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SURVEY OF FISHERIES RESOURCES IN THE FOREBAY OF FRANKLIN D. ROOSEVELT RESERVOIR, 1976-77

by

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1.0 SUMMARY

A survey of Franklin D. Roosevelt Reservoir forebay for the period from February 1976 through March 1977 is included in this report. These data were collected in order to aid in the impact assessment of the operation of Third Powerhouse generators G-19 and 20 or 21, which may be used to predict the effects with the eventual operation of all six generators.

Vertical temperature and velocity profiles were taken in the forebay each month. Thermal stratification occurred from May through October. Surface water temperature ranged from a low of 2.9 C in February to 19.6 C in late July.

Surface current velocity was highest in the Third Powerhouse forebay when G-19 and 20 or 21 were operating. Velocity profiles were taken at several sites close to the face of the dam; multiple regression analysis of water level and discharge indicated water level was the primary controlling factor of current velocity in nearshore stations (right and left forebay).

Analysis of the annual reservoir drawdown for 36 years of record showed a trend of increasing drawdown with time. Three periods were identified: 1941-51, when drawdown did not exceed 30 feet; 1952-65, when drawdown was relatively consistent at 40 feet; and 1966-1976, when drawdown reached extremes of 130 and 133 feet in 1969 and 1974, but ranged from 64 to 88 feet during the remaining years. Minimum water level elevations occurred from late winter to early spring but most often occurred in April.

The origins of fish species in the reservoir were reviewed. Twelve species were captured and two others were observed in the forebay during this survey. The history of salmonid plants into FDR was compiled, and data on the 1966 and 1967 catches of kokanee are presented. The gillnet catch totaled 709 fish, of which 51.0% were squawfish and 13.5% were walleye. The proportion of gamefish (seven species) to non-gamefish (five species) was 35.8:64.2%. Greatest abundance in the gillnet catch occurred in August in the surface water.

Acoustic surveys indicated highest fish abundance in August. Fish target density averaged one per 14,094 m^3 during March to June 1976 and January through March 1977, one per 37 m^3 in August, and one per 611,597 m^3 during September to November. The abundance of fish was greatest near the surface, with few targets below a depth of 45 m. All sampling techniques indicated low fish abundance in the FDR Reservoir forebay.

Comparisons to past studies indicated declines in the number of kokanee have occurred as well as increases in the number of walleye. Late spring spawning species (walleye and squawfish) are apparently less affected by drawdown than are fall and winter spawning species (kokanee and lake whitefish). Eggs and alevins of kokanee and lake whitefish have extended incubation periods in lakeshore spawning gravels, which are directly affected by extreme drawdown. The ability of stream-spawning species to populate the reservoir appears to be limited or insufficient for the size of the reservoir. Residence time of fish in the forebay appeared to be limited due to continual entrainment through the penstock and spillway openings in Grand Coulee Dam. Entrainment of fishes from the surface waters entering the Third Powerhouse forebay along the right side of the reservoir is expected to increase due to increased water velocity and drafting of water from the entire water column in this constricted area.

2.0 ACKNOWLEDGMENTS

This investigation was conducted under contract with the U.S. Bureau of Reclamation (USBR), Pacific Northwest Regional Office, Boise, Idaho. The Institute personnel responsible for the studies reported herein were as follows:

Dr. Q.J. Stober, Principal Investigator
Dr. R.E. Nakatani, Co-Principal Investigator
Mr. R.W. Tyler, Project Leader
Mr. C.E. Petrosky, Field Project Biologist
Mr. T.J. Carlson, Research Assistant
Mr. D. Gaudet, Research Aid
Mr. H. Bell, Research Aide

The cooperation received from the Washington Departments of Game and Fisheries in securing recent information regarding FDR Reservoir is appreciated. Mr. George R. Snyder, U.S. National Marine Fisheries Service, Seattle, was especially helpful in granting us permission to include previously unreported catch data on kokanee in the forebay. The cooperation from USBR personnel at Grand Coulee Dam in furnishing past operational data on the Reservoir is greatly appreciated. Dr. R.E. Thorne of the Fisheries Research Institute guided the acoustic assessment work.

3.0 INTRODUCTION

The eventual operation of six generators presently being installed in the Third Powerhouse at Grand Coulee Dam will change the water flow regime in the forebay and lead to possible alteration of the temperature and current regimes, as well as the distribution and abundance of fishes in the forebay. The little that is known of the sport fish resource of the forebay indicates that in some years substantial numbers of kokanee frequent the area during February and March, and many may be entrained through the penstocks and spillway openings. Our sampling in connection with the study of Banks Lake at the feeder canal headworks has shown that small numbers of age 0 kokanee are entrained into Banks Lake via the irrigation pumps. Other species entrained from FDR Reservoir in decreasing order of abundance include prickly sculpin, largescale sucker, lake whitefish, peamouth, carp, rainbow trout, mountain whitefish, northern squawfish, yellow perch, walleye, chinook salmon, and burbot which have been captured in the feeder canal (Stober et al. 1976). These data indicated that several species are present in the FDR forebay and probably are entrained into the penstocks and spillway flows through Grand Coulee Dam. Sampling data collected from several areas of FDR forebay was needed in order to adequately determine actual abundance and changes which might be imposed by operation of the Third Powerhouse.

The purpose of this study was to determine the distribution and movement of fishes in the forebay of the FDR Reservoir during routine operations which might entrain fishes through the three powerhouses and the pumping plant. Specific objectives of this study were to determine: (1) the vertical temperature and water velocity profiles during routine operation of various generator and pump combinations; (2) the relative abundance and distribution of game and non-game fishes in the immediate forebay area with special reference to the Third Powerhouse; and (3) the operational effects on movement and location of fishes in the forebay. The information obtained will be used to evaluate the operational effects on the existing Third Powerhouse (with G-19 and 20 or 21 in operation) and the potential environmental impacts which may result with Third Powerhouse extension on the fishery resources of FDR forebay. G-21 became operational late in the study period, but because of a water conservation program the Third Powerhouse generators were not operated at full capacity. During the study period, no more than two Third Powerhouse generators were operated during the actual time when samples were collected.

This report includes data collected during a period of 14 months from February 1976 through March 1977. The sampling period included two winter seasons in which kokanee had previously been found abundant in the forebay. This is the final contract report following a preliminary report issued in February 1977. Additional limnological data collected during this study in the FDR forebay will be reported in the final 1977 contract report of the Banks Lake ecological studies.

4.0 DESCRIPTION OF STUDY AREA

Grand Coulee Dam, located at RM 597, was completed in 1941 creating FDR Reservoir. The impoundment has a surface area of 80,000 acres extending 151 miles upstream. Total reservoir storage capacity to elevation 1288.0 ft msl is 9.4×10^6 acre feet; active storage between elevations 1208-1288 ft msl is 5.07×10^6 acre feet. The annual average flow of the Columbia River for the period 1913-1955 was 78.3×10^6 acre ft (USBR 1976). The present survey has only included the reservoir area extending from Grand Coulee Dam upstream to Spring Canyon, a distance in the immediate forebay of about three miles. Five sampling transects established in the main forebay were located near the dam face (Transect 1), inner logboom (Transect 2), outer logboom (Transect 3), Crescent Bay (Transect 4), and Spring Canyon (Transect 5) (Fig. 1). Each transect was located at right angles to the central axis of the reservoir at distances increasing from the dam. The Third Powerhouse forebay was sampled with a series of transects located in a grid system (Fig. 2).

The area of the reservoir included in this survey is characterized by vertical rock walls and steep erosive banks. The morphometry of the reservoir in the forebay restricts the area of littoral zone to a minimum. The maximum depth of the Reservoir in the forebay extends to about 380 feet.

The original hydraulic capacity of Grand Coulee Dam (Right and Left Powerhouses) was 92×10^3 cfs, which will increase to 291×10^3 cfs once all six generators in the Third Powerhouse become fully operational (USBR 1975). The maximum total potential hydraulic capacity of the dam with extension of the Third Powerhouse with an additional six units will be 495×10^3 cfs. This study is intended to add to the background data on which a judgment may be made on the potential effects of extension.

The mean weekly water level for the study period, February 1976 through March 1977, fluctuated 71.6 feet, from a low of 1218.4 ft msl in late April 1976 to a high of 1290.0 ft in early September (Fig. 3). The annual drawdown for flood storage was begun in February 1976. Full pool was reached again in late June and maintained into January 1977, when drawdown was begun again. Weekly fluctuation of water level at full pool was usually less than one foot. During drawdown and filling, mean weekly water level changed as

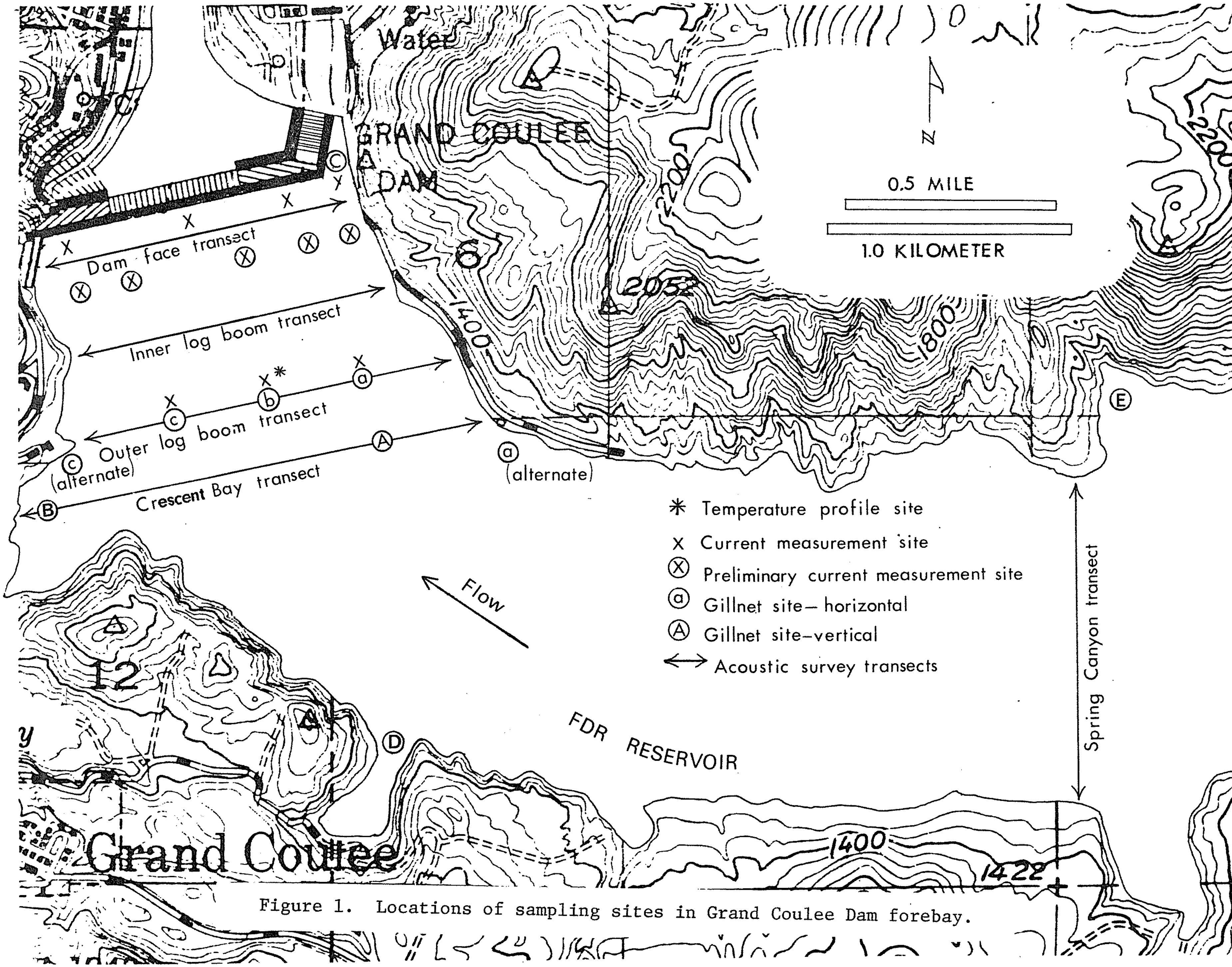


Figure 1. Locations of sampling sites in Grand Coulee Dam forebay.

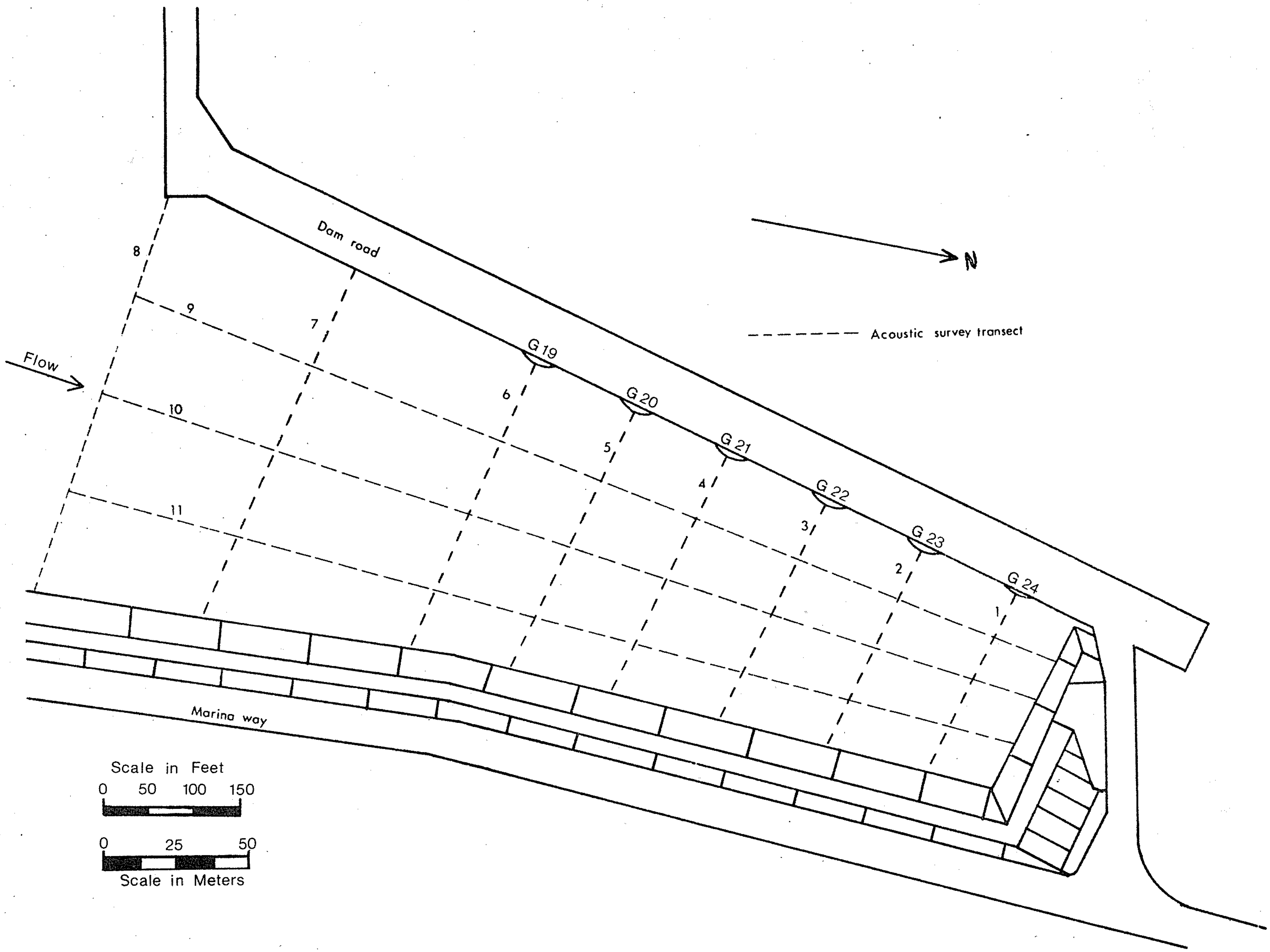


Figure 2. Locations of acoustic transects within the Third Powerhouse bay.

little as 1.4 feet in April and as much as 19 feet in May.

Mean weekly total discharge for the period varied from 86.4 x 10^3 cfs in February 1977 to 201.2 x 10^3 cfs in August 1976 (Fig. 3). Mean weekly spill, surface and sub-surface combined, ranged from 67.1 x 10^3 cfs in August to zero spill for one week in April and for the period mid-September through March 1977. High spring and summer runoff was experienced in 1976, while the beginning of 1977 was a period of lower than average precipitation, and the spilling which normally occurred in winter to lower the lake level did not occur. There was no discharge via the spillway from March through May 1976 when reservoir elevation was less than 1260 ft msl; however, sub-surface spill was considerable during this period.

5.0 MATERIALS AND METHODS

5.1 Water Temperature

Water temperature was measured *in situ* with a Hydrolab Model 6D Surveyor. A vertical temperature profile was recorded monthly in the mid-forebay, upstream from the logboom (Fig. 1). Temperature (C) was measured at 2-m intervals from the surface down to 20 m and at 4-m increments from 21 to 99 m. Measurements were limited to the upper 99 m of water by the cable length connecting the sonde to the deck unit.

5.2 Water Velocity

Current velocity measurements were taken using a directional flow meter with remote velocity readout. A static line, weighted with anchors, running from surface to bottom served to maintain the position of boat and current meter. Velocity in knots and direction were measured at 4-m increments of depth. Current measurements were taken at right, mid-, and left forebay locations upstream from the logboom (Fig. 1) on April 22, May 20, June 15, August 2, and September 4, 1976, and February 15 and March 17, 1977, over a wide range of operational conditions. No measurements were made during fall 1976 quarter due to breakdown of the current meter and the length of time required for its repair.

Measurements were also made at the entrance to the Third Powerhouse forebay (March 16, April 21, and May 20, 1976, and February 15 and March 17, 1977) and 50 m upstream from the face of the dam (April 21, and May 20, 1976), when safety restrictions permitted sampling these locations. In addition, five preliminary sites in a transect about 175 m from the dam were sampled on March 13, 1976; two of these sites were sampled again on March 16, 1976.

5.3 Gillnet Sampling

Horizontal and vertical gillnets were used in a systematic, semi-monthly sample program from April 1976 through March 1977, except that sample effort was reduced to monthly in December and January at a time of low fish abundance. Occasional exploratory gillnetting was conducted during both summer and winter. In addition, preliminary gillnet sampling was carried out in March 1976 to develop consistent methods for conditions in the Grand Coulee

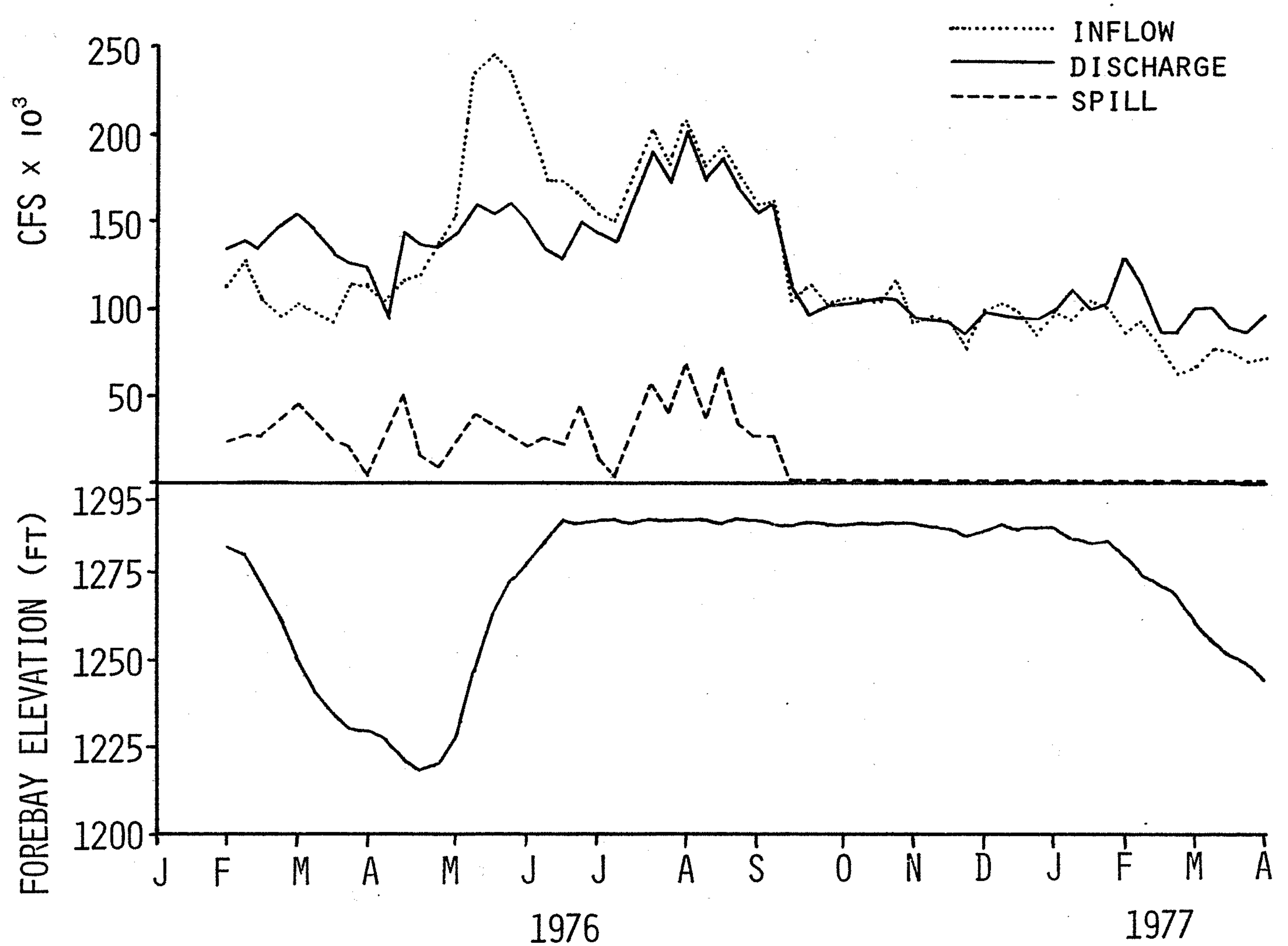


Figure 3. Weekly inflow to FDR Reservoir, spill, and total discharge from Grand Coulee Dam, and forebay surface elevation (USBR data).

Dam forebay. Sites and number of nets varied in March 1976, and catch data will be considered separately from the systematic sampling. Preliminary gillnet samples consisted of a 24-hour quintuple vertical gillnet set (March 8-9, 1976), 24-hour surface horizontal net sets at right and left forebay locations (March 10-11, 1976), and two consecutive 24-hour double vertical net sets at the Third Powerhouse bay site (March 18-20, 1976).

Horizontal gillnets 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 to 5 inches) graduated in 1.3-cm (1/2-inch) intervals. Semi-monthly sets were made at the surface and bottom of the water column at right, center, and left forebay locations along the logboom (Fig. 1). Sampling with a bottom horizontal net at the center forebay site was discontinued after June due to problems with accumulated debris.

Vertical gillnets were fished semi-monthly at the right forebay location, in Crescent Bay, and in the Third Powerhouse bay. Vertical gillnets were constructed of 6.4-cm (2.5-inch) stretched monofilament nylon, 24.4 m (80 ft) deep by 3.0 m (10 ft) wide; two or three vertical nets were joined to fish most locations at full pool. Support lines to the embayment walls were necessary to prevent the vertical net from drifting in the current at the Third Powerhouse bay site.

Additional exploratory vertical gillnet sites were established in the forebay upstream of Crescent Bay on the left bank and opposite Spring Canyon (Fig. 1) during high fish densities in August. Additional shallow water bottom horizontal gillnet sites were fished in February 1977 at right and left forebay locations.

Gillnet sets were usually fished for two consecutive 24-hour periods, except two vertical net sites (right forebay and Crescent Bay) were fished for 24 hours each for the period October through December. Full-pool conditions in the fall combined with a limited number of vertical nets resulted in this alteration. The adjusted fall sample design utilized a double vertical net for one 24-hour set at the right forebay site and one 24-hour set at the Crescent Bay site; two consecutive 24-hour sets were made with a triple vertical net at the Third Powerhouse bay site. Adjustments were not needed for the horizontal gillnet sites. The Third Powerhouse bay site downstream of the logboom was not sampled in the summer when surface spill over the dam was occurring because of safety restrictions. This site was also not fished in February 1977 because the reservoir elevation made it impossible to reach attachment points for the gillnet support lines.

Data taken at the time of fish collection included date, location, time of set and recovery, gear type, depth and catch. Every fish caught was identified to species, measured (fork length in mm), weighed and examined for determination of sex, maturity, stomach fullness (empty, trace, moderate, or full), food type and incidence of parasites or disease.

Daily catches were recorded for each horizontal net and for each 4-m increment of vertical net. Gillnet catches were standardized by calculating catch per unit of effort as follows: (1) Horizontal net catches were expressed as catch per net-day; (2) vertical net catches were expressed as catch per 4 m of vertical net per day. Bottom catches were considered separately, regardless of depth, because of an apparent bottom influence on catch and the fact that depth varied between and within vertical net sites.

Between-site comparisons for each gear type were used to analyze seasonal variations in the horizontal distributions of major species. Seasonal variations in the vertical distributions of major species were analyzed by comparing the catches of surface and bottom horizontal nets and by comparing the catch by 4-m increments of the vertical nets.

Scale samples were taken from the right side of all fish between the base of the dorsal fin and the lateral line. Otoliths were taken from kokanee, rainbow trout, and burbot. The scales were impressed on cellulose acetate cards and magnified with a Bausch and Lomb micro-projector (47.5 X) to determine age and measurments for back-calculation of growth according to the method described by Tesch (1968). Maturity was determined for each fish using an index modified from Nikolsky by Bagenal and Braum (1968).

5.4 Townet Sampling

The feasibility of townet sampling was tested to determine the distribution and relative abundance of juvenile fishes in the FDR Reservoir forebay. The townet has been adopted by the University of Washington College of Fisheries since 1965 as a standard gear for sampling juvenile fishes occurring in surface waters of marine estuaries and of many lakes and reservoirs. It has been particularly effective in catching juvenile salmonids.

The townet is a two-boat trawl without wings or otter boards (Fig. 4). When fishing, it is held open from top to bottom by two vertical spacer bars attached to the corners of the entrance and is held open from side to side by two towing vessels which immediately precede the net on either side of the path of the net. The townet is more effective as a surface trawl than other nets because water to be sampled is neither disturbed by the towing vessels nor by the warp lines.

The version used in this study measured 20 feet wide by 10 feet deep at the entrance and 56 feet long. The body was tapered uniformly and constructed of knotless nylon in mesh sizes graduated from 3.5 inch to 1.25 inch to 0.75 inch to 0.25 inch (stretch measure). The last 4 feet of the cod end was double-layered and the catch was accessed via a zipper. The vertical spacer bars of 0.75-inch pipe were fitted with net attachments at both ends. The net attachments also served as securing points at the surface for two 16-inch diameter neoprene floats and at the bottom for two 20-pound lead weights. The floats and weights maintained proper configuration of the net when towing and facilitated setting and hauling. A method was devised which enabled three persons to fish the 10 x 20 ft townet satisfactorily using a 20-ft outboard-powered boat, although the size of this net usually requires that it be fished from a much larger vessel. The other tow boat used was a 16-ft outboard. Townet hauls were made from shore to shore along established sampling transects at Spring Canyon and Crescent Bay.

5.5 Acoustic Technique and Data Acquisition System

The acoustic techniques and data acquisition system used are those that have been developed by the Marine Acoustic Group at the University of Washington. These methods and equipment have been used extensively to gather acoustic data on fish stocks and are described in detail elsewhere (Thorne et al. 1972; Nunnallee 1973).

A block diagram of the data acquisition system is shown in Figure 5. The chart recorder provides output in real time; the interface amplifier and magnetic tape recorder allow data to be stored for later analysis.

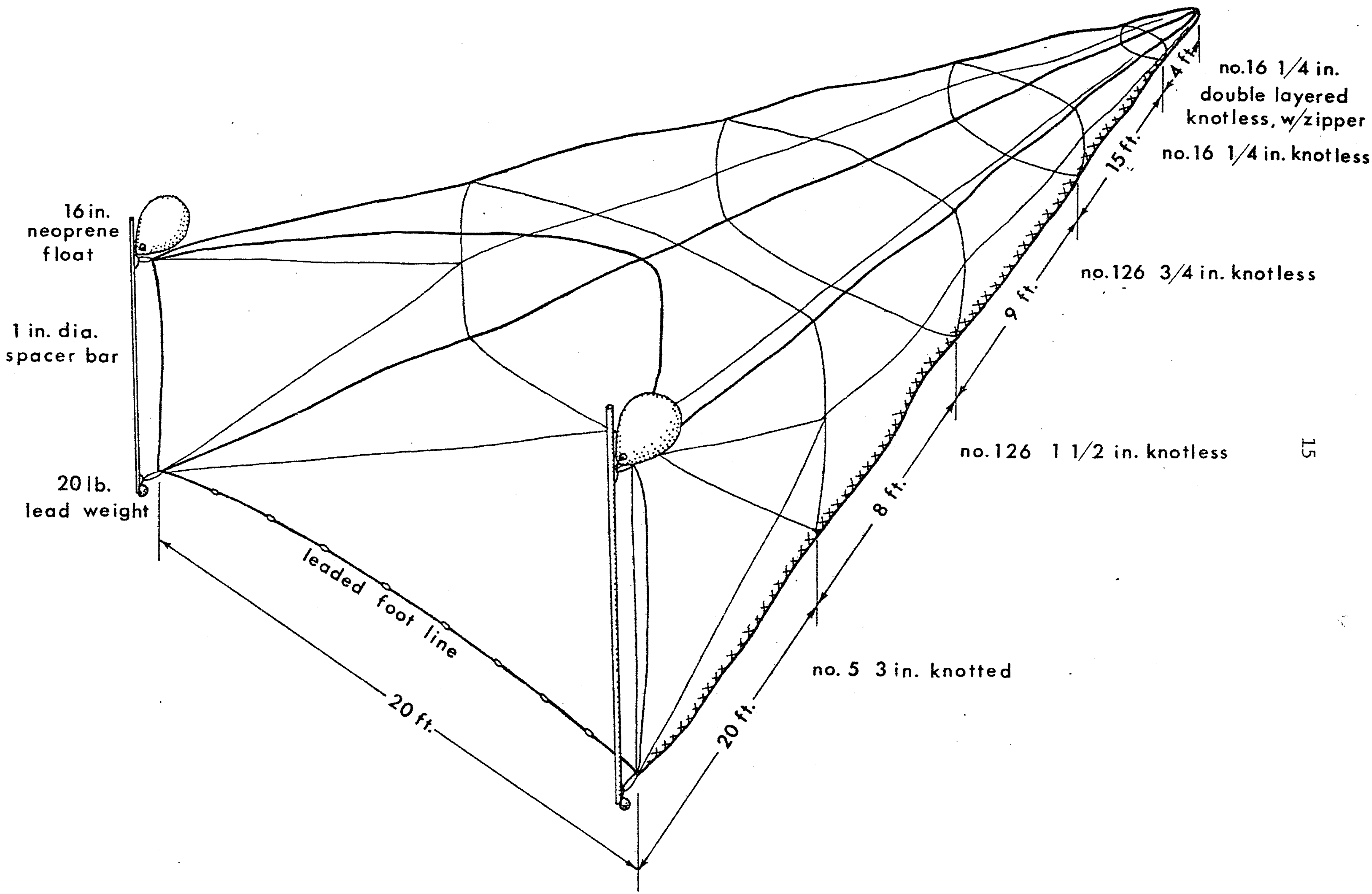


Figure 4. Diagram of townet used to sample juvenile fishes in the forebay.

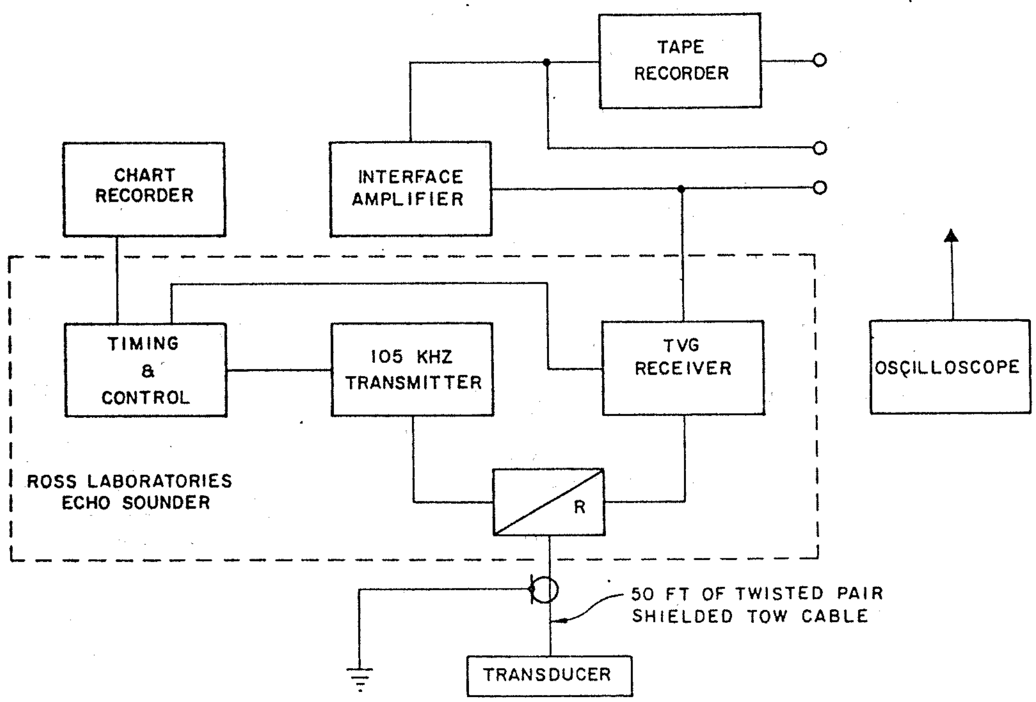


Figure 5. Block diagram of acoustic data acquisition system

During each survey, acoustic data were collected continuously along line transects in the survey area. The location of the transects outside the Third Powerhouse forebay and those within the forebay are shown in Figures 1 and 2.

The number of transects over which data were collected varied somewhat between surveys mainly because transects within the log boom could not be followed when water was being spilled from the reservoir.

The acoustic data were analyzed by the technique of echo counting. Utilizing this method, the magnetic tape upon which the data for the survey were recorded was played back through a tape recorder and the analog acoustic data record displayed on an oscilloscope. Fish target echoes were counted as they appeared on the oscilloscope. The peak amplitude and horizontal and vertical location of each target was also determined as the target was counted. Sample volume and target densities were estimated using methods described by Forbes and Nakken (1972).

6.0 RESULTS AND DISCUSSION

6.1 Water Temperature

Water temperature in the mid-forebay of FDR Reservoir during the study period ranged from a high of 19.6 C in late July 1976 to a low of 2.4 C in February 1977 (Fig. 6, App. Table 1). Thermal stratification began to appear in May, and by July there was about a 6-C difference in temperature between the surface and 90-m depths. A lag of about a month was observed between the maximum temperatures at the surface (19.6 C in late July) and at the 90-m depth (16.0 C in late August). Near homothermous conditions were observed during the periods February through April 1976 and November 1976 through March 1977.

6.2 Water Velocity

Water velocity in the FDR forebay was generally low during the study period. Current velocities were usually less than 0.1 m/sec at all forebay locations, except at the entrance to the Third Powerhouse bay, where velocities ranged from about 0.2 to 0.5 m/sec (App. Tables 2-7).

The mean current velocity from surface to bottom was calculated from measurements taken at each of the three sampling stations above the logboom (Table 1). Mean current velocities at these locations ranged from a high of 0.081 m/sec on April 22, 1976 at the right forebay station to a low of 0.015 m/sec on August 2, 1976 at the same station. Mean water velocity tended to be higher when the reservoir water level was drawn down.

Relationships between current velocity, reservoir elevation, and discharge were examined by use of a stepwise multiple regression (Nie et al. 1975). Step one involved a simple linear regression of mean current velocity with reservoir elevation at a single station, and step two involved a multiple regression with the addition of discharge as the second independent variable (Table 2). Tests were conducted at the 0.05 level of significance.

Simple linear regressions of current velocity and reservoir elevation produced significant negative correlations at the right ($P \leq 0.01$) and left ($P \leq 0.05$) forebay stations but not at the mid-forebay station. Multiple regressions with the addition of the discharge variable also produced a

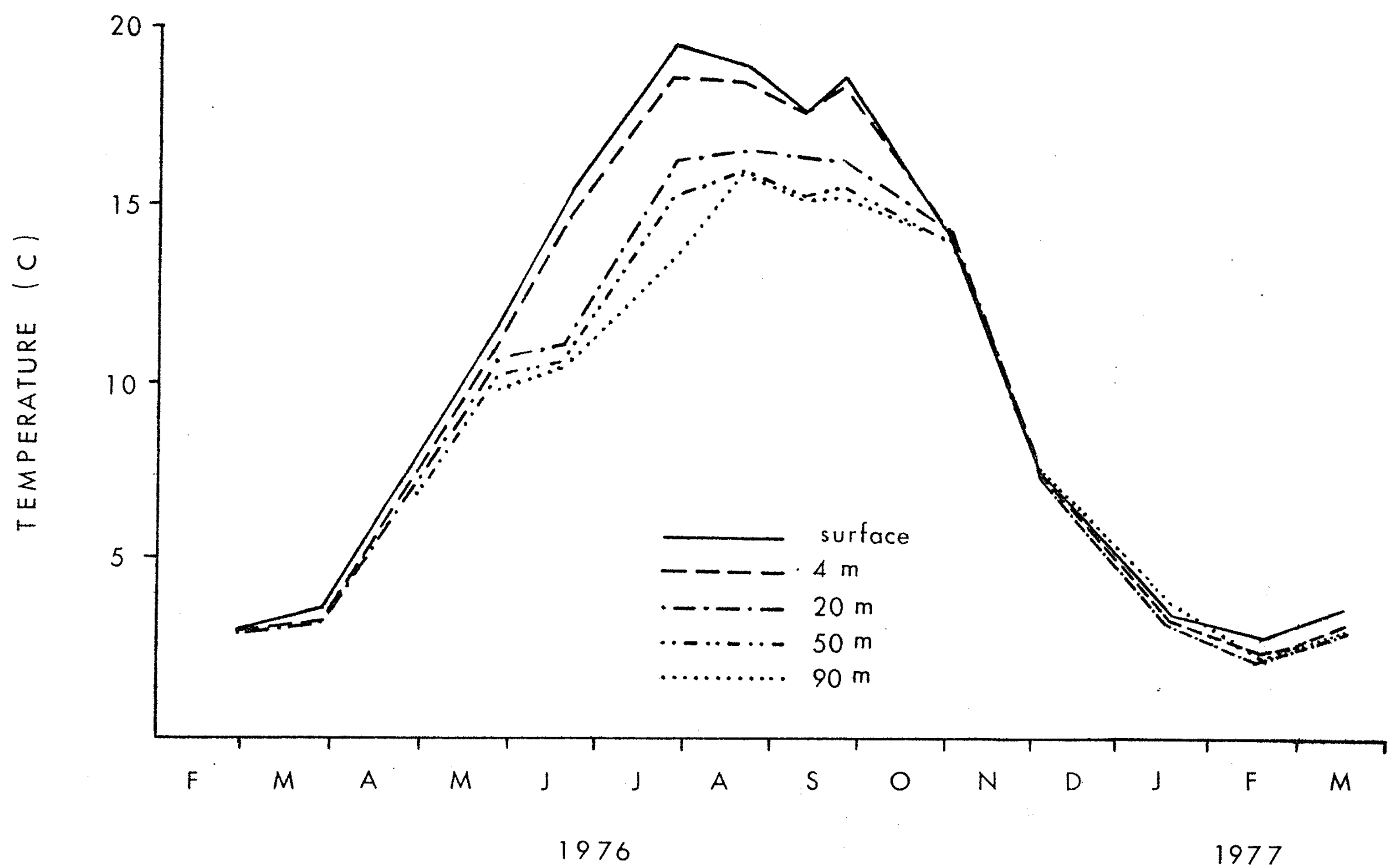


Figure 6. Monthly water temperature at 5 depth strata in FDR forebay.

Table 1. Mean of monthly current measurements from surface to bottom at three locations across the log boom, FDR Reservoir forebay, 1976-77.

	Mean Current Velocity by Date (m/sec)						
	1976					1977	
Location	4/22	5/20	6/15	8/02	9/14	2/15	3/17
Right boom	.081	.026	.025	.015	.019	.020	.035
Mid boom	.048	.036	.049	.025	.045	.024	.041
Left boom	.060	.057	.026	.018	.025	.020	.032
Reservoir Elev.	1219.9	1250.6	1283.4	1290.0	1287.1	1270.2	1249.0
Total Discharge (K cfs)	130	150	131	194	119	97	102

Table 2. Results of stepwise multiple regression analysis of mean velocity at three sampling stations and reservoir elevation and total discharge.

	Left Boom		Mid Boom		Right Boom	
	Step 1 Elevation	Step 2 Elevation & Discharge	Step 1 Elevation	Step 2 Elevation & Discharge	Step 1 Elevation	Step 2 Elevation & Discharge
F to enter variable	13.60751	1.26693	.56130	.18011	16.72093	.09125
Significance	.014	.323	.487	.693	.009	.778
Multiple r	.85516	.89215	.31769	.37372	.87739	.88031
r^2	.73129	.79593	.10093	.13967	.76981	.77494
r^2 change	.71329	.06464	.10093	.03874	.76981	.00513
Simple r	-.85516	.01317	-.31769	-.27550	-.87739	-.16861
Overall F	13.60751	7.80045	.56130	.32468	16.72093	6.88658
Significance	.014	.042	.487	.740	.009	.051

significant negative correlation at the left forebay station ($P \leq 0.05$) but not at the right or mid-forebay stations. The significance level was reduced in each case when the discharge variable was added.

Apparently, within the range of water levels and discharge rates examined here, water level is the primary controlling factor of current velocity for the nearshore stations (right and left forebay). Neither reservoir elevation nor discharge satisfactorily explained changes in current velocity at the mid-forebay site.

Current profile measurements at the entrance to the Third Powerhouse forebay were attempted on five occasions (March 16, April 21, and May 20, 1976; and February 15 and March 17, 1977); only the first and last were successful (App. Table 5). Only surface measurements were obtained on the other three occasions due to difficulty encountered in maintaining a stationary position in the moderately-strong current over a smooth hardpan bottom.

Surface current velocity at the entrance to the Third Powerhouse forebay ranged from 0.180 m/sec on March 16, 1977 to 0.515 m/sec on April 21, 1976 (Table 3). Surface current velocity was found to increase with the addition of operating generators and with decreased water level. Highest surface velocities recorded occurred with G19 and 20 or 21 in operation and with the reservoir drawn down to elevation 1220 ft msl.

Vertical current velocity profiles were obtained at several sites close to the face of the dam when reservoir elevation was lower than 1260 ft msl. Water velocity was low in all cases, and no definite correlations were found which related to operational conditions (App. Tables 6 and 7).

The weak water current may have caused some imprecision in the velocity and direction measurements. Readings were usually taken from the lower end of the low-range scale on the readout, and, at times, the current was too weak to hold the directional wing of the meter in steady alignment.

Generally, water currents in FDR forebay were characterized as weak and variable during periods when surface elevations were above 1215 ft msl, as was the case throughout sampling. However, the data indicate that an inverse relationship exists between reservoir surface elevation and current velocity, and it is anticipated that much higher water velocities would prevail in the direction of the powerhouse during periods of maximum drawdown.

Table 3. Surface water velocity, operating generators and forebay water elevation for third powerhouse station, 1976 and 1977.

	Date				
	1976			1977	
	3/16	4/21	5/20	2/15	3/17
Surface Velocity (m/sec)	.180	.515	.206	.185	.247
Operating third powerhouse generators	G 19	G 19, 20	G 19, 20	G 20, 21	G 19, 21
Reservoir Elevation (ft msl)	1242.3	1220.2	1250.6	1270.2	1249.0

This may be especially true in the vicinity of the Third Powerhouse with the eventual operation of six generators.

6.3 Historical Reservoir Operation

The historical operating data for FDR Reservoir were analyzed beginning with the first full operational year in 1941. A composite plot of FDR Reservoir elevations presented in Figure 7 indicates the general late winter to early spring water level decline for flood control and power generation purposes. A plot (Fig. 8) of the minimum annual reservoir elevation and drawdown indicates a general decline throughout the 36-year record. Three periods in the level of maximum annual drawdown appear. The years from 1941-51, which included startup, indicate a period during which drawdown did not exceed 30 feet and was generally less than 20 feet. The period from 1952-65 began with an increased degree of annual variation which became relatively consistent at about 40 feet of annual drawdown. The period from 1966-76 was characterized by a further increase in drawdown. Extremes were reached in 1969 and 1974 of 130 and 133 feet, respectively, while drawdown during the remaining years in this period ranged from 64 to 88 feet and indicated a further general increase in drawdown compared to the earlier years of operation.

A plot of the month of occurrence when the minimum reservoir elevation was reached indicated a recent trend to the months of April and May (Fig. 9). Earlier years of operation tended to be less consistent and occurred earlier in the year. The weekly frequency of occurrence indicated March 31 and April 22 were frequently the time of minimum reservoir elevation (Fig. 10). April was most frequently the month in which minimum elevation occurred.

6.4 Origin of Fish Populations

Twelve species of fish have been captured and two additional have been observed in the forebay of FDR Reservoir (Table 4). Comparison of the number of species captured in this study to those previously reported for Lake Roosevelt (Gangmark and Fulton 1949; Earnest and Spence 1965) indicate that fewer species have been caught during 1976-77 sampling. Previous sampling in

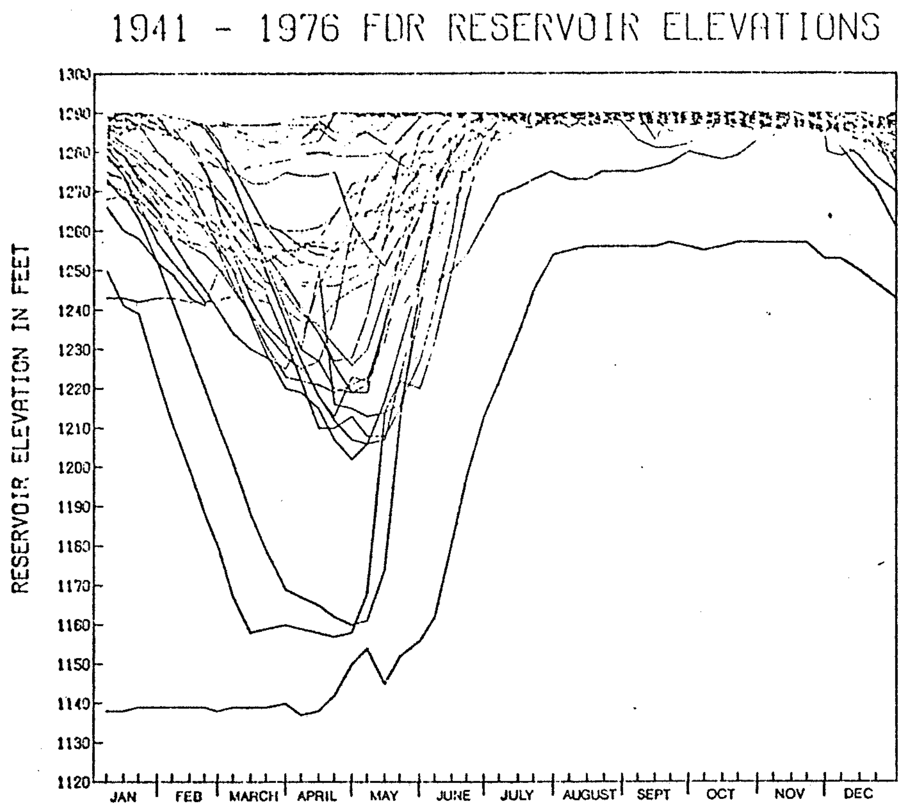


Figure 7. Composite of weekly FDR Reservoir elevations for the period 1941-1976 (USBR data).

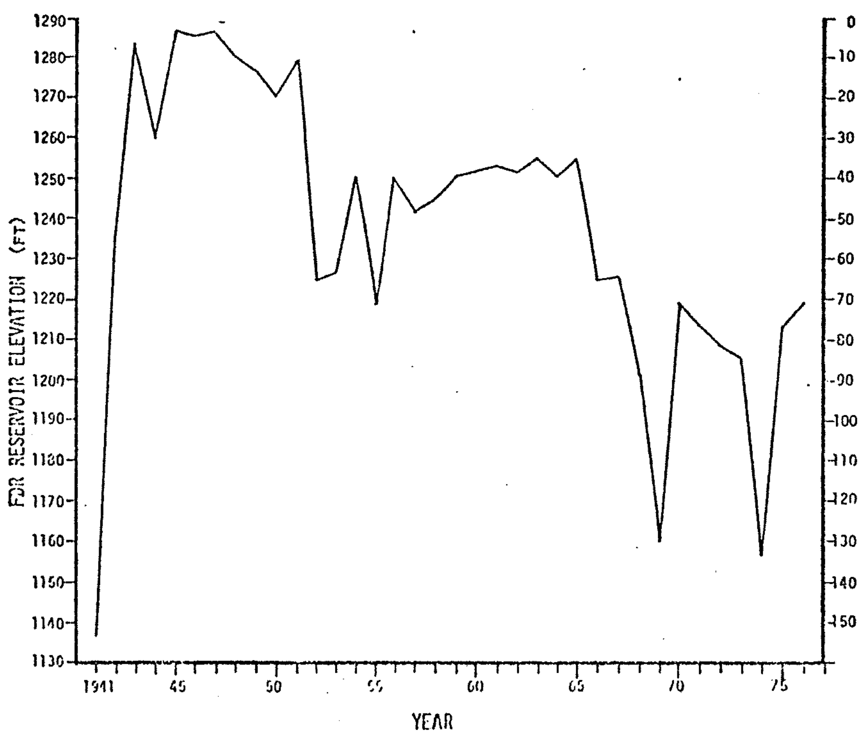


Figure 8. Minimum annual FDR Reservoir elevations and drawdown for the period 1941-1976 (USBR data).

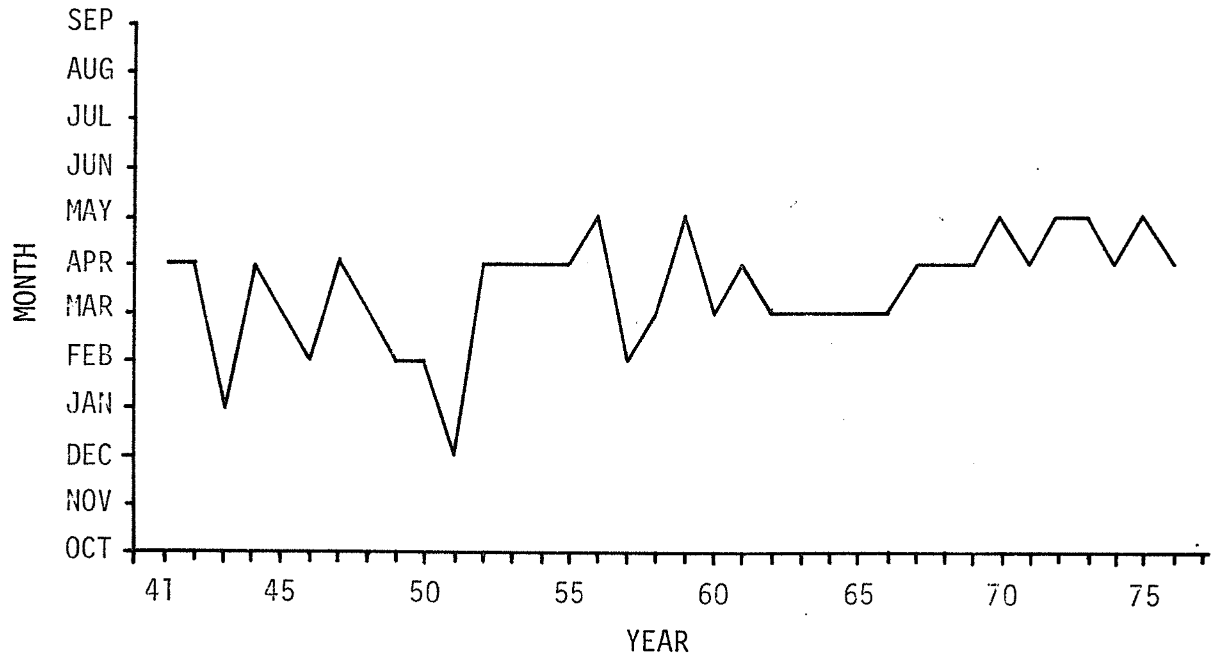


Fig. 9. Month of occurrence of minimum FDR Reservoir elevation for each year from 1941 to 1976 (U.S.B.R. data).

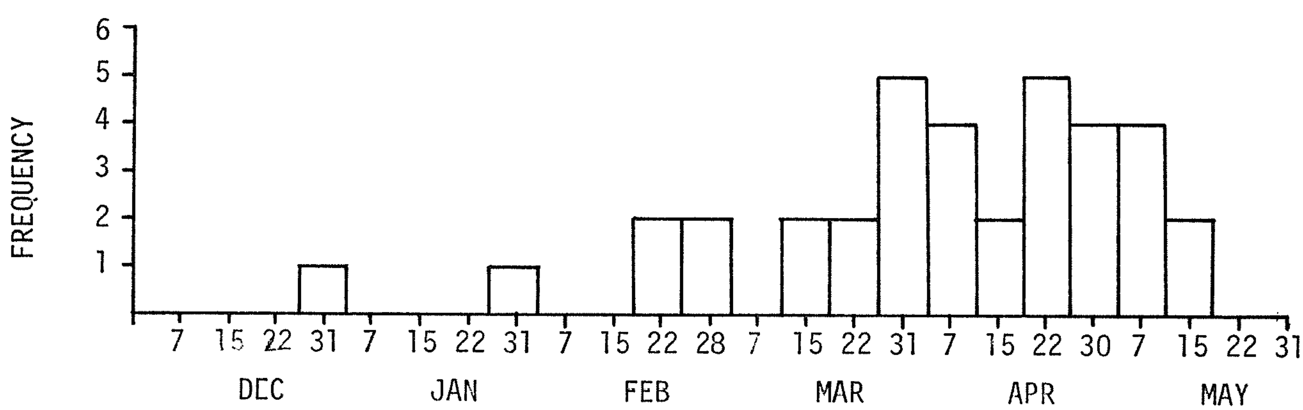


Fig. 10. Weekly frequency of occurrence of minimum FDR Reservoir elevation from 1941 to 1976 (USBR data).

TABLE 4. Fish species caught in Lake Roosevelt Forebay and those reported for Rufus Woods Reservoir, Lake Roosevelt and Banks Lake. [(a) Stober, 1977 (b) Lanmeyer, 1972 (c) Gangmark and Fulton, 1949 (d) Earnest and Spence, 1965 (e) Stober *et al.*,1976]

SPECIES	SCIENTIFIC NAME	FDR FOREBAY	RUFUS WOODS		LAKE ROOSEVELT		BANKS LAKE
		1976-77	1974-5(a)	1972(b)	1949(c)	1963-4(d)	1974-76(e)
1 Walleye	*Stizostedion vitreum*	X	X	X			X
2 Yellow perch	*Perca flavescens*	X	X	X	X	X	X
3 Mountain whitefish	*Prosopium williamsoni*	X	X		X	X	X
4 Lake whitefish	*Coregonus clupeaformis*	X	X			X	X
5 Kokanee	*Oncorhynchus nerka*	X	X	X	X	X	X
6 Rainbow trout	*Salmo gairdneri*	X	X	X	X	X	X
7 Cutthroat trout	*Salmo clarki*		X		X	X	
8 Brook trout	*Salvelinus fontinalis*		X		X	X	
9 Dolly Varden	*Salvelinus malma*		X		X	X	
10 White sturgeon	*Ascipenser transmontanus*		X	X			
11 Black crappie	*Pomoxis nigromaculatus*		X				X
12 Burbot	*Lota lota*	X	X	X			X
13 Northern squawfish	*Ptychocheilus oregonensis*	X	X	X	X	X	X
14 Peamouth	*Mylocheilus caurinus*	X	X	X	X	X	X
15 Chiselmouth	*Arcocheilus alutaceus*		X	X		X	
16 Largescale sucker	*Catostomus macrocheilus*	X	X	X		X	X
17 Bridgelip sucker	*Catostomus columbianus*	X	X	X		X	X
18 Longnose sucker	*Catostomus catostomus*	X	X			X	X
19 Redside shiner	*Richardsonius balteatus*		X		X	X	
20 Speckled dace	*Rhinichthys osculus*		X				
21 Carp	*Cyprinus carpio*	*	X	X	X	X	X
22 Prickly sculpin	*Cottus asper*	*	X				X
23 Torrent sculpin	*Cottus rhotheus*		X				X
24 Brown trout	*Salmo trutta*			X			X
25 Whitefish	*Prosopium sp.*			X			
26 Sucker	*Catostomus sp.*			X	X		
27 Tench	*Tinca tinca*				X	X	
28 Pumpkinseed sunfish	*Lepomis gibbosus*				X	X	X
29 Largemouth bass	*Micropterus salmoides*				X	X	X
30 Smallmouth bass	*Micropterus dolomieui*				X	X	
31 Pygmy whitefish	*Prosopium coulteri*				X		
32 Brown bullhead	*Ictalurus nebulosus*						X
33 Chinook salmon	*Oncorhynchus tshawytscha*						X
34 Sculpin	*Cottus sp.*				X	X	X

* observed but not caught

FDR and Rufus Woods Reservoirs (Lanmeyer 1972; Stober 1977) and in Banks Lake (Stober et al. 1976) have indicated the existence of a greater variety of species. The limited number of species found in this survey was largely due to restriction of the sampling to the area of the forebay where the amount of littoral habitat was restricted. Nearly all of the aquatic environment sampled in this survey was either pelagic or profundal. Previous surveys have included larger geographic areas both upstream and downstream, with an associated increase in diversity of habitat and species. In addition, the number of fish species occurring in the Rufus Woods reach of the Columbia River was found to decline downstream with fewest in the Rufus Woods forebay area (Stober 1977). A similar relationship may exist in the forebay of FDR Reservoir. The species captured or observed in the FDR forebay are native to the Columbia River system, except for the walleye, yellow perch, and carp which were introduced to the river basin.

Kokanee, rainbow (Kamloops), and fall chinook have been planted into FDR Reservoir since the Columbia River was impounded behind Grand Coulee Dam (Table 5). During the period 1942-45, relatively large numbers of kokanee were planted each of those four successive years, amounting to a total of 7,490,306 (Earnest and Spence 1965). These plants were reported to be a failure in spite of suitable spawning areas in streams tributary to Lake Roosevelt (Earnest and Spence 1965). Probably of more importance were the sockeye impounded behind the dam which reverted to kokanee. Rainbow trout (Kamloops) planted in 1956 and 1961 also failed since no evidence of survival was found in streams where these plants were made.

Fall chinook plants in FDR Reservoir have been made more recently. In January 1972, about 1.7 million chinook fingerlings were planted at seven locations in the reservoir with most in, or near, tributaries (W.S.D.F. 1972). Little effort was made to determine whether any adults from this plant returned to spawn in the accessible tributaries; however, the plant was generally considered a failure. Some individuals of this plant were apparently pumped into Banks Lake as juveniles and reared to a large size. A ripe male chinook salmon 87 cm in length and weighing 2,270 gms was caught in the feeder canal on August 29, 1975 (Stober et al. 1976). This individual was apparently attempting to exit via the feeder canal inlet tunnels when

TABLE 5. History of known gamefish introductions to FDR Reservoir.

SPECIES	COMMON NAME	YEAR	NUMBER	SIZE	AGENCY	LITERATURE SOURCE
Oncoryhnchus nerka	Kokanee	1942	1,299,375		WDG	Earnest & Spence, 1965
"	Kokanee	1943	2,813,573		WDG	"
"	Kokanee	1944	1,980,227		WDG	"
"	Kokanee	1945	1,397,131		WDG	"
Salmo gairdneri	Rainbow (Kamloops)	1956	26,670		WDG	"
"	Rainbow	1961	77,500	3" fingerling	WDG	"
Oncoryhnchus tshawytscha	Fall chinook	1972	1,747,200	∿ 540/lb	WDF	WSDF, 1972
"	Fall chinook	1975	117,000	16 & 19/lb	WDF	*WSDF (Ben Turner) *USFWS (Frank Halfmoon)

* personal communication

captured. Other smaller chinook have been taken in the Banks Lake sport fishery which were probably from this plant. No chinooks were captured in Rufus Woods Reservoir during gillnet sampling conducted from May 1974 to August 1975 (Stober 1977), indicating that few remained in the immediate downstream reaches. The most recent plant of chinooks was made into the San Poil River on FDR Reservoir in 1975 (Table 5). None have been captured in the 1976-77 sampling effort. No enhancement of the FDR Reservoir sport fishery has been documented from the planting of salmonids. Salmonids do not presently support an active sport fishery in the forebay of FDR Reservoir.

A survey by Nielson, 1975 found that walleye supported the only sport fishery on FDR Reservoir. The fishery and apparently the greatest abundance of walleye are concentrated around the mouth of the Spokane River arm of the reservoir. This non-native species was illegally introduced sometime during the 1940's or early 1950's. It has apparently adapted to the conditions found in FDR Reservoir and is presently under-exploited by the sport fishery. A portion of this population is probably recruited through the FDR forebay and dam since the walleye was also the most abundant gamefish species found in the upper portion of Rufus Woods Reservoir (Stober 1977).

6.5 NMFS Data 1966-67

Mr. George Snyder of the U.S. National Marine Fisheries Service (NMFS) provided previously unpublished data collected in the FDR forebay in 1966 and 1967. We have his permission to include these data in this report which represent the only empirical information which has been found indicating that kokanee were once abundant in the FDR forebay and are therefore important in the evaluation of more recent data.

The gillnet catches in February and March of 1966 and 1967 are summarized in Table 6. Kokanee were found to be distributed to a depth of 32.0 m in February, extending to 50.3 m in March of both years. Maximum CPUE (per gillnet set) in the water column occurred in the depth strata from 9.1 - 13.7 m in February and shifted to the surface to 4.6 m depth interval in March of both years. The overall CPUE of kokanee was 15.0 and 7.8 in February and March of 1966. The CPUE declined to 7.3 and 3.5 for the same

TABLE 6. Summary of gillnet catch and CPUE of kokanee at 4.6 m depth intervals at three sites located in FDR forebay in February and March of 1966 and 1967. (Data Source: Mr. George R. Snyder, USNMFS, Seattle, WA.)

DATE	DEPTH INTERVALS (m) 0-4.6	4.6-9.1	9.1-13.7	13.7-18.3	18.3-22.9	22.9-27.4	27.4-32.0	32.0-36.6	36.6-50.3	TOTAL
FEB. 1966										
Site 1	23	118	262	168	148	86	21			826
2	9	42	128	125	84	52	7			447
3	35	46	136	72	16	-	-			305
Total	67	206	526	365	248	138	28			1578
No.Sets	15	17	22	17	16	12	6			105
CPUE	4.5	12.1	23.9	21.4	15.5	11.5	4.7			15.0
FEB. 1967										
Site 1	11	13	20	27	10	4	-			85
2	4	22	15	17	16	5				79
3	8	-	2	-	0	-				10
Total	23	35	37	44	26	9				174
No. Sets	3	5	4	5	4	3				24
CPUE	7.7	7.0	9.3	8.8	6.5	3				7.3
MARCH 1966										
Site 1	83	138	161	136	65	59	23	27	14	706
2	34	68	148	162	128	83	47	46	4	720
3	237	54	116	54	-	-	-	-	-	461
Total	354	260	425	352	193	142	70	73	18	1887
No. Sets	29	28	44	38	29	31	22	14	5	240
CPUE	12.2	9.3	9.7	9.3	6.7	4.6	3.2	5.2	3.6	7.9
MARCH 1967										
Site 1	38	15	25	32	8	21	1	3	2	145
2	0	8	10	11	6	1	-	0	-	36
3	5	-	2	9						16
Total	43	23	37	52	14	22	1	3	2	197
No. Sets	9	7	9	10	6	9	1	3	2	56
CPUE	4.8	3.3	4.1	5.2	2.3	2.4	1	1	1	3.5

months in 1967.

The purse seine catch and CPUE (per haul) for 1966 and 1967 are summarized in Tables 7 and 8, respectively. Kokanee during February, March, and April were clearly the most abundant species taken in both years. The CPUE in 1966 was 197, 658.5, and 30.3 during February, March, and April, respectively, while the CPUE in 1967 declined to 18.5 and 14.4 during February and March, respectively. The overall CPUE for 1966 was 422.7, while that for 1967 was 16.3 kokanee per haul. The numbers of kokanee captured in the forebay are in definite contrast to those found in the present survey. Although no length or age statistics were available, photographs of the kokanee caught in the 1966 and 1967 sampling effort appeared to be in about the 3-year-old age group, based on comparable sizes of known-age kokanee from Banks Lake.

In addition to kokanee, other species reported in low numbers included rainbow trout, carp, squawfish, peamouth, whitefish, walleye, burbot (ling cod) and longnose sucker.

6.6 Gillnet Catch

A total of 709 fish representing twelve species was captured between April 1976 and March 1977 in the gillnet survey. The catch was dominated by northern squawfish, comprising 51.0% of the total number and 50.6% of the total weight (Table 9). Walleye, the most abundant game fish, comprised 13.5 and 8.9% of the total number and biomass, respectively. The other species taken, in decreasing order of abundance, were kokanee, rainbow trout, largescale sucker, peamouth, longnose sucker, bridgelip sucker, yellow perch, burbot, Rocky Mountain whitefish, and Lake whitefish. Five species of non-game fish totaled 64.2% of the total catch, and seven species of game fish made up the remaining 35.8%.

Gillnet catches were generally small. The largest catches occurred in August and September (Table 10, Fig. 11) during the highest water temperatures. Catches were smallest from December through February when water temperatures were low. Gillnets are a passive gear, and catches depend on fish activity as well as fish abundance; in general, activity increases with temperature.

TABLE 7. Purse seine catch and CPUE in the forebay of FDR Reservoir upstream of log boom in 1966. (Data Source: Mr. George R. Snyder, USNMFS, Seattle, Washington.)

C A T C H

DATE 1966	HAUL	KOKANEE	R.B.TROUT	CARP	SQUAWFISH	PEAMOUTH	WHITE-FISH	LING COD	LONGNOSE SUCKER
02-22	2	2							
02-23	2	-		1					
02-24	2	945	1	1					
02-28	1	432							
03-01	3	-							
03-02	2	219							
03-03	1	1794							
03-04	1	-		1					
03-08	1	2595		1	1				
03-11	1	1291							
03-15	1	5413							
03-17	2	402			1	1			
03-18	1	104							
03-21	3	2					1		
03-22	2	561							
03-23	3	1575	1				1		
03-24	2	179							
03-25	1	3144			1	1			
03-26	3	-							
13-28	1	3929	1		1				
03-29	3	1	2						
03-30	1	1711		2					
03-31	3	126							
04-01	2	10	1						
04-04	4	12	3						
04-05	2	2						1	
04-06	2	25							
04-07	3	342							
04-22	1	67				1			1
04-29	3	57							
TOTAL	59	24,940	9	6	4	3	2	1	1
CPUE		422.7	.15	.1	.07	.05	.03	.02	.02

TABLE 8. Purse seine catch and CPUE in the forebay of FDR Reservoir upstream of log boom in 1967. (Data Source: Mr. George R. Snyder, USNMFS, Seattle, Washington.)

		CATCH						
DATE 1967	HAUL	KOKANEE	R.B. TROUT	CARP	SQUAWFISH	W.PIKE	PEAMOUTH	LONGNOSE SUCKER
02-13	3	-						
02-14	3	197						
02-15	1	4						
02-16	3	35	2					
02-17	1	125	1					
02-20	3	2	1	1				
02-21	5	-	2					
02-23	5	90	1					
02-24	5	73	2					
02-27	3	105	5	1				
02-28	3	17	1	2				
03-01	4	71	1					
03-02	4	137	3					
03-03	4	31	2					
03-06	2	-	2					
03-07	2	56	1					
03-09	5	58	1					
03-10	2	21			1			
03-13	5	25				1		
03-15	2	10						
03-16	1	57	1					
03-17	2	64						
03-20	2	40		1		1		
03-21	2	1			1			
03-22	2	50		2			1	
03-24	1	-						
03-27	1	-						
03-28	1	-						1
03-30	1	-	2					
TOTAL	78	1,269	28	7	2	2	1	1
CPUE		16.3	.36	.07	.03	.03	.01	.01

Table 9. Abundance and biomass of all fish species taken from April 1976 through March 1977 by surface and bottom horizontal and vertical gill nets.

Species	Total Number	Percent	Total Weight (kg)	Total Weight Percent
Northern squawfish	361	51.0	165.8	50.6
Walleye *	96	13.5	29.3	8.9
Kokanee *	85	12.0	31.7	9.7
Rainbow trout *	57	8.0	38.6	11.8
Largescale sucker	41	5.8	31.9	9.7
Peamouth	26	3.7	9.1	2.8
Longnose sucker	15	2.1	5.9	1.8
Bridgelip sucker	11	1.6	9.1	2.8
Yellow perch *	8	1.1	1.7	0.5
Burbot *	3	0.4	2.3	0.7
Rocky Mountain whitefish *	3	0.4	1.8	0.5
Lake whitefish *	3	0.4	0.7	0.2
TOTAL:	709	100	327.9	100

* Considered as game fish. Total of 255 game fish (35.8% of total catch).

Table 10. Total FDR forebay gillnet catch and percent composition by species for 1976 and 1977, all nets combined.

Date	Total No.	% Composition of Catch: Squaw-fish	Wall-eye	Kokanee	Rainbow trout	Large-scale sucker	Other species
4/15-16/76	20	15.0	5.0	30.0	20.0	-	Peamouth (15.0); Bridgelip sucker (15.0)
4/21-22	39	15.4	-	25.6	30.8	2.6	B. sucker (12.8); peamouth (10.3); yellow perch (2.6)
5/5-6	41	29.3	-	7.3	22.0	17.1	Peamouth (24.4)
5/19-20	18	22.2	-	16.7	22.2	27.8	Peamouth (5.6); burbot (5.6)
6/3-4	14	35.7	7.1	-	14.3	-	Peamouth (21.4); Longnose sucker (14.3); B. sucker (7.1)
6/17-18	17	70.6	-	-	5.9	-	Lake whitefish (17.6); burbot (5.9)
6/30, 7/1	31	54.8	6.5	12.9	6.5	3.2	Peamouth (12.9); burbot (3.2)
7/22-23	35	74.3	-	2.9	11.4	5.7	Rocky Mountain whitefish (2.9); yellow perch (2.9)
8/5-6	97	81.4	4.1	-	7.2	3.1	Longnose sucker (3.1); Bridgelip sucker (1.0)
8/18-19	68	66.2	13.2	1.5	4.4	4.4	Longnose sucker (10.3)
9/1-2	96	74.0	7.3	6.2	2.1	9.4	Longnose sucker (1.0)
9/14-15	60	61.7	21.7	6.7	-	10.0	
9/30, 10/1	40	62.5	25.0	5.0	2.5	-	Longnose sucker (2.5); yellow perch (2.5)
10/12-13	40	22.5	62.5	-	2.5	2.5	R.M. whitefish (5.0); Longnose sucker (2.5); B. sucker (2.5)
10/26-27	21	9.5	52.4	14.3	4.8	4.8	Yellow perch (9.5); peamouth (4.8)
11/16-17	20	30.0	40.0	15.0	5.0	5.0	Yellow perch (5.0)
12/7-8	7	-	28.6	42.9	-	-	Yellow perch (28.6)
1/25-26/77	9	-	-	100.0	-	-	
2/11-22	8	-	-	100.0	-	-	
2/23-24	7	14.3	14.3	28.6	42.9	-	
3/15-16	21	4.8	9.5	81.0	-	4.8	

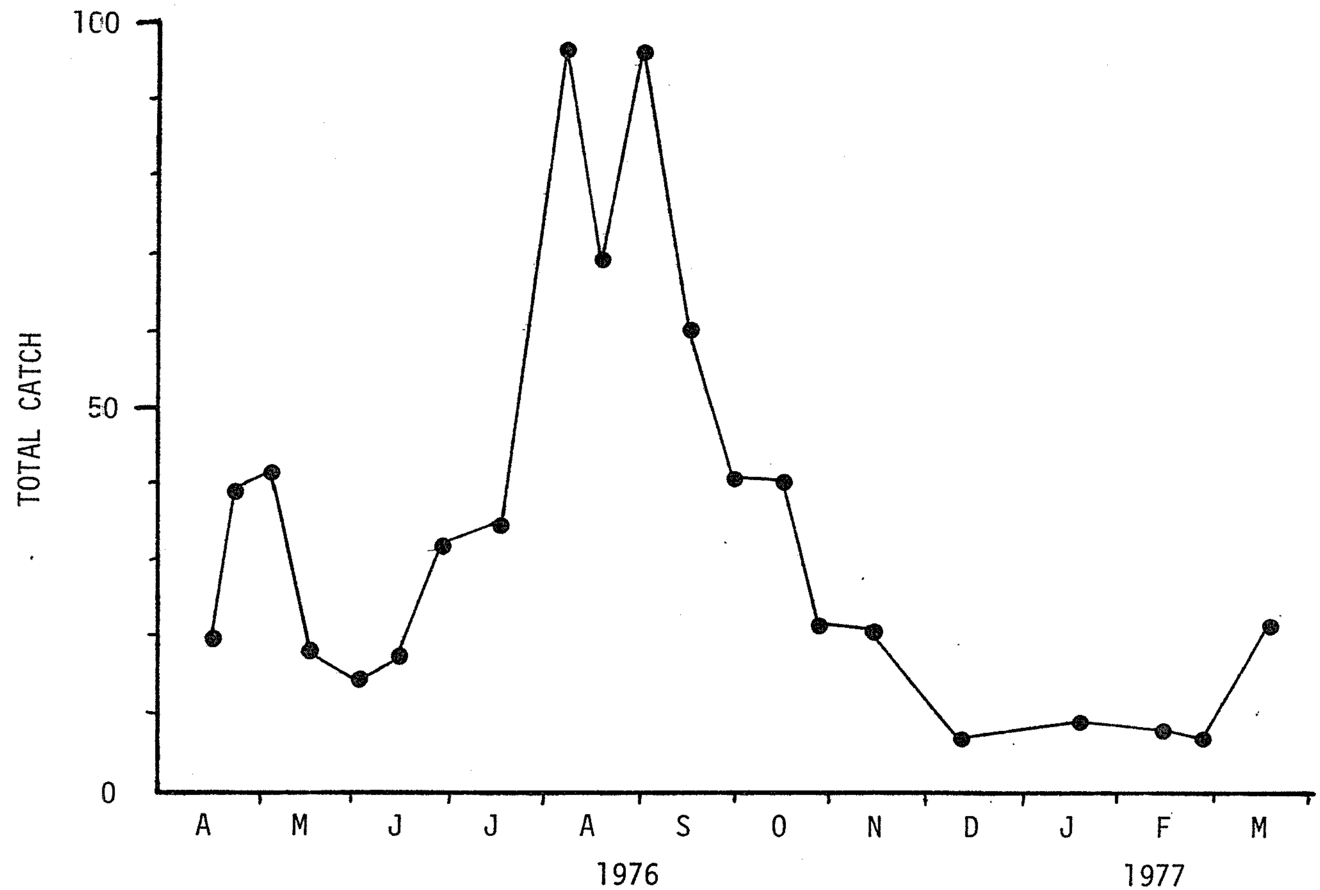


Figure 11. Total gillnet catch from FDR forebay, March 1976 to March 1977, all species and nets combined.

Mean catch per net-day was calculated for surface and bottom horizontal gillnet (Fig. 12) and vertical gillnet (Fig. 13) catches. Due to differences in mesh size and length of net, detailed comparisons were not possible between vertical net catches and horizontal net catches. However, seasonal trends and, in some cases, net selectivity were evident in a general comparison.

Squawfish catches were highest from mid-June through September for surface horizontal and vertical nets. Squawfish comprised from 55 to 81% of the total catch during this period. Walleye catches peaked in October for bottom horizontal and vertical nets. Kokanee catches were generally higher in winter and spring months. Kokanee were caught more frequently in the vertical nets than in either the surface or bottom horizontal nets because of their pelagic distribution in the water column and the selectivity of the vertical nets. Rainbow trout were caught by all gear types. Small peaks in the rainbow catch were evident in April and May for both horizontal net depths and in August for the vertical nets. Largescale sucker were taken only in horizontal gillnets; their relatively large size may have excluded them from the vertical nets which had a mesh size of 6.4 cm (2.5 inch).

Exploratory gillnet sampling was conducted in August 1976 and February 1977 to increase sampling of a greater variety of habitat in the study area. This gillnetting was conducted to confirm that catches at the regular stations adequately represented fish populations in the forebay area. No different fish species or unusual composition of catch occurred.

Exploratory sampling in August was done at a time of high fish abundance. A vertical net was fished at the entrance to the bay immediately upstream of Crescent Bay from August 4-6, and a vertical net was fished near the right shoreline opposite Spring Canyon Park from August 17-19. Catches at both sites consisted entirely of squawfish (48-hr catch = 18 squawfish at each site); squawfish comprised 81.4 and 66.4% of the total catch on the respective sampling periods.

Exploratory sampling on February 22-24, 1977 consisted of shallow water (about 3 m deep) bottom horizontal sets at right and left forebay stations. This was done to determine if walleye, which had almost disappeared from the winter catch, had moved into shallow water at this time. No walleye were

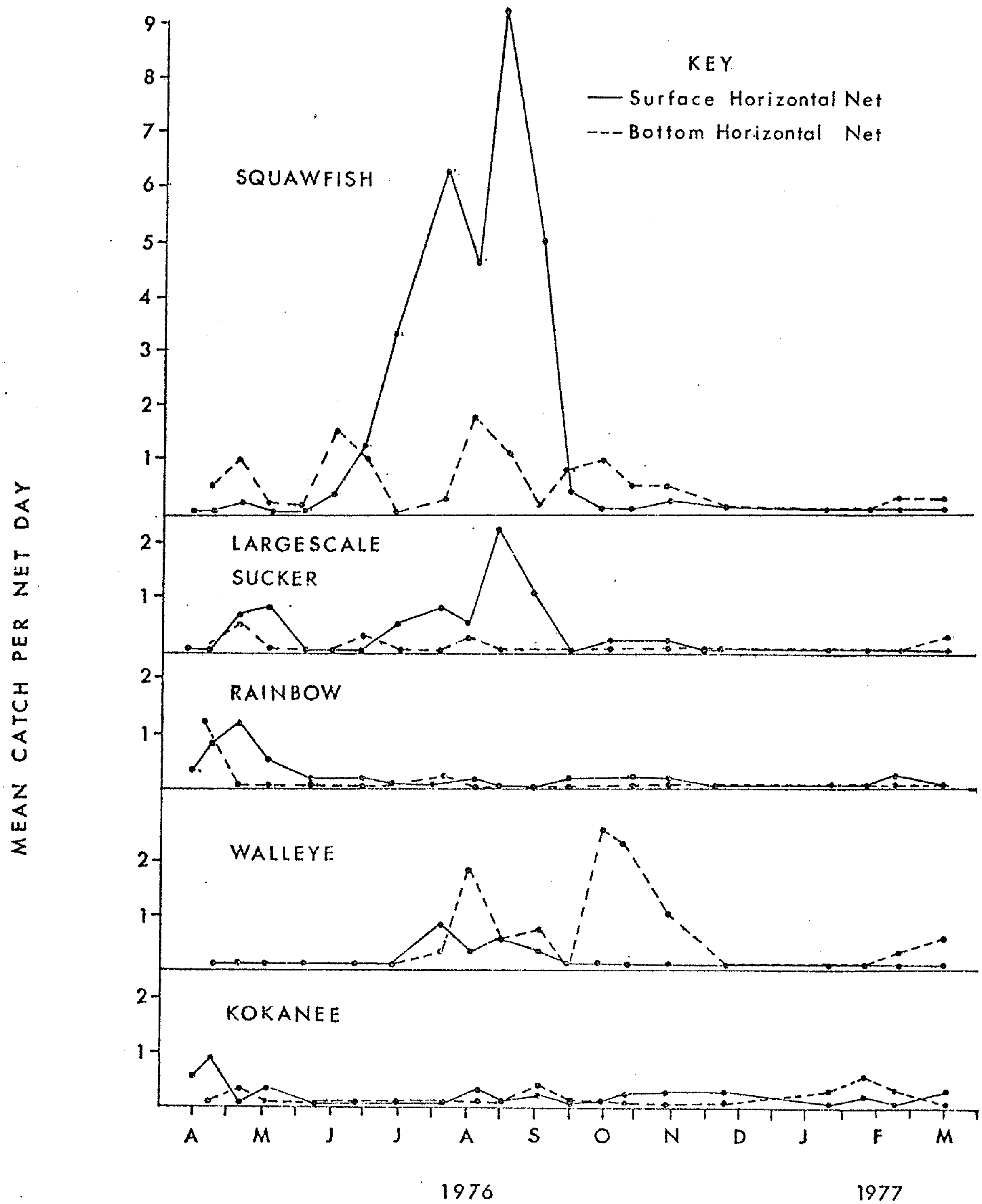


Figure 12. Mean bi-weekly surface and bottom horizontal gillnet catches from FDR forebay, 1976-77.

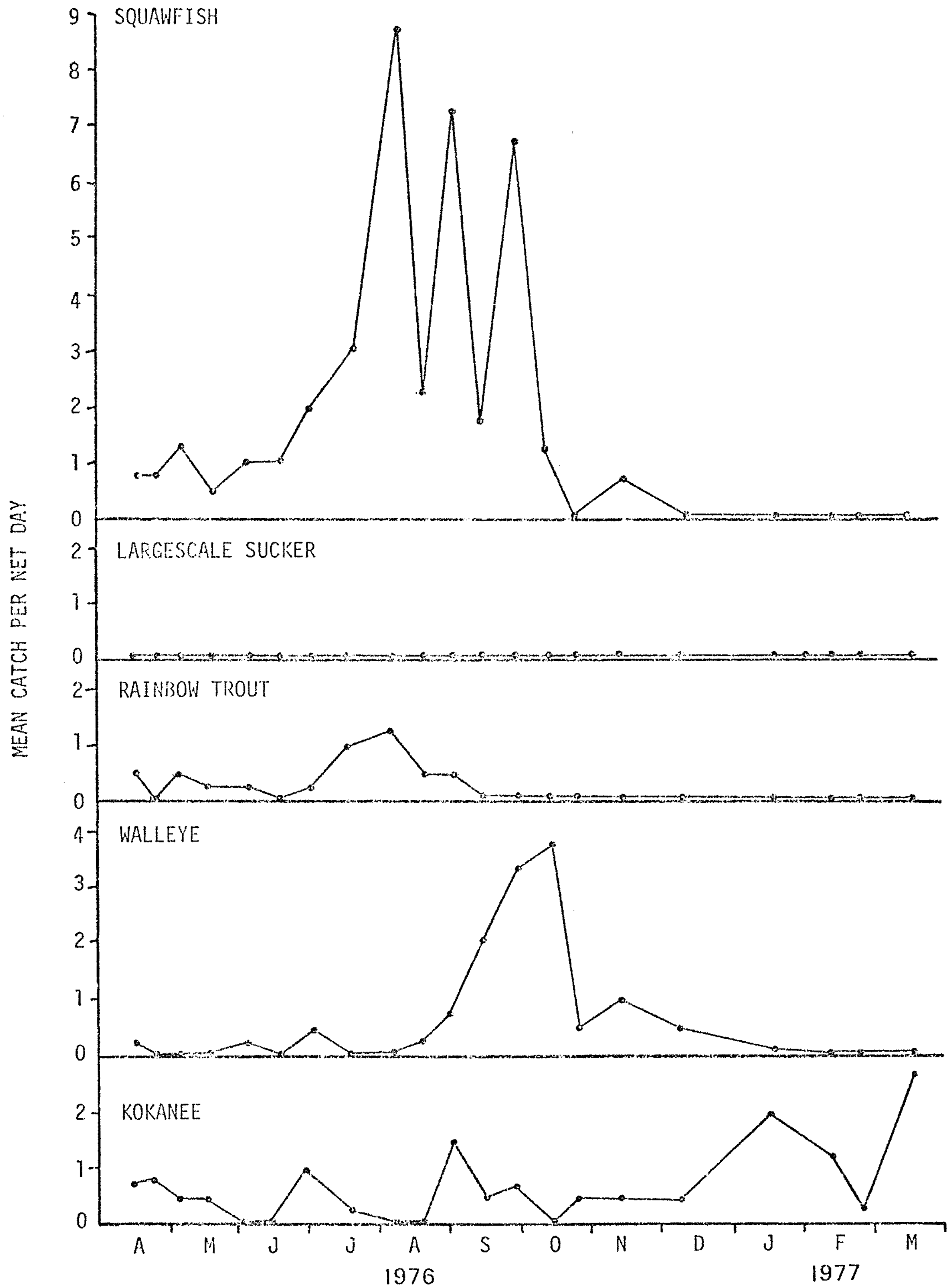


Figure 13. Mean bi-weekly vertical gillnet catches from FDR forebay, 1976-77.

taken; however, two rainbow trout were caught.

Catches from the preliminary gillnet sampling in March 1976 were also relatively small. The quintuple vertical net (120 m deep) fished for 24 hours at the mid-forebay site caught only two kokanee, both in the upper 20 m of water. The two surface horizontal nets, fished 24 hours each, caught one rainbow trout. The first of two consecutive 24-hour double vertical net sets at the Third Powerhouse bay site yielded six kokanee, four rainbow trout, one walleye, and one peamouth; the second 24-hour set yielded two kokanee. The kokanee catches in March 1976 were comparable to those in March 1977.

6.6.1 Walleye

6.6.1.1 Importance. The walleye is the largest member of the perch family (Percidae) and an important game fish. Little sport fishing was observed in the study area; however, anglers using the boat dock facilities at Spring Canyon Park reported fishing for walleye immediately upstream of the study area. Nielson (1974) reported a substantial walleye fishery in the vicinity of the Spokane River arm of the reservoir.

6.6.1.2 Distribution. The gillnet catch of walleye in the study area was seasonal in nature. The majority were taken from September through November. A comparison of walleye catches between net sites indicated a non-uniform horizontal distribution. Catches in summer and fall were relatively large at the right forebay bottom horizontal net site (Fig. 14), while no walleye were taken at the left forebay horizontal site. The fall walleye catches in the bottom 4 m of the vertical net for the Crescent Bay and Third Powerhouse sites were substantially larger than for the right forebay vertical net site (Fig. 15).

Walleye catches at the bottom were consistently larger than for the surface for both horizontal (Fig. 14) and vertical (Fig. 15) nets. Few walleye were taken between 20 m and 4 m from the bottom in any season.

6.6.1.3 Age and Growth. Length frequency histograms of the walleye catch were compiled for each season (Fig. 16). The size of walleye ranged from 170 mm to 470 mm FL for all seasons combined. Modal lengths of 270 mm and 300 mm were observed for summer and fall, respectively. This increasing

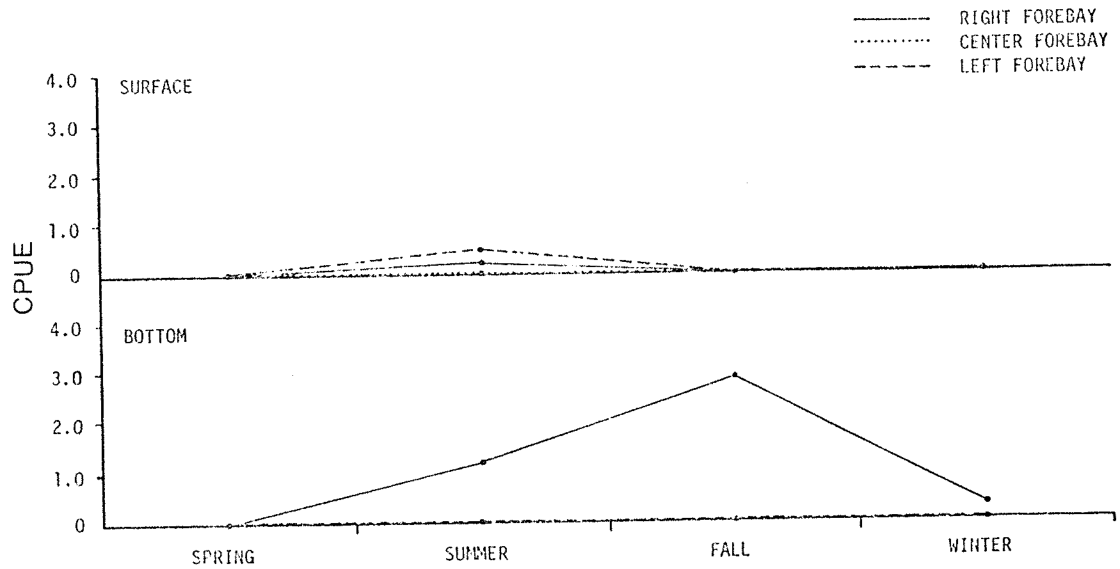


Figure 14. Seasonal catch per net day of walleye for three surface horizontal and two bottom horizontal gillnet sites in FDR forebay.

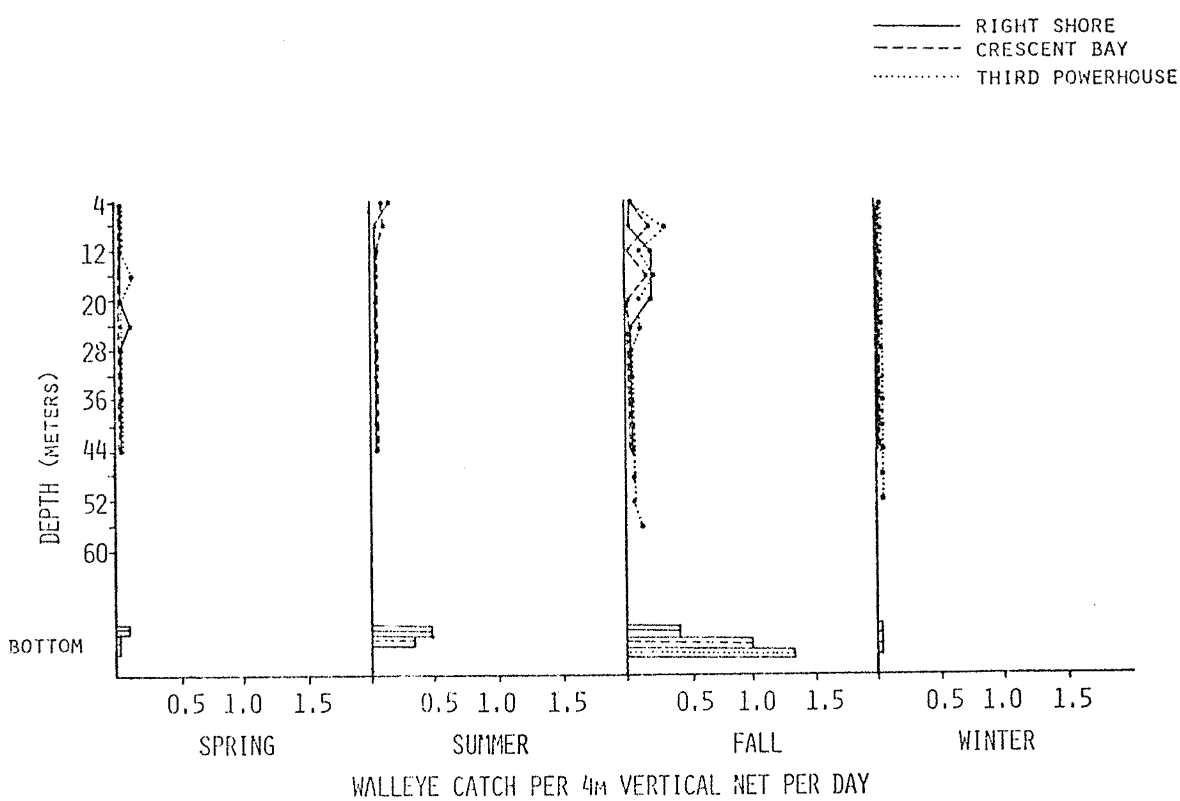


Figure 15. Seasonal catch per net day of walleye for three vertical gillnet sites in FDR forebay.

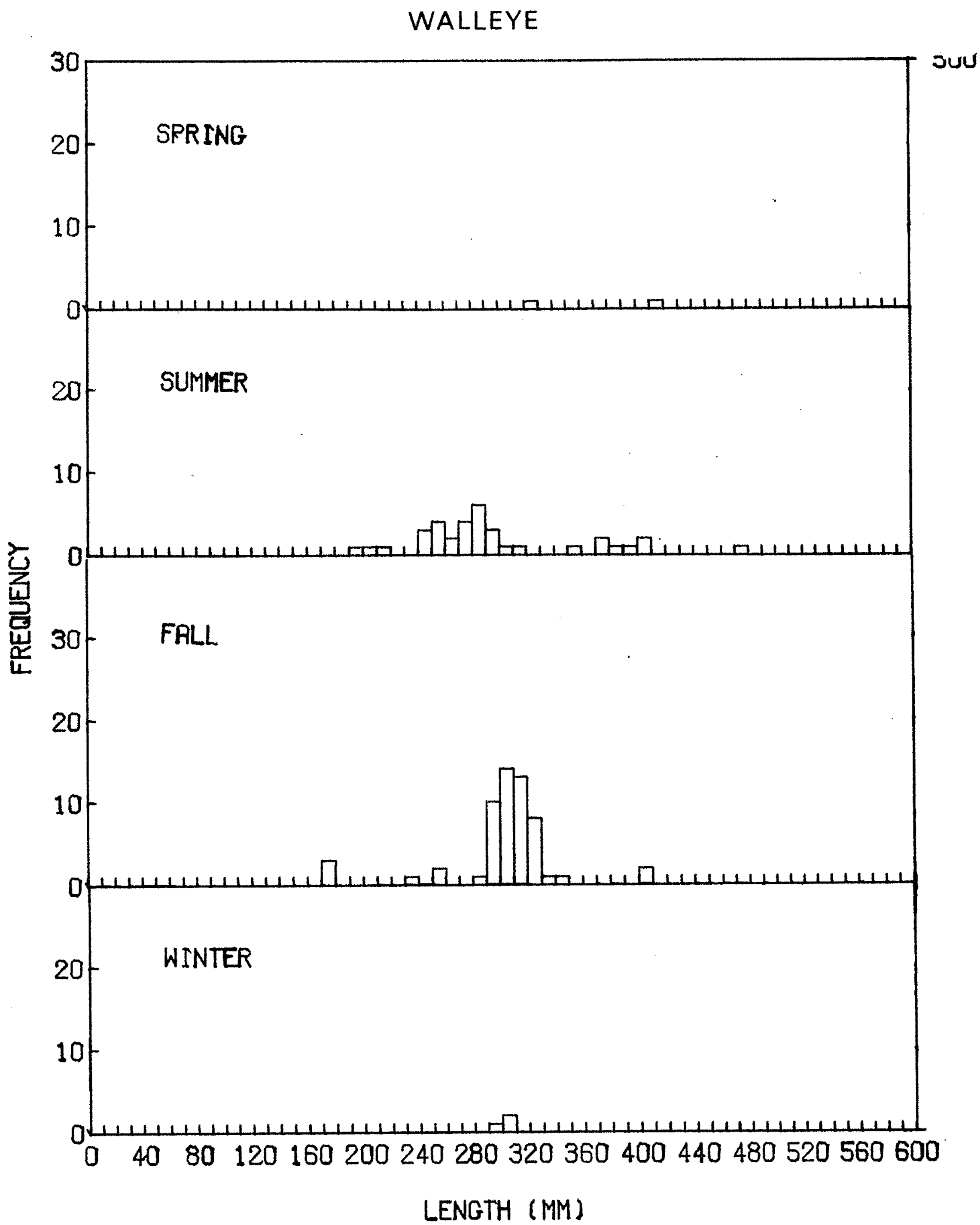


Figure 16. Length frequency distributions of walleye gillnet catch for spring, summer, and fall 1976, and winter 1977, in FDR forebay.

modal length represents the growth of age 1 fish from summer to fall.

The length-weight relationship for walleye was determined by fitting fork length (mm) and weight (g) to the logarithmic form of the general length-weight equation: $W = aL^b$ for 96 walleye taken from all seasons. The length-weight relationship in logarithmic form is:

$$\text{Log } W = -4.519 + 2.819 \text{ Log } L$$

$$N = 96$$

$$r^2 = 0.97$$

Scales from 93 walleye were analyzed to determine age with 3.2% age 0, 81.7% age 1, 14.0% age 2, and 1.1% age 3.

Lengths at annulus were calculated proportionately using scale measurements and fork length at capture as described by Tesch (1968). Analysis to determine a correction factor for the y-intercept was conducted, but the calculated body scale regression correlation coefficient ($r^2 = 0.47$) was low. Mean back-calculated fork lengths were 195 mm at annulus 1 (n = 90), 236 mm at annulus 2 (n = 14), and 334 mm at annulus 3 (n = 1). Back-calculated length at annulus 2 was less than the capture length of age 1 walleye in the fall (age 1 fish had completed two growing seasons at this time). Possible reasons for this discrepancy are the presence of a false annulus on some fish, actual growth differences between years, gillnet selectivity, or movement into FDR forebay based on size rather than age. The age structure of walleye in the forebay indicates a lack of older individuals and suggests a short residence time for the younger age groups occurring in the catch.

6.6.1.4 Food Habits. Walleye are primarily predators. Stomachs from 91 walleye were examined and 18 were found empty. Of the 73 stomachs containing food, 40 contained fish remains and 34 contained unidentifiable animal detritus (Table 11). The only identifiable fish remains were of sculpins; however, less than half of the fish in the stomachs were identifiable.

6.6.1.5 Reproduction. Walleye spawn between early April and June when the water temperature is between 5.6-11.1 C. Spawning grounds are the

Table 11. Food types found in the stomachs of all fish species caught during the study.

Species	Number of Stomachs Examined	Empty	Zooplankton	Fish	Insects	Benthos	detritus	Plant Detritus	Other
Walleye	91	18		40			34		1
Kokanee	83	20	57		2		4		
Rainbow trout	55	20	6	1	19		8	1	
Yellow perch	7					1	5	1	
Burbot	3			2		2			
Rocky Mountain whitefish	3	1	2						
Lake whitefish	2		1				1		
Northern squawfish	354	58	15	19	6	73	191	2	
Largescale sucker	39				1		8	33	
Peamouth	26	14	3		4		4	1	
Longnose sucker	15	1					6	8	
Bridgelip sucker	10						8	2	

rocky areas in whitewater, below impassable falls and dams in rivers or boulder to coarse gravel shoals in lakes (Scott and Crossman, 1973). Hatching occurs in 2 to 3 weeks (Table 12, Fig. 17). Since temperature strongly controls initiation of spawning and development rates, a mean monthly surface temperature curve for FDR Reservoir was plotted from data taken in 1951, 1963, and 1976-77. Approximate timing of the spawning season and development rates can be correlated with the annual reservoir temperature regime (Table 12).

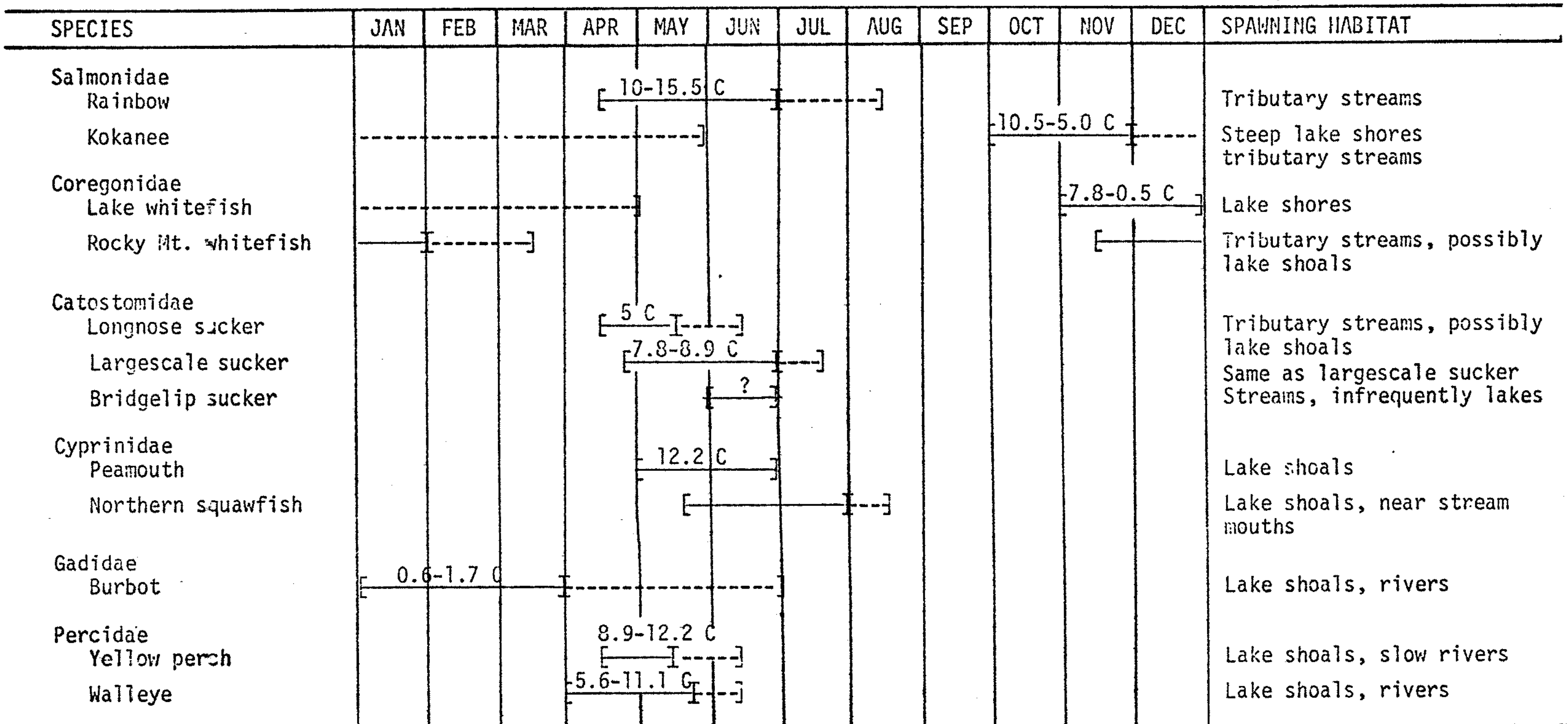
The study area is probably not an important spawning ground for walleye since few mature fish were taken and walleye catches were low during the spawning period. Of the fish examined, 83% were found to be immature.

Nielson (1974) reported that the walleye sport fishery and apparently the greatest walleye abundance were concentrated around the mouth of the Spokane River arm of the reservoir. Spawning was not observed in Nielson's study, but apparently walleye spawned in shoal waters and large tributaries from late March to early May at low pool or during rising water levels. Water levels continued to rise during the incubation period. The timing of the spawning and incubation periods with increasing water level was considered the major reason for the survival and expansion of walleye populations in FDR Reservoir.

6.6.2 Kokanee

6.6.2.1 Importance. Immediately following impoundment of Lake Roosevelt, kokanee populations flourished (Earnest et al. 1966). Large numbers of kokanee were caught in FDR forebay during February and March as recently as 1966 and 1967 (Snyder, data presented above). Local reports by fishermen and observations of gulls and eagles feeding in the tailrace of Grand Coulee Dam coincided in time with increased numbers of kokanee in FDR forebay. The meager historical data on this native species suggest a decline in abundance since impoundment of Grand Coulee Dam. No data have been found which indicate that kokanee have supported a large sport fishery in FDR Reservoir; however, when it exists in abundance it is highly sought by fishermen.

Table 12. Spawning (solid line) and development times [hatching or emergence](dashed line) for fish species in FDR Reservoir with spawning habitat and temperature ranges (Scott and Crossman, 1973).



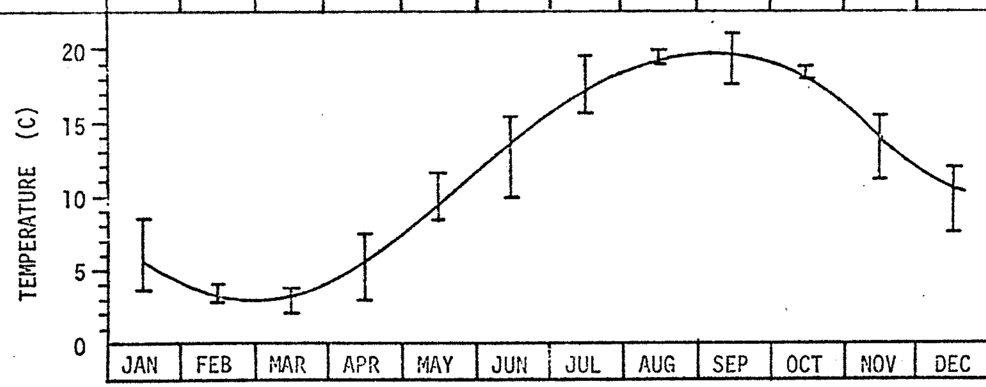


Figure 17. Mean monthly FDR Reservoir water surface temperature regime and ranges. Data from 1951 (Sylvester, 1958), 1963 (Earnest, *et al.*, 1966), and 1976-77 (present study).

6.6.2.2 Distribution. Kokanee gillnet catches were seasonal in nature (Figs. 18, 19). Largest catches occurred during late winter and early spring, but were not of the magnitude described by Snyder in 1966 and 1967. Horizontal distribution of the catch was relatively uniform, with minor exceptions. The Third Powerhouse bay vertical net had a higher catch per unit effort than the other vertical nets in winter (Fig. 19), but these data were biased somewhat by missing the February 1977 samples at that site. Kokanee were distributed through the water column down to 36 m. Few were caught on the bottom or surface (Figs. 18, 19) during any season.

6.6.2.3 Age and Growth. Seasonal length-frequency distributions of the kokanee gillnet catch (Fig. 20) indicated a modal length of 280 mm FL in winter. Modes were not apparent in other seasons.

The length-weight relationship for 85 kokanee in logarithmic form was $\text{Log } W = -4.382 + 2.796 \text{ Log } L$ ($r^2 = .92$).

Scale analysis from 55 kokanee indicated that age composition of the gillnet catch was 49% age 1, 49% age 2, and 2% age 4. Body lengths at annulus were calculated using a direct proportion. An attempt to establish a correction factor for the body-scale regression was unsuccessful since the regression had a low correlation coefficient ($r^2 = .69$). Mean back-calculated fork lengths at annulus were 113 mm at annulus 1 ($n = 55$), 262 mm at annulus 2 ($n = 28$), 251 mm at annulus 3 ($n = 1$), and 365 mm at annulus 4 ($n = 1$).

6.6.2.4 Food Habits. Kokanee are primarily planktonic feeders; of the 63 stomachs containing food, 57 contained zooplankton (Table 11). Stomachs were empty in about one quarter of the specimens examined.

6.6.2.5 Reproduction. Kokanee spawn in the fall during decreasing water temperatures from 10.5 to 5.0 C (51-41 F) and in 0.3 to 9.2 m (1-30 ft) of water (Scott and Crossman 1973) (Table 12, Fig. 17). Adults of both sexes usually die a few days to several weeks later.

Individuals from all stages of maturity were collected by gillnet. About one-fourth (24 fish) were immature; the rest were in various stages of pre-spawning development. Six kokanee were fully mature.

Kokanee reproduction by beach spawners in FDR Reservoir was very likely unsuccessful because of the annual drawdown. Beach spawning is possible;

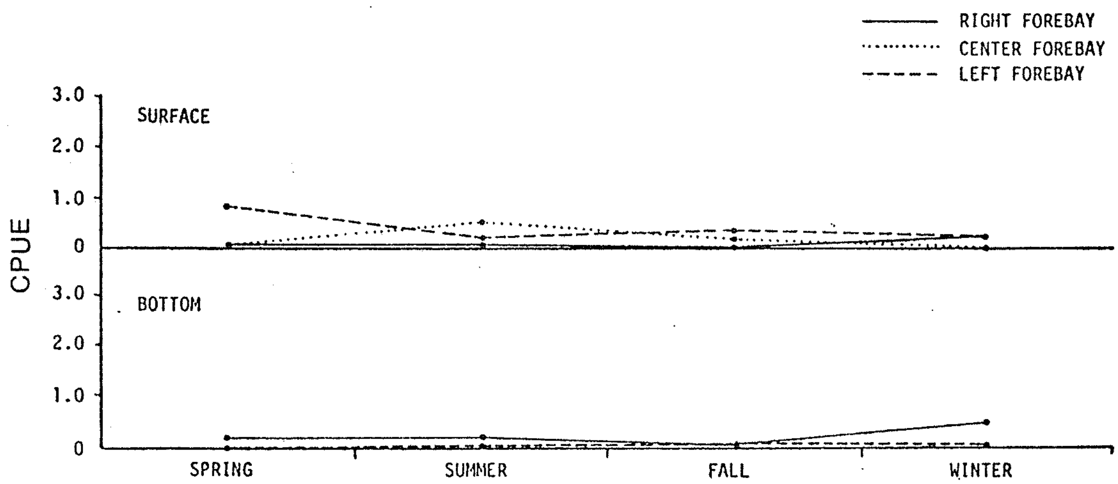


Figure 18. Seasonal catch per net day of kokanee for three surface horizontal and two bottom horizontal gillnet sites in FDR forebay.

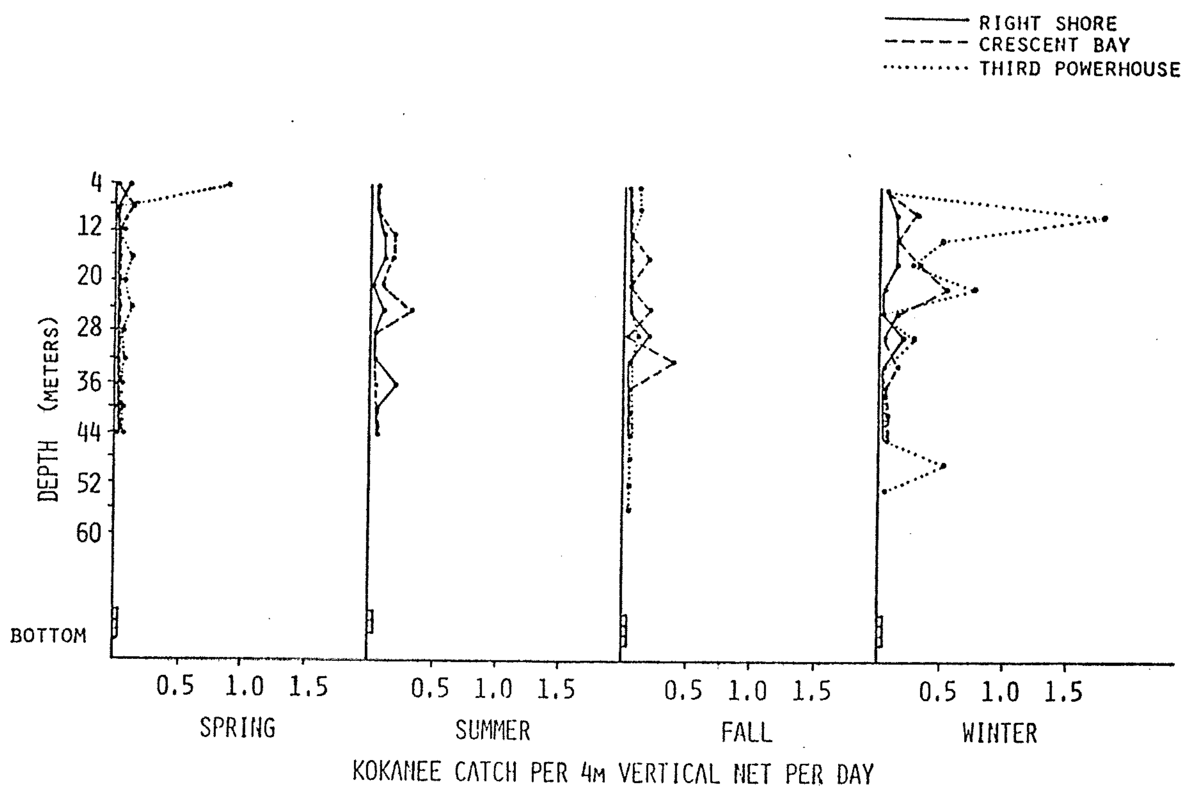


Figure 19. Seasonal catch per net day of kokanee for three vertical gillnet sites in FDR forebay.

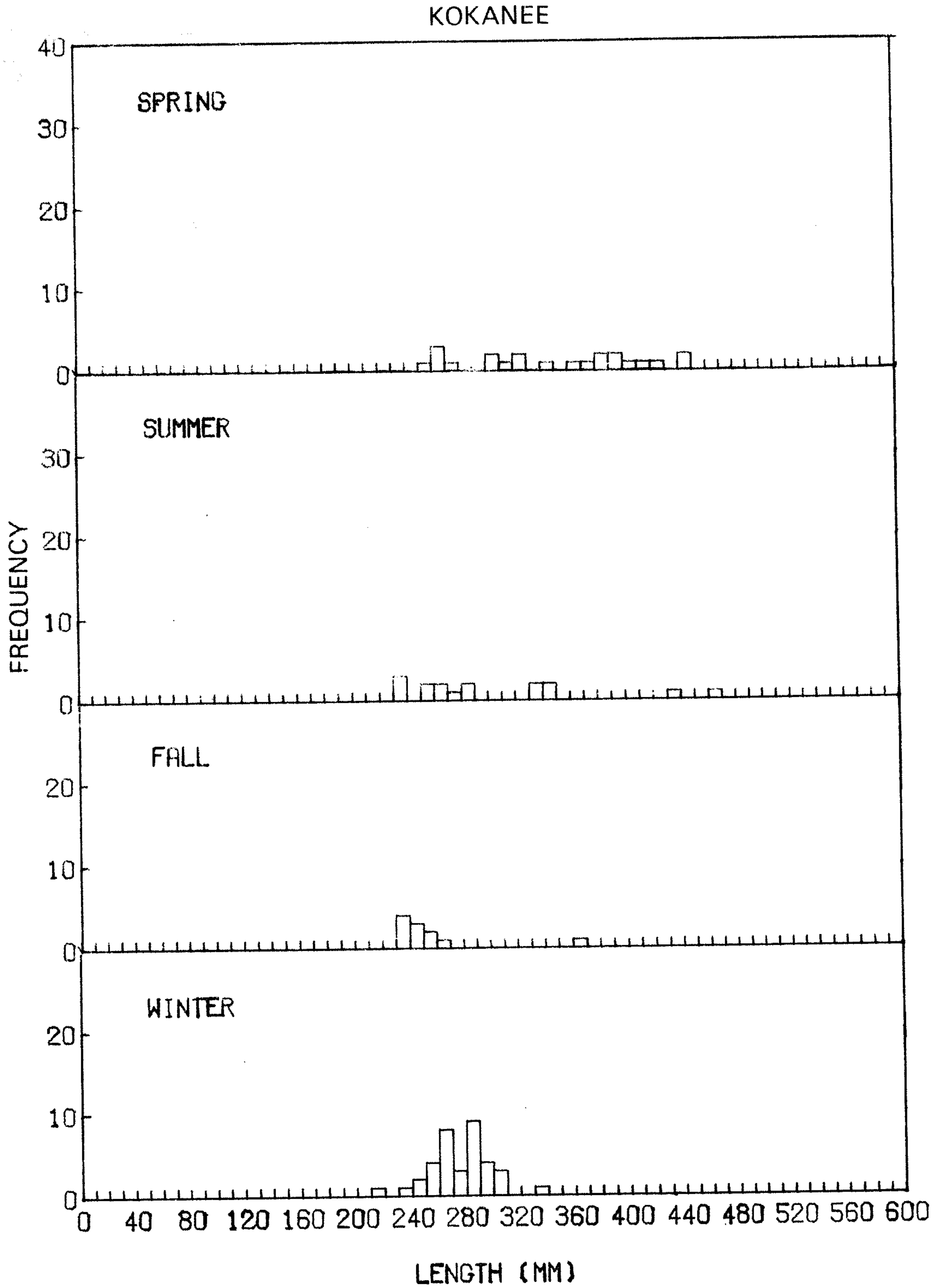


Figure 20. Length frequency distributions of kokanee gillnet catch for spring, summer, and fall, 1976 and winter 1977, in FDR forebay.

however, the long incubation period extending through the period of annual drawdown would ensure little or no survival due to desiccation of eggs or alevins. Observation of kokanee spawning sites was not a part of this survey. Fulton and Laird (no date, quoted by Bennett and White 1977) surveyed tributaries to Lake Roosevelt to appraise their possible value for salmon production in 1965 and 1966. Of the 31 streams surveyed in their study, the best spawning areas were found in the San Poil River and tributaries, Kettle River, and Sheep Creek. Tributaries are not subject to the effects of drawdown; however, the ability of stream-spawning populations to sustain an adequate reservoir population appears to be limited. The decline of kokanee abundance in FDR Reservoir from 1966-67 to 1976-77 may have resulted from the increased minimum annual drawdown of the Reservoir during the 10-year period. This suggests that kokanee beach spawning may have been successful at minimum drawdown levels of less than 40 feet, which occurred in 1963 and 1964 when those yearclasses were in the gravel.

6.6.3 Rainbow Trout

6.6.3.1 Importance. The rainbow trout is an important sport fish in Washington. The rainbow trout fishery at the mouths of some tributaries to Lake Roosevelt was classified as "mediocre" (Earnest et al. 1966). A very limited rainbow trout fishery was noted in Crescent Bay during the winter months of the present study.

6.6.3.2 Distribution. The catch of rainbow trout in the gillnet survey was seasonal with most taken in spring and summer months. Due to the small number of fish captured, horizontal distribution was not analyzed. A few rainbow trout were caught at every horizontal and vertical net site except the left forebay bottom horizontal site.

Surface horizontal net catches of rainbow trout tended to be slightly larger than bottom horizontal catches. Rainbow trout were caught in vertical nets from the surface to 28 m deep.

6.6.3.3 Age and Growth. Two different length distributions were apparent in comparing seasonal length frequencies (Fig. 21). The modal length of rainbow trout in spring was about 390 mm, whereas in summer 390 mm

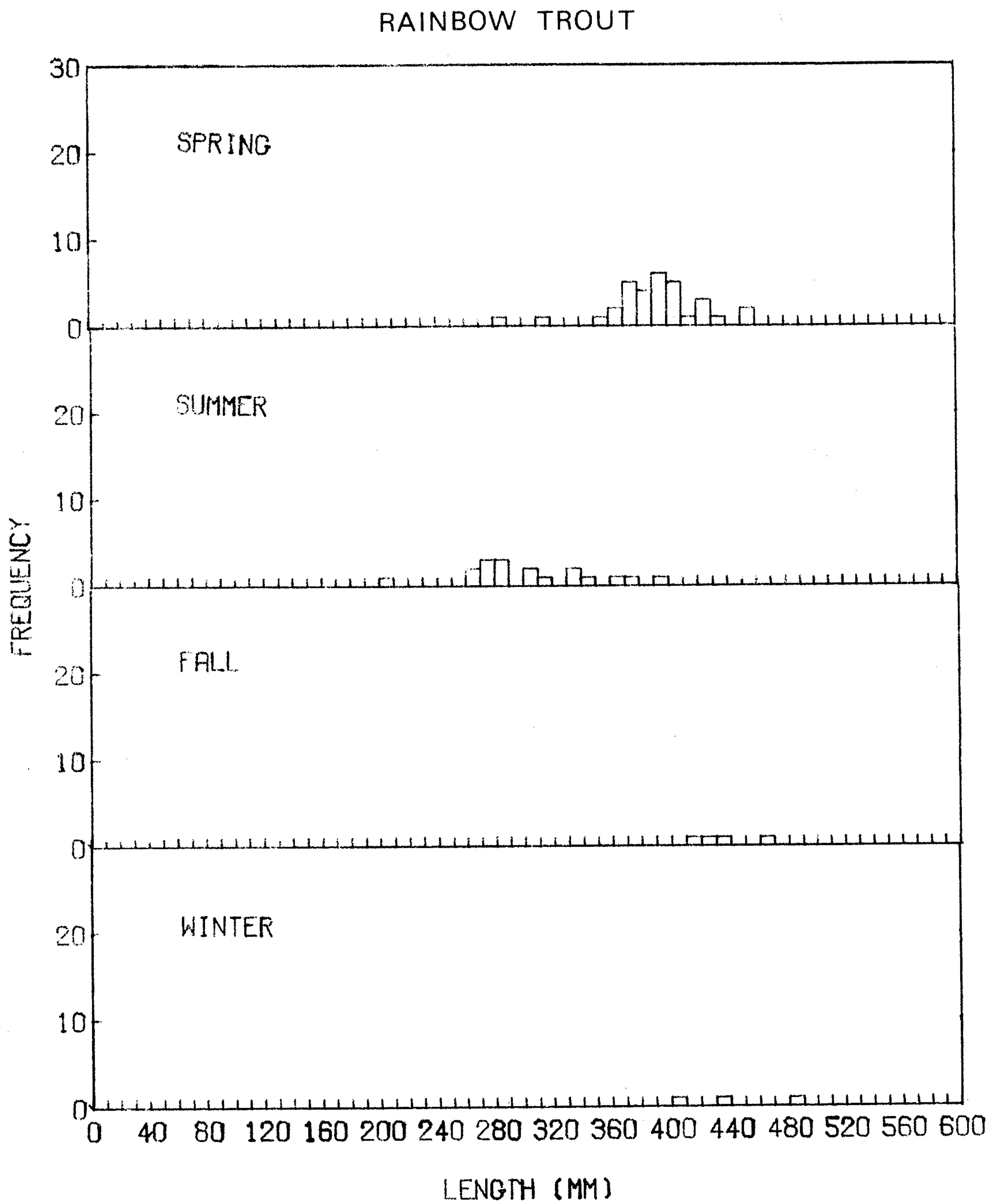


Figure 21. Length frequency distributions of rainbow trout gillnet catch for spring, summer, and fall 1976, and winter 1977 in FDR forebay.

was the maximum length. The larger fish in the spring were caught primarily in the variable-mesh horizontal nets. The smaller fish in summer were mainly taken in the single mesh vertical nets. Some degree of net selectivity was indicated in this data; however, due to small catches no attempt to separate gear types was made.

The length-weight regression for 57 rainbow trout was $\text{Log } W = -3.230 + 2.349 \text{ Log } L$ $(r^2 = .93)$.

Age analysis of scales from 40 rainbow trout indicated that age 1 fish comprised 40% of the rainbow trout catch, age 2 50%, and age 3 10%. The majority (67%) in spring were age 2 while in the summer 67% were age 1.

Lengths at annulus were calculated using a direct proportion. An attempt to establish a correction factor from the body scale regression was unsuccessful since the regression had a low correlation coefficient $(r^2 = 0.43)$.

Mean back-calculated fork lengths for rainbow trout were 97 mm at annulus 1 (n = 40), 255 mm at annulus 2 (n = 24), and 322 mm at annulus 3 (n = 4).

6.6.3.4 Food Habits. Stomachs were analyzed from 55 rainbow trout with 20 empty (Table 11). Insects were found in half the stomachs which contained food. Other stomach items included detritus, zooplankton, fish and plant debris. Identifiable insects consisted of beetles, caddis larvae, and chironomid larvae. Identifiable fish consisted of one sculpin.

6.6.3.5 Reproduction. Rainbow trout are basically spring spawners which select smaller tributaries of rivers from mid-April to late June (Scott and Crossman 1973) (Table 12, Fig. 17). Spawning temperature is usually between 10.0 and 15.5 C (50-60 F). Eggs usually hatch in 4 to 7 weeks and alevins take an additional 3 to 7 days to absorb the yolk and emerge. Rainbow trout seeking access to spawning tributaries during April and early May, may find ascent difficult because of effects of drawdown; however, later spawners should be unaffected. The ability of stream-spawning populations to sustain an adequate reservoir population appears to be limited.

The majority of rainbow trout taken in the gillnets were mature fish (86%). The small peak in catch per net-day observed in spring may be due to increased pre-spawning activity and movement.

6.6.4 Other Sport Fish

The catches of other species of sport fish (yellow perch, burbot, lake whitefish and Rocky Mountain whitefish) were too small to warrant detailed analysis or discussion of distribution and life history. It is interesting to note, however, the low abundance of yellow perch in FDR forebay, considering it was found to be the most abundant species in nearby Banks Lake (Stober et al. 1976). Stober (1977) found relatively few yellow perch in Rufus Woods Reservoir, immediately downstream of FDR, but assumed that some spawning occurred there based on the presence of a limited number of fry. Lake whitefish abundance was also low in FDR forebay, in contrast to Banks Lake where it is a major species. Successful reproduction of lake whitefish in FDR Reservoir is probably limited by the annual drawdown, since this species is a winter beach spawner which doesn't emerge until late April (Table 12, Fig. 17).

6.6.5 Squawfish

6.6.5.1 Importance. The squawfish was the most abundant fish in the gillnet survey. Other studies in FDR (Earnest et al. 1966; Gangmark and Fulton 1949) also found a high relative abundance of squawfish. Earnest et al. (1966) attributed the dominance of cypriniforms (primarily peamouth and squawfish) in FDR to the physical characteristics of the impoundment which governs their food supply. Cypriniforms utilize greater amounts of plant material and organic debris than do salmonids. Suitable habitat for cypriniforms was increased by impoundment while that of competitive species was reduced. Squawfish have been found to be important predators on juvenile salmonid populations.

6.6.5.2 Distribution. The gillnet catch of squawfish was high in summer, moderate in spring and fall, and small in winter. The maximum catch corresponded well with the highest seasonal water temperature.

Comparison between sampling sites indicated a relatively uniform horizontal distribution of squawfish, with two exceptions (Figs. 22, 23). There were fewer squawfish taken at the right forebay surface horizontal site in the summer than at the center or left forebay site, and there were more

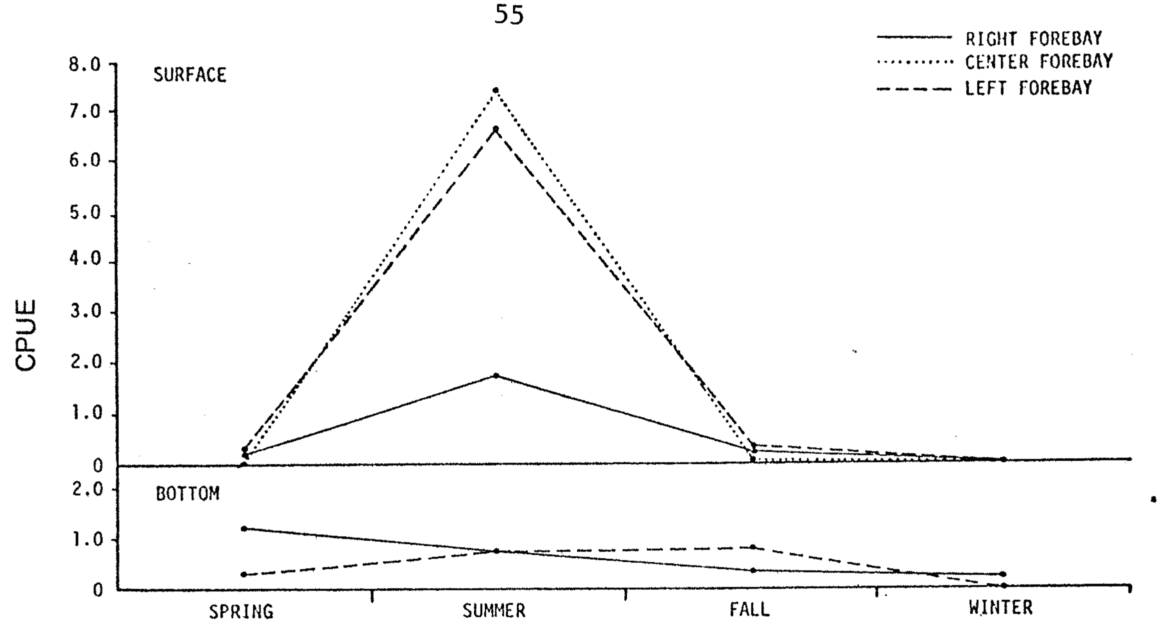


Figure 22. Seasonal catch per net day of squawfish for three surface horizontal and two bottom horizontal gillnet sites in FDR forebay.

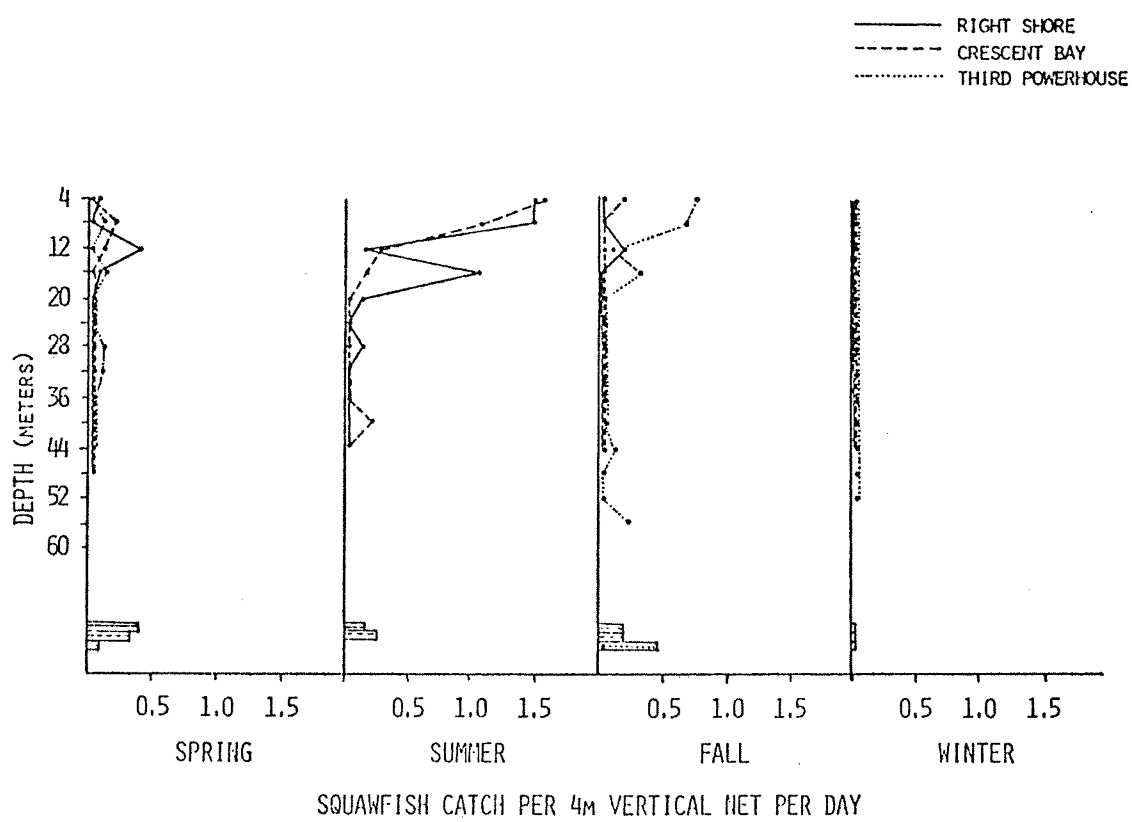


Figure 23. Seasonal catch per net day of squawfish for three vertical gillnet sites in FDR forebay.

squawfish at the surface and bottom of the Third Powerhouse vertical net site in the fall than at the respective depths of either the right forebay or Crescent Bay vertical net site.

The vertical distribution of the squawfish catch indicated a preference for the surface water down to 20 m and for the bottom. Few squawfish were in the zone between 20 m and bottom in any season as determined from the vertical net catches. The catch of squawfish in the summer was much higher in the surface layer than at the bottom for both horizontal (Fig. 22) and vertical (Fig. 23) nets.

6.6.5.3 Age and Growth. Seasonal length-frequency distributions (Fig. 24) indicate a pronounced mode at 300 mm for the three seasons with a substantial catch (spring, summer and fall). Few fish were exceptionally smaller or larger than the modal length.

The length-weight regressions for 358 squawfish was Log W = -3.914 + 2.620 Log L (r^2 = .85).

An attempt at age determination of squawfish from scale analysis was unsuccessful. Individuals in the 280-360 mm size range generally had two identifiable annulii. Carl et al. (1967) reported that sexual maturity was reached in about 6 years when the squawfish are about 305 mm long.

6.6.5.4 Food Habits. Squawfish were utilizing a broad range of food types (Table 11). The gut contents of 354 squawfish were inspected during the study; 58 were empty. The major gut content was detritus, occurring in 65% of the cases with food. Benthos, including amphipods and occasionally crayfish, were found in 25% of the cases, fish (sculpins or unidentified remains) in 6%, zooplankton in 5%, and insects in 2% of the gut contents which contained food.

6.6.5.5 Reproduction. Squawfish spawn from late May through July in gravelly shallows (Scott and Crossman 1973) (Table 12, Fig. 17). Spawning in the FDR forebay study area was not observed directly but probably occurred, based on the large number of mature squawfish captured in the gillnets and on the large number of cyprinid fry observed along the shoreline at this time. Spawning occurred during a time of increasing or stable water level which ensured successful reproduction.

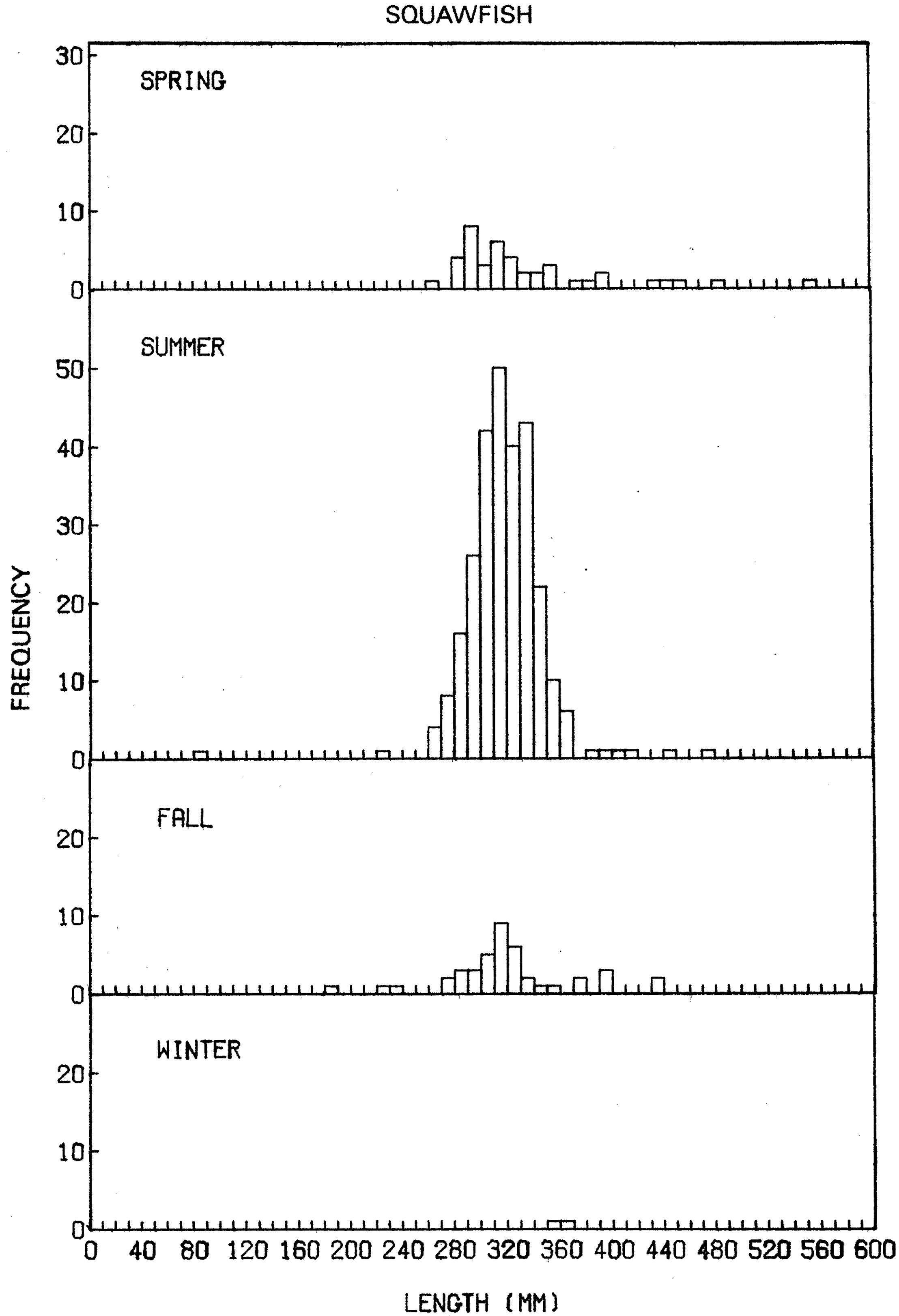


Figure 24. Length frequency distributions of squawfish in the gillnet catch for spring, summer, and fall 1976, and winter 1977, in FDR forebay.

The majority (96%) of squawfish taken by gillnets were mature. Ripe males and females were collected in June and July. Spent fish were taken from June through August. The peak catch of squawfish in the forebay occurred in August and September. Most of these fish were in the resting (post-spawn) stage of development.

6.6.6 Largescale Sucker

6.6.6.1 Importance. The largescale sucker was the fifth most abundant fish in the gillnet survey. It comprised 5.7% of the total number and 9.7% of the total weight. All were larger than 340 mm FL. Their large size was probably the reason that no largescale sucker were caught in the vertical nets.

6.6.6.2 Distribution. The catch of largescale sucker was also seasonal in nature. Largest catches occurred in August and September, although they were sporadically taken during other months.

Due to the small sample size, detailed analysis of the horizontal distribution was not attempted. Largescale sucker were taken at each horizontal net site but tended to be clumped in distribution on the occasions they occurred in the catch. This is consistent with their schooling behavior. Largescale sucker occurred more frequently in the surface horizontal nets than in the bottom nets (Fig. 12).

6.6.6.3 Age and Growth. Seasonal length-frequency distributions (Fig. 25) of the largescale sucker catch indicated little difference in size over the seasons. All were of adult size.

A length-weight relationship for 41 largescale sucker in logarithmic form was $\text{Log } W = -3.427 + 2.435 \text{ Log } L \quad (r^2 = .72)$.

As in the case of squawfish, age determination of largescale sucker by scales proved unreliable. Beamish and Harvey (1969) report that for white sucker (*Catostomus commersoni*) ages by scales are reliable only to the fifth year due to slowed growth rate and skipped annulus formation. The same probably is true for these suckers. Based on their size and maturity, all largescale suckers in the gillnet samples were probably older than age 5. However, only two or three annulii were discernable on most of the scales.

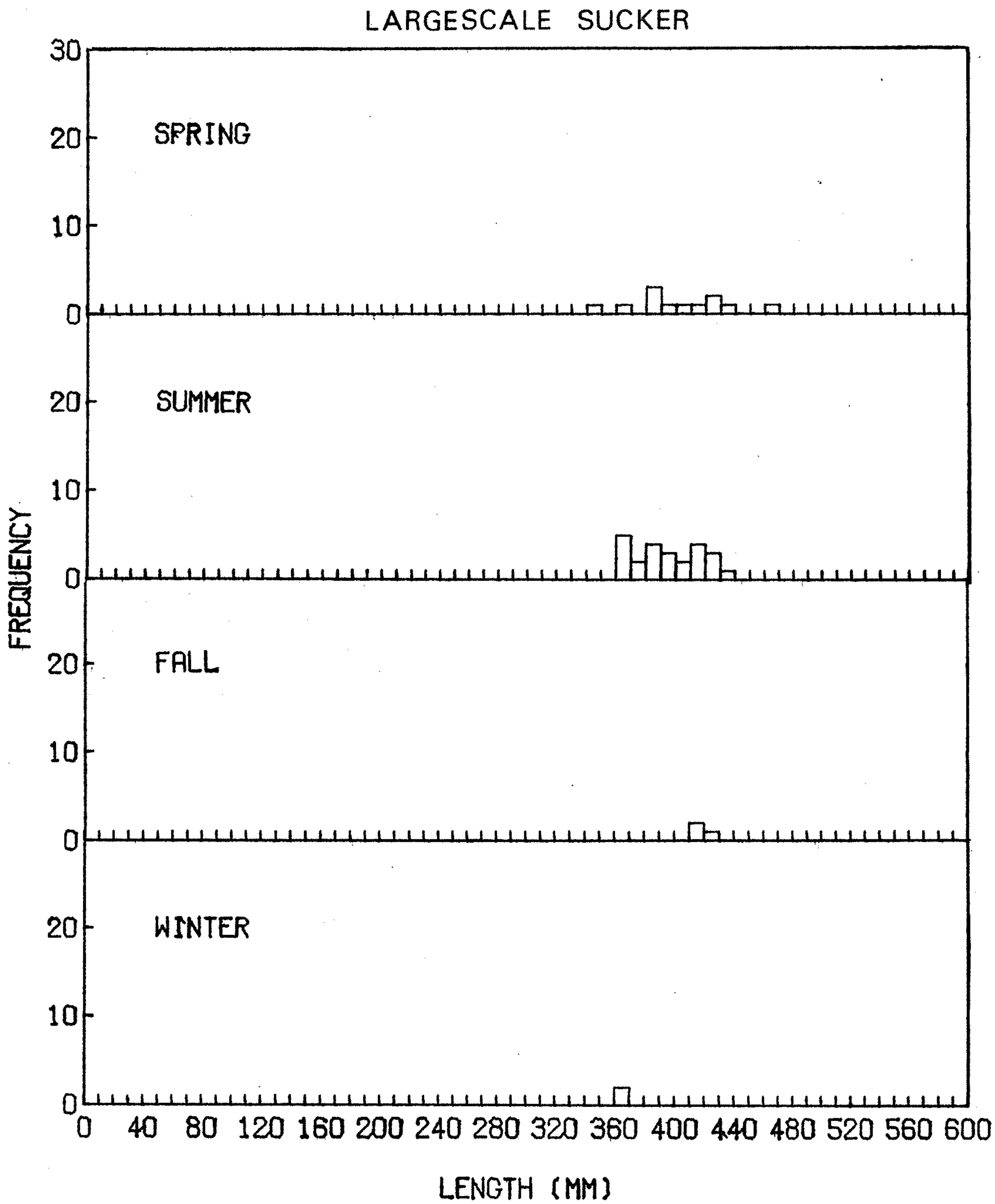


Figure 25. Length frequency distributions of largescale sucker in the gillnet catch for spring, summer, and fall 1976, and winter 1977, in FDR forebay.

6.6.6.4 Food Habits. The gut contents of 39 largescale sucker were examined and 33 contained plant debris (Table 11), primarily algae. Other food items were detritus and insect parts.

6.6.6.5 Reproduction. The largescale sucker usually spawns from late April to late June in deeper, sandy areas in streams and sometimes on gravelly or sandy shoals in lakes (Scott and Crossman 1973) (Table 12, Fig. 17). The eggs hatch in about two weeks and the fry remain in the gravel or over sand until the yolk is absorbed.

Spawning by suckers probably occurred in or near the study area, based on observations of many young-of-the-year in August. These young were only identified to the genus level. All largescale sucker captured in the gillnets were mature fish.

6.6.7 Other Non-Game Fish

Three additional species of non-game fish, peamouth, longnose sucker, and bridgelip sucker, each composed less than 5% of the total gillnet catch. Peamouth was found to be the third most abundant fish in Rufus Woods Reservoir (Stober 1977) but decreased in abundance in a downstream direction. A similar longitudinal distribution may exist in FDR Reservoir. All three species are late spring spawners. The suckers prefer streams while the peamouth selects lake shoals (Table 12). Reproductive success should not be curtailed by the increasing or stable water levels which occur at this time.

6.7 Townet Catch

Townet sampling was conducted during August to coincide approximately with the peak abundance of fishes in the forebay, as indicated by the acoustic and gillnet surveys. Juvenile fish were abundant also at this time, as was indicated by numerous schools of small fish visible along the shorelines.

The survey was conducted on August 23-24, 1976, principally during the darkest hours of the night, when it was anticipated that juveniles would be distributed offshore and more available to the townet.

A single haul was made during the daytime along the Spring Canyon transect, and two hauls each were made during nighttime along the Spring Canyon and Crescent Bay transects. The catches indicated a low occurrence of juvenile fish offshore in surface waters less than 10 feet deep, particularly in the Crescent Bay transect area (Table 13). No offshore movement of juvenile fish at night was detected. Due to the low catches and lack of juvenile sport fishes, further townetting to determine distribution patterns was suspended.

6.8 Acoustic Surveys

Acoustic surveys of the Grand Coulee Dam forebay were conducted March 16, April 19-20, May 15, June 14, August 2, September 13, and November 10, 1976; and January 18, February 15, and March 31, 1977. The information was transcribed from taped recordings of targets into numerical tables by date, diel period, depth strata, and location. These data appear in Appendix Tables 8 through 18. Brief discussions and graphical representations of pertinent findings for each parameter are presented below.

6.8.1 Seasonal Variation in Target Density

Monthly acoustic surveys indicated target densities occurred at three levels. Medium densities occurred from March through June 1976 and January through March 1977 and averaged 1.90×10^{-4} targets/m^3. A relatively high density of 2.64×10^{-2} targets/m^3 occurred in August, with low densities in September and November, which averaged 1.64×10^{-6} targets/m^3 (Fig. 26). These densities may be visualized better if expressed as cubic meters of water occupied by a single target, in which case the medium densities averaged one target per 14,094 m^3, the August high density was one target per 37 m^3, and the low September-November average density was one target per 611,597 m^3.

The large seasonal changes in fish density in FDR forebay suggest a seasonal migration rather than changes in activity of local fishes. An apparent downstream migration of fishes in FDR Reservoir during the summer resulted in a gradual increase in abundance in the forebay during the summer,

TABLE 13. Townet catches from Grand Coulee forebay, Roosevelt Lake, August 24-25, 1976.

DATE	TIME	TRANSECT	DIRECTION of HAUL	CATCH
9/24	1405-1430	Spring Canyon	Left to right bank	3 squawfish, age 0
	2310-2335	Spring Canyon	Left to right bank	2 squawfish, age 0 2 sucker, age 0
	2345-0010	Spring Canyon	Right to left bank	1 squawfish, age 0 1 sucker, age 0
9/25	0035-0100	Crescent Bay	Left to right bank	0
	0110-0135	Crescent Bay	Right to left bank	0

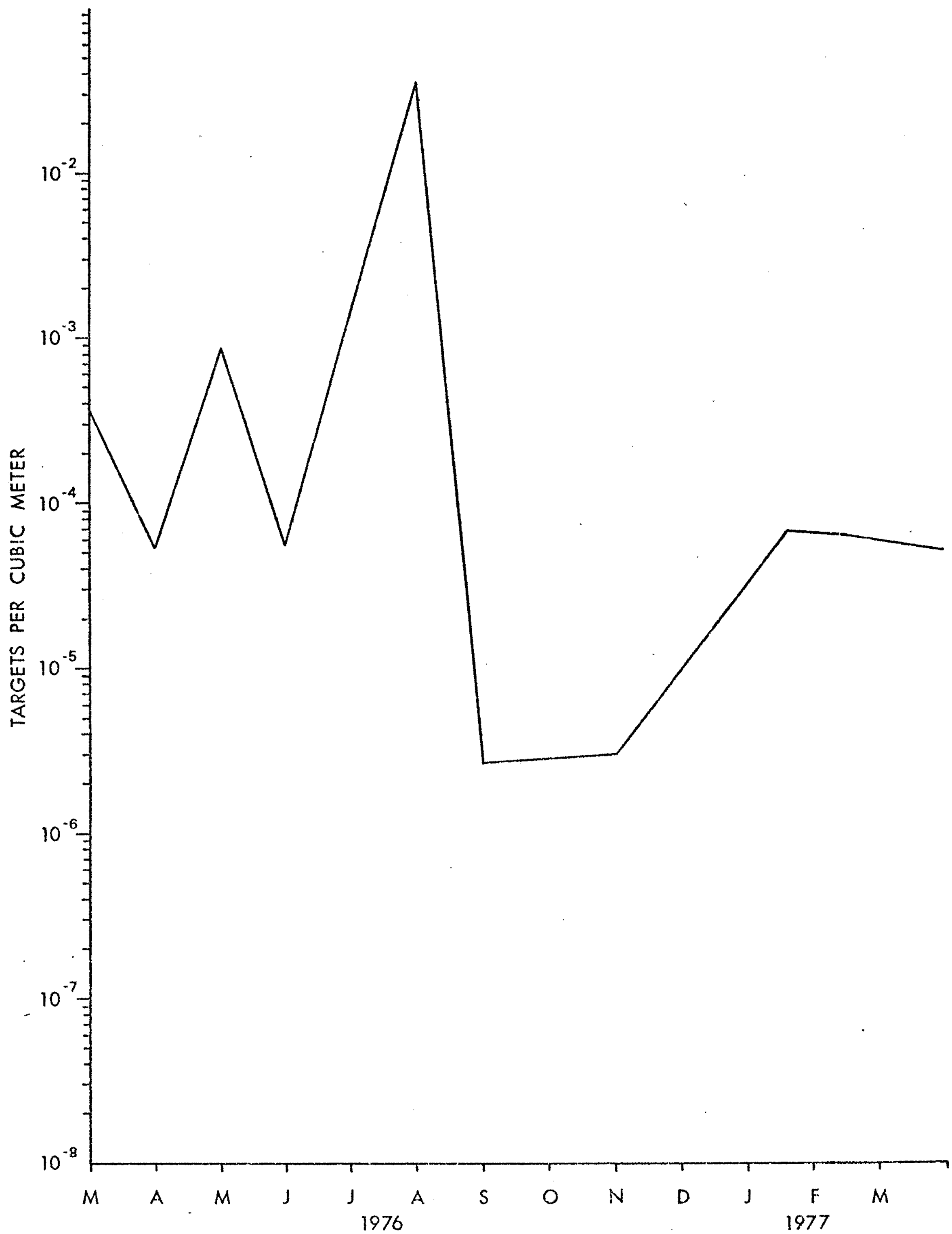


Figure 26. Seasonal variation in acoustic target density in FDR forebay from March 1976 to March 1977.

which peaked in August. The increased abundance coincided with thermal stratification of the surface waters in the forebay. The rapid decrease from August to September suggested either an upstream migration in FDR Reservoir or a cessation of downstream movement coupled with the entrainment through Grand Coulee Dam of most of the available fishes. Thermal stratification began to break down during the period in which the fish density declined. The increase in fish density in winter was probably the result of migration of kokanee into the forebay area. Timing of the kokanee migration was also supported in the data supplied by Snyder (NMFS).

6.8.2 Horizontal Distribution

Horizontal distribution of targets was fairly uniform between and within transects throughout the sample year (Fig. 27 through 30). The March 1976 series of transects was excluded from this presentation because a narrow beam transducer was used. This resulted in a sample volume and relative signal strength which were different from the rest of the surveys.

A total of nine comparable day/night surveys were run throughout the year at the Spring Canyon Transect (Fig. 27). There were generally a few more targets along the left shore, which was a sandy shoal. Seasonal trends were quite apparent at this transect, with the most targets observed in August. Few targets were observed below a depth of 45 m.

Nine comparable day/night surveys were made along the Crescent Bay transect throughout the year (Fig. 28). No consistent pattern of horizontal distribution was noted. At times (April 19, 1976, day and night and January 18, 1977, night), more fish were recorded near the right shore and at other times (June 14, 1976, day and March 31, 1977, day) more were recorded near Crescent Bay. A strong seasonal trend was noted on this transect, with the most target observations occurring in August. Few targets were observed below 45 m.

The inner logboom transect was situated on the downstream side of the logboom. It was surveyed six times during the year (Fig. 29). The August acoustic survey was run immediately upstream of the logboom during the spill season when safety restrictions prevented sampling inside the logboom (Fig. 29). Horizontal distribution did not indicate any consistent pattern throughout the sampling period; however, a similar seasonal increase in targets occurred

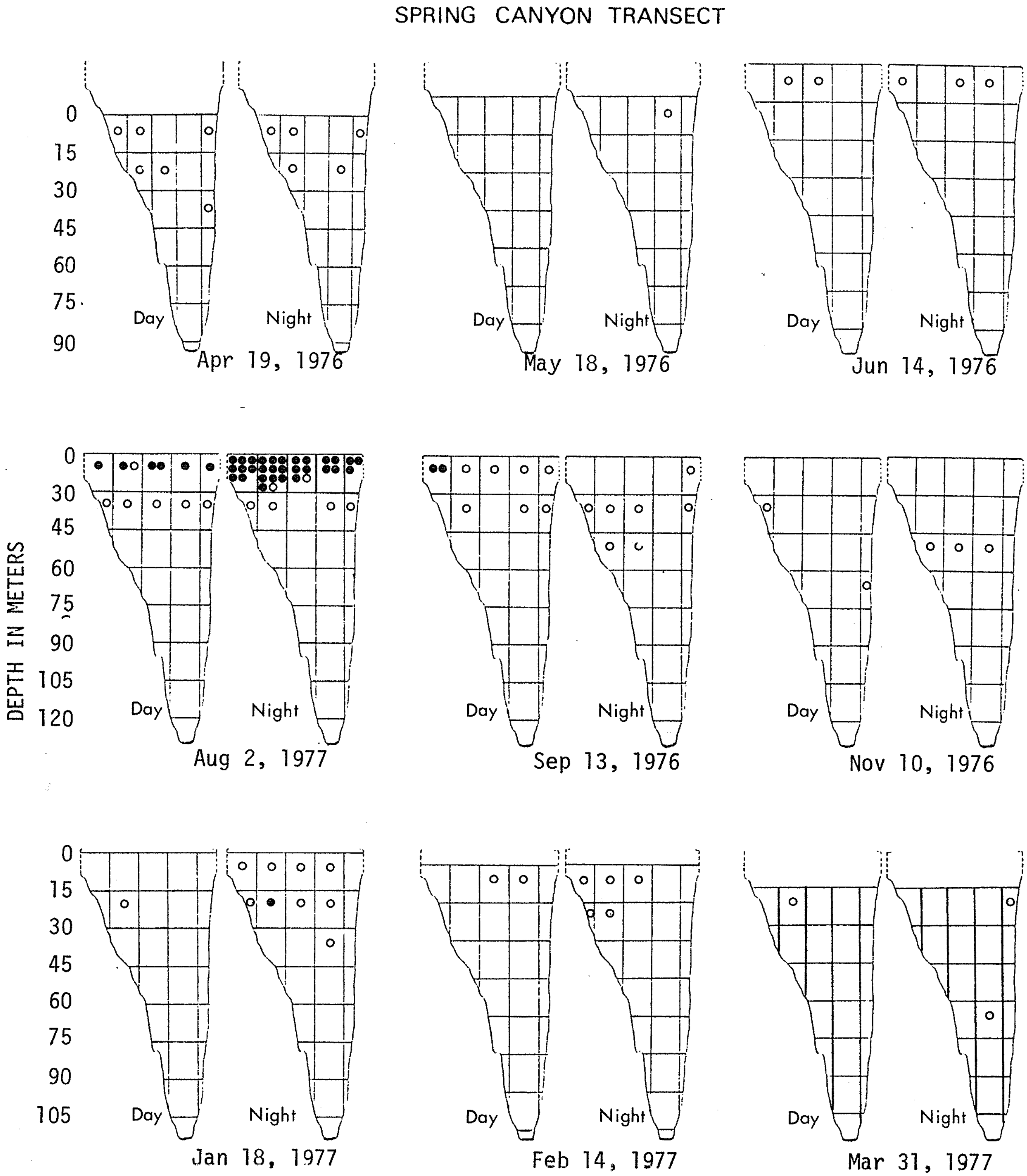


Figure 27. Horizontal and vertical distribution of acoustic target density during nine day and night surveys on the Spring Canyon transect. Open circles are equal to 1-5 targets, and solid circles are equal to 6-10 targets. The horizontal scale at full pool is about 1.33 km.

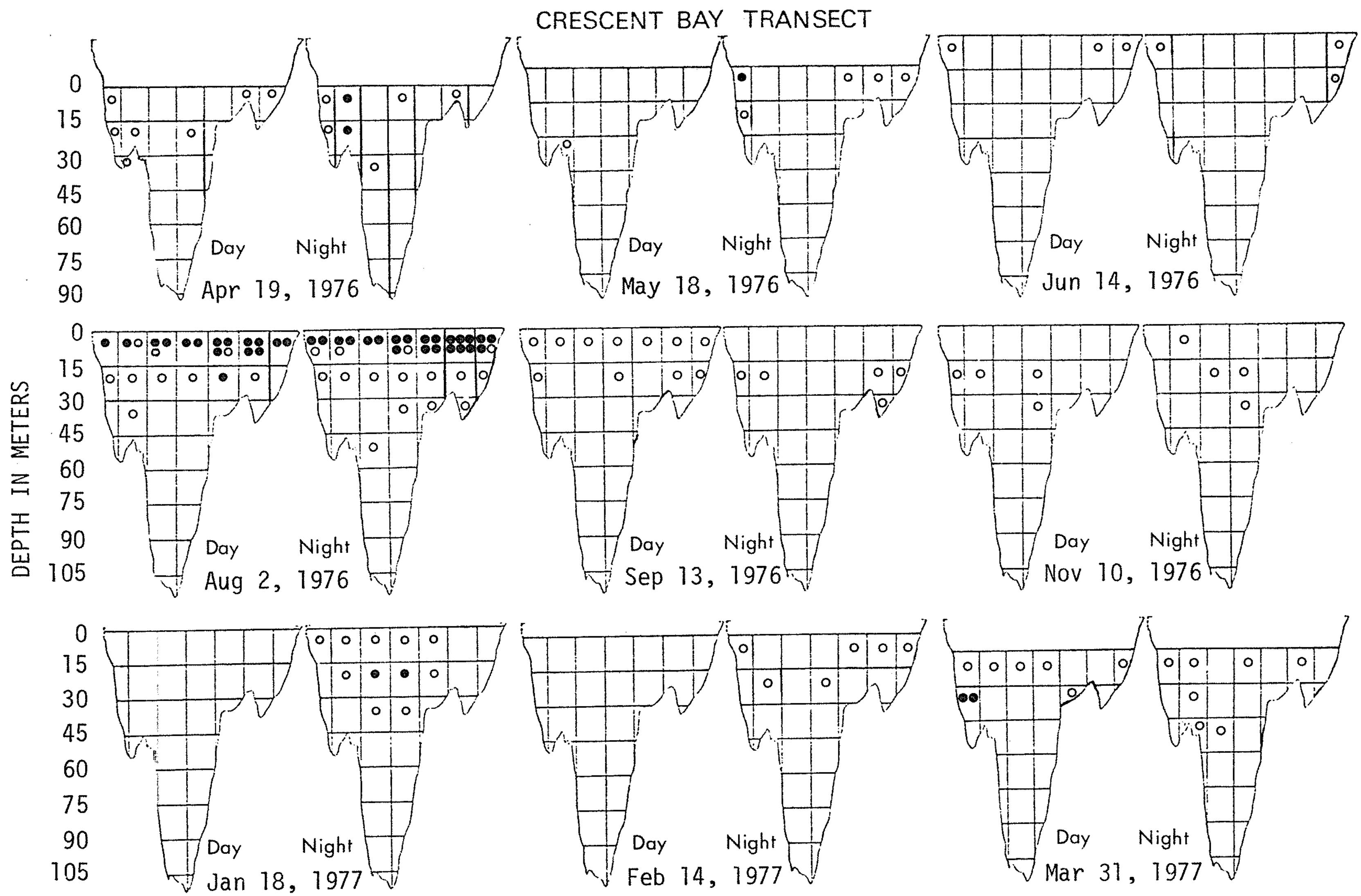


Figure 28. Horizontal and vertical distribution of acoustic target density during nine day and night surveys on the Crescent Bay transect. Open circles are equal to 1-5 targets and solid circles are equal to 6-10 targets. The horizontal scale at full pool is about 2.0 km.

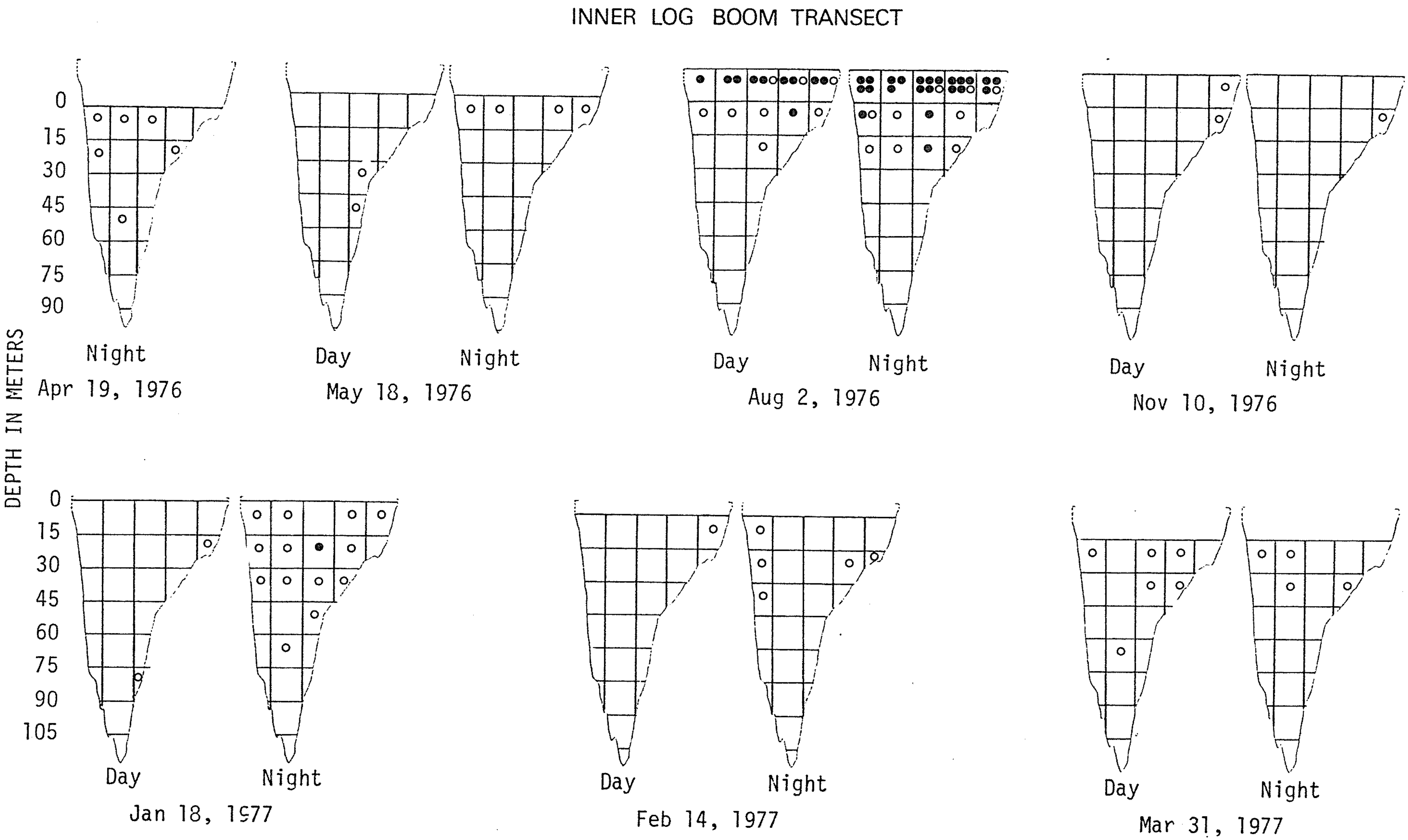


Figure 29. Horizontal and vertical distribution of acoustic target density during seven night and six day surveys on the inner log boom transect. Open circles are equal to 1-5 targets, and solid circles are equal to 6-10 targets. The horizontal scale at full pool is about 1.39 km.

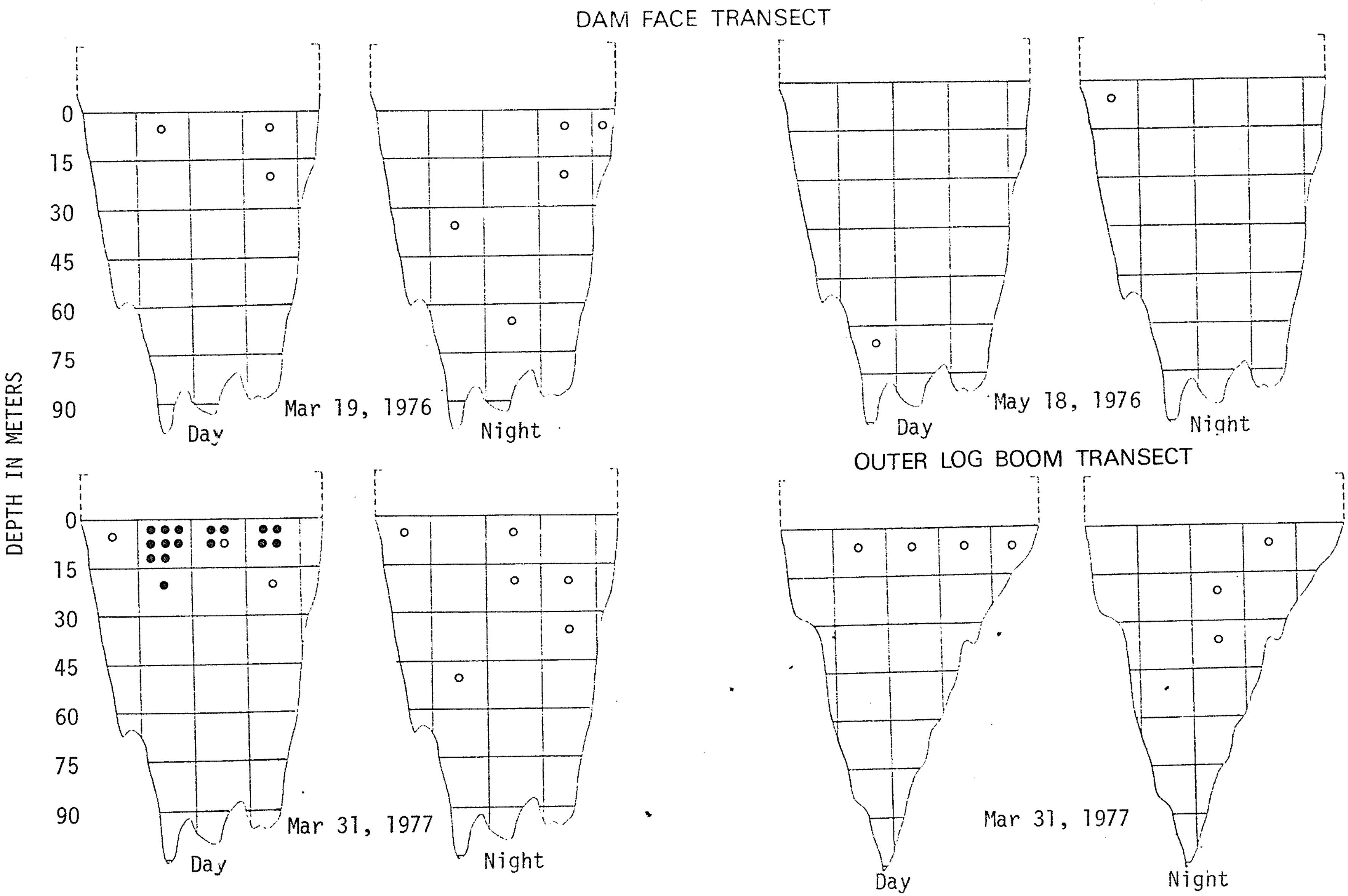


Figure 30. Horizontal and vertical distribution of acoustic target density during three day and night surveys on the dam face transect and one day and night survey on the outer log boom transect. Open circles are equal to 6-10 targets and solid circles are equal to 1-5 targets. The horizontal scales at full pool on the dame face and outer log boom transects were 1.39 and 1.65 km, respectively.

in August.

The transect adjacent to the dam face was sampled three times during the year. Horizontal distribution was fairly uniform (Fig. 30). More targets were recorded for the day series of this transect on March 31, 1977 than for any other transect on that sample date. This peak corresponded with the general timing of reported kokanee migrations and possible entrainment through Grand Coulee Dam. The outer logboom transect was surveyed only once during the period (March 31, 1977). Few targets were recorded (Fig. 30).

6.8.3 Vertical and Diel Distribution

Generally, targets were most abundant near the surface and became less abundant with increasing depth (Fig. 31). Vertical distributions of targets were similar for transects inside and outside the Third Powerhouse forebay.

Target distributions tended to occur nearer the surface at night than during the day from May through September and in January but were undifferentiated in April and November and in March of both years (Fig. 31). A photonegative reaction by fishes was suggested by this data for the summer months.

6.8.4 Acoustic Survey to North Gorge

On June 15, an acoustic survey was conducted up the reservoir to Mile 119 (North Gorge). In all, seven locations were surveyed, including the mouths of the San Poil River, Spokane River, Nez Perce Creek, Hall Creek, Colville River, Kettle River, and North Gorge. The echograms indicated that the densities upriver were substantially less than were observed the previous day during an acoustic survey of the forebay near Grand Coulee Dam. The echograms from the upriver locations enable a rough comparison with the June 14 survey of the forebay on the basis of targets per unit of sampling time. This calculation showed one target per 0.33 minutes of sampling in the forebay area and 0.08 targets per minute in the upriver areas, or roughly four times more targets per unit of surface area in the forebay area.

6.8.5 Comparison of Target Density between FDR Reservoir and Banks Lake

An acoustic survey of Banks Lake on September 14, 1976 provided a basis

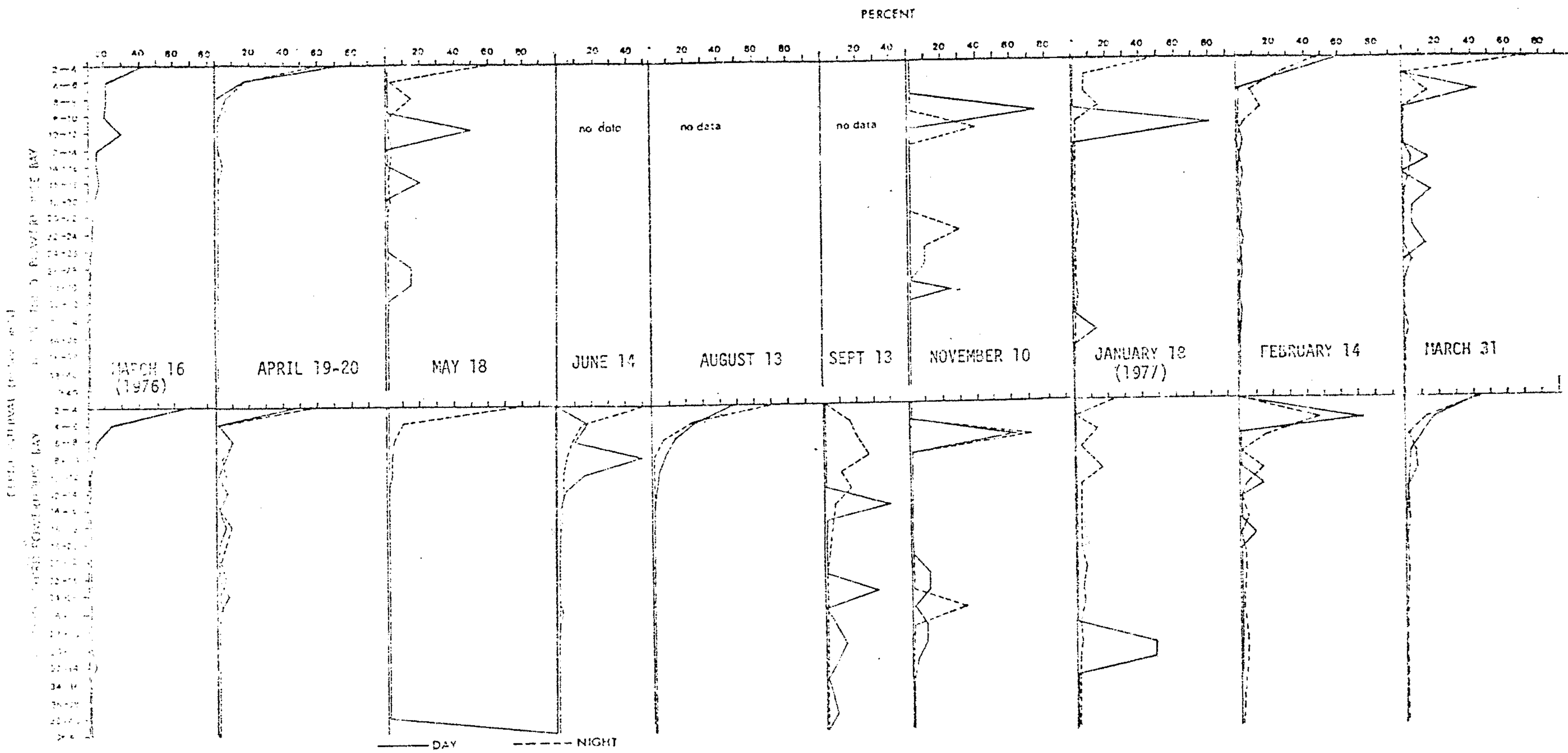


Figure 31. Comparison of vertical acoustic target distribution of all transects outside Third Powerhouse bay with all transects inside Third Powerhouse bay during day and night sampling.

for comparing the relative densities of fishes between FDR forebay and Banks Lake. The Banks Lake survey entailed seven east-west acoustic transects south of Steamboat Rock spaced at intervals of 2¼ miles. Analysis of the nighttime survey data was made in which the target densities over all depths were calculated. The mean target density was $1.95 \times 10^{-4}/m^3$. This density was two orders of magnitude greater than observed during the September 13 nighttime acoustic survey of FDR forebay in which the mean target density was $1.55 \times 10^{-6}/m^3$. Expressed another way, the density in Banks Lake was 125 times greater than the density in FDR Reservoir forebay for that date but comparable to the medium densities in FDR forebay during much of the year.

6.9 Entrainment

Some inferences may be made concerning the entrainment of fishes through the various openings in Grand Coulee Dam by comparing the depths of the penstock and spillway openings with the depths at which fishes were observed acoustically. The elevations of the spillway, penstock, spill discharge openings, pump, and pump-generator openings were compared to the 95% level of fish target occurrence during the sampling period (Fig. 32). Draft tube openings were plotted with seasonal water elevation and time of operation for the various openings. Shaded areas in Figure 32 indicate times when at least 95% of the targets were located at a depth corresponding with an operating opening of the dam. Inferences regarding relative entrainment were based on the assumption that entrainment was passive and that fish were not actively seeking out current and descending near the dam face.

Entrainment occurred probably through the spillway and Third Powerhouse penstocks and, to some extent, the pump-discharge openings and the uppermost spill-discharge openings. The right and left powerhouse penstocks and the lower two groups of spill-discharge openings were all located at depths well below the 95% target occurrence.

In August, the time of highest target density, fish were congregated near the surface. Entrainment over the spillway may have been substantial at this time, especially for squawfish. Discharge over the spillway, which usually occurred in January and February to lower the lake level, did not

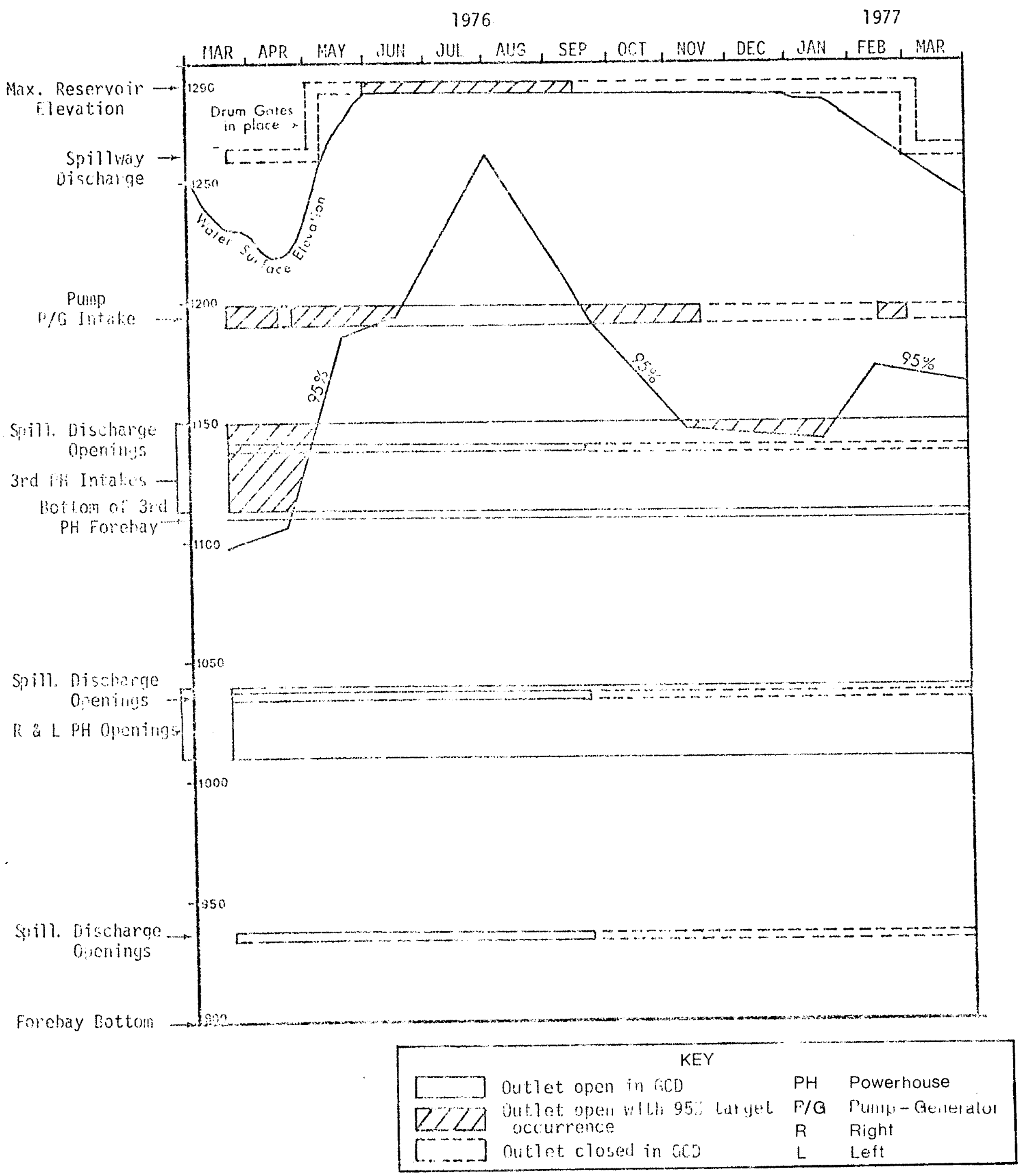


Figure 32. Comparison between elevation of penstocks, spillway, and spill-discharge openings in Grand Coulee Dam and the monthly 95% level of fish target occurrence in FDR forebay, 1976-77.

occur in 1977 due to near-drought conditions. This lack of discharge may have decreased the winter entrainment of kokanee.

The depth of 95% target occurrence coincided with the Third Powerhouse penstock openings in spring and fall. The Third Powerhouse penstocks may entrain substantial numbers of fish during all seasons because they are situated in a constricted area which forces water to be drawn down from the surface. Bottom-dwelling fish such as walleye may have been entrained through the Third Powerhouse penstocks, since the penstock opening was only about 2 m from the bottom of the Third Powerhouse forebay. These bottom-dwelling fish were very likely underestimated by the acoustic gear because of a "dead zone" of interference of at least 40 cm at the bottom. Passive entrainment of walleye as well as all other species occupying the water column in the Third Powerhouse forebay may be increased in comparison to the other openings in the dam.

Entrainment into the feeder canal via the pump-discharge openings was measured directly in 1976 (Stober et al. 1977, in preparation). Relatively little entrainment occurred. The spill-discharge openings at about 1140 ft msl may have entrained some fish, but the volume of discharge was small relative to other openings.

7.0 CONCLUSIONS

Gillnet sampling and acoustic surveys during this 14-month sampling period indicated a low fish abundance in the FDR forebay. The number of species may have declined from those found during previous surveys by other investigators, although this was difficult to verify due to the restricted sampling area of this study.

Squawfish dominated the catch and reached maximum abundance in the surface waters during August when thermal stratification occurred. Walleye was the most abundant gamefish species, with kokanee the next most abundant.

Historical analysis of the annual changes in reservoir operation indicated a trend toward increased late-winter, early-spring drawdown for flood control and power generation. Minimum reservoir elevation occurred most frequently during April. This annual fluctuation in reservoir water level elevation has apparently influenced the survival or decline of several of the fish species found in the reservoir.

For example, walleye and squawfish are both late-spring spawning species and are known to be able to successfully reproduce in lakeshore shoal areas. The timing and incubation period coincides with the time of minumum reservoir elevation followed by a period of rapid increase to stable summer levels. This imposes considerably less stress on the survival of the juveniles of these species than if the water level were declining, a situation which poses the possibility of destruction of the eggs by desiccation. The spawning locations of kokanee and lake whitefish in the Roosevelt Lake system were not identified as these determinations were beyond the scope of this study. However, it is general knowledge that kokanee and lake whitefish utilize suitable gravel in steep lakeside shorelines and that these species spawn in the fall and winter, respectively. Both have incubation periods which extend through the annual drawdown period, and both were found to exist in very low abundance in this survey. Data on kokanee abundance taken in 1966-67; and the fact that the annual abundance of kokanee supported a fishery in the tail race of Grand Coulee Dam in the late 1960's suggests that survival of this species remained relatively high when annual drawdown did not exceed about 40 feet. However, kokanee may also spawn in streambed tributaries. The construction of Lower Arrow Dam in British Columbia in 1968 may have also substantially reduced the upstream spawning areas on which this species depended. The low reservoir abundance of the remaining species which prefer tributary streams for spawning and incubation suggest that either stream production is limited compared to the volume of the reservoir, or, residence time in the reservoir is reduced due to continual loss of fish through Grand Coulee Dam. It is also apparent that early as well as recent planting of several salmonid species into FDR Reservoir has been unsuccessful.

Distribution of fishes along the acoustic transects indicated that most were surface-oriented. Draft tubes above elevation 1100 ft msl included the Third Powerhouse, upper spill discharge openings, pump/generator intakes, and spillway--all of which probably entrained fish at some time during the annual cycle of operation. Operation of the Third Powerhouse penstocks may entrain more walleye since this species is bottom-oriented, and the draft tube openings are at the bottom of the Third Powerhouse forebay (approximately 1110 ft msl). In the constricted area of the Third Powerhouse forebay, highest water velocities were found which increased with the addition of each new generator. Water was found to be drawn from the surface in the Third Powerhouse forebay, which probably causes the entrainment of fishes from throughout the water column entering the forebay along the right side of the reservoir. The most abundant game and non-game species in the upper reaches of Rufus Woods Reservoir are walleye and squawfish, respectively. Because the behavior of these species is similar, their entrainment through Grand Coulee Dam and survival is probably in proportion to their abundance in the FDR forebay.

8.0 REFERENCES CITED

Beamish, R.J., and H.H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Bd. Canada, 26(3)633-638.

Bennett, D.H., and R.G. White. 1977. A survey of existing literature on Franklin D. Roosevelt Lake. Forest, Wilelife and Range Experiment Station, Univ. Idaho, Moscow. Contribution No. 61. 94 pp.

Carl, G.C., W.A. Clemens, and C.C. Lindsey. 1967. The freshwater fishes of British Columbia. B.C. Prov. Mus. Handbook 5, 192 pp.

Earnest, D.E., M. Spence, R.Kiser, and W. Brunson. 1963. A survey of the fish populations, zooplankton, bottom fauna, and some physical characteristics of Roosevelt Lake. Wash. State Dept. Game. 45 pp. [Unpublished.]

Forbes, S.T., and O. Nakken. 1972. Manual of methods for fisheries research survey, and appraisal. Part 2: The use of acoustic instruments for fish detection and abundance estimation. Manuals in Fisheries Science, No. 5. Food and Agriculture Organization of the United Nations. Rome.

Fulton, L.A., and M.C. Laird. [No date.] A cursory survey of tributaries to Roosevelt Lake with reference to spawning potential for salmon, 1965-1966. Rough draft of unpublished mimeo report. NOAA, National Marine Fish. Serv., Seattle, Wash. 100 pp.

Gangmark, H.A., and L.A. Fulton. 1949. Preliminary surveys of Roosevelt Lake in relation to game fishes. USDI, Fish and Wildlife Service, Special Scientific Report, Fisheries No. 5. 29 pp.

Lanmeyer, P. 1972. Gillnet survey--reservoir behind Chief Joseph Dam. 5 pp. [Unpublished.]

Nie, N.H., C.H. Hull, J.G. Jenkens, K. Steinbrenner, and D.H. Bent. 1975. Statistical package for the social sciences. Second ed. McGraw-Hill Co., New York. 675 pp.

Nielsen, J.R. 1974. A survey and evaluation of sport fisheries in Region I with special emphasis on the walleye fishery. Job Final Report, Project F-64-R-2, Wash. State Dept. Game.

Nunnallee, E.P. 1973. A hydroacoustic data acuqisition and digital data analysis system for the assessment of fish stock abundance. Univ. Wash., F.R.I. Circular 73-3. 47 pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada, Bull. No. 184. 966 pp.

Stober, Q.J. 1977. Fishery resource study of Rufus Woods Reservoir. IN Erickson, A.W., Q.J. Stober, J.J. Brueggeman, and R.L. Knight: An assessment of the impact on the wildlife and fisheries resources in Rufus Woods Reservoir expected from the raising of Chief Joseph Dam from 946 to 956 ft msl. Final Report to Coleville Tribal Council.

Stober, Q.J., R.W. Ryler, C.E. Petrosky, T.J. Carlson, D. Gaudet, and R.E. Nakatani. 1977. Preliminary survey of fisheries resources in the forebay of FDR Reservoir. Annual Report, FRI-UW-7701. College of Fisheries, Fish. Res. Inst., Univ. Wash., Seattle. 70 pp.

Stober, Q.J., R.W. Tyler, G.L. Thomas, L. Jensen, J.A. Knutzen, D.L. Smith, and R.E. Nakatani. 1976. Operational effects of irrigation and pumped/storage on the ecology of Banks Lake, Washington. Third Annual Progress Report, FRI-UW-7610. College of Fisheries, Fish. Res. Inst., Univ. Wash., Seattle. 313 pp.

Tesch, F.W. 1968. Age and Growth. IN Ricker, W.E., ed., pp 98-130, Methods for assessment of fish production in freshwaters. Blackwell Scientific publications, IBP Handbook No. 3, Oxford and Edinburgh.

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

U.S. Bureau of Reclamation, Pacific Northwest Region. 1975. Background of studies investigating desirability of enlarging the Third Powerplant at Grand Coulee Dam, Washington. 8 pp.

Washington State Department of Fisheries. 1972. Roosevelt Lake, chinook plant scheme for enhancement of a landlocked salmon fishery.

9.0 APPENDICES

APPENDIX TABLE 1. FDR Temperature Profile (C) at Mid-Forebay.

Depth	1976											1977		
(m)	2/29	3/25	4/28	5/26	6/23	7/28	8/25	9/10	9/27	11/2	12/22	1/18	2/22	3/17
0	2.9	3.6	7.4	11.5	15.4	19.6	19.0	17.7	18.7	13.9	7.5	3.6	2.9	3.5
2	2.9	3.6	7.3	11.3	14.8	19.0	19.0	17.7	18.6	14.0	7.5	3.6	2.6	3.2
4	2.9	3.5	7.2	11.3	14.6	18.6	18.5	17.7	18.5	14.0	7.5	3.6	2.5	3.2
6	2.9	3.5	7.2	11.3	13.8	18.5	18.0	17.5	18.0	14.0	7.5	3.6	2.5	3.2
8	2.9	3.5	7.0	11.3	12.5	18.4	17.6	17.5	17.7	14.0	7.5	3.6	2.5	3.1
10	2.9	3.5	6.9	11.2	12.0	17.8	17.2	17.5	17.4	14.0	7.5	3.6	2.5	3.1
12	2.9	–	6.9	11.1	12.0	17.6	17.0	17.4	17.0	14.0	7.5	3.6	2.4	3.2
14	–	3.5	6.9	11.1	11.8	17.4	17.0	17.3	16.8	14.0	7.5	3.6	2.4	3.1
16	2.9	–	6.8	11.0	11.8	16.8	17.0	17.0	16.7	14.0	7.5	3.6	2.4	3.1
18	–	3.5	6.8	10.8	11.6	16.4	16.8	16.7	16.3	14.0	7.5	3.6	2.4	3.0
20	2.9	–	6.8	10.7	11.5	16.1	16.5	16.3	16.2	14.0	7.5	3.6	2.4	3.0
22	–	3.5	–	10.7	–	16.0	–	–	–	–	–	–	–	–
24	2.9	–	6.8	–	11.4	–	16.5	16.0	16.1	14.0	7.5	3.6	2.4	3.0
26	–	3.5	–	10.5	–	15.8	–	–	–	–	–	–	–	–
28	2.9	–	6.8	–	11.2	–	16.5	15.7	15.9	14.0	7.5	3.6	2.4	3.0
30	–	3.5	6.8	10.3	–	15.6	16.5	15.7	15.8	–	7.5	–	–	–
32	2.9	–	–	–	11.0	–	16.3	15.7	15.8	14.0	7.5	3.6	2.4	3.0
34	–	–	6.8	10.3	–	15.4	–	–	–	–	–	–	–	–
36	2.9	3.5	–	–	11.0	–	16.0	15.7	15.8	14.0	7.0	3.6	2.4	3.0
38	–	–	6.8	10.3	–	15.3	–	–	–	–	–	–	–	–
40	3.0	3.5	–	–	11.0	–	16.0	15.5	15.6	14.0	7.0	3.6	2.4	3.0
42	–	–	6.8	10.2	–	15.3	–	–	–	–	–	–	–	–
44	3.0	–	–	–	11.0	–	16.0	15.5	15.6	14.0	7.0	3.6	2.4	3.0
46		–	6.8	10.2	–	15.2	–	–	–	–	–	–	–	–
48		3.5	–	–	10.9	–	16.0	15.3	15.6	14.0	7.0	3.6	2.4	3.0
50			6.8	10.2	10.7	15.1	16.0	–	15.5	–	–	–	–	–
52			–	–	10.7	–	16.0	15.2	15.4	14.0	7.0	3.6	2.4	3.0
54			6.8	10.2	–	15.0	–	–	–	–	–	–	–	–
56			–	–	10.7	–	16.0	15.2	15.4	14.0	7.0	3.6	2.4	3.0
58			6.7	10.2	–	15.0	–	–	–	–	–	–	–	–
60			–	–	10.7	–	16.0	15.2	15.3	14.0	7.0	3.6	2.4	3.0
62			6.7	10.2	–	14.8	–	–	–	–	–	–	–	–
64			–	–	10.6	–	16.0	15.2	15.3	14.0	7.0	3.6	2.4	3.0
66			6.7	10.2	–	14.8	–	–	–	–	–	–	–	–
68			–	–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.6	2.4	3.0
70			6.7	10.1	–	14.6	–	–	–	–	–	–	–	–
72			–	–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.6	2.4	3.0
74			6.7	10.1	–	14.4	–	–	–	–	–	–	–	–
76			–	–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.6	2.4	3.0
78			–	10.1	–	14.0	–	–	–	–	–	–	–	–
80			6.6	–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.6	2.4	3.0
82				10.0	–	13.7	–	–	–	–	–	–	–	–
84				–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.7	2.4	3.0
86				9.9	–	13.3	–	–	–	–	–	–	–	–
88				–	10.6	–	16.0	15.2	15.2	14.0	7.0	3.7	2.4	3.0
90				9.9	–	13.3	–	–	–	–	–	–	–	–
92				9.8	10.6		16.0	15.2	15.2	14.0	7.0	3.8	2.4	3.0
94					–	–	–	–	–	–	–	–	–	–
96					10.6	13.0	16.0	15.2	15.2	14.0	7.0	3.8	2.4	3.0
99						12.7	16.0	15.2	15.2	14.0	7.0	3.8	2.4	3.0

APPENDIX TABLE 2. FDR Current Profile - Left Boom Station. (Velocity in m/sec.)

Depth (m)	1976										1977			
	4/22		5/20		6/15		8/2		9/14		2/15		3/17	
	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.
0	.103	288	.010	172	.026	180	.041	014	.026	330	.026	013	.036	*
2	.062	276	.010	224	.026	165	–	–	.010	020	–	–	–	–
4	.046	286	.010	242	.026	160	.010	113	.010	080	.026	013	.062	*
6	.041	283	.010	328	.026	155	–	–	.010	275	–	–	–	–
8	.062	300	.026	292	.010	150	.010	088	–	–	.031	013	.052	*
10	.077	300	.026	282	.010	145	–	–	.005	300	–	–	–	–
12	.041	285	.026	304	.026	125	.016	060	–	–	.016	013	.036	*
14	.067	302	.041	325	.010	130	–	–	–	–	–	–	–	–
16	.072	286	.052	312	.021	145	.010	068	–	–	.021	013	.031	*
18	.082	302	.041	320	.010	170	–	–	.005	355	–	–	–	–
20	.082	298	.041	315	.010	175	.010	076	–	–	.021	013	.052	*
22	.077	328	.026	318	–	–	–	–	–	–	–	–	–	–
24	.062	330	.041	331	.010	155	.010	080	–	–	.021	012	.041	*
26	.077	320	.041	322	–	–	–	–	0	235	–	–	–	–
28	.067	328	.026	323	.010	170	.010	075	–	–	.021	012	.041	*
30	.072	332	.041	324	–	–	–	–	–	–	–	–	–	–
32	.072	328	.041	332	.010	180	.031	360	–	–	.016	012	.026	*
34	.077	322	.010	330	–	–	–	–	.010	320	–	–	–	–
36	.082	322	.041	318	.010	185	.036	348	–	–	.021	012	.021	*
38	.077	340	.052	306	–	–	–	–	.026	325	–	–	–	–
40	.062	354	.041	313	.041	220	.021	352	–	–	.021	012	.005	*
42	.041	002	.052	308	–	–	–	–	.021	300	–	–	–	–
44	.041	352	.062	302	.005	230	.031	013	–	–	.021	013	.005	*
46	.052	325	.062	292	–	–	–	–	.052	330	–	–	–	–
48	.057	332	.052	301	.005	235	.010	360	–	–	.016	013	.005	*
50	.046	344	.052	290	–	–	–	–	.036	320	–	–		
52	.036	348	.041	295	.041	220	.010	016	–	–	.016	012		
54	.036	346	.010	277	–	–	–	–	.036	330	–	–		
56	.036	338	.010	282	.041	220	.010	274	–	–	.016	012		
58	.010	002	.026	279	–	–	–	–	.036	330	–	–		
60			.010	210	.052	230	.016	280	–	–	.016	012		
62					–	–	–	–	.010	310	–	–		
64					.052	230	.016	153	–	–	.016	014		
66					–	–			.010	290	–	–		
68					.041	230					.016	014		
70					–	–								
72					.026	215								
74					–	–								
76					.026	220								

* No valid direction measurements on 3/17/77 due to equipment malfunction.

APPENDIX TABLE 3. FDR Current Profile, Mid Boom Station. (Velocity in m/sec.)

Depth	4/22/76		5/20/76		6/15/76		8/02/76		9/14/76		2/15/77		3/17/77	
(m)	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.
0	.124	306	.062	270	.103	315	.010	333	.052	210	.072	089	.031	*
2	.129	314	.052	284	.113	315	–	–	.062	310	–	–	–	–
4	.103	328	.052	318	.103	315	.010	303	.052	330	.031	093	.036	*
6	.108	324	.052	335	.077	315	–	–	.052	320	–	–	–	–
8	.088	327	.052	337	.082	355	.010	292	–	–	.036	097	.026	*
10	.077	320	.041	357	.062	015	–	–	.052	330	–	–	–	–
12	.067	318	.041	355	.041	065	.010	332	–	–	.031	110	.021	*
14	.067	318	.041	352	.041	065	–	–	.041	325	–	–	–	–
16	.067	302	.041	344	.010	095	.010	354	–	–	.031	113	.026	*
18	.052	319	.041	338	.021	100	–	–	.026	270	–	–	–	–
20	.046	315	.041	334	.021	095	.010	338	–	–	.021	119	.036	*
22	.046	322	.041	315	.010	110	–	–	.026	090	–	–	–	–
24	.046	324	.052	330	.021	100	.010	334	–	–	.026	122	.021	*
26	.046	322	.052	326	.026	090	–	–	.010	100	–	–	–	–
28	.052	324	.077	314	.041	090	.010	296	–	–	.021	130	.036	*
30	.057	322	.062	325	.026	090	–	–	.010	060	–	–	–	–
32	.041	324	.041	336	.046	080	.010	298	–	–	.016	130	.016	*
34	.041	324	.026	352	.062	075	–	–	.010	330	–	–	–	–
36	.041	314	.026	332	.052	070	.010	303	–	–	.010	130	.010	*
38	.041	313	.026	305	.062	060	–	–	.026	315	–	–	–	–
40	.041	312	.010	320	.077	055	.010	300	–	–	.010	130	.005	*
42	.036	308	.026	329	.077	050	–	–	.072	330	–	–	–	–
44	.041	312	.026	332	.067	060	.010	288	–	–	.031	129	.046	*
46	.041	306	.010	329	.067	060	–	–	.093	330	–	–	–	–
48	.031	306	.026	344	.052	070	.010	286	–	–	.036	130	.046	*
50	.036	310	.026	002	.052	080	–	–	.093	335	–	–	–	–
52	.031	302	.010	314	.052	085	.010	270	–	–	.010	130	.016	*
54	.021	298	.010	309	.062	100	–	–	.052	340	–	–	–	–
56	.026	295	.010	300	.052	095	.010	234	–	–	.010	130	.031	*
58	.021	290	.010	325	.062	085	–	–	.052	350	–	–	–	–
60	.026	292			.062	075	.010	203	–	–	.031	130	.072	*
62	.016	288			–	–	–	–	.062	335	–	–	–	–
64	.016	279			.062	070	.010	244	–	–	.031	130	.088	*
66	.010	278			–	–	–	–	.052	335	–	–	–	–
68	.010	273			.077	075	.010	301	–	–	.026	130	.041	*
70	.005	272			–	–	.010	304	.052	335	–	–	–	–
72					.052	100	.082	304	–	–	.021	130	.062	*
74					–	–	.103	311	.026	320	–	–	–	–
76					.010	105	.113	308	–	–	.016	130	.067	*
78					–	–	–	–	.010	280	–	–	–	–
80					.010	140	.077	316	–	–	.016	086	.067	*
82					–	–	–	–	.005	200	–	–	–	–
84					.010	140	.082	306			.021	099	.067	*
86							–	–			–	–	–	–
88							.010	230			.016	097	.062	*
90							–	–			–	–	–	–
92							.010	220			.010	093	.062	*
94							.010	210			–	–		
96											.010	092		

* No valid direction measurements on 3/17/77 due to equipment malfunction.

APPENDIX TABLE 4. Current profile at right log boom station, FDR forebay (velocity in m/sec).

	4/22/76		5/20/76		6/15/76		8/2/76		9/14/76		2/15/77		3/17/77	
Depth (m)	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.
0	.108	295	.026	310	.052	196	.052	308	.010	342	.082	263	.026	*
2	.103	310	.016	302	.077	220	-	-	.010	308	-	-	-	-
4	.098	310	.026	312	.041	200	.010	304	.010	290	.010	262	.031	*
6	.088	306	.016	305	.026	150	-	-	.026	350	-	-	-	-
8	.088	316	.041	315	.026	135	.010	312	.041	340	.010	263	.031	*
10	.077	316	.041	315	.026	120	-	-	.041	350	-	-	-	-
12	.067	316	.026	318	.026	150	.010	315	.026	342	.010	263	.052	*
14	.026	296	.016	332	.010	110	-	-	.010	030	-	-	-	-
16			.026	235	.010	110	.010	332	.010	030	.010	265	.036	*
18					.010	110	-	-	.010	010	-	-		
20					.010	110	.010	332	.010	025	.005	261		
22					.010	090	-	-			-	-		
24					.010	065	.010	337			.010	260		
26					.005	340	.010	029			-	-		
28											.021	262		

* No valid direction measurements on 3/17/77 due to equipment malfunction.

APPENDIX TABLE 5. Current profile at entrance to third powerhouse bay (velocity in m/sec).

	3/16/76		4/21/76*		5/20/76*		2/15/77*		3/17/77**	
Depth (m)	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.
0	.180	330	.515	.348	.206	340	.185	030	.247	**
2	.180	345							-	-
4	.206	354							.288	**
6	.154	355							-	-
8	.129	352							.324	**
10	.154	352							-	-
12	.180	352							.345	**
14	.180	352							-	-
16	.180	353							.294	**
18	.180	353							-	-
20	.180	355							.201	**
22	.175	351							-	-
24	.154	348							.191	**
26	.175	347							-	-
28	.144	348							.221	**
30	.165	342							-	-
32	.165	343							.242	**
34	.154	346							-	-
36	.154	343							.258	**
38	.149	340							-	-
40	.098	328							.221	**

* Unable to maintain position with boat for entire current profile. Surface velocity measurements only.

** No valid direction measurements on 3/17/77 due to equipment malfunction.

APPENDIX TABLE 6. Current profile at mid-logboom station, FDR forebay (velocity in m/sec).

Depth (m)	4/22/76 vel.	4/22/76 dir.	5/20/76 vel.	5/20/76 dir.	6/15/76 vel.	6/15/76 dir.	8/2/76 vel.	8/2/76 dir.	9/14/76 vel.	9/14/76 dir.
0	.124	306	.062	270	.103	315	.010	333	.052	210
2	.129	314	.052	284	.113	315	-	-	.062	310
4	.103	328	.052	318	.103	315	.010	303	.052	330
6	.108	324	.052	335	.077	315	-	-	.052	320
8	.088	327	.052	337	.082	355	.010	292	-	-
10	.077	320	.041	357	.062	015	-	-	.052	330
12	.067	318	.041	355	.041	065	.010	332	-	-
14	.067	318	.041	352	.041	065	-	-	.041	325
16	.067	302	.041	344	.010	095	.010	354	-	-
18	.052	319	.041	338	.021	100	-	-	.026	270
20	.046	315	.041	334	.021	095	.010	338	-	-
22	.046	322	.041	315	.010	110	-	-	.026	090
24	.046	324	.052	330	.021	100	.010	334	-	-
26	.046	322	.052	326	.026	090	-	-	.010	100
28	.052	324	.077	314	.041	090	.010	296	-	-
30	.057	322	.062	325	.026	090	-	-	.010	060
32	.041	324	.041	336	.046	080	.010	298	-	-
34	.041	324	.026	352	.062	075	-	-	.010	330
36	.041	314	.026	332	.052	070	.010	303	-	-
38	.041	313	.026	305	.062	060	-	-	.026	315
40	.041	312	.010	320	.077	055	.010	300	-	-
42	.036	308	.026	329	.077	050	-	-	.072	330
44	.041	312	.026	332	.067	060	.010	288	-	-
46	.041	306	.010	329	.067	060	-	-	.093	330
48	.031	306	.026	344	.052	070	.010	286	-	-
50	.036	310	.026	002	.052	080	-	-	.093	335
52	.031	302	.010	314	.052	085	.010	270	-	-
54	.021	298	.010	309	.062	100	-	-	.052	340
56	.026	295	.010	300	.052	095	.010	234	-	-
58	.021	290	.010	325	.062	085	-	-	.052	350
60	.026	292			.062	075	.010	203	-	-
62	.016	288			-	-	-	-	.062	335
64	.016	279			.062	070	.010	244	-	-
66	.010	278			-	-	-	-	.052	335
68	.010	273			.077	075	.010	301	-	-
70	.005	272			-	-	.010	304	.052	335
72					.052	100	.082	304	-	-
74					-	-	.103	311	.026	320
76					.010	105	.113	308	-	-
78					-	-	-	-	.010	280
80					.010	140	.077	316	-	-
82					-	-	-	-	.005	200
84					.010	140	.082	306		
86							-	-		
88							.010	230		
90							-	-		
92							.010	220		
94							.010	210		

APPENDIX TABLE 7. Water temperature profile at mid-logboom station, FDR forebay. (Temperature in C)

Depth (m)	2/29	3/25	4/28	5/26	6/23	7/28	8/25	9/10	9/27	11/2	12/22
0	2.9	3.6	7.4	11.5	15.4	19.6	19.0	17.7	18.7	13.9	7.5
2	2.9	3.6	7.3	11.3	14.8	19.0	19.0	17.7	18.6	14.0	7.5
4	2.9	3.5	7.2	11.3	14.6	18.6	18.5	17.7	18.5	14.0	7.5
6	2.9	3.5	7.2	11.3	13.8	18.5	18.0	17.5	18.0	14.0	7.5
8	2.9	3.5	7.0	11.3	12.5	18.4	17.6	17.5	17.7	14.0	7.5
10	2.9	3.5	6.9	11.2	12.0	17.8	17.2	17.5	17.4	14.0	7.5
12	2.9	-	6.9	11.1	12.0	17.6	17.0	17.4	17.0	14.0	7.5
14	-	3.5	6.9	11.1	11.8	17.4	17.0	17.3	16.8	14.0	7.5
16	2.9	-	6.8	11.0	11.8	16.8	17.0	17.0	16.7	14.0	7.5
18	-	3.5	6.8	10.8	11.6	16.4	16.8	16.7	16.3	14.0	7.5
20	2.9	-	6.8	10.7	11.5	16.1	16.5	16.3	16.2	14.0	7.5
22	-	3.5	-	10.7	-	16.0	-	-	-	-	-
24	2.9	-	6.8	-	11.4	-	16.5	16.0	16.1	14.0	7.5
26	-	3.5	-	10.5	-	15.8	-	-	-	-	-
28	2.9	-	6.8	-	11.2	-	16.5	15.7	15.9	14.0	7.5
30	-	3.5	6.8	10.3	-	15.6	16.5	15.7	15.8	-	7.5
32	2.9	-	-	-	11.0	-	16.3	15.7	15.8	14.0	7.5
34	-	-	6.8	10.3	-	15.4	-	-	-	-	-
36	2.9	3.5	-	-	11.0	-	16.0	15.7	15.8	14.0	7.0
38	-	-	6.8	10.3	-	15.3	-	-	-	-	-
40	3.0	3.5	-	-	11.0	-	16.0	15.5	15.6	14.0	7.0
42	-	-	6.8	10.2	-	15.3	-	-	-	-	-
44	3.0	-	-	-	11.0	-	16.0	15.5	15.6	14.0	7.0
46		-	6.8	10.2	-	15.2	-	-	-	-	-
48		3.5	-	-	10.9	-	16.0	15.3	15.6	14.0	7.0
50			6.8	10.2	10.7	15.1	16.0	-	15.5	-	7.0
52			-	-	10.7	-	16.0	15.2	15.4	14.0	7.0
54			6.8	10.2	-	15.0	-	-	-	-	-
56			-	-	10.7	-	16.0	15.2	15.4	14.0	7.0
58			6.7	10.2	-	15.0	-	-	-	-	-
60			-	-	10.7	-	16.0	15.2	15.3	14.0	7.0
62			6.7	10.2	-	14.8	-	-	-	-	-
64			-	-	10.6	-	16.0	15.2	15.3	14.0	7.0
66			6.7	10.2	-	14.8	-	-	-	-	-
68			-	-	10.6	-	16.0	15.2	15.2	14.0	7.0
70			6.7	10.1	-	14.6	-	-	-	-	-
72			-	-	10.6	-	16.0	15.2	15.2	14.0	7.0
74			6.7	10.1	-	14.4	-	-	-	-	-
76			-	-	10.6	-	16.0	15.2	15.2	14.0	7.0
78			-	10.1	-	14.0	-	-	-	-	-
80			6.6	-	10.6	-	16.0	15.2	15.2	14.0	7.0
82				10.0	-	13.7	-	-	-	-	-
84				-	10.6	-	16.0	15.2	15.2	14.0	7.0
86				9.9	-	13.3	-	-	-	-	-
88				-	10.6	-	16.0	15.2	-	14.0	7.0
90				9.9	-	13.3	-	-	15.2	-	-
92				9.8	10.6	-	16.0	15.2	-	14.0	7.0
94					-	-	-	-	-	-	-
96					10.6	13.0	16.0	15.2	15.2	14.0	7.0
99						12.7	16.0	15.2	15.2	14.0	7.0

APPENDIX TABLE 8. Target densitites outside third powerhouse bay by date, depth stratum, location.

DATE	PERIOD	DEPTH STRATUM (m)	LOCATION: DAM FACE	INNER LOG BOOM	OUTER LOG BOOM	CRESCENT BAY	SPRING CANYON	Σ	$\bar{X}$
4/19-20	day	2- 5	0		0	0	$9.73x10^{-5}$	$9.73x10^{-5}$	$2.43x10^{-5}$
		5-20	$7.44x10^{-6}$		$3.66x10^{-5}$	$1.02x10^{-5}$	$1.09x10^{-5}$	$9.73x10^{-5}$	$2.43x10^{-5}$
		> 20	0		$1.71x10^{-6}$	$1.74x10^{-7}$	$1.81x10^{-7}$	$2.07x10^{-6}$	$5.14x10^{-7}$
	night	2- 5	$1.59x10^{-4}$		$9.74x10^{-4}$	$7.88x10^{-5}$	$8.68x10^{-5}$	$1.30x10^{-3}$	$2.60x10^{-4}$
		5-20	$2.07x10^{-6}$		$9.35x10^{-5}$	$4.21x10^{-5}$	$1.71x10^{-5}$	$1.65x10^{-4}$	$3.30x10^{-5}$
		> 20	$1.43x10^{-7}$		$8.00x10^{-7}$	$6.53x10^{-8}$	$5.37x10^{-8}$	$1.10x10^{-6}$	$2.37x10^{-7}$
5/18	day	2- 5	0		0	0	0	0	0
		5-20	0		0	0	0	0	0
		> 20	$1.60x10^{-6}$		$3.66x10^{-6}$	$1.10x10^{-6}$	0	$6.36x10^{-6}$	$1.27x10^{-6}$
	night	2- 5	0		$1.16x10^{-3}$	$2.98x10^{-3}$	0	$1.18x10^{-2}$	$2.35x10^{-3}$
		5-20	$1.85x10^{-5}$		$6.45x10^{-5}$	$8.29x10^{-5}$	$4.85x10^{-5}$	$5.42x10^{-4}$	$1.08x10^{-4}$
		> 20	0		0	0	0	0	0
6/13	day	2- 5				$6.19x10^{-5}$	$1.20x10^{-4}$	$1.82x10^{-4}$	$9.10x10^{-5}$
		5-20				$9.48x10^{-6}$	$3.38x10^{-6}$	$1.29x10^{-5}$	$6.45x10^{-6}$
		> 20				0	0	0	0
	night	2- 5				$7.13x10^{-5}$	$9.80x10^{-5}$	$1.69x10^{-4}$	$8.45x10^{-5}$
		5-20				$1.09x10^{-5}$	$5.51x10^{-6}$	$1.64x10^{-6}$	$8.20x10^{-6}$
		> 20				0	0	0	0
8/3	day	2- 5			$2.07x10^{-2}$	$1.91x10^{-2}$	$3.02x10^{-2}$	$1.16x10^{-1}$	$1.04x10^{-2}$
		5-20			$6.31x10^{-4}$	$1.02x10^{-3}$	$4.17x10^{-4}$	$5.97x10^{-3}$	$6.62x10^{-4}$
		> 20			$2.89x10^{-6}$	$7.29x10^{-6}$	$6.47x10^{-6}$	$3.03x10^{-5}$	$5.06x10^{-6}$
	night	2- 5			$9.49x10^{-2}$	$7.43x10^{-2}$	$6.77x10^{-2}$	$3.57x10^{-1}$	$8.92x10^{-2}$
		5-20			$1.34x10^{-3}$	$2.41x10^{-4}$	$4.56x10^{-6}$	$3.91x10^{-5}$	$9.78x10^{-6}$
		> 20			$2.41x10^{-5}$	$8.02x10^{-6}$	$4.56x10^{-6}$	$3.91x10^{-5}$	$9.78x10^{-6}$
9/13	day	2- 5				$1.76x10^{-4}$	0	$1.76x10^{-4}$	$4.40x10^{-5}$
		5-20				$2.69x10^{-5}$	$9.65x10^{-5}$	$2.37x10^{-4}$	$5.93x10^{-5}$
		> 20				$1.46x10^{-7}$	$8.50x10^{-8}$	$4.05x10^{-7}$	$1.01x10^{-7}$
	night	2- 5				0	0	0	0
		5-20				$1.89x10^{-6}$	$5.54x10^{-6}$	$1.24x10^{-5}$	$3.10x10^{-6}$
		> 20				$6.13x10^{-8}$	$2.44x10^{-7}$	$6.95x10^{-7}$	$1.74x10^{-7}$

APPENDIX TABLE 8, Continued.

DATE	PERIOD	DEPTHS STRATUM (m)	LOCATION: DAM FACE	INNER LOG BOOM	OUTER LOG BOOM	CRESCENT BAY	SPRING CANYON	Σ	$\overline{X}$
11/10	day	2- 5			0	0	0	0	0
		5-20			$1.34x10^{-6}$	$2.89x10^{-6}$	0	$4.23x10^{-6}$	$1.41x10^{-6}$
		> 20			$4.03x10^{-8}$	$1.89x10^{-7}$	$1.79x10^{-7}$	$4.07x10^{-7}$	$2.04x10^{-7}$
	night	2- 5			0	0	0	0	0
		5-20			$2.30x10^{-6}$	$6.54x10^{-6}$	0	$8.84x10^{-6}$	$2.95x10^{-6}$
		> 20			0	$1.41x10^{-7}$	$2.55x10^{-7}$	$3.96x10^{-6}$	$1.98x10^{-6}$
1/18/77	day	2- 5			0	0	0	0	0
		5-20			0	0	0	0	0
		20			$1.73x10^{-7}$	0	$5.61x10^{-8}$	$2.29x10^{-7}$	$7.63x10^{-8}$
	night	2- 5			0	$2.91x10^{-4}$	0	$2.91x10^{-4}$	$9.70x10^{-5}$
		5-20			$2.42x10^{-5}$	$2.60x10^{-5}$	$2.87x10^{-5}$	$7.89x10^{-5}$	$2.63x10^{-5}$
		20			$1.24x10^{-6}$	$6.03x10^{-7}$	$3.16x10^{-7}$	$2.16x10^{-6}$	$7.20x10^{-7}$
2/14	day	2- 5			0	0	$6.79x10^{-5}$	$6.79x10^{-5}$	$2.26x10^{-5}$
		5-20			$2.06x10^{-6}$	0	$1.91x10^{-6}$	$3.97x10^{-6}$	$1.32x10^{-6}$
		20			0	0	0	0	0
	night	2- 5			$9.21x10^{-5}$	$1.64x10^{-4}$	$6.79x10^{-5}$	$3.24x10^{-4}$	$1.08x10^{-4}$
		5-20			$2.30x10^{-6}$	$5.57x10^{-6}$	$1.14x10^{-5}$	$1.93x10^{-5}$	$6.43x10^{-6}$
		20			$4.16x10^{-7}$	$9.05x10^{-8}$	$1.26x10^{-7}$	$6.32x10^{-7}$	$2.11x10^{-7}$
3/31	day	2- 5	$7.80x10^{-3}$	$3.30x10^{-4}$	$1.68x10^{-4}$	$3.33x10^{-4}$	$1.37x10^{-4}$	$8.77x10^{-3}$	$2.02x10^{-3}$
		5-20	$1.65x10^{-4}$	$6.39x10^{-6}$	$6.30x10^{-6}$	$2.83x10^{-5}$	0	$2.06x10^{-4}$	$6.87x10^{-5}$
		20	0	0	$6.33x10^{-8}$	$9.20x10^{-8}$	0	$1.55x10^{-7}$	$5.17x10^{-8}$
	night	2- 5	$2.78x10^{-4}$	$8.50x10^{-5}$	$1.16x10^{-4}$	$1.68x10^{-4}$	$1.18x10^{-4}$	$7.65x10^{-4}$	$2.55x10^{-4}$
		5-20	$7.18x10^{-6}$	0	$1.45x10^{-5}$	$1.93x10^{-5}$	$6.62x10^{-6}$	$4.76x10^{-5}$	$1.59x10^{-5}$
		20	$1.10x10^{-7}$	$1.01x10^{-7}$	$8.74x10^{-8}$	$2.09x10^{-7}$	0	$5.07x10^{-7}$	$1.69x10^{-7}$

APPENDIX TABLE 9. Vertical distribution of targets on March 16, 1976.

	DAY SERIES							
	TRANSECTS INSIDE THIRD POWERHOUSE FOREBAY				TRANSECTS OUTSIDE THIRD POWERHOUSE			
DEPTH STRATUM (m sec)	TOTAL TARGETS	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	3	1.00	3.00	30.06	4	1.00	4.00	55.53
4 - 6	3	.37	1.11	11.12	3	.37	1.11	15.41
6 - 8	4	.23	.92	9.22	2	.19	.38	5.28
8 -10	5	.17	.85	8.52	2	.13	.26	3.61
10-12	13	.14	1.82	18.24	1	.08	.08	1.11
12-14	4	.11	.44	4.41	1	.07	.07	.97
14-16	3	.10	.30	3.01	1	.06	.06	.83
16-18	5	.10	.50	5.01	2	.05	.10	1.39
18-20	2	.10	.20	2.00	3	.05	.15	2.08
20-22	2	.07	.14	1.40	2	.04	.08	1.11
22-24	3	.07	.21	2.10	2	.04	.08	1.11
24-26	2	.06	.12	1.20	2	.03	.06	.83
26-28	2	.06	.12	1.20	4	.03	.12	1.67
28-30	0	.05	0	0	3	.03	.09	1.25
30-32	1	.05	.05	.50	3	.03	.09	1.25
32-34	0	.05	0	0	8	.03	.24	3.33
34-36	0	.05	0	0	5	.03	.15	2.08
36-38	1	.05	.05	.05	3	.02	.06	.83
38-40	1	.05	.05	.05	1	.02	.02	.28
> 40	24	.004	.10	1.00	6	.0005	.003	.04

1 millisecond≃.735 meters

APPENDIX TABLE 10. Vertical distribution of targets on April 19-20, 1976.

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
TRANSECTS OUTSIDE THIRD POWERHOUSE BAY								
2 - 4	1	1.00	1.00	44.44	4	1.00	4.00	55.78
4 - 6		.39				.39		
6 - 8	1	.21	.21	9.33	3	.21	.63	8.79
8 -10	1	.14	.14	6.22	2	.14	.28	3.90
10-12		.10			4	.10	.40	5.58
12-14	2	.08	.16	7.11		.08		
14-16		.07			2	.06	.12	1.67
16-18	4	.06	.24	10.67	10	.06	.60	8.37
18-20	1	.06	.06	2.67	7	.06	.42	5.86
20-22	1	.04	.04	1.78	5	.04	.20	2.79
22-24	2	.04	.08	3.56	6	.04	.24	3.35
24-26	5	.03	.15	6.67	2	.03	.06	.84
26-28	1	.03	.03	1.33	4	.03	.12	1.67
28-30	2	.02	.04	1.78	2	.02	.04	.56
30-32	1	.02	.02	.89		.02		
32-34	2	.02	.04	1.78	1	.02	.02	.28
34-36		.02				.02		
36-38	2	.02	.04	1.78	2	.02	.04	.56
38-40		.02				.02		
> 40	3	.0001	.0003	.01	5	.0001	.0005	.0001
TRANSECTS INSIDE THIRD POWERHOUSE BAY								
2 - 4	3	1.00	3.00	68.80	10	1.00	10.00	61.27
4 - 6	2	.37	.74	16.97	7	.37	2.59	15.87
6 - 8	0	.20		0	6	.20	1.20	7.35
8 -10	0	.13		0	4	.13	.52	3.19
10-12	0	.10		0	3	.10	.30	1.84
12-14	0	.07		0	4	.07	.28	1.72
14-16	3	.06	.18	4.13	2	.06	.12	.74
16-18	2	.04	.08	1.83	7	.04	.28	1.72
18-20	1	.04	.04	.92	5	.04	.20	1.23
20-22	2	.03	.06	1.38	4	.03	.12	.74
22-24	2	.03	.06	1.38	4	.03	.12	.74
24-26	2	.03	.06	1.38	5	.03	.15	.92
26-28	2	.03	.06	1.38	6	.03	.18	1.10
28-30	2	.02	.04	.92	6	.02	.12	.74
30-32	1	.02	.02	.46	3	.02	.06	.37
32-34	1	.02	.02	.46	3	.02	.06	.37
34-36	0	.02			0	.02		0
36-38	0	.02			1	.02	.02	.12
38-40	0	.02			0	.02		0
> 40	1	.0005	.0005	.01	1	.0005	.0005	.00003

1 millisecond ≈ .735 meters

APPENDIX TABLE 11. Vertical distribution of targets on May 18, 1976.

TRANSECTS OUTSIDE THIRD POWERHOUSE BAY

DEPTH STRATUM (msec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	0	1.00	0	0	11	1.00	11.00	74.22
4 - 6	0	.37	0	0	4	.37	1.48	9.99
6 - 8	0	.20	0	0	3	.20	.60	4.05
8 -10	0	.13	0	0	3	.13	.39	2.63
10-12	0	.09	0	0	5	.09	.45	3.04
12-14	0	.07	0	0	4	.07	.28	1.89
14-16	0	.06	0	0	5	.06	.30	2.02
16-18	0	.05	0	0	3	.05	.15	1.01
18-20	0	.05	0	0	1	.05	.05	.34
20-22	0	.04	0	0	2	.04	.08	.54
22-24	0	.04	0	0	0	.04	0	0
24-26	0	.04	0	0	0	.04	0	0
26-28	0	.04	0	0	1	.04	.04	.27
28-30	0	.03	0	0	0	.03	0	0
30-32	0	.03	0	0	0	.03	0	0
32-34	0	.03	0	0	0	.03	0	0
34-36	0	.03	0	0	0	.03	0	0
36-38	0	.03	0	0	0	.03	0	0
38-40	0	.03	0	0	0	.03	0	0
> 40	4	.0005	.002	100.00	0	.0005	0	0
TRANSECTS INSIDE THIRD POWERHOUSE BAY								
2 - 4	0	1.00			7	1.00	7.00	65.79
4 - 6	0	.37			1	.37	.37	3.48
6 - 8	0	.20			7	.20	1.40	13.16
8 -10	0	.13			2	.13	.26	2.44
10-12	1	.10	.10	49.88	2	.10	.20	1.88
12-14	0	.07			7	.07	.49	4.61
14-16	0	.06			4	.06	.24	2.26
16-18	1	.04	.04	19.95	3	.04	.12	1.13
18-20	0	.04			7	.04	.28	2.63
20-22	0	.03			2	.03	.06	.56
22-24	0	.03			1	.03	.03	.28
24-26	1	.03	.03	14.96	4	.03	.12	1.13
26-28	1	.03	.03	14.96	1	.03	.03	.28
28-30	0	.02			1	.02	.02	.19
30-32	0	.02			0	.02	0	0
32-34	0	.02			1	.02	.02	.19
34-36	0	.02			0	.02	0	0
36-38	0	.02			0	.02	0	0
38-40	0	.02			0	.02	0	0
> 40	1	.0005	.0005	00.25	1	.0005	.0005	.00005

1 millisecond ≃.735 meters

APPENDIX TABLE 12. Vertical distribution of targets on June 14, 1976.

	TRANSECTS OUTSIDE THIRD POWERHOUSE BAY							
DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	0	1.00	0	0	1	1.00	1.00	48.31
4 - 6	1	.39	.39	19.21	1	.37	.37	17.87
6 - 8	1	.22	.22	10.84	1	.20	.20	9.66
8 -10	7	.14	.98	48.28	1	.13	.13	6.28
10-12	3	.11	.33	16.26	1	.10	.10	4.83
12-14	1	.09	.09	4.43	1	.08	.08	3.86
14-16	0	.07	0	0	1	.06	.06	2.90
16-18	0	.05			1	.05	.05	2.42
18-20	0	.05			1	.05	.05	2.42
20-22	0	.04			0	.04	0	0
22-24	0	.04			0	.04	0	0
24-26	0	.03			0	.03	0	0
26-28	0	.03			1	.03	.03	1.45
28-30	0	.02			0	.02	0	0
30-32	0	.02			0	.02		
32-34	0	.02			0	.02		
34-36	0	.02	0	0	0	.02		
36-38	1	.02	.02	.99	0	.01		
38-40	0	.02	0	0	0	.01		
> 40	0	.0002	0	0	0	.0001	0	0

1 millisecond≃.735 meters

APPENDIX TABLE **13.** Vertical distribution of targets on **August 2, 1976.**

	TRANSECTS OUTSIDE THIRD POWERHOUSE BAY							
DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	78	1.00	78.00	45.71	405	1.00	405.00	67.91
4 - 6	122	.37	45.14	26.47	381	.37	140.97	23.63
6 - 8	105	.19	19.95	11.70	183	.19	34.77	5.83
8 -10	94	.13	12.22	7.17	69	.13	8.97	1.50
10-12	71	.08	5.68	3.33	33	.08	2.64	.44
12-14	49	.06	2.94	1.72	21	.06	1.26	.21
14-16	25	.05	1.25	.73	14	.05	.70	.12
16-18	20	.05	1.00	.59	11	.05	.55	.09
18-20	17	.05	.85	.50	5	.05	.25	.04
20-22	27	.04	1.08	.63	2	.04	.08	.01
22-24	31	.04	1.24	.73	6	.04	.24	.04
24-26	13	.03	.39	.23	6	.03	.18	.03
26-28	3	.03	.09	.08	3	.03	.09	.02
28-30	7	.03	.21	.12	7	.03	.21	.04
30-32	8	.03	.24	.14	2	.03	.06	.01
32-34	1	.03	.03	.02	1	.03	.03	.01
34-36	5	.03	.15	.09	5	.03	.15	.03
36-38	1	.02	.02	.0	4	.02	.08	.01
38-40	1	.02	.02	.01	3	.02	.06	.01
> 40	11	.0004	.004	.00	20	.0004	.08	.01

1 millisecond ≈ .735 meters

APPENDIX TABLE 14. Vertical distribution of targets on September 13, 1976.

TRANSECTS OUTSIDE THIRD POWERHOUSE BAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4		1.00	0		0	1.00	0	0
4 - 6		.37	0		3	.37	1.11	14.32
6 - 8		.20	0		7	.20	1.40	18.06
8 -10		.13	0		15	.13	1.95	25.16
10-12		.10	0		7	.10	.70	9.03
12-14		.08	0		14	.08	1.12	14.45
14-16	2	.06	.12	37.45	7	.06	.42	5.42
16-18		.05	0		7	.05	.35	4.52
18-20		.05	0		6	.05	.30	3.87
20-22		.04	0		5	.04	.20	2.58
22-24		.04	0		1	.04	.04	.52
24-26	3	.03	.09	28.09	1	.03	.03	.39
26-28		.03	0		1	.03	.03	.39
28-30	1	.02	.02	6.24	2	.02	.04	.52
30-32	2	.02	.04	12.48	0	.02	0	0
32-34	1	.02	.02	6.24	3	.02	.06	.77
34-36		.02	0		0	.02	0	0
36-38	1	.01	.01	3.12	0	.01	0	0
38-40	2	.01	.02	6.24	0	.01	0	0
> 40	4	.0001	.0004	.12	0	.0001	0	0

1 millisecond ≃.735 meters

APPENDIX TABLE 15. Vertical distribution of targets on November 10, 1976.

TRANSECTS OUTSIDE THIRD POWERHOUSE BAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	0	1.00			0	1.00		
4 - 6	0	.37			0	.37		
6 - 8	1	.20	.20	60.55	1	.20	.20	68.00
8 -10	0	.14			0	.14		
10-12	0	.10			0	.10		
12-14	0	.08			0	.08		
14-16	0	.06			0	.06		
16-18	0	.05			0	.05		
18-20	0	.05			0	.05		
20-22	0	.03			0	.03		
22-24	1	.03	.03	9.08	0	.03		
24-26	1	.03	.03	9.08	0	.03		
26-28	0	.03			3	.03	.09	30.00
28-30	1	.02	.02	6.06	0	.02		
30-32	0	.02			0	.02		
32-34	1	.02	.02	6.06	0	.02		
34-36	1	.02	.02	6.06	0	.02		
36-38	1	.01	.01	3.03	0	.01		
38-40	0	.01			0	.01		
> 40	3	.0001	.0003	.09	5	.0001	.0005	00.19

TRANSECTS INSIDE THIRD POWERHOUSE BAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2 - 4	0	1.00			0	1.00		
4 - 6	0	.37			0	.37		
6 - 8	0	.20			0	.20		
8 -10	1	.13	.13	76.00	0	.13		
10-12	0	.10			1	.10	.10	39.92
12-14	0	.07			0	.07		
14-16	0	.06			0	.06		
16-18	0	.04			0	.04		
18-20	0	.04			0	.04		
20-22	0	.03			0	.03		
22-24	0	.03			3	.03	.09	35.93
24-26	0	.03			1	.03	.03	11.98
26-28	0	.03			1	.03	.03	11.98
28-30	0	.02			0	.02		
30-32	2	.02	.04	24.00	0	.02		
32-34	0	.02			0	.02		
34-36	0	.02			0	.02		
36-38	0	.02			0	.02		
38-40	0	.02			0	.02		
> 40	0	.0005			1	.0005	.0005	00.20

1 millisecond ≈.735 meters

APPENDIX TABLE 16. Vertical distribution of targets on January 18, 1977.

TRANSECTS OUTSIDE THIRD POWERHOUSE BAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	0	1.00			1	1.00	1.00	23.25
4- 6	0	.37			0	.37		
6- 8	0	.20			3	.20	.60	13.95
8-10	0	.14			2	.14	.28	6.51
10-12	0	.10			7	.10	.70	16.27
12-14	0	.08			3	.08	.24	5.58
14-16	0	.06			3	.06	.18	4.18
16-18	0	.05			2	.05	.10	2.32
18-20	0	.05			2	.05	.10	2.32
20-22	0	.03			2	.03	.06	1.39
22-24	0	.03			11	.03	.33	7.67
24-26	0	.03			3	.03	.09	2.09
26-28	0	.03			6	.03	.18	4.18
28-30	0	.02			3	.02	.06	1.39
30-32	1	.02	.02	49.90	9	.02	.18	4.18
32-34	1	.02	.02	49.90	5	.02	.10	2.32
34-36	0	.02			2	.02	.04	.93
36-38	0	.01			4	.01	.04	.93
38-40	0	.01			2	.01	.02	.46
> 40	1	.0001	.0001	.20	16	.0001	.0016	.04

TRANSECTS INSIDE THIRD POWERHOUSE FOREBAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	0	1.00			2	1.00	2.00	46.08
4- 6	0	.37			1	.37	.37	8.53
6- 8	0	.20			2	.20	.40	9.22
8-10	1	.13	.13	86.67	5	.13	.65	14.98
10-12	0	.10			1	.10	.10	2.30
12-14	0	.07			2	.07	.14	3.23
14-16	0	.06			2	.06	.12	2.76
16-18	0	.04			1	.04	.04	.92
18-20	0	.04			1	.04	.04	.92
20-22	0	.03			2	.03	.06	1.38
22-24	0	.03			5	.03	.15	3.46
24-26	0	.03			2	.03	.06	1.38
26-28	0	.03			1	.03	.03	.69
28-30	0	.02			2	.02	.04	.92
30-32	0	.02			4	.02	.08	1.84
32-34	0	.02			2	.02	.04	.92
34-36	1	.02	.02	13.33	0	.02		
36-38	0	.02			1	.02	.02	.46
38-40	0	.02			0	.02		
> 40	0	.0005			0	.0005		

APPENDIX TABLE 17. Vertical distribution of targets on February 14, 1977.

TRANSECTS OUTSIDE THIRD POWERHOUSE FOREBAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	0	1.00			0	1.00		
4- 6	1	.37	.37	74.00	3	.37	1.11	49.99
6- 8	0	.20			2	.20	.40	18.01
8-10	0	.14			0	.14		
10-12	0	.10			3	.10	.30	13.51
12-14	1	.08	.08	16.00	1	.08	.08	3.60
14-16	0	.06			0	.06		
16-18	0	.05			1	.05	.05	2.25
18-20	1	.05	.05	10.00	0	.05		
20-22	0	.03			1	.03	.03	1.35
22-24	0	.03			2	.03	.06	2.70
24-26	0	.03			1	.03	.03	1.35
26-28	0	.03			0	.03		
28-30	0	.02			2	.02	.04	1.80
30-32	0	.02			3	.02	.06	2.70
32-34	0	.02			2	.02	.04	1.80
34-36	0	.02			0	.02		
36-38	0	.01			1	.01	.01	.45
38-40	0	.01			1	.01	.01	.45
> 40	0	.0001			4	.0001	.0004	.02

TRANSECTS INSIDE THIRD POWERHOUSE FOREBAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	1	1.00	1.00	61.73	2	1.00	2.00	49.26
4- 6	1	.37	.37	22.84	2	.37	.74	18.23
6- 8	0	.20			2	.20	.40	9.85
8-10	0	.13			5	.13	.65	16.01
10-12	0	.10			1	.10	.10	2.46
12-14	1	.07	.07	4.32	1	.07	.07	1.72
14-16	0	.06			0	.06		
16-18	0	.04			1	.04	.04	.99
18-20	0	.04			0	.04		
20-22	2	.03	.06	3.70	1	.03	.03	.74
22-24	0	.03			0	.03		
24-26	1	.03	.03	1.85	1	.03	.03	.74
26-28	1	.03	.03	1.85	0	.03		
28-30	0	.02			0	.02		
30-32	2	.02	.04	2.47	0	.02		
32-34	1	.02	.02	1.23	0	.02		
34-36	0	.02			0	.02		
36-38	0	.02			0	.02		
38-40	0	.02			0	.02		
> 40	0	.0005			0	.0005		

APPENDIX TABLE 18. Vertical distribution of targets on March 31, 1971.

TRANSECTS OUTSIDE THIRD POWERHOUSE FOREBAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	20	1.00	20.00	43.89	2	1.00	2.00	45.35
4- 6	25	.37	9.25	20.30	2	.37	.74	16.78
6- 8	33	.20	6.60	14.48	1	.20	.20	4.53
8-10	22	.14	3.08	6.76	3	.14	.42	9.52
10-12	20	.10	2.00	4.39	4	.10	.40	9.07
12-14	18	.08	1.44	3.19	1	.08	.08	1.81
14-16	21	.06	1.26	2.76	2	.06	.12	2.72
16-18	19	.05	.95	2.08	3	.05	.15	3.40
18-20	5	.05	.25	.55	1	.05	.05	1.13
20-22	4	.03	.12	.26	3	.03	.09	2.04
22-24	7	.03	.21	.46	2	.03	.06	1.36
24-26	3	.03	.09	.20	1	.03	.03	.68
26-28	4	.03	.12	.26	1	.03	.03	.68
28-30	7	.02	.14	.31	1	.02	.02	.45
30-32	0	.02			0	.02		
32-34	2	.02	.04	.09	0	.02		
34-36	1	.02	.02	.04	0	.02		
36-38	0	.01			2	.01	.02	.45
38-40	0	.01			0	.01		
> 40	1	.0001			6	.0001	.0006	.01

TRANSECTS INSIDE THIRD POWERHOUSE FOREBAY

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
2- 4	0	1.00			2	1.00	2.00	76.63
4- 6	0	.37			0	.37		
6- 8	1	.20	.20	43.48	2	.20	.40	15.33
8-10	0	.13			0	.13		
10-12	0	.10			0	.10		
12-14	0	.07			0	.07		
14-16	1	.06	.06	13.04	2	.06	.12	4.60
16-18	0	.04			1	.04	.04	1.53
18-20	2	.04	.08	17.39	0	.04		
20-22	1	.03	.03	6.52	0	.03		
22-24	1	.03	.03	6.52	0	.03		
24-26	2	.03	.06	13.04	0	.03		
26-28	0	.03			2	.03	.06	1.15
28-30	0	.02			0	.02		
30-32	0	.02			0	.02		
32-34	0	.02			0	.02		
34-36	0	.02			1	.02	.02	.77
36-38	0	.02			0	.02		
38-40	0	.02			0	.02		
> 40	0	.0005			0	.0005		