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BENDIX CORPORATION 1984 MODEL SIDE-SCANNING SONAR COUNTER EXPERIMENTS IN THE SUSITNA RIVER, 1984

By:

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April 1987

ALASKA DEPARTMENT OF FISH AND GAME
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Commissioner

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Studies were conducted to determine the capability of a new (1984 model) side-scanning sonar counter developed by Bendix Corporation for enumerating adult salmon (*Oncorhynchus* spp.) in the Susitna River. The objectives of the studies were to assess salmon migration in the water column above the volume sampled by existing side-scanning sonar counters, determine the maximum counting range of the new counter at the study site, assess horizontal distribution of fish targets from shore, and compare salmon enumeration capabilities of the new and existing sonar counters within the normal counting range of the existing counters. Results indicated that an average of 5.9% of the fish counted were in the upper portion of the water column, and not available for counting with the existing equipment. In addition, 32% of the fish enumerated were offshore of the counting range of the existing counter. Changes in temporal variation in horizontal distribution of fish were also detected. Comparison of counts recorded by the existing and new counters within the same counting range resulted in a 1% difference in total count.

KEY WORDS: Side-scanning sonar counters, salmon enumeration, migration, horizontal distribution, Susitna River.

INTRODUCTION

The Susitna River is located in the northern portion of Cook Inlet and drains an area exceeding 49,000 km^2 (Figure 1). The salmon stocks of the Susitna River drainage are major contributors to the Cook Inlet sport and commercial salmon harvest. Five species of Pacific salmon (*Oncorhynchus* spp.) spawn within the drainage and the system is widely thought to be the largest single producer of pink salmon *(O. gorbuscha)*, chum salmon *(O. keta)*, coho salmon *(O. kisutch)*, and chinook salmon *(O. tshawytscha)* in Cook Inlet.

Determining total escapement into the Susitna River is complicated by the glacial nature, multiple channels, and constantly changing riverbed morphology of the mainstream river and major tributaries. A variety of escapement monitoring programs have been conducted on the river since 1963 (Tarbox et al. 1983), culminating in the operation of two Bendix Corp. 1978 model side-scanning sonar counters at Susitna Station beginning in 1978.

Results of hydroacoustic studies conducted from 1978 through 1983 are documented in the Alaska Department of Fish and Game, Division of Commercial Fisheries Technical Data Report series (Tarbox et al. 1983; King and Tarbox 1983; and King and Tarbox 1984). Additional comment on the accuracy of Susitna River escapement estimates can be found in Thompson and Barrett (1983) and King (1984). Conclusions drawn to date relative to the ability of the 1978 model counter to accurately assess escapement into the Susitna River at Susitna Station in past years are generally summarized below.

1) The distribution of fish targets from shore has exceeded the 18 m counting range of the existing 1978 model Bendix side-scanning sonar counter and associated substrate. This has resulted in a low estimate of the total number of fish migrating past the counting site.

2) The degree of shore orientation varied by species. The resultant sonar counts apportioned to species reflected only the proportion of each species caught by fishwheels sampling within 9 m of shore.

3) Salmon migration has been influenced by a number of factors, including river morphology and water discharge level. These factors affect salmon swimming behavior and may result in fish migration through areas of the water column not monitored with hydroacoustic equipment.

Prior to the 1984 field season, Bendix Corporation was contracted by the Alaska Department of Fish and Game to develop a side-scanning sonar counter with long range counting capabilities which did not require the use of the existing 18 m tubular aluminum substrate. Because of the enumeration problems encountered in previous years, Susitna Station was chosen as a test site for the Bendix Corp. experimental long-range substrateless side-scanning sonar counter. This report describes the results of preliminary testing of the 1984 counter in the Susitna River at Susitna Station from 19 July through 24 July 1984. Objectives of the study were to:

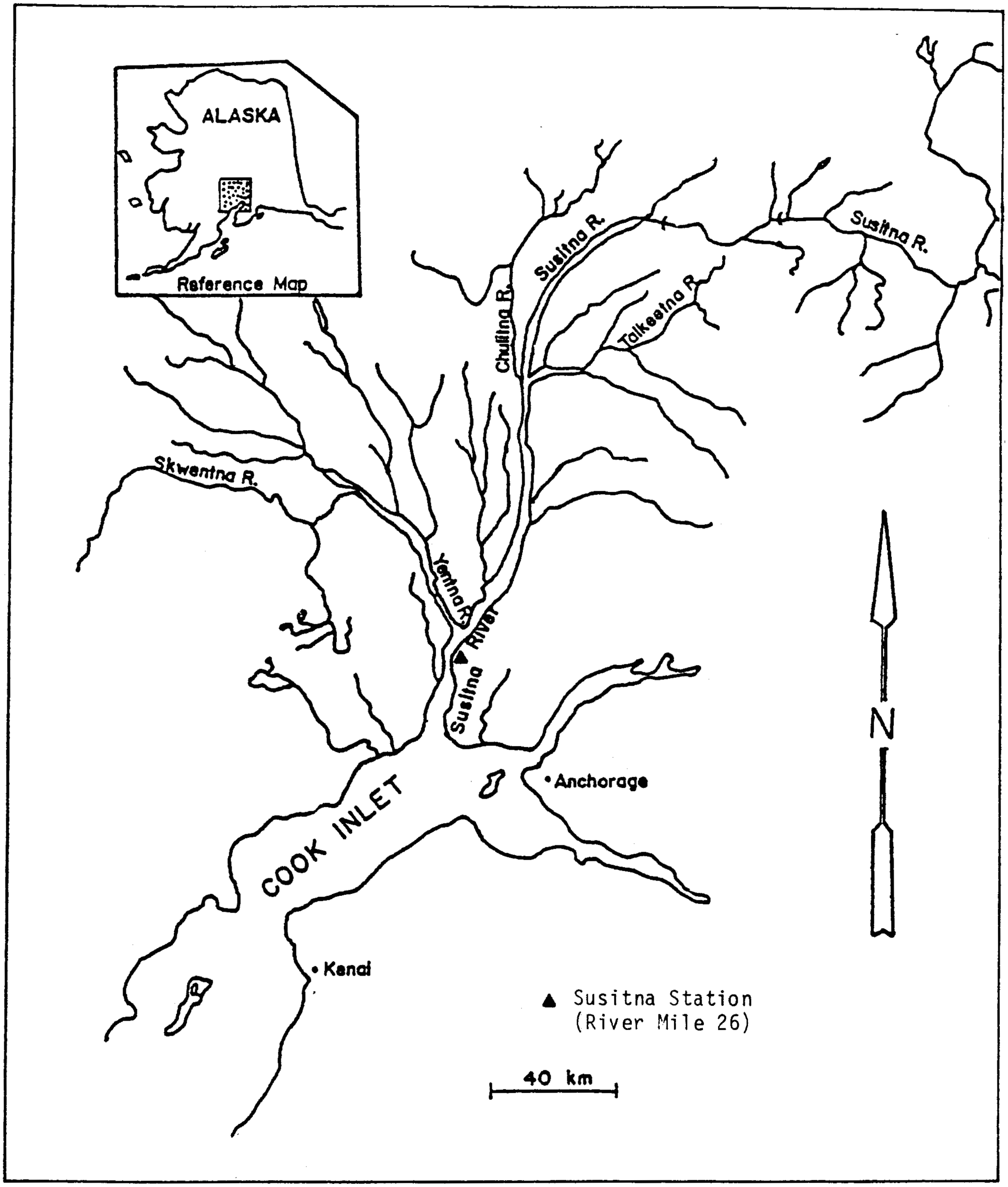

Figure 1. Susitna River drainage and major tributaries.

1) Assess salmon migration in the water column above the volume normally sampled by the 1978 counter;

2) Determine maximum counting range of the 1984 counter at the study site, and assess horizontal distribution of fish targets within that counting range; and

3) Compare salmon enumeration capabilities of the 1978 and 1984 counters within the normal electronic counting range of the 1984 counter.

METHODS

Equipment Description

The 1978 and 1984 side-scanning sonar counters, as with all sonar systems, convert electrical energy into acoustical energy (sound waves) and provide information about underwater targets by measuring returning echoes. Both counters consist of an electronic sounder/processor, transducer, oscilloscope, 12 v batteries, solar panels, and necessary electric cable. The effective angles of detection are 2 degrees and 4 degrees. Pulse width of the transmitted sound wave is 100 microseconds, and the pulse repitition rate and source level (level of voltage applied to the transducer) are variable.

Both sounder/processors enumerate targets on the basis of returning echo strength and number of echoes returned. The processor accumulates and prints the counts on tape, in one-hour intervals, for each of the linear sectors. Each sector is defined as one-twelfth (1978 model) or one-sixteenth (1984 model) of the total counting range.

The 1978 counter was designed to be used in conjunction with an 18 m tubular aluminum substrate (Figure 2). The substrate provides an aiming surface, and forces fish into the ensonified area as they attempt to migrate upstream. The substrate is made up to three 5.6 m long sections with two 0.9 m couplers that slide together with a 0.5 m overlap forming a single unit. Offshore target and onshore transducer housing sections terminate the assembly ends. The substrate design includes two vortex shedding fins which provide stability in the current and aid in positioning the substrate relative to the bottom. The substrate rests on the stream bottom perpendicular to the channel axis. Aiming is accomplished by manually adjusting knobs attached to the transducer which control vertical and horizontal movement.

The 1984 counter is fitted with two transducers which can be used individually, or alternately fired for variable time periods. Different transducer housings were developed at Susitna Station for each transducer in 1984 (Figure 3). One transducer was attached to the vertical arm of a tripod which rested on the streambed. Vertical and horizontal movement (aiming) of the transducer after deployment required the use of two electric rotators manufactured by Biosonics, Inc. This transducer was referred to as the tripod mounted transducer. The second transducer was placed in a stationary nearshore housing which could be moved vertically in the water column, and

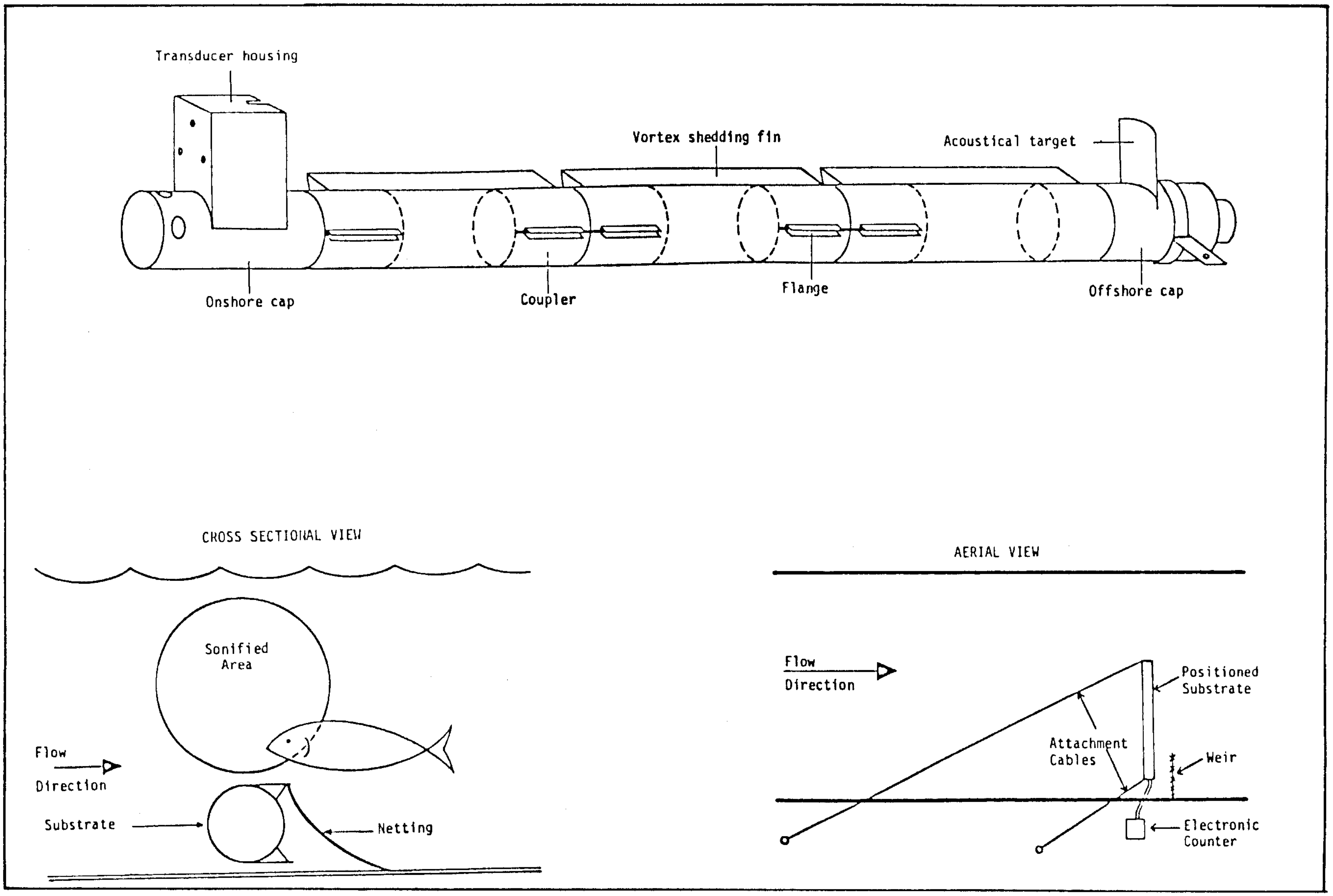

Figure 2. Bendix Corporation side-scanning sonar substrate.

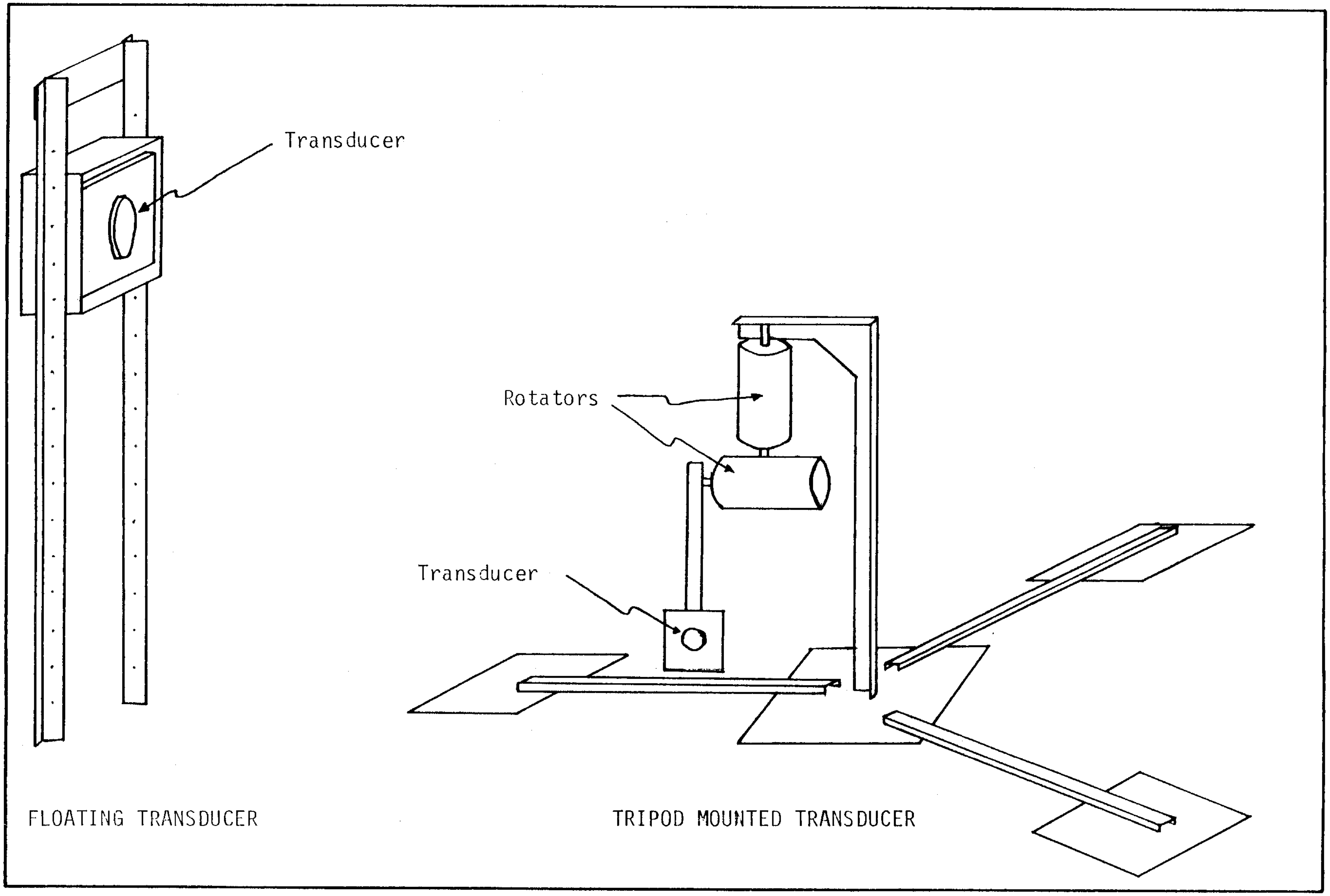

Figure 3. Substrate designs used to deploy Bendix Corp. 1984 model side-scanning sonar transducers in the Susitna River at Susitna Station, 1984.

aimed in a manner similar to that of the 1978 model. This transducer was designated the floating transducer.

Additional differences between the counters includes a maximum source level (volts peak to peak) for the 1984 counter of 240 v as contrasted to the maximum 60 v available from the 1978 counter. The 1984 counter also includes a "rock inhibitor" function (Menin, pers. comm.). This feature eliminates counts from any stationary targets which return a target strength in excess of -38 db. The blanking affect, which also includes fish passing through the area, has a resolution of 0.4% of the counting range for each stationary target encountered. Field modification of the counter at Susitna Station allowed observers to monitor targets passing through the inhibited area via the oscilloscope.

The accuracy of both counters is assessed by comparing the ratio of visual (oscilloscope) counts to processor counts. This ratio can then be used to adjust the pulse repetition rate of either counter. In addition, the 1984 model counter is constructed to allow manual adjustment of the fish criteria (number of hits required to count a target as a fish) within each linear sector.

A more detailed description of the theory of operation of the Bendix Corporation side-scanning sonar counter (pre-1984 models), and a description of the electronic equipment are presented in Gaudet (1983). Procedures for deployment and operation of the 1978 model side-scanning sonar counter are described in Bendix Corp. (1980). Comparable information for the 1984 model side-scanning sonar counter can be found in Bendix Corp. (1984).

Study Site

The 1978 counter tubular aluminum substrate was deployed at a site on the east bank of the Susitna River near Susitna Station originally established in 1978 (Figure 4). The 1984 counter floating transducer housing and tripod mounted transducer housing were deployed approximately 3 m and 9 m downstream of the 1978 model counter substrate, respectively (Figure 5).

River bottom profiles were established at the 1978 counter and 1984 counter tripod mounted transducer installation sites. A staff gauge was installed at the study site to monitor water depth changes. A current velocity profile was developed along a transect from shore starting at the 1978 counter and ending at a distance of 123 m offshore. Stations were selected at 6 m to 15 m intervals and velocity measurements were taken at the surface, bottom, and four mid-water intervals with depths equal to 20, 40, 60, and 80% of the distance from surface to bottom.

The distance from shore at which each piece of equipment was deployed was primarily a function of bottom topography and water depth. The 1978 counter requires a minimum water depth of 0.5 m at the transducer for correct operation. At the Susitna Station east bank sonar site, this meant deployment at a distance offshore of 3.4 m for the water levels experienced during the study period. In order to ensonify the water volume immediately above that of the 1978 counter via the 1984 counter and floating transducer, it was necessary to place this transducer in water approximately 0.6 m deep. At the study site this meant placement of the floatation transducer housing at a

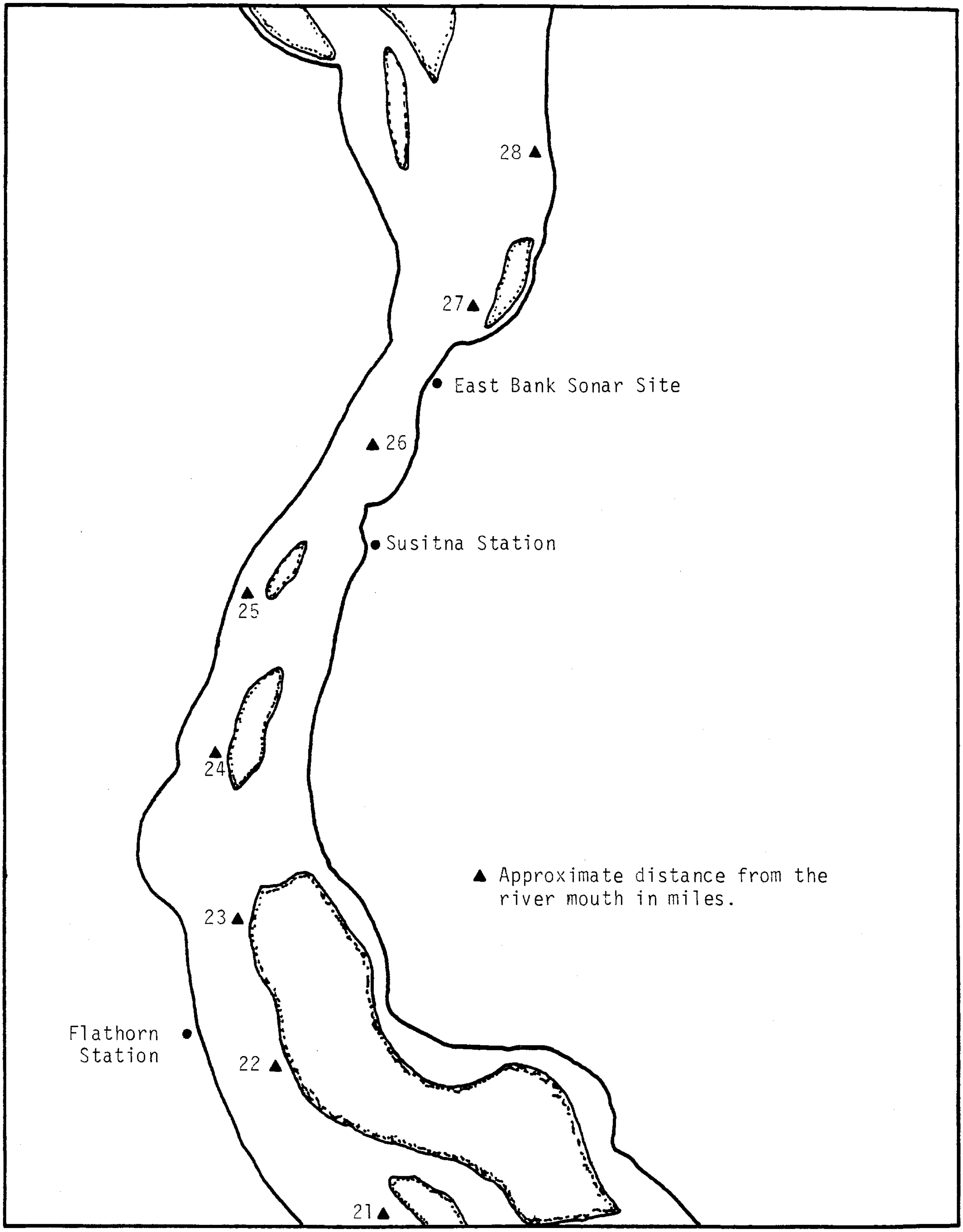

Figure 4. Upper Cook Inlet Commercial Fisheries Division lower Susitna River sampling site locations, 1984.

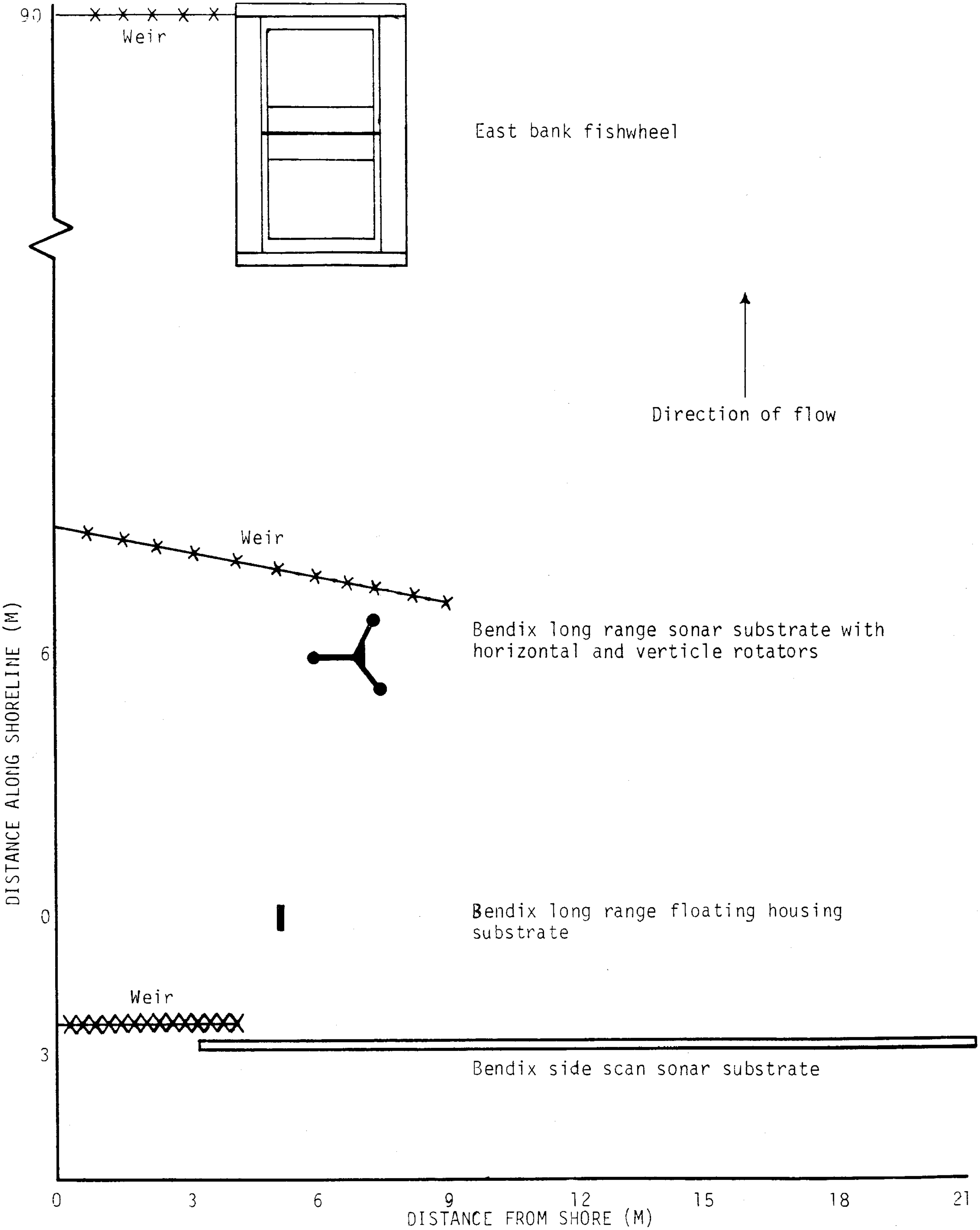

Figure 5. Approximate location of sampling equipment on the east bank of the Susitna River at Susitna Station, 1984.

distance offshore of 5 m. Placement of the 1984 counter tripod mounted transducer required a flat or gradually changing straight bottom configuration which was available only at a distance offshore of 7.3 m.

Sampling Design

During the study period of 19 July through 24 July, three tests were designed to meet the project objectives. Each test required a different sampling design.

Vertical Distribution of Targets:

The 1984 counter transducer mounted in the floating housing was fixed at a distance from the riverbed bottom calculated to be immediately above the depth of the transducer mounted in the 1978 counter substrate housing. The transducer was then aimed to cover the water column above that ensonified by the 1978 counter. Data collected with this transducer were compared with counts from the 1978 counter for the same hours to assess the degree of salmon migration in the upper water column.

In order to aim the 1984 counter floating transducer so that it was ensonifying the area above that of the 1978 counter (Figure 6), the following steps were taken.

1) After aiming the 1978 counter transducer, the maximum beam width at the end of the 18 m electronic counting range was calculated (0.64 m).

2) This maximum beam width was added to the depth required for the substrate (0.2 m) for a total distance from the bottom ensonified by the 1978 model counter at an 18 m electronic counting range of 0.84 m.

3) Total water depth at the end of the 18 m electronic counting range of the 1978 counter was 3.4 m.

4) The 1984 counter floating transducer was aimed to hit the water surface at the same distance from shore as the end of the 1978 counter beam. At the resultant electronic counting range of 16.5 m, the beam width was calculated to be 0.57 m.

5) The maximum width of the area ensonified by both counters was then calculated to be 1.41 m (the sum of the distance from river bottom to top of area ensonified by the 1978 counter, and the distance from the water surface to the bottom of the area ensonified by the 1984 counter).

6) This left a depth of approximately 2 m between the areas ensonified by the two counters at the end of the counting range.

7) The number of turns necessary to reaim the 1984 counter floating transducer down vertically so that it was ensonifying the area immediately above that of the 1978 counter was calculated (0.2 m per turn, or 10 turns for 2 m).

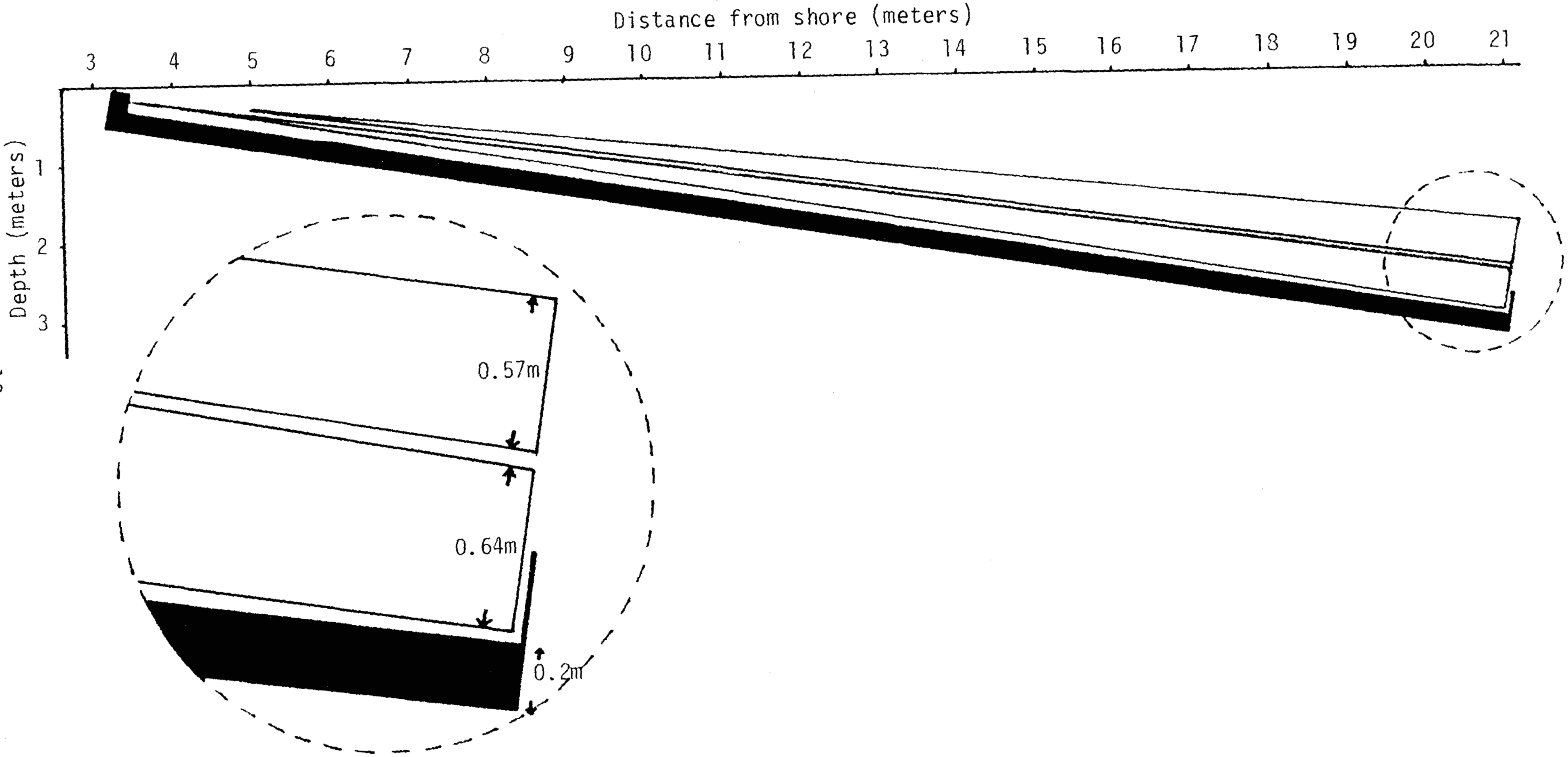

Figure 6. Relative size and location of transducer beams used to collect fish vertical distribution data in the Susitna River at Susitna Station, 1984.

Operation of the 1978 counter encompassed a distance from shore of 21.4 m (sum of the 18 m electronic counting range and 3.4 m distance from shore to the transducer). Since the 1984 counter was positioned an additional 1.6 m offshore, only counts from within an electronic counting range of 16.5 m were used for a total counting distance from shore of 21.5 m. Data analysis consisted of computation of proportion of counts in the upper water column, and linear regression analysis to determine if the proportion of targets in the middle strata of the water column was dependent on the density of targets in the bottom strata of the water column.

Horizontal Distribution of Targets:

The 1984 counter and tripod mounted transducer were used to collect information on horizontal distribution of fish targets offshore to the maximum counting range available for this counter at the study site. The maximum counting range was established by initially setting the counting range to it's maximum of 150 m, aiming along the bottom, and determining the point at which a characteristic bottom trace was no longer visible. At the selected study site, this distance equated to an electronic counting range of 33 m. Because the transducer was deployed 7.3 m from shore, the actual distance from shore that the counter was able to monitor fish passage was 40.3 m.

Data were grouped in blocks of 24 hours or less and the proportion of targets calculated by sector. Data were then subjected to a chi-square test to determine if apparent changes in distribution of counts by sector over time were significant.

Comparison of 1978 and 1984 Model Counters:

Counts recorded by the 1978 and 1984 counters set to enumerate fish targets within the same distance from shore and during the same hour periods were collected to evaluate the performance of the 1984 model counter relative to the 1978 model counter and associated substrate currently in use at Susitna Station.

Comparison of fish targets enumerated by the 1978 counter and 1984 counter with the tripod mounted transducer at equal distances from shore required different electronic counting ranges for each counter, because the transducers were deployed at different distances from shore. The 1978 counter electronic counting range was set at 24.4 m and the 1984 counter electronic counting range was set at 20.5 m. When these electronic counting ranges were active, the distance from shore monitored by each counter was approximately 27.8 m.

In all hourly testing periods, both counters used the alternate counting mode (alternating 2 degree and 4 degree transmissions), and were calibrated prior to and immediately after each test or set of tests. In addition, each hourly test period was scheduled to begin on the hour to correspond with the normal 1978 counter data printout schedule.

In order to prevent biasing of comparative data, attending biologists worked independent of each other as much as possible. Tests were conducted and results recorded without comparison of data or discussion of results.

Data collected were subjected to Wilcoxen's distribution-free signed rank test (Zar 1974) to test statistically the hypothesis of no difference in total fish targets counted by the counters during comparative testing periods.

RESULTS AND DISCUSSION

Bottom profile measurements taken in the vicinity of the Susitna Station east bank sonar site are given in Table 1. The two profiles are plotted out to 44 m in Figure 7. Negligible difference in the two profiles offshore of approximately 20 m was attributed to a relatively uniform bottom profile throughout the area.

Current velocity measurements taken on 22 June are presented in Table 2. The staff gauge reading of 0.12 m for that day fell within the range of staff gauge readings during the study period of 0.11 m to 0.29 m. Changes in current velocity on the river bottom are generally related to changes in discharge. Changes in current velocity at Susitna Station in the summer months probably are not measurable at changes in discharge of less than approximately 600 cubic meters per second (m^3/sec), or a change in depth greater than 0.3 m (Lavine, pers. comm.). The total change in discharge at Susitna Station during the study period was estimated to be approximately 175 m^3/sec (provisional data, USGS), with a maximum daily change of approximately 100 m^3/sec increase from 21 July to 22 July and 100 m^3/sec decrease from 22 July to 23 July. Since discharge levels did not vary appreciably during the period of study, changes observed in fish distribution and behavior were not thought to be a response to changes in current velocity.

A total of 30 hours of data were collected simultaneously by both the 1978 counter and the 1984 counter with the transducer mounted in the floating housing. These data were used to assess the degree of migration which occurred in the water column above that monitored by the 1978 counter. Results are presented in Table 3. Of the 16,707 total fish counted by both counters, 991 (5.9%) were enumerated by the 1984 counter. The proportion of counts enumerated in the area not normally monitored by the 1978 counter ranged from 1.2% to 14.5%.

These proportions probably represent minimum levels of migration in the water column above that normally monitored by the 1978 counter since there remained an unmonitored cross-sectional area of the water column near the surface. This unmonitored portion of the water column was calculated to extend to a depth from the surface of approximately 0.4 m at the floating transducer to approximately 2.0 m at the 18 m counting range. Also, because the two beams were not in the same vertical plane, the percentage of fish above the 1978 counter beam may have been higher due to the affect of the weir and substrate on fish behavior.

Counts from the 1984 counter were plotted against counts from the 1978 counter to illustrate possible correlation between the two data sets (Figure 8). The apparent correlation was confirmed by subjecting the data to a simple linear regression analysis. The calculated r value of 0.73 was greater than the tabled r value (alpha = 0.05, 28 df) of 0.361, leading to rejection of

Table 1. Bottom profile measurements taken at the Susitna Station east bank sonar site, Susitna River, 1984.

Distance from Shore (m)	Depth (m) Transect 1	Depth (m) Transect 2	Distance from Shore (m)	Depth (m) Transect 1	Depth (m) Transect 2
0.8	0.2		47.2	4.0	3.8
1.5	0.3	0.0	48.8	3.7	3.9
2.3	0.5	0.5	50.3	4.0	3.8
3.1	0.7	0.5	51.8	4.0	4.0
3.8	0.7	0.9	53.3	3.9	3.7
4.6	0.8	1.0	54.9	4.0	3.9
5.3	0.9	1.4	56.4	4.1	3.8
6.1	1.0	1.5	57.9	3.9	3.9
7.6	1.5	1.9	59.4	4.0	3.8
9.1	1.8	2.2	61.0	3.6	3.9
10.7	1.8	2.5	62.5	3.6	3.7
12.2	2.0	2.5	64.0	3.7	3.9
13.7	2.3	2.6	65.5	3.8	4.0
15.2	2.5	2.7	67.1	3.8	3.7
16.8	2.8	2.7	68.6	3.7	3.7
18.3	3.4	3.0	70.1		3.9
19.8	3.4	3.2	71.6		3.7
21.3	3.6	3.4	73.2		3.7
22.9	3.7	3.6	74.7		3.7
24.4	3.8	3.8	76.2		4.0
25.9	4.0	3.8	77.7		4.1
27.4	3.9	3.8	79.3		4.2
29.0	4.0	3.8	80.8		4.2
30.5	3.8	3.7	82.3		4.5
32.0	3.8	3.7	83.8		4.7
33.5	4.0	4.2	85.3		4.7
35.0	4.1	4.2	86.9		4.9
36.6	3.9	4.0	88.4		5.1
38.1	3.9	4.0	89.9		5.3
39.6	4.0	4.1	91.4		5.5
41.2	4.0	3.9	93.0		5.6
42.7	4.0	3.7			
44.2	3.7	3.8			
45.7	3.8	3.8			

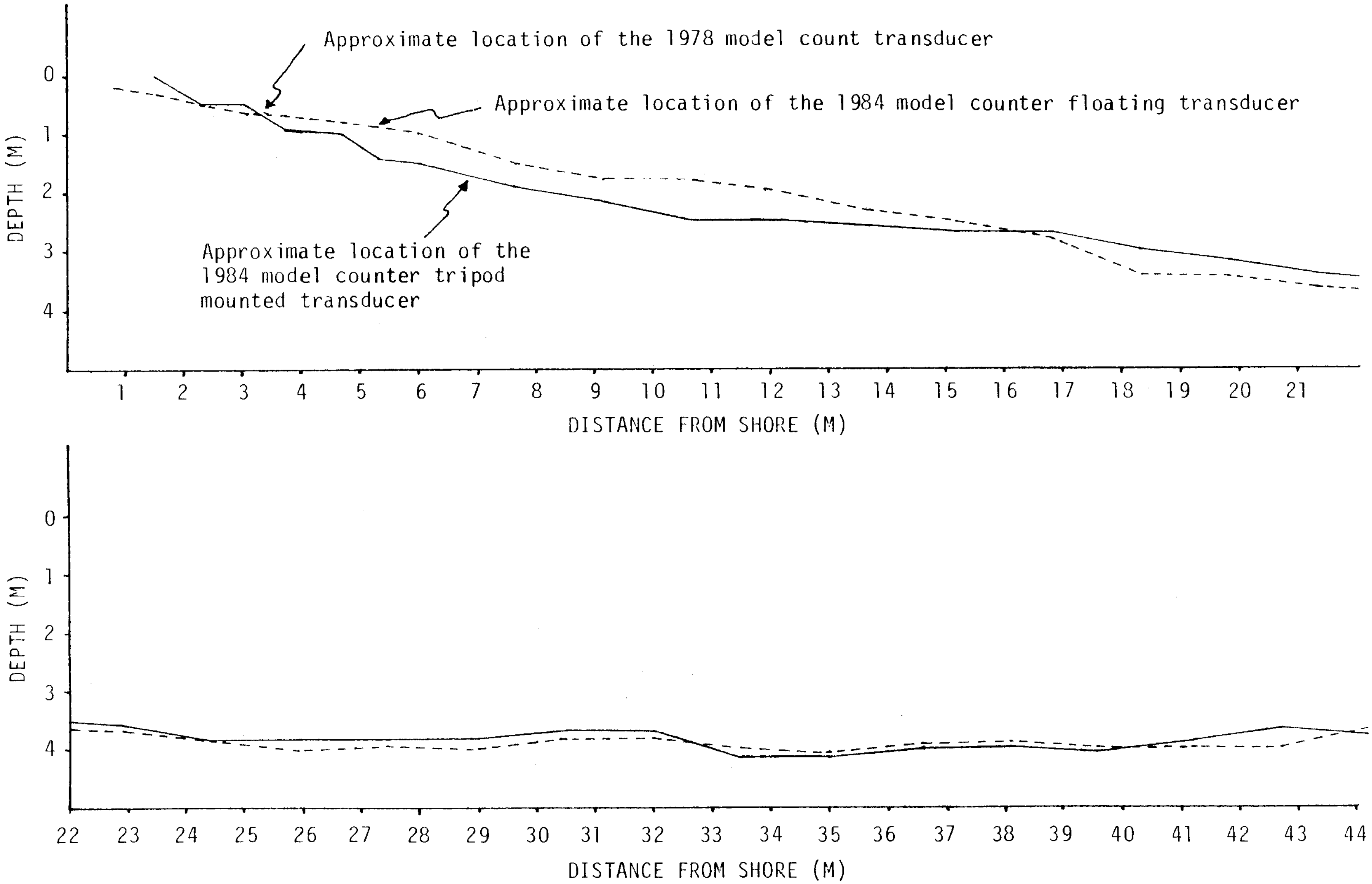

Figure 7. Bottom profiles measured at the Susitna Station east bank 1978 model counter (----) and 1984 model counter (——) transducer locations.

Table 2. Current velocity in meters per second at selected distances from shore in the Susitna River at the Susitna Station east bank sonar site, 1984[1/].

Depth of Velocity Reading	Distance from shore (m)									
	3	9	18	33	48	63	78	93	108	123
0.3-m from surface	0.15	0.73	1.10	1.22	1.13	1.19	1.13	1.04	0.79	0.82
0.2d-m		0.73	1.04	1.22	0.91	1.13	1.01	0.91	0.79	0.79
0.4d-m		0.73	1.04	0.94	1.01	0.94	0.94	0.76	0.64	0.73
0.6d-m		0.73	0.85	0.88	0.91	0.79	0.70	0.61	0.58	0.76
0.8d-m		0.67	0.85	0.70	0.61	0.67	0.67	0.46	0.58	0.58
0.3-m from bottom	0.15	0.18	0.67	0.43	0.40	0.40	0.43	0.37	0.24	0.40
Total Depth (d)-m	0.60	2.10	3.70	4.60	4.90	5.20	5.20	6.70	7.30	7.90

1/ Measurements taken on 22 June 1984. Staff gauge reading - 0.1 m.

Table 3. Comparison of fish targets enumerated in the middle and bottom strata of the water column during selected time periods between 19 July and 24 July 1984 at Susitna Station.

Date	Hour	Middle Strata	Bottom Strata	Combined	Percent in Middle Strata
19 July	1300	8	296	304	2.6
20 July	1100	4	238	242	1.7
	1200	4	327	331	1.2
	1900	23	362	385	6.0
	2000	17	393	410	4.1
	2100	13	459	472	2.8
21 July	1900	16	479	495	3.2
	2000	10	484	494	2.0
	2100	12	460	472	2.5
22 July	0100	22	553	575	3.8
	0300	31	660	691	4.5
	0500	42	711	753	5.6
	0700	40	647	687	5.8
	0900	47	591	638	7.4
	1900	38	627	665	5.7
	2100	65	628	693	9.4
	2300	43	538	581	7.4
23 July	0100	91	634	725	12.6
	0300	32	662	694	4.6
	0500	50	757	807	6.2
	0700	40	606	646	6.2
	0900	30	445	475	6.3
24 July	0100	57	753	810	7.0
	0300	142	838	980	14.5
	0500	41	741	782	5.2
	0700	10	520	530	1.9
	0900	30	457	487	6.2
	1800	5	301	306	1.6
	2000	4	298	302	1.3
	2200	24	251	275	8.7
Total		991	15716	16707	5.9

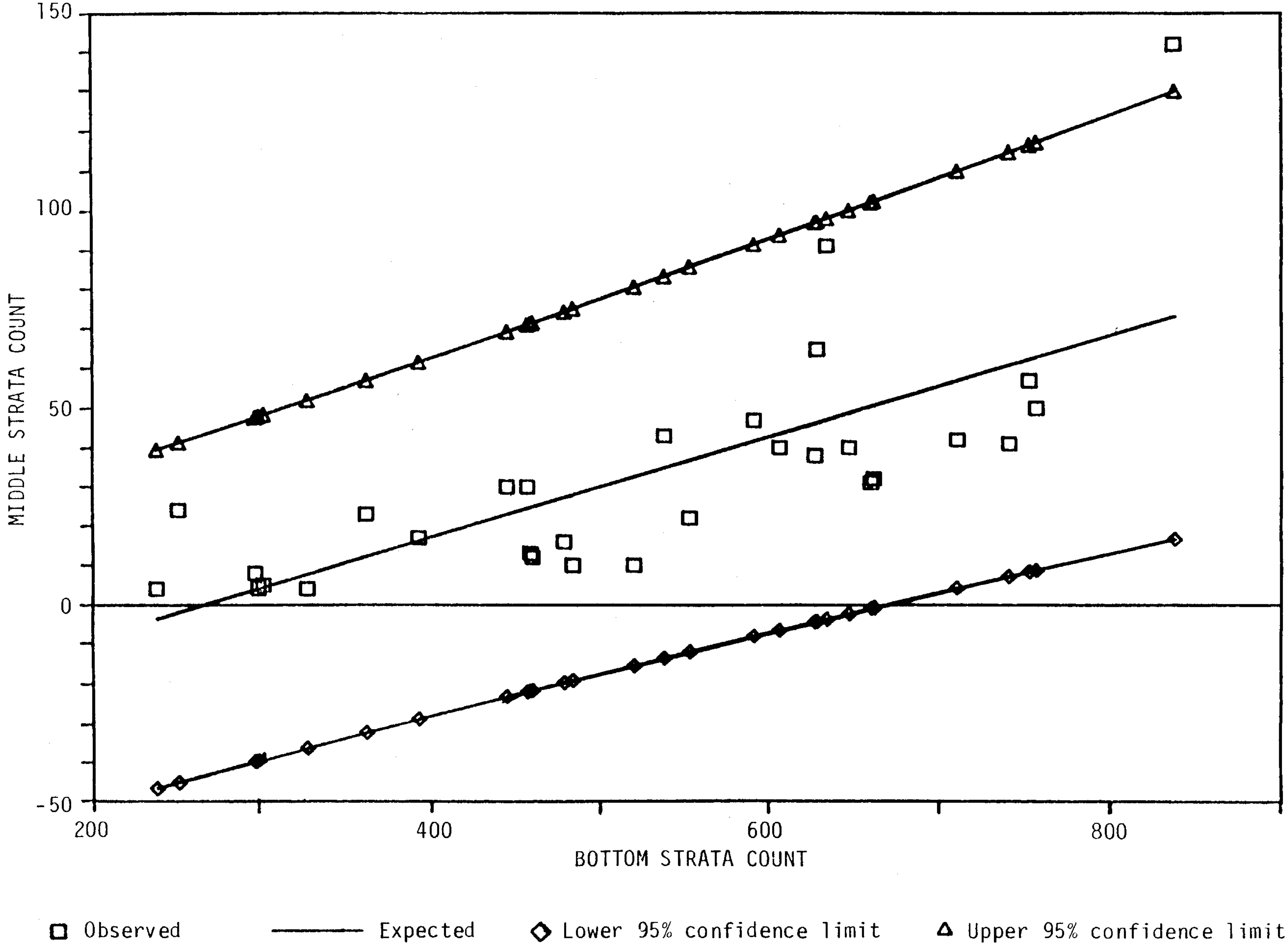

Figure 8. Regression analysis of the number of fish per hour recorded simultaneously in the bottom and middle strata of the water column on the east bank of the Susitna River at Susitna Station, 19 July through 24 July 1984.

the hypothesis (H_0: r = 0). Analysis of variance calculations provided an f-statistic of 32.86, indicating that variance of the y-values over the range x-values was equal. However, only 54% of the total variability was due to the regression. This was interpreted to mean that, although there was a positive correlation between fish density within the two water column strata, unidentified sources of error limit the value of the regression slope for predictive purposes. In contrast, Nickerson and Gaudet (1984) found no correlation between fish densities at various strata in the water column at their Yukon/Kuskokwim River test sites.

Horizontal distribution of fish target from shore was assessed via the 1984 counter using the tripod mounted transducer. The selected electronic counting range of 33 m, beginning 7.3 m offshore provided information on targets migrating within 40.3 m of the shoreline. The 33 hours of data gathered in this counting mode are summarized in Table 4.

A total of 32,275 fish targets were recorded, with 43% of the targets passing between 21.4 m and 28.3 m from shore (sectors six through eight). Seventy-five percent of the targets were counted offshore of the distance typically monitored by the 1978 model counter (21.4 m).

However, recognition of offshore migration in previous years at Susitna Station led to an adaptation of the counting technique for the 1978 counter used initially in 1983 (King and Tarbox 1984). This technique, which was continued in 1984, periodically extended the electronic counting range to a known distance beyond the normal counting range (the normal counting range is defined as the offshore target end of the substrate or 18 m), and a ratio of counts within the normal counting range to counts outside the normal counting range was generated. This ratio was then applied to the daily count to more accurately estimate the daily escapement. Fish targets recorded by the 1984 counter outside of the adjusted counting range of the 1978 counter (28.3 m) contributed approximately 32% of the total counts during the 33 hours of long-range counting.

The change in distribution of counts from shore over time was analyzed by grouping hourly counts in contiguous blocks starting in late evenings and ending in mid-morning of the following day (Table 4 and Figure 9). The proportion of targets by sector varied significantly between periods, with calculated chi-square value of 32,275 greater than the chi-square value from the table of 61.63 (alpha = 0.05, 45 df). Significant differences were also detected in the proportion of fish by sector between successive periods.

The reasons for the temporal variation in horizontal distribution of fish from shore were not readily apparent. Changes in species composition at Flathorn Station and Susitna Station (Table 5) appeared to consist primarily of an increase in the number of pink salmon, a species previously thought to be shore oriented in the Susitna River at Susitna Station. If there was a substantial increase in the proportion of pink salmon in the river during the study period, one would expect the distribution of fish to be closer to shore. The fishwheel data may, however, be misleading since shore-based fishwheels have been found to be biased toward capture of pink salmon, and away from chum salmon (Thompson and Barrett 1983). Previous assumptions concerning offshore migration of pink salmon at the study site may also be suspect. It also appears unlikely that changes in water stage discharge level

Table 4. Fish targets recorded by the Bendix Corp. 1984 model long range substrateless side-scanning sonar counter during selected hourly periods at Susitna Station, 20 July through 24 July 1984.

		Sector																
Date	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
20 July	2300	29	104	70	32	24	56	100	198	94	25	41	55	44	158	10	11	1051
	2400	17	51	60	16	14	35	89	169	67	25	34	37	56	150	30	45	895
21 July	100	0	76	56	18	18	65	144	198	103	51	50	45	89	384	6	0	1303
	200	1	107	63	30	29	79	112	258	87	88	46	96	376	25	0	0	1397
	300	6	106	45	3	23	59	131	212	75	44	56	58	36	306	1	0	1161
	400	0	50	34	24	5	60	154	261	86	52	45	68	63	101	1	1	1005
	500	2	77	48	29	26	36	121	225	65	33	34	26	32	26	2	0	782
	600	1	66	56	7	15	49	89	123	66	45	25	34	16	50	40	0	682
	700	16	51	40	5	20	37	100	193	74	15	16	41	157	31	12	4	812
	800	13	31	25	14	12	24	93	138	77	35	36	39	243	21	131	0	932
	900	9	56	28	9	30	64	132	167	65	50	25	33	69	69	20	0	826
	1000	24	44	64	25	11	47	83	201	70	28	28	27	14	20	0	2	688
Total		118	819	589	212	227	611	1348	2343	929	491	436	559	1195	1341	253	63	11534
Percent		1.0	7.1	5.1	1.8	2.0	5.3	11.7	20.3	8.1	4.3	3.8	4.8	10.4	11.6	2.2	0.5	
21 July	2300	7	22	42	24	28	66	129	246	155	67	96	13	38	0	3	0	936
	2400	26	58	51	24	40	100	145	298	216	64	53	124	12	0	0	0	1211
22 July	200	37	96	59	19	40	105	204	303	58	15	5	1	0	0	0	0	942
	400	68	119	49	23	27	57	178	220	44	9	0	0	0	0	0	0	794
	600	58	138	78	24	20	82	160	261	49	9	2	0	0	0	0	0	881
	800	39	99	55	14	24	60	135	172	64	5	1	1	0	0	0	0	669
Total		235	532	334	128	179	470	951	1500	586	169	157	139	50	0	3	0	5433
Percent		4.3	9.8	6.1	2.4	3.3	8.7	17.5	27.6	10.8	3.1	2.9	2.6	0.9	0.0	0.1	0.0	

-Continued-

Table 4. Fish targets recorded by the Bendix Corp. 1984 model long range substrateless side-scanning sonar counter during selected hourly periods at Susitna Station, 20 July through 24 July 1984 (continued).

		Sector																
Date	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
22 July	1800	32	136	98	19	27	123	160	228	284	52	27	203	105	0	0	0	1494
	2000	5	131	84	26	29	53	95	197	310	70	49	550	31	0	0	0	1630
	2200	3	17	24	12	35	86	134	220	167	59	40	52	14	1	3	0	867
	2400	23	139	84	34	22	74	138	210	324	43	47	47	8	2	0	0	1195
23 July	200	21	135	71	24	43	77	77	221	155	100	39	61	8	3	0	0	1035
	400	19	99	75	23	32	106	249	221	426	69	57	27	6	8	0	0	1417
	600	9	87	70	53	33	65	158	126	335	78	28	11	18	37	0	0	1108
	800	23	65	60	27	37	76	137	74	386	116	85	14	99	3	0	0	1202
	1000	14	34	38	19	23	72	121	116	309	88	43	33	54	0	0	0	964
Total		149	843	604	237	281	732	1269	1613	2696	675	415	998	343	54	3	0	10912
Percent		1.4	7.7	5.5	2.2	2.6	6.7	11.6	14.8	24.7	6.2	3.8	9.1	3.1	0.5	0.0	0.0	
23 July	2400	5	34	19	4	10	20	43	67	15	10	61	43	168	11	25	153	688
24 July	200	22	62	39	11	26	38	83	108	38	19	45	32	37	127	14	735	1436
	400	8	52	44	9	14	17	31	36	23	7	1	11	11	13	279	4	560
	600	11	57	40	43	16	23	19	46	19	2	6	10	6	21	9	100	428
	800	16	48	20	5	10	19	27	26	9	5	5	4	8	6	40	7	255
	1000	19	41	27	9	8	24	12	26	9	10	5	8	3	55	20	753	1029
Total		81	294	189	81	84	141	215	309	113	53	123	108	233	233	387	1752	4396
Percent		1.8	6.7	4.3	1.8	1.9	3.2	4.9	7.0	2.6	1.2	2.8	2.5	5.3	5.3	8.8	39.9	
Total all periods		583	2488	1716	658	771	1954	3783	5765	4324	1388	1131	1804	1821	1628	646	1815	32275
Percent		1.8	7.7	5.3	2.0	2.4	6.1	11.7	17.9	13.4	4.3	3.5	5.6	5.6	5.0	2.0	5.6	

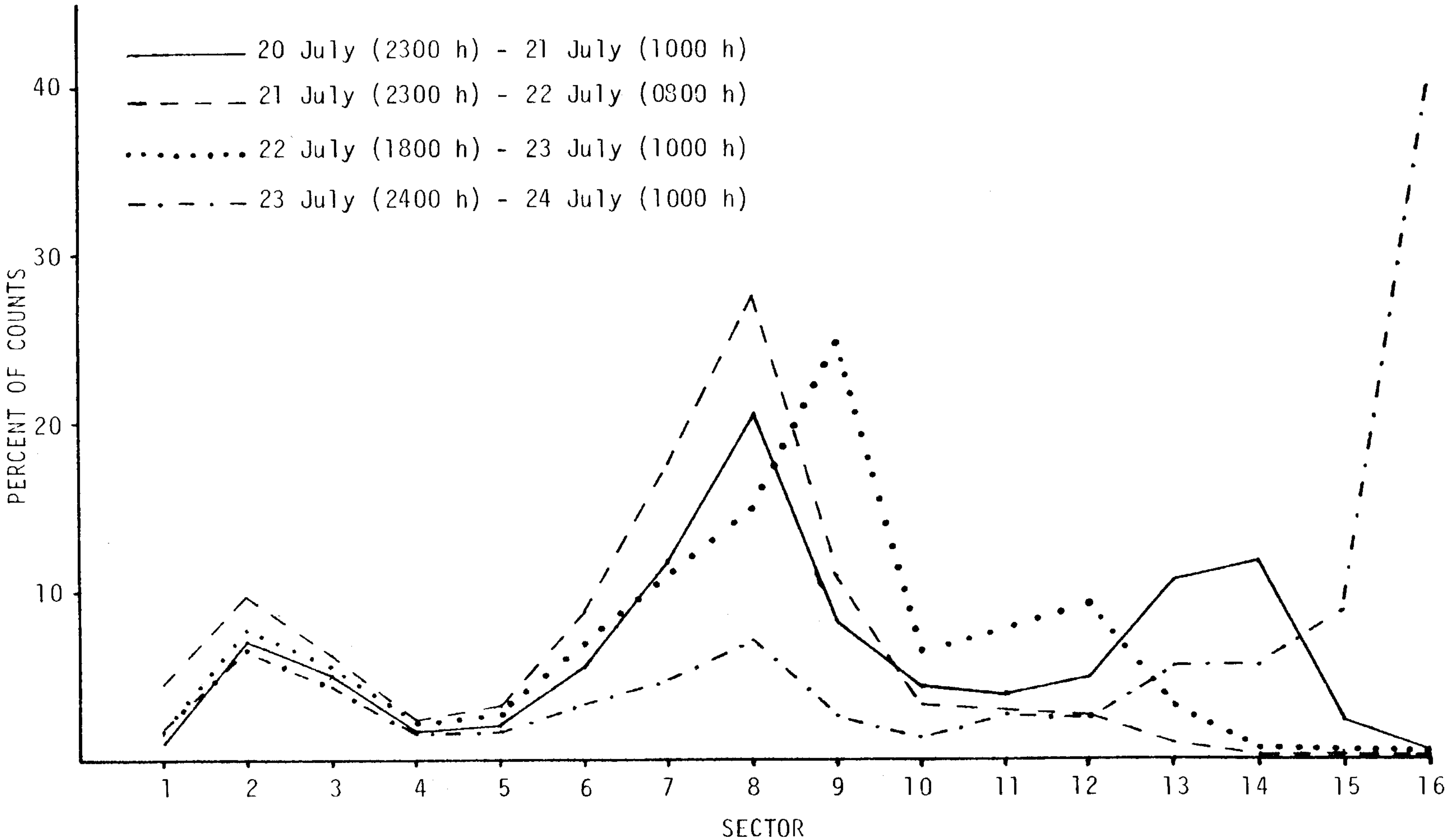

Figure 9. Proportion of counts by sector recorded by the 1984 model Bendix long range side-scanning sonar counter (tripod mounted transducer) at the Susitna River (Susitna Station) east bank sonar site, 1984.

Table 5. Daily fishwheel catch by species from the Susitna River at Flathorn and Susitna Stations, 17 July through 26 July 1984.

Date	Susitna Station						Flathorn Station					
	Sockeye	Pink	Chum	Coho	Chinook	Other	Sockeye	Pink	Chum	Coho	Chinook	Other
17-Jul	50	4	5	4		3	1010	42	251	39	1	10
	75.8%	6.1%	7.6%	6.1%		4.5%	74.6%	3.1%	18.6%	2.9%	0.1%	0.7%
18-Jul	48	8	12	9	1	4	1013	145	495	79		3
	58.5%	9.8%	14.6%	11.0%	1.2%	4.9%	58.4%	8.4%	28.5%	4.6%		0.2%
19-Jul	74	77	24	5	3		587	353	394	62	1	5
	40.4%	42.1%	13.1%	2.7%	1.6%		41.9%	25.2%	28.1%	4.4%	0.1%	0.4%
20-Jul	45	148	17	11			475	778	402	84	2	1
	20.4%	67.0%	7.7%	5.0%			27.3%	44.7%	23.1%	4.8%	0.1%	0.1%
21-Jul	23	234	6	4			360	1264	390	76	5	1
	8.6%	87.6%	2.2%	1.5%			17.2%	60.3%	18.6%	3.6%	0.2%	0.0%
22-Jul	23	216	9	4			405	1605	538	161	1	1
	9.1%	85.7%	3.6%	1.6%			14.9%	59.2%	19.8%	5.9%	0.0%	0.0%
23-Jul	31	316	14	9		2	458	2084	449	269	3	10
	8.3%	84.9%	3.8%	2.4%		0.5%	14.0%	63.7%	13.7%	8.2%	0.1%	0.3%
24-Jul	18	221	14	5			462	1590	283	177	2	5
	7.0%	85.7%	5.4%	1.9%			18.3%	63.1%	11.2%	7.0%	0.1%	0.2%
25-Jul	17	287	20	3		2	543	1659	288	177	2	14
	5.2%	87.2%	6.1%	0.9%		0.6%	20.2%	61.8%	10.7%	6.6%	0.1%	0.5%
26-Jul	20	400	10	7			281	1293	166	92	1	1
	4.6%	91.5%	2.3%	1.6%			15.3%	70.5%	9.1%	5.0%	0.1%	0.1%

recorded during the study period were responsible for changes in water velocity which would result in rapid and significant changes in fish distribution.

There did, however, appear to be relatively constant "zones of migration" at distances offshore of 12 m to 15 m and 20 m to 30 m (Figure 9). The small peak in counts observed at a distance offshore of 12 to 15 m is likely a result of the weir placed immediately below the tripod mounted transducer. A stream block of this type has the affect of funneling all shore oriented migrants out past the weir and concentrating them in the first few counting sectors. Speculation about the reasons for the consistent movement of fish in the 20 to 30 m offshore range is more difficult. No barrier or bottom irregularity was detected which might provide orientation for upstream migrants. There was, however, an area of increased water velocity near bottom at a sampling station 18 m offshore (Table 2).

Counts recorded by the 1978 and 1984 counters set to count the same distance from shore for the same hourly periods are presented in Table 6. These data were collected to evaluate the overall counting ability of the 1984 counter relative to the existing 1978 counter and associated substrate.

During the 13 hours of comparative testing, in excess of 12,000 fish targets were counted by each counter. The difference in counts between counters ranged from 2% to 56% by hour, but was approximately 1% for all hours combined.

Paired hourly data were submitted to a Wilcoxen paired sample test (Zar 1974). Results are presented in Table 7. Since the calclulated t and t prime values were not less than the t value from the table, the null hypothesis was accepted. This analysis suggests that the total number of fish enumerated by the 1978 counter using an 18 m tubular aluminum substrate to force fish into the ensonified area was the same as the number of fish enumerated by the 1984 counter aimed along the natural substrate.

There were, however, two additional considerations in the counter comparison. The results do not take into account the differences in cross-sectional area of the two counters set at different counting ranges. Vertical distribution data indicated that some fish were present in the upper portion of the water column, and because the maximum beam vertical diameter of the 1978 counter was approximately 0.14 m larger than that of the 1984 counter, some additional targets may have been available to the 1978 counter. Secondly, the end of the counting range for both counters occurred in the middle of the most active area of migration. This fact complicates interpretation of the results. It does not appear that individual fish maintained the precise distance from shore which would have placed them consistently within both beams, or the range of hourly variation (2 to 56%) between would have been much less. Rather, it seems that random movement of fish within the 20 to 30 m "zone of migration" influenced hourly variation. These two considerations imply that the extremely close total count produced in this situation may have been a result of chance.

It does appear that some features of the 1984 counter offer improvement over the existing (1978-1981 model) counters. The ability to count without the aid of the 18 m substrate could provide the opportunity for increased mobility

Table 6. Results from comparative testing of Bendix Corp. substrateless (1984 model) and substrate (1978 model) equipped side-scanning sonar counters in the Susitna River at Susitna Station, 1984 1/.

Date	Hour Start	Hour End	1984 counter	1978 counter
21 July	1100	1200	920	844
	1200	1300	953	970
	1500	1600	1012	902
	1600	1700	1098	1067
22 July	1100	1200	963	1009
	1400	1500	1146	1328
	1500	1600	976	1170
23 July	1400	1500	895	836
	1500	1600	1259	963
24 July	1000	1100	555	356
	1100	1200	806	754
	1400	1500	748	1171
	1500	1600	975	811
Total			12306	12181

1/

Counter Model	Counting Range	Counting Distance from Shore
1984	20.5 m	28 m
1978	24.4 m	28 m

Table 7. Results of a Wilcoxen paired sample test conducted on data collected with the 1978 model substrate equipped and 1984 model long range substrateless side-scanning sonar counters at Susitna Station, 1984[1/].

Hour Number	Sonar count: 1984 counter ($X1_j$)	Sonar count: 1978 counter ($X2_j$)	Difference ($d_j = X1_j - X2_j$)	Rank (d_j)	Signed Rank (d_j)
1	920	844	76	6	6
2	953	970	-17	1	-1
3	1012	902	110	7	7
4	1098	1067	31	2	2
5	963	1009	-46	3	-3
6	1146	1328	-182	9	-9
7	976	1170	-194	10	-10
8	895	836	59	5	5
9	1259	963	296	12	12
10	555	356	199	11	11
11	806	754	52	4	4
12	748	1171	-423	13	-13
13	975	811	164	8	8

1/ n = 13
m = number of ranks with less frequent sign = 5
T = sum of ranks with less frequent sign = 36
T_1 = m (n+1)-T = 34
T = 0.05(2), 13 = 17

Since T and T_1 are not less than T 0.05(2), 13, the null hypothesis (count from the 1984 model is the same as the count from the 1978 model) is accepted.

and decreased substrate maintenance. The lack of an extensive substrate may also provide better counting conditions relative to fish behavior in avoidance of the artificial barrier. In addition, the counting range is not limited to the maximum 30 m available to the 1978 counter. Finally, the addition of variable hit criteria by sector provides more accurate information on fish distribution from shore.

Several factors were identified during the study which should receive additional attention. A mechanical device must be engineered which correctly orients the transducer perpendicular to the channel axis, allows for maximum vertical and horizontal movement of the transducer via remotely controlled electric rotators, and is easily deployable from shore or by boat in deeper water. The degree in deviation from a straight bottom contour and the minimum natural substrate size which could alter counting ability should be documented. Investigation of bottom topography limitations should also included devising a method which allows precise initial aiming of the hydroacoustic beam, and a relatively easy way of checking aiming on a periodic basis.

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