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College of Fisheries
University of Washington
Seattle, Washington 98195

A FEASIBILITY STUDY OF HYDROACOUSTIC ASSESSMENT TECHNIQUES IN THE COLUMBIA RIVER AT HANFORD, WASHINGTON

by

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FINAL REPORT
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Richland, Washington

Approved

Roy E. Nakatani

Submitted September 20, 1977

Director

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RECOMMENDATIONS

The present report is based on field studies by Mr. R.L. Johnson of the Fisheries Research Institute, University of Washington, with primary assistance from ~~and~~ Mr. E. W. Lusty of Battelle Pacific Northwest Laboratories. The data were analyzed and a report was written by Mr. Johnson.

A few facts clearly emerge from this study:

1. The fish targets present in the Columbia River can be acoustically illuminated if they are 1 1/2-2 meters below the surface.

2. Targets were seen ~~not only~~ toward the surface, ~~in the central channel part but also~~ and in the deeper parts of the central channel ~~in addition to targets~~ and over the shelf areas.

3. There is a variable amount and, at times, substantial background noise caused by air bubbles ~~especially~~ and ~~also~~ various types of debris.

4. To study fish migrations in the river, we are suggesting that three up-looking transducers be planted on the river bottom on a line crossing the river upstream from the discharge. These transducers would be placed in the river center and as near as practical to each shore, with cables run to a data acquisition and recording system on shore. To help eliminate noise (from bubbles, debris, etc.), the transducer would be monitored continuously for a period beginning a few weeks before the major migrations and ending a few weeks after the migrations end. In this way, the ambient "background" return can be measured and removed from the data before analysis. Periodic sampling of

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these transducers and river conditions throughout a one-year period would yield useful data on ambient noise conditions as a function of various river parameters, especially discharge level, and would be useful for any future calibration studies.

5. To study the fish in the vicinity of the intake structure, we suggest that transducers be mounted on the structure itself, looking out (or across) horizontally, and that transducers be planted on the bottom around the intake. The exact locations and orientation of these transducers would be determined by the physical arrangement of the intake. These transducers would be monitored periodically over a one-year period (perhaps continuously at critical times) and correlated with data taken in other ways (in-plant monitoring, sample fishing, etc.). Ambient noise problems would be treated as described above.

6. Any acoustic assessment can give the number of targets or biomass. Some ideas on size distribution can be obtained from target strength analysis. But the species composition must be obtained from net sampling. One should therefore look at future hydroacoustic surveys initially as combined with a net sampling program until the pattern of species distribution has been established.

~~7. Alternatives and costs~~

INTRODUCTION

A hydroacoustic data acquisition and analysis system, developed at the University of Washington (Nunnallee 1973, 1975), has been successfully applied to assessment of populations of juvenile sockeye salmon, adult sockeye salmon, and other limnetic fish. It has not been known, however, whether this system is applicable to shallow lotic habitats such as the Columbia River near Hanford. There appear to be two limiting factors in the application of hydroacoustic techniques to lotic habitats: (1) the presence of excessive ambient noise; and (2) the difficulty associated with defining sample volume due to the absence of discernible fish targets in relation to ambient noise and with navigational difficulties.

Migrant juvenile chinook salmon (*Oncorhynchus tshawytscha*) is the species of primary interest in this study. Other studies have been conducted with regard to the out-migrant timing of juvenile chinook salmon utilizing conventional sampling techniques, i.e., seining, fyke netting, etc. Early data was gathered by Mains and Smith (1964) in which the migrants were observed to be moving in March and April (76%) and again in June and July (24%). No juvenile chinook salmon were observed in August. Another study conducted by Battelle-Northwest biologists in 1969 (Becker 1970) largely substantiated the results of Mains and Smith. They observed juveniles as early as mid-March, becoming abundant in the second week of April, and remaining so until mid-June. The abundance declined rapidly in July, and no juvenile chinook salmon were present in August.

The methods employed for collecting the above data have limited applicability in lotic habitats such as the Columbia River; therefore, an alternative is desirable. The purpose of this study has been to establish the feasibility of applying hydroacoustic assessment techniques to seaward migrant juvenile chinook salmon in the Columbia River near Hanford, Washington.

STUDY AREA

The study area is located at the northernmost end of the Hanford Reservation in Eastern Washington, associated with the plutonium production reactor at the 100-N area (Fig. 1). Large intake structures draw water into the plant from the adjacent Columbia River, which is subsequently discharged back into the central Columbia as heated effluent.

The stretch of main channel along the Hanford Reservation is the last free-flowing environment of the Columbia River as inundation by hydroelectric dams has stilled the remaining primordial spawning areas of the chinook salmon. This stretch extends 90 km, primarily within the boundaries of the Hanford Reservation, from Richland to Priest Rapids Dam. The river ranges from 400-500 m in width at the 100-N area with recorded flows, during the period of interest, ranging from $40.5\text{-}161.7 \times 10^3$ CFS (flows recorded at Priest Rapids Dam).

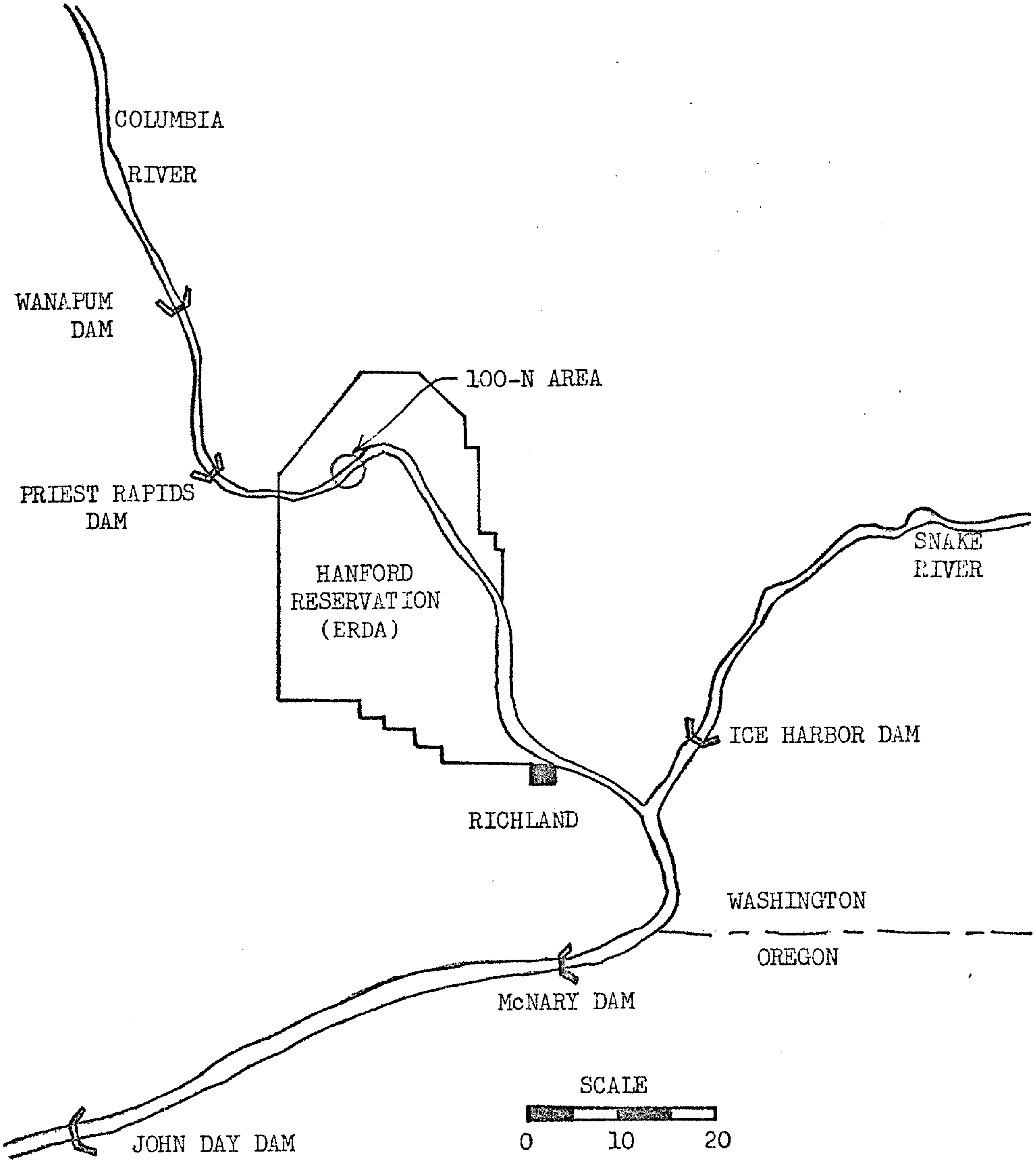

Fig. 1. Location of the 100-N area at Hanford, Washington.

MATERIALS AND METHODS

Hydroacoustic Data Acquisition System

The hydroacoustic data acquisition system utilized in this study has been described by Thorne, Nunnallee, and Green (1972) and Nunnallee (1973). Basically, the system is comprised of three separate components: a recording echo sounder, an interface amplifier, and a magnetic tape recorder (Fig. 2). The echo sounder used was a modified 105 kHz Ross 200A (transceiver and chart recorder). The single turn potentiometer was replaced with a vernier type ten-turn potentiometer to permit a more precise gain adjustment; an isolation amplifier was installed to prevent loading the receiver circuitry by the associated equipment; and a calibration oscillator was added to allow simple, rapid checks of the receiver gain. An interface amplifier is necessary in order to connect the signal output of the echo sounder to the signal input of the tape recorder since direct connection between the two is not possible due to bandpass limitations of the tape recorder. The echo sounder operates at a frequency of 105 kHz, while the maximum frequency response of the tape recorder at unity gain is about 8 kHz at the tape speed used during data collection (3 3/4 ips). The interface amplifier converts the 105 kHz output frequency of the echo sounder to a frequency of 5 kHz by using chopper and filter circuits. The gain of the interface amplifier is assumed to be unity for any signal amplitude within the operating limits of the circuitry. Once adjusted for unity gain, the echo signals at the output of the interface amplifier were recorded on a standard stereophonic tape recorder. The only modification necessary on the tape recorder was replacement of the input and output signal cable connectors on the rear panel with coaxial signal cable

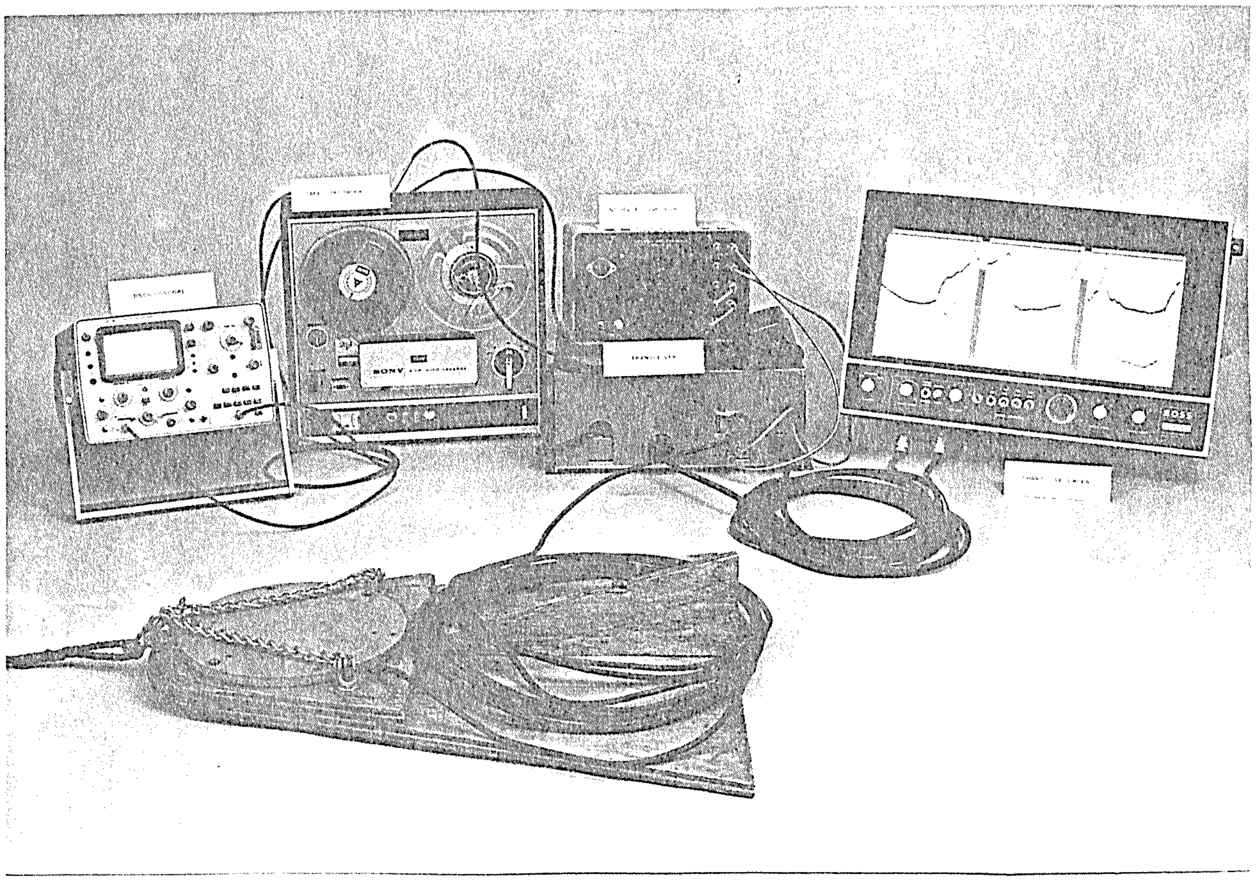

Fig. 2. The hydroacoustic data acquisition system.

connectors (BNC type) to prevent accidental cable disconnection during the survey.

Power to the system was provided by two lead acid batteries connected in parallel and converted to 115 VAC by an inverter. A Continental model inverter was used for this purpose providing 110 WATTS of 115 VAC power to the system. The two batteries in parallel allowed for approximately 4-5 hours of continuous survey time, after which they required charging.

Two types of transducers were used in conjunction with the river surveys. The primary transducer was a wide angle, single element barium titanate core producing a circular beam angle of approximately 28° at the -3 dB level, referenced to the acoustic axis. An alternate narrow beam, barium titanate array (7-element) transducer was incorporated during side-looking tests, characterized by a beam width of 7° at the -3 dB level, referenced to the acoustic axis.

The wide beam transducer was mounted in a hydrodynamically-designed towing vehicle which was suspended from a 2" x 4" beam strapped across the gunnels of the boat. A boat and driver were provided by Battelle-Northwest. The narrow beam transducer was attached to a ridged channel bar which allowed adjustment from horizontal aspect to approximately 45° down-looking (Fig. 3).

Transect Design

Exploratory sounding was conducted on April 27 to determine locations suitable for transecting. As a result, three transects were designated in the immediate vicinity of the 100-N area, to be referred to as transects A-C for the purpose of this study (Fig. 4). The transects were run orthogonal to the direction of flow on transects A and C; however, transect B

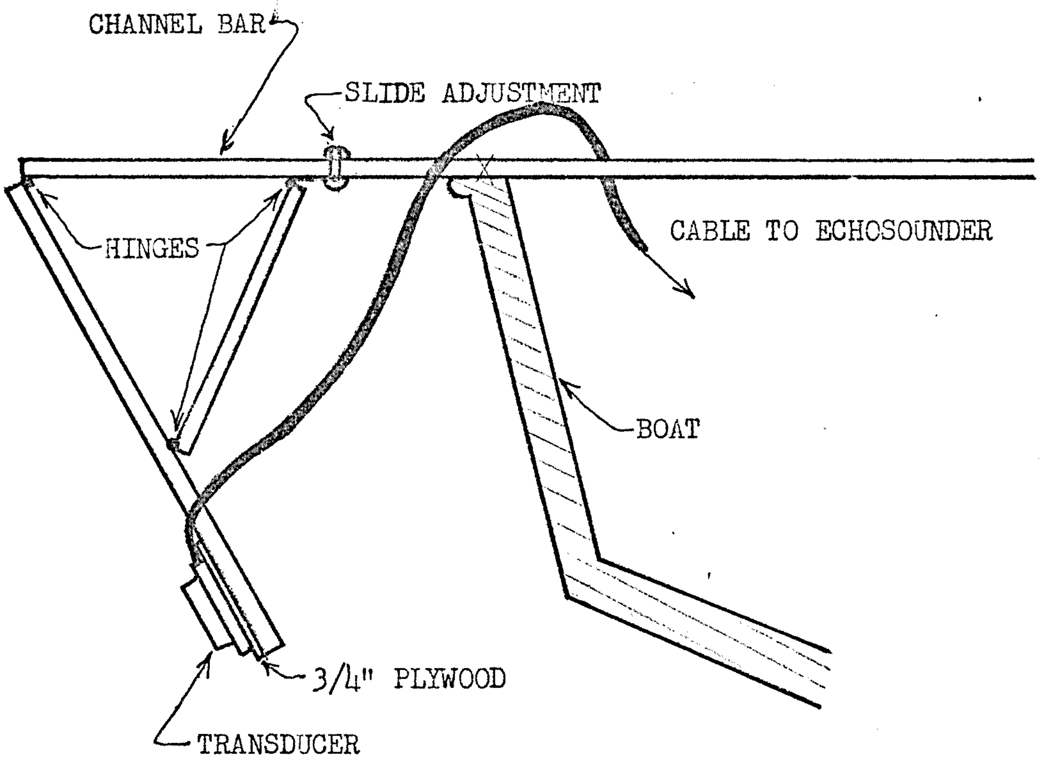

Fig. 3. Variable angle side-looking transducer mount used on transects 2-1 - 2-4.

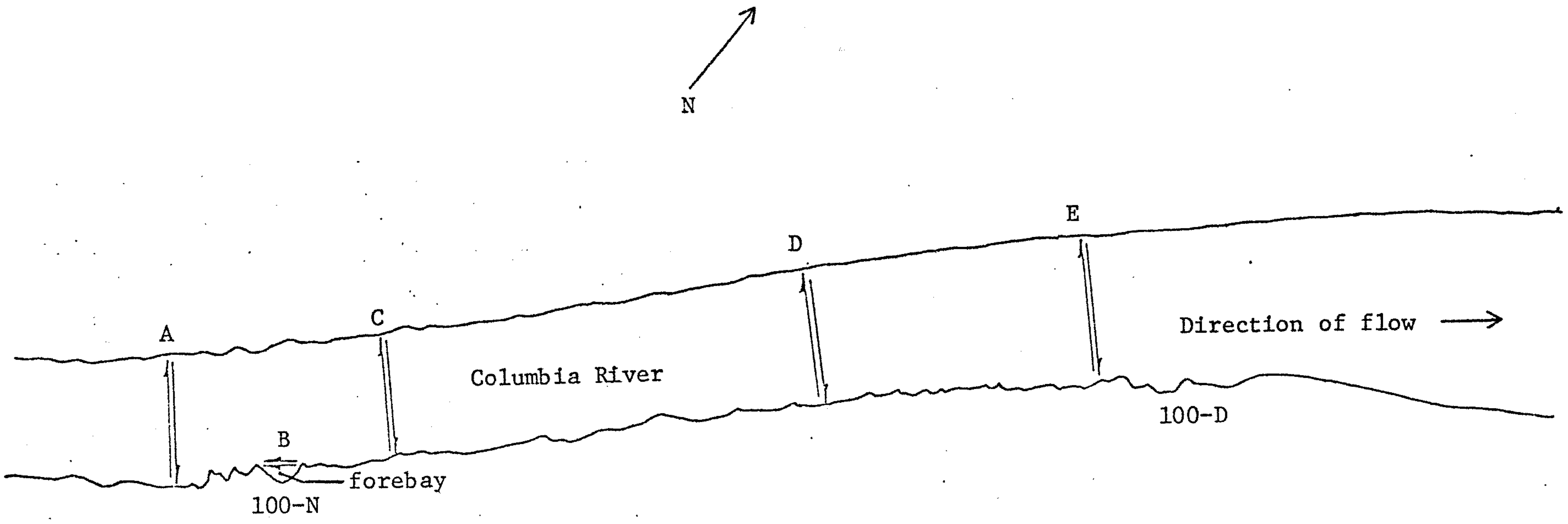

Fig. 4. Location of echosounding transects on the Columbia River near the 100-N area.

was run against the current in the 100-N forebay. As transecting commenced, it became apparent that transect C was of little use due to bubble noise from the HGP and 100-N mid-river discharges; therefore, an additional transect (X) was run further downstream to eliminate this noise. The downstream transect (D) was subsequently moved further downstream near the 100-D area to provide navigational reference points on either shore. This transect will be designated transect E. The remaining surveys were conducted at transects A, B, and E with consecutive replication of each.

Data Acquisition

Surveys were conducted both during daylight hours and at night in hope of discerning diurnal differences in the migratory behavior of the juvenile chinook salmon. The acoustic data was recorded on magnetic tape. Each transect was preceded by a brief voice log describing the transect, location, and system settings. Next, a calibration tone was recorded to account for any system drift. The transect was now ready to be executed. Each transect was replicated consecutively followed by boat speed measurements in both directions across the river using a Gurley current meter. The pertinent field data is tabulated in Table 1.

Data Analysis

For the purpose of data analysis, the water column was divided into five contiguous depth strata as follows: 1.46-2.93 m; 2.93-4.39 m; 4.39-5.85 m; 5.85-7.32 m; 7.32-8.78 m. Furthermore, the transects were divided into 300 sec or 150 sonic transmission segments for the purpose of counting the targets at various stages across the river.

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Table 1. Hydroacoustic field data for Columbia River surveys of April, May, and July, 1977 near Hanford

Date	Transect	Start time	Sounder gain	Boat speed (m/s)	Weather (Sky/wind)
4-28	1-1	1124	7.0	1.975	Partly cloudy/slight breeze
4-28	1-2	1140	7.0	--	Partly cloudy
4-28	1-3	1158	7.0	--	Partly cloudy
4-28	1-4	1202	7.0	1.235	Partly cloudy
4-28	1-5	1217	7.0	1.738	Partly cloudy
4-28	1-6	1225	7.0	1.674	Partly cloudy
4-29	1-7	1029	7.0	1.994	Partly cloudy
4-29	1-8	1035	7.0	2.024	Partly cloudy
4-29	*1-9	1058	7.0	1.957	Partly cloudy
4-29	*1-10	1060	7.0	--	Partly cloudy
4-29	1-11	1114	7.0	1.987	Partly cloudy
4-29	1-12	1121	7.0	1.966	Partly cloudy
4-29	1-13	2342	7.0	1.878	Partly cloudy
4-29	1-14	2348	7.0	2.012	Partly cloudy
4-30	1-15	0010	7.0	1.933	Partly cloudy
4-30	1-16	0016	7.0	1.957	Partly cloudy
4-30	*1-17	0025	7.0	1.842	Partly cloudy
4-30	*1-18	0030	7.0	--	Partly cloudy
4-30	1-19	0046	7.0	--	Partly cloudy
4-30	1-20	0052	7.0	--	Partly cloudy
5-24	2-1	0940	7.0	--	Partly cloudy
5-24	2-2	0958	7.0	--	Partly cloudy
5-24	2-3	1019	7.0	1.966	Partly cloudy
5-24	2-4	1030	7.0	1.885	Partly cloudy
5-24	2-5	1121	8.0	1.966	Partly cloudy/slight breeze
5-24	2-6	1129	8.0	2.061	Partly cloudy
5-24	*2-7	1147	8.0	--	Partly cloudy
5-24	2-8	1207	8.0	2.140	Partly cloudy
5-24	2-9	1215	8.0	2.061	Partly cloudy
5-24	*2-10	1239	8.0	2.073	Partly cloudy
5-24	*2-11	1241	8.0	--	Partly cloudy
5-24	2-12	2347	8.0	2.149	Partly cloudy/mod. wind
5-24	2-13	2354	8.0	2.060	Partly cloudy
5-25	*2-14	0039	8.0	--	Partly cloudy
5-25	*2-15	0042	8.0	--	Partly cloudy
5-25	2-16	0053	8.0	2.173	Partly cloudy
5-25	2-17	0100	8.0	2.262	Partly cloudy
5-25	2-18	0828	8.0	2.190	Partly cloudy/slight breeze
5-25	2-19	0834	8.0	2.150	Partly cloudy
5-25	*2-20	0848	8.0	--	Partly cloudy
5-25	*2-21	0852	8.0	--	Partly cloudy
5-25	*2-22	0910	8.0	2.178	Partly cloudy
5-25	2-23	0917	8.0	2.190	Partly cloudy
5-25	2-24	2325	8.0	2.354	Overcast/mod. wind
5-25	2-25	2335	8.0	2.299	Overcast

Table 1. Hydroacoustic field data for Columbia River surveys of April, May, and July, 1977 near Hanford - Continued

Date	Transect	Start time	Sounder gain	Boat speed (m/s)	Weather (Sky/wind)
5-26	*2-26	0025	8.0	--	Overcast
5-26	*2-27	--	--	--	Overcast
5-26	2-28	0030	8.0	--	Overcast
5-26	2-29	0037	8.0	--	Overcast
7-27	3-1	1800	7.5	2.564	Clear/calm
7-27	3-2	1806	7.5	2.564	Clear/calm
7-27	*3-3	1826	7.5	0.972	Clear/calm
7-27	*3-4	1829	7.5	--	Clear/calm
7-27	3-5	1837	7.5	2.496	Clear/calm
7-27	3-6	1842	7.5	2.638	Clear/calm
7-27	3-7	2212	7.5	2.260	Clear/calm
7-27	3-8	2218	7.5	2.002	Clear/calm
7-27	*3-9	2242	7.5	1.965	Clear/calm
7-27	*3-10	2245	7.5	--	Clear/calm
7-27	3-11	2254	7.5	2.262	Clear/calm
7-27	3-12	2259	7.5	2.211	Clear/calm

*Excessive bubble noise.

A counting threshold was established to account for one-way acoustic spreading loss. The counting threshold is illustrated in Fig. 5. Target counting was executed by recording the total number of insonifications above the target threshold. The resulting counts are tabulated in Appendix A.

The relative densities for each transect were determined by the method described by Nunnallee (1973), incorporating an effective pulse volume based on an assumed beam angle of 22°. The density of fish/1000 m^3 is derived by the following equation:

$$\text{Fish}/1000\ \text{m}^3 = \frac{(1000)(\text{total detections in stratum i})}{(\text{effective pulse volume stratum i})(\#\ \text{sonic transmissions})}$$

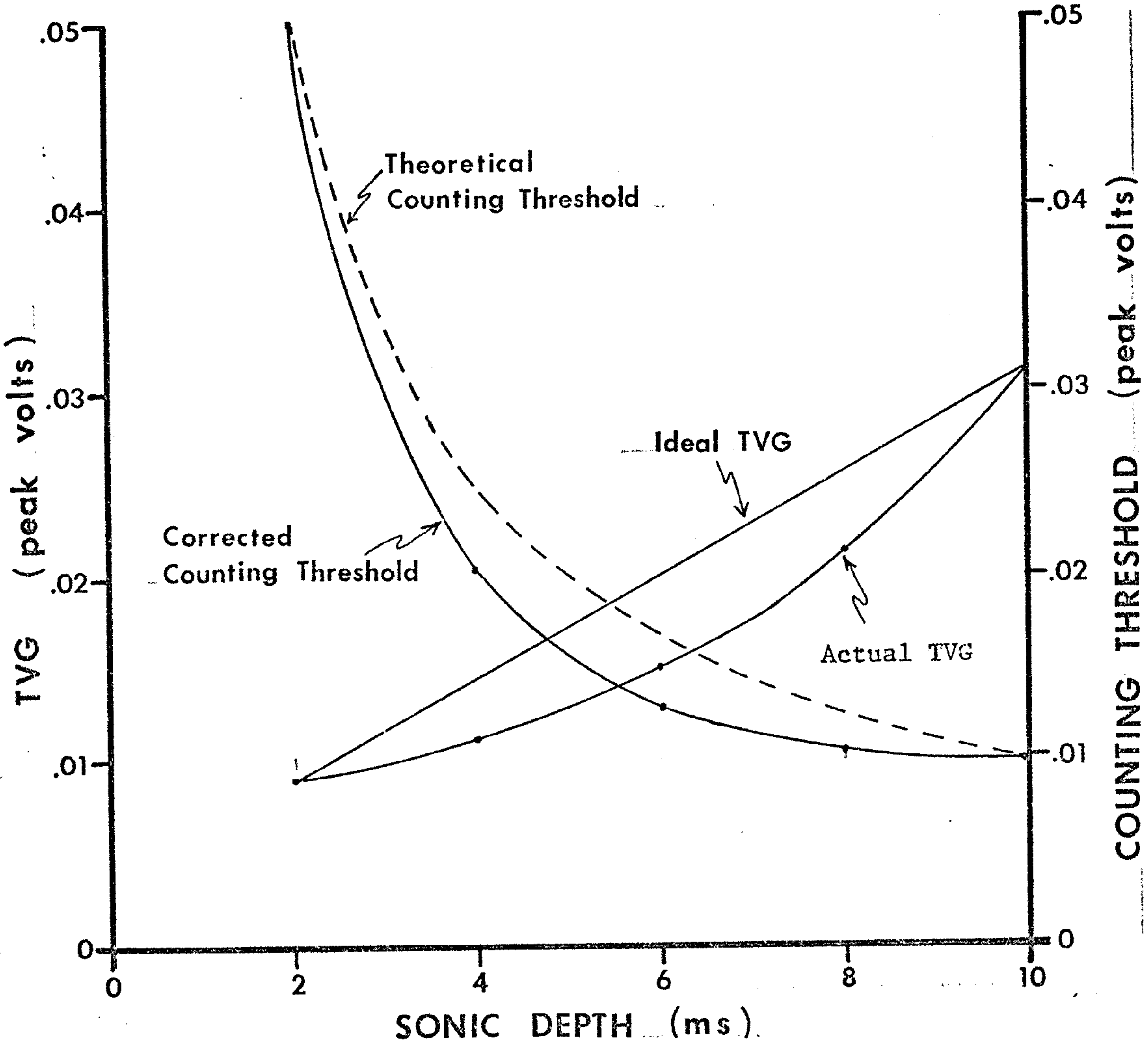

Fig. 5. Counting threshold referenced to a noise level of 0.01 volt peak at 10 milliseconds.

RESULTS

The densities of fish/1000 m^3 were determined manually based on an assumption of target homogeneity (all targets are chinook salmon) for each transect. Appendix A lists the densities in both fish/1000 m^3 and fish/are.[1] Numbered transects not listed in Appendix B were deleted due to excessive bubble noise on the surface or from the discharge of the HGP and 100-N ~~plant~~ facilities. Transects 2-1, 2-2, 2-3, and 2-4 represent the results of the side-looking narrow beam transducer test paralleling the 100-N forebay (2-1, 2-2) and at transect location A (2-3, 2-4). Consecutive replications were made with the wide beam down-looking transducer (transects 2-5 and 2-6) in which approximately one-third the density was observed. The narrow beam transducer would be more susceptible to bubble noise detection due to the higher concentration of sound energy, assumably accounting for the higher densities.

Obvious differences occurred between day and night surveys with the daytime densities being consistently higher than night densities. (Appendix B). This occurred despite unfavorable flow conditions, particularly during the May survey (Table 2). In addition, Fig. 6, a histogram of mean flows and densities, shows little correspondence between the change in flow and change in density, again particularly in May.

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[1] are = 100 m^2.

Table 2. Flow data collected from Priest Rapids Dam on the Columbia River for 1977

Date	Hour	Elevation (feet)	Temperature (^{o}C)	Flow (CFS x 10^3)	Mean flow (CFS x 10^3)
4-28	00	398.6	10.0	51.1	
	01				
	02	400.3	9.6	64.2	
	03				
	04	398.7	9.8	51.8	
	05				
	06	398.2	9.7	48.2	
	07				
	08	398.8	9.8	52.5	
	09				
	10	401.0	9.8	70.2	
	11				
	12	402.4	9.9	83.1	
	13				
	14	403.0	10.1	89.0	
	15				
	16	400.2	10.3	63.4	
	17				
	18	400.5	10.1	65.9	
	19				
	20	401.5	10.1	74.6	
	21				
	22	399.8	10.2	60.1	64.5
	23				
4-29	00	402.3	10.0	82.1	
	01				
	02	398.4	10.4	49.6	
	03				
	04	397.0	10.3	40.5	
	05				
	06	397.6	9.9	58.6	
	07				
	08	400.9	10.0	69.3	
	09				
	10	401.4	10.1	73.7	
	11				
	12	404.0	10.2	99.4	
	13				
	14	404.6	10.0	106.0	
	15				
	16	401.2	10.2	71.9	
	17				
	18	401.5	10.1	74.6	
	19				
	20	402.0	10.1	79.2	
	21				
	22	399.5	10.1	57.8	71.9
	23				

Table 2. Flow data collected from Priest Rapids Dam on the Columbia River for 1977 - Continued

Date	Hour	Elevation (feet)	Temperature (^{o}C)	Flow (CFS x 10^3)	Mean flow (CFS x 10^3)
5-24	00	403.8	11.6	97.2	
	01				
	02	403.4	11.3	93.0	
	03				
	04	403.6	11.4	95.0	
	05				
	06	402.8	11.3	87.0	
	07				
	08	404.4	11.2	103.8	
	09				
	10	404.7	11.5	107.1	
	11				
	12	406.2	11.4	124.8	
	13				
	14	408.6	11.4	156.1	
	15				
	16	407.2	11.3	137.4	
	17				
	18	408.0	11.3	147.8	
	19				
	20	409.0	11.4	161.7	
	21				
	22	406.9	11.3	133.5	120.4
	23				
5-25	00	406.2	11.5	124.8	
	01				
	02	406.2	11.5	124.8	
	03				
	04	405.3	11.5	114.0	
	05				
	06	405.8	11.5	120.0	
	07				
	08	405.8	11.5	120.0	
	09				
	10	404.8	11.6	108.2	
	11				
	12	402.7	11.8	86.0	
	13				
	14	402.0	12.0	79.2	
	15				
	16	403.9	11.6	98.3	
	17				
	18	406.2	12.0	124.8	
	19				
	20	407.3	12.0	138.7	
	21				
	22	408.6	11.8	156.1	116.2
	23				

Table 2. Flow data collected from Priest Rapids Dam on the Columbia River for 1977 - Continued

Date	Hour	Elevation (feet)	Temperature (°C)	Flow (CFS x 10^3)	Mean flow (CFS x 10^3)
5-26	00	407.7	11.7	143.9	
	01				
	02	407.0	11.8	134.8	
	03				
	04	404.3	11.6	102.7	
	05				
	06	402.4	11.7	83.1	
	07				
	08	405.2	11.7	112.8	
	09				
	10	405.5	11.9	116.4	
	11				
	12	406.9	11.9	133.5	
	13				
	14	405.2	12.0	112.8	
	15				
	16	405.6	12.0	117.6	
	17				
	18	405.8	11.8	120.0	
	19				
	20	406.4	11.8	127.2	
	21				
	22	408.2	11.6	150.5	121.75
	23				
7-27	00	402.6	17.0	85.0	
	01				
	02	400.2	17.3	63.4	
	03				
	04	399.8	17.6	60.1	
	05				
	06	399.7	17.7	59.3	
	07				
	08	399.6	17.8	58.6	
	09				
	10	401.5	17.8	74.6	
	11				
	12	404.9	17.5	109.3	
	13				
	14	405.8	17.6	120.0	
	15				
	16	404.4	17.5	103.8	
	17				
	18	404.6	17.5	106.0	
	19				
	20	405.2	17.9	112.8	
	21				
	22	403.8	18.1	97.2	87.5
	23				

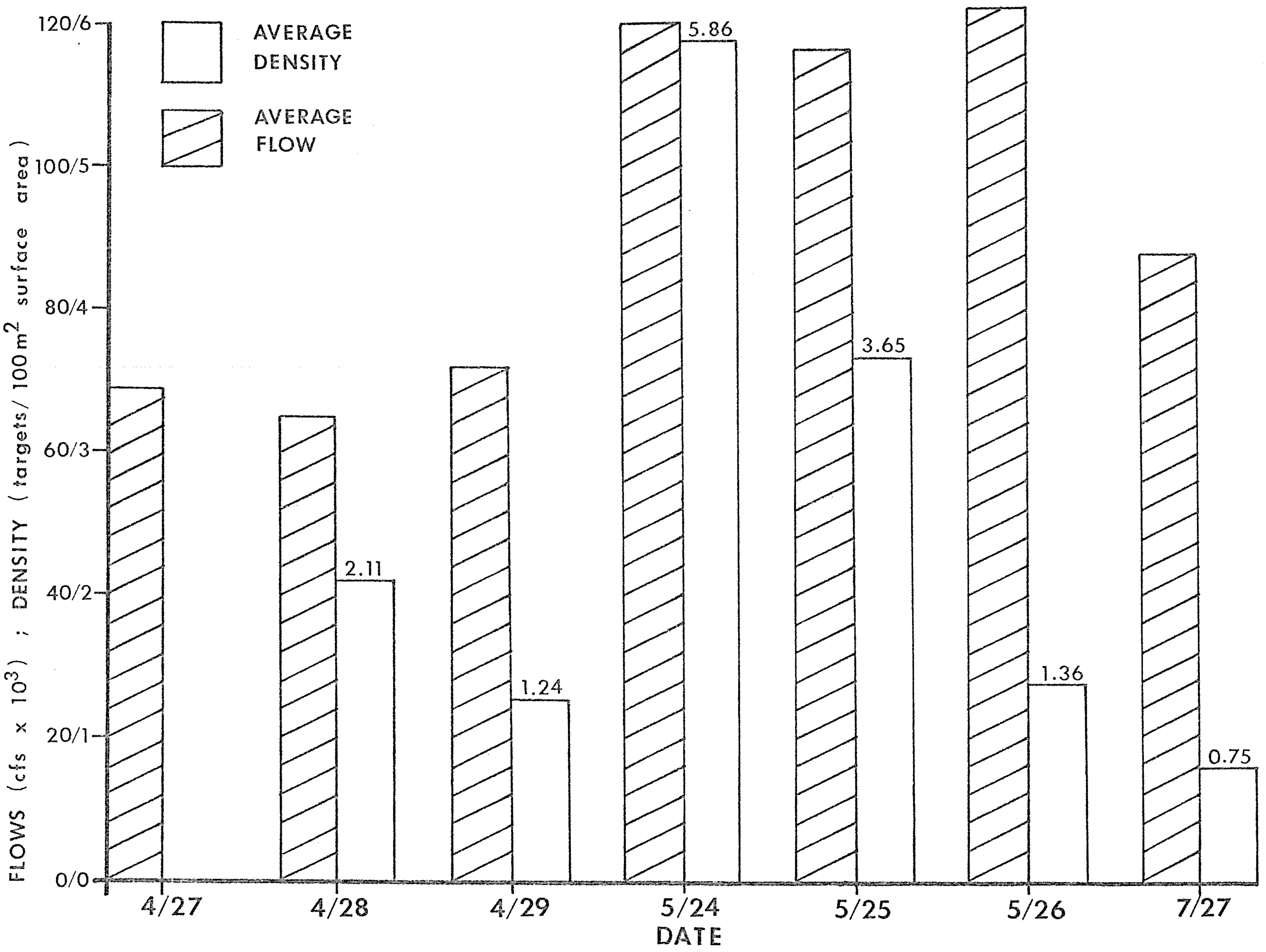

Fig. 6. Flows and target densities (targets/100 m^2) for Columbia River near Hanford.

DISCUSSION

The conventional hydroacoustic data acquisition system described earlier has limited applicability in the shallow lotic habitat of the Columbia River at Hanford. The presence of excess surface bubble noise, presumably generated by swift currents, is highly suspect. The densities of counted targets exceeding a counting threshold level referenced to ambient noise at the maximum depth of interest suggests the presence of bubbles in the upper two strata of the water column. In addition, about 30% of the transect sections were completely masked by bubble noise particularly in the 100-N forebay and downstream from the 100-N mid-river discharge.

Navigation on the Columbia River near the 100-N area also presented a problem. Due to the swift variable current, it was difficult to maintain a steady course while crossing the river. The currents not only varied between surveys but within a given transect. This phenomena makes good quantitative work difficult, as effective sample volume is dependent upon boat speed as described by Nunnallee (1973).

Conventional echosounding may yield relative distributional information, but the aspect of quantitative assessment appears clouded primarily by the presence of surface turbulence. Visual observations indicated that the juvenile chinook were primarily on the surface near shore. Other methods of sampling, i.e., electroshocking failed to produce any juveniles in the vicinity of the 100-N area in mid-river at transect 1. It appears as though the juveniles are not accessible by the down-looking echosounder since the minimum range of the sounder is approximately 1.5 m. Distributional information would then be derived primarily from those fish which ventured into the deeper waters by chance or current influence.

Side-looking tests conducted during the second survey (May) apparently indicated a higher susceptibility to surface noise using the conventional echosounding system. Therefore, further investigation and modification of existing equipment is needed.

. Acknowledgement

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APPENDICES

APPENDIX A

Target counts at 150 sonic transmission intervals across each transect.

APPENDIX A

Tape #1

Counts - Hanford Survey

Transect number	0-150	150-300	300-450	450-600	600-750	750-900	8-4-77 Average index fish/10^3 pings in parentheses
1	Noise	Noise	3 0 0 0 0 (20)	2 0 0 0 0 Stop 59 (34)			(27)
2	5 0 Start 73 3 0 1 (60)	Noise at 203	Noise Stop 111				(60)
3	5 Start 62 0 0 1 0 (40)	20 Noise					(40)
4	7 2 0 0 0 (60)	0 9 0 0 0 0 0					(30)
5	12 2 0 0 0 (93)	10 1 0 0 0 (73)	4 0 0 0 0 (27)	11 1 0 0 0 (80)	42 Too shallow		(68.25)
6	2 0 0 0 0 (13)	1 2 0 0 0 (20)	10 0 0 0 0 (67)	10 131 0 0 0 0 (76)			(44)
7	Noise	Noise	5 127 1 0 0 0 (47)				(47)
8	5 2 0 1 0 (53)	Noise	46 Noise				(53)
9	101 Noise						
10	108 Noise						

Tape #1 - Continued   Counts - Hanford Survey

Transect number	0-150	150-300	300-450	450-600	600-750	750-800	8-4-77 Average index fish/10^3 pings in parentheses
11	4 0 0 0 0 (27)	3 1 0 0 0 (27)	5 0 0 0 0 (33)	0 22 0 0 0 0 (0)			(21.75)
12	3 0 0 0 0 (20)	6 0 0 0 0 (40)	2 119 0 0 0 0 (17)				(25.67)
13	Noise	2 1 1 2 0 (33)	0 77 0 0 0 0 (0)				(16.5)
14	0 0 0 0 0 (0)	Noise	89 Noise				(0)
15	Noise	Noise	2 0 0 2 0 (27)	0 20 0 0 0 0 (0)			(13.5)
16	1 1 1 1 2 (40)	Noise	Noise				(20)
17	Noise						
18	Noise						
19	0 0 0 0 0 (0)	0 0 1 0 0 (7)	2 0 0 0 2 (27)	0 11 0 0 0 0 (0)			(8.5)
20	0 0 0 3 0 (20)	0 0 2 1 0 (20)	0 119 0 0 0 0 (0)				(13.33)

Tape #3

Counts - Hanford Survey

Transect number	0-150		150-300		300-450		450-600		Cal tone 600-750		.4 vp-p @ 50 ms 750-900	8-12-77 Average index fish/10^3 pings in parentheses
1	4		2		4	125						(26.33)
	0		0		2							
	0		0		0							
	0		0		0							
	0	(26)	0	(13)	0	(40)						
2	3		1		2		Noise	35				(15.67)
	0		0		1							
	0		0		0							
	0		0		0							
	0	(20)	0	(7)	0	(20)						
3	Noise											
4	Noise											
5	2		4		0	38						(37.67)
	1		0		0							
	0		1		0							
	0		5		0							
	0	(20)	4	(93)	0	(0)						
6	1		1									(46.5)
	2		1									
	2		0									
	3		0									
	4	(80)	0	(13)								
7	1		2		0	135						(11)
	1		0		1							
	0		0		0							
	0		0		0							
	0	(13)	0	(13)	0	(7)						
8	4		3		1		Noise		0	17		(18)
	0		2		1				0			
	0		0		0				0			
	0		0		0				0			
	0	(26)	0	(33)	0	(13)			0	(0)		
9	Noise											
10	Noise											

Tape #3 - Continued Counts - Hanford Survey

Transect number	0-150	150-300	300-450	450-600	Cal tone 600-750	.4 vp-p @ 50 ms 750-900	8-12-77 Average index fish/10^3 pings in parentheses
	0	3	0 65				
	1	1	0				
11	0	1	0				(20)
	0	1	0				
	0 (7)	2 (53)	0 (0)				
	1	0	0 22				
	1	0	0				
12	1	0	0				(9)
	0	0	0				
	1 (27)	0 (0)	0 (0)				

Tape #2

Counts - Hanford Survey

Transect number	0-150	150-300	300-450	450-600	Cal tone 1 v pp .1 v/div @ 50 ms 600-750	750-900	8-4-77 Average index fish/10^3 pings in parentheses
1	5 70						(127)
	9						
	5						
	0						
	0 (127)						
2	1 49						
	6 Noise on						
	1 last						
	0 half						
	0						
3	4	12	11	15	8 116		(148.4)
	11	9	7	9	4		
	2	5	2	5	0		
	0	0	1	3	0		
	0 (113)	0 (173)	0 (140)	0 (213)	0 (103)		
4	12	13	7	7 133			(151.75)
	8	5	12	7			
	7	6	2	2			
	0	0	0	1			
	0 (180)	0 (160)	0 (140)	2 (127)			
5	16	20	22	12	13 100		(222.6)
	15	18	14	10	1		
	1	3	6	4	0		
	0	1	1	2	0		
	0 (213)	0 (280)	0 (287)	1 (193)	0 (140)		
6	20	16	15	19			(189.75)
	3	7	10	13			
	2	3	1	3			
	1	1	0	0			
	0 (173)	0 (180)	0 (173)	0 (233)			
Cancel due to noise 7							
8 High degree of backgroud noise	22	22	30	18 182			(253)
	7	14	13	12			
	0	1	2	5			
	1	0	0	0			
	0 (200)	0 (247)	0 (300)	0 (265)			
9	16	29	28	13			(285)
	14	14	20	12			
	2	7	3	5	Noise		
	2	1	0	0			
	0 (227)	0 (340)	0 (340)	0 (233)			
Noise 10							

Tape #2 - Continued

Transect number	0-150	150-300	300-450	450-600	Cal tone 1 v pp .1 v/div @ 50 ms 600-750	750-900	8-4-77 Average index fish/10^3 pings in parentheses
11	Noise	3	3	4	3 92		(25.5)
		1	0	1	0		
		0	0	1	0		
		0	0	0	0		
		0 (27)	0 (2)	0 (40)	0 (33)		
12	2	6	4	Noise	Noise	Noise	(35.67)
	1	1	2				
	0	0	0				
	0	0	0				
	0 (20)	0 (47)	0 (40)				
13	Cancel due to noise						
14	Cancel due to noise						
15	0	1	0	3	48		(25)
	0	0	2	1			
	0	1	0	0	Noise		
	0	0	0	0			
	0 (0)	0 (13)	7 (60)	0 (27)			
16	2	2	1	0			(11.75)
	1	0	0	0			
	1	0	0	0			
	0	0	0	0			
	0 (27)	0 (13)	0 (7)	0 (0)			
17	19	22	16	9 76			(148)
	3	4	1	0			
	0	1	0	0			
	0	0	1	0			
	0 (147)	1 (187)	3 (140)	0 (118)			
18	23	20	17	2 31			(103.25)
	2 Noisy	9	6	0			
	1 back-	0	0	0			
	0 ground	4	0	0			
	0 (173)	0 (22)	0 (153)	0 (65)			
19	Cancel due to noise						
20	Cancel due to noise						

Tape #2 - Continued

					Cal tone 1 v pp .1 v/div @ 50 ms		Average index fish/10^3 pings in parentheses
Transect number	0-150	150-300	300-450	450-600	600-750	750-900	
21	Noise	Noise	Noise	103 Noise			
22	31 8 0 0 0 (260)	37 13 0 0 0 (333)	30 5 0 0 0 (233)	25 6 0 0 0 (207)	3 78 0 0 0 0 (38)		(214.2)
23	6 2 0 0 0 (53)	22 4 0 0 0 (173)	9 5 0 0 0 (93)	0 47 1 0 0 0 (21)			(85)
24	8 1 1 0 0 (67)	Noise	Noise	Noise	121 Noise		(67)
25	Cancel due to noise						
26	Cancel due to noise						
27	10 2 0 0 0 (80)	2 0 0 0 0 (13)	Noise	38 Noise			(46.5)
28	5 0 0 3 0 (53)	2 1 2 0 0 (33)	1 0 0 0 0 (7)	1 29 1 0 0 0 (69)			(40.5)

APPENDIX B

Target densities in targets/are and targets /1000 m^3

```
           HANFORD SURVEY,TAPE =1  TRANSECTS =  1-1  1-2  1-3  1-4  1-5  1-6  1-7  1-8 1-11

           TIME INTERVALS OF   VARIABLE DURATION

           DENSITY PER 100 SQUARE METERS SURFACE AREA

  DEPTH
(  METER)  INTERVAL:   1-1        1-2        1-3        1-4        1-5        1-6        1-7        1-8        1-11
*****************************************************************************************************************
 1 -  3              .84895    1.90418    1.92214    2.41734    2.66855    1.88960    3.91823    1.95911    1.17547
 3 -  4              .00000     .00000     .00000     .33084     .16637     .09672     .50196     .34659     .06588
 4 -  6              .00000     .34332     .00000     .00000     .00000     .00000     .00000     .00000     .00000
 6 -  7              .00000     .00000     .00000     .00000     .00000     .00000     .00000     .00000     .00000
 7 -  9              .00000     .07339     .00000     .00000     .00000     .00000     .00000     .00000     .00000
*****************************************************************************************************************
           TOTAL     .84895    2.32089    1.92214    2.74818    2.83492    1.98632    4.42019    2.30570    1.24135



           DENSITY PER 1000 CUBIC METERS

  DEPTH
(  METER)  INTERVAL:   1-1        1-2        1-3        1-4        1-5        1-6        1-7        1-8        1-11
*****************************************************************************************************************
 1 -  3             5.77520   12.95360   13.07580   16.44450   18.15340   12.85440   26.65460   13.32730    7.99640
 3 -  4              .00000     .00000     .00000    2.26600    1.13950     .66250    3.43810    2.37390     .45120
 4 -  6              .00000    2.35150     .00000     .00000     .00000     .00000     .00000     .00000     .00000
 6 -  7              .00000     .00000     .00000     .00000     .00000     .00000     .00000     .00000     .00000
 7 -  9              .00000     .50270     .00000     .00000     .00000     .00000     .00000     .00000     .00000
*****************************************************************************************************************
```

```
            HANFORD SURVEY,TAPE =1  TRANSECTS = 1-12 1-13 1-14 1-15 1-16 1-19 1-20

            TIME INTERVALS OF   VARIABLE DURATION

            DENSITY PER 100 SQUARE METERS SURFACE AREA

  DEPTH
 ( METER)  INTERVAL:   1-12         1-13         1-14         1-15         1-16         1-19         1-20
*******************************************************************************************************.
  1 -  3            1.37358       .41161       .00000       .64681       .37730       .21059       .00000
  3 -  4             .00000       .08414       .00000       .00000       .18663       .00000       .00000
  4 -  6             .00000       .06583       .00000       .00000       .11271       .06047       .13524
  6 -  7             .00000       .11197       .00000       .14628       .07557       .00000       .19504
  7 -  9             .00000       .00000       .00000       .00000       .13083       .07430       .00000
*******************************************************************************************************
           TOTAL    1.37358       .67356       .00000       .79309       .88305       .34536       .33028



            DENSITY PER 1000 CUBIC METERS

  DEPTH
 ( METER)  INTERVAL:   1-12         1-13         1-14         1-15         1-16         1-19         1-20
*******************************************************************************************************
  1 -  3            9.34410      2.80010       .00000      4.40010      2.56670      1.43260       .00000
  3 -  4             .00000       .57630       .00000       .00000      1.27830       .00000       .00000
  4 -  6             .00000       .45090       .00000       .00000       .77200       .41420       .92630
  6 -  7             .00000       .76170       .00000       .99510       .51410       .00000      1.32680
  7 -  9             .00000       .00000       .00000       .00000       .89610       .50890       .00000
*******************************************************************************************************
```

```
             HANFORD SURVEY.TAPE =2  TRANSECTS =  2-1  2-2  2-3  2-4  2-5  2-6  2-8  2-9 2-12

             TIME INTERVALS OF   VARIABLE DURATION

             DENSITY PER 100 SQUARE METERS SURFACE AREA

  DEPTH
(  METER)  INTERVAL:        2-1           2-2           2-3           2-4           2-5           2-6           2-8           2-9          2-12
*************************************************************************************************************************************
  1 -   3                14.32749       4.38597      15.07103      14.37663       4.97385       4.77002       6.45259       4.87922       1.00141
  3 -   4                 9.17277       9.35997       4.84562       5.18236       1.37509        .89124       1.21307       1.17237        .06091
  4 -   6                 2.60360        .79703       1.61883       1.40661        .22064        .15569        .00000       1.94548        .03647
  6 -   7                  .00000        .00000        .41952        .10262        .07256        .04798        .00000        .00000        .00000
  7 -   9                  .00000        .00000        .00000        .22897        .01917        .00000        .00000        .00000        .00000
*************************************************************************************************************************************
           TOTAL         26.10386      14.54297      21.95501      21.29719       6.66130       5.86494       7.66566       7.99707       1.09879



             DENSITY PER 1000 CUBIC METERS

  DEPTH
(  METER)  INTERVAL:        2-1           2-2           2-3           2-4           2-5           2-6           2-8           2-9          2-12
*************************************************************************************************************************************
  1 -   3                97.46590      29.83650     102.52400      97.80020      33.83570      32.44910      43.89520      33.19200       6.81230
  3 -   4                62.82720      64.10940      33.18920      35.49560       9.41840       6.10440       8.30870       8.02990        .41720
  4 -   6                17.83290       5.45910      11.08790       9.63430       1.51120       1.06640        .00000      13.32520        .24980
  6 -   7                  .00000        .00000       2.85390        .69810        .49360        .32640        .00000        .00000        .00000
  7 -   9                  .00000        .00000        .00000       1.56830        .13130        .00000        .00000        .00000        .00000
*************************************************************************************************************************************
```

```
          HANFORD SURVEY,TAPE =2  TRANSECTS = 2-13 2-16 2-17 2-18 2-19 2-23 2-24 2-25 2-28

          TIME INTERVALS OF   VARIABLE DURATION

          DENSITY PER 100 SQUARE METERS SURFACE AREA

  DEPTH
(  METER)  INTERVAL:   2-13         2-16         2-17         2-18         2-19         2-23         2-24         2-25         2-28
*************************************************************************************************************************************
 1 -  3             1.08665       .27167       .43816      5.54530      5.56492      7.68629      3.07700      2.18789      1.62998
 3 -  4              .13896       .08350       .03595       .27727       .63780      1.02153       .38992       .11462       .09705
 4 -  6              .00000       .01952       .02424       .03365       .03957       .00000       .00000       .11443       .00000
 6 -  7              .00000       .00000       .00000       .03024       .16341       .00000       .00000       .00000       .00000
 7 -  9              .00000       .11573       .00000       .09786       .00000       .00000       .00000       .00000       .00000
*************************************************************************************************************************************
           TOTAL    1.22562       .49042       .49834      5.98432      6.40569      8.70782      3.46693      2.41695      1.72703



          DENSITY PER 1000 CUBIC METERS

  DEPTH
(  METER)  INTERVAL:   2-13         2-16         2-17         2-18         2-19         2-23         2-24         2-25         2-28
*************************************************************************************************************************************
 1 -  3             7.39220      1.84810      2.98070     37.72310     37.85660     52.28770     20.93200     14.88360     11.08830
 3 -  4              .95180       .57190       .24620      1.89910      4.36850      6.99680      2.67070       .78510       .66470
 4 -  6              .00000       .13370       .16600       .23050       .27100       .00000       .00000       .78380       .00000
 6 -  7              .00000       .00000       .00000       .20570      1.11160       .00000       .00000       .00000       .00000
 7 -  9              .00000       .79270       .00000       .67030       .00000       .00000       .00000       .00000       .00000
*************************************************************************************************************************************
```

```
                 HANFORD SURVEY,TAPE =2  TRANSECTS = 2-29

                 TIME INTERVALS OF   VARIABLE DURATION

                 DENSITY PER 100 SQUARE METERS SURFACE AREA

   DEPTH
 (  METER)  INTERVAL:   2-29
**********************************************************************************************************************************
  1 -   3              .76405
  3 -   4              .06693
  4 -   6              .06763
  6 -   7              .09514
  7 -   9              .00000
**********************************************************************************************************************************
            TOTAL      .99374



                 DENSITY PER 1000 CUBIC METERS

   DEPTH
 (  METER)  INTERVAL:   2-29
**********************************************************************************************************************************
  1 -   3             5.19760
  3 -   4              .45840
  4 -   6              .46320
  6 -   7              .64720
  7 -   9              .00000
**********************************************************************************************************************************
```

```
          HANFORD SURVEY,TAPE =3  TRANSECTS =  3-1  3-2  3-5  3-6  3-7  3-8 3-11 3-12

          TIME INTERVALS OF   VARIABLE DURATION

          DENSITY PER 100 SQUARE METERS SURFACE AREA

  DEPTH
 ( METER)  INTERVAL:    3-1        3-2        3-5        3-6        3-7        3-8        3-11       3-12
**************************************************************************************************************
  1 -  3              .95881     .50412     .75230     .27167     .28233     .69806     .35129     .12616
  3 -  4              .10324     .03967     .05392     .15997     .10324     .19323     .11112     .05514
  4 -  6              .00000     .00000     .05390     .12607     .00000     .00000     .05999     .06097
  6 -  7              .00000     .00000     .29068     .17005     .00000     .00000     .05273     .00000
  7 -  9              .00000     .00000     .17701     .18237     .00000     .00000     .08851     .05100
**************************************************************************************************************
           TOTAL     1.06204     .54379    1.32781     .91013     .38556     .89129     .66363     .29327



          DENSITY PER 1000 CUBIC METERS

  DEPTH
 ( METER)  INTERVAL:    3-1        3-2        3-5        3-6        3-7        3-8        3-11       3-12
**************************************************************************************************************
  1 -  3             6.52250    3.42940    5.11770    1.84810    1.92060    4.74870    2.38970     .85820
  3 -  4              .70710     .27170     .36930    1.09570     .70710    1.32350     .76110     .37770
  4 -  6              .00000     .00000     .36920     .86350     .00000     .00000     .41090     .41760
  6 -  7              .00000     .00000    1.97740    1.15680     .00000     .00000     .35870     .00000
  7 -  9              .00000     .00000    1.21240    1.24910     .00000     .00000     .60620     .34930
**************************************************************************************************************
```