

OPERATIONAL EFFECTS OF IRRIGATION AND PUMPED/STORAGE
ON THE ECOLOGY OF BANKS LAKE, WASHINGTON

by

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1.0 EXECUTIVE SUMMARY

Banks Lake was created in 1951 by the U. S. Bureau of Reclamation to serve as the equalizing reservoir for the Columbia Basin Irrigation Project. An important sport fishery resource has developed for both salmonid and spiny ray fish and recent data indicate this fishery continues to increase. Expansion of the electrical generating capacity of the Grand Coulee Dam complex includes installation of six pump-generating (P/G) units in the pumphouse, which supplies Banks Lake from Lake Roosevelt.

The objectives of this study are to 1) establish a comprehensive ecological baseline (physical, chemical and biotic components) for Banks Lake which first determines the operational effects of water input and withdrawal for irrigation, and 2) assess the additional effects imposed by operation of P/G 7 & 8. Studies reported herein focus on operational effects of irrigation with limited analysis of P/G operational effects during test operations.

1.1 Aquatic Environment

Limnological sampling each month since July 1973 indicated that Banks Lake is a complex system dominated by the seasonal flow-through of irrigation water. Physical and chemical characteristics indicate the division of the lake into two pools due to the inflow of Lake Roosevelt water during the irrigation season. The north pool, which extends from the north dam to the Steamboat Rock area, receives water pumped from Lake Roosevelt, and is characterized by reduction of the temperature, transparency, retention time, and zooplankton abundance, than similar

properties in the south pool. In addition, the north pool showed thorough mixing of the water column, greater concentrations of plant nutrients (nitrates and phosphates), silica, and a corresponding greater phytoplankton production than found in the south pool. Nitrate limitation occurred throughout the lake after pumping and drafting had ceased for a period of time. Development of zooplankton occurred in the south pool, the more stable portion of the lake.

1.2 Fish Population Ecology

Twenty-one species of fish were identified in Banks Lake. Yellow perch, lake whitefish and kokanee comprised about 90% of the catch. Responses of the three major species indicated general avoidance of the reduced temperature, food supply and increased water velocities in the north pool. Yellow perch remaining in the north pool exhibited lower growth rates and condition. All three species were dependent on the cladoceran zooplankton *Daphnia* as the major food source.

Water level decline in the lake appeared to be a major factor affecting fish reproduction and survival. Irrigation drafting each spring reduced the shoreline spawning habitat and stranded eggs and fry of yellow perch. The population of large perch decreased coincident with the extremely large drawdowns of 1973 and 1974; however, the mechanism which caused the decrease is unknown. The extreme drawdown of 1973 greatly reduced the 1974 recruitment of kokanee. The incubation period for kokanee eggs and fry emergence from the shoreline gravel appears to extend into June; and, therefore, the young kokanee apparently become vulnerable to water level decline due to irrigation drafting. Lake

whitefish were not affected since winter spawning and early spring hatching occurred prior to spring drawdown.

Fish loss due to entrainment occurred principally through the irrigation canal in 1975-76, which amounted to an estimated loss of 436,216 fish weighing 110,338 kg. Point estimates of the total entrainment for the three major species were: yellow perch (241,367); kokanee (128,747); and lake whitefish (21,776). Fish loss through the feeder canal during limited P/G testing has thus far been minimal at about 4.1 and 1.6 fish per unit per hour in 1975 and 1976, respectively.

1.3 Sport Fishery

A 12 month creel census in 1975-76 estimated 350,866 angler-hours were spent catching 173,695 fish, or about 0.5 fish per angler-hour. The principal species caught included: kokanee (75,035); perch (59,788); rainbow (19,358); chinook (8,133); crappie (6,501); sunfish (3,529); and bass (1,036). The present census indicated a 21% increase in effort since 1971-72 and a continued shift from spiny-rayed to a predominantly salmonid fishery.

1.4 Impact Assessment

Future changes to be imposed on the lake due to P/G operation require further evaluation; however, the following appear likely based on past observation. Winter water temperature of the north pool will increase, thereby reducing ice cover. Nutrient input will increase further stimulating primary production in the north pool. The flushing rate of the north pool will increase. Fish entrainment through the

feeder canal will increase fish loss from the lake. Movement of water in two directions through the feeder canal may increase the numbers of non-game fish in the north pool. Winter fluctuation of the lake level due to P/G operation may further affect reproduction of kokanee and lake whitefish. Feeder canal modification in 1978, 1979 and 1980 will prohibit filling until mid-May; spring irrigation drafting will impact yellow perch and kokanee eggs and fry survival. The eventual installation of six P/G units will provide the additional capacity needed to minimize major lake level fluctuation, which could minimize impacts on the future sport fishery.

2.0 ACKNOWLEDGEMENTS

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Mr. D. Smith, Research Assistant, fish entrainment
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The cooperation received from the Washington Department of Game in planting marked populations of rainbow trout, and kokanee salmon, is greatly appreciated. The Washington State Department of Fisheries assisted by the loan of coded wire tagging machines. Mr. Rufus Kiser provided valuable taxonomic assistance in the identification of zooplankton species. Messrs. Frank Dimmick, Tom Spiker and Jesse Jones, U.S.B.R., provided essential engineering liaison, assisted in TV monitoring studies, and diving surveys of fish spawning areas. The assistance of Dr. D. A. McCaughran in reviewing the statistical analysis of the entrainment data is greatly appreciated. Field and laboratory assistance was

provided by Charles Petrosky, Regina Gaffke, Dave Gaudet and Steve Plakas. Webly's Sporting Goods, Grand Coulee cooperated with efforts to recover rainbow trout tags from anglers and to compile catch information.

3.0 PREFACE

This third annual report contains the scientific results of the ecological studies of Banks Lake. This study was initiated in 1973 to determine the effects of the operation of two pump generators (P/G 7 & 8) on the ecology and fish populations in the lake. It soon became evident that the lake was subjected to major influences due to annual operational changes in supply of irrigation water to the Columbia Basin Project. Determination of the operational effects on the lake related to irrigation water supply became the general focus of the project since it was obvious that the additional impacts of P/G operation could not be evaluated without that basic understanding of the system. Operation of P/G 7 & 8 since the initiation of the study has been limited due to mechanical difficulties, to infrequent and limited testing during the winter. Therefore, this report describes the ecological responses and impacts on the lake in its primary function as an irrigation equalizing reservoir. Inferences from these data regarding P/G operation have been drawn where possible.

The organization of this report is by sub-project dealing with the limnology of the lake, benthic ecology, fish population ecology and 1975-76 sport fishery. Fish entrainment of marked rainbow trout populations have been addressed. A summary and discussion of the major findings is also provided.

This study has been extended through June 1977 in order to allow assessment of the routine operation of P/G 7 & 8, as well as a second year of sampling of the fish loss through the irrigation canal.

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4.0 LAKE LIMNOLOGY

4.1 Introduction

The limnology of impounded waters continues to receive considerable attention (Hubbel 1967; Beckmann and Kutkuhn 1953; Hall 1971; Fraser 1972). This is not surprising, considering the fact that the United States has 5.25 million hectares (13 million acres) of artificial waters at maximum pool levels (Stroud 1966). As the requirements for water and energy increase new impoundments will be established and existing reservoirs will be expanded. Biological information is needed, not only to improve our knowledge of the behavior of aquatic ecosystems, but also to provide vital background for the establishment of effective resource management programs, particularly where recreational use of artificial waters is important.

A comprehensive study of the limnology of Banks Lake was begun to establish a data base for the assessment of the environmental impact of a pumped storage power generation facility at Grand Coulee Dam utilizing Banks Lake as the forebay reservoir. This data base will also describe the responses of the lake to changes imposed by the pumped input and withdrawal of irrigation water, its primary function as the equalizing reservoir for the Columbia Basin Irrigation Project. Determination of an ecological baseline under existing operating conditions and description of the effects of the input and withdrawal of irrigation water were of primary importance prior to the implementation of pumped storage power generation.

Specific objectives of the limnological studies were to document the temporal and spatial changes in certain aspects of the physical,

chemical and biological limnology (temperature, transparency, conductivity, pH, calcium-magnesium hardness, total alkalinity, dissolved oxygen, major plant nutrients, and ion composition), in the distribution and abundance of chlorophyll a as an index of phytoplankton abundance, $^{14}\text{CO}_2$ uptake as a measure of primary production rate by phytoplankton, and in the distribution and abundance of zooplankton. The period from January 1975 to March 1976 is herein reported with additional data included from June 1973.

4.2 Description of Study Area

Banks Lake was established in 1951 by flooding 10,926.5 hectares (27,000 acres) along a 46.5 km (28.9 mile) section of the upper Grand Coulee between two earth fill dams (Wolcott 1964) (Fig. 4.1). The Grand Coulee gorge is located in the high scrub desert of Central Washington. It was cut from the massive plain of lava flow by the Columbia River which was temporarily diverted from its present course by an ice blockage during recent glaciation. The present climate is one of hot, dry summers and cold, dry winters. Average summer daytime temperatures range from 23.9 to 29.4 C (75° to 85° F). January temperatures average from -9.4 to -1.1 C (15° to 30° F) with occasional extremes of -28.9 C (-20° F). Annual rainfall averages 27.5 cm (11 inches) (U.S.B.R. 1974). An ice cover lasting one to three months may develop on Banks Lake during severe winters, however, in recent years of this study complete ice cover was only observed during January and early February of 1974.

The North Dam constitutes the northern boundary of the lake. Dry Falls Dam (also known as South Dam) bounds the southern end of the lake. The pumping plant located at the left forebay of Grand Coulee Dam pumps

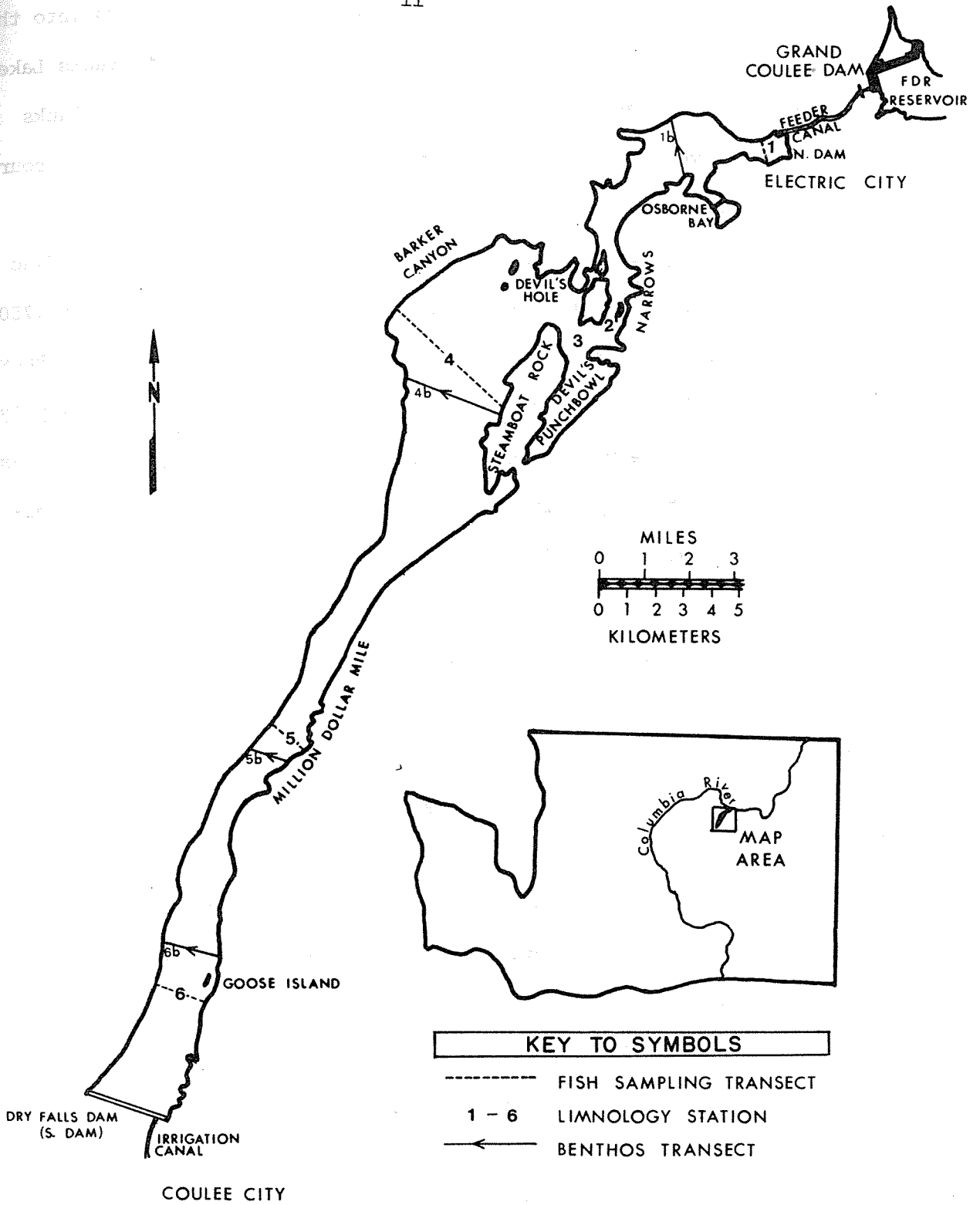


Figure 4.1 Geographical location and features of Banks Lake, and locations of sampling sites.

water from Franklin D. Roosevelt Reservoir up 111.2 m (365 ft) into the 2.5 km (1.6 mile) long feeder canal which supplies water to Banks Lake adjacent to the North Dam. Some runoff and spring water enter Banks Lake but the volume of water contributed to the system from these sources is negligible compared with the pumped water supply.

The pumping plant contains six pumps, each rated at $487.7 \text{ m}^3/\text{sec}$ (1,600 cfs) and two pump generators, each rated at $533.4 \text{ m}^3/\text{sec}$ (1,750 cfs) in the pumping mode. Water for irrigation is withdrawn from Banks Lake through the irrigation canal headworks at Dry Falls Dam to supply the agricultural requirements on about 202,000 hectares (500,000 acres) of farmland in the Columbia Basin. The present maximum rate of irrigation withdrawal is $2,407.9 \text{ m}^3/\text{sec}$ (7,900 cfs). Variations in the operational rates of water supply and withdrawal to Banks Lake result in water level fluctuations of the lake. Rates of irrigation water input and withdrawal and changes in water level elevation from January 1973 to March 1976 are presented in Fig. 4.2. Maximum surface elevation is 478.5 m (1,570 ft) (Table 4.1) and at maximum drawdown the surface elevation is 469.4 m (1,540 ft). The annual drawdown does not normally exceed 4.6 m (15 ft) but during the study period drawdown reached 7.6 m (24.9 ft) and 7.2 m (23.6 ft) during the spring of 1973 and summer of 1974 (Fig. 4.2). The maximum width of Banks Lake is 8 km (5 miles); however, the mean width is considerably less. The mean lake depth at maximum elevation is 13.5 m (41.1 ft) and the maximum depth is greater than 25 m (86.0 ft). The mean depth at surface elevation 496.4 m (1,540 ft) is 8.1 m (26.6 ft) (Table 4.1).

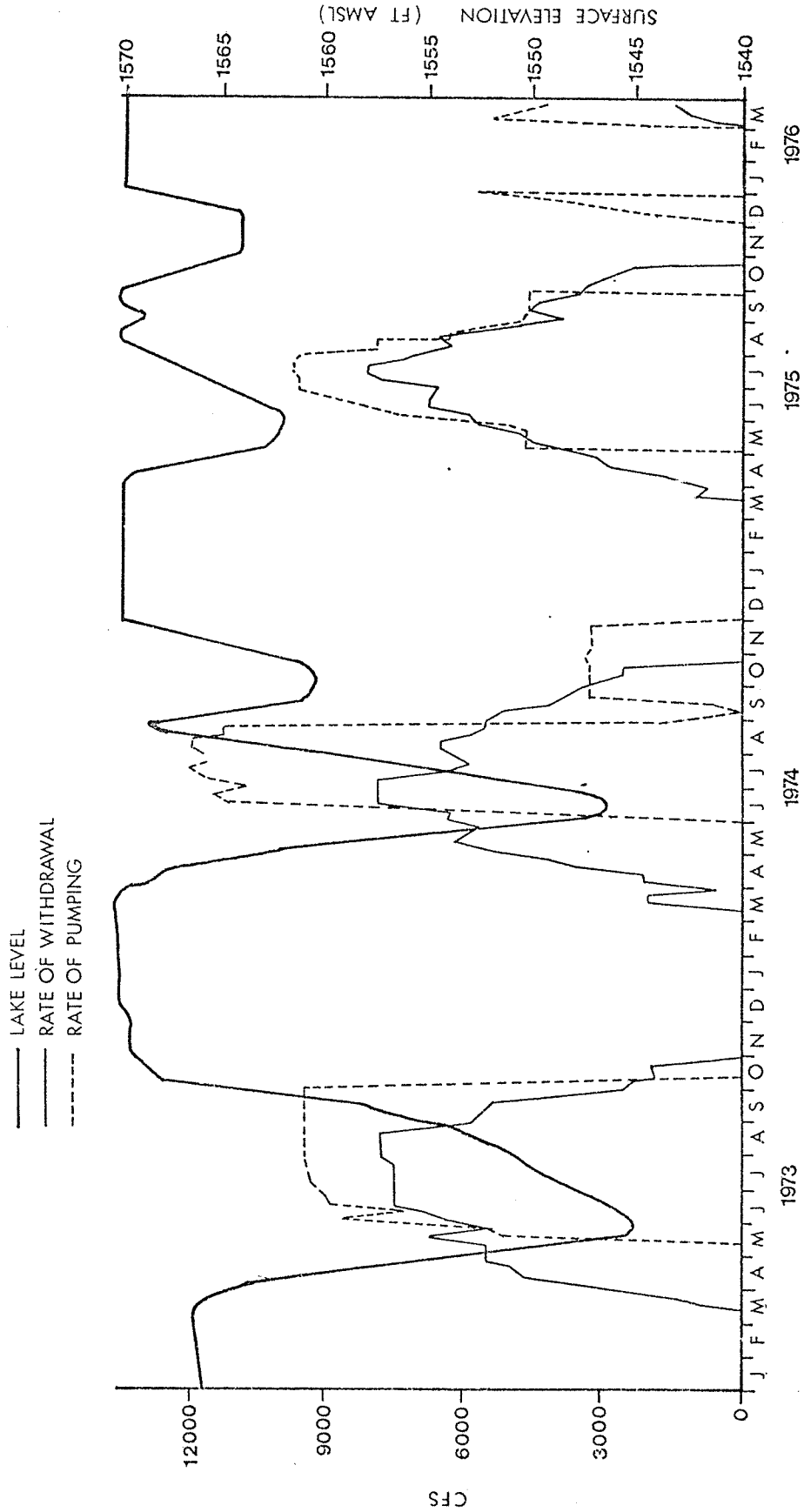


Figure 4.2 Banks Lake surface elevation relative to rates of irrigation water input and withdrawal, 1973 to 1976 (U.S.B.R.).

Table 4.1 Morphometric characteristics of Banks Lake.

	Elevation (m)	Area (ha)	Volume (ha m)	Maximum Length (km)	Maximum Width (km)	Mean Depth (m)	Perimeter (km)	Shoreline ¹ Development
Maximum level	478.5	11,008	148,269	46.8	8.0	13.5	131.5	3.53
level								
Irrigation drawdown:								
- 1.5 m	477.0	10,562	131,740	46.5	8.0	12.5		
- 4.6 m	474.0	9,384	101,394	46.5	7.9	10.8		
- 9.1 m	469.4	7,689	62,416	46.5	7.9	8.1	155.9	5.01

$$^1 \text{Shoreline Development} = \frac{\text{shoreline length}}{2 \left(\sqrt{\text{surface area} \times \pi} \right)}$$

The lake perimeter is 131.5 km (81.7 miles) at maximum elevation and 155.9 km (96.8 miles) at maximum drawdown. Shoreline development (Welch 1948) is 3.53 at maximum elevation and 5.01 at maximum drawdown.

Flushing time (lake volume \div rate of withdrawal) was determined for various elevations at different rates of withdrawal (Fig. 4.3). Under given conditions the general estimated flushing times for the entire lake ranged from 30 days to 2 years. The volume of water passing through the lake in a season was determined by irrigation requirements. This annual requirement has been approximately 271,366 hectare meters (2,200,000 acre feet) in recent years which represents effective replacement of the storage capacity approximately twice each year (U.S.B.R. 1974). This occurs generally during the irrigation season beginning in March and ending in October each year. This analysis of retention time is an oversimplification of the conditions existing in the lake and is provided only as a general description.

Initial limnological investigations, carried out during July and August 1973, indicated that a minimum of six sampling stations were required to document the limnology of the reservoir. A monthly sampling schedule was established. On occasion, severe weather conditions precluded a partial or complete set of observations. No samples were obtained in February 1975. Only Station 1 was sampled in January 1975 and Stations 2 and 3 were not sampled in February 1976 due to ice cover.

Stations were established at midlake locations. Station 1 was located 0.2 km (0.1 mile) from the North Dam near the feeder canal discharge point. Station 2 was 10.8 km (6.7 miles) from the North Dam, in the area of the morphometric constriction. Station 3 was 11.9 km (7.4 miles) from the North Dam, south of the morphometric constriction.

Station 4 was 18.0 km (11.2 miles) from the North Dam, west of the southern end of Steamboat Rock. Station 5 was 33.3 km (20.7 miles) from the North Dam, adjacent to Million Dollar Mile. Station 6 was 41.7 km (25.9 miles) from the North Dam, about 4.8 km (3.0 miles) from the irrigation water discharge structure.

4.3 Materials and Methods

4.3.1 Physical Measurements

During January and March 1975 in situ temperature was measured using an Applied Research temperature/conductivity probe. In April 1975 a Hydrolab Model 6D replaced this probe. Vertical temperature profiles were determined by recording temperature in 2 m depth intervals at each station. During summer stratification 1 m intervals were measured in the region of the metalimnion.

Transparency was measured with a standard 20 cm Secchi disc (Welsh 1948). Readings were taken by lowering the disc over the shaded side of the boat until it disappeared and then raising it until it just became visible. The mean of these two depths was recorded. All observations were made with the aid of polarizing sunglasses.

4.3.2 Chemical Measurements

Beginning in April 1975 the Hydrolab Model 6D was used to make in situ measurements of depth, temperature, conductivity, dissolved oxygen, pH and oxidation reduction potential (ORP). The Hydrolab model 6D consists of a deck read-out scale, six measuring probes fitted in a plastic housing called the sonde, and a watertight cable connecting the deck unit to the sonde and the probes. These parameters were measured

by lowering the sonde through the water column in two meter intervals from surface to bottom. Each parameter was read in turn from the deck read-out scale. The thermistor temperature sensing probe was also used to internally compensate all other readings to 25 C.

Dissolved oxygen was measured with a membrane covered passive polarographic cell and recorded as mg/l. Prior to April 1975 dissolved oxygen had been determined by the azide modification of the Winkler titration, titrating with phenyl arsine oxide (USEPA 1974).

The pH was determined with a high sensitivity glass pH probe. Past pH measurements had not been in situ but made from field collected water samples measured in the field laboratory on a photovolt expanded pH scale.

Conductivity measurements were made with a 4-electrode temperature compensating probe. Before April 1975 conductivity had been measured with a conductivity/temperature probe of the same design made by Applied Research.

The oxydation-reduction potential probe was platinum-tipped with a silver-silver chloride core. The silver-silver chloride electrode had a standard potential of approximately +200 millivolts with respect to the standard hydrogen electrode.

Water samples for chemical and chlorophyll a analysis were taken at three depths using three 2.5 l Van Dorn bottles. Samples were taken at the surface, 4 m, and near the bottom.

Initially total hardness and total alkalinity were determined by standard techniques (APHA 1971), modified according to the methods manual of the Hach Chemical Company. Beginning in April 1975, hardness

was determined by the calculation method (APHA 1971) from the concentration of calcium and magnesium and expressed as mg CaCO₃/l. Total alkalinity was determined by titration with sulfuric acid against bromocresol green-methyl red indicator and expressed in mg CaCO₃/l. Starting in August 1975 alkalinity was not modified by the Hach technique.

Water for nutrient analysis was placed in 500 ml "Nalgene" plastic bottles and acidified with one drop of 25% hydrochloric acid. Samples were packed in ice and transported to the Fisheries Research Institute water quality laboratory for analysis within 24 hours of collection. Ortho, hydrolyzable and total phosphate was determined spectrophotometrically as phosphorus according to standard techniques (USEPA 1974). Total nitrate nitrogen was determined by hydrazine reduction (Kamphake, Hannah, and Cohen 1967).

A modification of this technique in which a chelating agent (Chelex) was used to complex metal ions which may have interfered with the determination was begun in May 1975.

Water chemistry analysis was expanded in April 1975 to include the measurement of major cations, anions and reactive silica. The concentration of calcium, magnesium, potassium, sodium and iron were determined by flame atomic absorption spectrophotometry (USEPA 1974).

The colormetric molybdosilicate method was used to measure reactive silica. Chloride concentration was determined by the automated colorimetric technique using ferric ammonium sulphate and saturated mercuric thiocyanate as the reactive reagents (USEPA 1974).

Sulphate levels were measured by the automated colormetric method (Lazrus 1966). The samples were run through a cation exchange column to

remove interfering cations and then reacted with barium chloride and methylthynol blue. The resulting sample was read on a colorimeter at 460 nm to determine the sulphate concentration in mg/l.

The measurements of calcium, magnesium and silica were conducted monthly. The concentrations of potassium, sodium and sulphate were determined monthly through September and quarterly thereafter. Because of undetectable levels of iron during the spring, iron analysis was discontinued after three months in June 1975. Additional water samples were taken for chloride analysis starting in September 1975 and quarterly thereafter. These samples were not preserved with hydrochloric acid.

4.3.3 Biological Measurements

Phytoplankton standing stock measurements were made by the determination of chlorophyll a concentrations according to the spectrophotometric method of Richards and Thompson (1952). One liter water samples were taken at three depths at each station. One drop of saturated aqueous magnesium carbonate solution was added to each sample immediately after collection. The samples were kept cold and dark during transportation to the field laboratory where each was filtered through a Millipore RA (1.2 μ) filter under slight vacuum. The filters were dried and refrigerated in a darkened dissicator for analysis. Storage of samples before analysis was less than two weeks. The filters were dissolved in 90% aqueous acetone. Light absorbance of the resultant solutions was determined at wave lengths of 480, 510, 630, 645, 665 and 750 μ with a Bausch and Lomb Spectronic 20 colorimeter. Plant pigment concentrations were calculated according to the equations of Parsons and Strickland (1963).

Measurement of primary production by phytoplankton was begun in May 1975. A procedure was used similar to that discussed by Vollenweider (1974), for in situ Carbon-14 liquid scintillation method. Water samples were taken from 0, 1, 2, 3 and 5 m and, a depth 2 to 3 times Secchi disc depth. Starting in August a sample was also taken from 7 m. Three pyrex 125 ml bottles were filled with this water for each depth. Two of the bottles were clear and one taped with black electrician tape and the top covered with tinfoil to prevent light penetration. Each bottle was inoculated with approximately $0.5 \mu\text{Ci}$ of $\text{Na}^{14}\text{CO}_3$ using a Clay Adams Selectapette automatic pipet. At all times, except during filling and inoculation, the bottles were kept out of the light in a rectangular box with a sliding top. After inoculation each group of three bottles were attached to a wire spreader which was clipped to a loop of heavy gauge seine twine and lowered to the appropriate depth. This line had a 0.5 lb weight attached below the deepest bottle to maintain its vertical position. After all the bottles had been lowered, the line was affixed to an 8 ft bar that was supported at either end by a 1.5 x 1.5 x 4 ft styrofoam float. These floats were then anchored at one end and left to incubate 4 to 6 hours during the mid-day period.

Solar radiation was recorded on a Belfort pyroheliometer during the day of incubation. The total available carbon was determined from pH, temperature, and alkalinity using a conversion table in Saunders, et al. (1962). Temperature and pH were measured in situ at each depth sampled. Alkalinity was determined from water samples at 1, 3 and 7 m and the depth of the deepest bottles.

After the bottles had incubated they were retrieved and put back in the light-tight box and taken to the field laboratory. Within two hours after retrieval the contents of each bottle were filtered through a 1.2 μ RA Millipore filter under 5 to 10 lb/in² vacuum. After the contents had been filtered, 20 to 40 ml of distilled water was filtered through each filter to wash non-assimilated Na¹⁴CO₃ from the filter. Each filter was then placed into a glass scintillation vial and 20 ml scintillation solution (1 liter toluene, 40 g Bio-Solv, 5 g PPO, 0.5 g POPOP) added to each. Vials were kept in the dark and returned to the University of Washington, College of Fisheries, Laboratory of Radiation Ecology, where the ¹⁴C activity of the filters was determined on a Packard Tri-carb Model 3375 liquid scintillation counter.

Stations 1 and 4 were used as monthly index stations of lake primary production and station 6 as a periodic comparison. To minimize the effects of daily variation in light, both stations were measured on the same day. Since all operations were done from one boat, both stations could not be set simultaneously, but were staggered in their starting and retrieval time. Station 4 bottles were set 1.5 hours before Station 1 and picked up 0.5 hours before Station 1. When Station 6 was sampled it was on the same day as either Station 1 or 4. Some months were not reported because of severe weather conditions inhibiting sampling or problems with the quantity of Na¹⁴CO₃ used.

Zooplankton standing stock estimates for each station were determined from data obtained by vertical hauls of a 0.5 m diameter plankton net of 73 μ (No. 20) mesh (Edmondson and Winberg 1971). Duplicate hauls were made at each station from near the bottom to the surface and from 4 m to

the surface. The net was hauled with a Warn electric winch at an approximate speed of 30 m/min. Samples were preserved in 10% formalin through April 1974; later samples were preserved in 90% ethanol. Net clogging was frequently significant with this type of gear and since it was not possible to quantify the degree of clogging it was assumed to be constant in all determinations of relative abundance.

Zooplankton samples were diluted in the laboratory to a concentration of 100-200 organisms per ml. From two to four one-milliliter subsamples from each sample were counted with a low power stereo microscope (10 - 30X magnification) over a grid etched on a glass dish. Numbers of each genus of cladoceran and copepod and of copepod nauplii were recorded. The volume of water sampled was calculated by multiplying the net mouth area by the distance hauled. The number of each zooplankton genus per m^3 was calculated. Taxonomic identification of zooplankton crustacean species was carried out by Mr. Rufus Kiser (personal communication).

The quantity of zooplankton pumped into Banks Lake during the irrigation season was estimated by assuming that the concentration of zooplankton at Station 1 during pumping was equivalent to the concentration of zooplankton in the water pumped from FDR Reservoir.

Thus

$$T_Z = \sum_{m=1}^K (V_m \times Z_m)$$

T_Z = number of individuals of zooplankton group Z pumped in during the season

K = duration of pumping season (months)

V_m = volume of water pumped in (m^3) during month m

Z_m = estimated concentration (numbers/ m^3) of zooplankton group Z at Station 1 during month m

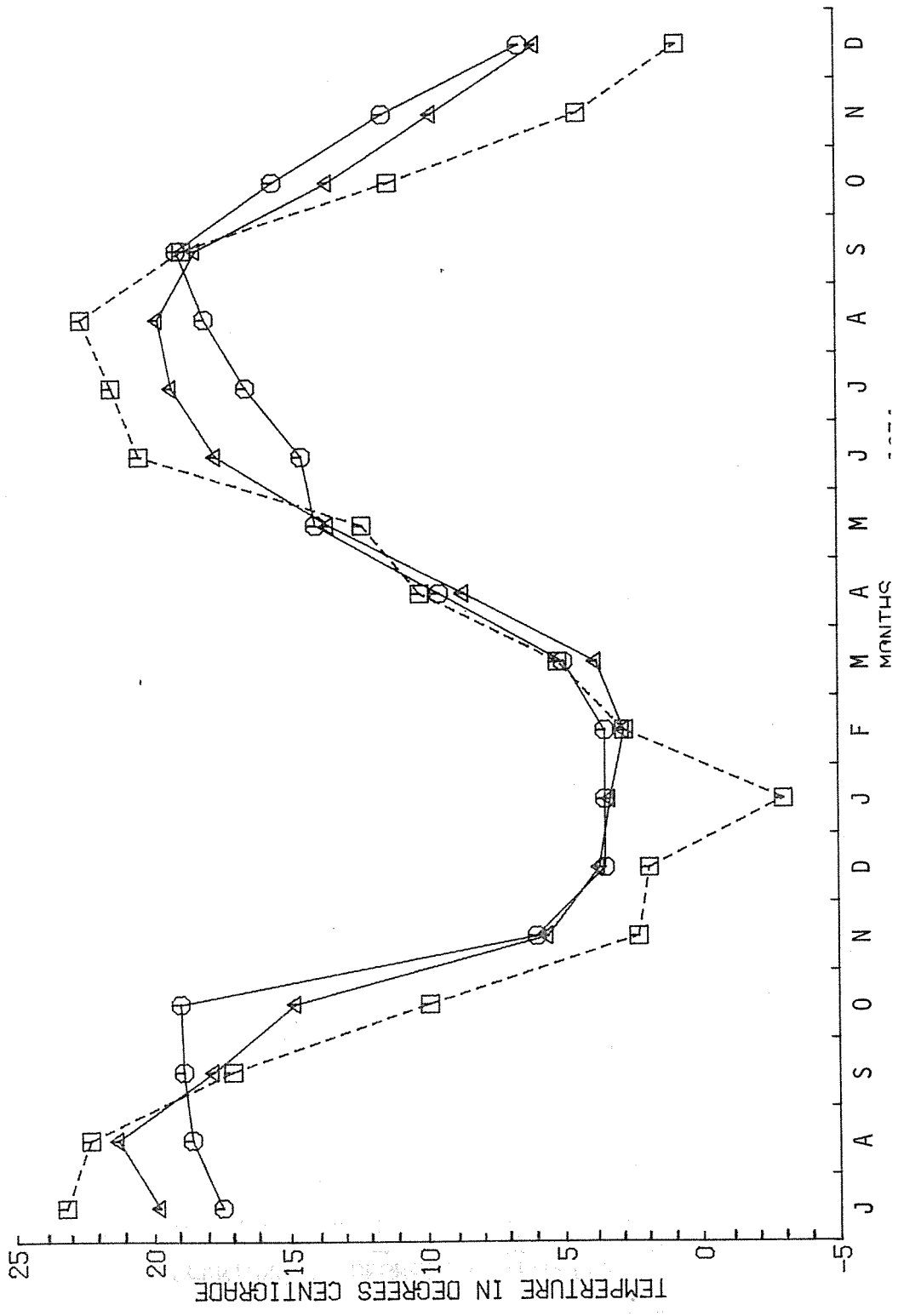
In the same manner the quantity of zooplankton removed from Banks Lake with the irrigation withdrawal was estimated by assuming that the concentration of zooplankton at Station 6 during irrigation withdrawal was equivalent to the concentration of zooplankton in the water withdrawn from the lake.

4.4 Results

4.4.1 Water Temperature

The predominant pattern of seasonal water temperature change in Banks Lake was directly related to the annual air temperature cycle (Figs. 4.4 and 4.5). Mean maximum summer air temperature was 24.5 C in July 1975. This compared with mean maximum temperatures of 23.2 and 22.5 C which occurred during July 1973 and August 1974, respectively. Mean winter air temperatures were -3.4 C and -1.5 C in January 1975 and 1976, respectively. A mean winter air temperature of -3 C occurred during January 1974. Maximum air temperatures during the summer of 1975 and the winter of 1976 were warmer than comparable seasons during 1973 and 1974. Mean maximum summer water temperature for Stations 2 through 6 was 19.8 C in July 1975 (Fig. 4.5); however, a maximum water temperature of 19.2 C did not occur until August at Station 1. The divergence of temperatures in July of 4.6 C between Station 1 and Stations 2 through 6 combined, resulted from the pumped input of irrigation water into the north end of the lake. A mean minimum winter water temperature of 0.9 C

MEAN AIR TEMPERATURE
STATION 1
STATIONS 2 - 6



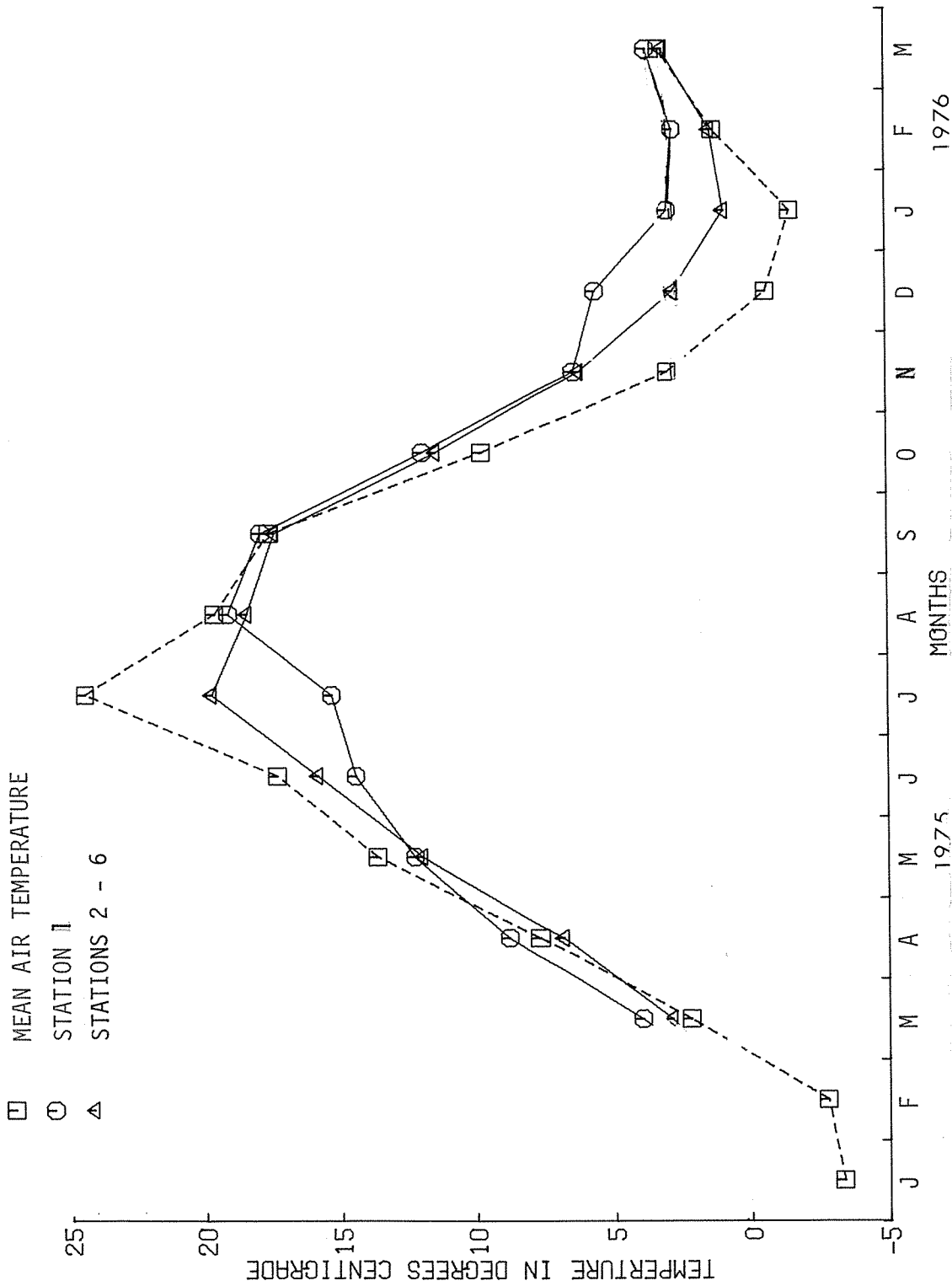


Figure 4.5 Banks Lake mean water temperatures at 4 meters versus mean monthly air temperatures, comparing Station 1 and Stations 2-6, for the period January 1975 to March 1976.

occurred at Stations 2 through 6 in January. Minimum winter temperatures at Station 1 were higher during the period December 1975 through March 1976. The north end of the lake was warmer by 2.9, 2.1, 1.4 and 0.6 C during December 1975, and January, February and March 1976. This increase in temperature occurred in response to sporadic pumped input of warmer water from FDR Reservoir. Pumping occurred during this time to refill the lake during December 1975 and due to P/G operational testing which occurred from January through March 1976. The lake was nearly homothermous during periods of spring and fall overturn. However, the main body of the lake (Stations 2 through 6) was cooler than Station 1 during March and April 1975. This suggests that higher temperatures occurred at Station 1 during December 1974 and January and February 1975 due to pumpback during P/G operation.

The same summer divergence of temperature between Station 1 and Stations 2 through 6 that was noted in 1975 was apparent in 1973 and 1974 (Fig. 4.4). However, the homothermous fall temperature during 1975 was different than during 1973 and 1974. Late fall pumping in these two years caused Station 1 to be warmer than Stations 2 through 6. Pumping stopped October 21, 1973, and at that time Station 1 was 4.2 C warmer than Stations 2 through 6. By November, Station 1 was only 0.4 C warmer, and in December, 0.2 C cooler than Stations 2 through 6. Pumping continued through November 30 in 1974, which maintained the temperature at Station 1, 0.7, 2.0 and 1.8 C warmer than at Stations 2 through 6 during September, October and November, respectively.

During the irrigation season a convergence zone was established in the lake approximately 7 miles from the north dam. The convergence

resulted from the flow of cooler water pumped into the north end of Banks Lake from FDR Reservoir during the late spring and summer. Pumped input coincided with irrigation drafting from the south end of the lake, establishing a general southward flow through the lake. The basin narrows and shoals forming a constricted zone of flow in the area of the convergence. An extremely sharp convergence occurred during August 1973 (Stober, et al., 1975). The same phenomenon was observed during July 1974 and 1975 (Figs. 4.6 and 4.7) but was less pronounced than in 1973, due to an increase in the lake level which correspondingly increased the area of the channel. The convergence was also observed to shift northward with decreased flow and/or higher lake levels. The north 6 to 7 miles of Banks Lake was cooler and nearly homothermous throughout the year due to turbulent mixing (Fig. 4.8). Minor stratification to 12 m occurred during May and July at Station 1 and minimum temperatures did not decline below 2.8 C during January 1976. The lack of pronounced stratification resulted from pumped input of water for irrigation in the summer and from pumpback during P/G testing in the winter. Vertical stratification began to develop at Stations 2 through 6 during May 1975 and became pronounced by July (Figs. 4.8 and 4.9). The lake became nearly homothermous during September 1975 and remained so as temperatures declined throughout the fall. Solid ice cover occurred only at Stations 2 and 3 in enclosed bays and near Dry Falls Dam during January 1976 while the rest of the lake remained largely ice free throughout the winter.

The dissolved oxygen levels remained high for the entire year, ranging from 54% to 119% saturation (Table 4.2). Surface saturation levels never dropped below 97%, and were highest during May, June and

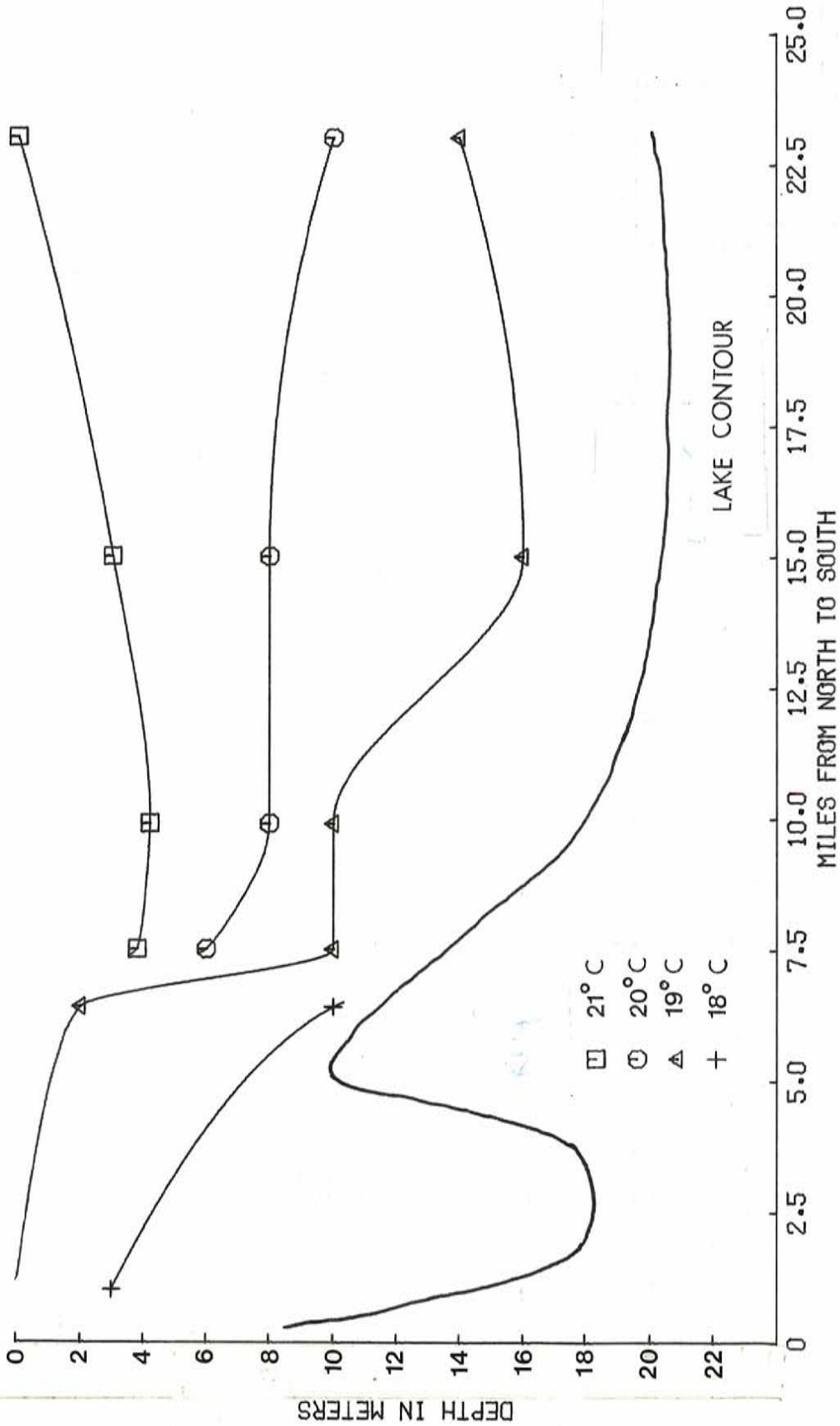


Figure 4.6 Banks Lake isotherms (July 22, 1974) showing the convergence zone between miles 6 and 7 where cold water, pumped in from FDR Reservoir, descends under a warm epilimnetic layer south of mile 7.5.

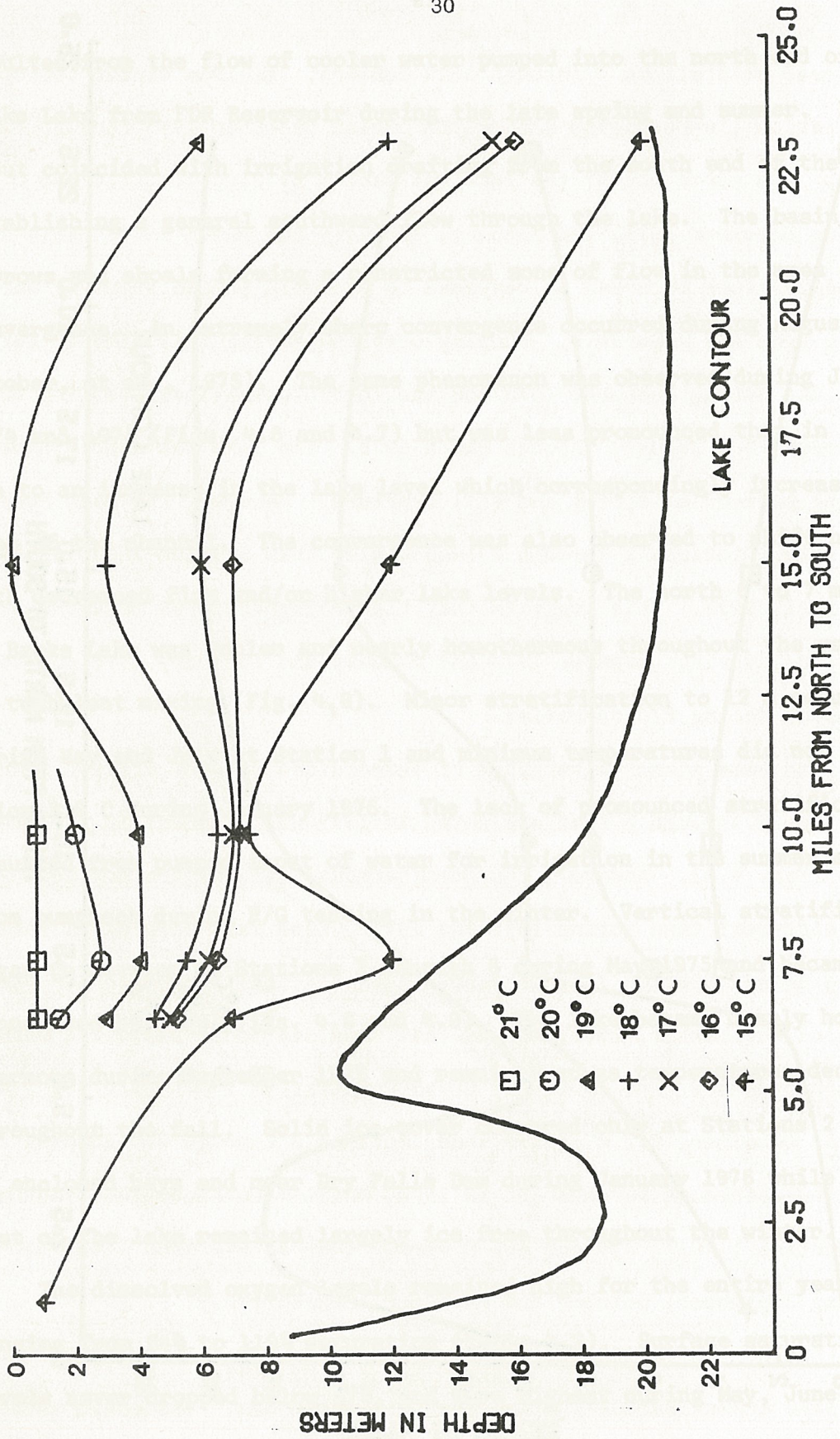


Figure 4.7 Banks Lake isotherms (July 23, 1975) showing the convergence zone north of mile 6 where cold water, pumped in from FDR Reservoir,

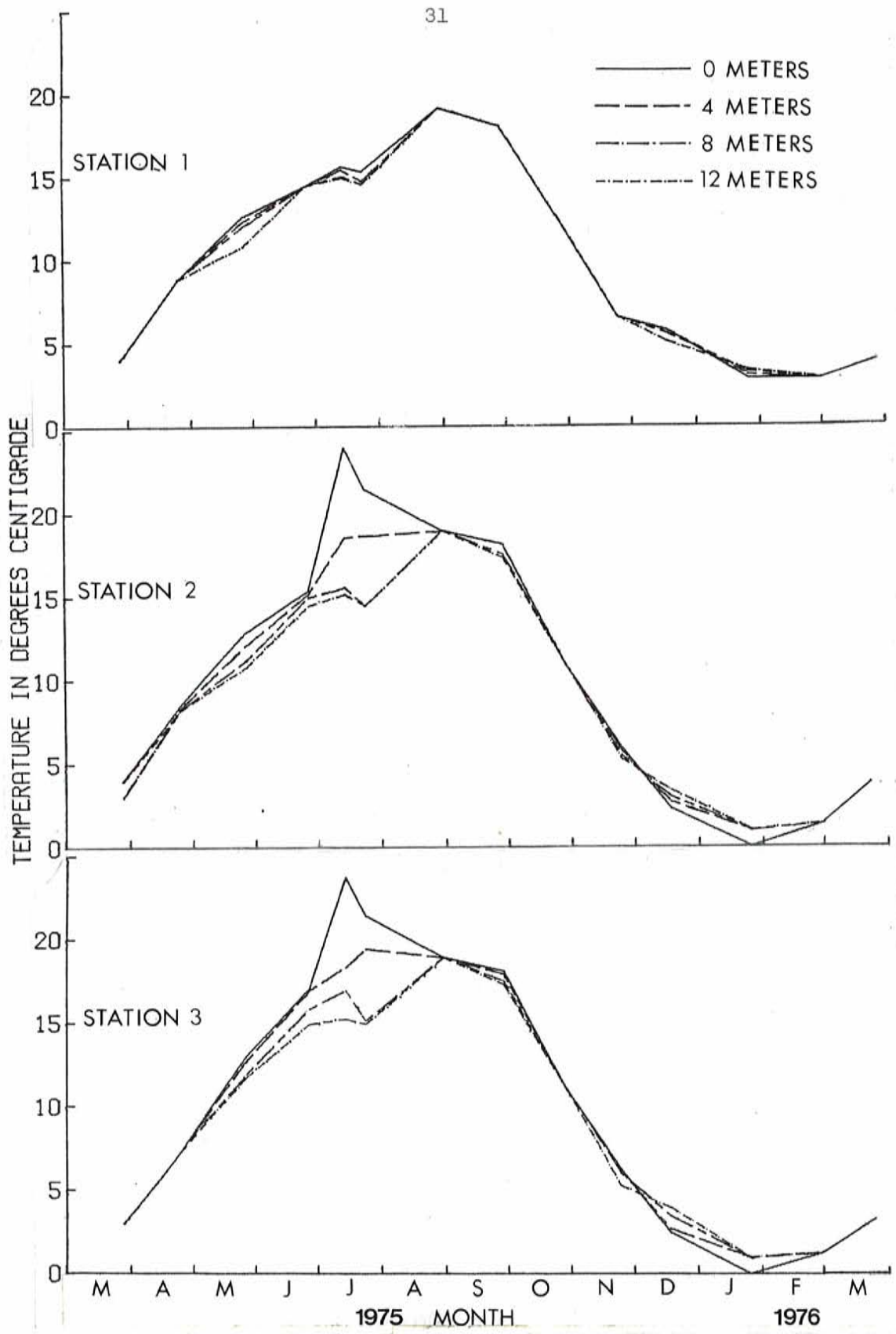


Figure 4.8 Monthly changes in water temperature at 4-meter depth intervals at Stations 1, 2, and 3.

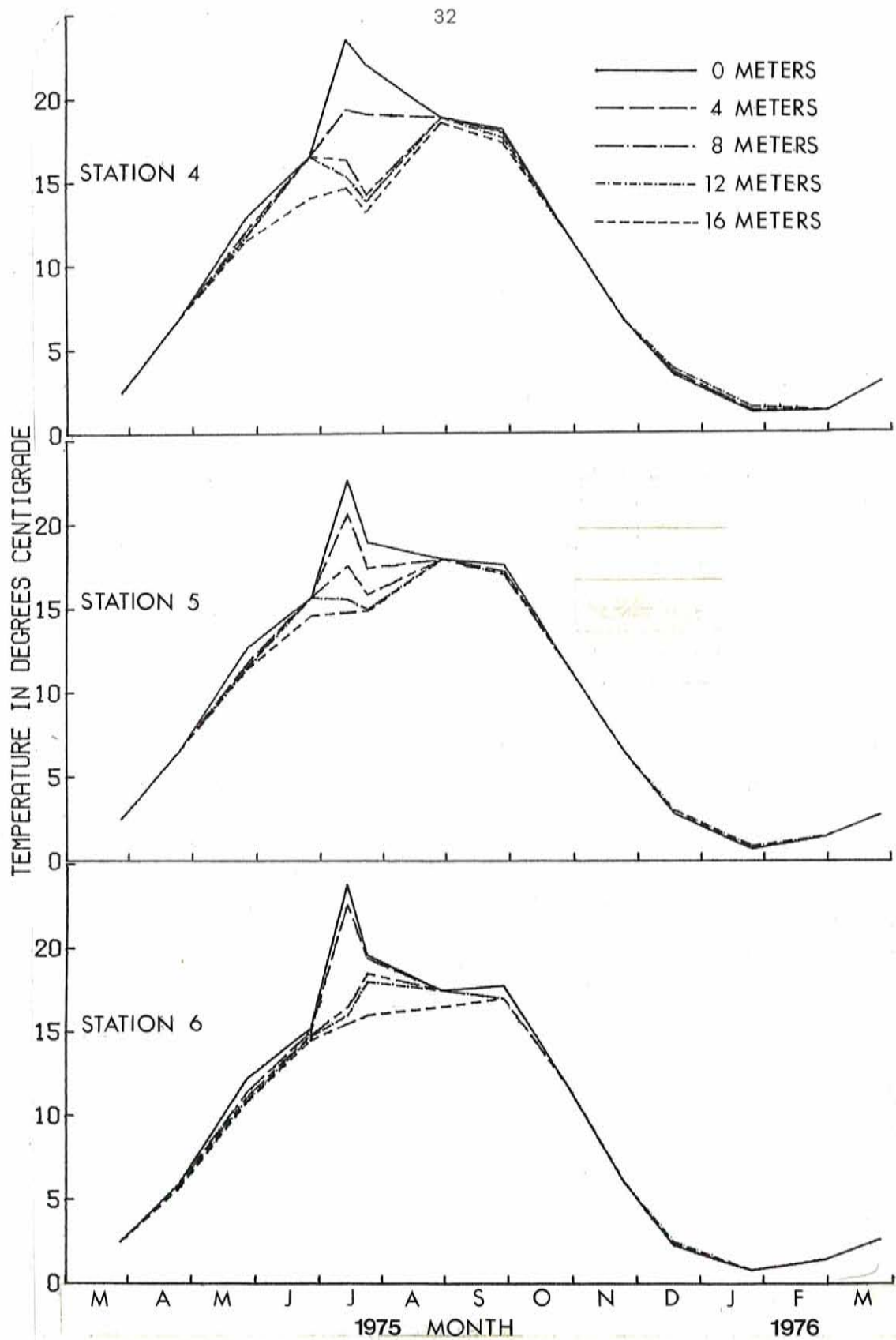


Figure 4.9 Monthly changes in water temperature at 4-meter depth intervals at Stations 4, 5, and 6.

Table 4.2 Average percent dissolved oxygen saturation by depth strata for Banks Lake from April 1975 to March 1976.

Station	Depth Strata	Month												Mean for each Depth Strata
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	
1	*0-6	107	116	119	106	107	102	104	101	106	105	117	113	109
	**B4	110	112	115	98	106	102	104	101	105	102	115	111	107
	***W.C.	109	114	118	103	107	102	104	101	106	104	116	112	108
2	0-6	108	111	119	116	109	110	102	103	102	108	112	109	
	B4	109	105	116	100	110	82	103	103	100	107	110	104	
	W.C.	108	108	118	109	109	96	102	103	101	107	111	107	
3	0-6	106	108	114	113	109	106	102	103	101	108	109	107	
	B4	110	104	118	104	90	82	102	104	102	107	109	103	
	W.C.	109	106	116	109	103	95	102	103	101	108	109	106	
4	0-6	108	101	105	116	102	106	101	101	103	107	109	106	
	B4	110	98	99	76	85	83	104	102	101	109	109	98	
	W.C.	110	99	103	97	97	98	102	101	102	109	109	103	
5	0-6	110	99	105	112	100	104	103	103	104	109	109	105	
	B4	110	94	96	76	102	95	103	100	101	109	108	100	
	W.C.	110	97	102	94	101	100	103	101	103	109	109	105	
6	0-6	107	102	105	113	97	105	103	102	106	110	111	106	
	B4	109	98	90	73	64	98	102	100	103	110	109	97	
	W.C.	108	100	99	100	85	101	102	101	105	110	110	102	
High	110	117	121	122	111	110	106	106	105	107	117	113	107	
Low	106	91	81	63	54	64	102	99	99	100	107	108	105	
Monthly Mean	0-6	108	106	111	113	104	106	103	102	104	110	111	107	
	B4	110	101	106	89	93	90	103	102	105	110	109	101	
	W.C.	109	104	109	102	100	99	103	102	106	110	110	105	

*0-6 Mean of surface to 6 meters
 **B4 Mean of bottom 4 meters
 ***W.C. Mean of water column

July most often at Stations 1, 2 and 3. Lowest saturation levels occurred near the bottom during July and August at Stations 4, 5 and 6.

The effect of thermal stratification on oxygen saturation is shown in selected vertical profiles taken during July and November (Fig. 4.10). Turbulent mixing due to pumped input of water through the feeder canal resulted in very little change in both parameters through the water column during July at Station 1. Temperature stratification occurred during July at Stations 2 and 3 and the dissolved oxygen exhibited a clinograde curve with depth which remained above 90% saturation at the bottom. These levels remained high probably because pumping was pushing saturated cooler water into the lower strata from Station 1 and also the shallow depth allowed photosynthesis to proceed near the bottom. Stations 4, 5 and 6 showed the greatest reduction of dissolved oxygen with depth and vertical temperature stratification during July. The dissolved oxygen curves tended to follow the change in temperature, but continued to decrease toward the bottom. The thermal stratification had reduced mixing between the epilimnion and the hypolimnion. Reduction of oxygen occurred at the greater depths due to exceedence of photosynthetic rate by respiration. The November measurements showed that during fall, thermal stratification broke down and the water became mixed from top to bottom at all stations, allowing dissolved oxygen levels to become uniform at all depths.

4.4.2 Transparency

Monthly Secchi depth water transparency measurements of Banks Lake from August 1973 to May 1976 showed temporal and spatial variation throughout the observation period (Fig. 4.11 and 4.12). Mean trans-

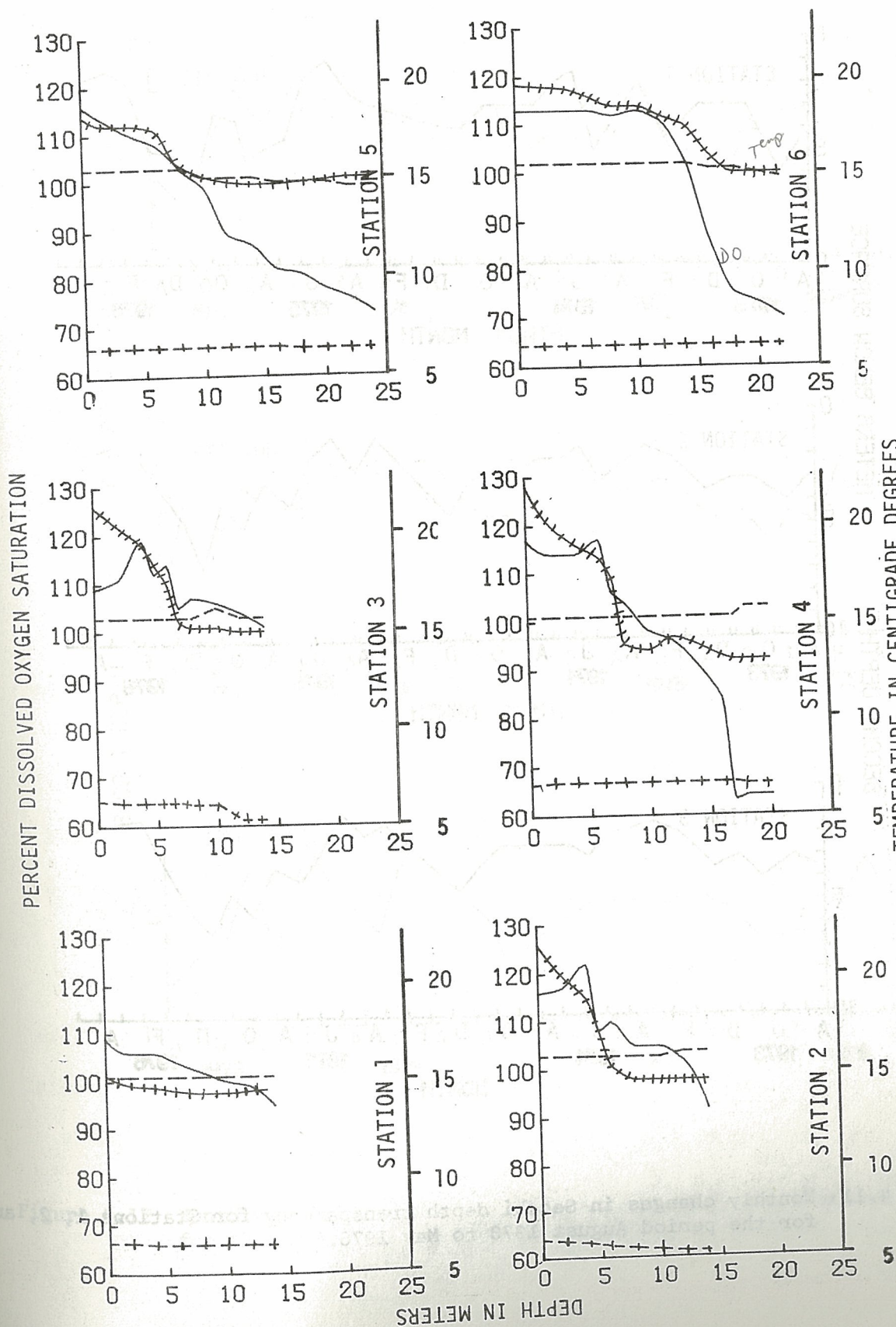


Figure 4.10 Temperature and dissolved oxygen saturation curves for all stations during July 23 and November 24, 1975.

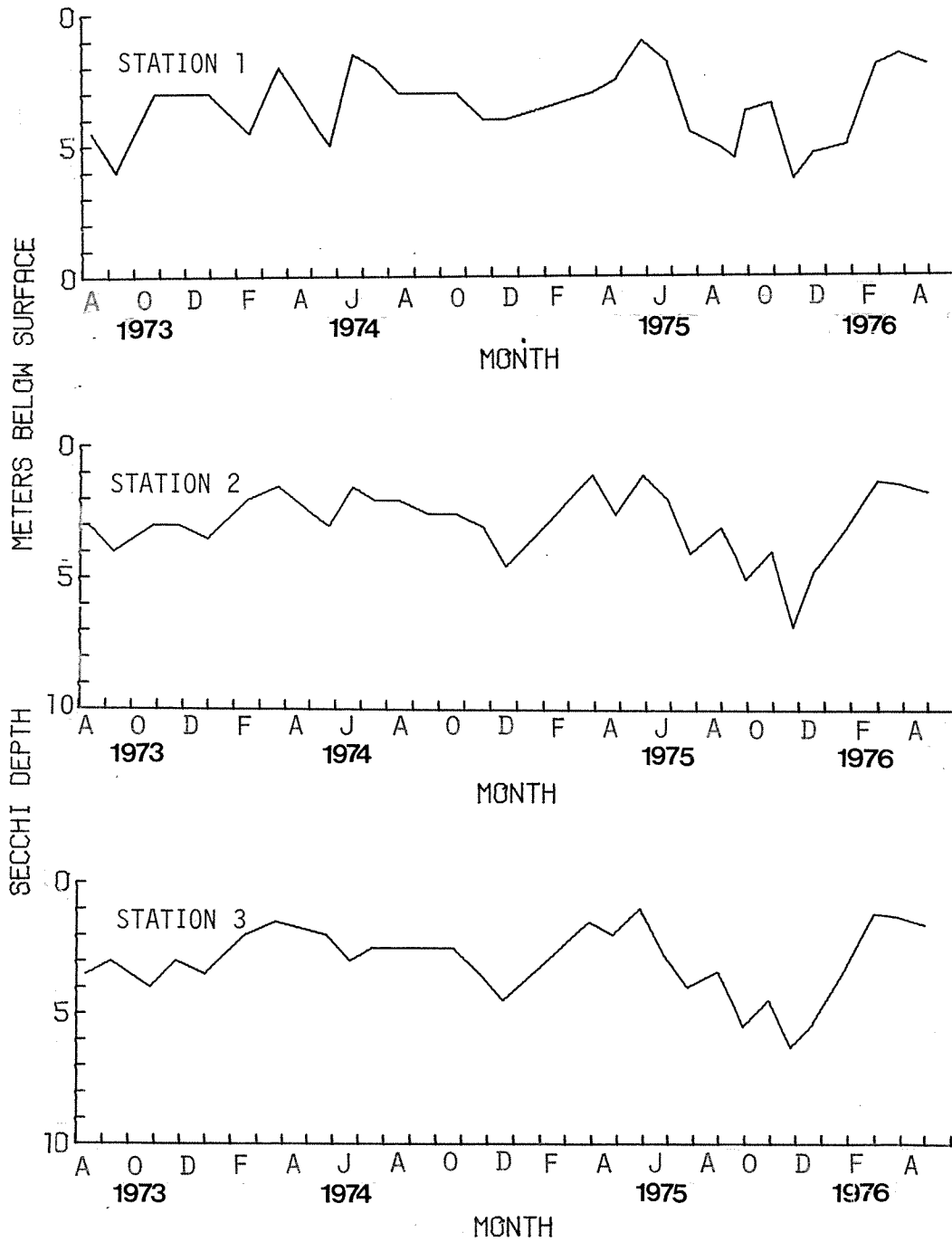


Figure 4.11 Monthly changes in Secchi depth transparency for Stations 1, 2, and 3, for the period August 1973 to May 1976.

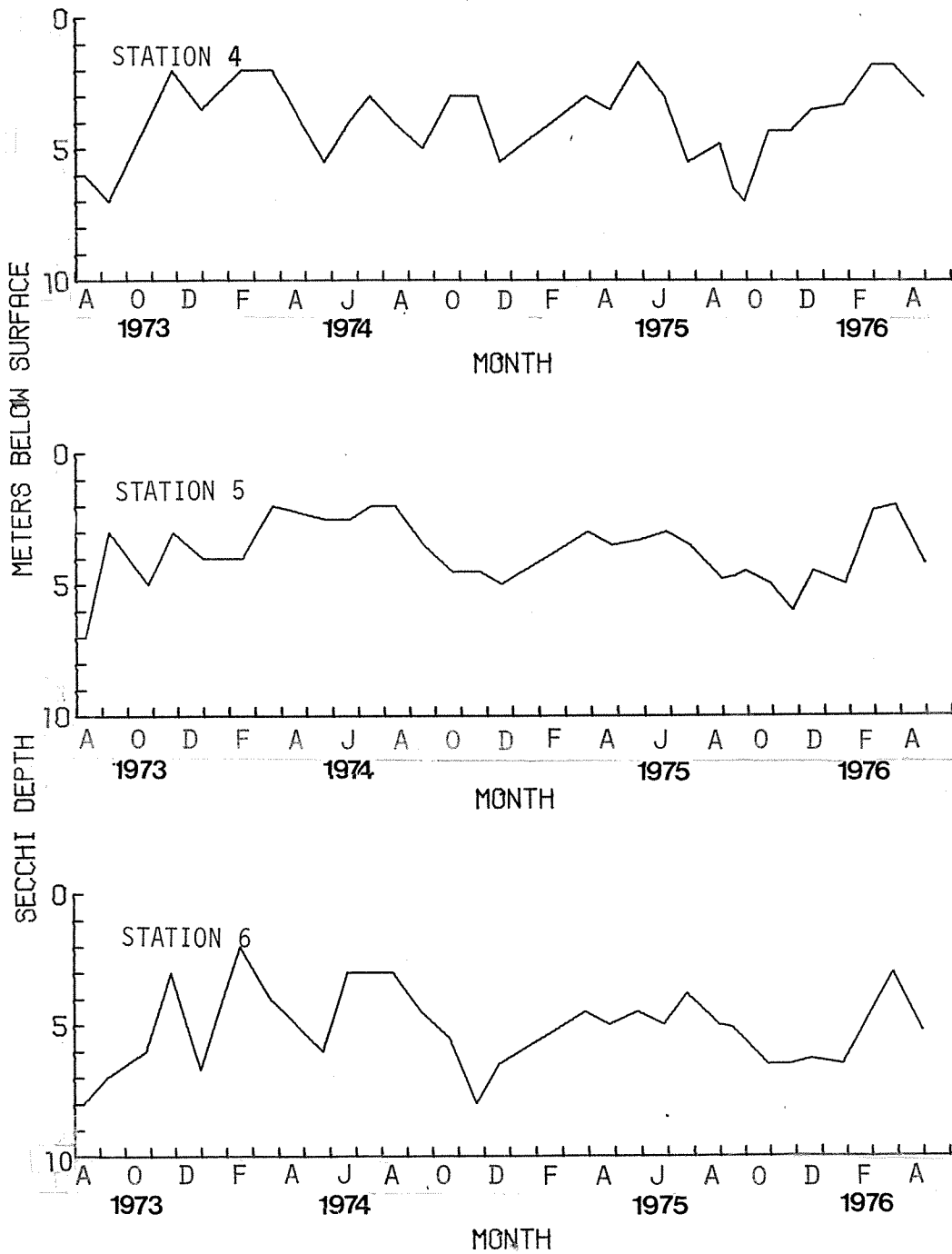


Figure 4.12 Monthly changes in Secchi depth transparency for Stations 4, 5, and 6 for the period August 1973 to May 1976.

parency values at Stations 1 through 6 were 3.4, 2.8, 3.0, 3.8, 3.8 and 5.3, respectively, and ranged from 1.0 to 8.0 m in depth. Station 2 generally exhibited the lowest transparency (Fig. 4.11), while Station 6 exhibited the greatest (Fig. 4.12). Seasonally, the minimum transparency occurred during the spring phytoplankton pulse and the maximum transparency occurred during the winters.

4.4.3 Water Chemistry

Conductivity data collected from April 1975 to March 1976 consistently averaged $120 \mu\text{mhos}/\text{cm}^2$ at Stations 1, 3, 4, 5 and 6; Station 2 averaged $121 \mu\text{mhos}/\text{cm}^2$ (Table 4.3). Monthly means indicated a high during May of $143 \mu\text{mhos}/\text{cm}^2$ and minimum mean values of $110 \mu\text{mhos}/\text{cm}^2$ during December, January and February. The maximum values in May occurred following the initiation of pumped input of irrigation water from FDR Reservoir.

The observed values for total alkalinity averaged a consistent 59 ppm as CaCO_3 at Stations 1, 2, 3, 4 and 6; Station 5 averaged 58 ppm as CaCO_3 during the January 1975 to March 1976 period (Table 4.4). Average monthly water column values indicated highest values during January, April and May. Calcium-magnesium hardness in the same period averaged 59 ppm CaCO_3 at Station 1, 2 and 3; 60 ppm at Station 4 and 5; and 58 ppm at Station 6 (Table 4.5). Monthly water column trends indicated a small decline in hardness during the summer period.

The in situ pH readings ranged from 7.0 to 9.0 throughout the lake during the period from April 1975 to March 1976 (Table 4.6). No trends in mean values between stations or with depth were apparent. Monthly mean water column values indicated a minimum of 7.8 during July and August while mean maxima of 8.7 and 8.5 occurred in May and December, respectively.

Table 4.3 Average conductivity ($\mu\text{mhos}/\text{cm}^2$) by depth strata for Banks Lake from April 1975 to March 1976.

Station	Depth Strata	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Mean for each Depth Strata
1	*0-6	120	145	110	98	130	130	120	120	114	114	120	125	120
	**B4	120	145	110	98	130	130	120	120	112	114	118	125	120
	***W.C.	120	145	110	98	130	130	120	120	113	114	120	125	120
2	0-6	120	150	115	107	130	130	120	120	110	110	110	125	122
	B4	120	150	110	98	130	130	120	120	110	110	110	126	120
	W.C.	120	150	112	102	130	130	120	120	110	110	110	125	121
3	0-6	120	150	125	105	125	130	120	120	110	110	110	118	121
	B4	120	150	114	100	125	130	120	120	110	110	105	118	119
	W.C.	120	152	120	101	125	130	120	120	110	110	108	118	120
4	0-6	115	140	125	123	125	130	120	120	110	110	105	120	120
	B4	115	140	125	119	125	130	120	120	109	109	105	120	119
	W.C.	115	140	125	120	125	130	120	120	110	110	105	120	120
5	0-6	115	135	125	119	135	131	120	120	109	109	111	110	119
	B4	115	135	127	126	133	131	120	120	109	108	110	110	120
	W.C.	115	135	126	121	135	131	120	120	109	108	110	110	119
6	0-6	112	132	125	131	127	131	120	120	109	109	110	111	120
	B4	115	132	125	132	125	131	120	120	110	108	110	111	120
	W.C.	114	132	125	131	127	131	120	120	109	108	110	111	120
High		115	170	130	135	135	132	120	120	114	115	120	130	
Low		110	132	109	97	120	130	120	120	109	108	105	110	
Monthly	0-6	117	142	121	114	128	130	120	120	110	109	109	118	120
Mean	B4	118	142	118	112	128	130	120	120	110	109	109	118	120
	W.C.	117	142	120	112	128	130	120	120	110	110	110	118	120

*0-6 Mean of surface to 6 meters

**B4 Mean of Bottom 4 meters

***W.C. Mean of water column

Table 4.4 Total alkalinity measurements (in mg/l CaCO₃) at Banks Lake from April 1975 to March 1976.

Station	Depth (m)	Month												Mean for Each Depth	Water Column Means
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR		
1	0	70	70	60	50	57	56	57	58	57	58	60	59	59	59
	4	60	70	50	60	58	55	59	58	58	60	60	59	59	
	*B	75	65	55	60	58	56	57	58	58	58	60	60	60	
2	0	65	65	50	60	57	56	57	58	58	59	59	58	58	59
	4	70	70	60	60	54	56	58	58	58	58	58	58	60	
	B	65	65	60	60	57	57	57	59	57	58	58	59	59	
3	0	70	55	60	60	58	57	58	58	58	58	58	58	59	59
	4	75	60	70	65	57	57	57	57	57	58	58	58	61	
	B	65	65	60	60	57	57	58	57	58	58	58	59	59	
4	0	65	60	65	60	56	56	57	58	57	57	58	56	58	59
	4	75	60	65	60	53	57	57	58	56	58	58	55	59	
	B	70	60	65	60	55	56	57	58	57	57	57	57	59	
5	0	70	60	55	60	56	56	58	59	57	56	57	57	58	58
	4	65	65	60	60	55	56	57	58	56	56	57	55	58	
	B	75	60	60	65	56	56	57	58	57	57	57	57	59	
6	0	75	60	65	60	56	57	56	57	58	54	57	55	59	59
	4	70	65	60	60	54	56	58	58	58	54	58	59	59	
	B	60	70	55	60	57	57	57	58	56	55	57	56	58	
Monthly Means for Each Depth	0	69	62	59	58	57	56	57	58	58	56	58	57	59	59
4	64	65	61	59	55	56	58	58	57	57	58	57	58		
B	68	64	59	61	57	57	58	58	57	57	58	57	57		
Monthly Water Column Mean		69	64	60	59	56	56	57	58	57	56	58	57	57	

* B Maximum depth sampled

Table 4.5 Calcium-magnesium hardness measurements (in mg/l CaCO₃) at Banks Lake from April 1975 to March 1976.

Station	Depth (m)	Means for												Water Column Means	
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR		Each Depth
1	0	61	62	54	58	55	56	57	65	63	63	67	58	60	59
	4	61	58	54	52	52	54	59	65	51	64	69	57	59	
	*B	59	56	55	52	56	55	59	64	63	69	69	58	59	
2	0	60	63	57	59	53	55	60	62	63	66	66	58	60	59
	4	63	63	56	55	55	56	59	64	60	67	58	60	60	
	B	58	61	54	52	53	57	59	65	61	67	58	57	57	
3	0	60	61	63	58	57	57	58	65	61	65	65	55	61	59
	4	60	63	58	59	58	57	59	59	60	66	56	59	59	
	B	62	63	54	52	56	53	59	64	60	64	64	58	58	
4	0	59	59	68	59	65	56	57	66	60	66	66	56	60	59
	4	59	60	60	60	53	55	60	63	61	64	64	55	60	
	B	59	61	62	57	55	56	58	64	60	63	65	57	60	
5	0	58	58	62	58	56	56	58	63	60	68	68	57	60	60
	4	59	63	61	58	55	55	58	62	60	67	55	60	60	
	B	59	59	61	57	56	57	57	62	58	63	63	59	59	
6	0	59	57	61	58	57	56	59	63	61	69	69	54	59	58
	4	62	68	62	60	53	55	59	63	58	66	66	55	59	
	B	60	55	61	58	53	59	57	64	58	62	62	54	58	
Monthly Means for Each Depth	0	61	61	61	58	56	56	58	64	61	67	67	56	60	
Monthly Water Column Means	60	60	59	57	55	55	58	58	63	60	66	66	57	60	57

*B Maximum depth sampled

Table 4.6 Average pH by depth strata in Banks Lake from April 1975 to March 1976.

Station	Depth Strata	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Means for each Depth Strata
1	*0-6	8.2	8.8	8.2	7.5	7.8	8.2	8.4	8.2	8.4	8.4	8.7	8.6	8.3
	**B4	8.2	8.6	8.0	7.6	7.7	8.0	8.3	8.2	8.5	8.4	8.8	8.7	8.2
	***W.C.	8.2	8.7	8.1	7.6	7.7	8.4	8.4	8.2	8.4	8.4	8.7	8.6	8.3
2	0-6	8.3	9.0	8.2	7.6	8.1	8.4	8.2	8.2	8.5	8.4	8.4	8.5	8.3
	B4	8.3	8.9	7.9	7.6	8.0	7.6	8.2	8.2	8.4	8.3	8.3	8.5	8.2
	W.C.	8.3	9.0	8.1	7.6	8.0	8.0	8.2	8.2	8.5	8.4	8.4	8.5	8.3
3	0-6	8.3	9.0	8.2	7.6	8.1	8.4	8.2	8.2	8.5	8.4	8.4	8.4	8.3
	B4	8.3	8.8	8.2	7.7	7.7	7.6	8.2	8.2	8.5	8.4	8.4	8.4	8.2
	W.C.	8.3	8.9	8.2	7.6	7.9	8.0	8.2	8.2	8.5	8.4	8.4	8.4	8.2
4	0-6	8.3	8.7	8.2	7.6	7.9	8.3	8.2	8.2	8.5	8.4	8.4	8.4	8.3
	B4	8.3	8.4	7.9	7.6	7.6	7.7	8.2	8.2	8.5	8.3	8.4	8.4	8.1
	W.C.	8.3	8.6	8.1	7.6	7.8	8.0	8.2	8.2	8.5	8.4	8.4	8.4	8.2
5	0-6	8.3	8.5	8.0	7.7	7.8	8.2	8.2	8.2	8.5	8.3	8.3	8.4	8.2
	B4	8.2	8.2	7.7	8.2	7.7	8.0	8.2	8.2	8.5	8.3	8.4	8.4	8.2
	W.C.	8.3	8.4	7.9	7.8	7.8	8.1	8.2	8.2	8.5	8.3	8.3	8.4	8.2
6	0-6	8.3	8.6	8.0	8.4	7.7	8.2	8.2	8.1	8.4	8.3	8.3	8.4	8.2
	B4	8.2	8.4	7.8	8.4	8.4	8.1	8.2	8.0	8.4	8.2	8.4	8.4	8.1
	W.C.	8.2	8.4	7.9	8.4	7.5	8.2	8.2	8.1	8.4	8.3	8.3	8.4	8.2
High	8.4	9.0	8.4	8.4	8.1	8.4	8.4	8.4	8.2	8.5	8.4	8.8	8.7	
Low	8.1	8.2	7.6	7.5	7.0	7.4	7.4	8.2	7.8	8.4	8.2	8.3	8.4	
Monthly M	0-6	8.3	8.7	8.1	7.7	7.9	8.3	8.2	8.2	8.5	8.3	8.4	8.4	8.2
Mean for	B4	8.2	8.5	7.9	7.8	7.6	7.8	8.2	8.2	8.5	8.3	8.4	8.5	8.2
Each Depth	W.C.	8.3	8.7	8.0	7.8	7.8	8.1	8.2	8.2	8.5	8.3	8.4	8.4	8.2

*0-6 Mean of surface to 6 meters
 **B4 Mean of Bottom 4 meters
 ***W.C. Mean of Water Column

The concentrations of sodium, potassium, chloride and sulphate are shown in Table 4.7. No trends were apparent by month or depth, but some changes were apparent by Station. An increase in sodium and potassium concentrations occurred from north to south. Although no trend was apparent for the anion chloride, sulphate concentrations were consistently higher at Stations 1, 2 and 3 than in the three southern stations.

Calcium and magnesium values were taken every month starting in April 1975 (Tables 4.8 and 4.9, respectively). Calcium concentrations ranged from 13.5 to 19.6 mg/l and magnesium from 3.8 to 5.9 mg/l. Highest magnesium concentrations occurred in April and February. Calcium levels were low in April and high in February. There were no apparent trends by station or by depth.

The oxydation-reduction potential remained high during the period sampled (Table 4.10). No consistent trends occurred by station or depth. The range was from 190 to 370 mv with lowest levels occurring in June and highest in January.

Highest silica levels were observed at Station 1 during feeder canal pumping and a general decreasing trend from north to south was apparent (Table 4.11). The silica concentration ranged from 0.39 to 3.10 mg/l with the highest levels in May at Station 1 and lowest at Stations 1 and 2 during October and November after pumping had stopped. During May, June and July the bottom samples were usually higher in silica concentration than the two surface samples.

4.4.4 Plant Nutrients

Nutrient data are reported for the period from May 1974 to March 1976, except during the winter of 1975 when ice cover prevented sampling.

Table 4.7 Concentration of selected ions in Banks Lake for the period April through September 1974 and January and March 1975.

Ion	Station Averages					
	1	2	3	4	5	6
Na ⁺ (mg/l)	2.01	2.29	2.32	2.33	2.40	2.42
K ⁺ (mg/l)	0.814	0.863	0.869	0.885	0.921	0.926
Cl ⁻ (mg/l)	0.457	0.575**	0.570**	0.500	0.490	0.523
SO ₄ ⁻ (mg/l)	11.54	11.13	11.51	10.93	10.48	10.78

Month	Whole Lake Average			
	Na ⁺ (mg/l)	K ⁺ (mg/l)	Cl ⁻ (mg/l)	SO ₄ ⁻ (mg/l)
April	1.95	0.975	*	10.28
May	2.45	0.995	*	12.30
June	2.32	0.848	*	10.36
July	2.18	0.875	*	10.55
August	2.07	0.805	0.720	9.82
September	2.32	0.806	0.363**	9.95
January	2.37	0.918	0.405	11.73
March	2.73	0.832		13.68

* no samples taken

** Stations 2 and 3 not sampled in January

Table 4.8 Calcium concentrations measured (in mg/l) in Banks Lake from April 1975 to March 1976.

Station	Depth (m)	Month												Mean for Each Depth	Water Column Means
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR		
1	0	15.0	15.8	19.2	14.4	15.4	15.5	15.7	19.6	18.0	17.5	18.7	15.9	16.4	16.3
	4	16.0	15.3	19.2	13.8	14.8	14.8	16.2	19.0	17.0	17.9	19.5	15.5	16.3	
	*B	14.0	15.0	15.4	13.7	15.6	15.1	16.0	18.6	18.0	16.5	19.2	16.6	16.1	
2	0	15.0	17.2	16.2	16.2	14.5	15.2	16.5	17.8	18.0	19.1	16.7	16.6	16.5	
	4	16.0	17.2	15.9	14.8	15.0	15.5	16.0	18.7	17.0	19.2	16.2	16.9		
	B	15.0	16.6	15.0	13.9	16.7	15.4	16.1	19.0	18.0	19.1	16.2	16.4		
3	0	14.0	17.2	17.9	15.4	15.6	15.7	16.0	18.4	17.0	19.0	15.1	16.5	16.3	
	4	15.0	17.1	16.5	16.8	16.5	15.2	16.2	17.2	17.0	18.7	15.6	16.5		
	B	15.0	17.1	15.1	13.5	15.1	14.1	16.0	18.7	17.0	17.9	16.1	16.0		
4	0	15.0	16.5	18.3	16.1	15.2	15.4	15.4	19.3	17.0	17.8	18.6	15.4	16.7	16.5
	4	14.0	16.0	17.4	16.6	15.3	14.7	16.5	18.1	17.0	17.9	18.0	15.3	16.4	
	B	15.0	17.2	17.9	15.2	14.7	15.3	15.7	18.4	17.0	17.8	18.3	15.8	16.5	
5	0	15.0	16.3	17.9	15.7	14.8	15.2	15.6	18.3	17.0	18.6	18.8	16.1	16.6	16.4
	4	15.0	16.7	17.6	15.6	14.4	15.9	15.6	18.0	17.0	17.4	18.1	15.0	16.4	
	B	15.0	16.5	17.5	14.7	14.2	15.7	15.6	17.9	17.0	17.7	17.7	16.6	16.3	
6	0	15.0	16.0	17.6	15.5	16.0	15.1	16.6	18.1	17.0	15.4	19.9	15.2	16.5	16.2
	4	15.0	16.4	18.0	15.6	14.4	14.9	16.2	18.2	16.0	15.4	18.7	15.6	16.2	
	B	15.0	15.7	17.8	15.6	14.4	14.6	15.4	18.4	16.0	15.5	17.5	15.4	15.4	
Monthly Means for each Depth	0	14.8	16.9	17.2	15.6	15.3	15.4	16.0	18.6	17.3	17.3	19.0	15.7	16.6	16.4
	4	15.2	16.9	16.8	15.5	15.1	15.2	16.1	18.2	16.8	17.2	18.7	15.5	16.4	
	B	14.8	16.4	16.5	14.4	15.1	15.0	15.8	18.5	17.0	16.9	18.3	16.1	16.2	
Monthly Water Column Means		15.0	16.4	16.8	15.2	15.1	15.2	16.0	18.4	17.0	17.1	18.7	15.8		

*B maximum depth sampled

Table 4.9 Magnesium concentration (in mg/l) measured in Banks Lake from April 1975 to March 1976.

Station	Depth (m)	Mean for Each Depth												Water Column Means	
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR		
1	0	5.7	4.2	3.9	4.2	4.1	4.2	4.3	4.2	4.4	4.7	5.0	4.3	4.1	4.3
	4	5.0	4.7	3.9	4.1	3.8	4.2	4.4	4.2	4.4	4.6	4.9	4.5	4.4	
	*B	5.7	4.3	4.0	4.3	4.1	4.3	4.4	4.2	4.4	4.2	5.0	4.1	4.4	
2	0	5.4	4.8	4.4	4.5	4.1	4.2	4.4	4.2	4.5		4.5	4.1	4.4	4.4
	4	5.5	4.2	4.2	4.2	4.2	4.4	4.3	4.3	4.4	4.6	4.6	4.3	4.4	
	B	5.0	4.3	3.9	4.2	4.0	4.4	4.4	4.2	4.4	4.8	4.8	4.3	4.4	
3	0	5.1	4.6	4.4	4.6	4.3	4.3	4.3	4.2	3.9	4.7	4.7	4.1	4.4	4.4
	4	5.5	4.9	4.2	4.5	4.1	4.3	4.3	3.8	4.3	4.6	4.6	4.2	4.4	
	B	5.4	4.2	3.9	4.3	4.0	4.3	4.5	4.3	4.3	4.6	4.6	4.2	4.4	
4	0	5.1	4.4	4.4	4.5	4.3	4.3	4.4	4.2	4.3	4.4	4.7	4.2	4.4	4.5
	4	5.7	4.1	4.0	4.4	4.2	4.4	4.4	4.2	4.4	4.7	4.7	4.2	4.5	
	B	5.3	5.1	4.2	4.4	4.0	4.3	4.2	4.3	4.3	4.5	4.6	4.2	4.5	
5	0	5.0	4.2	4.2	4.4	4.0	4.3	4.3	4.3	4.3	4.4	5.2	4.0	4.4	4.5
	4	5.5	4.7	4.3	4.5	3.9	4.3	4.5	4.2	4.3	4.5	4.6	4.1	4.5	
	B	5.3	4.8	4.2	4.5	3.9	4.3	4.4	4.3	4.4	4.5	4.6	4.2	4.5	
6	0	5.3	4.9	4.2	4.5	4.7	4.4	4.3	4.2	4.6	4.6	4.6	4.0	4.4	4.4
	4	5.9	4.8	4.1	4.5	4.1	4.2	4.5	4.2	4.4	3.9	4.6	3.9	4.4	
	B	5.4	4.6	4.1	4.6	4.1	4.3	4.5	4.3	4.4	4.0	4.5	3.7	4.4	
Monthly Means for Each Depth	0	5.3	4.5	4.2	4.5	4.2	4.3	4.4	4.2	4.3	4.4	4.8	4.1	4.4	4.4
	4	5.5	4.6	4.1	4.4	4.1	4.3	4.4	4.2	4.4	4.4	4.7	4.2	4.4	
	B	5.4	4.6	4.1	4.4	4.0	4.3	4.5	4.3	4.4	4.3	4.7	4.1	4.4	
Monthly Water Column Means		5.4	4.5	4.1	4.4	4.1	4.3	4.4	4.2	4.4	4.7	4.7	4.1	4.4	

*B maximum depth sampled

Table 4.10 Average oxidation-reduction potential (millivolts) by depth strata in Banks Lake from April 1975 to March 1976. Measurements are relative to a silver-silver chloride electrode.

Station	Depth Strata	Means for												
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Each Depth
1	*0-6	360	313	275	348	333	344	335	350	398	363	338	345	333
	**B4	360	318	238	345	315	338	330	350	389	363	332	340	327
	***W.C.	360	315	257	347	326	341	333	350	294	363	335	363	330
2	0-6	357	304	246	319	317	319	340	350	318	340	323	340	321
	B4	357	312	215	337	305	323	340	350	311	340	320	340	319
	W.C.	357	307	232	329	312	322	340	350	315	340	321	340	320
3	0-6	361	315	293	318	325	336	322	330	280	340	340	345	323
	B4	360	314	272	335	332	348	312	330	280	333	333	345	324
	W.C.	360	309	284	327	327	342	318	330	280	337	337	345	323
4	0-6	364	320	322	319	325	333	352	320	321	370	316	365	336
	B4	360	333	329	356	312	339	350	298	313	370	330	360	338
	W.C.	362	327	325	341	319	335	351	310	319	370	323	363	337
5	0-6	360	330	280	333	345	330	318	346	310	370	345	370	336
	B4	360	343	209	350	335	330	303	338	305	370	336	364	329
	W.C.	360	337	251	347	340	330	312	340	307	370	339	367	331
6	0-6	359	313	329	335	360	325	308	272	330	370	321	370	333
	B4	362	334	329	355	358	313	266	217	340	370	298	365	326
	W.C.	360	325	330	345	360	319	292	250	335	370	312	368	331
High		365	348	341	369	365	350	352	350	370	370	345	370	370
Low		355	301	190	311	300	310	259	200	280	362	290	340	340
Monthly	0-6	360	314	291	329	334	331	329	328	310	368	331	356	331
Means for	B4	360	326	265	346	326	332	317	314	306	368	325	352	336
Each Depth	W.C.	360	315	280	339	331	332	324	322	308	368	328	354	330

*0-6 Mean of surface to 6 meters

**B4 Mean of bottom 4 meters

***W.C. Mean of Water Column

Table 4.11 Silica concentration (mg/l) measurements in Banks Lake from April 1975 to March 1976.

Station	Depth (m)	Means for												Water Column Means	
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR		Each Depth
1	0	1.07	2.90	2.06	1.86	1.80	1.50	0.70	1.04	1.50	2.02	1.76	1.55	1.69	1.63
	4	1.15	3.00	2.21	1.86	1.90	1.50	0.70	0.48	1.50	2.00	1.75	1.52	1.63	
	* B	1.29	3.10	2.42	1.93	1.90	1.50	0.70	0.44	1.40	1.98	1.11	1.57	1.61	
2	0	0.93	1.60	1.90	1.29	1.60	1.70	1.00	0.39	0.70	1.07	1.03	1.18	1.27	
	4	1.00		1.87	1.50	1.60	1.30	1.00	0.96	0.70	1.09	1.01	1.25		
	B	0.98	2.20	2.07	1.89	1.60	1.80	0.90	0.76	0.70	1.07	1.03	1.27		
3	0	1.00	1.60	1.00	1.39	1.70	1.30	1.10	0.98	0.70	1.01	1.03	1.21	1.29	
	4	1.00	1.50	1.42	1.32	1.60	1.30	1.10	1.04	0.70	1.01	1.10	1.21		
	B	0.98	2.20	1.85	1.75	1.90	1.80	1.00	1.00	1.00	1.04	1.07	1.44		
4	0	1.14	1.00	1.36	1.29	1.70	1.40	1.30	1.07	1.00	1.10	0.98	1.20	1.24	
	4	1.31	0.90	1.32	1.32	1.70	1.40	1.30	1.05	1.20	1.06	1.01	1.22		
	B	1.42	0.90	1.36	1.86	1.60	1.80	1.40	1.07	1.20	1.12	1.07	0.93		1.31
5	0	1.90	0.90	1.09	1.25	1.60	1.40	1.30	1.13	1.20	1.12	1.07	1.11	1.21	
	4	1.13	0.80	1.08	1.29	1.70	1.40	1.30	1.07	1.20	1.04	1.20	1.38		
	B	1.11	0.90	1.36	1.36	1.60	1.40	1.30	1.09	1.00	0.98	2.44	1.01		1.29
6	0	1.16	0.94	1.09	1.29	1.80	1.30	1.20	1.04	1.00	1.02	1.24	1.16	1.21	
	4	1.24	0.98	1.08	1.21	1.60	1.40	1.30	1.04	1.70	1.02	1.26	1.18		
	B	1.18	1.48	1.19	1.46	2.40	1.30	1.20	1.01	1.00	1.00	1.13	1.09		1.30
Monthly Means for Each Depth	0	1.20	1.49	1.45	1.39	1.70	1.35	1.10	0.94	1.02	1.32	1.19	1.12	1.27	1.31
4	1.14	1.44	1.47	1.42	1.68	1.38	1.12	0.94	0.94	1.28	1.22	1.18	1.27		
B	1.16	1.80	1.68	1.71	1.83	1.67	1.08	0.90	0.90	1.27	1.31	1.12	1.38		
Monthly Water Column Means		1.17	1.58	1.53	1.51	1.74	1.47	1.10	0.93	1.06	1.29	1.24	1.14		

* B maximum depth sampled

Orthophosphate levels ranged from zero to 28 $\mu\text{g}/\text{l}$ (as P) during the sampling period. Analysis of the data elucidated the north-south gradient in orthophosphate level by comparing Station 1 against Stations 2-3 combined and against Stations 4-5-6 combined. The 1974 data indicate an early increase in orthophosphate (Fig. 4.13) during May and June with slightly higher levels in the northern half of the lake. A general decline was evident during the summer period with a general increase during the fall. No clear response to pumped input of water was evident between stations in 1974.

A horizontal gradient did occur in the period May through September 1975 during the pumped input of irrigation water from FDR Reservoir. Consistently higher orthophosphate levels were found at Station 1 with intermediate values at Stations 2-3 and consistently lowest values at Stations 4-5-6. Pumping of irrigation water ceased on September 21, 1975, and did not reoccur until December 9, 1975. Irrigation drafting from the reservoir declined and stopped on October 21, 1975. After October 21, while conditions reverted to a lentic environment, the horizontal orthophosphate gradient was found to reverse, with minimum values at Station 1, intermediate values at Station 2-3, and maximum values at Stations 4-5-6. Pumping to increase the reservoir level from 1,564 ft to 1,570 ft (full pool) was initiated on December 9, 1975 and completed December 31, 1975. Orthophosphate levels at Station 1 showed an increase from 4 $\mu\text{g}/\text{l}$ in November to 13 $\mu\text{g}/\text{l}$ in December following initiation of pumping. Orthophosphate levels declined during January 1976 when no pumping occurred. P/G 8 was operated during February and March which resulted in a corresponding increase in orthophosphate from

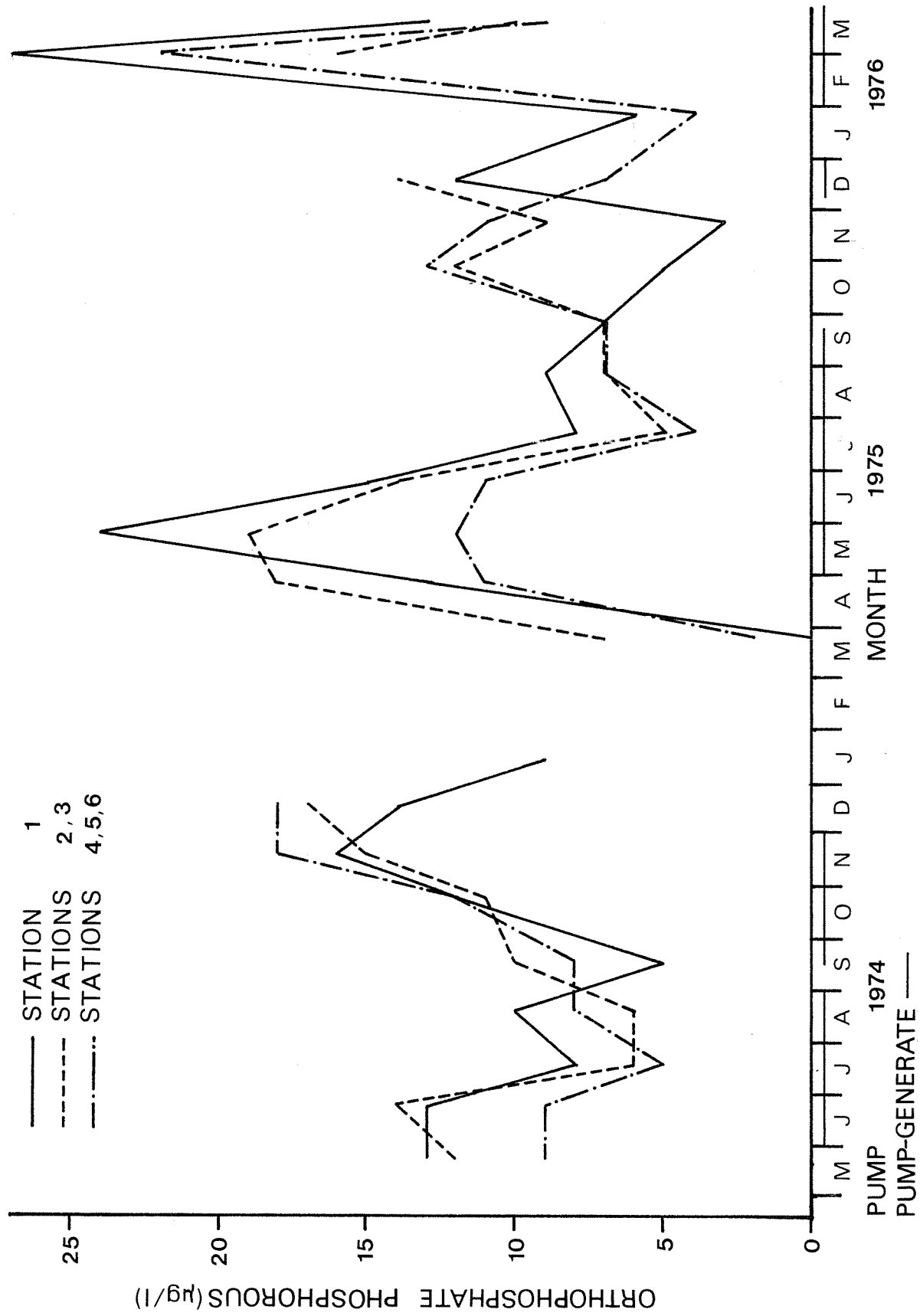


Figure 4.13 Mean monthly orthophosphate concentrations for Station 1, Stations 2 and 3 combined, and Stations 4, 5, and 6 combined; with the occurrence of feeder canal pumping or pump-generation from May 1974 to March 1976.

6 $\mu\text{g}/\text{l}$ in January to 28 $\mu\text{g}/\text{l}$ in February 1976 at Station 1. Stations 2-3, and 4-5-6 were 16 and 23 $\mu\text{g}/\text{l}$, respectively, suggesting that additional phosphates were added from winter run-off and spring overturn.

Amounts of total phosphate-phosphorus (Fig. 4.14) ranged from a minimum of 7 $\mu\text{g}/\text{l}$ in August 1974 to a maximum of 49 $\mu\text{g}/\text{l}$ in June 1975. North-south gradients established in response to pumped input of water from FDR reservoir and irrigation drafting which followed closely those described for orthophosphate-phosphorus.

Nitrate analysis indicated that concentrations were generally low in the lake, particularly during the phytoplankton production season (Fig. 4.15). Rapid declines in concentrations at all stations were indicated from June to July 1974. Nitrate was unavailable at Stations 2 through 6 and only 3 $\mu\text{g}/\text{l}$ was found at Station 1. A north-south gradient occurred during October and November 1974. Concentrations at Station 1, 2-3, and 4-5-6, were 19 , 15 and 7 $\mu\text{g}/\text{l}$, respectively in November, indicating a response to pumped input from FDR Reservoir. A decline to 4 $\mu\text{g}/\text{l}$ at Station 1 was evident by January 1975, following cessation of pumping at the end of November. Nitrates were limiting throughout most of the lake during March through November 1975. A reverse gradient was indicated during July, suggesting that rapid assimilation was occurring during June at Station 1 when high phytoplankton abundance occurred. As the phytoplankton production season passed, larger amounts of nitrate were found at Station 1. With cessation of pumping and irrigation in October and November, nitrate levels declined to zero except at Station 1. However, following initiation of pumping in December 1975, nitrate increased from zero to 48 $\mu\text{g}/\text{l}$ at Station 1 and reached a maximum of

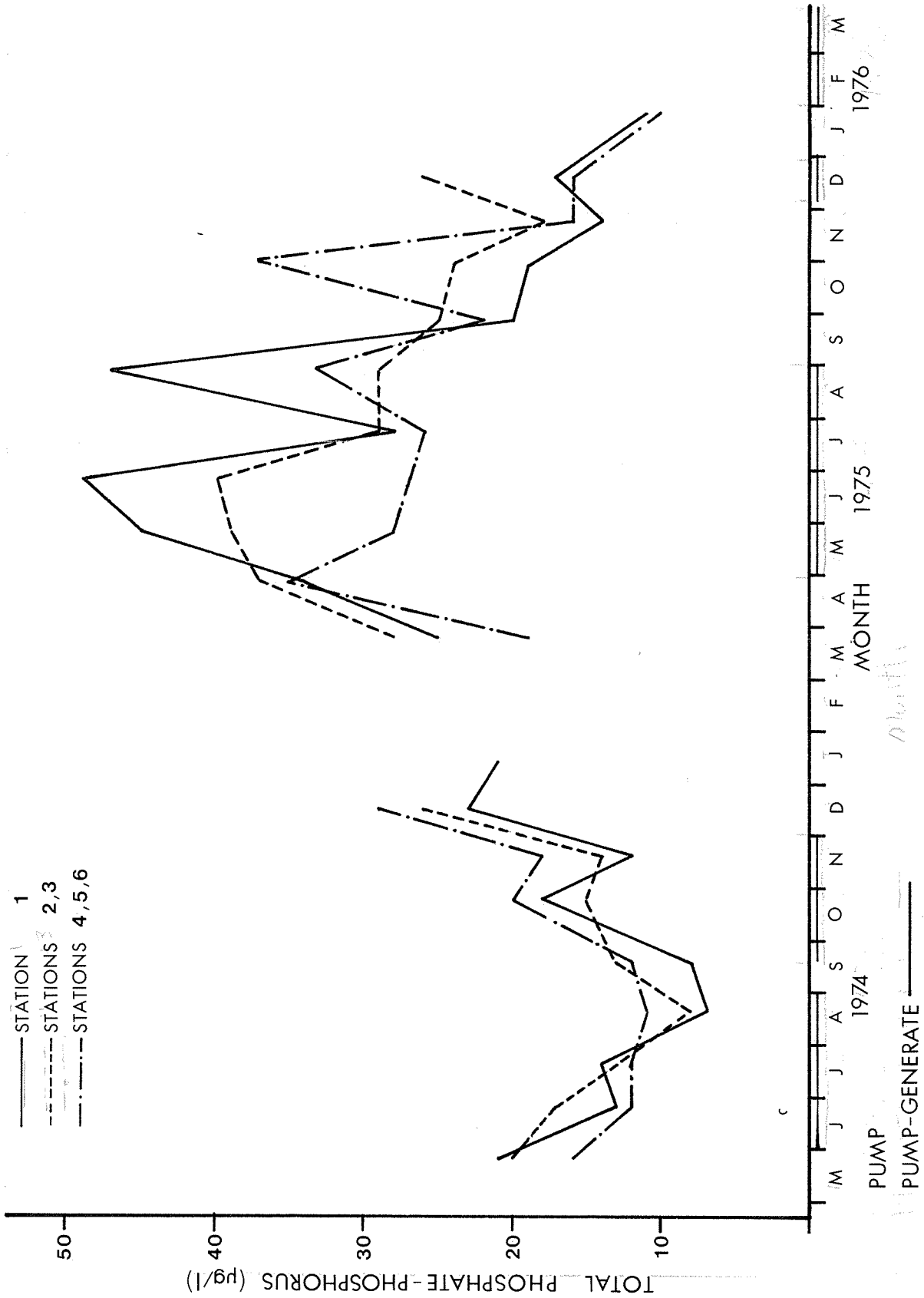


Figure 4.14 Mean monthly total phosphorus concentration for Station 1, Stations 2 and 3 combined, and Stations 4, 5, and 6 combined; with the occurrence of feeder canal pumping or pump-generation from May 1974 to March 1976.

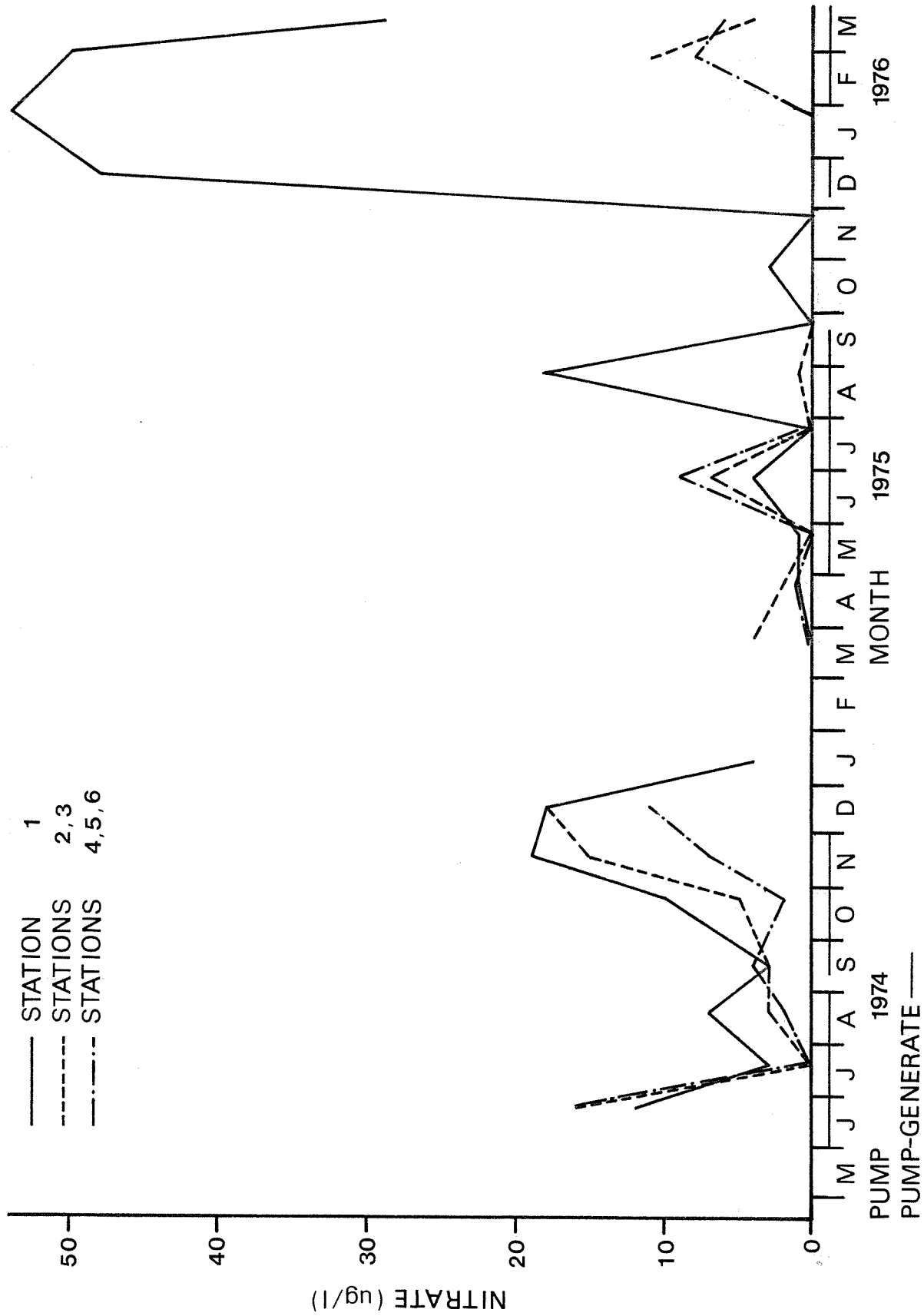


Figure 4.15 Mean monthly concentration of nitrate for Station 1, Stations 2 and 3 combined, and Stations 4, 5, and 6 combined; with the occurrence of feeder canal pumping or pump-generation from May 1974 to March 1976.

54 $\mu\text{g}/\text{l}$ in January 1976. Operation of P/G 7 during January and February 1976 resulted in continued high nitrate levels at Station 1 during February.

4.4.5 Primary Productivity

The chlorophyll a data indicated two functionally separate regions within the lake. The changes observed at Stations 1, 2 and 3 demonstrated marked similarities (Fig. 4.16) while the changes observed at Stations 4, 5 and 6, although different from the observations at the northern stations, were similar to each other (Fig. 4.17) throughout the 31 months for which data are reported. Pooled data for Stations 1 through 3 and 4 through 6 averaged 3.28 and 1.75 mg chlorophyll a/liter, respectively.

Responses to pumped input of irrigation water appear at Stations 1 through 3 and were not evident in the rest of the lake. For example, prior to the initiation of pumped input of irrigation water on June 1, 1974, chlorophyll a levels declined from February through May 1974. Upon initiation of pumping at an approximate rate of 11,500 cfs, maximum chlorophyll a values were recorded in June with 7.5, 7.1 and 5.1 $\mu\text{g}/\text{l}$ at Stations 1, 2 and 3, respectively. A general seasonal decline occurred following this peak concentration. However, pumping declined and stopped briefly during the first week in September 1974. This interruption may have stimulated the observed September increase in chlorophyll a which was 3.3, 7.1 and 7.2 $\mu\text{g}/\text{l}$ at Stations 1, 2 and 3, respectively. A general decline was then observed through December 1974 with pumping at the rate of about 3,000 cfs from mid-September to December 1, 1974.

A seasonal increase in chlorophyll a levels was observed from December 1974 through March 1975. A decline, greatest at Station 1,

CHLOROPHYLL A (MICROGRAMS/LITER)

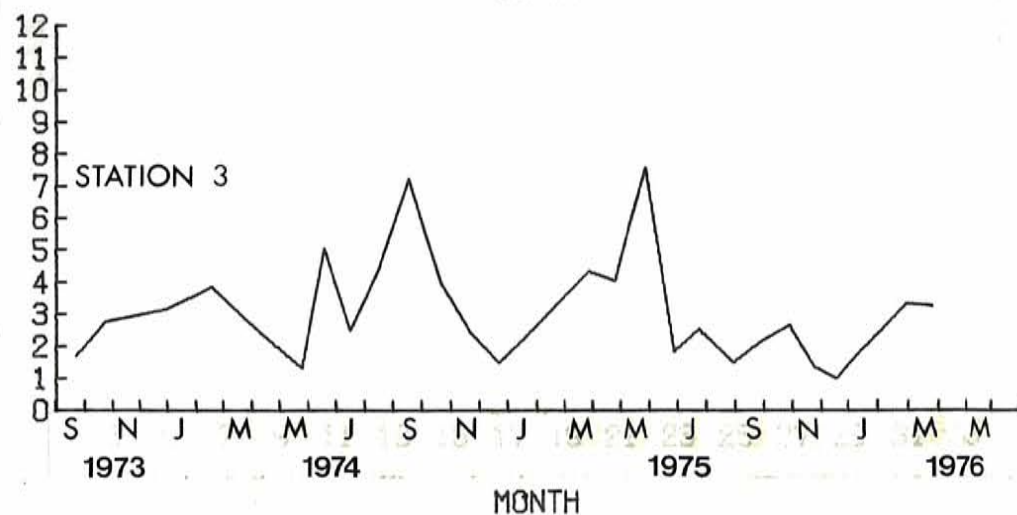
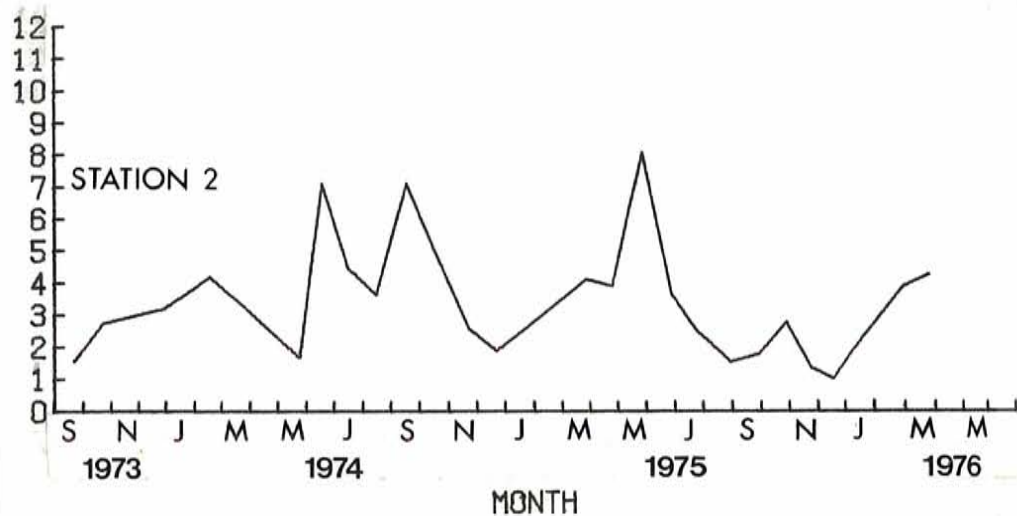
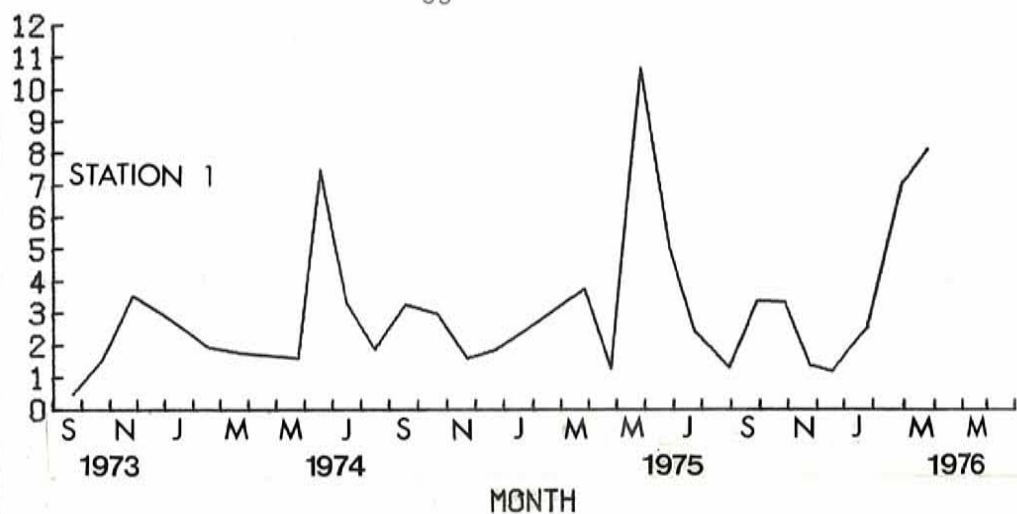


Figure 4.16 Chlorophyll a mean concentrations in Banks Lake at Stations 1, 2, and 3, from September 1973 to March 1976.

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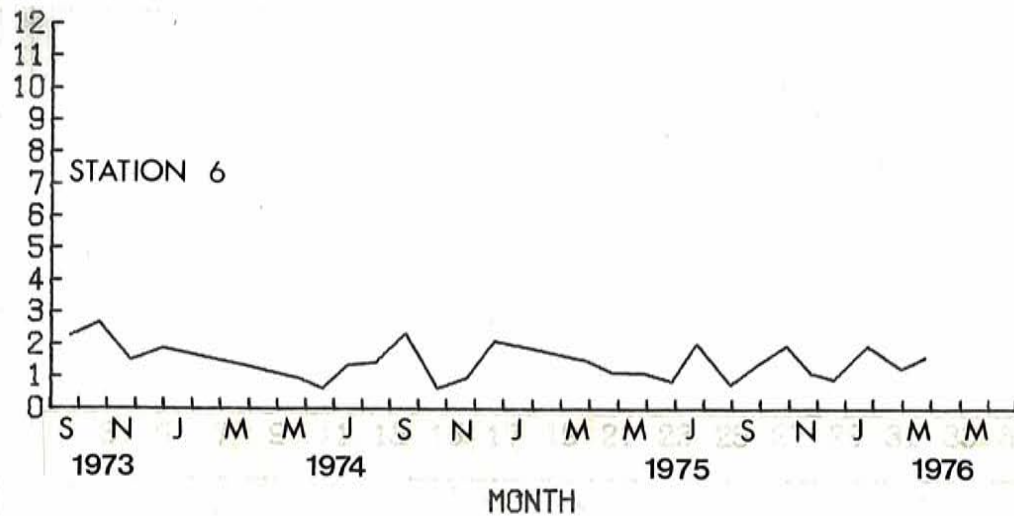
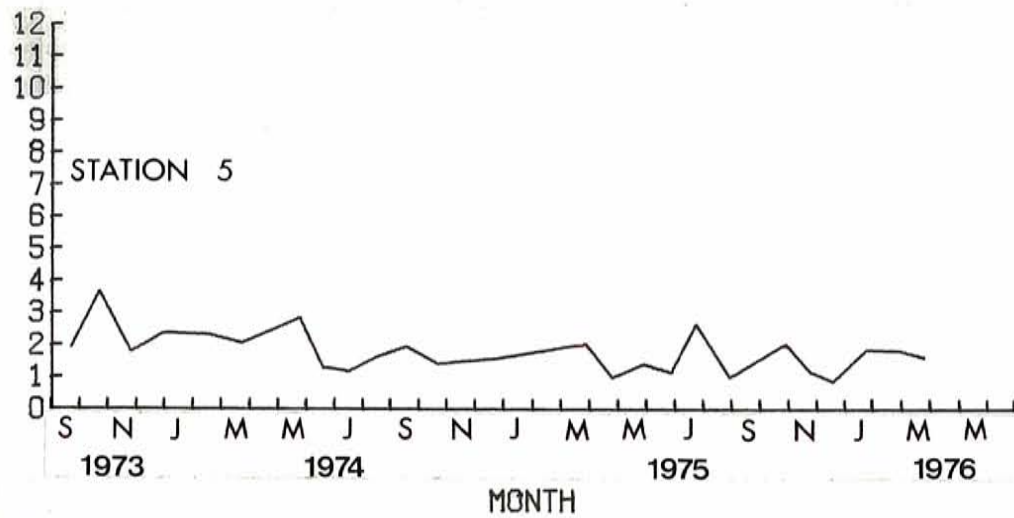
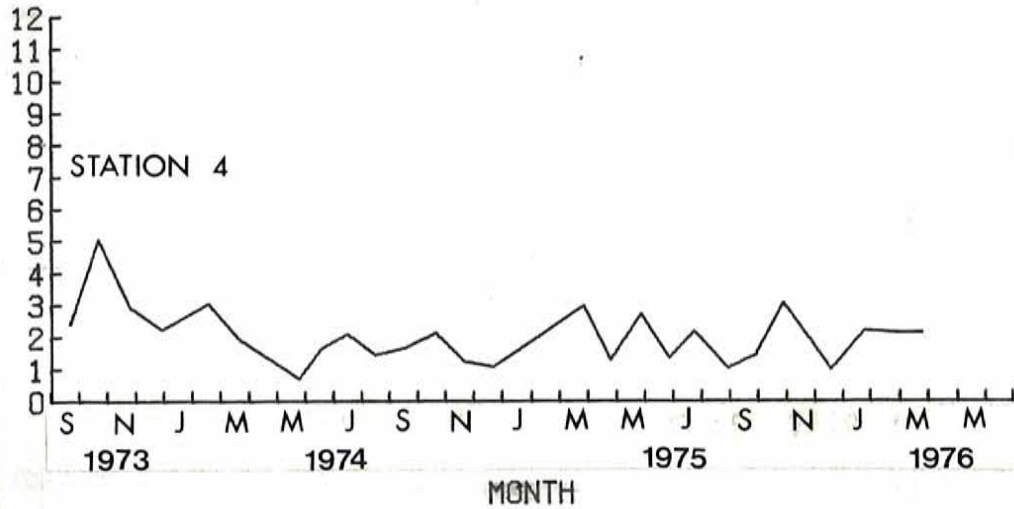


Figure 4.17 Chlorophyll a mean concentrations in Banks Lake at Stations 4, 5, and 6, from September 1973 to March 1976.

occurred in April, immediately prior to the initiation of pumping in early May 1975. By late May a major increase in chlorophyll a concentrations of 10.7, 8.1 and 7.6 $\mu\text{g}/\text{l}$ were found at Stations 1, 2 and 3, respectively. Pumping of irrigation water increased from zero in early May to 4,500 cfs by mid-May to about 7,300 cfs by the end of May. A seasonal decline in chlorophyll a was observed throughout the summer at Stations 1, 2 and 3, however, a small increase during September and October 1975 occurred. This followed the cessation of pumping between the last week of September and the first week of December 1975. Following pumping during December 1975 and P/G testing in February and March 1976, chlorophyll a levels showed a seasonal increase from low December levels of 1.2, 1.0 and 1.0 through March 1976, with 8.0, 3.8 and 3.0 $\mu\text{g}/\text{l}$ at Stations 1, 2 and 3, respectively. Chlorophyll a maxima, stimulated by pumped input of water which occurred during the spring when chlorophyll a concentrations were normally expected to increase, showed a consistently decreasing gradient from Stations 1 to 3 (June 1974, May 1975, and March 1975), indicating that the effects of pumping were greatest on Station 1 and diminished successively at Stations 2 and 3.

Chlorophyll a concentrations at Stations 4, 5 and 6 were consistently low. Seasonal trends were lacking as were any responses to pumped input of water. These data indicate the major phytoplankton blooms occurred in the northern portion of the lake, while only minor phytoplankton blooms occurred in the southern portions of the lake.

Comparisons of C^{14} primary production at Stations 1, 4 and 6 are illustrated by the vertical profiles in Fig. 4.18. Primary production at Station 1 consistently exceeded Stations 4 and 6, except during November when relative incident light reached a minimum and no water had

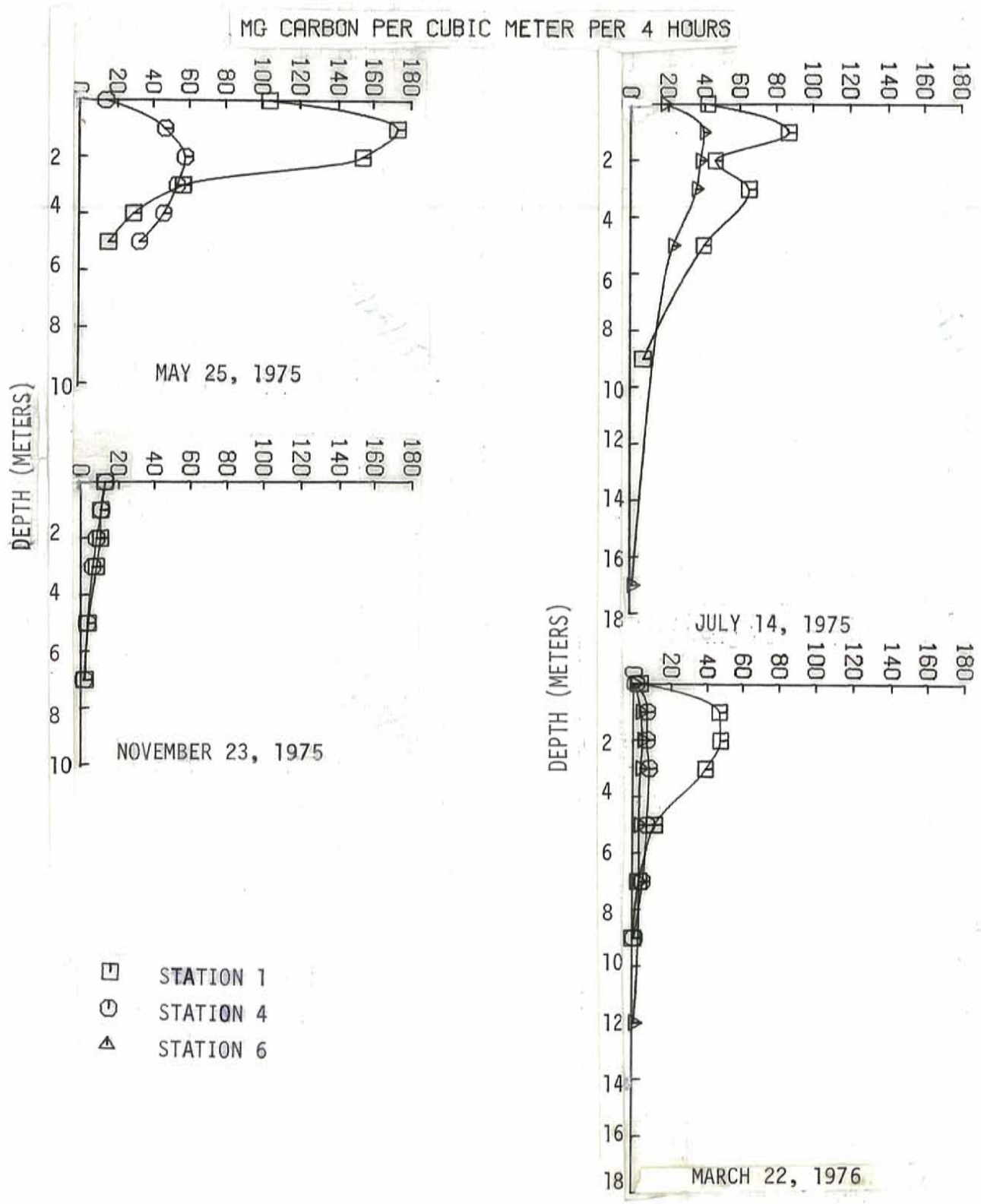


Figure 4.18 Carbon¹⁴ primary production depth profiles comparing Station 1 to Stations 4 and 6, for selected months.

been pumped for about two months (Fig. 4.19). Primary production showed a seasonal November decline and a similar low level of production throughout the lake. Pumped input of water showed a consistently high C^{14} primary production at Station 1 with a maximum divergence from Station 4 occurring during the spring.

4.4.6 Zooplankton Composition and Abundance

Sixteen species of crustacean zooplankton were identified from the samples (Kiser 1974, personal communication). Ten of these were cladocerans and six were copepods (Table 4.12). In addition, the rotifers *Keratella*, *Asplanana* and *Kellicotia* were observed in small numbers.

The most frequently observed cladocerans were *Daphnia pulex* and *Bosmina longirostris*. The most frequently observed copepods were *Diaptomus ashlandii* and *Cyclops bicuspidatus thomasi*. Many of the species listed were encountered only rarely.

Quantitative analysis included five groups: *Diaptomus* spp., *Cyclops* spp., copepod nauplii, *Daphnia* spp., and *Bosmina* sp. With minor exceptions, the changes in zooplankton relative abundance observed in the upper 4 m were similar to those observed in the total water column (Figs. 4.20 to 4.25). In almost all cases the data indicate a higher concentration of zooplankton in the upper 4 m than throughout the water column.

The greatest abundance of *Bosmina* in the lake occurred at Station 1 in late spring and early summer most often when pumping was in operation. The highest density was over $79,000/m^3$ on May 26, 1975, three weeks after pumping was initiated. In June 1974, *Bosmina* abundance was low but by mid-July peaked to the season high at Station 1. Station 6 density was low and averaged the lowest of all stations over the study

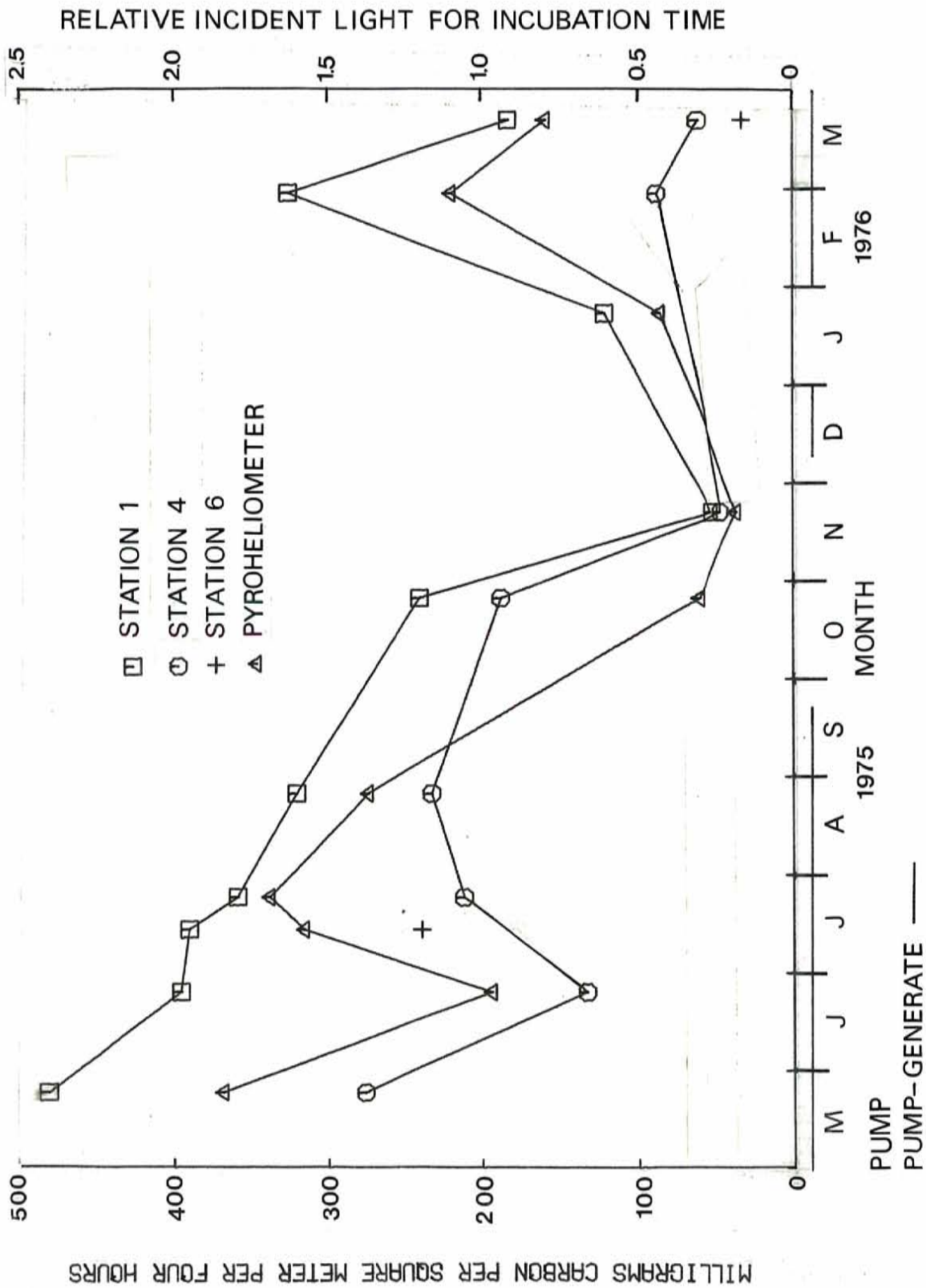


Figure 4.19 Primary production rate comparing Station 1 to Stations 4 and 6, and its relation to incident light and feeder canal pumping or pump-generation.

Table 4.12 Species of crustacean zooplankton identified from Banks Lake samples. (Courtesy of Mr. Rufus Kiser).

Cladocera

- Daphnia schodleri* Sars 1862
Daphnia pulex Leydig 1860 amend Richard 1896
Daphnia galeata mendotae Birge 1918
Diaphanosoma brachyurum (Lieven) 1846
Bosmina longirostris (O. F. Muller) 1745
Ceriodaphnia lacustris Birge 1893
Ceriodaphnia quadrangula (O. F. Muller) 1785
Camptocerus rectirostris (Schödler) 1862
Chydorus sphaericus (O. F. Muller) 1785
Leptodora kindtii (Pocke) 1844

Copepoda

- Diaptomus sicilis* S. A. Forbes 1882
Diaptomus ashlandi Marsh 1893
Epischura nevadensis Lilljeborg 1889
Cyclops vernalis Fischer 1853
Cyclops bicuspidatus thomasi S. A. Forbes 1882
Cyclops agilis (Koch) 1838
-

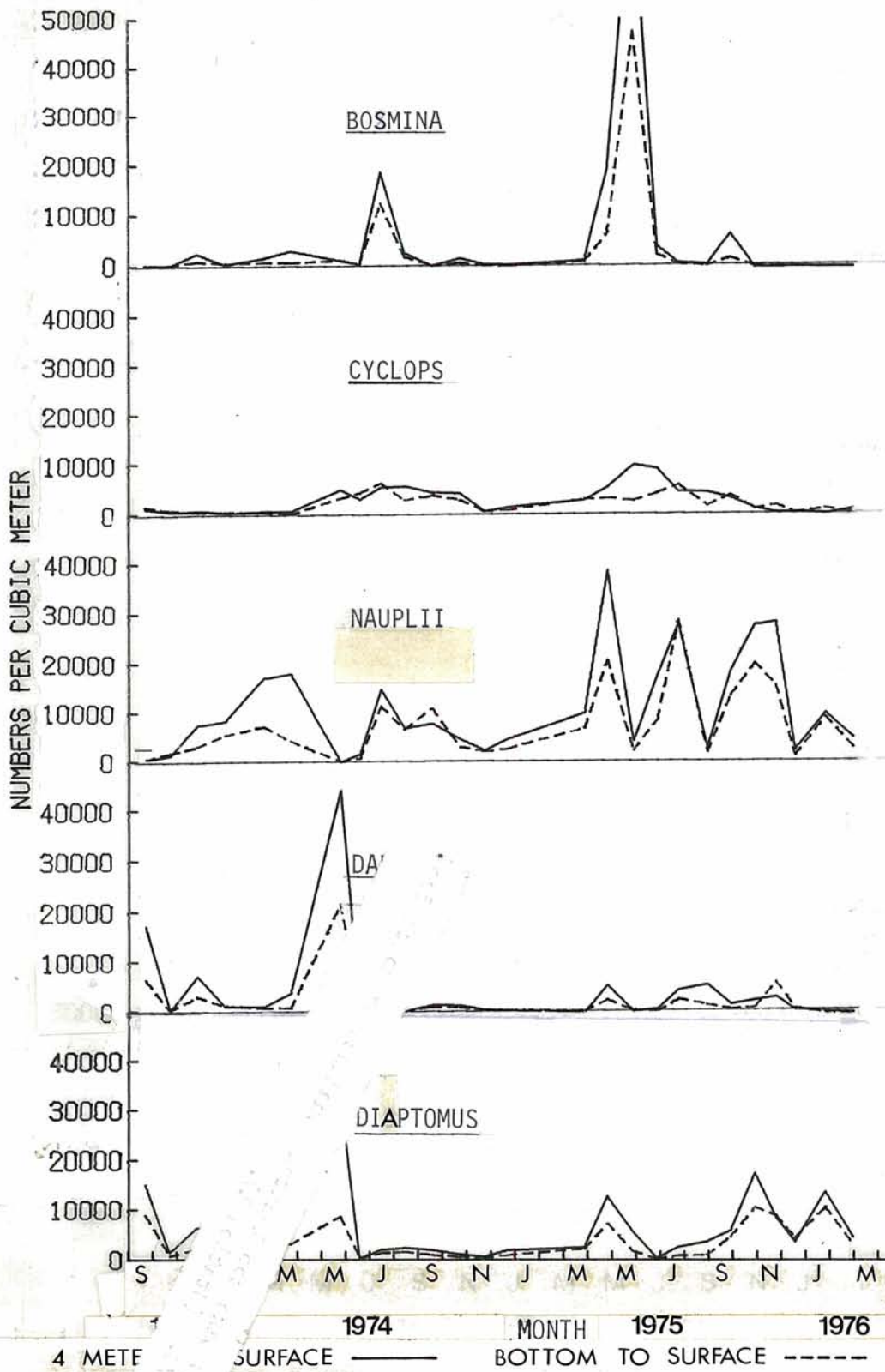


Figure 4.20 Char to

September 1973

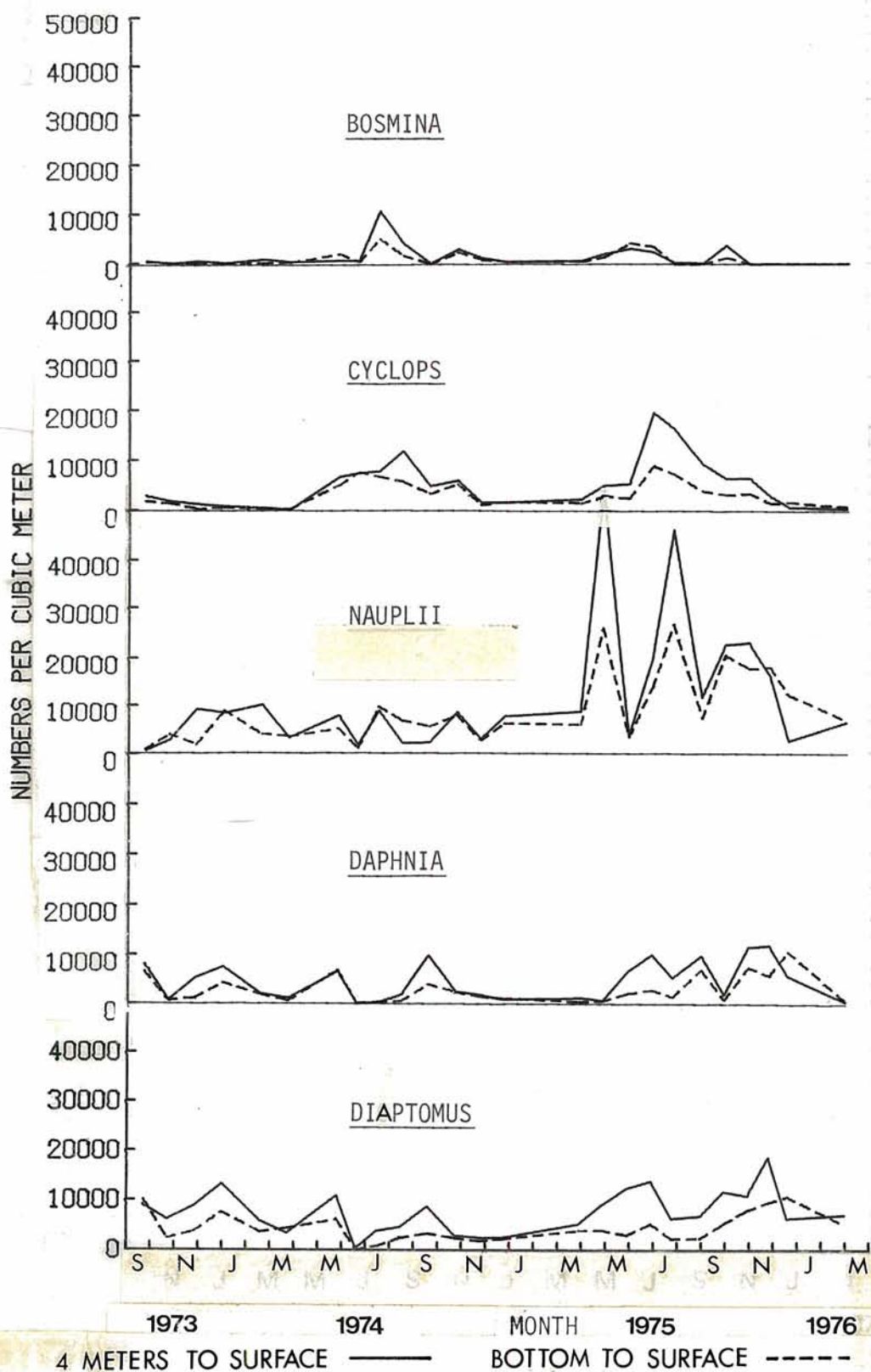


Figure 4.21 Changes in Banks Lake zooplankton abundance by month from September 1973 to February 1976. (Station 2).

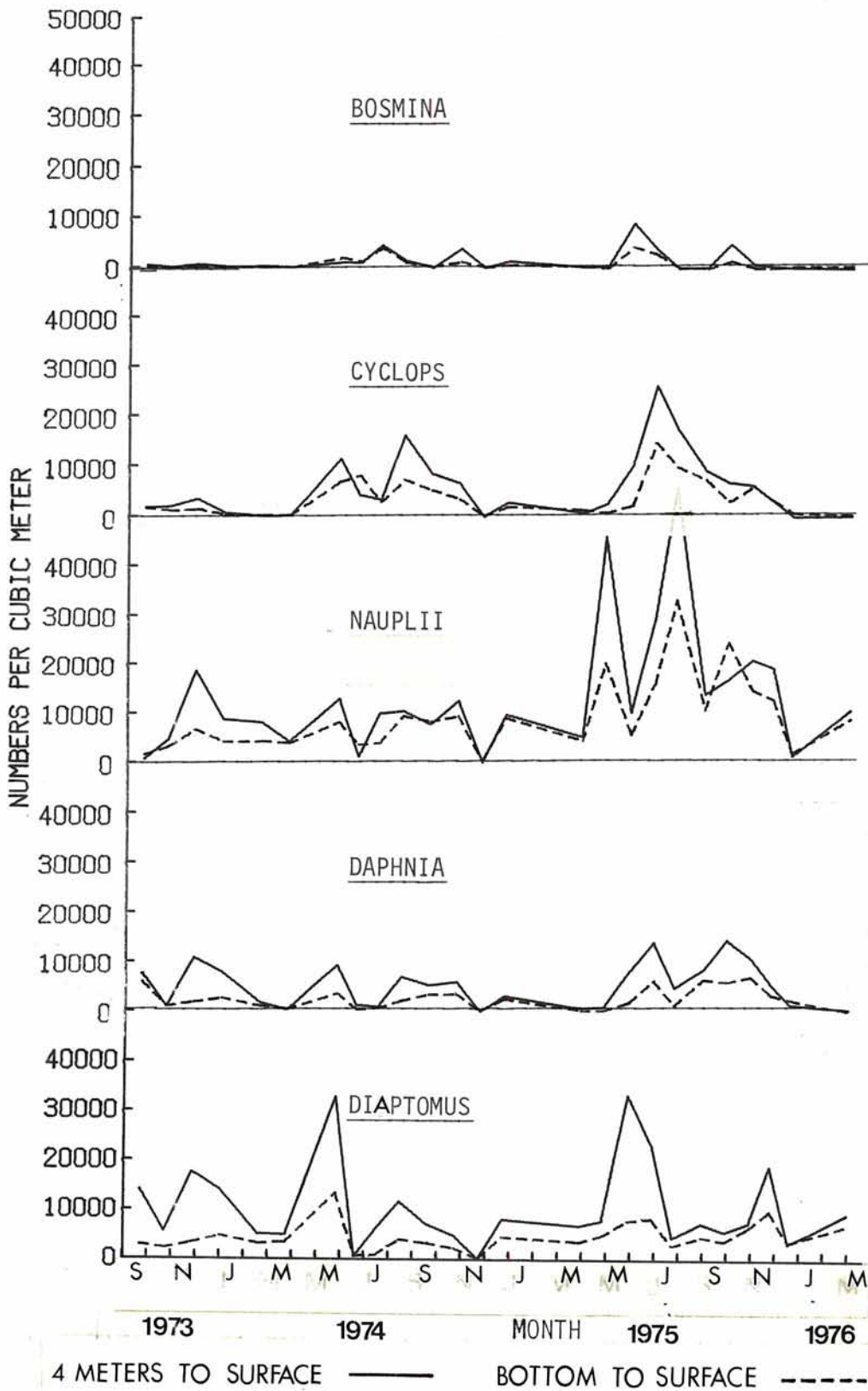


Figure 4.22 Changes in Banks Lake zooplankton abundance by month from September 1973 to February 1976. (Station 3).

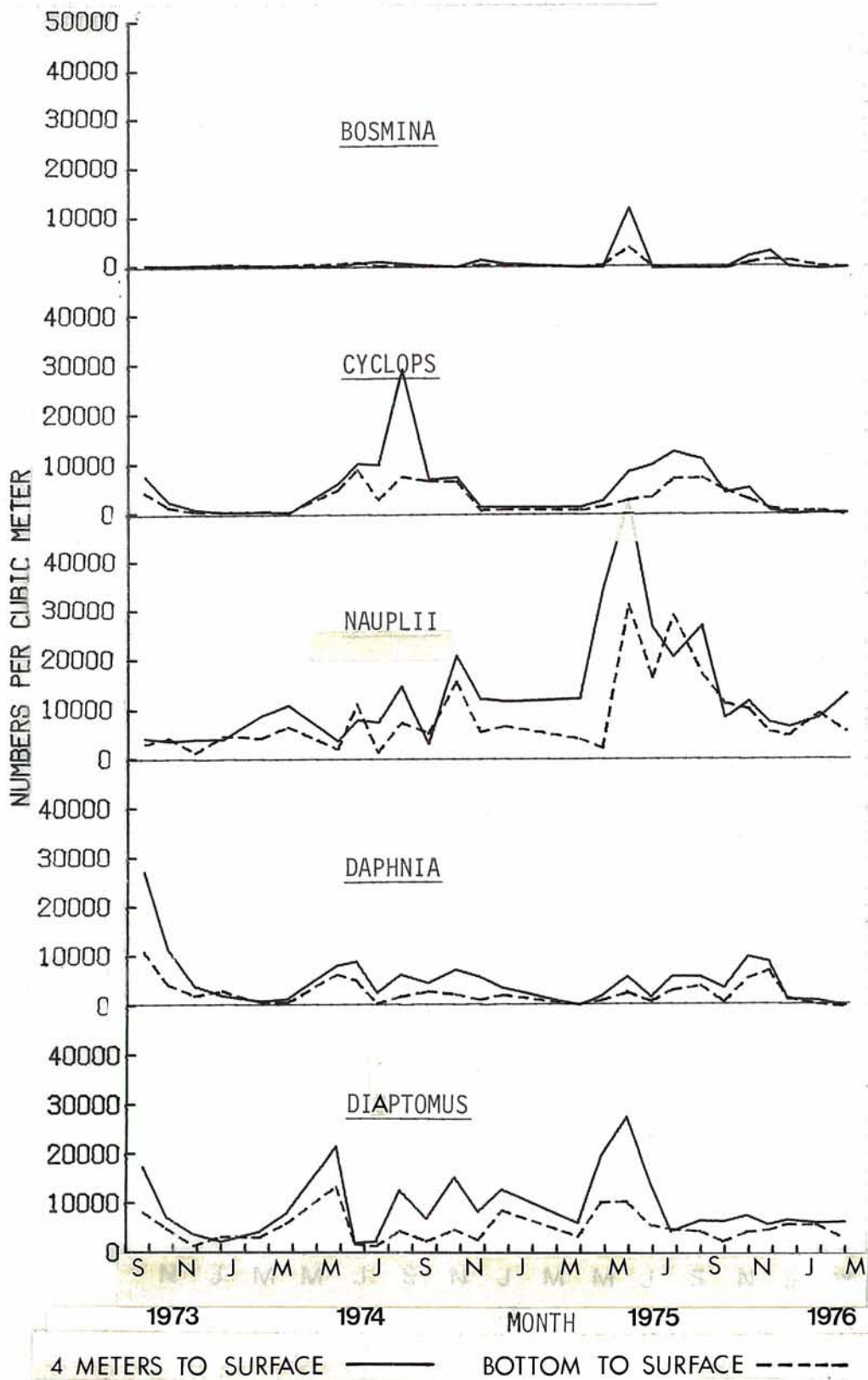


Figure 4.23 Changes in Banks Lake zooplankton abundance by month from September 1973 to February 1976. (Station 4).

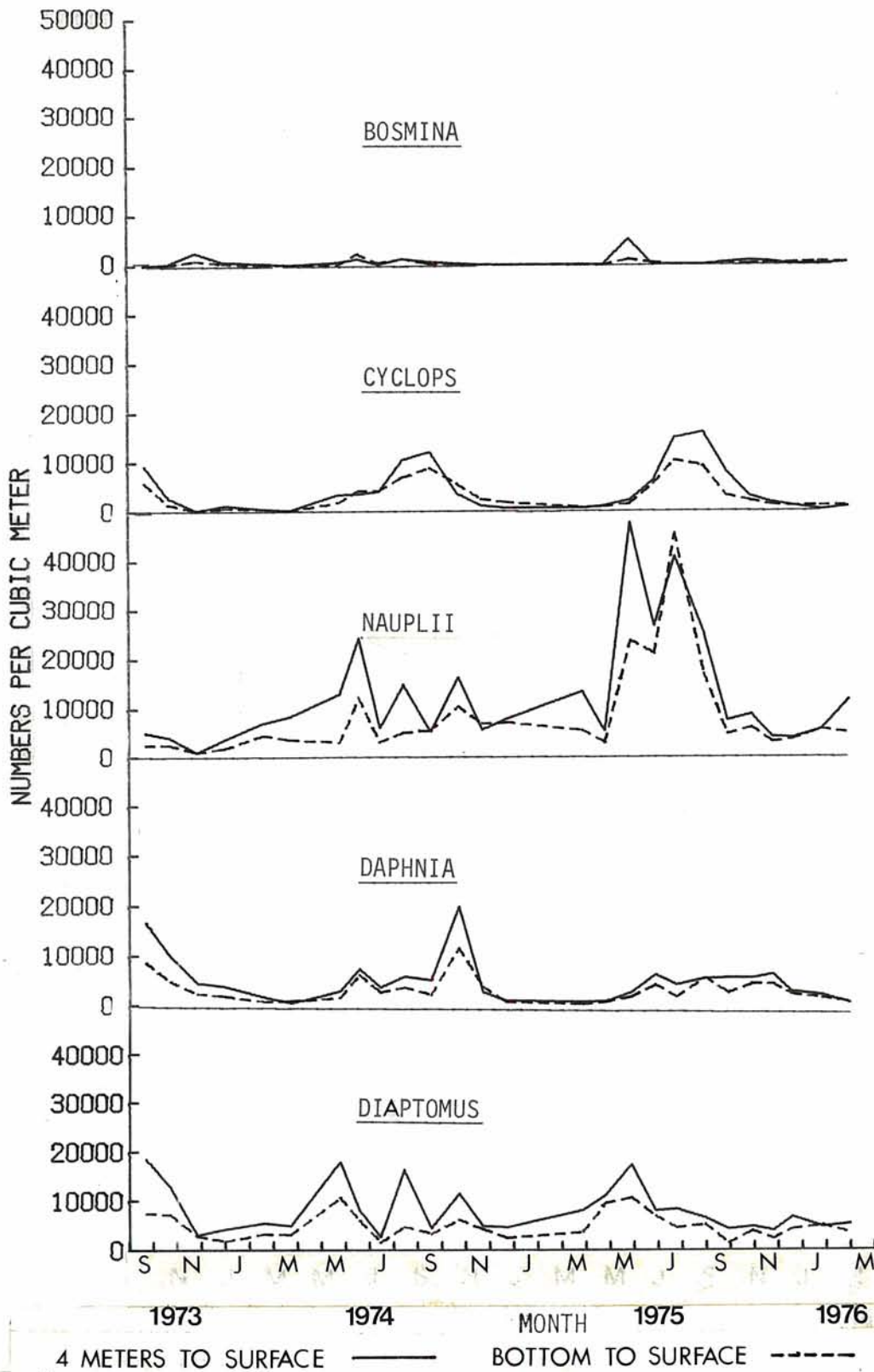


Figure 4.24 Changes in Banks Lake zooplankton abundance by month from September 1973 to February 1976. (Station 5).

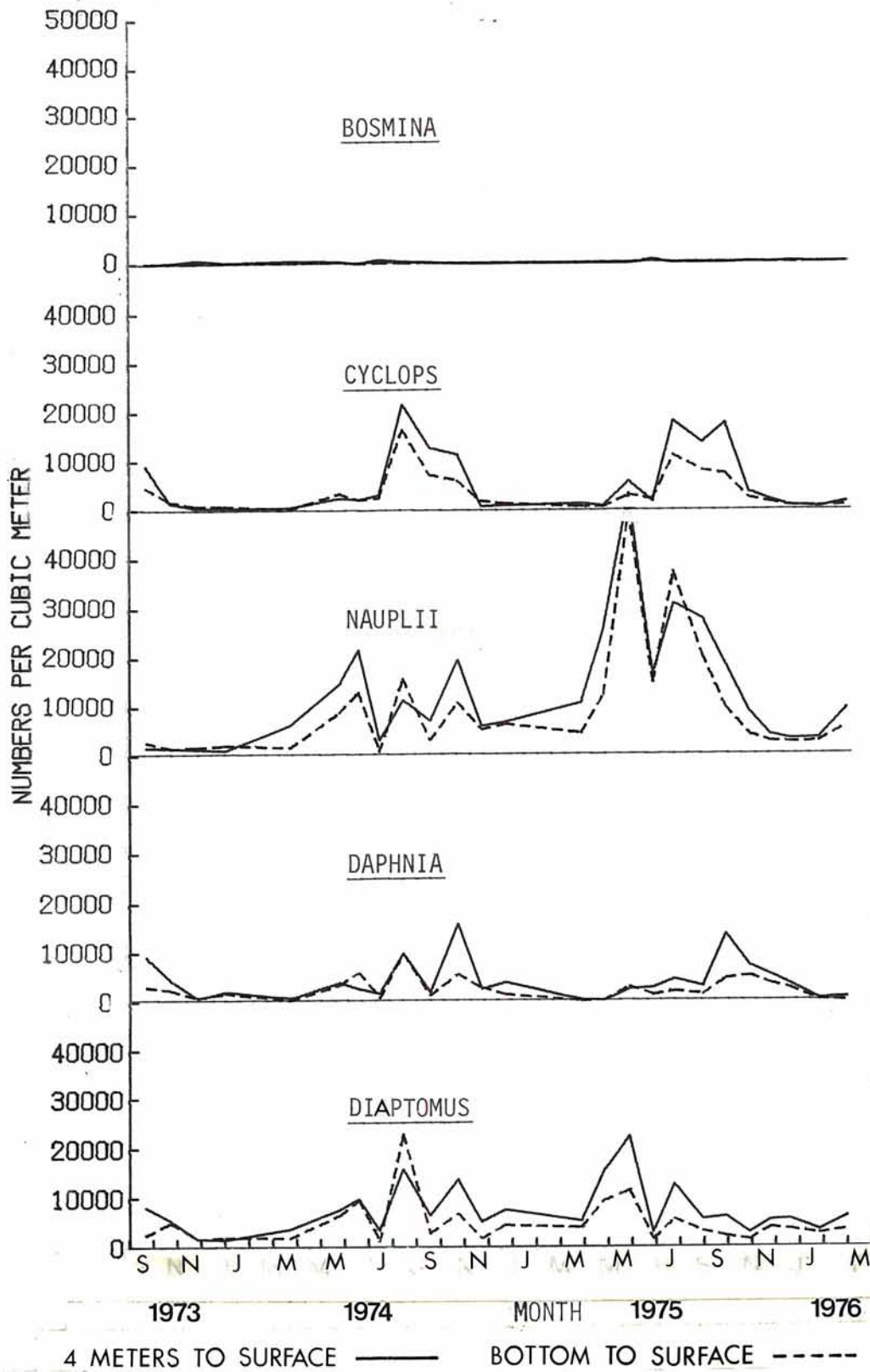


Figure 4.25 Changes in Banks Lake zooplankton abundance by month from September 1973 to February 1976. (Station 6).

area. Stations 2 and 3 showed similar patterns to that of Station 1, but averaged lower in density than Station 1. *Bosmina* density at Stations 4 and 5 was sporadic but did show small peaks in May and September similar but of smaller magnitude than those in the north. These data suggest that when the greatest density of *Bosmina* occurred, they were being produced in FDR Reservoir and pumped into Banks Lake.

The seasonally high abundance of *Cyclops* occurred from May to October in 1974 and 1975, with highest average lake abundance occurring in August 1974 and July 1975. Although no trends were seen from north to south during the pumping season, Station 1 was most often the lowest in density, suggesting that more *Cyclops* were being produced than were being pumped into Banks Lake.

The copepod nauplii showed several peaks of abundance during the sampling with similarities within Stations 1, 2 and 3, and within Stations 4, 5 and 6. The maximum nauplii density in 1975 averaged for all Stations, occurred in July. In 1974 this maximum occurred in June. Seasonal peaks in 1974 occurred in May, July and October at Stations 2 and 3, and in June, August and October at Stations 4, 5 and 6.

In 1975 three peaks were prominent at Stations 1, 2 and 3, occurring in April, July and October. Only two distinct peaks occurred in May and July in the southern three stations. In both years when pumping was begun in the spring, Stations 1, 2 and 3 showed a reduction in nauplii numbers, while the southern stations showed an increase in numbers. This suggests that late spring and early summer densities of nauplii in FDR Reservoir were less than those produced in Banks Lake.

Daphnia and *Diaptomus* both increased to maximum numbers at Station 1 in May 1974 prior to initiation of pumping of irrigation water in June 1974. A rapid decline in numbers was evident by June, indicating that both genera were flushed southward in the lake and that no abundant source was pumped in from FDR Reservoir. A similar buildup was not observed in 1975, probably due to an earlier initiation of pumping in May.

Spring abundance peaks of *Diaptomus* most often occurred in May at all stations in 1974 and 1975. Stations 1, 2 and 3 showed late fall peaks in October and November 1975. *Diaptomus* reached greatest peak abundance at Stations 3 and 4 and persisted at moderate abundance at Stations 5 and 6. *Daphnia* peaks also occurred in September or October in all three years, with the exception of Station 1. *Daphnia* has remained second only to *Bosmina* in average lake minimum abundance.

4.4.7 Zooplankton Input and Withdrawal

The same pattern of loss and gain of zooplankton through the canals was observed in both 1975 and 1976 (Table 4.13). The input and loss of zooplankton during the irrigation season was assumed to be equal to the concentration at Stations 1 and 6, respectively. The seasonal loss of total zooplankton from irrigation withdrawal was greater than the gain from feeder canal pumping. *Bosmina* was the only zooplankter that showed a greater total gain than loss during the pumping season. In both years the inflow of *Bosmina* was in excess of 10 times the quantity in the outflow.

The total loss of *Diaptomus* was seven times greater than the inflow. The loss of *Cyclops* and nauplii was only slightly larger than the gain

Table 4.13 Estimated relative abundance of zooplankton pumped into Banks Lake through the feeder canal and withdrawn with the irrigation water during 1974 and 1975.

Period	Generic Group	Estimated Numbers Pumped In	Estimated Numbers Removed in Irrigation Water
Irrigation Season 1974	<i>Diaptomus</i>	2.994×10^{12}	2.245×10^{13}
	<i>Cyclops</i>	1.202×10^{13}	2.141×10^{13}
	nauplii	1.903×10^{13}	2.112×10^{13}
	<i>Daphnia</i>	8.905×10^{11}	1.160×10^{13}
	<i>Bosmina</i>	1.301×10^{13}	1.334×10^{12}
	Total	4.771×10^{13}	7.824×10^{13}
Irrigation Season 1975	<i>Diaptomus</i>	3.527×10^{12}	2.039×10^{13}
	<i>Cyclops</i>	1.041×10^{13}	1.401×10^{13}
	nauplii	3.131×10^{13}	6.516×10^{13}
	<i>Daphnia</i>	3.300×10^{12}	5.720×10^{12}
	<i>Bosmina</i>	2.767×10^{13}	4.329×10^{11}
	Total	7.618×10^{13}	10.571×10^{13}

for both years. Although more *Daphnia* were washed out than were pumped during both years, the difference between loss and gain was much less in 1975 than in 1974.

A qualitative examination of feeder canal samples in 1974 showed that *Cyclops* and *Bosmina* were the major zooplankton being pumped in. A similar qualitative analysis of July and August 1975 feeder canal samples indicated a different composition of genera than 1974.

Cyclops was still the major zooplankter, comprising 53% in July and 77% in August 1975, of all zooplankton, excluding nauplii, in the feeder canal. However, *Bosmina* accounted for less than 1% of all zooplankton sampled during both months. *Daphnia* was abundant in the July 1975 samples comprising 25%, but fell off to less than 1% in August samples. *Diaptomus* was 20% of the zooplankton pumped in for July and August 1975.

4.5 Discussion

4.5.1 Physical Limnology

The seasonal thermal characteristics of Banks Lake classify it as a modified dimictic lake (Hutchinson 1957). The characteristics of a partially stratified lake and river-run reservoir are apparent during the summer. The effects of cold dense water being pumped in and diving under a warmer layer describes the complex thermal characteristics of the lake (Stober, et al., 1975).

The higher summer lake level of 1975 and winter pumping and pump-generating have caused additional effects on the thermal regime. The increased lake level has caused the convergence (Hoffman and Jonez 1973) to remain north of Station 2 even during peak July pumping. Although maximum surface temperatures were the same all three summers, reduced

summer drawdown in 1975 caused the temperature range from surface to bottom to be much greater at Stations 2 through 6. Pumping in December and P/G operation in February have maintained greater winter temperatures at Station 1. The pumping and P/G testing in winter, and irrigation pumping in summer have caused Station 1 to show the same trends in peak summer and minimum winter temperatures as those described for Lake Roosevelt (Sylvester 1953, and USGS 1972).

Maximum surface temperatures occurred at Station 3 all three summers. This suggested the lack of mixing of epilimnetic surface water and cold irrigation water from Lake Roosevelt in the region of the convergence. Although surface temperature was warmest in this region, an increase in water column mean temperatures was seen from north to south through the lake during summer stratification. As air temperature cooled in the fall, stratification ended in mid-September in 1973 and 1974 and in late August in 1975.

Transparency was primarily influenced by phytoplankton standing stock and suspended sediment due to wave action and pump-related turbulence. Much of the shoreline and lake bottom consisted of disturbed fines. Stations 2, 3 and 5 were most susceptible to the resuspension of fines due to wave action. Just north of Stations 2 and 5, shallow spits of land extend into the water. During wave action visible turbidity could be seen downwind from these shorelines. This wave-induced turbidity was measured at Station 5 in August 1975 when a visible line of turbid water extended across the lake which resulted in a reduction of the Secchi depth from 4.2 to 2.1 m. Stations 4 and 6 were least affected by silt-induced turbidity, because Station 4 was located in the widest

portion of the lake and Station 6 was surrounded by a steep rocky shoreline. Although the local shoreline at Station 1 was composed of a rocky bottom, sediments were probably suspended in the water pumped in from FDR Reservoir.

The Secchi depth values of less than 3 m most often correlated with increased chlorophyll a values in the three northern stations. Autumn reduction in Secchi depth at these stations in October 1973 may have been caused by phytoplankton blooms after pumping was stopped. When pumping began in June 1974 and May 1975, peak chlorophyll levels and season low Secchi depths were observed. Similar phytoplankton blooms and reduced transparency were seen in fall 1975 and late winter 1976 when pumping or pump-generation was occurring. Station 6 consistently averaged the greatest Secchi depth and lowest chlorophyll a concentration. Stations 4 and 5 Secchi depths were not correlated with phytoplankton levels.

4.5.2 Chemical Limnology

The ionic composition of Banks Lake water was dominated by calcium, magnesium, carbonate and bicarbonate, which classifies the lake as a Type I system (Rainwater 1962). The ionic concentrations were similar to but slightly less than those reported for Lake Roosevelt (USGS 1972). The hardness levels indicate water of soft to moderately hard (Hem 1970). The alkalinities were low but consistent with other data reported for the area (Seattle Marine Laboratories 1974; USGS 1972).

The 1975 pH readings were higher than those previously reported but were measured in situ and this eliminated the effects of transportation and respiration which tend to reduce the levels. The maximum pH readings occurred in May 1975 at the three northern stations when the maximum

primary production rate was measured. The higher pH readings were expected in a low alkalinity lake during peak production from CO_2 depletion of the carbonate-bicarbonate system. The lowest pH readings occurred in the summer near the bottom at the southern stations, indicating respiration exceeded photosynthesis at that time.

The conductivity levels were low during the study but similar to other data reported for the Columbia Basin (USGS 1973). A conversion factor of 0.55 to 0.75 multiplied by conductance gave approximate values for total dissolved solids (TDS) (Hcm 1970). The approximate TDS range was 63-108 ppm and averaged 78 ppm. Kiser (1965) found TDS ranging from 88.6 to 118.8 ppm (mean: 95.4) at Steamboat Rock in 1965-66. Lake Roosevelt levels of TDS in 1971-72 ranged from 84 to 180 ppm (mean: 104) (USGS 1972). Studies done on the Columbia River in 1910-11 and Lake Roosevelt in 1951-52 (Sylvester 1953) showed mean TDS levels of 84 and 94 ppm, respectively. Although the mean value estimated for 1975-76 was slightly lower than all values shown, this value was only an estimate. It is doubtful that any real change has occurred since Kiser's work.

The oxidation-reduction potential (ORP) remained high, rarely dropping to 400 mv (Hydrogen-standard electrode measurements) near the bottom. The high levels and lack of large reduction near the bottom during summer stratification characterize an oligotrophic lake (Welch 1952).

Silica has been shown to be a growth limiting nutrient for the diatoms, *Asterionella formosa*, when levels were less than 0.5 mg/l in Lake Windemere (Lund 1950). Stations 1, 2 and 3 showed seasonal highs when pumping was initiated in May 1975 but declined throughout the

season until levels of 0.5 mg/l were again approached in October and November, when pumping had stopped. These low levels may have affected season lows in primary production in November at Station 1. Silica levels at Stations 4, 5 and 6 averaged lower than the northern stations, but did not show limiting levels at any time.

The dynamics of nutrient supply of Banks Lake appear complex. The principal source of nutrients was the water supplied from Lake Roosevelt and the upper Columbia River Basin. Seasonal runoff from small streams and ground water in the basin adjacent to the lake may also contribute small amounts. Some quantity of nutrients was continually removed by irrigation withdrawal. Intrinsic supplies of nutrients were most important when irrigation operations and pumping ceased. During years of high drawdown the development and breakdown of littoral and terrestrial vegetation contributed to the lake nutrient budget, recycling both sedimented nutrients and nutrients removed from the water column.

The use of nutrient data plus chlorophyll a was used to classify the trophic status of north and south Banks Lake (Karp 1975). This table has been expanded to include Carbon¹⁴ primary production and comparison between 1974, 1975 and 1976 (Table 4.14). The loading rate of nitrogen and phosphorus was calculated by assuming the nutrient concentration at Station 1 was equal to the incoming water. The total supplies of phosphorous and nitrogen remained constant for 1974 and 1975; 0.3 g P/m²/yr, and 0.1 g N/m²/yr. This classifies the lake as eutrophic by phosphorous supply and oligotrophic by nitrogen supply (Stamnes 1971). Winter mean concentrations of orthophosphate and nitrate indicate the same classification (Welch and Spyridakis 1972). The

Table 4.14 Trophic status of Banks Lake with respect to various parameters.

Criterion	Year	Banks Lake Values ²			Oligotrophic	Eutrophic	Authority
		North	South	Total			
Chlorophyll <i>a</i> , µg/l (growth season mean) ¹	1974	4.2	1.6	2.8	0 - 4	10 - 1000	Welch and Spyridakis (1972)
	1975	3.7	1.5	2.6			
Orthophosphate - P, µg/l (winter mean)	1974-75	15.8	19.6	17.8	> 10	> 10	Welch and Spyridakis (1972)
	1975-76	13.0	11.0				
Nitrate - N, µg/l (winter mean)	1974-75	17.8	9.6	13.8	> 300	> 300	Welch and Spyridakis (1972)
	1975-76	19.0	2.7	10.9			
Total P annual supply g/m ²	1974			.3	< .1	> .2	Stammes (1972), Vollenweider (1968)
	1975			.3			
Total N annual supply g/m ²	1974			.1	< 2.0	> 3.0	Stammes (1972) Vollenweider (1968)
	1975			.1			
mg C/m ² /day (growing season mean) ¹	1975	770	490	630	30 - 100	1000 - 3000	Rhode (1959) Schindler and Mighswander (1970)

¹ May to September

² North Banks Lake = Stations 1-3; South Banks Lake = Stations 4-6.

Chlorophyll a data suggest that the northern region was mesotrophic in 1974 but oligotrophic in 1975. The southern region was oligotrophic both years. The primary production for Station 1 was $767 \text{ mg C/m}^2/\text{day}$ compared to $488 \text{ mg C/m}^2/\text{day}$ for Station 4, indicating north and south as mesotrophic (Rhode 1959; Schindler and Nighswander 1970).

The effects of pumping and the morphometry have separated the lake into two functionally separate pools. The northern pool encompasses the area from Station 3 to north dam and represents less than 15% of the lake volume. It is apparent from the nutrient levels that nitrogen is the most limiting nutrient in Banks Lake. The water that passes into southern Banks Lake has already been highly depleted of its nutrients, especially nitrate. This gradual loss of nitrate and its depletion from north to south is indicated by the N:P ratio. In 1974, 1975 and winter 1976, the N:P ratio showed a gradual decline from north to south. This ratio ranged from 0.0 to 1.9 in 1974; 0.0 to 2.0 in 1975; and 0.0 to 9.0 in winter 1976, and yearly averages for all years were less than 1.0.

These ratios were extremely low in relation to algae cell composition. In saltwater systems, which are naturally nitrate-limited, average cell compositions have an N:P ratio of 7.2 to 1, with the lower range approaching 1.5 to 1 (Ryther and Dunstan 1971). The lower N:P ratio and low nitrate concentration was probably a major limiting factor in phytoplankton biomass formations. This limitation was more inhibiting in the south pool of Banks Lake than in the north.

4.5.3 Biological Limnology

The phytoplankton dynamics of north Banks Lake were controlled by irrigation water inflow. This becomes apparent when one considers that

during peak pumping the entire volume of water north of Station 3 was replaced once every 3 to 6 days. During the four major irrigation months, the maximum residence time for the area was less than 15 days. Prior to initiation of pumping in 1974 and 1975, Stations 1 to 3 showed either a low or declining chlorophyll a concentration. Seasonal maxima were found after pumping started at all three stations. This was followed by declining summer concentrations and a fall bloom. Rufus Woods reservoir chlorophyll a data taken 6 miles below Grand Coulee Dam showed the same trends and similar concentrations as those found at Station 1 from the period May to August 1975 (Stober, in press).

On three different occasions, during July and August 1975, chlorophyll a was determined in the feeder canal, although these levels were lower than those found at Station 1, the difference was not greater than 1 $\mu\text{g}/\text{l}$. During this period, the pumping rate was high and residence time of the north end was less than 15 days. These data suggest that chlorophyll a levels were similar to those being pumped in but some biomass increase occurred at Station 1, even during high rates of pumping.

The effect of reducing the flushing rate was apparent in all three years. After the cessation of pumping in October 1973, chlorophyll levels increased at all three stations. Another increase was observed when pumping was stopped for ten days in September 1974, and then resumed, resident time averaged greater than 30 days. At that time, peak chlorophyll levels occurred showing a season high at Station 3. Although chlorophyll levels were increasing in September 1975 when resident time was greater than 30 days, a post-pumping peak did not occur until October.

The direct effect of nutrient input from pumping and its effect on phytoplankton biomass was demonstrated in the winter of 1975-76. The pumping in December and pump-generation starting in late January and continuing through March caused nitrate and orthophosphate at Station 1 to reach maximum concentrations in January and February, respectively. The N:P ratio at Station 1 also increased during December to March, from 1.9 to 9.0 while remaining below 1.0 at all other stations. No immediate response to these levels were seen in December, probably because of light limitations. But in February and March high nutrient levels at Station 1 resulted in the highest winter chlorophyll levels recorded in Banks Lake. Chlorophyll increases at Stations 2 and 3 at this time were similar to February 1974 levels and may have been in response to normal winter nutrient release.

The phytoplankton blooms at Stations 4, 5 and 6 were of lower magnitude than those seen in the north portion of the lake and occurred sporadically. Seasonal peaks were poorly defined but some trends were observed. The effects of fall overturn were most apparent with small peaks in chlorophyll occurring in September or October all three years. Spring blooms were very sporadic and did not occur consistently between years or stations. Station 4 peaks occurred most often at the same time as the northern region. The simultaneous occurrence of these peaks may have been partially related to pumping effects but natural seasonal factors probably were of greater importance. Station 6 peaks were always lower in magnitude and occurred most often at different times than the other stations. The low levels of chlorophyll a at these stations was mainly a function of the longer residence time and lower nutrient supply relative to the northern stations.

The C^{14} primary production measurements distinctly separated the two portions of the lake. On all dates sampled, total production was higher at Station 1. The productivity (carbon assimilation) per unit biomass (chlorophyll a) called the P/B ratio, gives an indication of growth rate per unit cell. A high P/B ratio indicates cells in a rapid growth phase. Except for May 1975, P/B ratios were higher at Station 1 than at Station 4, indicating the effects of nutrient supply and/or mixing. The curtailment of pumping resulted in seasonal low nutrient levels at Stations 1 and 4, causing production to be approximately equal during November. Production measurements for March 1976 showed how the gradual decrease in production occurred from north to south. Production measured 184, 52 and 33 mg C/m²/4 hrs for Stations 1, 4 and 6, respectively. This also demonstrated the similarity of the southern pool and how it differed from the northern pool.

The separation between north and south Banks Lake was also shown in the difference in zooplankton density and composition. The *Bosmina* population showed an average decrease from north to south. This larger density may be caused by the greater limnetic area of the north. *Bosmina longirostris* is known to be a limnetic species (Brooks and Dodson 1965). The possibility of *Bosmina* being pumped in from FDR Reservoir may be likely, but this theory is not confirmed by Rufus Woods data (Stober, in press). The density in Rufus Woods was only about 500/m³ during May 1975, when levels were 50,000/m³ at Station 1 after pumping was in operation. However, *Bosmina* can be depth selective (Carlson 1974) and may have avoided the depth strata that would cause them to be washed down river. An increase in the vulnerability to pumping may have occurred

if the 90 foot depth strata was selected in FDR Reservoir. Competition with *Daphnia* may inhibit the *Bosmina* population (Brooks 1968), their peaks in abundance occurred at different times in Banks Lake.

The *Daphnia* population showed the same trend in 1974 and 1975, with high summer and low winter density. The average density in the southern region was similar both years. The northern region density changed from 1974 to 1975. This suggested greater stability in the southern region. The *Daphnia* density in the 1974-75 pumping season was similar in fluctuation and density to that of Rufus Woods Reservoir (Stober, in press). It appeared that the inflow of *Daphnia* into Banks Lake may have been greater in 1975 than in 1974. Station 1 showed an increase in mean pumping season density of $473/m^3$ in 1974 to $1,149/m^3$ in 1975. But Stations 2 and 3 showed an even larger increase from $1,450/m^3$ in 1974 to $2,747/m^3$ in 1975 and Station 2 from $1,751/m^3$ in 1974 to $4,454/m^3$ in 1975. This larger increase at Stations 2 and 3 may have been caused by longer residence time in the north pool in 1975, allowing reproduction to occur in a slightly larger input of *Daphnia* before being flushed from the northern region. An increase of *Daphnia* from Station 1 to Station 3 was coincident with a decrease in *Bosmina* both years. This suggested the competitive effects of the two genera.

The *Daphnia* population may be affected by feeding of the three most abundant species of fish in Banks Lake (Kokanee, lake whitefish and yellow perch). *Daphnia* has been shown to make up more than 90 percent of the diets of these fish species in Banks Lake (Section 6.0). Work by Lewis (1972) on Lake Odelle, Oregon, suggests that kokanee may play a large role in controlling *Daphnia* populations. Lewis also noted a

decline in kokanee year class with low *Daphnia* density. The density in Lake Odell from May to October averaged 3000 to 16,000/m³ from the period 1968 to 1973. Banks Lake density from May to October ranged from 1,200 to 2,800/m³ for Stations 1 through 3, and 3,900 to 2,800/m³ for Stations 4 through 6 in 1974 and 1975, respectively. These densities were on the lower range of those found in the high kokanee-producing Lake Odell. It seems quite possible that the three main fish species in Banks Lake may be undergoing competition for *Daphnia* as well as controlling its density.

Peaks in the abundance of copepod nauplii occurred at different times in north and south Banks Lake. In both years when pumping was initiated, Stations 1, 2 and 3 showed a decline in nauplii density. At the same time as the decline in the north, maximum seasonal abundance occurred at Stations 4, 5 and 6. The same pattern of abundance that occurred at Station 1 from May to August 1975 occurred in Rufus Woods, suggesting that the nauplii density in the north was controlled by inflow concentrations. Seasonal peaks were apparent at all stations in spring and summer, and in the north an additional fall peak occurred. These peaks may correspond to new brood classes of *Cyclops* or *Diatomus*.

Cyclops was the most consistent in seasonal abundance of all the zooplankton, showing mid-summer and fall maximums and winter minimums at all stations. The average density was about the same in the northern and southern regions. The *Cyclops* density at Station 1 was lower than at other stations, but did not show a sharp drop when pumping was initiated. The high percentage of *Cyclops* in the feeder canal samples in July and August 1975 (53 percent and 77 percent, respectively), and the similar

density found in Rufus Woods suggested that *Cyclops* was the major genus of zooplankton being entrained into Banks Lake from FDR Reservoir.

Diaptomus usually had highest densities in May. Although high summer levels occurred, they were usually not concurrent with *Cyclops* peaks. This may have been a result of the predatory nature of *Cyclops* (Rutner 1963), which may have been feeding on *Diaptomus*. *Diaptomus* was pumped in but to a lesser degree. It consisted of 20 percent of the feeder canal samples, and was consistent with Rufus Woods densities during the summer.

Pedersen (1974) reported development times for a number of zooplankton species at 20 C. Copepods have relatively long lifespans; 338 to 387 days for *Diaptomus ashlandi* and 163 to 173 days for *Cyclops*. Cladoceran lifespans are considerably shorter; 11 to 16 days for *Daphnia* and 19 days for *Bosmina*. Water pumped into Banks Lake was always cooler than 20 C, resulting in slightly longer generation times. Thus, washout of zooplankton must have been of major significance in the north pool of the lake during pumping and almost all zooplankton observed in the north lake under these conditions were probably pumped into the lake. This helps to explain the almost complete absence of *Bosmina* in the south pool of the lake since *Daphnia* would always have had a competitive advantage. Longer retention times and warmer temperatures in the south pool would have favored a greater stability in the zooplankton community of that region.

The two-pool basin and hydrology of this system makes the classification of the trophic type difficult. The winter mean nitrate concentration and nitrogen loading rate and the level of chlorophyll a in the south pool make the lake oligotrophic, but northern chlorophyll a levels and

C^{14} primary production rates could classify as mesotrophic. Phosphate levels indicate a eutrophic state. It appears that the nitrate levels are the major controlling factor, and any additional nitrates added to the system should cause a corresponding increase in phytoplankton biomass. If this nitrogen loading rate were high enough, the system could become completely eutrophic.

5.0 BENTHIC ECOLOGY

5.1 Introduction

The benthos of unregulated (natural) lakes has generally been found to be most abundant in the upper littoral region, decreasing with depth in total numbers and numbers of taxa (Welch 1935; Humphries 1936; Berg 1938; Grimås 1961). All of these studies report maximum abundance at 3 m or less, suggesting that water level fluctuations in lakes and reservoirs which alternately expose and inundate the littoral zone may reduce the quantity and diversity of the bottom fauna. This effect has been described in natural lakes which have been impounded as reservoirs and have undergone significant changes in lake level. The impact on the bottom fauna may include severe reduction or elimination of selected species, significant quantitative reduction of the total population throughout a lake, and relocation of the area of maximum abundance (usually the upper littoral) to immediately below the level of drawdown (Stube 1958; Grimås 1961; Nilsson 1961 and 1964). These effects have been associated with a change in feeding habits of trout and char in Lake Blåsjön (Nilsson 1961) and implicated as the most influential factor contributing to the steady decline of mean length and weight of spawning char in Lake Torrön (Runnström 1958).

The littoral zone of Banks Lake is periodically affected by lake level fluctuations (Fig. 4.2) similar to those found in lakes reported in the literature. cursory observations of the adult insect populations around Banks Lake, particularly chironomids and damselflies, suggested smaller densities compared to those observed around Sun Lakes in the lower Grand Coulee to the southwest. This suggested that Banks Lake may

have reduced benthic littoral populations. A preliminary study was initiated to determine the relative abundance and distribution of benthos in the lake in relation to fluctuations of water level. Some insight into the rate and extent of repopulation of the affected littoral zone was also desired.

5.2 Materials and Methods

5.2.1 Sampling Design

Transects were selected at four sites in the lake. Three transects (4B, 5B, and 6B) were located in areas with broad, gradually sloping bottom contours in the littoral zone (Fig. 4.1). The fourth transect (1B) had a steeply sloping bottom contour. Three sets of samples were taken following the extreme drawdown during Spring-Summer 1974. The first series of samples was taken in July 1974, following a maximum drawdown of 23.6 ft. The second series was taken on December 17, 1974, 17 days after maximum lake level was attained. However, during this time, the lake level reached 1568.7 ft (MSL) in late August, with subsequent drawdown to 1560.3 ft by early October, reexposing the upper 9.7 ft of the littoral zone. The third sample series was taken on March 27, 1975, four days prior to initiation of the 1975 drawdown due to irrigation withdrawal. The number of samples per transect ranged from four to eleven, depending on width of the lake at each location.

Transects 1B and 4B were sampled on July 1, 1974, and Transects 5B and 6B were sampled two weeks later on July 13, 1974. Drawdown on these dates was 22.2 ft and 16.1 ft, respectively. Transect 1B was sampled beginning from the northwest shore at a depth of 1 m. Successive samples

were taken from this point at equal intervals along the entire transect. Intervals were determined by operating the boat at 2,000 rpm for 1.5 min. Transects 4B, 5B, and 6B were sampled starting from the east shore. Intervals between sample sites were determined by operating the boat at 2,000 rpm for 2 min. One grab sample was taken at each site.

December samples were collected to assess rate of repopulation by the benthos in the area affected by drawdown. Depths of 2 m, 5 m, 8 m, and 10 m, inclusive of the area above and just below 1974 maximum drawdown level, were sampled at all transects. Transect 1B was sampled beginning at the west shore, taking two replicate samples at each site. The east shore of the three southern transects was sampled, taking one sample at each site.

March field procedure consisted of sampling depths of 2 m, 5 m, 8 m, and 10 m as above; however, sampling was continued at sites spaced equidistant along each transect. The interval was determined by operating the boat for 2 min at 2,000 rpm. It was desirable to sample as extensively as possible, but, considering the time required for collecting and especially processing benthos, sampling sites were restricted to the west half of Transect 1B and the east half of 4B. The width of the lake at Transects 5B and 6B, even though the lake was at full pool, was sampled from the east to the west shore until large rocks and boulders were encountered.

5.2.2 Sampling Technique

A Ponar grab was used for all samples taken in July. This grab sampled an area of 529 cm^2 (81 inches^2) and was found to be more efficient than other commonly used grab samplers in both hard and soft sediment

(Powers and Robertson 1967). All samples were sieved at the time of collection through a Ponar wash frame sieve, mesh size 0.52 mm (0.0203 inch), to separate organisms from extraneous material. A 12-v Jabsco waterpuppy, Model 6360-001, was used to pump lake water to facilitate the sieving process. Specimens were preserved in 70% ethanol.

Qualitative samples of shoreline habitats were taken by insect collecting dipnet on November 1, 1975, to determine if species composition varied from that found in dredge samples. Six locations along the lake were sampled. Sampling sites varied in habitat to enable sampling as wide a variety of organisms as possible. The contents of each sample were kept alive and examined in the lake for composition.

5.2.3 Sorting and Processing

The initial sieving procedure reduced the samples to volumes ranging from 31 ml to 2 liters of material, primarily consisting of detritus. This material was sorted by hand with the aid of a low-power illuminated scanning lens to separate out individual organisms. Many other sorting techniques have been developed, including sugar flotation, carbontetrachloride flotation and elutriation. Hand sorting was considered the most accurate and thorough method. This procedure was greatly improved by staining the March samples with 0.05% solution of rose bengal in 70% ethanol. This selectively stained the organisms red, making them readily discernible from surrounding debris.

After sorting, each sample was examined separately using a Bausch & Lomb dissecting microscope (7X) with a 2X adapter. Each organism was counted and classified individually. Oligochaetae specimens, which were fragile and often broken during processing, were enumerated by considering

two end pieces as one organism and disregarding all other pieces. Keys utilized for identification of organisms included Pennak (1953), Ward and Whipple (1959), Usinger (1956), and Jensen (1966).

5.3 Results and Discussion

Organisms encountered in Banks Lake during this study are listed in Table 5.1. All groups found below a depth of 10 meters were also present in samples taken above 10 meters, Hirudenia was the only group found more often in the deeper waters. The diversity of organisms encountered was low in July, doubling after inundation in December and March. Five groups were found to be missing from the July samples including Turbellaria, Trichoptera, Zygoptera, Gastropoda, and Diptera (except chironomids), all of which were represented in December and March (Table 5.1). The relatively small number of samples taken above the 10 m depth in July as compared to December and March may account for the reduced number of organisms. In July these organisms were also affected by drawdown. At the time these samples were taken, the water level had reached maximum drawdown at 7.2 m (23.6 ft) and was increasing. Most of the organisms sampled generally prefer shallow water habitats (Pennak 1953) and were affected by the decreasing water level which may have forced migration of some organisms with the drawdown. Others may have become dormant (e.g., aestivation in gastropods), or simply become stranded and subjected to dessication and subsequent loss to the aquatic system.

Chironomids and oligochaetes consistently dominated the total benthic fauna, with composition of 56.2 percent and 36.9 percent, respectively. Amphipods and water mites (Hydracarina) made up the major

Table 5.1 Relative abundance of the benthic macroinvertebrates recovered from Banks Lake at depths ranging from 1 to 10 m.

Group	July #	December #	March #	November (Qualitative)
<i>Hydra</i>	(0)	(0)	* (3)	*
Turbellaria	(0)	+	(1) ++	(8) *
<i>Dugesia tigrina</i>				
Nematoda	* (1)	* (14)	* (15)	*
Oligochaetae	+++ (11)	++++ (21)	++++ (17)	*
Hirudinea	++ (3)	++ (2)	(0)	
<i>Helobdella stagraalis</i>				
<i>Helobdella elongata</i>				
Ostracoda	++ (2)	+	(3) +++	(7) *
Amphipoda	+	(2) +++	(12) +++	(11) *
<i>Hyalella azteca</i>				
Ephemeroptera	(0)	(0)	(0)	*
<i>Caenia sp.</i>				
Odonata				
Zygoptera	(0)	+	(4) +	(5) *
<i>Ischnura sp.</i>				
Hemiptera				
Notonectidae	(0)	(0)	(0)	*
Coleoptera				
Crysolmelidae	(0)	(0)	(0)	*
<i>Donacia sp.</i>				
Trichoptera				
Hydroptilidae	(0)	+	(1)	(0)
Leptoceridae	(0)	(0)	+	(3)
Limnephilidae	(0)	(0)	(0)	*
Diptera				
Chironomidae	+++ (10)	++++ (21)	++++ (17)	*
Ceratopogonidae	(0)	+	(1) +	(1) *
Empididae	(0)	+	(1)	(0)
Dolichopodidae	(0)	+	(2) +	(1)
Tipulidae	(0)	(0)	+	(1)
Hydracarina	++ (3)	+++ (13)	+++ (13)	*
Pelecypoda	+	(1) +	(4) ++	(4)
<i>Pisidium sp.</i>				
Gastropoda	(0)	+	(3) +	(3) *
<i>Gyraulus sp.</i>				
<i>Physa sp.</i>				
<i>Lymnaea sp.</i>				

++++ > 1,000 organisms/m²

+++ 100 to 1,000 organisms/m²

++ 10 to 100 organisms/m²

+ > 10 organisms/m²

Number of samples in which organism occurred

* Present, and not enumerated

portion of organisms in all remaining groups. Ostracods were found in only 21 percent of the samples, but were often abundant in those samples. All other organisms occurred infrequently or in such small numbers as to be considered incidental. Percent composition of chironomids and oligochaetes in Banks Lake was similar to that found in Lake Washington, an unregulated lake (White 1975). These organisms in Lake Washington averaged 47 percent and 45 percent, respectively. Chironomid abundance ranged from 19 to 15,936/m² in Banks Lake and from 19 to 15,457/m² in Lake Washington. Oligochaete abundance ranged from 0 to 11,184/m² in Banks Lake and 10 to 19,181/m² in Lake Washington.

Oligochaetes and chironomids, as well as the total benthic invertebrates demonstrated an increasing trend in abundance from the north to the south end of the lake (Table 5.2). Temporal variations at Transects 1B and 4B included a sixfold and ninefold increase in average abundance, respectively, in March 1975, over that found in July 1974. Organisms were twice as abundant at Transects 5B and 6B in March as in July. December abundance values were exclusive of deep water samples and therefore were not comparable to those reported for July and March. One can only speculate at this time as to what caused July abundance to be so low relative to March samples. Brinkhurst (1974) offers an excellent review of papers which reports a "midsummer minimum in benthic standing stock" in unregulated lakes. It has been suggested that fish predation is constantly eroding benthic production during the summer, allowing it to rebuild through the winter when fish feeding is inhibited by cold weather. Yellow perch, lake whitefish, rainbow trout, black crappie, pumpkinseed, and mountain whitefish are all reported to feed on benthos

Table 5.2 Variations in abundance of benthic invertebrates in Banks Lake with respect to spatial and temporal factors.

JULY								
(Depth Range: 5.9 to 24.9 m from full pool)								
Transect:	1B		4B		5B		6B	
	No./m ²	%	No./m ²	%	No./m ²	%	No./m ²	%
Chironomids	277	51.5	344	71.7	1,129	74.4	1,125	41.9
Oligochaetes	255	47.5	106	22.0	222	14.6	817	30.4
Misc. Organisms	5	1.0	30	6.3	166	10.9	742	27.7
TOTAL	537	100.0	480	100.0	1,517	100.0	2,684	100.0
No. of Samples	28							
DECEMBER								
(Depth Range: 2 to 10 m from full pool)								
Chironomids	590	40.5	1,072	60.8	2,152	79.1	3,356	44.5
Oligochaetes	420	28.8	446	25.3	384	14.1	3,384	51.5
Misc. Organisms	448	30.7	244	13.8	184	6.8	300	4.0
TOTAL	1,458	100.0	1,762	100.0	2,720	100.0	7,540	100.0
No. of Samples	21							
MARCH								
(Depth Range: 2 to 26 m from full pool)								
Chironomids	2,013	62.3	1,788	42.0	2,350	65.7	2,507	43.0
Oligochaetes	768	23.8	2,265	53.2	846	23.7	2,725	46.8
Misc. Organisms	451	13.9	202	4.8	379	10.6	597	10.2
TOTAL	3,232	100.0	4,255	100.0	3,575	100.0	5,829	100.0
No. of Samples	35							

to some extent in Banks Lake (Section 6.0). Ball and Hayne (1952) have reported, however, a "midsummer minimum" in both the presence and absence of fish, the decline in abundance beginning with the establishment of the ice cover. With fish predation absent, this decline may have been due to overcrowding, depleted food supply, and/or cannibalism by the benthic invertebrates, necessitating the continued consideration of fish predation as a possible contributing factor. Emergence of chironomids observed in late May could contribute to summer decline, however, other taxa which are aquatic throughout their life cycles also exhibited this phenomenon. Water level fluctuations must be considered as a factor contributing to low benthos populations.

Just prior to initiation of drawdown in March 1975, organisms were found to be most prevalent at 5 m, at three of the four transects (Fig. 5.1). This was 2.2 m (7.2 ft) above the maximum drawdown level of the previous year. The 5 m maximum in Banks Lake was due primarily to the chironomid populations (Fig. 5.2), the oligochaetes demonstrated a definite 5 m maximum only at Transect 6B (Fig. 5.3). The miscellaneous organisms exhibited greater numbers in the deeper waters, except at Transect 5B (Fig. 5.4).

Repopulation of the drawdown area after the lake level had come to within 2 ft of full pool was confounded by another period of drawdown. Beginning on August 26, 1974, and continuing through October 3, the water level dropped to a low of 1560.3 ft, rising again to full pool (1570 ft) on November 30 (Fig. 4.2). This divided the area exposed into two sections, above and below the 1560.3 ft elevation level. The area above was exposed for 82 to 153 days, depending on depth, then re-exposed for 1 to 97 days. The area below 1560.3 ft was exposed for 1 to

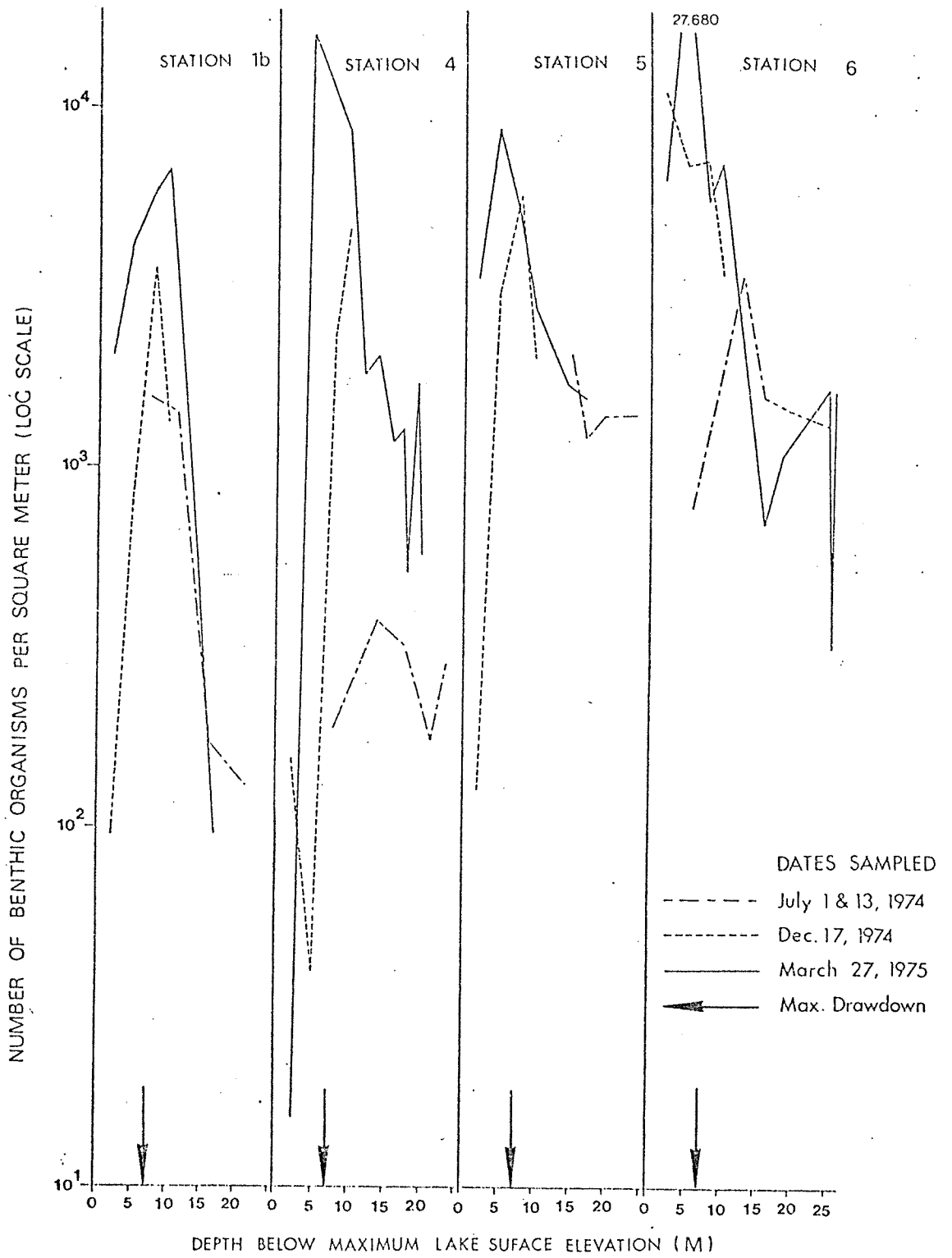


Figure 5.1 Depth distribution, relative to maximum drawdown, of the total number of benthic organisms per square meter by station and sampling date.

ABUNDANCE OF CHIRONOMIDS

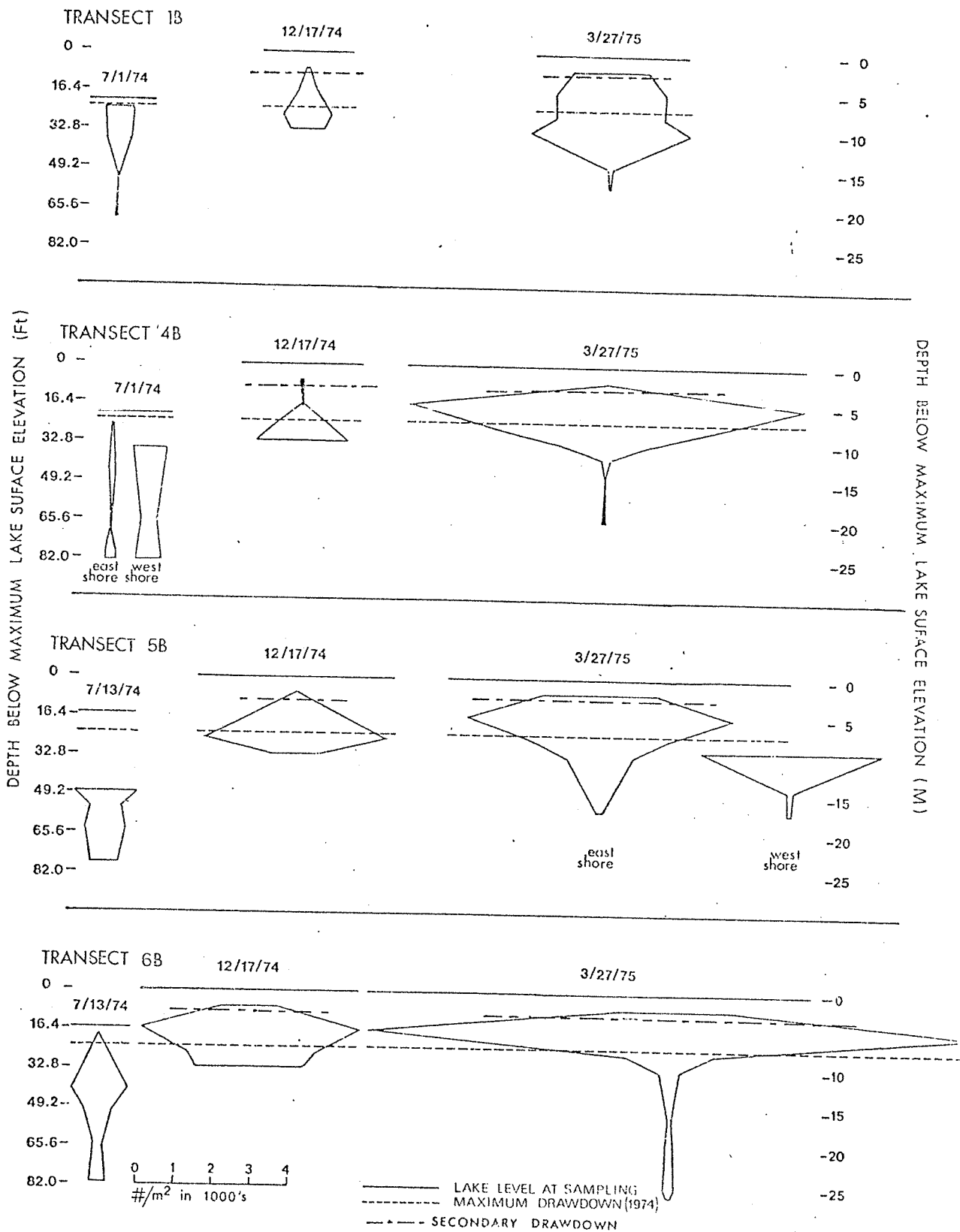


Figure 5.2 Abundance of chironomids (no./m²) with depth on each sampling date.

ABUNDANCE OF OLIGOCHAETA

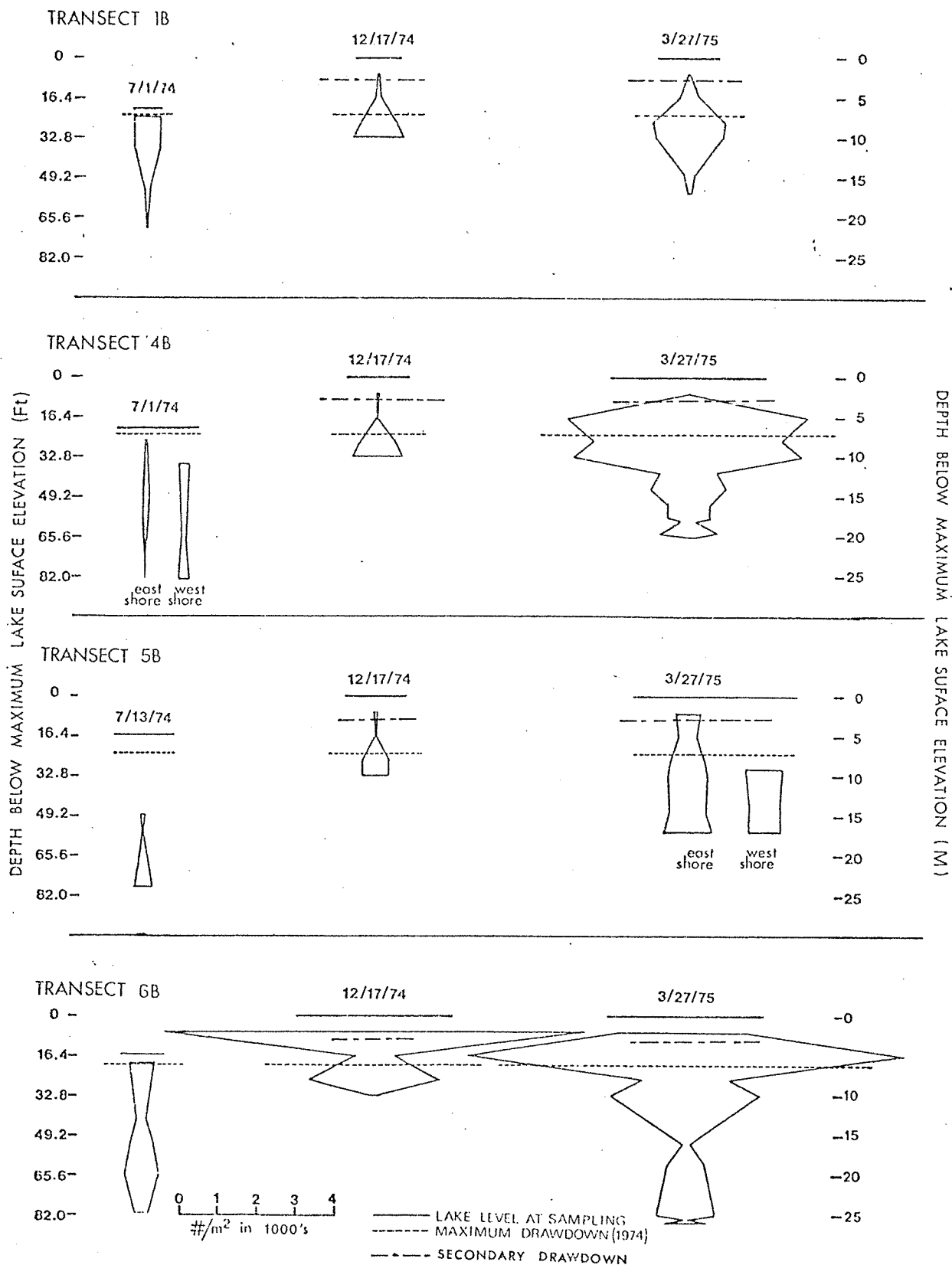


Figure 5.3 Abundance of oligochaeta ($\text{no.}/\text{m}^2$) with depth on each sampling date.

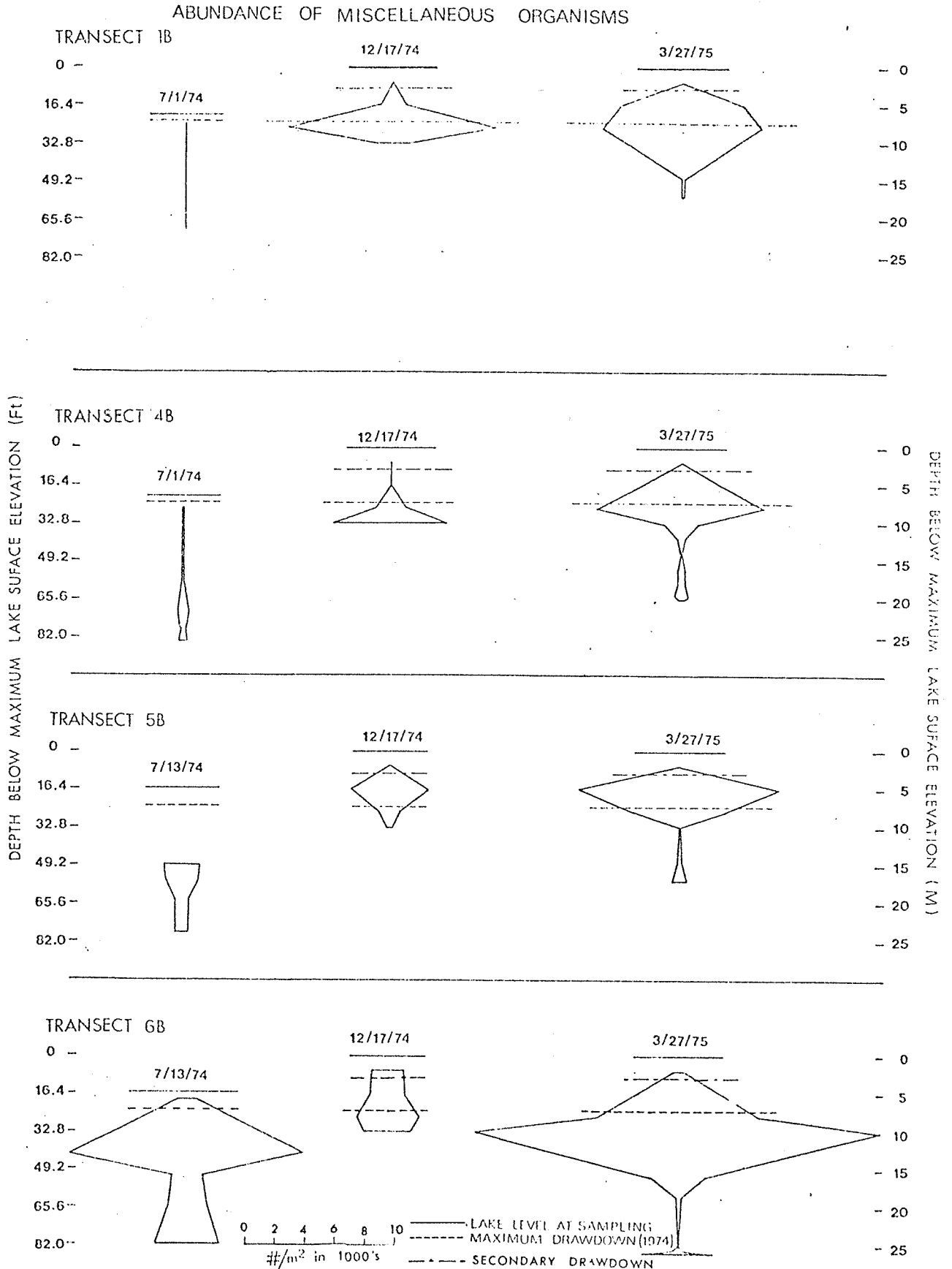


Figure 5.4 Abundance of miscellaneous organisms (no./m²) with depth on each sampling date.

82 days. This difference was reflected in the bathymetric distribution curves for each group of organisms (Figs. 5.2, 5.3, and 5.4). Abundance at 2 m (6.6 ft) in December, the only sample directly affected by the secondary drawdown, ranged from 0 to 128 individuals/m² at all transects except 6B. Considering these small numbers, compared to the larger populations found in March, it was evident that repopulation did occur resulting in maximum numbers of organisms above the maximum drawdown (5 m) level at Stations 4B, 5B and 6B. Comparable recovery at Station 1B was not evident and maximum numbers remained below (10 m) the maximum drawdown level.

6.0 FISH POPULATION ECOLOGY

6.1 Introduction

A very diverse fish community has become established in Banks Lake since its creation in 1951. As a result, an important multi-species sport fishery has developed (Duff 1973). In June 1973, this investigation was initiated to develop baseline information on the fish populations in Banks Lake, in order to assess the potential effects of planned increases in irrigation and pumped storage operation. Relative abundance, distribution, and life history of all species in the lake were investigated, with emphasis placed on yellow perch (*Perca flavescens*), lake whitefish (*Coregonus clupeaformis*), and kokanee (*Oncorhynchus nerka*). These were found to be the dominant species in the lake. This report summarizes the data collected from June 1973 through March 1976, during the time the lake was primarily influenced by the input and withdrawal of irrigation water.

6.1.1 Origin of Stocks

The origin of specific stocks of fish in Banks Lake was considered important, since many of the species were pumped in from Franklin D. Roosevelt Lake. In addition, some of the species originated from the small lakes existing in the Grand Coulee prior to inundation, and from stocking programs carried out by state agencies.

Recruitment of fish from Franklin D. Roosevelt Lake through the feeder canal was the likely origin of most species in Banks Lake. Twenty-one species have been described by two independent investigations of the fish fauna of Franklin D. Roosevelt Lake. Eight additional

species have been personally observed or stocked by state agencies since June 1971, totaling the 29 species of fish found in Franklin D. Roosevelt Lake (Table 6.1).

Of special interest were the unconfirmed reports of a kokanee fishery that existed before the stocked kokanee became available to the sport fishery. Gangmark and Fulton (1949) reported that kokanee were entrained through the Grand Coulee Dam generators, indicating a movement of kokanee out of Franklin D. Roosevelt Lake. The irrigation pump intakes leading from Franklin D. Roosevelt Lake to Banks Lake are located in close proximity to the Grand Coulee Dam generator intakes. It is assumed that kokanee and other species have been pumped into Banks Lake from Franklin D. Roosevelt Lake, since the initiation of the irrigation project. Feeder canal sampling conducted in 1975 confirmed this assumption and results are detailed under Entrainment, Section 9.0 of this report.

Large chinook salmon (5 to 15 lb) were captured in Banks Lake by sports fishermen in 1975. Chinooks this large were not from the 1974 plant into Banks Lake, and therefore were probably pumped up from Franklin D. Roosevelt Lake. Approximately 1.8 million juvenile chinook salmon were planted in Lake Roosevelt in 1971-72.

The brown trout, *Salmo trutta*, and the brown bullhead, *Ictalurus nebulosus*, have not been described in Franklin D. Roosevelt Lake, but have been captured in Banks Lake. These species may occur in Franklin D. Roosevelt Lake; however, due to their desirability as sport fish, they may have been introduced into Banks Lake by local sport fishermen.

Table 6.1 Fishes of Lake Roosevelt

Common Name	Scientific Name	Gangmark and Fulton 1949	Earnest and Spence 1956	Additional species observed personally or stocked by State agencies since 1972
1 Rainbow trout	<i>Salmo gairdneri</i>	+	+	
2 Brook trout	<i>Salvelinus fontinalis</i>	+	+	
3 Mountain whitefish	<i>Prosopium williamsoni</i>	+	+	
4 Pygmy whitefish	<i>Prosopium coulteri</i>	+	0	
5 Kokanee salmon	<i>Oncorhynchus nerka</i>	+	0	
6 Cutthroat trout	<i>Salmo clarki</i>	+	+	
7 Dolly Varden	<i>Salvelinus malma</i>	+	+	
8 Largemouth bass	<i>Micropterus salmoides</i>	+	+	
9 Smallmouth bass	<i>Micropterus dolomieu</i>	+	+	
10 Northern squawfish	<i>Ptychocheilus oregonensis</i>	+	+	
11 Peamouth	<i>Mylocheilus caurinus</i>	+	+	
12 Redside shiner	<i>Richardsonius balteatus</i>	+	+	
13 Yellow perch	<i>Perca flavescens</i>	+	+	
14 Tench	<i>Tinca tinca</i>	+	0	
15 Carp	<i>Cyprinus carpio</i>	+	+	
16 Pumpkinseed sunfish	<i>Lepomis gibbosus</i>	+	+	
17 Chiselmouth	<i>Acrocheilus alutaceus</i>	0	+	
18 Lake whitefish	<i>Coregonus clupeaformis</i>	0	+	
<u>Suckers</u>	<u><i>Catostomus species</i></u>	+	+	
19 Bridgelip sucker	<i>C. columbianus</i>		+	
20 Largescale sucker	<i>C. macrocheilus</i>		+	
21 Longnose sucker	<i>C. catostomus</i>		+	
<u>Sculpins</u>		+	+	
22 Prickly sculpin	<i>Cottus asper</i>		0	+
23 Walleye	<i>Stizostedion vitreum</i>		0	+
24 Burbot	<i>Lota lota</i>		0	+
25 Black crappie	<i>Pomoxis nigromaculatus</i>		0	+
26 White sturgeon	<i>Acipenser transmontanus</i>		0	+
27 Speckled dace	<i>Rhinichthys osculus</i>		0	+
28 Chinook salmon	<i>Oncorhynchus tshawytscha</i>		0	+ *
29 Coho salmon	<i>Oncorhynchus kisutch</i>		0	+ *

* released in 1976 by WDF

Devils Lake was the largest of several small lakes in the upper Grand Coulee Basin prior to inundation in 1951. Unfortunately, no records were made of the fish fauna of these small lakes. Information from local fishermen indicated that before inundation, dense populations of largemouth bass, (*Micropterus salmoides*), and pumpkinseed sunfish, (*Lepomis gibbosus*), existed. Shortly after inundation the largemouth bass population increased and Washington Department of Game catch records from 1952, 1953 and 1954 indicate that largemouth bass and sunfish dominated the creel and represented 64 percent and 32 percent of the catch, respectively (Atley Nelson, WDF records, unpublished). Yellow perch, (*P. flavescens*); rainbow trout, (*Salmo gairdneri*); and eastern brook trout, (*Salvelinus fontinalis*), were also identified in the 1952-54 catches.

State agencies have introduced four species of salmonids: rainbow trout, kokanee, chinook and coho salmon (Appendix Table 1). The Washington Department of Game through continuous plants maintained substantial populations of rainbow trout and kokanee in Banks Lake. The program was initiated in 1953 when the Washington Department of Game planted 4,000 Kamloops rainbow trout. Subsequently, plants of 1,054,000 kokanee fry and 24,200 rainbow trout were made in 1956. Thereafter rainbow trout were planted annually and kokanee were planted every year except 1961-62, 1967-70, 1972-73, and 1975. The Washington Department of Game introduced 101,750 coho salmon, *O. kisutch*, in 1971. The Washington Department of Fisheries introduced 40,000 and 54,000 chinook salmon, *O. tshawytscha*, in 1974 and 1975, respectively.

6.1.2 The Sport Fishery

The magnitude and value of the sport fishery were the primary justifications for this investigation. Duff (1973) estimated the 1971-72 fishing effort to be 92,236 fishermen-days with a catch of 81.6 metric tons (90 tons) worth \$1.6 million to the angler.

The sport fishery was described as a multi-species fishery containing three salmoniforms (rainbow trout, kokanee and lake whitefish); five perciforms (yellow perch, largemouth bass, black crappie, walleye, sunfish); the brown bullhead, and the burbot. Largest catches by species in the 1965, 1972 and 1975 creels were of yellow perch and kokanee. Since 1952-54, when the creel survey indicated predominantly bass and sunfish in the catch, the species composition shifted to predominantly yellow perch and kokanee as these fishes became established in the reservoir (Fig. 6.1). Presently the populations of kokanee and yellow perch are well established, having dominated the sport catch since 1965. However, lake whitefish, walleye, and burbot, which were captured by sport fishermen in 1965 and 1972 have virtually disappeared from the creel. The recent introduction of chinook salmon and the continued stocking may cause further shifts in the order of species abundance in the lake.

6.2 Materials and Methods

6.2.1 Sampling Gear

Horizontal gill nets 30.5 m (100 ft) long by 1.8 m (6 ft) deep with nine panels of variable mesh monofilament nylon were used. The mesh sizes ranged from 2.5 cm to 12.7 cm (1 inch to 5 inches), graduated in 1.3 cm (1/2 inch) intervals. Sets were made at the surface and bottom

SPECIES COMPOSITION OF SPORTFISHING CREEL - BANKS LAKE

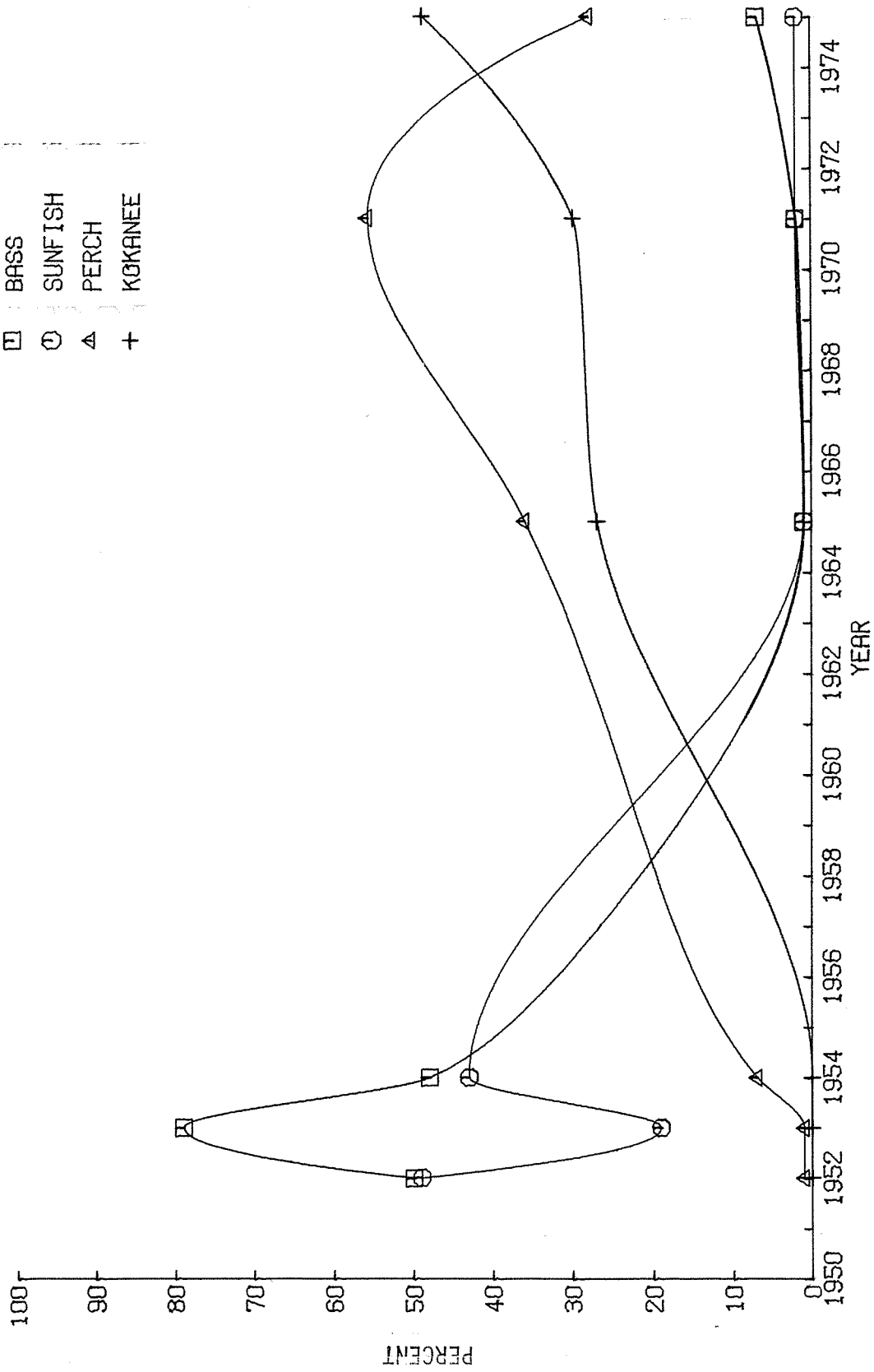


Figure 6.1 Relative abundance of fishes in 1952, 1953, and 1954 (Atley Nelson); 1965 (Merrill Spence); 1971-72 (Ray Duff); and 1975-76.

of the water column. The variable mesh horizontal gill nets caught all age groups greater than zero of yellow perch, lake whitefish and kokanee. The extent of selectivity for or against age groups greater than zero is unknown but assumed to be zero in the analysis of the gill net catch data.

A vertical gill net was utilized to determine distribution of fish within the water column. Vertical gill nets were constructed of 6.4 cm (2 1/2 inch) stretched monofilament nylon 24.4 m (80 ft) deep by 3.0 m (10 ft) wide. The 2.5 inch mesh was chosen since the largest catches of yellow perch, lake whitefish, and kokanee in the variable mesh net were made with this mesh size. Horizontal spreader bars of 6.4 mm (1/4 inch) aluminum rod were attached at the bottom, at 8 m (24 ft) intervals above the bottom and at the surface of the water column. Excess mesh was tied off at the surface.

The beach seine was 30.5 m (100 ft) long, having a center depth of 1.8 m (6 ft) tapered to 1.2 m (4 ft) on each end. The mesh size was graduated from 3.8 cm (1 1/2 inches) at each end to 3.2 mm (1/8 inch) stretched at the bunt. Rope leads 30.5 m long were attached to each end of the seine to facilitate hauling the net. Large catches of age 0 fishes were made in the beach seine hauls which complemented the large gill net catches of age 1+ fish.

Three tow nets were used to collect pelagic age 0 fishes. A 3 m x 3 m x 9 m midwater trawl was used for kokanee. A 0.5 m diameter 243 μ mesh plankton net and a 0.2 m diameter 505 μ mesh bongo net were used to catch lake whitefish fry.

Three traps used to capture live specimens for mark and recapture experiments included a 2/3 size Lake Merwin trap; 1.22 x 2.44 m (4 x

8 ft), 1.2 cm (1/2 inch) stretch mesh fyke nets; and 1.2 m (4 ft) diameter, 12.7 cm (5 inch) stretch mesh hoop nets.

6.2.2 Sampling Design and Data Analysis

The fish sampling was coordinated with the limnology and entrainment phases of this study to provide information on the effects of water input, withdrawal, and water level fluctuation on the fish populations. A sampling plan was designed which entailed standardized, periodic sampling by nets at each of four transects across the lake (Fig. 4.1, Transects 1, 4, 5 and 6). The deployment of gear monthly at each transect was designed to compare the abundance of fishes between and within transects (Fig. 6.2). To determine the north-south distribution in the lake, the total catches from two 24-hr sets of a surface horizontal net and of a bottom horizontal net at each transect were compared. To determine the vertical distribution of each transect, the two 24-hr catches of the surface horizontal net were compared with the two 24-hr catches of the bottom horizontal net. The vertical net provided additional specimens for analysis of growth, maturation and food habits of the dominant species.

Shoreline gill net sampling was conducted quarterly in conjunction with the offshore sampling to detect seasonal shifts in the inshore and offshore distributions and to provide life history data. The shoreline sampling consisted of eight horizontal gill net sets according to the following schedule. On completion of the monthly sampling, the horizontal nets at each transect were moved to the east shoreline and fished in from 2 to 5 m of water for two 24-hr periods. One net was positioned over rock substrate and the other net over mud substrate. Then the nets

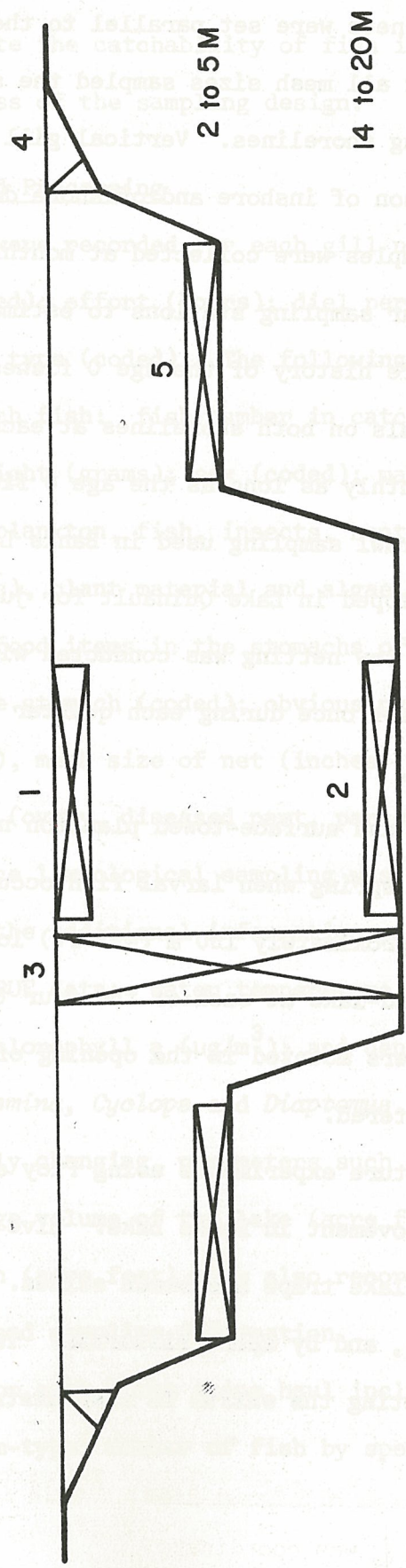


Figure 6.2 Schematic section through one transect illustrating sampling site for each gear type. 1) surface set horizontal gill nets (monthly), 2) bottom set horizontal gill nets (monthly), 3) vertical gill nets (monthly), 4) beach seine hauls (monthly), and 5) shoreline bottom set horizontal gill nets (quarterly, parallel to shoreline).

were moved to the west shoreline and fished similarly for two consecutive 24-hr periods. The nets were set parallel to the shoreline at uniform depth to insure that all mesh sizes sampled the same habitat and depth along steeply sloping shorelines. Vertical gill net catches were not utilized in comparison of inshore and offshore data.

Beach seine samples were collected at monthly intervals along the shoreline of the four sampling stations to estimate the relative abundance, distribution and life history of the age 0 fishes. The beach seining consisted of two hauls on both shorelines at each of the four transects and was repeated monthly as long as the age 0 fish were inshore.

The midwater trawl sampling used in Banks Lake followed the successful techniques developed in Lake Quinault for juvenile sockeye salmon and kokanee. Night tow netting was conducted with the aid of echolocation gear at least once during each quarter (spring, summer, fall and winter) of 1974.

The bongo nets and surface-towed plankton nets were fished on a weekly basis in the spring when larval fish occurred in the pelagic zone. The hauls approximately 150 m (492 ft) long, were made along the shorelines and at mid-lake at each of the four transects. Tsurumi-Seiki Kosakusho (TSK) meters mounted in the opening of each net recorded the volume of water filtered.

Mark and recapture experiments using Floy anchor tags were conducted to determine fish movement in Banks Lake. Live specimens for tagging were captured with lake traps and beach seines. Specimens were recaptured in gill nets, traps, and by sport fishermen. Tagged specimens were helpful in interpreting the shifts in fish distribution suggested by the

gill net catch per unit effort (CPUE). Mark and recapture information was also used to calibrate the catchability of fish in the gill nets and evaluate the effectiveness of the sampling design.

6.2.3 Data Recording and Processing

The following data were recorded for each gill net set: month; day; year; location (coded); effort (hours); diel period (coded); gear type (coded); and bottom type (coded). The following catch information then was recorded for each fish: fish number in catch; species number (coded); length (mm); weight (grams); sex (coded); maturity (coded); the relative quantity of zooplankton, fish, insects, benthos (all benthic animals excluding insects), plant material and algae, unidentifiable material, eggs, and non-food items in the stomachs of the fishes (coded); the total fullness of the stomach (coded); obvious parasites (coded); depth of capture (meters), mesh size of net (inches); and the samples preserved from each fish (ovary, diseased part, parasite, stomach, otolith, or scale). Since limnological sampling was conducted at each fish sampling transect, the additional information was recorded and used in the analysis of the CPUE data: water temperature (degrees centigrade); secchi depth (meters); chlorophyll a ($\mu\text{g}/\text{m}^3$); and densities of the zooplankters *Daphnia*, *Bosmina*, *Cyclops* and *Diaptomus*. Since hydrological conditions were constantly changing, parameters such as volume of pumping input (acre feet), average volume of the lake (acre feet), and the volume of water withdrawn (acre feet) were also recorded as monthly averages with the catch and sampling information.

The data recorded for each beach seine haul included: date, location, water temperature, bottom-type, number of fish by species, length, and

weight. The total catch, or a random subsample thereof, was preserved in a solution of 10% Formalin for the length, weight, and stomach content measurements which were made later in the laboratory.

All fish in the catch were measured except in extremely large, uniform catches which were subsampled. Subsampling of the variable-mesh gill net catches was done by uniform stratified random sampling since the fish were selected by size due to differing mesh sizes. The minimum subsample size selected was 24 from each mesh size in order to approximate the normal probability distribution. Weighting the catch of each mesh size equally may have introduced some bias toward larger fish. Because the mesh sizes were graduated arithmetically rather than geometrically, the area increment between successive mesh sizes was greater for the smaller meshes than for the larger meshes.

Scales of lake whitefish and kokanee were taken consistently from the right side below the dorsal fin and above the lateral line. Scales of yellow perch were taken from the right side below the lateral line. The scales were impressed on plastic cards and the impressions examined under magnification to determine age using a Bausch and Lomb microprojector. Otoliths were taken from all species, cleaned with glycerol, then examined with a Bausch and Lomb laboratory scope with zoom lens of 7 to 300 X power.

Stomach samples were taken for determination of food habits. Stomach contents were examined visually and described by eight codes for food type and four codes for stomach fullness. Microscopic examination was conducted on a subsample of the fish stomachs for identification of organisms to genus, enumeration and size estimates of food items.

Sex and maturity were recorded for each fish using an index modified from Nikolsky (Bagenal and Braum 1968). This maturity index was used to

help establish time, interval, and location of spawning for each species examined. Direct observations from the shoreline, from boats, and by SCUBA and skin diving was conducted in order to locate spawning fish, nests, depth of spawning, eggs, and spent or dying fish. Ovaries were preserved for fecundity and estimation of ova size.

Data were analyzed using versions 5.5 and 6.0 of the Statistical Package for the Social Sciences (SPSS). Non-parametric tests were used when the data did not approximate known distributions. When testing hypotheses with small numbers of data, non-parametric tests were selected from Siegel (1956) and computation was done by hand.

Linear regression techniques were used for length-weight analysis instead of non-linear techniques, since the increased precision due to non-linear regression was negligible. Programmable hypothesis testing techniques were used for comparing different regression equations (Analysis of Covariance, SPSS, version 6.0).

6.3 Results and Discussion

6.3.1 Species Composition and Relative Abundance

From July 1973 to June 1976, 21 species of fishes were captured. The order of abundance in the total gill net and beach seine catch combined was as follows: (1) yellow perch (*Perca flavescens*), (2) lake whitefish (*Coregonus clupeaformis*), (3) prickly sculpin (*Cottus asper*), (4) longnose sucker (*Catostomus catostomus*), (5) peamouth (*Mylocheilus caurinus*), (6) kokanee (*Oncorhynchus nerka*), (7) largemouth bass (*Micropterus salmoides*), (8) black crappie (*Pomoxis nigromaculatus*), (9) carp (*Cyprinus carpio*), (10) rainbow trout (*Salmo gairdneri*), (11) pumpkinseed sunfish (*Lepomis gibbosus*), (12) mountain whitefish (*Prosopium williamsoni*), (13) chinook salmon (*Oncorhynchus tshawytscha*), (14) longnose sucker

(*Catostomus macrocheilus*), (15) brown bullhead (*Ictalurus nebulosus*), (16) walleye (*Stizostedion vitreum*), (17) northern squawfish (*Ptychocheilus oregonensis*), (18) burbot (*Lota lota*), (19) brown trout (*Salmo trutta*), (20) bridgelip sucker (*Catostomus columbianus*), (21) dolly varden trout (*Salvelinus malma*). All species except dolly varden were captured in the gill nets. All species except burbot, brown trout, and dolly varden were taken in the beach seine catch. Yellow perch, lake whitefish, and kokanee were selected for detailed study because they dominated the beach seine (97.7% by number and 97.6% by weight) and gill net (89.3% by number and 77.3% by weight) samples (Table 6.2).

The relative abundance of species was derived from gill nets and beach seine catches. These gear types underestimated some species while overestimating others; however, the two gear types tended to display opposite selection. Those species which were not vulnerable to the gill nets were found to be vulnerable to the beach seine, and vice versa. The results of the irrigation canal sampling with nets which were probably not as selective for species as the gill nets and beach seine, also indicated dominance of kokanee, yellow perch, and lake whitefish. Therefore the species composition derived from independent gear types produced similar results indicating these data were representative of the fish populations in the lake.

6.3.2 Yellow perch, *Perca flavescens* (Mitchell)

6.3.2.1 Importance. The yellow perch is a small perciform (spiny ray), indigenous to the north central and eastern United States and south, central and eastern Canada. Through introduction by man, its range has extended to the Pacific Coast. The yellow perch successfully

Common Name	Scientific Name	Gill Nets			Beach Seine		
		No. in Catch	Relative Abundance	Relative Weight	No. in Catch	Relative Abundance	Relative Weight
1 Yellow perch	<i>Perca flavescens</i>	9,764	63.88	25.89	130,134	95.60	95.60
2 Lake whitefish	<i>Coregonus clupeaformis</i>	2,760	18.01	40.00	2,941	2.10	2.00
3 Kokanee salmon	<i>Oncorhynchus nerka</i>	1,131	7.40	11.48	2	Trace	Trace
4 Longnose sucker	<i>Catostomus catostomus</i>	424	2.77	8.86	1,470	1.05	Trace
5 Peamouth	<i>Mylocheilus caurinus</i>	491	3.21	3.00	975	0.70	Trace
6 Carp	<i>Cyprinus carpio</i>	88	0.58	3.38	217	0.15	Trace
7 Rainbow trout	<i>Salmo gairdneri</i>	240	1.57	3.70	31	Trace	Trace
8 Chinook salmon	<i>Oncorhynchus tshawytscha</i>	80	0.52	0.38	0	0.00	0.00
9 Black crappie	<i>Pomoxis nigromaculatus</i>	38	0.25	0.20	853	0.61	Trace
10 Largemouth bass	<i>Micropterus salmoides</i>	46	0.30	0.64	890	0.63	0.30
11 Mountain whitefish	<i>Prosopul williamsoni</i>	91	0.60	0.77	10	0.01	Trace
12 Pumpkinseed sunfish	<i>Lepomis gibbosus</i>	35	0.23	Trace	70	0.05	Trace
13 Brown bullhead	<i>Ictalurus nebulosus</i>	13	0.09	Trace	13	0.01	Trace
14 Walleye	<i>Stizostedion vitreum</i>	24	0.16	0.59	1	Trace	Trace
15 Burbot	<i>Lota lota</i>	3	Trace	Trace	0	0.00	0.00
16 Brown trout	<i>Salmo trutta</i>	1	Trace	Trace	0	0.00	0.00
17 Largescale sucker	<i>Catostomus macrochelys</i>	35	0.23	1.11	*	Trace	Trace
18 Northern squawfish	<i>Ptychocheilus oregonensis</i>	10	0.07	Trace	3	Trace	Trace
19 Prickly sculpin	<i>Cottus asper</i>	3	Trace	Trace	2,667	1.90	2.00
20 Bridgelip sucker	<i>Catostomus columbianus</i>	1	Trace	Trace	*	0.00	0.00
21 Dolly Varden trout	<i>Salvelinus malma</i>	**	---	---	---	---	---

* Not separated from Age 0 Longnose sucker.

** Taken in irrigation canal.

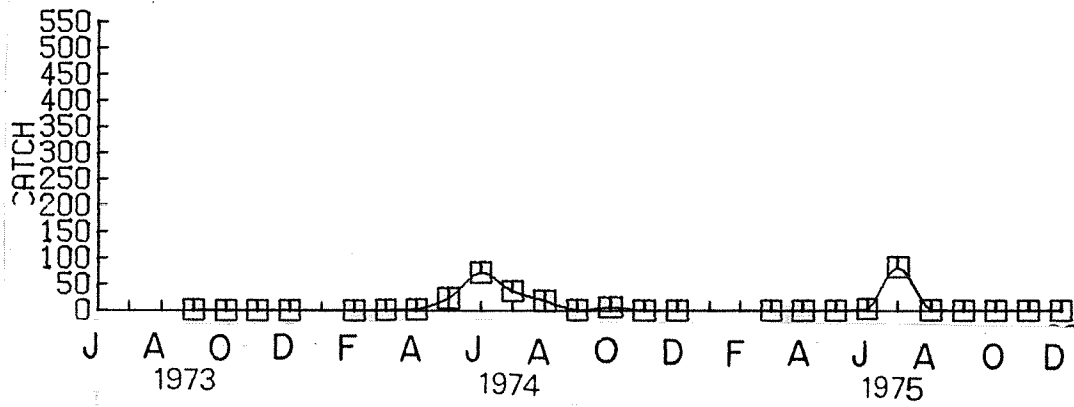
adapts to lentic waters (lakes) and once established has a tendency to overpopulate. In waters where it maintains a reasonable size, rarely exceeding 11 inches, it represents a common and highly prized game fish since it is easily caught and has an excellent food quality.

The abundance of yellow perch was low during the early years of Banks Lake as indicated by the 1952-54 creel census by Atley Nelson (Fig. 6.1). However, by the creel census in 1965, 1971-72, and 1975, yellow perch dominated numerically. Although the 1952-54 creel census indicated only small numbers of yellow perch were present in the early years of the reservoir they adapted well. Several species prey on yellow perch but a high reproductive potential coupled with flexibility in habitat and feeding requirements enabled them to become one of the most abundant species in Banks Lake.

6.3.2.2 Distribution. Vertical distribution of yellow perch in the water column was based upon monthly offshore surface and bottom horizontal gill net catches (Fig. 6.3). Yellow perch were caught predominantly on the bottom throughout the year. Surface catches were made only during June and July. Surface net catches were entirely composed of small (less than 150 mm) yellow perch. The vertical gill net which sampled only the larger yellow perch (due to a 6.35 cm [2.5 inch] mesh size) indicated perch were predominantly taken within the bottom 4 m of the water column, regardless of season.

The horizontal distribution among stations was based upon the combined analysis of two days of consecutive sampling with surface and bottom horizontal gill nets offshore at each transect (Fig. 6.4). The

SURFACE CATCH OF YELLOW PERCH



BOTTOM CATCH OF YELLOW PERCH

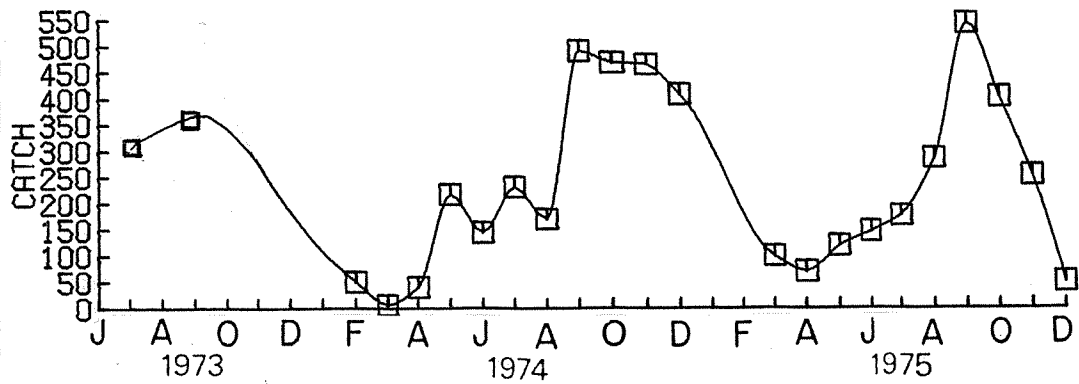


Figure 6.3 Vertical distribution of yellow perch offshore. Each point represents 8 24-hr horizontal variable-mesh gill net sets: Four sets were made at each of the 4 transects monthly: 2 on the surface and 2 on the bottom of the water column.

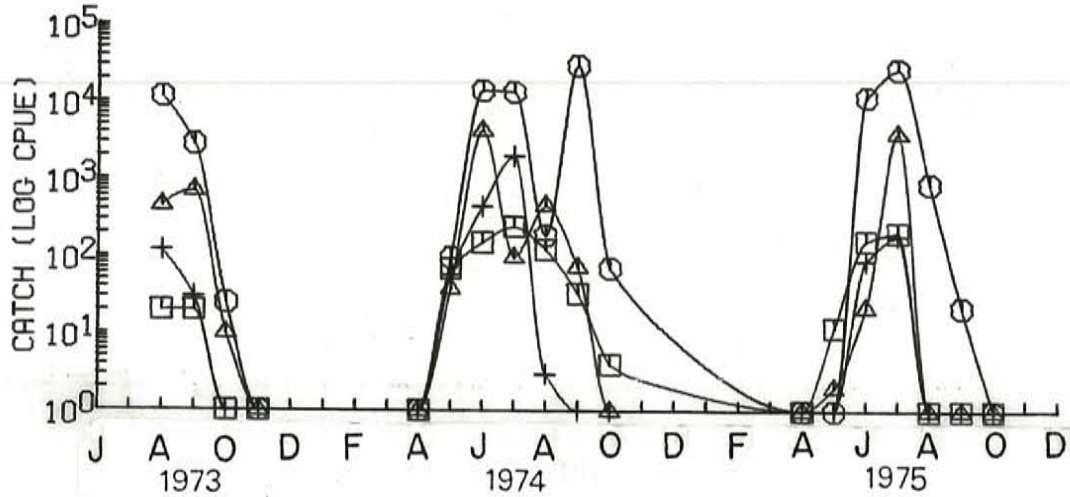
offshore catches of yellow perch by transect indicated a substantial population existed in all areas of the lake. Highest catches of perch at all transects were made in the fall when recruitment of smaller fishes occurred. Recruitment was observed at all four transects in 1973, 1974 and 1975. In addition to recruitment, a general seasonal pattern of low winter and high summer catches was also observed.

The horizontal distribution of age 0 perch captured by beach seining indicated a different trend than did the gill net catches (Fig. 6.5). Transect 4 consistently had the largest catches and Transect 1 the lowest catches of age 0 perch. However, the catches of age 0 fish did decline in the fall as recruitment into offshore gill net catches occurred.

The seasonal distributions of the total gill net catch of adult yellow perch at inshore and offshore stations were determined from the quarterly sampling during 1974 and 1975 (Figs. 6.6 and 6.7). To test the significance of inshore and offshore trends in the catch, comparisons for both years were made using the Mann Whitney U (Siegel 1956). The results showed that the inshore and offshore distributions were significantly different in the spring ($p = 0.024$), with largest catches made inshore but not different in the summer. The offshore distributions observed in the fall and winter were significantly different from the inshore ($p = 0.002$; $p = 0.002$, respectively) with the highest catches made offshore.

Two factors, temperature and recruitment, explain much of the seasonal variation in the combined offshore yellow perch CPUE. Gill nets are a passive sampling gear and rely upon the frequency of fish

BEACH SEINE CATCH OF YELLOW PERCH



- TRANSECT 1 AD 18 VALUES
- TRANSECT 4 AD 18 VALUES
- △ TRANSECT 5 AC 18 VALUES
- + TRANSECT 6 AD 18 VALUES

Figure 6.5 Beach seine catch of yellow perch by Transect from July 1973 to December 1975.

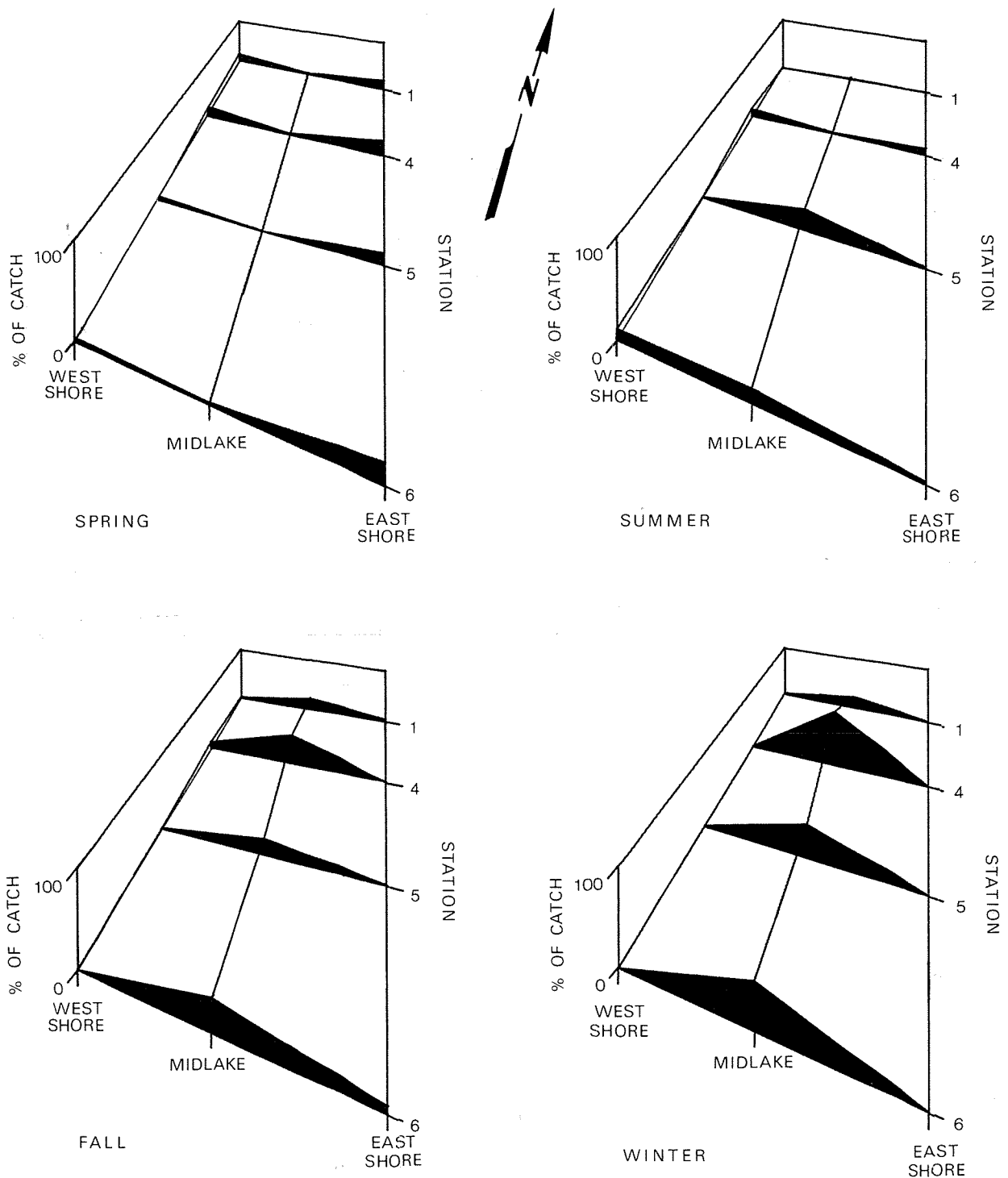


Figure 6.6 The inshore/offshore distributions of yellow perch for the spring, summer, fall and winter seasons of 1974. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, a midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1 (Electric City), 4 (Steamboat Rock), 5 (Million Dollar Mile), and 6 (Coulee City).

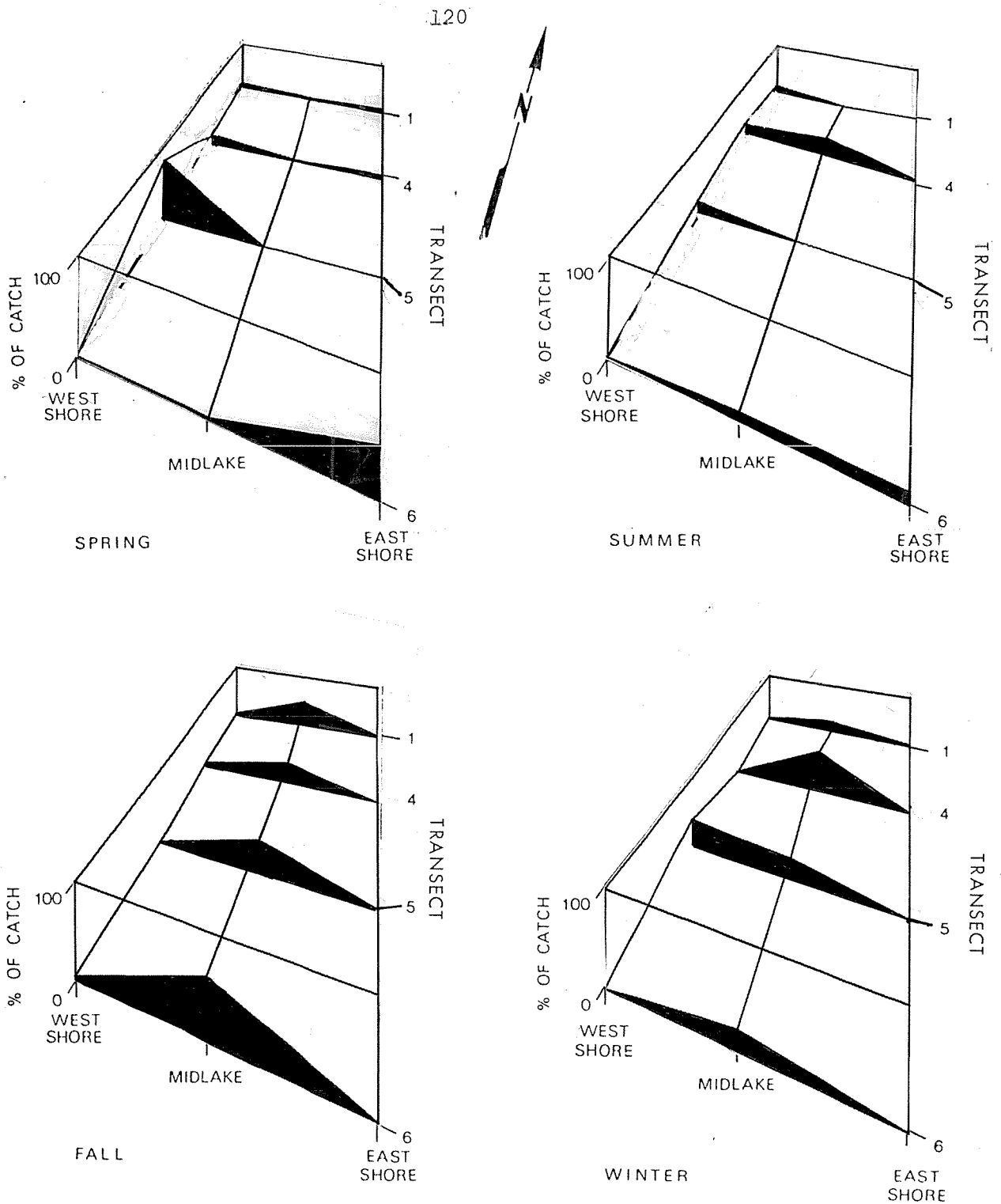


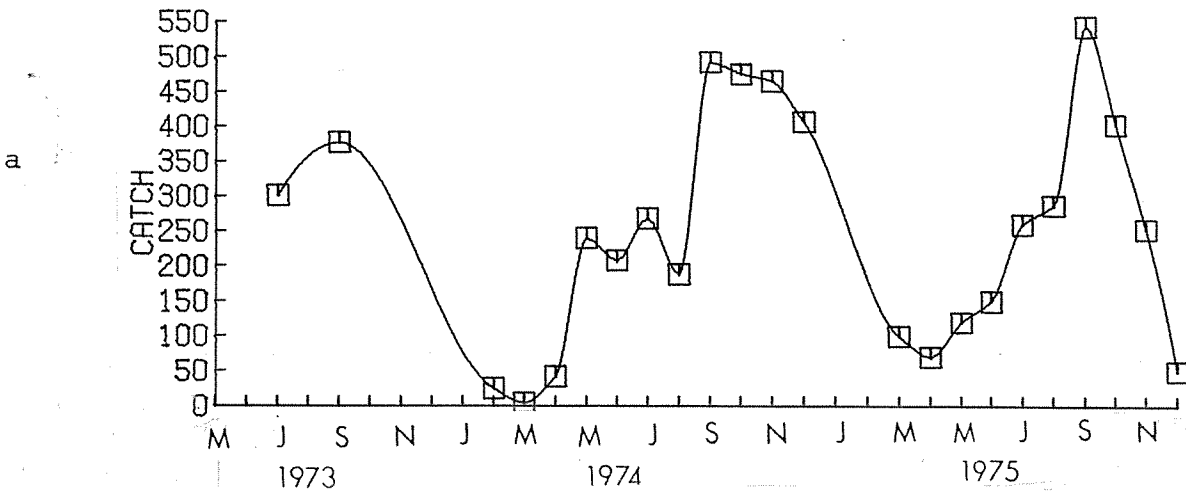
Figure 6.7 The inshore/offshore distributions of yellow perch for the spring, summer, fall and winter seasons of 1975. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, a midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1(Electric City), 4(Steamboat Rock), 5(Million Dollar Mile), and 6(Coulee City).

encounters in order to facilitate capture. The rate of encounter is a function of activity, and yellow perch activity increases as the water temperature increases, as does the activity of most spiny-rayed Perciform fishes (commonly called warm-water fishes). The mesh sizes of the gill nets used were selective for larger fishes and as the summer and fall seasons progressed, larger fishes became vulnerable to the gear and were captured, i.e., recruited.

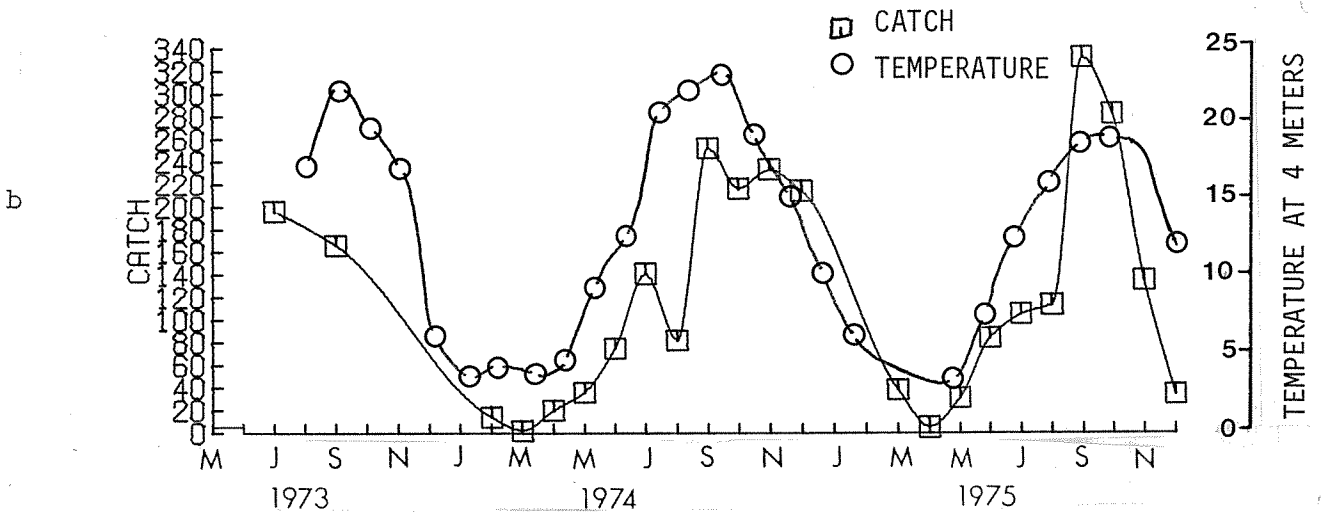
Figure 6.8a illustrates the total offshore seasonal catch (surface and bottom horizontal gill net) of yellow perch from June 1973 through December 1975. During two complete sampling years, the catch increased during the spring and summer from low winter values to September when highest catches occurred. Recruitment was removed from the catches by subtracting perch 175 mm and less from the total. This essentially removed all age 0 perch. Comparison of the seasonal catch between years was then possible without the confounding effect due to recruitment. A high correlation of the catch of yellow perch to the annual water temperature cycle was evident once recruitment had been removed (Fig. 6.8b). Some recruitment of perch less than 175 mm occurred during May 1974 and 1975; however, the greatest numbers were recruited offshore during September and October (Fig. 6.8c). No trends between years were apparent in the catches.

Two trends were observed in the horizontal distribution which indicated response by yellow perch to operational changes due to irrigation. The first phenomenon observed was a decrease in catch at Transect 1 in June 1974 and May 1975, while the catches at Transects 4 through 6 were relatively stable or increasing (Fig. 6.4). June 1974 and May 1975 were

OFFSHORE CATCH OF YELLOW PERCH



OFFSHORE CATCH OF LARGE YELLOW PERCH (> 175 MM)



OFFSHORE CATCH OF SMALL YELLOW PERCH (< 175 MM)

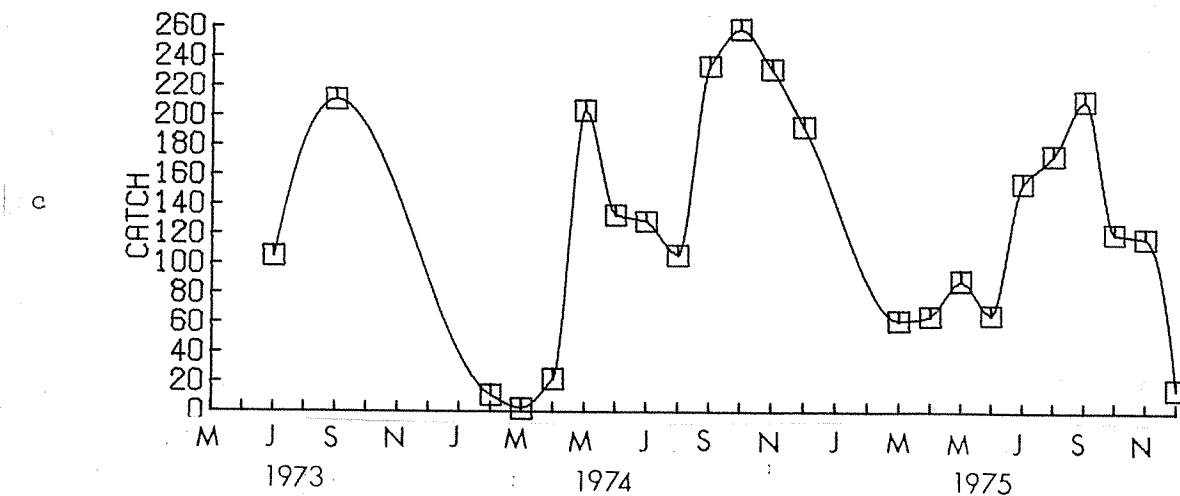


Figure 6.8 The offshore catch represents 16 24-hr gill net sets: 8 on the surface and 8 on the bottom of the water column. This represents the combination of two days consecutive sampling at four transects.

the months when pumping of Roosevelt Lake water into the Transect 1 area was initiated at high rates of flow. Figures 4.4 and 4.5 illustrate the depression in the natural spring-summer water temperature increase at Station 1, relative to the other five stations. The reduction of the water temperatures at Transect 1 appeared to reduce the catch of perch (Table 6.3). However, Fig. 6.9 illustrates that despite the input of cooler FDR water at Station 1 relative to other stations, the temperature did increase seasonally. Therefore, the observed depression in monthly catch cannot be explained by the cooler water temperature. In addition, the literature regarding yellow perch behavior indicated a general preference for lentic (lake) environments. Seldom have yellow perch been found to dominate lotic (river) systems. The additional change at Station 1 after initiation of pumping was an increase in water velocity. Therefore, it was deduced that the yellow perch catch was reduced by a partial avoidance of the area where currents were induced by pumping.

The second phenomenon was the shift in high CPUE from Transect 4 to Transect 1 in 1975. This was probably the result of the combined effect of high lake level and reduced pumping throughout the latter half of the 1975 season, reducing water velocities at Transect 1, thus making the area more suitable for yellow perch. The large decrease in water level during 1973 and 1974 reduced the retention time of water at Transect 1 and resulted in a corresponding increase in the water velocity. Therefore, during years of large drawdown (1973 and 1974) the northern portion of the lake shifted from a lentic to a somewhat lotic environment, and the CPUE of perch declined.

Table 6.3 Yellow perch catch at Station 1, representing one surface and one bottom horizontal variable-mesh gill net set (24 hr).

Month	1974						1975					
	First Day		Second Day		Total		First Day		Second Day		Total	
	#	Δ	#	Δ	#	Δ	#	Δ	#	Δ	#	Δ
3	1		0		1		14		12		26	
4	11	+	14	+	25	+	27	+	20	+	47	+
5	56	+	44	+	100	* -	11*	-	23*	-	34*	-
6	33*	-	20*	-	53*	+	8	-	2	-	10	-
7	29	-	33	+	62	+	74	+	72	+	146	+
8	24	-	45	+	69	+	107	+	104	+	211	+

* Initial month of pumping at Station 1. Note correlation between * and Δ

Number of fish in catch

Δ Direction of change in catch from previous month

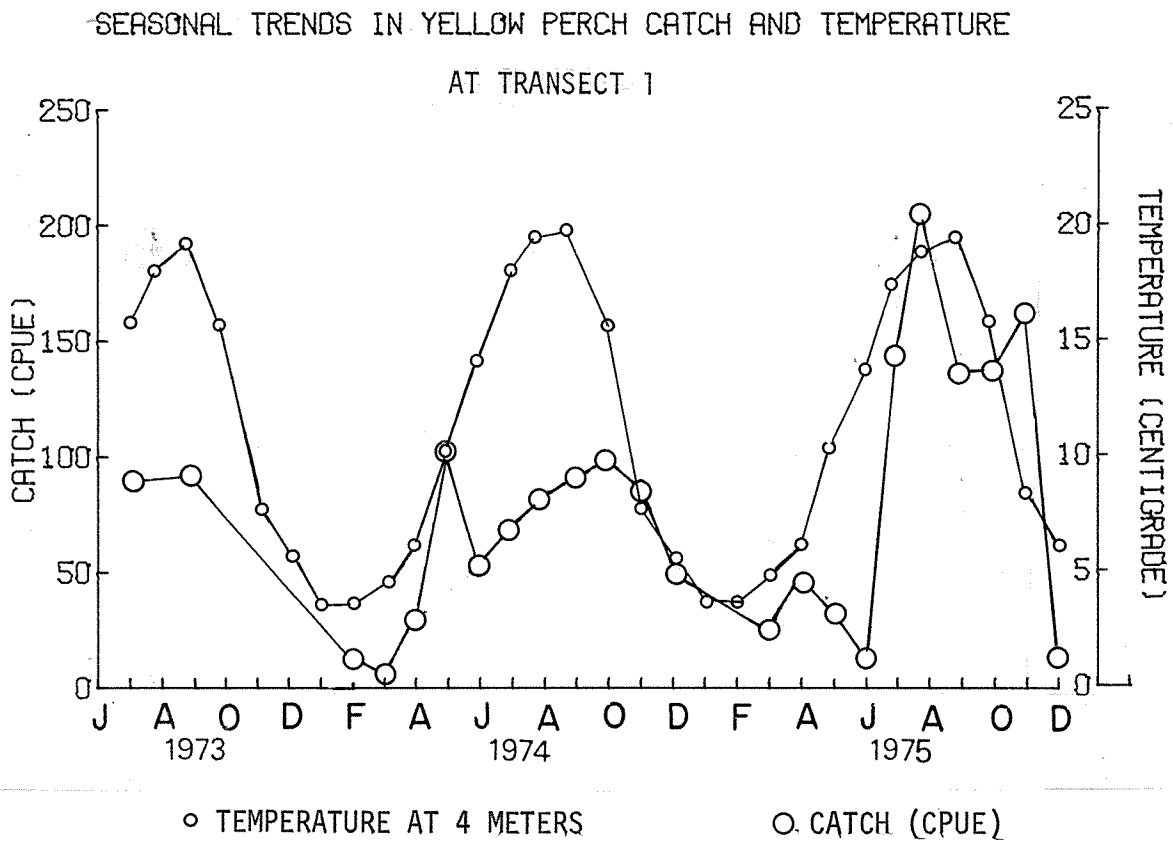


Figure 6.9 Yellow perch catch representing 4 24-hr horizontal variable-mesh gill net sets: 2 at the surface and 2 at the bottom of the water column.

The increased inshore abundance of yellow perch during the spring was due to an inshore spawning movement. However, after the spring spawning season, the summer distribution indicated that large numbers of age 1+ perch remained inshore. The warm inshore water in the summer probably contributed to the continued high CPUE following the spawning season. Abundant food may also have attracted yellow perch inshore. Age 0 perch were densely concentrated inshore during the summer (Table 6.4), and since they comprised a substantial part of the yellow perch diet, may have attracted the age 1+ perch inshore. The offshore movement of yellow perch of all ages occurred in the fall and winter when thermal stratification ended or reversed and the shallow shoreline water lost heat faster than at mid-lake. The greater offshore abundance remained until the following spring when the onshore movement of spawning fish was repeated.

6.3.2.3 Age and Growth. The age analysis of yellow perch was based upon the examination of scales collected from 1973 to 1975 with variable-mesh horizontal gill nets. In addition, samples of age 0 perch were taken by beach seine.

A total of 1006 perch were aged in this study. Seven percent were one year old; 19 percent, two years old; 40 percent, three years old; 28 percent, four years old; 5 percent, five years old; and 1 percent, six years old. Because the gill nets were selective for large fish, the numbers of one- and two-year-old fish were not accurately represented in this analysis. Table 6.5 illustrates the length at age for perch from Banks Lake, Lake Erie, Lake Michigan and Minnesota lakes. In order to

Table 6.4 Monthly catch of age 0 fishes by beach seine in Banks Lake.

Month	Yellow Perch		Lake Whitefish	Pea-mouth	Longnose Sucker	Carp	Black Crappie	Pumpkin-seed Sunfish	Brown Bull-head	Walleye	Rainbow Trout
6/73	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-
2	12,290	0	0	11	2	6	1	3	1	0	1
3	5,576	0	0	54	26	9	13	28	0	0	4
4	63	0	0	3	6	7	74	0	9	0	0
5	1	0	0	0	0	0	0	0	1	0	0
6	3	0	0	0	0	0	8	0	0	0	0
1/74	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-
4	18	2,023	0	0	0	0	0	0	0	0	0
5	263	854	29	29	3	0	0	4	0	0	0
6	18,988	2	1	1	1	1	12	25	0	0	0
7	15,812	0	0	7	8	0	2	3	0	0	0
8	1,779	0	0	39	24	12	34	0	0	1	0
9	30,327	0	0	9	9	30	704	2	1	0	0
10	75	1	1	0	0	0	5	2	1	0	0
11	3	0	0	0	0	0	0	0	0	0	0
12	-	-	-	-	-	-	-	-	-	-	-
1/75	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	14	12	12	0	0	0	0	0	0	0	26
6	12,173	49	49	14	1	0	0	0	0	0	0
7	31,836	0	0	806	1,354	151	0	0	0	0	0
8	886	0	0	2	36	0	0	0	0	0	0
9	23	0	0	0	0	1	0	3	0	0	0
10	4	0	0	0	0	0	0	0	0	0	0
11	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-
Subtotals											
1973	17,933	0	0	68	34	22	96	31	11	0	5
1974	67,265	2,880	2,880	85	45	43	757	36	2	1	0
1975	44,936	61	61	822	1,391	152	0	3	0	0	26
TOTALS	130,134	2,941	2,941	975	1,470	217	853	70	13	1	31

Table 6.4 Monthly catch of age 0 fishes by beach seine in Banks Lake (cont'd.).

Month	Prickly Sculpin		Largemouth Bass	Kokanee Salmon	Large-scale Sucker		Brown Trout	Mountain Whitefish	Northern Squaw-fish		Chinook Salmon	n
	Burbot	Burbot			Sucker	Sucker			fish	fish		
6/73	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	130	0	180	0	0	0	0	0	0	0	0	12,625
9	26	0	124	0	0	0	0	0	0	0	0	5,860
10	126	0	187	0	0	0	0	0	0	0	0	475
11	13	0	0	0	0	0	0	0	0	0	0	15
12	1	0	1	0	0	0	0	0	0	0	0	13
1/74	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	22	0	0	0	0	0	0	0	0	0	0	2,063
5	141	0	16	0	0	0	0	0	0	0	0	1,310
6	644	0	13	0	0	0	0	0	1	0	0	19,688
7	185	0	156	1	0	0	0	0	0	0	0	16,174
8	87	0	122	0	0	0	0	0	0	0	0	2,098
9	75	0	82	0	0	0	0	7	2	0	0	31,248
10	7	0	4	0	0	0	0	0	0	0	0	95
11	3	0	0	0	0	0	0	0	0	0	0	6
12	-	-	-	-	-	-	-	-	-	-	-	-
1/75	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	3	0	0	0	0	0	0	0	0	0	0	3
4	14	0	0	0	0	0	0	0	0	0	0	14
5	96	0	0	0	0	0	0	0	0	0	0	148
6	307	0	0	0	0	0	0	2	0	0	0	12,546
7	451	0	3	1	0	0	0	0	0	0	0	34,602
8	248	0	0	0	0	0	0	0	0	0	0	1,172
9	87	0	3	0	0	0	0	0	0	0	0	117
10	1	0	0	0	0	0	0	0	0	0	0	5
11	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-
Subtotals												
1973	296	0	492	0	0	0	0	0	0	0	0	18,988
1974	1,164	0	393	1	0	0	0	7	3	0	0	72,682
1975	1,207	0	6	1	0	0	0	2	0	0	0	48,607
TOTALS	2,667	0	891	2	0	0	0	9	3	0	0	140,277

Table 6.5 Yellow perch length at age in millimeters for Banks Lake and other waters [*Jobes (1952); **Van Oosten (1948); ***Smith and Moe (1944)].

Location	Age							
	1	2	3	4	5	6	7	8
Banks Lake, Washington								
Median ^{/1} total length	146 ^{/2}	160	210	235	249	216	-	-
(n)	(71)	(193)	(402)	(282)	(54)	(4)	(0)	(0)
Δ Growth between annuli	+146 ^{/2}	+26	+50	+25	+14	-33	-	-
Median total length - ♂	150 ^{/2}	155	182	196	222	-	-	-
(n)	(14)	(55)	(87)	(39)	(5)	(0)	(0)	(0)
Δ Growth between annuli	+150 ^{/2}	+5	+27	+14	+26	-	-	-
Median total length - ♀	157 ^{/2}	171	214	238	253	216	-	-
(n)	(35)	(120)	(307)	(236)	(49)	(4)	(0)	(0)
Δ Growth between annuli	+157 ^{/2}	+14	+43	+24	+15	-37	-	-
Lake Erie *								
Mean total length	94	170	216	241	264	279	-	-
(n)	-	-	-	-	-	-	(0)	(0)
Δ Growth between annuli	+94	+76	+46	+25	+23	+15	-	-
Lake Michigan **								
Mean total length	71	114	152	180	216	246	-	-
(n)	-	-	-	-	-	-	(0)	(0)
Δ Growth between annuli	+71	+43	+38	+28	+36	+30	-	-
Minnesota ***								
Mean total length	61	114	160	196	234	244	264	276
(n)	-	-	-	-	-	-	-	-
Δ Growth between annuli	+61	+53	+46	+36	+38	+10	+20	+12

^{/1} Median values given instead of means, due to high variability inherent in scale aging techniques.

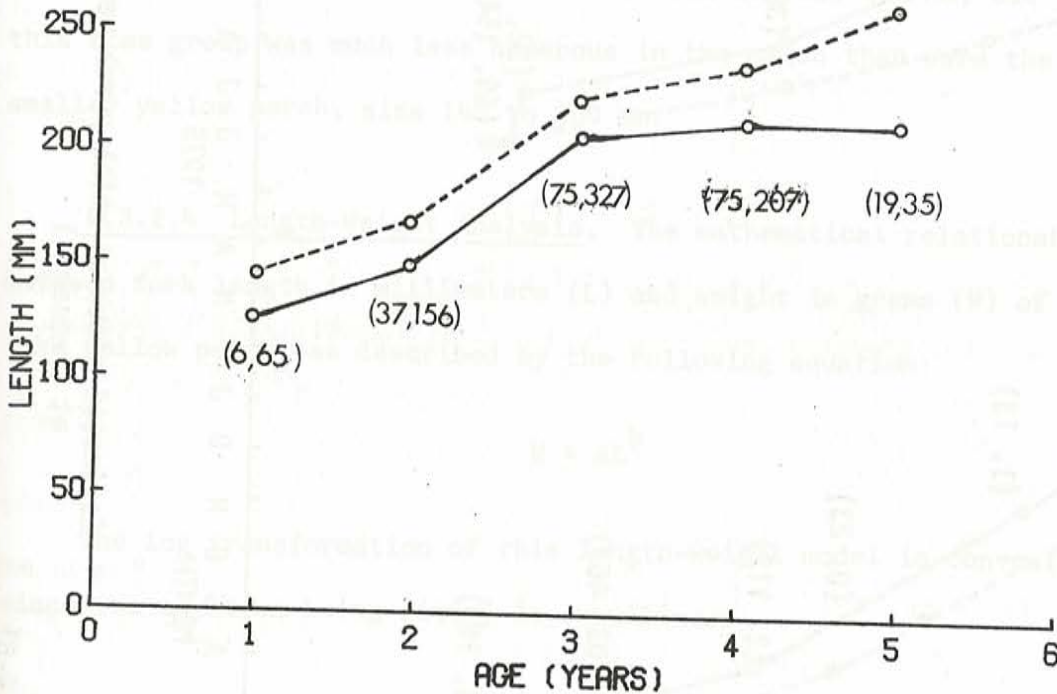
^{/2} The length of age 1 yellow perch was overestimated because the gill nets were selective for large fish of this age group.

make growth comparisons, the fork length of Banks Lake perch was converted to total length using the correction factor, Total Length = 1.053 Fork Length (Parsons 1950). Although the literature did not report age composition, the age range was similar to that of Banks Lake perch. Table 6.5 shows that Banks Lake yellow perch exhibited an excellent rate of growth through age 5. Only four fish in the samples reached age 6.

The direct calculated growth increment for perch was highest the first year and decreased with age thereafter (Table 6.5). The age composition and growth of male and female perch was found to be quite different. First, the oldest male perch caught were age 3. Second, the median length at age 2 and 3 was shorter for male perch (Table 6.5).

The length-at-age for perch was compared between transects. Perch at Transect 1 appeared to have shorter lengths at all ages than did the perch caught at Transects 4 through 6 (Fig. 6.10). Since age analysis displayed large variability with length, median total lengths were used to represent length at age. Length of age 0 perch captured in monthly beach seine samples was also examined for differences in growth. Since yellow perch normally grew faster in the first year of life (Table 6.5), a comparison of length at age 0 between transects was the most sensitive test for differential growth rate. Figure 6.11 compares the median length of age 0 fish captured in monthly beach seine hauls in 1973-75 at Transect 1 and Transects 4 through 6 combined. The median length in later months was consistently longer at Transects 4, 5 and 6 than at Transect 1, despite nearly equal lengths at first capture in June of 1974 and 1975. This indicated the difference in lengths was not due to a difference in time of spawning or emergence but to difference in growth conditions.

LENGTH AT AGE FOR YELLOW PERCH



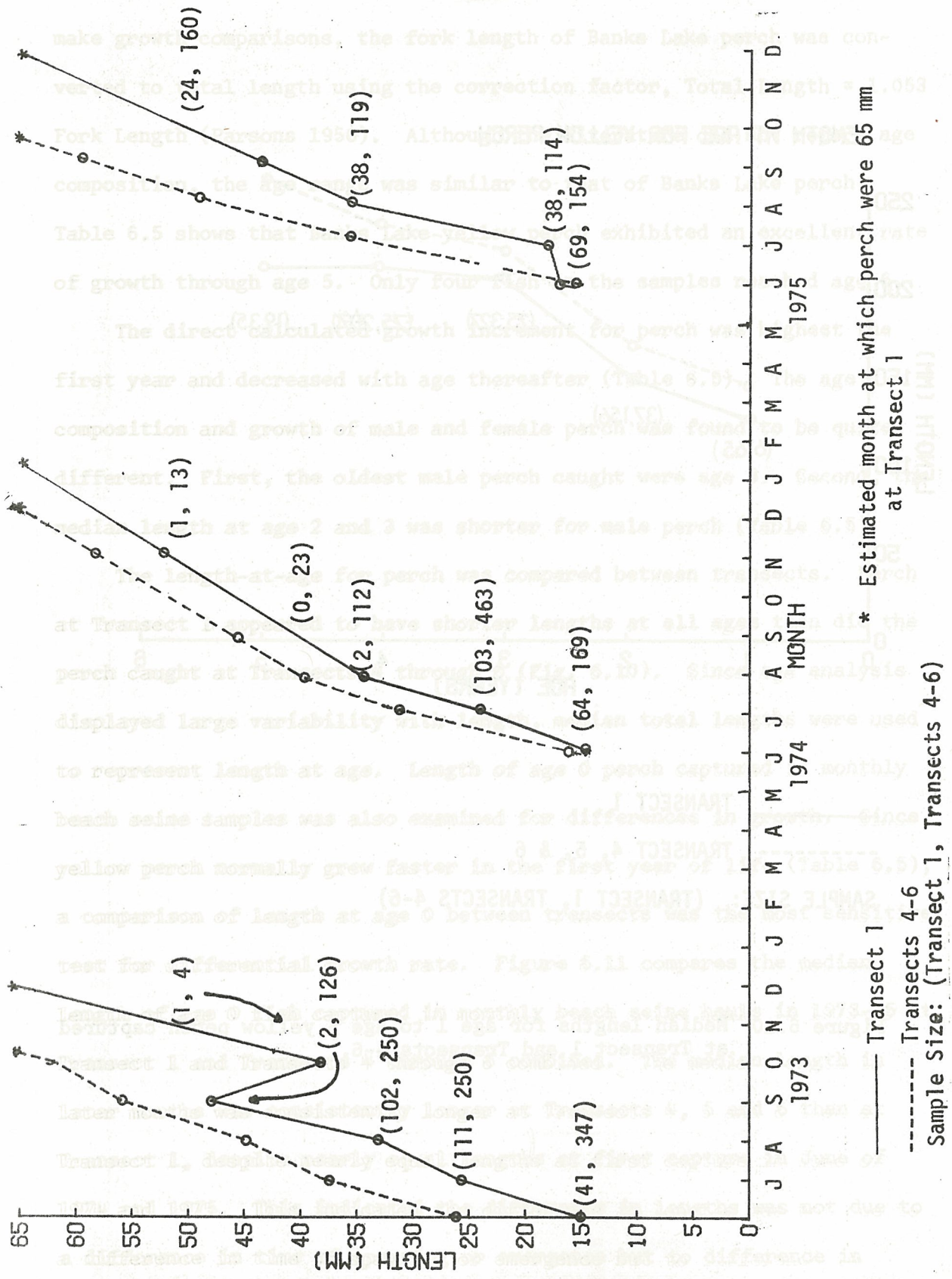
———— TRANSECT 1

----- TRANSECT 4, 5, & 6

SAMPLE SIZE: (TRANSECT 1, TRANSECTS 4-6)

Figure 6.10 Median lengths for age 1 to age 5 yellow perch captured at Transect 1 and Transects 4-6.

LENGTH OF AGE 0 YELLOW PERCH (MEDIAN)



* Estimated month at which perch were 65 mm at Transect 1

— Transect 1
 - - - Transects 4-6
 Sample Size: (Transect 1, Transects 4-6)

Figure 6.11 Median lengths for age 0 yellow perch captured in the monthly beach seining at Transect 1 and Transects 4-6.

A comparison of length frequencies between years shows a changing predominance from large to small sizes between 1973 and 1975 (Fig. 6.12). In 1973, the frequency mode occurred between 210 and 240 mm, but in 1975 this size group was much less numerous in the catch than were the smaller yellow perch, size 140 to 200 mm.

6.3.2.4 Length-Weight Analysis. The mathematical relationship between fork length in millimeters (L) and weight in grams (W) of Banks Lake yellow perch was described by the following equation:

$$W = aL^b \quad (1)$$

The log transformation of this length-weight model is convenient since the equation being fitted is curvilinear:

$$\text{Log}_{10}(W) = \text{Log}_{10}a + (b)\text{Log}_{10}(L) \quad (2)$$

which has the linear equivalent of

$$Y = a + b(X) \quad (3)$$

and allows calculation of the length-weight equation by linear regression.

Many variables affect the length-weight relationship of a particular fish species, such as sex, maturity and season. It was necessary to select fish captured over a short time interval to test for differences between sexes. September was selected because a large sample was available. It also corresponded with the end of the growing season, and was six months from the peak spawning month (April), which allowed for the least difference in length-weight relationships due to sex.

FORK LENGTHS OF YELLOW PERCH

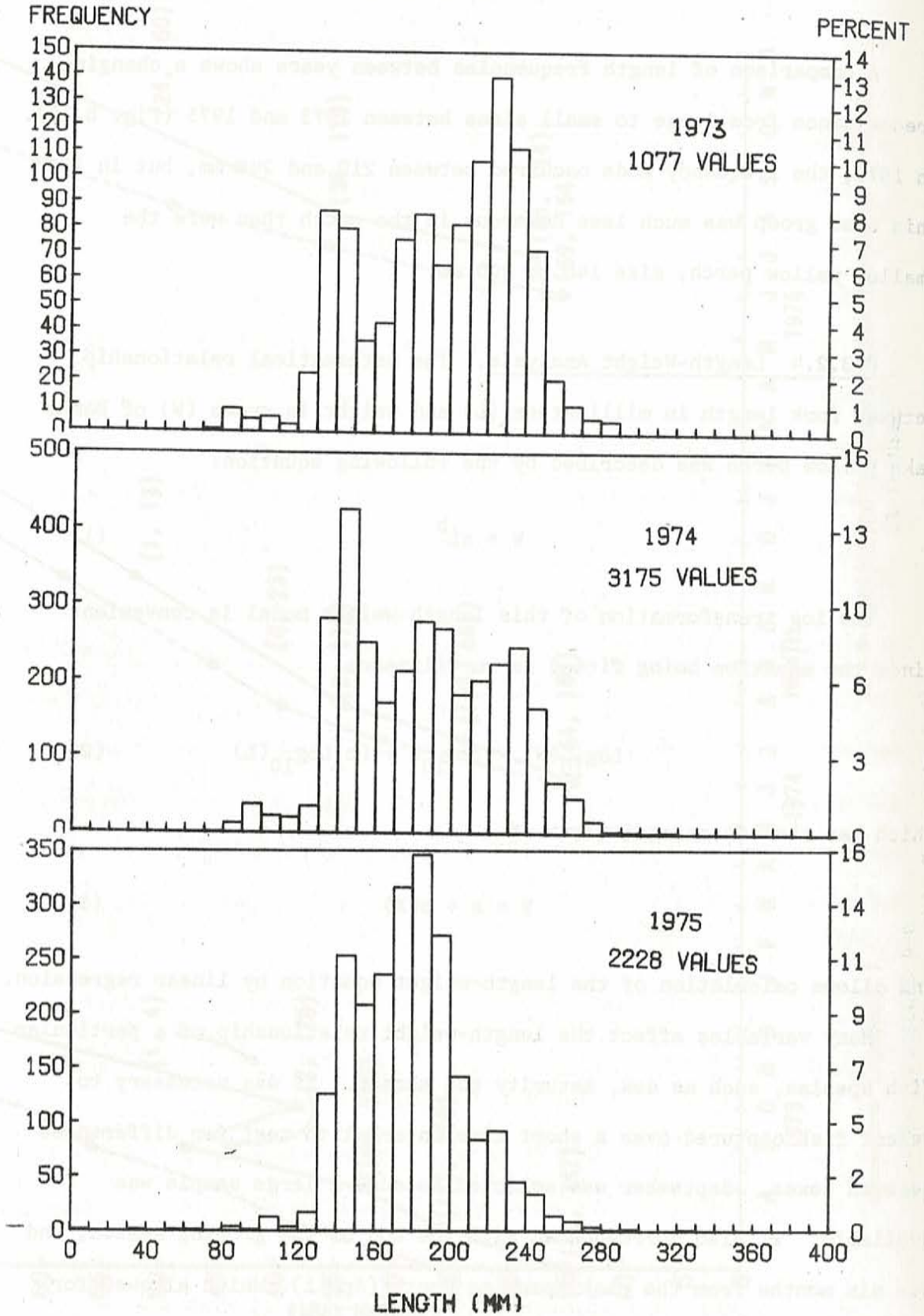


Figure 6.12 Comparison of yellow perch length frequency histograms for 1973, 1974, and 1975.

The length-weight relationships for perch captured at Transects 1 through 6 for 1973 and 1974 are presented below in logarithmic form:

1973

September--all transects combined-- $y = -4.5266 + 2.8476X$; $N = 359$; $r^2 = .99$

Transect 1 $y = -3.7826 + 2.3442X$; $N = 19$; $r^2 = .97$

Transect 4 $y = -4.2526 + 2.7640X$; $N = 134$; $r^2 = .99$

Transect 5 $y = -4.4731 + 2.8495X$; $N = 24$; $r^2 = .98$

Transect 6 $y = -4.5172 + 2.8694X$; $N = 182$; $r^2 = .99$

1974

September--all transects combined-- $y = -4.8176 + 2.9916X$; $N = 557$; $r^2 = .99$

Transect 1 $y = -4.7327 + 2.9474X$; $N = 97$; $r^2 = .99$

Transect 4 $y = -4.7510 + 2.9656X$; $N = 114$; $r^2 = .99$

Transect 6 $y = -4.8413 + 3.0029X$; $N = 131$; $r^2 = .99$

The length-weight relationships for total sample are presented graphically in Fig. 6.13.

The value of $b = 3$ indicates isometric growth which is described by the equation

$$W = aL^3 \quad (4)$$

When $b < 3$, the fish is lighter for its length, and when $b > 3$, the fish is heavier for its length. The regression results suggested that perch in 1974 were heavier for their length than the 1973 perch, and that the perch at Transect 1 were lighter for their length than the perch at Transects 4 through 6 for both years. Confirmation of these trends remains to be tested by covariance analysis.

LENGTH WEIGHT-RELATIONSHIP FOR YELLOW PERCH

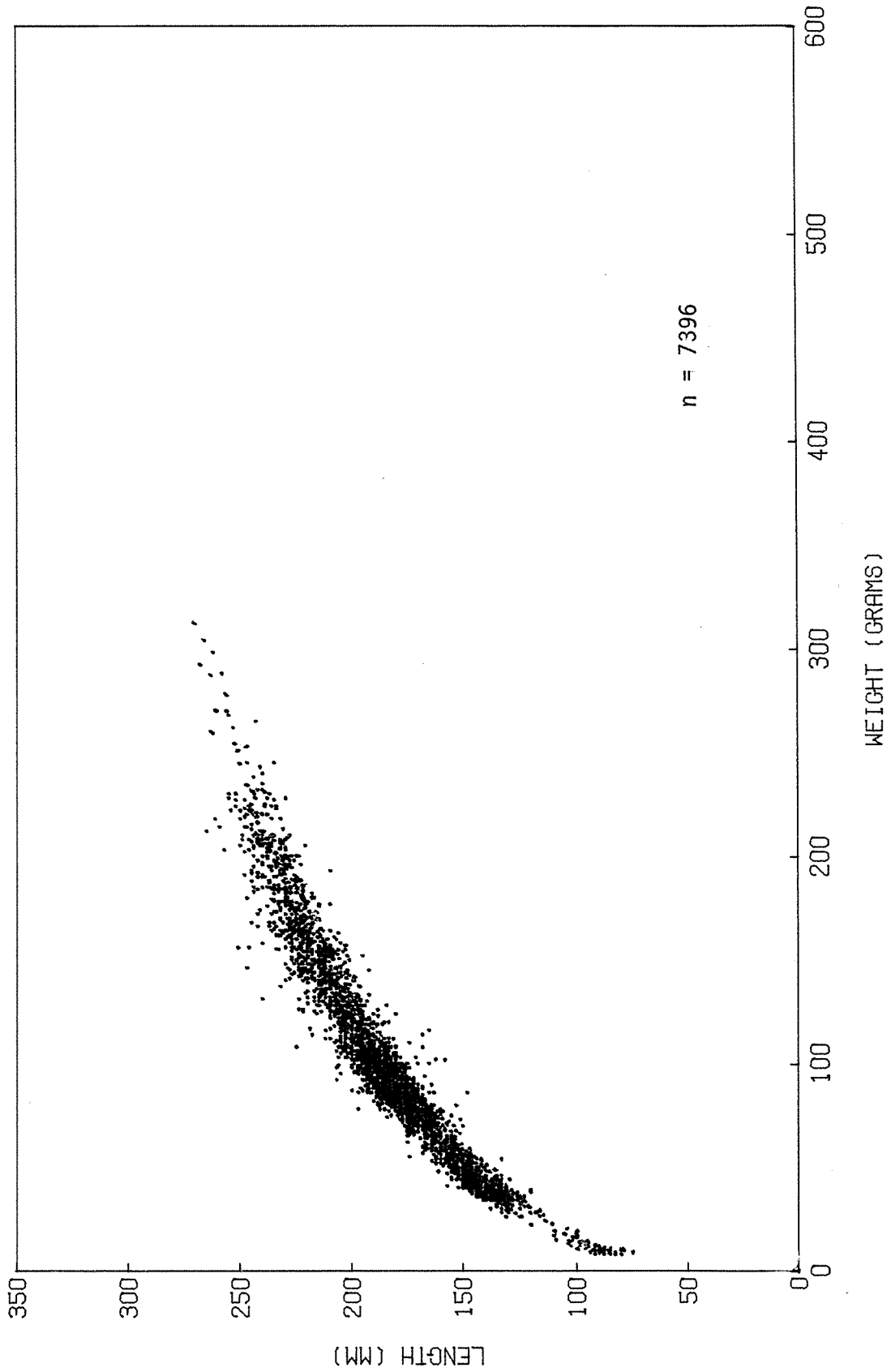


Figure 6.13 Scattergram of length-weight relationships for yellow perch captured in September 1973-1975.

6.3.2.5 Food Habits. The stomachs of 5,996 yellow perch were inspected in fresh condition for the presence of food, fullness, and the type of food consumed. These visual inspections were not meant to be comprehensive but to give a general idea of the perch food habits.

Five types of food were observed in perch stomachs: zooplankton, fish, flying insects, benthos, and unidentifiable animal debris. Zooplankton was the most frequent food item found in the perch stomachs (Fig. 6.14). Rarely, fish became equivalent in occurrence to zooplankton in perch stomachs. Since zooplankton was of such importance to the diet of gillnet-caught yellow perch, 283 stomach samples containing zooplankton were collected from 1973 to 1975 and preserved in Formalin for a more comprehensive analysis of food habits. Approximately 97 percent of the zooplankters present were identified to belong to one cladoceran genus, *Daphnia*. In addition, stomachs of 160 age 0 perch caught by beach seine (preserved in 10% Formalin) were examined for species composition. Zooplankton was again the most frequent food observed. However, for the first two months, May and June, the yellow perch fed heavily upon the pelagic copepod *Diaptomus* as well as *Daphnia*. After June, *Daphnia* was the exclusive food item.

Fish was the second most frequent food item observed in perch stomachs. Eighty-nine percent of the identifiable fish were prickly sculpins and the remaining 11 percent were age 0 yellow perch. Insects (damselflies and chironomids) and benthos (snails and crayfish) were observed occasionally in perch stomachs.

Due to regurgitation and digestion of stomach contents during capture, the absence of food in stomachs and the percentage of emptiness

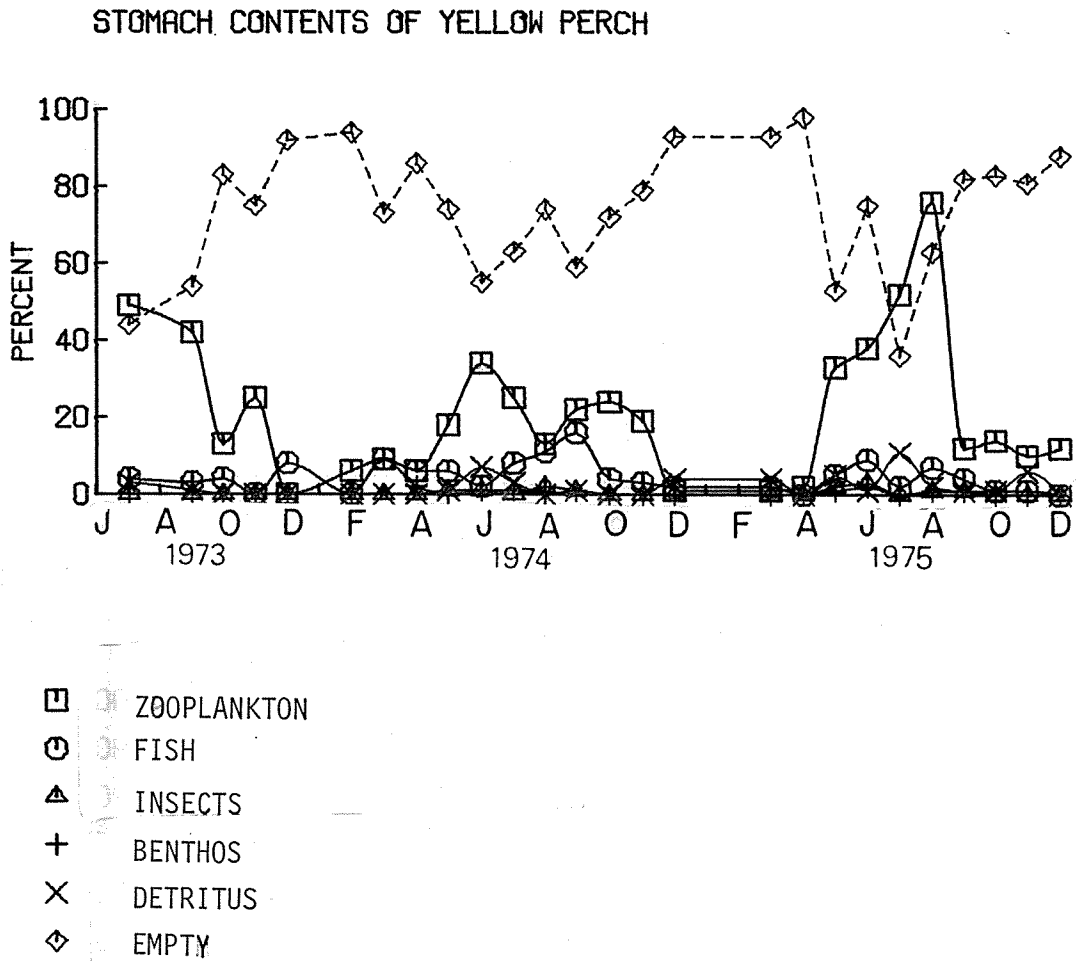


Figure 6.14 The stomach contents of yellow perch. The vertical axis represents the percent of the yellow perch stomachs containing a specific food category. Dashed line represents percent of stomachs which were empty. The yellow perch were caught in gill nets between July 1973 and December 1975.

(Fig. 6.14) were overestimated. For this reason, the fullness indices were disregarded.

6.3.2.6 Reproduction. Yellow perch spawn along the shoreline of Banks Lake over rocky and mud substrate in the early spring (March-April) when water temperatures range from 7 to 10 C. Yellow perch are unique among the freshwater fish in that they spawn their eggs in long gelatinous strands which are translucent, semibuoyant, and non-adhesive, on a variety of substrates (rock and mud). Egg masses were most common inshore but some were recovered in gill nets in over 20 m of water. Larval yellow perch were first taken in large numbers in the beach seine in June, one month after peak spawning was observed. This indicated an incubation of less than four weeks. From May through September large schools of juvenile yellow perch were observed along shallow beaches and were captured by beach seines (Fig. 6.5). The adults, after spawning, increased their feeding activity, and by mid-summer their gonads began to develop in preparation for the next spawning season. The CPUE of mature and spawning fish in the offshore and inshore gill net catch was determined for each sampling period (Fig. 6.15). Male perch were captured abundantly along the shoreline during spring. Some matured at age 1 and most matured by age 2. Perch of both sexes reached maturity by the third year.

6.3.2.7 Irrigation Effects on Perch. The horizontal separation of the lake into two limnologically distinct water masses (north and south pools) during the growing season was due to irrigation pumping into the north end. The north pool included the area from North Dam to the

INSHORE AND OFFSHORE SPAWNING YELLOW PERCH

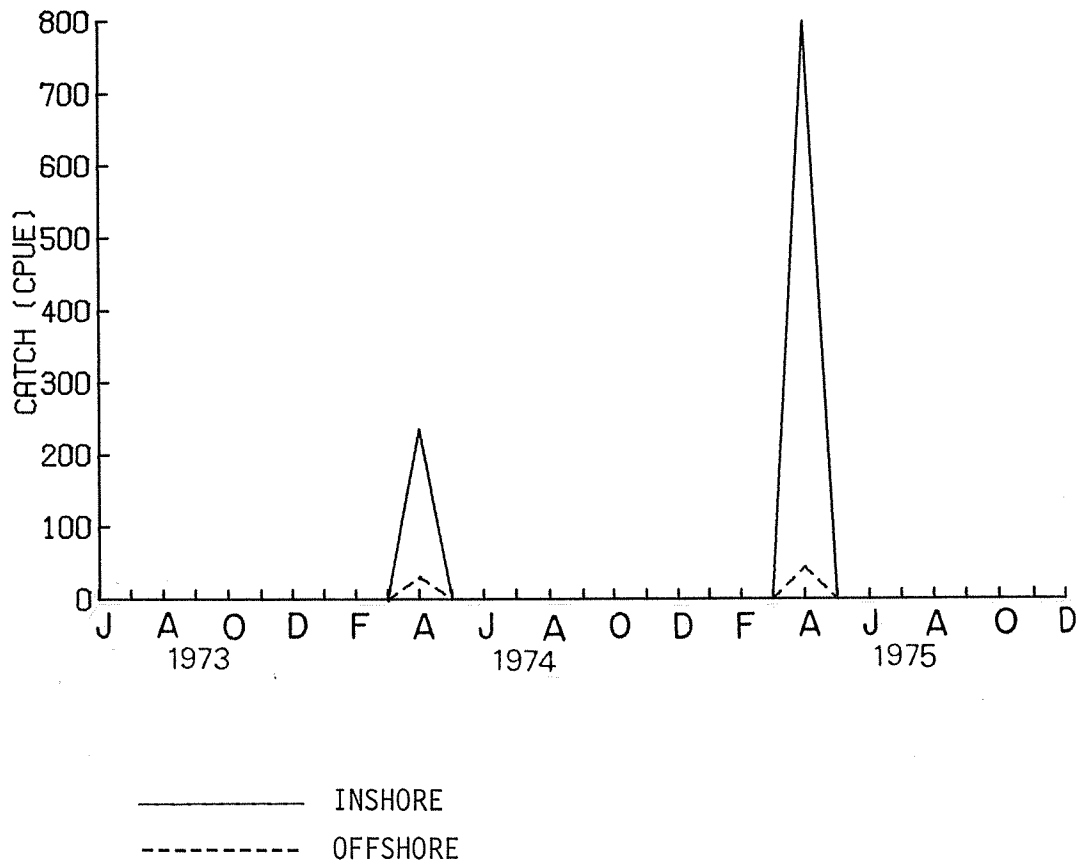


Figure 6.15 Number of spawning yellow perch captured inshore and offshore by month.

Narrows including Transect 1. The south pool ranged from the Narrows to South Dam and included Transects 4, 5 and 6. The major differences affecting the fishes between the north and south pool environments were reduced water temperature, lower food supply, and higher water velocity in the north pool than in the south pool. The major response of yellow perch to these different conditions was a partial avoidance or reduced activity in the north pool. Those perch which remained in the north pool showed a reduced rate of growth and condition.

The large drawdown in 1973 and 1974 reduced the lake volume by one-half, but the amount of shoreline habitat increased, due to the relatively flat bottom configuration of the lake basin. The recruitment of juvenile yellow perch apparently was enhanced.

The volume at full pool (478.5 m; 1,570 ft) and perimeter of the lake were 148,269 ha m (1,202,000 acre-ft) and 131.5 km (81.7 miles), respectively, whereas at a drawdown of -9 m (30 ft) the volume and perimeter were 62,416 ha m (506,000 acre-ft) and 155.9 km (96.8 miles), respectively (Table 4.1). Therefore, the percentage reduction of volume at -9 m (-30 ft) was about 58%, whereas the percentage of shoreline increased by about 24%. The number of recruits appeared to increase each fall possibly as a result of an increased amount of shoreline rearing habitat.

The magnitude of the drawdown has to be closely evaluated with the time interval over which it occurs. If drawdown occurs during or following the spawning season of a fish species it can result in a detrimental effect on reproduction due to egg stranding and/or habitat loss. Stranding apparently occurred during and following the yellow

perch spawning season since irrigation drafting reduced the water level during March, April, and May each year. A multi-diagrammatic scheme of the spawning and incubation seasons, the observed seasonal water level fluctuation and the depth distribution of spawning for yellow perch is presented in Fig. 6.16. These diagrams enable an analysis of possible effects of maximum and minimum water level fluctuation on the yellow perch spawning and incubation habitat. The yellow perch spawned from March to May with a peak in April each year. Spawning occurred during a declining water level which may have reduced available spawning area or stranded previously spawned eggs. In order to estimate habitat loss and potential stranding a one-month interval centered on the incubation period was used. This assumes that once spawning had been completed the incubating eggs were vulnerable to stranding or exposure as the water level continued to decline. The incubation period lasted one month. This time period was determined by the appearance of fry in the beach seine catches. A 3 to 4 week incubation period was reported by Coots (1965) for yellow perch lakes in California. Even though California lakes are at a lower latitude, temperature regimes were approximately similar to Banks Lake. Use of the incubation period does not provide an estimate of the maximum effect since it accounts for neither the decrease in spawning habitat prior to initiation of incubation nor does it include the worst case which affects the latest incubating eggs. The onset and completion of incubation were then superimposed on the water level regimes observed during the study years (Fig. 6.16). To estimate

HYPOTHETICAL MODEL ILLUSTRATING THE EFFECT OF WATER LEVEL FLUCTUATION ON THE INCUBATION HABITAT OF YELLOW PERCH.

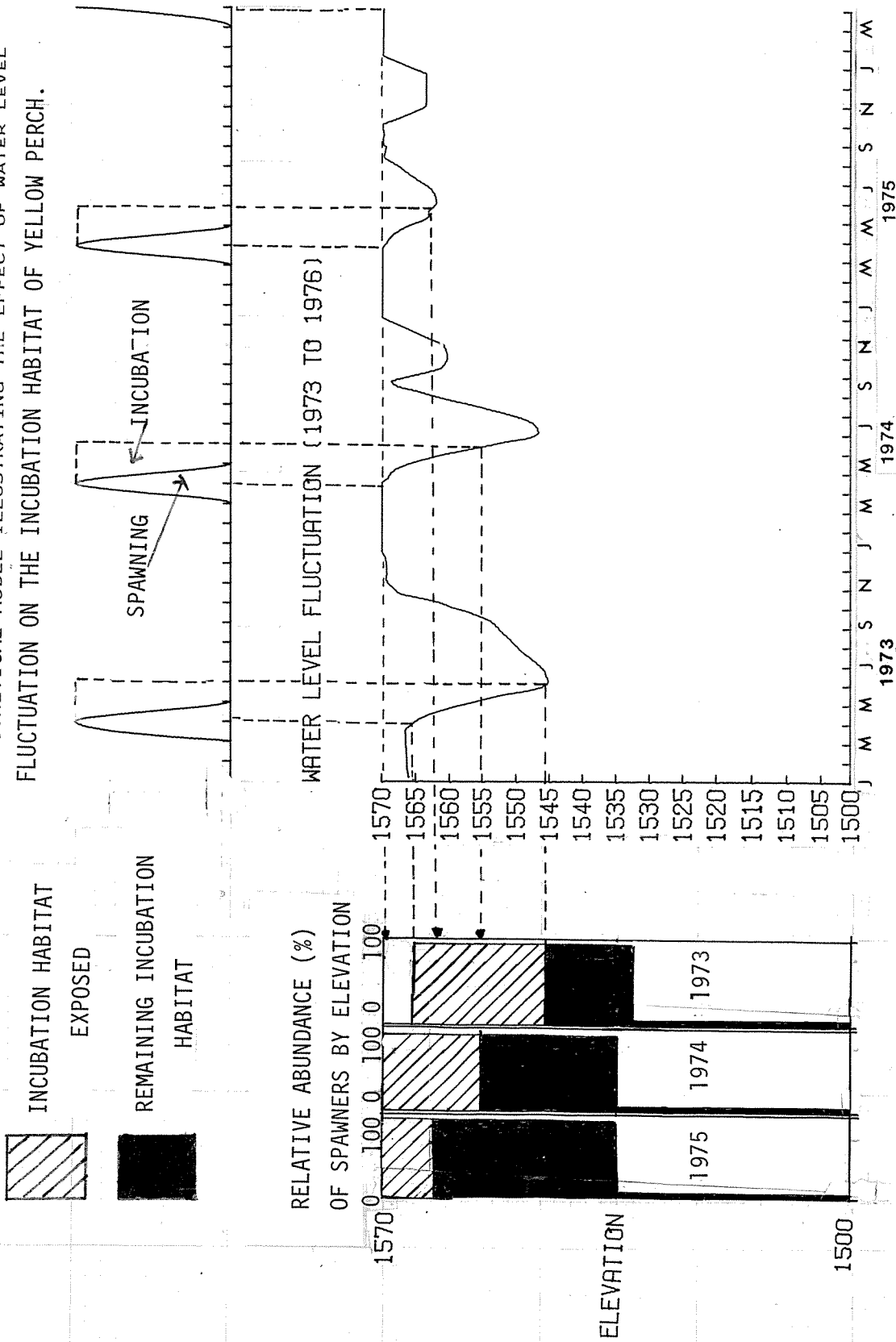


Figure 6.16 Observed spawning and estimated incubation seasons (1973-75) of yellow perch superimposed over the water level regimes of these years, and projected to the histogram of estimated spawning depths, illustrating the proportion of incubation habitat exposed by lake level fluctuation.

the effect on incubation habitat, horizontal lines were projected for each year to the left from the water level graph onto a final graph which shows the distribution of spawners in inshore and offshore areas and the portion of the inshore area which was exposed during drawdown (crosshatched). In this graph the relative abundance of spawners by elevation has been adjusted to account for the differential areas designated as "inshore" and "offshore." While this treatment of the data infers that varying losses of incubating eggs occurred in 1973, 1974, and 1975, no estimates of loss are presented because the actual distribution of spawning was not determined. The areas exposed were relatively large in 1973 and 1974 and small in 1975. During the study period a decline in the abundance of larger perch occurred with an increase in the number of smaller individuals. The actual mechanisms affecting the perch population remain to be determined.

6.3.3 Lake Whitefish, *Coregonis clupeaformis*

6.3.3.1 Importance. The lake whitefish is the largest coregonid indigenous to Washington State. Its desirability among commercial fisheries led to introduction into many southern Canadian and northern U.S. waters. The lake whitefish, even when abundant, does not support a fishery due to its unwillingness to take a hook.

Lake whitefish were not artificially stocked into Banks Lake. Lake whitefish were recorded by Earnest and Spence (1965, unpublished) in

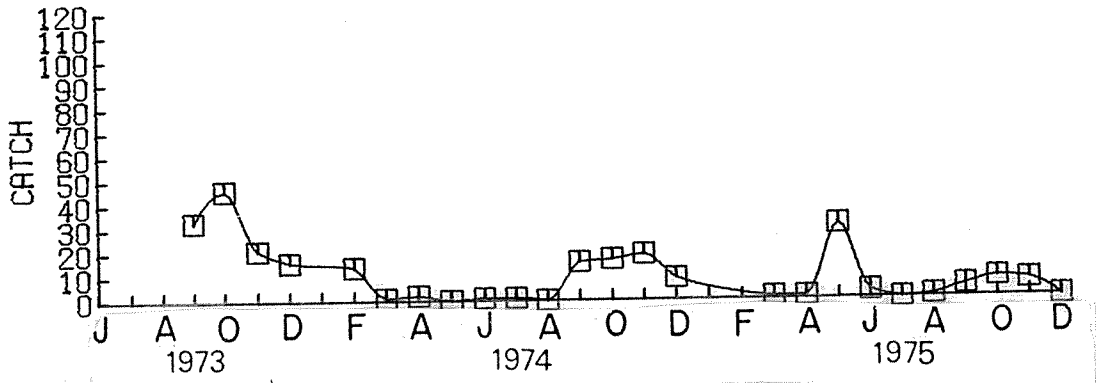
Lake Roosevelt. Introduction into Banks Lake has apparently been through the feeder canal. The first record of lake whitefish from Banks Lake was in a 1965 creel survey by Merrill Spence (cited from Duff 1973). During the years 1968 to 1970 the lake whitefish population suffered large winter dieoffs (Duff, personal communication), and their ability to recover as a dominant species in the lake was questioned. However, the lake whitefish population has successfully sustained itself despite these apparently large natural mortalities and now appears to be one of the three most numerous species in Banks Lake.

The lake whitefish is unique among freshwater fish since it has a pelagic larval stage. Except during this early life history stage, the lake whitefish in Banks Lake appear to have few predators. There is an abundance of suitable shoreline for spawning, allowing successful reproduction in most years.

6.3.3.2 Distribution. Vertical distribution of lake whitefish in the water column was determined from monthly offshore surface and bottom horizontal gill net catches (Fig. 6.17). Surface net catches of lake whitefish were low and bottom net catches were relatively high during the summer. Lake whitefish were caught throughout the water column by vertical nets during the fall, winter and spring.

The horizontal distribution among transects was determined by comparing the catch totals from each transect for two consecutive days

SURFACE CATCH OF LAKE WHITEFISH



BOTTOM CATCH OF LAKE WHITEFISH

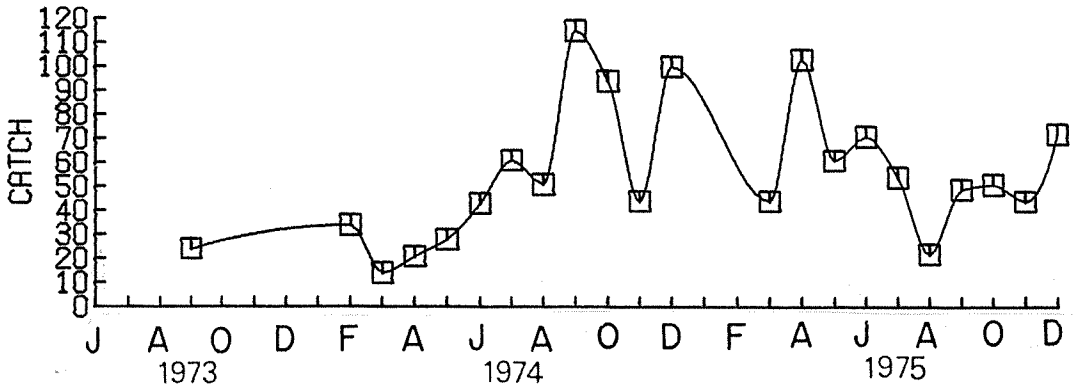


Figure 6.17 Vertical distribution of lake whitefish offshore. Each point represents 8 24-hr horizontal variable-mesh gill net sets. Four sets were made at each of the 4 transects monthly: 2 on the surface and 2 on the bottom of the water column.

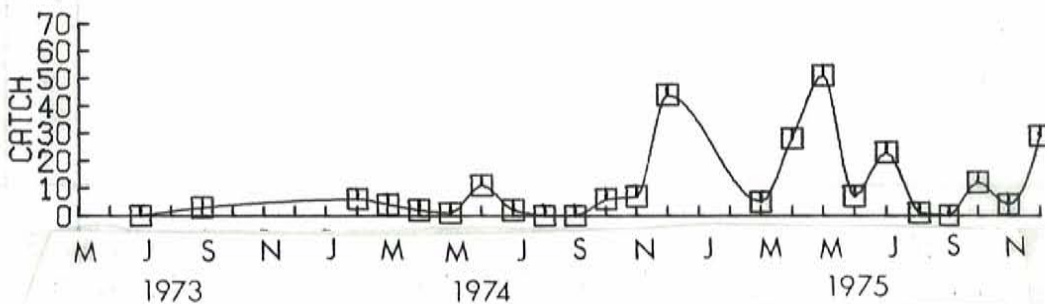
of sampling offshore with surface and bottom horizontal gill nets (Fig. 6.18). The offshore catches in 1973 were low at Transects 4, 5 and 6 and 0 at Transect 1. In 1974 the catches increased at Transects 4, 5 and 6, and remained near zero at Transect 1 until November. In 1975 high catches were made at all four transects.

The offshore catches of lake whitefish indicated that a large year class (year of emergence) was recruited in the fall of 1974. Prior to fall 1974, only large whitefish (> 350 mm) were taken, indicating a limited recruitment during the previous two years, 1971-72 and 1972-73.

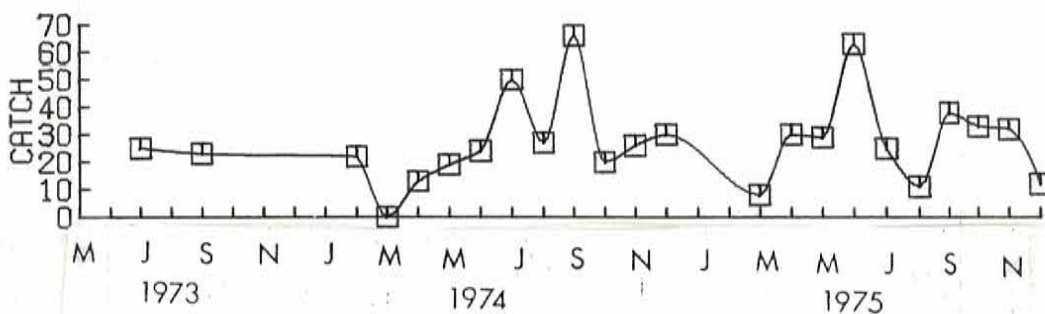
The catches of larvae and juvenile lake whitefish by tow-netting and beach seining, respectively, indicated generally that the larvae occur pelagially during March and April and then move shoreward into the littoral zone in May and June. Opposing trends in north-south abundance were observed. The pelagic larvae occurred in greatest number at the south end of Banks Lake (Table 6.6); while the littoral stage occurred in greatest numbers at the north end (Fig. 6.19).

Inshore-offshore distributions of lake whitefish age ≥ 1 were determined from the total quarterly gill net catch during 1974 and 1975, (Figs. 6.20 and 6.21, respectively). Trends in inshore-offshore distributions were tested in the same manner as for yellow perch. During winter, the inshore catches were exclusively of lake whitefish age ≥ 3 . During the spring, distribution of age groups was similar in the inshore and offshore catches. During the summer and fall, all age groups were captured in significantly greater numbers in offshore gill net sets than in inshore sets.

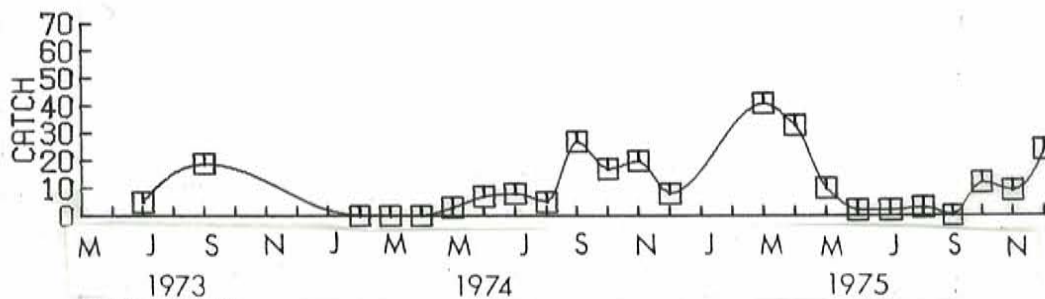
OFFSHORE CATCH OF LAKE WHITEFISH BY STATION STATION 1



STATION 4



STATION 5



STATION 6

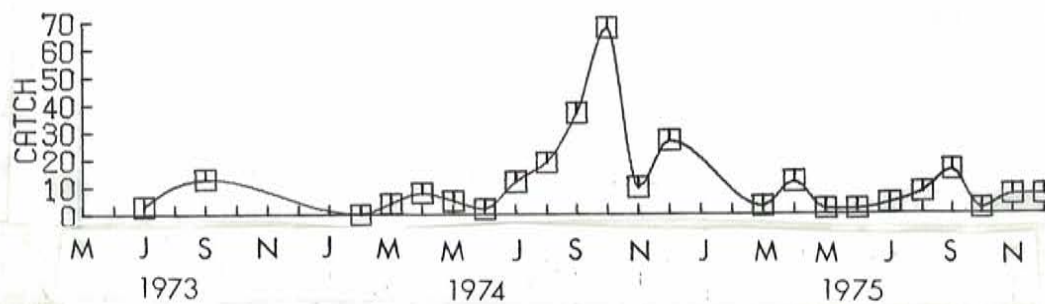


Figure 6.18 Horizontal distribution of lake whitefish. Each point represents 4 24-hr horizontal variable-mesh gill net sets: 2 at the bottom and 2 at the surface of the water column.

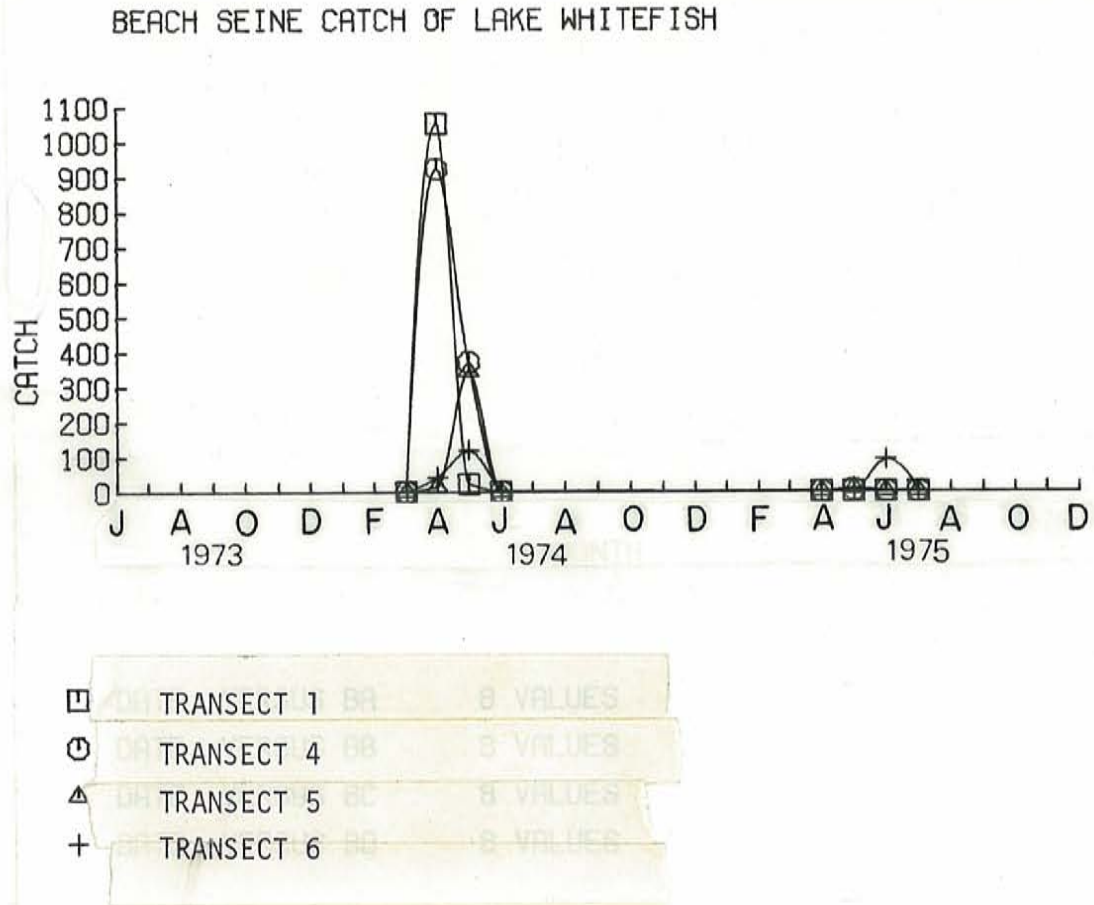


Figure 6.19 Beach seine catch of lake whitefish from July 1973 to December 1975.

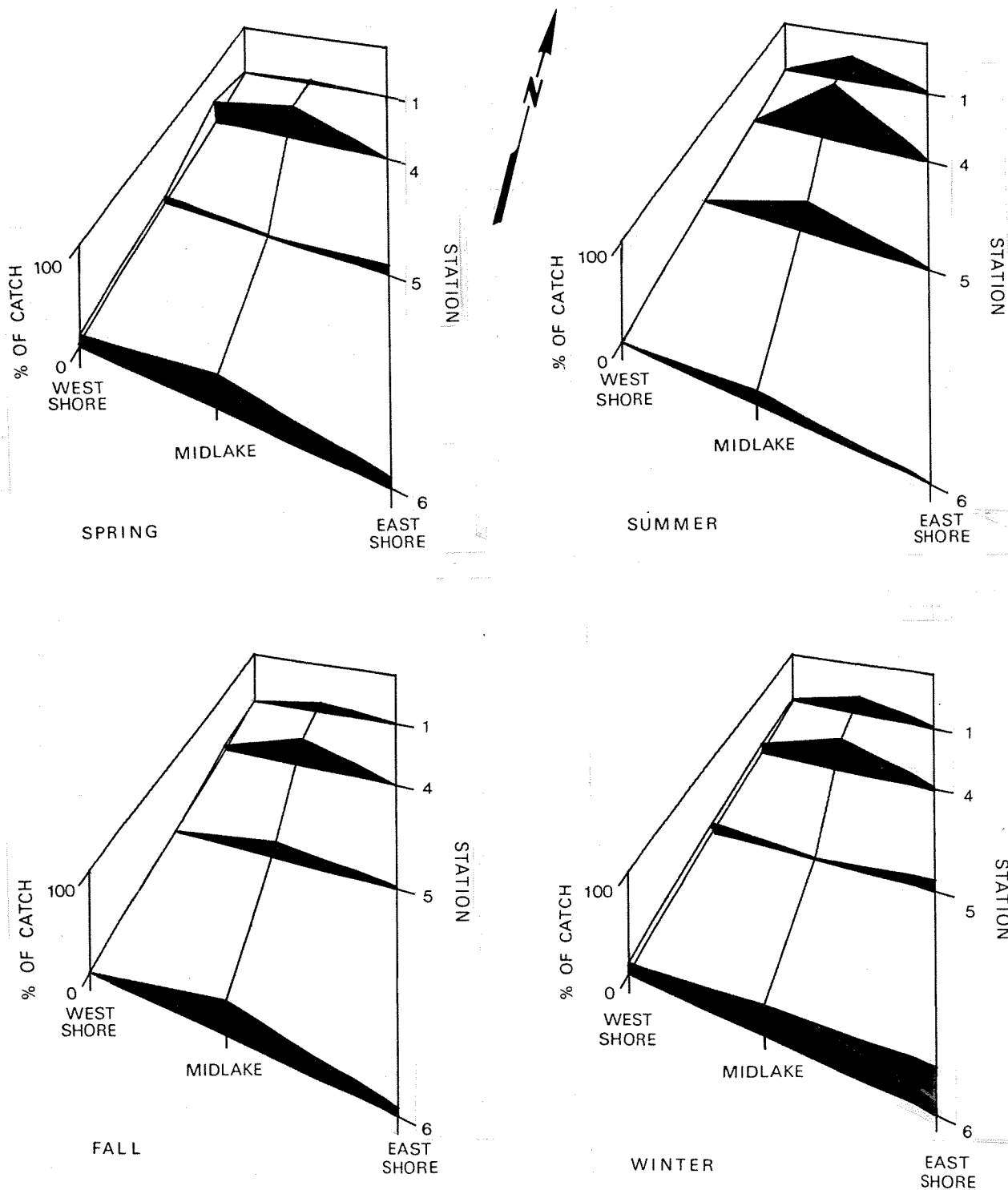


Figure 6.20 The inshore/offshore distributions of lake whitefish for the spring, summer, fall and winter seasons of 1974. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1(Electric City), 4(Steamboat Rock), 5(Million Dollar Mile), and 6(Coulee City).

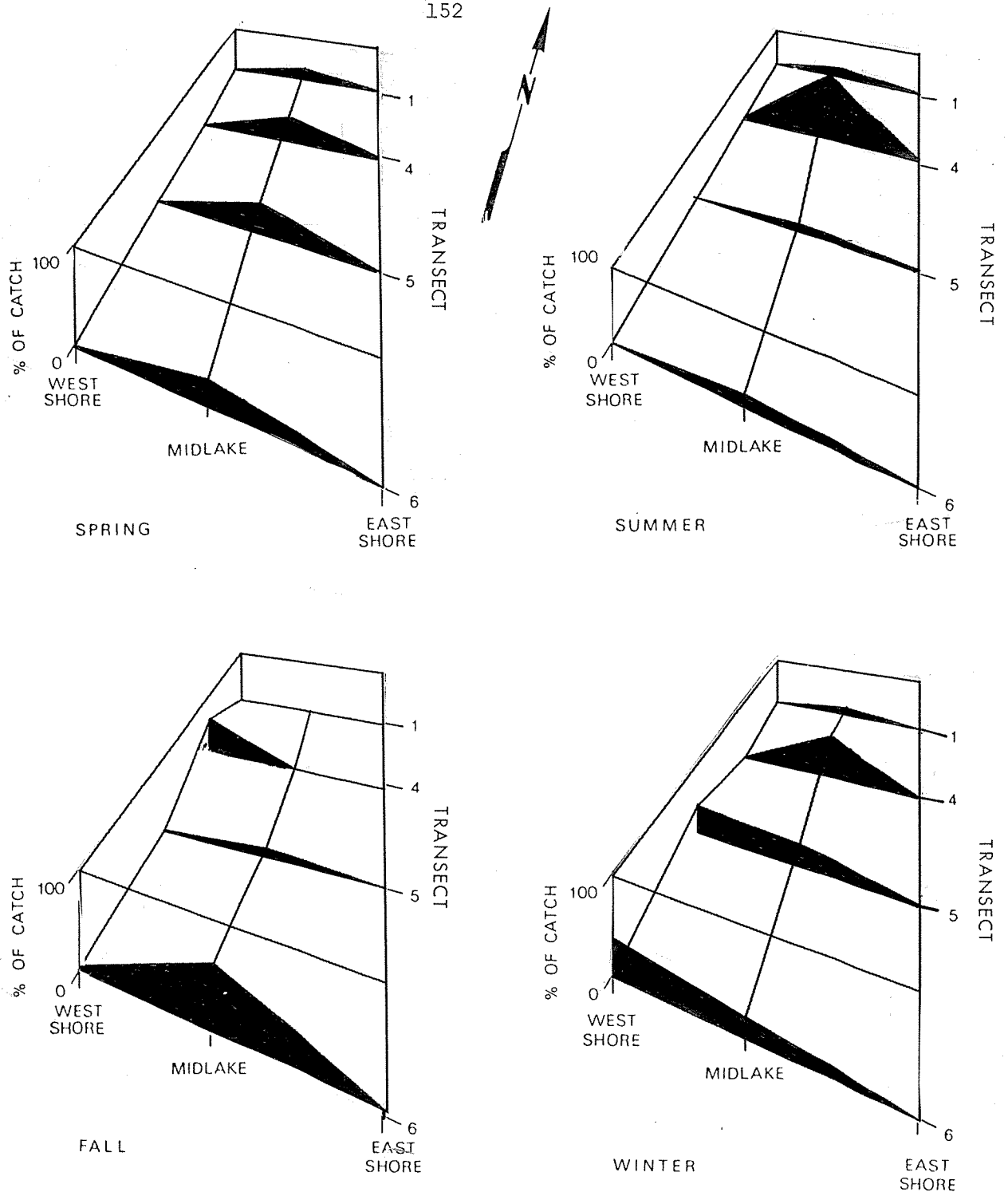


Figure 6.21 The inshore/offshore distributions of lake whitefish for the spring, summer, fall and winter seasons of 1975. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1(Electric City), 4(Steamboat Rock), 5(Million Dollar Mile), and 6(Coulee City).

The offshore CPUE of lake whitefish is illustrated in Fig. 6.22a. Low CPUE was observed in 1973 followed by increased CPUE in 1974 and decreasing CPUE in 1975. The low CPUE in 1973 was composed entirely of adult lake whitefish. The increasing catch in 1974 was due to recruitment of the 1974 year class (Fig. 6.22c).

The lake whitefish CPUE was closely related to temperature and recruitment. However, unlike the yellow perch, which became increasingly more active as the temperature increased to the seasonal maxima, the lake whitefish CPUE declined during periods of maximum seasonal temperatures. The decreased catch in summer apparently resulted from decreased activity--a response by lake whitefish to temperatures which exceeded their preferred range. The catch also decreased during winter. These responses were evidenced by the annual bimodality of the CPUE, with peaks during spring and fall as the temperature passed through the preferred range, and lows during summer and winter as the temperature departed from the preferred range (Fig. 6.22b). Valtonen (1970) reported the optimum temperature for broad whitefish (*Coregonus nasus*) to be 12 C. A similar optimum appears to be true for lake whitefish at Banks Lake.

The effects of temperature and recruitment on CPUE were useful in explaining the vertical, horizontal and inshore-offshore distributions of lake whitefish. As water temperatures increased during the summer through August the CPUE decreased in the epilimnion and increased in the hypolimnion. Catches at Transect 1 were absent or low from June 1973 to

OFFSHORE CATCH OF LAKE WHITEFISH

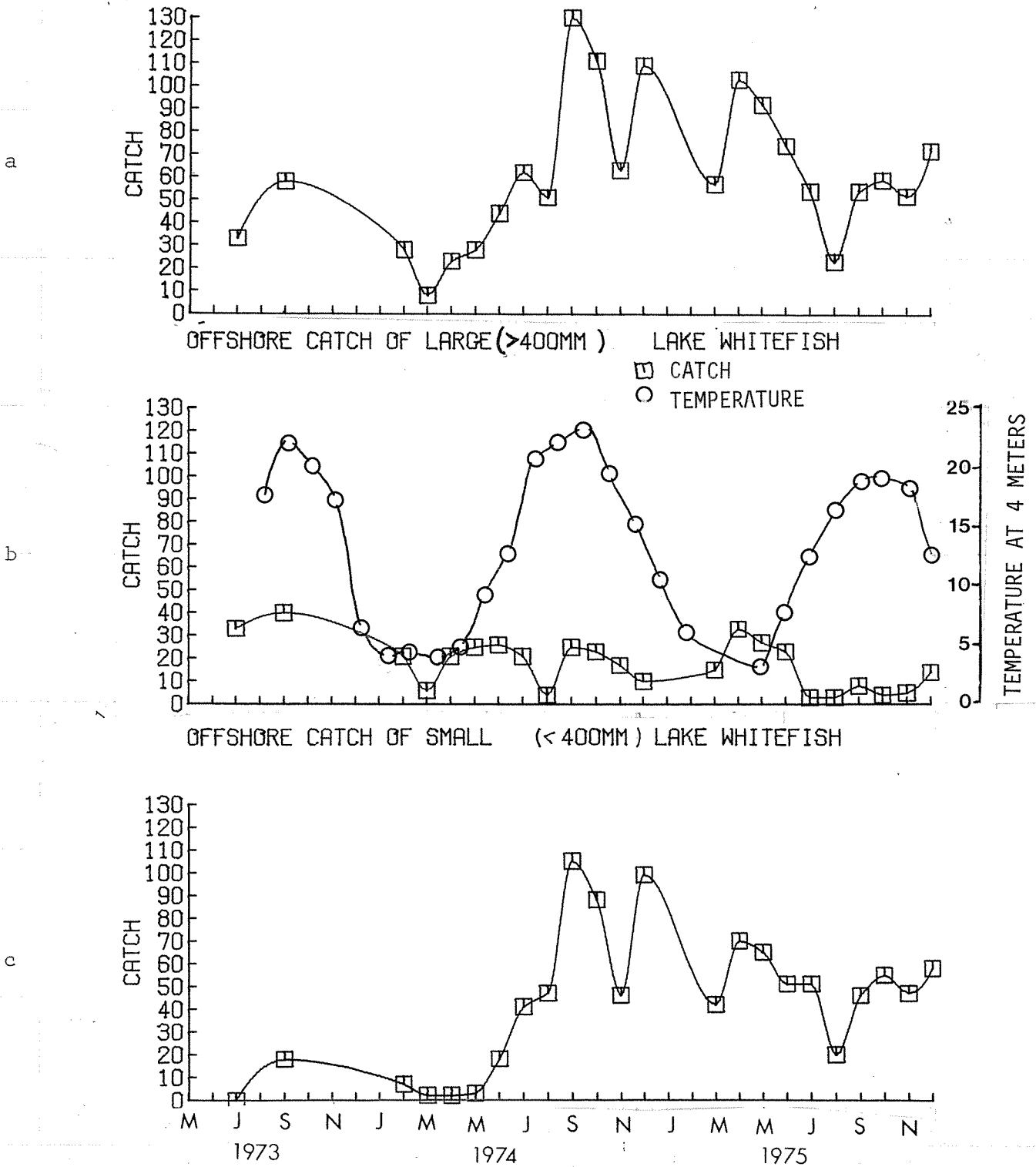


Figure 6.22 Offshore catches of lake whitefish. Large and small sizes are graphed together and separately. The catch of large lake whitefish is compared with water temperature at 4 meters.

November 1974 indicating that lake whitefish partially avoided the north pool in spite of the cooler, preferred water temperatures which existed there due to pumped input (Fig. 6.18). The partial avoidance of the north pool may also have been due to the decrease in density of the preferred food, *Daphnia*, which occurred with the initiation of pumping.

The high CPUE at Transect 1 in the fall of 1974 occurred after the pumping season had ceased, when Transect 1 was limnologically similar to the rest of the lake. The CPUE was high at all transects during this period due to recruitment in the catch of the large year class.

Seasonal variations in the inshore-offshore distributions were caused by spawning behavior and annual temperature changes. The increased inshore abundance of large lake whitefish during winter was due to beach spawning activity. The avoidance of warm surface temperatures resulted in an offshore distribution of lake whitefish in the hypolimnion during the summer and fall.

6.3.3.3 Age and Growth. The growth of lake whitefish was determined by analysis of scales from 366 fish collected from 1973 to 1975 with variable mesh horizontal gill nets. Additional samples of age 0 whitefish for length measurement were taken by tow net and beach seine in 1974 and 1975.

Age composition was determined from 366 fish to be: 29% age 1; 29% age 2; 19% age 3; 17% age 4; 5% age 5 and 1% age 6. Age 0 fish were not recruited into the gill net catch until July (>120 mm +), which caused the percentage of age 0 fish to be underestimated.

A comparison of length at age between lake whitefish from Banks Lake, Lake Michigan, Lake Erie and Swan Lake, Montana shows considerable variability among systems. (Table 6.7). The growth of Banks Lake whitefish between ages 1 and 3 was similar to Lake Erie, but the Lake Erie fish were long-lived and continued to grow throughout their life span, whereas growth of Banks Lake whitefish reached an asymptote at 435 mm.

The scarcity of age ≥ 5 fish was possibly due to migration to other parts of the lake, or mortality. Large dead whitefish (>400 mm) were observed every year in the lake (including massive dieoffs in 1971-72 [Duff 1973]). The limited age and size may result from the diet which is almost exclusively zooplankton, whereas in other lakes, such as Lake Erie, the diet is predominantly benthos. Banks Lake is also at the southern limits of the lake whitefish range which may be indirectly influencing growth and longevity.

The direct calculated growth increment was highest the first year and decreased thereafter (Table 6.7). The age composition and growth of male and female whitefish were similar. Since lake whitefish avoided the Transect 1 area during months of pumping there were no data to compare difference in growth rates among transects. A comparison of the sizes of larval lake whitefish obtained by townetting showed no significant differences among transects. This was expected because growing conditions during early spring were similar at all transects.

Table 6.7 Lake whitefish lengths at age in millimeters from length-frequency analysis and scale readings.

Location	I	II	III	IV	V	VI ...XVI	Author
Banks Lake, Washington							Present Study
Median fork length	250	345	435	435	435	430	
(n)	(105)	(106)	(74)	(62)	(118)	(1)	
Δ	+250	+95	+90	0	0	-5	
Lake Michigan							Roelofs, 1958
Mean total length	126	217	307	391			
(n)	(-)	(-)	(-)	(-)			
Δ	+126	+91	+90	+84			
Lake Erie							Van Oosten and Hilde, 1947
Mean total length	279	349	418	446	478	506 ... 648	
(n)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Δ	+279	+60	+69	+28	+32	+28	+
Swan River or Lake							Montana F&G 1961
Mean total length	99	198	290	333	371		
(n)	(6)	(6)	(6)	(5)	(2)		
Δ	+99	+99	+92	+43	+38		

The procedures used to analyze the length-weight relationships of lake whitefish were the same as described for yellow perch. The regression results indicated similar slopes for male and female fish. Length-weight relationships were not compared among transects because of the small sample size at Transect 1, which indicated movement out of the area during unfavorable growth conditions.

The length-weight relationships for lake whitefish captured in September 1973 and 1974 are presented below in logarithmic form:

September 1973

$$Y = -5.2131 + 3.1522 X \quad N = 128, r^2 = .97$$

September 1974

$$Y = -5.2455 + 3.1331 X \quad N = 535, r^2 = .98$$

Figure 6.23 is a scattergram of 1973-75 lake whitefish, showing the predicted line through the untransformed data.

6.3.3.4 Food Habits. Stomachs of lake whitefish were inspected fresh for the presence of food, fullness and the type of food consumed. Intestines were not inspected. These visual inspections gave a general idea of the whitefish food habits.

Four types of food were observed in whitefish stomachs: zooplankton, flying insects, benthos and unidentifiable animal debris. The zooplankton, on a relative basis, was the dominant food item found in the whitefish stomachs (Fig. 6.24). Since zooplankton was of such

LENGTH-WEIGHT RELATIONSHIP FOR LAKE WHITEFISH

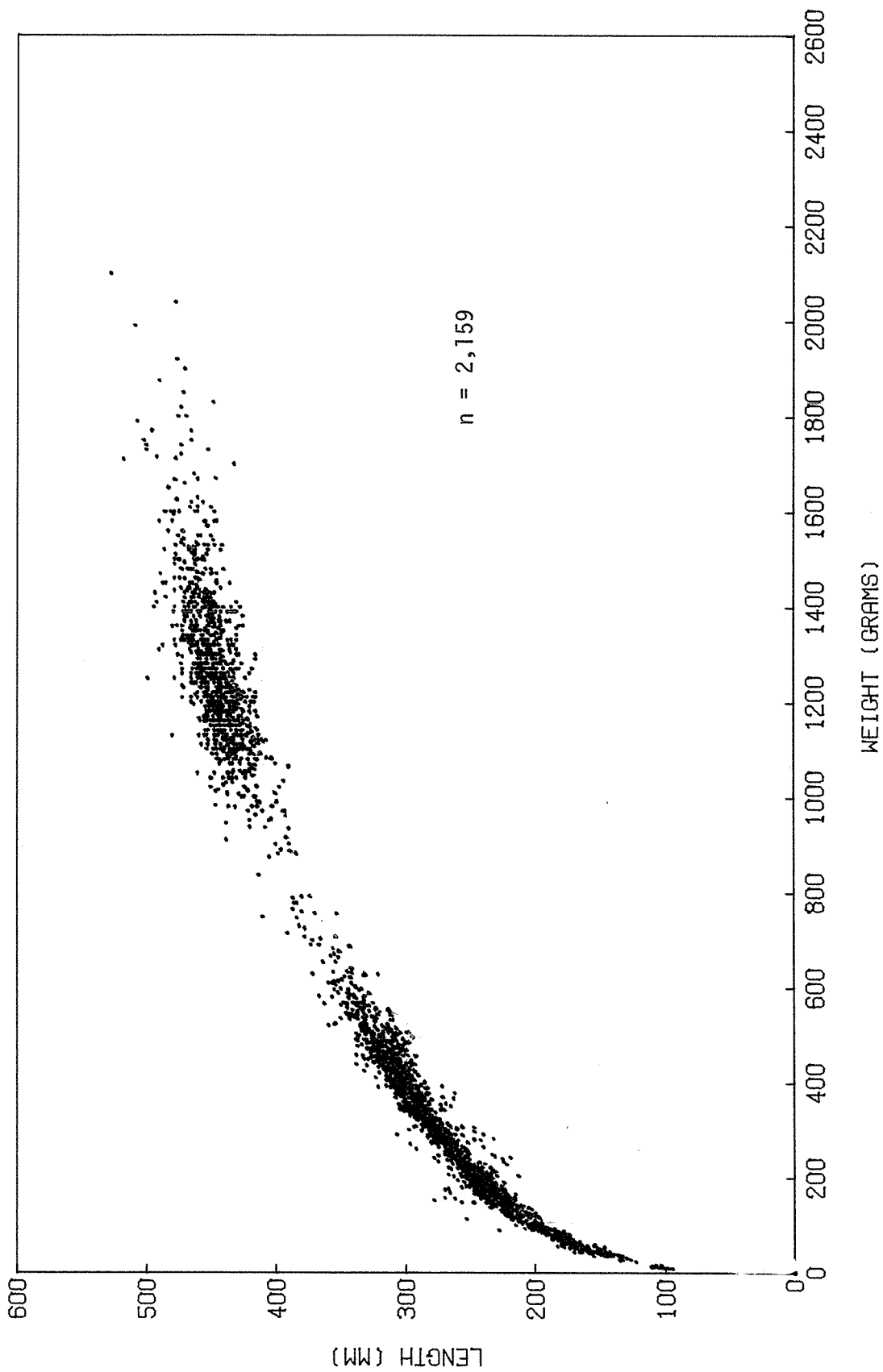


Figure 6.23 Scattergram of length-weight relationship for lake whitefish captured in September 1973 - 1975.

STOMACH CONTENTS OF LAKE WHITEFISH

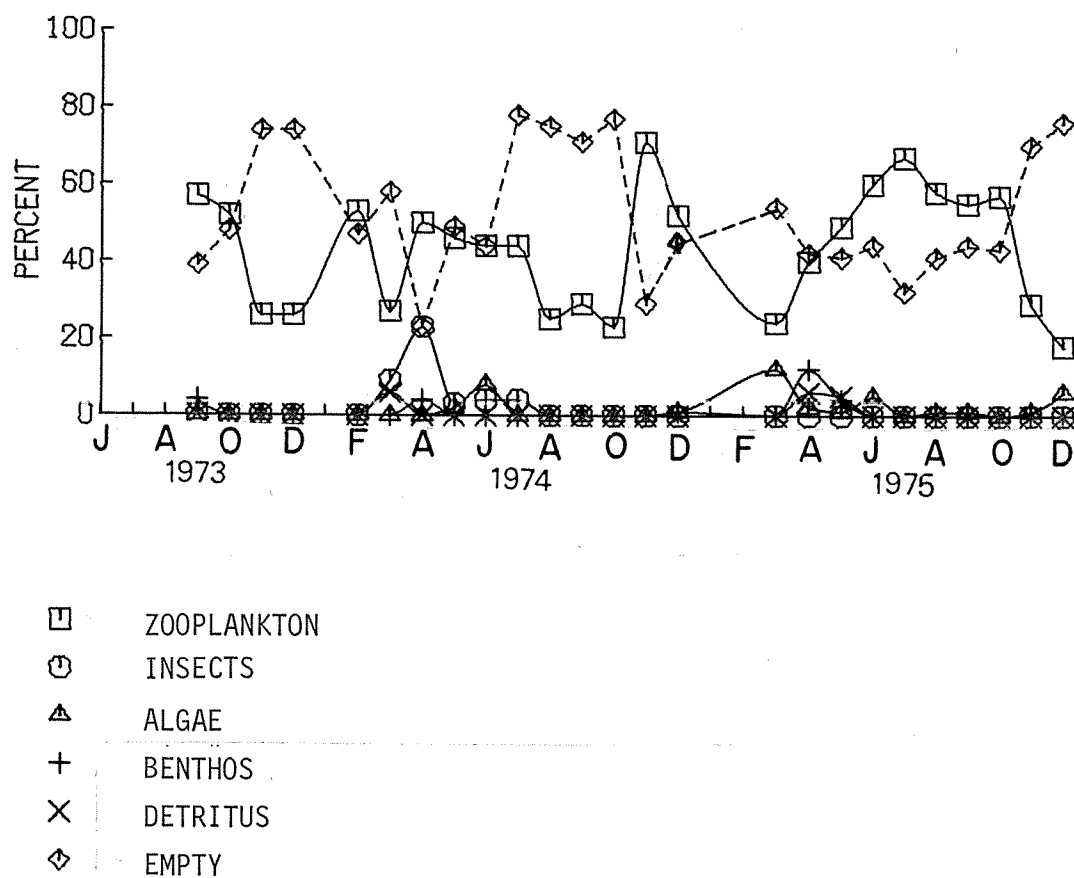


Figure 6.24 The stomach contents of lake whitefish. The vertical axis represents the percent of the lake whitefish stomachs containing a specific food category. Dashed line represents percent of stomachs which were empty. The lake whitefish were caught in gill nets between July 1973 and December 1975.

importance to the diet of the lake whitefish, stomach samples containing zooplankton were collected from 1973 to 1975 and preserved in Formalin for a more comprehensive analysis of food habits. Approximately 99% of the zooplankters present were identified to belong to the cladoceran genus *Daphnia*. Since these samples were from gill net caught fish, very few age 0 fish were observed. The stomach contents of 50 townet-caught age 0 whitefish (preserved in 10% Formalin) were examined for species composition. Zooplankton was again the dominant food observed. However, for the first two months, March and April, the whitefish larvae fed heavily upon the pelagic copepod *Diaptomus* as well as *Daphnia*. Insects were the second most frequent food item observed in whitefish stomachs. Eighty percent of the identifiable insects were chironomids and 20 percent were damsel flies. Some benthos (snails and crayfish) were observed in the whitefish stomachs. Due to regurgitation and digestion, the percentage of emptiness (Fig. 6.24) was overestimated. For the same reasons, the fullness indices were disregarded.

6.3.3.5 Reproduction. Lake whitefish spawned along the shoreline from November to January (Fig. 6.25). Spawning occurred primarily over rock substrate along the steep talus shoreline of Transects 5 and 6 when the water temperatures ranged from 4 to 6 C. However, a few spawning fish were captured along the shoreline and mid-lake at all transects and on mud substrate. A large percentage of adult fish did not mature in

INSHORE AND OFFSHORE SPAWNING LAKE WHITEFISH

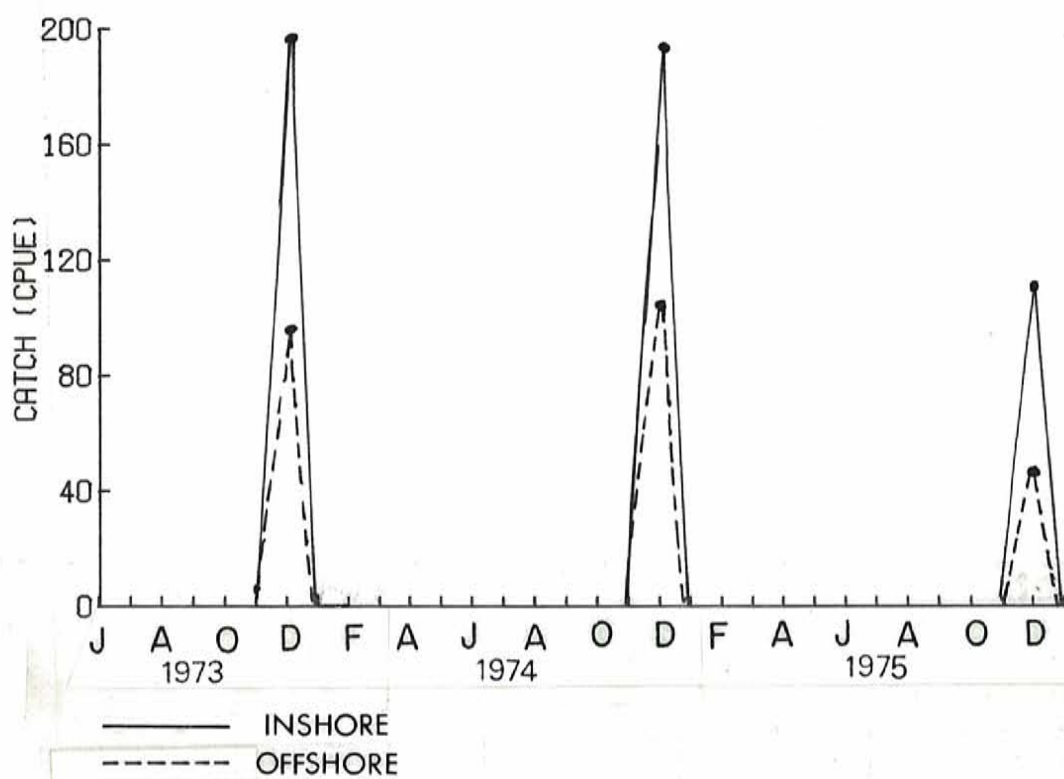


Figure 6.25 Number of spawning lake whitefish captured inshore and offshore by month.

1974, suggesting that Banks Lake whitefish may not spawn annually. The fecundity was large, estimated at 40,000 eggs for a 454 mm female. The lake whitefish broadcast their eggs over the bottom and there is no parental care. The eggs averaged less than about 3 mm in diameter. Spawning fish were taken primarily in the shallow shoreline sets. Incubation was estimated to occur between early December and early April, a period of approximately four months, which agrees with Hoagman (1973). Most of this incubation was spent under the ice cover in 1974 and 1975, and was quite successful as indicated by the large densities of age 0 fish taken in the tow net, beach seine, and gill net catches. Emerging yolk sac larvae were captured in emergence traps in late March and early April of 1976. Emergence appeared to end by late April.

6.3.3.6 Irrigation Effects on Lake Whitefish. The annual CPUE of recruits illustrates the dominance of the large 1974 year class of lake whitefish. The 1974 year class grew to a mean length of 220 mm by December 1974 and to 330 mm by December 1975.

The critical period concept is common in fish with extended pelagic larval stages and commonly results in large fluctuations in year class strengths. Hjort (1914) discussed the critical period concept in the early life history of fish. Evidence in support of this hypothesis continues to accumulate (Lasker 1976). The fishes having marine pelagic larval stages illustrate this phenomenon and all are known for dominant

year classes. The lake whitefish has a two-month (March and April) pelagic larval stage.

The horizontal separation of the lake into two pools during the growing seasons resulted in characteristic responses by the lake whitefish. The location of the north and south pools was described in the yellow perch section. The major difference between the north pool environment and the south pool environment affecting the lake whitefish appeared to be the food supply. The lake whitefish tended to leave the north pool when the food supply was low. The food supply was lowest when the retention time was shortest and occurred during periods of maximum pumping at minimum water levels.

An analysis of the possible effects of water level fluctuation on lake whitefish spawning and emergence (Fig. 6.26) indicated very limited habitat loss during these periods. Spawning, incubation and emergence occurred during the winter when the lake level was held nearly constant at full pool. Variance in year class strength was not affected by artificial change in water level during embryonic development.

6.3.4 Kokanee, *Oncorhynchus nerka* (Walbaum)

6.3.4.1 Importance. The kokanee is the nonanadromous form of the sockeye salmon (*O. nerka*) which is indigenous to the Columbia River system. Kokanee have existed in Lake Roosevelt since the construction of Grand Coulee Dam. This population is believed to have been one of

HYPOTHETICAL MODEL ILLUSTRATING THE EFFECT OF WATER LEVEL FLUCTUATION ON THE INCUBATION HABITAT OF LAKE WHITEFISH.

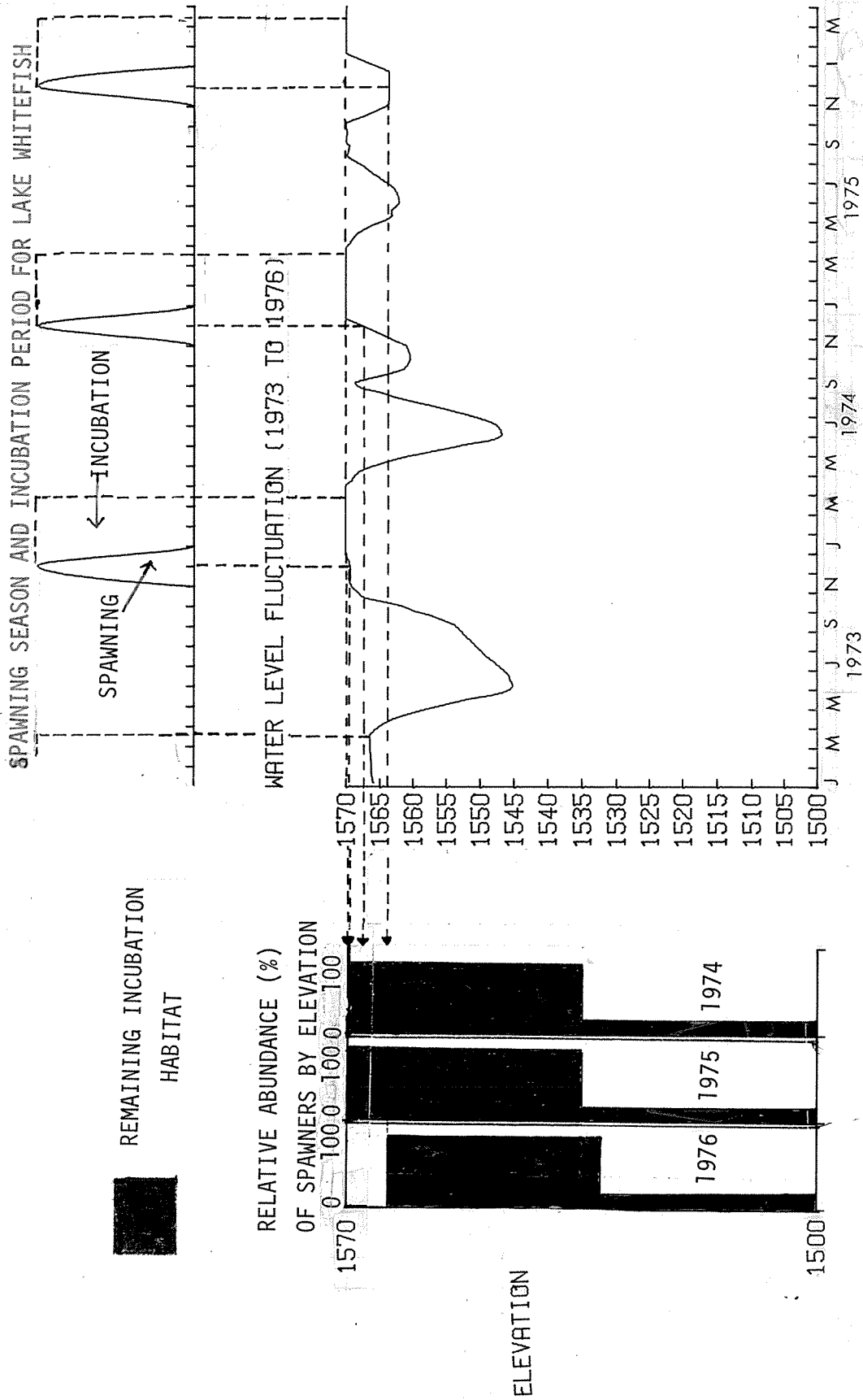


Figure 6.26 Observed spawning and incubation periods (1974-76) superimposed over the water level regimes of these years, and projected to the histogram of estimated spawning depths, illustrating the proportion of incubation habitat exposed by water level fluctuation.

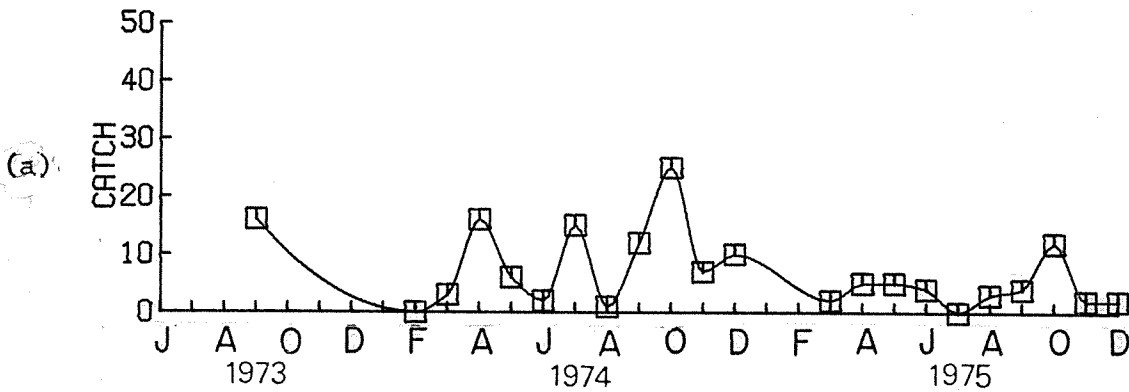
the sources of the original stocks in Banks Lake which have been pumped in with the irrigation water. Kokanee from the Leavenworth hatchery have also been planted at irregular intervals since 1956. The origin of the parent stocks was Lake Whatcom (Duff, personal communication). The kokanee has been extensively introduced to inland waters throughout the U.S., in attempts to create sport fisheries and as a forage fish for large gamefish (Calhoun 1956). Kokanee are caught with standard sports fishing gear and their excellent food quality makes them highly desirable.

The kokanee population in Banks Lake appears to be self-sustaining since the 1972 creel survey showed large numbers of 2-, 3- and 4-year-old fish which could not have originated from the most recent plant in 1966 by the Washington Department of Game. The annual contribution from Lake Roosevelt stocks is being investigated under the entrainment phase of this study. The success of kokanee appears to be related to a sufficient food supply (zooplankton) and its pelagic habitat which offers it "spatial isolation" from the primary predators in the lake (except diving birds). However, the recent introduction of the chinook salmon by the Washington State Department of Fisheries represents the addition of a new pelagic predator into an unexploited niche in the food web. The feeding behavior of the chinook salmon may have considerable impact on the species composition of the lake, depending upon its preference of food types.

The general life history of Banks Lake kokanee is summarized below using the 1970 year class as an example:

		Scale age (no. of annuli)	Total age (from spawning)
1970	spawned in October		
1971	emerged from gravel during spring	age 0	<1
1972	reared to fork length of 130 mm small entrainment to irrigation canal	age 1	2
1973	reared to fork length of 220 mm recruited into sample gill net catch recruited into sport catch	age 2	3
1974	high occurrence in sample gill net catch high occurrence in sport catch large number entrained into irrigation canal most spawned and died in fall	age 3	4
1975	low occurrence in sample gill net catch low occurrence in sport catch few entrained into irrigation canal all spawned and died in fall	age 4	5

SURFACE CATCH OF KOKANEE



BOTTOM CATCH OF KOKANEE

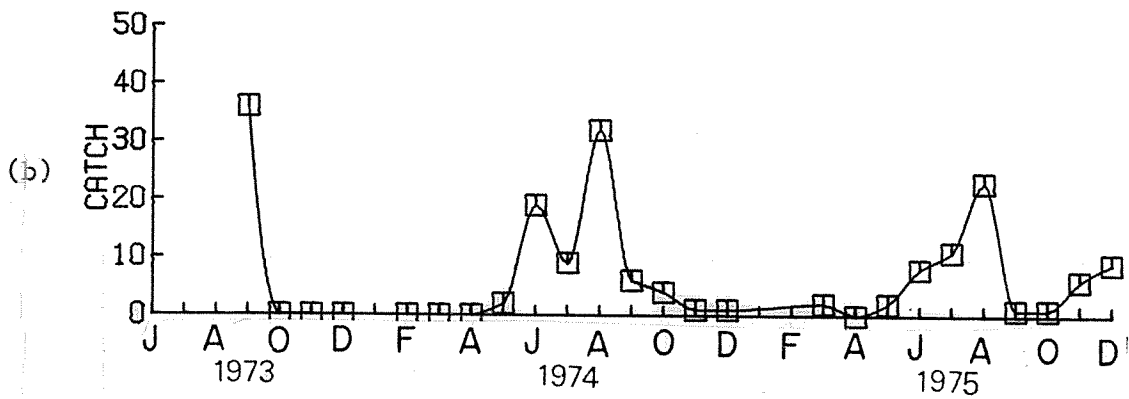
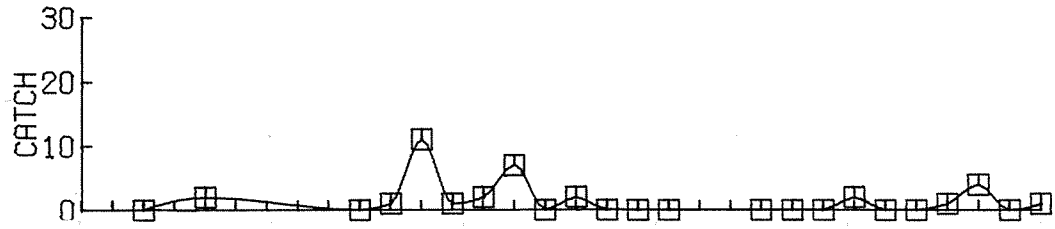
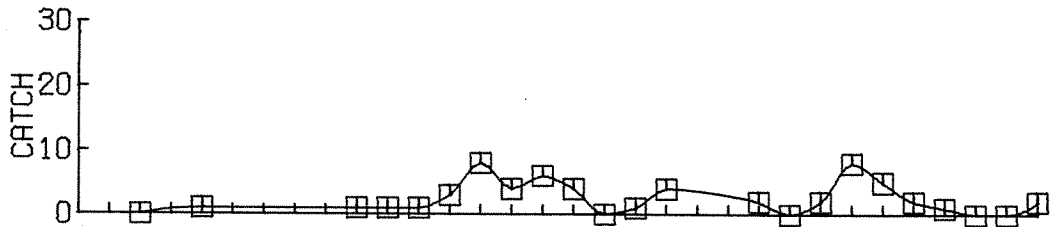


Figure 6.27 Vertical distribution of kokanee. Each point represents 8 24-hr horizontal variable-mesh gill net sets. Four sets were made at each of the 4 transects monthly: 2 on the surface (a) and 2 on the bottom (b) of the water column.

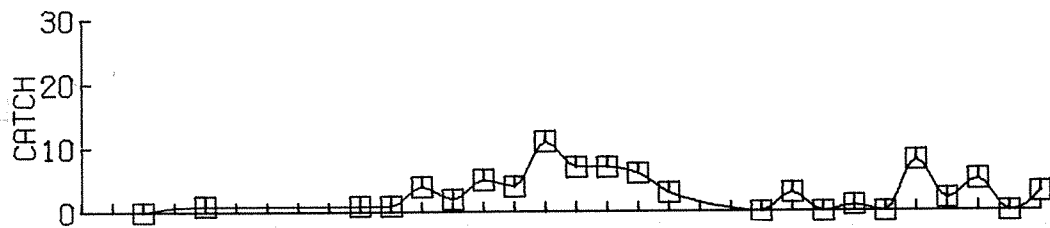
OFFSHORE CATCH OF KOKANEE BY STATION STATION 1



STATION 4



STATION 5



STATION 6

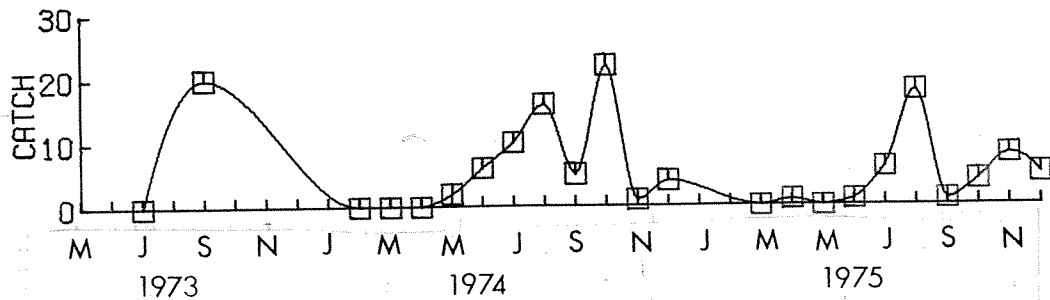


Figure 6.28 Horizontal distribution of kokanee. Each point represents 4 24-hr horizontal variable-mesh gill nets: 2 on the bottom and 2 on the surface of the water column.

Kokanee catches at inshore and offshore locations were comparable during the spring and fall months and were highest offshore during the summer (Figs. 6.29 and 6.30). Catches made inshore during the fall were of maturing or spawning kokanee.

Temperature, food and spawning behavior explain much of the variation found in kokanee distribution in Banks Lake. Juvenile sockeye have been found to prefer a temperature of 15 C (Brett 1965) and kokanee are assumed to have a similar preference. Kokanee prefer *Daphnia* for food, and spawn on a shoreline substrate of mixed gravel and boulders in areas of steep talus slopes.

The increased concentration of kokanee offshore near the bottom during the summer months appeared to be an effort to escape the warm surface waters. Each year the catches in the bottom horizontal nets greatly exceeded the catches of the surface horizontal nets beginning in June, as temperatures in the epilimnion exceeded 15 C.

The avoidance by kokanee of the north end of Banks Lake (Transect 1) during irrigation pumping may have been due to the low abundance of *Daphnia* in that area. This avoidance existed in spite of cooler, more favorable water temperatures at Transect 1. The kokanee apparently tolerated temperatures 4 to 5 C above optimum at Transects 4, 5 and 6 in favor of a more abundant food supply.

The shoreline catch of kokanee increased, particularly at Transects 5 and 6, during the fall as the result of spawning behavior. The catch was composed entirely of mature fish. Shoreline catches of mature fish were greatest at Transects 5 and 6 because much of the total available spawning substrate occurred along the west shore between Transects 5 and 6.

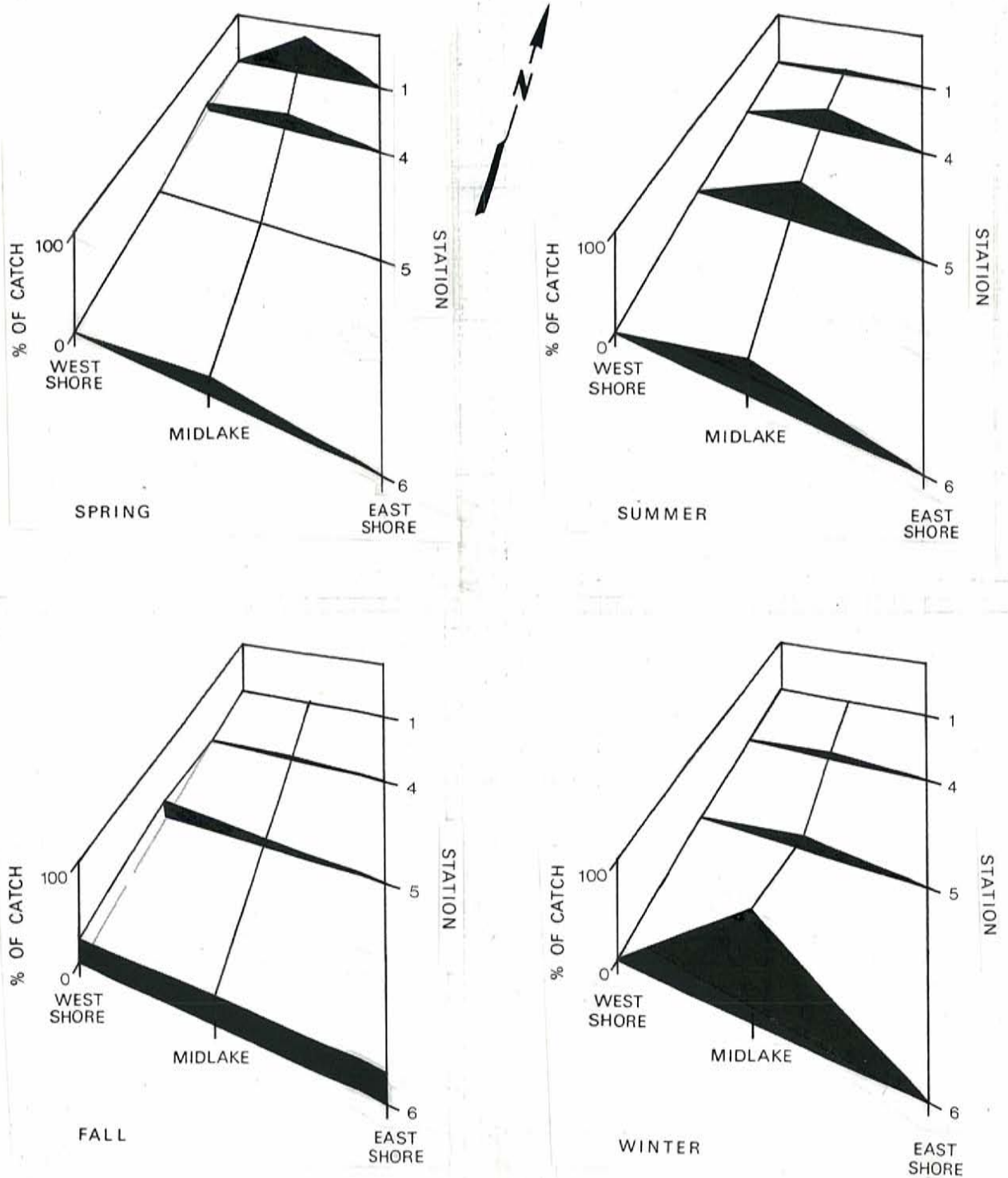


Figure 6.29 The inshore/offshore distributions of kokanee for the spring, summer, fall, and winter seasons of 1974. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, a midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1 (Electric City), 4 (Steamboat Rock), 5 (Million Dollar Mile), and 6 (Coulee City).

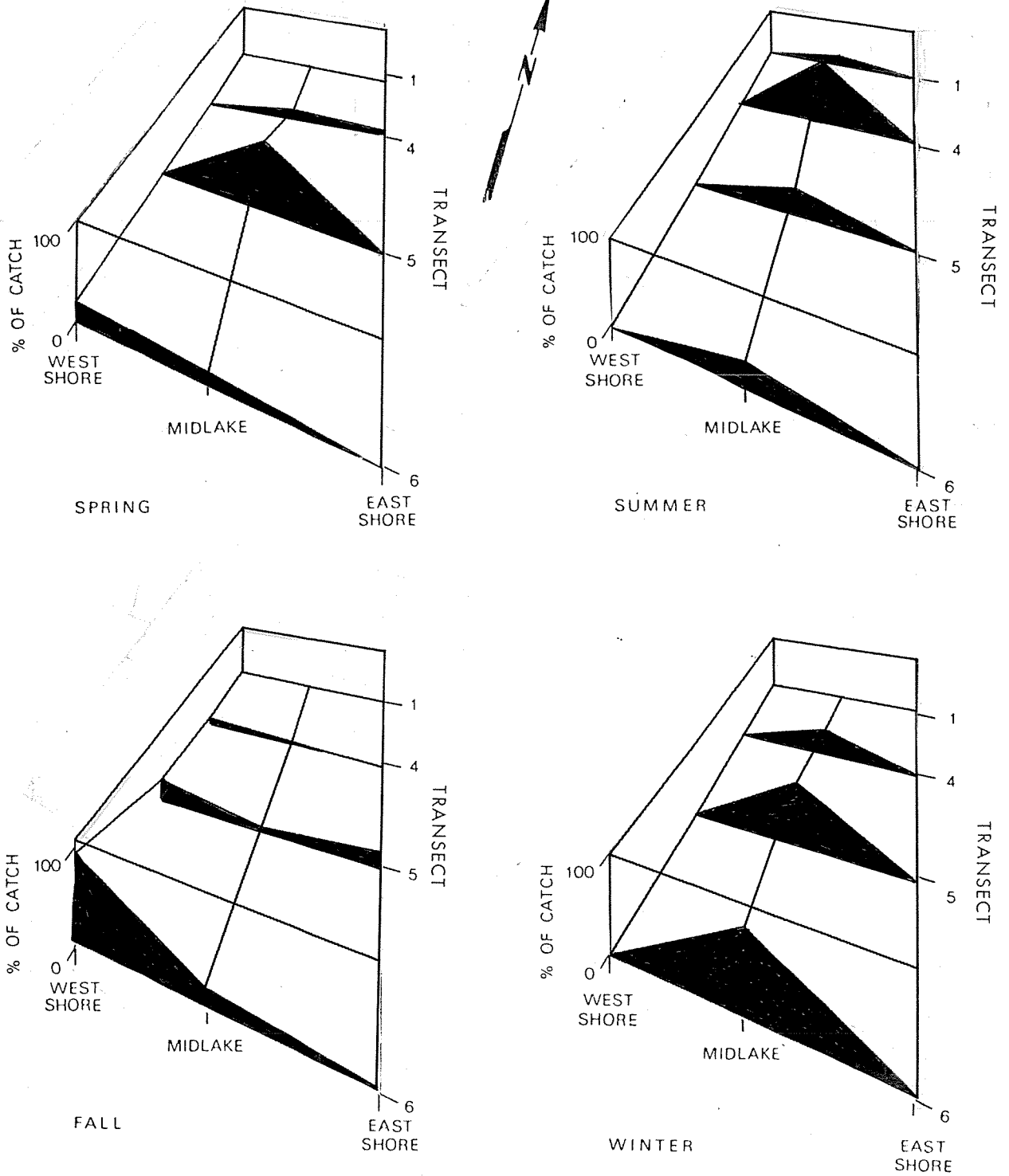


Figure 6.30 The inshore/offshore distributions of kokanee for the spring, summer, fall, and winter seasons of 1975. The vertical axis represents the percent of the total catch for each season. The horizontal plane represents 12 sampling locations: an east shore, a midlake, and a west shore site for 4 transects. The transects run from north to south and are: 1 (Electric City), 4 (Steamboat Rock), 5 (Million Dollar Mile), and 6 (Coulee City).

The seasonal change in abundance of kokanee due to recruitment and spawning mortality was determined by comparing between months the offshore catch for surface and bottom horizontal gill nets from all transects combined (Fig. 6.31a). This comparison eliminated possible bias due to vertical and north-south movements of kokanee but did not eliminate possible bias due to inshore-offshore movements. Because kokanee sought out deeper, cooler water during the summer months, they were more concentrated in the offshore waters where the monthly gill net array was positioned. Thus, the summer abundance figures may be biased upwards.

The recruitment of large year classes into the sample gill net catches in 1973 and 1974 and of a small year class in 1975 is visible in Fig. 6.31c. The 1971 year class first entered the catch in September 1973. During the fall and winter 1973, the catches declined to a low level due to dispersal of the kokanee throughout the lake and/or to decreased activity. As temperatures warmed during spring 1974, the catches increased, and by August they equalled the 1973 catches. In September 1974, the 1972 year class was recruited into the gill net catches. Concurrently, the mature adults of earlier year classes disappeared from the catch (Fig. 6.31b). During fall 1974, the catches declined, but not to the same low level of the previous winter. During spring 1975, the catches increased as water temperatures warmed. In September 1975, the 1971 year class matured, moved shoreward to spawn, and thus disappeared from the catch. At this time the catch dropped sharply because little recruitment was available from the 1973 year class.

6.3.4.3 Age and Growth. The growth study of Banks Lake kokanee was based upon analysis of scales from 592 fish collected from 1973 to 1975 with variable mesh horizontal gill nets.

OFFSHORE CATCH OF KOKANEE

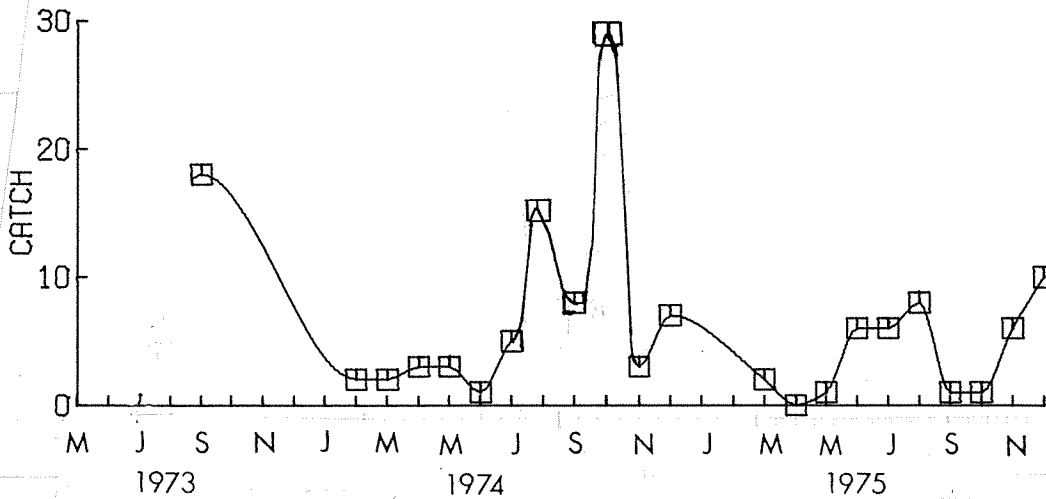
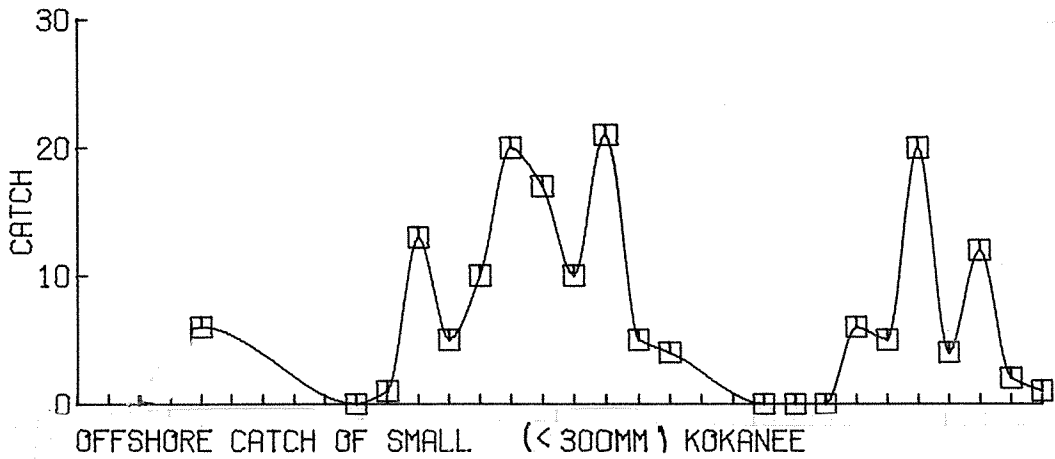
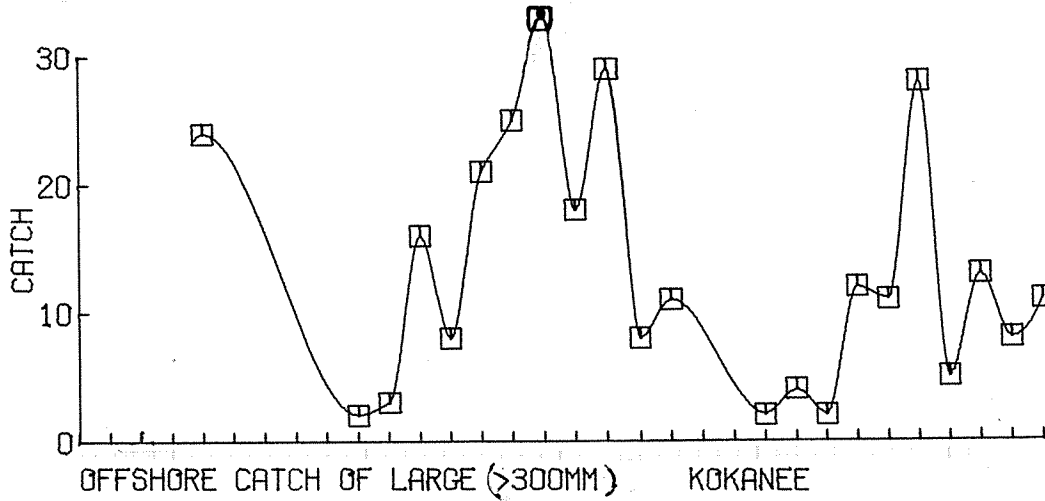


Figure 6.31 Total offshore catch of kokanee salmon, representing 16 24-hr gill net sets: 8 on the surface and 8 on the bottom of the water column. This represents the combination of two days consecutive sampling at four transects.

Of the 592 kokanee aged in the study, 7% were age 1, 40% age 2, 40% age 3, 12% age 4, 1% age 5. Age 1 fish were gradually recruited into the gill net catches during spring and summer as they exceeded 220 mm in length. Until August the percentage of age 1 fish in the population was underestimated. Table 6.8 shows the kokanee length at age for Banks Lake based on length frequency mode analysis and scale annulus readings, including the assumption of false summer checks. Daily Lake, Montana and Pend Orielle Lake, Idaho are presented for comparison. Daily Lake kokanee showed a similar age composition to Banks Lake kokanee. However, growth of kokanee was highly variable among systems (Table 6.8). The growth rate for Banks Lake kokanee was comparatively fast based on scale measurements. The rate of growth was highest during the first year and decreased thereafter (Table 6.8). The age composition and growth was similar for male and female kokanee. Since kokanee avoided the Transect 1 area during months of pumping there were no data to compare differences in growth rates between Transect 1 and Transects 4 to 6.

The small number of kokanee > age 4 was due to mortality, since the majority of the kokanee mature at 3 or 4 years and die after spawning. Banks Lake has been planted with Lake Whatcom kokanee which spawn mainly at age 3.

The procedures used to analyze the length-weight relationships of kokanee were the same as described for yellow perch. The regression results indicated similar slopes for male and female fish. Analysis of kokanee length-weight relationships was not compared between transects because of the small sample size at Transect 1.

The length-weight relationships for kokanee salmon captured in September 1973 and September 1974 are presented below in logarithmic form:

Table 6.8 Kokanee length at age in millimeters from length frequency analyses and scale readings.

Location		Age						
		I	II	III	IV	V	VI	VII
<u>Banks Lake, Washington</u>								
Median fork length	med	130	270	375	440			
from length frequency	(n)	(-)	(-)	(-)	(-)			
mode analysis		+130	+140	+105	+65			
Median fork length	med	232	272	294	343	378		
by scale annulus	(n)	(46)	(234)	(238)	(69)	(5)		
readings		+232	+40	+22	+49	+35		
Assuming false checks	med		(232)	(292)	(378)		summer checks	
in summer	(n)	-	-	-			winter checks	
		+102	+40	+20	+51	+35		
<u>Dailey Lake, Montana</u> 1955								
Mean total length	mean	114	259	340	412	468		
	(n)	(26)	(26)	(26)	(16)	(3)		
		+114	+145	+81	+72	+56		
<u>Pend Orielle</u> 1956								
Mean total length	mean	61	163	175	221	231	231	216
	(n)	-	-	(75)	(217)	(254)	(97)	(2)
		+61	+102	+12	+56	+10	0	-15

September 1973

$$Y = -4.1582 + 2.7236X \quad N = 190; r^2 = .97$$

September 1974

$$Y = -4.2486 + 2.7525X \quad N = 231; r^2 = .97$$

Figure 6.32 is a scatter-gram of 1973-75 kokanee lengths versus weights, showing the predicted line through the untransformed data.

6.3.4.4 Food Habits. Stomach samples from 1,113 kokanee were inspected for the presence of food, fullness and the type of food contained. All stomachs were inspected fresh. These visual inspections gave a general idea of the kokanee food habits.

Two types of food were observed in kokanee stomachs: zooplankton and insects. The zooplankton on a relative basis was the dominant food item in the stomach (Fig. 6.33). Since zooplankton was of primary importance in the diet of the kokanee, stomach samples containing zooplankton were collected from 1973 to 1975 and preserved in formalin for a more comprehensive analysis of food habits. Approximately 99% of the zooplankters present were identified as belonging to the cladoceran genus *Daphnia*. Since these samples were from gill nets, no age 0 fish were observed. The insects which were observed incidentally in kokanee stomachs in April 1975 were entirely chironomids.

Due to regurgitation and digestion, the absence of food in stomachs and the percentage of emptiness indices were overestimated (Fig. 6.33). For the same reasons, the fullness indices were disregarded.

LENGTH-WEIGHT RELATIONSHIP FOR KOKANEE

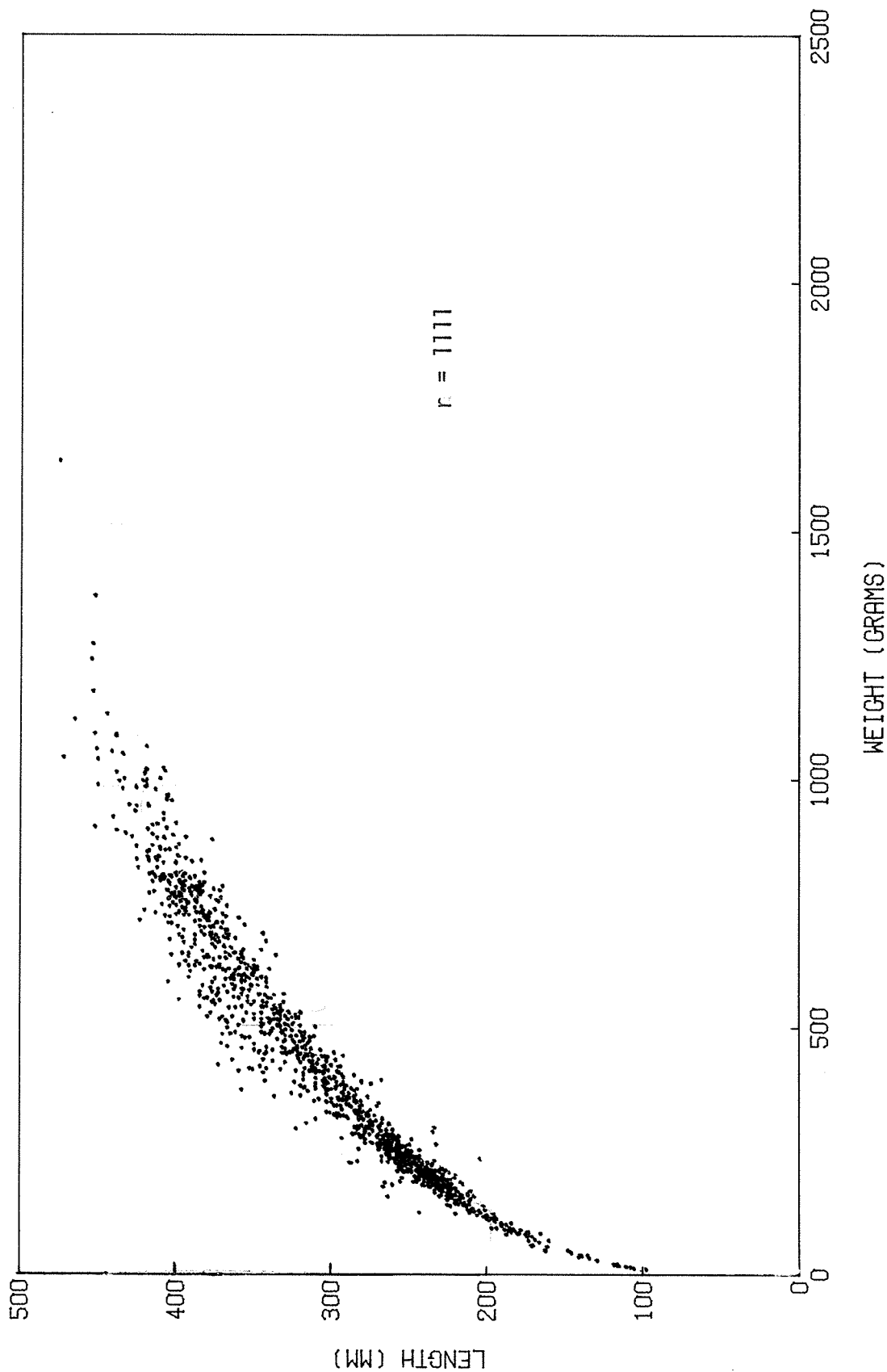
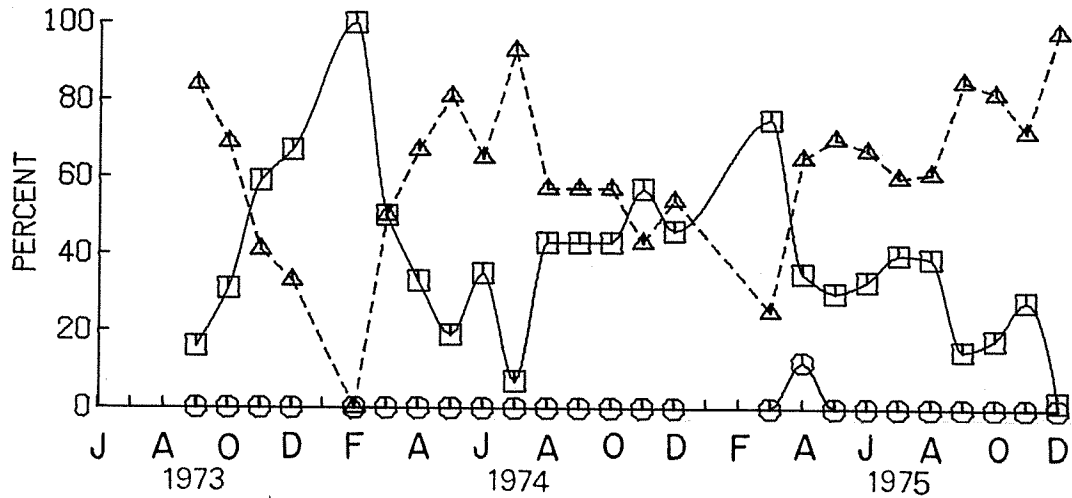


Figure 6.32 Scattergram of length-weight relationships for kokanee captured in September 1973 to 1975.

STOMACH CONTENTS OF KOKANEE



- ZOOPLANKTON
- INSECTS
- △ EMPTY

Figure 6.33 The stomach contents of kokanee. The vertical axis represents the percent of the kokanee stomachs containing a specific food category. Dashed line represents percent of stomachs which were empty. The kokanee were caught in gill nets between July 1973 and December 1975.

6.3.4.5 Reproduction. Maturity of kokanee was estimated monthly from the gill net catches. The percentages of mature kokanee in inshore and offshore waters were determined during the September quarterly gill net sampling (Fig. 6.34). The relative abundance and locations of kokanee spawning along the shorelines were determined in October and November by SCUBA. The kokanee spawning occurred in October and November during a change in the average water temperature from 13 to 6 C. Spawning-out kokanee were observed as late as December.

In October and November, diving surveys were conducted along the shoreline of each transect and in other areas of suspected spawning (Fig. 6.35). Mature and spawning individuals were observed in largest numbers along the steep talus slopes of the west shoreline of Transects 5 and 6. As many as 250 to 300 spawners were observed in a 100 ft length of shoreline. The fish were spawning on shelves which were 3 to 10 ft wide and from 3 to 25 ft deep. In major spawning areas, shelves were found at two depths, 6 ft and 18 ft, respectively. The shelf substrate was composed of basalt rubble ranging from less than 1 cm to 15 cm in diameter. The spawning areas were easily recognized because they were comparatively free of the dense periphyton which covered the surrounding area. Aggressive behavior among kokanee (chasing) and unsuccessful attempts at redd digging were observed. The eggs appeared to be broadcast over the rubble. Several single and a few aggregations of eggs were observed. The average fecundity for female kokanee was estimated at 1,222 (N = 67, Fig. 6.36).

The characteristics of beach spawning, incubation of eggs and emergence of kokanee fry were examined by SCUBA surveys and with the aid of 100 (1 m²) emergence traps in 1976. Due to rock slides, late fry

INSHORE AND OFFSHORE SPAWNING KOKANEE

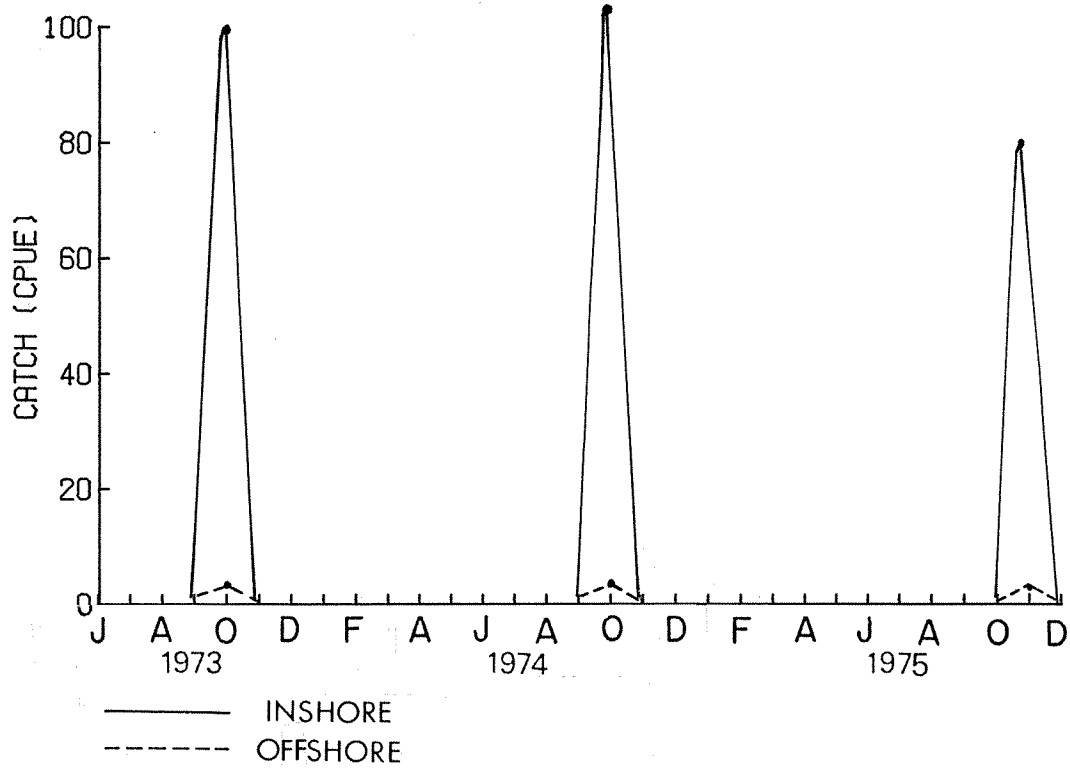


Figure 6.34 Number of spawning kokanee captured inshore and offshore by month.

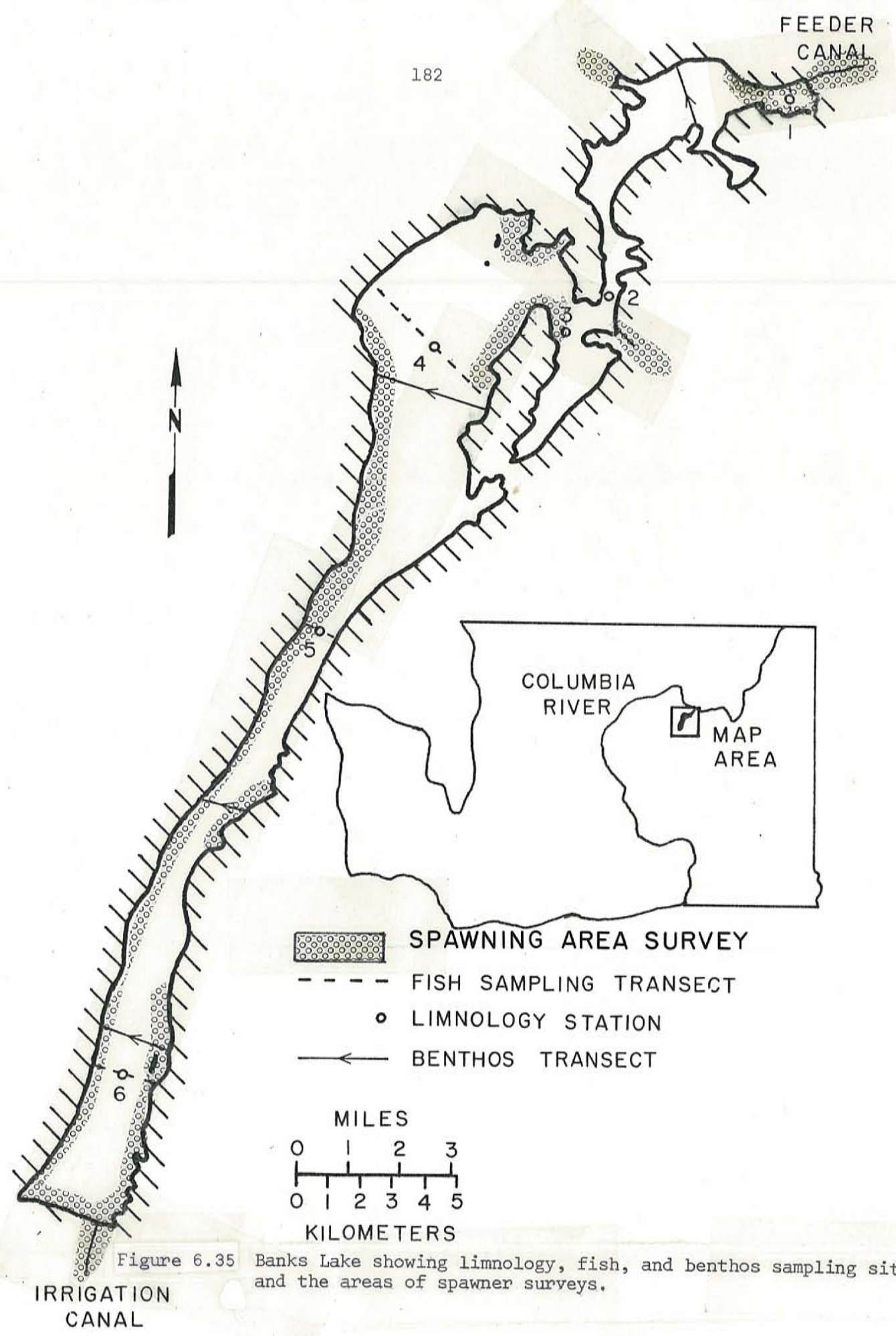

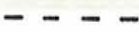




Figure 6.35 Banks Lake showing limnology, fish, and benthos sampling sites, and the areas of spawner surveys.

IRRIGATION CANAL

FEEDER CANAL

COLUMBIA RIVER
MAP AREA

-  SPAWNING AREA SURVEY
-  FISH SAMPLING TRANSECT
-  LIMNOLOGY STATION
-  BENTHOS TRANSECT

MILES
0 1 2 3

KILOMETERS
0 1 2 3 4 5

LENGTH-FECUNDITY RELATIONSHIP OF KOKANEE SALMON

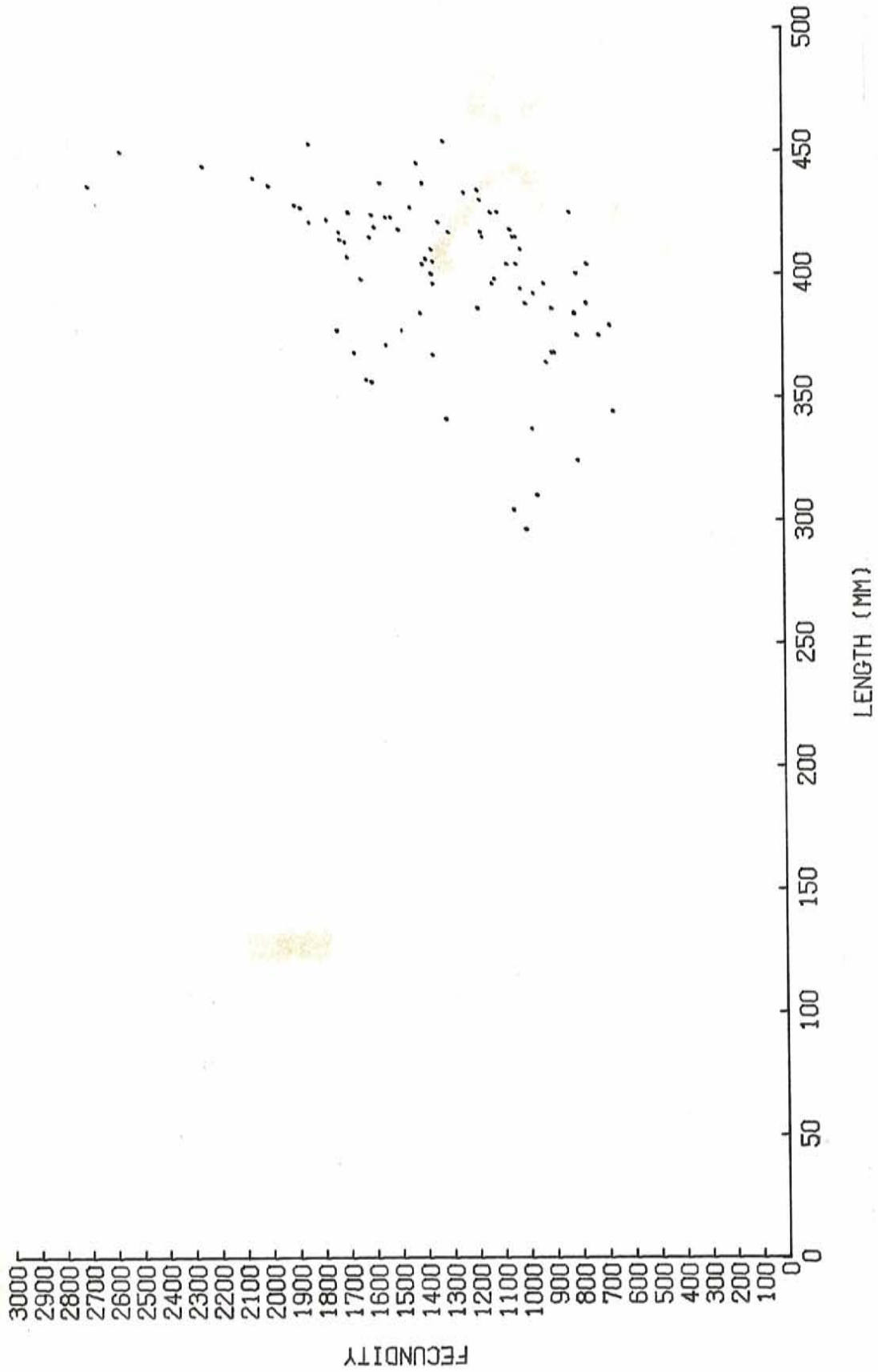


Figure 6.36 Scattergram showing the length-fecundity relationships of kokanee.

emergence and an earlier than normal lowering of the lake level in March, which allowed wave action to reach the traps, all 100 traps were destroyed. The time of emergence was not determined, but live, developing kokanee eggs were found in the substrate by SCUBA as late as May 14. This finding indicated that kokanee eggs and larvae are vulnerable to the spring drawdown of Banks Lake.

6.3.4.6 Mark and Recapture. Fourteen mature kokanee were tagged in mid-July 1974 at Transect 1 with Floy anchor tags. Six of these fish were recaptured in the feeder canal in late July and August 1974 by sport fishermen. Several other tagged kokanee were observed at the feeder canal outlet in August 1974, but were not recovered.

6.3.4.7 Irrigation Effects on Kokanee. The low recruitment in 1975 resulted from low abundance of the 1973 year class. The cause of this low abundance is a matter for speculation because no direct evidence is available to determine the life stage at which mortality occurred. The size of the 1975 year class may have been reduced by mortality at one or more stages including: spawning, incubation of eggs, hatching, pre-emergence and pre-recruitment of juveniles.

Circumstantial evidence is available which indicates that the extreme drawdown of Banks Lake during spring 1973 may have caused stranding of incubating eggs and/or pre-emergent alevins. A computation of temperature units (TU's) based on water temperatures from a depth of 4 m at Station 6 indicated that kokanee eggs laid after November 15 would not accumulate the necessary TU's to hatch before April 16 (assuming 1,100 TU's to hatching). Thus, eggs unhatched by mid-April in years of early drawdown, as occurred in 1973 and 1974, would have been stranded. Further, eggs laid after October 15 would not have absorbed the yolk sac

before April 16 and would have been forced to emerge prematurely or to migrate through the substrate to a lower elevation (assuming 1,690 TU's to yolk absorption). The effort of forced premature emergence or downward migration on the alevins is unknown.

The temperature units cited above are averages for sockeye based on a summary of the literature (Foerster 1968), there being no reference to kokanee incubation rate in the available literature. However, indirect evidence indicates that Banks Lake kokanee eggs may incubate more slowly than do sockeye. This evidence is based on observations of kokanee spawning during fall 1975, and of incubating kokanee eggs during spring 1976. SCUBA observation and gill net sampling during October, November, and December 1975, revealed that spawning had been completed by November 30. During a SCUBA survey in mid-May 1975, eyed, incubating kokanee eggs were found in the spawning gravel at the same location. Temperature records indicate that eggs which were spawned on the latest possible date (November 30) would have accumulated 1,280 TU's by mid-May. The presence of eggs still unhatched after 1,280 TU's indicates that the rate of incubation for Banks Lake kokanee may be slower than for sockeye and therefore that eggs laid shortly before November 15 may also have been stranded during the extreme drawdown of 1973 and 1974.

The extended time interval required for development of kokanee eggs and pre-emergent alevins increases the potential for exposure to water level decline more than that previously discussed for yellow perch or lake whitefish. A multi-diagrammatic scheme of spawning and incubation seasons, the observed seasonal water level fluctuation and the depth distribution of spawning kokanee is presented in Fig. 6.37. These diagrams enable an analysis of possible effects of maximum and minimum

HYPOTHETICAL MODEL ILLUSTRATING THE EFFECT OF WATER LEVEL FLUCTUATION ON THE INCUBATION HABITAT OF KOKANEES.

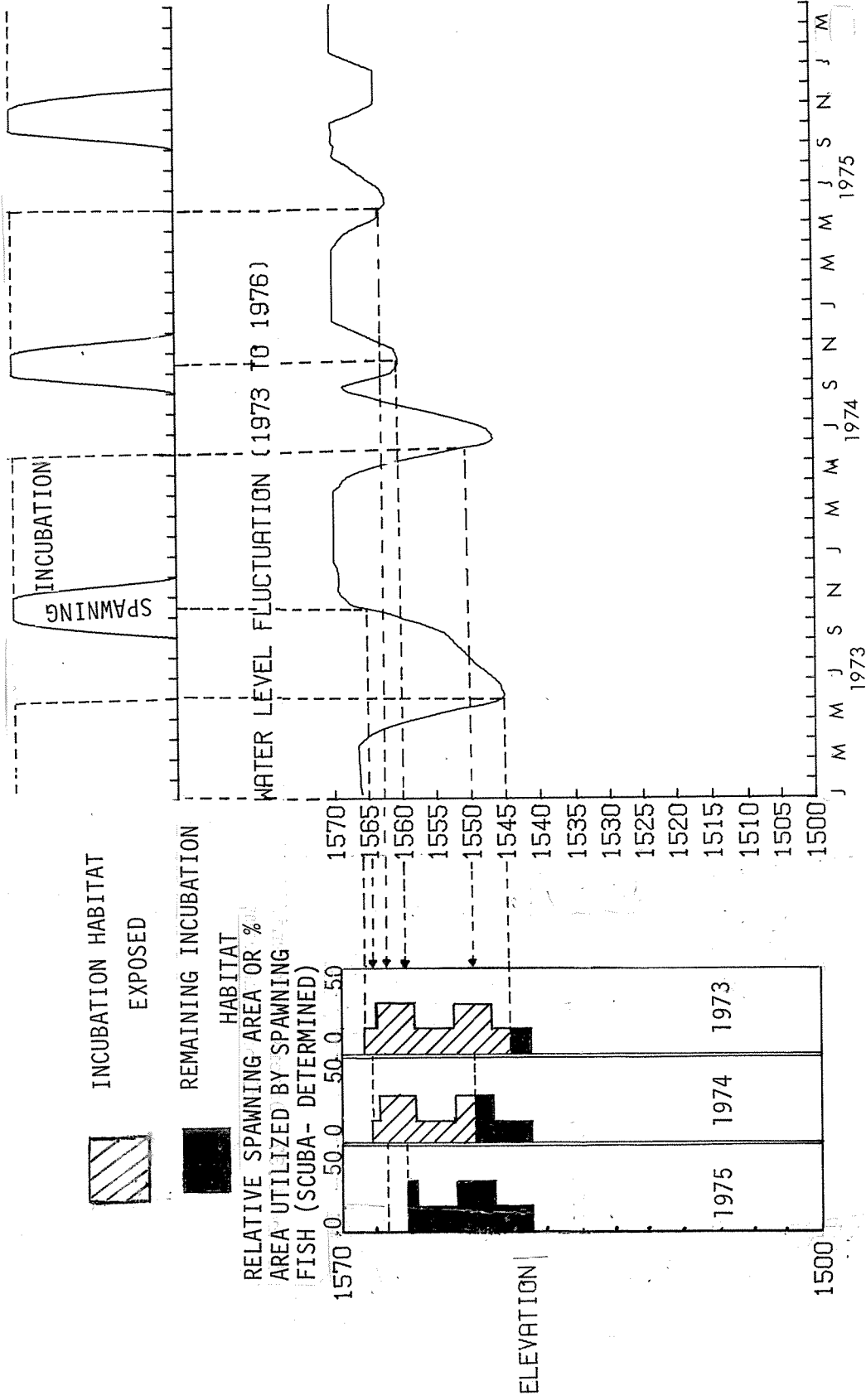


Figure 6.37 Observed spawning and estimated incubation periods (1973-75) of the kokanee salmon, superimposed over the water level regimes for these years, and projected to the histogram of observed spawning depths, illustrating the proportion of incubation habitat exposed by lake level fluctuation.

water level fluctuation on the kokanee spawning and incubation habitat. Kokanee spawned during September, October, and November during an increasing water level which made some additional spawning area available. The maximum lake level occurring on October 15 (peak of spawning) was considered the upper limit of the spawnable area each year, i.e., 1,565 ft in fall 1973 and 1,560 ft in fall 1974. The 1972-73 fall-winter lake level was held at 1,565 ft which reduced the area available to spawners in the fall of 1972. A reduction of the lake level during the spawning season cannot be assumed to shift the spawning distribution downward as in perch because kokanee appear to select two principal shelf areas along shore. Once the eggs were dispersed, the incubation period extended to late May or June on the basis of field observations and calculated development time. During the spring, irrigation drafting began each year resulting in decline of the lake water level. Drafting proceeded for an extended period in 1973 and 1974 without replacement pumping resulting in exposure of large areas of kokanee reproductive habitat utilized during each of these years. Although direct evidence on the effect of drawdown on kokanee eggs and alevins is limited, the magnitude of the spring water level decline correlates well with the observed low year class recruitment two years later. More direct information is needed, however, on the success or failure of the kokanee beach spawning in Banks Lake and the effects of water level fluctuation.

6.3.5 Black Crappie

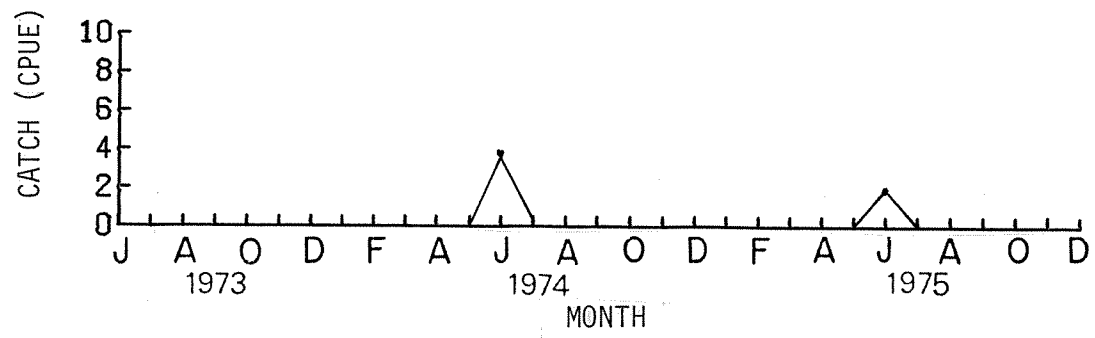
The origin of the black crappie in Banks Lake was probably Lake Roosevelt as indicated by preliminary sampling in the feeder canal. However, the fact that black crappie have been widely introduced to

lakes throughout Washington by the local fishermen suggests this may have occurred at Banks Lake. The black crappie is well established in Banks Lake and supports a substantial sport fishery. The total gill net catch of black crappie was only 38 fish, of which 33 were taken in the summer shoreline sampling. The beach seine captured 855 age 0 black crappie in September, 760 of these at Station 4. The stomach contents of black crappie caught in the gill nets consisted of 57% fish, 10% insects and 8% zooplankton with 25% of the fish empty. Spawning fish have been taken in June 1973. Figure 6.38a illustrates the seasonal spawning distribution of black crappie. The largest fish was a 316 mm, 563 g mature female which was 4 years old. Figure 6.38b illustrates the length-weight relationship of black crappie. The median lengths for each age were determined as follows: 145 mm for age 1 (n = 4); 218 mm for age 2 (n = 46); 234 mm for age 3 (n = 63); and 267 mm for age 4 (n = 4).

6.3.6 Pumpkinseed Sunfish

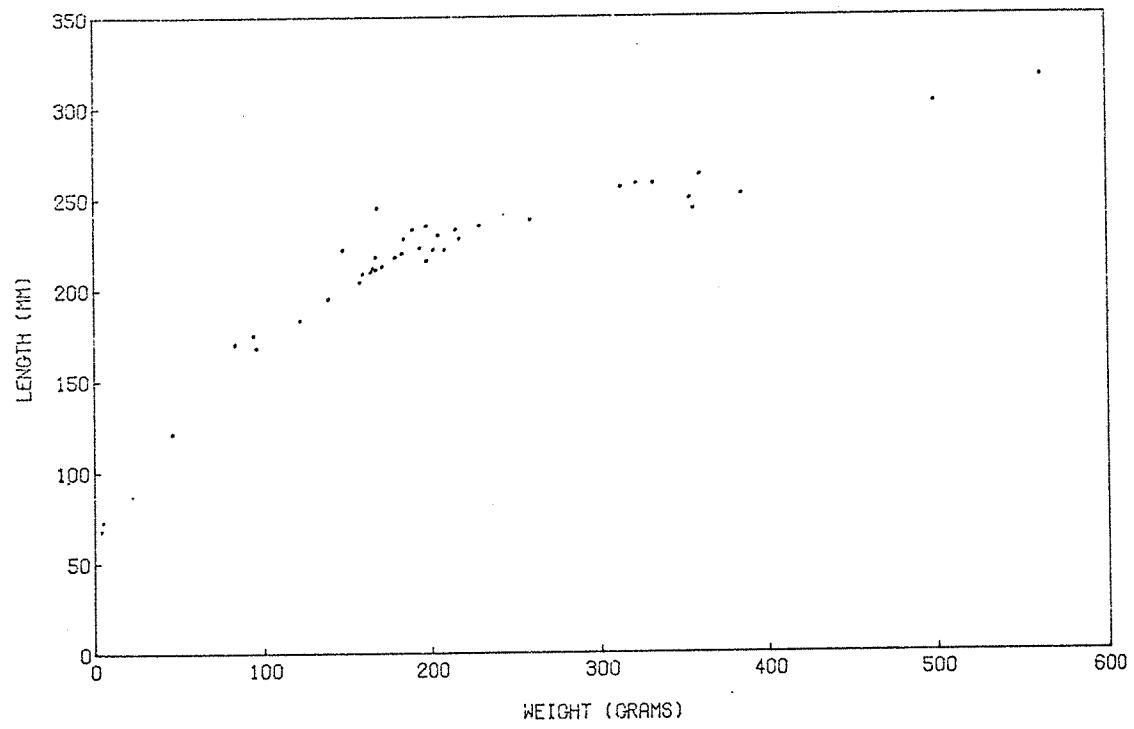
The pumpkinseed sunfish was present in the small lakes prior to the inundation of the Grand Coulee. It was a dominant species in the 1952-54 sport catch. The present sport fishery for pumpkinseed is limited to incidental catches made by shoreline fishermen pursuing other species and is seldom kept, owing to its small size. Thirty-five have been captured in gill nets and 34 of these were taken in the summer shoreline catch. Seventy age 0 pumpkinseed have been taken in the beach seine sampling. Figure 6.39a illustrates the seasonal spawning distribution for pumpkinseed sunfish. The stomach contents of pumpkinseed sunfish in the gill net catch consisted of 23% zooplankton, 24% fish and 23% insects, with 30% of the fish empty. Figure 6.39b illustrates the length-weight

CATCH OF SPAWNING BLACK CRAPPIE



a)

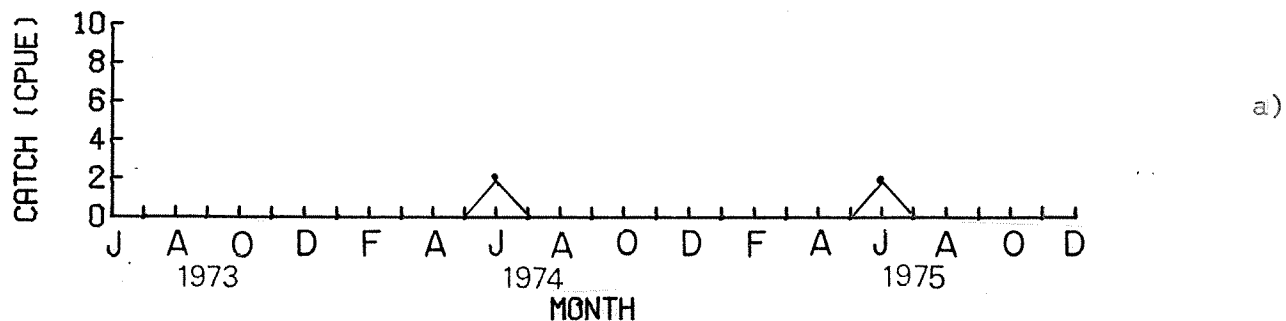
LENGTH-WEIGHT RELATIONSHIP FOR BLACK CRAPPIE



b)

Figure 6.38 a) Catch of spawning black crappie from September 1973 to December 1975.
b) Length-weight relationships for black crappie.

CATCH OF SPAWNING PUMPKINSEED SUNFISH



LENGTH-WEIGHT RELATIONSHIP FOR PUMPKINSEED SUNFISH

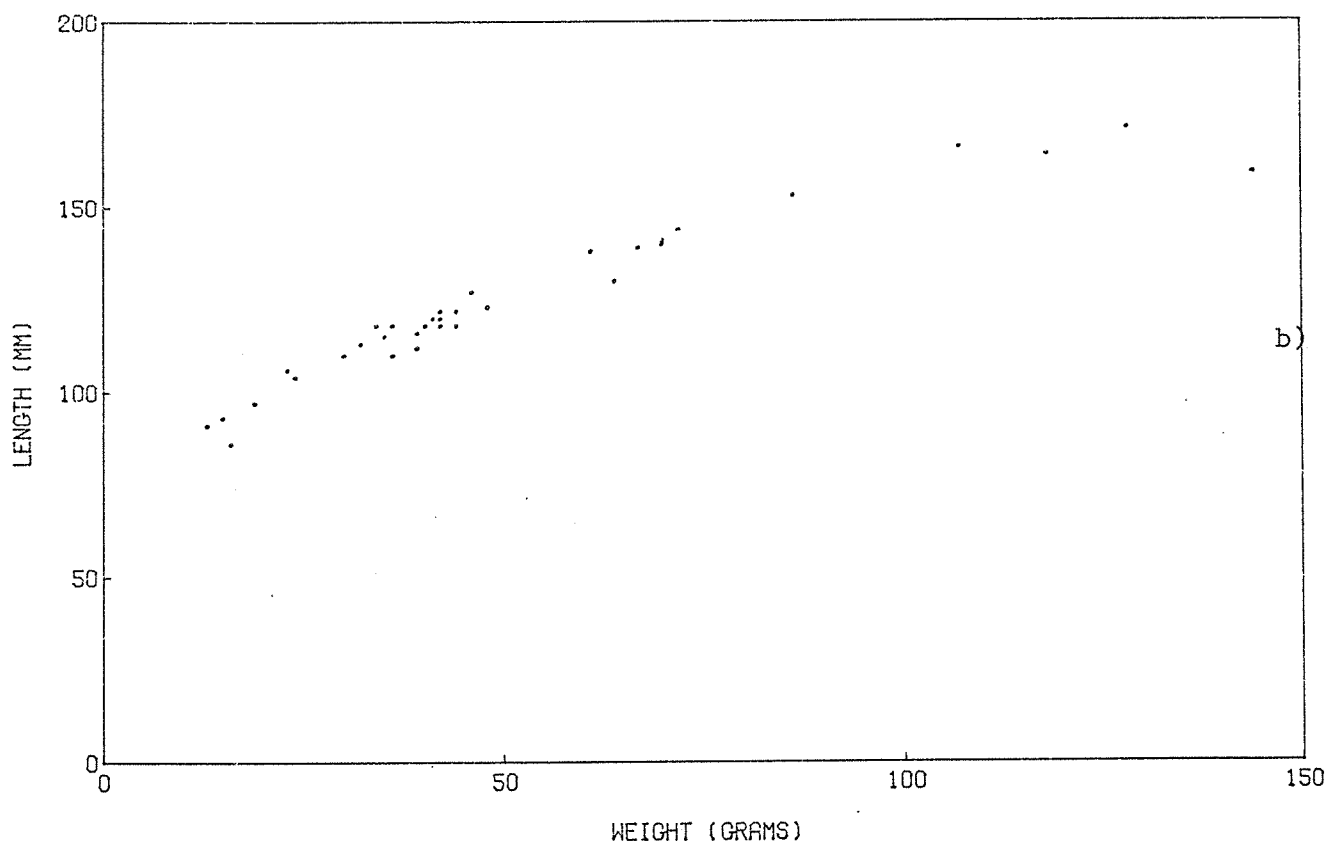


Figure 6.39 a) Catch of spawning pumpkinseed sunfish from September 1973 to December 1975.
 b) Length-weight relationships for pumpkinseed sunfish.

relationship of pumpkinseed at Banks Lake. The largest fish captured was a 184 mm, 103 g mature female taken in the June gillnetting.

6.3.7 Brown Bullhead

The brown bullhead is the only catfish (ictalurid) found in Banks Lake. Its introduction was most likely by local fishermen since it has not been described in Roosevelt Lake. It supports a minor sport fishery in Osborne Bay at the north end of the lake. The total gill net catch of brown bullhead consisted of 23 fish captured in the beach seine hauls at Transects 4 and 6. Figure 6.40a illustrates the seasonal spawning distribution transects of brown bullhead. Figure 6.40b illustrates the length-weight relationship of brown bullhead at Banks Lake. The stomach contents of the gill net catch consisted of 40% fish, 23% eggs, 4% unidentifiable animal debris, and 33% empty. The largest fish was a 337 mm, 793 g female.

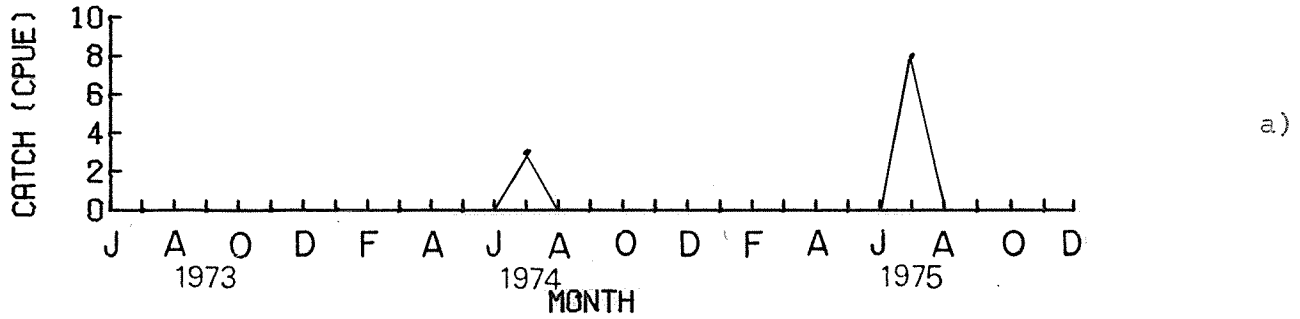
6.3.8 Walleye

The walleye is a native spiny ray which was probably introduced to Banks Lake in the irrigation storage water pumped in from Roosevelt Lake. It was not very abundant and was taken most frequently by fishermen trolling for kokanee. Only 24 fish were taken in the gill net sampling and one age 0 fish in the beach seine sampling. Half of the gill net-caught fish were taken at Transect 1. Three fish contained yellow perch in their stomachs. Figure 6.41 illustrates the length-weight relationship of walleye in Banks Lake. The largest fish was a 667 mm, 3,620 g male which was captured along the shoreline in June.

6.3.9 Burbot

The burbot is a native Gadidae (codfish) which was probably introduced to Banks Lake in the irrigation storage water pumped in from

CATCH OF SPAWNING BROWN BULLHEAD



LENGTH-WEIGHT RELATIONSHIP FOR BROWN BULLHEAD

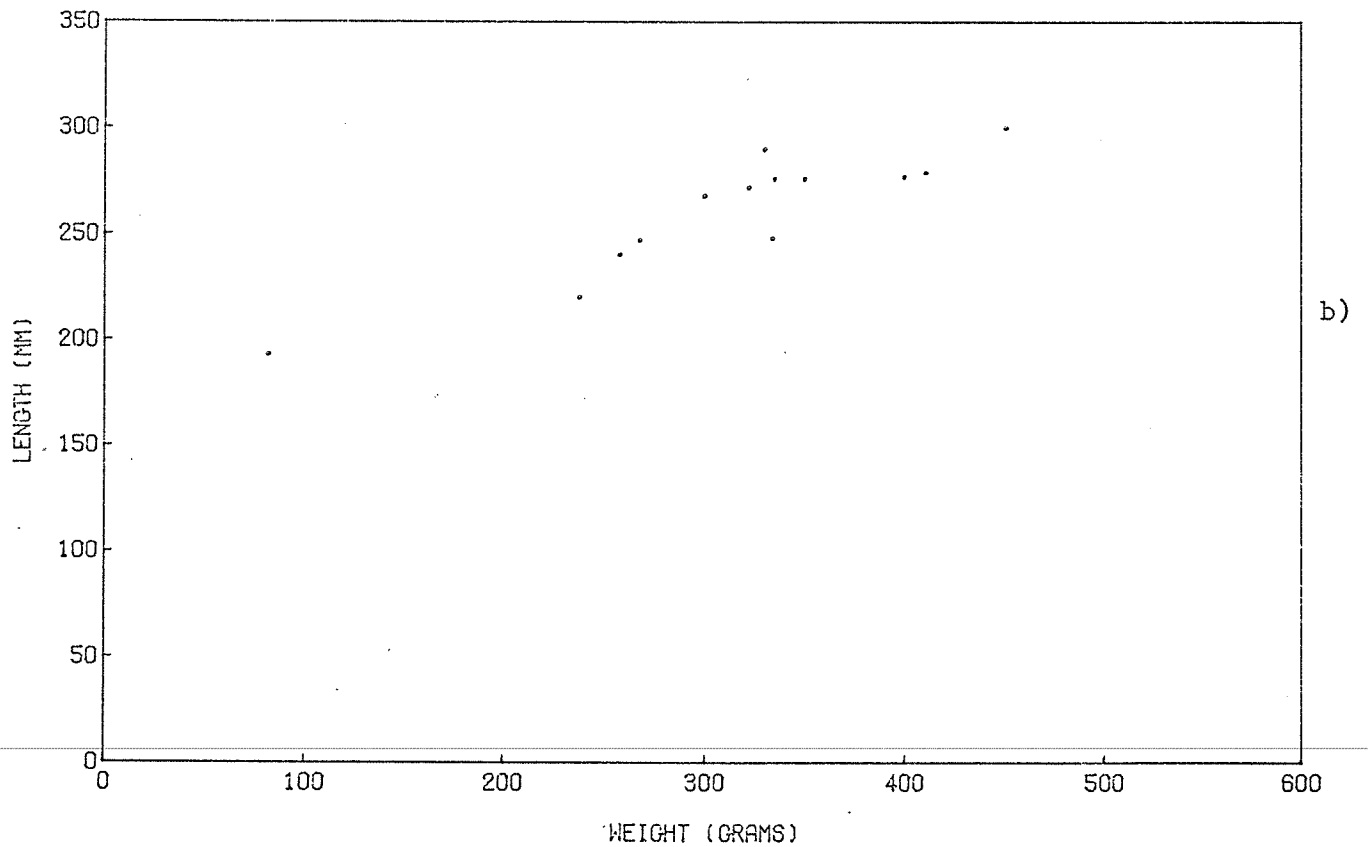


Figure 6.40 a) Catch of spawning brown bullhead from September 1973 to December 1975.
b) Length-weight relationships for brown bullhead.

LENGTH-WEIGHT RELATIONSHIP FOR WALLEYE

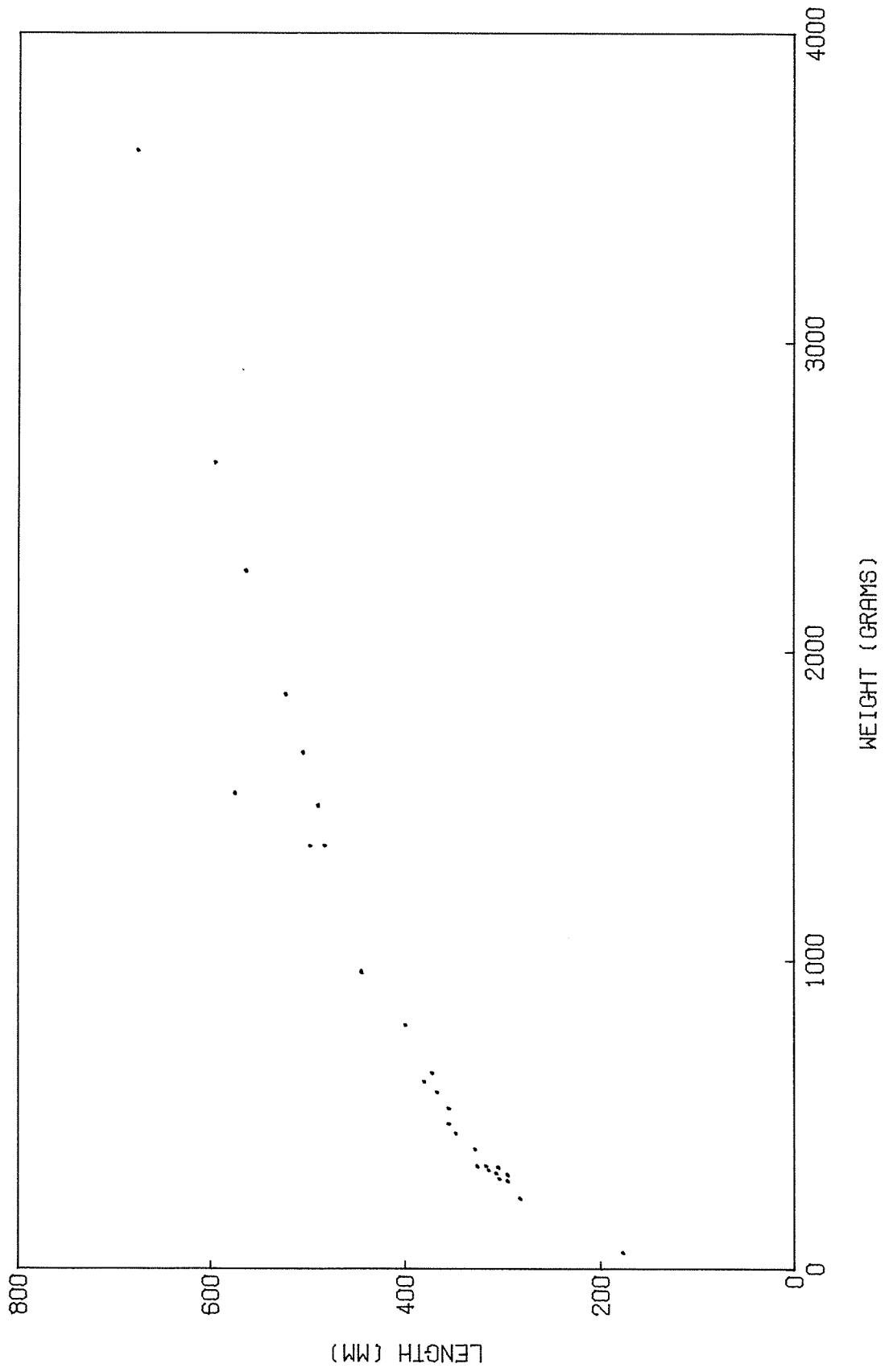


Figure 6.41 Length-weight relationships for walleye.

Roosevelt Lake. The burbot supported a substantial winter fishery in 1965, but since that time has almost disappeared from the lake. Four fish were taken in the offshore gill net catch. Spawning normally took place in winter under ice cover. Spawning, or mature fish were not observed. Age 0 fish were not captured. All four burbot were taken on the bottom and had empty stomachs. The largest fish was a 730 mm, 3,980 g male, which was 7 years old.

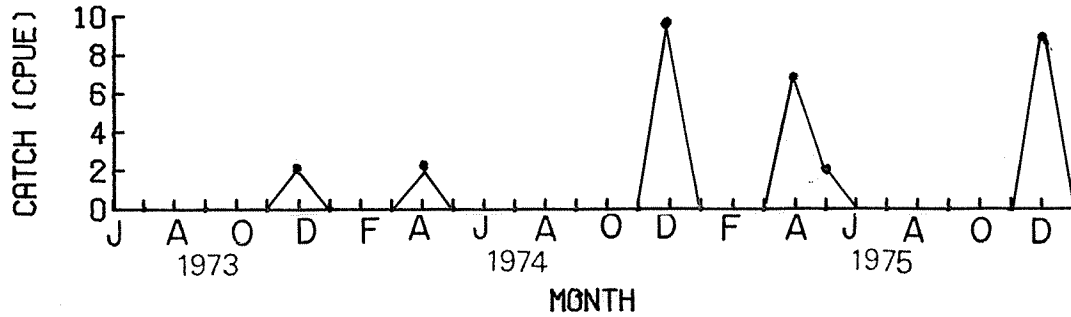
6.3.10 Rainbow Trout

The rainbow trout has been stocked in Banks Lake on an annual basis since 1953. Despite the continued stocking program, the salmonid fishery has always been dominated by the kokanee. The gill net catch of 240 fish appeared to consist primarily of hatchery fish, and distribution between transects was strongly influenced by the fish which were recently introduced. Seven percent of the spring shoreline catch of rainbow trout were spawning fish. Figure 6.42a gives the seasonal spawning distribution for rainbow trout with the unusual occurrence of winter spawners. Native age 0 fish were indentified in the beach seine catch. The stomach contents of 24% zooplankton, 24% fish, 20% insects, 8% detritus and 20% empty. Figure 6.42b illustrates the length-weight relationship of Banks Lake rainbow trout. The largest rainbow captured was a 561 mm, 2,600 g, 5-year-old mature male, in the winter shoreline gill net samples at Transect 6.

6.3.11 Largemouth Bass

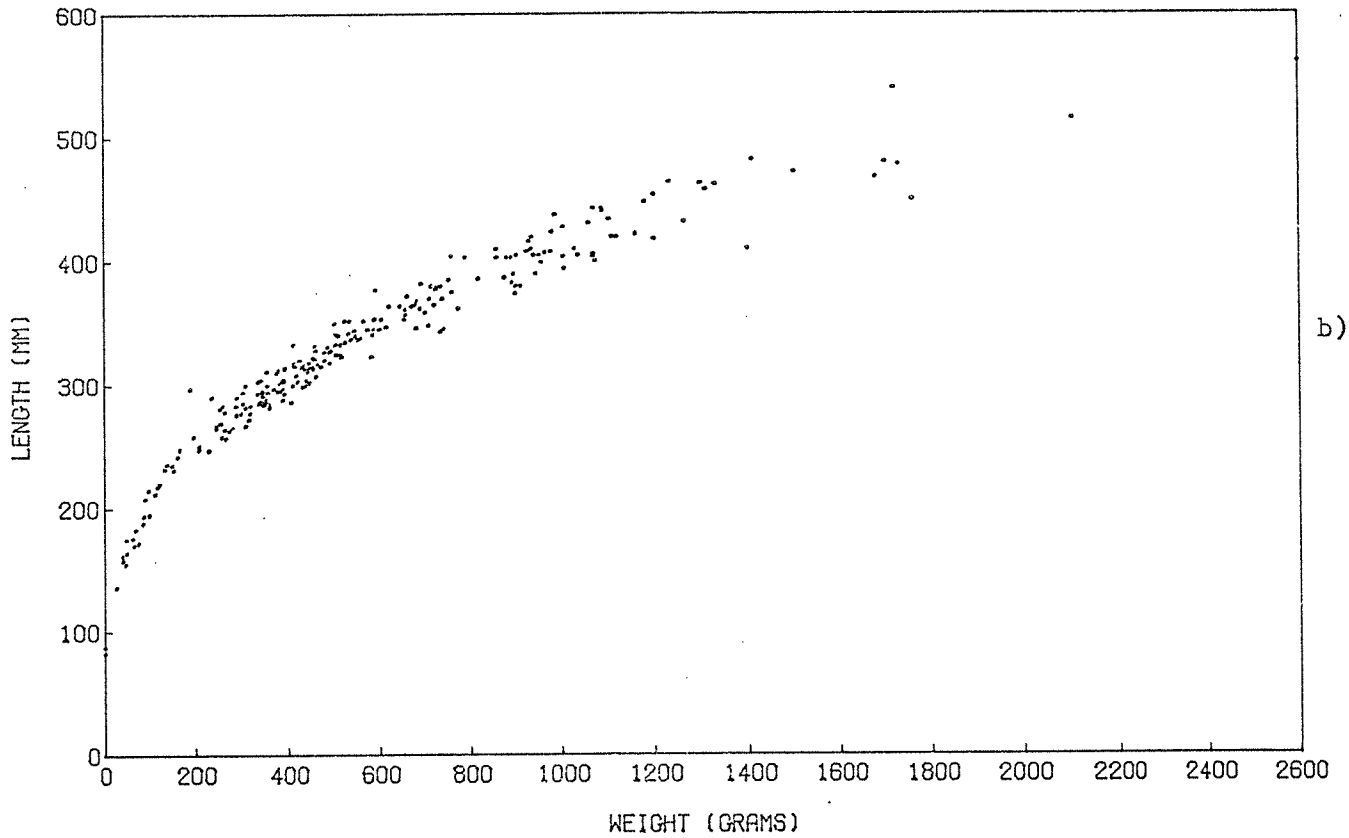
The largemouth bass is an introduced centrarchid which was present in the small lakes of the Grand Coulee prior to inundation. It was the dominant sport fish (along with the pumpkinseed sunfish) in the 1952-54 creel census. Although the present sport fishery catch per unit of

CATCH OF SPAWNING RAINBOW TROUT



a)

LENGTH-WEIGHT RELATIONSHIP FOR RAINBOW TROUT



b)

Figure 6.42 a) Catch of spawning rainbow trout from September 1973 to December 1975.
b) Length-weight relationships for rainbow trout.

effort is lower, the annual catch of bass is approximately the same as in 1952-54. On a comparative basis, Banks Lake is considered to support one of the finest bass fisheries in the State of Washington. Forty-six largemouth bass were taken exclusively inshore with highest gill net catches in June at Transect 4. Large numbers (1,336) of age 0 largemouth bass were taken in the early fall (September) beach seine catch. Twenty-three percent of the bass contained fish in their stomachs, primarily yellow perch. Spawning fish were predominantly taken in June 1974. The median fork length at age was calculated as follows: 122 mm for age 0 (n = 7), 290 mm for age 1 (n = 2); 310 mm for age 2 (n = 10); 400 mm for age 3 (n = 3); 440 mm for age 4 (n = 2) and 550 mm for age 6 (n = 2). The length-weight relationship for Banks Lake largemouth bass is illustrated in Fig. 6.43. The largest bass taken was a 558 mm, 3,980 g spawning male taken in the summer shoreline sampling at Transect 4.

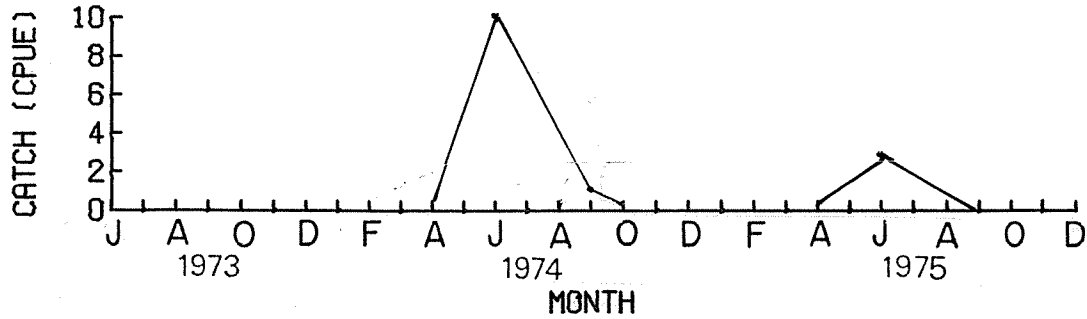
6.3.12 Brown Trout

The brown trout has been described in the Colville River which enters Lake Roosevelt but not for Lake Roosevelt itself. It could have been introduced through the feeder canal or planted by local sport fishermen. Only two individuals have been observed, both taken along the shoreline at Transect 1. The largest fish was a 710 mm, 4,100 g male which was aged at 7 years.

6.3.13 Chinook Salmon

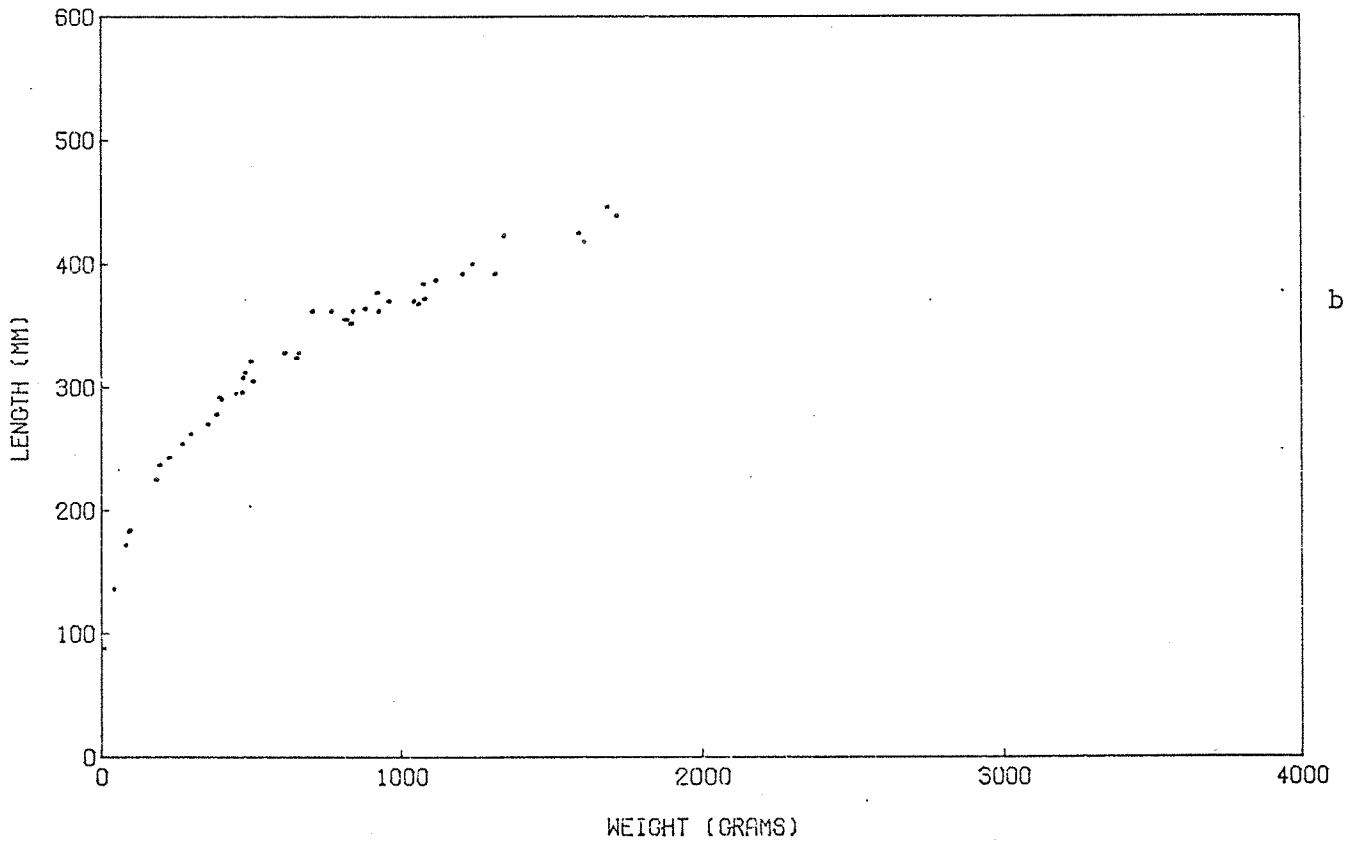
The chinook salmon was introduced to Banks Lake in the fall of 1974 by the Washington Department of Fisheries. Sixty-two chinook salmon were captured in the fall of 1974, 36 offshore and 26 inshore. The offshore catch was made predominantly at the surface. Large numbers of

CATCH OF SPAWNING LARGE MOUTH BASS



a)

LENGTH-WEIGHT RELATIONSHIP FOR LARGE MOUTH BASS



b)

Figure 6.43 a) Catch of spawning largemouth bass from September 1973 to December 1975.
 b) Length-weight relationships for largemouth bass.

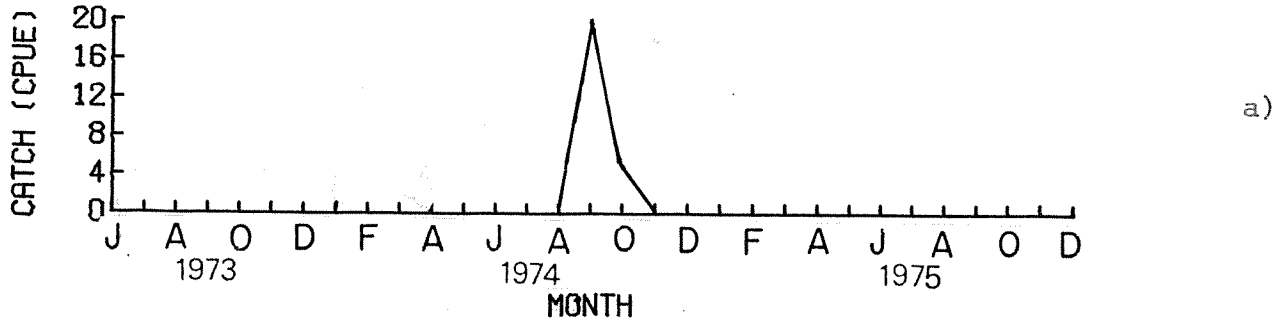
precocious male chinook (jack) were taken the first year (1974) (Fig. 6.44a). Fifty-seven of the 62 chinook salmon captured in September 1974 gill nets were precocious males. The catch decreased in numbers from Transect 1 (the release site) to Transect 6. Stomach contents consisted of 30% fish, 30% zooplankton, 10% contained insects and 30% were empty.

The total length-weight relationships and mean lengths vs. time relationship have been computed (Fig. 6.44b). Assuming a constant growth rate up to maturity at age 4 (the expected lifespan), the salmon may average 700 mm in length and weigh nearly 4,000 g. The largest chinook caught to date was a 700 mm, 7,000 g fish taken in August 1975 in the feeder canal.

6.3.14 Peamouth

The peamouth is a native cypriniform which occurs incidentally in the creel. Its introduction is assumed to be from Roosevelt Lake through the feeder canal. They appear well-established in Banks Lake, with 491 caught in the gill nets and 975 taken by beach seining. The shoreline gill net catch was largest in spring and early summer when mature and spawning fish dominated the catch. Figure 6.45a illustrates the seasonal spawning distribution of peamouth. The offshore gillnet catch was largest in the spring and fall; the majority of the catch was taken at Transect 1 from surface to 10 m depth. Stomach contents consisted of 82% zooplankton and the remaining 18% empty. Age 0 fish with a mean length of 15 mm were first taken in July by beach seining. The length-weight relationship for peamouth is illustrated in Fig. 6.46. The growth rates of age 0 resident peamouth at Transect 1 lagged behind those at Transects 4-6 combined, a result similar to that for age 0 yellow perch growth.

CATCH OF SPAWNING CHINOOK SALMON



LENGTH-WEIGHT RELATIONSHIP FOR CHINOOK

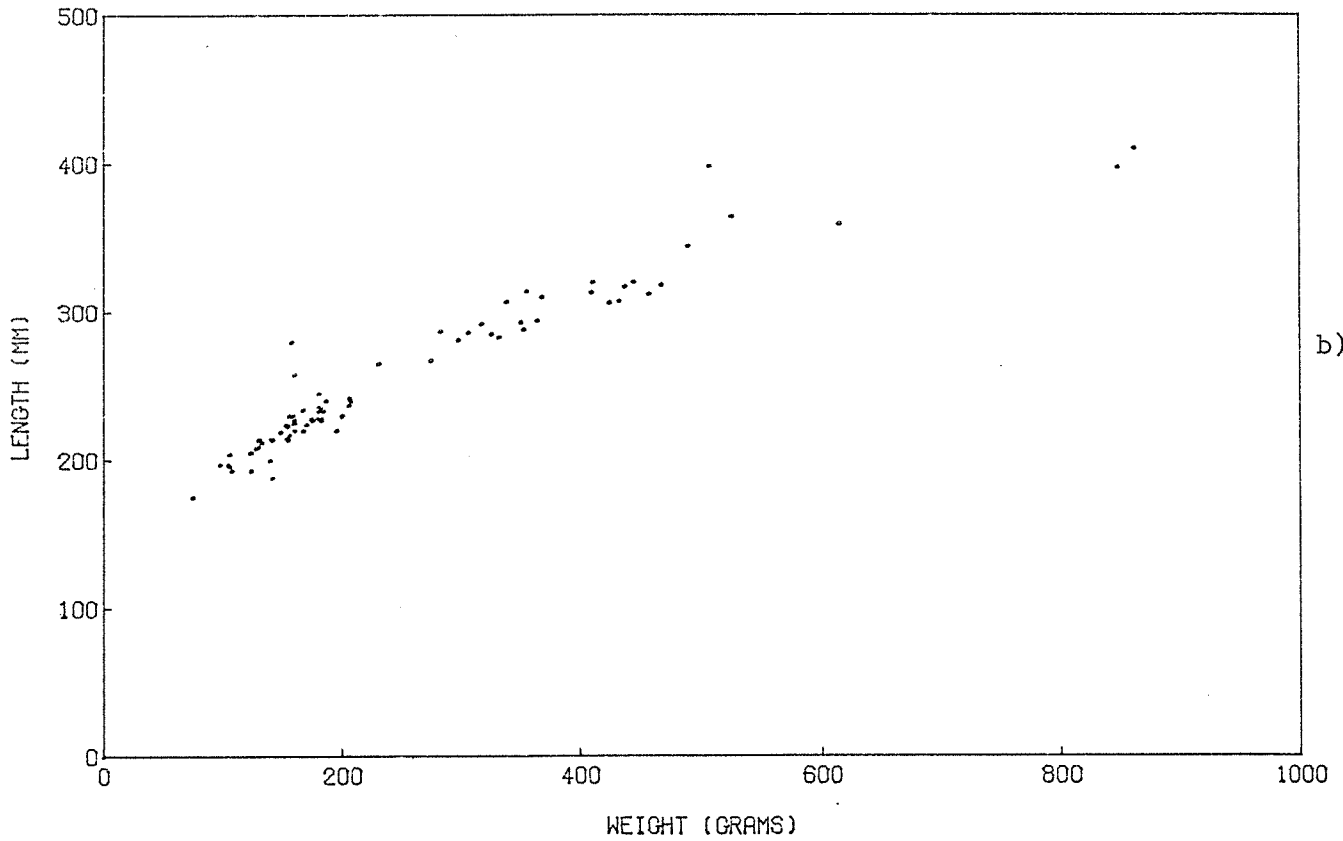
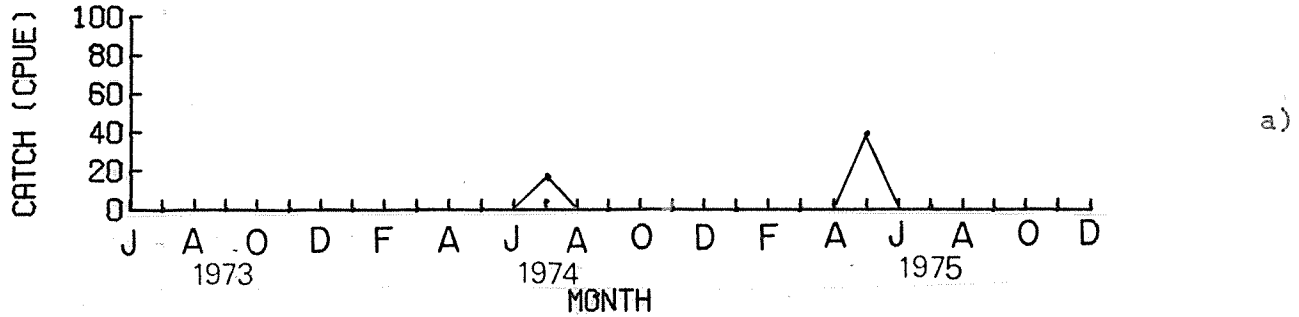


Figure 6.44 a) Catch of spawning chinook salmon from September 1973 to December 1975.
b) Length-weight relationships for chinook salmon.

CATCH OF SPAWNING PEAMOUTH



LENGTH OF AGE 0 PEAMOUTH (MEDIAN)

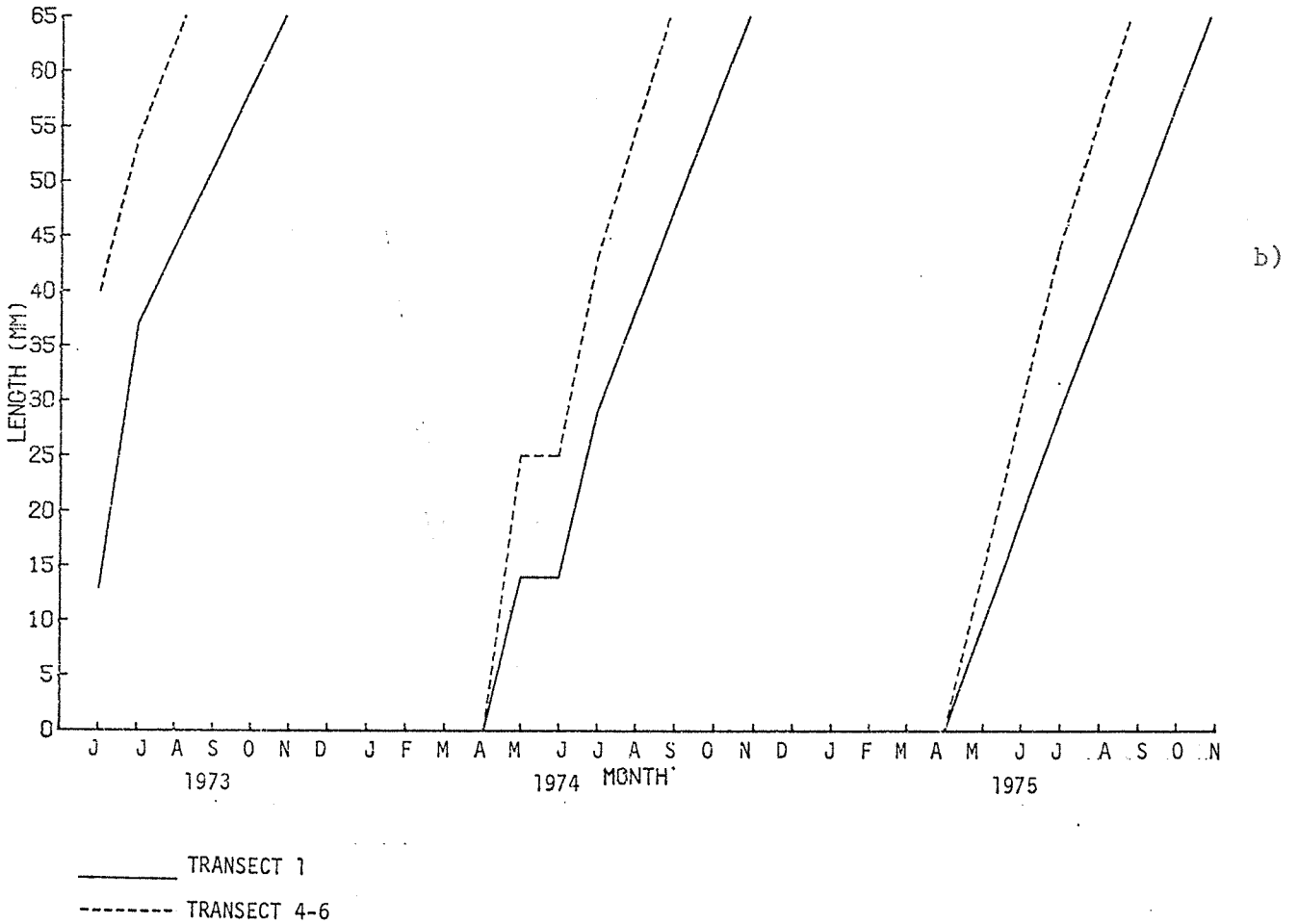


Figure 6.45 a) Catch of spawning peamouth from September 1973 to December 1975.
b) Median length of age 0 peamouth.

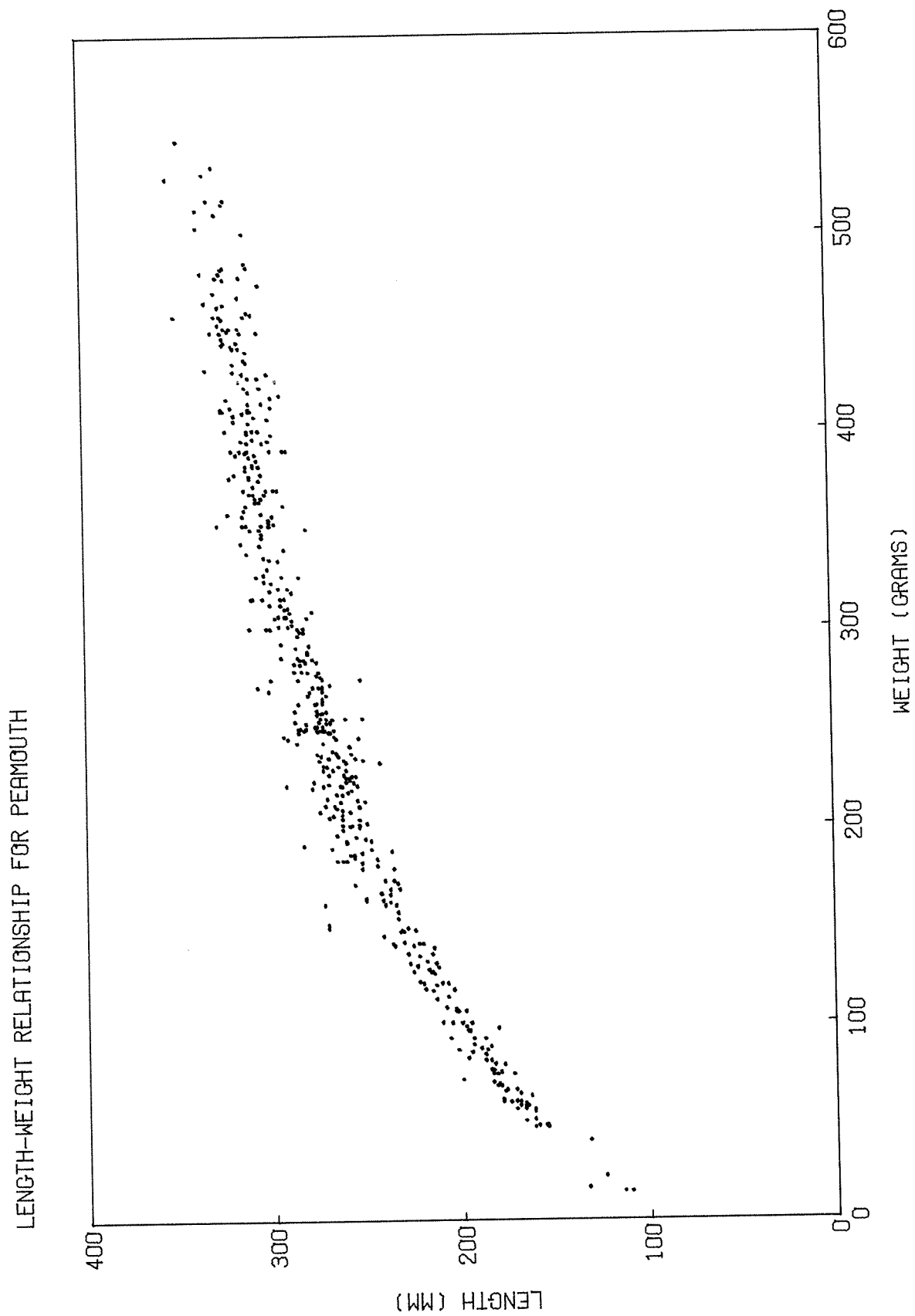


Figure 6.46 Length-weight relationships for peamouth.

(Fig. 6.45b). The largest peamouth taken was a 352 mm, 497 g female which was 4 years old.

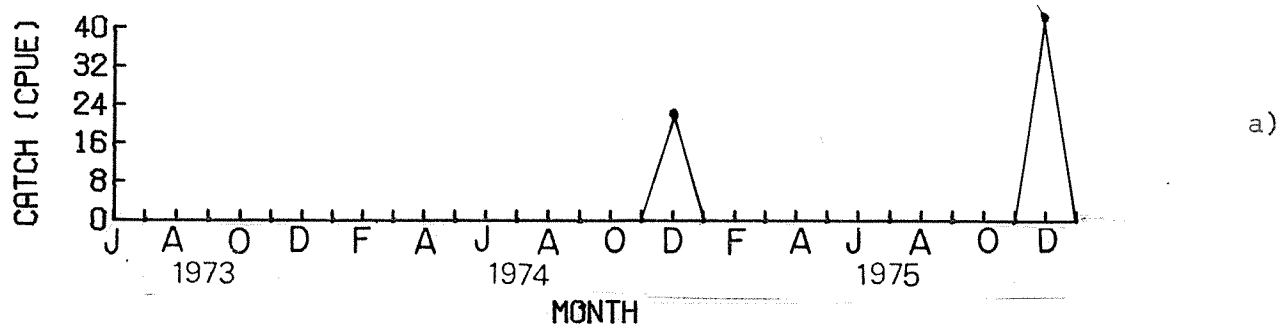
6.3.15 Mountain Whitefish

The mountain whitefish is native to the Columbia River and was first described in Roosevelt Lake by Gilbert and Evermann (1894). It appears incidentally in the creel and is separated from the lake whitefish. Ninety-one mountain whitefish were taken in the gill net sampling with highest catches made during the winter spawning season (Fig. 6.47a). Twenty-five age 0 fish were taken in the beach seine catch. Stomach contents consisted of 30% zooplankton, 8% insects, 20% eggs and 12% detritus, with 30% of the fish empty (n = 41). Figure 6.47b illustrates the Banks Lake mountain whitefish length-weight relationship. The largest fish was a 398 mm, 508 g mature male taken in the winter gill net sampling.

6.3.16 Longnose Sucker

The longnose sucker is a native cypriniform which was assumed to have been introduced from Roosevelt Lake through the feeder canal. They appear well-established and represent the second most abundant non-game species taken in the gill net sampling (4% of the total gillnet catch, or 424 fish). The largest gill net catches of longnose sucker were made in the spring and early summer at Transect 1. During spring both the offshore and the inshore gill net catches consisted of mature and spawning fish (Fig. 6.48a). The longnose sucker was taken almost exclusively in the bottom 2 m of the water column. Stomach contents consisted of 22% algae and 78% unidentifiable debris. Total number of age 0 fish taken by beach seining was 1,470. Figure 6.48b illustrates the length-weight

CATCH OF SPAWNING MOUNTAIN WHITEFISH



LENGTH-WEIGHT RELATIONSHIP FOR MOUNTAIN WHITEFISH

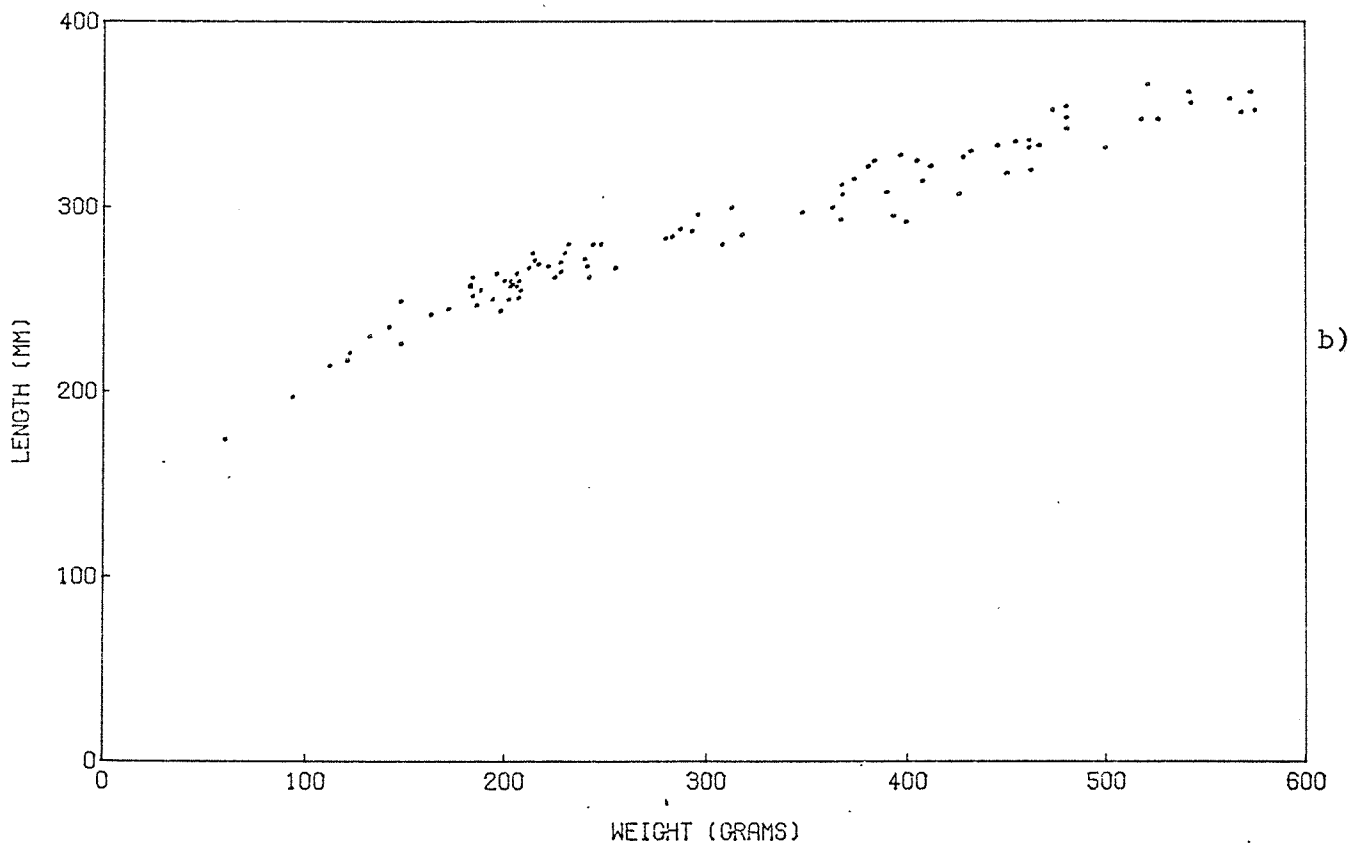
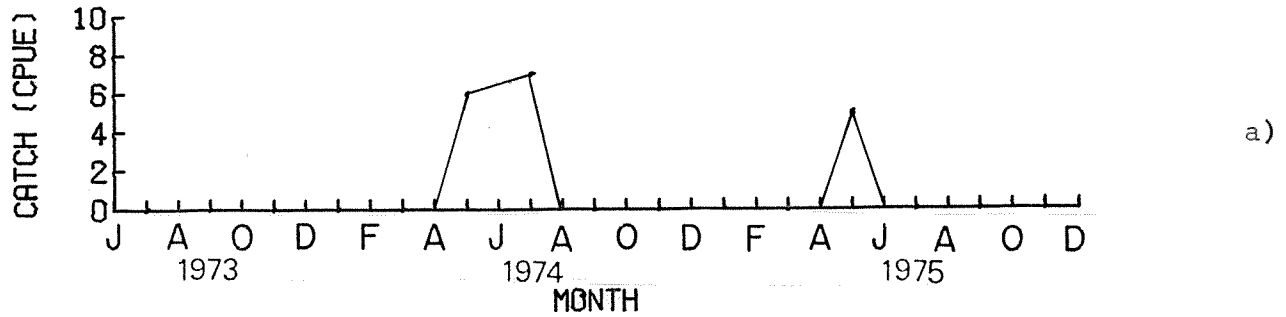


Figure 6.47 a) Catch of spawning mountain whitefish from September 1973 to December 1975.
 b) Length-weight relationships for mountain whitefish.

CATCH OF SPAWNING LONGNOSE SUCKER



LENGTH-WEIGHT RELATIONSHIP FOR LONGNOSE SUCKER

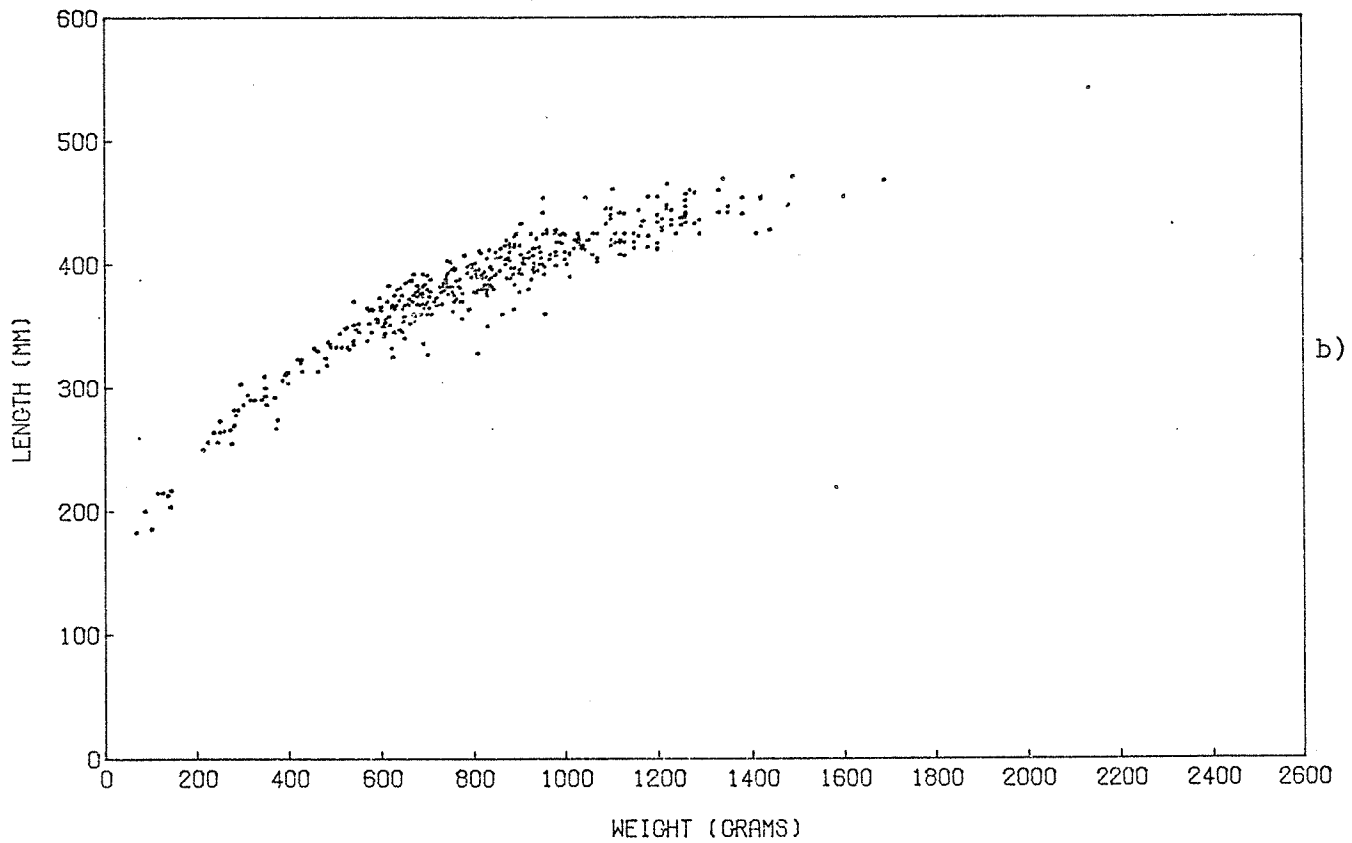


Figure 6.48 a) Catch of spawning longnose sucker from September 1973 to December 1975.
 b) Length-weight relationships for longnose sucker.

relationship for longnose sucker. The largest longnose sucker was a 461 mm, 1,270 g mature female.

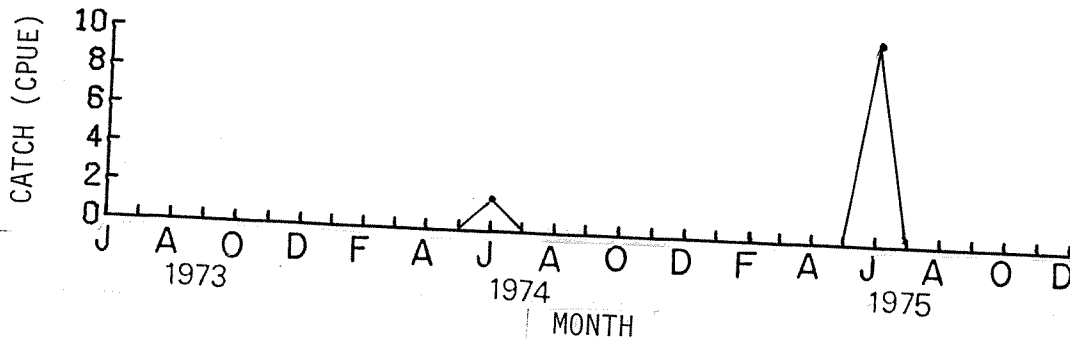
6.3.17 Carp

The carp is a cypriniform which was assumed to have been introduced from Roosevelt Lake through the feeder canal. They appear to be well-established; the largest catches were made at Transects 1 and 6. Spawning occurred during June (Fig. 6.49a). The gill net catch of 88 fish was almost exclusively restricted to the shoreline, and was largest in the summer. Beach seining produced 217 age 0 fish. Algae was the only food type observed in carp stomachs, but adult carp were observed actively feeding on larval stages of yellow perch. Figure 6.49b illustrates the carp length-weight relationship. The largest carp taken was a 798 mm, 8,440 g female which was estimated to be 7 years old.

6.3.18 Prickly Sculpin

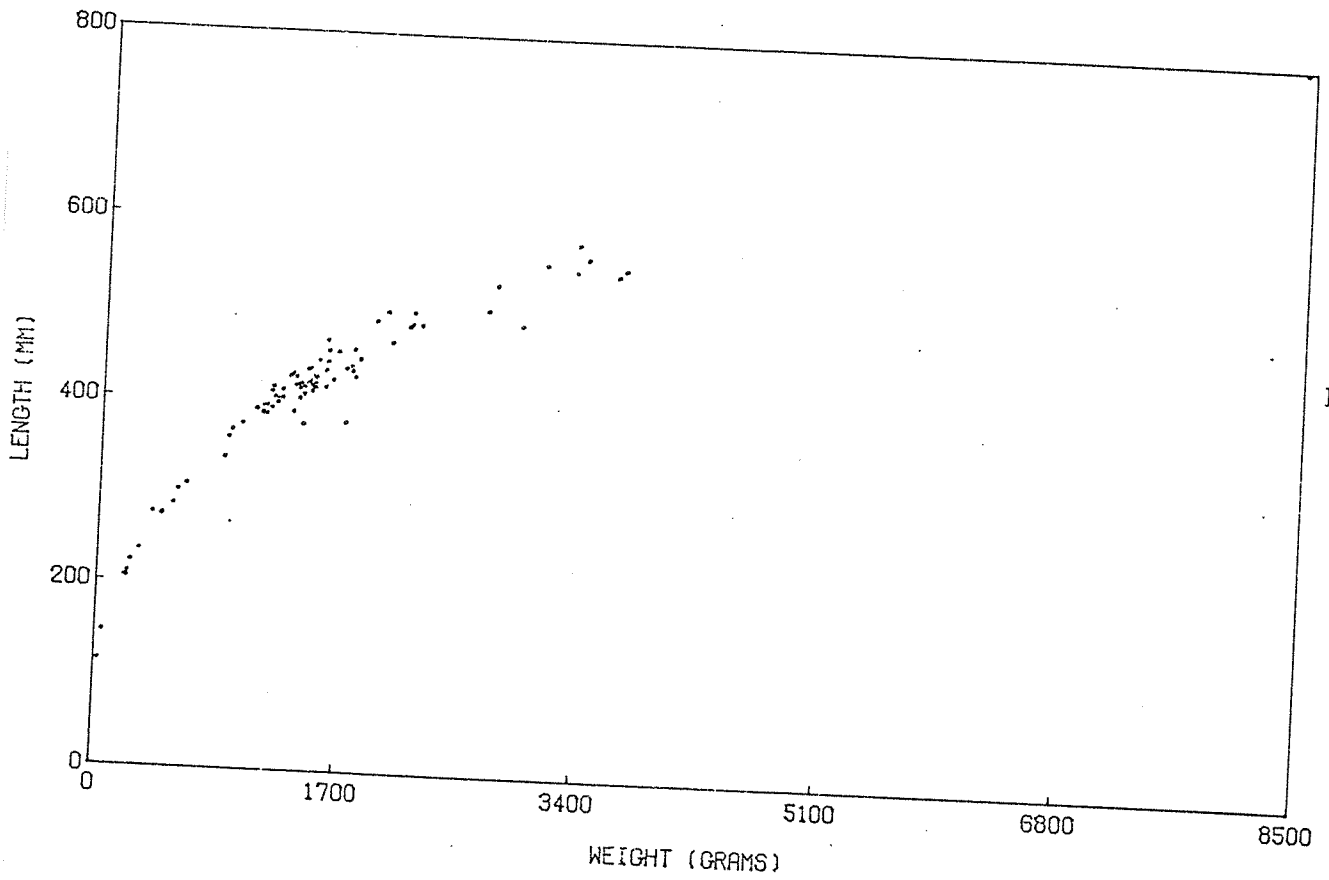
The prickly sculpin, *Cottus asper*, was the only cottid identified in the catch. This species is indigenous to the Pacific Northwest and was probably introduced from Roosevelt Lake by the feeder canal. The prickly sculpin was the most abundant non-game species in the catch and was taken almost exclusively by the beach seine gear (n = 2,667). The largest beach seine catches were made at Transect 1 in June when the first age 0 fish of the season were captured. The largest fish was a 160 mm, 92 g female taken in a shoreline gill net set. A 155 mm specimen taken in the winter shoreline samples was full of whitefish eggs. The growth rates of age 0 residual sculpin at Transect 1 lagged behind those at Transects 4-6 combined, which was similar to age 0 yellow perch and peamouth growth results (Fig. 6.50).

CATCH OF SPAWNING CARP



a)

LENGTH-WEIGHT RELATIONSHIP FOR CARP



b)

Figure 6.49 a) Catch of spawning carp from September 1973 to December 1975.
b) Length-weight relationships for carp.

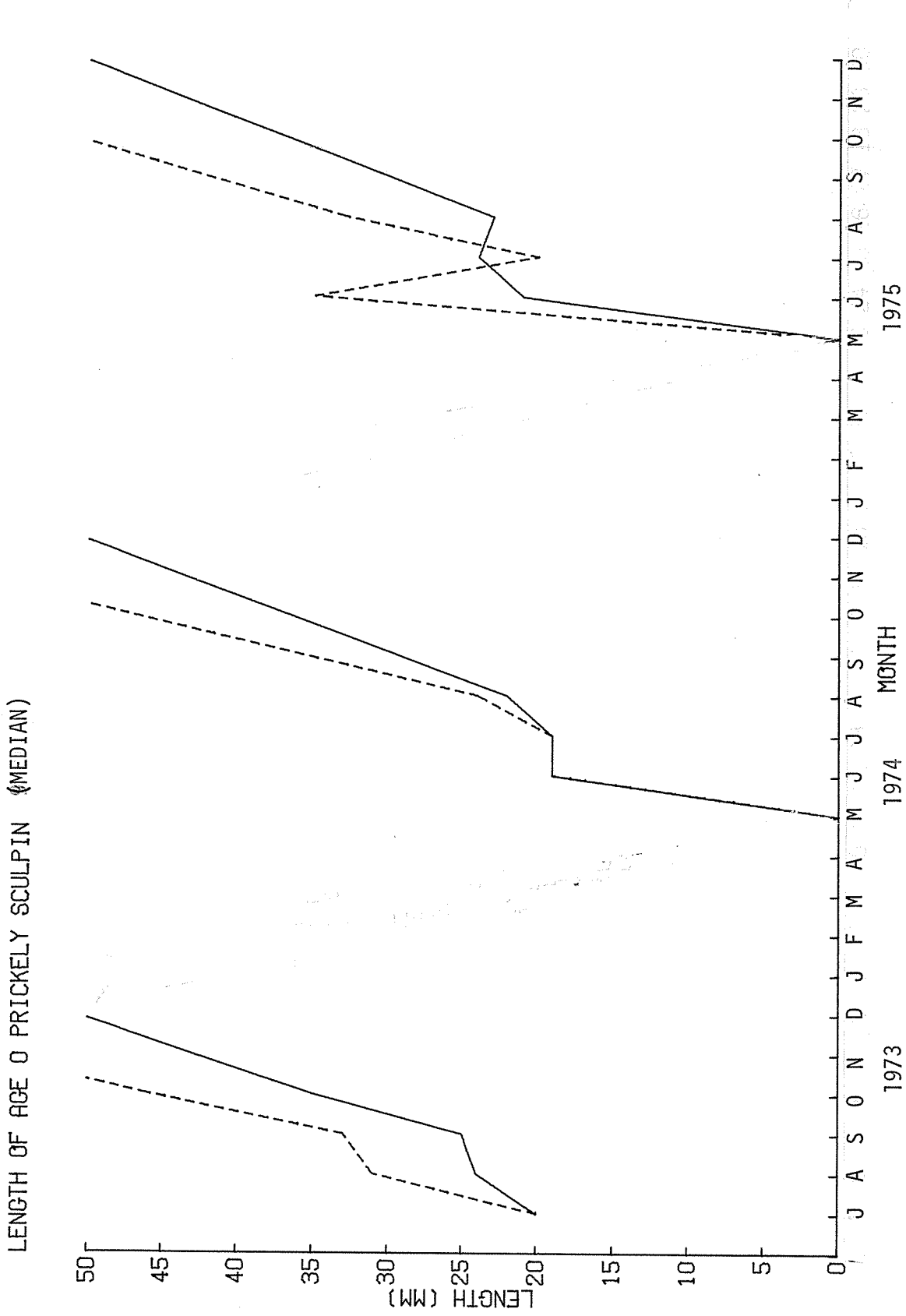


Figure 6.50 Median length of age 0 prickly sculpin.

— Transect 1
 - - - Transects 4-6

6.3.19 Largescale Sucker

The largescale sucker is a native cypriniform which was assumed to have been introduced from Roosevelt Lake through the feeder canal. Only 35 individuals of this species have been captured in the gill nets with 26 of these taken along the shoreline at Transect 1. The largest fish was a 528 mm, 2,180 g spawning female taken in the spring.

6.3.20 Northern Squawfish

The northern squawfish is a native cypriniform which was assumed to have been introduced from Roosevelt Lake by the feeder canal. Ten squawfish have been taken at Transect 1 in the gill nets and four age 0 fish in the beach seining. The largest fish was a 528 mm, 2,570 g mature female taken in the spring. It is interesting to note that northern squawfish do not appear to have invaded the entire lake even though abundant in Lake Roosevelt.

7.0 SPORT FISHERY 1975-76

7.1 Introduction

The history of the Banks Lake sport fishery shows that it has been very dynamic since creation of the lake in 1951. The composition and size of the catch has undergone substantial changes from predominantly largemouth bass and sunfish to yellow perch and kokanee (Fig. 6.1). A dramatic increase in sport fishing effort has also occurred throughout this period and the fishery continues to increase. A creel census immediately preceeding routine seasonal operation of P/G 7 and 8 was necessary to assess the state of the sport fishery catch and effort. Creel censuses conducted by the Washington Department of Game in 1965 (Spence 1965) and in 1971-72 (Duff 1972) have documented the following changes in the intervening six-year period: fishing effort, +317%; rainbow catch, -37%; kokanee catch, +313%; burbot catch, -92%; perch catch, +425%; walleye catch, +226%; whitefish catch, +248%.

Because of these relatively rapid pre-pump generation changes in the sport fishery, an updated estimate of the sport catch and effort was necessary to identify possible effects of P/G operation. A creel census was also essential to recover marked rainbow trout to provide data on movement and migration. Determination of the size of the sport catch of each species during simultaneous sampling in the lake and canals provided comparative data essential to assessment of the fishery resource.

7.2 Methods

7.2.1 Data Acquisition

The creel census was designed to be comparable with the 1971-72 census by Duff and consequently employed similar methods. Each daily census was conducted by driving the length of Banks Lake and checking the principal angler access locations including boat launch ramps and popular shoreline fishing areas within reach of access roads.

Duff's data showed a 70-30 division in percentage of fishing effort between summer and winter months, therefore sampling days for the present study were apportioned accordingly. Further, because the fishing effort was considerably greater during weekends and holidays, the sampling days were apportioned equally during weekend days and weekdays. Sixty sample days were selected for the year, beginning April 1, 1975, with 42 days devoted to the period April through October, and 18 days from November through March. Saturdays and Sundays were selected alternately and weekdays were selected progressively. Sampling times during sample days were established initially but abandoned shortly after the census began. It became apparent that little information would be obtained from early morning censuses, because boats tended not to return until late afternoon or evening and winter bank anglers generally did not begin fishing until mid- or late morning. Thereafter, each census was conducted during afternoon and evening during the summer and during afternoons in the winter.

A daily census entailed driving from north to south, starting at the feeder canal and finishing at the west end of the South dam. All access areas were sampled except for the Barker Canyon boat launch,

which was omitted due to its remoteness and the time required. Generally, all areas were checked on the return to the north end. The round trip averaged 75 miles and required from 1.5 to 5 hours, depending on angler density.

The census data were recorded directly onto coding sheets under two general categories: interview and non-interview. Interview data were obtained during direct contact with anglers, while non-interview data pertained to such information as the number of empty boat trailers parked at a launch ramp. The data included the following information:

I. General

- A. Date
- B. Location
- C. Time

II. Interview Data

- A. Time fishing began
- B. Estimated termination of fishing
- C. Lengths and weights of catch, by species
- D. Number of anglers in party

III. Non-Interview Data

- A. Empty boat trailers
- B. Boats on trailers
- C. Empty car-top carriers
- D. Boats on car-top carriers
- E. Boats at the beach or dock
- F. Bank anglers not interviewed

7.2.2 Data Analysis (Boat Fishery)

Because of marked differences in the seasonal timing and catch composition of the boat and bank fisheries, the analysis and reporting of these data were done separately. The boat fishery operated principally during the summer months from April through September and concentrated mainly on kokanee and bass. The bank fishery operated throughout the year and concentrated mainly on perch, crappie and rainbow trout.

The principal statistics presented herein are the catch per unit of effort (CPUE) and the estimated catch by species. The CPUE is expressed in angler-hours and both statistics are summarized by month.

Analysis of the boat fishery was hampered by lack of interview data because boat anglers could only be contacted within a few minutes of the time they returned to the launch ramp. Because of the difficulty in obtaining interviews, the non-interview data (empty trailers and boat racks) became a very important supplement to the boat fishery data. It was assumed that all empty boat trailers and empty car top racks represented boats on the water. However, it was recognized early in the study that biases were inherent in the use of these data, therefore considerable effort was spent attempting to minimize bias by developing correction factors. For example, the empty trailer counts were an unknown fraction of the total boats launched for a given day. Thus, it was necessary to establish a rate of exchange, or boat turn-over rate. Also, since a variety of boating activities occurred on the lake, it was necessary to determine the percentage of boats actually engaged in fishing. In some cases, it was possible to adjust the fishing effort data for boats which exclusively sought certain species such as bass in the vicinity of the narrows and kokanee in the Million Dollar Mile area.

The correction values were determined by conducting intensive creel censuses, bi-monthly during the summer, in which observers were stationed at the launch ramps for at least several hours to record boat launchings and take-outs and the types of boating activity. Additional information on boat turn-over rate was obtained monthly by recording the license numbers of all vehicles parked at the launch ramps at bi-hourly intervals throughout the day.

The following equations were used to calculate fishing effort and catch statistics:

$$E_e = BRAT$$

where:

E_e = estimated fishing effort in angler-hours

B = estimated boats fishing during surveys

R = mean daily turn-over rate of boats

A = mean anglers per boat

T = mean angler fishing time

$$CPUE = C_o E_e^{-1}$$

where:

CPUE = catch per unit of effort

C_o = observed catch per angler-hour

$$C_e = E_e \times (CPUE)$$

where:

C_e = estimated total catch

These statistics were calculated on a monthly time basis.

The boat turn-over rate was greater for the north end of Banks Lake than for the south end; 3.0 for Electric City and Old Steamboat Park access areas; and 2.0 for all other areas.

The other principal boating activity was water skiing, which accounted for 11% of the launchings from June through September. This value was established from observations of boating activity on the water as well as from intensive censuses at the launch ramps.

7.2.3 Data Analysis (Bank Fishery)

Calculation of the effort and catch statistics for the bank fishery was more direct, with one exception, than for the boat fishery because it involved principally interview data which were directly convertible into CPUE. However, where the boat interviews dealt with completed trips, the interviews of bank anglers were usually for incomplete trips. It was necessary therefore to adjust the angler-hours with correction factors when determining the estimated catch. The mean angler-hours was determined by two methods: 1) Questionnaire postcards were prepared and given to bank anglers to fill out and return upon completion of their trips. These cards asked for information on date, fishing location, catch, and hours fished; 2) Anglers were asked during the interviews to estimate the termination time of their trip.

Method 1 provided the most accurate and useful information but involved greater effort and expense. Also, the return rate of cards, initially high, dwindled after anglers had responded once or twice. The estimates of trip duration based on method 2 compared closely with the information from the questionnaire card returns. These were easily obtained and considered an adequate basis for adjusting the mean angler-hours.

The following equations were used to calculate fishing effort and catch statistics for the bank fishery:

$$E_e = RAT$$

where:

E_e = estimated fishing effort in angler hours

R = mean daily turn-over rate of anglers

A = mean anglers observed and interviewed during surveys

T = mean daily angler fishing time

$$CPUE = C_o E_e^{-1}$$

where:

CPUE = catch per unit effort

C_o = observed catch per angler-hour

$$C_e = E_e \times (CPUE)$$

where:

C_e = estimated total catch

The daily turn-over rate among bank anglers was determined by replicate census to be 1.5. The mean fishing time per trip was longest during the summer months (4.5 hours) and shortest during December (4.0 hours).

Catch and effort means were calculated monthly. During the summer months, when censuses were conducted frequently, sufficient data were obtained to calculate separate means for weekend days and weekdays. Separate means could not be calculated for the winter months because of insufficient weekend censuses. Alternatively, the weekend effort was estimated by summarizing the winter data, which showed 2.3 times more anglers during weekend days than during weekdays.

7.3 Results and Discussion

7.3.1 Catch and Effort

The census results are based on interviews of 1,386 anglers on 73 days from April 1, 1975 to March 31, 1976. An estimated total of 350,866 hours was expended to catch an estimated 173,695 fish, or about 0.5 fish per angler-hour. Censuses were conducted on 41 days during the summer months and on 32 days during the winter months.

The effort, catch per unit of effort, and estimated catch for the seven most commonly caught species in the boat and bank fisheries are summarized for the period April-September 1975 (Table 7.1) and October 1975 - March 1976 (Table 7.2). These species in order of decreasing abundance in the catch were: kokanee, 43.2%; perch, 34.4%; rainbow, 11.1%; chinook, 4.7%; crappie, 3.7%; sunfish, 2.0%; and bass, 0.6%.

The boat fishery began early in April, continued actively through September, and diminished during the first half of October. Little boat fishing occurred after mid-October. Kokanee was the species most sought by the boat fishery. Because kokanee were fished principally by trolling offshore, the fishery was easily identified. Observations of the boat fishery made from promotories at several locations along the length of Banks Lake indicated that 92% of the boats seen were engaged in fishing for kokanee and that 8% were fishing for spiny-rayed fish. A majority of the rainbow and chinook catch was made incidentally in the offshore troll fishery.

The bank fishery was most active from January through May, and was least active in December. Bank fishing began with the formation of solid ice along the South Dam, and at Devil's Punchbowl and occurred

Table 7.1 Summary of the Banks Lake sport fishery and catch per unit of effort, April through September 1975.

Month	Fishery	Total Fishing Effort (hr)	Rainbow		Kokanee		Chinook		Perch		Crappie		Bass		Sunfish	
			Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
Apr.	Boat	33,531	2,261	0.067	3,284	0.097	1,434	0.042	964	0.251	1,377	0.410	0	0	13	0.004
	Bank	7,025	553	0.078	97	0.014	240	0.034	2,910	0.414	1,677	0.239	67	0.010	31	0.004
		40,556	2,814		3,381		1,674		3,874		3,054		67		44	
May	Boat	79,926	2,218	0.027	25,250	0.316	2,282	0.028	1,585	0.198	1,471	0.184	169	0.021	305	0.038
	Bank	6,643	1,043	0.157	162	0.024	477	0.072	3,880	0.584	1,090	0.164	348	0.052	694	0.104
		86,569	3,261		25,412		2,759		5,465		2,561		517		999	
Jun.	Boat	58,841	1,283	0.021	8,501	0.144	856	0.014	4,427	0.752	365	0.062	181	0.031	489	0.083
	Bank	3,471	147	0.042	494	0.142	591	0.170	1,979	0.570	436	0.126	230	0.066	513	0.145
		62,312	1,430		8,995		1,447		6,406		801		411		1,002	
Jul.	Boat	58,910	4,105	0.069	14,984	0.254	774	0.013	8,984	1.525	0	0	0	0	850	0.144
	Bank	1,708	346	0.203	398	0.233	358	0.210	92	0.054	0	0	39	0	0	0
		60,618	4,451		15,382		1,132		9,076		0		39		850	
Aug.	Boat	51,375	2,355	0.045	14,121	0.275	926	0.018	9,098	1.771	0	0	0	0	507	0.100
	Bank	1,683	242	0.144	170	0.101	101	0.060	0	0	0	0	0	0	0	0
		53,058	2,597		14,291		1,027		9,098		0		0		507	
Sep.	Boat	28,324	1,397	0.049	6,170	0.217	56	0.002	8,642	3.051	0	0	0	0	121	0.043
	Bank	639	0		0		0		143	0.224	82	0.128	0	0	0	0
		28,963	1,397		6,170		56		8,785		82		0		121	
Total		332,076	15,950		73,631		8,095		42,704		6,498		1,034		3,523	

Table 7.2 Summary of Banks Lake sport fishery catch, effort, and catch per unit of effort: October 1975 through March 1976.

Month	Fishery	Total Fishing Effort (hr)	Rainbow		Kokanee		Chinook		Perch		Crappie		Bass		Sunfish	
			Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
Oct.	Boat	547	0	0	831	1.519	0	0	0	0	0	0	0	0	0	0
	Bank	787	115	0.146	0	0	0	0	362	0.460	3	0.004	2	0.002	6	0.008
		<u>1334</u>	<u>115</u>		<u>831</u>			<u>362</u>		<u>3</u>		<u>2</u>		<u>6</u>		
Nov.	Boat	91	0	0	134	1.472	0	0	0	0	0	0	0	0	0	0
	Bank	1647	138	0.084	439	0.267	0	0	51	0.038	0	0	0	0	0	0
		<u>1738</u>	<u>138</u>		<u>573</u>			<u>51</u>		<u>0</u>		<u>0</u>		<u>0</u>		
Dec.	Boat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bank	1447	447	0.309	0	0	0	0	1334	0.929	0	0	0	0	0	0
		<u>1447</u>	<u>447</u>		<u>0</u>			<u>1334</u>		<u>0</u>		<u>0</u>		<u>0</u>		
Jan.	Boat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bank	1513	260	0.172	0	0	0	0	4749	3.139	0	0	0	0	0	0
		<u>1513</u>	<u>260</u>		<u>0</u>			<u>4749</u>		<u>0</u>		<u>0</u>		<u>0</u>		
Feb.	Boat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bank	5157	1315	0.255	0	0	0	0	2553	0.495	0	0	0	0	0	0
		<u>5157</u>	<u>1315</u>		<u>0</u>			<u>2553</u>		<u>0</u>		<u>0</u>		<u>0</u>		
Mar.	Boat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bank	7601	1133	0.149	0	0	0	38	8035	1.057	0	0	0	0	0	0
		<u>7601</u>	<u>1133</u>		<u>0</u>		<u>38</u>	<u>8035</u>		<u>0</u>		<u>0</u>		<u>0</u>		
TOTAL		18,790	3408		1404		38	17,084		3		2		6		
Annual Total		350,866	19,358		75,035		8,133	59,788		6,501		1,036		3,529		

almost exclusively at these locations until ice break-up late in February. The fishery then redistributed to many of the rocky shorelines. Ice formed over most of Banks Lake late in January, but remained too thin to permit a general ice fishery. Rainbow trout and yellow perch were the principal species sought from January through May and crappie and sunfish, as well, were sought during April and May. Chinook salmon and whitefish also entered the catch of bank fishermen during this period but occurred incidentally to the aforementioned species. The timing of the catch by species is shown in Fig. 7.1.

Kokanee. The annual sport catch of kokanee was estimated at 75,035. The peak monthly catch occurred in May and was estimated at 25,412 or 33.9% of the annual total. Nearly all kokanee were caught during the period April through September by trolling.

Perch. The annual catch of perch was estimated at 59,798. Perch were present in the catch during all months of the year and were prevalent from January through September. While bank anglers caught few perch from July through August, boat anglers made their largest catches during this period. Perch were caught principally while stillfishing with bait and lures.

Rainbow. The rainbow catch was estimated at 19,358. The peak monthly catch was made during May, however, consistently good catches were made from February through September. Rainbow were caught during all months of the year. They were principally sought by bank anglers during February and March, and caught in largest numbers offshore by the kokanee troll fishery. Rainbow were caught by nearly all angling methods.

Chinook. The chinook catch was estimated at 8,133. The catch peaked in May, and was made largely from April through August by the

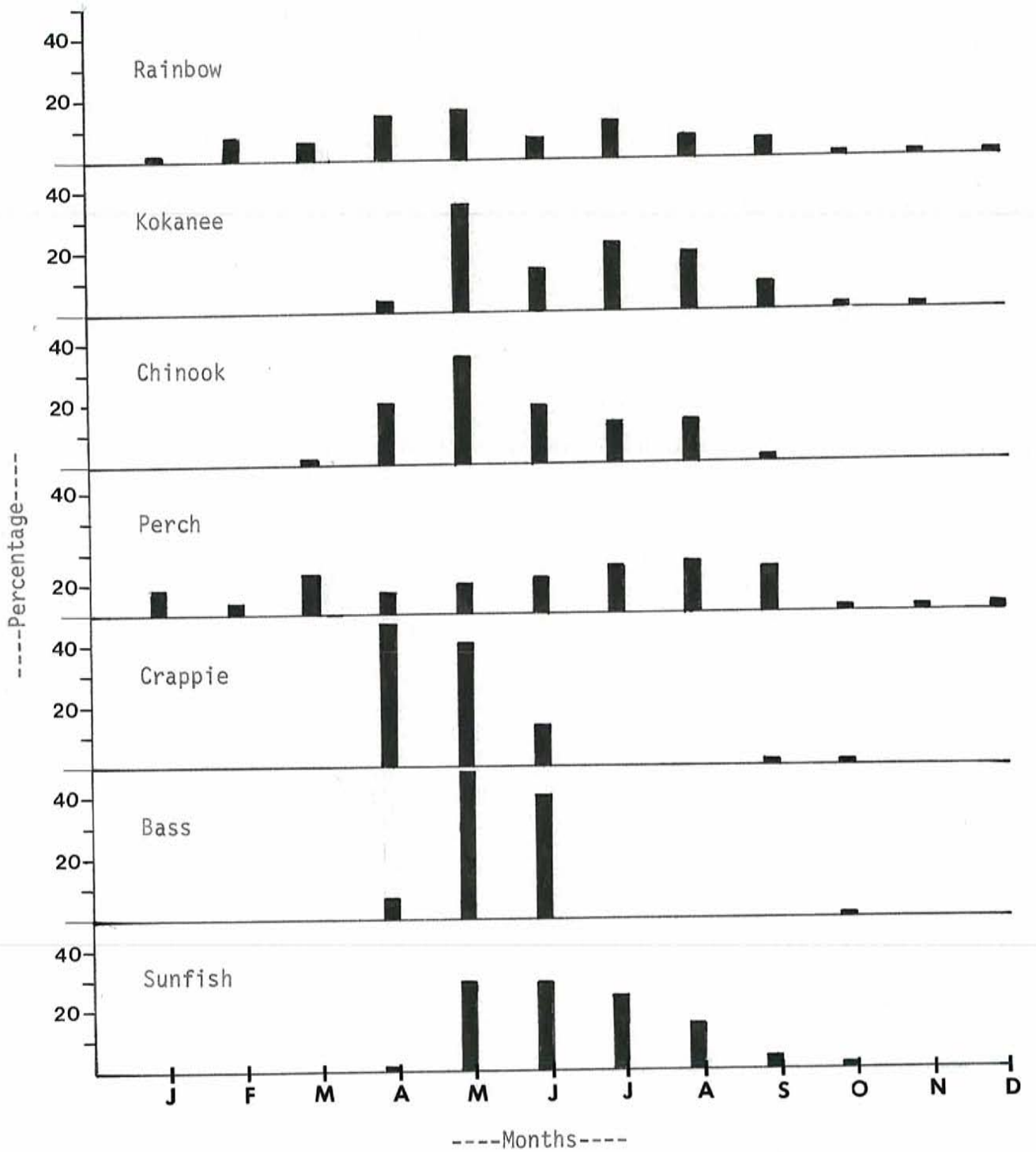


Figure 7.1

Timing of Banks Lake sport catch by species, 1975-6. Bars represent monthly percentage of annual catch for each of the seven most-caught species.

kokanee troll fishery. A relatively small number was caught by the bank anglers during March and April. The timing and location of the chinook catch approximated that of the rainbow catch which indicated similar habitat and feeding preferences for the two species. The catch represented about 20% of the 1974 plant of 40,000 chinook, indicating a high rate of return.

Crappie. The estimated catch of 6,501 crappie was divided equally between bank and boat anglers and occurred almost entirely during April, May and June.

Bass. The bass catch was estimated at 3,529, and occurred principally during May and June. On May 24, 1975, a bass tournament was held at Banks Lake which yielded 144 bass for an estimated effort of 842 angler-hours. Accurate statistics were difficult to obtain because many anglers released their catch.

Lake whitefish. An estimated 321 lake whitefish were caught by bank anglers during February, March and April. These were caught incidental to the rainbow and perch fishery.

Walleye. No walleye were observed during this census.

Burbot. No burbot were observed during this census.

Brown bullhead. No brown bullhead were observed during this census.

7.3.2 Census

A comparison between this census and censuses conducted three years earlier by Duff and ten years earlier by Spence revealed that changes were continuing in the sport fishery but that the differences were smaller than observed during the interim between 1965 and 1971-2. A comparison of monthly catch and effort statistics between the 1971-2

census and the present census is shown in Table 7.3. In summary, these data show a 21% increase in fishing effort, increases in the percentage catches of rainbow (+53%), kokanee (+2.95%) and chinook (+100%), and decreases in the percentage catches of perch (-55%), crappie (-37%), bass (-76%), sunfish (-15%), lake whitefish (-35%), walleye (-100%) and burbot (-100%).

Determination of confidence limits for estimations of catch and effort statistics were beyond the limited scope of this study. Considerable variability was present in the observed census data and in the correction factors used to derive these estimates. For this reason, percentage differences between censuses of less than 25 are not considered significant.

Although Banks Lake is one of Washington's most popular fishing lakes, with an impressive annual catch of over 173,000 fish, the success per angler-hour is not an impressive statistic. These data show an average catch of 0.5 fish per angler-hour, or 2 hours of fishing to catch one fish. The CPUE estimated from censuses conducted in 1971-72 and in 1965 were somewhat higher: 0.8 fish per angler-hour, or 1.25 hours to catch one fish (Table 7.4).

Table 7.3 Comparison of Banks Lake sport catch and effort between creel censuses conducted in 1971-2 and 1975-6.

Month	Year	Total Fishing Effort (hr)	Lake										
			Rainbow	Kokanee	Chinook	Perch	Crappie	Bass	Sunfish	Whitefish	Walleye	Burbot	
Jan.	1971-2	7,740	107	0	-	44,654	0	0	0	0	0	82	49
	1975-6	1,513	260	0	00	4,749	0	0	00	00	0	0	0
Feb.	1971-2	2,878	38	0	-	16,308	0	0	0	0	0	0	224
	1975-6	5,157	1,315	0	00	2,553	0	0	0	0	0	144	0
Mar.	1971-2	5,561	782	0	-	580	0	0	0	0	0	0	
	1975-6	7,601	1,133	0	338	8,035	0	0	0	0	0	160	
Apr.	1971-2	16,094	677	1,757	-	16,791	253	173	0	0	0	122	
	1975-6	40,556	2,794	3,381	1,674	3,874	3,054	67	44	0	0	17	
May	1971-2	47,611	1,064	17,946	-	20,119	7,726	92	1,194	0	0	0	
	1975-6	86,569	3,261	25,412	2,759	5,465	2,561	517	999	0	0	0	
Jun.	1971-2	32,743	1,560	5,121	-	9,158	1,137	280	93	0	0	0	
	1975-6	62,312	1,430	8,995	1,447	6,406	801	411	1,002	0	0	0	
Jul.	1971-2	36,548	2,068	10,121	-	4,289	818	1,728	250	0	0	93	406
	1975-6	60,618	4,451	15,382	1,132	9,076	0	39	850	0	0	0	0
Aug.	1971-2	36,193	1,798	22,794	-	3,724	93	789	1,859	0	0	0	46
	1975-6	53,058	2,597	14,291	1,027	9,098	0	0	507	0	0	0	0
Sep.	197102	76,050	1,239	12,380	-	9,457	322	355	664	0	0	0	
	1975-6	28,963	1,397	6,170	56	8,785	82	0	121	0	0	0	
Oct.	1971-2	21,708	1,414	2,766	-	4,260	0	0	93	0	0	0	
	1975-6	1,334	115	831	0	362	3	2	6	0	0	0	
Nov.	1971-2	4,816	1,773	0	-	3,376	0	0	0	0	0	200	
	1975-6	1,738	138	573	0	51	0	0	0	0	0	0	
Dec.	1971-2	894	120	0	-	1,542	0	0	0	0	0	0	
	1975-6	1,447	447	0	0	1,334	0	0	0	0	0	0	
Totals	1971-2	288,836	12,640	72,885	-	134,258	10,349	4,237	4,153	497	452	273	
	1975-6	350,866	19,358	75,035	8,133	59,788	6,501	1,036	3,529	321	0	0	

Table 7.4. Summary of catch and effort statistics from creel censuses conducted in 1965, 1971-2, and 1975-6.

<u>Species</u>	<u>Census Year</u>		
	<u>1965</u>	<u>1971-72</u>	<u>1975-76</u>
Rainbow	20,170	12,640	19,338
Kokanee	17,630	72,885	75,035
Perch	23,560	134,258	59,798
Crappie	no record	10,349	6,501
Bass	no record	4,237	1,036
Sunfish	no record	4,153	3,529
Lake whitefish	200	497	321
Walleye	200	452	0
Burbot	3,250	273	0
Effort (Angler-hours)	91,126	258,836	350,866

appear to correlate with the major spring water level declines which occurred in 1973 and 1974. Therefore, fewer larger perch were available to be caught and the fish in the creel were the smaller, recently recruited year classes which were less desired by the angler. This may also have stimulated a reduced effort by anglers to fish for perch during 1975-76.

These factors may have been operating on the crappie fishery as well. The estimated catch declined from 10,349 in 1971-72 to 6,501 in 1975-76 and, commensurately, the average length decreased from 281.2 mm to 256.0 mm. This size decrease of 25.2 mm probably reduced angler interest in crappie.

That less effort was expended for perch and crappie is evident by comparing the estimate of effort specifically for spiny-rayed fish. Duff estimated that 21% of the 1971-72 effort was directed at spiny-rayed fish, while the present estimate for 1975-76 was 8.3%.

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8.0 FISH ENTRAINMENT (IRRIGATION CANAL)

8.1 Introduction

Determination of fish entrainment into and out of Banks Lake was essential in the evaluation of the effects of pumping, pump/generation, and irrigation flows on the fish populations of the lake. The specific objectives of this portion of the study were to estimate the fish entrainment loss from Banks Lake by species, numbers and biomass; and to assess the effects of this entrainment on the fish population of the lake.

An appreciable amount of literature has been published regarding the entrainment of the "nonscreenable" biota (zoo- and phytoplankton, larval fish and eggs) in aquatic systems. Most of this work concerns the evaluation of entrainment through the condenser cooling systems of thermal power plants.

Studies of this sort are exemplified by the Proceedings of the Second Workshop on Entrainment and Intake Screening (1974). Another segment of the literature concerns the entrainment of fishes through the turbines of hydroelectric facilities. Bell, et al., (1967) provides a rather extensive literature review on the subject and also discusses some of the fish sampling gear which has been used in entrainment studies. However, attempts in the literature to quantify the entrainment of a broad size range of fishes in reservoir or pump storage systems have been notably sparse. This is to be expected when consideration is given to the difficult sampling problems which must be overcome.

Walburg (1971) has shown that many age 0 fish of several species are lost yearly from Lewis and Clark Reservoir on the Missouri River. Robbins and Mathur (1976) studied the effects of pump/generation entrainment of fishes on the ecology of Conowingo Pond and Muddy Run Pumped Storage Pond. Because of sampling problems, they were unable to assess either magnitude of fish entrainment or percentage mortality of those fish which passed through the pump turbines. Simmons (1971) also reported on assessment of the effects of pump/storage on the fishes of Leesville Reservoir. The study concluded that very few live fish were entrained from the upper impoundment (Smith Mountain Reservoir) into Leesville Reservoir.

8.2 Irrigation Canal

The irrigation canal (main canal) headworks are located in the South Dam, a short distance from Coulee City (Fig. 8.1). The canal itself has been cut through basalt rock and extends south for 2.1 miles where it leads into Bacon Siphon. During the 7-month long irrigation season which began in March and ended in October, the irrigation canal received a steady flow of Banks Lake water which reached a maximum rate of 7,900 cfs. This water was used to irrigate approximately 500,000 acres of Columbia Basin farmland.

The headworks of the irrigation canal is constructed of concrete. A concrete apron extends 108 ft downstream into the canal where it abruptly ends. Six outlet tunnels, each 12 ft wide by 21 ft high, empty into the canal. Flow of water through each tunnel was regulated by a large radial gate. At the full 1,570 ft lake elevation, water was

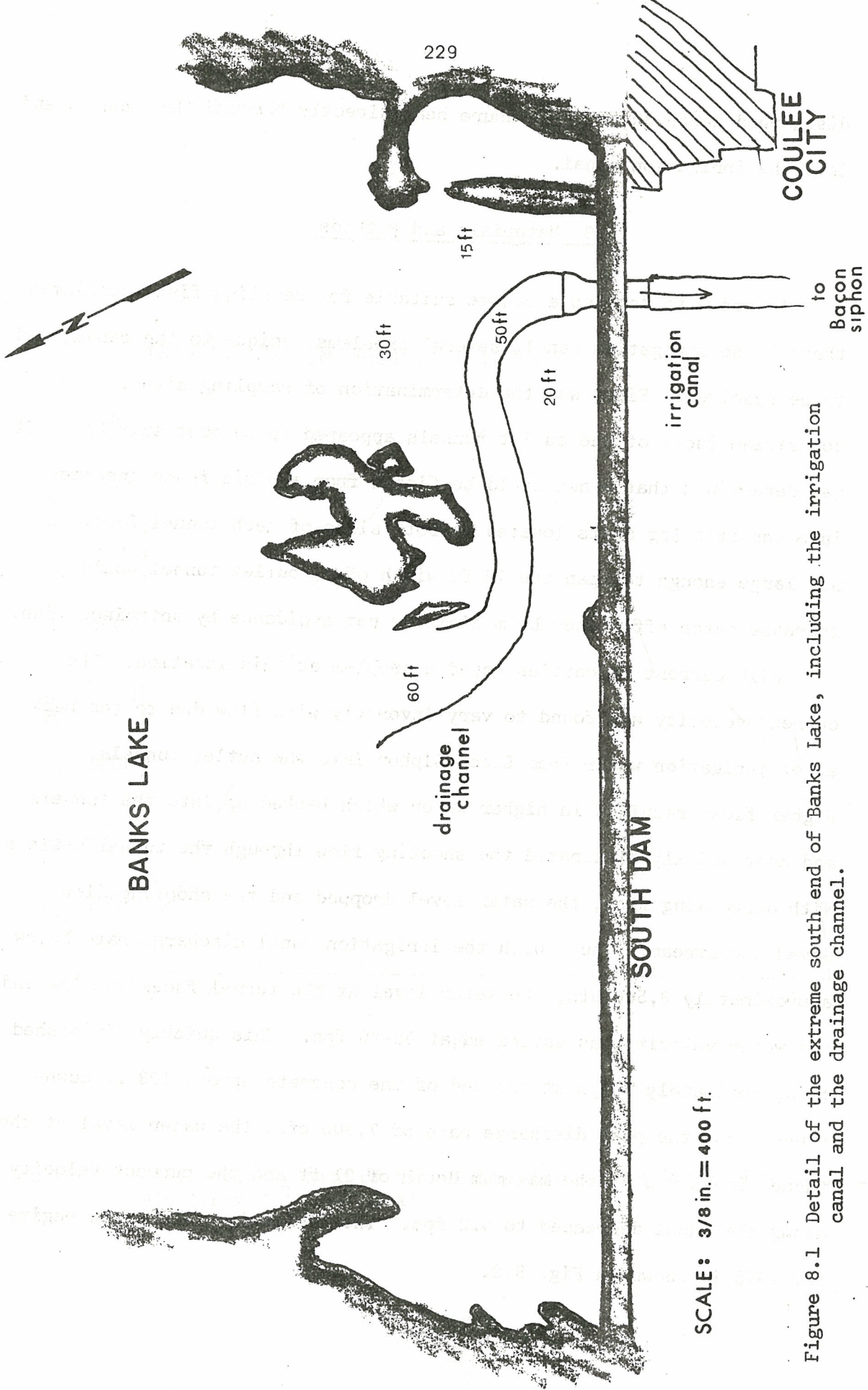


Figure 8.1 Detail of the extreme south end of Banks Lake, including the irrigation canal and the drainage channel.

discharged under 30 ft of pressure head directly through the tunnels and into the irrigation canal.

8.3 Materials and Methods

In order to develop a scheme suitable for sampling fish entrainment through the irrigation canal, several problems, unique to the canal, had to be resolved. First was the determination of sampling sites. The downstream faces of the outlet tunnels appeared to be most suitable. It was determined that a net could be fished from a rigid frame inserted into the stop log slots located on both sides of each tunnel face. A net large enough to span the 12 ft width of an outlet tunnel would increase catch efficiency by minimizing net avoidance by entrained fish.

High current velocities posed a problem at this location. The current velocity was found to vary inversely with flow due to the back-up of irrigation water from Bacon Siphon into the outlet tunnels. Higher flows resulted in higher water which backed up into the tunnels and more quickly dissipated the shooting flow through the tunnel outlets. With decreasing flow, the water level dropped and the shooting flow moved downstream. Thus, with the irrigation canal discharge rate below approximately 3,500 cfs, the water level at the tunnel faces was low and the water velocity was estimated at 35-40 fps. This quickly diminished to approximately 5 fps at the end of the concrete apron, 108 ft downstream. At the peak discharge rate of 7,900 cfs, the water level at the tunnel faces was at the maximum depth of 21 ft and the current velocity along the canal decreased to 4.2 fps. The irrigation canal flow regime for 1975 is shown in Fig. 8.2.

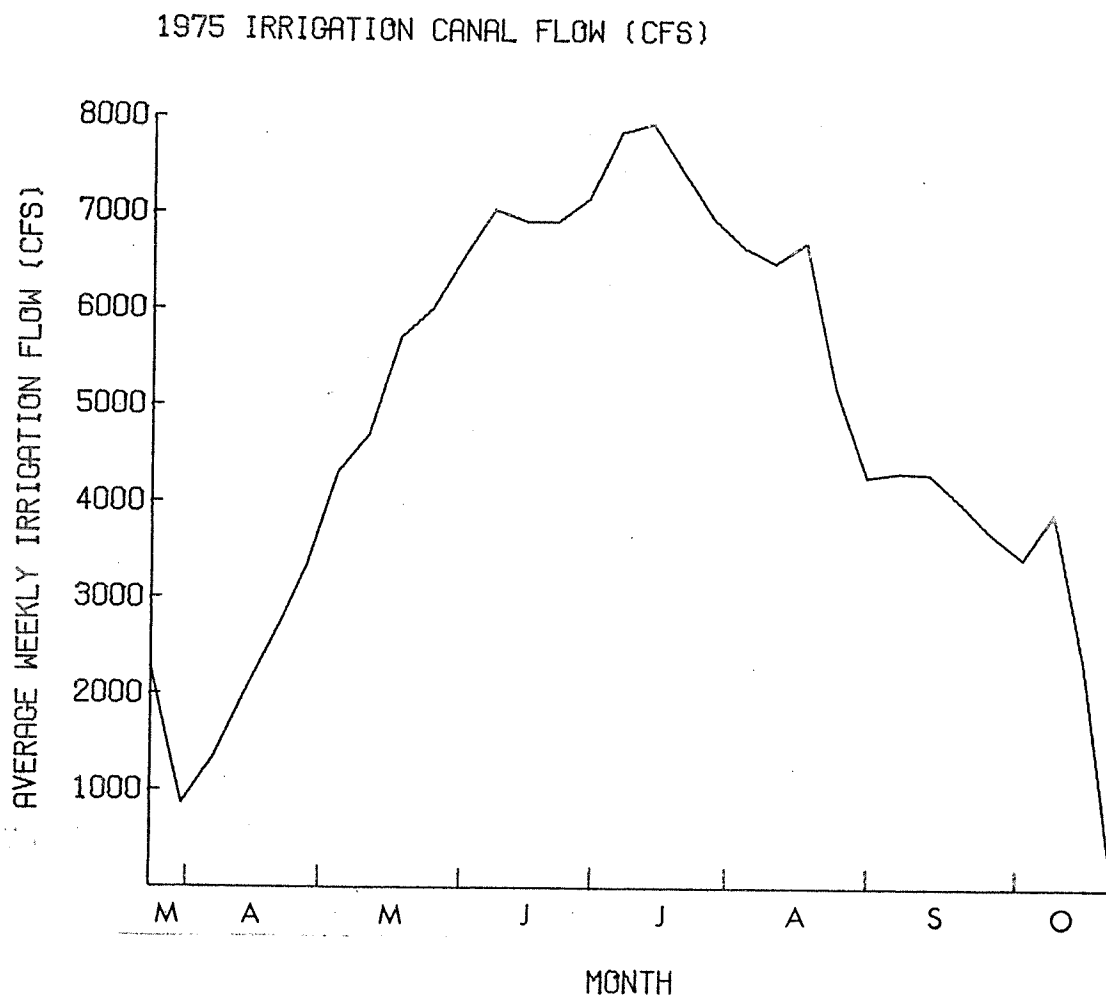


Figure 8.2 Average weekly rate of flow (cfs) through the irrigation canal during 1975 (from U.S.B.R. data).

The problem with excessively high current velocities was satisfactorily resolved by locating the initial sampling sites downstream 148 ft in lower velocity water. As irrigation canal discharge increased during the season, the sampling site was moved upstream to the foot of the concrete apron and later to the trash rack slots. Gradually diminishing discharge later in the season was accommodated by locating the sampling gear back downstream to the initial sampling sites.

The design and development of suitable fish sampling nets to meet the rigorous conditions in the canal had several requirements. Nets had to be designed to fish for rather extended periods of time, with the capability of withstanding the tension and wear associated with relatively high, constantly fluctuating water velocities. The mesh size must catch and retain the broadest possible size range of each of 21 species of fish, with the least amount of selectivity.

Several different nets were tested at each of the 3 canal sampling sites. Gear description is limited only to those nets which proved most effective. On March 23, 1975, a net was placed in the mid-channel white-water 148 ft downstream from the tunnel openings. The 6.5 x 8.5 ft rigid rectangular frame supporting the net was held against the current by 150 ft cable warps (1/4 inch diameter) and was hauled, set and positioned by means of a 1/4 inch diameter cross-channel suspension cable and net retrieval line (Fig. 8.3). The net and frame were suspended by two blocks from the overhead cable.

In responses to decreased current velocity due to back-up water in the irrigation canal, the net and support gear were moved upstream on May 8 to a new sampling site at the end of the concrete apron 108 ft downstream from the tunnel openings. The sampling net which was used at

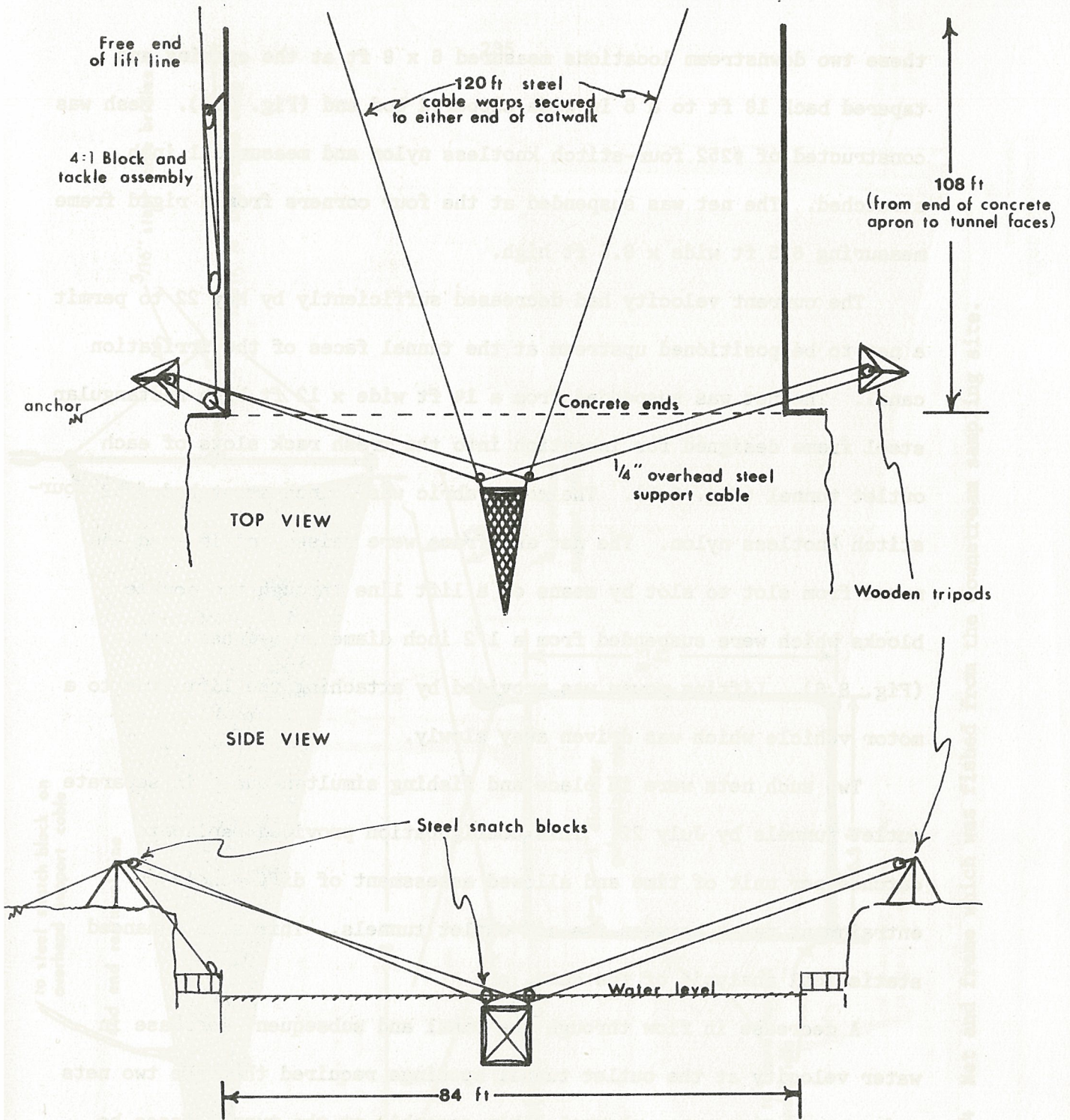


Figure 8.3 Semi-diagrammatic detail of the downstream sampling and support gear fished from near the end of the concrete apron of the irrigation canal headworks.

these two downstream locations measured 6 x 8 ft at the opening and tapered back 18 ft to a 6 in wide zippered cod end (Fig. 8.4). Mesh was constructed of #252 four-stitch knotless nylon and measured 1 inch stretched. The net was suspended at the four corners from a rigid frame measuring 6.5 ft wide x 8.5 ft high.

The current velocity had decreased sufficiently by May 22 to permit a net to be positioned upstream at the tunnel faces of the irrigation canal. The net was suspended from a 14 ft wide x 12 ft high rectangular steel frame designed for insertion into the trash rack slots of each outlet tunnel (Fig. 8.5). The mesh fabric was 1 inch stretched #252 four-stitch knotless nylon. The net and frame were raised and lowered and moved from slot to slot by means of a lift line through two double blocks which were suspended from a 1/2 inch diameter overhead cable (Fig. 8.6). Lifting power was provided by attaching the lift line to a motor vehicle which was driven away slowly.

Two such nets were in place and fishing simultaneously in separate outlet tunnels by July 22. This configuration provided replicate catches per unit of time and allowed assessment of differences in entrainment rates between the six outlet tunnels. This also enhanced statistical analysis of the data.

A decrease in flow through the canal and subsequent increase in water velocity at the outlet tunnel openings required that the two nets and accompanying cross-channel cable assembly at the tunnel faces be discontinued on September 25. On September 27, the sampling location was moved downstream to the end of the concrete apron. Both the site and the sampling apparatus were identical to those employed earlier in

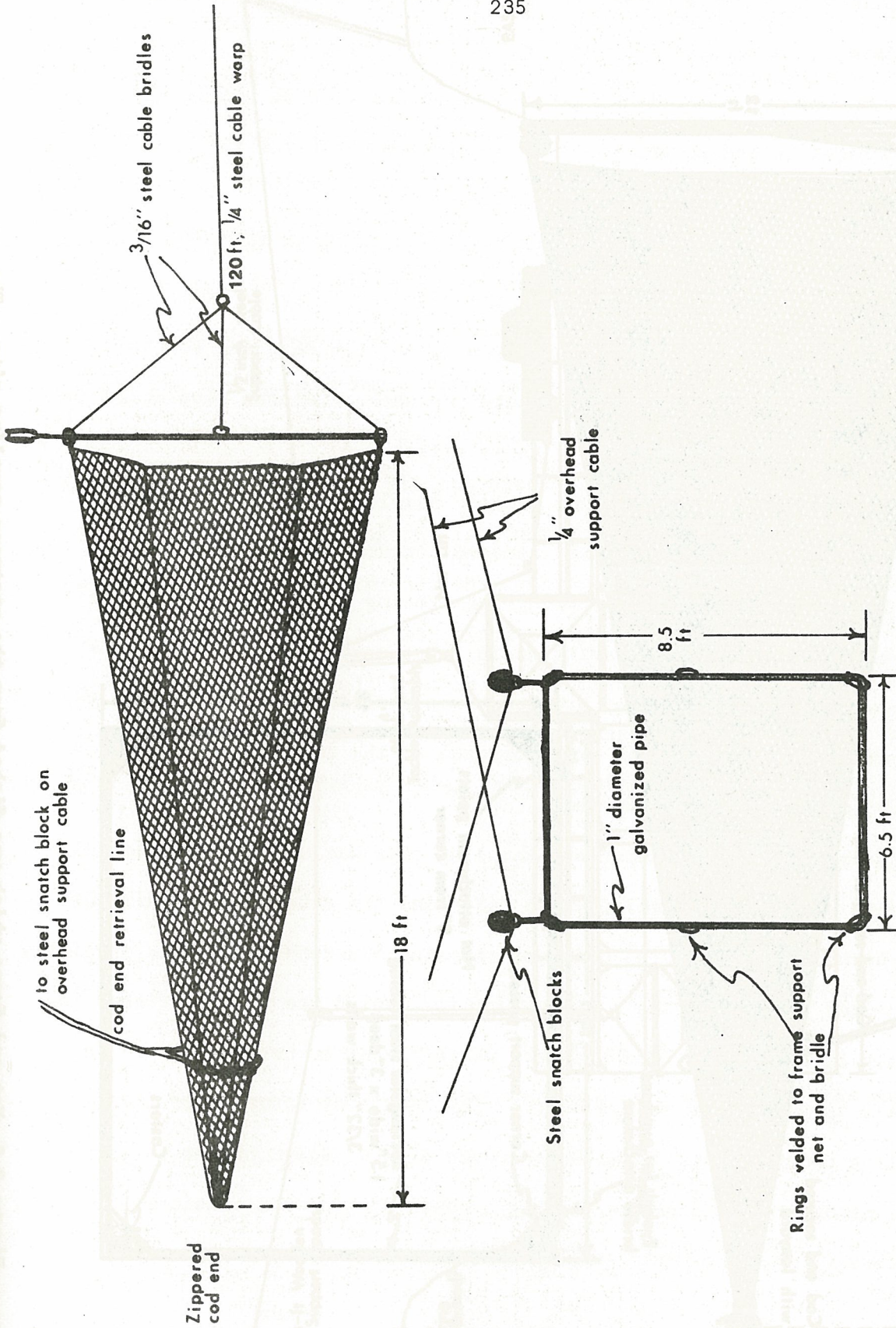


Figure 8.4 Net and frame which was fished from the downstream sampling site.

Figure 8.6 Downstream view of the upstream sampling site showing the tunnel

1500 (P. cobecija)

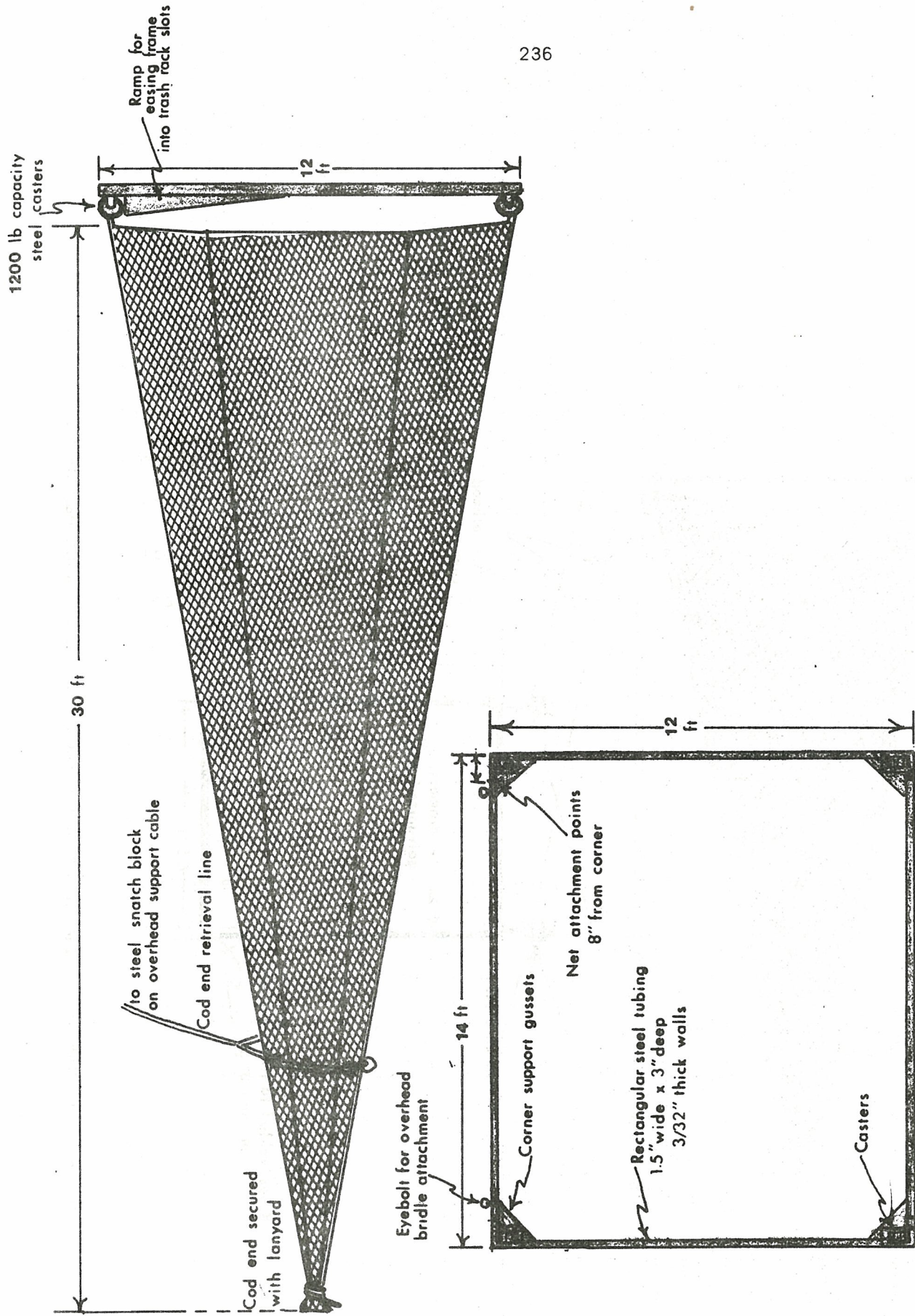


Figure 8.5 Net and frame which was fished from the upstream sampling site. The frame was inserted into the trash rack slots located on either side of the outlet tunnels.

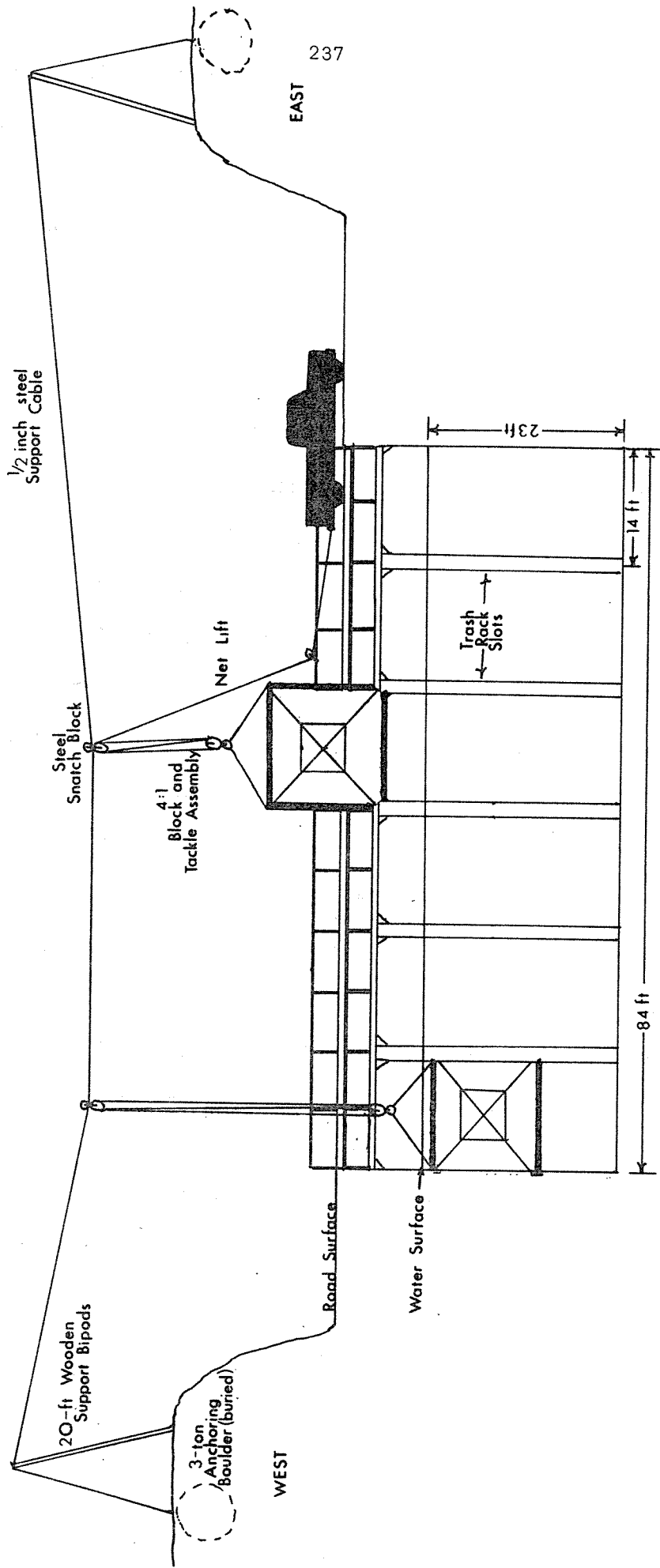


Figure 8.6 Downstream view of the upstream sampling site showing the tunnel openings and trash rack slots, the overhead support gear, sampling nets, and the vehicle-powered lifting apparatus.

the season, from May 8 to May 22, 1975, during the time discharge was increasing. On October 14, the high water velocity caused irreparable damage to the net. In view of the short period of time remaining in the 1975 irrigation season and the lack of time required for the construction of a new net, sampling was discontinued.

The canal sampling schedule for the upstream site included 6 consecutive 12-hr sets per week per net. Each gate received 1 day of sampling effort each week. For the 2 downstream sites, the sampling schedule also entailed 6 consecutive 12-hr sets per week. Catches were collected every morning and evening at all three sites.

Three consecutive days were usually sampled each week, but occasionally the sampling period was reduced because of gear failure. Removing the catch at 12-hr morning-and-evening intervals enabled the determination of the diel variation in entrainment rates by species at the upstream site, where net avoidance was probably negligible, and gave indication of the extent of net avoidance at the downstream site where net avoidance probably occurred.

Each tunnel at the upstream sampling site was sampled for one full day each week, which enabled us to determine the extent of entrainment bias between tunnels. The order of sampling between tunnels was partially randomized in that during a 3-day sampling period one net was fished in tunnels 1, 2 and 3 in random order, while the other net was fished in tunnels 4, 5 and 6 in random order. Complete randomization of the sampling order was not expedient because of the design of the net-handling apparatus; however, complete randomization was considered unnecessary in the present study.

The catches were then transported to the field laboratory in the pumphouse at Grand Coulee Dam where they were subsequently processed. Data recorded included number, species, length, weight, sex, stage of maturity, stomach fullness and content, obvious disease or parasites and scales or otoliths. The volume of water sampled by each net was determined weekly by suspending a digital flowmeter (Ocean Dynamic Model 2030) across the net opening for a timed period of approximately 20 min. The flowmeter reading was used to calculate the average velocity which, when multiplied by the area of the net opening, yielded a sample flow rate.

The total entrainment of fish (numbers and biomass) was estimated by species at weekly intervals throughout the sampling period according to the following general statistical procedure. Sampling between outlet gates determined that all species were uniformly mixed in the discharge except for kokanee. The average daily catch (\bar{C}_i) was calculated for each week for each species using the following formula:

$$\bar{C}_i = \frac{C_{ij}}{M_i} \quad (1)$$

where

C_{ij} = j^{th} daily catch in the i^{th} week, and

M_i = number of catches in the i^{th} week.

Weekly entrainment rates were estimated for each species by the expression:

$$T_i = \frac{\bar{C}_i Q_i n_i}{Qs_i} \quad (2)$$

where

T_i = estimated weekly entrainment rate

Q_i = average daily canal discharge rate (cfs) for weekly period

Qs_i = weekly rate of flow through nets in cfs

n_i = number of days in the week (usually 7)

The point estimate for the total (32 weeks) seasonal entrainment of each species through the irrigation outlet structure was calculated from:

$$T_c = \sum_{i=1}^{32} a_i \bar{C}_i = \sum_{i=1}^{32} T_i \quad (3)$$

where

T_c = estimated total number entrained by species

$$a_i = \frac{Q_i n_i}{Qs_i}$$

The weekly variance was estimated from

$$\text{Var}(T_i) = \text{Var}(a_i \bar{C}_i) = a_i^2 \text{Var}(\bar{C}_i) \quad (4)$$

and utilized in calculating interval estimates about T_c . Assuming that \bar{C}_i are independent random variables, $\text{Var}(\hat{T}_c)$ can be estimated from

$$\sum_{i=1}^{32} a_i^2 \text{Var}(\bar{C}_i).$$

The interval estimate was then obtained from

$$T_c \pm Z_{\alpha} \sqrt{\sum_{i=1}^{32} a_i^2 \text{Var}(\bar{C}_i)} \quad (5)$$

where Z_{α} = 95% normal probability, critical value = 1.96.

Use of the Friedman two-way analysis of variance established that kokanee was the only species which showed differences in rate of entrainment through the six outlet tunnels. Entrainment through the two outside

tunnels was significantly and consistently higher than entrainment through the four inside tunnels. To establish the greatest precision in the calculation of T_c for kokanee, a weighted weekly average catch was calculated in the following manner:

$$\bar{C}_{w_i} = 1/3\left(\frac{Co_{ij}}{2} + \frac{2Cb_{ij}}{4}\right) \quad (6)$$

where

\bar{C}_{w_i} = weighted weekly average catch

Co_{ij} = the j^{th} daily catch in the i^{th} week for the outside gates

Cb_{ij} = the j^{th} daily catch in the i^{th} week for the inside gates.

The weekly estimated entrainment rates were then calculated from the formula

$$T_i = a_i \bar{C}_{w_i}.$$

The estimated total number entrained was calculated in the same manner as before

$$T_c = \sum T_i$$

Assuming that Co_{ij} and Cb_{ij} are independent random variables, the estimated weekly variances are calculated from:

$$\text{Var}(a_i \bar{C}_{w_i}) = a_i^2 [\text{Var}(Co_{ij}/2) + \text{Var}(Cb_{ij}/4)] \quad (7)$$

which is utilized in calculating interval estimates about T_c . Assuming (\bar{C}_{w_i}) are independent random variables.

$$\text{Var}(\hat{T}_c) = \sum_{i=1}^{32} a_i^2 \text{Var}(\bar{C}_{w_i}) \quad (8)$$

The interval estimate was then obtained from

$$T_c \pm Z_{\alpha} \sqrt{\sum_{i=1}^{32} a_i^2 \text{Var}(\bar{C}_{w_i})} \quad (9)$$

where $Z = 95\%$ normal probability, critical value = 1.96.

It was possible to obtain replicate samples of kokanee during a seven-week period from July 27 to September 21. Therefore, an interval estimate was calculated on this period and extrapolated in direct proportion to the total estimated catch. This procedure was justified on the basis that 30.5 percent of the total estimated entrained kokanee catch occurred during this period of time.

The random variable C_{ij} can be modelled by the Poisson distribution with parameter (λV) where $\lambda =$ the average occurrence of fish in $V =$ the volume of water filtered through the sampling nets each day.

The value of V is very large, ranging from 6 million ft^3 to 54.5 million ft^3 per day. This caused the value of the parameter (λV) to become exceedingly large, so the Poisson was closely approximated by the Normal distribution. Because the sample statistic \bar{C}_i was used to calculate the point estimate \hat{T}_c , the central limit theorem applies and an even closer approximation to the Normal distribution was obtained. The assumption that \bar{C}_i are independent random variables therefore appears reasonable.

8.4 Results

8.4.1 Relative Abundance

Estimates of the numbers of fishes entrained through the irrigation canal in 1975 are presented in Table 8.1. The species are listed in the

Table 8.1 Total estimated entrainment through the irrigation canal for each species during the 1975 season.

Species	Scientific Name	Estimated Total No. Entrained	Interval Estimate $\alpha = .05$	Relative Number	Estimated Total Weight (kg)	Relative Weight
Yellow perch	<i>Perca flavescens</i>	241,367 ±	21,537	.553	10,741	.097
Kokanee	<i>Oncorhynchus nerka</i>	128,747 ±	12,517	.295	64,386	.584
Lake whitefish	<i>Coregonus clupeaformis</i>	21,776 ±	2,932	.050	13,828	.125
Longnose sucker	<i>Catostomus catostomus</i>	10,018 ±	1,141	.023	6,011	.054
Carp	<i>Cyprinus carpio</i>	8,618 ±	2,693	.020	9,988	.091
Rainbow trout	<i>Salmo gairdneri</i>	7,347 ±	1,295	.017	2,756	.025
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	7,098 ±	1,150	.016	1,170	.011
Prickly sculpin	<i>Cottus asper</i>	4,255 ±	931	.010	27	Trace
Mountain whitefish	<i>Prosopium williamsoni</i>	2,223 ±	531	.005	613	.006
Peamouth	<i>Mylocheilus caurinus</i>	2,072 ±	633	.005	381	.003
Pumpkinseed sunfish	<i>Lepomis gibbosus</i>	1,225 ±	359	.003	76	.001
Black crappie	<i>Pomoxis nigromaculatus</i>	1,097 ±	700	.003	77	.001
Walleye	<i>Stizostedion vitreum</i>	245 ±	230	.001	233	.002
Largemouth bass	<i>Micropterus salmoides</i>	56 ±	46	Trace	28	Trace
Brown bullhead	<i>Ictalurus nebulosus</i>	38 ±	50	Trace	13	Trace
Burbot	<i>Lota lota</i>	34 ±	67	Trace	10	Trace
		436,216			110,338	

relative order of numbers entrained. The total estimated entrainment of all species was 436,216 fish, which represented a fish biomass of about 110 metric tons.

Sixteen species of fish were taken from the irrigation canal during the entrainment sampling period. Of the 21 species known to occur in the lake only largescale sucker (*Catostomus macrocheilus*), northern squawfish (*Ptychocheilus oregonensis*), brown trout (*Salmo trutta*) and bridgelip sucker (*Catostomus columbianus*) were not found in the irrigation canal catch. A Dolly Varden trout (*Salvelinus malma*) was taken in the 1976 irrigation canal sampling.

8.4.2 Yellow Perch

An estimated 241,367 yellow perch weighing 10,741 kg were entrained through the irrigation canal (Table 8.1). These comprised 55% of the total catch of all species entrained, but due to their relatively small average size (44.5 g), accounted for only 9.7% of the total fish biomass entrained. Peak entrainment rates for perch were reached during the spawning season from mid-April to early May (Fig. 8.7), when 61% of the perch catch was in or nearing spawning condition. The remaining 39% were immature. Another peak occurred during early July when temperatures at Station 6 were highest for the year. From March through mid-May, nearly all perch occurred in the nighttime catches. By late May, daytime catches were equal to nighttime catches, and from early June until the end of the irrigation season, day catches were nearly twice as large as night catches (Fig. 8.7).

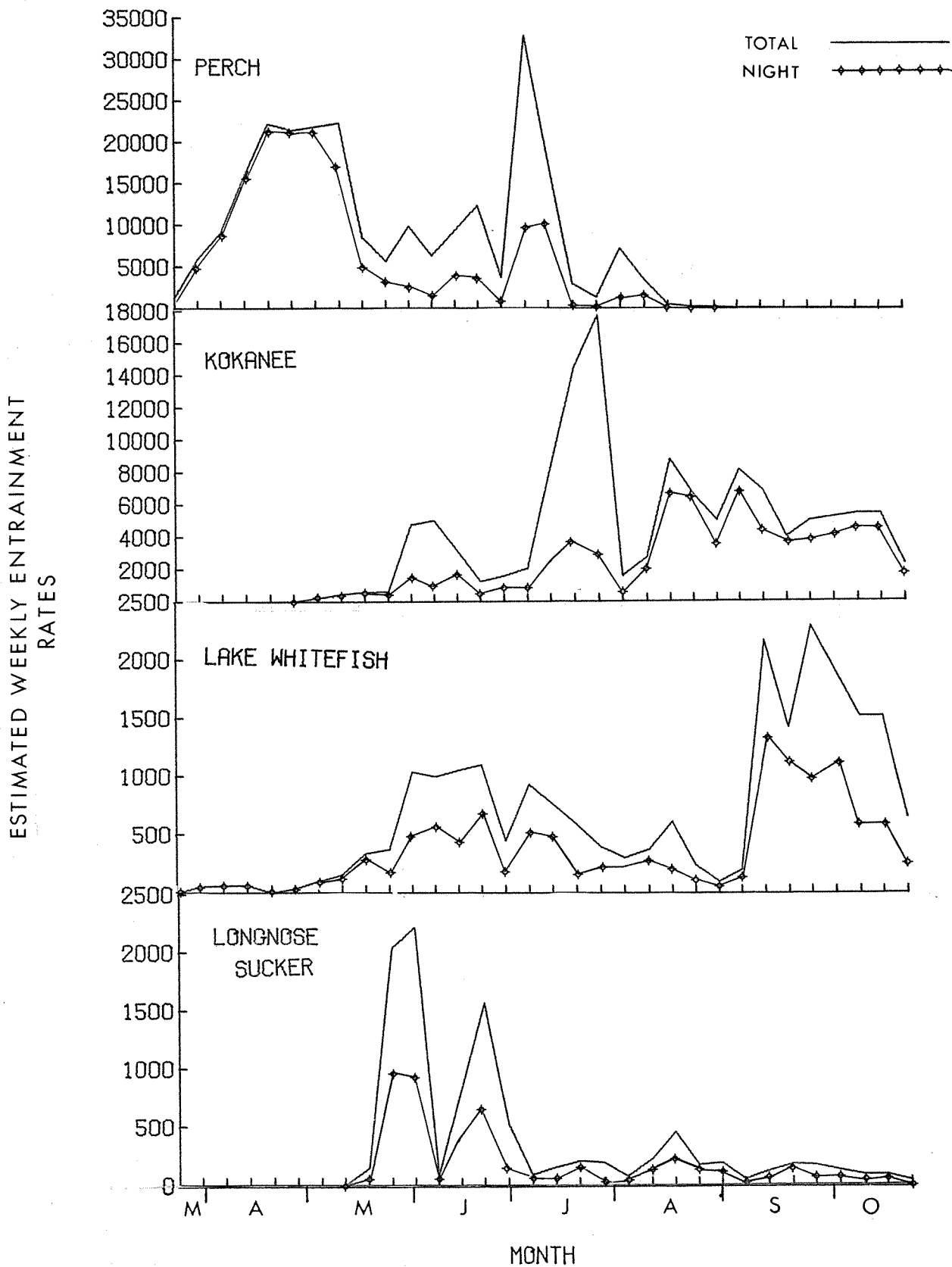


Figure 8.7 Total estimated weekly entrainment rates and the fraction entrained at night through the irrigation canal in 1975.

8.4.3 Kokanee

An estimated 128,747 kokanee salmon weighing 64,386 kg were entrained through the irrigation canal (Table 8.1). These comprised 29.5% of the total catch of all species entrained, because of their relatively large average size (501 g) they comprised 58.4% of the total fish biomass entrained.

Figure 8.7 illustrates the estimated daytime versus nighttime kokanee entrainment for each week. The July-to-August shift from a daytime to a nighttime entrainment maximum was found. For any given week, daytime and nighttime catches never exhibited consistent significant differences in age class composition.

Age class composition of the catch was determined from otolith readings and mode analysis of length frequency data (Fig. 8.8). Where overlapping occurred in the length frequency distribution of successive year classes, the length interval of lowest frequency was arbitrarily chosen as the boundary between the year classes. These data show that the kokanee appearing in the irrigation canal catch through the late July entrainment maximum were about 3% age 1; 39% age 2; 54% age 3; and 4% age 4 fish.

During the period from the August entrainment maximum until the end of irrigation, there was a pronounced shift in the age composition and size of the entrained kokanee. These kokanee were predominantly (93%) mature and maturing individuals. Otolith and length frequency data showed the approximate age composition to be less than 1% age 1; 8% age 2; 75% age 3; 18% age 4; and less than 1% age 5. The average size for the period from March-through-July was 296 mm and 363 g. From mid-August to the end of the season the average size increased to 355 mm and

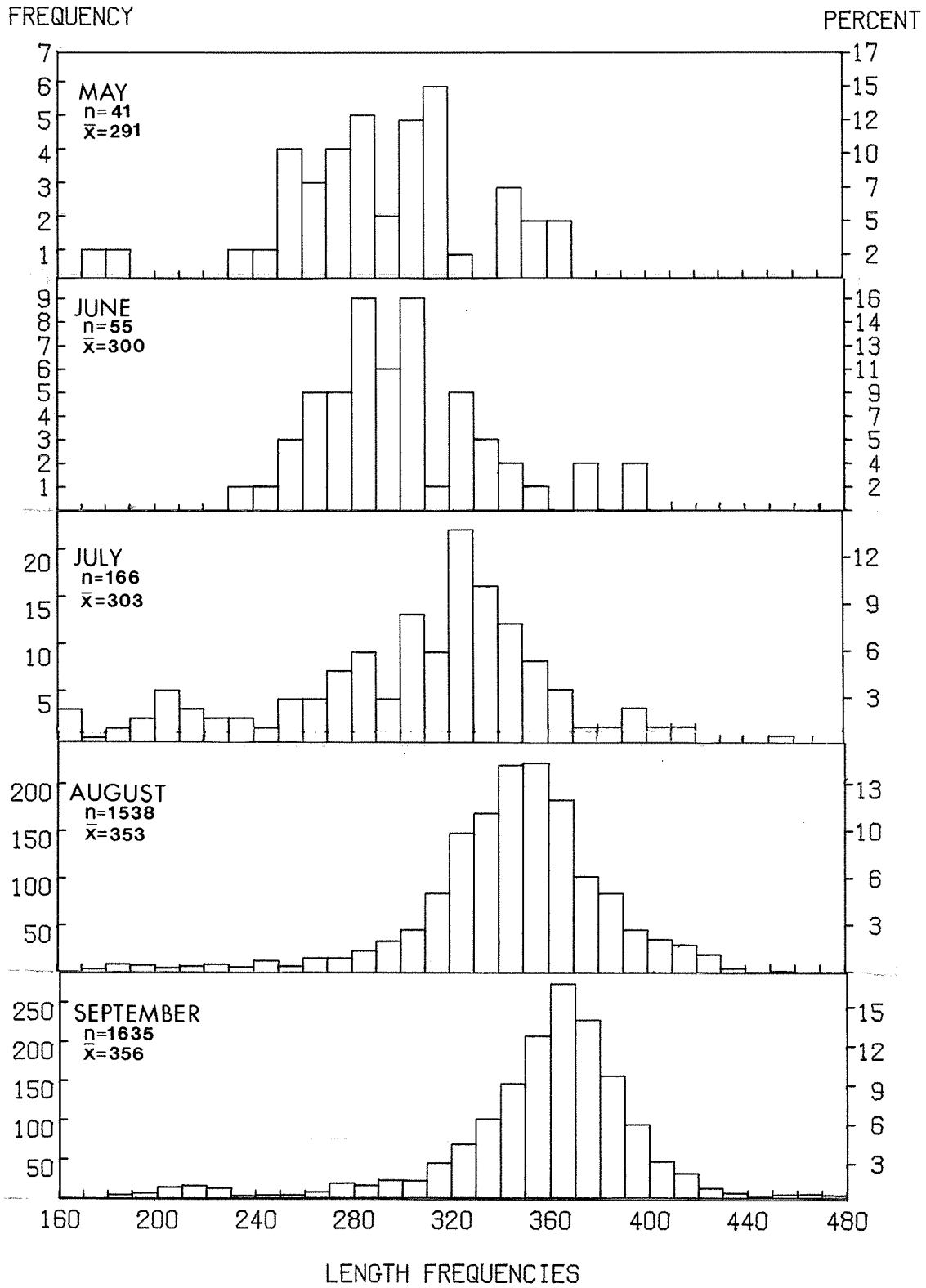


Figure 8.8 Monthly length frequency distributions of kokanee entrained through the irrigation canal during 1975.

563 g (Fig. 8.8). Kokanee spawn during October and November. During the entire sampling period, only two age 0 fish were caught.

An attempt was made to determine the age composition of the kokanee catch from otolith readings. Scales were not collected because the abrasive action of the net fabric and the relatively deciduous nature of kokanee scales made consistent collection of scales difficult.

The otoliths were submerged in glycerine and the opaque bands were read at 20 X under incident light. Kokanee fork length at age is presented in Fig. 8.9. Comparison of these results with those obtained from scale readings presented in Table 6.8 shows close agreement between the two methods for age 3 and 4 fish. However, the median fork length for age 2 fish as determined from otolith readings is substantially larger than that determined from scale readings. It is possible that this disparity was due to erroneous otolith readings resulting from the addition of an opaque annulus during July and August. Further work is being done on otoliths collected from kokanee in conjunction with the fish populations aspect of this study to clarify this problem.

8.4.4 Lake Whitefish

An estimated 21,776 lake whitefish weighing 13,828 kg were entrained through the irrigation canal. These comprised 5.0% of the total catch of all species entrained and 12.5% of the total biomass due to a relatively large mean size (635 g). Lake whitefish exhibited relatively low and uniform entrainment throughout the first five months of the sampling period until reaching peak entrainment rates of 2296 per week from mid-September to mid-October (Fig. 8.7).

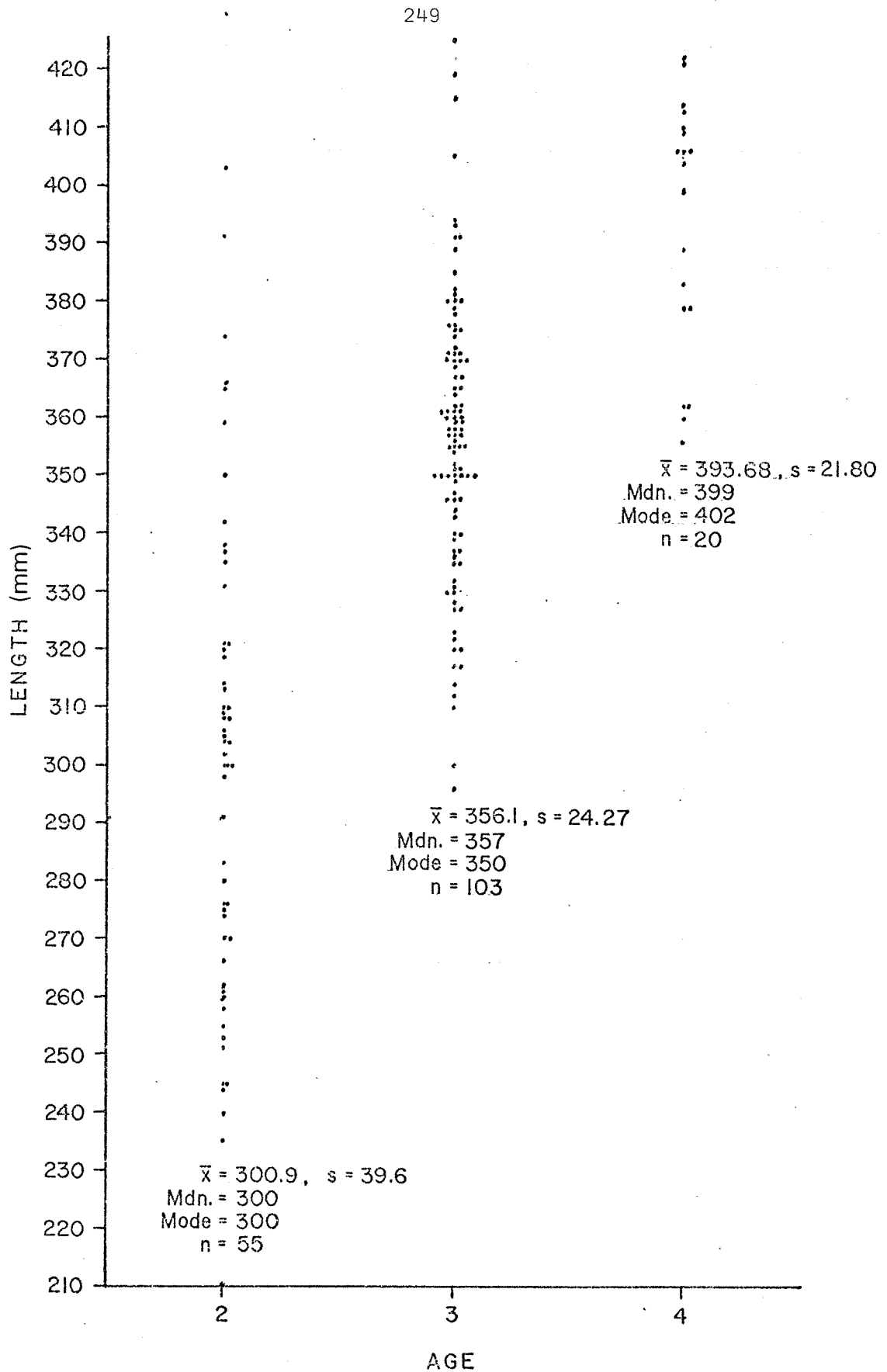


Figure 8.9 A scattergram of kokanee age at length, as determined from otolith readings.

Estimated daytime versus nighttime entrainment rates showed that except for the period March through mid-May, daytime and nighttime entrainment rates were approximately equal. This species spawns in the lake during December and January. Of those lake whitefish entrained during the period March to September, about 77% were immature, with an average weight of 236 g. The increased catch of lake whitefish which occurred during September and October was predominantly of mature individuals (74%) with an average weight of 852 g. Figure 8.10 illustrates the strongly bimodal length frequency distribution of the entrained lake whitefish.

Fry emerge during March and April and are pelagic near the surface for approximately one month. Lake whitefish fry are weak swimmers during this period and were probably entrained to the extent that surface waters were drawn into the irrigation canal discharge. Movement onshore follows the pelagic stage. The entrainment rate was probably greatest during this early period of shoreline existence because the fry were concentrated in the vicinity of the discharge. An estimate of the entrainment of fry was made on May 9, 1975 by suspending a sampling net (20 cm dia., 505 μ mesh) at the downstream sampling location in the irrigation canal. The density of fry caught was calculated as 2.06×10^{-4} per m^3 . Comparing this density to the daily discharge yielded an estimated entrainment of 81,686 fry for that day.

8.4.5 Longnose Sucker

An estimated 10,018 longnose suckers weighing 6,011 kg were entrained through the irrigation canal (Table 8.1). These comprised 2.3% of the total catch of all species, or 5.4% of the total fish biomass entrained.

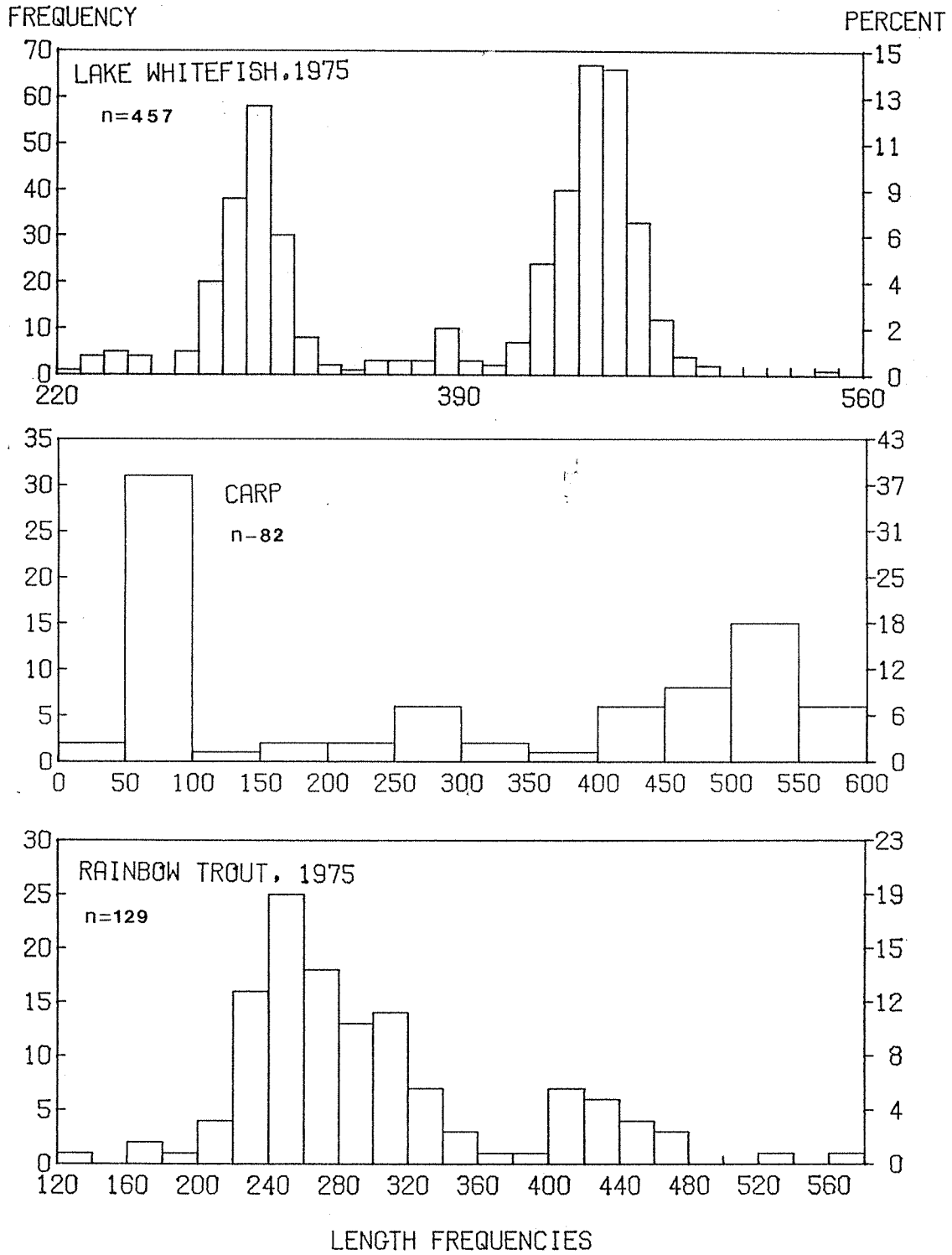


Figure 8.10 Length frequency distributions of lake whitefish, carp, and rainbow trout entrained through the irrigation canal during 1975.

over

Figure 8.7 gives the estimated seasonal entrainment rate for this species. The longnose sucker first appeared in the catch during mid-May and one week later, it reached the peak seasonal entrainment rate of 2,310. Nearly 100% of these were adult spawners. The entrainment rate reached a second peak of 1,400 per week in mid-June and then dwindled to a relatively low and uniform rate for the remainder of the season. Throughout the sampling period, daytime and nighttime entrainment rates were nearly equal.

8.4.6 Carp

An estimated 8,618 carp weighing 9,988 kg were entrained through the irrigation canal. These comprised 2.0% of the total catch of all species entrained, but due to their large size, accounted for 9.1% of the total fish biomass entrained. Carp first appeared in the irrigation canal catch in mid-May during the first portion of their spawning season (Fig. 8.11). Peak entrainment rates were attained in mid-August when large numbers of age 0 carp appeared in the catch. Figure 8.10 shows the roughly tri-modal distribution of the carp. The first mode represents age 0 juveniles. This group comprised 39% of the catch and averaged 12 g each in weight. The second mode represents age 1 fish which comprised 14% of the catch and weighed an average 1,027 g each. The third and largest mode represented a mixture of classes > age 1. This group comprised 47% of the catch and averaged 2,150 g each. Entrainment rates of the two largest groups were quite uniform during the sampling period. Daytime and nighttime catches were about equal and no consistent diel entrainment patterns were observed.

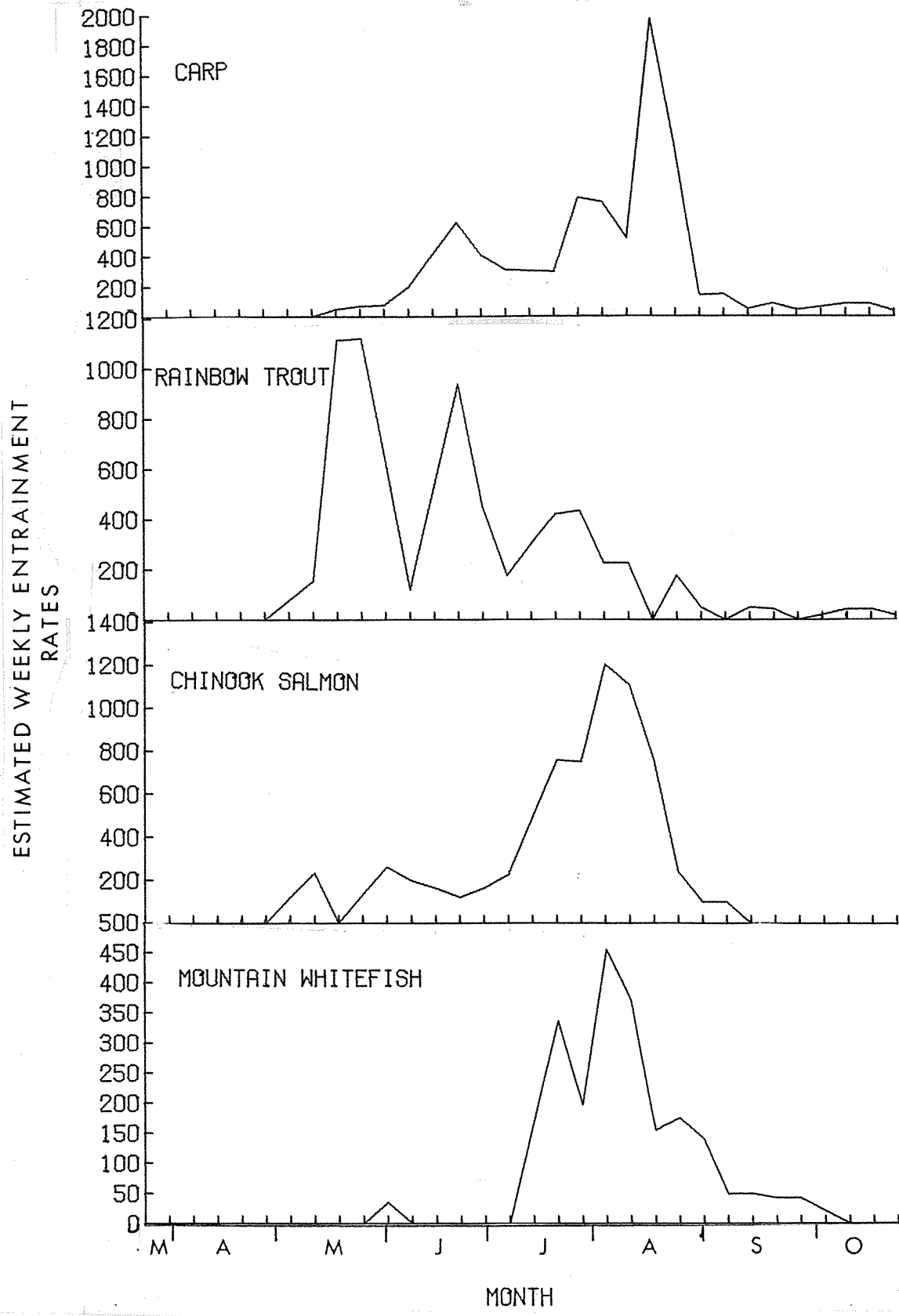


Figure 8.11 Estimated weekly entrainment rates through the irrigation canal in 1975.

8.4.7 Chinook Salmon

An estimated 7,098 chinook salmon weighing 1,170 kg were entrained through the irrigation canal. These comprised 1.6% by number and 1.1% by weight of the total catch of all species entrained.

The first direct plant to Banks Lake of 40,000 age 0 chinook was made in August 1974 (Appendix Table A.1) from holding pens at the north end of the lake. Another group of 19,000 chinook were released from the same location during June 1975. A third release of 35,000 was made on October 19, 1975, after the canal sampling had terminated.

The 1974 plants began to appear in the irrigation canal catch in early May. All were immature females. On July 3, moderate numbers of the 1975 chinook salmon plants first appeared. The timing of the appearance of the 1975 plants and their steady increase in the chinook catch is illustrated in Fig. 8.12. By August the 1974 plants had nearly disappeared. Entrainment rates were equal for day and night. No consistent trends were observed.

A composite of length-frequency data taken throughout the season shown in Fig. 8.12 serves to illustrate the relative abundance of the two year classes in the irrigation canal catch. The entrainment of 1974 plants was estimated at 1,550, or 3.9% of the 40,000 planted. Individuals averaged 297 mm in length and 316 g in weight. The entrainment of the June 1975 plants was estimated at 5,850, or 30.8% of the 19,000 planted, and these averaged 223 mm in length and 125 g in weight.

8.4.8 Rainbow Trout

Rainbow trout were entrained at about the same rates as chinook salmon. Appendix Table A.1 shows the history of rainbow trout planting

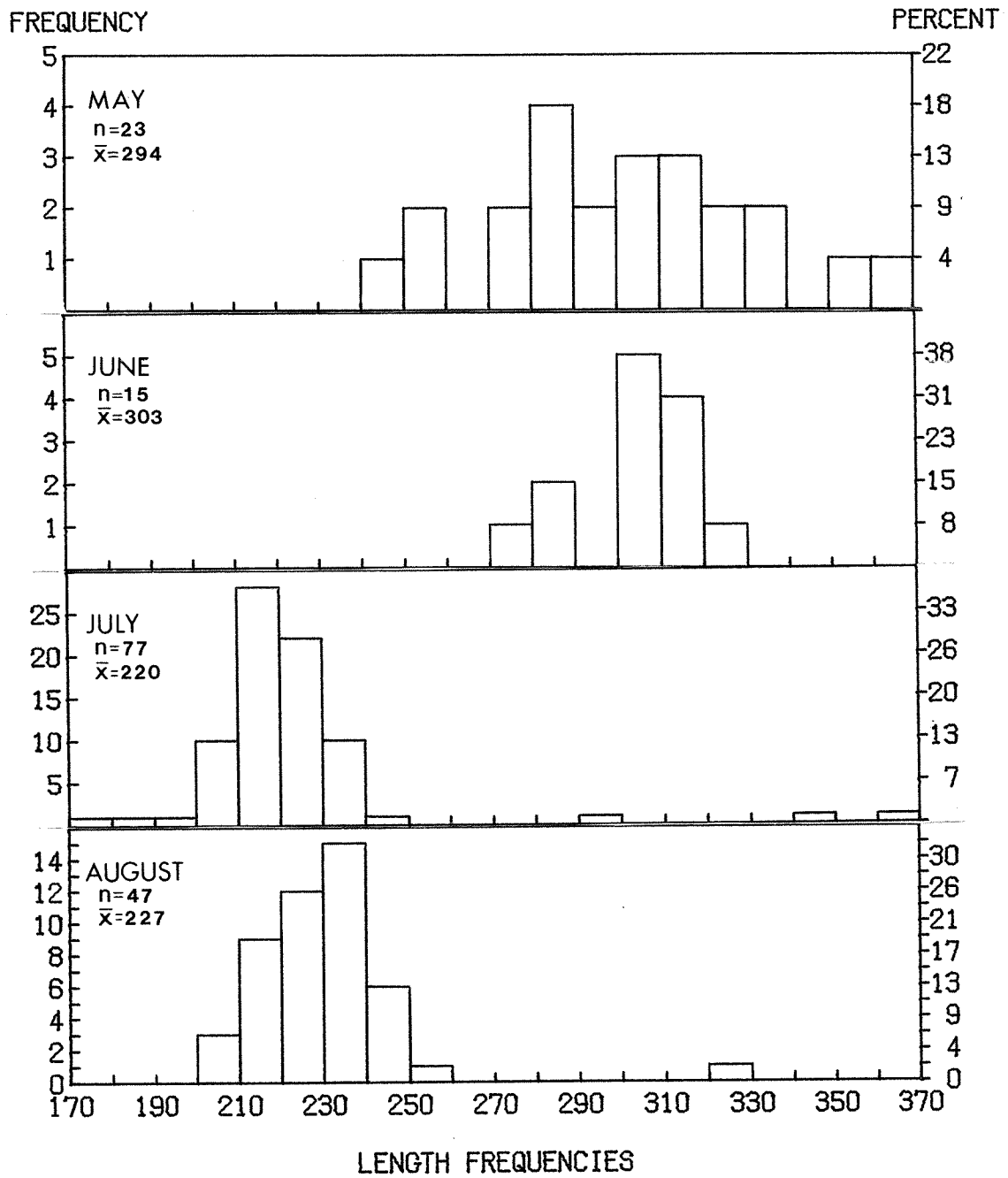


Figure 8.12 Monthly length frequency distributions of chinook entrained through the irrigation canal in 1975.

programs in Banks Lake. On October 23 and 24, 1974, 47,118 marked rainbow were planted at four locations in the northern third of Banks Lake. On June 3, 1975, 44,696 marked rainbow were planted at three locations in the southern third of the lake. The significance of tag recoveries in the irrigation canal catch is summarized, along with the rest of the rainbow mark-recapture data in section 10.0.

An estimated 7,347 rainbow trout weighing 2,756 kg were entrained through the irrigation canal. These comprised 1.7% of the total catch of all species entrained and 2.5% of the fish biomass entrained. Maximum entrainment rates occurred during May and June decreasing throughout the summer irrigation season (Fig. 8.11). Length frequency analysis of entrained rainbow indicated a mean length of 299 mm (Fig. 8.10).

8.4.9 Prickly Sculpin

An estimated 4,255 prickly sculpin weighing 27 kg were entrained through the irrigation canal. These comprised 1.0% of the total catch of all species entrained.

This small inshore fish (average entrained weight = 6 g) was of no direct importance to the Banks Lake sports fishery, but is a potentially important forage fish and a possible predator on kokanee eggs and larvae. Because of its small girth, which approximates the mesh openings of the sampling nets, the entrainment of this species was probably underestimated. One or two individuals appeared in most of the catches.

8.4.10 Mountain Whitefish

The estimated entrainment of mountain whitefish was 2,223. Their appearance in the irrigation canal nets was sporadic, peaked sharply in July and diminished almost to zero by September (Fig. 8.11). Although

the timing and habits of spawning of mountain and lake whitefish were similar, the catch curves were dissimilar. No consistent diel differences in entrainment rates were observed. The average size of captured specimens was 275 mm, and 277 g. The size range of the captured specimens was relatively ranged from 209 to 396 mm.

8.4.11 Peamouth

The estimated entrainment of peamouth was 2072. The peak entrainment rate occurred in June commensurate with spawning (Fig. 8.13). No noticeable differences between daytime and nighttime entrainment rates were observed. The size range of captured peamouth ranged from 186 to 314 mm. The average size of this species was 241 mm, and 184 g.

8.4.12 Pumpkinseed Sunfish

The estimated entrainment of pumpkinseed sunfish was 1,225. The entrainment rate was sporadic and although the peak coincided with spawning, which occurred during May and June, the individuals caught were largely immature (Fig. 8.13). Individuals caught ranged in length from 71 to 170 mm. The average length was 108 mm and the average weight was 62 g.

8.4.13 Black Crappie

The estimated entrainment of black crappie was 1,097. Peak entrainment occurred during May, none were caught during June and July, and lesser numbers were caught during the first and fourth weeks in August. The catches did not coincide with spawning, which occurred in June. Scale readings determined that the catch consisted entirely of immature fish of two age classes; age 1 (79%) and age 2 (21%).

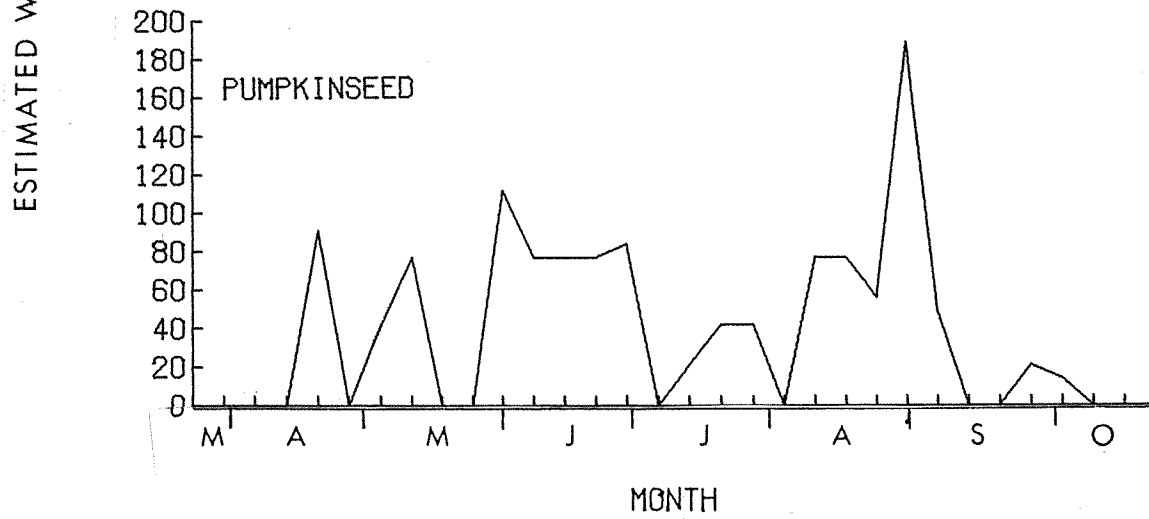
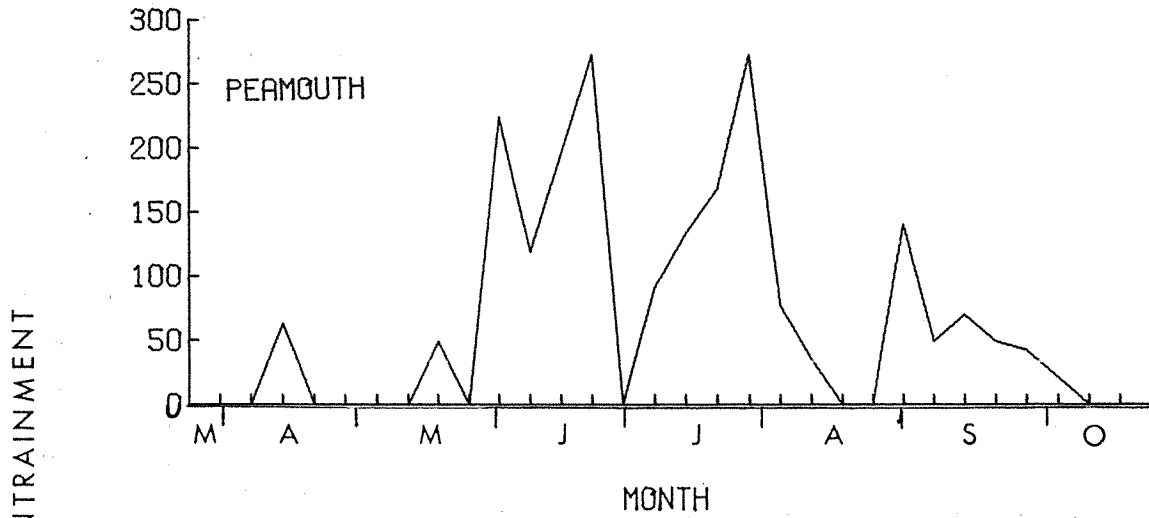


Figure 8.13 Estimated weekly entrainment rates through the irrigation canal in 1975.

The average length and weight of captured specimens was 105 mm, 69 g and the range in length was between 53 mm and 187 mm.

8.4.14 Other Species

The estimated entrainment rates of the remaining four species which appeared in the irrigation canal sampling nets were relatively low. A total of 11 walleye were captured; 2 during May, the remainder throughout August.

Only 5 largemouth bass were caught, 4 during August, and 1 during the first week of September. They ranged in size from 19 g to 1,008 g.

A total of 3 brown bullhead were caught in the canal nets, all during mid-July.

The burbot catch consisted of only a single specimen, an immature which was caught during mid-May which measured 250 mm and weighed 300 g.

8.5 Discussion

8.5.1 Gear Development

Several factors considered in the net selection in order of importance were: (1) current velocity, (2) range of fish sizes, (3) swimming capabilities of fish species, (4) volume of the catch anticipated during a 12-hr sampling period. These factors dictated selection of three sampling locations, a 25.4 mm (1 inch) stretch mesh size of No. 252 fine-thread knotless nylon, and net openings of 6 x 8 ft (downstream net) and 12 ft² (upstream net).

The principal consideration was whether the net strength was adequate to withstand the relatively high velocity of the water surges (5 f.p.s.) in the turbulent flow below the canal headworks. Stress was increased

as catches accumulated during the 12-hr sampling periods, at times weighing up to 136 kg (300 lbs). Net material was selected for high tensile strength (test 34 kg, 75 lbs) and resistance to abrasion.

Mesh size was of secondary importance. This selection necessarily was a compromise between the benefits and deficits of small and large mesh sizes. Small mesh reduced the bias against catching small fish, but increased drag by decreasing the ventilation rate, and thereby slowed the current and allowed larger fish to escape. Large mesh, conversely, increased the bias against catching small fish, but reduced drag, promoted higher current velocity through the net and more effectively sampled the larger fish. A mesh size of 1 inch was selected as the best compromise for sampling the aggregation of species present in Banks Lake.

The sampling location of the downstream net influenced catch selectivity. Downstream nets were fished in turbulent white water of highest velocity consistent with the strength of the net and supporting gear. This reduced the visibility of the net and consequently the rate of avoidance. Comparison of results obtained by concurrently fishing a net from the tunnel faces (upstream location) and from the end of the concrete apron (downstream location) indicated that the larger, faster swimming salmonids (rainbow, kokanee) may have been able to escape from and avoid the downstream net.

The size of the net opening influenced the degree of selectivity for larger fish at the downstream site. As the net opening increased, the selectivity against larger fish decreased. However, because the downstream net was handled manually, the size of the opening was limited for practical reasons to the 6 x 8 ft dimensions used. The upstream

sampling nets were nearly as wide as the outlet tunnels and thus the opportunity for avoidance was greatly reduced. As the upstream nets were positioned in turbulent white water immediately below the outlets of the darkened tunnels, the opportunity for avoidance was negligible, even for the largest salmonids.

8.5.2 Factors Affecting Entrainment

Two modes of entrainment were observed: active and passive. Fish may actively seek an outlet from the lake for spawning, feeding or smolting purposes, and may be guided by the direction and magnitude of water currents. Fish may be passively entrained as a result of their position in the water column and proximity to the outlet. This entrainment is most likely to occur at night when the fish are resting and when unable to maintain visual orientation to the bottom.

Factors which influenced the entrainment of Banks Lake fishes were those which affected distribution and activity related to foraging, spawning or smolting behavior. Important among these factors were water temperature, availability of food, photo-period and rate of irrigation withdrawal. Rate of irrigation withdrawal was the single overriding factor which influenced the entrainment rates of all species.

The entrainment of perch was influenced primarily by nearshore spawning activity, which took place during April and May, and secondarily by foraging activity, which peaked in July commensurate with maximum water temperatures. The entrainment rate dropped sharply from August through the remainder of the season due to the normal offshore movement which occurred during the fall months.

The peak entrainment rate of kokanee during the third and fourth weeks of July coincided with peak abundance at Station 6 and with highest levels of pumping and irrigation water withdrawal. Of these fish 58% were maturing age 3 and 4 year olds.

One puzzling difference between the July and August entrainment maxima was the diel difference in entrainment rates. During July, the majority of entrainment occurred during the day, while during August most entrainment occurred at night. During neither of these time periods did the catch length-frequency composition vary significantly from day to night. The decreasing rate of entrainment during September and October was related to decreasing irrigation withdrawal.

Kokanee were entrained differentially through the six outlet tunnels. The two outside tunnels had consistently higher entrainment rates and were about equal; while entrainment through the four inside tunnels was consistently lower and approximately equal. During June and August, gill nets were set along the shoreline adjacent to the irrigation canal headworks. Kokanee catches were very small in relation to the canal net catches. This suggests that kokanee were not following the shoreline formed by Dry Falls Dam but were entering the irrigation canal headworks via the 16 m deep drainage channel which leads into the headworks from a point north of the center of Dry Falls Dam.

The entrainment of lake whitefish was influenced by temperature and by spawning activity. Catches were reduced during July and August in response to warm surface water temperatures which lake whitefish tended to avoid. During mid-summer the lake whitefish were concentrated in the deep, cool water of the hypolimnion which placed them below the level of the discharge flow. Until the second week in September, the entrained

lake whitefish were predominantly immature. From September until the end of irrigation in mid-October, the majority were mature.

The entrainment of longnose suckers was largely influenced by spawning behavior. The spawning period was relatively short. Spawning individuals were observed in the catch only during a two-week period from May 11 to May 25.

Carp were entrained in small numbers during the peak of spawning which occurred in June. This low rate may have resulted from the preference by spawning carp for shoreline habitat with abundant aquatic vegetation. The outlet of the irrigation canal was probably avoided by spawning carp because it lacks aquatic vegetation. Entrainment rates peaked when foraging schools of age 0 juveniles were entrained during mid- and late-August.

The marked decline after June in the canal catch of 1974 planted age 1 chinook probably reflects decreasing abundance of that year class in the lake. The age 0 chinook which were planted in June 1975 appeared in the irrigation canal for the first time on July 3, nearly 30 days after the date of first release. The peak entrainment of chinook occurred during the next four weeks and consisted almost entirely of the June 1975 plants. An estimated 30.8% of the 19,000 chinook planted in June 1975 were entrained during the 1975 irrigation season. This represents a rather substantial loss, particularly since natural mortality and sports catch had already reduced the population. The high entrainment rate was probably due to the combined factors of foraging and smolting behavior, with the latter being the principal factor involved.

The timing of the appearance of mountain whitefish in the irrigation canal catch was dissimilar to that of the lake whitefish, another winter spawner. The mountain whitefish has a more southerly zoogeographic distribution than the lake whitefish and tolerates much warmer water. This may in part explain the correspondence of the mid-July to mid-August entrainment maximum with peak yearly temperature at Station 6.

The entrainment of peamouth was influenced by spawning activity during June and possibly by temperature-induced activity during middle and late July.

The prickly sculpin is a small benthic fish which exists in moderate numbers along the rocky shorelines of Banks Lake. Because of its small size, it seems likely that individuals of this species were able to pass through the sample net and the entrainment estimates were substantially biased.

Pumpkinseed, black crappie, largemouth bass and walleye are found only infrequently at Station 6 near Dry Falls Dam, but are relatively abundant elsewhere in the lake. The entrainment rates for these four species were consistently low. No entrainment occurred during the spawning period of these fishes which suggests that they spawn elsewhere in Banks Lake.

The brown bullhead occurred infrequently in Banks Lake, except at a few locations near the north end of the lake. The appearance of only three individuals in the irrigation canal catch was insufficient basis for conclusions.

The burbot is now rare in Banks Lake. A single 250 mm immature individual was captured, indicating that a remnant population exists.

For nearly all species, the weekly entrainment curves exhibit a downward trend during September and October. Water temperature was still relatively high during this period, but the rate of flow through the irrigation canal had sharply decreased. Therefore, it seems likely that the decrease in entrainment which most species showed during this period was related to the decreasing rate of water withdrawal.

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9.0 FISH ENTRAINMENT (FEEDER CANAL)

9.1 Introduction

The feeder canal conducts irrigation water from Roosevelt Lake to Banks Lake during the irrigation season, which normally begins in March and ends in October. During the winter months from November to March, the feeder canal conducts water for the operation of pump-generators.

9.2 Description of Feeder Canal

The feeder Canal (Fig. 4.1) is a 1.6-mile long, concrete-lined structure leading from the pumphouse conduits in Grand Coulee Dam into Banks Lake. This canal receives water which is pumped up 360 ft from Roosevelt Lake at a present maximum rate of 13,100 cfs (8 pumps). During periods of peak power demand, water is siphoned from Banks Lake through the feeder canal to the pumphouse in the left forebay of Grand Coulee Dam, and back into Roosevelt Lake where the two pump/generation units now in operation produce 50,000 kw each of peaking power. Future plans call for the installation of four additional pump/generation units and consequent modifications of the feeder canal to handle increased flows for a total of 6 pump/generator units.

The headworks of the feeder canal is a concrete structure with 12 tunnels 15 ft high x 12 ft wide, which empty into the canal. The original six irrigation pumps were installed to operate in Tunnels 1 to 6 and pump/generation (P/G) units presently operate in Tunnels 7 and 8. The remaining four tunnels will eventually connect with future pump/generation units. The depth of the canal at the headworks is approximately 30 ft. P/G operation will occur during the months from November through March and will not occur simultaneously with irrigation withdrawal.

9.3 Materials and Methods

9.3.1 Sampling Gear

Attempts to develop a sampling capability to measure the entrainment of fishes through the feeder canal met with several formidable obstacles which stymied the work initially, but which were gradually overcome. The development of fixed-net sampling was complicated by:

- 1) bi-directional flow over a range of velocities from 1 to 6 fps in the canal and approximately 10 fps at the stop log slots of the headworks;
- 2) the presence of a variety of fish species encompassing a broad range of sizes, swimming capabilities, and behavioral responses to water velocity.

During P/G operation, the direction of flow is reversed for pump-back, either daily or on weekends, and thus, the flow must be sampled in opposing directions. The water velocity in the feeder canal below the headworks has been relatively constant during P/G operation, but has varied from 1 to 8 fps during irrigation pumping, depending on the number of pumps operating. Because some fish species swim actively against the current (such as maturing kokanee, rainbow, carp, and chinook), while others drift passively with the current (such as juvenile perch, whitefish, and kokanee), the variety of responses required bidirectional sampling capabilities. The large variety of fish species of all age classes presented a broad range of net-avoidance capabilities with which to contend. Thus, the combined factors of varied response to current, varied size and avoidance capabilities, varied direction and velocity of flow thwarted the development of a quantitative net-sampling program through the first 18 months of study. While several sampling

gears, including a trap, two types of trawls, and gill nets were tried, all proved ineffective.

Developing a method of sampling the irrigation flow by net was much more difficult in the feeder canal than in the irrigation canal for two reasons: 1) a wider range in current velocity in the feeder canal; and 2) aerated water did not occur in the feeder canal which could be used to reduce net visibility. The net sampling in the irrigation canal was greatly facilitated by aeration of the water at the headworks, which enabled nets to be fished downstream from high velocity water, yet still be effective because they could be positioned in aerated (white) water which reduced the visibility.

The sampling problem in the feeder canal was solved by employing two types of gear. A downstream net similar to the one used in the irrigation canal was used in the stop log slots of pump units 1-6 to monitor entrainment during pumping, and a closed circuit television camera installed and operated by the Engineering and Maintenance Division at Grand Coulee Dam was used to monitor the pump and generation modes of P/G units 7 and 8 (Fig. 9.1).

9.3.2 Irrigation and Pumpback Mode

A quantitative net-sampling capability was developed in the feeder canal during the spring and summer, 1975. This gear underwent considerable revision during the 1975 irrigation season due to underdesign of the net and frame, and was not standardized until late summer. These revisions precluded quantitative assessment of the 1975 entrainment, but the method was determined to be valid and will be used through the 1976

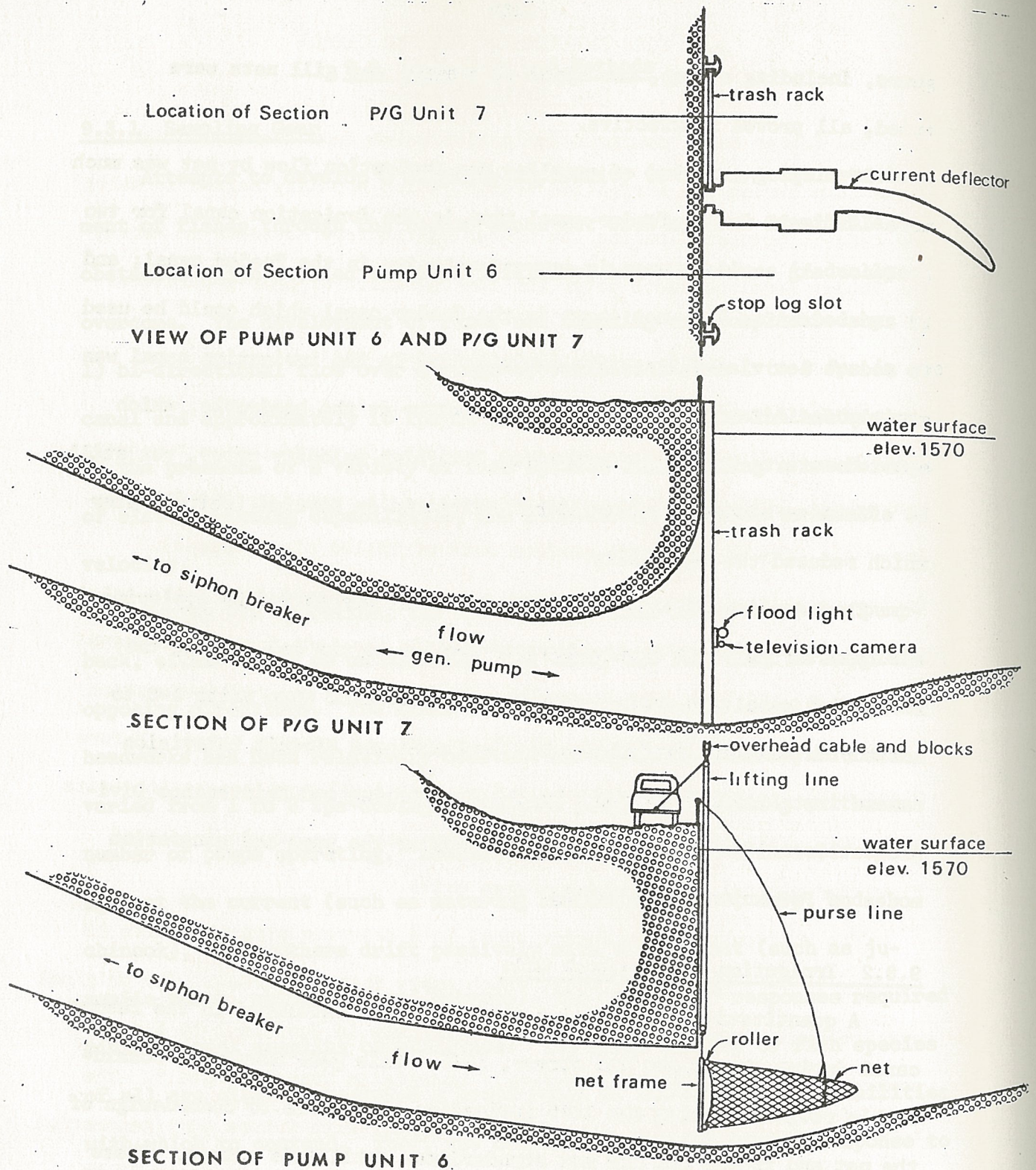


Figure 9.1 Position of sampling apparatus in the flows of P/G and pump units at feeder canal headworks.

irrigation season.

The sampling gear consisted of a cableway directly over the trash rack slots of the feeder canal headworks from which a 14 ft x 14 ft net frame was suspended. Nets of 1 inch mesh (stretched measure) were attached to the downstream side of the frame. The frame was equipped with casters on the downstream side at each corner, which allowed the frame to roll up and down in the slots while under tension from the drag of the net.

The net was raised and lowered from the cableway by a lift line through two double blocks. Lifting was accomplished by securing the lift line to a vehicle which was driven away slowly. A purse line located 4 ft forward of the cod-end served to prevent loss of the catch when hauling and as a means of retrieving the cod-end. After the frame was lifted out of the water, the purse line was pulled to secure the catch and to draw the cod-end up and over the guard rail.

9.3.3 Generation Mode

The television camera was mounted to a vertical bar on the outer edge of the trash rack by means of a specially-constructed bracket which held both the television camera (Edo Western) and floodlamp (150-W thalium iodide) (Fig. 9.1). A team of USBR divers installed the bracket with the camera and floodlamp aimed horizontally across the opening of the P/G unit. The power supply-video cable was led to a video unit and tape recorder (Sony AV650) housed in the siphon-breaker house 150 ft away from the trash racks. The camera angle was 48 degrees, which enabled viewing of approximately one-fourth of the entire area of the

trash rack during conditions of low turbidity which included a 54 ft² area. The viewed area during turbid water conditions was determined by counting the number of vertical bars visible across the face of the trash rack.

The high current velocity through the trash rack (12 fps) made positive identification of most fish difficult even during stop-action and slow-motion playback of the videotape; however, rainbow, chinook, and lake whitefish were positively identified.

9.4 Results

9.4.1 Irrigation and Pumpback Mode

A 12 ft square net was used for sampling during July and August. The portion of the flow sampled by this net was not determined precisely because the frame would not gravitate completely into the laminar flow of the tunnels and no mechanism was available to force it down.

In September, a smaller 6 ft x 8 ft net was installed which created less drag and therefore would gravitate to the bottom of the canal. The fact that this net fished well within the laminar flow greatly reduced the opportunity for upstream migrating salmonids to enter the net.

A summary of the catch data from the feeder canal during the irrigation season shows a total catch of 188 fish during 285 hours of test fishing (rate = 0.66 fish per hour). In all, 13 species were caught, as listed in Table 9.1.

The catch included specimens which had sustained injuries during entrainment from Roosevelt Lake to the feeder canal. In all cases, the injuries involved transverse sectioning of the body. Only one part of

Table 9.1 Relative order of abundance of fishes entrained in the feeder canal during July, August, and September, 1975.

Order	Species	Scientific Name
1	prickly sculpin	<i>Cottus asper</i>
2	kokanee salmon	<i>Oncorhynchus nerka</i>
3	largescale sucker	<i>Catostomus macrocheilus</i>
4	lake whitefish	<i>Coregonus clupeaformis</i>
5	peamouth	<i>Mylocheilus caurinus</i>
6	carp	<i>Cyprinus carpio</i>
7	rainbow trout	<i>Salmo gairdneri</i>
8	mountain whitefish	<i>Prosopium williamsoni</i>
9	northern squawfish	<i>Ptychocheilus oregonensis</i>
10	perch	<i>Perca flavescens</i>
11	walleye	<i>Stizostedion vitreum</i>
12	chinook	<i>Oncorhynchus tshawytscha</i>
13	burbot	<i>Lota lota</i>

each specimen was recovered. The injury rate due to transverse sectioning was approximately 5%.

The catches of kokanee fry (age 0) are of particular interest to this study because they indicate that Roosevelt Lake may be an important source of recruitment to the Banks Lake kokanee population. Even though our nets were not designed to effectively sample small fish, a total of 23 fry were retained in the net. This relatively high frequency indicates a substantial entrainment of juvenile kokanee.

Also of interest was the catch on August 29 of a chinook salmon measuring 32 inches (87 cm) and weighing 14 lb 6 oz (2,270 gm). This fish originated from a plant of approximately 1.8 million chinook fry into Roosevelt Lake in 1972 and was mature at the time of its capture. Because of its excellent growth we believe the individual was entrained soon after its release and reared in Banks Lake where small perch provide an abundant food source. This capture coincides with the reported sports catch of several other large chinooks during the summer.

9.4.2 Generation Mode

The operating schedule of P/G units 7 and 8 since November 1974 is summarized by week in Table 9.2. During the winter of 1974-75, P/G units 7 and 8 were run primarily for performance testing on a sporadic schedule for relatively short time periods. The units were operated on request of the Fisheries Research Institute once each month during January, February, and March 1975, during which times observations of entrainment rates were made using closed circuit television (see Fisheries Research Institute annual report, 1975).

Table 9.2 Summary of operating times, discharge volumes, and weeks sampled for P/G units 7 and 8.

Date	P/G 7 & 8 - Pumping		P-1 - P-6 Pumping		P/G 7 & 8 - Generating		Weeks Sampled
	Run Time (hrs)	Acre-ft	Acre-ft	Acre-ft	Run Time (hrs)	Acre-ft	
12/01-07/74	00:45	119.01	0	0	15:56	3,242.97	
12/08-14/74	10:41	1,709.75	0	0	06:11*	1,243.64	
12/15-21/74	01:03	166.61	0	0	00:63	186.45	
12/22-28/74	00:11	27.77	0	0	03:43	704.13	
12/29-1/4/75	00:00	0	0	0	00:45	107.11	
1/26-2/01/75	00:00	0	3,584.13	0	44:18	7,352.72	X
2/02-08/75	16:05	2,513.06	0	0	00:00	0	
2/09-15/75	31:03	4,851.57	0	0	08:48	1,315.04	X
2/16-22/75	00:00	0	0	0	20:58	3,544.46	
2/23-3/01/75	40:49	6,253.88	0	0	38:38	5,162.97	
3/02-08/75	38:55	5,918.68	0	0	07:57	1,311.07	X
1/18-24/76	00:52	140.83	0	0	23:56	3,574.21	X
1/25-31/76	13:54	2,207.60	5,875.04	0	29:31	5,063.80	
2/01-07/76	64:12	10,195.04	0	0	53:29	9,911.40	
2/08-14/76	53:17	8,467.43	0	0	36:32	6,585.12	X
2/15-21/76	31:58	4,982.48	49.59	0	36:44	6,884.62	
2/22-28/76	65:48	9,822.14	0	0	37:40	7,429.16	
2/29-3/06/76	35:33	6,436.36	0	0	69:40	12,846.94	
3/07-13/76	60:30	8,495.20	6,390.74	0	39:27	7,207.93	
3/14-20/76	46:56	6,083.30	12,751.73	0	15:32	2,723.30	
3/21-27/76	22:56	2,624.13	21,235.03	0	25:41	4,308.10	
3/28-4/03/76	48:59	5,246.28	29,722.30	0	00:00	0	

* estimated value

During the winter of 1975-76, P/G 7 was operated solely because P/G 8 was disassembled for mechanical repair. A minimal operation schedule, similar to that of 1974-75, was forecast by Grand Coulee Operations until late January, at which time a relatively full operating schedule was begun in response to increased power demand. The entrainment of fishes was observed by means of closed circuit television during two weekly periods--January 20 to 23 and February 9 to 11. The results are summarized in Table 9.3. The visibility was greatly reduced during the February sampling and a third sampling which was scheduled for March 5 to 7 was cancelled because of high turbidity caused by spring runoff and by drawdown of Roosevelt Lake.

The portion of the total flow which was observed was determined by counting the number of bars visible across the trash rack on which the camera was mounted. During good visibility in January, approximately one-fourth of the 12 ft x 16 ft opening was visible, but during turbid conditions in February, only one-eighth of the area was visible.

The estimated entrainment rate for P/G 7 was 1.58 fish/hour during generation and 0.00 fish/hour during pumping. Of the eight fish actually observed, five were identified as rainbow, one as a whitefish, and two were unidentified. This entrainment rate was less than that observed during a similar period in 1975 when 4.7 fish/hour/PG unit were estimated.

9.5 Discussion

The entrainment of fish during P/G operation appears to occur largely during the generation mode, resulting in a net loss of fish from

Table 9.3 Summary of observations of entrained fishes of the feeder canal headworks during P/G operation, 1975 and 1976.

Date	Gear	Time	Hours	Mode	Fish Viewed (Identified)	Observed		Adjusted	
						Entrainment Rate/hr	Entrainment Rate/hr	Entrainment Rate/hr	Entrainment Rate/hr
1/30/75	TV	0800 to 1130	3.7	G	6 (2 rainbow)	1.62	6.49	1.62	6.49
		1600 to 2000	4.0	G	8 (1 lake whitefish)	2.00	8.00	2.00	8.00
1/31/75	TV	0800 to 1200	4.0	G	5 (1 chinook, 3 perch)	1.25	4.00	1.25	4.00
		1600 to 2000	4.0	G	1	0.25	1.00	0.25	1.00
2/01/75	TV	0800 to 1200	4.0	G	2 (1 rainbow)	0.50	2.00	0.50	2.00
		1600 to 2000	4.0	G	1	0.25	1.00	0.25	1.00
2/10/75	TV	1030 to 1330	3.0	G	2	0.67	2.67	0.67	2.67
		1600 to 2000	4.0	G	2	0.50	2.00	0.50	2.00
3/02/75	TV	1500 to 2000	5.0	P	0	0.00	0.00	0.00	0.00
3/03/75	TV	0800 to 1200	4.0	G	1	0.25	1.00	0.25	1.00
			4.0	G	2	0.50	2.00	0.50	2.00
			40.5		30				
1/20/76	TV	1705 to 2040	2.0	G	1 (rainbow)	0.50	2.00	0.50	2.00
1/21/76	TV	0700 to 1000	3.0	G	3 (2 rainbow)	1.00	4.00	1.00	4.00
1/23/76	TV	0655 to 1100	4.0	G	0	0.00	0.00	0.00	0.00
		1700 to 2000	3.0	G	2 (rainbow)	1.00	4.00	1.00	4.00
1/25/76	net	0800 to 1700	9.0	P	0	0.00	0.00	0.00	0.00
2/09/76	TV	1750 to 2005	2.0	G	1 (whitefish)	0.50	1.80	0.50	1.80
2/10/76	TV	0405 to 0605	2.0	P	0	0.00	0.00	0.00	0.00
		0700 to 0900	2.0	G	1	0.50	2.80	0.50	2.80
		1700 to 2000	3.0	G	0	0.00	0.00	0.00	0.00
2/11/76	TV	0400 to 0600	2.0	P	0	0.00	0.00	0.00	0.00
		0700 to 0900	2.0	G	0	0.00	0.00	0.00	0.00

/1 counts are adjusted for portion of opening sampled.

Banks Lake. The species most often observed were those which are most active during the winter months: rainbow, whitefish, and chinook. Because rainbow were by far the most frequently observed, we conclude that extensive P/G operation will affect principally the rainbow population.

The extent of sampling by means of closed circuit television is, as yet, insufficient to establish meaningful entrainment rates for rainbow relative to P/G operation. Because the 1974-75 observations indicated a decreasing entrainment rate with generation time, the impact of an extensive operation may be far less than that projected from present data.

Conversely, the lower rate of rainbow entrainment observed in 1976 may have resulted from the operation of only one P/G unit that year rather than two P/G units which operated in 1975. Thus, the attraction rate of rainbow from Banks Lake into the feeder canal during generation may not be directly proportional to the flow, but may vary as some power of the flow.

These factors can be determined only by extensive sampling of the P/G flow, as the units are operated according to a schedule which facilitates the documentation of entrainment rate over time, with varied flow, and by season.

10.0 MOVEMENTS AND ENTRAINMENT OF PLANTED RAINBOW TROUT

10.1 Introduction

Rainbow trout are planted annually into Banks Lake since a sport fishery for this species is almost totally dependent on artificial stocking. The popularity of this species among anglers is attested to by a concentration of fishing effort at times and places when rainbows are readily caught. Rainbows are particularly sought by a late winter-early spring fishery which concentrates where the ice cover is adequate for ice fishing, along the rocky shorelines after ice breakup, and at the headworks of the irrigation canal. Although the fishing emphasis shifts to other species when boat fishing begins in mid-spring, many rainbows are caught incidentally during the summer by fishermen who are angling for kokanee, perch and bass. Thus the rainbow is an important contribution to the angler's creel and the stocking program which supports it is essential in maintaining a viable, year-round sport fishery in Banks Lake.

With the commencement of pump-generation flow through the feeder canal, concern was expressed by anglers and the Washington Department of Game that considerable numbers of rainbow trout might be entrained out of Banks Lake during the winter months to the detriment of the sport fishery. If knowledge of the habits of the rainbow were better known, the locations and timing of the plantings might be altered to reduce entrainment losses to minimal levels.

In order to learn about the movements and distribution of rainbows as a means to determining whether a particular planting strategy would

reduce the entrainment losses, a mark-recapture study was undertaken in which rainbow trout were released during spring and fall at varying locations throughout the length of Banks Lake.

10.2 Materials and Methods

Juvenile rainbow trout were tagged on two occasions at the Columbia Basin Hatchery: October 8 to 12, 1974, and February 22 to 25, 1975. The first group was composed of larger fish, averaging 150 mm (fork length) long and weighing 20 per pound. These were marked externally by removal of the adipose fin and were tagged internally by means of a coded, magnetic wire tag injected into the cartilage of the snout. The group was separated into four lots of approximately 12,000 each marked with a distinctly coded wire tag. These lots were planted two weeks later on October 23 and 24, 1974, at four locations in the northern third of Banks Lake.

The second group was of smaller fish, averaging 75 mm long and weighing 40 per pound. These were marked and tagged in the same manner as the first group, but were held at the hatchery until June 3, by which time they had reached a size of 10 per pound. The four separate lots were reduced to three when a windstorm blew down the divider screen at the hatchery and mixed two adjacent lots. On June 3 the three lots were planted in the southern third of Banks Lake.

Recovery of the tags was accomplished by voluntary return of the heads by anglers to a predesignated local sport shop, by monitoring the sport creel during routine creel censusing and from sampling nets in Banks Lake and in the feeder and irrigation canals. The heads of all

the rainbows lacking adipose fins were removed and preserved in formaldehyde. Posters asking anglers to turn in the tags to a local sports shop were placed at popular shoreline fishing locations and announcements publicizing the tagging study were made in the local news media. These announcements requested cooperation by anglers in returning the heads of marked rainbows.

The tags were recovered from the heads by sectioning the snout into segments which were passed through an electronic tag detector. The segment containing the tag was divided into a progressively smaller segment until the tag was identified under microscope.

10.3 Results and Discussion

The recovery rate of tags was too low to warrant a detailed analysis of the returns (Table 10.1). In all, 78 tags were returned from 47,118 rainbows planted in the fall of 1974, and 140 were returned from the spring, 1975, plant of 44,696 rainbows. The low recovery rate was due primarily to the poor return of sports-caught rainbow and secondarily to a relatively high rate of tag loss. Most of the recoveries from the angler creel were obtained during the creel census. Relatively few were returned voluntarily by the anglers. The rate of tag loss was determined by comparing the number of rainbow heads bearing tags (218) to those without tags (65). The tag loss rate was 30%. General factors which may account for the high loss rate include inexperience of the persons operating the tagging machines, head molds too small for the fish, innate difficulty in tagging rainbow trout with injected nose tags because of the species' blunt snout, and a relatively large amount of epidermal mucous.

Table 10.1. Rainbow trout mark-recovery information.

Group I					
Date tagged: 10/8-12/74					
Date planted: 10/23-24/74					
Lot number					
	1	2	3	4	Total
Number tagged and planted	11,708	12,586	10,277	12,547	47,118
Location planted	Sta. 1	Airport	Sta. 3	Sta. 4	
Tags recovered	37	25	10	6	78
Average days to recovery	186	186	300	235	
Recoveries by location *1)	24	11	3	0	38
	2)	1	9	0	11
	3)	1	1	0	4
	4)	11	4	7	25
Group II					
Date tagged: 2/22-25/75					
Date planted: 6/10/75					
Lot number					
	5	6	7	Total	
Number tagged and planted	24,450	11,269	8,977	44,696	
Location planted	Sta. 5	S. M\$M	Goose I.		
Tags recovered	55	37	49	141	
Average days to recovery	164	157	132		
Recoveries by location *1)	13	2	2	17	
	2)	7	5	20	
	3)	10	5	16	
	4)	25	25	88	

*Banks Lake divided into fourths lengthwise from north to south.

The recovery patterns were greatly influenced by the location of fishing effort and the location of release. Return rates for all releases were greatest at the north and south ends of the lake where the fishing effort for rainbows was concentrated. Fish which were released north of the Narrows (lots 1 and 2) were returned in greatest numbers from the north end, and fish which were released south of the Narrows (lots 3, 4, 5, 6 and 7) were returned in greatest numbers from the south end (Fig. 10.1).

The apparent tendency of rainbows to move to the south end, however, was an artifact of the data, resulting from an intensive sampling effort in the irrigation canal. The 62 recoveries from the irrigation canal substantially inflated the recovery rate for the south end.

The return rates from lots released at or near the ends of the lake (lots 1, 2, 6 and 7) were greatest from the immediate area of release. This was especially true for releases at the south end (lots 6 and 7) from which 72% of the returns occurred.

Quantitative sampling in the irrigation canal provided information from which to extrapolate the catch of tagged rainbow to the number entrained out of Banks Lake. Because the canal nets sampled approximately 1/213 of the irrigation flow during 1975, the total entrainment of rainbow was estimated by multiplying the catch of tagged rainbow by 213 (Table 10.2).

The entrainment rate apparently was greater for lots 6 and 7 (2.1 and 5.9%) near the south end than for lots 1 and 5 at the more northerly locations. This implied that the entrainment of rainbow may be minimized

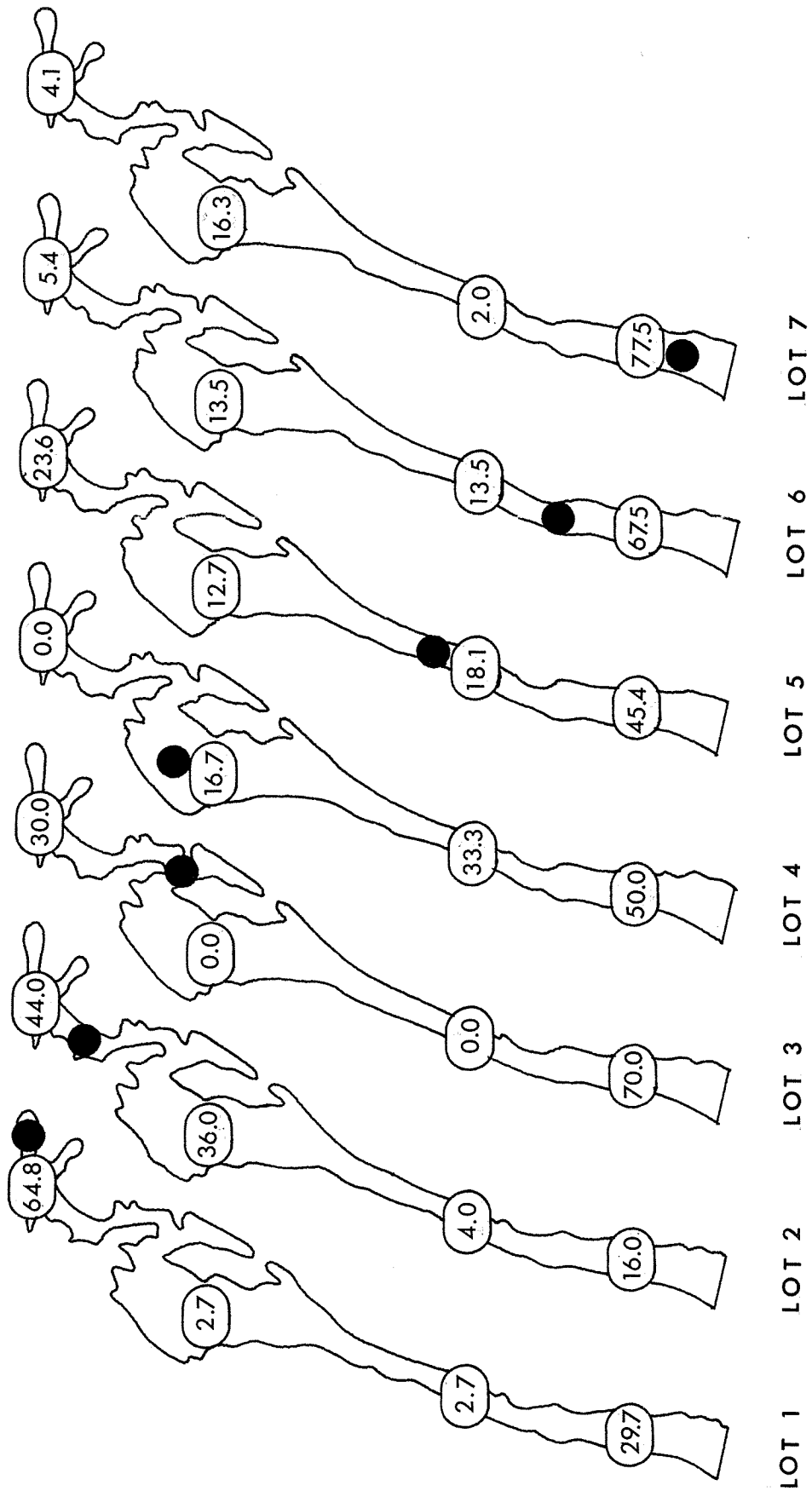


Figure 10.1 Recovery of tagged rainbow trout by planting location (●).. Numbers are percentages of recoveries in quarter-sections of Banks Lake.

Table 10.2 Recovery of tagged rainbow trout from the irrigation canal and estimated entrainment out of Banks Lake.

	Lot number						
	1	2	3	4	5	6	7
Recoveries from irrigation canal	7	4	5	2	8	11	25
Estimated total entrainment of tagged rainbows	149	85	106	43	170	234	533
Estimated percentage entrainment of tagged rainbows	1.2	0.8	1.0	0.4	0.7	2.1	5.9

in the future by avoiding plants near the south end, during the irrigation season or immediately prior to initiation of drafting.

Although the entrainment of marked rainbows in the feeder canal during P/G operation was not determined, it seems likely that a higher entrainment rate would also exist for any plants made near the north end of Banks Lake, particularly during the fall and winter months.

11.0 SUMMARY AND DISCUSSION

11.1 Aquatic Environment

Limnological investigations have indicated that Banks Lake is a very complex system dominated by the flow-through of irrigation water. The temperature regime is one of modified dimixis possessing properties of both a stratified lake and a river-run reservoir. The turbulent inflow of cooler irrigation water from Roosevelt Reservoir restricts the summer water temperatures in the north end of the lake. The lake is characterized by division into northern and southern pools due to an emphasis of the thermal dissimilarity by a morphometric constriction and shoaling of the lake basin. A convergence zone occurs in this area of the lake during the irrigation season where the cooler water pumped into the north pool flows under the warmer stratified water of the southern pool. A horizontal surface temperature gradient was observed to increase toward the south during the summer; however, during fall, winter, and early spring, the gradient reversed, due to greater radiational cooling in southern Banks Lake as well as pumped input of the warmer water from Roosevelt Reservoir during the cooler seasons of the year.

Secchi depth transparency generally increased from north to south due to a larger phytoplankton standing stock and turbulence due to pumping in the northern pool of the lake.

Ionic composition of Banks Lake water was dominated by calcium, magnesium, carbonate and bicarbonate. The hardness levels indicated a soft to moderately hard water. Alkalinities were low but consistent with other data reported for the lake and Roosevelt Reservoir. Maximum pH occurred in May in the northern pool during maximum primary production.

Minimum pH occurred in the summer near the bottom of the southern pool, indicating respiration exceeded photosynthesis. Conductance values and conversion to total dissolved solids indicated no significant change since the early pre- and post-impoundment data taken on the Columbia River, Lake Roosevelt, and Banks Lake. The oxidation-reduction potentials remained high, characteristic of an oligotrophic lake.

Silica, an important nutrient for diatom production, was found to increase with initiation of pumping in the spring and decline through the production season. A general decline was also observed from north to south in the lake; however, levels which would have limited diatom production were not indicated.

The dynamics of the nutrient supply to Banks Lake are complex and directly influenced by the pumped input of water from Lake Roosevelt. Available plant nutrients (N & P) were pumped from Lake Roosevelt into Banks Lake whenever pumping occurred. During the irrigation period, March - October, which coincided with the natural production season, the input of available nutrients stimulated an increase in primary phytoplankton production in the north pool. Plant production was also enhanced by the turbulent mixing in the north pool which occurred due to pumped input. Nitrate and phosphate levels were shown to become depleted in the lake from north to south, particularly during the production season. Nutrient limitation due to a lower N:P ratio and low nitrate concentrations reduced primary production in the south pool. The entire lake has shown nitrate limitation after pumping and drafting had ceased for a period of time.

During irrigation the retention time of the north pool (15 percent of the total lake volume) ranged from a minimum of three days to a maximum of 15 days. The plant production which occurred flowed into the south pool which had a much longer retention time. Utilization of plant cells by zooplankton occurred primarily in the south pool. Zooplankton composition and density exemplified the differences in the north and south pools. The washout of zooplankton from the north pool reduced abundance and restricted development due to the short retention times during pumping. Some zooplankton were pumped into the north pool from Lake Roosevelt; however, the major zooplankton source important to the lake developed in the south pool. Longer retention times, warmer temperatures, and an inflow of phytoplankton from the north pool favored greater stability and development of the zooplankton community in the south pool.

A preliminary study showed drawdown affected organisms in the benthic littoral zone. Chironomids and oligochaetes dominated the benthos and showed increased numbers from the north pool to the south pool. Recovery of the affected benthic areas appeared quite rapid when water levels remained stable for several months.

11.2 Fish Population Ecology

Twenty-one species of fish were identified in Banks Lake. These stocks originated from several sources including Lake Roosevelt, small lakes existing in the Grand Coulee prior to inundation, artificial stocking programs carried out by state agencies and possible release by sport fishermen. Yellow perch, lake whitefish, and kokanee salmon were

the three dominant species in the lake which were selected for detailed analysis.

Analysis of 30 months of baseline sampling data indicated the numerically dominant species in the lake was yellow perch. This species was found consistently in the lower 4 m of the water column, except during the summer months when surface temperatures reached maximum levels. Yellow perch moved inshore during spring for spawning and offshore in the fall as temperatures decreased. Juvenile perch remained inshore to rear in warmer water and to take advantage of a diverse food supply. A partial avoidance of the north pool was observed during irrigation pumping. Those perch which were resident in the north pool exhibited reduced growth rates and body condition. Food habits indicated nearly complete dependence on zooplankton of the genus *Daphnia*. Excellent growth rates for yellow perch up through age 5 were found in the south pool where *Daphnia* were abundant.

Yellow perch spawning occurred during March and April in shallow shoreline areas. Depth distribution of spawners ranged from 0 to 60 ft, with maximum abundance at 6 ft. Incubation required from 3 to 4 weeks. Major drawdown of Banks Lake occurred during the spring-summer spawning, incubation, and rearing period for yellow perch. Water level declines of 24.9 ft, 23.6 ft, and 8 ft in 1973, 1974, and 1975, respectively, affected the reproductive habitat of perch; however, absolute estimates of population level effects could not be determined. During 1973 and 1974 the lake volume was reduced by about 50 percent during drawdown; however, the amount of shoreline habitat increased by about 25 percent. During the 30-month study period a decline in the abundance of larger

perch occurred with an increase in the number of smaller individuals. This resulted in a smaller population of large perch available to the sport fishery. The actual mechanisms affecting the perch population remain to be determined.

The lake whitefish was found to be a dominant species by numbers and biomass in the 1974 year class. Lake whitefish were found throughout the water column except during the summer months when they were restricted primarily to the bottom strata. This distribution resulted in part because of a negative response to warmer surface water temperatures which probably exceeded the optimum. Lake whitefish were distributed offshore during summer and fall during maximum seasonal water temperatures. Juvenile and adult whitefish were captured inshore during the spring while temperatures remained cool. Adult lake whitefish moved inshore during December and January to spawn on the beaches. A nearly complete avoidance of the north pool was observed during irrigation pumping. Maximum abundance was found in the northern area of the south pool west of Steamboat Rock. This may indicate a compromise between preferred low temperature and high food abundance. In summer the lowest water temperatures and lowest food abundance occurred to the north pool, and warmest water and highest food abundance occurred to the south pool. The preferred food type was the cladoceran zooplankton *Daphnia*.

Growth rates could not be compared between pools due to general avoidance of the north pool. The growth between ages 1 and 3 was similar to that reported in other systems; however, growth appeared to stop at a length of about 435 mm. Age 5 appeared to be the maximum age obtained. Limited longevity and growth probably resulted from water temperatures which exceeded the preferred range for lake whitefish and

from an almost exclusive dependence on zooplankton as compared to benthic diets in other systems. Recruitment of juvenile lake whitefish indicated a dominant year class age structure typical of a species with a pelagic larval stage. The mechanism(s) controlling year class strength does not now appear to be affected by operational characteristics on the lake; however, these interactions are not presently understood. Large numbers of pelagic whitefish larvae were entrained through the irrigation canal during the spring; the effects on the population are unknown. Spawning, incubation, and emergence did not appear to be affected since lake level fluctuation was held to a minimum during the winter and early spring months. However, spawning occurred during December at depths ranging from 0 to 60 ft, with maximum abundance at 6 ft. Therefore, potential harm to recruitment exists should the lake level be lowered more than three feet during the period December to April. Reduction in lake volume during the extreme 1973 and 1974 summer drawdowns did not appear to significantly affect the population of lake whitefish.

The kokanee salmon is indigenous to the upper Columbia River system and occurs in Lake Roosevelt, which is one source of the Banks Lake stock. The kokanee were found to be one of the dominant fishes by number and biomass in Banks Lake. Kokanee were pelagic throughout the year, but showed a preference for cooler hypolimnetic waters during maximum summer water temperatures. They preferred the pelagic offshore areas except during the fall when spawners were concentrated inshore. Avoidance of the north pool was evident during irrigation pumping at

which time maximum abundance occurred in the southern portion of the south pool. *Daphnia* was the preferred food type and occurred in highest abundance in the south pool.

The kokanee has a thermal tolerance which is intermediate between lake whitefish and yellow perch as demonstrated by increase in the CPUE up to 19°C. This tolerance enabled kokanee to forage in the southern portion of the south pool where food abundance was greatest.

Comparison of growth rates between pools was not possible due to avoidance of the north pool; however, rapid growth rates were indicated in the south pool. Maturity was reached at 3 and 4 years of age.

Kokanee spawning occurred during October and November in the shallow shoreline areas. The largest concentration of spawners was found along the steep talus slopes of the southwest quarter of the lake. The fish were spawning on shelves which were 3 to 10 ft wide and from 3 to 25 ft deep. In major spawning areas shelves were found at two depths: 6 ft and 18 ft, resulting in two maximum spawning densities. Live developing eggs were recovered from the gravel up to May 14, 1976, suggesting that emergence may not be concluded until late May or early June. No emerging fry or juvenile kokanee were captured. An analysis of possible effects of spring drawdown in 1973 and 1974 estimated exposure of large areas of reproductive habitat used by kokanee for spawning, which probably resulted in the large decline in abundance of 3-year-old fish in 1976. This year class was small from the time it was recruited into the gill net samples. Evaluation of stranding mortality requires a better understanding of the reproductive efficiency of kokanee in the lake.

11.3 Sport Fishery

A 12-month creel census of the Banks Lake sport fishery from April 1975 to March 1976 indicated that 350,866 angler-hours were spent in catching 173,695 fish, or about 0.5 fish per angler-hour. The principal species and estimated catch were: kokanee (75,035); perch (59,798); rainbow (19,358); chinook (8,133); crappie (6,501); sunfish (3,529); and bass (1,036). A comparison of these data with two previous censuses indicated that a shift in the creel from spiny-rayed to salmonid fishes is continuing as the result of salmonid stocking by the game and fisheries management agencies and of decreased average size of the spiny-rayed fishes. The present census indicated a 21 percent increase in effort since 1971-72.

The boat fishery was active from April to October and concentrated mainly on kokanee and bass. The bank fishery was most active from January through May and concentrated mainly on perch, crappie and rainbow trout.

An estimated sport catch of 8,133 chinook salmon constituted 20 percent of the entire 1974 plant of 40,000 chinooks. This is considered a very high rate of return in view of losses due to entrainment and natural mortality which occurred. The timing and location of the chinook catch approximated that of the rainbow catch which indicated similar habitat and feeding preferences for the two species.

11.4 Entrainment

Sampling of the irrigation inflow and outflow by means of nets and of the pump-generation flow by means of closed-circuit television

revealed that a substantial loss of fish occurred from Banks Lake in 1975-76. The loss occurred principally through the irrigation outlet canal, from which an estimated 436,216 fish, weighing 110,338 kg were entrained. Point estimates and 95 percent confidence limits for 3 of 16 species observed were: yellow perch (241,367 \pm 21,537); kokanee (128,747 \pm 12,517); and lake whitefish (21,776 \pm 2,932). The entrainment timing of most species was associated with sexual maturity and pre-spawning activity.

Fish were introduced to Banks Lake through the feeder canal during the summer irrigation period at a relatively low rate and in different species composition and abundance by comparison with the loss via the irrigation canal. The 3 principal species of the 13 observed were prickly sculpin, kokanee and largescale sucker. The total entrainment in the feeder canal was not estimated due to inconsistent sampling frequency caused by very difficult sampling conditions. The kokanee entrained from Roosevelt Lake were principally age 0 and therefore may have constituted an important source of recruitment to the Banks Lake kokanee population.

The pump-generation flow during testing of P/G 7 and 8 in the past two winters resulted in a relatively minor loss of fish from Banks Lake by comparison with the fish loss during irrigation drafting. Preliminary fish entrainment rates based on small samples indicated mean rates per P/G unit per hour during the generation mode of 4.1 in 1975 and 1.6 in 1976. Rainbow trout was the species most commonly entrained from Banks Lake through the feeder canal. Other species observed were lake whitefish, chinook, and perch. The entrainment of fish into Banks Lake during the pumping mode was negligible during the winter.

Since rainbow trout are maintained in the lake by an artificial stocking program, the movements, distribution, and entrainment rates were studied by mark-recapture of a known population. Mark-recoveries suggested that fish released in either the north or south pools tended to be recaptured in the same pool. Releases made closest to the canals in either end indicated higher loss due to entrainment, particularly during the summer irrigation season in the irrigation canal and through the feeder canal in winter. Plants during these seasons should be made at alternate ends of the lake to minimize entrainment losses.

11.5 Impact Assessment

The primary purpose of Banks Lake is to function as an equalizing reservoir for the Columbia Basin Irrigation Project. The operational changes imposed on the lake by irrigation result in dramatic effects on the water quality which are exemplified in the aquatic ecosystem and the important fish populations. Some of these changes may be considered beneficial, such as nutrient addition and mixing. Other changes such as frequent, major water level fluctuations as well as entrainment and flushing can impose strict limitations on the ability of the system to produce and sustain aquatic life and fish. Although the full range of interaction has not been determined completely, the extreme drawdown imposed on Banks Lake due to third powerhouse construction at Grand Coulee Dam in 1973 and 1974 created some undesired reductions of the sport fish species in the lake.

In spite of the operational effects imposed on Banks Lake throughout its history a popular sport fishery has developed due to the

production of relatively large sport fish populations. This occurred along with an average annual maximum water level fluctuation of about 15 ft. Therefore, some operational fluctuation of the lake level can be tolerated; however, the magnitude, timing, and rate of water level change could be managed in the future to maintain a larger standing crop of sport fishes and to minimize the occasional severe year class reduction of key sport fish.

The entrainment of fishes through the irrigation canal is an annual loss which has been imposed on every year class to date. There is little doubt, however, that the entrainment loss constitutes a substantial reduction in the population of mature age 3 and 4 kokanee from the lake.

This does not represent a total loss to the sport fishery since an undetermined number are taken by anglers downstream in the irrigation canal as well as in Billy Clapp Lake. However, it does constitute a movement of mature fish away from a concentrated sport troll fishery on Banks Lake. This loss of large kokanee is more acute in a year following drawdown in which eggs and fry were stranded and the recruitment of a particular year class was reduced. Therefore, management of the lake to sustain the reproductive potential of kokanee and yellow perch would help to insure continuation of a viable sport fishery for these species.

The future impacts to be imposed on the lake due to the development of pumped storage have not yet been fully evaluated. This activity will largely be restricted to the winter period when aquatic production reaches an annual minimum and therefore changes imposed may be less pronounced than those already occurring due to irrigation. Some effects have been indicated by research conducted to date while other impacts remain to be tested. 1) Winter temperatures in the north pool will increase, thereby reducing ice cover; 2) nutrient input to the north pool will probably increase, thereby stimulating further primary production; 3) flushing rates of the north pool will increase; 4) entrainment of fish through the feeder canal (generation mode) will increase the loss of fish from Banks Lake. The significance of this loss presently is considered small relative to the loss through the irrigation canal; however, it remains to be adequately tested; 5) increased movement of water in two directions between Roosevelt Lake and Banks Lake may increase the numbers of non-game fish in the north pool; 6) fluctuation in water level during winter due to P/G operation will increase to a potential seasonal maximum of about 7 ft, which can further impact reproduction of shore spawning species such as kokanee and lake whitefish; 7) modifications to the feeder canal, planned for 1978, 1979, and 1980, will prohibit filling of the lake until mid-May each year, even though irrigation drafting will begin in March. Impacts on the fishes due to major drawdowns such as those experienced in 1973 and 1974 may reoccur during these future years and cause stranding of yellow perch and kokanee eggs and fry. Since the majority of kokanee in the lake

mature in three years this could virtually eliminate the natural kokanee population in the lake. 8) The eventual installation of six P/G units will provide a larger capacity pumpback capability than previously available and will allow a means of maintaining a more constant lake level. This management capability could be utilized to minimize draw-down impacts on the fishery if integrated into the irrigation and power programs for the lake.

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Appendix Table 1 Known fish introductions to Banks Lake /1

Date	Number	Species	Common Name	Size	Origin
2/53	4,000	<i>Salmo gairdneri</i>	Rainbow trout (Kamloops)	30/lb	-
4/56	10,010	<i>Salmo gairdneri</i>	rainbow trout	11/lb	-
5/56	1,504,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
10/56	14,190	<i>Salmo gairdneri</i>	rainbow trout	11/lb	-
6/57	1,533,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
9/57	12,250	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	-
10/4-8/57	28,000	<i>Salmo gairdneri</i>	rainbow trout	14/lb	-
4/4/58	10,035	<i>Salmo gairdneri</i>	rainbow trout	9/lb	-
6/5/58	29,500	<i>Salmo gairdneri</i>	rainbow trout	59/lb	-
6/13/58	39,600	<i>Salmo gairdneri</i>	rainbow trout	66/lb	-
7/2/58	63,000	<i>Salmo gairdneri</i>	rainbow trout	45/lb	-
8/5/58	18,000	<i>Salmo gairdneri</i>	rainbow trout	30/lb	-
9/3-16/58	97,300	<i>Salmo gairdneri</i>	rainbow trout	20/lb	-
5/23/58	1,298,800	<i>Oncorhynchus nerka</i>	kokanee salmon	1,640/lb	Leavenworth
6/10/59	89,060	<i>Salmo gairdneri</i>	rainbow trout	20-22/lb	-
6/3-9/59	59,980	<i>Salmo gairdneri</i>	rainbow trout	9-18/lb	-
7/14/59	28,270	<i>Salmo gairdneri</i>	rainbow trout	22/lb	-
7/23/59	24,988	<i>Salmo gairdneri</i>	rainbow trout	30-45/lb	Tucannon
3/23/60	949,560	<i>Oncorhynchus nerka</i>	kokanee salmon	5,790 lb	Leavenworth
4/27/60	946,400	<i>Oncorhynchus nerka</i>	kokanee salmon	5,200 lb	Leavenworth
6/28/60	14,400	<i>Salmo gairdneri</i>	rainbow trout	18/lb	-
7/1-17/60	72,000	<i>Salmo gairdneri</i>	rainbow trout	17-20/lb	-
8/16/60	50,100	<i>Salmo gairdneri</i>	rainbow trout	14-19/lb	-
9/28/60	12,000	<i>Salmo gairdneri</i>	rainbow trout	15/lb	-
1961 NO RECORDS					
6/13/62	31,430	<i>Salmo gairdneri</i>	rainbow trout	14/lb	Columbia Basin
6/15/62	14,300	<i>Salmo gairdneri</i>	rainbow trout	13-lb	Columbia Basin
7/13/62	14,980	<i>Salmo gairdneri</i>	rainbow trout	14/lb	Columbia Basin
9/20/63	65,680	<i>Salmo gairdneri</i>	rainbow trout	8.5-12/lb	Columbia Basin
8/20/63	10,000	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin

/1 Unpublished information obtained from Washington State Departments of Game and Fisheries.

Appendix Table 1 Known fish introductions to Banks Lake (cont)

Date	Number	Species	Common name	Size	Origin
7/1-2/63	47,340	<i>Salmo gairdneri</i>	rainbow trout	10-12/lb	Columbia Basin
6/17-24/63	44,040	<i>Salmo gairdneri</i>	rainbow trout	11-12/lb	Columbia Basin
4/25/63	506,000	<i>Oncorhynchus nerka</i>	kokanee salmon	6,175 lb	Leavenworth
5/8/64	954,000	<i>Oncorhynchus nerka</i>	kokanee salmon	5,600 lb	Leavenworth
5/6/64	56,000			125/lb	Spokane
5/20-26/65	1,000,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
9/65	25,000	<i>Oncorhynchus nerka</i>	kokanee salmon	9/lb	Leavenworth
10/65	85,000	<i>Oncorhynchus nerka</i>	kokanee salmon	7-12/lb	Leavenworth
9/22/65	24,000	<i>Oncorhynchus nerka</i>	kokanee salmon	25/lb	Leavenworth
	26,300			20/lb	Leavenworth
5/13/66	1,000,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
4/27-29/66	50,400			9/lb	Columbia Basin
5/6/66	9,000			9/lb	Columbia Basin
7/7/66	8,500			12/lb	Columbia Basin
7/21/66	17,550	<i>Salmo gairdneri</i>	rainbow trout		
			(Kamloops)		
8/25-31/66	39,120	<i>Salmo gairdneri</i>	rainbow trout	15/lb	Columbia Basin
6/13/67	46,000	<i>Salmo gairdneri</i>	rainbow trout	10-12/lb	Columbia Basin
7/19/67	32,300	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
8/8/67	11,600	<i>Salmo gairdneri</i>	rainbow trout	9-10/lb	Columbia Basin
	5,400	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/31/67	6,500	<i>Salmo gairdneri</i>	rainbow trout	-	
11/21/67	15,000	<i>Salmo gairdneri</i>	rainbow trout	19/lb	Chelan
10/3/68	20,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/3/68	21,150	<i>Salmo gairdneri</i>	rainbow trout	20/lb	Columbia Basin
10/30/68	11,250	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/6/68	32,600	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
11/7/68	28,525	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
11/8/68	16,500	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
6/11/69	8,500	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/23/69	12,000	<i>Salmo gairdneri</i>	rainbow trout	5/lb	Columbia Basin
9/25/69	12,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
			rainbow trout	10/lb	Columbia Basin

Appendix Table 1 Known fish introductions to Banks Lake (cont.)

Date	Number	Species	Common Name	Size	Origin
9/30/69	26,100	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/1/69	24,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/6/69	11,500	<i>Salmo gairdneri</i>	rainbow trout	9-10/lb	Columbia Basin
10/15/69	12,300	<i>Salmo gairdneri</i>	rainbow trout	12/lb	Chelan
10/8/69	11,160	<i>Salmo gairdneri</i>	rainbow trout (Kamloops)	9/lb	Columbia Basin
11/20/69	19,575	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Tucannon
9/2/70	50,883	<i>Salmo gairdneri</i>	rainbow trout	21/lb	Chelan
9/4/70	20,265	<i>Salmo gairdneri</i>	rainbow trout	21/lb	Columbia Basin
10/8/70	20,230	<i>Salmo gairdneri</i>	rainbow trout	7/lb	Columbia Basin
10/13/70	12,500	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/21/70	26,200	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/22/60	13,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/29/70	10,350	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
11/10/70	10,950	<i>Salmo gairdneri</i>	rainbow trout	4/lb	Columbia Basin
11/18/70	7,600	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
11/18/70	11,825	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
3/30/71	20,000	<i>Salmo gairdneri</i>	rainbow trout	16/lb	Columbia Basin
3/30/71	9,000	<i>Salmo gairdneri</i>	rainbow trout	18/lb	Columbia Basin
3/30/71	42,000	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/5/71	21,750	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/19/71	20,116	<i>Salmo gairdneri</i>	rainbow trout	18/lb	Columbia Basin
5/10/71	150,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry ^{1b}	Leavenworth
5/12/71	12,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
4/27/71	8,850	<i>Salmo gairdneri</i>	rainbow trout	10/lb ^b	Columbia Basin
4/30/71	32,000	<i>Oncorhynchus kisutch</i>	coho salmon	160/lb	Columbia Basin
4/30/71	69,750	<i>Oncorhynchus kisutch</i>	coho salmon	150/lb	Columbia Basin
10/29/71	18,000	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/1/71	16,515	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/2/71	8,820	<i>Salmo gairdneri</i>	rainbow trout	9/lb ^a	Columbia Basin
11/2/71	7,850	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/5/72	11,475	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin

Appendix Table 1 Known fish introductions to Banks Lake (cont.)

Date	Number	Species	Common Name	Size	Origin
5/5/72	8,550	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/30/72	15,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/31/72	11,280	<i>Salmo gairdneri</i>	rainbow trout	19/lb	Columbia Basin
6/6/72	1,800	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
6/6/72	10,400	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/28/72	11,050	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Columbia Basin
6/28/72	3,500	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/28/72	10,800	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/29/72	7,600	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/29/72	4,950	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/2/72	16,335	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/3/72	15,500	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/3/72	6,215	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/26/72	25,542	<i>Salmo gairdneri</i>	rainbow trout	8.5/lb	Columbia Basin
11/8/72	3,120	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
11/8/72	3,300	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
5/1/73	37,290	<i>Salmo gairdneri</i>	rainbow trout	12/lb	Columbia Basin
8/73	110,660	<i>Salmo gairdneri</i>	rainbow trout	22/lb	Winthrop
5/28/74	16,445	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Columbia Basin
8/11/74	40,000	<i>Oncorhynchus tshawytscha</i>	chinook salmon	3/lb	Ringo
10/23/74	23,202	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
10/24/74	12,615	<i>Salmo gairdneri</i>	rainbow trout	10.7/lb	Columbia Basin
10/24/74	110,000	<i>Oncorhynchus nerka</i>	kokanee	50/lb	Leavenworth
10/24/74	11,748	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/31/74	21,004	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
10/31/74	22,375	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	Columbia Basin
11/6/74	15,750	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	Columbia Basin
11/13/74	1,350	<i>Salmo gairdneri</i>	rainbow trout	13.5/lb	Columbia Basin
11/13/74	11,024	<i>Salmo gairdneri</i>	rainbow trout	10.6/lb	Columbia Basin

Appendix Table 1 Known fish introductions to Banks Lake

Date	Number	Species	Common Name	Size	Origin
4/23/75	18,810	<i>Salmo gairdneri</i>	Rainbow trout	19/lb	Columbia Basin
4/23/75	250	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/24/75	1,500	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/24/75	7,820	<i>Salmo gairdneri</i>	rainbow trout	17/lb	Columbia Basin
4/25/75	13,753	<i>Salmo gairdneri</i>	rainbow trout	17/lb	Columbia Basin
4/25/75	9,800	<i>Salmo gairdneri</i>	rainbow trout	24/lb	Columbia Basin
4/27/75	10,735	<i>Salmo gairdneri</i>	rainbow trout	19/lb	Columbia Basin
4/27/75	15,950	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/29/75	11,320	<i>Salmo gairdneri</i>	rainbow trout	22/lb	Columbia Basin
4/29/75	6,825	<i>Salmo gairdneri</i>	rainbow trout	21/lb	Columbia Basin
6/3/75	11,030	<i>Salmo gairdneri</i>	rainbow trout	13.5/lb	Columbia Basin
6/3/75	10,050	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Columbia Basin
6/3/75	11,264	<i>Salmo gairdneri</i>	rainbow trout	10.5/lb	Columbia Basin
6/3/75	8,997	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
3/21/76	30,696	<i>Salmo gairdneri</i>	rainbow trout	24/lb	Columbia Basin
3/21/76	25,168	<i>Salmo gairdneri</i>	rainbow trout	26/lb	Columbia Basin
3/22/75	44,640	<i>Salmo gairdneri</i>	rainbow trout	32/lb	Columbia Basin
6/75	19,000	<i>Oncorhynchus tshawytscha</i>	rainbow trout	8/lb	Green River
10/75	35,000	<i>Oncorhynchus tshawytscha</i>	chinook salmon	17/lb	Deschute River