USE OF DUAL-BEAM HYDROACOUSTIC GEAR TO PROVIDE IN-RIVER ESTIMATES OF COHO SALMON ABUNDANCE:

1991 FEASIBILITY STUDY

By

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Many people made significant contributions toward the successful completion of this project's first year. Crew members worked beyond their normal shifts repairing and maintaining the fish wheel, mending gill nets,and generally doing whatever was needed to keep the project running smoothly. Their commitment to excellence in collecting precise, clean data was much appreciated. Crew members on the 1991 coho sonar project were Diane Campbell, Dale Kohlmoos, Linda Lowder, Bruce Whelan, and Tom McCutchan. Additionally, we would like to thank Ken Tarbox and Bruce King of ADF&G Commercial Fisheries Division for the use of several equipment items during the course of the project, including the fish wheel, sonar sheds, and portable weirs. Mary King (ADF&G, Sport Fish Division) also provided the use of a boat and motor for the test fishery, as well as coho age sex and length information from 1991 creel census data.

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ABSTRACT

A study was initiated in 1991 to determine the feasibility of using dual beam technology to obtain riverine abundance estimates of coho salmon (*Oncorhynchus kisutch*) in the Kenai River. Hydroacoustic data were collected from 22 August to 15 September to determine spatial and temporal distribution of fish species present during these dates. Target strength information for the above species was also collected. Concurrent with collection of the hydroacoustic data, length frequency data were collected for coho salmon, sockeye salmon (*O. nerka*) and other fish species from drift gill nets and fish wheels in the same study area. Differences in range distributions of acoustic targets were found between the months of August and September with higher rates of offshore passage occurring in September. In addition, diurnal patterns in fish passage were documented from the acoustic data. Fish wheel and gill net data indicated that sockeye salmon tend to move past the sonar site closer to shore and more nocturnally than do coho salmon.

KEYWORDS: salmon abundance, hydroacoustic sampling, gill net, fish wheel, dual beam sonar, migratory behavior

INTRODUCTION

The purpose of the 1991 season investigation was to begin a determination of the feasibility of using sonar to provide seasonal estimates of riverine coho salmon passage on the Kenai River. Hydroacoustic sampling has proved a successful method of estimating the chinook salmon return on the Kenai River, providing daily estimates of fish passage to management biologists since 1987. This project was part of a comprehensive coho research and management effort in Upper Cook Inlet initiated by the Division of Sport Fisheries (Meyer et al., 1991).

Specific objectives for the 1991 season were as follows:

1. locate a suitable site for deploying hydroacoustic gear;
2. determine optimal transducer beam widths for ensonifying the water column at the selected site;
3. estimate spatial distributions of fish species present;
4. collect preliminary data for acoustic size classes of fish species present;
5. estimate the physical length distribution of fish species present, using coho salmon creel census data and fish lengths obtained from the fish wheel catch; and
6. estimate a first approximation of fish species composition passing at ranges determined in objective 2 using a fish wheel and drift gillnets.

Study Area

Field investigations in the 1991 season took place at approximately river mile 19 (Figure 1). This site is also used by the Commercial Fisheries Division to estimate sockeye salmon passage with Bendix side-looking sonar. Preliminary information indicated the bottom profile at this site was suitable for hydroacoustic sampling (Bruce King, Alaska Department of Fish and Game, Soldotna, personal communication). Drive-up accessibility also made the site logistically attractive. Documented spawning of coho salmon (Booth,1990) placed this site at the extreme downstream limit of fish spawning in the Kenai River mainstem.

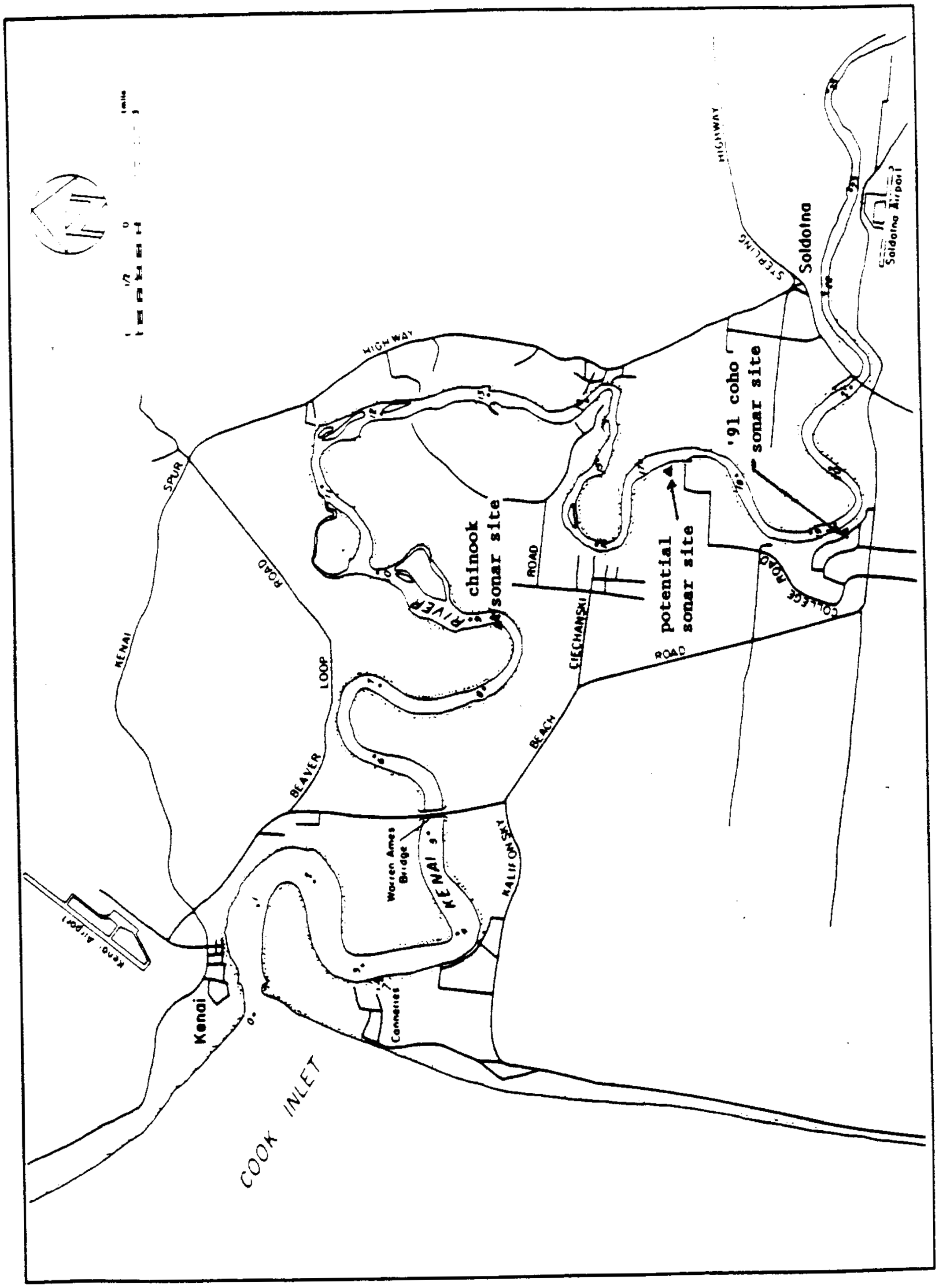

Figure 1. Study area on the Kenai River showing various sonar sites.

METHODS

Hydroacoustic Sampling

Sonar data were collected from 22 August through 15 September on the right bank. Left bank hydroacoustic samples were collected from 24 August through 15 September. Dual-beam 420 Khz transducers were deployed on each bank of the river on steel tripods. Remote aiming equipment allowed transducers to be aimed through pan and tilt planes for optimal beam aim. Sonar systems were run by a Biosonics[1] Model 102 echosounder on the right bank and a Biosonics Model 101 echosounder in conjunction with a Biosonics Model 151 multiplexer/equalizer on the left bank. Existing sheds on each side of the river were used to house remote aiming controls, sonar systems and support electronics. The right bank sonar system and support electronics were powered by a Yamaha EF3800 electric-start generator, while the right bank was powered directly by a connection to existing power lines.

Samples of 45-min duration, broken into three 15-min subsamples, were carried out at alternate hours on each bank. The period 00:00-08:00 hours was sampled on each bank on alternating nights (Table 1). Sampling was continuous during night periods. Sonar sampling was discontinued from approximately 12:00-14:00 hours and 19:00-21:00 hours each day in order to allow crew members monitoring the sonar system to assist in test fishing. Sonar data were collected in parallel on thermal chart recorders and computer file. A Grumman 5.5-m (18-ft) flat-bottomed river boat with a 25 h.p. Yamaha outboard engine was used to ferry between banks to monitor the sonar system on each side in order to keep the alternating hour sampling schedule. Because of wide-beam cable connection problems, dual beam data was not collected during the period 22-27 August on either bank. Additionally, on the right bank, dual beam data was not collected during the period 1-3 September.

Test-Fishing Program

Fish Wheel

A fish wheel was in operation on the right bank from 22 August through 31 August. Falling water levels necessitated moving the fish wheel to the left bank after 31 August. The wheel operated on the left bank from 5 September through 14 September. The right bank wheel location was approximately 75 m downstream from the transducer location; on the left bank the wheel was located about 40 m downstream from the transducer site. The fish wheel fished 24 h per day. Fish caught were held in a live box until they could be measured and released, generally immediately before the first test-netting period and immediately after the second test-netting period. All fish caught were measured from mid-eye to tail fork and recorded by species.

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[1] use of company names does not constitute endorsement.

Table 1. Hydroacoustic sampling schedule for each bank (L=left, R=right)

HOUR	M-W-F-SUN	T-TR-SAT
0000	L	R
0100	L	R
0200	L	R
0300	L	R
0400	L	R
0500	L	R
0600	L	R
0700	L	R
0800	L	R
0900	R	L
1000	L	R
1100	R	L
1200	TEST-FISHING	
1300	TEST-FISHING	
1400	L	R
1500	R	L
1600	L	R
1700	R	L
1800	L	R
1900	TEST-FISHING	
2000	TEST-FISHING	
2100	R	L
2200	L	R
2300	R	L

Drift Gillnets

Gillnets were fished in that area of the river sampled by hydroacoustic gear to qualitatively estimate species composition with range. Nets used were approximately 18.3 m (60-ft) in length. Two stretch mesh sizes were used, 13.65 cm (5.4-in) and 15.24 cm (6.0-in), to cover the effective fishing range for sockeye and coho salmon. Netting was carried out during two periods of about 2 h duration each, one at 12:00-14:00 hours and the other at 19:00-21:00 hours. This design provided sampling at the brightest period and at dusk to allow for possible differential diel passage. During each period, two drifts were made per mesh size on each bank for a total of 16 drifts per day. Nets were drifted as close to shore as possible. Drifts were modified in length and distance from shore to avoid snags identified from previous drifts. A 6.1-m (20-ft) open aluminum boat with a 70 h.p. Johnson outboard engine was used to driftnets. At the end of each drift, the net was pulled completely in. Fish caught were disentangled and held in the live box of the fish wheel to revive until the end of the fishing period. Fish mortalities were delivered to the Soldotna Fish & Wildlife Protection office for distribution to local charities and individuals. All fish captured were measured from mid-eye to tail fork and recorded by species.

Data Analysis

Sonar data were processed for range and target strength distributions. On the left bank, samples from the period 28 August- 15 September were analyzed. On the right bank, samples from 22-26 August and 7-10 September were used. Because of cable problems experienced early in the study, only range data were available from 22-26 August samples. Target strength of fish targets were corrected for wide-beam drop-off and attenuation and plotted in frequency histograms. Likewise, range data were plotted in frequency histograms expressed as frequency of fish passing at range from the shore.

Physical length data for coho and sockeye salmon were similarly plotted in frequency histograms. Length data came from three sources: (1) gillnet and fish wheel samples collected in this study, concurrent with hydroacoustic samples, (2) coho creel survey data (also collected concurrent with hydroacoustic sampling), and (3) sockeye salmon data collected prior to this study at the mile 19 fish wheel, by the sockeye salmon Bendix sonar project. Proportions from gillnets and fish wheel catch were compared graphically for a gross indication of onshore and offshore species composition. Additionally, historical length distribution data for sockeye (mile 19 fish wheel), coho (creel census), and pink salmon (mile 19 fish wheel) are presented graphically here.

The efficiency of the signal processing software in counting coho salmon size fish targets was estimated through regression analysis. Numbers of fish were scored from chart traces for clean (i.e., missing erroneous echoes such as boat wake) 15-min samples within the 7-10 September period (right bank). Software-generated fish numbers for each corresponding sample were regressed on chart scores.

Alternate Site Selection

A Lowrance X-16 graphing fathometer was used to perform transects in an effort to identify alternate sites suitable for hydroacoustic sampling. Transects were carried out on 10 August and 10 September, covering the area between river mile 12 and 19. Chart traces of the transects were reviewed and information concerning ownership of riverfront property was obtained from the Kenai Borough Planning Department.

RESULTS

Hydroacoustic Sampling

While the Biosonics 3° transducer beam was found to fit within the shallow water on the right bank, the very close fit between the surface and bottom resulted in an undesirably low signal:noise ratio. This can result in non-detection of small targets and in distortion of target strength for detected fish. Noise was not found to be a problem on the deeper left bank. During the period 7-15 September, samples were intermittently noisy, probably due to debris in the water (possibly leaves from riparian deciduous trees).

Range distributions of fish passage on the right bank during the periods 22-26 August and 7-10 September showed considerable offshore passage (Figure 2). In August, the modal range was about 17 m ($\bar{x}$= 30.85 m, SD = 15.2 m). In September, modes were at about 20 and 48 m ($\bar{x}$= 36.29 m, SD = 12.8 m). Range distribution for the left bank peaked at 15 m. Mean range and standard deviation were 12.36 and 2.93 m, respectively. Maximum range on the left bank was 17 m.

The diurnal passage pattern on the right bank was similar for August and September (Figure 3). During August, passage peaked at 13:00-16:00 hours and declined from there to a low at 05:00-06:00 hours. In September, passage peaked about 08:00 hours and stayed fairly stable until 17:00 hours, after which it declined to a low at 23:00-03:00 hours. Diurnal passage information was not estimated for the left bank, because signal processing software used for tracking fish on this bank did not provide time of signal acquisition.

Right bank target strength distribution from the September period shows several modes, with mean and standard deviation of -23.25 dB and 4.43 dB, respectively (Figure 4). Target strength distribution on the left bank was bimodal, the main mode being at -37.5 dB. Mean target strength and standard deviation were -36.72 and 2.17 dB, respectively. Target strength data presented here should be considered preliminary. Because of ongoing work concerning wide-beam drop off and attenuation phenomena, these distributions may require correction. Decibel units labeling X-axes should be considered relative until more information becomes available. Additionally, postseason calibrations of echo sounders used have not been completed.

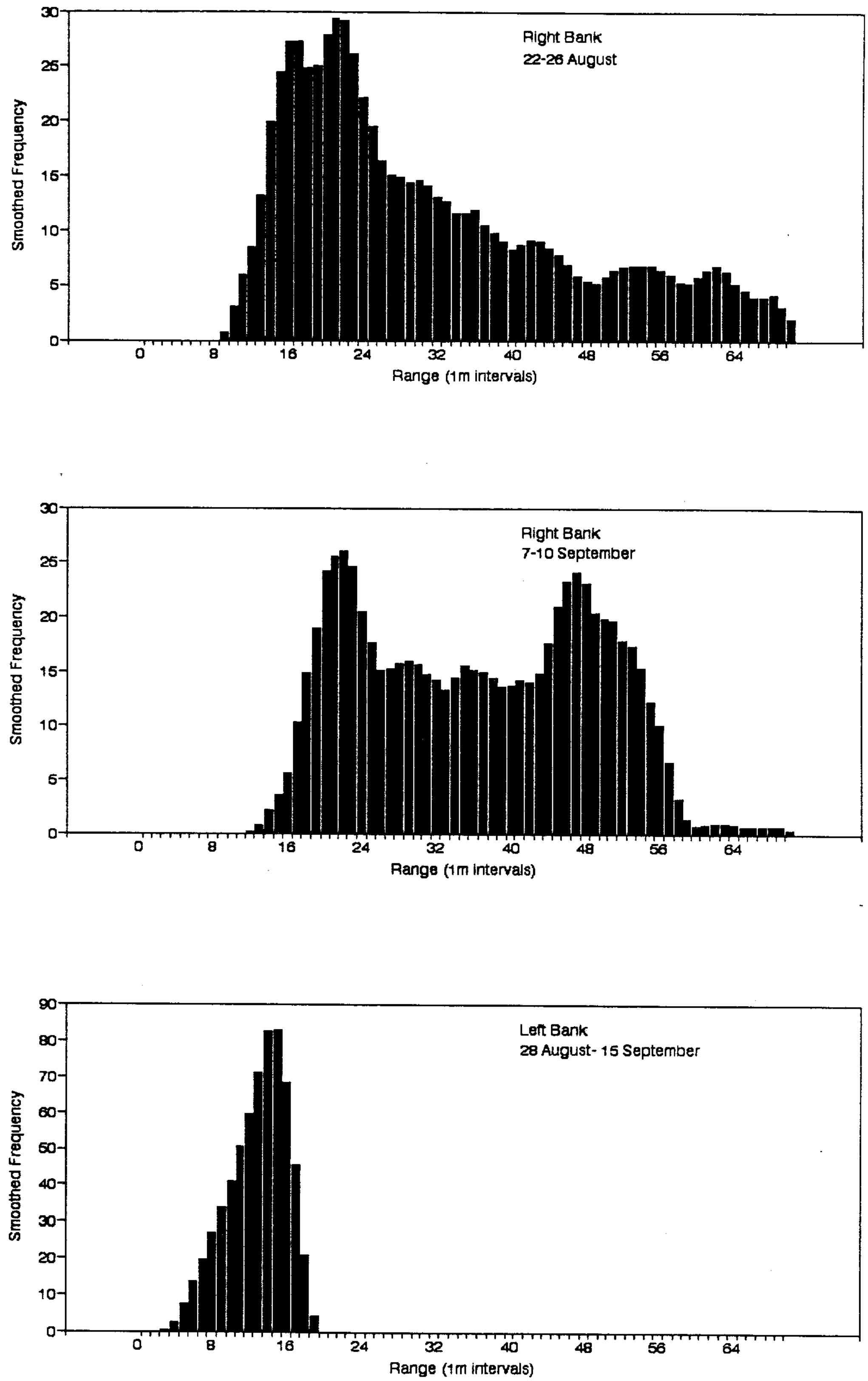
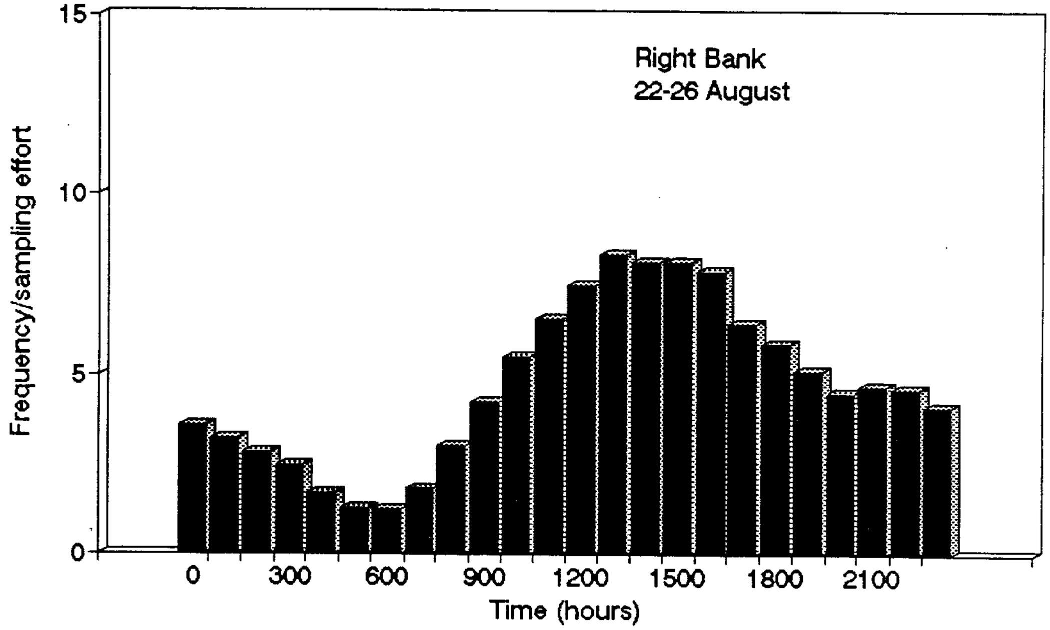


Figure 2. Range distribution for right and left banks.



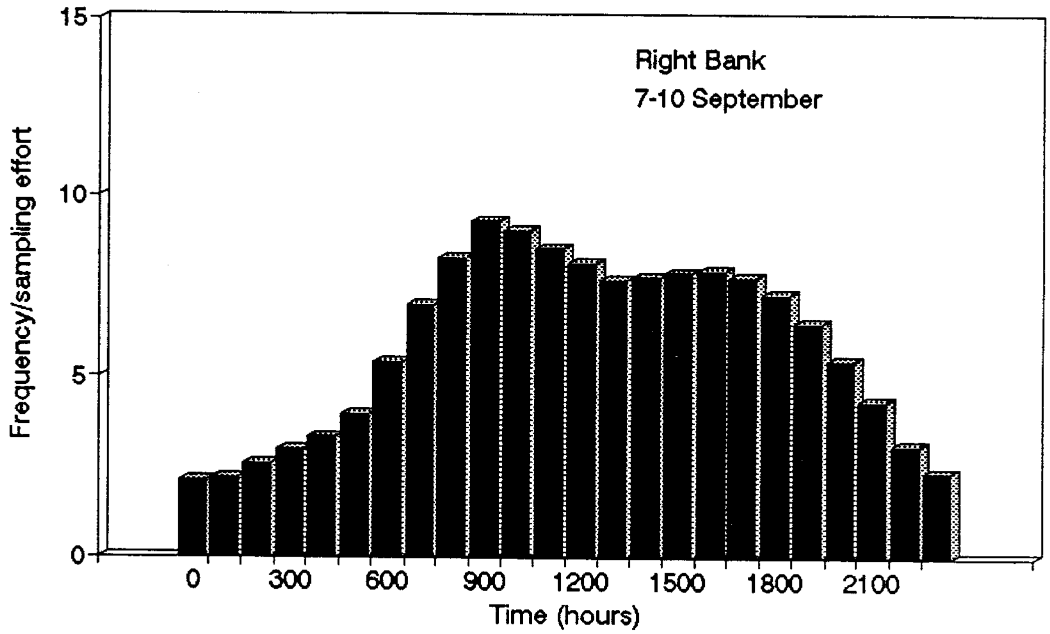


Figure 3. Right bank diurnal passage pattern.

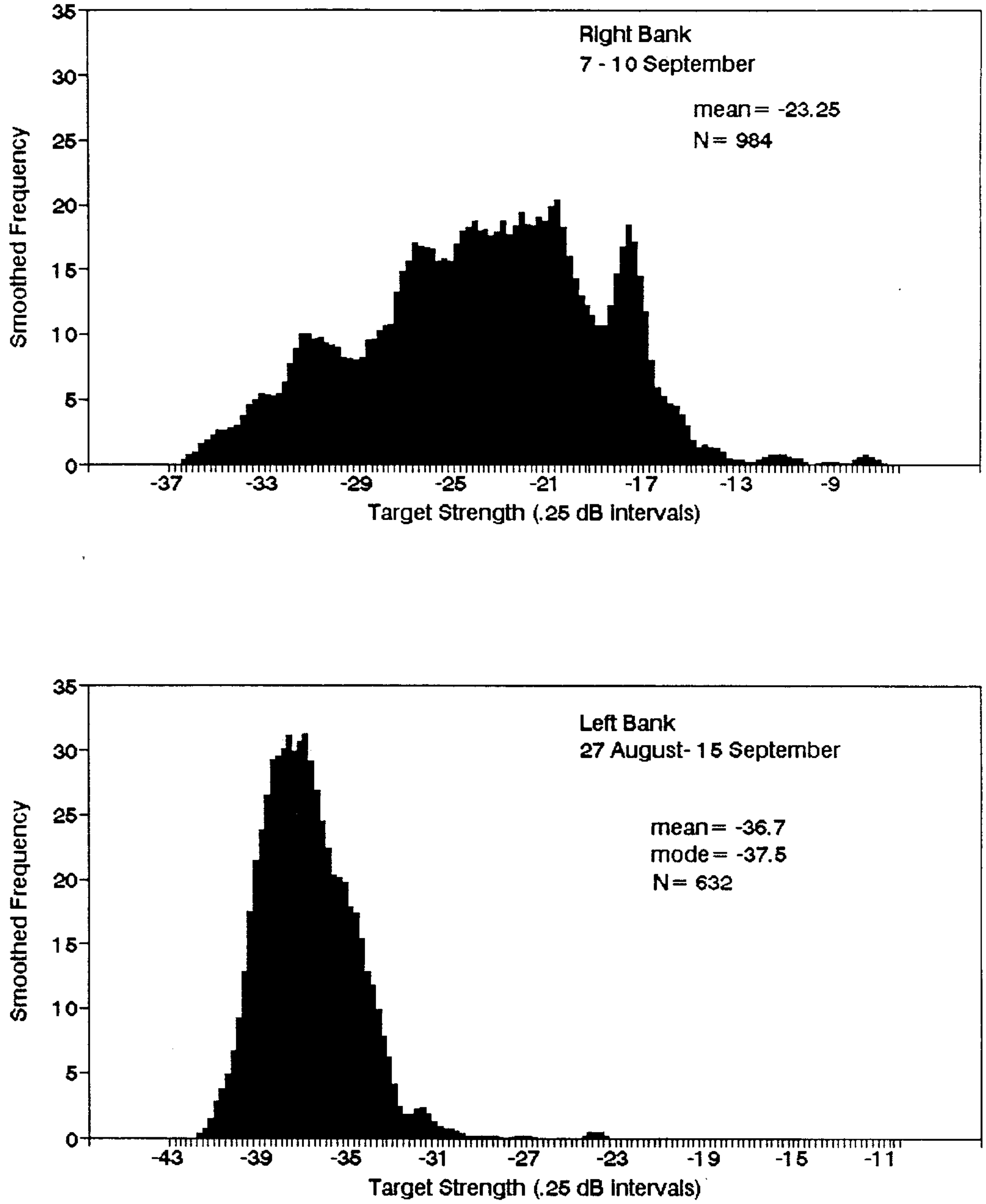


Figure 4. Target strength distribution for right and left bank.

Test-Fishing program

Fish Wheel

The species composition of the fish wheel catch went to 100% coho salmon after the fish wheel was moved to the left bank (Figure 5). There appeared to be a trend in this direction shortly before the wheel was moved, but time was insufficient for this to be clear. The night catch (21:00-11:00 hours) was predominantly sockeye salmon (63.7%, compared to 20.4% coho) until the wheel was moved to the left bank, while day catch sockeye and coho proportions were approximately equal during this time period (42.3% and 43.3%, respectively).

The fish wheel daily catch on the left bank was dramatically lower than the right bank. Over the 9-day period of fishing on this bank, a total of 10 fish (all coho salmon) were caught in the fish wheel. This compares with a mean daily catch on the right bank of 49 fish.

Drift Gillnets

Snags in the reach where hydroacoustic sampling was taking place prevented efficient fishing with drift gillnets. Drifts were shortened to avoid snags that routinely damaged nets. As the water level fell in late August and early September, drifts were moved farther offshore to avoid rocks that had now become snags in the shallower water. Thus, the nearshore zone was not being fished. Because of snags located upstream and downstream of the sonar site, drifts were limited to 1-2.5 min.

Species composition of drift gillnetting showed that sockeye salmon were only incidentally caught in nets, regardless of fishing period, date, bank, or mesh size (Figure 6). No sockeye salmon were caught in nets after 30 August. Other species caught incidentally in gillnets were not included in Figure 6.

Length Distribution

Length distribution of sockeye and coho salmon from pooled net and fish wheel catch showed a modal separation of approximately 90 mm between the two species (Figure 7). Of interest in the sockeye salmon catch is the distinct mode at approximately 360 mm. These small fish were usually *sea bright* and had sea lice attached. A small "tail" also appears in the coho distribution below 460 mm. Historical length distribution of sockeye and coho salmon in the Kenai River varied considerably from year to year (Appendices A.1-A.4). It appears from comparisons of historical length data available that the overlap in sockeye and coho distributions was less in 1991 than may be typical. Mean lengths (and standard error) for Kenai River sockeye (unpublished data), early run coho and late run coho from historical data (unpublished) were 536.0 (0.86) mm, 592.1 (2.5) mm, and 628.2 (2.0) mm, respectively (Appendix A.5). Mean pink salmon length for data collected over the years '70, '76, '78, and '80 was 486.3 mm (Davis et al.,1984).

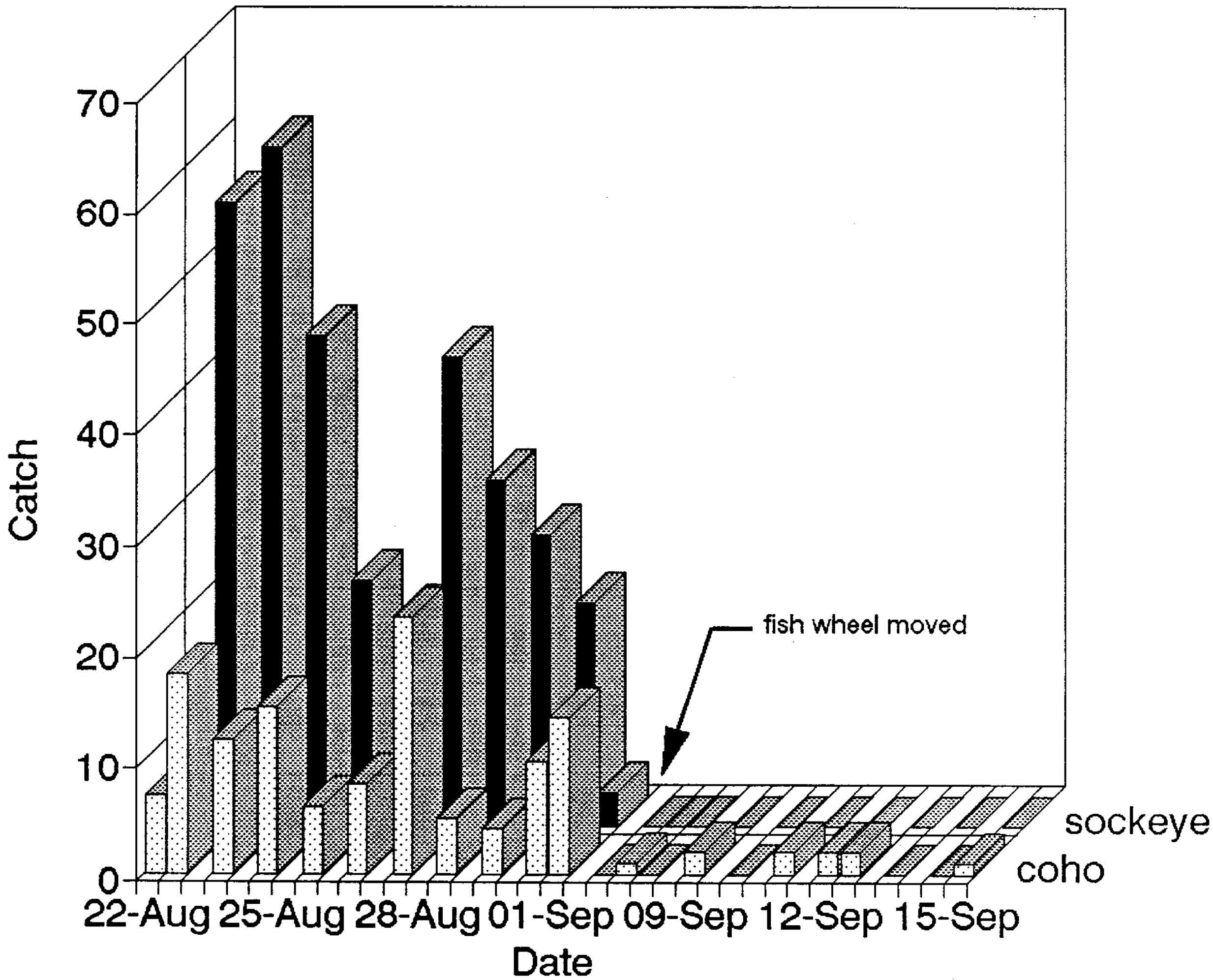


Figure 5. Species composition of fish wheel catch.

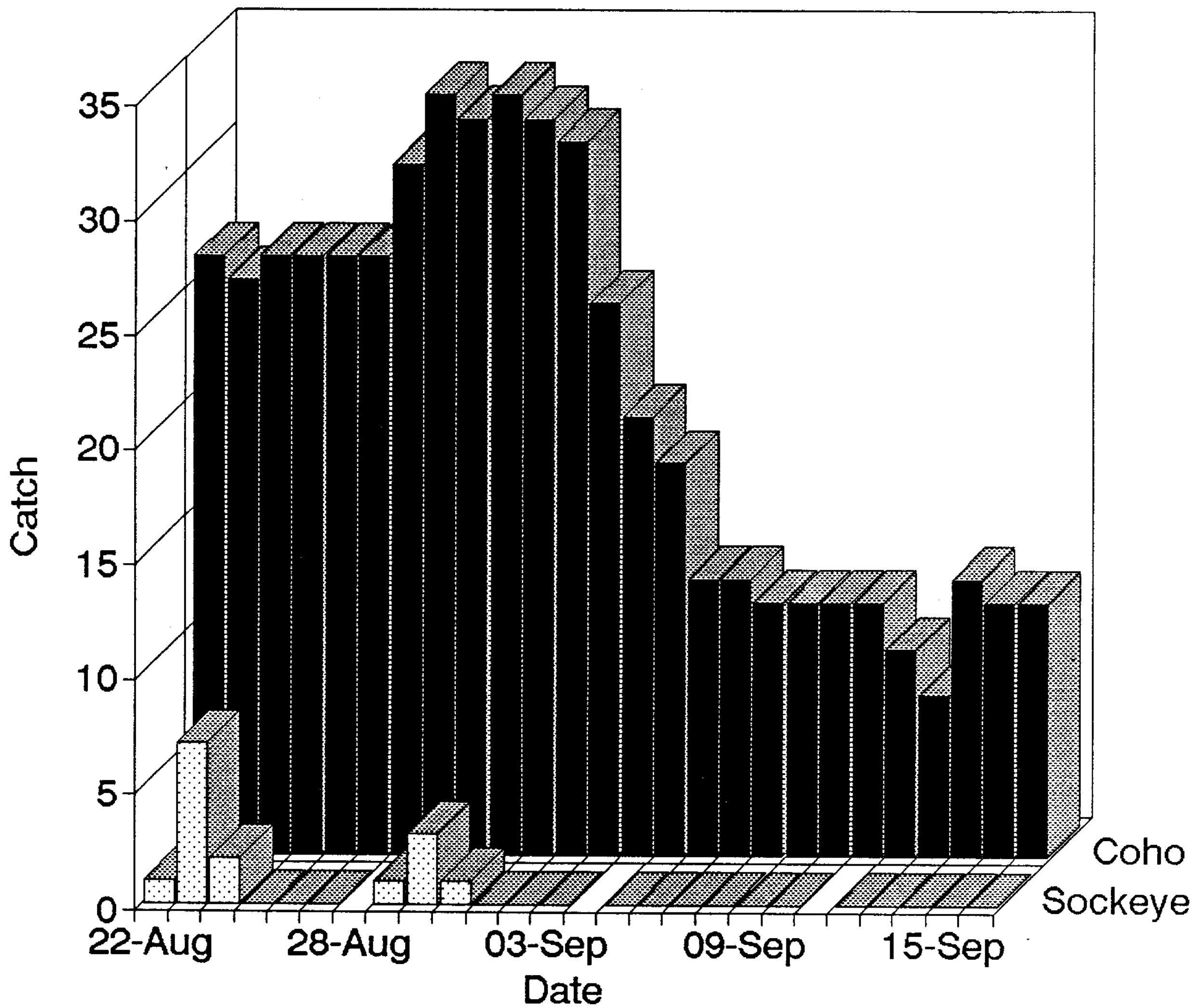


Figure 6. Species composition of drift gillnet catch.

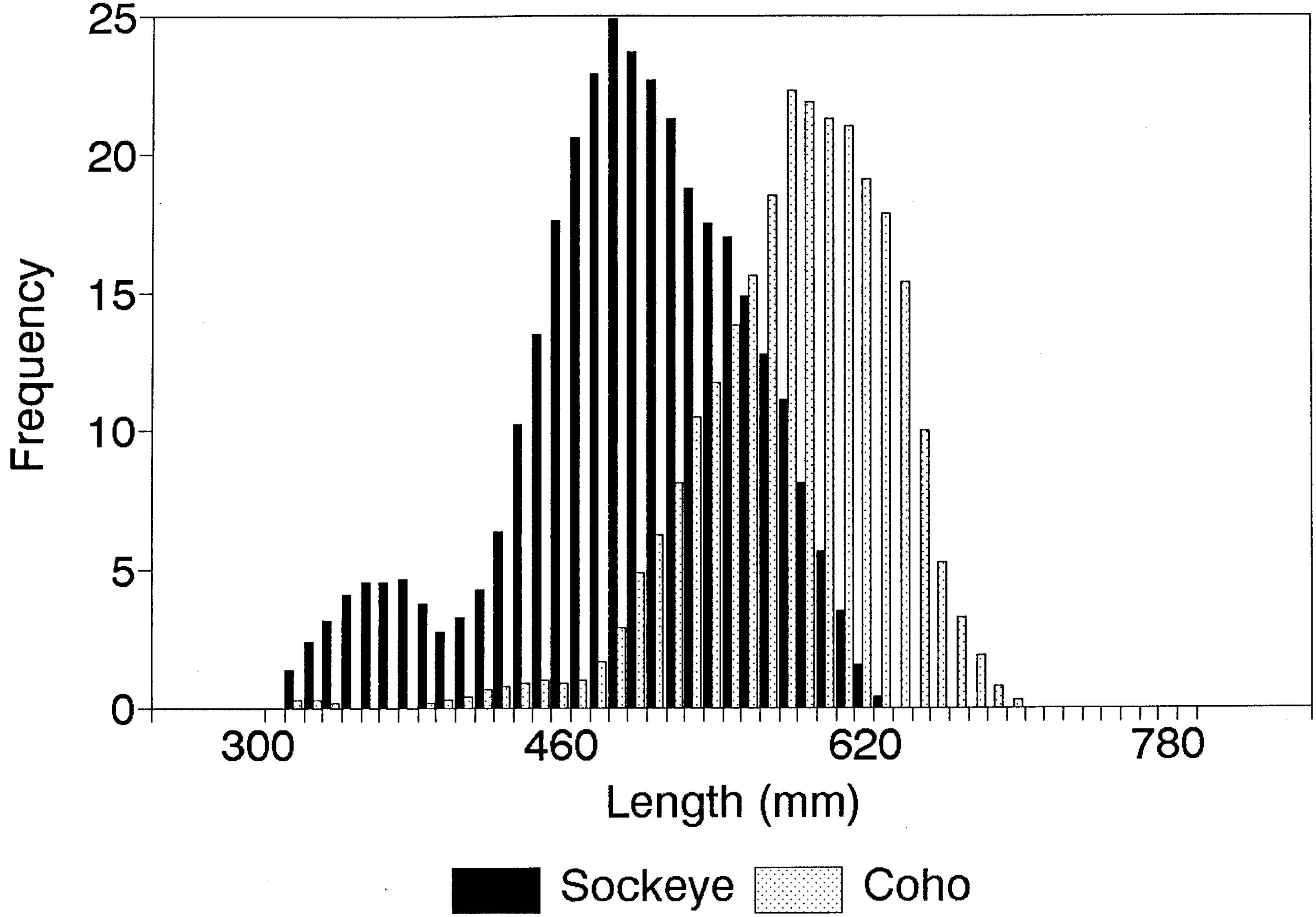


Figure 7. Length distribution of sockeye and coho salmon from fish wheel and gillnets.

Alternate Site Location

Fathometer transects were recorded over the area of the Kenai River between a site known as "The Pillars" and the mile 19 sonar site (Figure 1). No transects were recorded upstream of the mile 19 site. Only one site was located (approximately mile 17.5) as potentially suitable for hydroacoustic sampling. The site's bottom profile is smooth, with a fairly constant gradient, in addition to being approximately 0.3 m (1 ft) deeper than the mile 19 site at the river's thalweg. Land on both sides of the river at this location is privately owned. Sites rejected as suitable for a sonar site had uneven or stair-stepped bottom profiles with "sound shadow" areas, were too shallow, or had multiple channels.

Passage Estimate Efficiency

Regression analysis of 123 samples showed a nearly 1:1 relationship between visual estimates of fish passage from chart traces, and software generated passage estimates ($Y=1.06x - 0.493$, $r^2=0.67$, SE = 0.49). Of 123 data points, 2 were rejected as obvious outliers more than three SD from the sample mean.

DISCUSSION

Hydroacoustic Samples

The low signal:noise ratio characteristic of the right bank hydroacoustic samples (due to shallow water) is unacceptable for an operational project estimating coho passage. The relatively high background noise level distorts target strength estimates and pulse widths, parameters that have discriminative functions in identifying targets. Should the project be operational though October, historical water level records obtained from the U.S. Geological Survey, Water Resources Division for 1980-1990 show a worst case scenario of about 1.8 m (5.9-ft) maximum depth at the mile 19 site. The worst case scenario through the month of September would be approximately 1.9 m (6.2-ft). These maximum depths would require a beam angle of about 1.2°. The smallest beam angle practical to use because of expense and near-field phenomena is 2°. As transducer beam angle becomes narrower, the distance interval from the transducer face in which target strength cannot be estimated because of beam instability (near-field) increases. The near-field distance of the 3° transducers used in 1991 is 2.5 m; a 2° transducer would have a near-field distance of about 5 m. The fact that a 2° transducer beam at the present site would not be accommodated in the river channel at the lowest water stages points toward two options to deal with low water: (1) move the transducer out into deeper water as water level falls and extend a weir from the bank to a distance 5 m beyond the transducer face, or (2) locate a different site where channel depth will not be a problem.

Range distributions on the right bank do not suggest that sockeye and coho salmon utilize distinctly different range corridors at this site (Figure 2). During the period 7-10 September, the 25-60 m range corridor was utilized much more heavily than during 22-26 August. In August, 47.5% of passage occurred < 25 m from the bank, compared with 26.7% in September. This offshore shift in passage in bank, compared with 26.7% in September. This offshore shift in passage in September may have been caused by falling water levels at this time. Several years data will be required before any clear patterns may begin to emerge in range relationships.

The attenuated range distribution of the left bank suggests strongly that the sonar beam on this bank did not extend to the river thalweg (maximum channel depth). Fathometer transects at the transducer location showed a nonuniform, boulder-strewn bottom profile. It seems probable that the sonar beam was electronically truncated at a boulder rather than the river thalweg. This leaves a significant portion of the river channel unsampled, beginning at the end of the range distribution shown in Figure 2.

A strong daytime passage pattern is obvious in both August and September (Figure 3) with peak passages consistently between 09:00 and 16:00 hours. There appears to be two modes of passage in the August period, one at 13:00 hours and the other at 21:00-22:00 hours. The fish wheel catch was predominantly sockeye salmon in the night hours at this time, thus the later mode could be due to sockeye salmon passing at night. While this seems a reasonable explanation for the diurnal passage pattern in August, more data is needed to clarify this pattern.

Target strength distribution for the right bank (Figure 4) resembles the physical length distribution of sockeye and coho salmon pooled (Figure 8). Left bank target strength distribution does not resemble the pooled sockeye and coho length distribution. Few fish were caught in the fish wheel when it was on the left bank, and approximately 70% of fish caught in nets were in right bank drifts. It is possible that the species distribution in the river at this site is very different between banks, explaining the difference in target strength distributions between banks and the fact that the left bank target strength does not resemble the pooled sockeye and coho salmon length distribution. At this point, more acoustic data from the right bank needs to be analyzed in addition to having more physical length data originating from the left bank.

Test-Fishing Program

Based on the 1991 fish wheel and drift gillnet catch, it appears that sockeye salmon tend to move past the sonar site closer to shore and more nocturnally than do coho salmon. No distinct corresponding modal trends appear in the range distribution or diurnal passage pattern from right bank hydroacoustic samples, however. The fish wheel did not fish efficiently after being moved to the left bank. The fast current on the left bank caused a considerable amount of noise from rattling weir pickets, possibly spooking fish around the wheel. Difficulty was encountered in finding a location deep enough for the wheel to turn because of submerged boulders on this bank. An uneven bottom may have allowed most passing fish to swim beneath the turning fish wheel baskets. A fish wheel could be fished later on the right bank if it were modified to allow raising the axle about 1 ft.

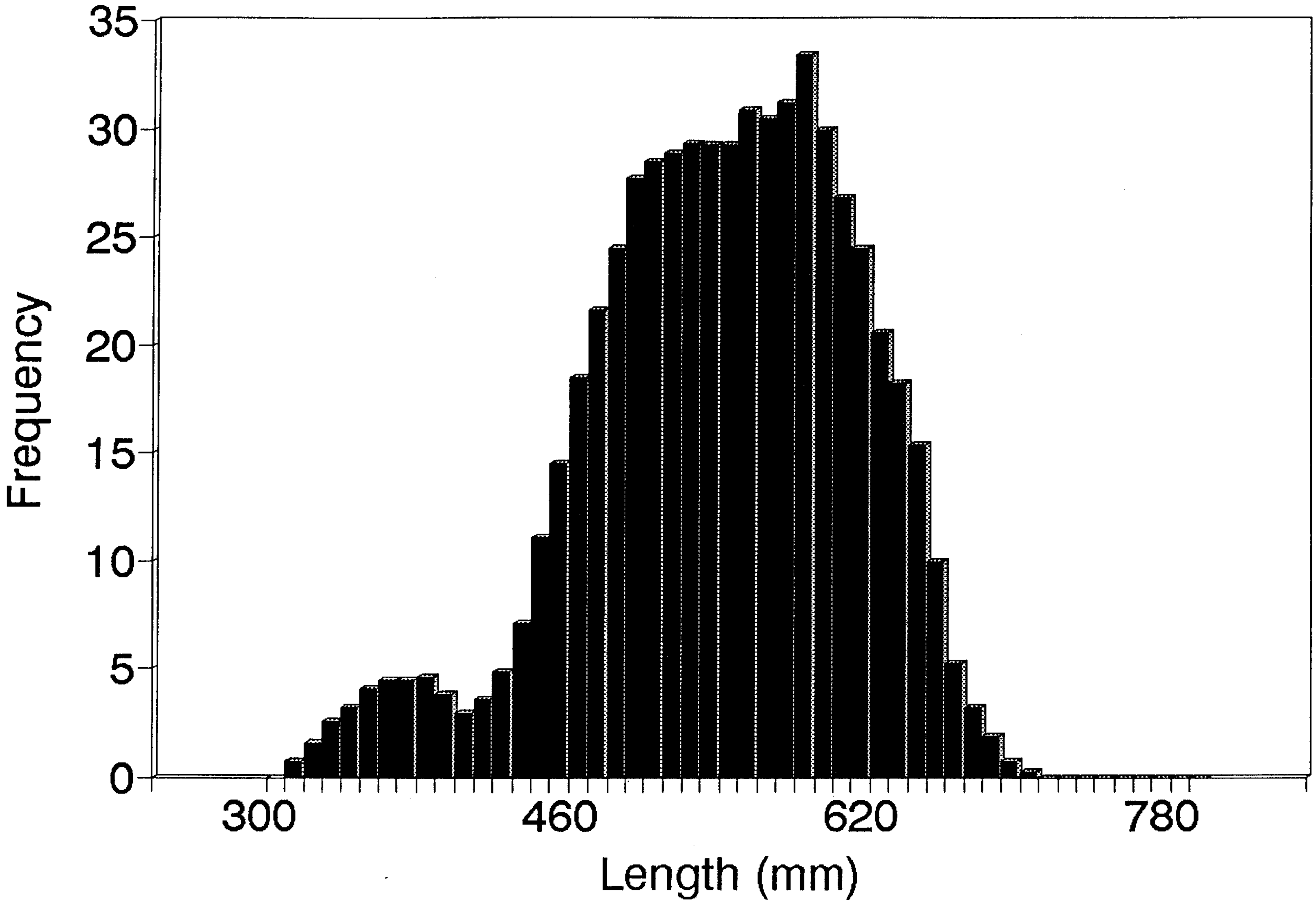


Figure 8. Length distribution of sockeye and coho salmon from fish wheel and gillnets.

Passage Estimate Efficiency

The slope of near unity in the regression relationship between chart traces and software generated fish indicates that on average, the signal processing software used (Biosonics ESP 2.0) estimated the same number of fish per sample as were estimated visually from chart traces. The fairly high variability of the relationship can probably be attributed to the parameters used in signal processing. Pulse width and maximum distance off axis parameters were set fairly restrictively to obtain the most reliable target strength distribution. As a result, many targets appearing on the chart traces did not fall within the range of acceptable parameter values and were rejected as targets. Additionally, the 0-12 m range was set at a lower voltage threshold than the sector beyond 12 m, resulting in some targets in the near range being recorded electronically in computer file but not on chart recordings. While it is expected that further experimentation with the ESP software might result in substantially decreased variability in passage estimates, it should also be emphasized that the data used in this test had been previously "cleaned" of erroneous echoes resulting from bottom or boat wake. For this software to be considered fully operational as an estimator of passage, existing routines to filter out these erroneous echoes must be tested and fine tuned.

RECOMMENDATIONS

A completely different hydroacoustic system is recommended for the 1992 season. To avoid the problem of attenuation of sound at 420 kHz (the frequency currently employed), it is recommended that a frequency of 120 kHz be used in 1992. The confounding influences of wide beam drop off and attenuation result in target strength estimates that are very uncertain. A switch to 120 kHz would also substantially decrease the background noise level, improving the signal:noise ratio of the acoustic environment. To make the change to sampling with 120 kHz sound, new transducers will be needed, as well as alterations to the existing echosounder. Transducers should have a beam angle of approximately 2° to accommodate shallow river channels.

It is further recommended that more time be spent in search of a suitable alternate site, preferably one with a deeper maximum depth. In addition to further investigation of the site identified in this report as suitable for hydroacoustic sampling, transects should be completed upstream of the mile 19 site, as well as further downstream than mile 12.

The drift gillnetting program in the 1991 field season provided crude information on species passage at range. In order for the test fishery program to yield data of substantial weight to verify species proportions estimated through model mixture analysis, considerably more thorough test netting would need to be initiated. This would be difficult in light of the problems encountered in the 1991 netting program. A decision needs to be made in the future concerning the relative value of a test gillnet fishery as a means of verifying species composition.

At this time, length distribution information obtainable from the coho creel census, together with sockeye salmon sampled in the mile 19 fish wheel during the sockeye Bendix sonar project, are considered adequate for the *a priori* length-at-age information required for model mixture analysis. It may be necessary to operate the fish wheel later than the traditional shut-off date of the sockeye project to obtain an adequate sample size for length and age of pink salmon in 1992.

The scope of the 1992 coho project as presently planned, focuses on two objectives, shown here in order of priority.

(1) collect acoustic size class information for later separation of distributions by model mixture analysis; and
(2) locate accessible sites more accommodating for deploying sonar gear than the mile 19 site and conduct preliminary sampling there.

Sampling should take place using 120 kHz equipment as previously discussed. Test fishing as a means of estimating species passage at range will not be a component of the 1992 project.

From our present position in the project's development, a future view of the successful Kenai Coho project is encapsulated as follows. The project is expected in the future to be operational from about early August through mid-October. Equipment using 120 kHz sound for hydroacoustic sampling will be employed. Coho salmon will be separated from other species post-seasonally by model mixture analysis. A seasonal estimate of coho salmon abundance will be available within about 1 month of return from the field.

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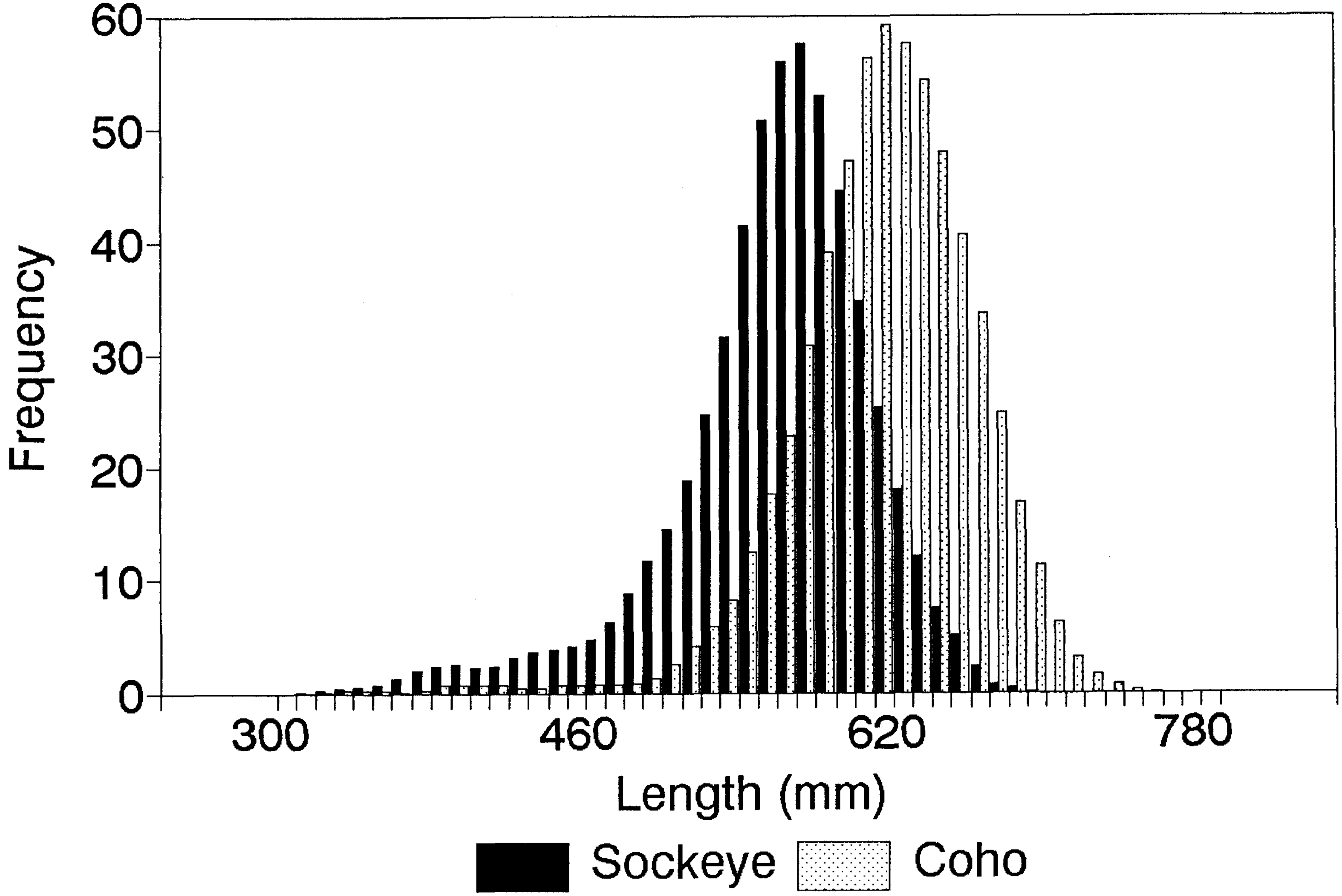
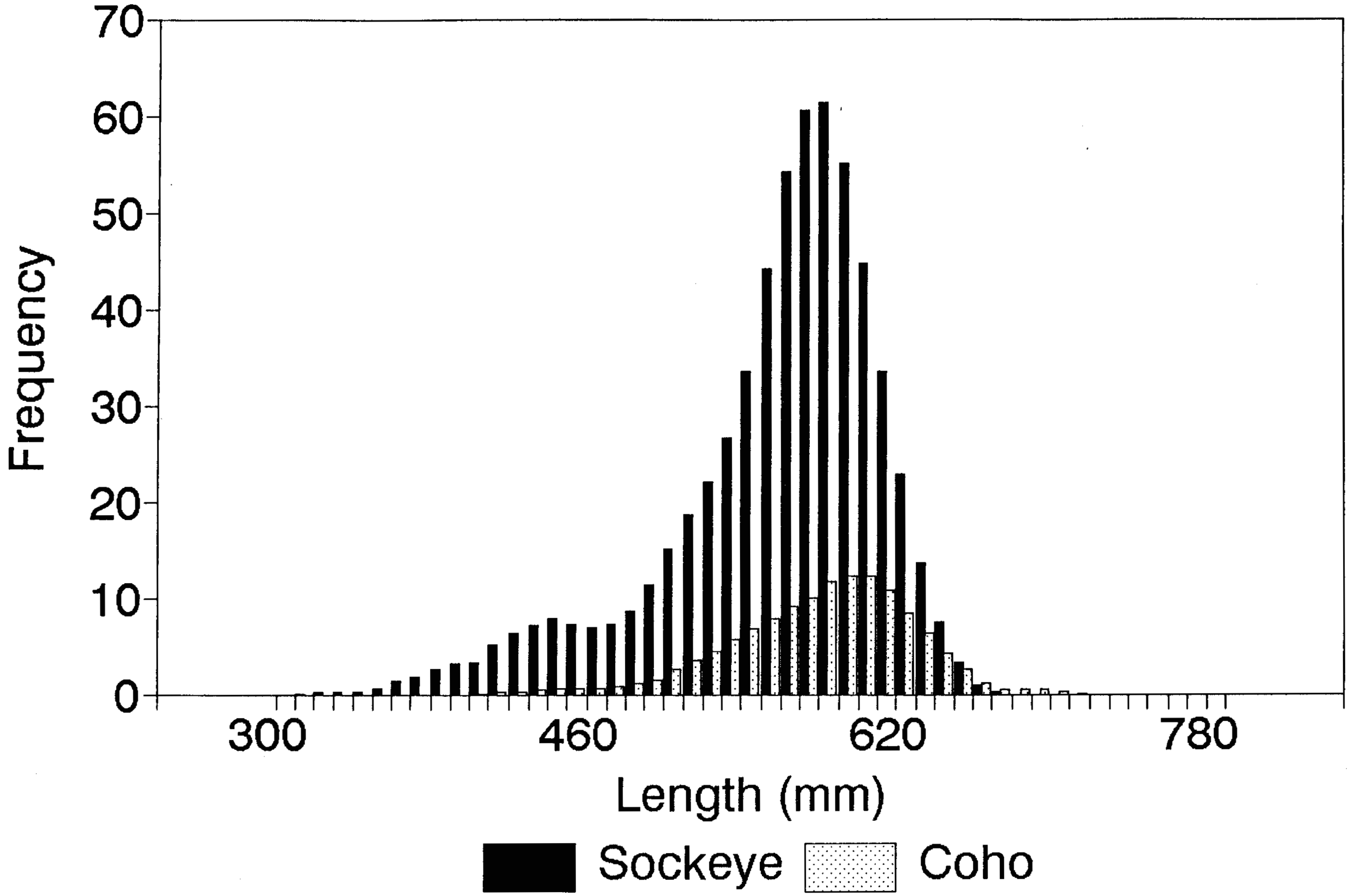
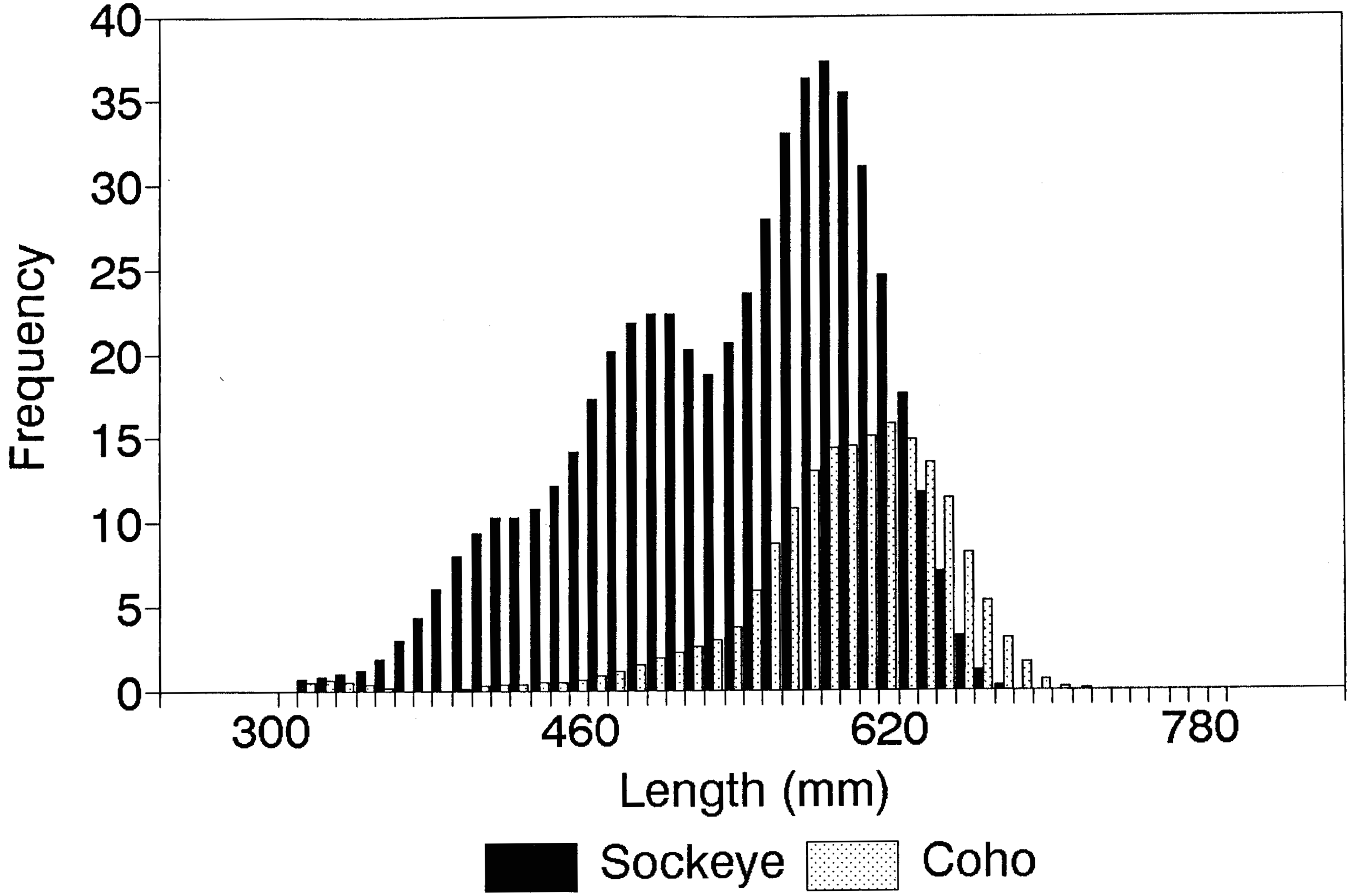
APPENDICES



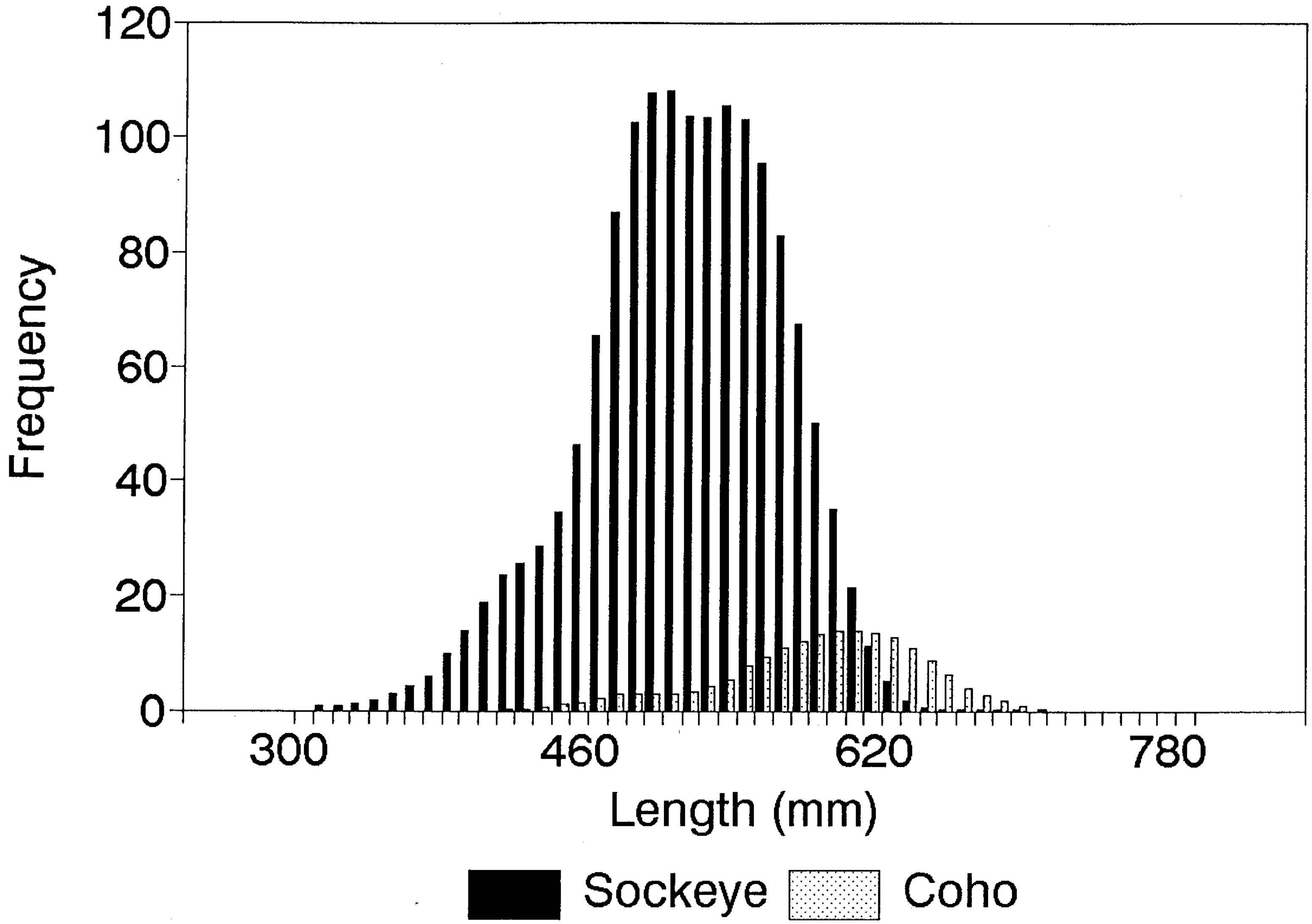
Appendix A.1. Length distribution of sockeye and coho salmon , 1988. Sockeye data from Comm. Fish Div., mile 19 fish wheel. Coho data from Sport Fish Div., creel census.



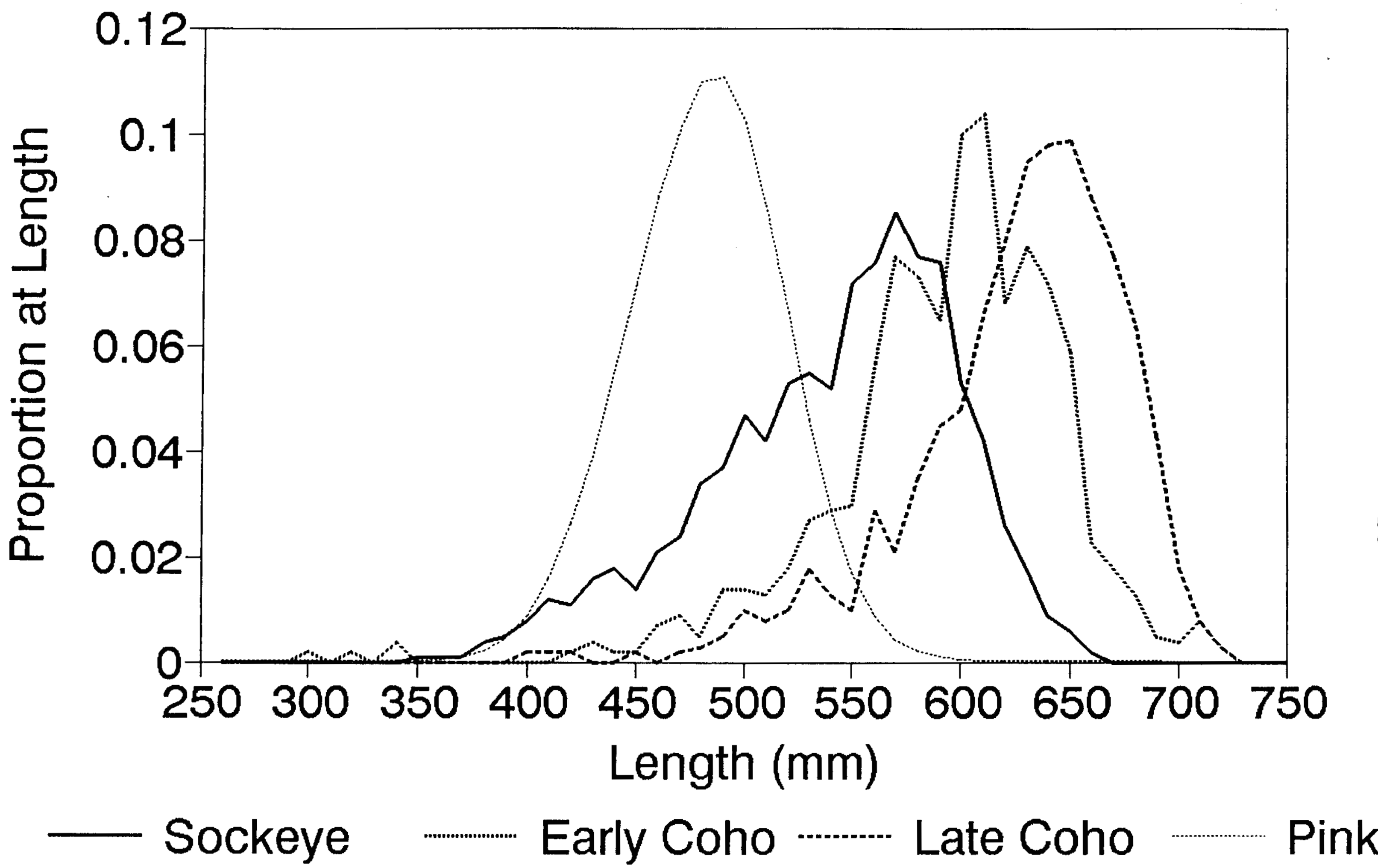
Appendix A.2. Length distribution of sockeye and coho salmon, 1989. Sockeye data from Comm. Fish Div., mile 19 fish wheel. Coho data from Sport Fish Div., creel census.



Appendix A.3. Length distribution of sockeye and coho salmon, 1990. Sockeye data from Comm. Fish Div., mile 19 fish wheel. Coho data from Sport Fish Div., creel census.

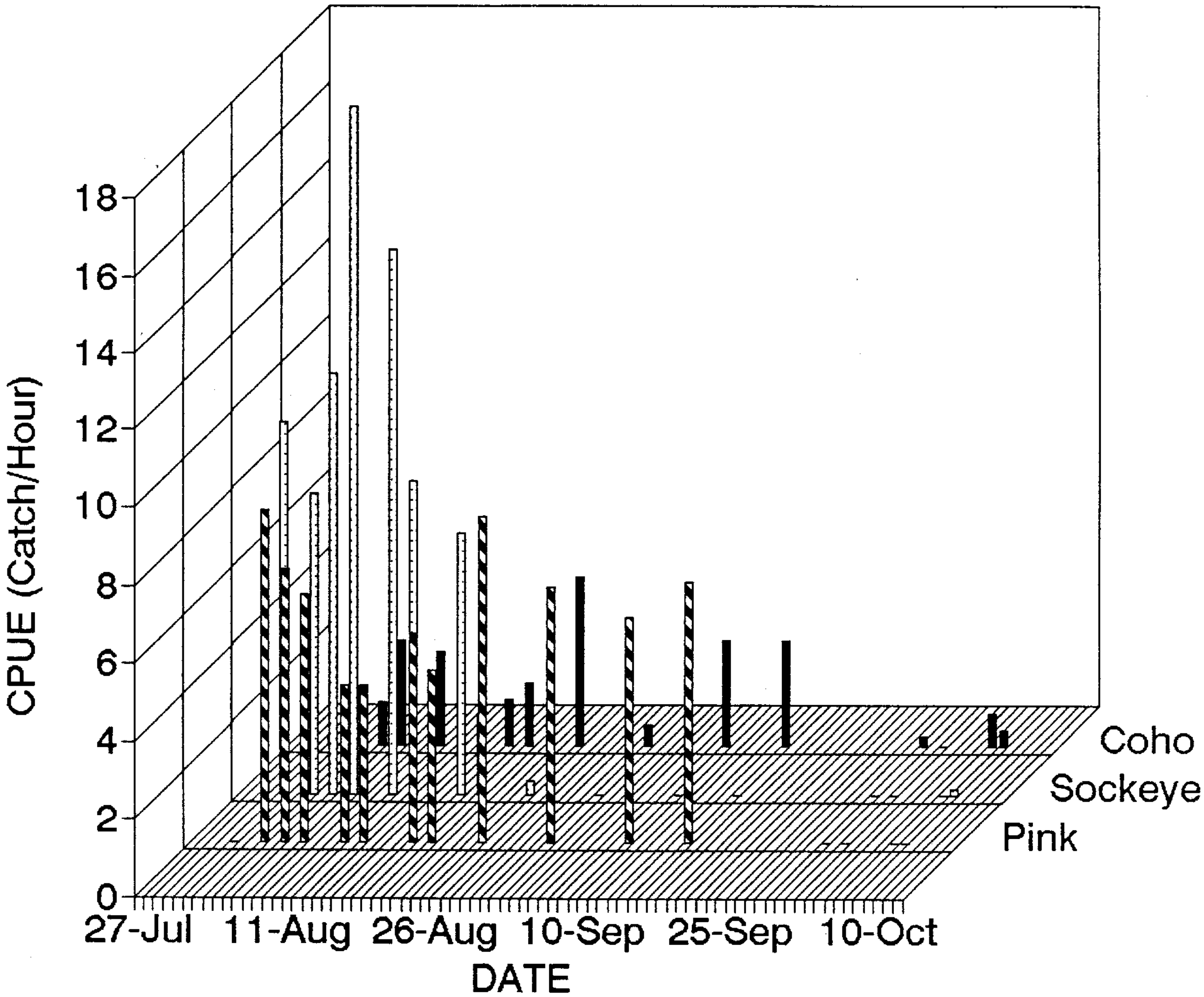


Appendix A.4. Length distribution of sockeye and coho salmon, 1991. Sockeye data from Comm. Fish Div., mile 19 fish wheel. Coho data from Sport Fish Div., creel census.

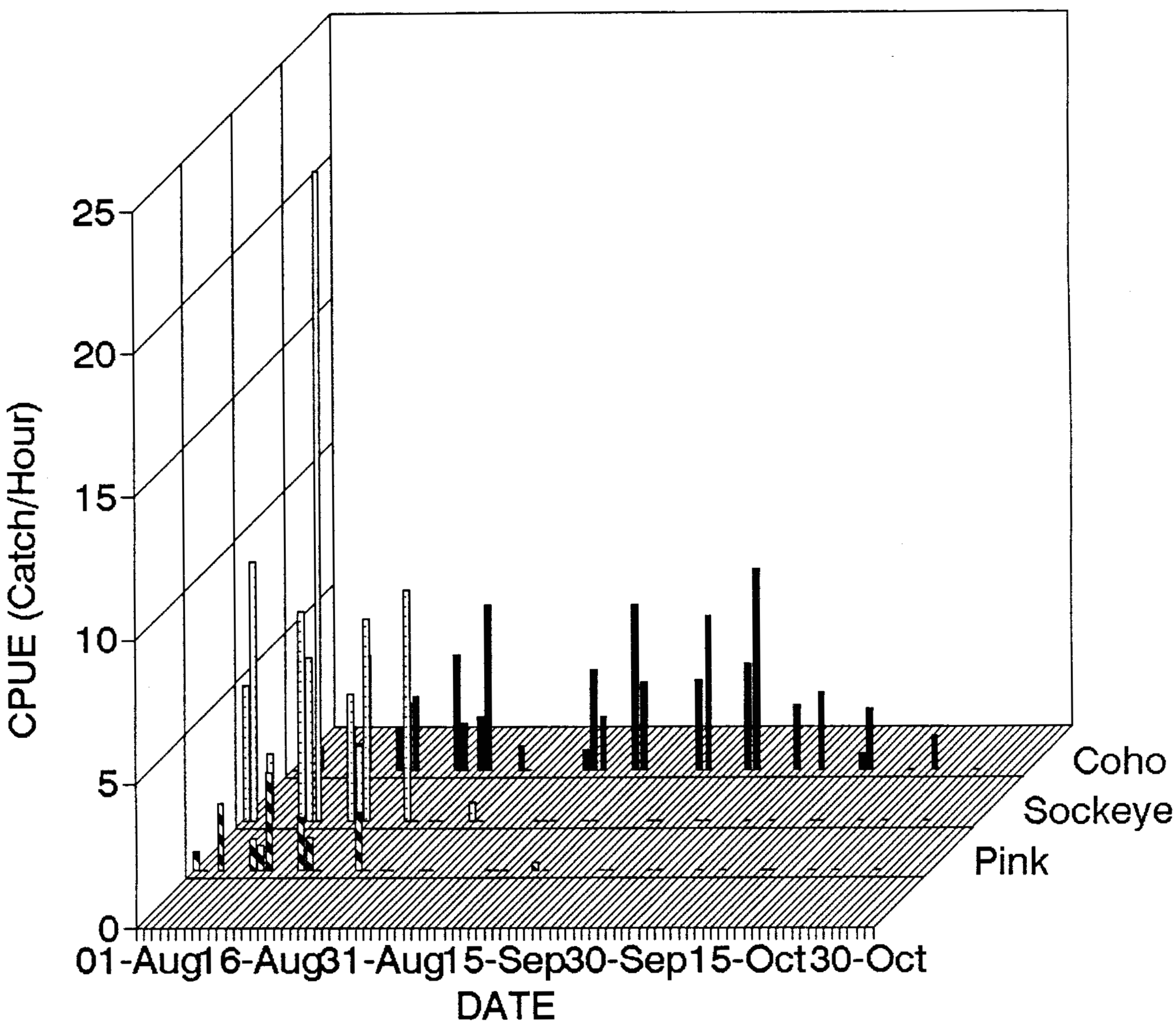


Appendix A.5. Length distribution of sockeye, coho, and pink salmon represented as proportion at length , pooled over years as noted below.

Sockeye data: (7/25 and later), '84-'91, Comm. Fish Div., mile 19 fishwheel , Coho data: '89-'91, Sport Fish Div. , creel census, Pink data: '70, '76, '78, '80, Comm. Fish Div., mile 19 fishwheel



Appendix B.1. Drift gillnet CPUE, 1988 (Booth, 1990).



Appendix B.2. Drift gillnet CPUE, 1989 (Booth, 1990).