

Fishery Data Series No. 94-50

Feasibility of Using Sonar to Estimate Adult Coho Salmon Returns to the Kenai River

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Terry Bendock

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ABSTRACT

A lack of quantifiable information concerning the magnitude of coho salmon *Oncorhynchus kisutch* returns to the Kenai River precludes defining exploitation rates or other key management objectives for this species. To determine the feasibility of estimating coho salmon abundance in the Kenai River using sonar, we evaluated a potential sonar site at river mile (rm) 14. Hydroacoustic sampling was conducted to measure background noise levels and radio telemetry was used to estimate the lateral distributions of adult salmon migrating past the site. We concluded that the distributions of migrating adult sockeye *O. nerka* and coho salmon overlapped significantly at rm 14. Background noise levels varied throughout the horizontal range that we measured and averaged -46.4 dB. The number of boats passing the site ranged from 0 up to 33 per hour, potentially compromising the amount of hydroacoustic sampling time available during some periods. These findings suggest that distinguishing between sockeye and coho salmon migrating concurrently in the Kenai River may not be practical, at this time, using differences in spatial distributions or modal target strength distributions.

KEY WORDS: Kenai River, coho salmon, *Oncorhynchus kisutch*, sonar, hydroacoustic, radio telemetry, lateral distribution.

INTRODUCTION

The Kenai River (Figure 1) is a glacial stream located in Southcentral Alaska on the Kenai Peninsula. Coho salmon *Oncorhynchus kisutch* return annually to spawn in the Kenai River, supporting the largest freshwater sport fishery for this species in Alaska (Mills 1993). Kenai River coho salmon also contribute to a large mixed-stock commercial fishery and to various personal use and subsistence fisheries in the marine waters of upper Cook Inlet. Despite the size and importance of these coho salmon fisheries, the only parameters currently estimated for this stock are angler effort and harvest for the lower Kenai River recreational fishery (Schwager-King 1993). There is currently a lack of quantifiable data regarding: (1) the stock-specific contribution of Kenai River coho salmon to the mixed-stock commercial fisheries, and (2) escapement of Kenai River coho salmon stocks. Without this information, exploitation rates can not be estimated. The sizable harvest and growing nature of the fisheries exploiting this stock, coupled with the lack of quantifiable information, raise fears that Kenai River coho salmon may be in danger of overexploitation. To provide data for defining meaningful management objectives, a long-term study was initiated to assess the status of Kenai River coho salmon stocks (Meyer et al. *Unpublished*). Developing methods to estimate the total inriver return of Kenai River coho salmon is identified as a priority in this long-term stock assessment effort and is the subject of this report.

Visual observations of migrating salmon are precluded by the size and turbidity of the Kenai River. Hence, inriver returns of chinook *O. tshawytscha* (Eggers et al. *In prep*) and sockeye salmon *O. nerka* (King and Davis 1991) are currently estimated using separate hydroacoustic (sonar) assessment programs. Sonar may also be the best tool for estimating inriver returns of coho salmon if a method for distinguishing between different salmon species exhibiting similar size and run timing characteristics can be developed. This concern has been an obstacle to enumerating coho salmon since they overlap in size or timing with sockeye and pink salmon (*O. gorbuscha*) in the Kenai River. In addition, the presence of spawning pink salmon throughout the lower Kenai River has caused significant problems with the tracking software used for hydroacoustic assessment. Methods used to apportion species in multi-species hydroacoustic assessment programs rely on differences in: (1) run timing, (2) spatial distributions, (3) target strength data from fish of different sizes, or (4) catch compositions resulting from test-fishing programs.

This project is a continuation of work begun in 1991 to explore the feasibility of using sonar to estimate coho salmon returns in the Kenai River. Studies conducted in 1991 and 1992 evaluated the use of two different hydroacoustic systems, dual-beam and split-beam, for estimating salmon passage at river mile (rm) 19. These studies concluded that the rm 19 site was unsuitable for either dual or split-beam sampling (Vaught et al. 1992; Vaught and Skvorc 1993). The site was undesirable due to its broad, shallow morphometry which resulted in high background noise levels. Also, spawning pink salmon were continually ensonified at rm 19, greatly complicating data processing. High background noise levels prevented accurate estimation of target strength values. Test fishing conducted at rm 19 using a fish wheel and drift gill nets indicated that species were mixed in both offshore and inshore locations. Fish wheel catches included both sockeye and coho salmon, while gill net

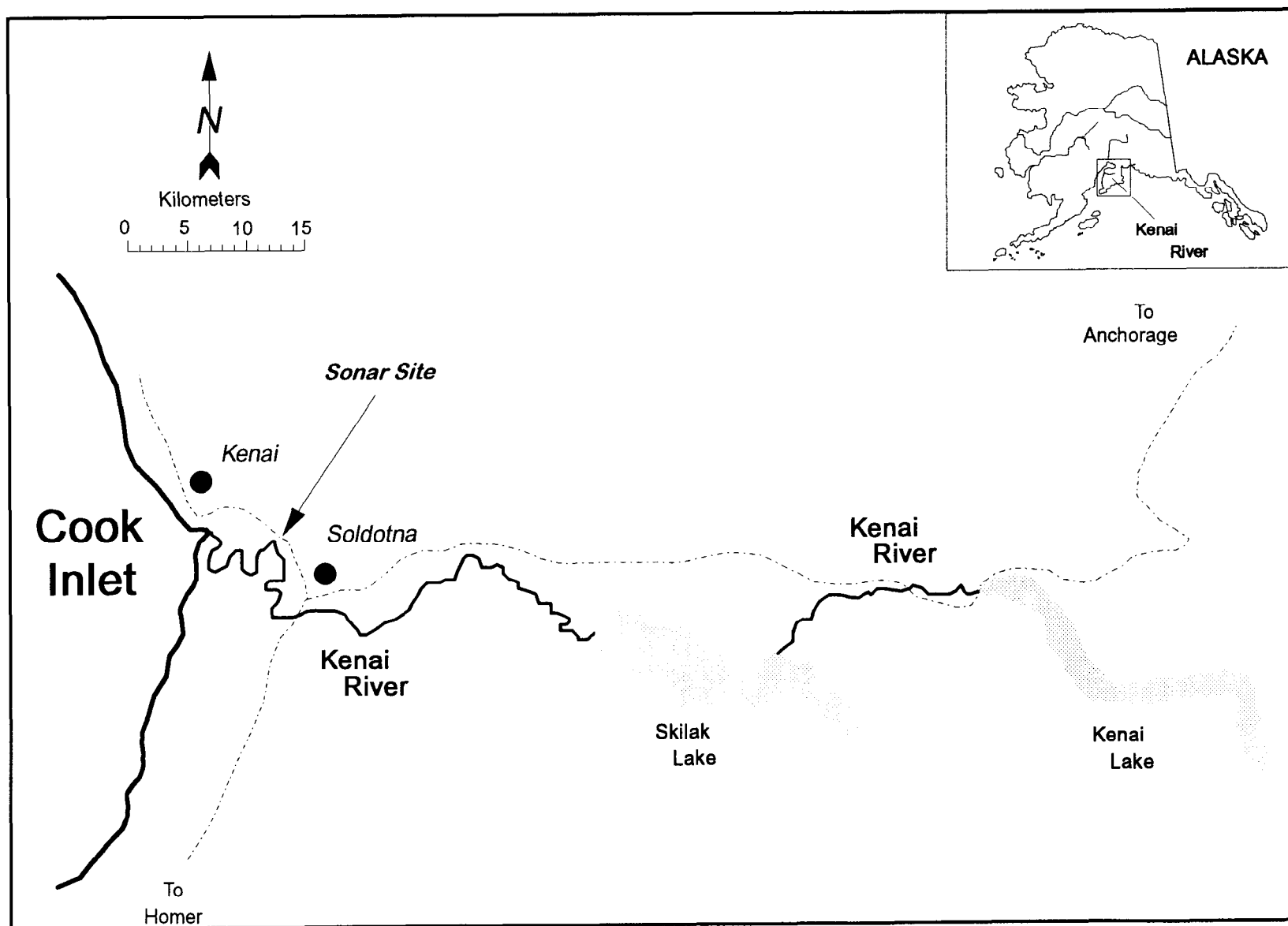


Figure 1. Map of the Kenai River drainage showing the sonar site located at rm 14.

catches included both pink and coho salmon. Problems with background noise and spawning salmon at rm 19 prompted a search for a new site.

A location that appeared superior to the rm 19 site was identified in 1991 at rm 14 (Vaught and Skvorc 1993). This site was chosen because it is deeper, swifter, and narrower than the rm 19 site which should result in lower background noise levels and be less attractive for spawning by pink salmon.

Since assumptions concerning improved hydroacoustic characteristics at rm 14 were based on morphometry, we deployed sonar gear in 1993 to verify these assumptions by measuring background noise and mean signal-to-noise ratio. Our study also used radio telemetry to examine the spatial distributions of adult sockeye and coho salmon as they migrated past rm 14. If these two species exhibited different lateral distributions (distances from shore) while migrating past the site, sonar transducers could be deployed in a manner that would exclude unwanted targets. Specific objectives during 1993 were to:

1. measure background noise level at rm 14,
2. estimate the mean signal-to-noise ratio at rm 14, and
3. test the hypothesis that there is no difference in the lateral distributions of adult coho and sockeye salmon migrating past rm 14.

METHODS

This report presents findings from two independent study components. The lateral distributions of migrating salmon at rm 14 were investigated using radio telemetry, and hydroacoustic sampling was conducted at rm 14 to measure levels of background noise and signal-to-noise ratio.

Lateral Distributions

Study Design:

To estimate the lateral distribution of migrating salmon in the Kenai River, adult coho and sockeye salmon were captured using gill nets, angling, or a fish wheel; fitted with radio transmitters; and released downstream of rm 14. Fish that were captured upstream from rm 14 were transported by river boat to rm 13 for tagging and release. We attempted to tag 50 salmon of each species, deploying tags systematically over a 5 to 6 week period beginning in early August. Each fish was identified by a unique transmitter frequency.

Automated data collection computers (DCCs) were located on each shoreline at rm 14 (the proposed sonar site). DCCs scanned a list of all transmitter frequencies that were currently in use and recorded the date, time, and number of pulses for each tagged fish passing the site. Limited reception corridors were created for each DCC by using modified underwater antennas and adjusting each receiver gain. The 240 ft river width at rm 14 was divided into three potential migration corridors: 70 ft wide corridors extending out from each shoreline, and a 100 ft wide mid-channel corridor. Radio-tagged salmon migrating past rm 14 were assigned to one of these three corridors. The

stationary DCCs identified fish passing within 70 ft of the right or left bank, while aerial tracking identified fish that migrated past the site, but were not recorded by either data logger (offshore migrants). The null hypothesis that there is no association between migration corridors (offshore vs. nearshore) and salmon species (coho vs. sockeye) was tested using chi-squared statistics. The major assumption of this study was that there were no differences between sockeye and coho salmon migration behaviors that could be attributed to handling and tagging.

Description of Telemetry Equipment:

Radio telemetry equipment used in this study was manufactured by Advanced Telemetry Systems, Inc., Isanti, Minnesota. Transmitters were encapsulated in electrical resin, measured approximately 2 x 3/4 x 3/8 in, and had a 12 in wire antenna. Each transmitter operated on a unique frequency between 48.000 and 49.999 MHz. The minimum transmitter battery life was 180 days. Mortality circuits (Eiler 1990) allowed each tag to operate in either a normal or mortality mode. Transmitters were mounted to the dorsal surface of the fish using nickel pins and Petersen disks (Bendock and Alexandersdottir 1992).

Stationary DCCs were positioned along each bank at rm 14. Each DCC was located in a wooden box that was elevated for protection against boat wakes and connected to an underwater antenna. A 166 in length of 3/4 in electrical conduit was bent to conform to the contour of the shoreline. One end of the conduit was connected to the bottom of the DCC box. The other end extended across the streambed and was held in place using sandbags. A 188 in length of coax was attached to the DCC receiver and threaded through the conduit. The length of coax (22 in) between the receiver and the open end of conduit was wrapped in aluminum foil. Each DCC was powered by a 12 v automobile battery. Data contained in each DCC was transferred in the field to a Hewlett Packard 95LX pocket computer.

Exclusive transmitter reception corridors were delineated along both shorelines using independent receivers and DCCs (Figure 2). Twenty-one transmitters were attached to a weighted line and slowly towed away (perpendicular) from each station using a power boat. A TLR 75 Rangefinder was used to measure the distance at which reception was lost for each transmitter. The maximum perpendicular distance measured for all 21 transmitters along each bank was used to define the nearshore corridor widths. The distance between the two nearshore areas was defined as the offshore corridor. Field trials also confirmed that transmitters deployed along one bank could not be received from the opposite bank.

Tagged fish were located approximately three times each week using a Piper PA-18 aircraft. A directional loop antenna was mounted to the left wing jury struts of the aircraft and connected to a portable scanning receiver. Flights were conducted at approximately 70 mph and 800 to 1,000 ft above the water column. The location of each tagged fish was assumed to be under the point of maximum acoustic signal strength.

Capture and Tagging Methods:

Most of the adult salmon used in this study were caught in a fish wheel located along the north bank at rm 19. Since our study site was at rm 14,

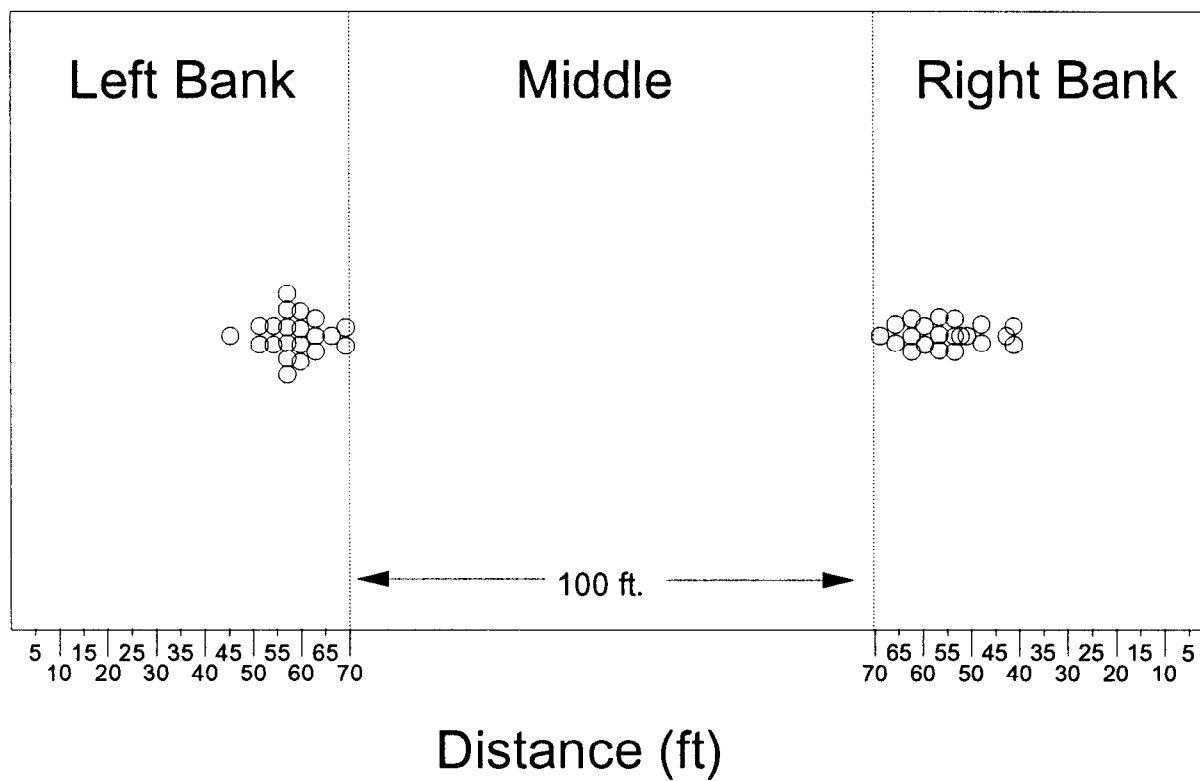


Figure 2. Maximum ranges obtained for 21 radio transmitters used to delineate corridor widths for each stationary data logger.

fish captured by the wheel were transported by boat downstream to rm 13 where they were tagged and released. Fish captured by the wheel were held in a live box until our arrival. A landing net was then used to transfer fish to a river boat where they were held in a plywood box measuring 2 x 3 x 2 ft that was filled with approximately 40 gal of river water. A maximum of four fish was transported in a single trip. Each 6-mile trip took approximately 15 minutes.

Fish held in the transportation box were maneuvered into a cradle (Hammarstrom et al. 1985) to confine them for tagging. Radio transmitters were mounted on the right side of each fish beneath the anterior half of the dorsal fin following procedures outlined in Bendock and Alexandersdottir (1992). Each tagged fish was measured for length (mid-eye to fork-of-tail) and examined for the presence of sea lice *Lepeophtheirus salmonis*. Sex was estimated from external characteristics and the date, time, and location of release were recorded for each fish. The cradle containing the tagged fish was then lifted out of the box and placed in the river. It was then opened, and the fish was allowed to swim away on its own initiative.

Two sockeye salmon were captured using a drift gill net at rm 7.2. Data collection and tagging procedures were similar for these fish except they were placed in the cradle while it was deployed over the side of the boat, and they were released at rm 7.

Twelve coho and one sockeye salmon were captured using spinning tackle. These fish were also tagged without being removed from the water and they were released at the capture locations which in all cases were downstream from rm 14.

Estimating Final Fates:

Aerial tracking was used to locate radio-tagged fish throughout the drainage. Tag recoveries in the sport fishery, interpretations of daily movement histories, and radio transmission modes were used to estimate the fates of tagged salmon. The following four classifications defined final fates:

1. mortality: fish that failed to move upstream from the release location, or transmitted radio signals in the mortality mode;
2. unknown: fish that we failed to re-locate;
3. sport harvest: fish tagged with transmitters that were recovered in the recreational fishery; and
4. spawner: fish that held position at an upstream mainstream or tributary destination prior to transmitting a mortality signal.

Hydroacoustic Sampling

Hydroacoustic sampling equipment included a Biosonics model 102 echosounder, a Biosonics Echo-Signal-Processor card mounted in an 80386 microcomputer, a

Dowty model 3700 thermal chart recorder, and a Nicolet model 310 digital storage oscilloscope. A Biosonics dual-beam transducer with a 30 x 100 nominal beam width was deployed on an aluminum tripod on the right bank (facing upstream) of the river. A Remote Ocean Sciences (ROS) PT-25 rotator was used in conjunction with a ROS PTC-1 remote control unit to remotely aim the transducer through pan and tilt axes for optimal aim. The echosounder and other electronic equipment were housed in an 8 x 10 ft self-supporting tent during the investigation.

Hydroacoustic samples were saved to disk with a Nicolet model 310 digital storage oscilloscope and analyzed at range increments of 2.8 m. One-way ANOVA analysis using Quattro Pro 5.0 for Windows was performed to test for significant differences in mean background noise at range. Overall average background noise was converted to decibels by:

$$TS = 20 \log V - (S_L + R_x + G_x) \quad (1)$$

where:

TS = target strength;
V = voltage;
S_L = source level;
R_x = receiver gain; and
G_x = through-system gain.

Boat passage frequencies for each hour of sampling were tallied from chart recordings. The average duration of boat wakes appearing on the chart recordings was estimated from a sample of 96 records. Mean duration of boat wake was multiplied by boat passage frequency to estimate sampling minutes lost per hour.

RESULTS

Lateral Distributions

A total of 86 coho and 25 sockeye salmon were captured, equipped with radio transmitters and released in the Kenai River during 10 August through 29 September 1993. Biological and physical parameters recorded for each fish are shown in Appendix A1. Stationary receiver and DCC stations located at rm 14 operated continuously during 10 August through 19 August and from 28 August through 14 October. During 20 to 27 August, flooding conditions along the river prompted the removal of the left bank DCC. Data from two coho salmon and eight sockeye salmon that passed the study site during that period were excluded from the analysis of lateral distribution due to the incomplete receiver coverage. Recovery data from both data loggers are presented in Appendix A2.

Of 86 coho salmon that were tagged and released, 12 were captured using spinning tackle and 56 were captured using a fish wheel. Coho salmon ranged from 440 mm to 680 mm mid-eye to fork length and averaged 599 mm. The mean length of coho salmon that were tagged and released during 2-week intervals between 1 August and 30 September increased; however, there was no significant

difference between the length frequency distributions of coho salmon in our telemetry sample and those in the sport harvest (KS test, $D = 0.644$, $P = 0.8550$). The male-to-female sex ratio for coho salmon was 0.789. Sea lice were present on 17 (57%) of the female and 17 (45%) of the male coho salmon.

Of 25 sockeye salmon that were tagged and released, 1 was captured using spinning gear, 2 were captured using a gill net, and 22 were captured using a fish wheel. Sockeye salmon ranged from 475 mm to 625 mm in mid-eye to fork length and averaged 563 mm. The male-to-female sex ratio for sockeye salmon was 1.777. Sea lice were present on five (56%) of the female and three (19%) of the male sockeye salmon.

Sixty (54%) tagged salmon either did not migrate upstream following release, or migrated past rm 14 when one of the DCCs was removed due to high water. Of the remaining 51 tagged fish, lateral distributions were estimated for 38 coho and 13 sockeye salmon.

A majority (58%) of tagged coho salmon exhibited lateral distributions that were bank-oriented (Figure 3). Nine (24%) coho salmon migrated past rm 14 using the left-bank corridor, 13 (34%) used the right-bank corridor and 16 (42%) used the middle-river corridor. Most (85%) sockeye salmon were also bank-oriented in distribution. Three (27%) sockeye salmon used the left-bank corridor, eight (73%) used the right-bank corridor and two (18%) used the middle-river corridor.

We failed to reject the hypothesis that lateral distributions are independent of species ($\chi^2 = 3.028$, $df = 1$, $P > 0.05$). Bank-oriented coho salmon were shorter in mean length than offshore oriented coho salmon; however, there was no significant difference in the length distributions of these groups (KS test, $D = 0.3500$, $P = 0.1515$). A similar analysis was not conducted for sockeye salmon lengths due to the small sample sizes.

Travel time data were available for all tagged adults that were recorded at the data loggers by subtracting the day and time of release at rm 13.5 from the day and time of passage at rm 14. The transit time for coho salmon ranged from 2.2 h to 165.6 h. The mean transit time for coho salmon was 53.2 h (SE = 9.9). Transit times for sockeye salmon over the same river reach ranged from 2.6 h to 30.4 h and averaged 16.0 h (SE = 2.6).

Final Fates:

Four classifications were used to describe the final fates of radio-tagged salmon (Table 1). Most (32 fish, 47%) tagged and released coho salmon were not subsequently re-located. Of the 36 remaining coho salmon, 18 (26%) were tracked to spawning locations, 14 (21%) died prior to spawning, and 4 (6%) were harvested in the recreational fishery. Only one radio-tagged coho salmon carcass was recovered in a spawning area 27 days after being tagged and released.

Most (16 fish, 64%) sockeye salmon were tracked to spawning locations, while 6 (24%) were not re-located and 3 (12%) died before spawning. We did not recover any radio-tagged sockeye salmon carcasses in spawning areas.

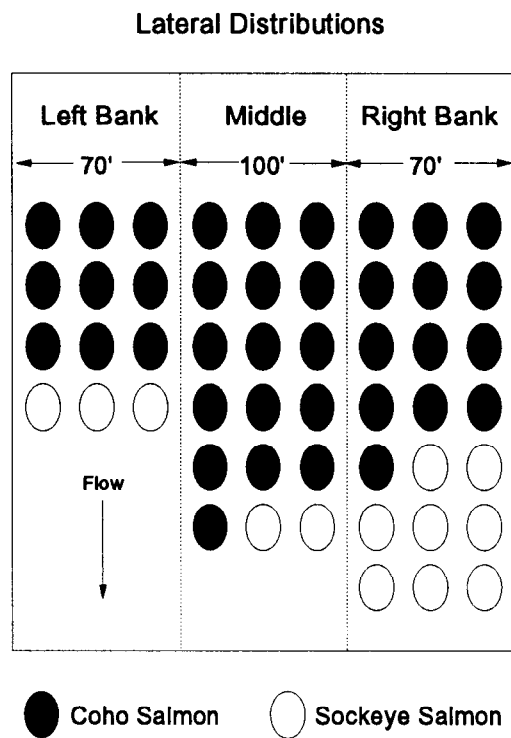


Figure 3. Lateral distributions of radio-tracked coho and sockeye salmon at rm 14 in the Kenai River, 1993.

Table 1. Final fates of radio-tracked coho and sockeye salmon released in the Kenai River, 1993.

Fate	Coho Salmon	Sockeye Salmon	Total
Harvest	4	0	4
Spawner	18	16	34
Mortality	14	3	17
Unknown	32	6	38
All	68	25	93

Spawning Destinations:

Eighteen coho salmon that were classified as spawners were tracked to both tributary (10 fish, 56%) and mainstream (eight fish, 44%) destinations (Table 2). Four coho salmon spawned in the vicinity of rm 44, while two each were tracked to King County, Slikok, and Quartz creeks, Killey River, and rm 46. Single fish were tracked to the Moose and Russian rivers, rm 66 and rm 74, respectively.

Sockeye salmon spawners were tracked to tributary (2 fish, 13%), lake (5 fish, 31%), and mainstream (9 fish, 56%) destinations. Most (50%) sockeye salmon were tracked to rm 66 near the inlet to Skilak Lake and to locations within Skilak Lake (25%). Single sockeye salmon spawners were tracked to Grebe Lake, lower Russian and Moose rivers, and rm 46. There was no conspicuous relationship between dates of tagging and spawning destinations.

Hydroacoustic Sampling

Hydroacoustic sampling took place at rm 14 in the Kenai River for 24 h beginning at 1300 hours on 17 August and ending at 1300 hours on 18 August. The right bank of the river was ensonified out to a range of 60 m. Due to cable connection problems and a low passage rate of fish targets during the sample period, an insufficient sample of fish targets was collected for estimating signal-to-noise ratio. Background noise was estimated from a series of 51 samples collected from throughout the range at approximately 1030 hours.

ANOVA analysis showed highly significant differences in mean background noise at range ($P < 0.001$, Table 3). This finding can partially be explained by the beam striking an object or irregularity in the bottom at 28.1 and 30.9 m (Figure 4). Overall average background noise through the range sampled was 126.7 mV (SD = 80.5 mV). This corresponds to an overall average background noise level of -46.4 dB.

Boat passage frequency varied from zero to 33 boats/h at the rm 14 site, while mean passage frequency was 10.7 boats/h (SD = 8.9, Figure 5). The mean duration of boat wakes from each vessel was 1.72 min (SD = 0.48). The number of minutes of sampling time lost per hour due to noise from boat wakes ranged from 0 to over 55 min (Figure 6).

DISCUSSION

Radio-tracked sockeye salmon exhibited a greater tendency to be bank oriented than did coho salmon, but there was no clear lateral separation of species within the design limits of our telemetry study. One coho salmon was recorded by both DCCs but at different times of the day. Thus, we concluded that this fish migrated upstream along the right bank, swam downstream in the middle corridor and returned upstream along the left bank. Our conclusion that distributions of migrating sockeye and coho salmon overlap in the vicinity of the sonar site are consistent with the test fishing data from rm 19 which found that species of migrating salmon were mixed at both onshore and offshore locations. Pink salmon are only abundant in the Kenai River during even years; consequently, there were insufficient numbers of pink salmon in 1993 to

Table 2. Spawning destinations of radio-tracked coho and sockeye salmon during 1993.

Species ^a	Sex	Frequency Released	Date	Final Destination
SS	M	48.062	08/10	King County Creek
SS	M	48.142	08/10	Slikok Creek
RS	M	48.240	08/12	RM 66
RS	M	48.262	08/12	RM 66
RS	M	48.302	08/12	RM 66
RS	M	48.460	08/12	Skilak Lake
RS	F	48.480	08/12	Skilak Lake
SS	M	48.500	08/17	King County Creek
SS	M	48.541	08/19	Killey River
RS	F	48.560	08/19	RM 66
RS	M	48.580	08/19	Grebe Lake
RS	M	48.700	08/19	RM 66
RS	M	48.740	08/19	RM 66
RS	F	48.760	08/19	Skilak Lake
RS	M	48.782	08/20	RM 66
RS	M	48.800	08/20	Skilak Lake
SS	F	48.860	08/30	RM 44
RS	M	48.840	08/30	RM 46
SS	M	48.880	08/31	Killey River
RS	M	48.902	08/31	RM 66
RS	M	48.922	08/31	Moose River
RS	M	48.962	09/01	Russian River
SS	M	48.980	09/01	Russian River
SS	M	49.000	09/01	Quartz Creek
SS	M	48.222	09/02	Quartz Creek
SS	F	49.020	09/09	RM 44
SS	M	49.220	09/17	Slikok Creek
SS	M	49.420	09/20	RM 46
SS	F	49.840	09/22	Moose River
SS	M	49.927	09/23	RM 74
SS	F	49.960	09/23	RM 44
SS	F	49.040	09/23	RM 66
SS	M	49.360	09/24	RM 46
SS	M	49.460	09/29	RM 44

^a

Species

SS - Coho Salmon

RS - Sockeye Salmon

Table 3. One-way analysis of variance for signal voltage at range measured at rm 14 in the Kenai River, 1993.

Groups	Count	Sum	Average	Variance
2.8 m	51	1,582	31.0	246.7
5.6 m	51	2,480	48.6	680.0
8.4 m	51	4,549	89.2	2,153.5
11.3 m	51	5,302	104.0	2,827.7
14.1 m	51	5,216	102.3	4,102.0
16.9 m	51	4,853	95.2	2,366.5
19.7 m	51	5,042	98.9	2,586.0
22.5 m	51	5,124	100.5	2,338.4
25.3 m	51	6,854	134.4	4,301.5
28.1 m	51	10,093	197.9	10,598.5
30.9 m	51	10,122	198.5	11,216.8
33.7 m	51	6,390	125.3	3,905.3
36.5 m	51	6,166	120.9	3,434.4
39.3 m	51	6,909	135.5	5,468.8
42.1 m	51	7,317	143.5	4,214.7
44.9 m	51	6,852	134.4	3,271.7
47.7 m	51	8,261	162.0	6,219.1
50.5 m	51	7,574	148.5	6,549.2
53.3 m	51	8,482	166.3	7,559.5
56.1 m	51	10,080	197.6	8,059.4

Analysis of Variance

Source of Variation:

	SS	df	MS	F	P-value	F-crit
Between Groups	2,003,458	19	105,445.2	22.89807	1.2E-65	1.596934
Within Groups	4,604,980	1,000	4,604.98			
Total	6,608,438	1,019				

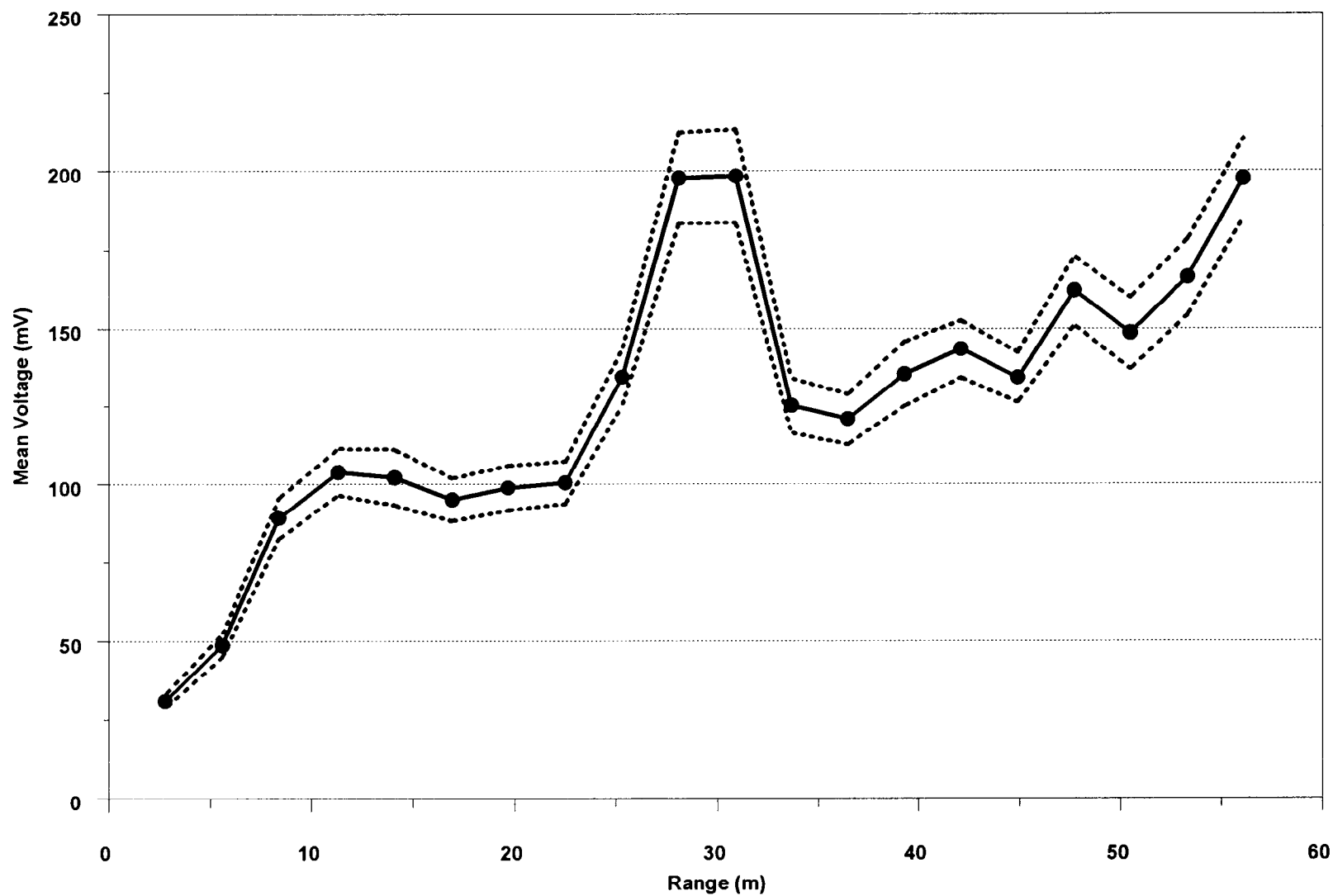


Figure 4. Mean voltage through sampling range. Broken lines represent plus or minus one standard error around the mean.

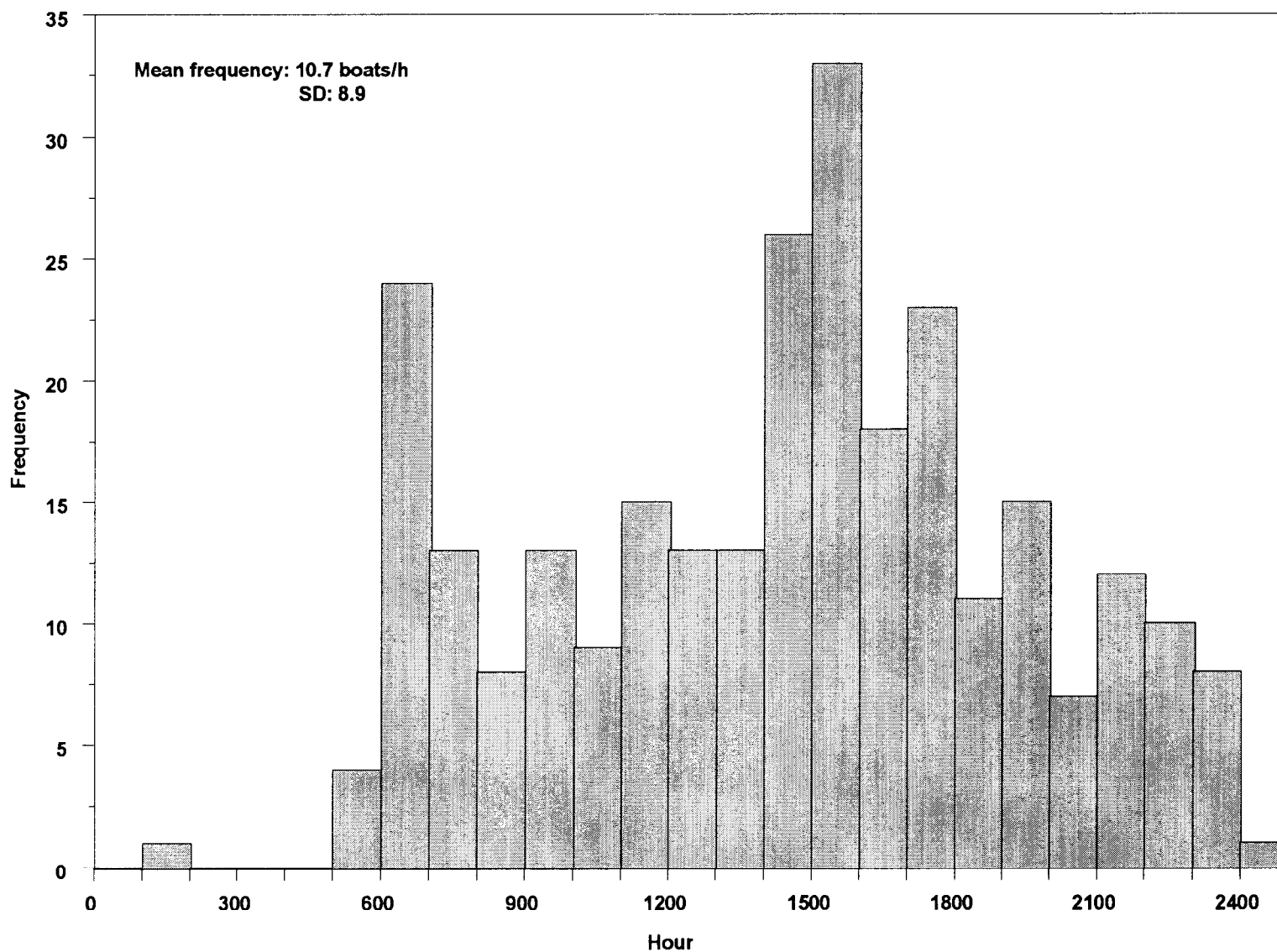


Figure 5. Diurnal frequency of boat passage at rm 14, as constructed from data collected during the period 1300 hours 17 August to 1300 hours 18 August 1993.

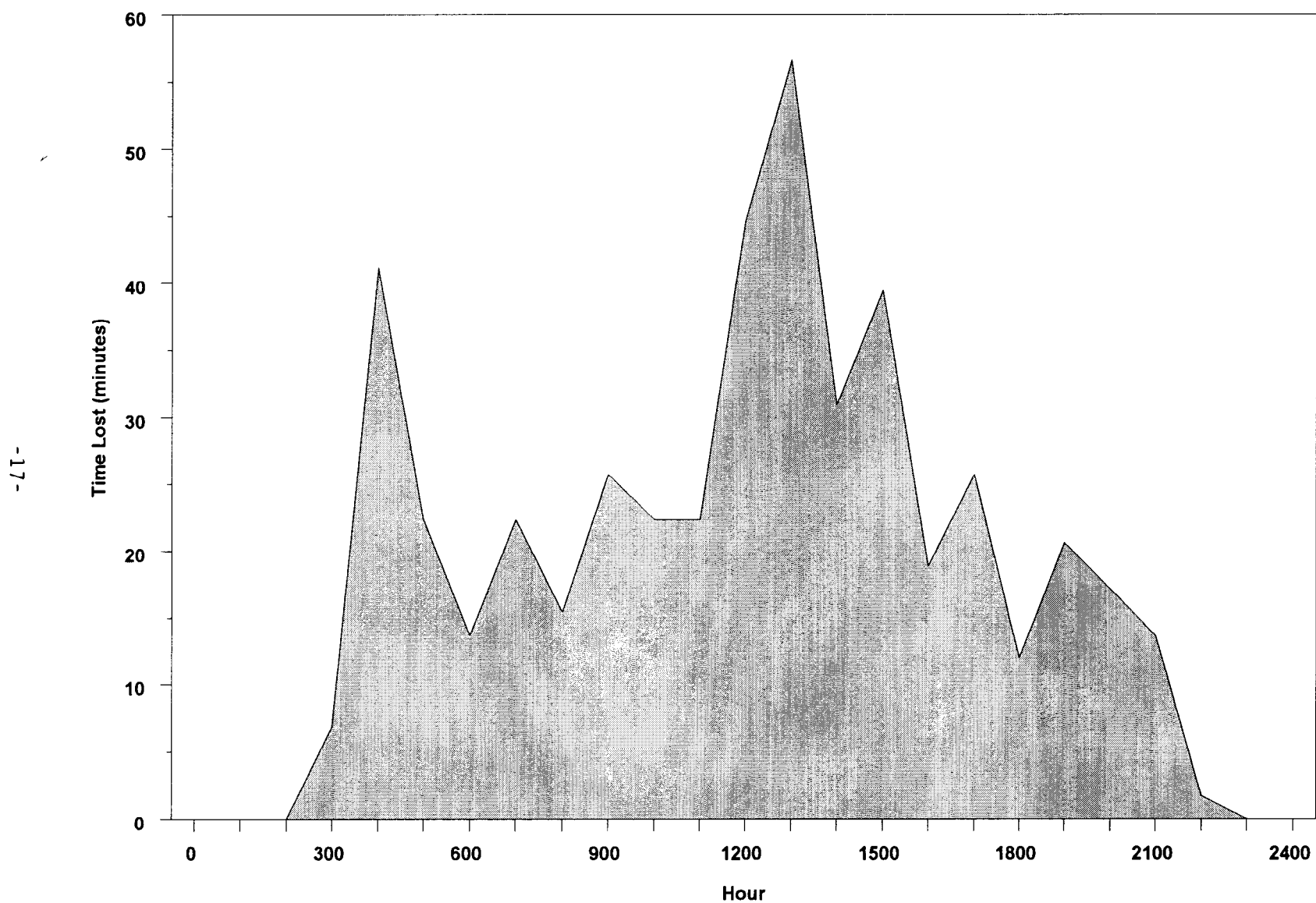


Figure 6. Average sampling time lost on a diurnal basis due to boat traffic at rm 14 during the period 1300 hours 17 August to 1300 hours 18 August 1993.

include an examination of their migratory behavior in our study design. It is likely, however, that the addition of a third species of migrating salmon at rm 14 would only complicate any effort to separate species spatially.

Hydroacoustic results were likewise discouraging. Although we were unable to obtain direct estimates of signal-to-noise ratio during this study, background noise levels were high and would have resulted in unacceptably low signal-to-noise ratios. Vaught and Skvorc (1993) concluded that noise levels of less than -56 dB (42 mV) were necessary to attempt to distinguish among species of salmon through target strength modal analysis. Mean background noise exceeded 42 mV in all but one range strata, and at ranges beyond 25 m mean background noise exceeded the minimum standard by a factor of three (10 dB) or more.

Using a transducer with a narrower beam would likely result in less background noise, as the beam could be fit more easily between the river bottom and the water's surface. However, the extent to which narrow beam-angle transducers would reduce noise levels is unknown.

During the summer of 1994, department researchers will begin an investigation using a 2.50 narrow-beam transducer in a split beam sonar application for counting chinook salmon. The results of this investigation could yield information concerning potential background noise decrease with the 2.50 transducer in split-beam application over the 3.00 transducer currently in use. The chinook sonar site and coho sonar site are not directly comparable, however. The chinook sonar site is located at rm 8.6 and is approximately 2 feet deeper midchannel than the site used for counting coho salmon. The chinook site is also subject to tidal influence which increases the water level by as much as 15 feet during rising, high, and falling tide stages.

The chinook sonar site was not considered a potential site for counting coho salmon due to tidal influences. Chinook salmon are bottom-oriented fish that predominantly favor the middle of the river (Eggers et al. *In prep*). This allows the majority of chinook salmon to be counted even when the water level rises adding water behind and above the stationary transducer. Data from fish wheels (Vaught and Skvorc 1993) indicate that coho salmon are present close to the bank. It is therefore likely that coho salmon will remain close to the bank as the tide rises. This would necessitate moving the transducer further up the bank as the tide rises to ensonify the nearshore area. This technique proved to be impractical when attempted in 1985 and 1986 in the developmental stages of the chinook salmon sonar project.

Efforts to obtain accurate and unbiased target strength data at rm 14 would be greatly complicated by the level of boat traffic observed during 1993. Angler effort in the coho salmon recreational fishery during our hydroacoustic sampling period was approximately 40% less than the average of the previous 2 years (Schwager-King 1994). Even in the reduced boat traffic regime experienced in 1993, sampling at midday would not have been possible due to interference from boat wakes (Figure 6). It is unlikely that a narrower-beamed transducer could alleviate the noise introduced by boat wakes.

The entire sampling range is not necessarily compromised by a boat wake. The fraction of the sampling range between the transducer and the boat could still collect valid echoes. However, a large portion of sampling in space and time would be lost. Also, sampling during periods of moderate to heavy boat

traffic and using the portions of the range not affected by boat wakes would greatly complicate the sonar operation and increase variability around any estimates.

Due to the overlap in species distributions and overall level of recreational boat traffic, we conclude that the rm 14 site is not suitable for a hydro-acoustic project that is designed to collect accurate target strength data.

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APPENDIX A
SUPPORTING STATISTICS

Appendix A1. Detailed capture and release information for each salmon tagged during 1993.^a

Species	Date	Hour	Length (mm)	Sex	Fishing Method	RM Location		Sea		Bank
	(1993)					Caught	Released	Lice	Fate	
SS	08/10	900	585	M	A	13.5	13.4	N	L	X
SS	08/10	951	680	M	A	13.5	13.4	N	L	X
SS	08/10	1013	585	M	A	13.5	13.5	Y	SP	C
SS	08/10	1129	620	F	A	12.0	11.7	Y	L	X
SS	08/10	1240	565	M	A	13.5	13.4	Y	L	C
SS	08/10	1319	575	F	A	13.5	13.4	Y	M	L
SS	08/10	1423	600	M	A	13.5	13.4	N	SP	L
SS	08/10	1500	510	F	A	13.5	13.4	Y	H	C
SS	08/10	1520	440	M	A	13.5	13.4	N	L	X
SS	08/11	940	565	M	A	13.5	13.4	Y	H	R
RS	08/12	1200	625	M	G	7.2	7.2	N	SP	C
RS	08/12	1200	600	M	G	7.2	7.2	N	SP	R
RS	08/12	1445	520	F	W	19.0	13.5	Y	L	L
RS	08/12	1445	510	M	W	19.0	13.5	N	SP	R
RS	08/12	1450	610	M	W	19.0	13.5	N	L	R
RS	08/12	1500	530	F	W	19.0	13.5	N	L	X
RS	08/12	1605	580	M	W	19.0	13.5	N	L	X
RS	08/12	1610	540	M	W	19.0	13.5	N	L	R
RS	08/12	1615	585	M	W	19.0	13.5	N	SP	L
RS	08/12	1625	510	F	W	19.0	13.5	N	SP	R
SS	08/17	1010	600	M	A	13.0	13.1	N	SP	L
RS	08/17	1100	475	F	A	12.8	12.8	Y	M	X
SS	08/19	1105	610	M	W	19.0	13.5	N	SP	X
RS	08/19	1110	580	F	W	19.0	13.5	Y	SP	X
RS	08/19	1115	575	M	W	19.0	13.5	N	SP	L
RS	08/19	1125	485	F	W	19.0	13.5	Y	M	X
SS	08/19	1225	600	M	W	19.0	13.5	Y	M	X

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Appendix A1. (Page 2 of 4).

Species	Date (1993)	Hour	Length (mm)	Sex	Fishing Method	RM Location		Sea Lice	Fate	Bank
						Caught	Released			
SS	08/19	1230	650	M	W	19.0	13.5	Y	M	X
SS	08/19	1235	565	F	W	19.0	13.5	N	L	X
RS	08/19	1240	595	F	W	19.0	13.5	N	M	X
RS	08/19	1405	615	M	W	19.0	13.5	Y	SP	X
SS	08/19	1410	570	F	W	19.0	13.5	Y	L	X
RS	08/19	1415	580	M	W	19.0	13.5	N	SP	X
RS	08/19	1415	545	F	W	19.0	13.5	Y	SP	X
RS	08/20	1255	590	M	W	19.0	13.5	N	SP	X
RS	08/20	1300	555	M	W	19.0	13.5	N	SP	X
SS	08/30	1500	570	F	W	19.0	13.5	Y	M	X
RS	08/30	1505	615	M	W	19.0	13.5	N	SP	R
SS	08/30	1645	580	F	W	19.0	13.5	N	SP	R
SS	08/31	1312	560	M	W	19.0	13.5	N	SP	C
RS	08/31	1316	605	M	W	19.0	13.5	Y	SP	R
RS	08/31	1320	540	M	W	19.0	13.5	N	SP	R
SS	08/31	1516	560	M	W	19.0	13.5	N	H	R
RS	09/01	1020	530	M	W	19.0	13.5	Y	SP	C
SS	09/01	1500	560	M	W	19.0	13.5	N	SP	R
SS	09/01	1506	670	M	W	19.0	13.5	Y	SP	R
SS	09/02	1043	585	M	W	19.0	13.5	Y	SP	L
SS	09/02	1048	530	F	W	19.0	13.5	N	L	R
SS	09/02	1330	640	F	W	19.0	13.5	Y	M	X
SS	09/03	1251	640	F	W	19.0	13.5	Y	M	C
SS	09/03	1556	605	F	W	19.0	13.5	Y	L	X
SS	09/09	1324	650	M	W	19.0	13.5	Y	M	X
SS	09/09	1540	515	F	W	19.0	13.5	Y	SP	L
SS	09/13	1538	565	F	A	13.5	13.1	Y	L	C

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Appendix A1. (Page 3 of 4).

Species	Date	Hour	Length (mm)	Sex	Fishing Method	RM Location		Sea		
	(1993)					Caught	Released	Lice	Fate	Bank
SS	09/14	1030	455	F	W	19.0	13.5	N	L	X
RS	09/15	957	570	F	W	19.0	13.5	N	L	X
SS	09/15	1500	650	M	W	19.0	13.5	N	L	X
SS	09/16	1626	575	F	W	19.0	13.5	N	M	C
SS	09/16	1629	595	F	W	19.0	13.5	N	L	X
SS	09/17	1020	585	M	W	19.0	13.5	N	SP	C
SS	09/17	1345	625	M	W	19.0	13.5	Y	L	X
SS	09/17	1350	575	M	W	19.0	13.5	N	L	X
SS	09/20	1600	650	F	W	19.0	13.5	Y	M	C
SS	09/20	1608	650	M	W	19.0	13.5	Y	M	X
SS	09/20	1610	570	M	W	19.0	13.5	Y	SP	R
SS	09/21	1435	645	M	W	19.0	13.5	N	L	X
SS	09/21	1442	585	F	W	19.0	13.5	Y	M	L
SS	09/21	1448	615	F	W	19.0	13.5	Y	M	X
SS	09/21	1455	600	M	W	19.0	13.5	Y	L	C
SS	09/21	1545	645	F	W	19.0	13.5	N	M	X
SS	09/21	1548	625	M	W	19.0	13.5	N	L	X
SS	09/21	1552	620	M	W	19.0	13.5	Y	L	R
SS	09/21	1557	645	M	W	19.0	13.5	N	L	B
SS	09/22	1600	625	M	W	19.0	13.5	N	L	C
SS	09/22	1600	600	M	W	19.0	13.5	N	L	X
SS	09/22	1600	635	F	W	19.0	13.5	N	L	X
SS	09/22	1600	620	F	W	19.0	13.5	N	SP	C
SS	09/22	1600	630	F	W	19.0	13.5	N	L	X
SS	09/23	1545	585	M	W	19.0	13.5	Y	SP	L
SS	09/23	1545	590	F	W	19.0	13.5	Y	L	X
SS	09/23	1545	625	F	W	19.0	13.5	N	SP	R
SS	09/23	1545	550	F	W	19.0	13.5	N	SP	R
SS	09/24	1440	625	F	W	19.0	13.5	Y	L	X
SS	09/24	1440	655	F	W	19.0	13.5	Y	L	C

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Appendix A1. (Page 4 of 4).

Species	Date	Hour	Length (mm)	Sex	Fishing Method	RM Location		Sea		
	(1993)					Caught	Released	Lice	Fate	Bank
SS	09/24	1440	605	M	W	19.0	13.5	Y	SP	L
SS	09/24	1440	575	F	W	19.0	13.5	Y	H	R
SS	09/28	925	670	M	W	19.0	13.5	Y	L	X
SS	09/28	928	635	M	W	19.0	13.5	N	L	X
SS	09/28	930	580	F	W	19.0	13.5	N	L	X
SS	09/28	940	545	M	W	19.0	13.5	N	L	R
SS	09/28	1030	620	M	W	19.0	13.5	Y	L	C
SS	09/29	1545	625	M	W	19.0	13.5	N	SP	C
SS	09/29	1545	665	M	W	19.0	13.5	N	M	C

^a

Species	Fishing Method	Fate	Bank
SS - Coho Salmon	A - Angling	L - Unknown	R - Right
RS - Sockeye Salmon	G - Gill Net	SP - Spawner	L - Left
	W - Fish Wheel	M - Mortality	C - Center
	H - Harvested		X - None

Appendix A2. Detailed recovery information from automated data loggers located at rm 14, 1993.

Julian Day	Hour	Minute	Frequency	Pulses	Species ^a	Bank
222	20	21	48.142	5	SS	L
224	21	3	48.120	5	SS	L
225	6	6	48.282	5	RS	L
225	7	47	48.203	11	SS	R
225	8	34	48.263	5	RS	R
225	9	14	48.482	4	RS	R
225	10	1	48.442	5	RS	R
225	11	17	48.362	5	RS	R
225	17	35	48.460	4	RS	L
225	21	8	48.303	5	RS	R
231	7	3	48.500	5	SS	L
231	15	47	48.580	5	RS	L
242	19	23	48.842	5	RS	R
243	16	2	48.922	4	RS	R
243	21	8	48.943	4	SS	R
244	8	1	48.903	4	RS	R
245	12	56	48.222	4	SS	L
246	4	22	48.863	4	SS	R
247	13	31	48.981	4	SS	R
248	8	41	49.000	5	SS	R
249	16	23	48.323	10	SS	R
259	13	19	49.020	4	SS	L
264	21	17	49.422	4	SS	R
265	12	17	49.722	4	SS	R
265	12	29	49.720	4	SS	L
266	11	10	49.682	5	SS	R
266	13	10	49.520	4	SS	L
267	9	43	49.927	5	SS	L
267	16	57	49.360	5	SS	L
268	12	40	49.041	4	SS	R
268	14	3	49.461	5	SS	R
272	8	58	49.962	5	SS	R
273	9	10	49.780	9	SS	R

^a

Species

SS - Coho Salmon

RS - Sockeye Salmon