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PRELIMINARY SURVEY OF FISHERIES RESOURCES IN THE FOREBAY OF FDR RESERVOIR

by

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1.0 SUMMARY

A survey of FDR Reservoir forebay for the period from March-December, 1976 is included in this preliminary report. These data were collected in order to aid in the impact assessment of the operation of Third Powerhouse generators G-19 and 20 which may be used to predict the effects of Third Powerhouse extension.

Vertical temperature and velocity profiles were taken in the forebay each month. Thermal stratification was seen 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 were operating. Current velocity tended to increase during periods when the Reservoir water level was drawn down. Although velocity profiles were taken at several sites close to the face of the dam, correlations with specific operational conditions were difficult to determine.

The origin of fish populations in the Reservoir is 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 to date has totaled 664 fish, of which 54.1% were squawfish and 14% were walleye. The proportion of gamefish (seven species) to non-gamefish (five species) was 32.1:67.9 %. Greatest abundance occurred in August in the surface water.

Acoustic surveys also indicated highest fish abundance in August. Fish density averaged one per 12,427 m^3 during March-June, one per 37 m^3 in August and one per 611,597 m^3 during September-November. The abundance of fish was greatest near the surface, and decreased with depth. All sampling techniques have thus far indicated low fish abundance in the FDR Reservoir forebay.

2.0 ACKNOWLEDGEMENTS

This investigation is being conducted under contract with the U.S. Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. The Institute personnel responsible for the studies reported herein are as follows:

Dr. Q. J. Stober, Principal Investigator

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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 fry 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 of the existing Third Powerhouse (with G-19 and 20 in operation) and the potential environmental impacts which may result with Third Powerhouse extension on the fishery resources of FDR forebay.

This report includes data collected through December 1976. Field sampling will be continued through March 1977 in order to gain an additional sample series during the spring period when kokanee were found abundant in surveys preceding the present. A final report will be supplied in June 1977. Due to an immediate need by the USBR for recent data, this periodic report has been expanded. The data analysis and interpretations must be considered preliminary in nature and scope.

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 9,402,000 acre feet, active storage between elevations 1208-1288 ft msl is 5,072,000 acre feet. The annual average flow of the Columbia River for the period 1913-1955 was 78,260,000 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 92,000 cfs which will increase to 291,000 cfs once all 6 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 495,000 cfs. This study is intended to add to the background data on which a judgement may be made on the potential effects of extension.

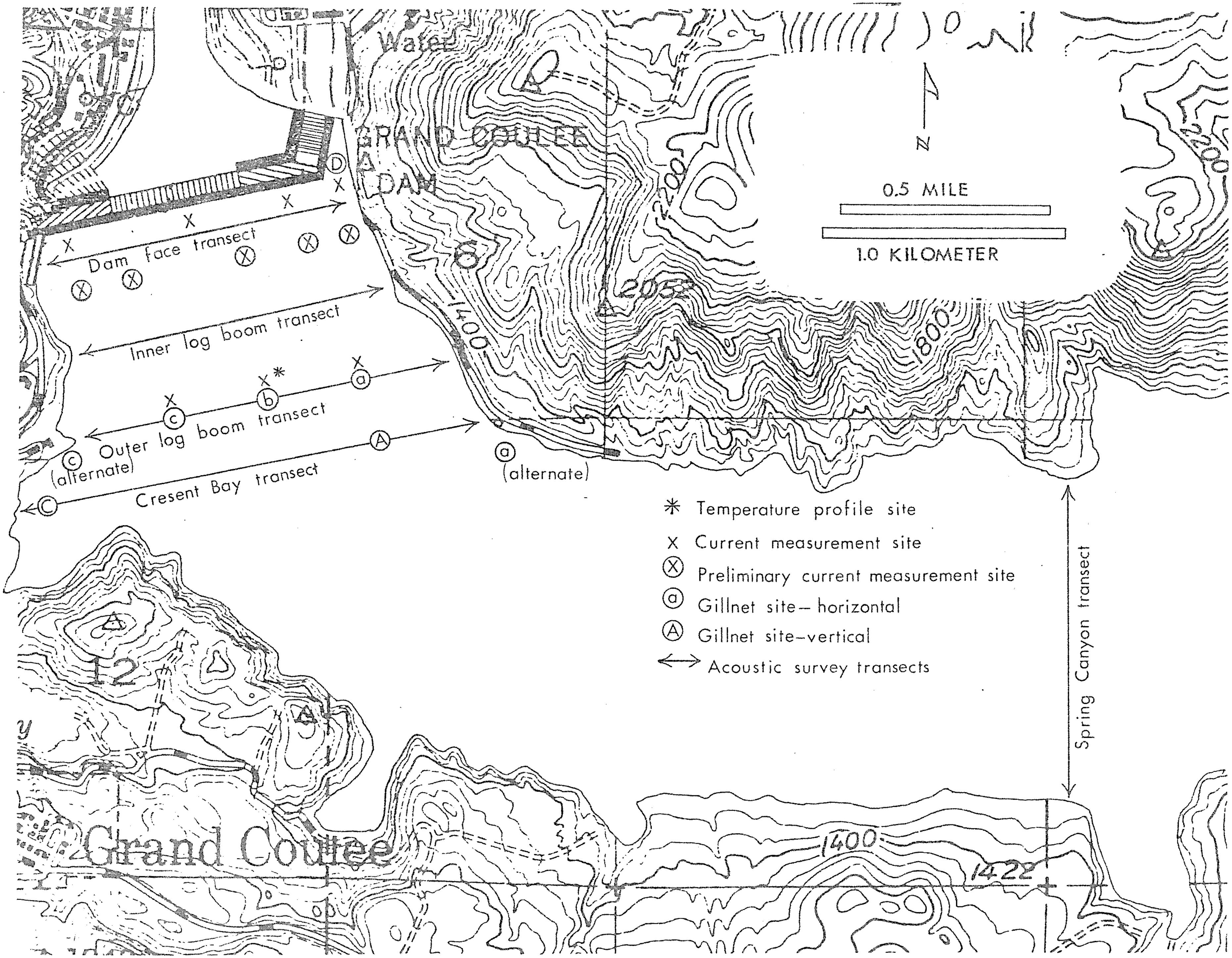


FIGURE 1. Locations of sampling sites in Grand Coulee Dam forebay.

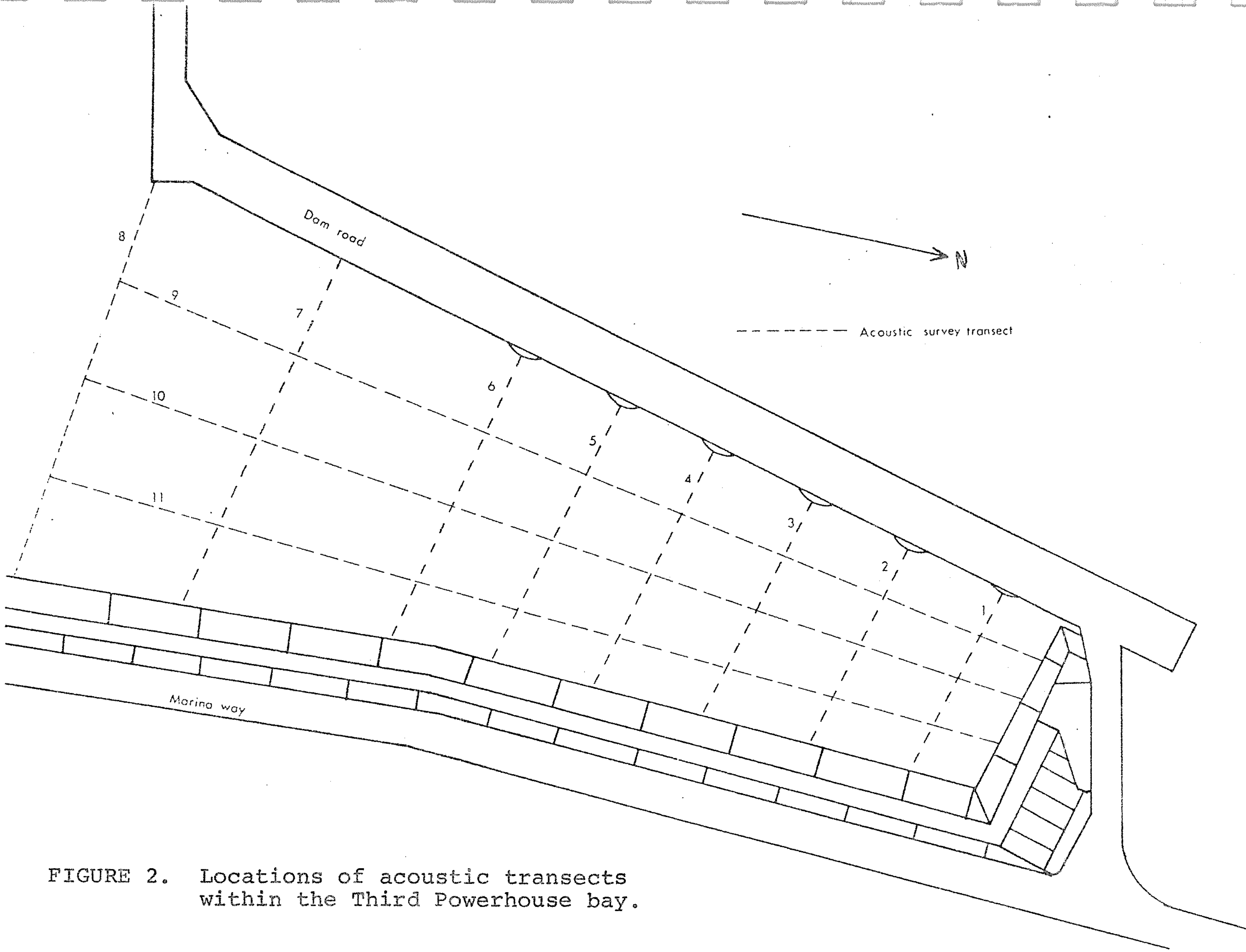


FIGURE 2. Locations of acoustic transects within the Third Powerhouse bay.

The mean weekly water level for the period February through December 1976 fluctuated 71.6 feet, from a low of 1218.4 ft/msl in late April to a high of 1290.0 ft in early September (Fig. 3). The annual drawdown for flood storage was begun in February. Full pool was reached again in late June and maintained through December. Weekly fluctuation of water level at full pool was usually less than one foot. During drawdown and filling, mean weekly water level changed as little as 1.4 ft in April and as much as 19 ft in May.

Mean weekly total discharge for the period varied from 88.8 kcfs in November to 201.2 kcfs in August (Fig.3). Mean weekly spill, surface and sub-surface spill combined, ranged from 67.1 kcfs in August to no spill for one week in April and for the period mid-September through December. There was no surface spill from March through May when reservoir elevation was less than 1260 ft/msl; however, sub-surface spill was considerable during this period.

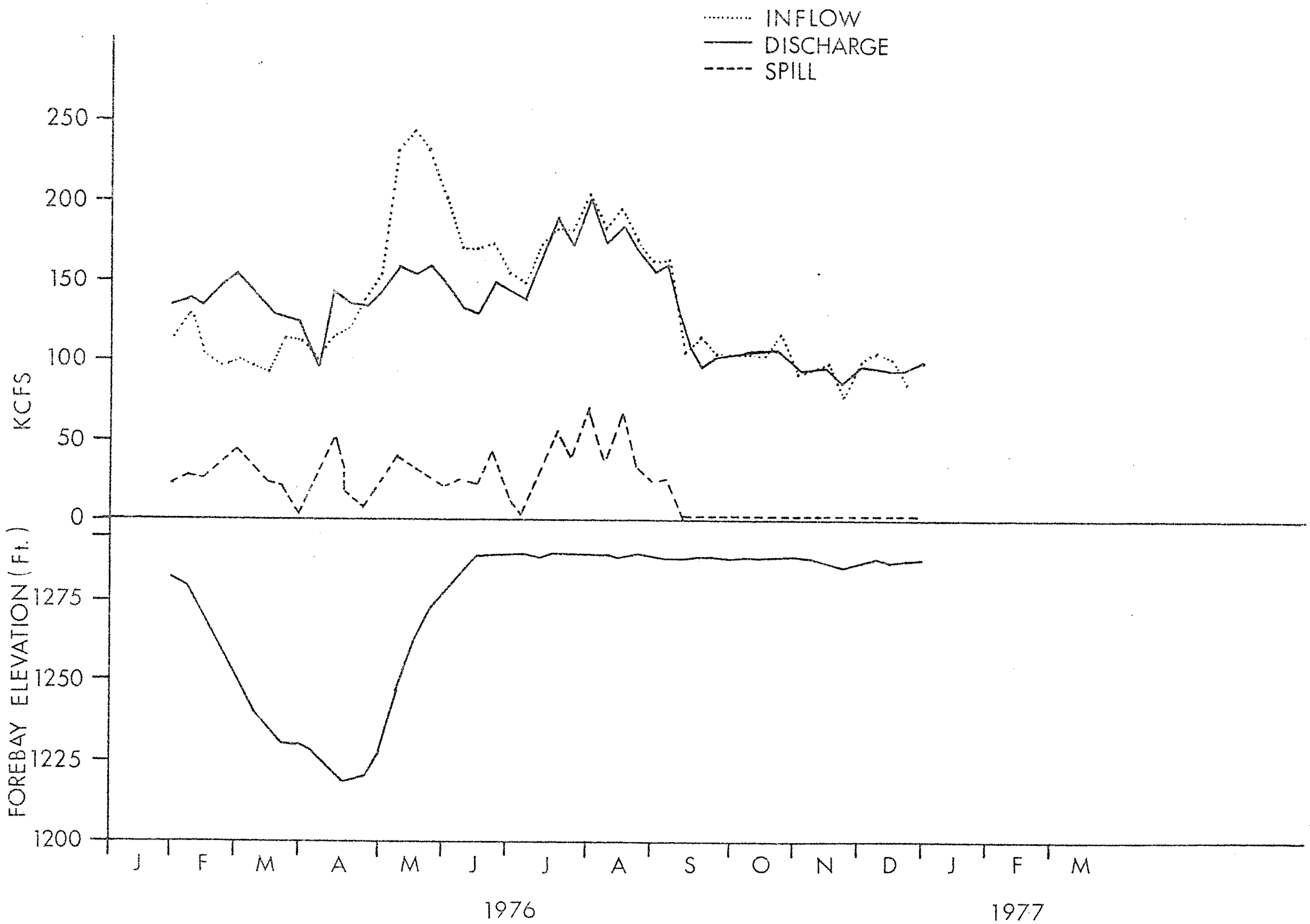


FIGURE 3. Weekly inflow to FDR Reservoir, spill, and total discharge from Grand Coulee Dam, and forebay surface elevation (USBR data).

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 m 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 2 m vertical intervals except when current was at a minimum, measurements were then at 4 m increments of depth. Current measurements were taken at Right, Mid, and Left forebay locations upstream from the logboom (Fig.1) on 22 April, 20 May, 15 June, 2 August, and 4 September, 1976 over a wide range of operational conditions. When the reservoir elevation was less than 1260 ft msl, measurements were made at the entrance to the Third Powerhouse forebay (16 March, 21 April, 20 May), 50 m off the face of the dam upstream of the right bank Powerhouse (21 April, 20 May) and 50 m from the pump and pump-generation units (20 May). In addition, five preliminary sites in a transect about 175 m from the dam were sampled on 13 March; two of these sites were sampled again on 16 March, 1976.

5.3 Gillnet Sampling

Horizontal and vertical gillnets were used in a systematic semi-monthly sample program from April through December 1976. In addition, preliminary gillnet sampling was carried out in March to develop consistent methods for conditions in the Grand Coulee Dam forebay. Sites and number of nets varied in March and catch data will be considered separately from the systematic sampling. Preliminary gillnet samples consisted of a 24-hour March quintuple gillnet set (8-9 March), 24-hour surface horizontal net sets at right and left forebay locations (10-11 March) and two consecutive 24-hour double vertical net sets at the Third Powerhouse bay site (18-20 March).

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.

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 had to be joined to fish most locations at full pool. Additional exploratory vertical net sites were established in the bay upstream of Crescent Bay on the left bank and opposite Spring Canyon (Fig.1).

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.

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 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 was analyzed by comparing the catches of surface and bottom horizontal nets and by comparing the catch by 4 m increments of the vertical nets.

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 or 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 four 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 lb 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

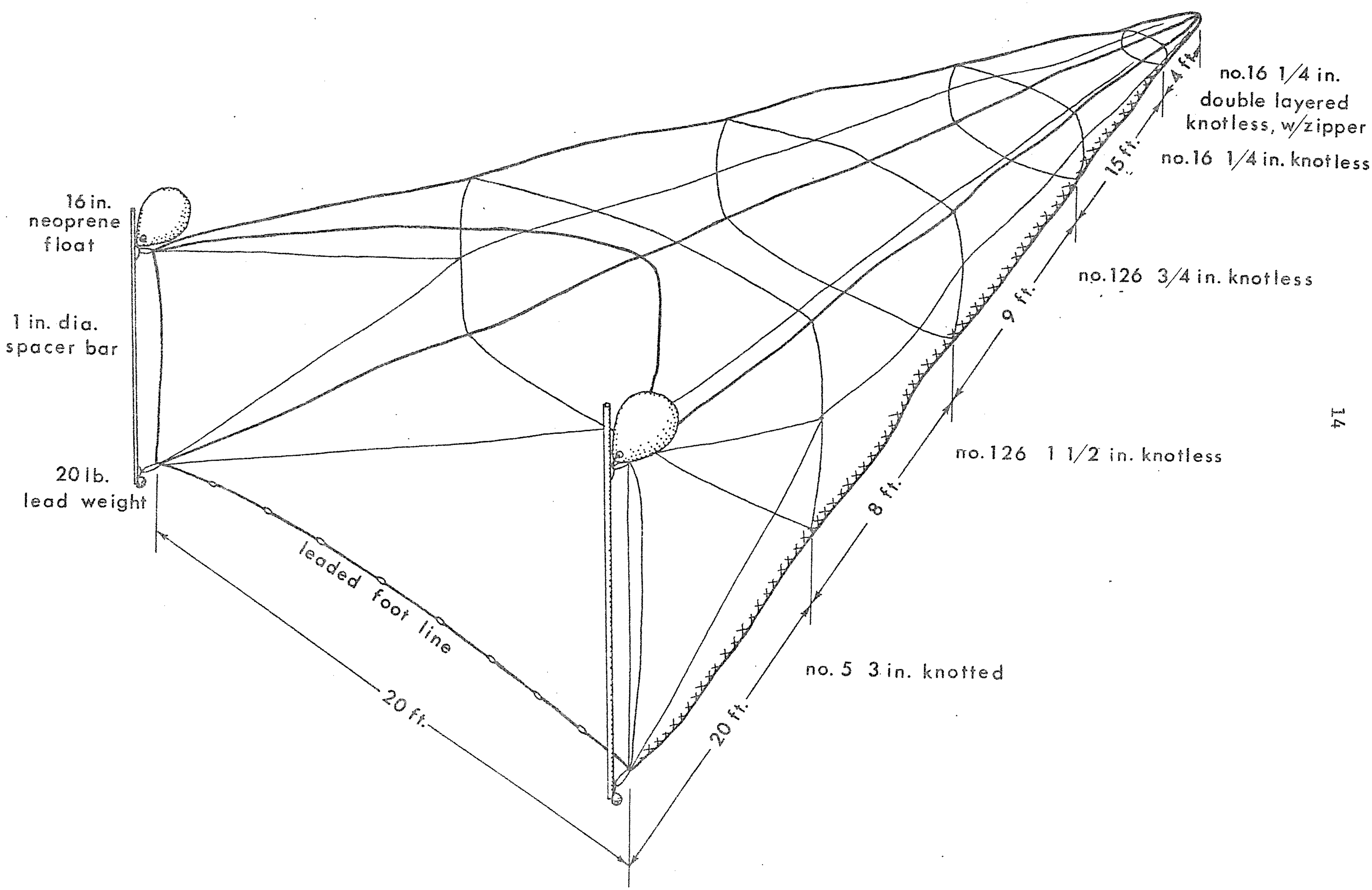


FIGURE 4. Diagram of townet used to sample juvenile fishes in the forebay.

to fish the 10 x 20 ft townet satisfactorily using a 20 ft outboard-powered boat, although due to the size of this net it is usually fished from a purse seine type boat. 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.

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 logboom 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).

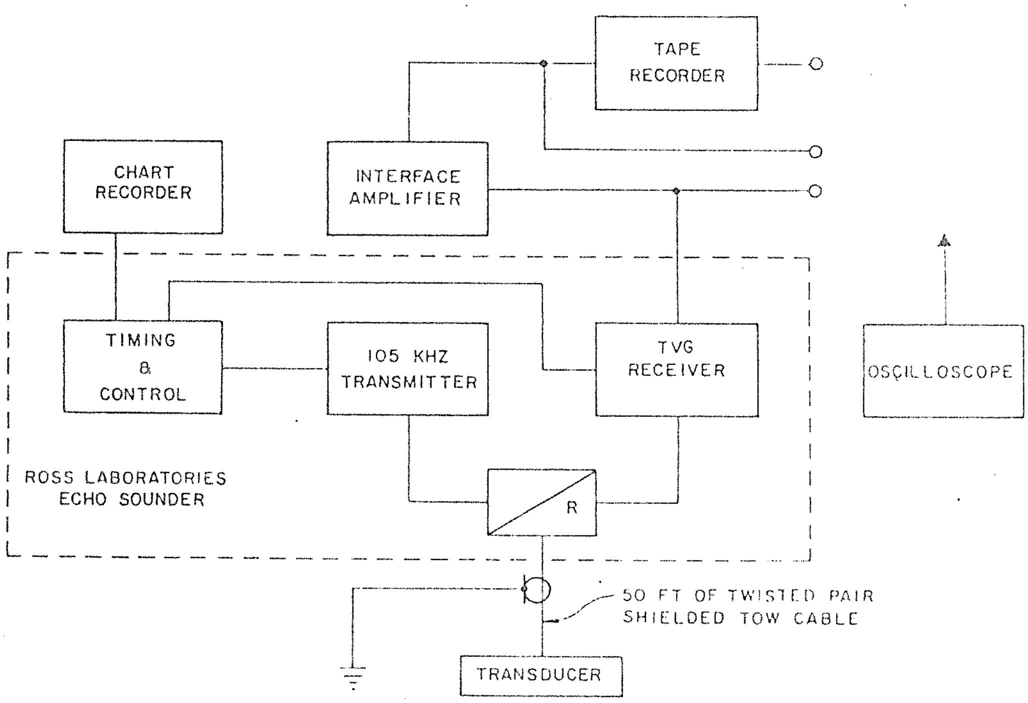


Figure 5. Block diagram of data acquisition system.

6.0 RESULTS AND DISCUSSION

6.1 Water Temperature

Water temperature in the mid-forebay of FDR Reservoir between 29 February and 22 December 1976 ranged from a high of 19.6 C in late July to a low of 2.9 C in February (Fig. 6). 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. The maximum temperature at the surface (19.6 C) occurred in late July and the maximum temperature at 90 m (16.0 C) occurred in late August. A lag of about one month between the maximum temperature at the surface and that at 90 m was found. Nearly homothermous conditions prevailed during February through April and during November through December.

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.

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

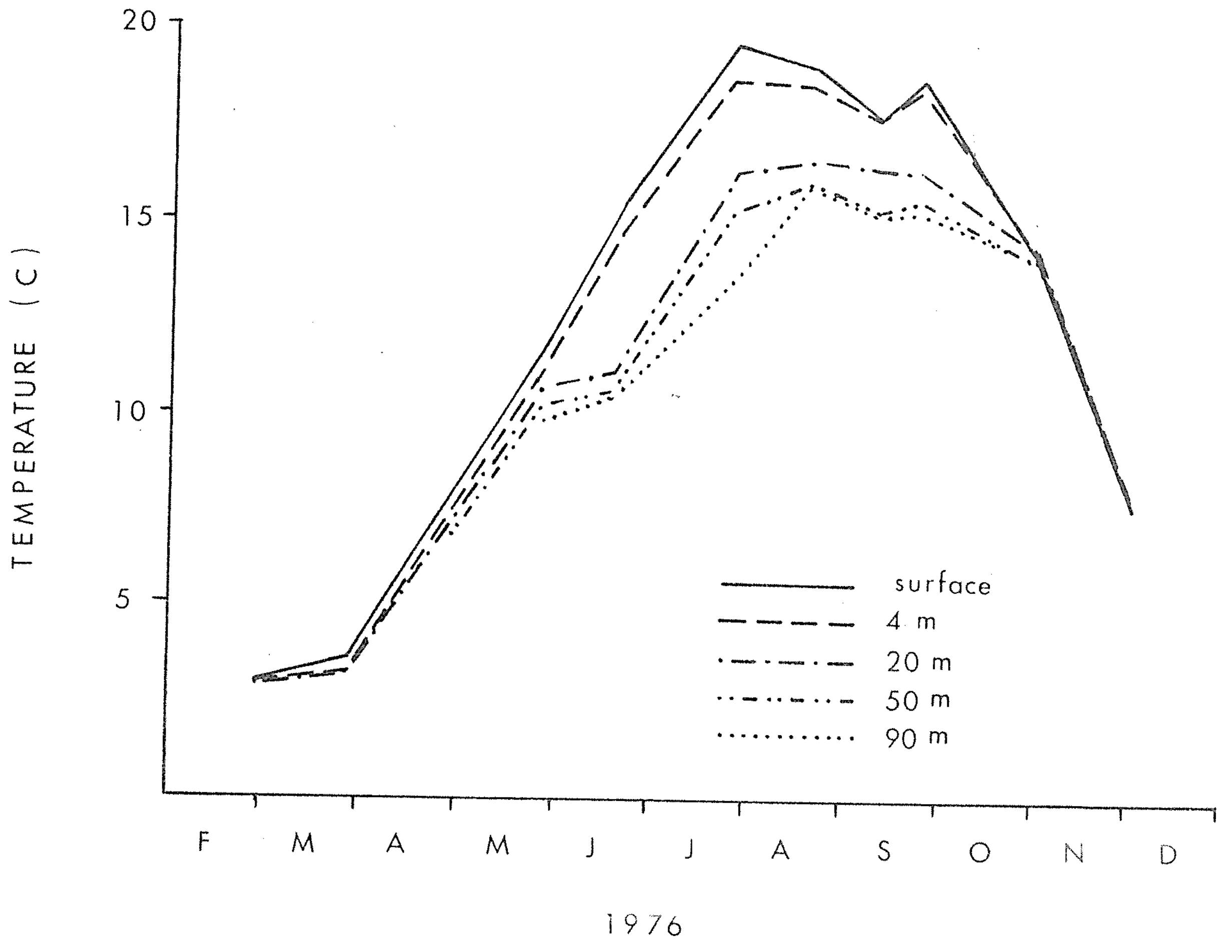


FIGURE 6. Monthly water temperature at 5 depth strata in FDR forebay.

Table 1. Mean of monthly current measurements from surface to bottom at three locations across the log boom, Grand Coulee Dam forebay, Roosevelt Lake, 1976.

LOCATION	Mean current measurement by date (meter/sec) 4/22	5/20	6/15	8/2	9/14
Right-boom	.081	.026	.025	.015	.019
Mid- boom	.048	.036	.049	.025	.045
Left -boom	.060	.057	.026	.018	.025
Reservoir elevation	1219.9	1250.6	1283.4	1290.0	1287.1
Total discharge (kcfs)	130	150	131	194	119

The relationships between current velocity, reservoir elevation, and discharge were examined by means of the non-parametric Kendall rank correlation coefficient (Siegel, 1956). One-tailed tests were used to test for a negative rank correlation between mean velocity at each of the three sites and reservoir elevation. A positive rank correlation was used to test between mean velocity and total daily discharge rate (Table 2). Tests were conducted at the 0.05 level of significance.

Mean current velocity was negatively correlated with reservoir elevation at the Right and Left Forebay locations ($P \leq 0.01$). There was no significant negative correlation at the mid-forebay site. No significant positive correlations with total daily discharge rate and velocity were found for any site.

Current velocity and direction were not recorded during fall 1976 quarter due to breakdown of the current meter and the lengthy time required for its repair. The currents may be characterized as weak and variable during periods when surface elevations were above 1,215 feet, as was the case throughout the sampling. However, the data indicate that an inverse relationship exists between reservoir surface elevation and current speed and it is anticipated that much higher speeds would prevail in the direction of the powerhouse during periods of maximum drawdown.

Explanation of the lack of positive correlation is not available at this stage of analysis, but due to the likely interdependence of discharge rate and reservoir elevation, relationships might be apparent in subsequent, more detailed analysis which will include additional data collected during the winter months.

Current profile measurements at the entrance to the third powerhouse forebay were attempted on three occasions (16 March, 21 April, and 20 May 1976); only the first was successful. The moderately strong current

TABLE 2. Results of significance tests for mean current velocities between sites. [Kendall rank correlation coefficient (tau)] Siegel (1956)

Reservoir Elevation (x)	Mean Velocity at Site (y)	tau	Significance Level (1 tail test)
	Right Boom	-1.00	$P \leq 0.01$
	Mid Boom	-0.40	n.s.*
	Left Boom	-1.00	$P \leq 0.01$
Total Discharge (x)	**Mean Velocity at Site (y)**	**tau**	**Significance Level (1 tail test)**
	Right Boom	-0.20	n.s.
	Mid Boom	-0.40	n.s.
	Left Boom	-0.20	n.s.

*n.s. = not significant at $P \leq 0.05$

combined with a smooth rock bottom prevented maintenance of a stationary position long enough to complete more than surface velocity measurements on the latter attempts.

Surface current velocity at the entrance to the third powerhouse bay ranged from 0.180 m/sec on 16 March to 0.515 m/sec on 21 April (Table 3). Surface current velocity was found to increase with the addition of operating generators. Highest surface velocities recorded to date occurred with G19 and G20 in operation and with the reservoir drawn down to elevation 1,220 ft msl.

Vertical current velocity profiles were obtained at several sites close to the face of the dam when reservoir elevation was lower than 1,260 ft msl. Water velocity was low in all cases and no definite correlations were found which related to operational conditions (Appendix Tables A1-A7).

6.3 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 sampling. Previous sampling in 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 is probably largely due to restriction of the sampling to the area of the forebay where the amount of littoral habitat is restricted. Nearly all of the aquatic environment sampled in the present

TABLE 3. Surface water velocity operating generators and forebay water elevation for Third Powerhouse.

	DATE		
	3/16/76	4/21/76	5/20/76
Surface Velocity (m/sec)	.180	.515	.206
Operating Third Powerhouse Generators	G19	G19,20	G19,20
Reservoir Elevation (ft above msl)	1242.3	1220.2	1250.6

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	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

survey is 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 long ago.

Kokanee, rainbow (Kamloops), and fall chinook have been introduced into FDR Reservoir since the Columbia River was impounded behind Grand Coulee Dam (Table 5). During the period 1942-1945, relatively large numbers of kokanee were introduced 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). 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 29 August 1975 (Stober, et al.,

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" fin-gerling	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

1976). This individual was apparently attempting to exit via the feeder canal inlet tunnels when 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 sampling effort. No enhancement of the FDR Reservoir sport fishery has been documented from planting 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 apparently recruited through the FDR forebay and dam since the walleye was the most abundant gamefish species found in the upper portion of Rufus Woods Reservoir (Stober, 1977).

6.4 NMFS Data 1966 - 1967

Mr. George Snyder of the U.S. National Marine Fisheries Service (NMFS) has 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 gill net 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 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.

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.)

					DEPTH INTERVALS (m)					
DATE	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	7.8
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	42	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	4.2	2.3	2.4	1	1	1	3.5

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	LONGNOS 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.)

C A T C H

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

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

6.5 Gillnet Catch

A total of 664 fish representing 12 species were captured between April and December 1976 in the gillnet survey. The catch was dominated by northern squawfish (Ptychocheilus oregonensis) comprising 54.1 percent of the total number (Table 9). Walleye, the most abundant game fish, comprised 14.0 percent of the total gillnet catch. The other species taken in decreasing order of abundance, were rainbow trout, kokanee, largescale sucker, peamouth, longnose sucker, bridgelip sucker, yellow perch, lake whitefish, Rocky Mountain whitefish and burbot. Five species of non-game fish totaled 67.9% of the catch and seven species of game fish made up the remaining 32.1%.

Gillnet catches were generally low. The largest catches occurred from August through October, the smallest in June and December (Table 10 and Fig. 7). The percentage composition of the total gillnet catch is shown in Table 11. Squawfish comprised from 55 to 81% of the catch from mid-June through September; their contribution was somewhat reduced in other seasons. Walleye comprised a major portion of the catch in October and November of 40 and 62%, respectively, but were infrequently taken from April through July. Rainbow trout and kokanee were both frequently present but rarely comprised more than 20% of the total catch. Largescale sucker, the fifth most abundant species, showed up sporadically in the catch.

TABLE 9. Abundance of all fish species taken from April through December 1976 by surface and bottom horizontal gill nets and vertical gill nets.

SPECIES	TOTAL NUMBER	PERCENT	TOTAL NUMBER TAKEN BY SURFACE HORIZONTAL GILL NET	BOTTOM HORIZONTAL GILL NET	VERTICAL GILL NET
Northern Squawfish	359	54.1	122	45	192
Walleye*	93	14.0	8	36	49
Rainbow Trout*	54	8.1	25	8	21
Kokanee*	49	7.4	16	2	31
Largescale Sucker	40	6.0	34	5	1
Peamouth	26	3.9	10	2	14
Longnose Sucker	15	2.3	0	7	8
Bridgelip Sucker	11	1.7	9	2	0
Yellow Perch*	8	1.2	0	2	6
Lake Whitefish*	3	0.5	0	0	3
Rocky Mountain Whitefish*	3	0.5	0	0	3
Burbot*	3	0.5	0	3	0
TOTAL:	664	(100.2)	224	112	328

*Considered as game fish. Total of 213 game fish (32.1% of total catch.)

TABLE 10. Total FDR forebay gillnet catch by species and date in 1976 (all nets combined).

	4/15,16	4/21,22	5/5,6	5/19,20	6/3,4	6/17,18	6/30,7/1	7/22,23	8/5,6	8/18,19	9/1,2	9/14,15	9/30,10/1	10/12,13	10/26,27	11/16,17	12/7,8
Salmonidae																	
Rainbow trout	4	12	9	4	2	1	2	4	7	3	2	--	1	1	1	1	--
Kokanee	6	10	3	3	--	--	4	1	--	1	6	4	2	--	3	3	3
Coregonidae																	
Lake whitefish	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--
Rocky Mountain whitefish	--	--	--	--	--	--	--	1	--	--	--	--	--	2	--	--	--
Catastomidae																	
Longnose sucker	--	--	--	--	2	--	--	--	3	7	1	--	1	1	--	--	--
Largescale sucker	--	1	7	5	--	--	1	2	3	3	9	6	--	1	1	1	--
Bridgelip sucker	3	5	--	--	1	--	--	--	1	--	--	--	--	1	--	--	--
Cyprinidae																	
Carp*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Peamouth	3	4	10	1	3	--	4	--	--	--	--	--	--	--	1	--	--
Northern squawfish	3	6	12	4	5	12	17	26	79	45	71	37	25	9	2	6	--
Gadidae																	
Burbot	--	--	--	1	--	1	1	--	--	--	--	--	--	--	--	--	--
Percidae																	
Yellow perch	--	1	--	--	--	--	--	1	--	--	--	--	1	--	2	1	2
Walleye	1	--	--	--	1	--	2	--	4	9	7	13	10	25	11	8	2
TOTALS	20	39	41	18	14	17	31	35	97	68	96	60	40	40	21	20	7

*Carp were not caught in gill nets but were observed at surface near P/G units (5/76, 6/76) and in 3rd powerhouse bight (9/30/76). Also, sculpins were observed in stomachs of many fish, but were not captured with gill nets.

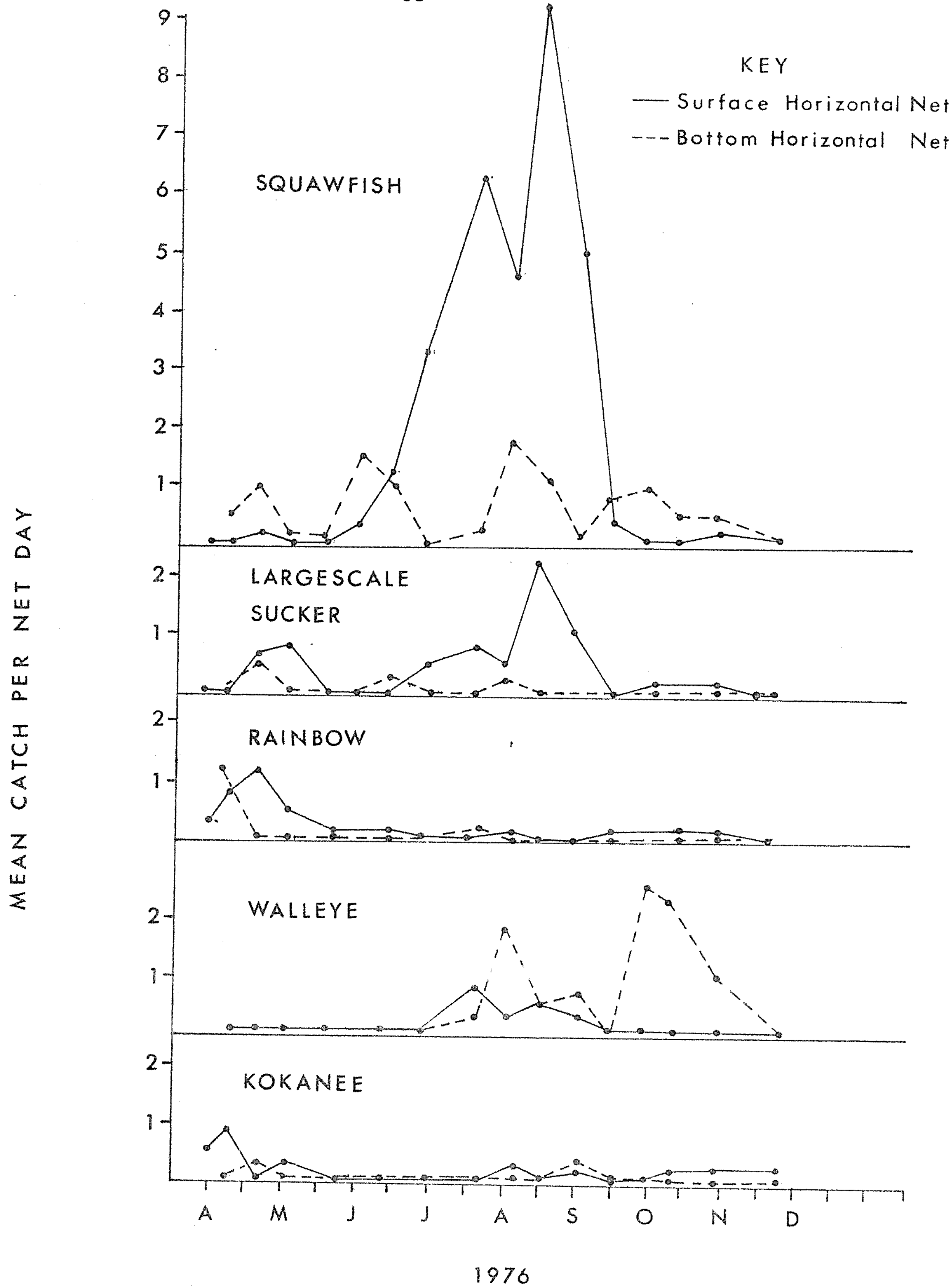


FIGURE 7. Mean bi-weekly surface and bottom horizontal gillnet catches from FDR forebay, 1976.

TABLE 11. Percentage composition of FDR forebay gillnet catch by species and date in 1976 (all nets combined).

	4/15,16	4/21,22	5/5,6	5/19,20	6/3,4	6/17,18	6/30,7/1	7/22,23	8/5,6	8/18,19	9/1,2	9/14,15	9/30,10/1	10/12,13	10/26,27	11/16,17	12/7,8
Salmonidae																	
Rainbow	20.0	30.8	22.0	22.2	14.3	5.9	6.5	11.4	7.2	4.4	2.1	--	2.5	2.5	4.8	5.0	--
Kokanee	30.0	25.6	7.3	16.7	--	--	12.9	2.9	--	1.5	6.2	6.7	5.0	--	14.3	15.0	42.9
Coregonidae																	
Lake whitefish	--	--	--	--	--	17.6	--	--	--	--	--	--	--	--	--	--	--
Rocky Mountain whitefish	--	--	--	--	--	--	--	2.9	--	--	--	--	--	5.0	--	--	--
Catastomidae																	
Longnose sucker	--	--	--	--	14.3	--	--	--	3.1	10.3	1.0	--	2.5	2.5	--	--	--
Largescale sucker	--	2.6	17.1	27.8	--	--	3.2	5.7	3.1	4.4	9.4	10.0	--	2.5	4.8	5.0	--
Bridgelip sucker	15.0	12.8	--	--	7.1	--	--	--	1.0	--	--	--	--	2.5	--	--	--
Cyprinidae																	
Carp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Peamouth	15.0	10.3	24.4	5.6	21.4	--	12.9	--	--	--	--	--	--	--	4.8	--	--
Northern squawfish	15.0	15.4	29.3	22.2	35.7	70.6	54.8	74.3	81.4	66.2	74.0	61.7	62.5	22.5	9.5	30.0	--
Gadidae																	
Burbot	--	--	--	5.6	--	5.9	3.2	--	--	--	--	--	--	--	--	--	--
Percidae																	
Yellow perch	--	2.6	--	--	--	--	--	2.9	--	--	--	--	2.5	--	9.5	5.0	28.6
Walleye	5.0	--	--	--	7.1	--	6.5	--	4.1	13.2	7.3	21.7	25.0	62.5	52.4	40.0	28.6

Catches from the preliminary gillnet sampling in March 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 were somewhat higher than the average for the rest of the year but did not provide evidence of the existence of large kokanee populations in the forebay.

6.5.1 Length-Frequency

Comparison of length-frequency distributions of the gillnet catch (March through December) for the five major species (Fig. 8) showed that all species except largescale sucker were of a wide range of sizes. No small suckers were captured. A wide range in length may indicate the presence of several age groups. Although age determinations are not yet complete, most fish were probably age one and older.

Pronounced single modal lengths of 340 mm and 310 mm fork length were noted for squawfish and walleye, respectively. Well defined modes may indicate strong year classes or gear selectivity.

A combination of gear selectivity and small sample size probably resulted in bias in the length frequency distributions presented. Because of small sample size, a combination of samples from all seasons and gear types was necessary. Vertical gillnets were constructed of one mesh size (2 1/2 inch) and the use of this catch data may have intensified modes for some species. The combination of length frequency data from before,

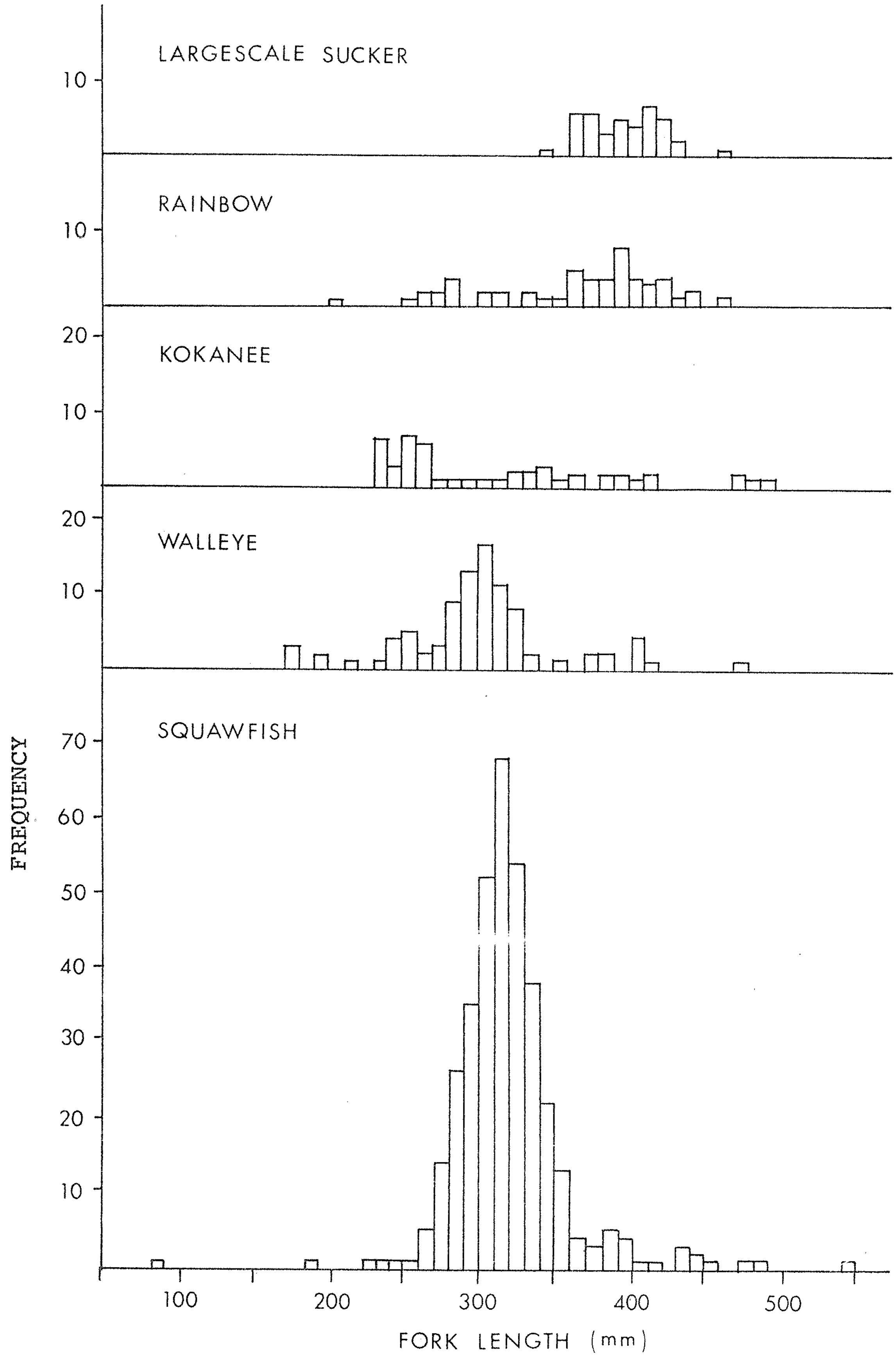


FIGURE 8. Length-frequency distributions for squawfish, walleye, kokanee, rainbow trout, and largescale sucker collected by gillnets in FDR forebay from March-December, 1976.

during and after the growing season may have resulted in widening and merging of some modes. The fact that catches of some species were seasonal added another variable. The presence of juvenile fish and small cyprinids in the forebay may have been undetected because of the relatively large minimum mesh size (1 inch stretch) of the horizontal gillnets.

6.5.2 Horizontal and Vertical Distribution

The horizontal distribution of the catch was analyzed on a seasonal basis by comparing the catches of the gillnets between sites. Vertical distribution of the catch was analyzed seasonally by comparing the catches of the three net types: bottom,horizontal, and vertical. Three major species selected for analysis of distribution were squawfish, walleye and kokanee.

A comparison of squawfish catches between net sites indicated a relatively uniform horizontal distribution, with two exceptions (Table 12, Fig. 9). 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 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 sites.

The vertical distribution of the squawfish catch indicates 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 catches of squawfish in the summer was much higher in the surface layer than at the bottom for both horizontal (Fig.7) and vertical nets (Fig. 9).

TABLE 12. Seasonal horizontal gill net catches for Left, Center and Right Forebay locations from FDR forebay, 1976.

CATCH PER NET DAY

SPECIES	LOCATION	SPRING			SUMMER			FALL		
		LEFT	CENTER	RIGHT	LEFT	CENTER	RIGHT	LEFT	CENTER	RIG
SQUAWFISH	Surface	0.17	0	0.08	6.75	7.50	1.67	0.20	0	0.1
	Bottom	0.30	0.14	1.20	0.75	-	0.75	0.80	-	0.3
LARGESCALE SUCKER	Surface	0.33	0.17	0.25	0.17	0	1.67	0.30	0	0
	Bottom	0	0	0.30	0.08	-	0.08	0	-	0
RAINBOW	Surface	0.67	0.50	0.42	0.17	0	0	0	0.10	0.3
	Bottom	0	0	0.70	0	-	0.08	0	-	0
WALLEYE	Surface	0	0	0	0.50	0	0.17	0	0	0
	Bottom	0	0	0	0	-	1.08	0	-	2.8
KOKANEE	Surface	0.83	0	0	0.08	0.50	0	0.20	0.10	0
	Bottom	0	0	0.10	0	-	0.08	0	-	0

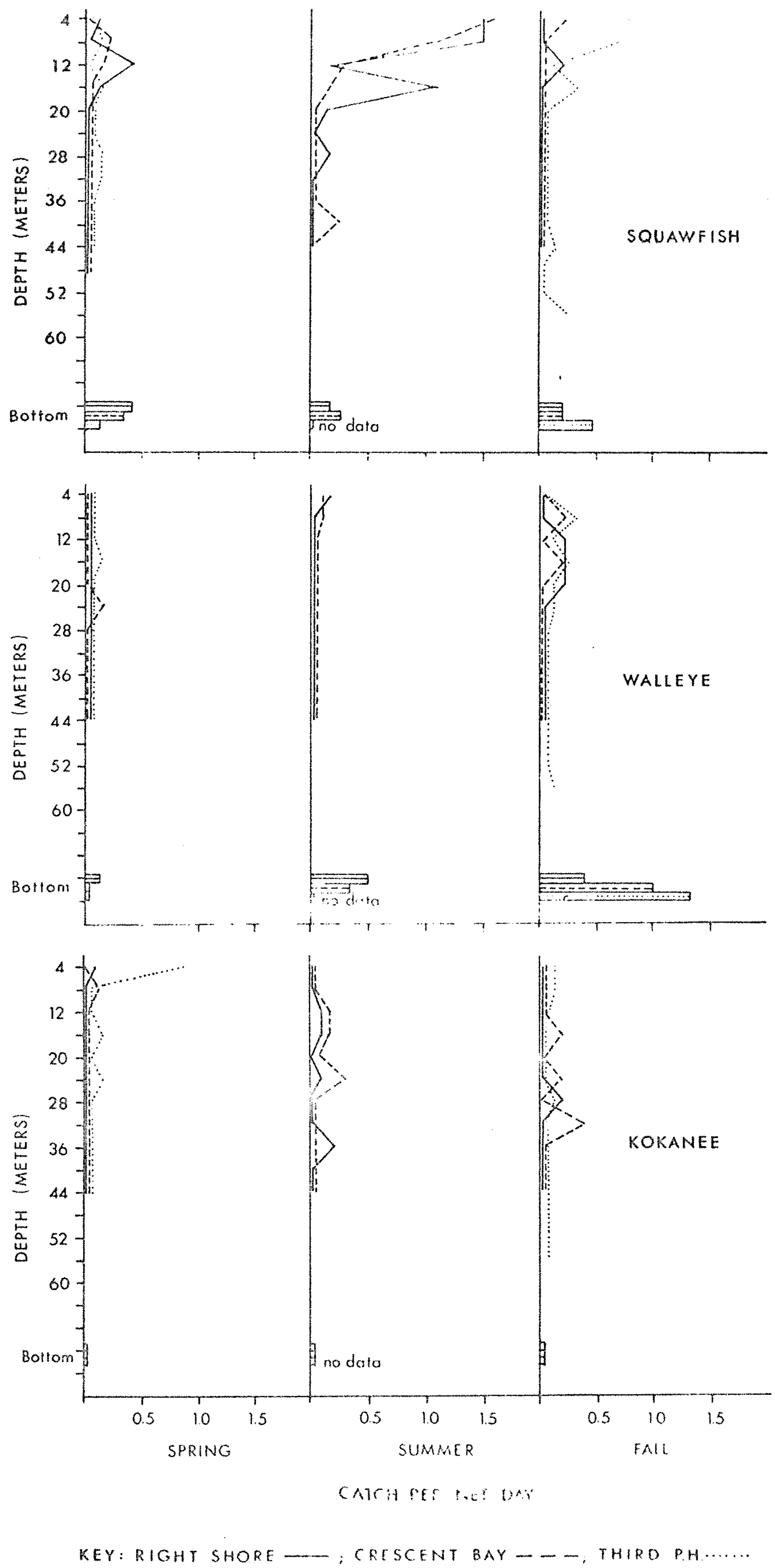


FIGURE 9. Seasonal vertical distribution of squawfish, kokanee, and walleye at right bank, Crescent Bay, and Third Powerhouse locations in FDR forebay as determined from vertical gillnet catches.

Walleye catches in summer and fall were relatively large at the right forebay bottom horizontal net site (1.08 and 2.88 fish per net day, respectively, Table 12) while no walleye were taken at the left forebay bottom horizontal site. The fall walleye catches in the bottom 4 m of the vertical net for the Crescent Bay and Third Powerhouse sites were greater than for the right forebay vertical net site.

Walleye catches at the bottom were consistently larger than at the surface for both horizontal (Fig. 7) and vertical sets (Fig. 9). Few walleye were taken between 20 m and the bottom.

No consistent trend in horizontal distribution of kokanee was apparent. The surface catch of kokanee in the spring at the Third Powerhouse vertical net site was high relative to the other vertical sites.

Kokanee catches were more uniformly distributed throughout the water column than were squawfish or walleye. There was no consistent tendency for association with surface or bottom during any season.

6.6 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, principally during the darkest hours of the night, when it was anticipated that juveniles would be distributed offshore and more available to the townet offshore.

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.

6.7 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. 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 15. Brief discussions and graphical representations of pertinent findings for each parameter are presented below.

6.7.1 Seasonal Variation in Target Density

Target densities from the monthly acoustic surveys were grouped into three levels; medium densities of March through June, which averaged 2.86 $\times 10^{-4}$ targets/m^3; a relatively high density of 2.64 $\times 10^{-2}$ targets/m^3, which occurred in August, relatively low densities in September and November, which averaged 1.64 $\times 10^{-6}$ targets/m^3 (Fig. 10). These densities may be visualized better if expressed as cubic meters of water occupied by a single target, in which case the March-to-April densities averaged one target per 12,427 m^3, the August density was one target/37 m^3, and the September-November average density was one target/611,597 m^3.

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

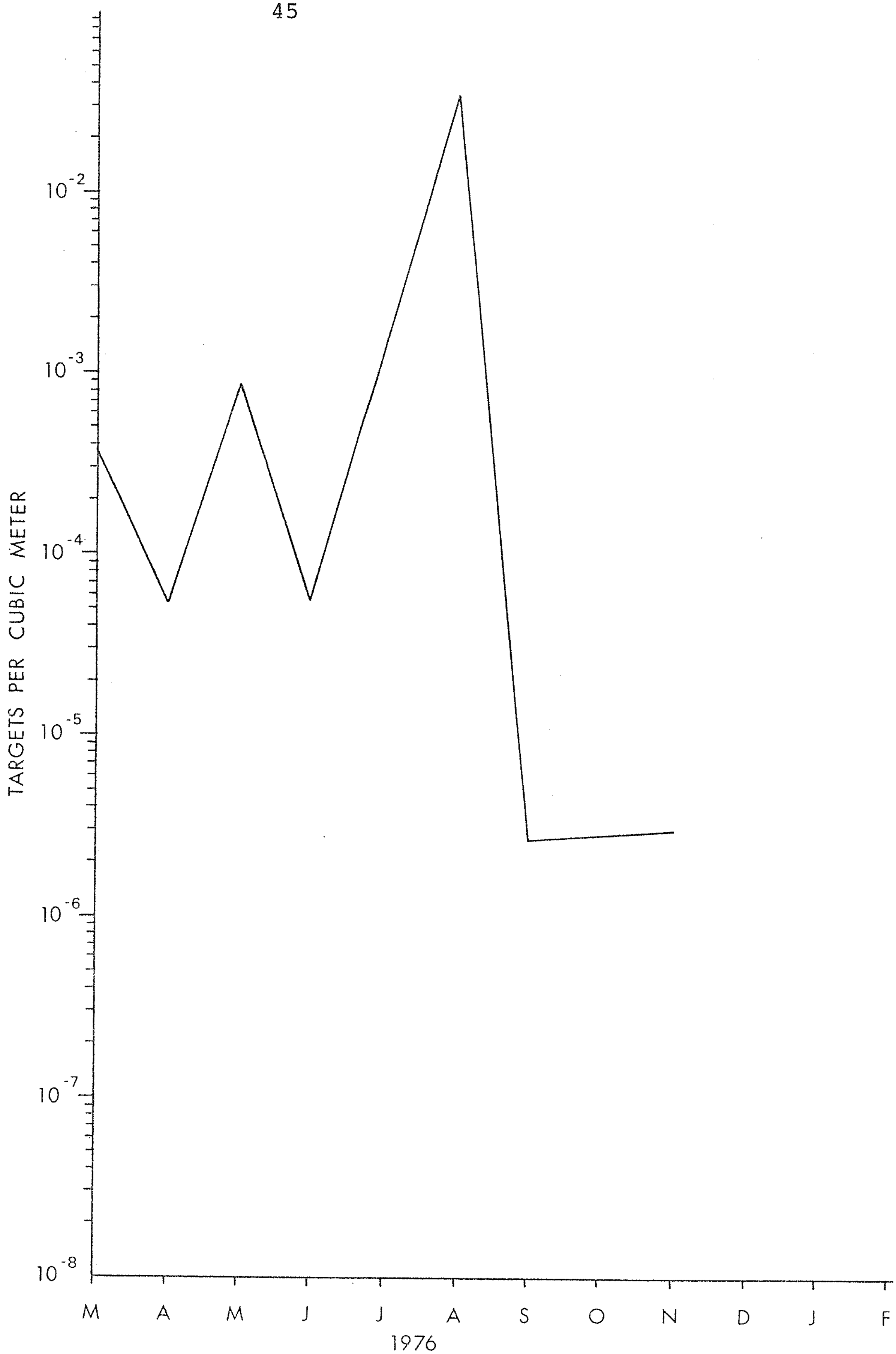


FIGURE 10. Seasonal variation in acoustic target density, Grand Coulee Dam forebay, 1976.

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 results in a gradual build-up in abundance in the forebay during the summer which peaks in August. The build-up coincides with thermal stratification of the surface waters in the forebay. The rapid decrease from August to September suggests 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 begins to break down during this same period.

6.7.2 Spatial Distribution

The horizontal distribution of targets was fairly uniform between and within transects, except in Crescent Bay where target frequency was consistently greater, and during the August survey when targets were more frequent offshore than near the shore (Fig. 11, 12, 13 and 14).

On June 15, an acoustic survey was conducted upriver to mile 119 (Fig. 2). 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. Although the survey data are not yet fully analyzed, 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.

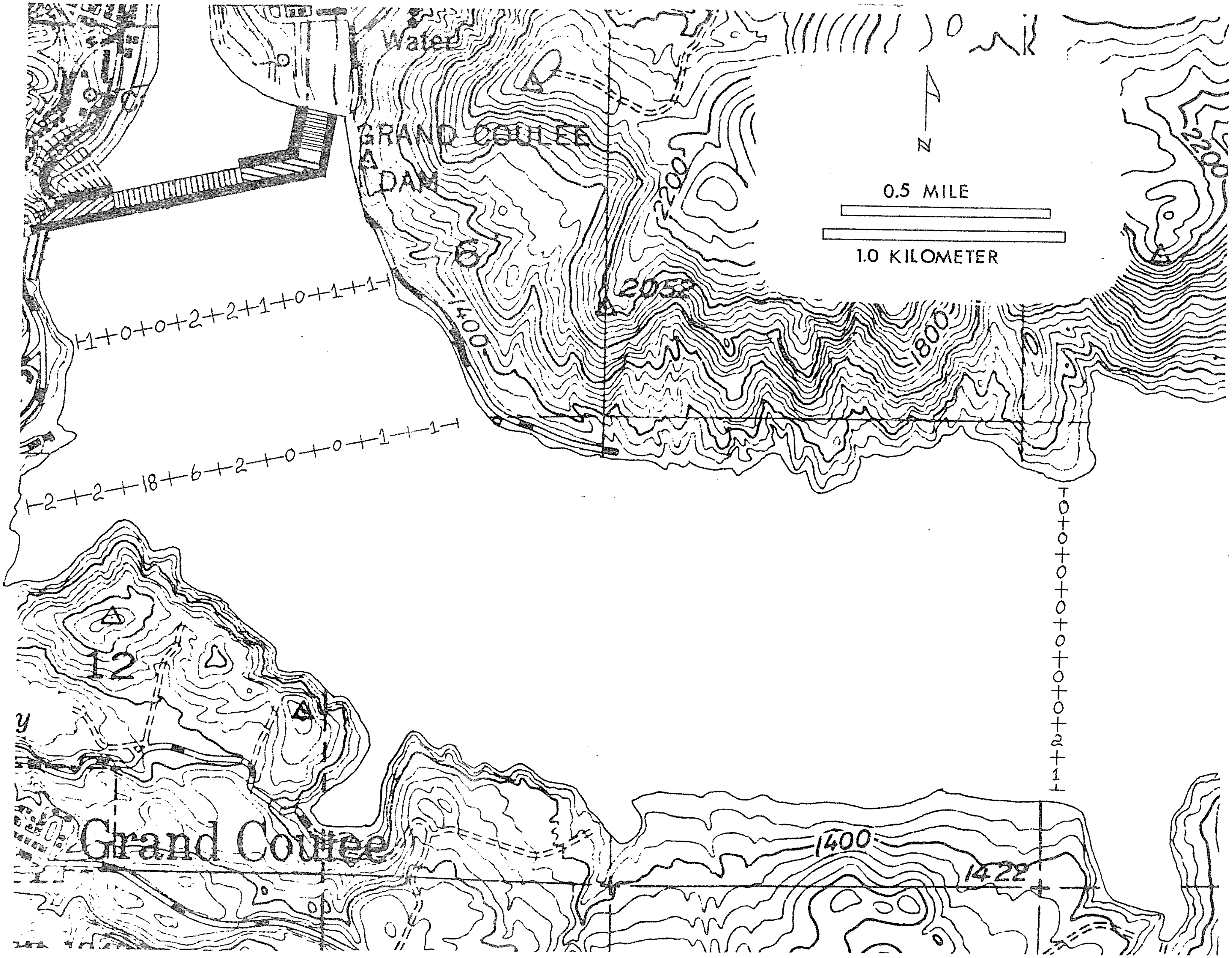
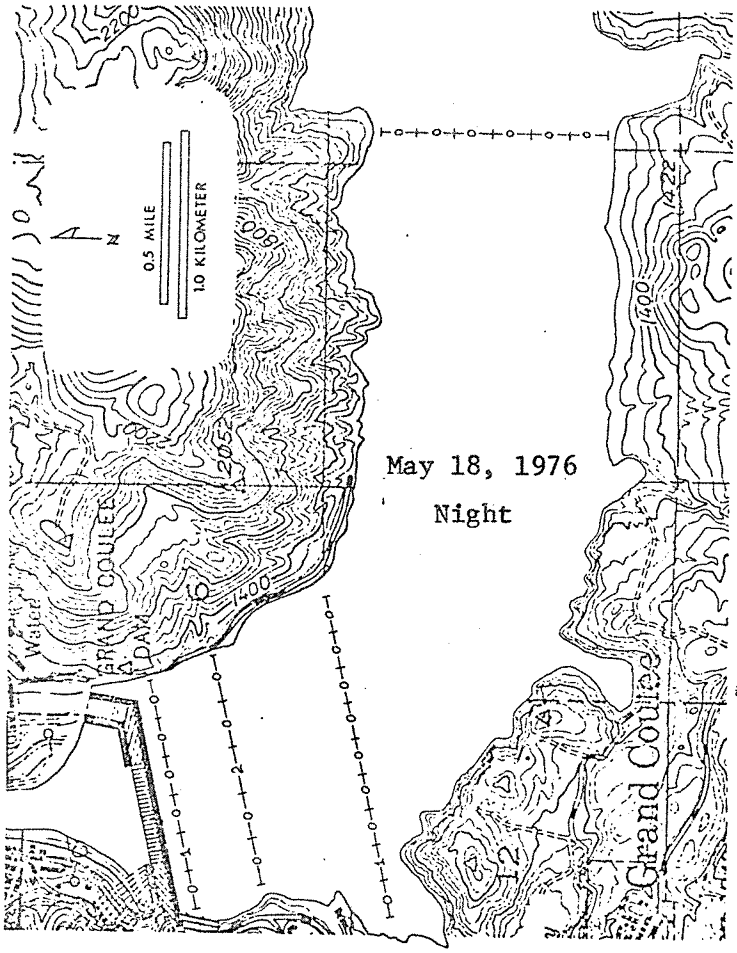
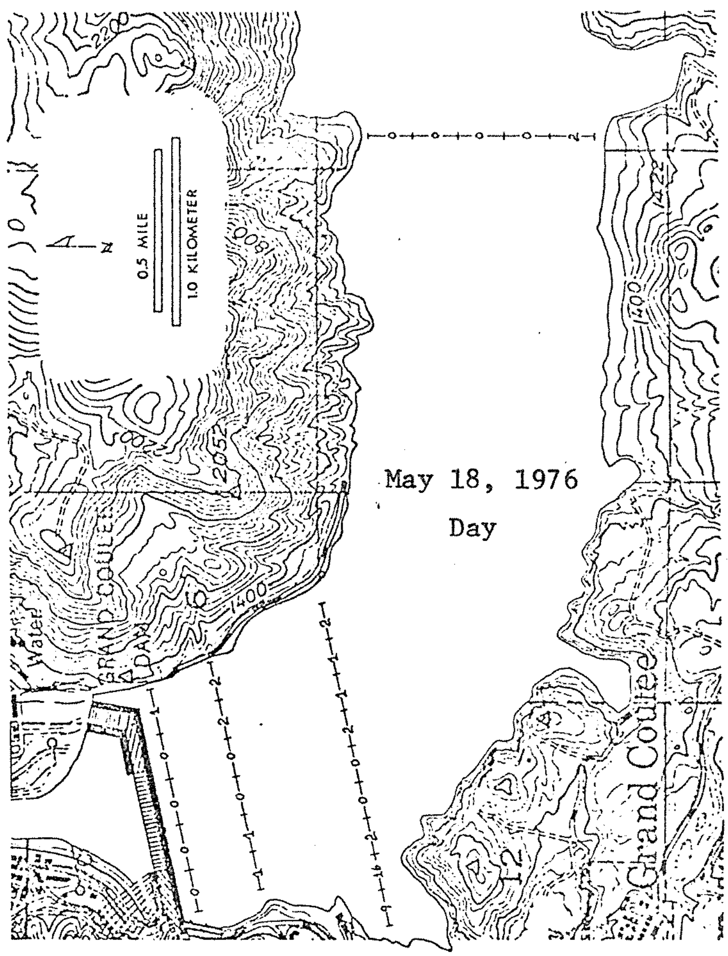


FIGURE 11. Distribution of acoustic targets on March 16, 1976.


May 18, 1976
Night
0.5 MILE
1.0 KILOMETER
GRAND COULEE DAM
Grand Coulee
Water


May 18, 1976
Day
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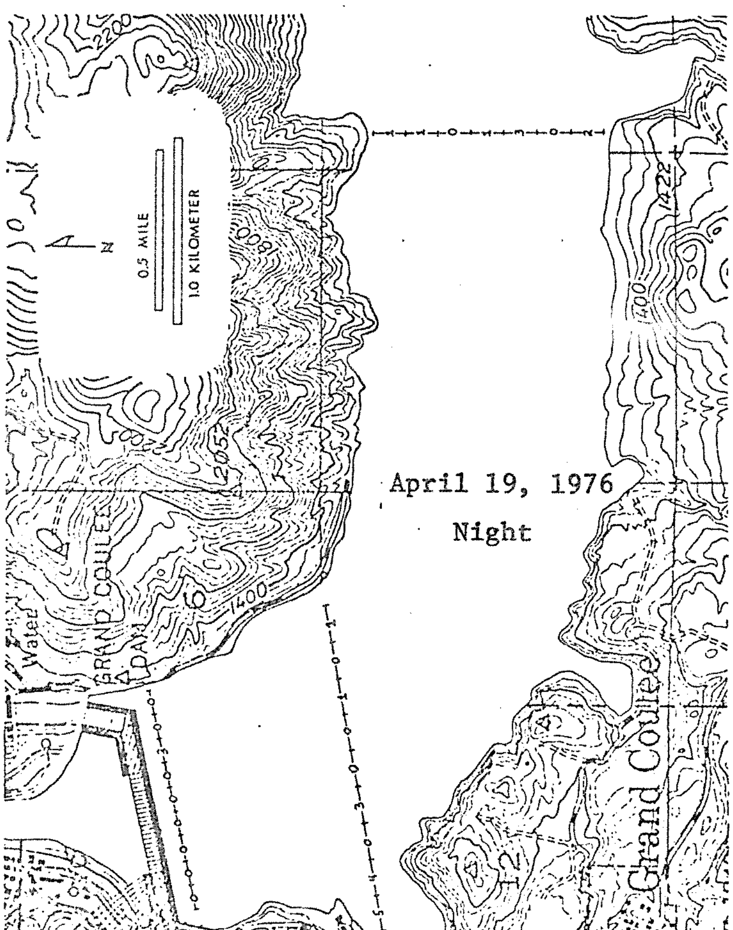
GRAND COULEE DAM
Grand Coulee
Water


April 19, 1976
Night
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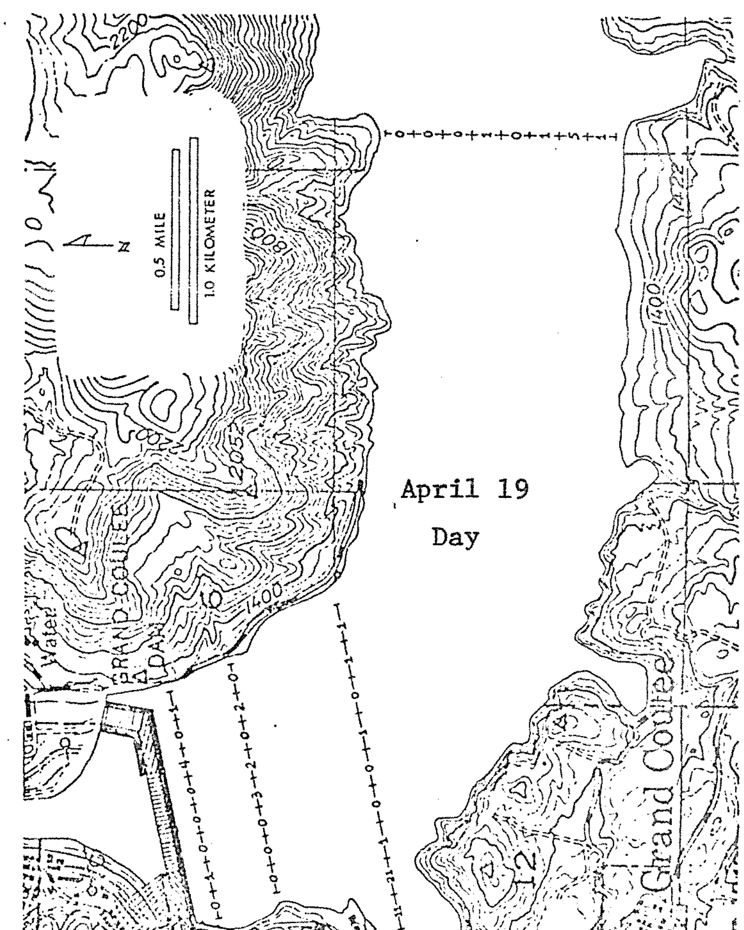
1.0 KILOMETER
GRAND COULEE DAM
Grand Coulee
Water


April 19
Day
0.5 MILE
1.0 KILOMETER
GRAND COULEE DAM
Grand Coulee
Water

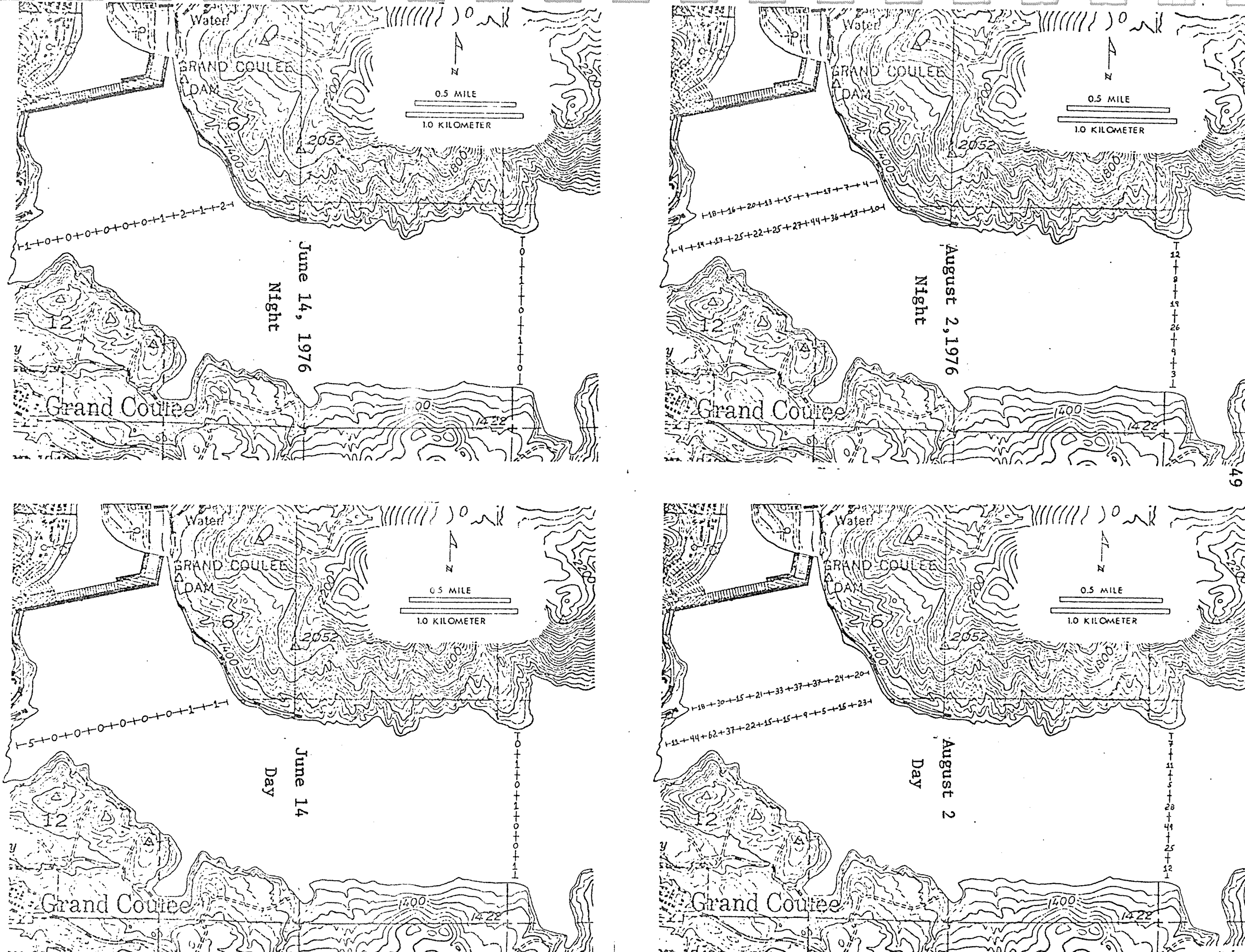


FIGURE 13 Distribution of acoustic targets during June and August [illegible]

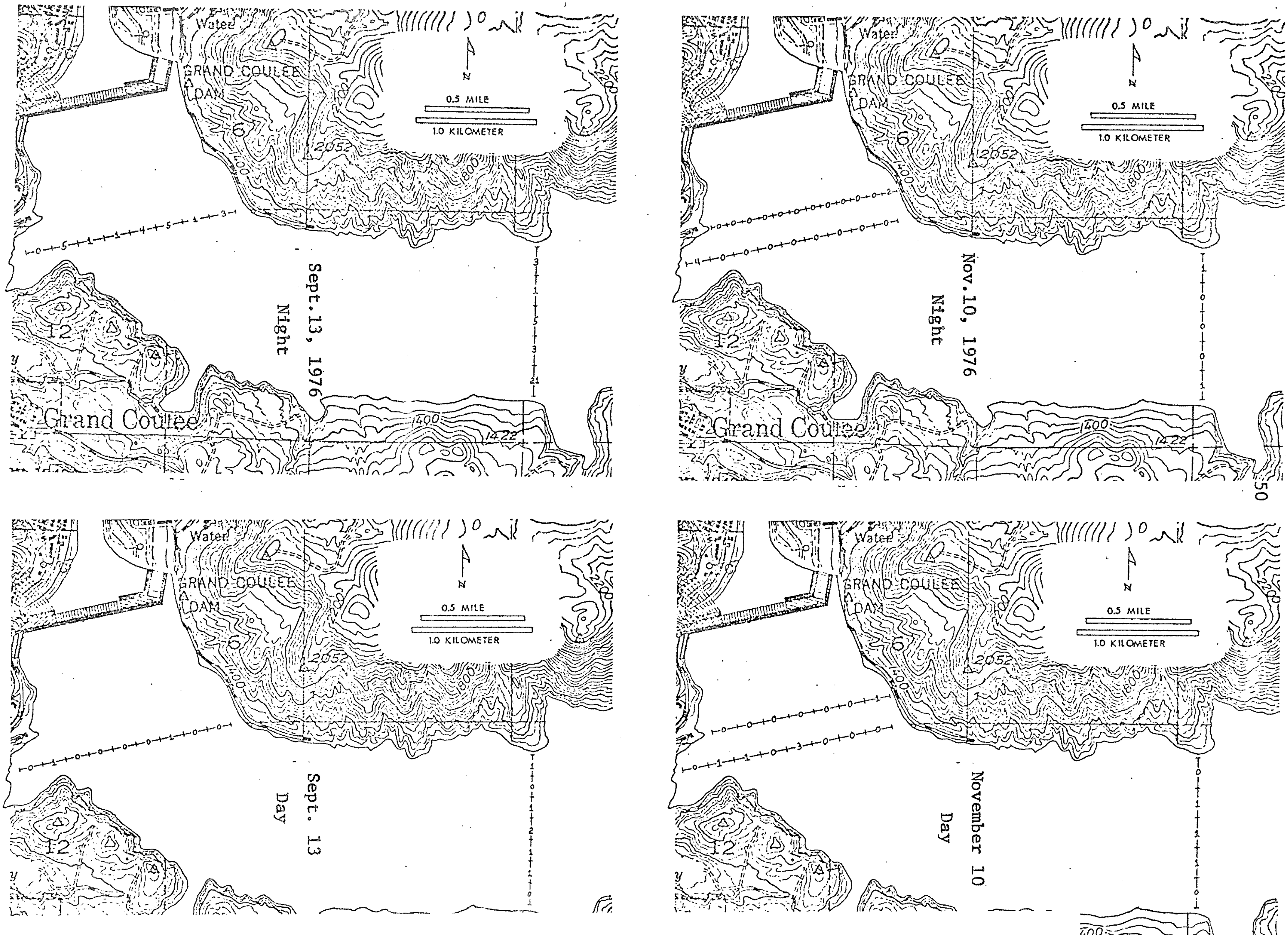


FIGURE 14. Distribution of acoustic targets during September and November surveys, by diel period.

6.7.3 Vertical Distribution

Generally, targets were most abundant near the surface and became less abundant with increasing depth (Fig. 15).

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, spillway discharge openings, pump and pump-generator openings are shown to the left of an elevation scale in Fig. 16. To the right of the elevation scale is shown a summary of all target density information expressed in percent of target occurrence by depth strata. The depth strata are divided into 2 millisecond intervals, which equals approximately 4.8 feet. Fig. 16 shows that 85 percent of all targets occurred within 15 feet of the surface and that 99 percent of all targets occurred within 50 feet of the surface. Because of the relatively high water level maintained in Roosevelt Lake during 1976 (Fig. 3). it appears that entrainment occurred largely via the spillway, that a relatively small amount occurred via pump-discharge openings (primarily during March, April and May), and that little entrainment occurred through subsurface spill openings and the right and left powerhouse penstocks. The Third Powerhouse penstocks are located at elevation 1170, which suggests low entrainment because they were at least 50 feet subsurface, but because the penstocks are situated in a constricted opening which forces water to be drawn from the surface, it is likely that the Third Powerhouse penstocks entrained fishes at all reservoir levels.

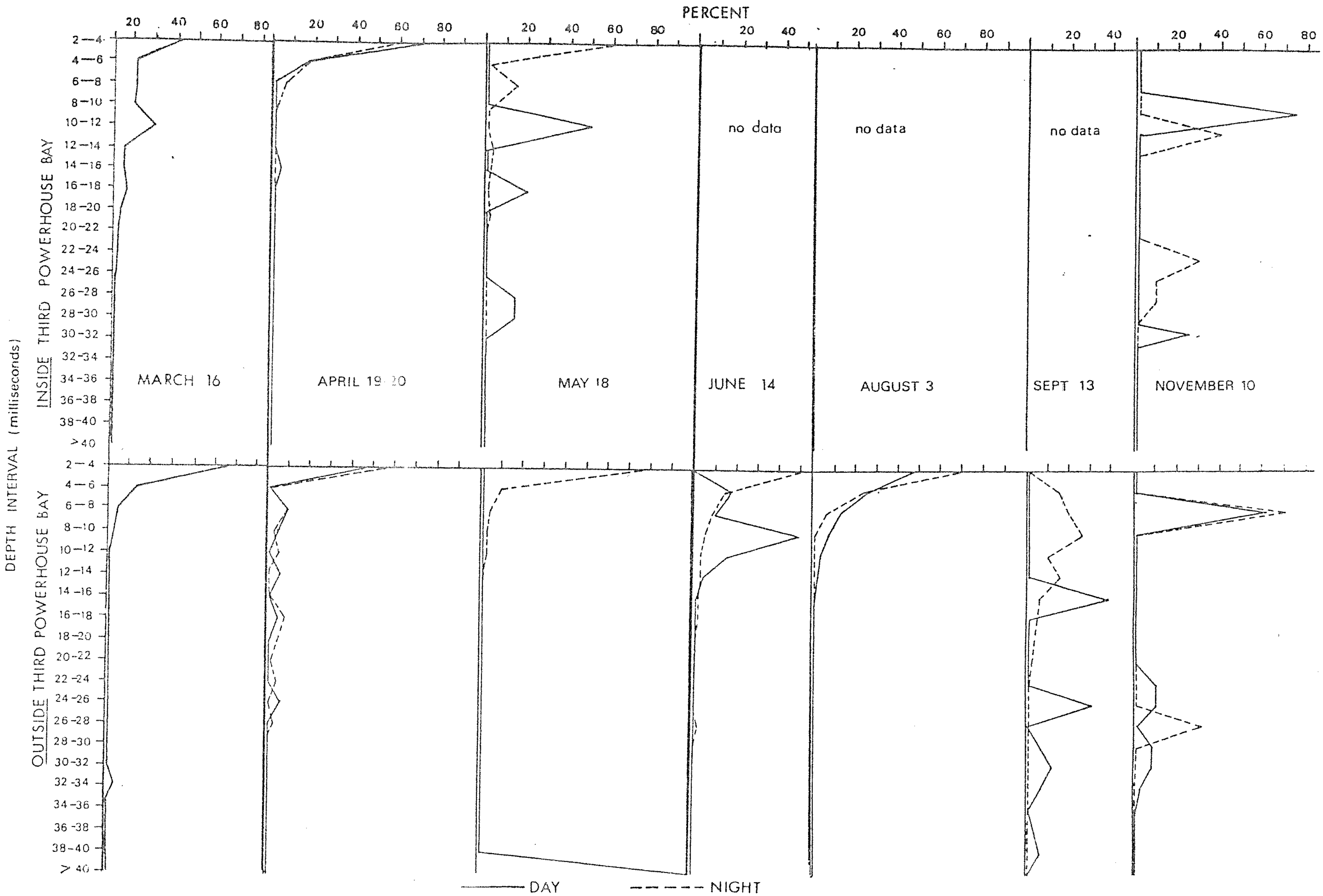


FIGURE 15. Comparison of vertical acoustic target distribution of all transects <u>outside</u> the Third Powerhouse bay with all transects <u>inside</u> the Third Powerhouse bay.

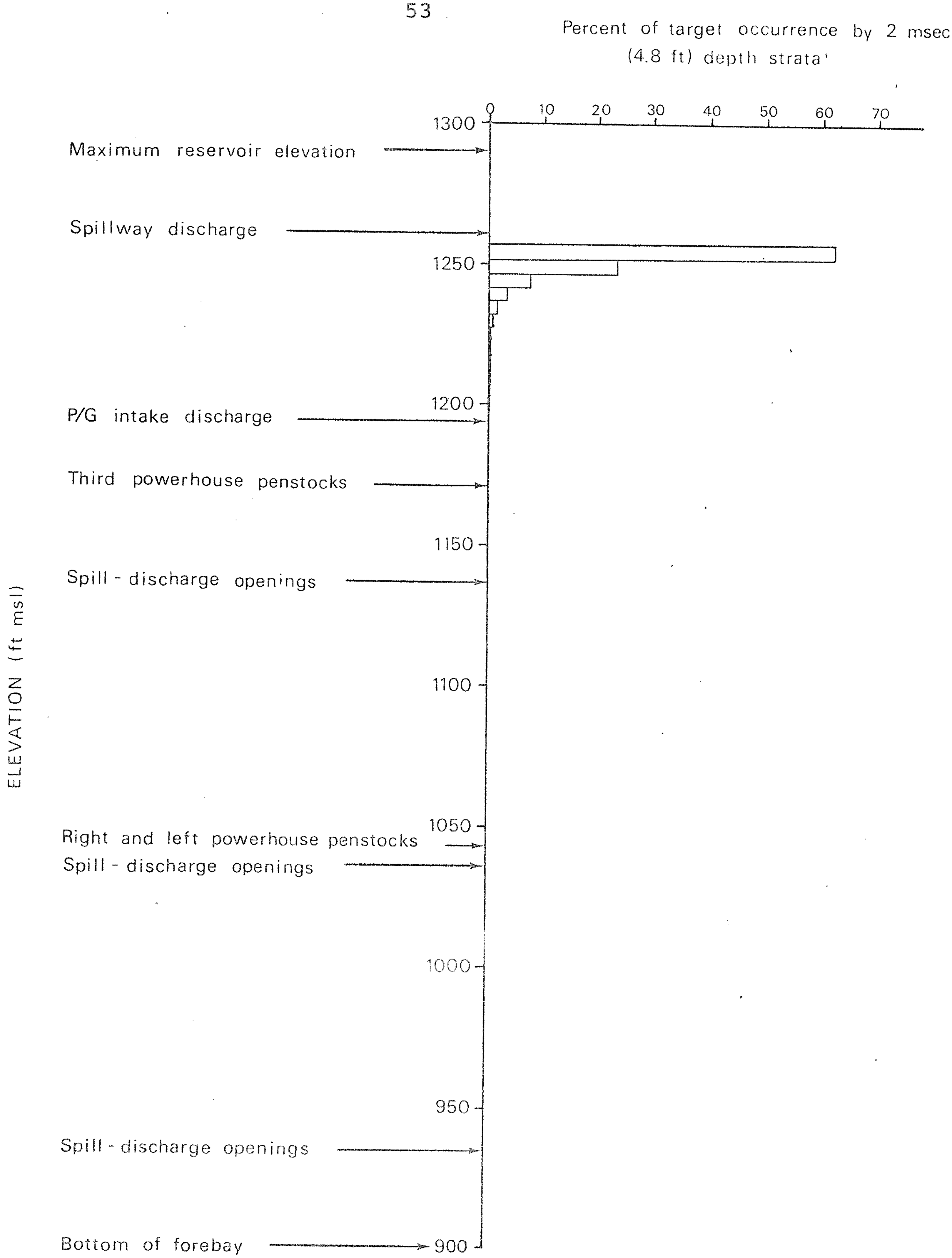


FIGURE 16. Comparison between elevations of penstocks, spillway, and spill-discharge openings and percent of acoustic target occurrence by depth strata in Grand Coulee forebay, 1976.

6.7.4 Diel Variation

Target distributions tended to occur nearer the surface at night than during the day from May through September, but were undifferentiated in April, March, and November (Fig. 15). This apparent seasonal difference suggests a photonegative reaction by fishes to the summer solstice.

6.7.5 Comparison of Target Density between FDR Reservoir and Banks Lake

An acoustic survey of Banks Lake on September 14 provided a basis 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 2 1/4 miles. A preliminary 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.

Low fish populations were indicated by all sample methods in 1976; it is unknown whether or not this is a temporary condition. In Lake Roosevelt, one of the most likely factors affecting fish populations is water level fluctuation; the 71.6 ft drawdown in 1976 was the least of any in the past five years. An extreme drawdown to a minimum of 1157 ft in 1974 may have greatly influenced fish populations, however. A weak year class in 1974 would result in few two year old fish in the 1976 samples, an age group that would normally be strongly represented in gillnet catches.

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APPENDIX TABLE 1. Current profile at entrance to Third Powerhouse bay (velocity in m/sec).

	3/16/76		4/21/76*		5/20/76*	
Depth (m)	vel.	dir.	vel.	dir.	vel.	dir.
0	.180	330	.515	348	.206	340
2	.180	345				
4	.206	354				
6	.154	355				
8	.129	352				
10	.154	352				
12	.180	352				
14	.180	352				
16	.180	353				
18	.180	353				
20	.180	355				
22	.175	351				
24	.154	348				
26	.175	347				
28	.144	348				
30	.165	342				
32	.165	343				
34	.154	346				
36	.154	343				
38	.149	340				
40	.098	328				

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

APPENDIX TABLE 2. Current profile 50 meters upstream from face of Grand Coulee Dam (velocity in m/sec).

Depth (m)	Right Generator Block 4/21/76 vel.	dir.	Right Generator Block 5/20/76 vel.	dir.	Center of Spillway 4/21/76 vel.	dir.	Left Generator Block 4/21/76 vel.	dir.	Left Generator Block 5/20/76 vel.	dir.	P/C Blo 5/20/7 vel.	dir
0	.108	360	.062	270	.088	262	.082	204	.062	205	.010	21[illegible]
2	.113	032	.093	304	.062	300	.103	232	.062	272	.052	27[illegible]
4	.124	066	.077	023	.041	302	.082	230	.052	270	.041	22[illegible]
6	.108	074	.052	020	.041	352	.067	222	.077	280	.041	24[illegible]
8	.118	078	.052	040	.041	354	.067	220	.062	270	.062	23[illegible]
10	.113	082	.077	050	.041	352	.062	220	.062	270	.067	24[illegible]
12	.113	070	.077	062	.036	002	.067	210	.077	270	.093	25[illegible]
14	.093	048	.062	064	.062	358	.052	190	.077	268	.052	265
16	.103	058	.077	038	.062	352	.072	218	.077	270	.052	262
18	.113	050	.077	034	.067	002	.062	214	.093	262	.026	262
20	.108	043	.041	012	.067	002	.067	230	.103	274	.026	268
22	.093	038	.041	020	.067	004	.062	220	.093	270	.026	268
24	.103	036	.062	036	.026	328	.067	226	.077	271	.026	278
26	.093	035	.077	035	.046	348	.067	222	.062	267	.010	276
28	.113	033	.077	034	.046	354	.067	228	.077	265	.041	272
30	.093	026	.052	022	.067	334	.072	228	.077	272	.010	280
32	.098	024	.062	355	.062	350	.062	218	.077	270	.010	280
34	.093	018	.062	004	.046	326	.067	220	.062	268	.026	292
36	.082	018	.062	005	.062	332	.062	226	.062	278	.026	302
38	.077	030	.041	010	.077	338	.067	224	.077	280	.026	270
40	.082	036	.052	010	.062	346	.062	220	.062	280	.026	279
42	.077	030	.010	348	.046	328	.067	230	.052	283	.026	267
44	.082	032	.026	340	.067	328	.067	218	.041	289	.010	310
46	.072	036	.026	342	.067	334	.062	220	.052	298	.010	285
48	.077	036	.026	342	.041	330	.052	216	.062	302	.026	280
50	.077	030	.026	005	.062	338	.041	216	.077	308	.041	293
52	.077	026	.026	010	.052	334	.041	216	.093	308	.026	310
54	.072	024	.010	338	.077	348	.041	210	.093	312	.041	310
56	.082	018	.026	008	.072	354	.041	208	.093	312	.041	312
58	.016	020	.026	030	.082	348	.046	206	.077	303	.026	304
60			.077	060	.041	008	.062	212	.062	305		
62			.077	092	.041	004	.036	240	.062	305		
64			.026	080	.062	330			.062	305		
66			.026	065	.041	338			.077	302		
68			.010	340	.052	352			.077	300		
70			.041	332	.041	326			.052	294		
72			.052	330	.052	278			.062	294		
74			.041	325	.062	278			.062	295		
76			.041	315	.077	246			.062	295		
78					.082	272			.077	258		
80					.026	210						
82					.026	006						
84					.041	190						
86					.072	246						
88					.062	228						
90					.026	232						

APPENDIX TABLE 3. Current profile 175 meters upstream from face of Grand Coulee Dam (velocity in m/sec).

Depth (m)	Center 3rd P.H. Bay 3/13/76		Right Side Right Gen. Block 3/13/76		Left Side of Right Generator Block 3/13/76		Left Side of Right Generator Block 3/16/76		Right Side of Left Generator Block 3/13/76		Right Side of Left Generator Block 3/16/76		Left Side Left Gen. Block 3/13/76	
	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.
0	.052	272	.041	208	.026	192	.052	290	.082	264	.067	282	.026	212
2	.026	202	.026	240	.026	190	–	–	.016	267	–	–	.041	240
4	.041	242	.026	235	.026	178	.062	295	.077	238	.031	335	.026	192
6	.052	278	.026	256	.026	210	–	–	.082	253	–	–	.026	188
8	.052	313	.010	246	.041	244	.036	280	.067	233	.031	346	.010	156
10	.026	266	.026	258	.041	252	–	–	.067	218	–	–	.010	176
12	.041	265	.026	258	.041	252	.046	292	.041	228	.031	300	.010	154
14	.041	250	.041	270	.041	252	–	–	.052	229	–	–	.010	156
16	.041	256	.041	252	.041	262	.062	290	.046	220	.031	303	.010	156
18	.041	252	.041	267	.041	260	–	–	.046	225	–	–	.026	154
20	.041	256	.026	283	.041	268	.036	268	.041	229	.031	310	.010	138
22	.041	253	.041	293	.052	272	–	–	.041	240	–	–	.026	120
24	.026	250	.041	296	.057	270	.046	268	.041	236	.031	318	.010	122
26	.041	253	.026	292	.052	270	–	–	.041	233	–	–	.010	230
28	.026	260	.041	297	.057	278	.031	250	.067	237	.031	324	.010	240
30			.041	291	.057	276	–	–	.052	222	–	–	.010	210
32			.041	294	.057	276	.041	246	.036	232	.026	316	.010	210
34			.026	287	.052	278	–	–	.036	240	–	–	.010	212
36			.026	288	.052	280	.041	250	.057	242	.021	312	.010	200
38			.026	281	.057	274	–	–	.041	236	–	–	.010	200
40			.026	275	.057	270	.016	238	.041	241	.031	316	.010	200
42			.026	277	.057	274	–	–	.041	250	–	–	.010	210
44			.041	277	.052	272	.026	246	.041	255	.036	320	.010	210
46			.041	275	.052	268	–	–	.041	257	–	–	.010	210
48			.026	269	.041	232	.026	248	.041	258	.036	316	.010	190
50			.026	265	.041	224	–		.041	258	–	–	.010	178
52					.041	224	.016	250	.046	260	.036	312		
54					.041	234	–	–	.041	257	–	–		
56					.041	236	.016	236	.046	245	.046	315		
58					.041	230	–	–	.046	251	–	–		
60					.041	236	.016	242	.046	254	.036	302		
62					.041	240	–	–	.041	254	–	–		
64					.026	222	.021	238	.041	244	.052	299		
66					.026	224	–	–	.052	236	–	–		
68					.026	226	.021	242	.041	237	.036	312		
70					.026	220	–	–	.041	232	–	–		
72					.026	228	.005	200	.046	228	.036	313		
74					.010	224			.046	236	–	–		
76									.041	232	.036	318		
78											–	–		
80											.036	325		

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

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

APPENDIX TABLE 5. Current profile at left logboom station, FDR forebay (velocity in m/sec).

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

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

Depth (m)	4/22/76		5/20/76		6/15/76		8/2/76		9/14/76	
	vel.	dir.	vel.	dir.	vel.	dir.	vel.	dir.	vel.	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 densities <u>outside</u> Third Powerhouse Bay by date, depth stratum, location.

1976 DATE	DIEL PERIOD	STRATUM	LOCATION: DAM FACE	INNER LOG BOOM	OUTER LOG BOOM	CRESCENT BAY	SPRING CANYON	Σ	$\overline{X}$
4-19,20	Day	2-5 m	0		0	0	9.73×10^{-5}	9.73×10^{-5}	2.43×10^{-5}
		5-20 m	7.44×10^{-6}		3.66×10^{-5}	1.02×10^{-5}	1.09×10^{-5}	6.51×10^{-5}	1.63×10^{-5}
		> 20 m	0		1.71×10^{-6}	1.74×10^{-7}	1.81×10^{-7}	2.07×10^{-6}	5.14×10^{-7}
	Night	2-5 m	1.59×10^{-4}	0	9.74×10^{-4}	7.88×10^{-5}	8.68×10^{-5}	1.30×10^{-3}	2.60×10^{-4}
		5-20 m	2.07×10^{-6}	1.03×10^{-5}	9.35×10^{-5}	4.21×10^{-5}	1.71×10^{-5}	1.65×10^{-4}	3.30×10^{-5}
		> 20 m	1.43×10^{-7}	1.25×10^{-7}	8.00×10^{-7}	6.53×10^{-8}	5.37×10^{-8}	1.19×10^{-6}	2.37×10^{-7}
5-18	Day	2-5 m	0	0	0	0	0	0	0
		5-20 m	0	0	0	0	0	0	0
		> 20 m	1.6×10^{-6}	0	3.66×10^{-6}	1.10×10^{-6}	0	6.36×10^{-6}	1.27×10^{-6}
	Night	2-5 m	0	7.61×10^{-3}	1.16×10^{-3}	2.98×10^{-3}	0	1.18×10^{-2}	2.35×10^{-3}
		5-20 m	1.85×10^{-5}	3.28×10^{-4}	6.45×10^{-5}	8.29×10^{-5}	4.85×10^{-5}	5.42×10^{-4}	1.08×10^{-4}
		> 20 m	0	0	0	0	0	0	0
8-3	Day	2-5 m			2.07×10^{-2}	1.91×10^{-2}	3.02×10^{-2}	1.16×10^{-1}	1.94×10^{-2}
		5-20 m			6.31×10^{-4}	1.02×10^{-3}	4.17×10^{-4}	3.97×10^{-3}	6.62×10^{-4}
		> 20 m			2.89×10^{-6}	7.29×10^{-6}	6.47×10^{-6}	3.03×10^{-5}	5.06×10^{-6}
	Night	2-5 m			9.49×10^{-2}	7.43×10^{-2}	6.77×10^{-2}	3.57×10^{-1}	8.92×10^{-2}
		5-20 m			1.34×10^{-3}	2.41×10^{-4}	7.99×10^{-5}	2.17×10^{-3}	5.41×10^{-4}
		> 20 m			2.41×10^{-5}	8.02×10^{-6}	4.56×10^{-6}	3.91×10^{-5}	9.78×10^{-6}
9-13	Day	2-5 m				1.76×10^{-4}	0	1.76×10^{-4}	4.40×10^{-5}
		5-20 m				2.69×10^{-5}	9.65×10^{-5}	2.37×10^{-4}	5.93×10^{-5}
		> 20 m				1.46 z 10^{-7}	8.50×10^{-8}	4.05×10^{-7}	1.01×10^{-7}
	Night	2-5 m				0	0	0	0
		5-20 m				1.89×10^{-6}	5.54×10^{-6}	1.24×10^{-5}	3.10×10^{-6}
		> 20 m				6.13×10^{-8}	2.44×10^{-7}	6.95×10^{-7}	1.74×10^{-7}
11-10	Day	2-5 m			0	0	0	0	0
		5-20 m			1.34×10^{-6}	2.89×10^{-6}	0	4.23×10^{-6}	1.41×10^{-6}
		> 20 m			4.03×10^{-8}	1.89×10^{-7}	1.79×10^{-7}	4.07×10^{-7}	2.04×10^{-7}
	Night	2-5 m			0	0	0	0	0
		5-20 m			2.30×10^{-6}	6.54×10^{-6}	0	8.84×10^{-6}	2.95×10^{-6}
		> 20 m			0	1.41×10^{-7}	2.55×10^{-7}	3.96×10^{-6}	1.98×10^{-6}

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

D A Y S E R I E S

DEPTH STRATUM (m sec)	TRANSECTS INSIDE THIRD POWERHOUSE FOREBAY TOTAL TARGETS	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TRANSECTS OUTSIDE THIRD POWERHOUSE 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.

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	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

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
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 (m sec)	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

DEPTH STRATUM (m sec)	TOTAL TARGETS DAY	WEIGHTING FACTORS	WEIGHTED TOTALS	%	TOTAL TARGETS NIGHT	WEIGHTING FACTORS	WEIGHTED TOTALS	%
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