Ref ID: 86116

MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS

FISHERIES DIVISION
JOB COMPLETION REPORT

STATE: Montana

PROJECT TITLE: Lake Fisheries Inventory

PROJECT NO.: F-33-R-18

JOB TITLE: Measure annual trends in recruitment and migration of kokanee populations and identify major factors affecting trends.

JOB NO.: I-b

PERIOD COVERED: July 1, 1983 to June 30, 1984

SUBMITTED BY: Delano A. Hanzel

ABSTRACT

Age and length of spawners, creel composition, and growth analysis of Flathead Lake kokanee have been monitored over 12 years. The collection of these parameters over a period of three life-cycles of the salmon provides a long-range overview of the population. Acoustic density estimates for salmon 250 mm (10 inches) and larger have provided an additional indice during the last five years.

Although length of spawners does reflect size changes, age of spawners was necessary to explain the interaction of age composition with the entire salmon population. Flathead Lake salmon have ranged in size from 277 mm (10.9 inches) in 1967 to 404 mm (15.9 inches) in 1938.

Length frequency of creel-caught kokanee provided the opportunity to measure the compensating effect of the interactions and contributions of strong and weak year classes to the overall lake population. Age 3+ salmon consistently provided the bulk of the angler catch in both summer and spring fishing seasons. Spring hand-line success rates were higher than experienced during the summer troll fishery.

Annual age and growth analyses were prepared to establish a base to evaluate future growth changes in the salmon population. A log-log relationship utilizing the Monastyrsky technique of back-calculating lengths was found to express fish length and body scale measurements best. Juvenile salmon (age 0 and 1) had completed formation of their annuli by January; annuli for older fish was not completed until May. The baseline growth analyses will provide information in the evaluation of future impacts caused by the recent buildup of Mysis shrimp in Flathead Lake.

Among Flathead River system spawners, age 3+ salmon was the dominant age comprising over 60% of spawners in all years. Although both sexes showed this dominance, more older males occurred in both river and lakeshore sites. The youngest aged spawners (age 2+) never contributed more than 12% of the total system spawners.

Variations in the patterns of thermal warming of the lake changed the availability of salmon to anglers and in turn influenced catch rates.

Acoustic density estimates of kokanee, 250 mm (10 inches) and larger, were made on the early fall mid-lake concentrations of salmon. These estimates did not include that portion of early-run kokanee which had already migrated into the river. Weighted average densities, representing total lake estimates, were calculated from 11 transects totalling over 80 km (50 miles). Total lake densities ranged from 38.7 fish/ha (16 fish/surface acre) in 1980 to 58.7 fish/ha (23 fish/sa) in 1982. The most notable change in the population was the fluctuation in numbers of large fish as they ranged from 3.9 fish/ha (1.6 fish/sa) in 1983 to 18.6 fish/ha (7.5 fish/sa) in 1980.

OBJECTIVES

Job Objective: It shall be the primary objective of the job to establish relative abundance of the six major fish species with the present segment emphasizing kokanee, and to identify the environmental factors affecting population changes.

BACKGROUND

Kokanee (Oncorhynchus nerka) salmon were originally introduced to Flathead Lake in 1916 but did not become well established until 1933. Salmon have provided a popular summer troll fishery and presently supports the second highest fishing pressure of any lake or reservoir in Montana (Montana Department of Fish and Game 1976). During the 1981-82 fishing season (May, 1981 to May, 1982), the lake provided 168,792 man-days of fishing pressure (Graham and Fredenberg 1982) with salmon representing 92 percent of the estimated 536,870 fish caught.

A snag fishery for the spawning kokanee was also available to the public along the lakeshores and in the river system above the lake. During the 1975 snagging season, an estimated 29,000 angler trips harvested 177,000 kokanee in the Flathead River (Hanzel 1977). Diminished numbers of river spawners in 1982 prompted the Montana Fish and Game Commission to close the upper Flathead River drainage to snagging. In 1983, the snagging season closure included Flathead Lake.

Although kokanee fry have been planted periodically in the past, it is believed that the lake fishery is dependent upon natural reproduction. Spawning areas extend from the lakeshore sites to gravel bar areas in the Flathead River system some 100 miles upstream from the lake. Water development projects in this system have had impacts on the salmon populations, primarily by altering lake elevations or river flows during spawning or egg incubation periods.

Phelps (1980) found a low amount of genetic variation within and between Flathead Lake and other regional lakes when he examined salmon electrophoretically at 70 loci. Only the locus, Pgm-2, was highly polymorphic. This variation present in the northwest kokanee populations is considerably lower than reported for other kokanee and sockeye stocks in the northwestern United States. Although genetic variation was small, subdivisions do exist in the kokanee of Flathead Lake and they should be treated as separate distinct units rather than be managed as one large population.

Size of mature salmon and general spawning location (Stephanich 1954 and Hanzel 1964) related the early status of the kokanee population in the lake and river. In 1966, the Flathead Lake fisheries study was initiated to gather baseline information on the fishes of

Flathead Lake (Hanzel 1970 and 1972). Since salmon is a pelagic species and is not easily collected in gill nets, this study offered only limited distribution patterns of the kokanee. With the development of a purse-seine and a mid-water trawl coupled with the use of an acoustical equipment (Hanzel 1974 and 1977), trend information on the salmon became available. Since then the salmon has been the target species of this study. Potter's (1978) description and comparison of the modern zooplankton population in the lake to that described by Forbes (1893) offered a basis for determining food availability to the plankton eating kokanee. Detailed food habits of kokanee, cutthroat trout and bull trout along with other associated species in Flathead Lake were described by Leathe and Graham (1982). Both investigations found the limnetic plankton to be dominated by the copepods Diaptomus and Cyclops and that the planktivorous fish in Flathead Lake prefer the large zooplankton, principally Daphnia thorata.

In 1978, an environmental impact study was initiated (Graham et al. 1980) over concern of potential adverse environmental effects on Flathead Lake and its upper river system by proposed coal mining in the Canadian portion of the North Fork Flathead River. Subsequently in 1979, Bureau of Reclamation (McMullin and Graham 1982) and Bonneville Power Administration (Fraley and Graham 1982) funded studies were undertaken to assess the effects of the operation of Hungry Horse Dam on the kokanee fishery of the Flathead River system. These studies in that portion of the Flathead River below the mouth of the South Fork exemplified that the most important factor affecting year class strength in Flathead kokanee was heavy incubating mortalities. These losses of salmon reproduction were incurred as a result of fluctuating river flows found below this peaking power facility. These flows during the cold winter incubation period caused spawning gravels to be dewatered and then the eventual drying or freezing of eggs. Stable spawning and incubation flows are part of the proposed recovery plan. A similar investigation (Decker-Hess and Graham 1982) on effects of the operation of Kerr Dam on kokanee shoreline reproduction was initiated in 1981 and is still in progress.

DESCRIPTION OF STUDY AREA

Flathead Lake is one of the largest natural lakes in the United States west of the Mississippi. It is located in northwestern Montana situated at an elevation of 882.4 m (2,893 ft. msl) in a glaciated valley 32 km (20 mi.) west of the Continental Divide and 105 km (65 mi.) south of the United States and Canadian Border (Figure 1). The lake has 509.9 km^2 (126,000 surface acres) with a maximum depth of 117.7 m (386 ft.). The 199.1 km (123.7 mi.) of shoreline delimits its maximum length of 43.9 km (27.3 mi.) and breadth of 24.9 km (15.5 mi.). Main physical features include a mid-lake river-delta depositional bar (10 km in length); a deep benthic trough (100+ m deep) which persists along its entire east shoreline; extensive shallow (less than 20 m) areas with sandy

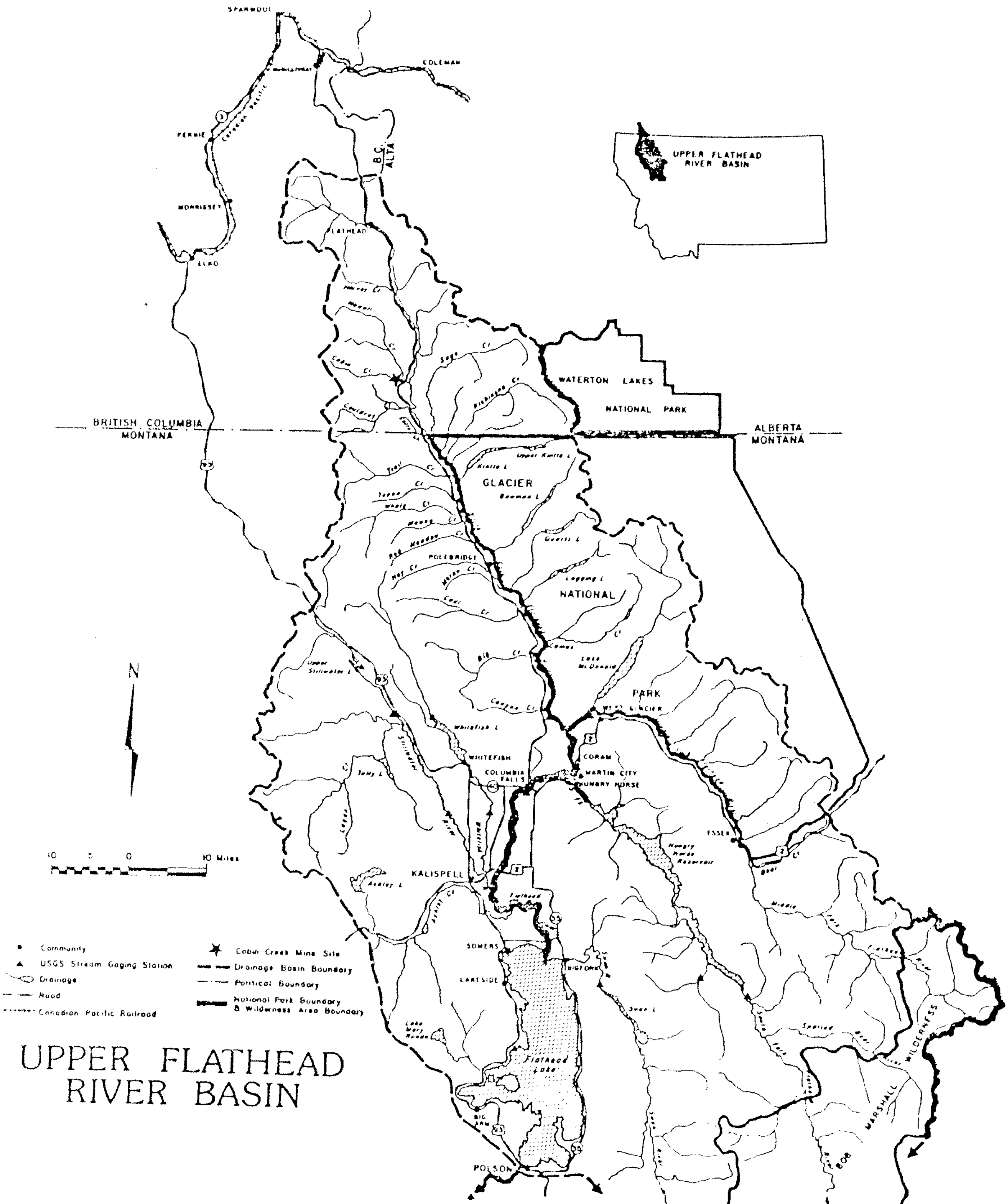


Figure 1. Map of the Upper Flathead River Basin. Adapted from Montana Department of Natural Resources and Conservation (1977).

bottoms at its extremities (inlet and outlet); and a large island 8.9 km^2 (2,200 acres) (Figure 2).

Flathead Lake is an integral part of a lake-river system which acts as a settling basin for most of southeastern British Columbia and northwestern Montana, a total drainage area of 21,876 km^2. The largest tributary to the lake is the Flathead River, with an average flow of 9,753 cubic feet per second (cfs) at Columbia Falls (U.S. Geological Survey 1981). Three forks of the Flathead River (North, Middle and South Forks) drain large areas of undisturbed lands including all areas west of the Continental Divide of Glacier National Park (2,266 km^2) and Bob Marshall Wilderness Area (3,842 km^2) and the 1,156 km^2 of the Great Bear Wilderness. The remoteness and relatively undisturbed resources of the upper Flathead River drainage area coupled with underlying nutrient-poor sedimentary rock enables Flathead Lake to remain in a pristine or oligotrophic state. The mean annual primary productivity of 123 grams carbon/m^2/year (Stanford et al. 1981) is somewhat higher than what would be considered for a oligotrophic lake and thus reclassification has been advanced to oligo-mesotrophic.

A paved highway surrounds the lake providing access to the permanent and summer homes found along its entire shore. Population centers on the lake are located at Polson, Somers, Lakeside and Bigfork. Kalispell, the largest city in the valley (22,860 inhabitants, 1983 census), lies 11 km (7 mi.) to the north of the lake. Moderating air temperatures, created by the heat capacitance of this large lake, have allowed successful orchard (cherry and apple) production along areas of the east and west shorelines.

Kerr Dam, a private power facility located 7 km (4 mi.) downstream from the lake on the Flathead River, was completed in 1938. This structure controls the upper 3.05 m (10 ft.) of the lake. Prior to Kerr Dam, lake elevations responded to natural runoff and precipitation. Levels remained relatively constant at low pool elevation (878.4 m or 2,882 ft.) from September to mid-April (Hanzel 1974). Spring runoff raised lake levels to the annual maximum (1.8 to 3.7 m or 6 to 12 ft. above low pool) during May or June and then levels receded slowly back to the sustaining low pool. Since impoundment, maximum operational lake elevation of 881.8 m (2,893 ft.) is reached by mid-June and is maintained until September when drafting for winter power begins. Be an agreement between power, agricultural and recreational interests, this facility's operation requires that the minimum operational pool of 878.7 m (2,883 ft.) be reached by mid-April. Filling occurs thereafter, with considerations given for flood control during this period. An elevation of 881.1 m (2,890 ft.) is to be reached by Memorial Day and then to full operational pool by mid-June and maintained through Labor Day (Montana Power Company, pers. comm.).

Of the 25 fish species listed for Flathead Lake by Gaufin et al. (1976), 19 persist in the lake today. Ten of these fish are native to these waters. Four of the seven common game fish species

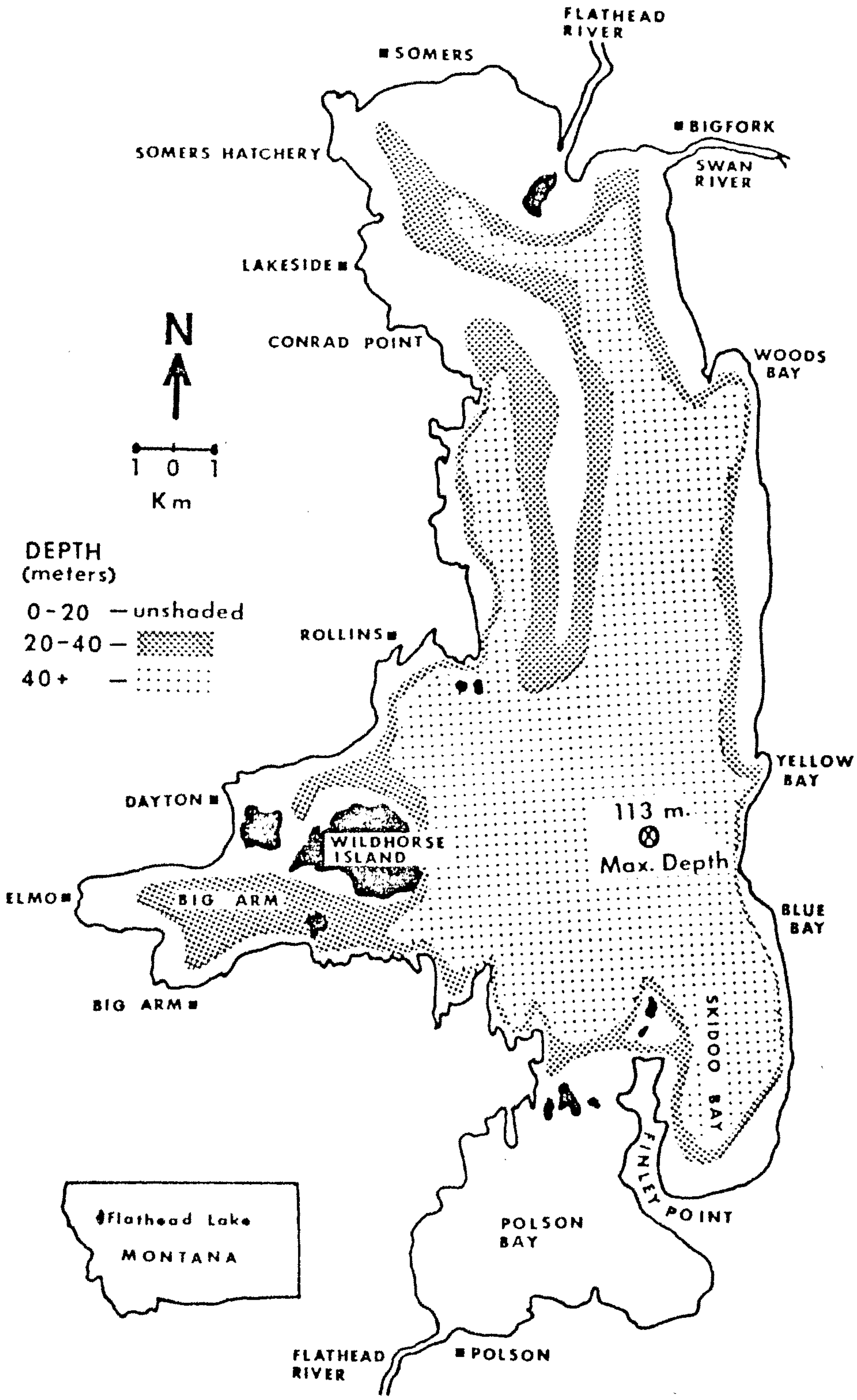


Figure 2. Map of Flathead Lake, Montana including 20 meter depth contours.

are native and include the westslope cutthroat trout (Salmo clarki lewisi), bull trout (Salvelinus confluentus), mountain whitefish (Prosopium williamsoni) and pygmy whitefish (Prosopium coulteri). Other common game fish include the kokanee, lake trout (Salvelinus namaycush) and lake whitefish (Coregonus clupeaformis). The remaining occasional game fish species are the rainbow trout (Salmo gairdneri), brook trout (Salvelinus fontinalis), largemouth bass (Micropterus salmoides) and black bullhead (Ictalurus melas). The first occurrence, in 1972, of one additional game fish species, the northern pike (Esox lucius) was the result of an illegal introduction of these species into the Flathead Lake system. Their present occurrence in the lake is rare. Common nongame fish include the yellow perch (Perca flavescens), pumpkinseed (Lepomis gibbosus), northern squawfish (Ptychocheilus oregonensis), peamouth (Mylocheilus cauarinus), longnose sucker (Catostomus catostomus), largescale sucker (Catostomus macrocheilus), redside shiner (Richardsonius balteatus) and slimy sculpin (Cottus cognatus). With the exception of the perch and pumpkinseed, all are native.

METHODS

WATER TEMPERATURE

Water temperature profiles were made using a resistance thermometer coupled to a depth sensor (Hydro Products - Bathythermonitor). Temperatures were measured in degree Fahrenheit from the surface to the bottom with water depths recorded at each degree change of temperature.

KOKANEE AGE AND GROWTH

Fish Sampling Methods

Over half (65.6%) of the 5,563 scale samples used in this age and growth analysis were extracted from kokanee caught by anglers. A purse seine (31.8%) and a mid-water trawl (2.5%) were also used to provide additional samples; particularly from younger salmon. Gill nets (floaters, sinkers, suspended-monofilament, nylon strand) were all used but failed to provide appreciable numbers of salmon.

Creel checks were made during the summer (June-August) from 1972 to 1983 and during the winter period from 1981 through 1983. The summer censuses were conducted in all of the major salmon fishing areas, while winter censuses were confined to area 7 (Figure 3).

All of the young-of-the-year and most of the yearling kokanee were collected in the 3.05 m x 3.05 m (10 x 10 ft.) mid-water trawl towed behind the research boat, the Dolly Varden. This fixed frame single-line trawl (Hanzel 1977) had a cod end mesh of 1.6 mm (bar measure) capable of retaining fish as small as 13 mm. Trawling was conducted at night in areas where concentrations of kokanee were detected by acoustic equipment. Summer concentrations of mature-sized salmon occurred in pelagic areas while juvenile salmon were found in the fall just off the bottom (1 m) at depths from 20-30 m. The trawl was employed from 1975 through 1983. Its use was limited to the months of June-November; the normal period when the use of the Dolly Varden was not restricted because of inadequate docking facilities during low pool elevations or winter icing. The majority of trawling occurred in kokanee areas 1, 2, and 3.

A purse seine developed by Hanzel (1972) was used in 1972, 1973, 1974 and 1981 and provided specimens of salmon age 2+ and older. The seine, 18.3 m x 171 m (60 x 560 ft.), was fished during daylight hours and fished to depths of 15 m (49 ft.). Sampling was accomplished during June and July, the period prior to the time when warming surface water temperatures forced the salmon to utilize depths greater than the fishable depth of the seine. The majority of sampling with the seine was accomplished in kokanee area 1, with additional samples from areas 3, 5, and 6.

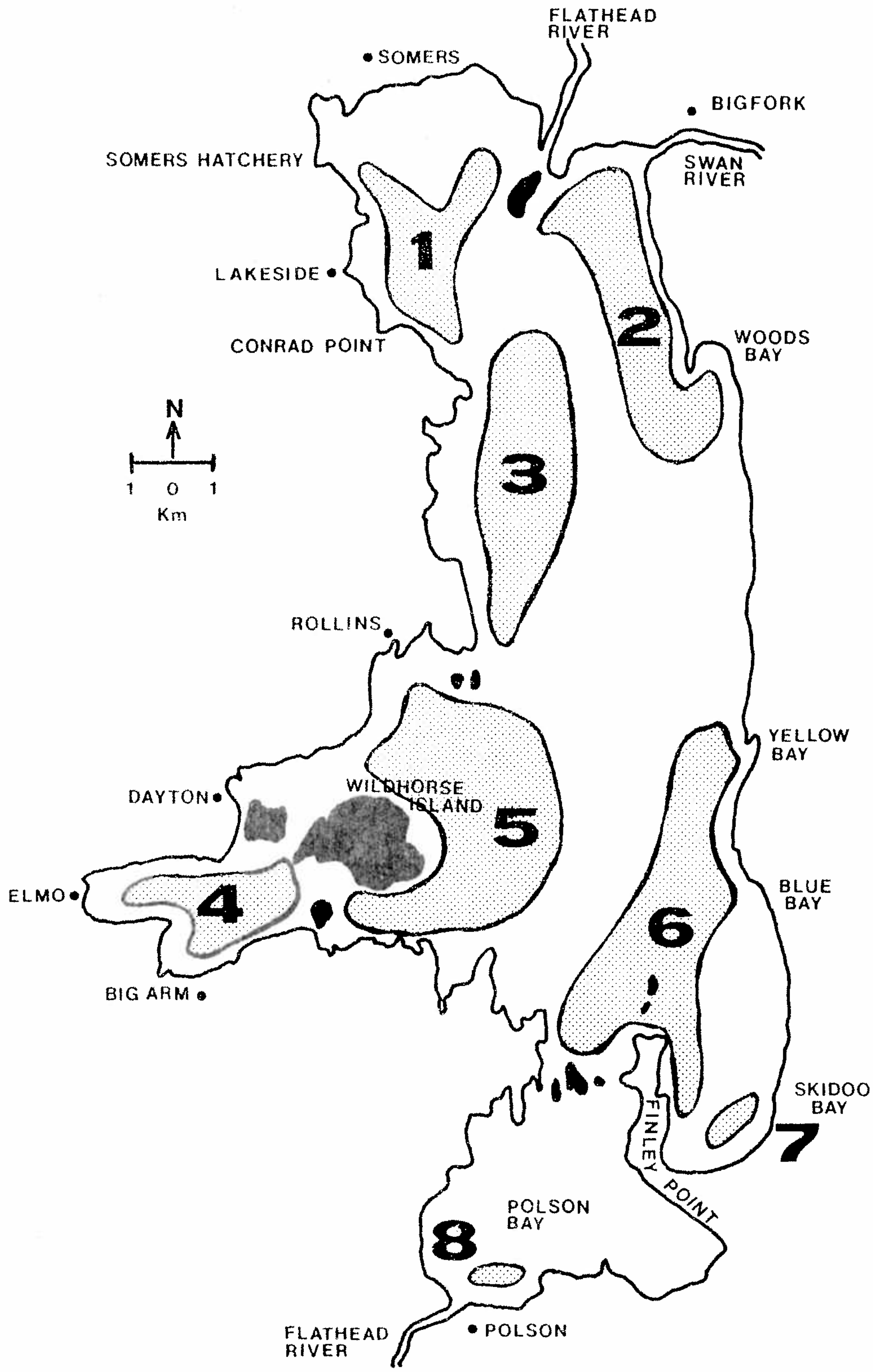


Figure 3. Locations of popular kokanee fishing areas (shaded portions) on Flathead Lake.

Sampling of mature kokanee taken on their spawning sites included five areas along the lakeshore and three areas in the river system above the lake. Sampling at the spawning sites generally did not occur until a majority of the fish on that site had already spawned. Methods used in capturing these fish included overnight sets of gill nets, a beach seine and electrofishing. On shallow spawning sites, less than 2 m deep along the lake and in the river, a sample was often obtained by setting a gill net shaped like a "U" and the fish driven into the net by the action of a boat or even throwing of rocks into the water.

Scales and Otoliths

Kokanee were first measured to the nearest millimeter to total length (T.L.) and weighed to the nearest gram. A scale sample was extracted from the fish in an area above the lateral line and just posterior to the dorsal fin. Scales were taken from the fourth row of scales above the lateral line and stored in individual envelopes. A representative sample of otolith bones (sagittae) were also collected from the same fish from each of the age groups represented. They were used as a method of age validation and assisted in reading age of otoliths collected from mature salmon taken during the spawning season.

All otolith bones were extracted from their cavities beneath the brain with the aid of forceps made accessible through an opening made with a knife 6 mm (1/4 inch) behind the eye and through the cranial bones. They were preserved in the dry state in individual scale envelopes. The bones were later submersed in water in a blacken-watch glass and examined under reflected light at 15X magnification using a dissecting microscope. The aging technique on otoliths was the same as described by Kim and Roberson (1968). The winter growth (hyaline zone) consisting of mainly organic matter appeared dark or black under reflected light, while the faster summer growth period (opaque zone) with a relative abundance of inorganic material appeared white. All hyaline zones, with the exception of hyaline in the nucleus, were counted as annuli.

Cellulose acetate impressions were made from the scales in a hydraulic press with heated plates and examined at magnifications of 43X an 71X using a microfiche reader or microbeam projector. Distances from the focus to annuli (anterior radii) were measured (to the nearest mm) along a ventral 20° radial line (Clutter and Whitesel 1956, Mosher 1969, Narver 1968).

Age and growth measurements were entered and stored in computer memory an analyzed using the FIRE 1 program (Hesse 1977). The Monastyrsky method, a log-log fish length-scale radius relationship (Ricker 1971), was selected as the technique to calculate lengths at previous annuli. This method expressed the fish length and scale radius better than the linear methods used in the program or the straight line regression data calculated by Hanzel (1974, 1974a, 1975). The back-calculated lengths of this log-log method agreed more closely to the actual length of fish collected in early spring or late fall. A validation of age was checked by reading otoliths of the same fish; ages assigned by scales agreed closely to those of the otoliths.

ACOUSTIC SURVEYS AND FISH DENSITY TECHNIQUES

A recording echo-sounder has been utilized to collect and record seasonal and depth distribution patterns of the salmon since 1967. In 1978, the unit was modified to a hydroacoustic unit by a group of engineers at the Applied Physics Lab located in Seattle, Washington. The modifications provided the capabilities of recording calibrated acoustic signals on magnetic tape. Recorded tapes can then be preserved and analyzed at a later date by computer or manual enumeration. This hydroacoustic acquisition system and the techniques used to estimate fish densities are more fully described by Nunnallee (1973), Nunnallee and Mathisen (1972), Thorne et al. (1972), and Lemberg (1975).

Acoustic transects were made in the evening hours during early September, a time of the year when sampling variability is minimal due to kokanee distributions (Nunnallee 1973, Hanzel 1977, Bowler and Reiman 1981). During this time, the salmon move into the mid-lake areas prior to their movements to spawning areas. Acoustic signals were recorded on magnetic tape while traveling 3.1 m/second (6.9 miles per hour). Speeds were regulated using an on-board direct read-out flow meter. Transect speed was the fastest speed that would enable accurate recording of fish targets. Annual acoustic surveys were conducted on nine lake transects totalling approximately 50 miles per year. The mid-water trawl was used to verify both species and sizes of acoustic fish targets. A standard cone volume was developed by averaging the length of time (number of insonifications in time converted to distance) fish targets remained in the signal cone. The beam angle of the standard cone was 16 degrees. Fish numbers were enumerated using the "direct count" method by playing back acoustic signals viewed on a delayed-sweep oscilloscope. Size of fish (small 10-12 inches and large 12-16 inches) could be separated by signal strength differences. Counting thresholds for these sizes were established and used during target enumeration. Densities were calculated from number of fish targets, by 12-foot intervals, from depths between 24 and 144 feet below the surface.

RESULTS

Kokanee length data, creel census information, age and growth summaries from both scale and otoliths, acoustic information and temperature profiles have been collected annually (1972-1983) from Flathead Lake to monitor the salmon population. A presentation of these annual summaries provides several populations indices and allows comparison of each. Long-term information of this type establishes a basis from which interpretation of changes in salmon population can be discerned. This presentation of data collected over a span of 12 years, three life cycles of the salmon, presents an overview and reflects interaction of age classes not readily available in shorter term studies. The review also provides a background that will aid in interpreting information from the past when only scat samples or when a single population indice is available.

LENGTH OF MALE SPAWNERS

The size (average length of male spawner - T.L.) of kokanee from Flathead Lake was first available in 1938 (Brunson et al.) and has been monitored since 1955 (Hanzel 1964). Continuous river information was not started until 1972; however some measurements are available during the early 1960's. Measurements from both sexes were taken; however only data from male spawners will be used to represent size of the Flathead kokanee (Figure 4 and Table 1). The size of the smaller spawning female salmon can be estimated by subtracting 15 mm (average difference between sexes, 1972-1983) from the length of the males.

The largest size kokanee, 404 mm (15.9 inches) occurred in 1938 during the early years when salmon were becoming established in the lake. Since that time, the size of salmon has fluctuated within the range of 127 mm that has twice experienced sharp decreases, each followed by abrupt increases (Figure 4). Moderate changes occurred between the lows but with no apparent cyclic pattern, time periods of three and five years. The most recent increase in size started in 1977 and reached its peak of 394 mm (15.5 inches) in 1982. The decrease shown in the size of the 1983 salmon would suggest an increase in numbers.

The recent period of increased size (1976-1982) has been attributed to decreases in numbers of kokanee caused by losses of salmon reproduction in the mainstem of the Flathead River due to operational patterns of Hungry Horse Dam (Graham et al. 1980, McMullin and Graham 1981, Fraley and Graham 1982). Causes of previous changes in numbers and/or size of salmon have not been documented; however they are believed to be reflecting changes in the salmon population caused by a combination of conditions resulting from operational patterns of both Hungry Horse Dam an Kerr Dam upon kokanee spawning grounds. The recent impacts of these hydro-

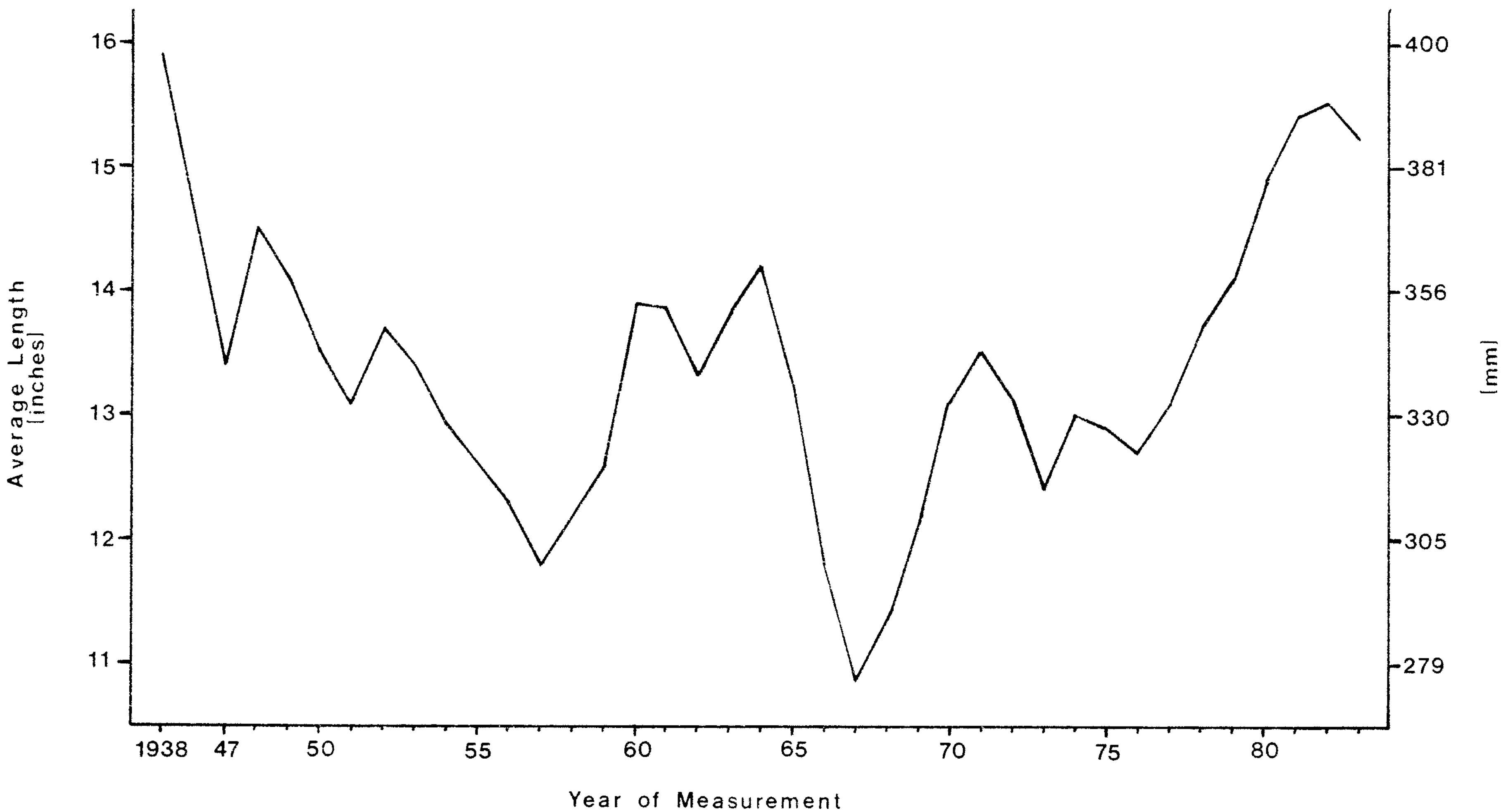


Figure 4. Average length (T.L.) of male kokanee at maturity, 1938-1983, on Flathead Lake.

Table 1. Average length of male kokanee (T.L.) in millimeters and inches from Flathead Lake, 1938-1983.

Year	Average length in mm	Average length in inches
1938	404	15.9
1947	340	13.4
1948	368	14.5
1949	358	14.1
1950	343	13.5
1951	333	13.1
1952	348	13.7
1953	340	13.4
1954	328	12.9
1955		
1956	312	12.3
1957	300	11.8
1958		
1959	320	12.6
1960	353	13.9
1961	351	13.8
1962	338	13.3
1963	351	13.8
1964	361	14.2
1965	335	13.2
1966	300	11.8
1967	277	10.9
1968	290	11.4
1969	310	12.2
1970	333	13.1
1971	343	13.5
1972	333	13.1
1973	315	12.4
1974	330	13.0
1975	328	12.9
1976	323	12.7
1977	333	13.1
1978	350	13.7
1979	358	14.1
1980	378	14.9
1981	391	15.4
1982	394	15.5
1983	387	15.2

structures upon salmon reproduction are presently being evaluated (Fraley and McMullin 1983, Decker-Hess and Graham 1982).

Although size has been used as a general salmon population index (Foerster 1968, Johnson 1965, Lewis 1971, Goodlad 1974, Stober et al. 1978) when used alone; caution should be advised, since age of maturity and age composition can both affect the size of salmon (Hanzel 1973, Bowler and Reiman 1981). Reiman and Bowler (1980) also described a density response curve (sine-wave form) that contains a flat portion in the area of the cross-over where considerable changes in density can occur and not be reflected in growth.

LENGTH AND AGE OF CREEL CAUGHT SALMON

Length frequencies of kokanee from angler creels were prepared from a total of 4,934 fish lengths collected from 1968 through 1983 (Figure 5). Lengths used in these frequencies represent a combination of sexes, since no differences were noted. All creel sampling was scheduled prior to early September when sexual dimorphism first becomes apparent. Length frequencies of creeled salmon from Flathead lake have demonstrated bimodal areas, each mode representing different age groups (Hanzel 1973). Thus any combined average length figure from these data would reflect age composition rather than the size-density relationship.

Creeled fish frequencies do represent the contributions and importance of strong and weak year classes. In eight of the 16 years of record, the contribution of younger fish is depicted in the bimodal frequencies. These years include 1970, 1972, 1976, 1978, 1980, 1981, 1982, and 1983. Average size of the angler-caught salmon has ranged from 250 mm (9.8 inches) to 316 mm (12.4 inches) in 1976 and 1983, respectively.

A total of 3,567 scale samples were collected from a majority (96.9%) of the creeled salmon during the period 1972 through 1983. This additional data provides the opportunity to establish annual age composition of the catch (Table 2). While ages 2+ to 5+ were found in fishermen creels, age 3+ salmon (fish in its fourth growth season) dominated the catch. This age group represented 50% or more (maximum of 76.8% in 1979) of the catch in eight of the 12 years measured. Their age group contribution to the catch averaged 56.0%.

Age 2+ salmon showed strong year class contributions in the 1976, 1982 and 1983 creels. During these years, these young salmon were the dominate age group and represented 46.8%, 46.5%, and 71.5%, respectively. The age 2+ salmon contribution averaged 25.5% of the angler-caught fish during the years of record.

Age 4+ salmon showed strong year class representation during 1972, 1974 and 1980. Their strongest showing, and only dominate year, occurred in 1972 when they represented 59.2% of the catch. These five-summer salmons' contribution averaged 18.5% of the total catch.

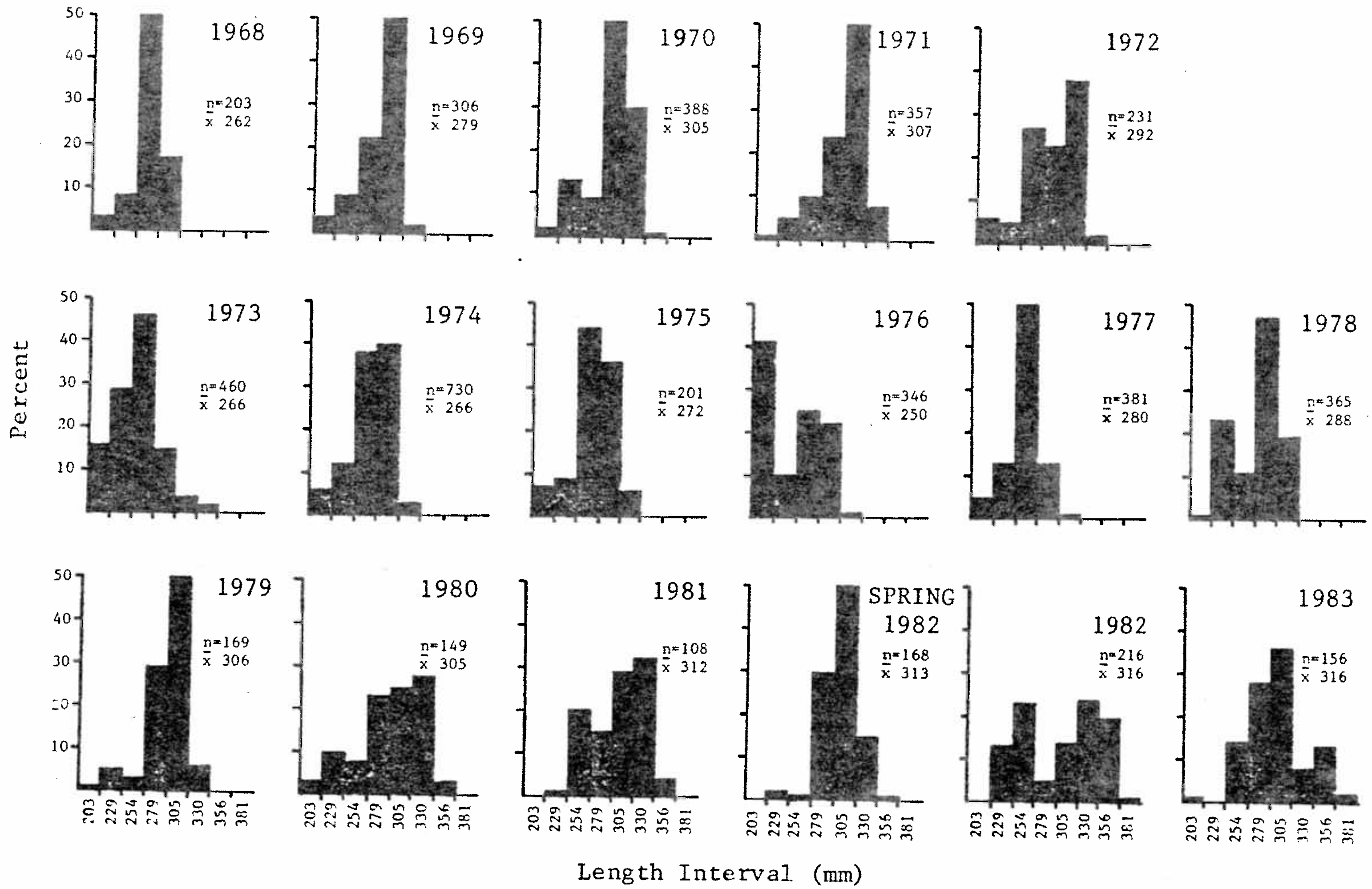


Figure 5. Length frequency polygrams of angler caught kokanee, sexes combined, during July and August, 1968-1983, on Flathead Lake. Spring 1982 polygram represents catch during January and February from Skidoo Bay.

Table 2. Age composition (percent of total) and average length (sexes combined) of angler-caught kokanee during the summer, June-July, 1972-1983, from Flathead Lake.

Year	Age	Percent of age group	Number of fish	Average length (mm)
1972	2	6.1	12	209
	3	34.2	67	270
	4	59.2	116	310
	5	0.5	1	336
			196	
1973	2	20.5	83	225
	3	60.9	246	260
	4	18.6	75	297
			404	
1974	2	15.5	98	230
	3	52.1	330	272
	4	32.4	205	286
			633	
1975	2	13.0	26	228
	3	69.0	138	274
	4	18.0	36	297
			200	
1976	2	46.8	162	221
	3	38.7	134	269
	4	14.5	50	294
			346	
1977	2	16.5	79	232
	3	75.8	363	285
	4	7.7	37	308
			479	
1978	2	24.4	95	245
	3	70.4	274	293
	4	5.1	20	298
			389	
1979	2	7.4	22	243
	3	76.8	228	299
	4	15.8	47	322
			297	
1980	2	20.6	27	249
	3	50.4	66	314
	4	29.0	38	339
			131	
1981	2	17.2	33	268
	3	71.4	137	313
	4	11.5	22	341
			192	
1982	2	46.5	66	277
	3	44.4	63	333
	4	9.2	13	357
			142	
1983	2	71.5	113	298
	3	27.2	43	352
	4	1.3	2	353
			158	

The oldest age group, age 5+ salmon, were only noted during the reading of scales from 1972, an then only one fish was placed in the age group. It is believed that more 5+ salmon are caught and/or live in the lake, but never does this age group comprise a significant portion of its kokanee.

The average length of kokanee, by age group, caught by anglers for the 12 years of record are presented in Table 2. The average size of older fish was consistently larger than the preceding age group even though length frequencies of age groups were found to overlap. There has been a gradual increase in the average length of each age group (Figure 6 - upper line in each age group). Age 2+ salmon ranged between 209 mm in 1972 to 298 mm in 1983, a difference of 89 mm (3.5 inches). The low ranges of ages 3+ and 4+ occurred in 1973 and 1974, respectively; showing that the small size of the age 2+ in 1972 (salmon hatched in 1970) was carried on through the life of the age class. Similar length and growth progressions were present for other years but not as vivid as in 1972. The high ranges of the older salmon were similar at 352 and 353 mm in 1983; for a span in ranges of 92 mm (3.6 mm) and 67 mm (2.6 inches), respectively.

Angler Catch Rates

Angler success, expressed as catch per hour, was compiled during the censusing of the major salmon fishing area during summer troll-fishing season of 1978 to 1983. This season starts in mid-May and extends to mid-September. Catch rates usually were considered good, one to two fish/hour, during the early summer fishing season (late May and early June). As surface waters warmed forcing the salmon to utilize the cool deeper waters, catch rates would drop usually to half of the earlier season success rates. Rates again improve during the latter part of the season and drop off rapidly in early September as the maturing salmon initiate their spawning movements. More details on fishing patterns and harvest of salmon from Flathead Lake is described by Graham and Fredenberg (1983). An average annual catch rate calculated throughout the season does provide an indice of population change in the salmon numbers. The average catch rates for the summer trolling seasons were as follows:

Year	Fish/Hour
1978	2.12
1979	2.10
1980	0.61
1981	0.56
1982	0.70
1983	0.51

A hand-line or still-boat fishery for salmon during the winter and spring months has gained popularity since 1980. This fishery is

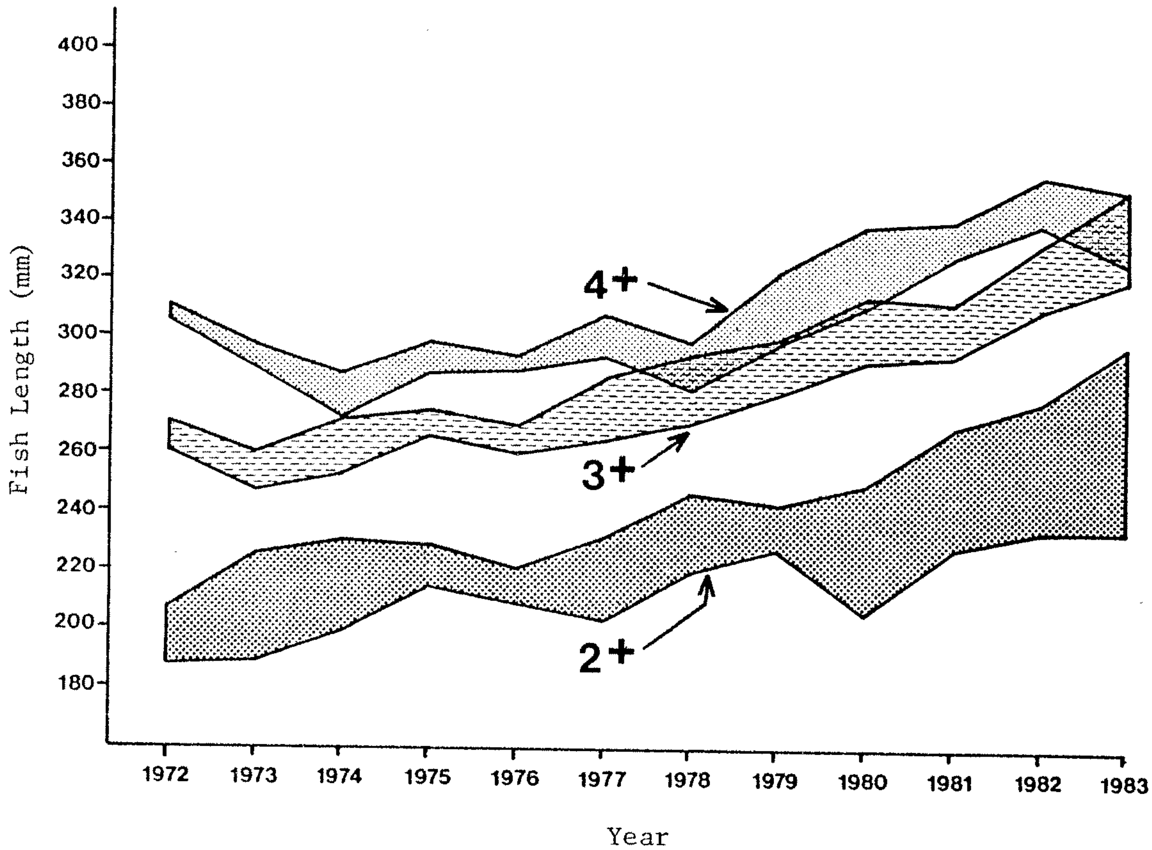


Figure 6. Average summer growth (shaded area) of age 2+, 3+ and 4+ kokanee determined from annulus formation to time of harvest, 1972-1983, on Flathead Lake. Each age group - upper line represents average length of angler-caught salmon; lower line represents average length at annulus formation.

concentrated within a small area (4 hectare - 10 acres) in Skidoo Bay, a large southern bay of the lake within salmon fishing area 7. Fishing usually begins in December and continues through mid-April. Fishing occurs in dense schools, depicted by echograms (Figure 7) at depths from 20 to 80 feet. Catch rates experienced during this spring fishery are higher than those of the summer troll fishery. Rates can range to highs of 10+ fish/hour when ice is on the bay. The average catch rate during the 1982 spring season was 3.7 fish/-hour. The maturing age classes, ages 3+ and 4+, of salmon made up the bulk of this spring harvest (Figure 5).

AGE AND GROWTH ANALYSIS

Scale Interpretations

Date of annulus formation in Flathead Lake for young salmon (age 1 and 2) generally occurs by February; however, formation in older fish is not completed until June. This differential of period of five months is partially explained by Leathe and Graham (1982) when they described the food habits of the kokanee in this lake. Salmon, during the winter period, experience a shift of major food items from large sized cladocerans to small copepods (primarily *Daphnia thorata* to *Cyclops* spp.). All the salmon experience a decrease in growth as the shift first takes place. As the younger salmon continue to feed on these smaller organisms, they show growth, proportionate to their length, and it is read as an annular mark on their scales. Proportionate growth of the larger salmon, while utilizing these smaller organisms, is less and is not shown on their scales. Therefore, they must depend upon the reoccurrence of the large zooplankton in their diet to shown enough growth to form an annulus mark. With this differential time to annulus formation, scale readers should consider growth between the first and second annuli to be approximately 12 months, while the time between the second and third annuli to be 16 months. Time span between the third and fourth annuli was 12 months.

When salmon scales are going to be used to develop a body-scale relationship, time of collection of scales is most important. Scales should not be included from fish that are sexually mature and have started to change dimorphically. Seasonal sampling has shown that mature fish continue to increase in total length; however, this growth was not considered "true growth" since it was not transferred as circuli on the scales or growth on otolith bones. This increase in length, dimorphic growth, was the result of the changes that occurs to the mature salmon prior to spawning. In Flathead Lake, scales on mature salmon should be taken prior to September to avoid dimorphic growth.

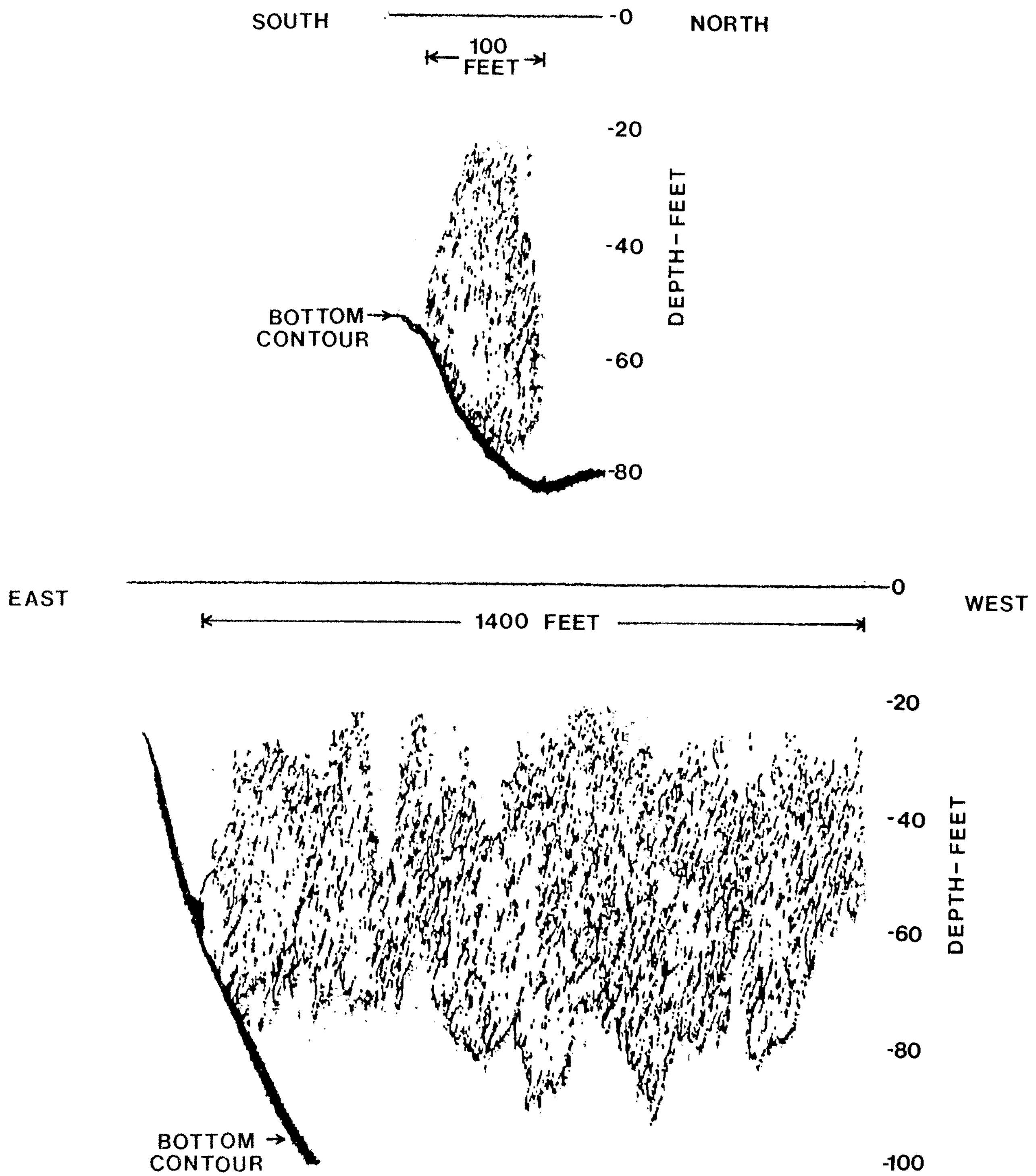


Figure 7. Echograms of a kokanee school located in Skidoo Bay during Spring 1983, Flathead Lake. Echograms illustrate cross-sectional depths and size of the school.

Body-Scale Relationship-Backcalculated Lengths

Scale collections, from 1972 through 1980, were first processed through the FIRE 1 computer program (Hesse 1977). Scale data from age groups 0 through 5 were included in the relationship. The percent of each age group of the total 4,836 scales were 0.8, 7.3, 26.5, 48.8, 16.5 and 0.1, respectively. The Monastyrsky method, which utilizes a logarithmic scale radius-body length relationship, was selected since it expressed fish length and body scale best. The backcalculated lengths of this log-log technique agreed more closely to the actual lengths of fish collected the time of annulus formation. This method calculates fish lengths at annuli by the following formula:

$$\text{Fish length at annulus} = \left(\frac{\text{Annulus radius}}{\text{Scale radius}} \times \text{fish length}\right)^{\text{slope of the line}}$$

A summation program was developed to better express changes in growth patterns between years. In the original program each time a set or year of data is processed a new body-scale relationship was calculated. If each year sample of fish did not represent a wide variety of age groups, the slope would likely change. Backcalculated lengths would then inturn express the changes in both slope and/or changes in fish growth. The new summation technique calculates fish lengths using a single slope developed from a mass of data from all age groups. It assumes the slope will not change over time. A correlation coefficient of 0.94819 was developed. The slope of this regression is 0.86373 with the Y-intercept of 5.596 or $10^{0.74504}$. The lengths at annuli were calculated using a separate program utilizing the standard Monastyrsky formula. A summation routine was then used to sum the age data by age, sex, etc.

A length-weight log relationship was calculated during the processing in the FIRE 1 program of 4,836 fish. A correlation coefficient of 0.97235 was developed with a slope of 2.97077 and a Y-intercept of $10^{-5.00388}$. Weight can be predicted using the following formula:

$$\text{Weight} = 10^{-5.00388} \times \text{Length}^{2.97077}$$

or

$$\text{Log Weight} = 10^{-5.00388} + 2.97077 \times \text{Log Length}$$

Age Analysis Summaries

Annual summaries of the age and growth analysis (a total of 5,561 scales) and age group length frequencies for the years 1972 through 1983 are presented in Appendix A. Summary data by age group for each sex and an unidentified classification is also presented. Although backcalculated lengths compiled for males were usually larger than those for females, rarely did these figures differ more than 3-10 mm. This evidence support a hypothesis that similar growth patterns are exhibited by male and female salmon in Flathead Lake. This also suggests that summaries of growth by sexes were not necessary.

Number of circuli to the first annulus has been used to distinguish different spawning groups of both trout and salmon (Narver 1968, Mosher 1969). This statistic was measured and was included in the scale summaries, Appendix A. The average number of circuli to the first annulus on Flathead Lake salmon ranged between 12 and 18 circuli. The statistic failed to differentiate spawning groups; however, it was used to aid in the placement of the first annulus.

A age class length frequency, utilizing fish lengths at capture, are presented below each of the annual age and growth summaries to provide a quick reference to discern the degree of overlap existing between ages. Difference in lengths of mature and not-mature fish of the same age would explain the bimodal distribution within the older age groups. Progressive increases and decreases of growth by the age groups can be noted while scanning through yearly data.

In the age analyses of the 1972-1974 Flathead Lake kokanee study by Hanzel (1974, 1974a, 1975), summaries for each sex were further broken down into groups that would or would not spawn that year. Backcalculated lengths of age groups 2+ through 4+ fish that were to spawn that year were significantly larger than for fish that would not mature that year. The percentage of mature fish in these age groups were as follows:

Age Group	Percent Mature		
	1972	1973	1974
2+	27.5	3.6	0.0
3+	41.1	71.7	83.4
4+	95.5	91.7	95.8

The degree of variation in the composition of maturing fish within these age groups should be considered when evaluating annual growth calculations.

Fish lengths, including only those measurements calculated to the last annulus, are depicted as annual incremental growths for each age group in Figure 8. This figure provides a quick resume of the 12 years of growth summaries. Average increment growth for age group 1, in the years when this age group was not present (1975, 1976, 1977, 1978, and 1982), are first year growths calculated from age 2+ fish collected the following year.

A plot of fish lengths at annulus formation (lower line) linked to the average length of that age group from creel caught salmon (upper line) of age groups 2, 3 and 4 are presented in visual form

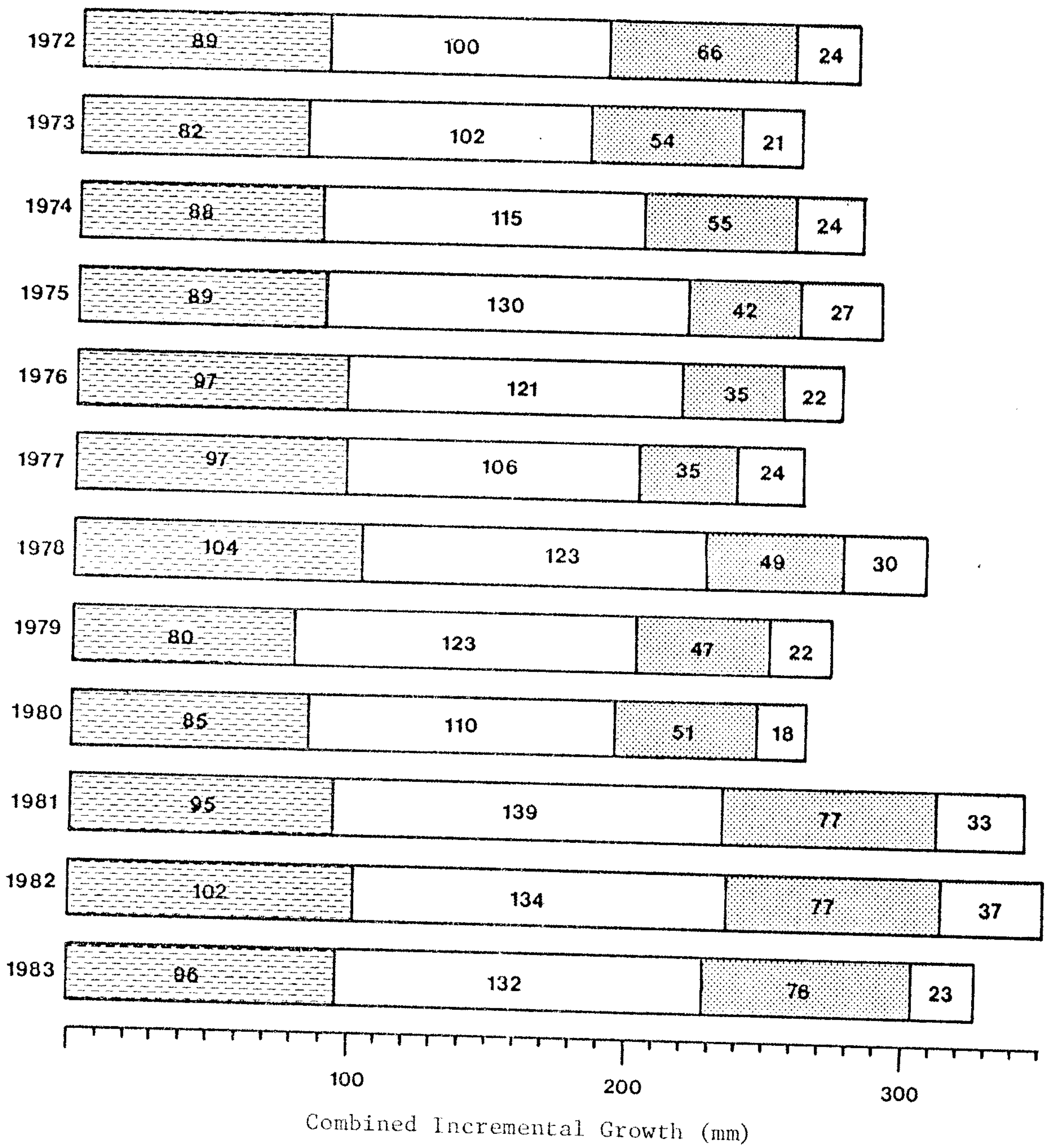


Figure 8. Average incremental growths (numbers in bar) for age groups 1 through 4 for kokanee as bar graphs for the years 1972 through 1983, Flathead Lake.

in Figure 6 to express the amount of summer growth (shaded area) exhibited by these year classes. The greater growth shown for the 2+ salmon can partially be explained by the longer time span for this age group since annulus formation. Seasonal growth for age 2+, 3+ and 4+ salmon shown during 1972, 1975, and 1976 were all significantly below (one standard deviation of the mean) the average growth for each age. The average summer growth for age 2, 3, and 4 was 31.0 mm, 18.5 mm and 15.4 mm, respectively. Growth was significantly higher than the norm during 1979 and 1980 for the 4+ salmon, indicating a good growth year for that year class. The 1983 growth period was considered good for all age classes when their average increment growths were higher than the calculated means.

Opossum shrimp (Mysis relicta) were first collected in Flathead Lake in mid-water trawl hauls during the fall of 1982 (Leathe and Graham 1982). It is believed that Mysis will become established during the next five to ten years. Their direct impact on zooplankton and on growth of kokanee will depend upon Mysis numbers achieved in the lake. This kokanee age analysis will provide baseline information in the evaluation of future impacts of the shrimp in Flathead Lake. Progress of the Mysis population is being monitored by a graduate level study (Personal communication, University of Montana, Yellow Bay Biological Station).

AGE AND LENGTH OF SPAWNING KOKANEE

The expression of fish lengths on spawning salmon is not standard, i.e. total, fork, standard, and mid-eye to fork. To aid data comparison and exchange of information, conversion formulas were derived from 356 male and 200 female spawning salmon (Hanzel 1978). These fish ranged in size from 218 mm to 358 mm (8.7 to 14.7 inches) T.L. The following equations are provided to convert measurements of mature salmon after dimorphic changes had occurred.

Fork Length From Total Length

Male - F.L. = 0.936 X T.L. - 6 mm
Female - F.L. = 0.968 X T.L. - 9 mm

Standard Length From Total Length

Male - S.L. = 0.839 X T.L. - 4 mm
Female - S.L. = 0.858 X T.L. - 10 mm

Mid-eye Fork From Total Length

Male - ME.F. = 0.800 X T.L. + 8 mm
Female - ME.F. = 0.913 X T.L. - 11 mm

Spawning Age Dominance

The age composition of spawning kokanee were determined by analysis of 7,426 otolith bones collected from five lakeshore and three upper river spawning sites during 1972 through 1983 (Table 3). This table includes average lengths of these spawning kokanee by sex, age and area of collection.

Age 3+ salmon was the dominate age group from the Flathead River system (both lake and river areas combined) spawners in 8 of the 12 years of comparison. This dominance represented 60% or more of the spawning fish from each year. The strength of this age group was represented even stronger with river spawning fish, exhibiting a 10-year dominance. Males within this age group did show less of a dominance than females. This tendency was exhibited every year among lakeshore spawners in all but two years in the river, 1973 and 1976. Comparisons of the annual percentages of males and females, in this dominate age group, showed only slight differences (less than 10%) during most years. Notable differences did occur in 1975 and 1980 among river spawners and in 1977 among lakeshore spawners.

Age 4+ spawners showed system dominance only once during 1980 when they represented 55% or more of the spawners. This older age group in 1974 showed an additional year of dominance among lakeshore spawners. Near equal numbers of age 3+ and 4+ salmon were found in the river spawning areas during 1972. Likewise, similar percentages of these two ages were shown in 1981 along lakeshore sites.

Age 2+ fish never represented more than 12% of the system spawners in any one year. The strongest showing occurred in 1972. None of these young fish were found among system spawners during 1975, 1980, and 1981. Only during three other years (1973, 1976 and 1983) did their system contribution exceed 1%. During these years they comprised 4.8%, 3.2% and 7.7%, respectively.

The percentage of age 3+ salmon in the system spawners did not always reflect similar amounts of contribution to the angler creels (Table 4). This variation did not allow future predictions of either indices by regression analysis.

TEMPERATURE PROFILES

Water temperature preferences of salmon have been described by Brett (1952); noting further that tolerances of the younger salmon were even more restrictive than for adults. The prescribed optimum temperature zone for kokanee occurs within the range between 53.7^{O}F and 57.6^{O}F. Salmon distribution patterns in Flathead Lake have been shown to be influenced by existing thermal condition (Hanzel 1970, 1971). The importance of knowledge on the thermal structure of lakes was also stressed by Goodlad et al. (1974) when he classified it as one of the two major factors influencing growth of juvenile salmon in four Canadian lakes.

Table 3. Age composition (from otoliths) and average length of mature kokanee, by sex, collected from Flathead Lake and River spawning sites, 1972-1983.

Year	Area	Sex[a/]	Percent of fish by age II	III	IV	V	Total number of fish	Average length by age group (mm) II	III	IV	V	Combined average length
1972	Lake	M	10.4	70.4	19.1	---	115	332	332	341	---	334
		F	21.6	71.0	7.4	---	162	314	320	327	---	319
1972	River	M	--	46.3	53.7	---	67	---	313	340	---	328
		F	--	55.1	44.9	---	49	---	301	325	---	312
1973	Lake	M	2.1	68.1	29.8	---	191	315	310	326	---	315
		F	7.4	72.8	19.8	---	162	296	300	314	---	302
1973	River	M	2.3	79.5	18.2	---	44	290	301	321	---	304
		F	13.6	72.7	13.6	---	22	278	292	305	---	292
1974	Lake	M	1.7	35.9	62.4	---	415	300	320	331	---	327
		F	--	39.9	60.1	---	421	---	312	321	---	317
1974	River	M	--	62.1	37.9	---	116	---	310	319	---	313
		F	--	72.2	27.8	---	79	---	300	305	---	301
1975	Lake	M	--	63.7	34.7	1.5	262	---	328	333	343	330
		F	--	76.7	23.0	0.3	305	---	315	322	333	317
1975	River	M	--	55.1	44.9	---	136	---	311	325	---	317
		F	--	70.7	29.3	---	140	---	303	311	---	305
1976	Lake	M	2.4	61.6	36.0	---	164	293	321	335	---	325
		F	1.0	71.9	27.1	---	203	282	308	322	---	312
1976	River	M	5.8	80.6	13.6	---	103	285	310	324	---	310
		F	6.3	69.8	24.0	---	96	281	296	317	---	300
1977	Lake	M	0.6	79.2	20.2	---	168	308	330	343	---	333
		F	--	92.7	7.3	---	193	---	318	332	---	319
1977	River	M	3.5	89.4	7.1	---	85	269	321	341	---	321
		F	1.2	92.9	6.0	---	84	274	307	327	---	308
1978	Lake	M	1.3	78.1	20.5	---	302	325	344	352	---	345
		F	0.4	84.3	15.3	---	248	320	331	336	---	332
1978	River	M	--	85.1	14.9	---	148	---	332	342	---	333
		F	--	94.6	5.4	---	112	---	316	325	---	316
1979	Lake	M	--	60.7	39.3	---	272	---	357	365	---	360
		F	--	92.4	7.6	---	249	---	345	348	---	345
1979	River	M	--	85.1	14.9	---	87	---	345	353	---	346
		F	1.0	97.1	2.0	---	102	328	328	336	---	328
1980	Lake	M	--	31.5	67.3	1.2	251	---	370	382	391	378
		F	--	44.8	55.2	---	163	---	356	365	---	361
1980	River	M	--	36.4	63.6	---	44	---	366	376	---	372
		F	--	65.1	34.9	---	63	---	342	346	---	343
1981	Lake	M	--	42.9	57.1	---	177	---	378	401	---	391
		F	--	48.6	50.9	0.6	173	---	361	380	378	371
1981	River	M	--	80.8	19.2	---	78	---	370	394	---	375
		F	--	94.0	6.0	---	83	---	356	354	---	356
1982	Lake	M	--	60.3	39.7	---	156	---	387	403	---	393
		F	--	75.5	24.5	---	94	---	374	386	---	377
1982	River	M	2.0	78.8	19.2	---	99	340	382	394	---	383
		F	1.0	88.7	10.3	---	97	317	366	375	---	366
1983	Lake	M	8.5	72.5	18.5	0.5	189	350	387	401	429	387
		F	16.1	72.9	11.0	---	155	336	371	379	---	366
1983	River	M	4.2	88.9	6.9	---	144	337	380	400	---	380
		F	1.9	94.9	3.2	---	158	318	362	368	---	361

a/ M = male; F = female.

Table 4. Proportion, percent of total, of age 3+ salmon in Flathead Lake creels and among system spawners, 1972-1983.

Year	Percent of 3+ Salmon	
	Creels	Spawners
1972	34.2	64.6
1973	60.9	71.4
1974	52.1	43.3
1975	69.0	68.2
1976	38.7	70.1
1977	75.8	87.9
1978	70.4	83.6
1979	76.8	80.0
1980	50.6	40.1
1981	71.4	58.9
1982	44.4	73.8
1983	27.2	81.7

Warm surface water temperatures tend to force salmon to the deep-cooler waters of the lake during summer. The width and depth of the preferred temperature zone of salmon is then governed by the thermal warming of the lake. The width and depth of this zone can influence angler success, another indice of salmon population (the one most often used by the fishermen). An example of this influence will aid in understanding this phenomenon. Assuming a similar density of fish, the more area (wider zone) that a fish can disperse, the less opportunity the angler has to fine them. The deeper the zone, the harder it is for the angler to reach the fish. Thermal warming patterns on the lake have been described by Hanzel (1970, 1971), Potter (1981), and Leathe and Graham (1982).

Kokanee distribution patterns, recorded by an acoustic sounder-"echograms", and corresponding water temperature profile data have been monitored from 1968 through 1983. Although temperature conditions in this large lake vary considerably over the lake surface (Hanzel 1971), conditions at a mid-lake station can express the general thermal warming of the lake. To illustrate the annual thermal warming of the lake and to follow the preferred temperature zone of salmon, temperature isotherms were prepared at a mid-lake station and are presented in Figure 9. The darkest shaded zone in the figures represents a 10-degree temperature zone, between 50°F and 60°F; considered to be the preferred temperature zone for salmon. The lighter shaded area near the surface is the temperature zone 70°F and warmer. In addition to depicting the salmon zone, the profiles also can be used as a relative indicator of heat storage. The deeper the warmer isotherms appear, the more heat the lake stores. This heat capacitance can be a major factor influencing the years when the lake freezes completely.

ACOUSTIC DENSITY ESTIMATES

Kokanee population density data was collected using the modified hydroacoustic unit whose design was developed by specialists at the University of Washington. Acoustic information was collected and recorded on magnetic tape on transects (Figure 10) covering the major salmon areas of the lake. Salmon densities were derived from data collected during nine transects in early September of 1979-1982. These transects (Nos. 1, 2, 3, 6, 7, 8, 9, 10, and 11) provided fish density data on over 45 miles of the lake annually. In 1983, two additional transects were added (Nos. 4 and 5) to include information when a change in fall distribution patterns of the salmon was noted. These transects added an additional 10 miles of fish density information. It should be noted at this time that the density figures derived from the early September transects represent salmon numbers that have remained in the lake after the early run has already left the lake and entered the river system. These fish leave the lake and enter the river system sometime during August. Estimates of numbers of salmon utilizing the river have

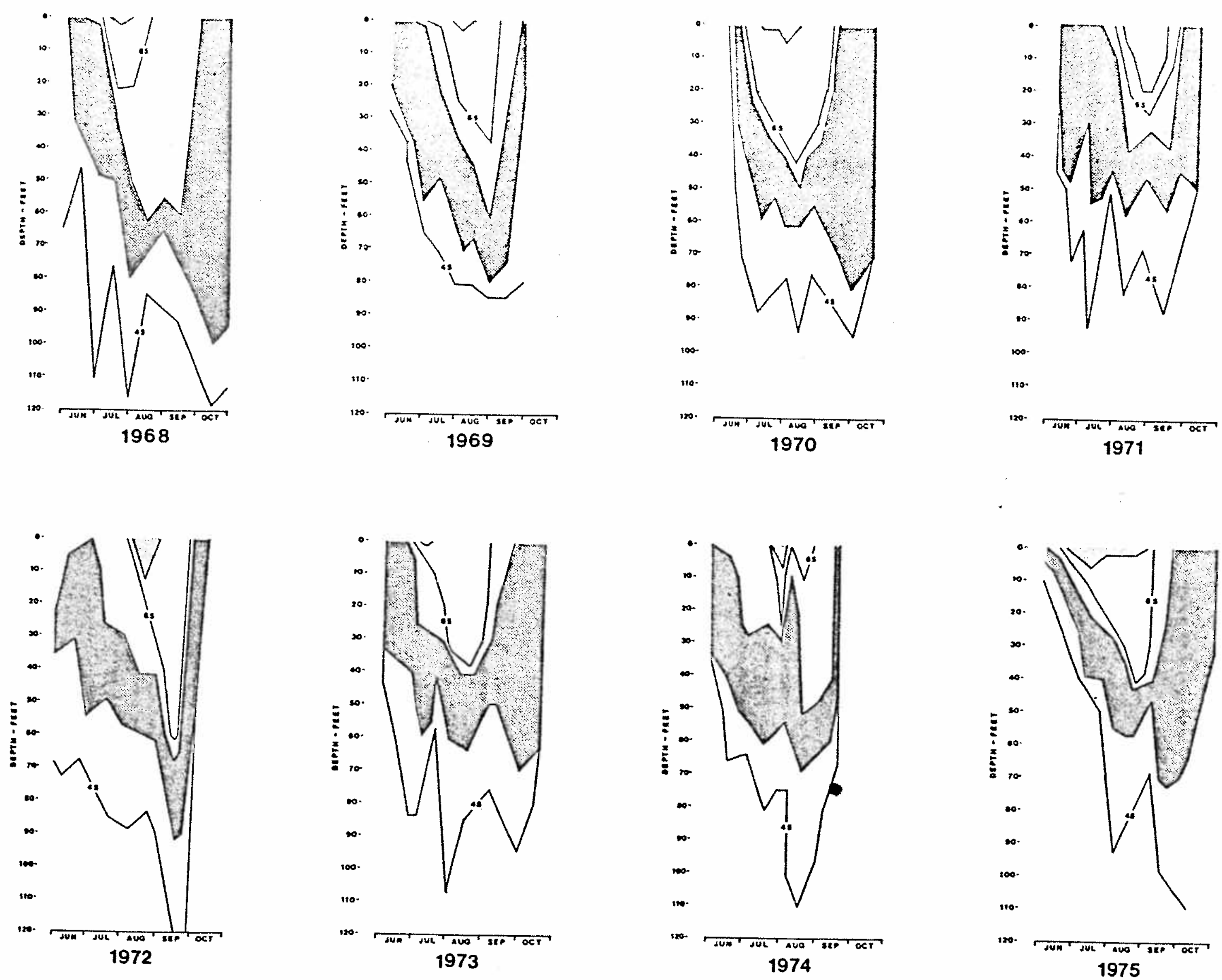


Figure 9. Seasonal isotherms (5°F) depicting preferred kokanee temperature zone (50°-60°F - dark shaded area) from a mid-lake station, 1968-1983, Flathead Lake.

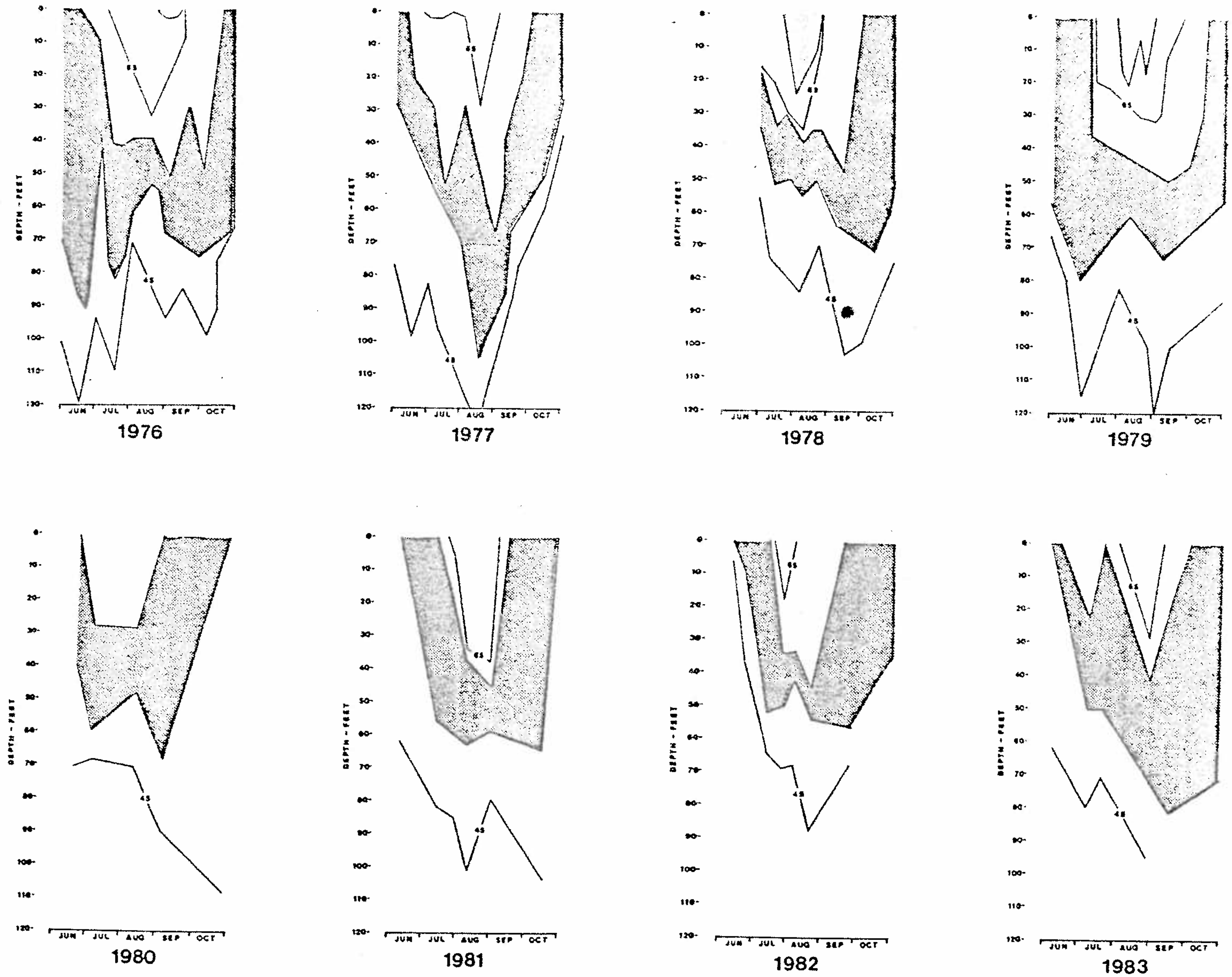


Figure 9. (Continued).

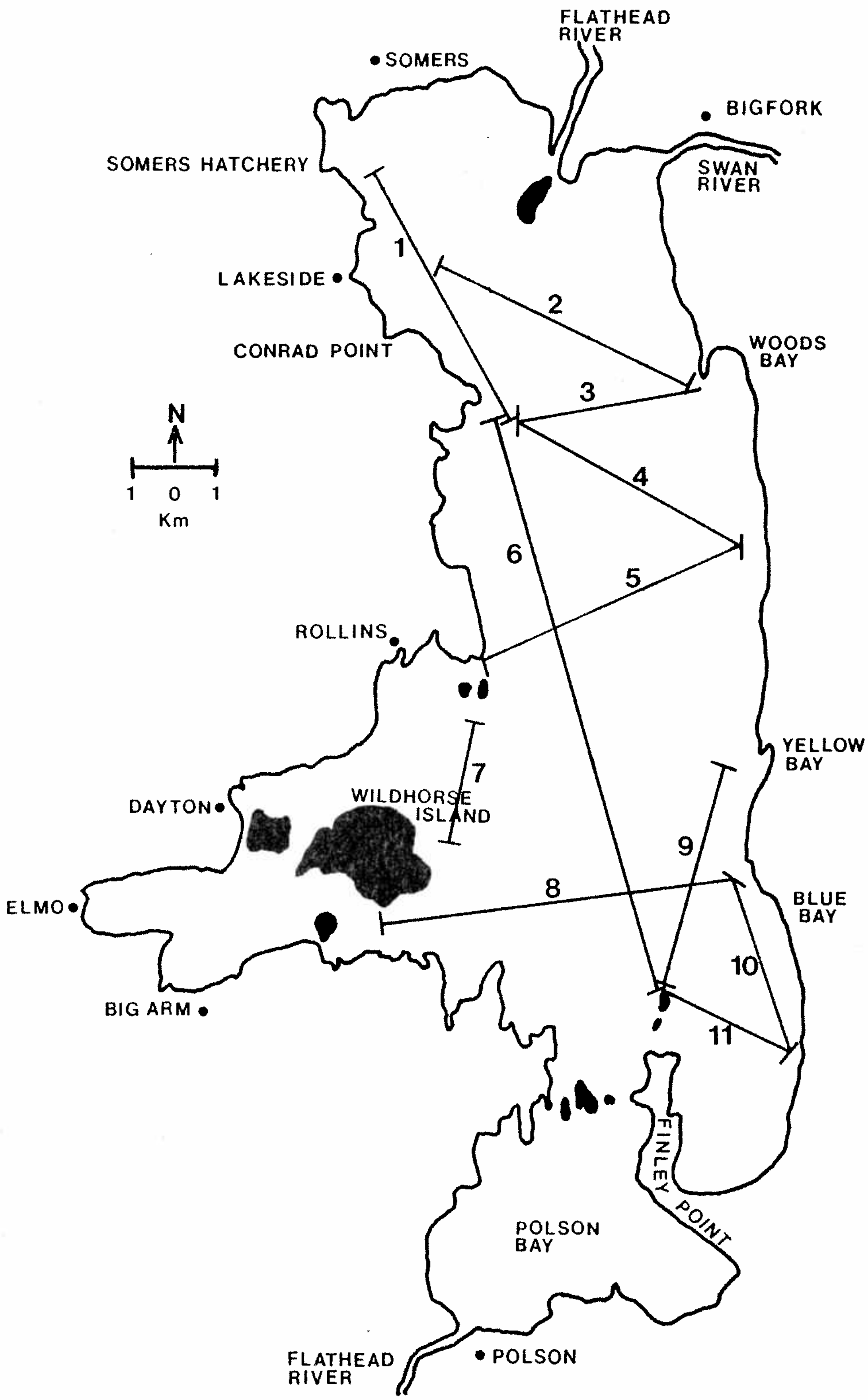


Figure 10. Locations of 11 acoustical transects used to determine fall kokanee density estimates on Flathead Lake.

ranged from 100,000 in 1983 to 400,000 in 1975 (Fraley and McMullin 1983).

Density estimates were derived for fish 10 inches and larger. Size of salmon in the mid-lake concentrations during 1980-83, as determined by collections with the mid-water trawl, allow a size differentiation and densities were made for both small and large fish. Small fish represented age 2+ salmon and large fish represented a combination of 3+ and 4+ fish. Sample densities were made by the "direct count" method utilizing an oscilloscope. The densities were made on five-minute distances along transects that showed similar fish densities on the echograms. An example of a typical echogram containing two sample density areas on transect number 8 is presented in Figure 11. Densities for an entire transect were weighted averages of the sample densities and inturn the average density of fish for the entire lake was a weighted average of the transect data.

Fish densities were calculated by 12-foot intervals starting at 24 feet below the surface. Salmon during the evening hours drop to depths ranging from 40 to 120 feet below the surface. During moonlite nights, salmon distributions can be found 20-30 feet shallower than on cloudy dark nights. The most reliable estimates can be derived when salmon concentrations are the deepest; for some fish targets can be missed if the fish are too shallow. Several transects had to be repeated when rough weather was encountered. Generally, all transects on Flathead Lake can be covered on five survey nights.

Fish densities were first calculated by interval into a volumetric unit of expression, fish per 1,000 m^3, then converted to a surface area measurement of fish per 100 m^2 by the following equation:

$$\text{Fish}/100\ m^2 = \sum_{i=1}^{n} \frac{D_{Li} - D_{Ui}}{10} \times \text{fish}/1{,}000\ m^3$$

Where: D_{Li} = lower depth limit of the interval i;
D_{Ui} = upper depth limit of interval i; and
n = total number of depth strata.

After conversion, the interval densities can be added together to derive a total or summary density in a surface area value. The following equations allow for conversion of density data into familiar surface area units.

Fish/hectare = Fish/100 m^2 X 100
Fish/surface area = Fish/100 m^2 X 40.5
Fish/hectare = Fish/surface area X 2.4691

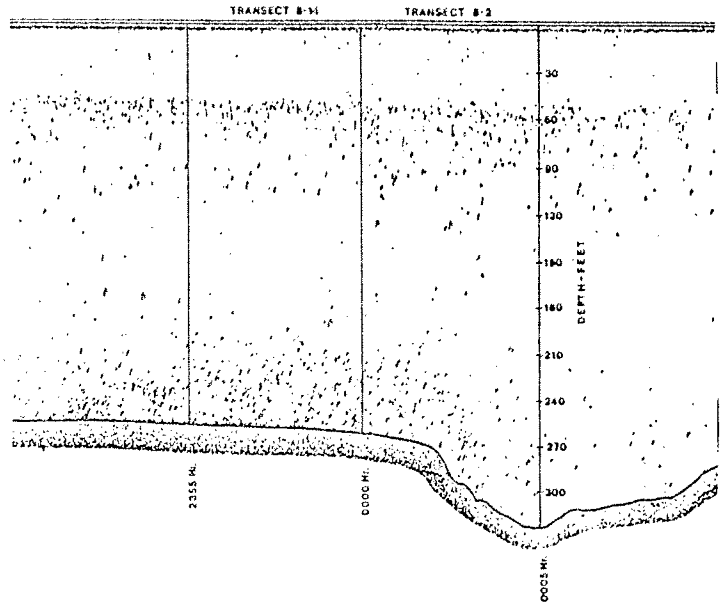
A computer program was developed to calculate surface area fish densities directly from an input of number of fish targets per interval. Program output printed fish numbers and densities by depth intervals and densities in bar-graph form (Figure 11).

A annual summary of kokanee density data by lake transect number is presented in Table 5. Although classification of the size of fish targets by signal strength can result in considerable overlap, particularly when there is not as much difference in the size of the 2+ and older salmon, total numbers of fish remains the same. It is only the proportion of small to large fish that would change.

During the time period, 1979 through 1983, the highest lake dwelling salmon density estimates occurred in 1982 with 56.7 fish/ha (22.9688 fish/surface acre-sa) and the lowest in 1980 with 38.7 fish/ha (15.7027 fish/sa). The most significant changes in densities occurred in the proportion of small to large fish. Large fish, most of which would spawn that fall, ranged from a high in 1980 with 18.6 fish/ha (7.5374 fish/sa) to a low of 3.9 fish/ha (1.5799 fish/ sa) in 1983. The percentage of large fish of the total was 31.8%, 41.2%, 32.0%, 29.2%, and 8.6% for the years 1979 to 1983, respectively. The small fish ranged from 41.4 fish/ha (16,7741 fish/sa) in 1983 to 26.4 fish/ha (10.6748 fish/sa) in 1981.

It is estimated that during September there are approximately 100,000 surface acres in the lake that contain salmon. An approximate estimate of total number of fish in the lake can be calculated by expanding the density figures, i.e. 1.5799 fish/sa X 100,000 = 157,990 large or maturing salmon in the lake. The estimates of neither large fish or total fish densities show any direct correlation when compared to the average size of the 3+ or 4+ from lakeshore spawning kokanee. Undoubtedly the absence of an estimate of early-run fish contributes, in a negative manner, to any correlation of numbers and size of salmon in Flathead lake. Most importantly, acoustic estimates do provide an index to numbers of late-run fish that will spawn that same year and an index of juvenile fish available for spawning in future years.

Salmon densities in two northern Idaho lakes, Pend Oreille and Coeur d'Alene Lakes, have experienced changes during the last 10 years (Bowler and Reiman 1981). Average size of salmon in these lakes have ranged between 250 to 270 mm during the period. Salmon numbers decreased from 6.78 million to 4.68 million in Lake Pend Oreille from 1977 to 1983, while in Coeur d'Alene Lake they increased from 6.04 to 6.55 million from 1979 to 1980. Salmon densities in Idaho lakes represent an estimate of the total numbers of salmon, all age groups, by expanding fish counts from echograms and estimates of age composition determined by the use of a midwater trawl (Bowler 1979). For comparison, the number of older or mature sized fish in the Idaho lakes were calculated using the average percentage (12-16%) of the older to total number of salmon. Densities of the large or mature sized salmon in Lake Pend Oreille would then represent 13.2 to 19.8 fish/sa and densities in Coeur



TRANSECT 8-14

INTERVAL	FISH NO. -SM-	FISH NO. -LG-	FISH DENSITY FISH/100 SQR METERS SMALL	FISH DENSITY FISH/100 SQR METERS LARGE	INTERVAL FEET	8/31/81- 2355 HRS (0 5 10 15 20 25)	FISH DENSITY FISH/SURFACE ACRE SMALL	FISH DENSITY FISH/SURFACE ACRE LARGE	PERCENT
1	0	0	0	0	24 - 36	+	0	0	0
2	0	0	0	0	36 - 48	+	0	0	0
3	7	1	.043109	9.01569E-03	48 - 60	+++++++	2.56	.37	27.99
4	10	4	.073505	.029402	60 - 72	++++++++XX	2.98	1.19	39.9399
5	2	2	.012841	.012841	72 - 84	++X	.52	.52	9.97
6	0	1	0	6.10375E-03	84 - 96	+	0	.25	2.37
7	1	4	6.29214E-03	.025168	96 - 108	+XX	.25	1.07	12.21
8	2	1	.012935	6.46757E-03	108 - 120	++	.52	.26	7.53
9	0	0	0	0	120 - 132	+	0	0	0
10	0	0	0	0	132 - 144	+	0	0	0
TOTAL =			.148483	.088999		TOTAL =	6.83169	3.60447	

EACH += 1 FISH (6 - 10 IN.)/HECTARE
EACH X= 1 FISH (10 - 16 IN.)/HECTARE

TRANSECT 8-2

INTERVAL	FISH NO. -SM-	FISH NO. -LG-	FISH DENSITY FISH/100 SQR METERS SMALL	FISH DENSITY FISH/100 SQR METERS LARGE	INTERVAL FEET	9/1/81- 1 HRS (0 5 10 15 20 25)	FISH DENSITY FISH/SURFACE ACRE SMALL	FISH DENSITY FISH/SURFACE ACRE LARGE	PERCENT
1	1	0	.020053	0	24 - 36	+++	.81	0	4.03
2	0	0	0	0	36 - 48	+	0	0	0
3	3	0	.027232	0	48 - 60	+++	1.1	0	5.47
4	17	7	.125817	.051807	60 - 72	++++++++++++++XXXXX	5.1	2.1	35.68
5	5	7	.032324	.045254	72 - 84	++++XXXX	1.31	1.83	15.58
6	4	1	.024582	6.14570E-03	84 - 96	+++	1	.25	6.17
7	10	2	.063353	.01267	96 - 108	+++++++X	2.57	.51	15.27
8	1	3	6.51202E-03	.019536	108 - 120	+X	.26	.79	5.23
9	5	0	.033477	0	120 - 132	++++	1.36	0	6.73
10	3	1	.021783	7.24114E-03	132 - 144	+++	.88	.29	5.83
TOTAL =			.355138	.142475		TOTAL =	14.3831	5.77836	

EACH += 1 FISH (6 - 10 IN.)/HECTARE
EACH X= 1 FISH (10 - 16 IN.)/HECTARE

Figure 11. Typical echogram, during fall acoustic survey, showing kokanee distribution within two sample count areas, 8-14 and 8-2, lake transect no. 8. Lower portion - computer printout of fish target counts and calculated densities by depth intervals of the two sample areas in the above echogram, August 1981, Flathead Lake.

Table 5. Fall acoustic density estimates of small (8-10 inch) and large (10-14 inch) sized kokanee, as fish/surface acre, by lake transect and the weighted average for Flathead Lake, 1979-1983.

Transect number	FISH DENSITY (Fish/Surface Acres) 1979			1980			1981			1982			1983		
	Small fish	Large fish	Total	Small fish	Large fish	Total	Small fish	Large fish	Total	Small fish	Large fish	Total	Small fish	Large fish	Total
1	17.2	---	17.20	12.27	8.36	20.63	8.54	0.53	9.07	23.16	10.54	33.70	9.17	0.72	9.89
2	18.98	---	18.98	9.26	8.07	17.33	12.78	10.05	22.83	27.38	9.04	36.42	10.04	0.84	10.88
3	14.16	---	14.16	19.91	10.31	30.22	12.06	4.91	16.97	26.08	7.18	33.26	14.11	---	14.11
4	---	---	---	---	---	---	---	---	---	---	---	---	21.03	1.41	22.44
5	---	---	---	---	---	---	---	---	---	---	---	---	20.72	2.14	22.86
6	11.57	15.30	26.87	12.90	8.37	21.27	10.89	4.63	15.52	6.67	3.53	10.20	10.40	1.42	11.82
7	14.56	6.83	21.39	---	---	---	---	---	---	21.93	6.16	28.09	11.32	3.23	14.55
8	10.11	6.75	16.86	5.09	7.07	12.16	10.55	7.03	17.58	17.69	9.84	27.53	23.46	2.29	25.75
9	6.51	---	6.51	11.64	5.20	16.84	9.12	4.27	13.39	9.49	3.44	12.93	26.51	3.08	29.59
10	10.31	8.68	18.99	3.53	2.69	6.22	9.38	4.32	13.70	16.81	4.60	21.41	23.09	1.31	24.40
11	14.58	6.83	21.41	10.16	7.70	17.86	14.37	6.69	21.06	12.88	7.67	20.55	25.75	1.85	27.60
Weighted Average	12.76	5.94	18.70	10.74	7.54	18.28	10.68	5.03	15.71	16.27	6.69	22.96	16.77	1.58	18.35

d'Alene Lake would range from 18.1 to 21.1 fish/sa. In comparison, Flathead Lake kokanee densities of 15.7 to 18.6 fish/sa were slightly lower than Idaho densities of mature or large sized salmon. Juvenile salmon, ages 0, 1+ nd 2+, in Flathead Lake during the fall were not found along with the older fish and did not provide the opportunity to estimate total numbers of salmon.

RECOMMENDATIONS

Collectively, age and length of spawners, creel composition, growth analysis and acoustic density estimates provided an index of Flathead Lake kokanee. These parameters were monitored from 1972 to 1983 to establish a baseline data from which changes can be determined. Each parameter described specific conditions about the kokanee and assisted in aiding in interpreting population changes.

Present trends in the kokanee populations are unstable as they respond to increases in reproduction resulting from stabilized flows in the Flathead River. A continuation of the monitoring of salmon population parameters in the lake would aid in interpreting and evaluating the salmon status during the recovery period. Continued monitoring would also aid in evaluating salmon density responses to impacts resulting from fluctuating lake levels upon lakeshore spawning areas or possibly to the rapidly increasing numbers of Mysis shrimp in the lake.

It is recommended to continue to monitor the following kokanee population parameters:

1. Age composition of lake and river spawners;
2. Lake creel age composition;
3. Fall acoustic density estimates.

It is recommended to continue monitoring of indices until the collective salmon studies in the basin arrive at a kokanee management plan to control numbers that will maintain the kokanee fishery and other recreational aspects of the Flathead River Basin.

It is further recommended to develop acoustic techniques to measure densities of early-run river salmon while still in the lake.

LITERATURE CITED

Bowler, B., and B. Reiman. 1981. Kokanee investigations: Kokanee-zooplankton interactions and descriptions of carrying capacity. Idaho Dept. Fish and Game, Job Performance Report. Project F-73-R-3, Subproject III, Study VI, Job V, pages 61-85.

Brett, J. R. 1952. Temperature tolerances in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Board Canada, 9(6):265-323.

Brunson, R, Castle and Pirtle. 1952. Studies of sockeye salmon (Oncorhynchus nerka) from Flathead Lake, Montana. Proc. Mont. Acad. Sci., 12:35-43.

Clutter, R. I., and L. E. Whitesel. 1956. Collections and interpretation of sockeye salmon scales. Int. Pac. Salmon Fish Bulletin IX. 159 pp.

Decker-Hess, J., and P. J. Graham. 1982. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Progress Report. Montana Dept. Fish Wildl. and Parks. Kalispell, Montana. 65 pp.

Foerster, R. E. 1968. The sockeye salmon, Oncorhynchus nerka. Bulletin 162, Fisheries Research Board of Canada. 422 pp.

Fraley, J. J., and P. J. Graham. 1982. The impact of Hungry Horse Dam on the fishery of the Flathead River. Final Report. Montana Dept. Fish Wildl. and Parks. Kalispell, Montana. 91 pp.

Fraley, J. J., and S. L. McMullin. 1983. Effects of the operation of Hungry Horse dam on the kokanee fishery in the Flathead River system. Progress Report. Montana Dept. Fish Wildl. and Parks. Kalispell, Montana. 100 pp.

Gaufin, A. R., G. W. Prescott, J. F. Tibbs, Montana Department of Health and Environmental Science. 1976. Limnological studies of Flathead Lake, Montana: A status report. EPA Offc., Res. Div., Corvallis Exp. Res. Lab., Corvallis, Oregon.

Goldman, C. R., M. D. Morgan, S. T. Threlkeld, and N. Angeli. 1979. A population dynamics analysis of the cladoceran disappearance from Lake Tahoe, California-Nevada. Limnol. Oceanogr. 24:289-297.

Goodlad, J. C., T. W. Gjernes, and E. L. Brannon. 1974. Factors affecting sockeye salmon (Oncorhynchus nerka) growth in four lakes of the Fraser River system. J. Fish. Res. Board Canada. 31:871-892.

Graham, P. J., and W. Fredenberg. 1982. Flathead Lake fisherman census. Montana Dept. Fish Wildl. and Parks, Kalispell, Montana. 44 pp.

Graham, P. J., D. Read, S. Leathe, J. Miller and K. Pratt. 1980. Flathead River Basin Fisheries Study. Mont. Dept. Fish, Wildl. and Parks. 168 pp.

Hanzel, D. A. 1964. Evaluation of kokanee spawning and population density in Flathead Lake and tributaries. Comp. Report, Montana Fish and Game Dept., F-7-F-12, Job II. 10 pp.

Hanzel, D. A. 1970. Flathead Lake, investigation of its fish population and its chemical and physical characteristics. Comp. Report, Montana Department of Fish and Game. F-33-R-3, Job I. 48 pp. Multilith.

Hanzel, D. A. 1971. The seasonal and depth distribution of fish populations in Flathead Lake. Comp. Report, Montana Department of Fish and Game. F-33-R-4, Job I-b 9 pp. Multilith.

Hanzel, D. A. 1972. The seasonal and depth distribution of the fish populations in Flathead Lake. Comp. Report, Montana Department of Fish and Game. F-33-R-5, Job I-a 14 pp. Multilith.

Hanzel, D. A. 1972. Develop techniques for sampling juvenile kokanee and determine trends in kokanee population. Comp. Report, Montana Department of Fish and Game. F-33-R-5, Job I-c 5p. Multilith.

Hanzel, D. A. 1973. The seasonal and depth distribution of the fish populations in Flathead Lake. Comp. Report, Montana Department of Fish and Game. F-33-R-6, Job I-a 10 pp.

Hanzel, D. A. 1974. Seasonal measurements of basic water chemistry, plankton production and certain physical characteristics of Flathead Lake. Comp. Report Montana Department of Fish and Game. F-33-R-7, Job II-a 28 pp.

Hanzel, D. A. 1974. Age and growth analysis of fishes of Flathead Lake - Kokanee. Comp. Report Montana Department of Fish and Game. F-33-R-7, Job I-b 7p.

Hanzel, D. A. 1974. Develop techniques for sampling juveniles and determining trends in Flathead Lake kokanee populations. Comp. Report, Montana Department of Fish and Game. F-33-R-7, Job I-c. 5 pp.

Hanzel, D. A. 1974. Develop techniques for sampling juveniles and determining trends in Flathead Lake kokanee populations. Comp. Report MOntana Department of Fish and Game. F-33-R-8, Job I-c 10p.

Hanzel, D. A. 1975. Measure annual trends in recruitment and migration of the kokanee populations and identify the major factors affecting trends. Comp. Report Montana Department Fish and Game. F-33-R-9, Job I-b. 6 pp.

Hanzel, D. A. 1977. Measure annual trends in recruitment and migration of kokanee populations and identify the major factors affecting trends. Performance Report Montana Department of Fish and Game. F-33-R-11, Job I-b. 2 pp.

Hanzel, D. A. 1978. Measure annual trends in recruitment and migration of kokanee populations and identify major factors affecting trends. Performance Report, Montana Department of Fish and Game. F-33-R-12, Job I-b. 3 pp.

Hesse, L. 1977. FIRE I, a computer program for the computation of fishery statistics. Nebraska Tech. Ser. No. 1, Nebraska Game and Parks Commission. Proj. NO. F-10-R. 60 pp.

Johnson, W. E. 1961. Aspects of the ecology of a pelagic, zoo-plankton-eating fish. Verh. Internat. Verein. Limnol. 14:727-731.

Kim, W. S., and K. Roberson. 1968. On the use of otoliths of sockeye salmon for age determination. University of Washington Publications in Fisheries, New Series, Vol III. 151-168 pp.

Leathe, S. A. and P.J. Graham. 1982. Flathead Lake and fish food habits study. Mont. Dept. Fish, Wildl. and Parks, Kalispell. Final Report. 137 pp.

Lewis, S. L. 1971. Life history and ecology of kokanee in Odell Lake. Oregon State Game Commission, Job Progres Report, Proj. No. F-71-R-7, Jobs 6 and 10.

Lemberg, N. A. 1975. Hydroacoustic assessment of the 1973 sockeye salmon escapement into Lae Quinault, Washington. Masters' Thesis, University of Washington, College of Fisheries. Multilith. 78 pp.

McKern, J. L., H. F. Harton, and K. V. Koski. 1974. Development of steelhead trout (<u>Salmo gairdneri</u>) otoliths and their use for age analysis and for separating summer from winter races and wild from hatchery stocks. J. Fish. Res. Board Can. 31:1420-1426.

McMullin, S. L. and P. J. Graham. 1981. The impact of Hungry Horse Dam on the kokanee fishery of the Flathead River. Mont. Dept. Fish, Wildl. and Parks, Kalispell. 98 pp.

Montana Department of Fish and Game. 1976. Estimated man-days of fishing pressure by region for the summer and winter season, May 1975-April 1976. Mont. Dept. Fish and Game, Helena, Montana.

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. U.S. Dept. Int. U.S. Fish and Wildlife, Bur. of Comm. Fish Div. 317 pp.

Narver, D. W. 1968. Identification of adult sockeye salmon groups in the Chignik River system by lacustrine scale measurement, time of entry, and time and location of spawning. Univ. of Washington. Pub. in Fisheries, Vol. III. 115-148 pp.

Nunnallee, E. P., and O. A. Mathisen. 1972. An acoustic survey of Lake Wenatchee, Washington. College of Fisheries, Fisheries Research Institute. Circular No. 72-13. 43 pp.

Nunnallee, E. P. Jr. 1973. Hydroacoustic data acquisition and digital data analysis system for the assessment of fish stock abundance. University of Washington College of Fisheries, Fisheries Research Institute. Circular No. 73-3. 47 pp.

Northcote, T. G. 1973. Some impacts of man on Kootenay Lake and its salmonids. Technical Report No. 25. Great Lakes Fishery Commission. 46 pp.

Phelps, S. R. 1980. The genetic populations structure of the kokanee, Oncorhynchus nerka, in Flathead Lake, Montana. Master Thesis. University of Montana, Missoula, Montana. 68 pp.

Potter, D. S. 1978. The zooplankton of Flathead Lake: An historical review with suggestions for continuing lake resource management. Ph.D. Diss., University of Montana, Missoula. 371 pp.

Reiman, B. E., and B. Bowler. 1980. Kokanee trophic ecology and limnology in Pend Oreille. Idaho Dept. Fish and Game, Fisheries Bulletin. No. 1. 27 pp.

Robbins, O. J. 1966. Flathead Lake (Montana) Fishery Investigations, 1961-64. U.S. Dept. Interior: Bureau of Sport Fisheries and Wildlife Tech. Paper No. 4

Stanford, J. A., T. J. Stuart, J. D. Coulter, and F. R. Hauer. 1981. Limnology of the Flathead River-Lake ecosystem, Montana: Annual Report. Flathead Research Group, University of Montana Biological Station, Bigfork, Montana. 340 pp.

Stefanich, F. A. 1954. Natural reproduction of kokanee in Flathead Lake and tributaries. Mont. Dept. Fish and Game Job Completion Report No. F-7-R-3, Job III-A. 10 pp.

Stober, Q. J., R. W. Tyler, J. A. Knutzen, D. Gaudent, C. E. Petrosky, and R. E. Nakatani. 1977. Operational effects of irrigation and pumped storage on the ecology of Banks Lake, Washington. Report REC-ERC-77-5, Engineering and Research Center and Pacific Northwest Region, Bureau o Reclamation. 153 pp.

Thorne, R. E., E. P. Nunnallee, and J. J. Green. 1972. A portable hydroacoustic data acquisition system for fish stock assessment. Washington Sea Grant Publ. 72-4. University of Washington, Seattle. 13 pp.

United States Geological Survey. 1981. Water resources data for Montana, Water Year 1981. U.S.G.S. Water Data Report MT-81-1.

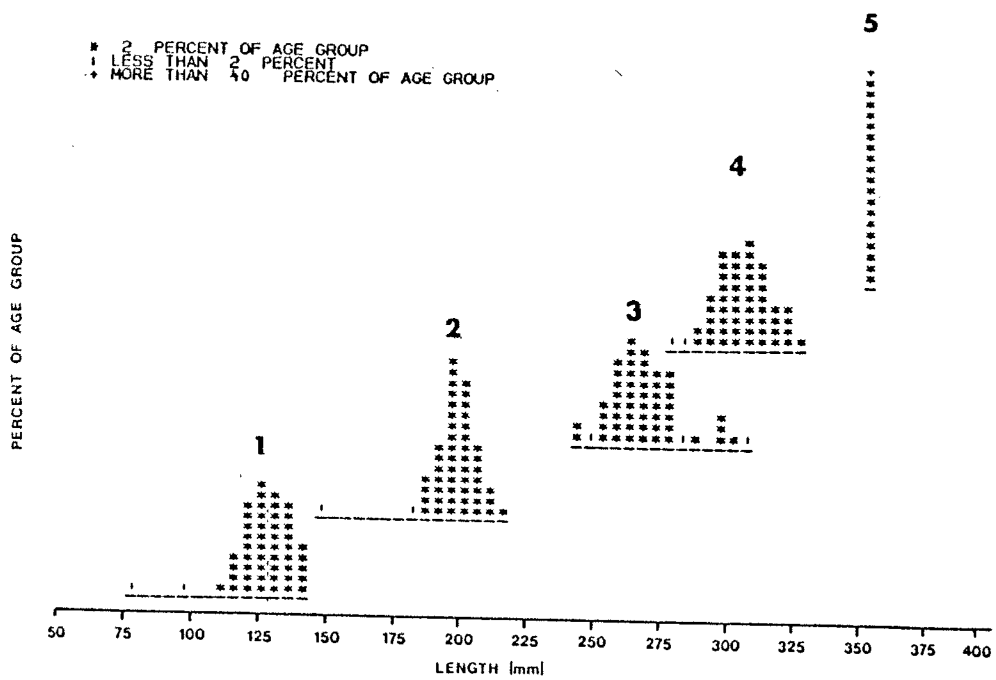
APPENDIX A

Average calculated total length (mm), average length at capture, number of circuli to first annulus by sex and age group, and length frequency histogram by length and age of kokanee for 1972 through 1983 in Flathead Lake.

-1972-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
1	M	--	---	---					
	F	2	125	14	92				
	U	81	133	14	89				
		(83)	(133)	(14)	(89)				
2	M	28	207	15	89	190			
	F	23	204	15	87	184			
	U	48	203	15	88	188			
		(99)	(204)	(15)	(88)	(188)			
3	M	50	271	15	88	197	264		
	F	41	266	15	89	195	261		
	U	16	259	14	85	186	250		
		(107)	(267)	(15)	(88)	(195)	(261)		
4	M	84	312	13	80	205	284	307	
	F	45	305	12	79	202	280	302	
	U	7	311	13	78	208	286	309	
		(136)	(310)	(13)	(80)	(204)	(282)	(306)	
5	M	1	336	12	78	206	271	317	(333)
	F	--							
	U	--							
		(1)	(336)	(12)	(78)	(206)	(271)	(317)	
TOTAL		(425)			(86)	(197)	(273)	(306)	(333)

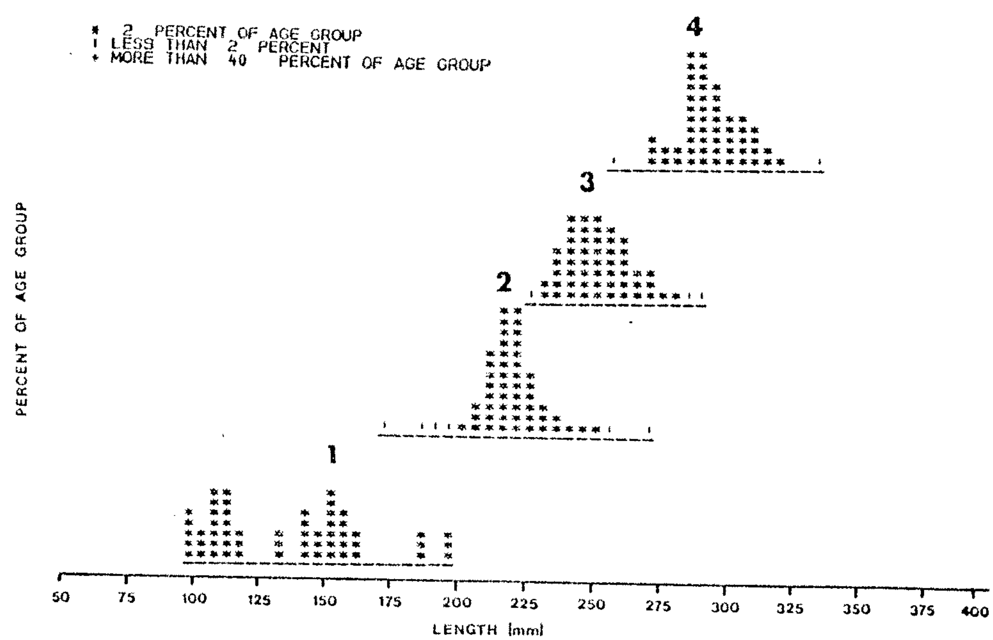
a/ M = male; F = female; U = undetermined.



-1973-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
1	M	5	128	12	79				
	F	3	138	14	88				
	U	14	136	13	83				
		(22)	(134)	(13)	(83)				
2	M	62	223	15	89	193			
	F	66	222	15	87	192			
	U	273	213	14	87	189			
		(401)	(215)	(14)	(87)	(189)			
3	M	159	263	15	92	196	251		
	F	124	257	15	92	194	245		
	U	230	253	14	88	192	247		
		(513)	(256)	(15)	(90)	(193)	(247)		
4	M	57	299	15	90	200	271	292	
	F	25	291	14	83	190	260	284	
	U	28	290	14	88	190	266	286	
		(110)	(294)	(14)	(88)	(195)	(267)	(288)	
TOTAL AVERAGE		(1046)			(88)	(192)	(251)	(288)	

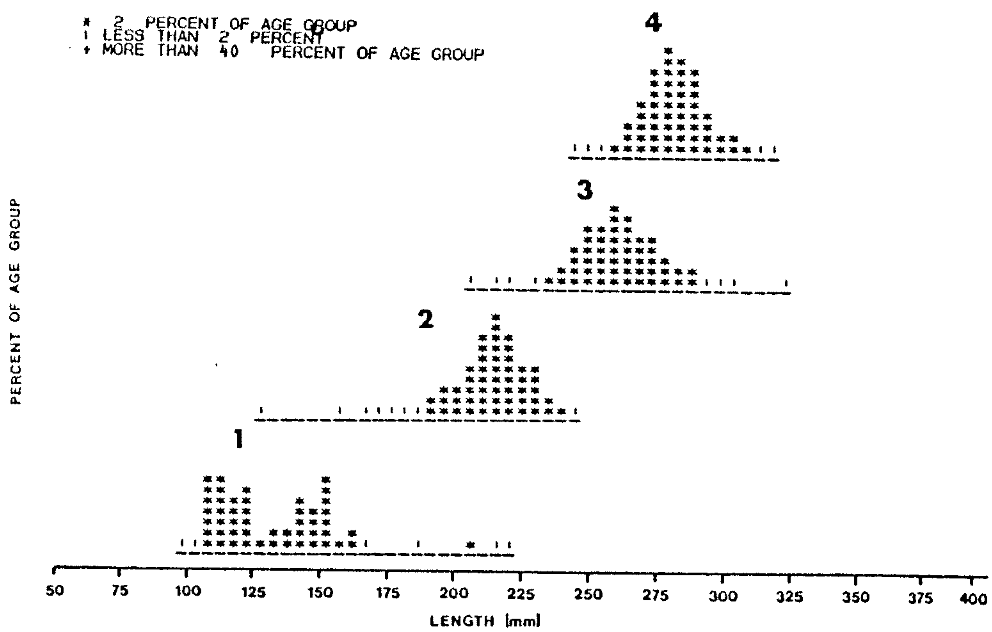
a/ M = male; F = female; U = undetermined.



-1974-

Age	Sex[a]	No.	Average length	Number of circuli to 1st annulus					
					I	II	III	IV	V
1	M	24	111	15	83				
	F	25	109	14	82				
	U	135	133	16	90				
		(184)	(127)	(16)	(88)				
2	M	83	228	15	85	204			
	F	62	229	15	86	206			
	U	224	215	14	81	195			
		(369)	(220)	(14)	(83)	(198)			
3	M	244	272	16	96	199	255		
	F	130	269	16	96	198	251		
	U	220	264	15	94	196	251		
		(594)	(268)	(16)	(95)	(197)	(252)		
4	M	158	288	15	91	196	250	273	
	F	74	285	15	91	191	245	270	
	U	137	279	15	89	189	246	269	
		(369)	(284)	(15)	(90)	(192)	(247)	(271)	
5	M	---							
	F	---							
	U	1	328	15	92	217	277	297	318
TOTAL AVERAGE		(1517)			(90)	(195)	(250)	(271)	(318)

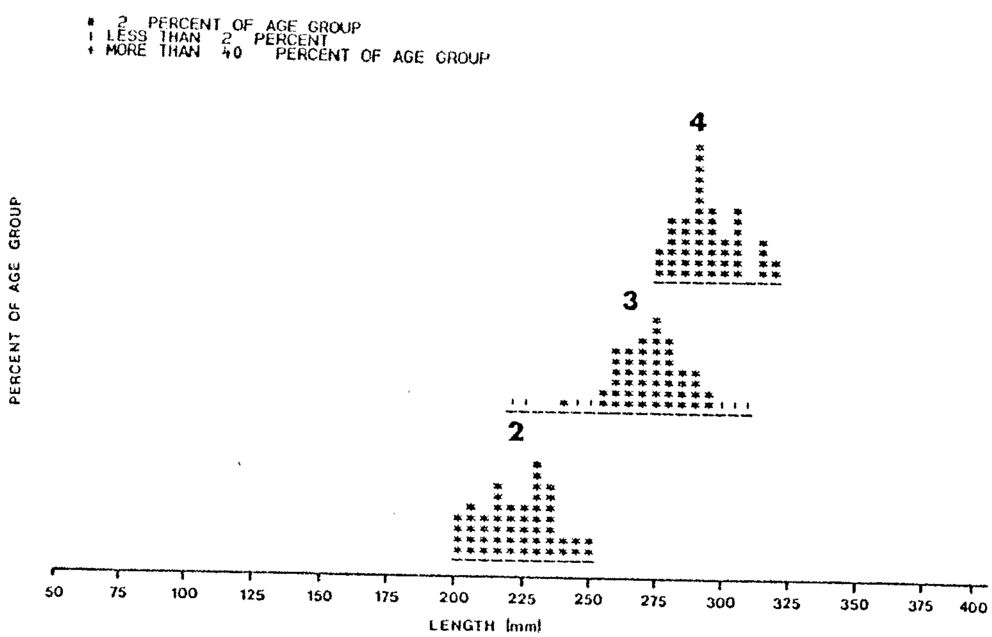
a/ M = male; F = female; U = undetermined.



-1975-

Age	Sex	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
2	M	12	231	14	85	217			
	F	17	228	15	85	213			
	U	---							
		(29)	(229)	(15)	(85)	(215)			
3	M	90	274	15	91	223	264		
	F	47	276	15	92	223	267		
	U	1	280	15	99	230	268		
		(138)	(274)	(15)	(92)	(223)	(265)		
4	M	25	299	15	97	201	261	289	
	F	11	290	15	97	203	255	279	
	U	---							
		(36)	(296)	(15)	(97)	(202)	(259)	(286)	
TOTAL AVERAGE		(204)			(92)	(218)	(264)	(286)	

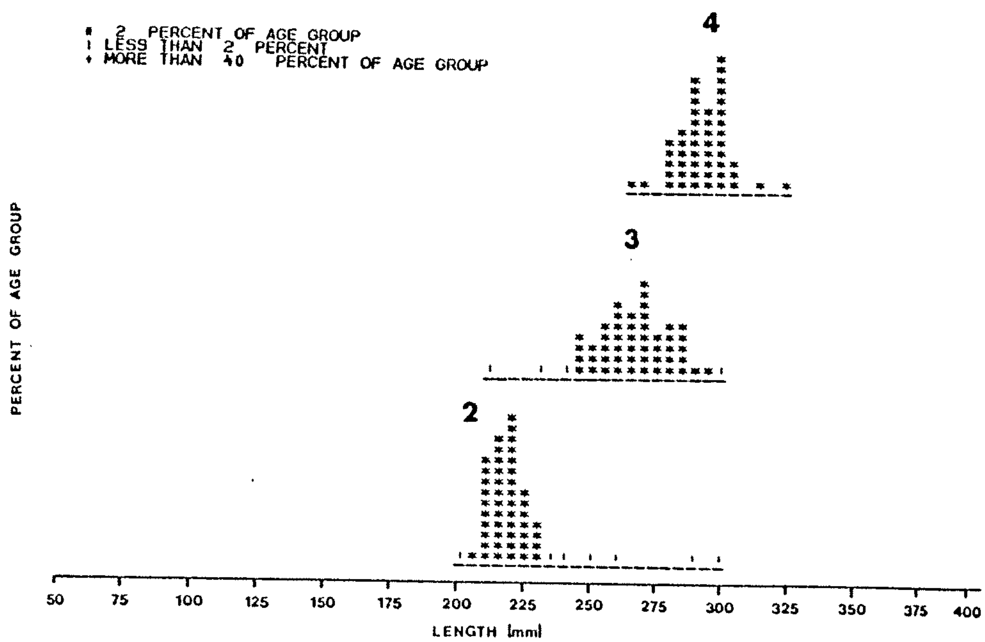
a/ M = male; F = female; U = undetermined.



-1976-

Age	Sex a/	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
2	M	87	222	15	88	212			
	F	75	220	15	89	208			
	U	---							
		(162)	(221)	(15)	(89)	(210)			
3	M	81	271	15	92	227	262		
	F	53	265	16	93	223	256		
	U	---							
		(134)	(269)	(14)	(92)	(225)	(260)		
4	M	32	296	15	87	217	265	288	
	F	18	291	14	87	219	264	283	
	U	---							
		(50)	(294)	(13)	(87)	(218)	(264)	(286)	
TOTAL AVERAGE		(346)			(90)	(217)	(261)	(286)	

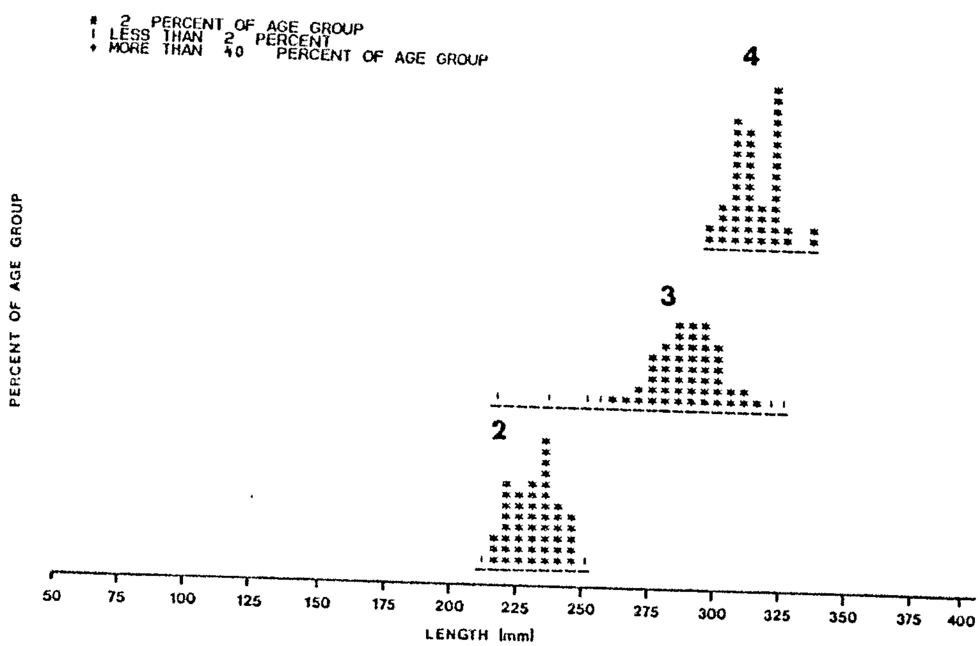
a/ M = male; F = female; U = undetermined.



-1977-

Age	Sex[a]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
2	M	41	232	15	99	204			
	F	28	234	15	96	202			
	U	10	227	15	90	203			
		(79)	(232)	(15)	(97)	(203)			
3	M	175	287	15	101	231	267		
	F	145	283	15	99	226	261		
	U	43	280	15	95	226	262		
		(363)	(285)	(15)	(99)	(229)	(264)		
4	M	18	311	16	107	228	269	295	
	F	10	306	14	103	227	268	292	
	U	9	307	17	114	231	271	290	
		(37)	(308)	(16)	(107)	(229)	(269)	(293)	
TOTAL AVERAGE		(479)			(100)	(224)	(264)	(293)	

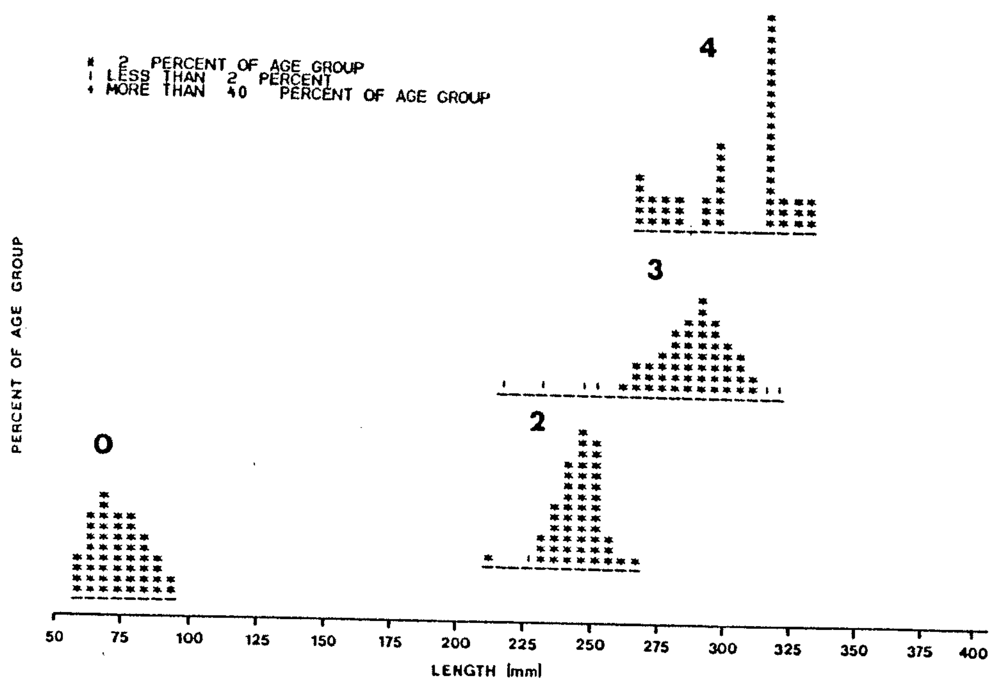
a/ M = male; F = female; U = undetermined.



-1978-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
0	M	0							
	F	0							
	U	25	75	8					
		(25)	(75)	(8)					
2	M	54	246	14	97	220			
	F	40	246	15	98	220			
	U	1	214	11	77	197			
		(95)	(245)	(14)	(97)	(220)			
3	M	126	295	15	105	221	273		
	F	124	294	15	103	221	270		
	U	24	282	15	99	218	259		
		(274)	(293)	(15)	(104)	(221)	(270)		
4	M	12	301	14	98	216	257	286	
	F	8	292	14	100	209	244	276	
	U	0							
		(20)	(298)	(14)	(99)	(213)	(252)	(282)	
TOTAL AVERAGE		(414)			(102)	(220)	(269)	(282)	

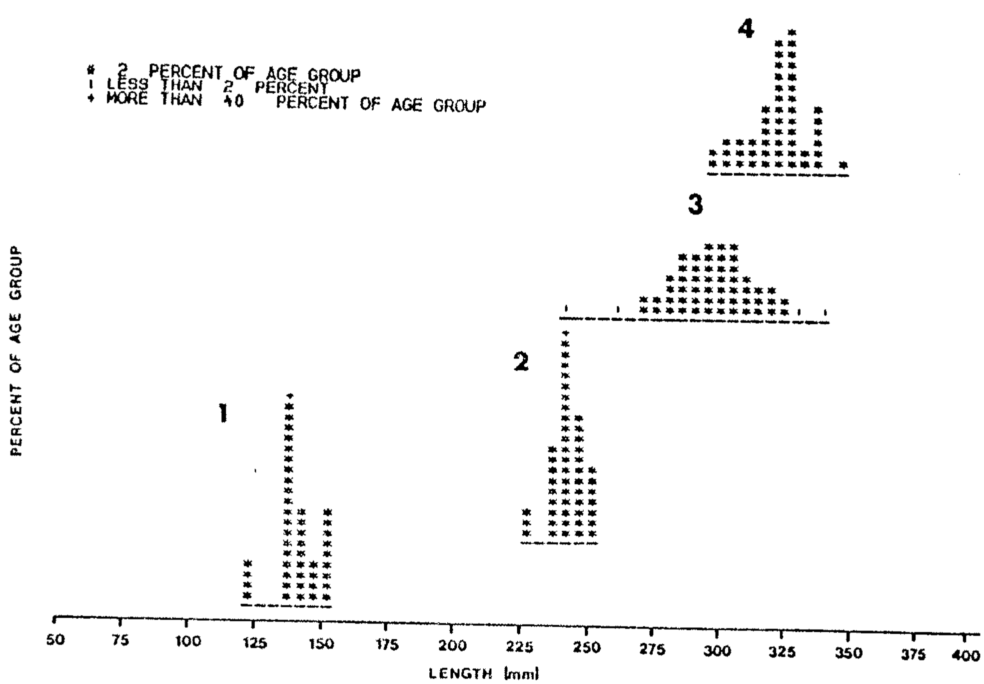
a/ M = male; F = female; U = undetermined.



-1979-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
1	M	0							
	F	0							
	U	12	140	12	80				
		(12)	(140)	(12)	(80)				
2	M	13	244	17	111	226			
	F	9	241	15	95	228			
	U	0							
		(22)	(243)	(16)	(104)	(227)			
3	M	118	299	15	103	232	279		
	F	110	300	14	104	234	280		
	U	0							
		(228)	(299)	(14)	(103)	(233)	(280)		
4	M	27	323	14	103	217	276	294	
	F	20	319	14	106	218	275	303	
	U	0							
		(47)	(322)	(14)	(104)	(217)	(276)	(298)	
TOTAL AVERAGE		(309)			(103)	(230)	(279)	(298)	

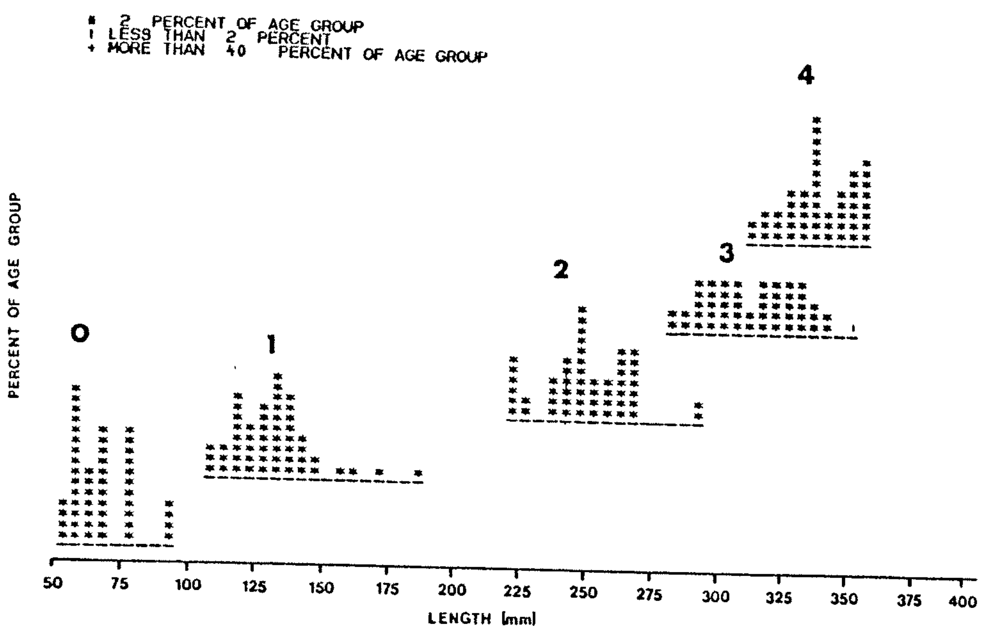
a/ M = male; F = female; U = undetermined.



-1980-

Age	Sex a/	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
0	M	5	70	10					
	F	9	71	8					
	U	0							
		(14)							
1	M	35	134	14	84				
	F	19	140	13	86				
	U	0							
		(54)	(136)	(14)	(85)				
2	M	20	251	16	96	208			
	F	8	246	16	100	204			
	U	0							
		(28)	(249)	(16)	(97)	(207)			
3	M	34	316	16	111	246	294		
	F	33	312	16	107	243	290		
	U	0							
		(67)	(314)	(16)	(109)	(244)	(292)		
4	M	26	340	16	117	255	298	310	
	F	13	338	15	109	246	290	316	
	U	0							
		(39)	(339)	(16)	(114)	(252)	(295)	(312)	
TOTAL AVERAGE		(202)			(101)	(238)	(293)	(312)	

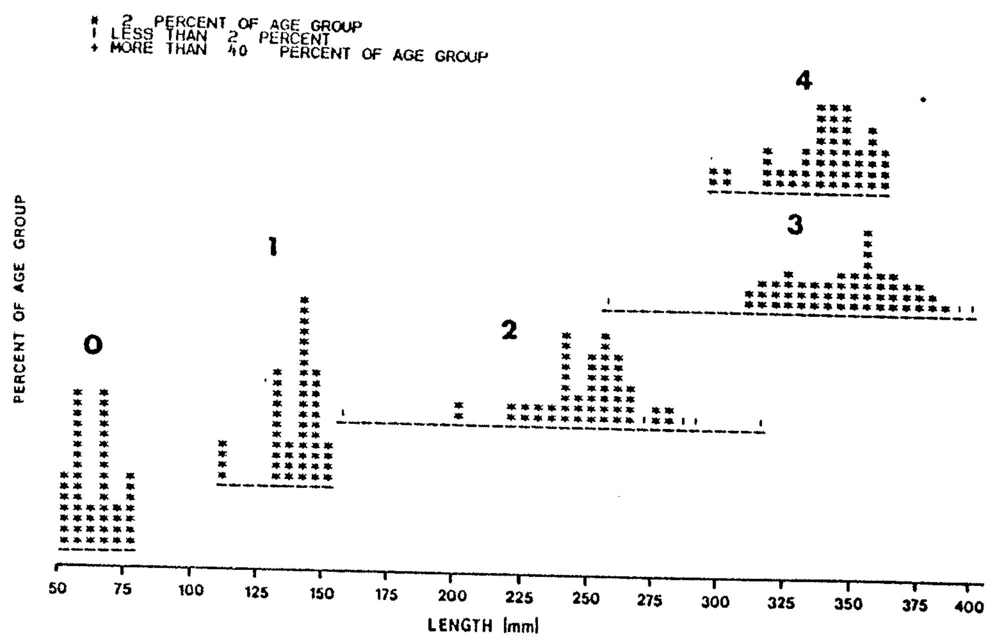
a/ M = male; F = female; U = undetermined.



-1981-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
0	M	0							
	F	0							
	U	(14)	69	8					
		(14)	(69)	(8)					
1	M	8	143	16	91				
	F	4	145	16	99				
	U	2	149	16	105				
		(14)	(144)	(16)	(95)				
2	M	35	252	15	88	222			
	F	32	262	15	91	237			
	U	10	257	14	87	219			
		(77)	(256)	(15)	(89)	(228)			
3	M	67	319	15	97	219	298		
	F	81	312	15	97	218	293		
	U	29	307	14	91	213	284		
		(177)	(316)	(15)	(96)	(217)	(294)		
4	M	12	349	14	101	250	304	334	
	F	8	335	16	102	242	289	321	
	U	5	342	13	95	232	288	324	
		(25)	(344)	(15)	(101)	(244)	(295)	(328)	
TOTAL AVERAGE		(307)			(98)	(222)	(294)	(328)	

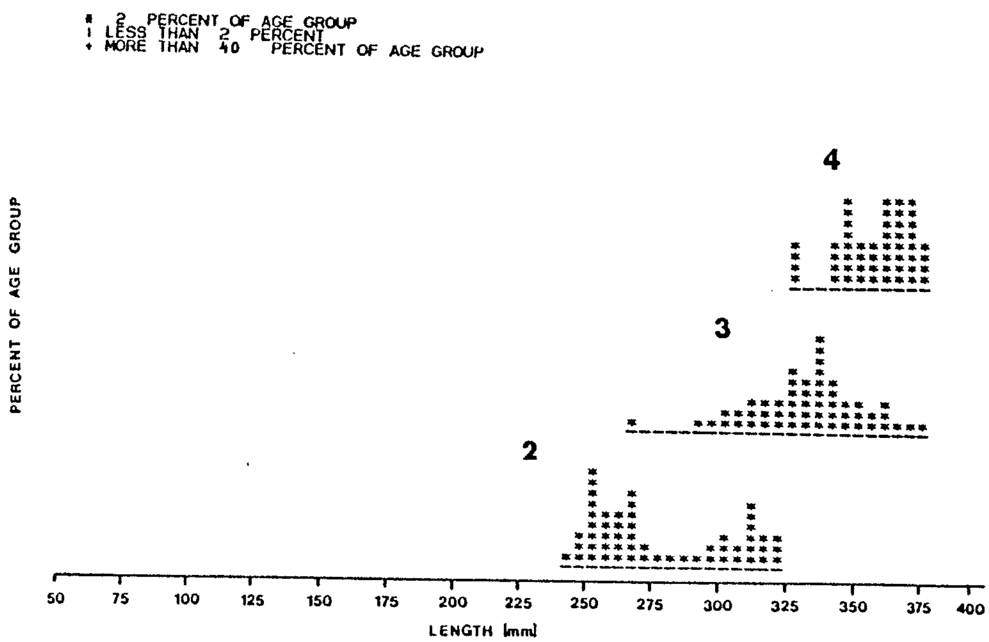
a/ M = male; F = female; U = undetermined.



-1982-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
2	M	24	263	18	101	225			
	F	18	256	16	96	220			
	U	24	307	17	102	254			
		(66)	(260)	(17)	(100)	(234)			
3	M	19	344	15	97	247	324		
	F	24	331	16	100	237	310		
	U	20	325	17	98	216	296		
		(63)	(337)	(16)	(99)	(233)	(310)		
4	M	8	356	16	98	211	310	342	
	F	5	359	17	98	209	293	336	
	U	0							
		(13)	(357)	(16)	(98)	(210)	(303)	(340)	
TOTAL AVERAGE		(142)			(99)	(231)	(309)	(340)	

a/ M = male; F = female; U = undetermined.



-1983-

Age	Sex[a/]	No.	Average length	Number of circuli to 1st annulus	Length at Annulus I	II	III	IV	V
0	M	0							
	F	0							
	U	13	72	8					
		(13)	(72)	(8)					
1	M	1	200	15	96				
	F	0							
	U	0							
		(1)	(200)	(15)	(96)				
2	M	52	308	16	103	240			
	F	37	294	16	101	230			
	U	24	284	18	103	228			
		(113)	(298)	(17)	(102)	(234)			
3	M	8	349	15	94	239	317		
	F	7	326	16	96	229	295		
	U	27	359	18	110	250	327		
		(42)	(352)	(16)	(105)	(244)	(320)		
4	M	1	327	14	88	142	254	327	
	F	0							
	U	0							
		(1)	(327)	(14)	(88)	(142)	(254)	(327)	
TOTAL AVERAGE		(170)			(95)	(236)	(318)	(327)	

a/ M = male; F = female; U = undetermined.