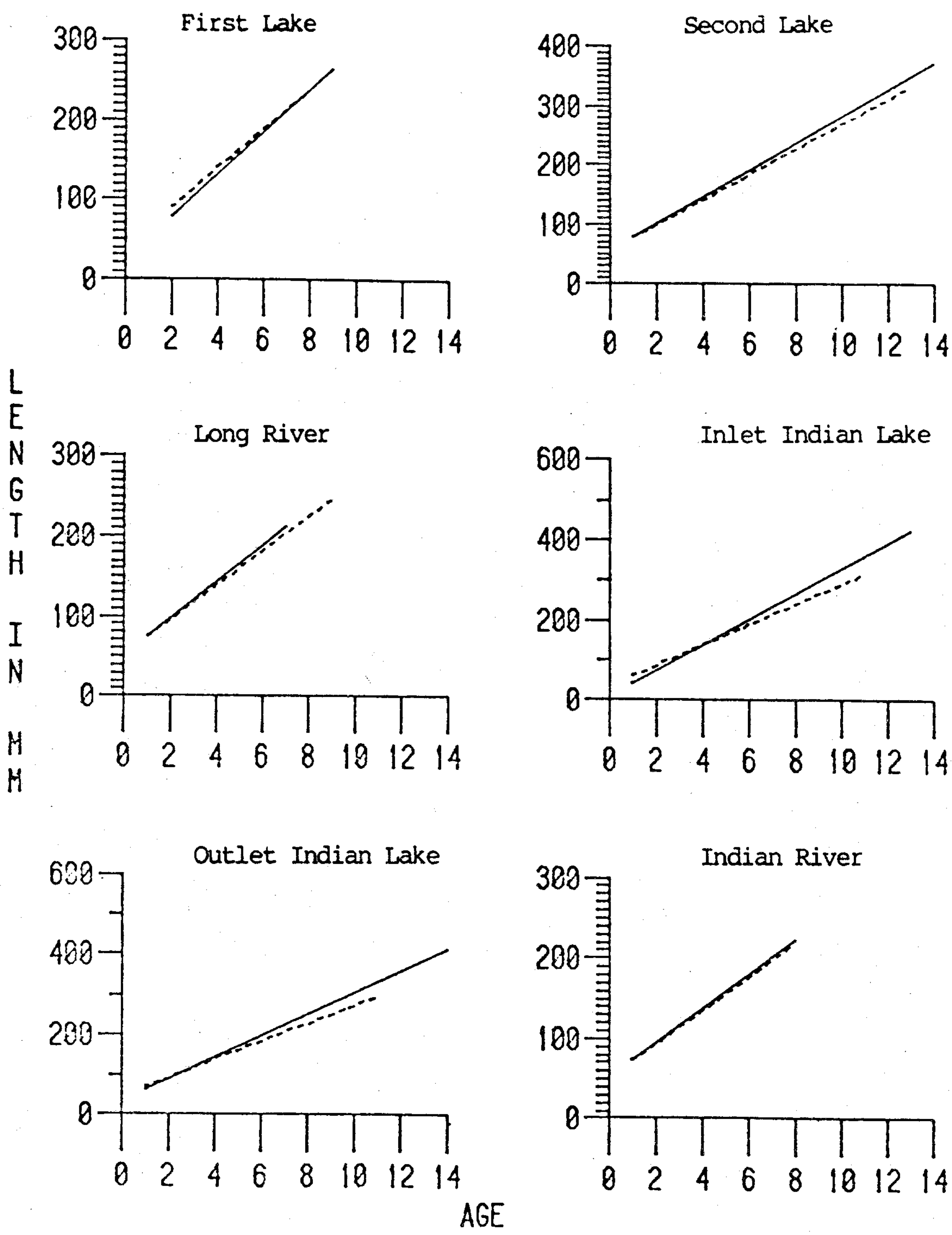

Figure 17. Age-length relationships for male (solid line) and female (dashed line) Dolly Varden char captured from each lake and river.

Table 12. Covariance analysis of the age (independent) vs length (dependent) relationship between male and female char collected from throughout the Indian Lake system.

Age groups considered in analysis	Sample Size		Mean Age		Mean Length		Slope		F-value for equality of growth rates (mm/yr)	Significant at (α = .05)
	M	F	M	F	M	F	M	F		
All age groups (ages 1-14)	818	858	3.69	3.72	134.44	132.46	25.2258	22.4097	25.2162	Yes
Immature (ages 1-3)	419	435	2.30	2.29	103.77	102.27	20.7484	20.3393	.1367	No
Ages 1-8	802	843	3.54	3.60	129.81	129.11	21.3218	20.1169	5.7839	Yes
Ages 8-14	24	30	9.92	9.03	317.67	263.07	50.3339	52.4124	.0457	No

If differences in growth rate between males and females result from differences in their reproductive biology then the growth rate of male and female immature char should be similar. A covariance analysis of immature char ages I, II, and III showed no significant difference in the age-length relationship between males and females (Table 12). The analysis of covariance was then restricted to char aged I to VIII. Again the age-length relationship for males was significantly greater than that for females (Table 12). When the analysis of covariance was restricted to char age VIII and older there was not a significant difference between males and females. Small sample sizes, 20 males and 30 females, did not permit a very powerful analysis. The slope for males was less than that for females. In other tests males consistently had the larger slope.

The length-weight relationships for male and female char sampled from each lake and river are presented in Table 13. No salient differences in the slopes of regression of the logarithm of weight on the logarithm of length were found, either among locations (Table 14), or between sexes (Table 15).

The mean condition factor of the char collected from throughout the Indian Lake system was 0.88 with a range of from 0.55 to 1.33 and a standard deviation of 0.13. The char in First Lake had the largest mean condition factor (Figure 18). Not all char measured in First Lake were fresh specimens. Perhaps absorption of water into the body tissues biased the weight and condition factor upward. Weights were not recorded for char which were noticeably decomposed. Analysis of variance tests were performed to determine if there was any effect on condition factor due to age or sex. No significant effects were found.

The sex ratio of char in the Indian Lake system is 1:1. Out of 1,800 char for which sex was determined, 876 (48.7%) were males and 924 (51.3%) were females. Chi-square testing indicated that none of the sex ratios of char sampled from each lake and stream (Figure 19) were significantly different from the expected 1:1 ratio. There is little difference in the length (Figure 20) or age composition (Figure 21) by sex of char sampled from throughout the Indian Lake system. The longest female char taken was 498 mm and the oldest was age XIII, compared to 556 mm and age XIV for males. To determine if there were any differences between sexes in the maximum age or length of char, more larger, older char need to be sampled.

Insight into the age at first maturity and frequency of spawning is gained by examining graphs of the percent composition by age of each maturity group of char sampled from each lake and river (Figures 22, 23, 24, and 25).

In the Indian Lake system male and female char mature as young as age II and are all mature by age VII. Most males and females are mature at age V or VI. The oldest "mature, spawning imminent" char captured in the system was an age XIV male captured from Indian Lake. In Indian Lake 67% of the females were mature at age V while only 42% of the males were mature at that age. This indicates that the females mature at an earlier age than males. However, this situation is not as clear when other lakes and rivers are considered in the analysis since relationships between age and stage of maturity were not consistent between each lake and stream. Perhaps determining the stage of maturity in August is too early in the year. Char could have been wrongly classified as "mature, spawning not imminent" when, in fact, they would soon undergo rapid gonadal development

Table 13. Length-weight relationship for male and female char collected from each lake and stream.

LAKE/STREAM	SEX	SAMPLE SIZE	LENGTH-WEIGHT RELATIONSHIP	R
FIRST LAKE	M	26	LOG W = -4.1631 + 3.0797 LOG L	.992
	F	25	LOG W = -4.0702 + 3.0356 LOG L	.989
	Both	51	LOG W = -4.1147 + 3.0567 LOG L	.990
SECOND LAKE	M	159	LOG W = -5.1438 + 3.0353 LOG L	.980
	F	168	LOG W = -5.2418 + 3.0773 LOG L	.996
	Both	327	LOG W = -5.1926 + 3.0561 LOG L	.987
LONG RIVER	M	135	LOG W = -5.3659 + 3.1465 LOG L	.995
	F	124	LOG W = -5.2257 + 3.0733 LOG L	.996
	Both	259	LOG W = -5.2915 + 3.1079 LOG L	.995
inlet half of INDIAN LAKE	M	201	LOG W = -5.1504 + 3.0503 LOG L	.990
	F	195	LOG W = -5.0673 + 3.0058 LOG L	.993
	Both	396	LOG W = -5.1151 + 3.0310 LOG L	.991
outlet half of INDIAN LAKE	M	233	LOG W = -5.1123 + 3.0306 LOG L	.998
	F	265	LOG W = -5.2329 + 3.0795 LOG L	.990
	Both	498	LOG W = -5.1737 + 3.0553 LOG L	.989
INDIAN RIVER	M	78	LOG W = -5.1293 + 3.0340 LOG L	.995
	F	102	LOG W = -5.0676 + 3.0019 LOG L	.997
	Both	180	LOG W = -5.0963 + 3.0168 LOG L	.996

Table 14. Covariance analysis of the log (length) (independent) vs log (weight) (dependent) relationship between char collected from each lake and stream.

Age groups considered in analysis	SAMPLE SIZE						MEAN LOG-LENGTH/LOG-WEIGHT						SLOPE						F-value for equality of slopes	Significant at (α = .05)
	FL	SL	LR	II	OI	IR	FL	SL	LR	II	OI	IR	FL	SL	LR	II	OI	IR		
All age groups (ages 1-14)	40	326	258	392	536	124	2.229 1.7027	2.092 1.202	2.026 1.006	2.148 1.396	2.129 1.332	1.997 .926	2.9781	3.0626	3.1077	3.0326	3.0512	2.9982	1.5428	No
Ages 1-8	39	319	257	381	525	124	2.223 1.683	2.084 1.176	2.025 1.001	2.137 1.360	2.121 1.306	1.997 .926	2.9769	3.0432	3.1118	2.9474	3.0346	2.9982	3.3755	Yes
Ages 8-14	-	10	-	12	27	-	-	2.426 2.235	-	2.531 2.591	2.389 2.110	-	-	3.3095	-	3.2263	3.2677	-	.0844	No

Table 15. Covariance analysis of the log(length)(independent) vs log(weight)(dependent) relationship between male and female char collected from throughout the Indian Lake system.

Age groups considered in analysis	Sample Size		Mean Log Length		Mean Log Weight		Slope		F-value for equality of slopes	Significant at (α = .05)
	M	F	M	F	M	F	M	F		
All age groups (ages 1-14)	818	858	2.1053	2.1014	1.2625	1.2385	3.0803	3.0791	.0039	No
Ages 1-3 (immature)	419	435	2.0101	2.0031	.9643	.9327	3.0232	3.0277	.0086	No
Ages 1-8	802	843	2.0967	2.0944	1.2356	1.2171	3.0626	3.0750	.3276	No
Ages 8-14	24	30	2.4709	2.4014	2.3980	2.1436	2.2391	3.2873	.1895	No

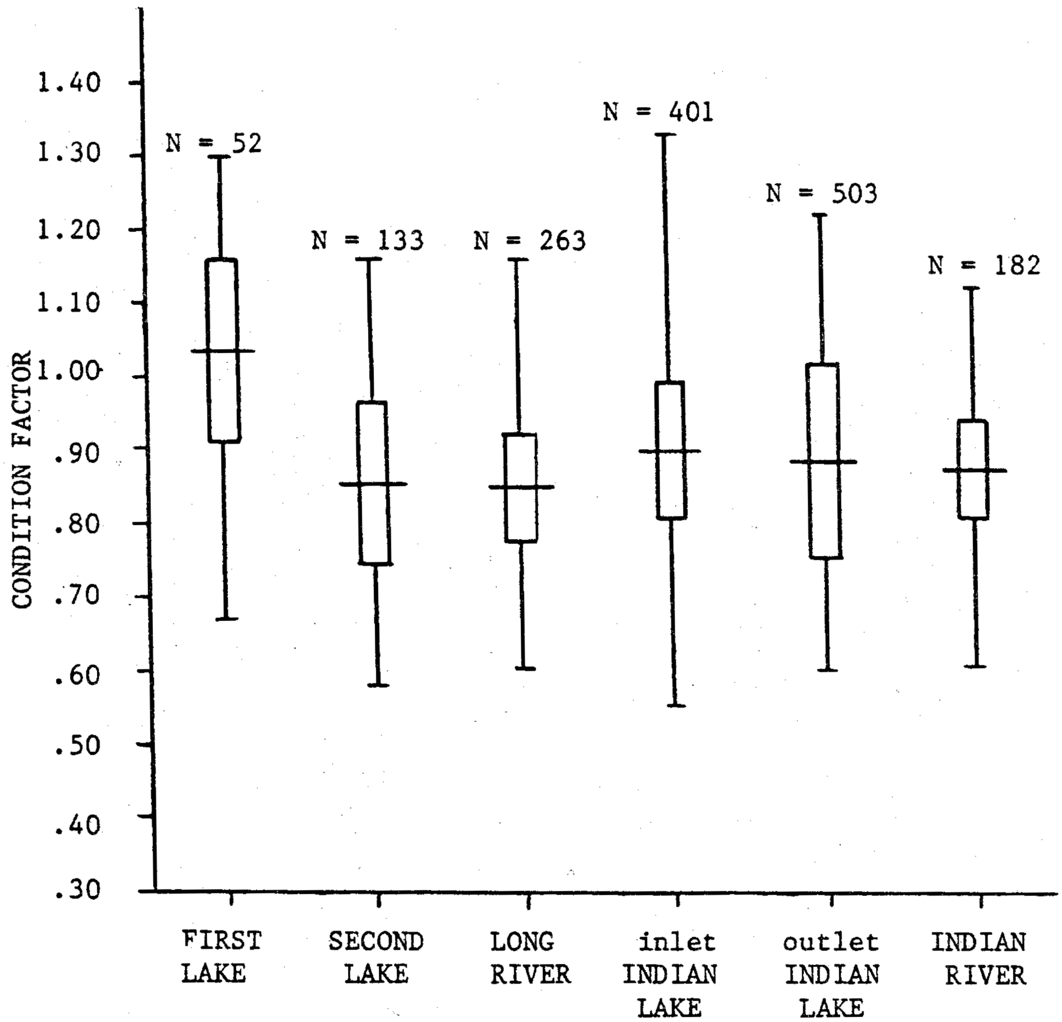

Figure 18. The mean, standard deviation, and range of condition factor of Dolly Varden char collected from each lake and river, 1979.

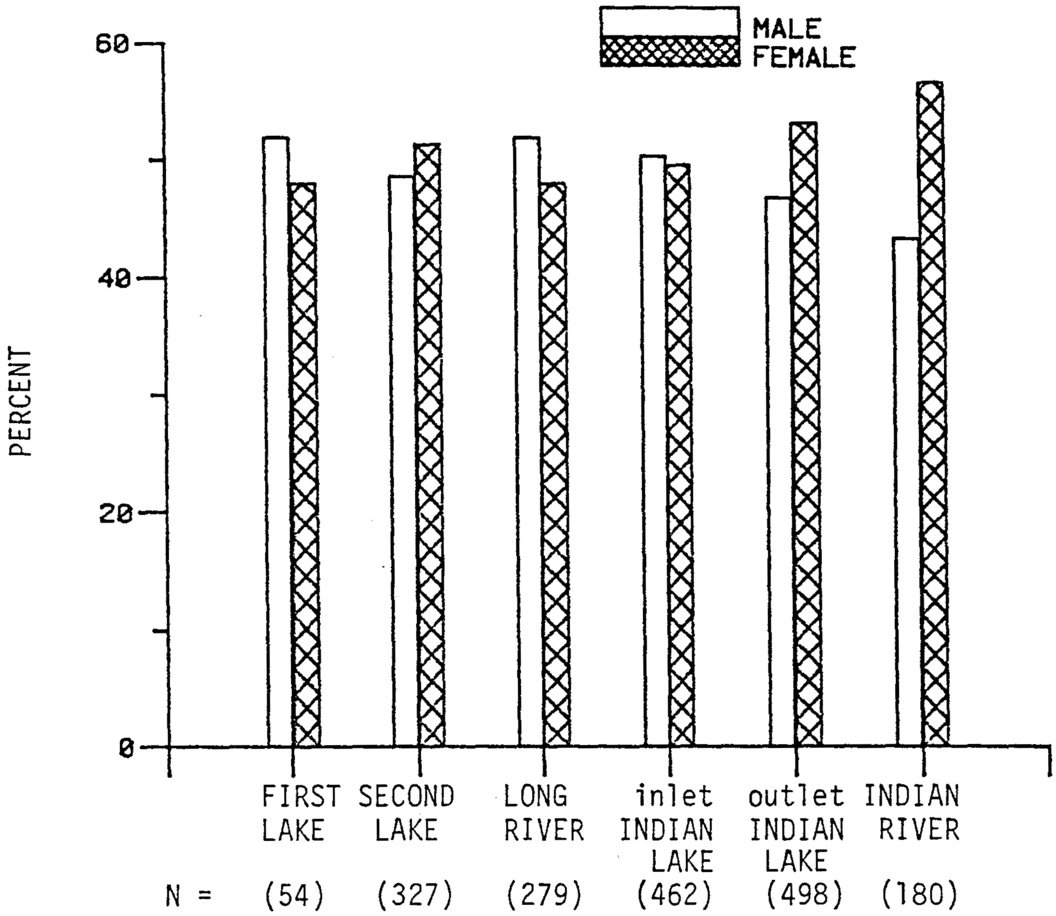

Figure 19. Sex frequency of Dolly Varden char collected from each lake and river.

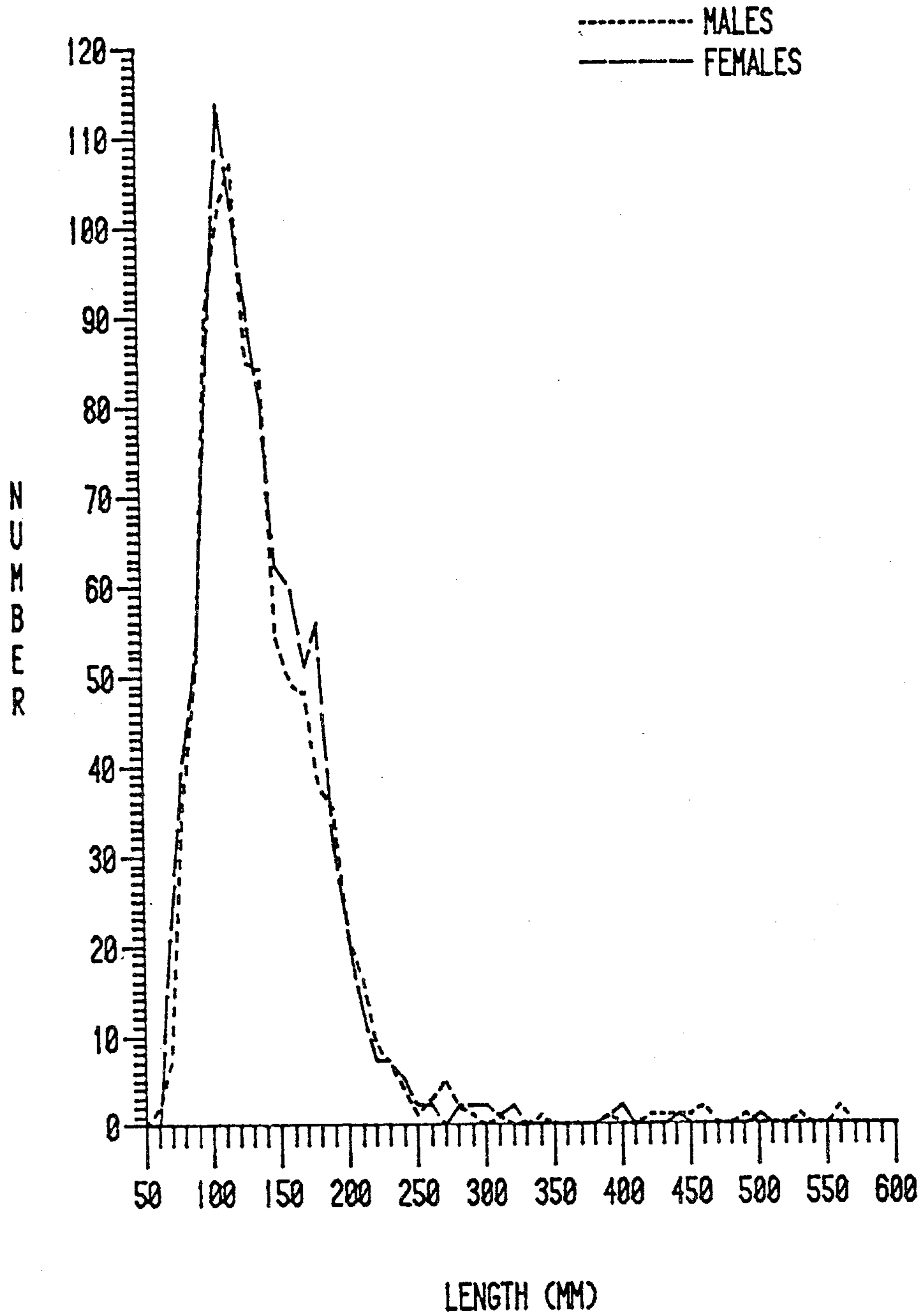

Figure 20. Length frequency by sex plotted in 10 mm increments for Dolly Varden char collected from throughout the Indian Lake system.

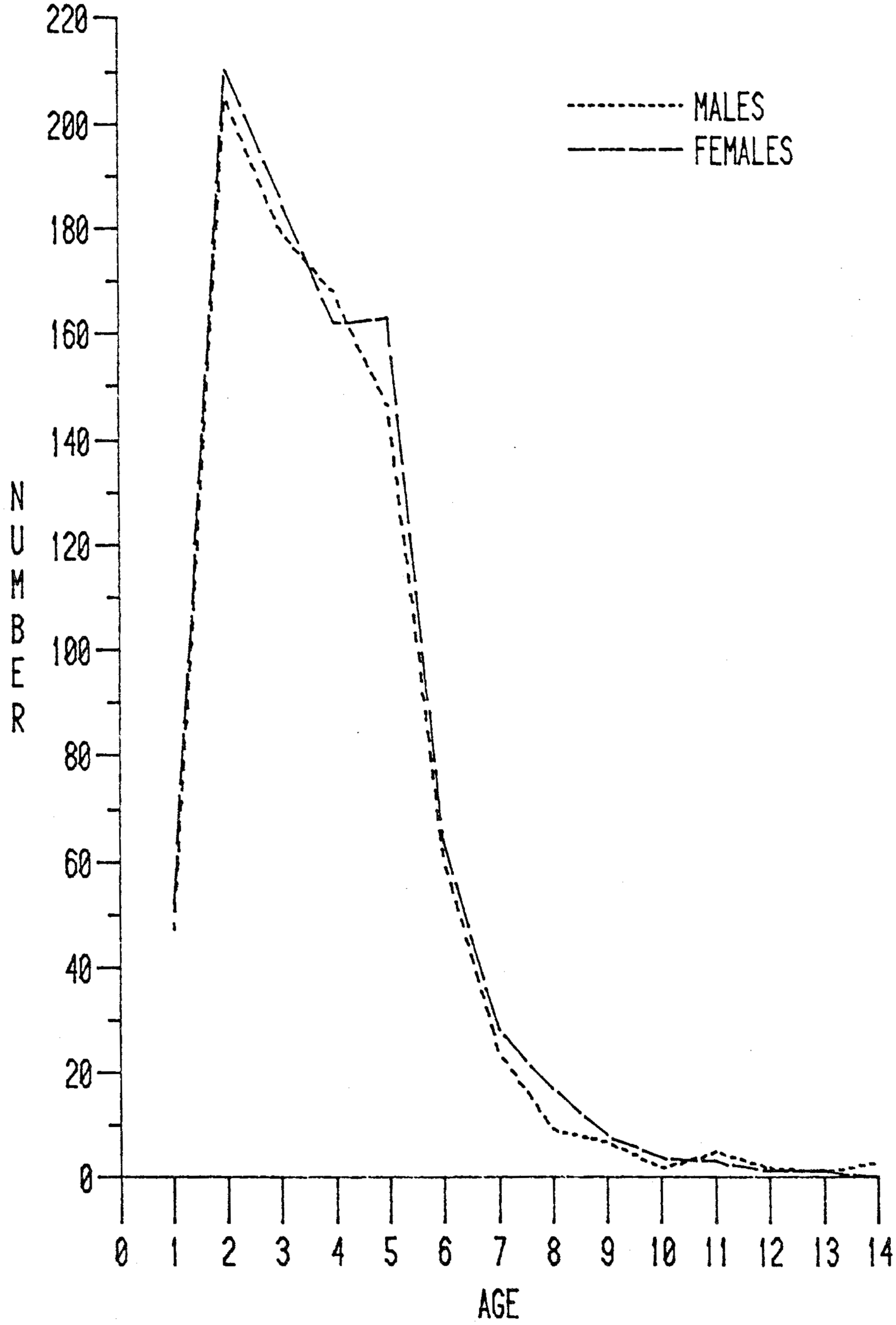

Figure 21. Age frequency by sex of Dolly Varden char collected from throughout the Indian Lake system.

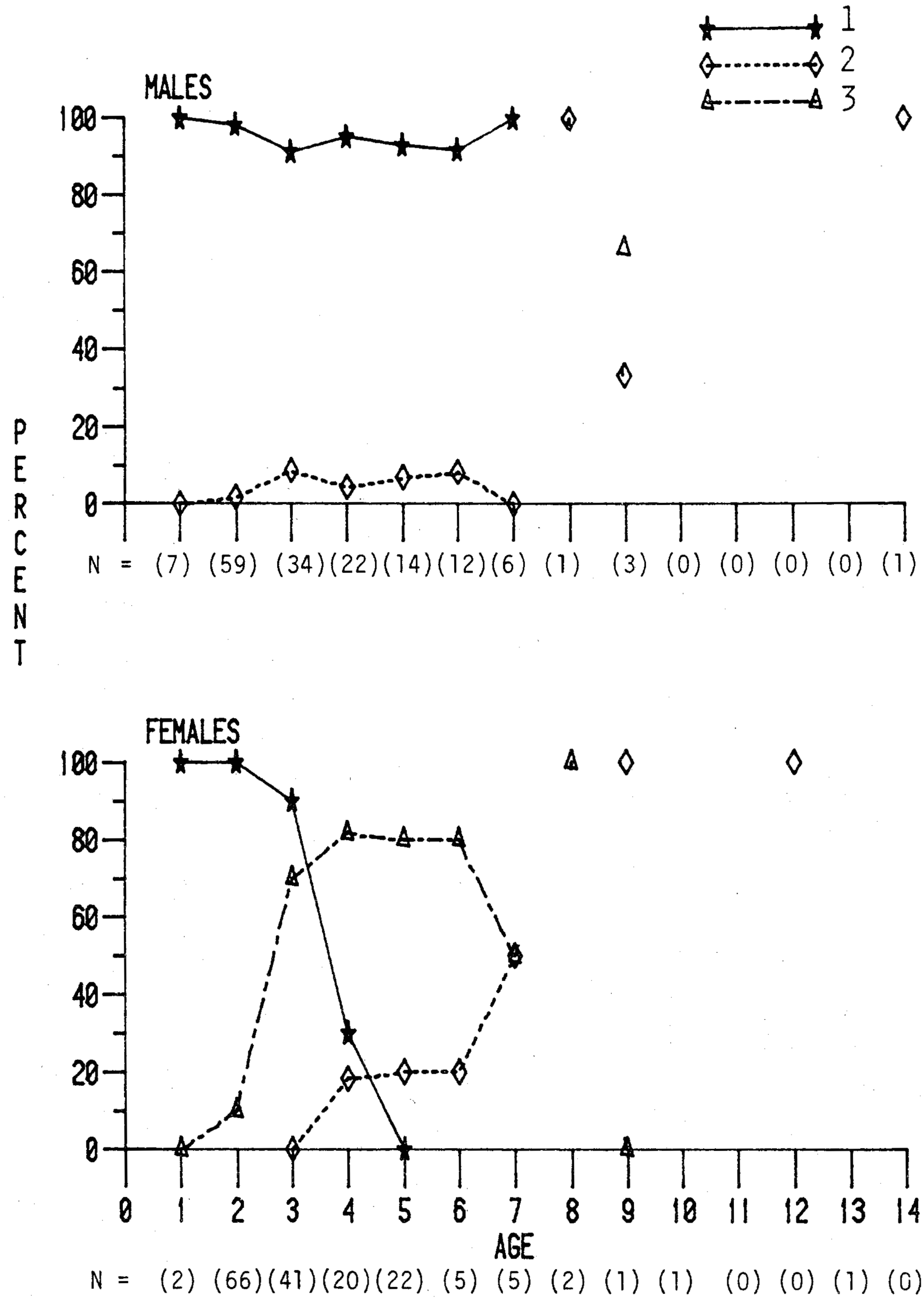

Figure 22. Gonad condition by percent of each age class of Dolly Varden char collected from Second Lake, 19 August to 23 August 1979. Upper graph is for males and lower graph is for females. The maturity classifications are: 1 = immature, 2 = mature, spawning imminent, and 3 = mature, spawning not imminent.

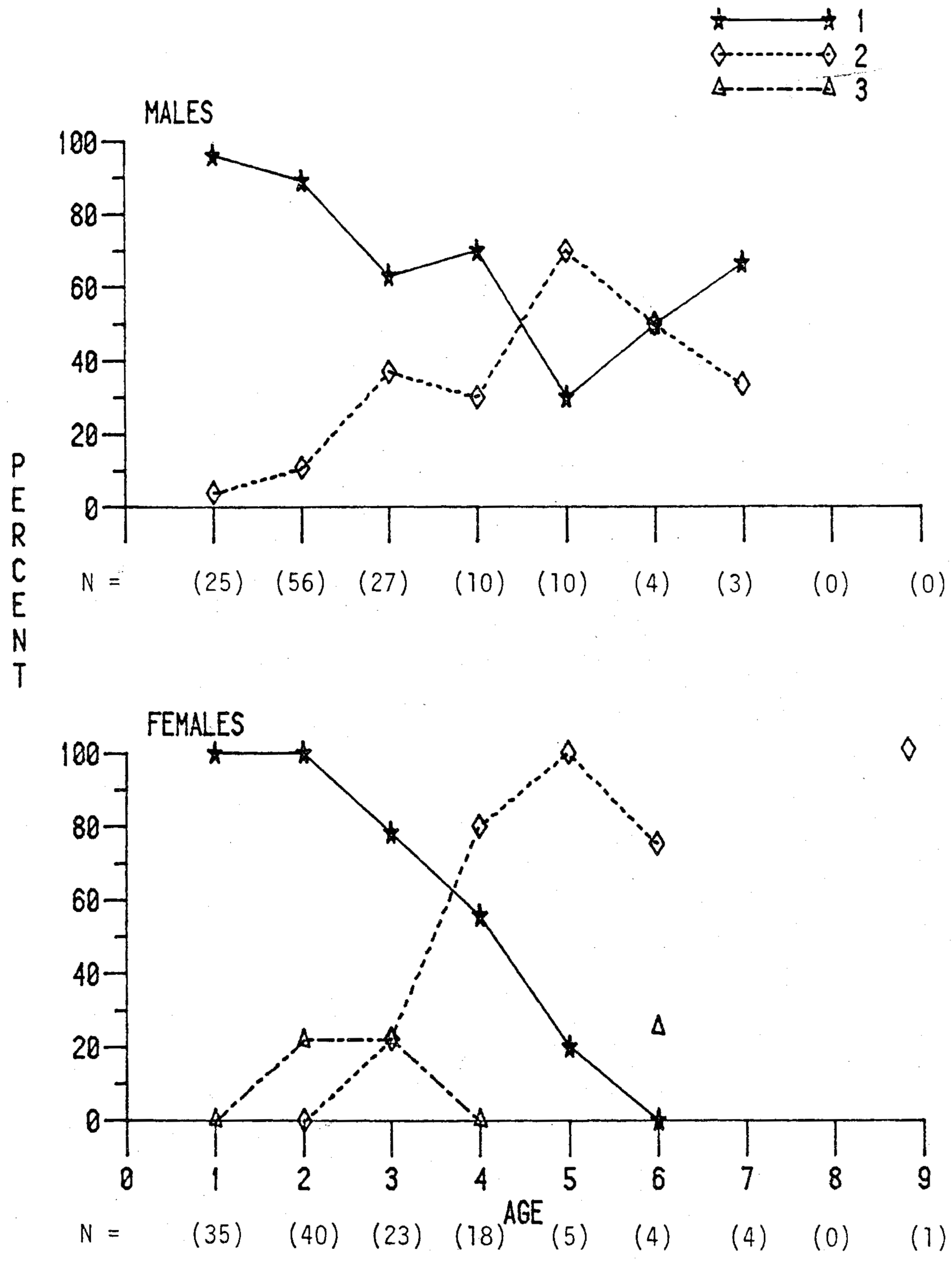

Figure 23. Gonad condition by percent of each age class of Dolly Varden char collected from Long River, 4 August to 23 August 1979. Upper graph is for males and lower graph is for females. The maturity classifications are: 1 = immature, 2 = mature, spawning imminent, and 3 = mature, spawning not imminent.

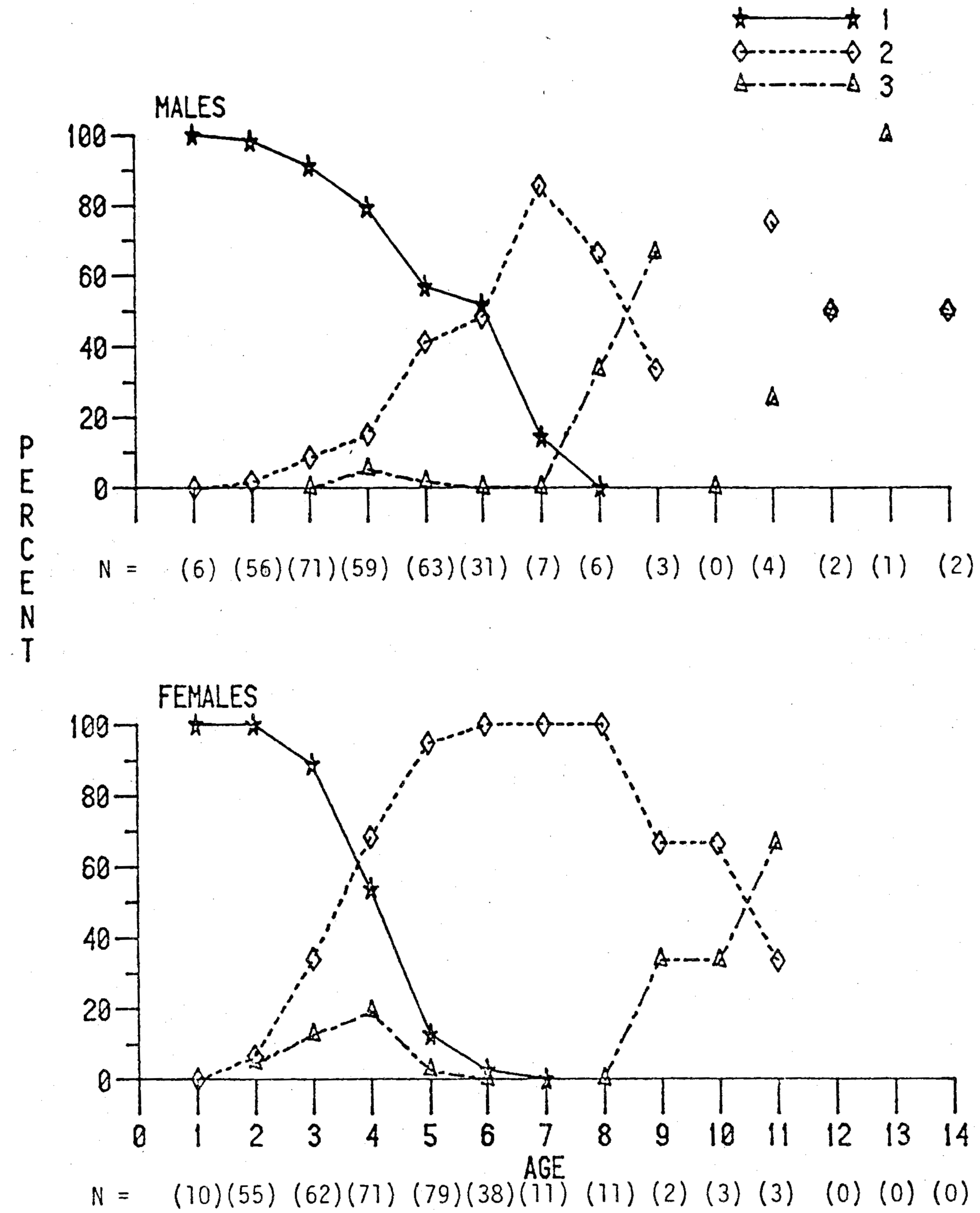

Figure 24. Gonad condition by percent of each age class of Dolly Varden char collected from Indian Lake, 4 August to 15 August 1979. Upper graph is for males and lower graph is for females. The maturity classifications are: 1 = immature, 2 = mature, spawning imminent, 3 = mature, spawning not imminent.

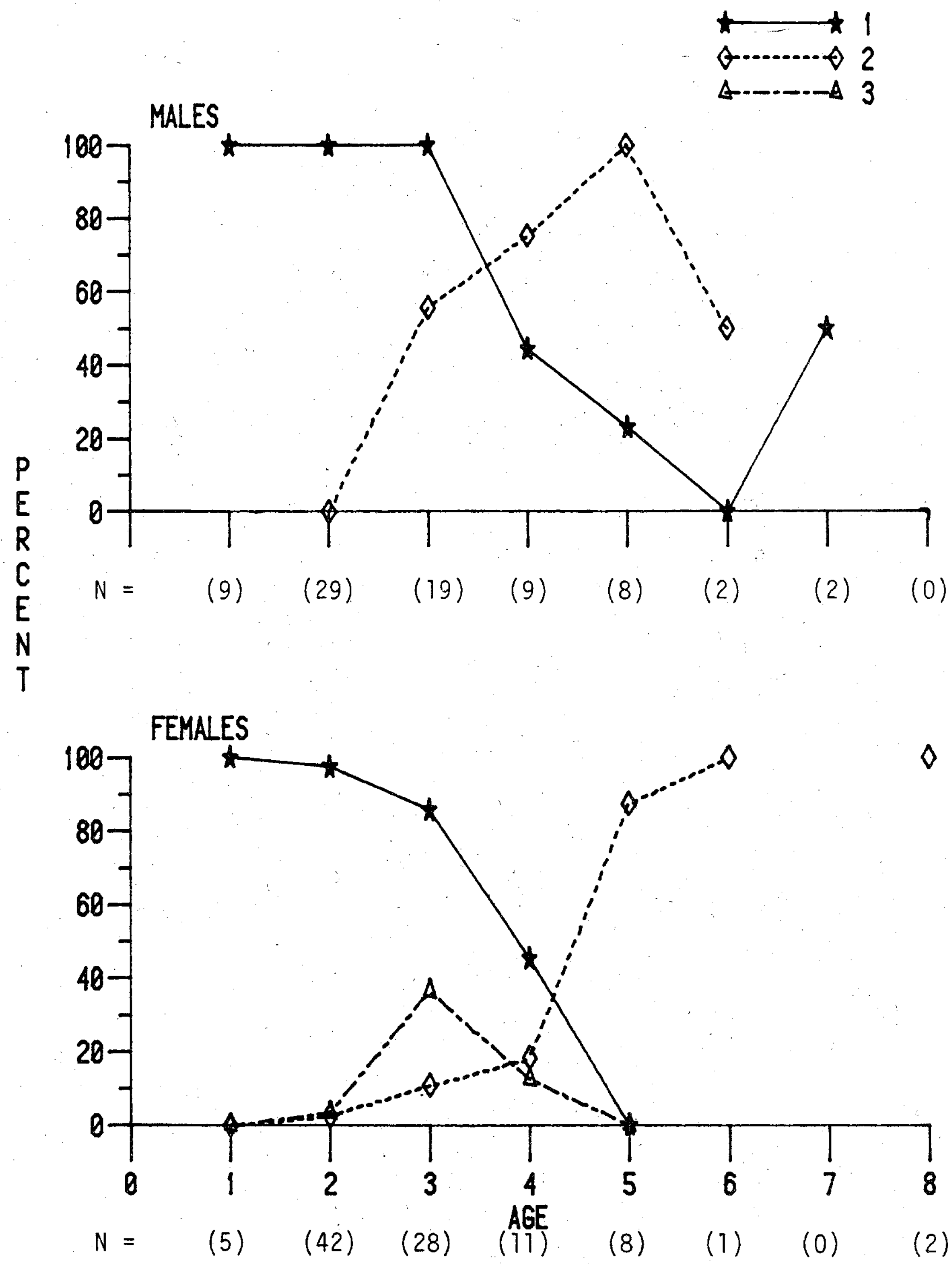

Figure 25. Gonad condition by percent of each age class of Dolly Varden char collected from Indian River, 10 August to 15 August 1979. Upper graph is for males and lower graph is for females. The maturity classifications are: 1 = immature, 2 = mature, spawning imminent, 3 = mature, spawning not imminent.

and spawn in late fall. Dolly Varden char in Southeastern Alaska spawn during September, October, and November (Armstrong and Morrow 1980, Blackett 1968). Armstrong (1974) felt that most anadromous Dolly Varden char from Hood Bay Creek spawned annually once reaching sexual maturity. Blackett (1968), however, tagged spawning anadromous char in Southeastern Alaskan streams and the following year recovered both "mature, spawning imminent" and "mature, spawning not imminent" char. No references to the spawning frequency of stream/lake resident form of Dolly Varden char could be located.

In Long River, Indian Lake, and Indian River most mature female char aged V to IX spawn annually. In Indian Lake 95% or more of all age VI to IX females were classified as "mature, spawning imminent". Not all females older than age IX spawn annually, however. Three of the eight female char sampled which were older than age IX were classified as "mature, spawning not imminent". The spawning frequency for males is more difficult to determine. Figures 24 to 27 do not show a succession of years in which all males spawn annually, as was the case for the females. Apparently the proportion of males which spawn on an annual basis is less than that for females.

The proportion of each maturity group by age of char in Second Lake is much different from that observed in the rest of the system. For males there was no decline in percent immature until age VII. A much larger proportion of females were classified as "mature, spawning not imminent". Most of the "mature, spawning imminent" char might have moved out of Second Lake into Long River to spawn.

Determination of sex and gonad condition for many of the larger, older char was difficult because the char were heavily parasitized with nematodes. In heavily parasitized char the internal organs are bound to the coelomic cavity making identification and classification of gonads difficult due to the unusual mass of connective fiber.

Ovaries were collected from eight "mature, spawning imminent" char. This sample size is too small to accurately describe char fecundity, however, this information provides a rough estimate.

Ovaries contained eggs of two distinct sizes. The smaller ones were less than 2 mm in diameter and the larger ones greater than 2 mm. The mean fecundity was 117 eggs from a sample of char with a mean length of 174 mm (Table 16). There were approximately equal numbers of small and large eggs in each ovary.

Stomach content analysis of Indian Lake and Long River Dolly Varden char by zone of capture is presented in Table 17. Food was present in all stomachs analyzed. Chironomidae were the food item eaten most often by char, occurring in 77.4% of all stomachs examined. The mean number of chironomids in the stomachs of char eating that particular food item is 112.3. Percent occurrences of other main food items were: miscellaneous Diptera, 38.2; Tricoptera, 28.4: Coleoptra, 25.5; Hymenoptera, 21.6; Homoptera, 12.7; Ephemeroptera, 11.8; and Plecoptera, 10.8. The mean numbers of these organisms per fish eating this particular food item were: miscellaneous Diptera, 8.6; Tricoptera, 9.2; Coleoptera, 4.5; Hymenoptera, 24.2; Homoptera, 4.0; Ephemeroptera, 7.3; and Plecoptera, 2.4.

Table 16. Char length, number of large eggs, and number of small eggs, captured from Indian Lake, 6 August to 8 August, 1979.

Char length (mm)	Number of large eggs[1]	Number of small eggs[2]
137	72	-
145	92	-
160	94	155
166	117	152
187	94	82
191	104	89
191	247	211
214	118	121
$\overline{X}$ = 173.9	$\overline{X}$ = 117.25	$\overline{X}$ = 135
S^2 = 26.23	S^2 = 54.48	S^2 = 48.14

[1] Fecundity, number of ripening eggs per female.

[2] Non-ripening eggs, missing values result from poorly preserved eggs.

Table 17. Stomach content analysis of Dolly Varden char by zone of capture; Indian Lake and Long River, 1979.

	LITTORAL Sample Size = 28		BENTHIC Sample Size = 40		STREAM Sample Size = 34		ALL ZONES Sample Size = 102	
	Percent occurrence[1]	Mean no. organisms[2]	Percent occurrence	Mean no. organisms	Percent occurrence	Mean no. organisms	Percent occurrence	Mean no. organisms
Collembola	3.6	2.0			8.8	1.3	3.9	1.5
Diptera	82.1	114.8	100.0	104.2	97.1	75.3	94.1	96.8
Chironomidae	60.7	138.1	100.0	103.8	64.7	107.8	77.4	112.3
Adults	10.7	13.7	12.5	2.4	32.3	2.5	18.6	4.3
Pupae	46.4	158.5	45.0	3.1	11.8	6.5	34.3	61.2
Larvae	32.1	27.3	97.5	104.7	58.8	115.8	66.7	97.7
Simuliidae	3.6	5.0			14.7	5.8	5.9	5.7
Tipulidae	10.7	7.7	2.5	1.0	11.8	1.7	7.8	3.9
Other diptera[3]	53.6	17.5	5.0	1.5	64.7	3.2	38.2	8.6
Adult	50.0	18.7	5.0	1.5	58.8	3.0	35.3	9.0
Pupae	3.6	1.0			2.9	1.0	2.0	1.0
Larvae	.				20.6	1.3	6.9	4.0
Ephemeroptera			7.5	4.3	26.5	8.3	11.8	7.3
Tricoptera	57.1	12.2	7.5	12.3	16.3	3.5	28.4	9.2
Adults	50.0	13.5	7.5	12.3	11.8	3.5	20.6	11.4
Larvae	3.6	5.0			17.6	3.5	6.9	3.7
Plecoptera	3.6	1.0	7.5	1.0	20.6	3.3	10.8	2.4
Thysanoptera					5.9	1.5	2.0	1.5
Acarina	7.1	1.5			8.8	1.3	4.9	1.4
Homoptera	7.1	1.5			32.3	4.4	12.7	4.0
Coleoptra	35.7	7.8	7.5	1.0	35.3	3.1	25.5	4.5
Terrestrial	35.7	7.7	7.5	1.0	35.3	3.1	24.5	1.5
Aquatic	3.6	1.0					1.0	1.0
Lepidoptera	14.3	1.7			8.8	1.0	6.9	1.4
Hymeroptera	32.1	3.2			35.3	39.9	21.6	24.2
Hemiptera					5.9	1.0	2.0	1.0
Aranea	10.7	1.0			5.9	1.0	4.9	1.0
Pelecypoda	10.7	14.3	10.0	14.2	5.9	1.5	8.8	11.4
Gastropoda	10.7	8.0			2.9	2.0	3.9	5.5
Nematade			7.5	4.0			2.9	4.0
Unknown invertebrate eggs	3.6	1.0			8.8	6.0	3.9	7.3
Fish	7.1	1.0			8.8	1.3	4.9	1.2
Cottidae					2.9	1.0	1.0	1.0
Gasterosterdae	3.6	1.0			2.9	1.0	2.0	1.0
Salmonidae	3.6	1.0			2.9	1.0	2.0	1.5

1 Percent occurrence = $\frac{\text{Number of stomachs containing a particular organism}}{\text{Total number of stomachs in sample}} \times 100$

2 Mean number of organisms = $\frac{\text{Total number of organisms}}{\text{Number of stomachs containing that particular organism}}$

3 "Other diptera" category is exclusive of the previously listed Diptera.

The char appeared to be opportunistic feeders, eating a wide variety of food items. The diet of char varied with zone of capture. Char captured from the streams showed the largest diversity of food items (28 food item categories), followed by littoral zone (23 categories), and benthic zone (11 categories) captures.

In all three zones, Chironomidae were the most frequent food item. The percent occurrences of Chironomidae in the stomachs of char collected from each zone were: stream 64.7; littoral 60.7; and benthic 100. Of the three metamorphic stages of Chironomidae (adult, pupae, and larvae), the percent occurrence varied by zone of capture. The largest frequency of occurrence of each Chironomid type by zone of capture was: stream 58.8% larvae; littoral 46.4% pupae; and benthic 97.5% larvae.

No zooplankton were identified in the char stomachs analyzed. In Osprey Lake, Cladocera were the fifth most frequent food item eaten, occurring in 13.4% of the stomachs (Schmidt and Robards 1976).

A total of one Cottidae, two Gasterosteidae, and three Salmonidae (char and kokanee) were found in the stomachs of four of the 102 char examined. No char collected from the benthic zone had fish in their stomachs. The four char which had eaten fish were 197 mm or larger. The largest fish eaten was a char approximately 120 mm in length. Two of the char which had fish in their stomachs were captured in gill nets and the other two were captured in large minnow traps. The char collected in the minnow traps could have eaten the fish while in the trap. Although fish were not numerically dominant in the stomachs of the char sampled, their nutritive contribution to the diet of char large enough to prey on fish is probably substantial.

Age, length, weight, sex, and gonad condition were determined from 64 Indian Lake and five Second Lake kokanee. The small sample sizes reflect the low abundance of kokanee and the difficulty of capturing them. The youngest kokanee found was age II and the oldest was age V. Of the 69 kokanee sampled, 40 were males and 29 were females. The mean fork length,range, standard deviation, and sample size by age and sex of kokanee collected from Second Lake and Indian Lake is presented in Table 18. The kokanee grew little between ages IV and V. The slow growth rate of older kokanee may result from limited food and from spawning stress. Males and females had similar growth rates. The condition factor (K) of the kokanee increased with age and size (Figure 26).

The relationships between percent immature and mature kokanee by age class and sex are presented in Figure 27. The data collected on kokanee from Second and Indian Lakes is combined. The youngest mature kokanee was age III. All age IV and V kokanee were classified as "mature, spawning imminent". A larger percentage of age III males were mature than females, 60 compared to 25, respectively. Thus the males might mature at an earlier age than the females. Ricker (1938) reported that kokanee males in Cultus Lake, British Columbia usually mature at age II or III and that females matured at age III and IV.

A more intensive investigation involving larger sample sizes and sampling of kokanee throughout the year would be needed to study spawning frequency. Post-spawning mortality appears to be high.

Table 18. Mean fork length, range, standard deviation, and sample size by age and sex of kokanee collected from Second Lake and Indian Lake.

	AGE			
	2	3	4	5
MALES	118.5 117-120 2.1 2	136.3 119-178 17.0 11	169.5 152-189 8.4 20	173.4 162-184 7.7 7
FEMALES	116 1	137.5 127-170 13.5 8	166.2 154-176 7.0 17	174.7 170-181 5.7 3
COMBINED	117.7 116-120 2.1 3	136.8 119-178 15.2 19	168.0 152-189 7.9 37	173.8 162-184 6.8 10

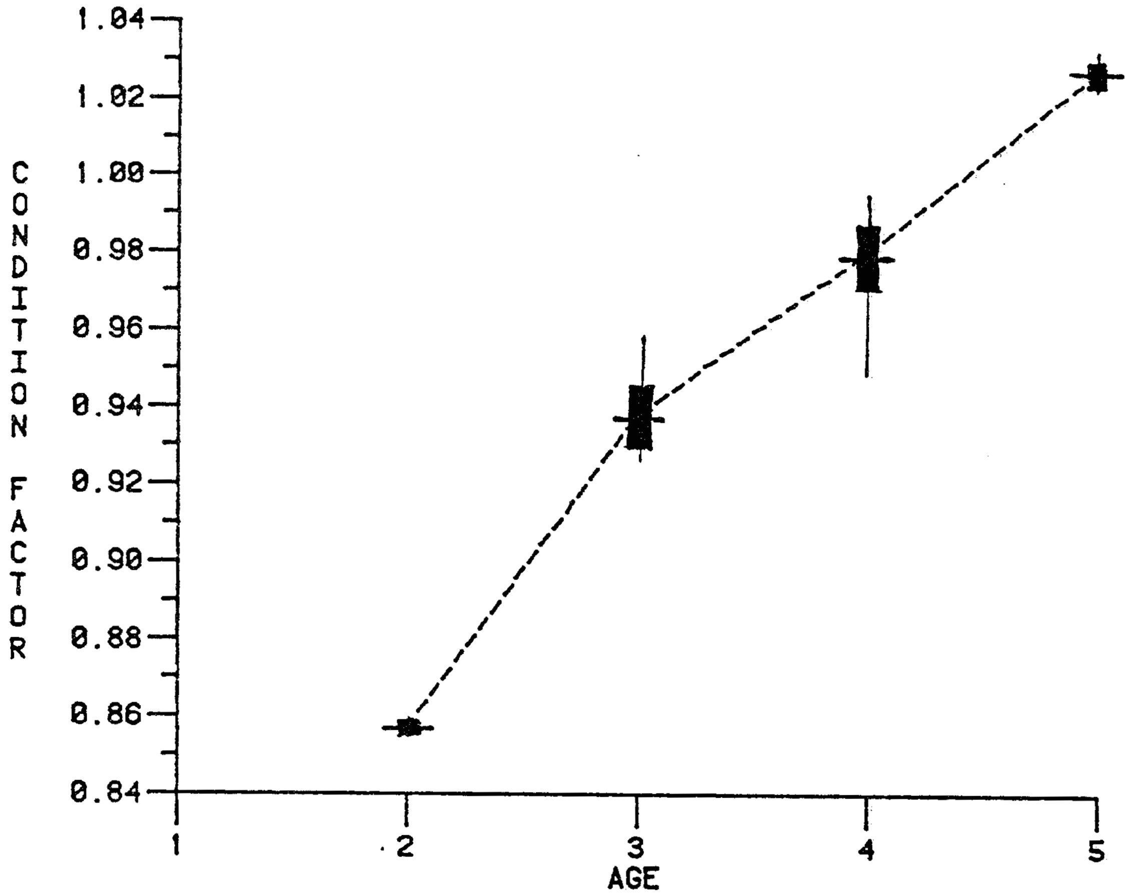

Figure 26. Age-condition factor relationship for kokanee collected from Second Lake and Indian Lake.

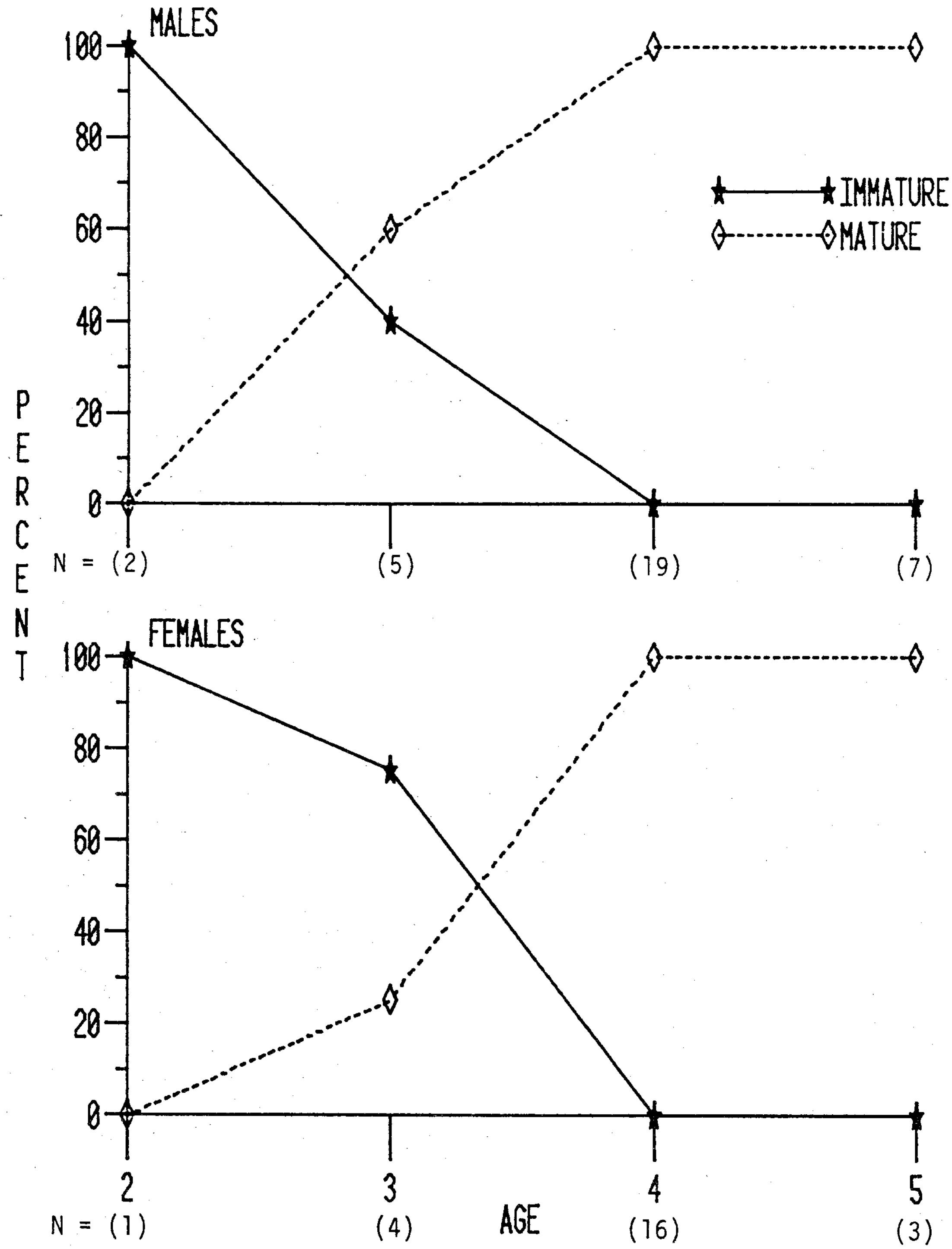

Figure 27. Gonad condition by percent of each age class of kokanee captured from Second Lake and Indian Lake in August. Upper graph is for males; lower for females.

Abundance, Movement, and Spatial Distribution

A total of 62 Dolly Varden char were captured and removed from First Lake from 1 June to 17 August; 12 during sampling period 1, when a variety of gear types were fished, and 50 during sampling period 2, when only variable-mesh gill nets were fished. Subsequent to the summer's sampling seven char were captured from First Lake; three on 15 September and four on 26 January. These fish were captured in small minnow traps.

First Lake char catch data used for the compilation of the Leslie population estimate are presented in Table 19. The Leslie estimate is 61 char with a confidence interval of 50 to 84 at the 95% confidence level. This is an estimate of the number of char present at the start of sampling period 2, when only variable-mesh gill nets were fished. Since 12 char were removed in sampling period 1 an estimate of the total number of char present in First Lake at the start of sampling (1 June) is 73 with a confidence interval of 62 to 96. The smallest char captured in a variable-mesh gill net set in the Indian First Lake was 102 mm in length. Since smaller char were not taken by the gill nets, the estimate of char abundance in First Lake is limited to char 102 mm or longer.

The spatial distribution of First Lake char can be analyzed by examining catch data for sampling period 1, when a variety of gear types were fished in all areas of the lake. Ten of the 12 char caught were captured in the littoral zone; the two remaining char were captured from the benthic zone. No char were captured in any gear set off the bottom. This information strongly indicates that the majority of char in First Lake between 1 June and 8 June were residing in the littoral zone. A look at the lake's limnology shows why so few char were captured in the benthic zone; the dissolved oxygen at the bottom of First Lake was extremely low (1 mg/L) on 2 June. The minimum tolerable dissolved oxygen for salmonid fry is 6 mg/L (McNeil and Bailey 1975). The sampling design used did not allow analysis of within-lake movement of First Lake char.

The numbers of char marked, examined for marks, and recaptured in each of the 5 release and recovery strata (Second Lake, Long River, inlet Indian Lake, outlet Indian Lake, and Indian River) are presented in Table 20. The recapture data is limited to dates when all gear was fished in each stratum.

The Chapman-Junge estimate of the number of char in the Indian Lake system, excluding First Lake, is 40,364. The approximated variance (V) for this estimate is 2351679.3125. The confidence interval around the estimate at the 95% confidence level (using $1.96 \times \sqrt{V}$) is ± 3,006 fish.

The $\hat{N}_{ij}$ matrix (Table 21) is the estimated number of char in a particular lake/stream$_i$ at time of marking which had either remained or moved to lake/stream$_j$ at time of recovery. The upper left to lower right diagonal is the estimated number of fish which remained in the particular stratum in which they were marked. All estimates outside this diagonal are numbers of fish which moved out of the stratum in which they had been marked into another. The sum of each row is the estimated number of char in a particular stratum at time of marking. The sum of each column is the estimated number of char in each stratum at the time of recovery.

Table 19. First Lake Dolly Varden char catch data for Leslie population estimate, 1979.

Date	No.	Days	Nets	Effort	Catch	Catch/ Effort	Cumulative Catch
6/10	1	3	5	15	4	.2667	0
6/13	2	3	5	15	5	.3333	4
6/15	3	2	5	10	3	.3	9
6/19	4	4	5	20	7	.35	12
6/21	5	2	5	10	3	.3	19
6/24	6	3	5	15	4	.2667	22
6/27	7	3	5	15	2	.1333	26
7/1	8	4	5	20	2	.1	28
7/6	9	5	4	20	4	.2	30
7/9	10	3	4	12	4	.3333	34
7/14	11	5	4	20	5	.25	38
7/19	12	5	4	20	5	.25	43
7/23	13	4	4	16	2	.125	48
7/27	14	4	4	16	0	0	50
7/31	15	4	4	16	0	0	50
8/5	16	5	4	20	0	0	50
8/10	17	5	4	20	0	0	50
8/17	18	7	4	28	0	0	50

Table 20. The number of Dolly Varden char marked, examined for marks, and recaptured in each of the release-recovery strata (Second Lake, Long River, inlet half of Indian Lake, outlet half of Indian Lake, and Indian River).

Lake/River Marked In:	#Marked	Lake/River Recaptured From: Second Lake	Long River	Inlet half Indian Lake	Outlet half Indian Lake	Indian River	Total
#Examined for Marks		1,634	738	1,805	1,363	360	
Release/Recovery Matrix:							
Second Lake	1,504	665	40	28	4	2	743
Long River	633	40	45	12	4	0	101
Inlet half Indian Lake	4,299	10	4	389	78	3	484
Outlet half Indian Lake	3,376	4	2	85	277	8	376
Indian River	199	0	0	4	2	21	27
TOTAL	10,011	719	95	518	365	34	

Table 21. Estimated N_{ij} matrix for char collected in the Indian Lake system. Estimates are from the Chapman-Junge procedure with five release-recovery strata.

In Stratum at Time of Recovery:

In Stratum at Time of Release:	Second Lake	Long River	Indian Lake Inlet half	Indian Lake Outlet half	Indian River	Total
Second Lake	1,166	655	384	55	21	2,281
Long River	669	6,395	1,570	528	0	9,162
Indian Lake -inlet half	36	122	10,968	2,221	64	13,411
-outlet half	17	73	2,844	9,360	204	12,498
Indian River	0	0	547	276	2,189	3,012
Total	1,888	7,245	16,313	12,440	2,478	40,364

The Chapman-Junge estimate was further refined by considering the littoral and benthic zones in each half of Indian Lake as separate strata, bringing the total to seven release-recovery strata. Dividing each half of Indian Lake into littoral and benthic strata permits analysis of inter-zone movement and spatial distribution of the char.

The numbers of char marked, examined for marks, and recaptured in each of the seven release-recovery strata are presented in Table 22. The Chapman-Junge estimate for the total number of char in the system when littoral and benthic Indian Lake strata are considered is 39,352 char, with a confidence interval of ±3,263 fish at the 95% confidence level. The estimated $\hat{N}_{ij}$ matrix with the row and column totals of the estimated number of char in each strata at time of marking and time of recovery is presented in Table 23.

The catch per unit effort for char by depth zone in Second Lake and each half of Indian Lake are presented in Table 24. One effort unit is equal to one piece of gear (large or small minnow trap) fished one day.

When capturing fish in large and small minnow traps for marking, a negative relationship between the CPUE and the number of days fished existed in both halves of Indian Lake. This relationship was significant for small minnow traps in the littoral zone in each half of Indian Lake and the outlet half of Indian Lake for benthic zone traps. Relationships between CPUE and days fished were not tested during recapture sampling. This decline in catch with each successive day fished might be due to trap avoidance and/or handling stress since sampling with replacement was done. Also, since captured fish were released between traps there could have been a reduction in density of char near each trap, thus fewer char would have been attracted and captured. In light of this decline in CPUE with each successive day fished, the CPUE computations are restricted to the first two days the gear was fished in each lake stratum.

The CPUE data for Second Lake (Table 24) shows a large decrease in benthic zone CPUE from June to August and a proportional increase in littoral zone CPUE over this time period. In Indian Lake the general trend shows slightly lower littoral zone CPUEs and slightly higher benthic zone CPUEs in August than in June. The CPUE in the littoral zone of the inlet half of Indian Lake was higher than in the outlet half; this corresponds with the Chapman-Junge abundance estimates.

Capturing the greatest number of fish with the least amount of effort is generally the optimum situation for efficient sampling of a fish population. This requires an estimate of the time interval in which the catch can be expected to be highest. The optimum fishing time was examined by plotting the relationship between fishing time and trap catch (Figure 28). The segment of this curve at which the greatest average number of char are caught corresponds to the optimum fishing time. The data used to compile this graph consists of all the trap catch information from each lake and river for both marking and recapture sampling. Unfortunately, an assumption is required. The data form used did not permit summing up the total number of char caught in each trap. What is graphed in Figure 28 is the average number of char caught in each trap which were either unmarked or recaptured (with various combinations of marks). The assumption which must be made is that the marked and unmarked char entered and escaped the traps in the same proportion. The greatest average number of char was taken when

Table 22. The number of Dolly Varden char marked, examined for marks, and recaptured in each of the seven release-recovery strata (Second Lake, Long River, littoral and benthic zones of each half of Indian Lake, and Indian River).

Lake/River Recaptured From:

Lake/River Marked In:			Second Lake	Long River	Inlet half of Indian Lake: Littoral	Inlet half of Indian Lake: Benthic	Outlet half of Indian Lake: Littoral	Outlet half of Indian Lake: Benthic	Indian River	TOTAL
		#Examined for Marks	1,634	738	1,067	738	603	760	360	5,900
		#Marked	Release/Recovery Matrix:							
Second Lake		1,504	665	44	20	8	3	1	2	743
Long River		633	40	45	10	2	2	2	0	101
Inlet half of Indian L.	L	2,630	7	2	204	41	4	17	3	278
	B	1,669	3	2	72	72	10	47	0	206
Outlet half of Indian L.	L	1,407	1	1	18	9	106	24	4	163
	B	1,969	3	1	22	36	51	96	4	213
Indian River		199	0	0	3	1	1	1	21	27
TOTAL		10,011	719	95	349	169	177	188	34	15,911

Table 23. Estimated N_{ij} matrix for char collected in the Indian Lake system. Estimates are from the Chapman-Junge procedure with seven release-recovery strata.

In stratum at Time of Marking:

In Stratum at Time of Recovery:	Second Lake	Long River	Inlet half of Indian Lake Littoral	Inlet half of Indian Lake Benthic	Outlet half of Indian Lake Littoral	Outlet half of Indian Lake Benthic	Indian River	Total
Second Lake	1,212	643	333	35	37	19	21	2,300
Long River	687	6,197	1,572	82	232	353	0	9,123
Inlet half of Indian Lake Littoral	9	21	2,458	129	36	230	23	2,906
Inlet half of Indian Lake Benthic	25	132	5,420	1,414	555	3,973	0	11,519
Outlet half of Indian Lake Littoral	4	29	597	78	2,593	894	83	4,278
Outlet half of Indian Lake Benthic	11	30	744	318	1,273	3,648	85	6,109
Indian River	0	0	513	45	126	192	2,243	3,119
Total	1,948	7,052	11,637	2,101	4,852	9,309	2,455	39,354

Table 24. Catch per unit effort (number of char per day per trap) for Dolly Varden char in large (LM) and small (SM) minnow traps by zone and depth in Second Lake and each half of Indian Lake.

	SECOND LAKE				inlet INDIAN LAKE				outlet INDIAN LAKE			
	June		August		June		August		June		August	
	LM	SM	LM	SM	LM	SM	LM	SM	LM	SM	LM	SM
Littoral	12.8	6.1	17.0	9.0	12.7	12.2	11.6	11.5	7.8	7.0	7.4	6.6
Benthic 15m	18.5	3.0	7.4	3.7	9.6	1.7	7.5	10.3	6.2	3.8	6.6	3.5
30m	10.0	3.8	1.6	1.2	2.7	2.7	7.6	1.0	9.4	5.8	9.2	3.0
46m	[1]	[1]	[1]	[1]	8.1	[1]	12.3	[1]	13.8	[1]	14.2	[1]
60m	[1]	[1]	[1]	[1]	3.5	[1]	16.7	[1]	6.4	[1]	8.1	[1]
Average Benthic CPUE	14.7	3.5	4.9	2.7	8.4	2.1	10.0	6.6	9.0	4.7	8.9	3.3
Average Lake CPUE	13.4	5.7	7.5	7.8	10.0	9.7	10.3	10.6	8.7	6.6	8.6	6.0

[1] This gear was not fished at this depth.

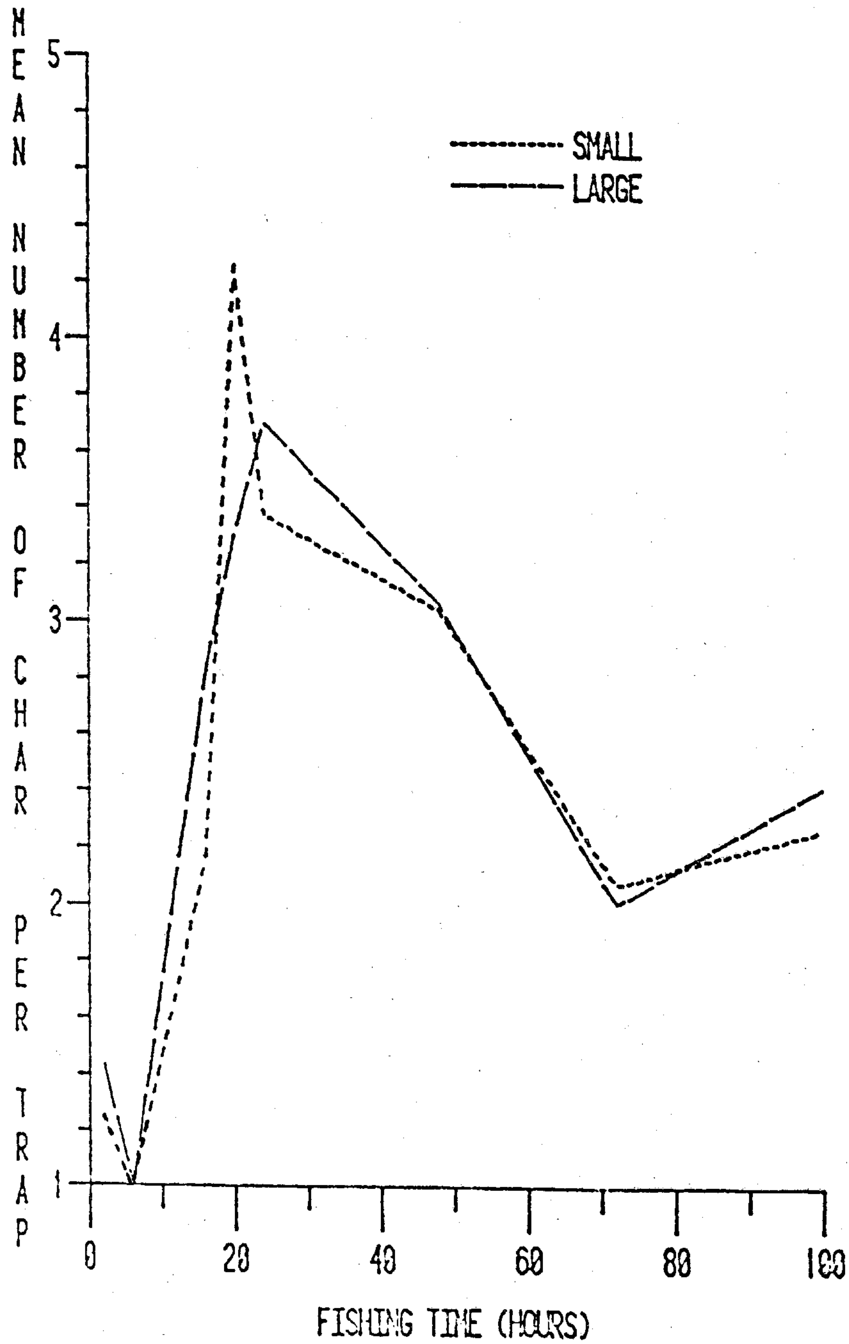

Figure 28. Relationship between number of char captured in minnow traps and duration the trap was fished.

the fishing time was between 20 and 48 hours. Fewer char, on the average, were captured in traps set and pulled the same day or after the traps had fished for two days.

The mean number of char per surface hectare in June in First Lake, Second Lake, and each half of Indian Lake was 30, 168, 121, and 113,respectively. The mean large-minnow-trap CPUE for char at time of marking (Table 24) in Second Lake was 13.4,for the inlet half of Indian Lake 10.0, and for the outlet half of Indian Lake 8.7. There are several problems with relating the density of char to lake surface area. The principal difficulty is that the char are not distributed evenly by depth; thus the spatial distribution of the char and the lake's bathymetry needs to be taken into account. In general the density of char (char/hectare) can be compared between lakes having like bathymetry if the spatial distribution of char is assumed to be similar.

Char moved between and within each lake and stream. The Chapman-Junge procedure estimated that 5,221 char, or 12.9% of the total char population, had moved into a different lake or stream.

There was considerable movement of char between the lake and rivers and within Indian Lake. Of the 9,162 char present in Long River in June an estimated 669 (7.3%) moved up into Second Lake and 2,098 (22.9%) dropped down into Indian Lake by time of recapture in August. Of the 3,013 char estimated in Indian River in June, 823 (27.3%) had moved into Indian Lake in August.

There was considerable movement of char between each half of Indian Lake. An estimated 2,221 (16.6%) char which were in the inlet half of Indian at time of marking had moved to the outlet half of Indian at time of recapture. Of the char which were in the outlet half of Indian Lake at the time of marking, 2,844 (22.7%) had moved to the inlet half of Indian at time of recapture. Most of the movement of char between the inlet and outlet halves of Indian Lake occurred with char in the benthic zone. For char in the littoral zone 1,932 (11.7%) had moved to the other half of the lake while 4,599 (40.3%) of the char marked in the benthic zone moved to the alternate half of the lake. This greater movement of benthic zone char may be related to the fact that the boundary dividing the benthic zone of each half of Indian Lake is much longer than the boundary dividing the littoral zones. This information suggests, however, that char residing in the benthic zone move throughout the lake basin and that char in the littoral zone have more restricted within-lake movement.

In Second Lake, of 53 Floy-tagged char released a total of 24 were recaptured (16 once, 4 twice, 3 three times, and 1 four times). No Floy-tagged char were recaptured outside of Second Lake; however, one tagged char was observed in Long River. Of these 24 recaptured fish all but five were recaptured in a different location or zone; 14 had moved to a different location with a zone and five had moved into a different zone entirely. This tagging experiment conclusively shows that there is a good amount of within-lake movement of the larger char and no indication of territorial behavior over the summer season.

The size of moving char was studied by comparing the size of char which moved out of the stratum in which they were marked with the size of char which did not move. This comparison can be seen in a matrix listing the mean length of char which were marked in a particular lake, stream, and zone in June and subsequently recaptured from a particular location in August (Table 25). The standard deviation, range, and sample size for each mean length value is given. The mean length of char recaptured in a different lake or stream was 12 mm less than the mean length of char which did not move.

Char sampled from the littoral zone of Indian Lake varied most in length (Figure 29), and age (Table 26). Char larger than 385 mm in length were captured at all depths of Indian Lake except the 47-60 m zone where the largest char captured was 218 mm (Figure 29). Gill nets were fished in the 47-60 m depth zone for 3 days. The absence of larger char in the net catch suggests that few large char reside in the deepest part of the lake.

Compared to other size and age groups, the smaller, younger char show the greatest decrease in numbers with increasing depth (Table 26). For example, in Indian Lake, of all the char captured which were 100 mm or less in length, the percentages caught in each depth zone were: 47.3 - littoral, 23.1 - 15 m, 14.3 - 30 m, 14.3 - 46 m, and 1.0 - 60 m.

Sixty-nine percent of the age I, II, and III char were captured in the rivers or the littoral zone of lakes. Only three age I char were captured at depths greater than 15 m; none were captured at depths greater than 46 m. The youngest char captured at depths greater than 46 m were age III. In Second Lake the percentage of age III and younger char captured in littoral, 15 m, and 30 m depth zones were: 71.4, 20.0, and 7.6, respectively. In Indian Lake the percentage of age III and younger char captured in littoral, 15 m, 30 m, 46 m, and 60 m depth zones were 50.6, 16.6, 14.6, 15.7, 2.5, respectively.

Only five char were captured in floating gill nets set over open water, two in Second Lake and three in Indian Lake. No char were captured in minnow traps set off the bottom on Indian Lake. None of the char captured in the pelagic zone were marked. The mean length of char caught in the pelagic zones of Second Lake and Indian Lake was 356 mm with a range of 178 to 524 and a standard deviation of 149 mm. The mean age was IX. Four of these char were males.

In the Indian Lake system the char captured in the pelagic zone could possibly represent a segment of the larger, older char population which resides entirely off the bottom. A more intensive mark and recapture effort would be required to determine whether a distinct pelagic population of char exists. Examination of the chars' diet would also give an insight into their spatial distribution. Do they feed entirely on limmetic food items or are benthic items included in their diet? Pelagic char might prey on kokanee inhabitating this zone. Schmidt and Robards (1976) speculate that there might be a distinct limnetic population of char in Osprey Lake.

The proportion of each size and age class of char captured from each depth zone is not representative of that in the true population. The large and small minnow traps did not catch the larger size-classes of char. Char greater than 200 mm in length were mostly captured in fyke and gill nets (Figure 15). A wide variety of gear types were fished to capture a broad size range of char but the sampling effort of each gear type was not the same in different depth strata. Minnow traps were fished at all depths, the two fyke nets were only fished in the littoral zone,

Table 25. Matrix of the mean length of recaptured char which either stayed in or moved from each lake or stream between June and August. The standard deviation, range, and sample size are listed.

LAKE/STREAM MARKED IN:

LAKE/STREAM RECAPTURED FROM:	SECOND LAKE		LONG RIVER	Inlet end of INDIAN LAKE		Outlet end of INDIAN LAKE		INDIAN RIVER
	Littoral	Benthic		Littoral	Benthic	Littoral	Benthic	
SECOND LAKE	140.1 40.212 92-348 101	164.1 42.059 85-231 27	111.4 31.764 75-195 13	118.8 15.611 102-139 5	140.0 0 1	0	112.0 0 1	0
LONG RIVER	126.2 20.841 96-155 12	200.5 3.536 198-203 2	115.6 32.329 63-182 10	127.0 42.950 88-169 4	216.5 94.045 150-283 2	195.0 0 1	0	0
inlet end of INDIAN LAKE	125.0 0 1	172.3 24.906 156-201 3	176.0 1.414 175-177 2	151.9 54.005 84-452 97	137.7 30.923 84-232 38	210.2 74.369 135-294 5	145.9 24.910 100-196 18	0
outlet end of INDIAN LAKE	0	0	0	150.7 38.153 93-265 21	144.8 30.090 95-216 26	141.9 38.381 77-257 55	159.2 34.013 96-236 34	123.0 0 123-123 3
INDIAN RIVER	0	94.0 1	0	118.8 26.546 93-156 5	164.0 5.657 160-168 2	148.7 32.958 116-194 4	151.0 36.524 94-207 9	124.8 24.733 96-158 5

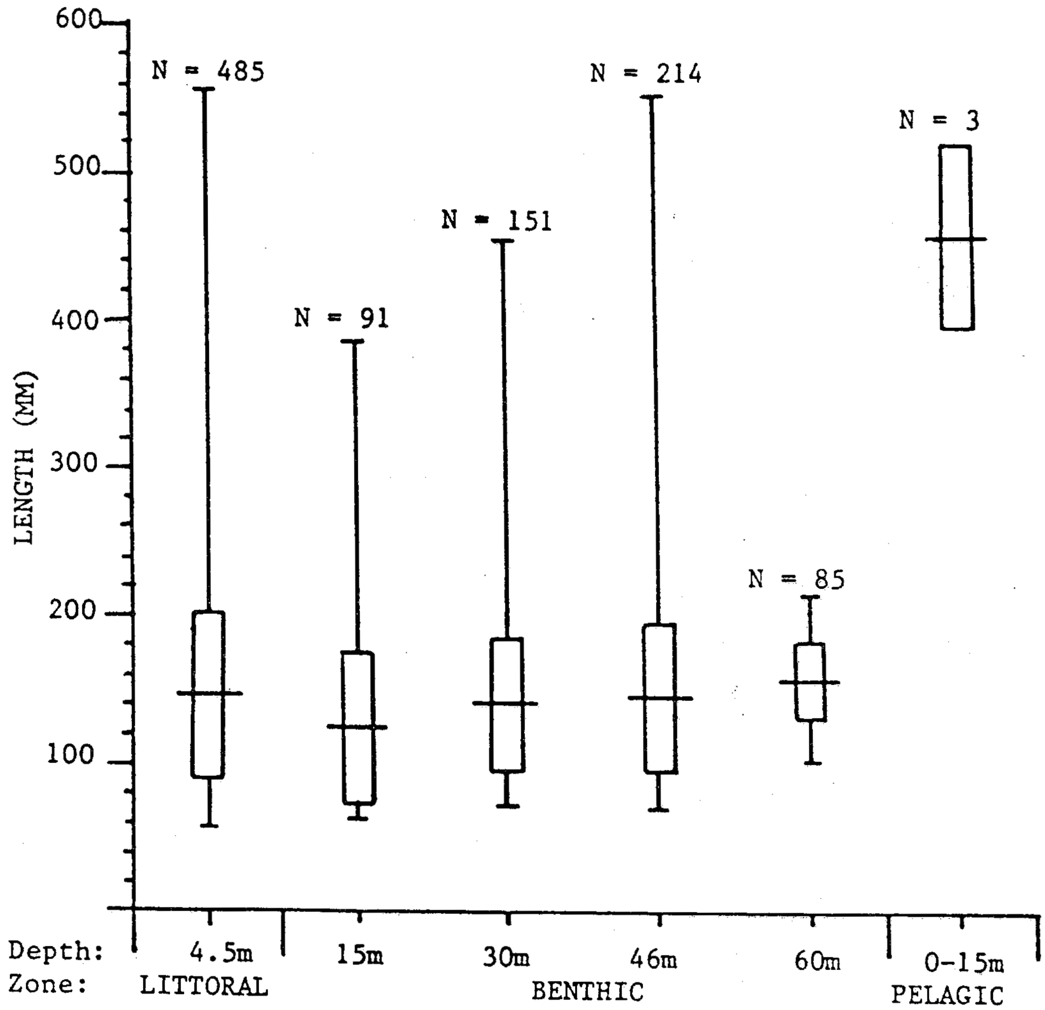

Figure 29. The mean, standard deviation, and range in length of char collected by depth in Indian Lake.

Table 26. Number of char sampled of each age class from the littoral and benthic zones in Indian Lake, 1979.

	AGE														
Depth Zone	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Mean
Littoral	14	71	95	98	102	53	13	14	8	4	3	1	-	1	4.3
15 m	4	29	26	15	9	6	-	-	-	-	-	-	-	-	3.2
30 m	-	17	35	38	42	6	2	1	4	1	2	-	-	-	4.2
46 m	2	11	43	67	54	17	4	1	2	2	5	-	1	-	4.5
60 m	-	-	9	23	33	8	1	3	2	1	-	-	-	-	4.9

and gill nets were fished at all depths (primarily the 46 m depth stratum), except between 5 and 15 m.

A total of 203 kokanee were captured; 108 were marked and released in June and only three were recaptured in August (Table 27). No valid Peterson population estimates could be made. The Peterson estimate is always biased low by the probability of getting no recapture. Ricker (1975) states that this statistical bias is negligible when recaptures are more than three. Few kokanee were captured due to their low susceptibility to the sampling gear and their apparent low density. Most kokanee were captured either in the shore-based fyke nets or in floating gill nets.

A total of 7,030 sticklebacks were marked, 5,323 were examined for marks and 200 were recaptured. Valid estimates for sticklebacks were obtained for Second Lake and each half of Indian Lake (Table 28). The total estimated stickleback abundance in these lakes was 187,625 with a 95% confidence interval of 145,595 to 301,535 fish based on a summation of the independent Peterson estimates. The density (fish/hectare) of stickleback in Second Lake was 3,988 and 602 in Indian Lake.

A total of 97 sticklebacks were removed from First Lake. No population estimate of stickleback was possible due to their low catchability (probably low abundance) and the fact that gill nets are not selective toward this species. All sticklebacks were captured from the littoral zone in minnow traps during the first sampling period.

Of the 12,553 sticklebacks captured from Second and Indian Lakes, 92% were captured from the littoral zone. All sticklebacks were captured at depths less than 30 m.

Only 13 coastrange sculpin were recaptured in the Indian Lake system from a total of 535 marked in June and 868 examined for marks in August. Table 29 lists the Peterson population estimates and confidence intervals for sculpin in each lake and stream. A more intensive sampling effort involving more traps and mark and recovery sampling would be needed to reliably estimate the abundance of sculpins in the system.

Of 1,416 sculpin caught in Second and Indian Lakes, 63% were captured in the littoral zone, 30% in the benthic zone to 15 m and 7% in the benthic zone between 15 and 30 m. No sculpin were captured in any gear fished off the bottom. None of the kokanee, sticklebacks, or sculpin were recaptured in a different lake than that in which they had been marked.

In order to evaluate the feasibility of using the Indian Lake system as a natural rearing area for coho salmon, it is natural to compare it to the Osprey Lake system located on southern Baranof Island in Southeastern Alaska. Osprey Lake is a 109-hectare oligotrophic lake with a resident population of Dolly Varden char. The U.S. National Marine Fisheries Service and ADF&G are cooperating in a research program to evaluate the potential of rearing coho salmon in Osprey Lake. In 1974, baseline limnological and ichthyological data were collected and in the following year 275,000 coho fry were released. This stocking program has been successful with 16% of the coho released emigrating at age 0 and 53% emigrating at age I (Heard 1977).

Table 27. Peterson population estimates for the abundance of kokanee in Second Lake, Long River, each half of Indian Lake, and Indian River.

Lake/River	Number Marked (M)	Number Examined For Marks (C)	Number Recaptured (R)	Population Estimate (N)	Confidence Interval Lower	Confidence Interval Upper
Second Lake	13	9	1	70	21	1,170
Long River	0	1	0	-	-	-
inlet half of Indian Lake	68	44	1	1,552	534	22,920
outlet half of Indian Lake	27	38	1	546	183	10,260
Indian River	0	0	0	-	-	-

Table 28. Peterson population estimates for the abundance of threespined stickleback in Second Lake, Long River, each half of Indian Lake, and Indian River.

Lake/River	(M)	(C)	(R)	(N)	Confidence Interval Lower	Confidence Interval Upper
Second Lake	2,360	2,342	101	54,234	45,040	66,492
Long River	53	213	1	5,778	2,016	112,890
inlet half of Indian Lake	449	739	7	41,625	23,042	118,504
outlet half of Indian Lake	4,164	2,026	91	91,766	77,513	116,539
Indian River	4	3	0	-	-	-

Table 29. Peterson population estimates for the abundance of coastrange sculpin in Second Lake, Long River, each half of Indian Lake, and Indian River.

Lake/River	(M)	(C)	(R)	(N)	Confidence Interval Lower	Confidence Interval Upper
Second Lake	245	279	9	6,888	3,997	17,089
Long River	8	88	0	801	190	open
inlet half of Indian Lake	118	194	0	23,205	6,187	open
outlet half of Indian Lake	154	301	4	9,362	4,544	46,354
Indian River	10	6	0	-	-	-

Comparisons between the morphological and limnological characteristics of the Indian Lake system and the Osprey Lake system are detailed in Table 30. Indian Lake has more than twice the surface area of Osprey Lake, it is half as deep, and has approximately three times more area less than 15 m in depth. The surface water temperature from June to August in Indian Lake averaged 12°C; Osprey Lake was slightly cooler at 11°C. The mean secchi disk reading (a measure of light extinction and thus depth of the euphotic zone) in First Lake was 3.9 m, in Indian Lake was 6.4 m and in Osprey Lake was 11.7 m. The very low value for First Lake was partially due to the high Colored Organic Matter (COM) level which imparts a dark color to the water and limits light penetration (Crone and Koenings 1975). The secchi disk readings in Indian Lake decreased with the inflow of glacial Long Lake water. This inflow of Long Lake water is expected to be negligible by 1985 as more of Long Lake water is diverted for hydroelectric power. The water temperature and clarity of Second and Indian Lakes will certainly increase as will the productivity of these lakes.

The mean zooplankton density in Indian Lake was four times greater than that in Osprey Lake in 1975 (Figure 30). First Lake had the highest zooplankton density. Comparison of the 1974 (pre-coho stocking) zooplankton density in Osprey Lake with the zooplankton density in Indian Lake is difficult because the nets used had different mesh sizes. The net specifications used in the 1975 sampling of Osprey Lake were the same as that used in the Indian Lake system, #10 nitex. Copepods were the only type of zooplankton sampled from Indian Lake and composed over 70% of the zooplankton sampled from Osprey Lake in 1975 (Figure 30). Rotifers were the dominant zooplankton in First Lake.

Some insight into the productivity of the Indian Lake system results from an examination of the abundance and growth of the resident fish and through comparisons with the Osprey Lake system (Table 31). In the Indian Lake system, kokanee, threespined stickleback, coastrange sculpin, and Dolly Varden char are present. In the Osprey Lake system Dolly Varden char are the only fish species present. The density of char (number of char per hectare) in Second and Indian Lakes is greater than the density of char in Osprey Lake. The mean annual length increment for char aged II to VIII in Osprey Lake is 21.2 mm. The mean annual length increment for the same age class of char in the Indian Lake system is 21.7 mm. Thus little difference in overall growth rate exists between these two populations of char. Larger, older char were captured in the Indian Lake system. The mean annual length increment for all age classes of char collected from throughout the Indian Lake system was 29.8 mm. Perhaps the longer life span, larger size, and slightly faster growth of the Indian Lake system char is related to the presence of kokanee, sticklebacks, and sculpins. These resident fish could contribute substantially to the diet of larger, older char. To answer this question a more intensive investigation of the diet of these larger char would be required.

The growth of larger char in the Indian Lake system was faster than that of smaller char. A change in slope in the growth curve occurred when the char were approximately 200 mm in length. Char larger than 200 mm might become more piscivorous.

The char in the Indian Lake system have relatively slow growth and a long life span. Their fecundity is low, averaging less than 200 eggs; however, their reproductive potential is great since they mature at an early age and spawn

Table 30. Morphological and limnological characteristics of First Lake, Second Lake, Indian Lake, and Osprey Lake.

Characteristic	First Lake	Second Lake	Indian Lake	Osprey Lake[1]
Surface Area (hectares)	2.4	13.7	221.6	109
Maximum Depth (m)	14	33	63	120
Mean Depth (m)	4	9	31	60
Percent Area < 15 m deep	100	62	45	14
Depth of Thermocline (m)	3	-	distinct thermocline absent	8
Mean Surface Water Temperature (°C), June - August	16	-	12	11
Mean Secchi Disk Transparency (m), June - August	3.9	-	6.4	11.7
Alkalinity (mg/L), surface	2	-	2	3
Hardness (mg/L), surface	2	-	2	4
pH, surface	5.5-5.8	-	6.6-6.8	5.8-6.3
Mean Zooplankton Density (organisms per m^2) June-August	14,090	-	2,521	426[2] 623[3]

[1] From Schmidt and Robards (1975) and Schmidt and Robards (1976).

[2] Mean zooplankton density in 1974, #20 Nitex net.

[3] Mean zooplankton density in 1975, #10 Nitex net, same net as that used in First and Indian Lakes.

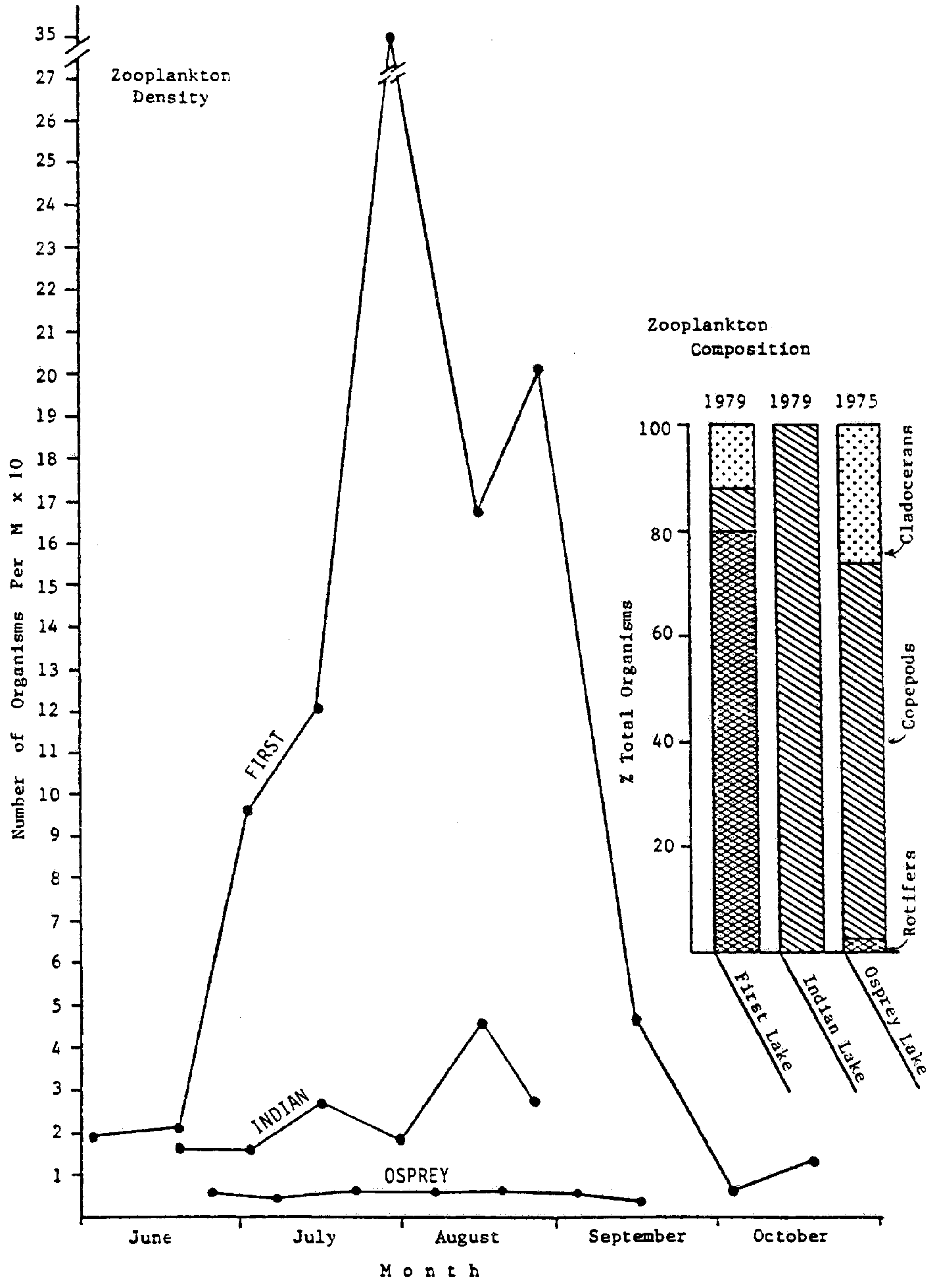

Figure 30. Zooplankton composition and density for First and Indian Lakes (1979) and Osprey Lake (1975).

Table 31. Comparison of icthyological data between the Indian Lake system and the Osprey Lake system.

Characteristics	First Lake	Second Lake	Long River	Indian Lake	Indian River	Osprey Lake[1]	Osprey River[1]
Kokanee abundance	absent	> 70	present	> 2,098	present	absent	absent
Stickleback abundance	present	54,234	> 5,778	133,391	present	absent	absent
Cottid abundance	absent	6,888	> 801	> 32,567	present	absent	absent
Dolly Varden char abundance[2]	73	2,281	9,162	24,909	3,012	12,327	1,200
Char per hectare	30	162	-	123	-	113	-
Mean char length and range (mm)[3]	168 (91-302)	131 (75-437)	112 (62-283)	145 (58-556)	102 (60-189)	160 (68-295)	? (55-160)

[1] From: Schmidt and Robards (1976).

[2] Abundance at time of release.

[3] Possible bias in lengths due to size selective capture gear.

annually or every two years throughout the remainder of their life. The overall slow growth of Indian Lake system char is certainly a factor of the general low productivity of the system.

Kokanee in Second and Indian Lakes were found to grow little between age IV and V. This reduction in growth rate is possibly due to insufficient food.

Interspecific competition between introduced rearing coho salmon and the resident fish species is expected to be minimal. Competition for space and food is anticipated to be greatest between coho salmon and Dolly Varden char in streams and littoral zones of lakes; however, differences in these species' preferred food items and vertical distribution limits this interspecific competition. Dolly Varden char and coho salmon have behavior patterns which allow them to live in close proximity and yet keep their competition for space and food to a minimum (Armstrong and Morrow 1980). Murrell (1977) and Armstrong and Elliott (1972) found that in streams inhabited by Dolly Varden char and juvenile coho salmon, the char tended to occupy the benthic region while the coho occupied the mid and upper sections of the water column. Coho salmon stocked in Osprey Lake distributed themselves throughout the surface of the lake with concentrations near shore (Schmidt and Robards 1976). The majority of Dolly Varden char in Osprey Lake were found to reside near the bottom with only a small portion of the population believed to be limnetic. In the Indian Lake system few char were captured in any gear fished off the bottom. Similar spatial segregation has been observed between Dolly Varden char and cutthroat trout *(Salmon clarki)* with the char residing primarily in the benthic zone and the cutthroat residing in the upper 2 m of the water column (Andrusak and Northcote 1971, Schutz and Northcote 1972).

Competition for space between coho salmon and the other resident species is likely to occur since their distributions coincide. Most kokanee in the Indian Lake system were found to reside in pelagic and littoral waters. The majority of sticklebacks and cottids were captured in streams and littoral areas. The extent of this competition is not predicted to be large.

Competition for food between coho and char may be minimal because of differences in the spatial distribution and preferred food items of these two species (Armstrong and Elliott 1972, Schmidt and Robards 1976, Murrell 1977). Coho in Osprey Lake fed almost exclusively on plankton and Chironomidae whereas the Dolly Varden char fed primarily on Chironomidae and other benthic invertebrates (Schmidt and Robards 1976). Plankton were the most frequently eaten food item of these coho and were felt to contribute the most to the growth of the coho. No zooplankton were found in the stomachs of char collected from the Indian Lake system. In streams insects comprise the bulk of both species' diet; however, char eat mainly sub-surface forms, and coho eat mainly surface forms (Armstrong and Elliott 1972, Murrell 1977).

Coho in Osprey Lake were found to selectively feed on a large species of copepod, *Diaptomus kenai*, and on larger cladocera. No *D. kenai* or cladocerans were present in the zooplankton hauls from Indian Lake. However, coho released into Indian Lake are expected to feed on zooplankton initially. Coho will probably select the larger, more visible zooplankton species. After depleting the zooplankton, the coho will begin feeding on aquatic or terrestrial invertebrates (Dr. Jeff Koenings, March 18, 1980. Memo: Sample analysis - Indian Lake System, ADF&G, Fisheries Rehabilitation, Enhancement, and Development Division, Soldotna, Alaska).

Some predation on coho by char can be expected, especially in the littoral zone which large char and coho would cohabit. Dolly Varden char preyed on coho salmon fry released in Osprey Lake (Crone 1976). Some large char contained up to 15 coho fry each. Char which had preyed on coho fry were usually larger than 150 mm. The incidence of char containing coho fry declined as the coho grew and as they dispersed throughout the lake. Heavy predation by Dolly Varden char on kokanee, sticklebacks, cottids or other char was not observed in the Indian Lake system. Likewise, predation by char on coho fry is not expected to be substantial.

Kokanee, sticklebacks, and cottids may also compete for food with rearing coho salmon. Kokanee feed on zooplankton in limnetic and pelagic regions of the lake (Forester 1968). The kokanee are primarily pelagic feeders although during some months a large proportion of their diet consists of emerging bottom fauna (Northcote and Lorz 1966). Sticklebacks are opportunistic feeders and will consume a wide variety of food items. The diet of sticklebacks is reported to include zooplankton, benthic and terrestrial invertebrates, gastropods, nematodes, molluscs, stickleback eggs and larvae, and some algae and higher plant tissue (Hynes 1950; Greenbank and Nelson 1959). In some lake systems sticklebacks are thought to compete strongly for food with juvenile sockeye salmon (Forester 1968); Harman and Burgner 1972). Coastrange sculpin are primarily bottom feeders. Their diet includes benthic invertebrates, molluscs, crustaceans, aquatic vegetation, and fish and fish eggs (Roger 1971). Since coho salmon eat a wide variety of food items including zooplankton and benthic invertebrates the diets of coho and these resident fish species will overlap to some degree.

CONCLUSIONS

The Indian Lake system is suitable for rearing coho salmon parr. The overall productivity of the Indian Lake system is greater than that of Osprey Lake. Competition for space and food between rearing coho and the resident fish species, is anticipated to be minimal. Some predation of coho by char can be expected.

The coho fry stocked in Osprey Lake were held in rearing pens until 15 July. This late stocking date enabled the coho to grow to an average size of 47 mm fork length (1.26 g) and also enabled the standing crop of zooplankton to bloom naturally following low winter zooplankton levels. It was felt that coho fry with a length of 45 mm or larger had a better chance of avoiding predation by the Dolly Varden char than newly-emerged fry (Crone and Koenings 1975). Also it was believed the larger coho would be better able to compete for food with the resident fish. Any coho stocking program in the Indian Lake system should follow this midsummer release strategy.

The limnology of the lake should be closely monitored to determine the optimal time to plant coho fry. In particular, the zooplankton composition, density, and biomass should be well understood. Recent work done in Hidden Lake, Alaska found that the peak zooplankton biomass occurred approximately six weeks later than the peak density (Gary B. Kyle, March 14, 1980. Memo: Zooplankton data analysis, ADF&G, Fisheries Rehabilitation, Enhancement, and Development Division, Soldotna, Alaska). The optimum fry release might best be synchronized with peak biomass rather than peak density. Further study, as required by ADF&G policy, will involve investigation of the primary productivity of the system. This includes monitoring the volumetric carbon density, chlorophyll "A", and intensive water chemistry and dissolved nutrient sampling. It is suggested that the stocking density of coho salmon fry in the Indian Lake system should be relatively low, 1,700 to 2,300 fry per surface hectare. Coho stocking density in Osprey Lake was approximately 2,470 fry per surface hectare. The optimum stocking density is one that produces the largest number of yearling smolt (Crone and Koenings 1975). The transformation from parr to smolt is believed to be size dependent. The threshold size is approximately 75 mm by October, for coho salmon in the Little Port Walter area, southern Baranof Island, Alaska (Crone and Koenings 1975). It is not believed that there is any survival advantage for coho which spend a second year in fresh water prior to smolting. In addition, if a large number of coho remain in fresh water for a second year the zooplankton and benthic invertebrates are unable to recover to their normal density. Subsequently, the growth of the older coho is slow and some might still not reach the threshold size for smolting. During this time the coho are subject to additional year(s) of freshwater mortality.

The available coho rearing area in Indian Lake is 28,607,500 m^3 and the estimated rearing area in Second Lake is 924,600 m^3, assuming a maximum rearing depth of 15 m. Based on minnow trapping of the coho released in First Lake, the maximum rearing depth is approximately 5 m; thus the available rearing area is approximately 73 m^3. Additional rearing area is available in Long and Indian Rivers which total approximately 3,100 m in length. A proportion of the coho released in Osprey Lake moved out of the lake into the outlet stream, but the growth rate of these stream-rearing coho was slower than that of the lake-rearing coho

Stocking of coho in the Indian Lake system should not be done annually. Restocking the system with coho should be done only after the secondary producers have reached the pre-stocking level of abundance. At a stocking density of 2,000 fry per surface hectare, approximately 475,000 coho can be released into the Indian Lake system. If the fry-to-smolt (yearling) survival is 40% and the marine survival is 5% approximately 9,500 coho salmon will return to contribute to sport, commercial, and subsistence harvests.

A lake stocking program in the Indian Lake system would probably benefit from an accompanying lake fertilization program. Fertilization with nitrogen and phosphorus might increase the zooplankton density. If sufficient numbers of zooplankton are available the rearing coho will reside primarily in the limnetic area of the lake, thus reducing interspecific competition with the four resident species. Addition of nutrients to the system should be done on a periodic basis throughout the summer months. Pre-existing water quality, chemistry, and nutrient levels should be well understood along with the density, biomass, and species composition of primary, secondary, and tertiary producers. There should be strong evidence that the nutrient(s) added to the system are in fact limiting factors in fish production.

At present there are no sure methods to accurately predict the outcome of a lake stocking or fertilization program. This is due to the complexity of the lacustrine environment; the difficulty in assessing all its physical, chemical, and biological characteristics; and the unknown relationships of these factors with fish production. The sampling program reported here provides insight into the ecology of the Indian Lake system and improves the likelihood that proper decisions can be made during a coho salmon stocking program.

SUMMARY

1. This study examines population characteristics of resident Dolly Varden char, kokanee, threespined stickleback, and coastrange sculpin in the Indian Lake system, Southeastern Alaska, during the summer of 1979. Dolly Varden char were the target species.

2. To determine the abundance, movement, and spatial distribution of char in each lake and river, a total of 15,911 char were captured of which 10,011 were marked and released in June, 5,900 were examined for marks in August, and 1,731 were recaptured. A total of 200 kokanee, 12,353 sticklebacks, and 1,403 sculpin were also captured for mark and recapture abundance estimation.

3. During recapture sampling in August a total of 1,829 char and 70 kokanee were killed from throughout the Indian Lake system to determine age (otolith), length, weight, sex, and gonad condition.

4. The abundance of char in First Lake was estimated to be 73 with a confidence interval of 62 to 96 (at the 95% confidence level). The combined abundance of char in Second Lake, Long River, each half of Indian Lake, and Indian River was estimated to be 40,364 ± 3,006 (at the 95% confidence level).

5. There was considerable movement of char within and between each lake and river. An estimated 12.9% of the char in a particular lake or stream in June had moved into another lake or stream by August.

6. In Second and Indian Lakes most char resided near the bottom at all depths. A small pelagic population of char might exist.

7. The smallest char sampled was 58 mm in length and the largest was 556 mm. The char ranged in age from I to XIV.

8. Char aged I, II, and III resided primarily in the rivers of littoral zones of lakes. Larger, older char were captured at all depths.

9. The sex ratio of char in each lake and river was 1:1.

10. The growth rate of male char was significantly higher than that of females. There was no difference in growth by sex for immature char. The slower growth of females is probably due to spawning stress.

11. The majority of char were mature at age V. Char spawned both annually and less frequently once sexual maturity was reached. The probability of annual spawning for females was greater than that for males. The mean fecundity of a sample of eight char was 117 eggs.

12. The char were found to consume a wide variety of food items with benthic invertebrates comprising the bulk of the diet. Chironomids (larvae and pupae) were the most common food item. Diet diversity was lowest for char sampled from the benthic zones and highest for char from the stream and littoral zones.

13. Sticklebacks and sculpin were captured most commonly in traps set on the bottom of lakes at depths down to 30 m. Kokanee were captured most frequently in shore-based fyke nets or in floating gill nets.

14. First Lake is eutrophic, with a high COM level, a shallow thermocline and euphotic zone, and relatively high zooplankton density. Second and June Lakes are oligotrophic, receiving cold silt-laden glacial water from August to November. Zooplankton density in First Lake averaged 14,090 organisms/m^3 from June to August and in Indian Lake 2,521 organisms/m^3. The surface of First Lake averaged 4°C warmer than the surface of Indian Lake.

15. The overall productivity of the Indian Lake system is greater than that of the Osprey Lake system, another Southeastern Alaska lake system which has had a successful coho salmon lake stocking program.

16. Based on the limnological and ichthyological data collected and on the comparison of the Indian Lake system with the Osprey Lake system, use of the Indian Lake system as a natural rearing area for coho salmon appears feasible.

17. The greatest competition for space and food between introduced rearing coho and the four resident species of fish is expected to be in the streams and littoral zones of the lakes.

18. The estimated rearing area available for coho salmon, assuming a maximum rearing depth of 15 m, is 924,600 m^3 in Second Lake and 28,607,500 m^3 in Indian Lake.

19. A midsummer stocking of advanced coho fry (larger than 45 mm) at a stocking density of from 1,700 to 2,300 fry/hectare is recommended initially.

20. A large scale coho stocking program in the Indian Lake system would probably benefit from an associated lake fertilization program.

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APPENDICES

Appendix A. Flow chart for disinfection[1] and preservation of salmon roe bait.

Procure roe from mature but not ripe salmon

↓

cut into 3 cm x 3 cm pieces

↓

disinfect eggs by soaking in 5% Betadine solution for 15 minutes

↓

remove eggs from Betadine solution and drain

↓

rub eggs with a generous amount of Borax (approximately 1 kg Borax per 5 kg eggs)

↓

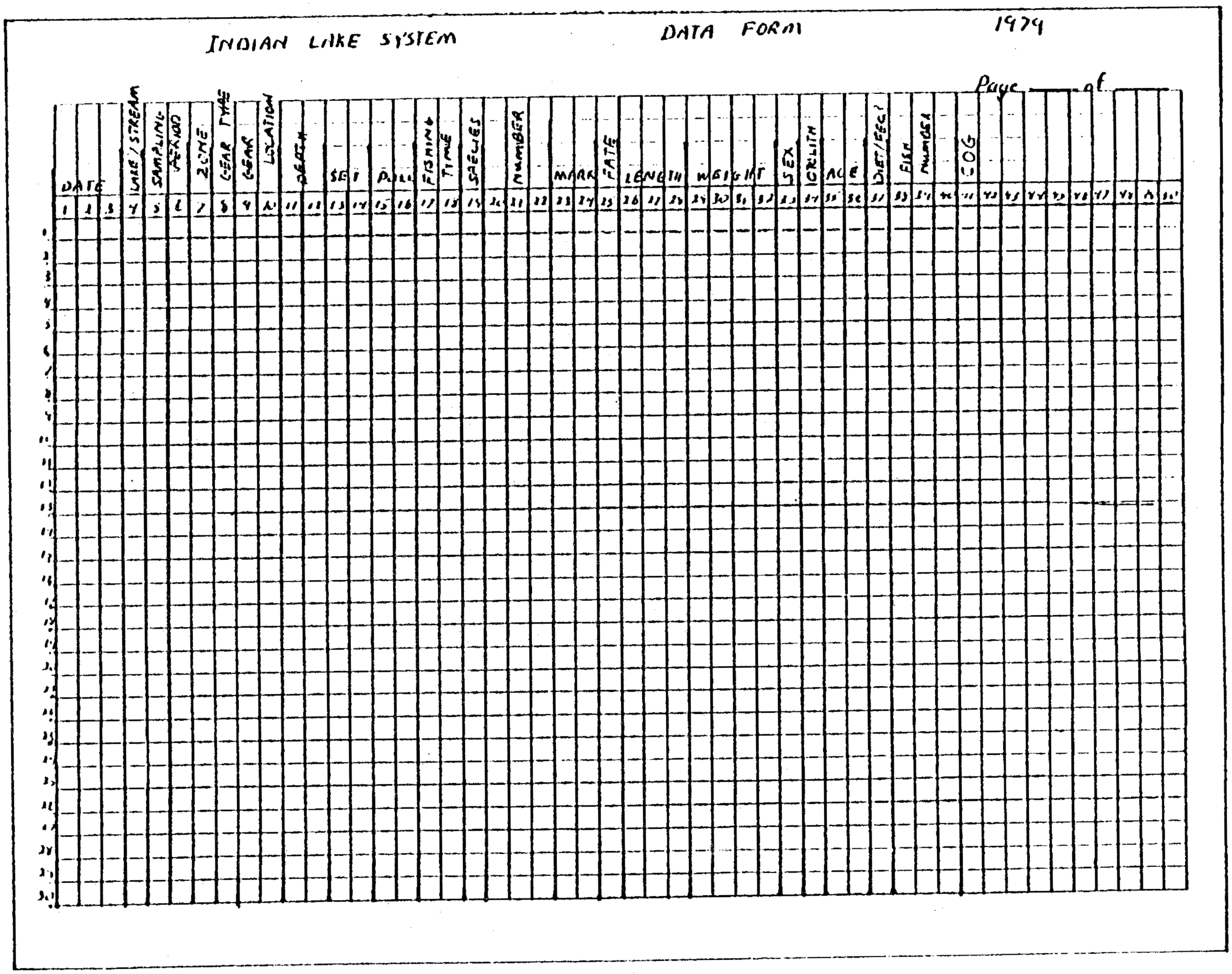
place Boraxed eggs in sandwich bags

↓

store frozen until use

[1] Disinfection procedure recommended by Al Didier, Regional Pathologist, ADF&G, FRED Division, Juneau.

Appendix B. Data form used for ichthyological sampling in the Indian Lake system. All entries were coded numerically.



Appendix C. Comparison of different mark and recapture population estimates of Dolly Varden char in the Indian Lake system[1].

Lake/ Stream	Number Marked (M)	Number Examined for Marks (C)	Number Recaptured[2] (R)	Schnabel[3]	Peterson	Schaefer	Chapman-Junge
Second Lake	1,504	1,637	665	1,979 (1,857-2,118)	3,701 (3,431-3,995)	-	1,977
Long River	633	738	43	3,610 (2,866-4,876)	10,648 (8,068-15,021)	-	8,837
Inlet end of Indian Lake	4,299	2,694	618	9,648 (9,133-10,224)	18,721 (17,320-20,277)	-	15,892
Outlet end of Indian Lake	3,376	1,914	380	9,188 (8,597-9,866)	16,974 (15,378-18,802)	-	10,805
Indian River	199	360	21	845 (567-1,657)	3,282 (2,239-5,511)	-	3,211
Combined				25,270[4]	53,326[5]		40,722
	10,011	7,357	1,727		42,632[6]	37,525	(37,635-43,809)
	10,011	7,357	2,169		33,948[7]		

[1] All estimates refer to the number of char present in the lake or stream at initial sampling (June 1979).

[2] Number recaptured from the lake or stream in which they had been marked.

[3] Computed from marking run data.

[4] Summing Schnabel estimates.

[5] Summing Peterson estimates.

[6] Estimate based on combined M, C, and R.

[7] Estimate based on total M, C, and R.