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SONAR ENUMERATION OF MIGRATING FISH IN THE NOATAK RIVER, 1984

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ABSTRACT

The collection of inseason salmon escapement data from the Noatak River is an important element for the effective management of the Kotzebue Sound commercial chum salmon *(Oncorhynchus keta)* fishery. Hydroacoustic counting, combined with gill net species apportionment techniques, was used to estimate daily upstream passage of chum salmon at Noatak River kilometer 45.2. Fish were counted on both banks of the river between 16 July and 3 September 1984 and counts were apportioned to species over several days of counts. A total of 113,073 fish were estimated to have passed the study site. Test nets were monofilament set gill nets of two mesh sizes, 102 and 149 mm, and were fished at three locations, north bank, south bank, and midriver. Test-fishing results indicated a significant difference in species proportions between the three locations so sonar counts were apportioned separately for the three locations. A total of 44,182 chum salmon and 68,891 other species were estimated to have passed the study site. The mean date of chum salmon migration as estimated from sonar counts was 31 July which differed from the mean date calculated from Noatak River test-net indices which occurred on 4 August. Seasonal trends in chum salmon abundance were generally similar when sonar counts, commercial fishery catch per unit effort (CPUE), and test-net CPUE were compared. The sonar-estimated chum salmon escapement of 44,182 was significantly different from the estimate obtained from a post-season aerial count of 67,873 conducted on Noatak River chum salmon spawning grounds. Potential sources of error in the estimates of fish passage and species apportionment are discussed and recommendations for further study are offered.

KEY WORDS: chum salmon, *Oncorhynchus keta*, hydroacoustic counting, species composition, Kotzebue Sound, Noatak River, test-fishing, escapement.

INTRODUCTION

The Noatak River is a major producer of chum salmon (*Oncorhynchus keta*) for the Kotzebue Sound commercial salmon fishery. The collection of Noatak River escapement data is an important informational element for the effective management of this fishery. Prior to 1979 management of the fishery was based on relative indicators of salmon abundance, including commercial fishery catch statistics, gill net indices, and aerial surveys. These assessments of relative abundance are often difficult to interpret. In particular, aerial surveys are highly variable due to year to year differences in availability and survey conditions. Fishery harvest strategies based on inaccurate assessments of abundance are likely to be too conservative in years of high abundance and too liberal in years of low abundance. Therefore, it is possible to develop optimal management programs only when accurate and timely abundance data are available.

Sonar was identified as a probable means of providing timely and accurate escapement data. Consequently, sonar equipment produced by the Bendix Corp. and similar to that used on the Kenai Peninsula (Gaudet 1983) was installed in the Noatak in 1979. However, this gear was limited to a range of about 30 meters and exploratory gill netting later demonstrated the presence of fish beyond this range (Bigler 1983).

Sonar equipment with a greater range capability was initially tested on the Yukon River (Nickerson and Gaudet, draft manuscript, 1985). This equipment made by Biosonics Inc. was selected for the 1984 Noatak River study. In addition, an intensive gillnet program designed to estimate the proportions of species present was also undertaken. The primary objective of this study was to produce species-specific estimates of fish moving upstream of Noatak River km 45.2. Accomplishment of this objective incorporated the following two tasks:

1. Development of a technique using sonar to estimate the total flux of fish at river km 45.2.

2. Development of a valid species apportionment method for allocation of sonar counts.

STUDY AREA DESCRIPTION

The Noatak River flows approximately 680 km, draining lands to the north and west of Kotzebue Sound. The relief of the lower river area is flat and the river is braided, wide, and slow moving. Further upstream, at river km 45.2, the river flows through a single channel with stable banks. River width in this area is approximately 260 m with a maximum depth of 11 m. This location was selected as the study site because of these favorable physical features and because of its close proximity to the river mouth (Figure 1).

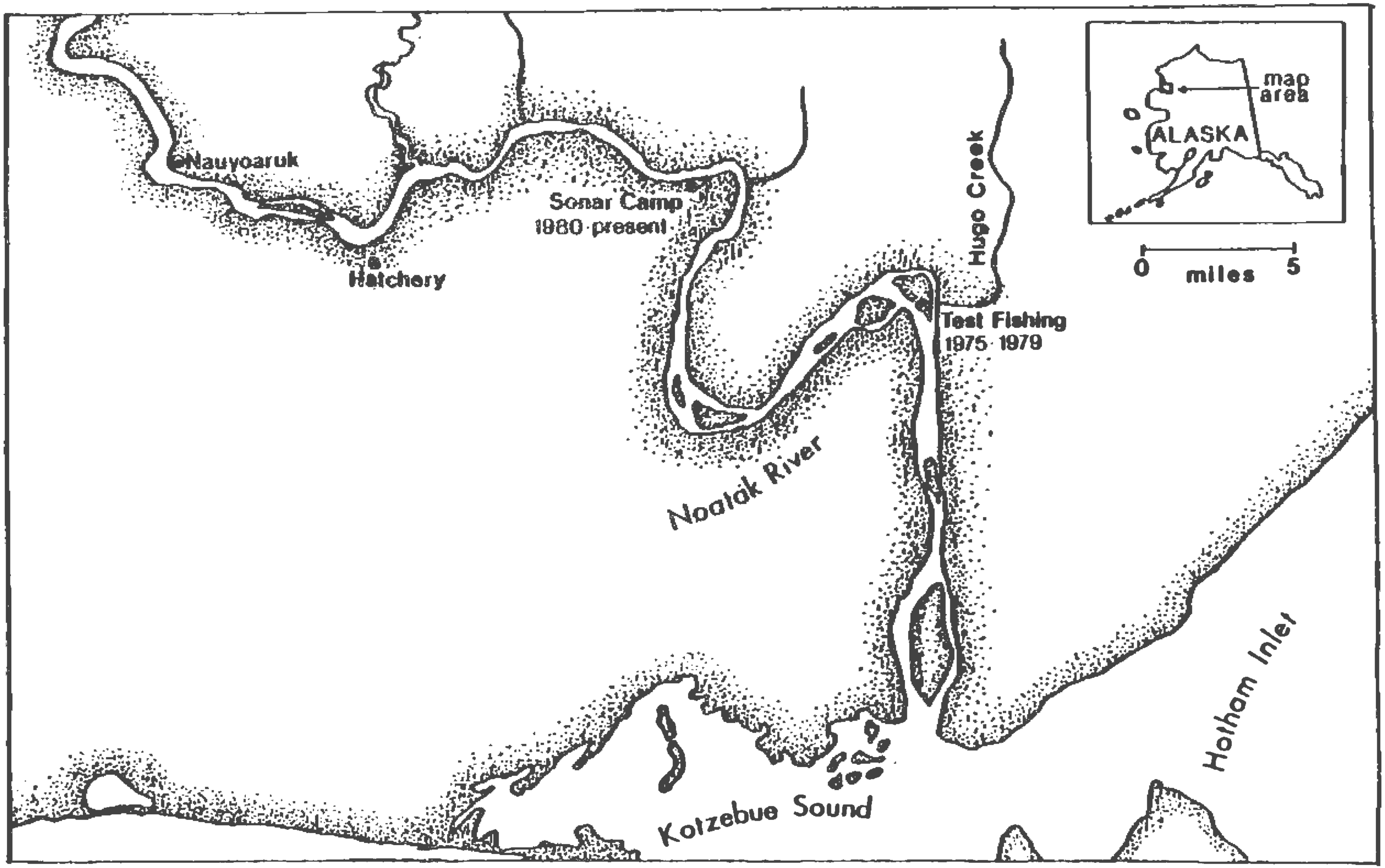

Figure 1. Noatak River and vicinity of test fishing and sonar projects, 1975 to present (taken from Bigler 1985).

The regularity of the banks' slopes also made the location favorable for sonar deployment. The slope of the river bottom on the north bank is approximately 6 percent out to 130 m from shore. The south bank slope is approximately 24 percent out to 45 m then becomes nearly flat from 50 m to 130 m distance from shore. The south bank had a higher water velocity and coarser substrate when compared to the north bank.

METHODS

The two components of the Noatak River sonar study, sonar sampling and species apportionment, were treated as independent elements of the project.

Sonar Sampling Design

The sonar project location was divided into two strata, north bank and south bank (Figure 2). These strata were sampled with equal intensity to obtain an estimate for the entire river. The two major considerations for developing a sampling design within each strata involved the expansion of sonar counts for time periods not sampled and spatial areas not ensonified.

Sample collection was temporally random. Fish were counted during 90 samples distributed within 4-day periods and counts were expanded to include periods of sonar inoperation. The samples were conducted within 45-min intervals, and each interval was randomly chosen from the 128 that were possible within the 4-day period. The sample size of 90 was estimated using Cochran's formula for n with continuous data (Cochran 1977, page 77). Sample location was alternated between each strata (north and south banks) which resulted in 45 samples for each strata per 4-day period.

The sonar beams did not ensonify the entire vertical water column during sampling. To compensate for this, the counts were expanded based on the fraction of the water column sampled. The beam location for each interval was randomly chosen from the range of allowable angles. The procedure for beam location selection is outlined as follows: Let t be the surface beam angle and b be the bottom beam angle. Then, the allowable range is t-b. If a random number r is selected from zero to t-b, then the beam setting is b+r. This procedure was executed before the beginning of each sample.

Sonar Equipment and Procedures

A single 420 khz Biosonics transceiver was utilized in conjunction with the transducers located on each bank of the river. Circular transducers of 2 and 6 degrees were used at the north and south bank sites, respectively. Each transducer was attached to a set of tripod-mounted rotator motors which permitted remote aiming in two axes. Received echoes were recorded on an EPC 1600 graphic chart recorder. The transceiver, chart recorder, and rotator control unit were operated from the south bank, with transducer and rotator cables routed to the south and north bank transducer assemblies.

The transducer assemblies were generally deployed in 1 to 2 m of water at each site. Transducer placement changed with fluctuating water levels.

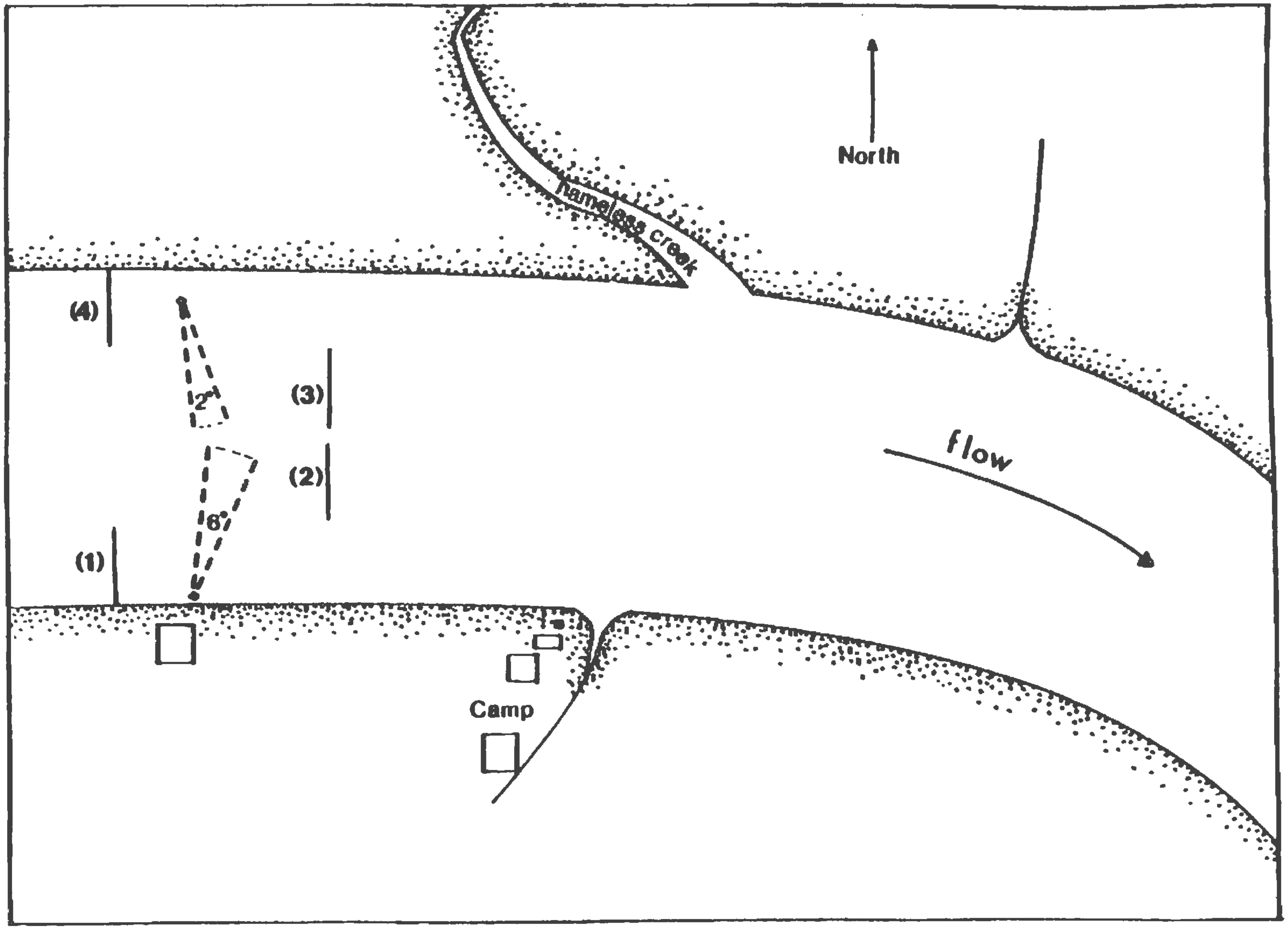

Figure 2. Noatak River sonar and test fish site, 1984. Map is not drawn to scale. Dashed lines show approximate location of sonar beams of indicated width. Numbers 1-4 represent test net locations (from Bigler 1985).

Transducers were aimed 15 degrees downstream from perpendicular to the river current to allow determination of the direction of fish travel by change-in-range techniques (Appendix 1). Fish deflectors composed of chicken-wire strung between iron poles were positioned just downstream from the transducer locations. Each deflector extended from shore out to about 2 m beyond the transducer face to direct fish beyond the transducer nearfield. Before the initiation of sonar counting, river depths were measured at distance intervals to construct depth profiles.

<u>Sonar Analytical Methods</u>

During each 45-min sampling interval, a sonar operator monitored the chart recorder output, classifying and tallying the detected targets. Targets were classified into one of three categories based on trace angle and form (Appendix 1). The categories were: 1) upstream directed and assumed to be fish (u); 2) downstream directed and assumed to be debris (d); and 3) direction unknown (z). The methods to determine the net number of upstream directed targets (fish) and the expansion of those counts to a daily estimate were performed in a similar manner to those which were used on the Yukon River (Mesiar et al. 1986). For each sector (i) and sample interval (j) the observed number of upstream directed targets, u, was increased by a proportion of those targets, z, which could not be classified as moving upstream or downstream. The proportion was calculated as the ratio of known upstream directed targets, u, to total observed targets of known direction, u+d. The adjusted u was taken to be the estimate of the net number of upstream directed targets, n.

$$n_{(i,j)} = u_{(i,j)} + \frac{u_{(i,j)}}{u_{(i,j)} + d_{(i,j)}} (z_{(i,j)})$$

The sonar beams from the north and south banks overlapped in the middle of the river. Therefore, the net upstream counts were adjusted by developing discrete strata for each bank. The middle of the river was defined as the midpoint distance from north to south shoreline with the water at a reference level. This level occurred at the time the depth profile measurements were taken and was marked with a reference stake driven into the substrate. Changes in transducer position, made coincident with changes in water level, were measured relative to the reference stake. The distance from the transducer to the river midpoint defined the usable counting range for each strata. All counts in sectors that were entirely beyond this range were omitted from the count expansion process. Sonar counts in sectors that were partially within the range were proportionally included in the expansion calculations. The beginning and ending range of these sectors were calculated relative to the reference stake. The proportion was expressed as:

$$n^{adj}_{(i,k)} = \frac{m_k - s_{(i,k)}}{e_{(i,k)} - s_{(i,k)}} (n_{(i,k)})$$

where:

$n^{adj}_{(i,k)}$ = net number of upstream targets adjusted for beam overlap in sector i and stratum k.

$n_{(i,k)}$ = net number of upstream targets in sector i and stratum k.

$s_{(i,k)}$ = starting range in sector i and stratum k.

$e_{(i,k)}$ = ending range in sector i and stratum k.

m_k = distance to river midpoint from the transducer for stratum k.

The net number of upstream-directed targets in each beam sector and stratum was expanded on a daily basis to periods not counted and areas not ensonified. The latter required the quantification of beam area and river cross-sectional area. Area in each sector (i) of the beam was calculated as $a_{(i,k)}$:

$$a_{(i,k)} = [0.5\ (r_{(i,k)}\ )\frac{b}{180}] - [0.5\ (r_{(i-1,k)}\ )\frac{b}{180}]$$

Where: $a_{(i,k)}$ = area (m) within sector i and stratum k.

$r_{(i,k)}$ = distance (m) from the transducer to the outer edge of sector i in stratum k.

b = beam width (degrees) for stratum k.

Estimation of river cross-sectional area required information on relative water level and transducer position, river bottom profile, and hydroacoustic beam range. For each sector (i) of the beam in a stratum (k), beginning and ending ranges, relative to the reference stake, were calculated. The river depth at beginning and ending ranges, adjusted for change in water level, were obtained from the bottom profile. Define the following for the beams used in each stratum (k):

R_i = River cross-sectional area in sector i.

s_i = starting range in sector i.

e_i = ending range in sector i.

f_i = starting depth in sector i.

g_i = ending depth in sector i.

Then:

$$R_i = (0.5)\ (e_i - s_i)\ (g_i + f_i)$$

For each sector (i) of the beam in stratum (k), area expansion factors were expressed as the ratio of water cross-sectional area ($R_{(i,k)}$) to beam cross sectional area ($a_{(i,k)}$). Area expanded net upstream counts ($n^{exp}_{(i,k)}$) were expressed as:

$$n^{exp}_{(i,k)} = (R_{(i,k)}/a_{(i,k)})\ (n_{(i,k)})$$

or in the case of sectors with beam overlap, the area expansion factors are expressed as:

$$n^{exp}_{(i,k)} = (R_{(i,k)}/a_{(i,k)})\ (n^{adj}_{(i,k)})$$

Temporal expansion of counts was accomplished by dividing the daily total of upstream directed targets, expanded for area ($n^{exp}_{(i,d)}$), in each sector of the beam i, by the proportion of the period sampled, to get $N_{(i,d)}$.

where:

$N_{(i,d)}$ = Estimated number of fish in sector i on day d.

$n^{exp}_{(i,d)}$ = net number of upstream directed targets in sector i on day d, expanded for areas not sampled.

$t_{(i,d)}$ = time (minutes) sampled in sector i and day d.

then:

$$N_{(i,d)} = (n^{exp}_{(i,d)})(24)(60)/t_{(i,d)}$$

Vertical distribution of sonar counts was examined to determine if a random distribution was a valid assumption. This consisted of comparing the relative aiming angle of the sonar beam to a relative frequency of count abundance. The relative aiming angle was expressed as r/t-b, where t is the surface beam angle of day (d), b is the bottom beam angle of day (d), and r is the random number that was selected between zero and t-b. Relative aiming angles ranged from zero to one, where zero is equivalent to the bottom beam angle and one is equivalent to the surface beam angle. The relative frequency of count abundance was expressed as the sum of expanded counts during sample (j) of day (d) divided by the sum of expanded counts during all samples (j) of day (d).

The diel periodicity of sonar counts was examined for each bank. First, the expanded counts from each sample interval were standardized relative to each other by dividing the count from each sample interval by the sum of counts from all sample intervals for the whole season. These standardized counts were then pooled by hourly time blocks (0,1,2...23) and averaged to compare between time blocks for diel trends.

Species Apportionment Sampling Design

The river was divided into four strata which were sampled with nets to determine species composition. On each bank of the river, one nearshore and one offshore stratum was sampled (Figure 2). Two mesh sizes were used and the general schedule for rotating the nets between strata was based on a 4-day sample period (Table 1).

The 4-day period was initially determined to be adequate for obtaining a sample size large enough to accurately represent the species composition. A sample size of 120 fish per period was derived from the method of Bernard (Alaska Dept. of Fish and Game memorandum, 1983) using an accuracy level (d) of 0.1 and a precision (α) of a one in ten chance of not having the correct species proportions (p_i) within the interval p_i + d for all i categories. In this case, i = 3 groups: chum salmon, pink salmon (*Oncorhynchus gorbuscha*), and other species.

Only fish with fork lengths greater than 300 mm were used for species-apportionment determination because fish with lesser lengths were excluded from the sonar counting process. Two mesh sizes were used to sample fish of different species and size. The larger mesh was intended for chum salmon, while the smaller mesh was fished for pink salmon, Arctic char *(Salvelinus alpinus)*, and the resident fish species.

Species Apportionment Equipment and Procedures

Monofilament (set) gill nets were used to sample for species apportionment. The stretched mesh sizes were 102 mm (4 in) and 149 mm (5 7/8 in) with depths of 40 and 25 meshes (2.75 and 2.55 m fishing depth), respectively (Bigler 1985). The length of each net was 45.7 m (25 fathoms). The nearshore nets were fished as floating sets from the river surface to the lower extent of the net's depth range. The offshore nets were submerged and fished from the river bottom to the upper extent of their depth range. The nearshore nets were fished close to the shoreline while the offshore nets were spaced evenly to sample the remaining width of the river. The nets were generally set at 2300 hours and pulled at 2000 hours the following day. The bank nets were checked every hour and the midriver nets every two hours to reduce mortality.

The collection of test-fish data included: fishing time, net location, species, sex, fork length, mid-eye to fork length, and number of recaptures. During the period of 6 August to 3 September 1984, additional data were collected specifying whether individual fish were gilled or tangled in the nets. Also during this period, offshore distance of fish caught in the nearshore nets was recorded by 7.62 m intervals.

Table 1. Rotation of two mesh sizes between sampling strata (four-day cycle) on the Noatak River, 1984.

	Day			
	1	2	3	4
South Nearshore	A	v	B	v
South Offshore	v	A	v	B
North Nearshore	B	v	A	v
North Offshore	v	B	v	A

Mesh sizes are denoted by "A" and "B", while "v" denotes vacant net site.

Species Apportionment Analytical Methods

A gill net of a particular mesh size selectively captures fish with girth sizes that are similar to those mesh size dimensions. It follows that fish with girth sizes that differ from the mesh size dimensions are less effectively captured. Since a population of fish is composed of many different sizes and it is not practical to sample with many mesh sizes, catches from two mesh sizes were used and were adjusted for this gillnet selectivity following methods developed by Peterson (1966) and summarized by Brannian (draft manuscript, 1984). Fish length, which is proportional to fish girth, was used to derive the selectivity coefficients. The relationship between fish length and girth differs between species, so it is necessary to determine selectivity coefficients for each species. Selectivity coefficients were calculated according to methods outlined in Petersen (1966) for each 10-mm length class for both mesh sizes.

Boundaries were set to define the fish lengths that were more effectively sampled by the larger mesh and also for the fish lengths more effectively sampled by the smaller mesh. There remains the intermediate-length portion of a population that was best sampled using catches from both mesh sizes combined. Length boundaries and species apportionment formulas (corrected for selectivity) were derived in a similar manner to the 1985 Yukon River study (Mesiar et al. 1986). The adjusted catches for each set were standardized to unit fishing effort and pooled by location.

The formula used to adjust catches for gillnet selectivity for each species apportionment period is expressed as follows:

$$A_n = \frac{{}_{k\,j}\; C_{(n,k,1)} / S_{(n,j,1)}}{{}_{k}\; E_{(k,1)}} + \frac{{}_{k\,j}\; C_{(n,k,2)} / S_{(n,j,2)}}{{}_{k}\; E_{(k,2)}}$$

$$+ \frac{1}{2}\, \frac{{}_{k\,j}\; C_{(n,k,1)} / S_{(n,j,1)}}{{}_{k}\; E_{(k,1)}} + \frac{1}{2}\, \frac{{}_{k\,j}\; C_{(n,k,2)} / S_{(n,j,2)}}{{}_{k}\; E_{(k,2)}}$$

Where: A_n = standardized selectivity-adjusted catch of species n.

$C_{n,j,k,m}$ = unadjusted catch of species n within length interval j for net set k, and mesh size m.

$S_{n,j,m,}$ = selectivity coefficient for species n, length interval j, and mesh size m.

$E_{k,m}$ = fishing effort (hrs) for net set k and mesh size m.

1 = large mesh size (m).

2 = small mesh size (m).

j_a = Length grouping (a) for large fish.

j_b = Length grouping (b) for small fish.

j_c = Length grouping (c) for intermediate-sized fish.

The proportion of species n (P_n) for a species apportionment period is:

$$P_n = A_n / {}_{\text{all } n} \; A_n$$

Sonar counts (N_d) were apportioned by:

$$E_n = {}_{\text{all } i} \; N_{(i,d)} \; (P_n)$$

where E_n is the passage estimate of species n on day d.

Nonparametric multiple comparisons using Kruskal-Wallis rank sums (Zar 1974) were used to test for significant differences in species composition between test-fish locations.

The offshore distance of fish caught in the nearshore nets was examined by dividing the total of each species caught at each position (7.62-m interval) during the season by the total number of fish caught in that net during the season.

RESULTS

Sonar Enumeration

Sonar counting began on 16 July and continued through 3 September - a period of 50 days. A river-bottom profile (Figure 3) was constructed from depth measurements recorded on 15 July. This profile was used throughout the season in conjunction with daily water levels (Figure 4) to determine the daily river cross-sectional area for each stratum. Water levels fluctuated

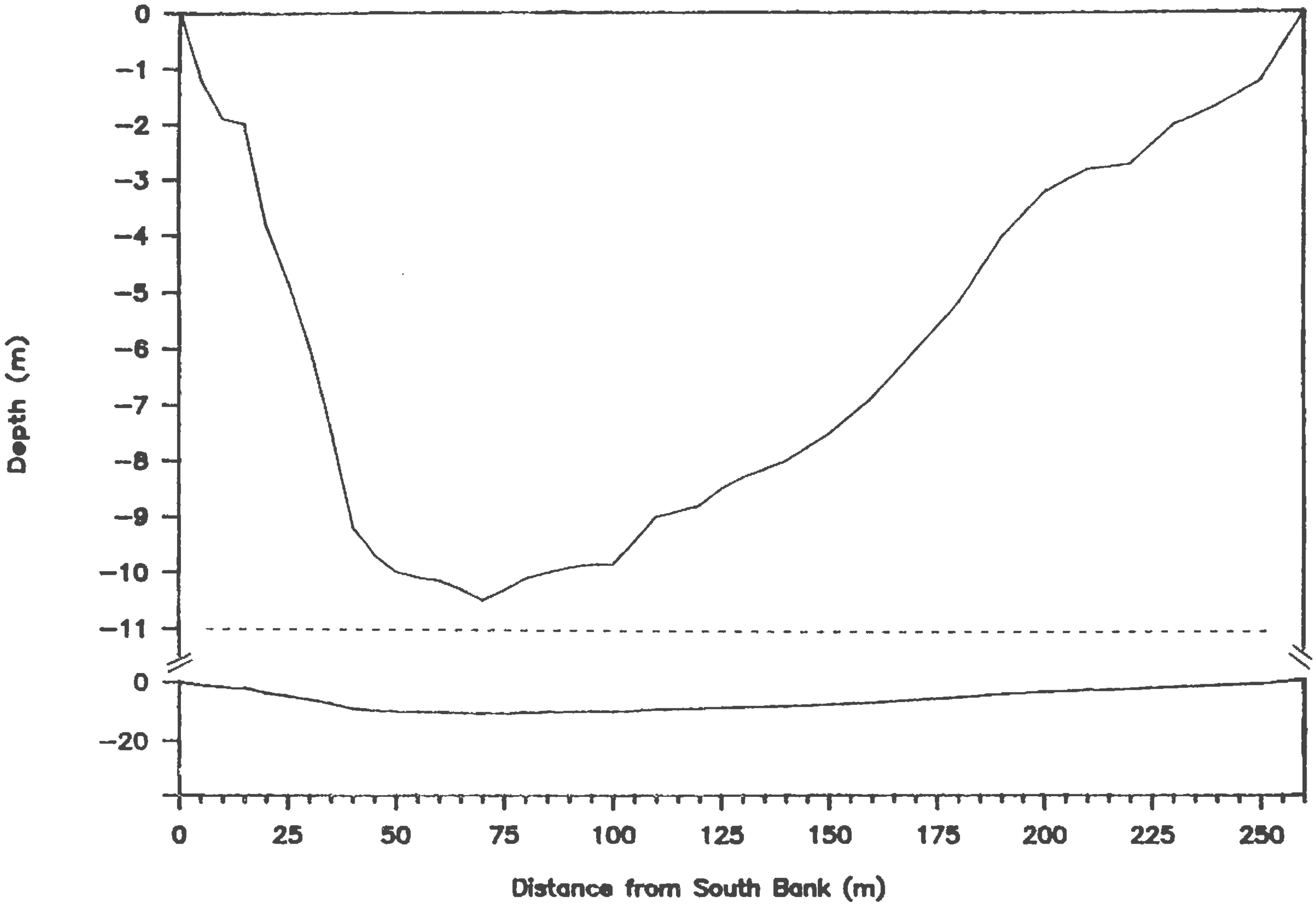

Figure 3. Bottom profile at 1984 Noatak River sonar site (measurements taken on 15 July). The profile is depicted twice: in the top plot, distance and depth scales are not equal to show river bottom detail whereas in the bottom plot the scales are equal.

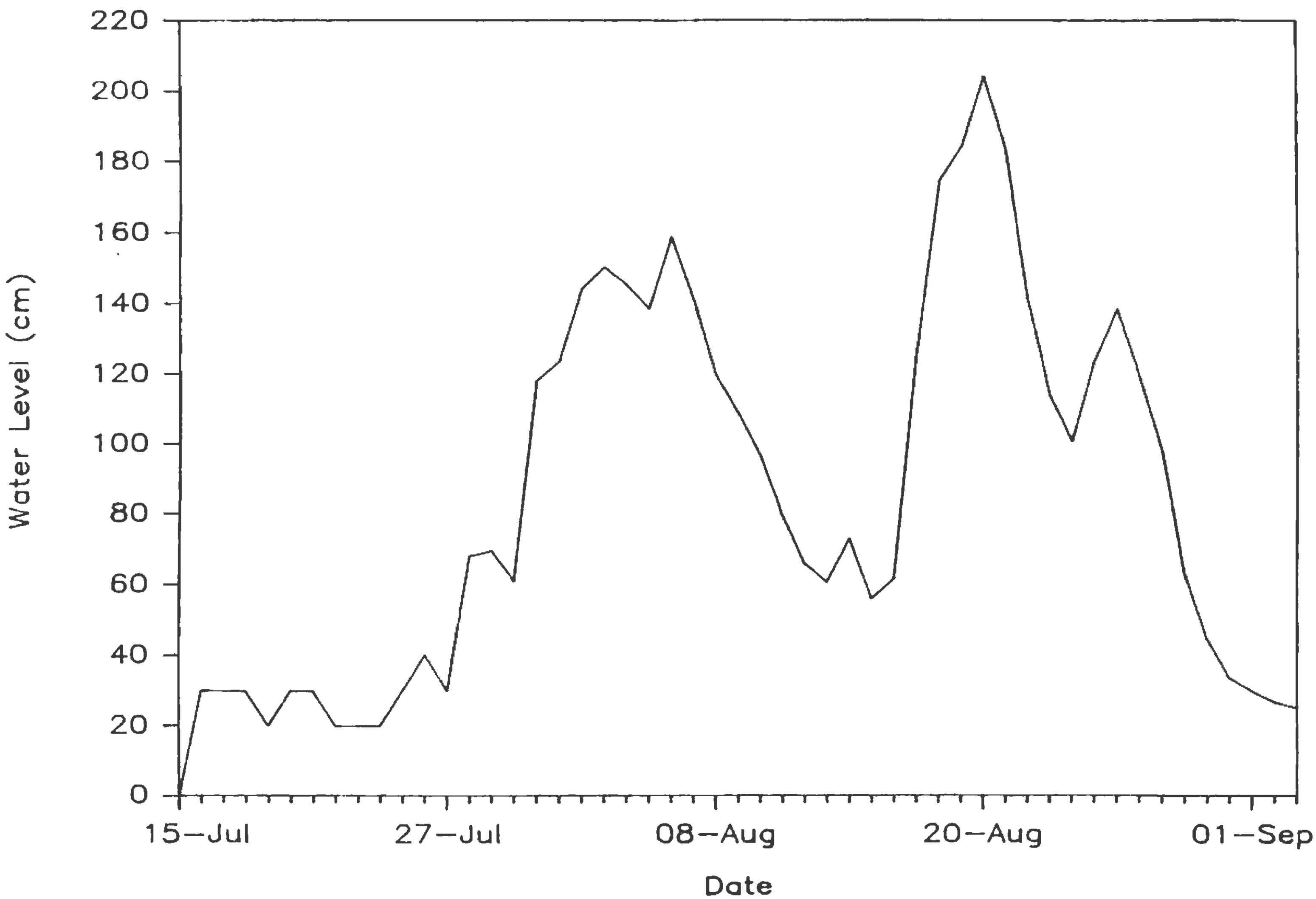

Figure 4. Daily water levels recorded at the 1984 Noatak River sonar site (reference level established on 15 July).

throughout the season with major increases in water level occurring in early August and then again in mid-August.

Expanded sonar counts (Table 2) ranged from 164 on 29 August to 8,274 on 24 July and totaled 113,073 for the season. Counts increased steadily from mid-July to a peak during the last week of July, then decreased until 9 August (Figure 5), becoming level thereafter.

The horizontal distribution of expanded sonar counts for the south bank site (Figure 6) indicates that the majority of fish passed close to shore. The same is true of the north bank horizontal distribution (Figure 7), although the fish passing the north bank site were distributed across more sectors when compared to the south bank.

Examinations of sonar count vertical distribution for each bank (Figures 8 and 9) reveal that there was no consistent trend for fish to orient towards either the bottom or the surface of the river. Data points from all depths appear to be equally distributed with respect to count abundance.

Fish traveling past the north bank (Figure 10) displayed no apparent temporal pattern of upstream migration. On the south bank (Figure 11), there seemed to be a slight decrease in activity between 0200 and 0700 hours.

The daily total of upstream targets (sum of targets from 45-min samples) by location is presented in Appendix 2.

<u>Species Composition</u>

Data from 73 gill net sets, fished from 18 July to 3 September, were used to determine the species composition for apportionment. The nets were fished for approximately 739 hours and caught 1,289 fish (Appendix 3). The two midriver test-fish sites were pooled to form a single midriver site to obtain a larger sample size. In comparison, gill nets used at the north bank site were fished about 214 hours and intercepted a season-total of 487 fish, the south bank nets yielded 456 fish in about 232 hours, and the midriver nets yielded 346 fish in approximately 293 hours fishing time. During the period of 16 July through 3 September, there were no length frequency or test-fish data for the 102-mm nets during 15 of the days and for the 149-mm nets during 13 of the days. Most of the non-fishing days were due to high water or high debris loads.

Length frequency distributions were constructed for chum salmon caught in the 149-mm and 102-mm mesh nets (Appendix 11). Most chum salmon were caught in the 149 mm mesh.

Chum salmon catches were adjusted using the selectivity coefficients (Appendices 4 and 5) developed by Brannian (1984). Selectivity curves were plotted from these coefficients (Figure 12). Length boundaries were set to define the chum length groupings that were effectively fished by the two net mesh sizes. Chum salmon with lengths less than 514.5 mm were more effectively sampled by the 102-mm mesh net while chum salmon with lengths greater than 604.5 mm were more effectively sampled using the 149-mm mesh net. The intermediate length grouping was sampled using catches from both net mesh sizes.

Table 2. Summary of daily and cumulative daily sonar counts for the Noatak River, 1984.

Date	Daily Count	Cumulative
16-Jul	1,991	1,991
17-Jul	1,086	3,078
18-Jul	1,402	4,480
19-Jul	1,814	6,293
20-Jul	3,567	9,860
21-Jul	4,143	14,003
22-Jul	4,794	18,797
23-Jul	6,856	25,653
24-Jul	8,274	33,928
25-Jul	7,377	41,305
26-Jul	6,992	48,296
27-Jul	7,235	55,531
28-Jul	3,699	59,231
29-Jul	2,399	61,630
30-Jul	2,415	64,044
31-Jul	2,884	66,928
01-Aug	3,242	70,170
02-Aug	2,877	73,047
03-Aug	5,390	78,437
04-Aug	2,844	81,281
05-Aug	2,469	83,750
06-Aug	2,318	86,068
07-Aug	3,301	89,369
08-Aug	3,019	92,388
09-Aug	768	93,156
10-Aug	858	94,013
11-Aug	599	94,612
12-Aug	705	95,317
13-Aug	724	96,041
14-Aug	1,012	97,053
15-Aug	1,650	98,703
16-Aug	582	99,285
17-Aug	221	99,506
18-Aug	268	99,774
19-Aug	1,025	100,798
20-Aug	1,635	102,433
21-Aug	1,693	104,126
22-Aug	837	104,964
23-Aug	634	105,598
24-Aug	268	105,866
25-Aug	770	106,636
26-Aug	430	107,067
27-Aug	747	107,814
28-Aug	307	108,121
29-Aug	164	108,285
30-Aug	247	108,532
31-Aug	439	108,972
01-Sep	1,195	110,166
02-Sep	2,243	112,409
03-Sep	664	113,073

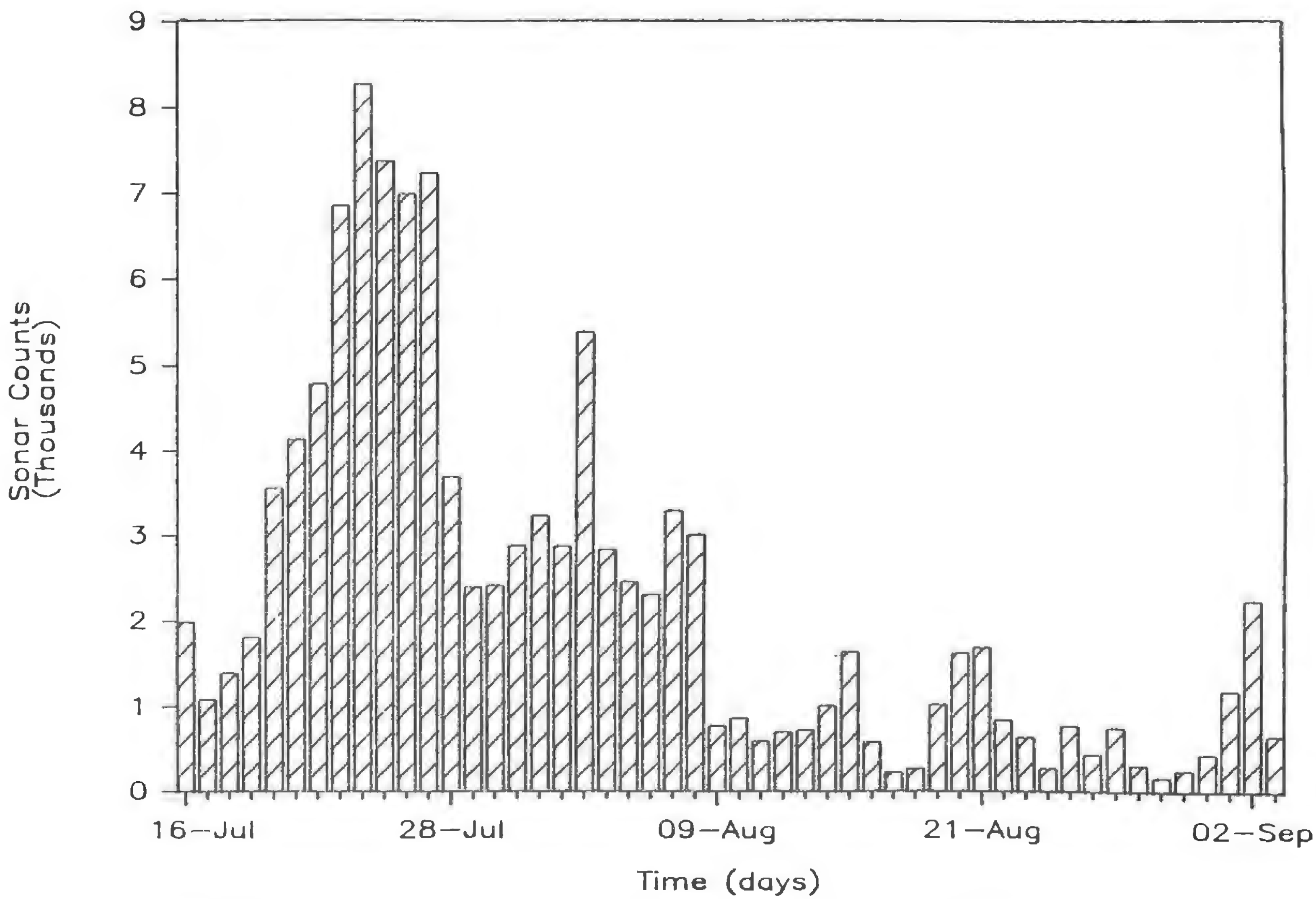

Figure 5. Total counts of fish past the Noatak River sonar site not apportioned to species, 1984.

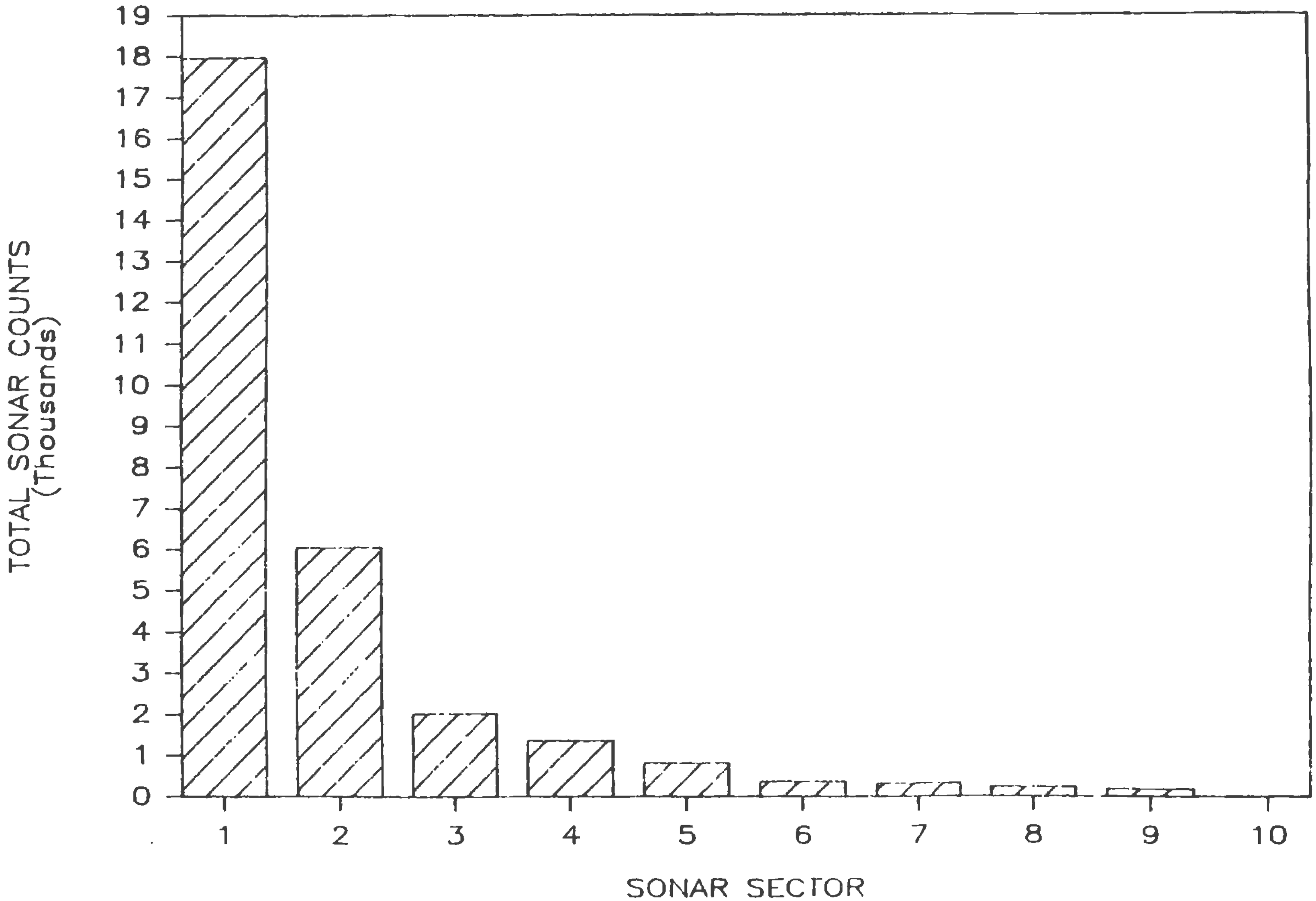

Figure 6. Horizontal distribution of sonar counts on the south bank of the Noatak River, 1984.

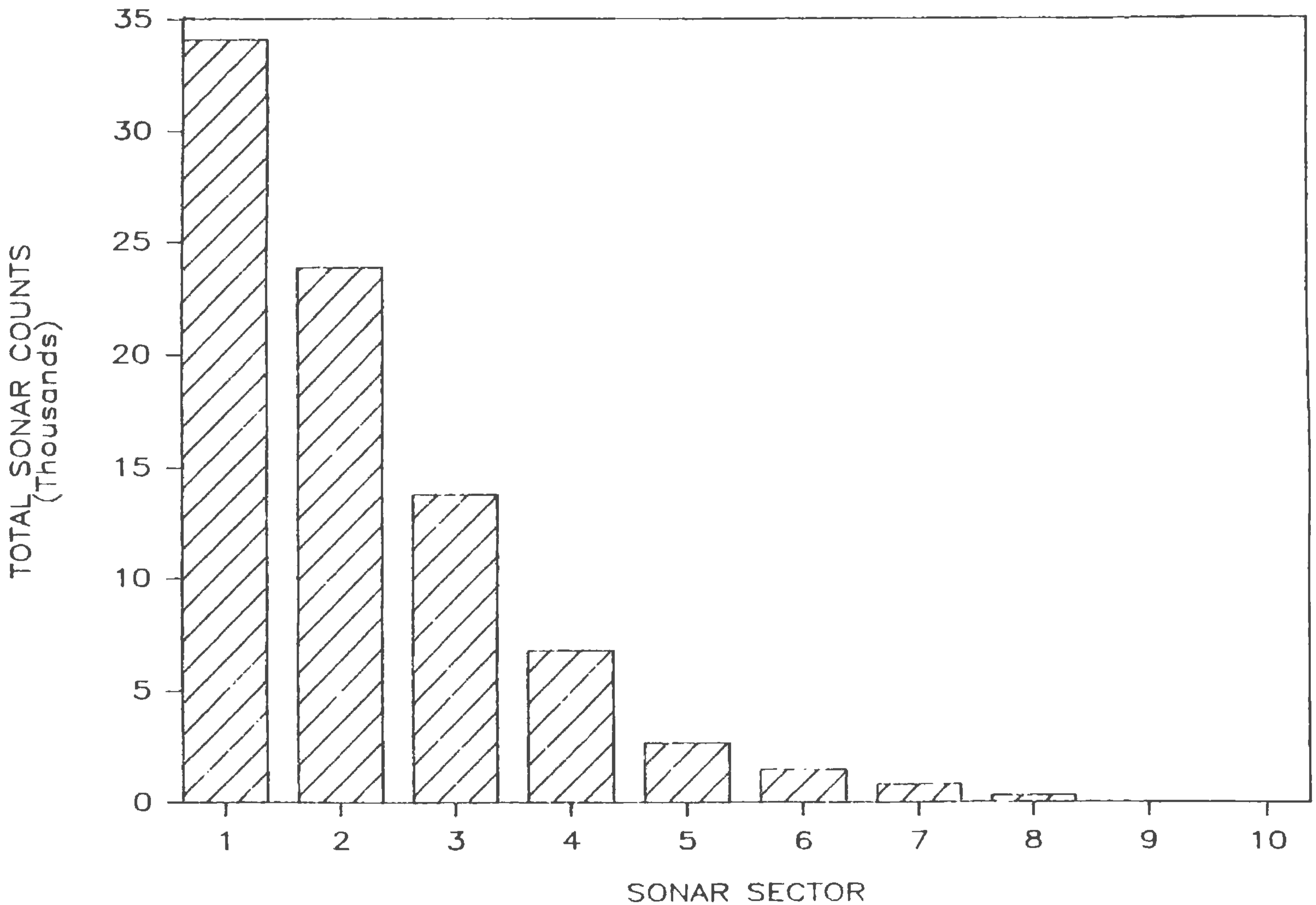

Figure 7. Horizontal distribution of sonar counts on the north bank of the Noatak River, 1984.

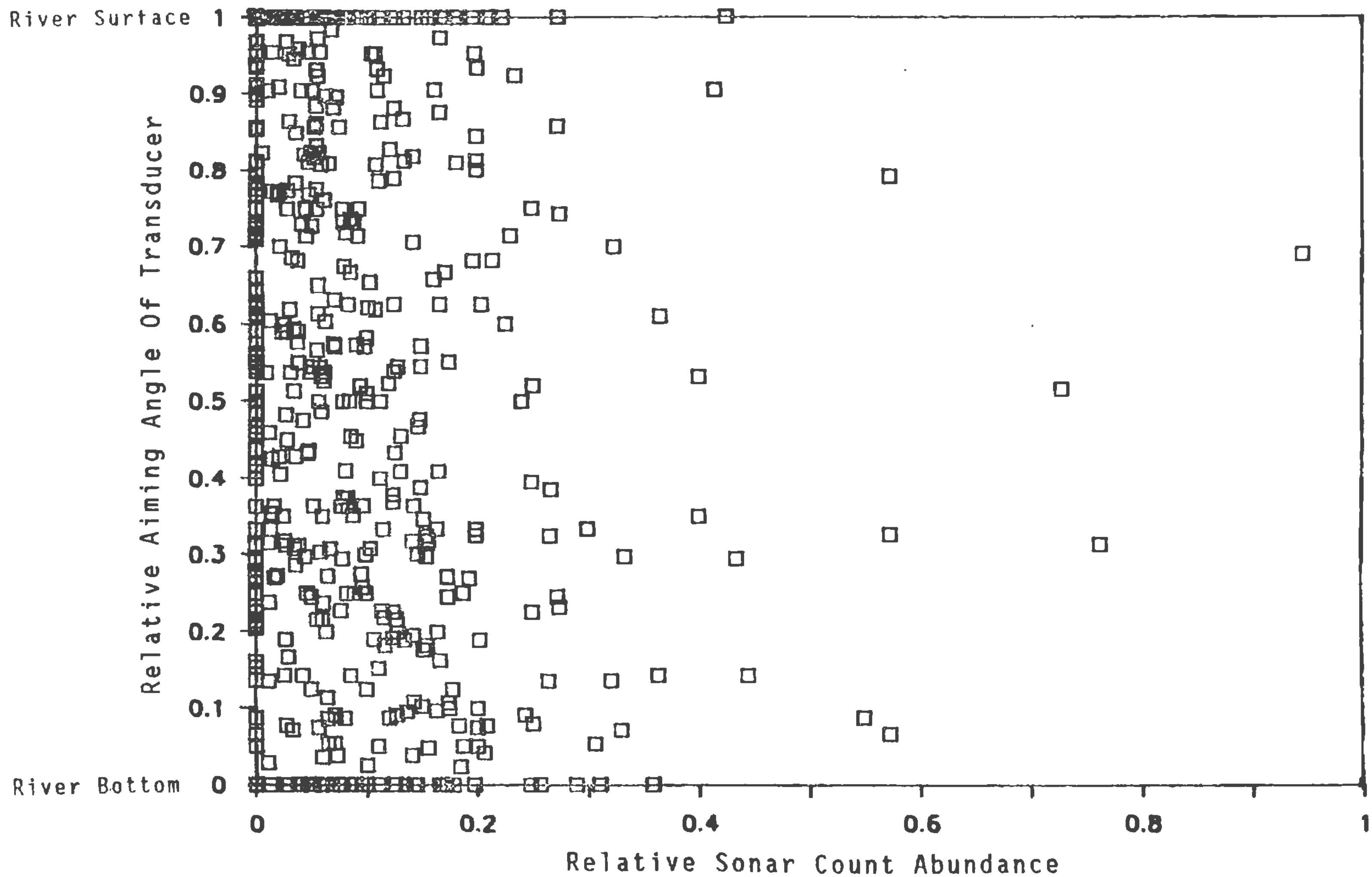

Figure 8. Vertical distribution of sonar count abundance on the south bank of the Noatak River, 1984. Each point (sonar count in 45-min) is plotted relative to counts occurring in the same day with respect to vertical aiming angle and count abundance.

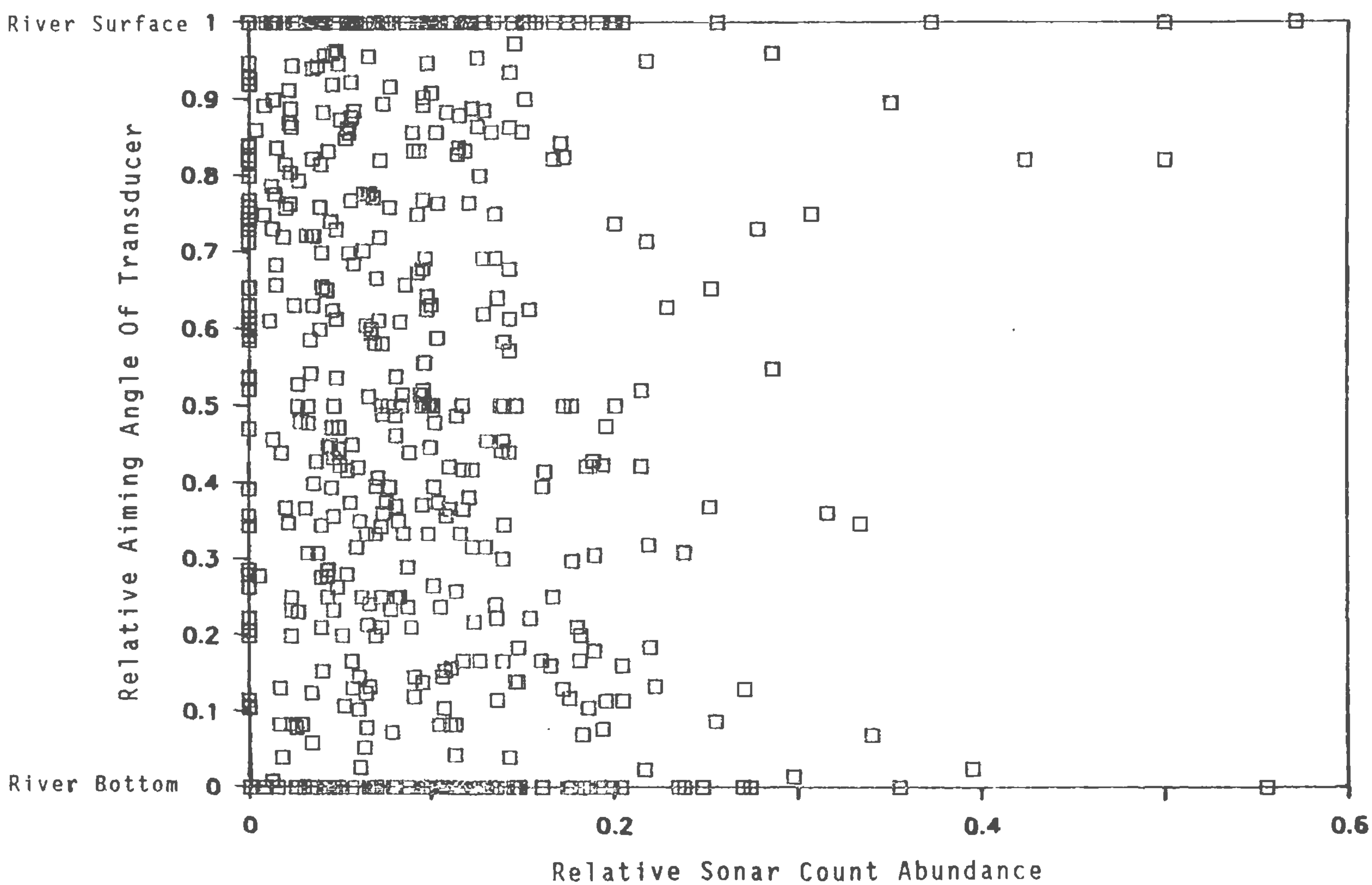

Figure 9. Vertical distribution of sonar count abundance on the north bank of the Noatak River, 1984. Each point (sonar count in 45-min) is plotted relative to counts occurring in the same day with respect to vertical aiming angle and count abundance.

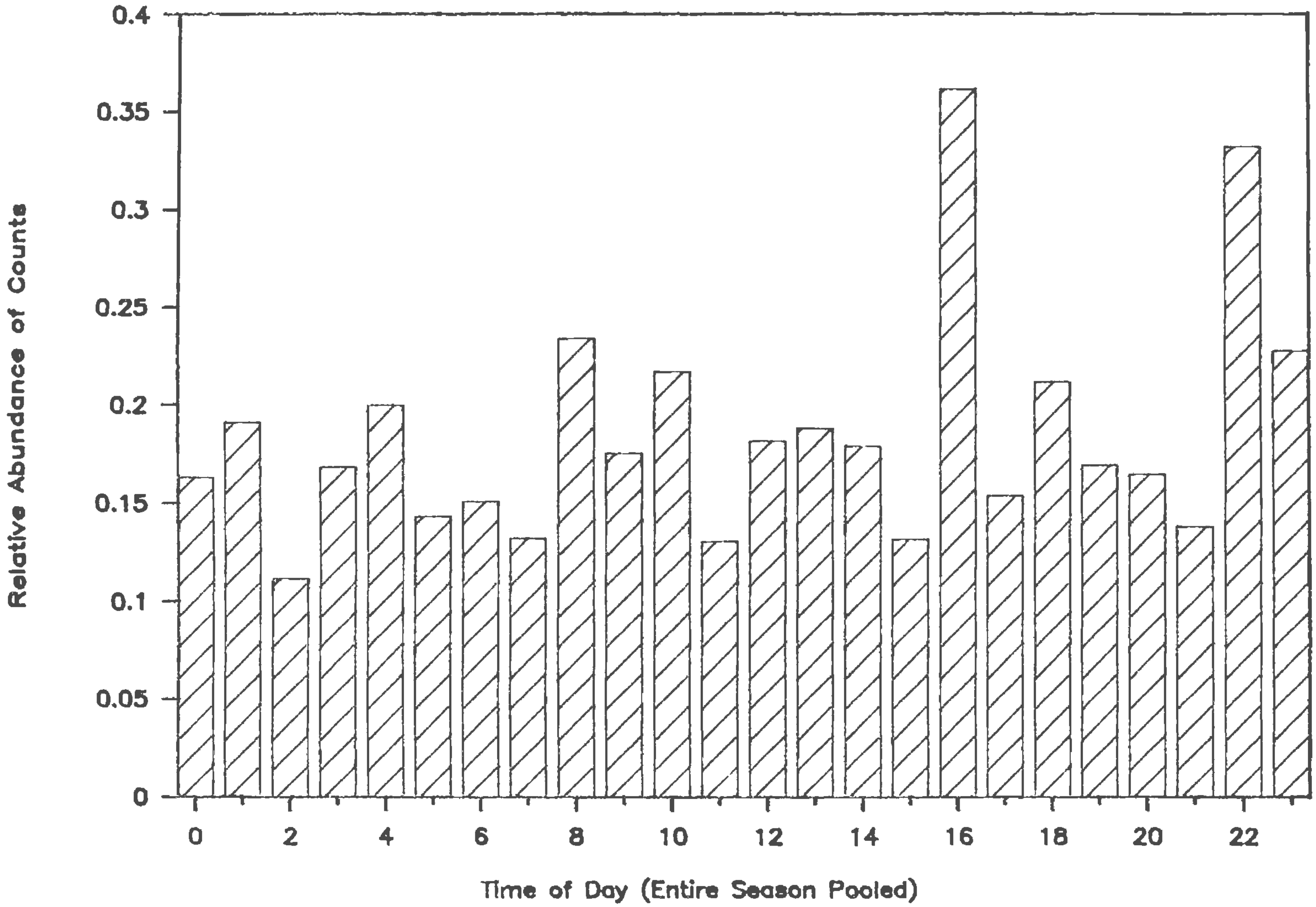

Figure 10. Diel periodicity of sonar counts on the north bank of the Noatak River, 1984.

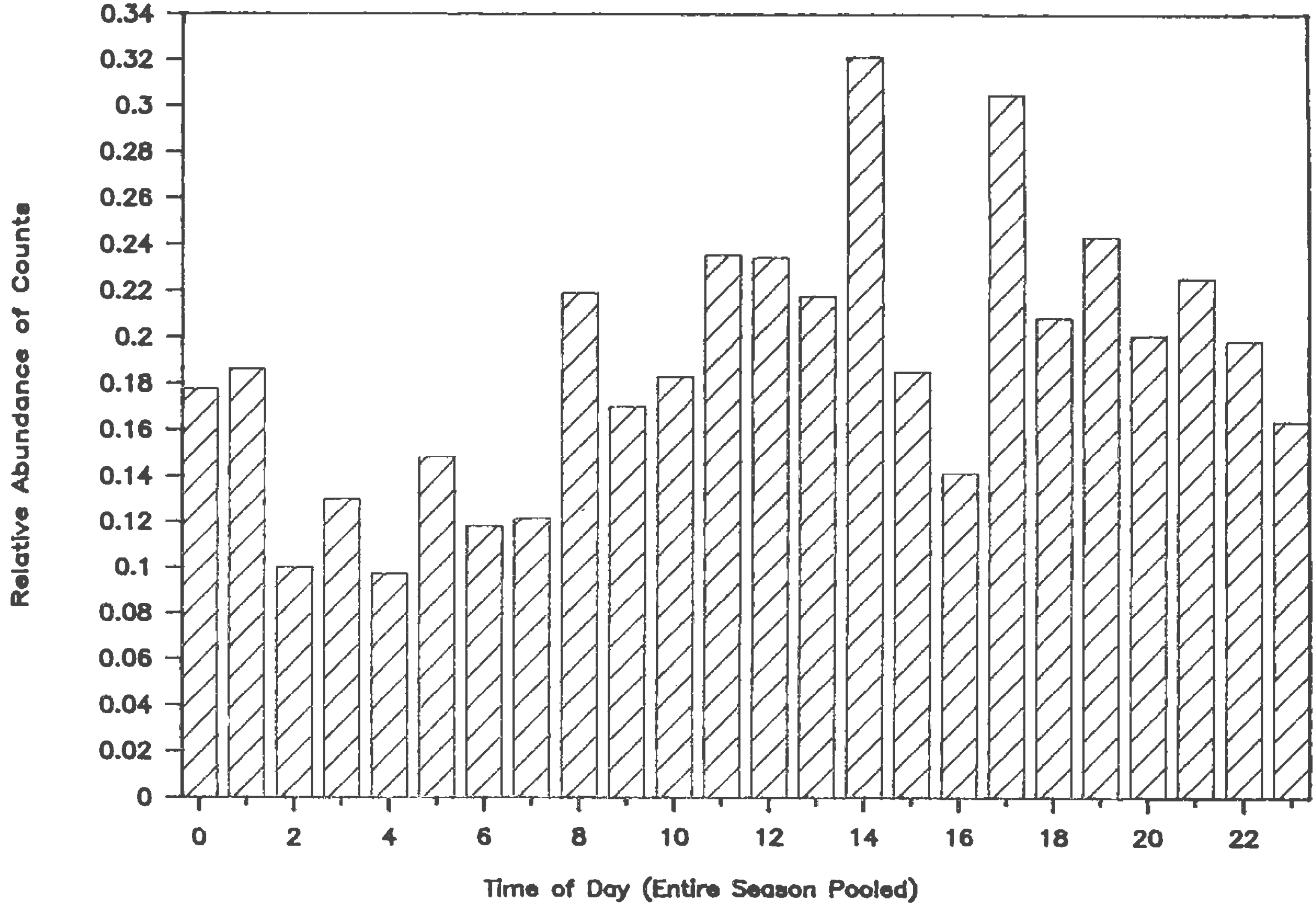

Figure 11. Diel periodicity of sonar counts on the south bank of the Noatak River, 1984.

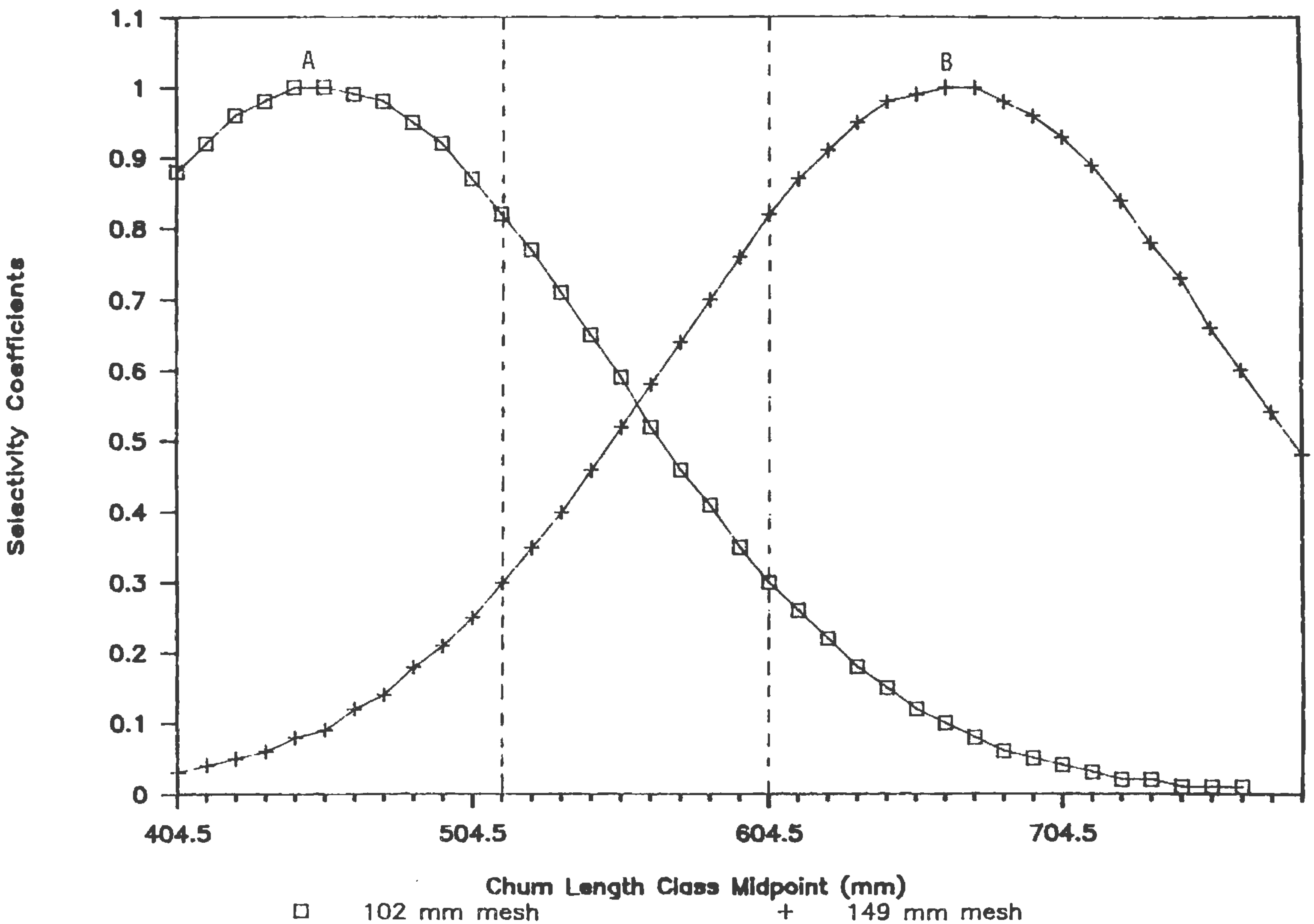

Figure 12. Selectivity curves for chum salmon captured in 102-mm and 149-mm mesh gill nets, Noatak River, 1984 (Regions A and B illustrate the size of chum salmon effectively sampled by 102-mm and 149-mm mesh, respectively).

Catch data for species other than chum salmon were inadequate for the development of selectivity coefficients. Very few Arctic char were caught in the larger mesh (Appendix 11); most were caught in the 102-mm mesh (Appendix 11). Negligible numbers of pink salmon and whitefish were caught in the larger mesh. Length frequency distributions were also constructed for pink salmon and whitefish caught in the 102-mm mesh (Appendix 11).

Fishing-time-standardized catches of species other than chum salmon were pooled to form the "other" species category. Selectivity coefficients could not be derived for the "other" species because of insufficient data from catches in the large mesh net. "Other" species were adjusted using an overall selectivity coefficient of 0.7. This is an approximated value obtained from species apportionment worksheets developed for the Yukon River sonar studies (Mesiar et al. 1986).

Species composition data were stratified into three locations within five species apportionment periods. The locations were north, south, and midriver and the periods ranged in length from four to sixteen days (Table 3). The periods were developed relative to catch sample sizes. Catches were further time-adjusted for comparison of catches between species apportionment periods. Species composition was determined for two categories: chum salmon and "other" species. The proportion of chum salmon peaked during the third period in the north and south locations with values of about 48% and 71%, respectively. The proportion of chum in the midriver location peaked in the fourth period with a value of about 90%. The adjusted chum salmon catches were greatest in the third period for north, south, and midriver locations with values of approximately 19, 34, and 16 percent, respectively. "Other" species catches fluctuated throughout the season.

A multiple comparison test was performed on the chum salmon proportions from each location to test for differences in species composition (Appendices 6 and 7). Results indicated that the proportions between the three sampled locations (north, south, and midriver) were not the same at a significance level of $\alpha = 0.10$.

The offshore distributions of fish caught in the test nets at north and south bank locations were determined for chum salmon and "other" species. On the north bank (Figure 13), "other" species were most abundant at about 22.9 m from shore and declined in abundance at greater distances. Chum salmon abundance increased steadily to peak abundance at about 45.7 m from shore, which was the offshore end of the net. On the south bank (Figure 14) "other" species abundance peaked at a distance of about 15.2 m from shore and declined in abundance at greater distances. Chum salmon abundance peaked at a distance of 22.9 m from shore and declined in a similar manner to the other species at this location.

Estimates of Fish Passage by Species

Sonar counts were divided into three strata: north, south, and midriver for species apportionment purposes because species composition results indicated that there was a significant difference in species composition between test-fish locations. The offshore distribution of fish in the test nets (Figures 13 and 14) was used as an aid to determine where the changes in species composition occurred. The north stratum counts were then defined as occurring

Table 3. Summary of fishing effort, selectivity-adjusted and standardized catches by species, and species proportions by period and stratum for the Noatak River, 1984.

	Stratum	# of Sets	Fishing Time (hr.)	Adj. Chum Catch	Adj. Other Catch	% Chum	% Other
	North	3	35.72	9.07	13.55	40.1	59.9
Period 1	South	3	26.87	6.31	35.77	15.0	85.0
(16-23 Jul)	Midriver	6	71.63	3.54	3.38	51.1	48.9
	North	2	24.50	10.13	20.55	33.0	67.0
Period 2	South	2	21.58	27.35	11.69	70.1	29.9
(24-27 Jul)	Midriver	4	44.57	8.25	3.08	72.8	27.2
Period 3	North	3	15.42	19.26	20.80	48.1	51.9
(28-Jul to	South	3	19.60	34.32	14.08	70.9	29.1
4-Aug)	Midriver	5	22.03	15.56	5.33	74.5	25.5
	North	6	74.22	7.64	24.44	23.8	76.2
Period 4	South	7	86.41	7.14	5.57	56.2	43.8
(5-20 Aug)	Midriver	8	89.06	6.59	0.77	89.5	10.5
Period 5	North	6	63.91	2.60	9.14	22.1	77.9
(21-Aug to	South	6	77.95	5.43	8.11	40.1	59.9
3-Sep)	Midriver	9	65.70	13.62	6.56	67.5	32.5

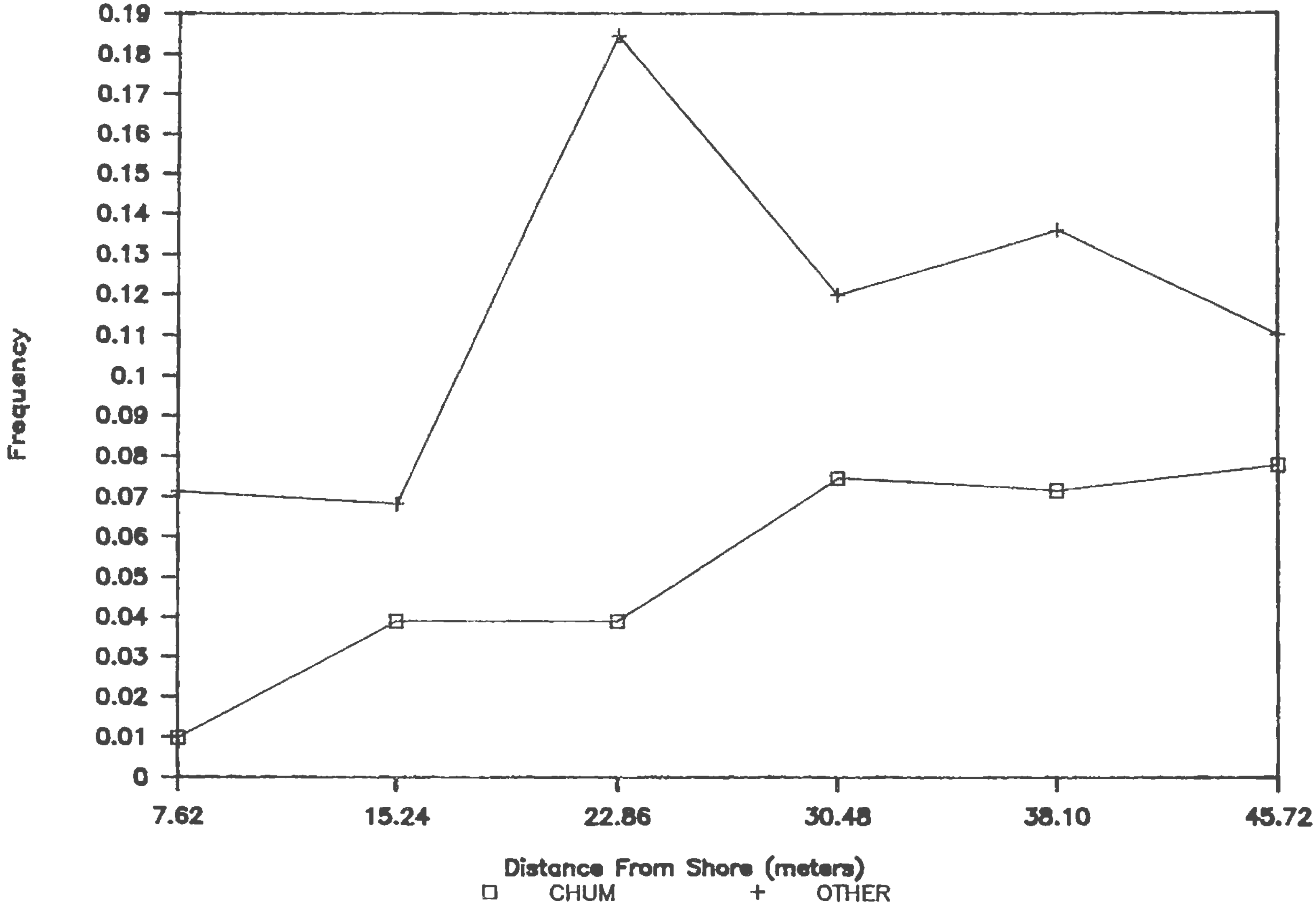

Figure 13. Offshore distribution of chum salmon and other species captured in gill nets on the north bank of the Noatak River in 1984 at 7.62-m intervals.

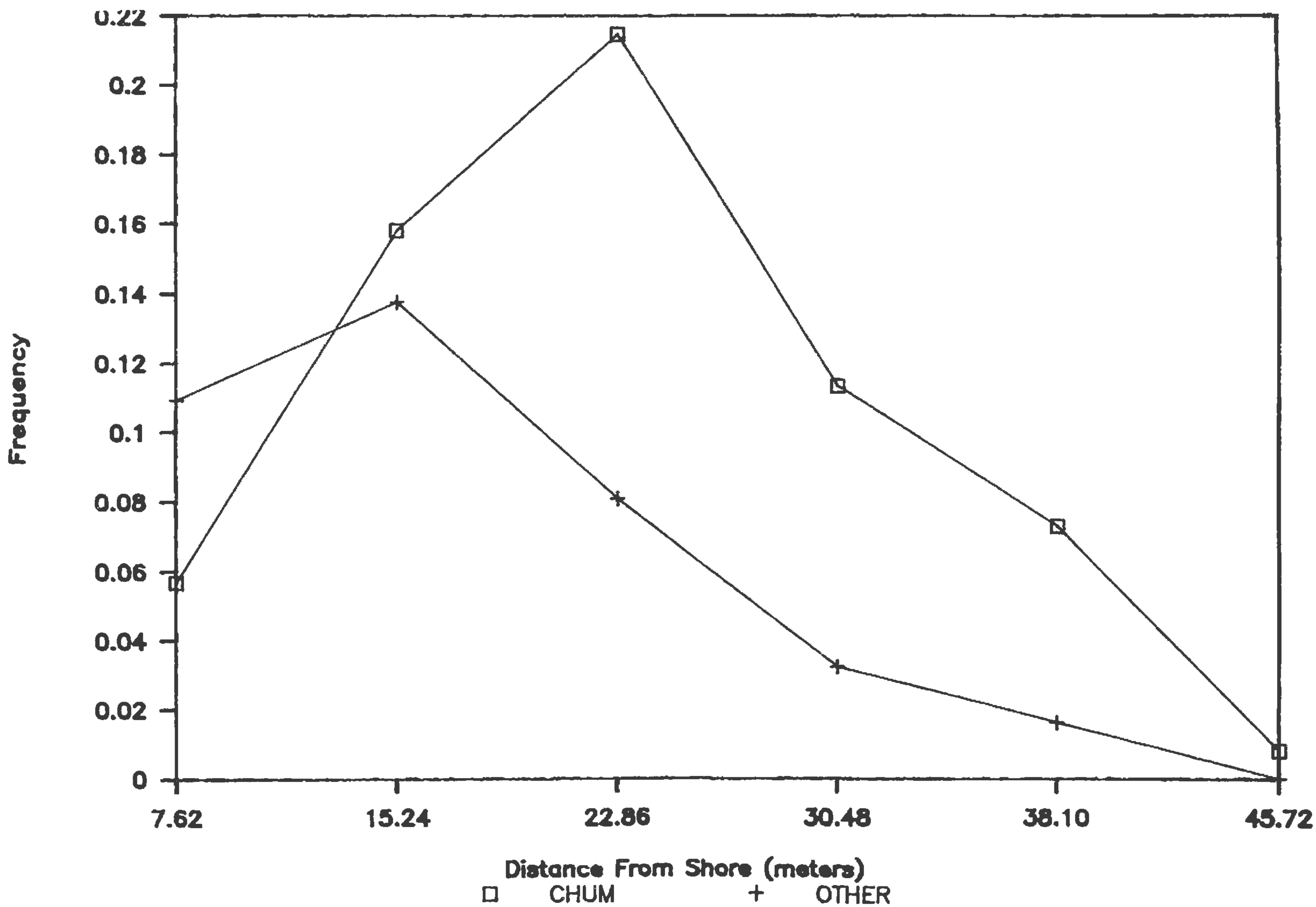

Figure 14. Offshore distribution of chum salmon and other species captured in gill nets on the south bank of the Noatak River in 1984 at 7.62-m intervals.

within north bank sonar sectors one through five, which were approximately one and a half times the length of the north nearshore net position. North bank sectors six through ten were allocated to the midriver location.

On the south bank, sonar sectors one through three were allocated to the south stratum which corresponds to the length of the south bank nearshore net. Sectors four through ten were allocated to the midriver location. The sectors that were allocated to midriver location from each of the banks were combined to form the midriver stratum.

The three species-apportionment locations yielded season totals of 81,109 fish passing the north bank, 25,986 fish on the south bank, and 5,978 in midriver (Appendix 10).

Sonar counts, when combined with species-apportionment data yielded estimates of species passage by period (Table 4). The total passage was comprised of 44,182 chum salmon and 68,891 other species. Chum salmon passage peaked during the third species-apportionment period (Figure 15).

Chum proportions by period were applied to daily sonar counts to derive daily chum passage (Appendix 8). Using this method of apportionment and cumulative time-density calculations (Mundy 1982), the mean date of chum passage was 31 July (Appendix 9).

Comparison With Other Abundance Indicators

An aerial survey of Noatak River spawning areas was conducted on September 4, 1984 (ADF&G 1985). Under excellent conditions, this survey resulted in a count of 67,873 chum salmon. This estimate is substantially higher than the sonar count of 44,182 that was apportioned to chum salmon in this study.

Abundance indicators from gill net catches were also compared to sonar counts. Chum salmon catch per unit effort (CPUE) values from the 1984 Kotzebue Sound commercial fishery (ADF&G 1985) and from the 1984 Noatak River test-net project are listed along with daily-apportioned and period-apportioned sonar counts in Appendix 8. Chum salmon CPUE values from the Noatak River test-net project were averaged from the individual values reported by Bigler (1985) for monofilament and multifilament 149-mm mesh nets. This was done by averaging the standardized CPUE's only on days when both nets were fished.

Comparison of daily chum sonar counts with the commercial fishery and test-net chum CPUEs plotted through time (Figure 16) reveals that peak sonar counts occurred earlier (24 July) than the peak in commercial fishery CPUE (26 July) and in test-net CPUE (28 July). Chum sonar counts are similar to the commercial fishery CPUE in that they rise steadily to peak abundance in late July and decrease steadily to low levels of abundance from 3 August to the end of the season. It should be pointed out that the low commercial fishery CPUE value that occurred on 30 July is a product of low fishing effort and poor fishing due to extremely poor weather (ADF&G 1985).

Chum CPUE derived from Noatak River test netting fluctuated greatly (Figure 16) throughout the season. The largest difference between test-net CPUE and sonar counts occured about 27 July when test-net CPUE increased greatly and

Table 4. Estimated upstream passage apportioned to species for the Noatak River, 1984, past the sonar study site (river km 45.2).

	Stratum	Unapportioned Estimated Passage	Chum %	Chum Passage	Other %	Other Passage
	North	14,379	40.1	5,766	59.9	8,613
Period 1	South	10,187	15	1,528	85	8,659
(16-23 Jul)	Midriver	1,088	51.1	556	48.9	532
	North	23,056	33	7,608	67	15,448
Period 2	South	5,714	70.1	4,006	29.9	1,708
(24-27 Jul)	Midriver	1,107	72.8	806	27.2	301
	North	18,458	48.1	8,878	51.9	9,580
Period 3	South	5,142	70.9	3,646	29.1	1,496
(28-Jul to 4-Aug)	Midriver	2,149	74.5	1,601	25.5	548
	North	16,231	23.8	3,863	76.2	12,368
Period 4	South	3,896	56.2	2,190	43.8	1,706
(5-20 Aug)	Midriver	1,026	89.5	918	10.5	108
	North	8,984	22.1	1,985	77.9	6,999
Period 5	South	1,048	40.1	420	59.9	628
(21-Aug to 3-Sept)	Midriver	608	67.5	410	32.5	198
	Total	113,073		44,182		68,891

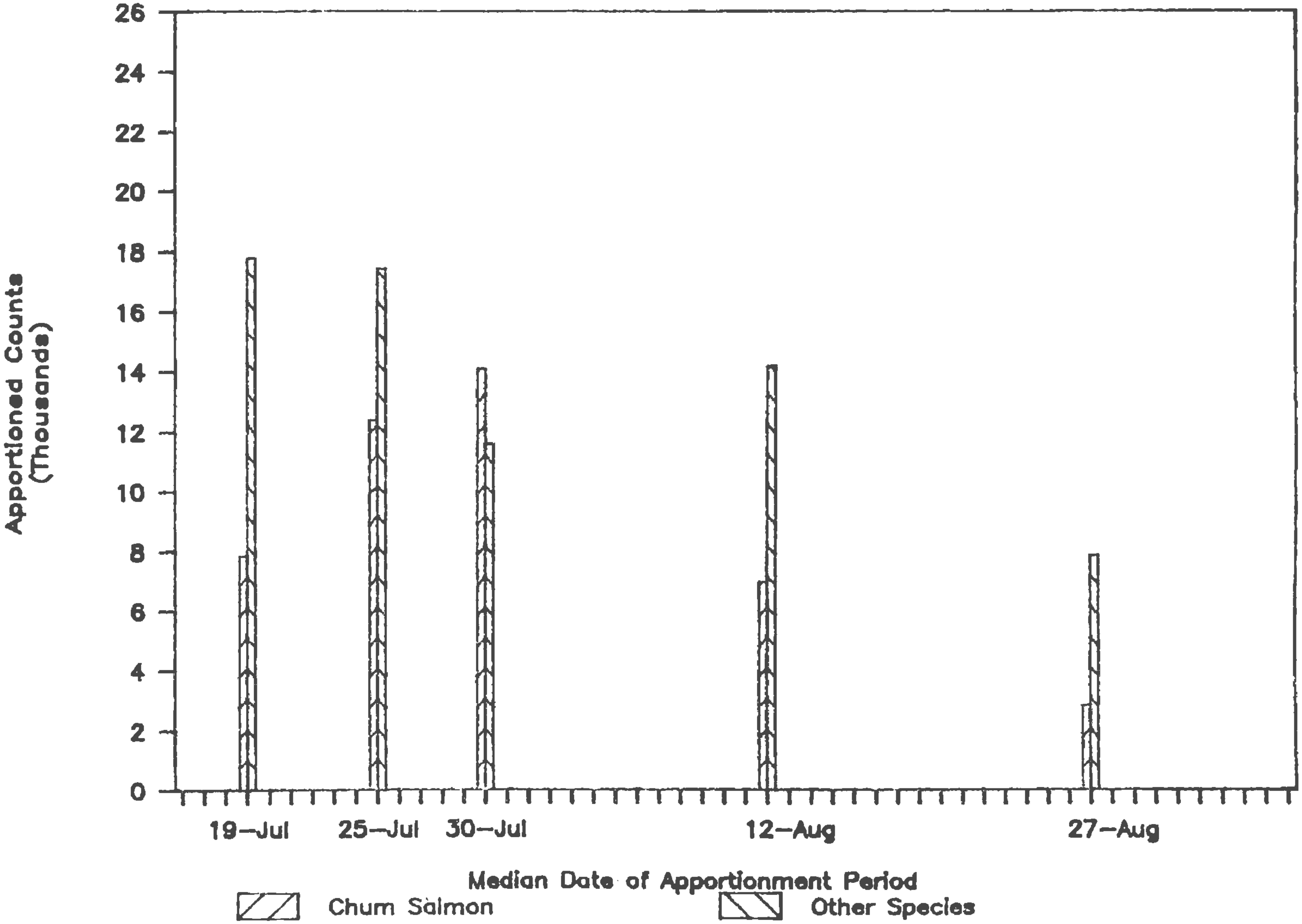

Figure 15. Total counts of fish passage by species over time, Noatak River, 1984.

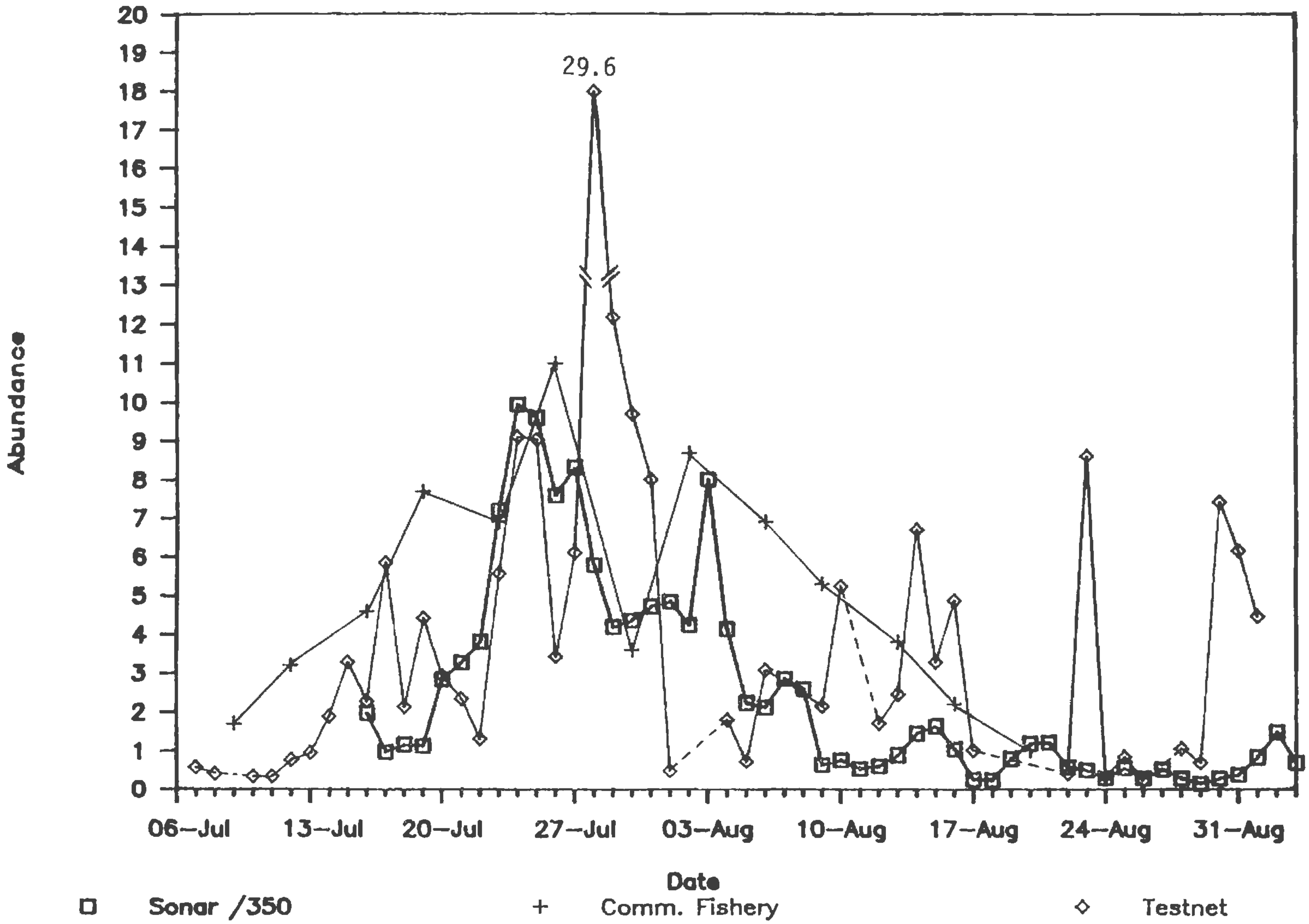

Figure 16. Comparison of Noatak River chum salmon sonar counts (chum proportions by period applied to daily sonar counts) with the Kotzebue Sound commercial chum salmon catch per unit effort (CPUE) and the Noatak River test-net chum CPUE through time in 1984.

sonar counts decreased. After the first week of August the test-net CPUE values fluctuated erratically from day to day while the sonar counts declined in abundance to a steady level. The irregularity of the test-net CPUE values can partially be explained by lack of data during periods of fluctuating water levels and high debris loads when the nets were not fished.

Comparison of daily test-net CPUE with the commercial fishery CPUE (Figure 16) revealed that both indicators peak in abundance within the last week of July, but test-net CPUE dropped sharply about 1 August and then rose in abundance while the commercial fishery CPUE declined steadily throughout August.

Pooling and averaging the test-net and commercial fishery CPUE values by sonar species-apportionment period reduces the daily variation. When plotted with the pooled CPUE values, chum sonar counts (also pooled by apportionment period), tracked similarly through time with the CPUE values (Figure 17), except that the peak of the commercial CPUE (25 July) occurred before the peaks of both chum sonar counts and test-net CPUE (1 Aug). An additional period was created for the commercial fishery and test-net CPUE values that occurred before the initiation of sonar sampling and these values were pooled and averaged for this period.

The mean date of chum passage was also calculated for commercial fishery CPUE and test-net CPUE (Appendix 9) using migratory time density methods (Mundy 1982). The mean date of chum salmon migrating past the location of the Kotzebue Sound commercial fishery was 28 July. At the Noatak River study site (river km 45.2), the mean date of chum passage estimated from test-net CPUE was 3 August. This was three days later than the mean date calculated from chum sonar counts at the study site (31 July).

The cumulative daily proportions (Appendix 9) for each of the three abundance indicators were plotted through time to examine seasonal trends (Figure 18). All three indicators showed the greatest proportional increase in late July and the least increase at the beginning and end of their respective time intervals, except for the test-net daily proportions which increased at the very end of the season. In comparison, the test-net proportions increased the least of the three in the latter part of the season and had a greater level of fluctuation throughout the season. The sonar and commercial fishery proportions progressed more gradually throughout the season with commercial fishery proportions building more rapidly than the sonar proportions, except for midseason (30 July).

DISCUSSION

Sonar Enumeration

The examination of sonar count vertical distribution suggests a random distribution of fish. The range of beam location angles was limited in relation to the river cross-sectional area which makes separation of discrete vertical strata difficult. Other sonar studies have shown that fish tend to orient towards river bottom while migrating upriver. Perhaps the water velocity in the Noatak River is a factor causing a more even vertical

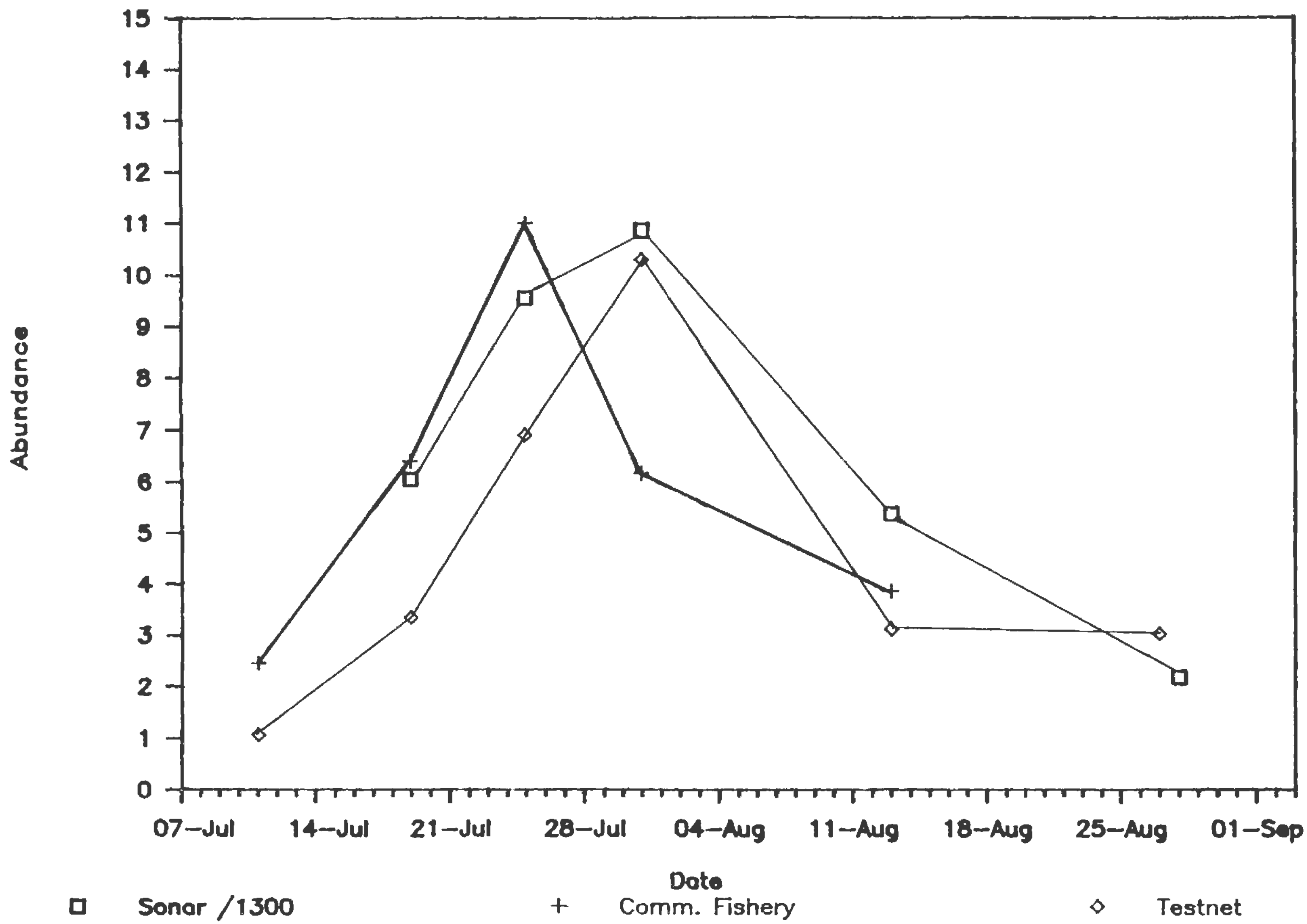

Figure 17. Noatak River sonar counts apportioned to chum salmon compared with the Kotzebue Sound commercial fishery chum CPUE and the Noatak River test-net chum CPUE, all pooled by species apportionment period and plotted through time, in 1984.

distribution. Recently-developed elliptical beam transducers are more conducive to ensonifying the river bottom when compared to the conventional circular beam transducer. Use of elliptical beam transducers on the Noatak River may shed light upon the vertical distribution of migrating fish.

A single depth profile was constructed during the 1984 field season. If future sonar studies are initiated on the Noatak, the river profile should be monitored for changes throughout the season. Irregularities in the bottom profile can cause undercounting of fish in the spaces between the river bottom and the sonar beam (Mesiar et al. 1986). River bottom with an even profile and stable substrate should be the critical element for site selection.

Species Composition

The data set for the species composition work done with monofilament nets is insufficient. It was possible to adjust for only chum salmon selectivity, because species other than chum salmon were not adequately represented in the larger mesh net. It is not known whether the estimated value chosen for other species selectivity is appropriate for this study. This is a possible source of error that would significantly affect the apportioned estimates of fish passage. Also, relatively few chum salmon were gilled in the 102-mm net because this mesh size is perhaps too small for most age classes of chum salmon returning to the Noatak River.

Future studies should probably employ three mesh sizes to sample from all portions of the population making it possible to develop selectivity coefficients for each species. Because the species composition differs with location, it is necessary to sample with greater intensity to obtain a sufficient sample size for each location. Possibly, more frequent sets of shorter duration would allow adequate sampling.

Comparison With Other Abundance Indicators

The comparison between the three chum salmon abundance indicators in Figure 16 reveals a similarity of peak abundance in late July. Specific conclusions can not be made about the daily chum sonar counts, because they are not truly representative of chum passage on a daily basis. The proportions were derived over a period of several days so are not representative of how much each component, chum salmon or other species, contributed to the sonar count magnitude on a single day.

The 1984 commercial fishery CPUE (Figure 16) rose gradually to peak abundance in late July then declines steadily until the season closure with only one notable aberrant point which occurred on 30 July and was due to extremely poor weather.

The high variability of daily test-net indices, as illustrated in Figures 16 and 18, is thought to be caused by varying water conditions which alter the effectiveness of the nets used for daily test-net indices and for species-apportionment of sonar counts. These conditions, which include water levels, water clarity, and debris loads, may affect the catchability of the set nets and also the migratory pattern of fish. Drift gill nets may be a solution to

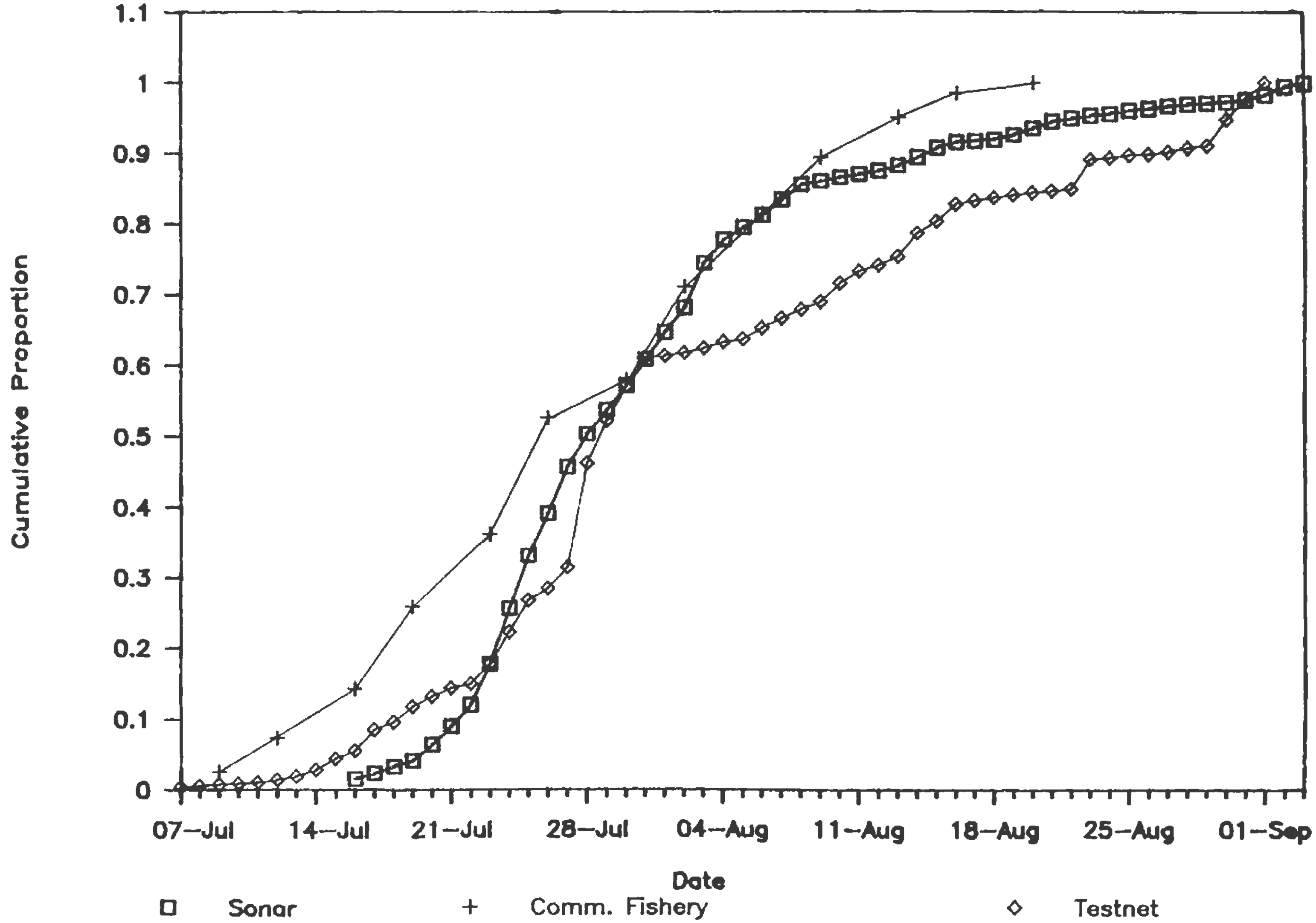

Figure 18. Cumulative daily proportions of season totals for Noatak River chum sonar counts and test-net CPUE and the Kotzebue Sound commercial fishery chum CPUE plotted through time in 1984.

this problem by reducing the effect of debris and allowing greater flexibility during high water periods.

Although scarcity of data points limit the comparison between the Kotzebue Sound commercial fishery CPUE, the Noatak River test-net chum CPUE, and the chum-apportioned sonar counts, all pooled by period, the three sources follow similar trends when tracked through time (Figure 17). When daily variations are eliminated by averaging test-net indices pooled by apportionment period, the test-net indices are similar in magnitude to the chum sonar counts pooled by apportionment period. The peaks of chum sonar counts and test-net CPUE are reached later than the commercial CPUE which is expected since the sonar site is located upstream from the commercial fishery.

The mean date of chum passage (Appendix 9) differed for test-net chum CPUE (3 August) and chum sonar counts (31 July). There should have been no difference because these indicators sampled from the same point of the migration route. Possible reasons for this difference include: (1) inaccurate estimation of sonar count species proportions during part of the season, (2) differing levels of sonar accuracy throughout the season, or (3) differing levels of test-net catchability throughout the season. From Figure 18 it appears that test-net proportions after 31 July did not increase in the same manner as did the sonar counts and the commercial fishery CPUE. This appears to be the most likely reason for the difference in mean date of chum passage. The earlier commercial fishery mean date of passage (28 July), coupled with the more rapid increase in cumulative proportion (Figure 24), as compared with the sonar counts, is expected since the chum migration through the fishery is separated in time from the Noatak River study site.

It should be noted that two factors have not been addressed in the comparison of abundance indicators which relate to the commercial fishery. First, the commercial fishery catch is composed of chum populations from the Noatak River and the Kobuk River, and it is difficult to clearly distinguish separate run timing of these populations because of overlap. Secondly, the fishery itself has an undefined effect upon the entry pattern of chum salmon into the Noatak River.

The aerial survey conducted on Noatak River spawning grounds shortly after the end of the sonar-sampling field season revealed that a larger number of chum salmon had migrated upstream than had been estimated with apportioned sonar counts. Test fishing at the sonar site before the initiation of sonar counting indicated a small number of upstream migrating chum salmon (Bigler 1985) which were consequently not counted by the sonar. While this is probably not a major factor, it is a contributing factor to the discrepancy between the aerial survey and this study. Both estimates are lower than the historical average escapement of 80,000 chum salmon, but high subsistence catches of bright chums were being made in the lower Noatak after both of these estimates had been made (ADF&G 1985). The escapement was probably closer to the historical average than the aerial survey indicates due to this late component of the chum salmon run.

Project Evaluation And Recommendations

Trends in sonar counts obtained from the Noatak River between 16 July and 3 September were similar to trends in CPUE from the commercial fishery and the gill net test-fishing program. However, the total count produced by the sonar is significantly lower than the number of chum salmon tallied on an aerial survey conducted on 4 September.

Several factors may have contributed to sonar undercounting which include: (1) incorrect estimation of the effective beam size, (2) inadequate sonar coverage of the middle river, and (3) inaccurate apportionment of species. Factors 1 and 2 would be relatively easy to remedy in the future. Effective beam width can be analyzed by using dual beam sonar techniques on selected segments of the run. Accurate sonar coverage of midriver can be easily accomplished by using additional transducers. If fish are traveling near the bottom in midriver, the additional transducers are essential because of the difficulty of aiming transducers over long ranges and an uneven bottom.

Recommendations for the third factor have been previously addressed and include: Larger sample sizes per stratum, use of three nets of differing mesh size, and possibly the use of drift gill net techniques.

With these changes, an accurate and timely estimate of chum salmon escapement into the Noatak River can be determined.

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LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1985. Norton Sound - Port Clarence - Kotzebue Sound annual management report, 1984. Division of Commercial Fisheries, Nome, Alaska.

Bernard, D.R. 1983. Statewide standards for sampling sizes for AWL's. Memorandum to John H. Clark and Scott Marshall. Alaska Department of Fish and Game, Commercial Fisheries Division. 27 January 1983.

Bigler, B. 1984. Noatak River salmon studies, 1983. Norton Sound/Kotzebue salmon escapement report #39, Region III, Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, Alaska.

Bigler, B. 1985. Noatak River test fishing project, 1984. AYK Region: Norton Sound/Kotzebue test fish, salmon escapement report #3. Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, Alaska.

Brannian, L. 1984. Gill net selectivity as applied to the allocation of sonar counts. Draft manuscript. Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, Alaska, 18 January 1984.

Cochran, W.G. 1977. Sampling Techniques, 3rd edition. John Wiley & Sons, Inc., New York.

Gaudet, D.M., Editor. 1983. 1981 Bendix adult counter manual. Alaska Department of Fish and Game, Commercial Fisheries Division, Juneau, Alaska.

Mesiar, D.C., D.M. Eggers, and D.M. Gaudet. 1986. Hydroacoustic enumeration of salmon escapement to the Yukon River in 1985. AYK Region: Yukon River Salmon Escapement Report #27. Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, Alaska.

Mundy, P. 1982. Migratory timing of adult chinook salmon *(Oncorhynchus tshawytscha)* in the lower Yukon River, Alaska with respect to fisheries management. Advisory report for Alaska Department of Fish and Game, Contract No. 81-334. Old Dominion University, School of Science and Health Professions Technical Report 82-1, Norfolk, Virginia.

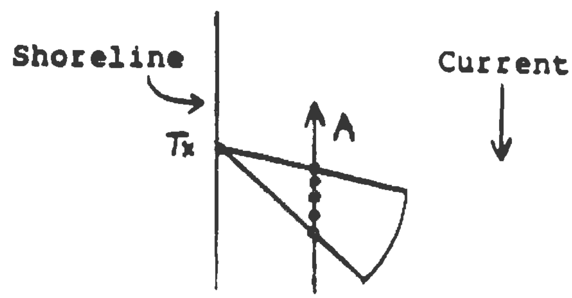
Nickerson, R.B., and D.M. Gaudet. 1985. Sonar feasibility studies in the lower Kuskokwim and Yukon Rivers 1980-1983. Draft Manuscript. Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, Alaska, 21 March 1985.

Zar, J.H. 1974. Biostatistical Analysis. 1st edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Appendix 1. Criteria for classification of targets.

Appendix 1. Criteria for classification of targets.

Classification of echogram traces as upriver migrant fish (as opposed to debris, boat traffic, or water turbulence) was based on direction of movement, amount of time spent in the beam, surface turbulence associated with the target, and width and intensity of the recorded trace. Direction of movement was determined using change-in-range techniques. The figure below shows a cross section of an acoustic beam.



The trajectory of a fish passing through the beam is represented bu vector A. Marks on the line identify positions along the trajectory where the fish is ensonified during successive transmissions. As the fish moves along its upstream trajectory, its slant range from the transducer decreases. Downstream movement is evidenced by increasing slant range. Determination of target direction separated debris from fish.

Appendix 2. Daily totals of upstream targets (sum of targets from 45 minute samples) by location.

Daily totals of upstream targets (sum of targets from 45 minute samples) by location.

Date	North	South	Midriver
16-Jul	329	70	43
17-Jul	156	45	16
18-Jul	182	73	34
19-Jul	117	146	22
20-Jul	319	153	35
21-Jul	590	240	87
22-Jul	335	213	62
23-Jul	363	101	62
24-Jul	627	255	129
25-Jul	391	279	72
26-Jul	494	94	14
27-Jul	512	195	45
28-Jul	133	59	154
29-Jul	64	108	76
30-Jul	72	71	165
31-Jul	134	100	46
01-Aug	154	67	19
02-Aug	136	43	3
03-Aug	268	87	7
04-Aug	149	30	3
05-Aug	89	49	3
06-Aug	83	62	12
07-Aug	135	60	21
08-Aug	135	69	3
09-Aug	28	12	6
10-Aug	39	10	12
11-Aug	23	6	8
12-Aug	28	4	6
13-Aug	22	16	10
14-Aug	38	83	75
15-Aug	118	54	39
16-Aug	16	29	49
17-Aug	6	6	2
18-Aug	12	8	0
19-Aug	28	3	9
20-Aug	48	11	0
21-Aug	57	30	9
22-Aug	48	18	0
23-Aug	38	20	4
24-Aug	13	25	10
25-Aug	50	11	4
26-Aug	32	1	1
27-Aug	42	9	4
28-Aug	21	14	8
29-Aug	16	2	6
30-Aug	15	8	19
31-Aug	43	8	16
01-Sep	69	3	14
02-Sep	116	2	15
03-Sep	55	42	39
Totals	6988	3103	1495

Appendix 3. Summary of 1984 Noatak River test-fish operations using monofilament set gill nets.

Summary of 1984 Noatak River test-fish operations using monofilament set gill nets.

		Mesh (mm)	# of Sets	Fishing Time (hr)	Catch: #Chum	#Pink	#Char	#Whitefish	#Suckers	#Sheefish	#Other	Total #Fish Caught	# of Recaptures
	North	102	1	13.75	2	12	1	11	7	3		36	1 whitefish
		149	2	21.97	27			1				28	1 chum
Period 1	South	102	2	13.75	11	7		19	16	1		54	
(16-23 Jul)		149	1	13.12	12	2						14	
	Midriver	102	3	35.55	6	3	2	2	10	2		25	
		149	3	36.08	27	2				1		30	
	North	102	1	10.75	27	11	1	15				54	
Period 2		149	1	13.75	19	1	1	3				24	
(24-27 Jul)	South	102	1	11	22	3	1	4	19			49	
		149	1	10.58	51							51	
	Midriver	102	2	22.72	6	6	1	5		1	1	20	
		149	2	21.85	33							33	
	North	102	2	10.42	23	9		10		1		43	
Period 3		149	1	5	18							18	
(28-Jul to	South	102	2	11.35	3		1	7	5			16	
4-Aug)		149	1	8.25	78	1						79	
	Midriver	102	2	12.25	21	19		2		1		43	
		149	3	9.78	28							28	
	North	102	3	36.28	20	17	16	98	1	4	1	157	1 whitefish
		149	3	37.94	45	2						47	1 chum
Period 4	South	102	2	33.51	18	12	9	14	8		2	63	1 whitefish
(5-20 Aug)		149	5	52.9	47	1			1			49	
	Midriver	102	5	61.24	5	2	2	1	2			12	
		149	3	27.82	44							44	
	North	102	2	22.58	4	5	25	15			2	51	3 whitefish
Period 5		149	4	41.33	18		11					29	2 chum
(21-Aug to	South	102	3	46.18	2	7	13	24	1		1	48	1 whitefish
3-Sept)		149	3	31.77	26	1	5		1			33	1 chum
	Midriver	102	5	44.57	3	2	35	4	1		1	46	
		149	4	21.13	60		5					65	
		Total	73	739.17	706	125	129	235	72	14	8	1,289	12 recaps.

Appendix 4. Worksheet for development of selectivity coefficients for Noatak River chum salmon captured in 102-mm mesh gill net in 1984 (from Brannian 1984).

Development of selectivity coefficients for Noatak River chum salmon caught in a 101.6 (4 in) mesh set gillnet.

Length Class	Mid-Point (L)	L - Lm / S 1/	Ordinate Height of Normal Distribution	Selectivity Coefficients	Catch	Catch Adjusted for Selectivity
400 -409	404.5	-0.50	0.3512	0.88	1.0	1
410 -419	414.5	-0.40	0.3680	0.92		0
420 -429	424.5	-0.30	0.3814	0.96		0
430 -439	434.5	-0.20	0.3913	0.98	1.0	1
440 -449	444.5	-0.09	0.3972	1.00	1.0	1
450 -459	454.5	0.01	0.3989	1.00		0
460 -469	464.5	0.11	0.3965	0.99	1.0	1
470 -479	474.5	0.21	0.3900	0.98		0
480 -489	484.5	0.32	0.3795	0.95		0
490 -499	494.5	0.42	0.3655	0.92		0
500 -509	504.5	0.52	0.3483	0.87	1.0	1
510 -519	514.5	0.62	0.3284	0.82		0
520 -529	524.5	0.73	0.3065	0.77	1.0	1
530 -539	534.5	0.83	0.2830	0.71	1.0	1
540 -549	544.5	0.93	0.2586	0.65	1.0	2
550 -559	554.5	1.03	0.2338	0.59	4.0	7
560 -569	564.5	1.14	0.2092	0.52	5.3	10
570 -579	574.5	1.24	0.1852	0.46	8.3	18
580 -589	584.5	1.34	0.1622	0.41	7.0	17
590 -599	594.5	1.44	0.1406	0.35		0
600 -609	604.5	1.55	0.1206	0.30		0
610 -619	614.5	1.65	0.1024	0.26	4.6	18
620 -629	624.5	1.75	0.0860	0.22		0
630 -639	634.5	1.85	0.0715	0.18	4.0	22
640 -649	644.5	1.96	0.0588	0.15	7.0	47
650 -659	654.5	2.06	0.0479	0.12	14.0	117
660 -669	664.5	2.16	0.0385	0.10	6.0	62
670 -679	674.5	2.26	0.0307	0.08		
680 -689	684.5	2.37	0.0242	0.06		
690 -699	694.5	2.47	0.0189	0.05		
700 -709	704.5	2.57	0.0146	0.04		
710 -719	714.5	2.67	0.0111	0.03	7.0	250
720 -729	724.5	2.78	0.0084	0.02		
730 -739	734.5	2.88	0.0063	0.02		
740 -749	744.5	2.98	0.0047	0.01		
750 -759	754.5	3.09	0.0034	0.01	2.0	233
760 -769	764.5	3.19	0.0025	0.01	1.0	161

1/ Where Lm = 453.7
S = 97.5

Appendix 5. Worksheet for development of selectivity coefficients for Noatak River chum salmon captured in 149-mm mesh gill net in 1984 (from Brannian 1984).

Development of selectivity coefficients for Noatak River chum salmon caught in a 149.3 mm (5 7/8 in) mesh set gillnet.

Length Class	Mid-Point (L)	L - Lm / S [1/]	Ordinate Height of Normal Distribution	Selectivity Coefficients	Catch	Catch Adjusted for Selectivity
400 -409	404.5	-2.69	0.0108	0.03		
410 -419	414.5	-2.58	0.0142	0.04		
420 -429	424.5	-2.48	0.0184	0.05		
430 -439	434.5	-2.38	0.0236	0.06		
440 -449	444.5	-2.28	0.0299	0.08		
450 -459	454.5	-2.17	0.0376	0.09		
460 -469	464.5	-2.07	0.0467	0.12		
470 -479	474.5	-1.97	0.0575	0.14		
480 -489	484.5	-1.87	0.0700	0.18		
490 -499	494.5	-1.76	0.0843	0.21		
500 -509	504.5	-1.66	0.1005	0.25		
510 -519	514.5	-1.56	0.1185	0.30		
520 -529	524.5	-1.46	0.1383	0.35		
530 -539	534.5	-1.35	0.1598	0.40		
540 -549	544.5	-1.25	0.1826	0.46	1	2
550 -559	554.5	-1.15	0.2065	0.52	2	4
560 -569	564.5	-1.05	0.2311	0.58	3	5
570 -579	574.5	-0.94	0.2559	0.64	10	16
580 -589	584.5	-0.84	0.2803	0.70	14	20
590 -599	594.5	-0.74	0.3040	0.76	22	29
600 -609	604.5	-0.63	0.3261	0.82	42	51
610 -619	614.5	-0.53	0.3462	0.87	40	46
620 -629	624.5	-0.43	0.3636	0.91	53	58
630 -639	634.5	-0.33	0.3782	0.95	53	56
640 -649	644.5	-0.22	0.3890	0.98	49	50
650 -659	654.5	-0.12	0.3960	0.99	44	44
660 -669	664.5	-0.02	0.3989	1.00	46	46
670 -679	674.5	0.08	0.3976	1.00	43	43
680 -689	684.5	0.19	0.3921	0.99	15	15
690 -699	694.5	0.29	0.3827	0.96	17	18
700 -709	704.5	0.39	0.3696	0.93	7	8
710 -719	714.5	0.49	0.3532	0.89	3	3
720 -729	724.5	0.60	0.3340	0.84	5	6
730 -739	734.5	0.70	0.3126	0.78	6	8
740 -749	744.5	0.80	0.2895	0.73	0	0
750 -759	754.5	0.90	0.2652	0.66	1	2
760 -769	764.5	1.01	0.2405	0.60	1	2
770 -779	774.5	1.11	0.2158	0.54	3	6
780 -789	784.5	1.21	0.1916	0.48	3	6

1/ where Lm = 666.4
S = 97.5

Appendix 6. Kruskal-Wallis one-way analysis of variance for chum salmon proportions among the three test-net locations within the five species apportionment periods.

Appendix 6. Kruskal-Wallis one-way analysis of variance for chum salmon proportions amoung the three test fish locations within the five periods.

Ho: there is no difference amoung chum salmon proportions of the three test fish locations: north, south, and midriver.

H_A: the three locations are not the same with respect to chum salmon proportions.

Let α = .10

Ranking of proportions by location and species apportionment period.

	North		South		Midriver	
Period	%Chum	Rank	%Chum	Rank	%Chum	Rank
1	40.1	5	15	1	51.1	8
2	33	4	70.1	11	72.8	13
3	48.1	7	70.9	12	74.5	14
4	23.8	3	56.2	9	89.5	15
5	22.1	2	40.1	6	67.5	10
Total		21		39		60

$$H = \frac{12}{15(15+1)}\left[\frac{(21)^2}{5} + \frac{(39)^2}{5} + \frac{(60)^2}{5}\right] - 3(15+1)$$

H = 7.62

$p < .049$

Conclusion: Reject Ho in favor of H_A

Appendix 7. Nonparametric multiple comparison using Kruskal-Wallis rank sums to test for differences in chum proportions between the three test-net locations within the five species apportionment periods.

Appendix 7. **Nonparametric multiple comparison using Kruskal-Wallis rank sums to test for differences in chum proportions between the three test fish locations within the five periods on the Noatak River, 1984.**

Ho: Chum salmon proportions are the same when comparing one test fishing location with another.

H_A: Chum salmon proportions are different between test fishing locations.

Let $\alpha = .10$

When p = 3, $SE = \sqrt{\dfrac{5(5\cdot3)16}{12}} = 10.00$

p = 2, $SE = \sqrt{\dfrac{5(5\cdot2)11}{12}} = 6.77$

	North	South	Midriver
Kruskal-Wallis rank sums	21	39	60
Rank Sums Ranked	1	2	3

Comparison	Rank Sum Difference	SE	q	p	q(.10, ,p)
3 vs. 1	60 - 21 = 39	10.0	3.9	3	2.902
3 vs. 2	60 - 39 = 21	6.77	3.1	2	2.326
2 vs. 1	39 - 21 = 18	6.77	2.66	2	2.326

Conclusion: Reject Ho at $\alpha = .10$

Accept H_A: Chum salmon proportions are different between test fishing locations.

Appendix 8. Summary of fish abundance indicators from the Kotzebue Sound commercial fishery and the Noatak River sonar and test-net projects in 1984.

Comparison of chum salmon abundance indicators from the Kotzebue Sound commercial fishery and the and the Noatak River sonar and test fish projects in 1984.

	Daily[1] Count	Cumul.[2] Count	Count by[3] Period	Test Fish[4] CPUE	Test Fish[5] CPUE Cum.	Ave. CPUE[6] Pooled by Period	Commercial[7] CPUE	Commercial[8] CPUE Cum.
07-Jul				0.6	0.6			
08-Jul				0.4	1.0			
09-Jul					1.0		1.7	1.7
10-Jul				0.3	1.3			1.7
11-Jul				0.3	1.6			1.7
12-Jul				0.8	2.4		3.2	4.9
13-Jul				0.9	3.3			4.9
14-Jul				1.9	5.2			4.9
15-Jul				3.3	8.5			4.9
16-Jul	693	693		2.3	10.7		4.6	9.5
17-Jul	342	1035		5.8	16.6			9.5
18-Jul	409	1445		2.1	18.7			9.5
19-Jul	398	1843	7,850	4.4	23.1	3.3	7.7	17.2
20-Jul	996	2839		2.9	26.0			17.2
21-Jul	1147	3986		2.3	28.4			17.2
22-Jul	1338	5323		1.3	29.7			17.2
23-Jul	2526	7850		5.6	35.2		6.9	24.1
24-Jul	3482	11331		9.1	44.3			24.1
25-Jul	3362	14693	12,420	9.0	53.4	6.9		24.1
26-Jul	2657	17351		3.4	56.8		11.0	35.1
27-Jul	2919	20270		6.1	62.9			35.1
28-Jul	2030	22301		29.6	92.5			35.1
29-Jul	1468	23768		12.2	104.7			35.1
30-Jul	1530	25298		9.7	114.4		3.6	38.7
31-Jul	1655	26954	14,125	8.0	122.4	10.3		38.7
01-Aug	1699	28653		0.5	122.9			38.7
02-Aug	1488	30141			122.9		8.7	47.4
03-Aug	2805	32946			122.9			47.4
04-Aug	1450	34396		1.8	124.6			47.4
05-Aug	781	35177		0.7	125.4			47.4
06-Aug	742	35919		3.1	128.4		6.9	54.3
07-Aug	1001	36920			128.4			54.3
08-Aug	909	37829			128.4			54.3
09-Aug	225	38055		2.1	130.6		5.3	59.6
10-Aug	266	38320		5.2	135.8			59.6
11-Aug	190	38511			135.8			59.6
12-Aug	214	38725		1.7	137.5			59.6
13-Aug	314	39039	6,971	2.5	140.0	3.1	3.8	63.4
14-Aug	512	39551		6.7	146.7			63.4
15-Aug	575	40126		3.3	149.9			63.4
16-Aug	367	40494		4.9	154.8		2.2	65.6
17-Aug	91	40585		1.0	155.8			65.6
18-Aug	83	40668			155.8			65.6
19-Aug	280	40948			155.8			65.6
20-Aug	418	41366			155.8		1.0	66.6
21-Aug	424	41790			155.8			
22-Aug	199	41989		0.4	156.2			
23-Aug	172	42161		8.6	164.8			
24-Aug	103	42263		0.3	165.1			
25-Aug	191	42454		0.8	166.0			
26-Aug	99	42553		0.2	166.2			
27-Aug	182	42736			166.2	3.0		
28-Aug	100	42836	2,816	1.1	167.2			
29-Aug	51	42887		0.7	167.9			
30-Aug	96	42983		7.4	175.3			
31-Aug	134	43118		6.1	181.5			
01-Sep	296	43414		4.5	185.9			
02-Sep	523	43938						
03-Sep	244	44182						

1/ Chum proportions by period applied to daily sonar counts from the Noatak River.
2/ Cumulative daily chum sonar counts from chum proportions by period on the Noatak River.
3/ Noatak River sonar counts apportioned to chum salmon and pooled by apportionment period.
4/ Average daily chum CPUE from the Noatak River testnet project using monofilament and multifilament 149 mm mesh gill nets. Days with no data are due to high water or heavy debris loads (taken from Bigler 1985).
5/ Cumulative average daily chum CPUE from the Noatak River testnet project.
6/ Noatak River testnet project Chum CPUE pooled by apportionment period and averaged.
7/ Kotzebue District (331) commercial chum CPUE by commercial fishing period (A.D.F.& G. 1985).
8/ Cumulative Kotzebue District commercial chum CPUE by commercial fishing period.

Appendix 9. Migratory time-density calculation of chum salmon mean-passage date in 1984 from the three abundance indicators: Noatak River sonar chum counts, Kotzebue Sound commercial fishery chum CPUE, and Noatak River test-net chum CPUE.

Calculation of chum salmon mean-date of migration using chum salmon sonar counts (chum proportions by period applied to daily sonar counts) on the Noatak River, 1984.

t	Date	Daily Chum Count	Daily Proportion	Coded Proportion	Cumulative Proportion
1	16-Jul	693	0.0157	0.02	0.02
2	17-Jul	342	0.0077	0.02	0.03
3	18-Jul	409	0.0093	0.03	0.06
4	19-Jul	398	0.0090	0.04	0.10
5	20-Jul	996	0.0225	0.11	0.21
6	21-Jul	1,147	0.0260	0.16	0.36
7	22-Jul	1,338	0.0303	0.21	0.58
8	23-Jul	2,526	0.0572	0.46	1.03
9	24-Jul	3,482	0.0788	0.71	1.74
10	25-Jul	3,362	0.0761	0.76	2.50
11	26-Jul	2,657	0.0601	0.66	3.16
12	27-Jul	2,919	0.0661	0.79	3.96
13	28-Jul	2,030	0.0460	0.60	4.56
14	29-Jul	1,468	0.0332	0.47	5.02
15	30-Jul	1,530	0.0346	0.52	5.54
16	31-Jul	1,655	0.0375	0.60	6.14
17	01-Aug	1,699	0.0385	0.65	6.79
18	02-Aug	1,488	0.0337	0.61	7.40
19	03-Aug	2,805	0.0635	1.21	8.61
20	04-Aug	1,450	0.0328	0.66	9.26
21	05-Aug	781	0.0177	0.37	9.63
22	06-Aug	742	0.0168	0.37	10.00
23	07-Aug	1,001	0.0227	0.52	10.52
24	08-Aug	909	0.0206	0.49	11.02
25	09-Aug	225	0.0051	0.13	11.15
26	10-Aug	266	0.0060	0.16	11.30
27	11-Aug	190	0.0043	0.12	11.42
28	12-Aug	214	0.0049	0.14	11.55
29	13-Aug	314	0.0071	0.21	11.76
30	14-Aug	512	0.0116	0.35	12.11
31	15-Aug	575	0.0130	0.40	12.51
32	16-Aug	367	0.0083	0.27	12.78
33	17-Aug	91	0.0021	0.07	12.84
34	18-Aug	83	0.0019	0.06	12.91
35	19-Aug	280	0.0063	0.22	13.13
36	20-Aug	418	0.0095	0.34	13.47
37	21-Aug	424	0.0096	0.35	13.83
38	22-Aug	199	0.0045	0.17	14.00
39	23-Aug	172	0.0039	0.15	14.15
40	24-Aug	103	0.0023	0.09	14.24
41	25-Aug	191	0.0043	0.18	14.42
42	26-Aug	99	0.0022	0.09	14.51
43	27-Aug	182	0.0041	0.18	14.69
44	28-Aug	100	0.0023	0.10	14.79
45	29-Aug	51	0.0012	0.05	14.84
46	30-Aug	96	0.0022	0.10	14.94
47	31-Aug	134	0.0030	0.14	15.09
48	01-Sep	296	0.0067	0.32	15.41
49	02-Sep	523	0.0118	0.58	15.99
50	03-Sep	244	0.0055	0.28	16.27
Totals		44,182	1.00	16.27	

Calculation of chum salmon mean-date of migration using commercial fishery chum salmon CPUE from the Kotzebue District, 1984.

t	Date	Fishery CPUE	Daily Proportion	Coded Proportion	Cumulative Proportion
1	09-Jul	1.7	0.03	0.03	0.03
2	10-Jul			0.00	0.03
3	11-Jul			0.00	0.03
4	12-Jul	3.2	0.05	0.19	0.22
5	13-Jul			0.00	0.22
6	14-Jul			0.00	0.22
7	15-Jul			0.00	0.22
8	16-Jul	4.6	0.07	0.55	0.77
9	17-Jul			0.00	0.77
10	18-Jul			0.00	0.77
11	19-Jul	7.7	0.12	1.27	2.04
12	20-Jul			0.00	2.04
13	21-Jul			0.00	2.04
14	22-Jul			0.00	2.04
15	23-Jul	6.9	0.10	1.55	3.60
16	24-Jul			0.00	3.60
17	25-Jul			0.00	3.60
18	26-Jul	11.0	0.17	2.97	6.57
19	27-Jul			0.00	6.57
20	28-Jul			0.00	6.57
21	29-Jul			0.00	6.57
22	30-Jul	3.6 *	0.05	1.19	7.76
23	31-Jul			0.00	7.76
24	01-Aug			0.00	7.76
25	02-Aug	8.7	0.13	3.27	11.02
26	03-Aug			0.00	11.02
27	04-Aug			0.00	11.02
28	05-Aug			0.00	11.02
29	06-Aug	6.9	0.10	3.00	14.03
30	07-Aug			0.00	14.03
31	08-Aug			0.00	14.03
32	09-Aug	5.3	0.08	2.55	16.58
33	10-Aug			0.00	16.58
34	11-Aug			0.00	16.58
35	12-Aug			0.00	16.58
36	13-Aug	3.8	0.06	2.05	18.63
37	14-Aug			0.00	18.63
38	15-Aug			0.00	18.63
39	16-Aug	2.2	0.03	1.29	19.92
40	17-Aug			0.00	19.92
41	18-Aug			0.00	19.92
42	19-Aug			0.00	19.92
43	20-Aug	1.0	0.02	0.65	20.56
Totals		66.60	1.00	20.56	

* denotes low fishing effort and poor fishing due to bad weather. (A.D.F.& G. 1985)

Calculation of chum salmon mean-date of migration using test-fish CPUE from 149-mm mesh gill nets on the Noatak River in 1984.

t	Date	Daily Chum CPUE	Daily Proportion	Coded Proportion	Cumulative Proportion
1	07-Jul	0.6	0.0028	0.00	0.00
2	08-Jul	0.4	0.0019	0.00	0.01
3	09-Jul	0.4 *	0.0018	0.01	0.01
4	10-Jul	0.3	0.0016	0.01	0.02
5	11-Jul	0.3	0.0016	0.01	0.03
6	12-Jul	0.8	0.0038	0.02	0.05
7	13-Jul	0.9	0.0047	0.03	0.08
8	14-Jul	1.9	0.0094	0.08	0.16
9	15-Jul	3.3	0.0164	0.15	0.30
10	16-Jul	2.3	0.0112	0.11	0.42
11	17-Jul	5.8	0.0291	0.32	0.74
12	18-Jul	2.1	0.0106	0.13	0.86
13	19-Jul	4.4	0.0220	0.29	1.15
14	20-Jul	2.9	0.0146	0.20	1.35
15	21-Jul	2.3	0.0116	0.17	1.53
16	22-Jul	1.3	0.0065	0.10	1.63
17	23-Jul	5.6	0.0278	0.47	2.10
18	24-Jul	9.1	0.0454	0.82	2.92
19	25-Jul	9.0	0.0450	0.86	3.78
20	26-Jul	3.4	0.0170	0.34	4.12
21	27-Jul	6.1	0.0304	0.64	4.75
22	28-Jul	29.6	0.1476	3.25	8.00
23	29-Jul	12.2	0.0607	1.40	9.40
24	30-Jul	9.7	0.0483	1.16	10.56
25	31-Jul	8.0	0.0399	1.00	11.55
26	01-Aug	0.5	0.0024	0.06	11.62
27	02-Aug	0.9 *	0.0046	0.12	11.74
28	03-Aug	1.4 *	0.0068	0.19	11.93
29	04-Aug	1.8	0.0089	0.26	12.19
30	05-Aug	0.7	0.0036	0.11	12.29
31	06-Aug	3.1	0.0153	0.48	12.77
32	07-Aug	2.8 *	0.0138	0.44	13.21
33	08-Aug	2.5 *	0.0122	0.40	13.62
34	09-Aug	2.1	0.0107	0.36	13.98
35	10-Aug	5.2	0.0261	0.91	14.89
36	11-Aug	3.5 *	0.0173	0.62	15.52
37	12-Aug	1.7	0.0085	0.32	15.83
38	13-Aug	2.5	0.0122	0.46	16.30
39	14-Aug	6.7	0.0333	1.30	17.60
40	15-Aug	3.3	0.0163	0.65	18.25
41	16-Aug	4.9	0.0242	0.99	19.24
42	17-Aug	1.0	0.0050	0.21	19.45
43	18-Aug	0.9 *	0.0044	0.19	19.64
44	19-Aug	0.8 *	0.0038	0.17	19.81
45	20-Aug	0.6 *	0.0032	0.14	19.95
46	21-Aug	0.5 *	0.0026	0.12	20.07
47	22-Aug	0.4	0.0020	0.09	20.16
48	23-Aug	8.6	0.0429	2.06	22.22
49	24-Aug	0.3	0.0017	0.08	22.30
50	25-Aug	0.8	0.0041	0.21	22.51
51	26-Aug	0.2	0.0010	0.05	22.56
52	27-Aug	0.6 *	0.0032	0.16	22.72
53	28-Aug	1.1	0.0053	0.28	23.00
54	29-Aug	0.7	0.0034	0.18	23.19
55	30-Aug	7.4	0.0369	2.03	25.21
56	31-Aug	6.1	0.0306	1.71	26.93
57	01-Sep	4.5	0.0222	1.26	28.19
Totals		200.66	1.00	28.19	

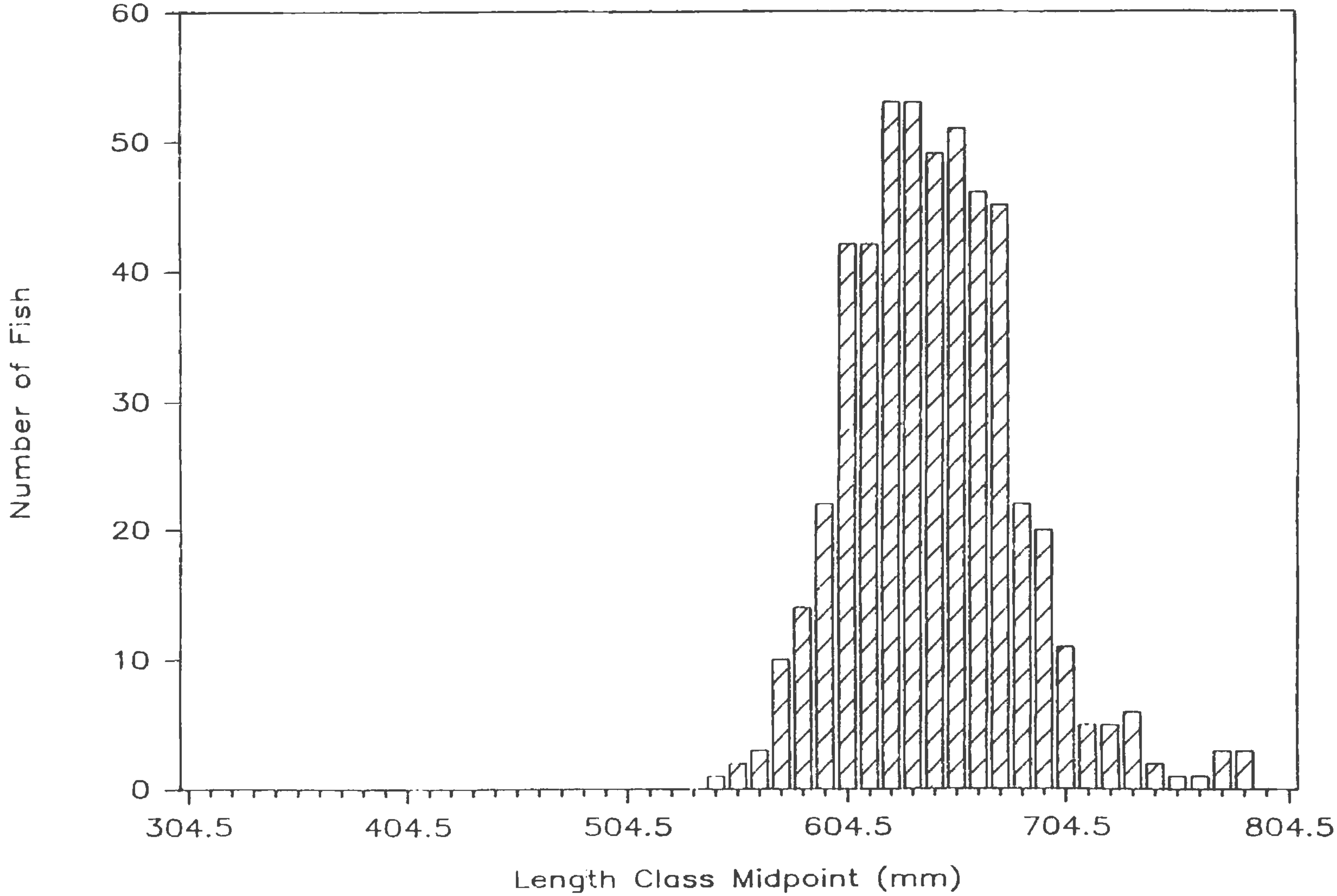
* denotes days of no fishing. Values were interpolated in a linear manner from adjacent days.

Appendix 10. Summary of daily and cumulative daily sonar counts by location on the Noatak River, 1984.

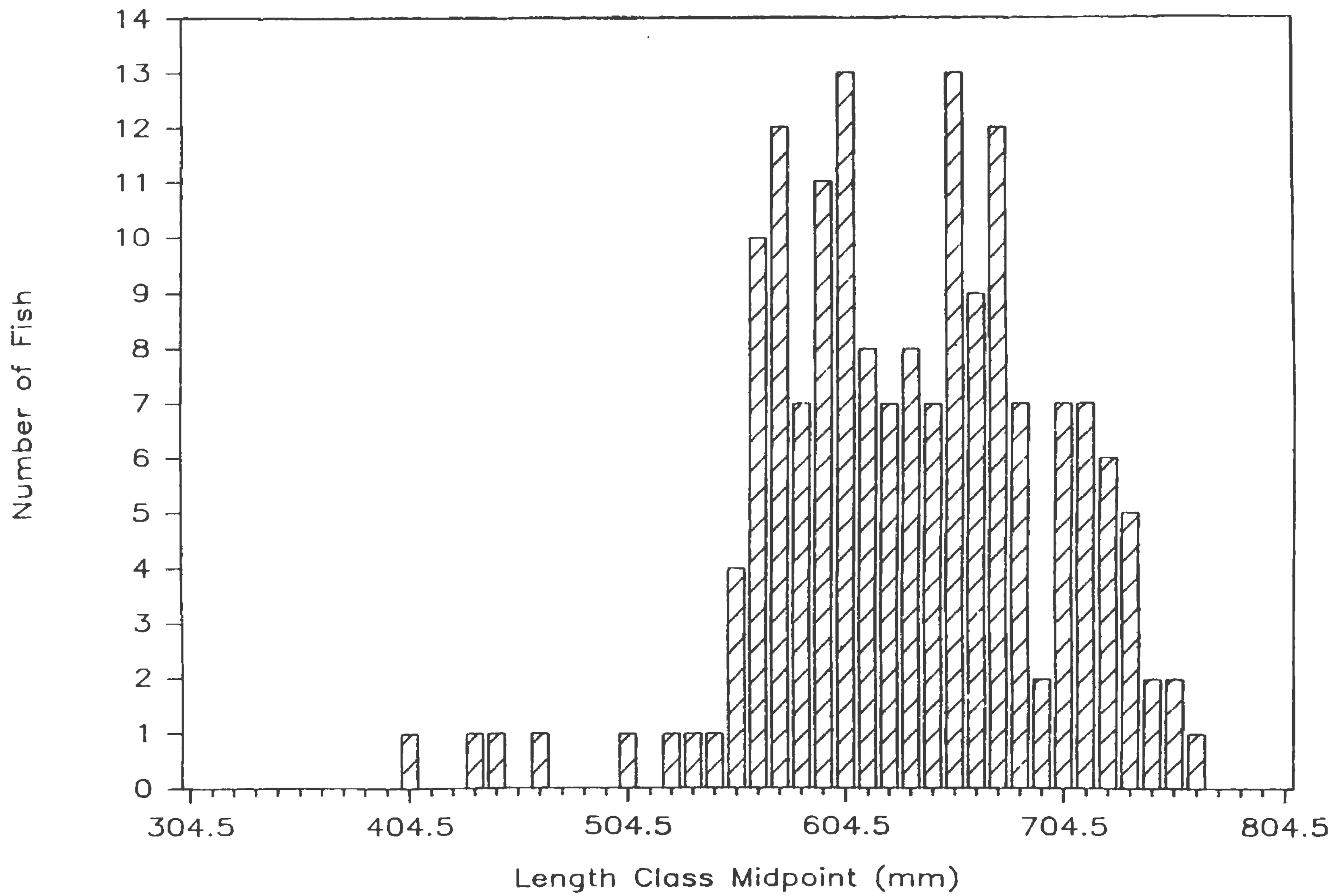
Summary of daily and cumulative daily sonar counts by location on the Noatak River, 1984.

Date	North Bank Daily	North Bank Cumulative	South Bank Daily	South Bank Cumulative	Midriver Daily	Midriver Cumulative
16-Jul	1,394	1,394	475	475	123	123
17-Jul	633	2,026	396	872	57	180
18-Jul	672	2,699	645	1,517	84	264
19-Jul	421	3,120	1,336	2,853	57	321
20-Jul	1,703	4,823	1,771	4,625	92	413
21-Jul	1,848	6,671	2,125	6,749	171	583
22-Jul	2,120	8,791	2,434	9,183	240	824
23-Jul	5,588	14,379	1,004	10,187	264	1,088
24-Jul	6,288	20,667	1,469	11,655	518	1,605
25-Jul	4,899	25,566	2,169	13,825	308	1,914
26-Jul	6,051	31,617	886	14,710	54	1,968
27-Jul	5,818	37,435	1,190	15,901	227	2,195
28-Jul	2,692	40,127	422	16,322	586	2,781
29-Jul	1,067	41,194	1,047	17,369	285	3,066
30-Jul	926	42,120	677	18,047	812	3,878
31-Jul	1,755	43,875	832	18,878	297	4,175
01-Aug	2,642	46,517	512	19,390	88	4,263
02-Aug	2,423	48,939	435	19,825	19	4,282
03-Aug	4,466	53,405	889	20,714	36	4,317
04-Aug	2,488	55,894	329	21,043	27	4,345
05-Aug	1,893	57,787	555	21,598	21	4,365
06-Aug	1,789	59,576	473	22,071	56	4,421
07-Aug	2,744	62,319	451	22,523	106	4,527
08-Aug	2,443	64,762	564	23,086	12	4,539
09-Aug	656	65,419	92	23,178	20	4,559
10-Aug	723	66,142	81	23,259	54	4,613
11-Aug	493	66,635	65	23,324	41	4,654
12-Aug	612	67,247	43	23,367	50	4,703
13-Aug	380	67,627	252	23,619	92	4,795
14-Aug	332	67,959	526	24,144	154	4,949
15-Aug	1,219	69,178	305	24,450	126	5,075
16-Aug	130	69,308	204	24,653	248	5,324
17-Aug	112	69,420	99	24,752	10	5,334
18-Aug	208	69,628	60	24,812	0	5,334
19-Aug	951	70,580	37	24,849	37	5,370
20-Aug	1,545	72,125	90	24,938	0	5,370
21-Aug	1,493	73,618	151	25,089	49	5,419
22-Aug	760	74,378	77	25,167	0	5,419
23-Aug	487	74,865	126	25,292	20	5,440
24-Aug	99	74,965	121	25,414	48	5,487
25-Aug	688	75,653	61	25,475	21	5,509
26-Aug	420	76,072	4	25,479	7	5,516
27-Aug	680	76,752	49	25,527	19	5,534
28-Aug	192	76,944	72	25,600	43	5,577
29-Aug	122	77,067	14	25,614	27	5,604
30-Aug	131	77,197	41	25,655	76	5,680
31-Aug	322	77,519	58	25,713	59	5,739
01-Sep	1,113	78,632	17	25,730	65	5,804
02-Sep	2,175	80,807	12	25,742	56	5,860
03-Sep	301	81,109	244	25,986	118	5,978

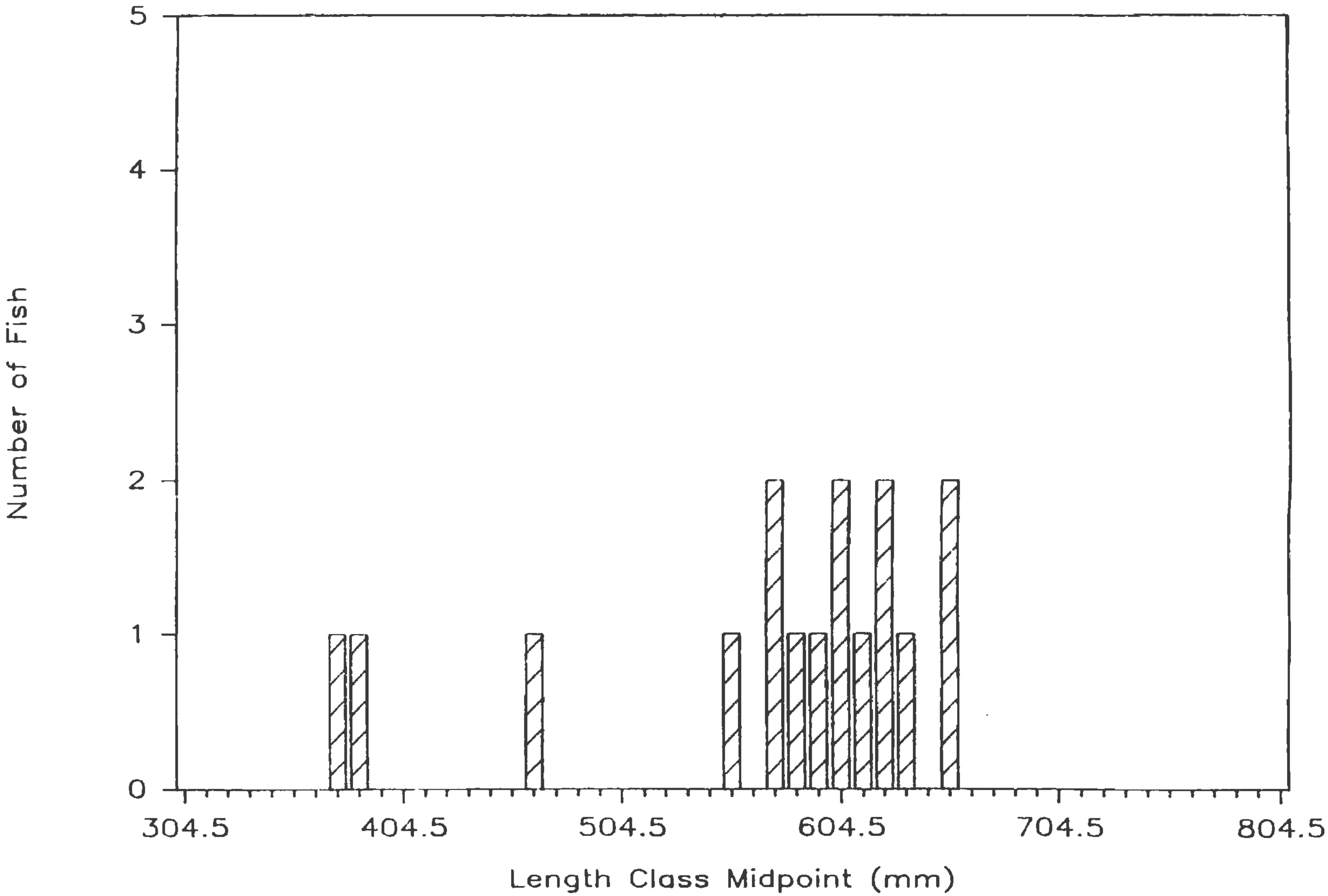
Appendix 11. Length frequency histograms of fish caught in monofilament gill nets in the Noatak River, 1984.



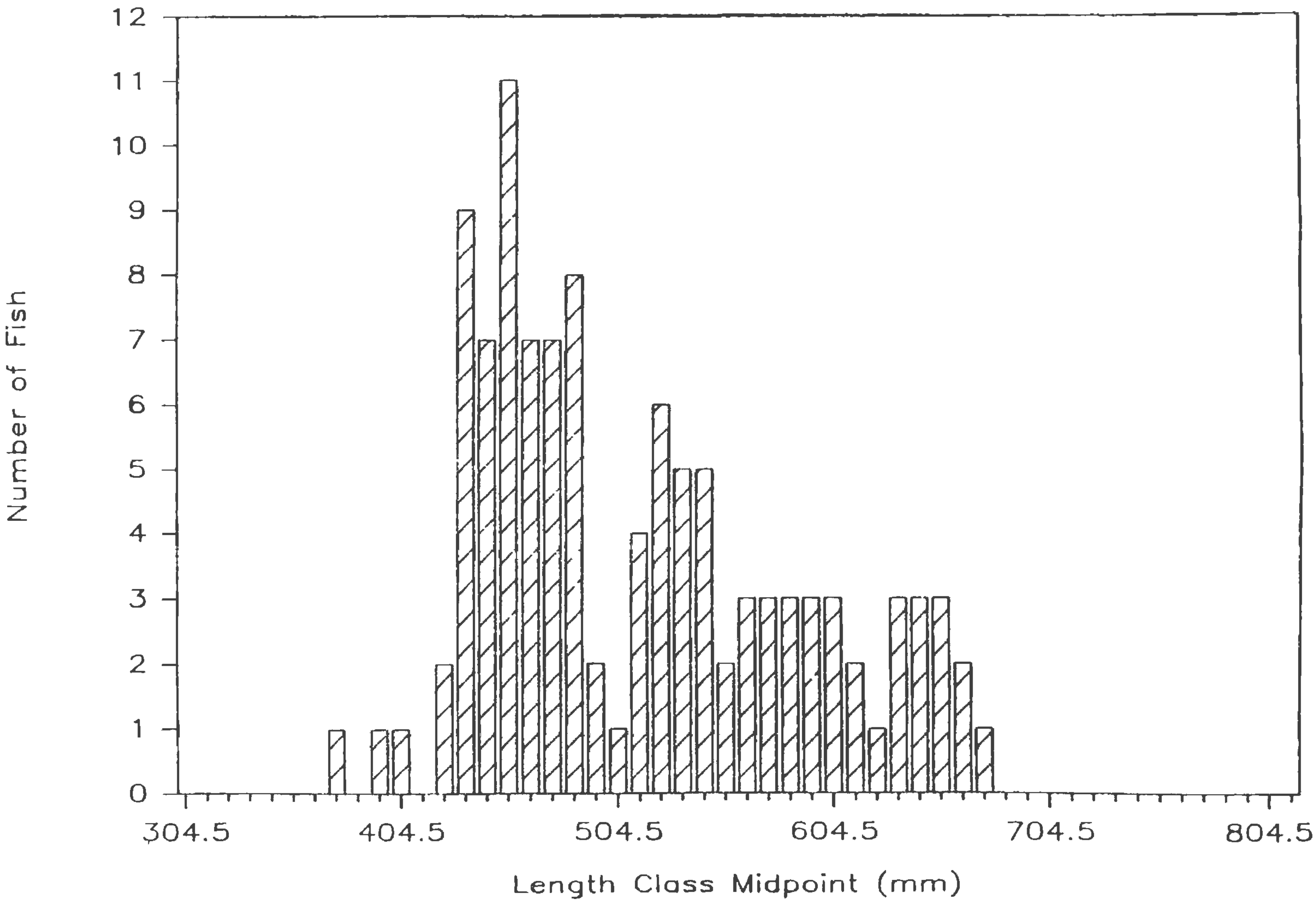
Length frequency histogram for chum salmon captured in 149-mm mesh monofilament gill nets in the Noatak River in 1984.



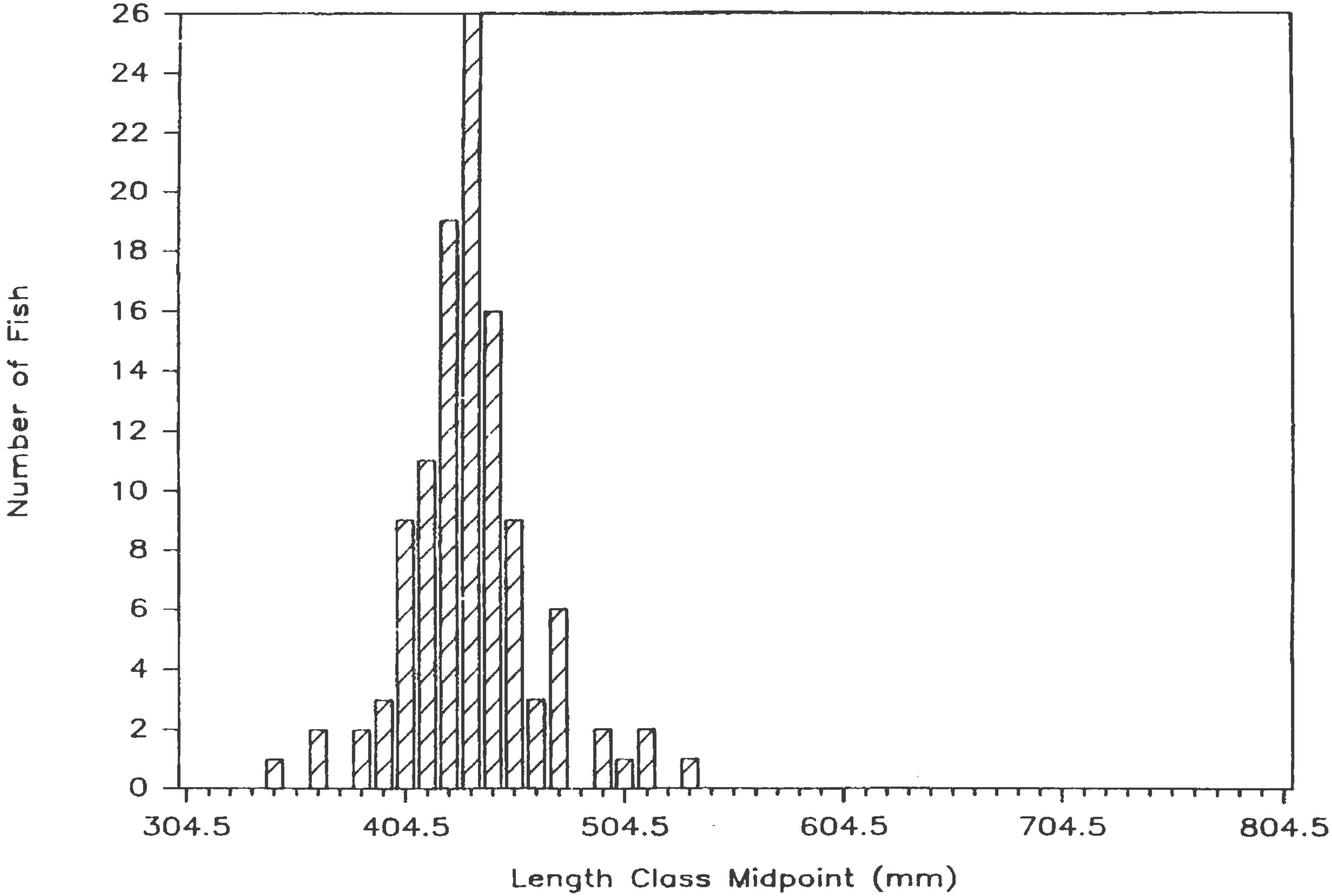
Length frequency histogram for chum salmon captured in 102-mm mesh monofilament gill nets in the Noatak River in 1984.



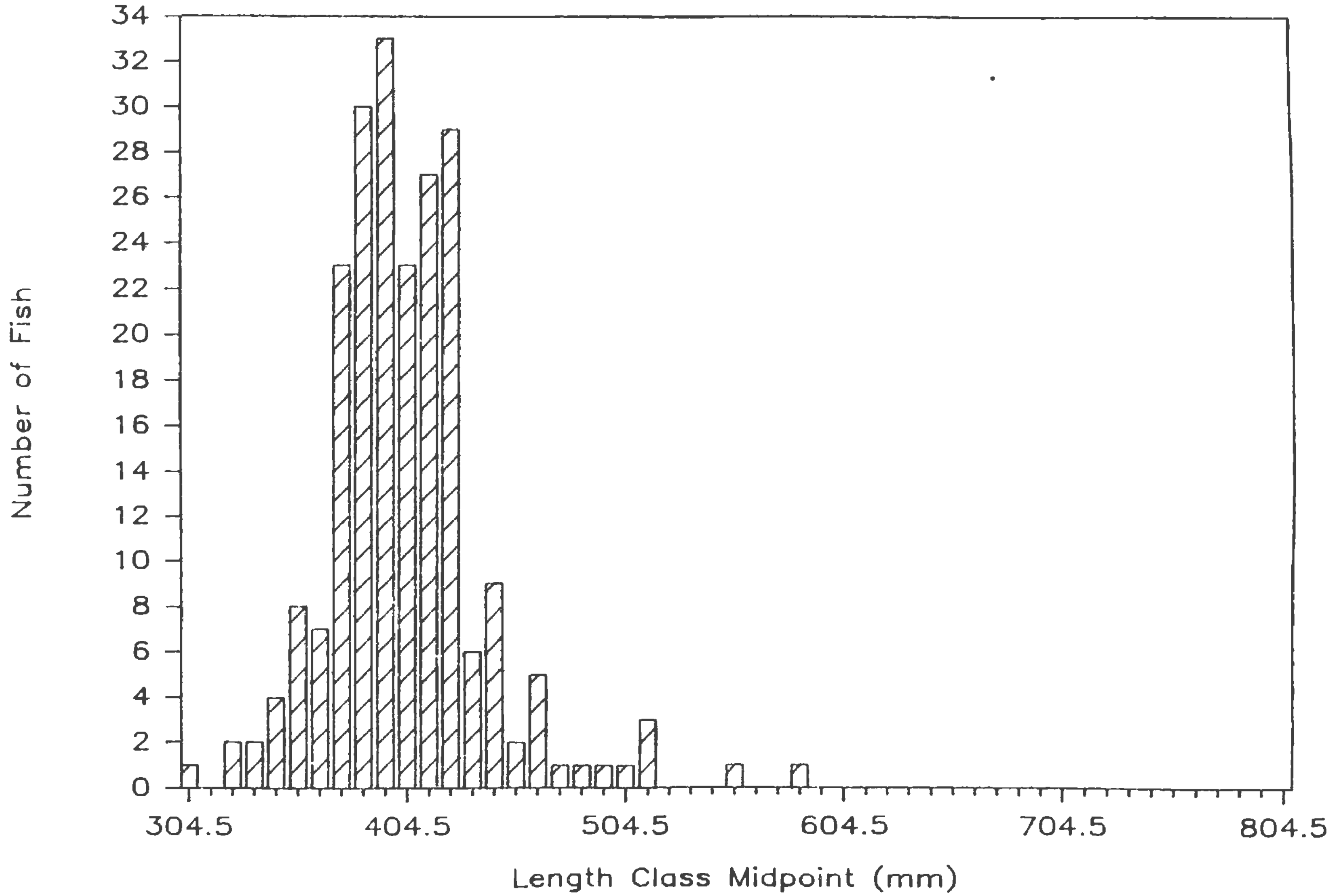
Length frequency histogram for artic char captured in 149-mm mesh monofilament gill nets, Noatak River, 1984.



Length frequency histogram for artic char captured in 102-mm mesh monofilament gill nets, Noatak River, 1984.



Length frequency histogram for pink salmon captured in 102-mm mesh monofilament gill nets, Noatak River, 1984.



Length frequency histogram for whitefish captured in 102-mm mesh monofilament gill nets, Noatak River, 1984.