FRI-UW-8005
March 1980

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and Robert L. Burgner

Annual Report

For the period July 1, 1978-June 30, 1979

Anadromous Fish Project

Project No. AFC-57
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Seattle, Washington 98195

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Approved:

Submitted March 28, 1980

Robert L. Burgner
Director

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## INTRODUCTION

The Chignik lakes watershed is located about 400 km southwest of King Salmon and supports the largest run (10-year average return is 1.9 million) of sockeye salmon (Oncorhynchus nerka) on the south side of the Alaska Peninsula (Fig. 1). The Fisheries Research Institute (FRI) has, for a number of years, conducted a research program in cooperation with the Alaska Department of Fish and Game (ADF&G) aimed at understanding factors limiting production from the system and at developing sound data bases from which management strategies can be developed.

The primary objectives of this report are to outline the various methods which have been used to compile the annual run statistics (number of fish by age class and stock), to illustrate the magnitude of the differences which arise in the statistics when the various methods are used, and to recommend procedures for use in the future. We also discuss the impact of the current management practices on the various stocks of Chignik sockeye. Specific objectives are to:

1) Calculate the catch, escapement, and total return by run (early vs. late) and by principal stock (Black Lake, Black River-early, and Chignik Lake) using the average time-of-entry curve of Dahlberg (1968), the shifted average time-of-entry curve of Shaul (1978), and a year-specific time-of-entry curve derived by scale pattern recognition techniques. We also report on efforts to estimate the run to Black Lake with sonar equipment.

2) Estimate the age composition in numbers of fish by run, stock, and nursery lake using the methods of Dahlberg (1968), Marshall and Burgner (1977), and by a modification of the method of Marshall and Burgner (1977). In each case the numbers of fish by run, stock, or nursery lake are estimated by the current year's time-of-entry curve. From this excercise we illustrate how violations in the assumptions underlying each method affect the results.

3) Make specific recommendations on techniques for future use and provide a set of what we consider to be the best estimates of the number of fish by age class and stock which returned in 1978.

4) Explore the pattern of exploitation and make recommendations for future management strategies.

Prior to outlining these methods, we briefly review the stocks of sockeye within the Chignik lakes and some basic management concepts. For additional information on these topics the reader is referred to the papers cited in each section.

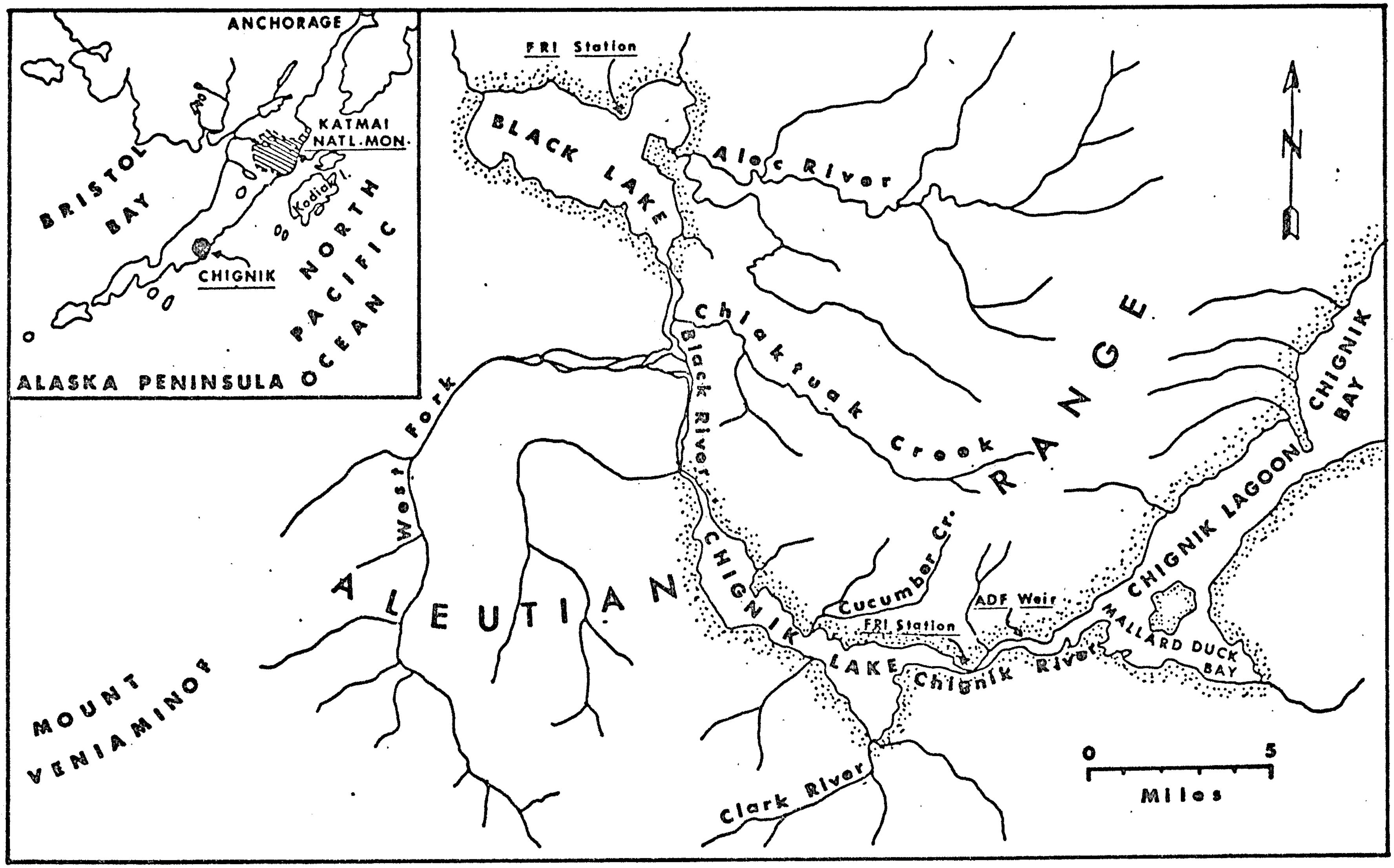


Fig. 1. Map of the Chignik River watershed with inset of western Alaska.

## Stocks of Sockeye Within the Chignik Lakes

The identification of spawning groups of sockeye salmon within the Chignik lakes were reported by Narver (1963). Five major and three minor groups were described based upon lacustrine scale pattern and age, time of entry of returning adults, and time and location of spawning. These groups and their characters are summarized in Table 1.

Returning sockeye bound for the tributaries of Black Lake or the upstream reaches of Chiaktuak, West Fork, and Bearskin Creeks (tributaries of Black River) enter the system from early June through early July. Sockeye bound for tributaries and beaches of Chignik Lake and the lower reaches of Black River tributaries enter the system from late June through September. Tagging studies by Narver (1963, 1966), Dahlberg (1968), Parr and Pedersen (1969), and others have shown that separation of these two conglomerate stocks can be made based solely on time of entry, but that considerable yearly variation is apparent. These two conglomerate stocks are termed the early run and the late run.

## Management Concepts

Studies by Narver (1966), Dahlberg (1968), Parr (1972), and Marshall and Burgner (1977), have indicated that production of sockeye in this system is probably not related to the availability of spawning area. Rather, they all point to the carrying capacity of the nursery lakes as the primary limiting factor. Optimization of the nursery capabilities of the lakes is approached by regulating the size of the spawning populations of each run. This approach is aimed at preventing excessive density-dependent interactions resulting in reduced growth and survival of juvenile sockeye while rearing in the nursery lakes.

Optimum escapements are sought by regulating the harvest. Decisions to open or close the fishery are based on historic entry patterns of the early and late runs, escapement goals and escapement to date during the season. A primary feature in this system is the logistic time-of-entry curve (Dahlberg 1968) which is used to estimate the proportion of each run present in the fishery on a daily basis.

Table 1. Characteristics of the spawning groups of Chignik sockeye salmon (adapted from Narver 1963a).

| Group | Lacustrine age | Time of entry | Spawning characteristics | | Rearing area | Lacustrine scale | Importance |
|---|---|---|---|---|---|---|---|
| | | | Time | Location | | | |
| Black Lake (early) | I | 6/10-7/6 | 7/25-8/20 | Alec River system, Fan Creek | Black Lake | $F_1$ radius large | Major |
| Black River (early) | I | 6/10-7/6 | 7/25-8/20 | Upstream areas of West Fork, Chiaktuak, Bearskin Creek | Chignik Lake | $F_1$ radius small | Major |
| Black River (late) | I | 6/20-8/10 | 8/20-9/20 | Lower areas of Chiaktuak, Bearskin Creek | Chignik Lake | $F_1$ radius small | Minor |
| Black Lake (early) | II | 6/10-7/6 | 7/25-8/20 | Alec River system, Fan Creek | Black Lake and Chignik Lake | $F_1 + F_2$ count large | Major |
| Black River (early) | II | 6/10-7/6 | 7/25-8/20 | Upstream areas of West Fork, Chiaktuak, Bearskin Creek | Chignik Lake | $F_1 + F_2$ count small | Minor |
| Black River (late) | II | 6/20-8/10 | 8/20-9/20 | Lower areas of Chiaktuak and Bearskin Creek | Chignik Lake | $F_1 + F_2$ count small | Minor |
| Chignik Lake | I | 6/20-9/20 | 8/20-11/15 | Cucumber, Home, Clark Hatchery Beach | Chignik Lake | $F_1$ radius small | Major |
| Chignik Lake | II | 6/20-9/20 | 8/20-11/15 | Cucumber, Home, Clark Hatchery Beach | Chignik Lake | $F_1 + F_2$ count small | Major |

## METHODS AND MATERIALS

### Estimation of Run Magnitude

Estimation of run magnitude on a daily basis requires that catchs in different areas be combined with escapement estimates. This is accomplished by adjusting the dates of catches and escapements to account for migration time. Numbers of fish in the catch and escapement are those of Shaul (1978) (Appendix Table 1). We adjusted all catches and escapements to coincide with catches made in Chignik Lagoon on day i. A 2-day lag between the Lagoon and weir was used (Dahlberg 1968). For the distant fisheries we used a migration rate of approximately 20 miles per day (Dahlberg 1968; French et al. 1976; Phillip Mundy, personal communication). The estimated number of days between the Lagoon and the distant fisheries is: Beaver-Balboa, 7 days; Stepovak, 6 days; Puale, 8 days; Cape Igvak, 6 days; Imuya, 6 days; Aniakchak, 3 days; Hook Bay-Kujulik, 2 days.

### Estimation of the Number of Early versus Late Run Fish

#### Average Time-of-Entry Curve Method

During the years 1961-1969, fish were tagged at Chignik weir with color-coded Petersen disks and later recovered on the spawning grounds (Dahlberg 1968; Parr and Pedersen, 1969). From observations of the percent of tags observed on early- vs. late-run fish which were tagged on a given day, the data were fitted to the linearized form of the model.

$$p = \frac{1}{1 + e^{-(a+bt)}} \qquad (1)$$

where:

- p = proportions of late run fish
- e = base of the Naperian system of logarithms
- t = time in days (we used Julian dates)
- a = intercept in the linearized form
- b = slope in the linearized form.

The linearized form of equation (1) is

$$-\text{Ln}\ [\frac{1-p}{p}] = a+bt \qquad (2)$$

#### Shifted Average Time-of-Entry Curve Method

In this method, the average time-of-entry curve is shifted over the time domain to account for perceived earliness or lateness of the run in a given year. The method has been used extensively since discontinuation of tagging in 1969. In 1978, the curve was shifted earlier so that the 50% point fell on June 29 as opposed to approximately July 7 for the 1961-1969 combined curve.

## Time-of-Entry Curve Based on Scale Pattern Recognition

Narver (1963) and Marshall and Burgner (1975) reported statistically significant differences in the scale patterns of stocks of Chignik sockeye. Based on these preliminary findings, we sought to develop a method for estimating the time-of-entry curve using features measured from scales as variables in a linear discriminant function analysis (Fisher 1936; Lachenbruch 1975).

In the analysis age 2.3 fish were used exclusively because insufficient numbers of samples were available from fish of other ages. A standard for the Black Lake stock was formed from samples collected at the outlet of Black Lake and from samples collected in the fishery prior to June 17. A standard for the Chignik Lake stock was formed from samples collected in the fishery after July 12.

Nine variables were measured (counted) from each scale (Table 2). We then used a stepwise procedure (Nie et al. 1975) to rank variables based upon maximizing the distance between group centroids. After ranking variables, we estimated classfication accuracy (percent of samples correctly classified) at each step.

We then selected a subset of these variables to measure on scales from fish of unknown origin which were sampled in the fishery between June 17 and July 12. Estimates of the proportion of early- and late-run fish in the sample were then made for each day on which sampling was conducted. The proportional estimates were corrected for misclassification error rates using the procedure of Cook and Lord (1978).

Estimates of a and b in equation (1) were made by fitting the data to the linearized form of the time-of-entry curve (equation 2).

## Sonar Enumeration of Early Run

Daily enumeration of the early run as it passed up Black River coupled with daily weir counts and migration times between sites would allow for estimation of a time-of-entry curve. To obtain estimates of the early run escapement (less fish bound for West Fork and Bearskin Creek) we deployed two Bendix multiple-transducer adult salmon counters in Black River (one on the north and one on the south bank) approximately 0.5 miles downstream from the mouth of Chiaktuak

Table 2. Scale characters evaluated for discriminating power of early- vs. late-run age 2.3 sockeye in 1978.

A. First freshwater zone

1. Number of circuli
2. Measured width

B. Second freshwater zone

1. Number of circuli
2. Measured width

C. Freshwater zones breakdown

1. Distance from scale focus to 3rd circulus
2. Distance from scale focus to 6th circulus
3. Distance from scale focus to 9th circulus
4. Distance from scale focus to 12th circulus
5. Distance from scale focus to 15th circulus

Creek. Standard methods[1] were used to install and operate the arrays, except that because of overlap of the arrays in mid-channel only 20 transducers were deployed from the south bank and the counts from only 17 of 30 transducers were included in the analysis from the array deployed from the north bank. Enumeration was conducted from June 6 to July 12, 1978.

## Estimation of the Numbers of Black Lakes versus Black River Tributary Fish in the Early Run

### Aerial Spawning Survey Method

Aerial counts of the number of sockeye in each spawning area, Black Lake vs. Black River tributaries, allow one to estimate the proportion of each in the early run escapement (Dahlberg 1968). In this report we use the estimates of 6.3% for Black River tributaries and 93.7% for Black Lake made by Shaul (1978). The reader is referred to his report for details of times of surveys and numbers of fish counted. It should be pointed out that this method assumes equal exploitation rates for the two stocks because the estimates of proportions in the early run are based on escapement data only.

### Age Composition Method

The Black River tributary and Black Lake stocks have significant differences in age composition (Tables 8b and 8c) and this allowed us to estimate the proportion of each stock present in the fishery by day, using the method of Fredin and Worlund (1974). We used a 2-class version of the model (age 1.3 vs. 2.3 plus other) because age 1.3 and 2.3 account for the majority of fish sampled and use of a third, "other" category would not substantially improve the results.

Estimates of the proportion of each stock present in the early run were made using spawning ground otolith samples as age composition standards for the Black River segment and scale samples collected from fish beach seined at the outlet of Black Lake as standards for the Black Lake stock. Because estimates were to be made based on the age composition of samples collected in the fishery, it was necessary to remove the influence of late run Chignik Lake fish from the samples. We estimated the number of early run fish by age class per day by subtracting the number of late fish by age class by

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[1] Methods used are those developed by the ADF&G and Bendix Corp. as summarized in "Assembly Procedure: Salmon Counter," an unpublished manuscript available from ADF&G, Division of Commercial Fisheries, Soldotna, AK. 99669.

day from the total number of fish by age class on that day. The method for estimating the number of fish by age class in the total return on a day is detailed in the following section. Estimates of the number of early- vs. late-run fish are those of the scale pattern time-of-entry curve. The age composition of the late run was estimated from otolith samples collected on the Chignik Lake and Black River tributary spawning grounds. We used these data instead of estimates obtained by the subtraction method of Marshall and Burgner (1977) in order to achieve independence in the data set.

## Estimation of Age Composition

### Available Data Sets

Scales and otoliths were collected from fishery catch samples by ADF&G. Scales were collected from adults which had been beach seined by FRI at the outlet of Black Lake. Otoliths were collected from spent fish on the various spawning grounds by ADF&G. Mr. Arnold Shaul (ADF&G) read all the scales and otoliths.

### Age Composition of Adjusted Daily Run

We calculated an age composition for the adjusted daily run using the periodic fishery samples. We smoothed the percent by age class data by a moving average of three sampling dates and used linear interpolation for missing data. Summarizing the number of fish by age class across all dates provides an estimate of the total return by age class.

### Age Composition by Stock

Fishery-Scale Method. This method of Dahlberg (1968) uses the age composition of the adjusted daily run (see previous section) and the time-of-entry curve to estimate age composition by stock. First, the number of fish by age class by day is estimated, then those numbers by age class are allocated to the early and late run based on proportional estimates from the time-of-entry curve. Summation across days by stock and age class provide estimates for each of the runs. The major shortcoming of this method is that it does not account for differences in age composition between stocks during the period of overlap in time of entry.

Subtraction Method. This method of Marshall and Burgner (1977) uses the age composition (numbers by age class) of the total run as determined from fishery samples and subtracts the numbers by age class in the early run to estimate the numbers by age class in the late run. An estimate of the number of early-run fish was made from the scale pattern time-of-entry curve. The proportion of Black Lake vs. Black River fish was made using the aerial spawning survey method. Black Lake age composition was estimated from scale samples collected from adults captured by beach seining at the outlet of Black Lake. The age composition of the Black River tributary stocks was estimated from otoliths collected on the spawning grounds.

Modified Subtraction Method. This method is identical to the subtraction method except that the number of Black Lake vs. Black River tributary fish in the early run is estimated from the age composition method of Fredin and Worlund (1974). The primary advantage of the technique is that it does not assume equal exploitation rates for the two stocks.

# RESULTS AND DISCUSSION

## Number of Fish

### Total Catch and Escapement in 1978

Catch by area and escapement for 1978 are summarized in Appendix Table 1. The total run strength by adjusted (Lagoon) date is shown in Fig. 2. The run was clearly composed of at least two principal segments in 1978, one prior to July 4 (Julian day 185) and one after this date. The total return was estimated at 2,498,428 sockeye of which 682,547 escaped to spawn. The catch was 1,815,881.

### Sonar Enumeration of Early Run

The daily and cumulative counts recorded at the sonar enumeration site on Black River are summarized in Table 3. A total of 636,643 counts was recorded during the period June 6 through July 12, inclusively. This count includes fish bound for Chiaktuak Creek exiting the river below Black Lake as well. The total early-run escapement to Black Lake and Chiaktuak Creek was also estimated by contructing a time-of-entry curve using scale pattern recognition, and peak aerial spawning surveys. The latter technique provided an estimate of 418,456 fish. The sonar count was 218,187 greater than the current time-of-entry curve estimate.

The daily sonar count and weir count time-of-entry curve data are shown in Fig. 3. Reasonably good correlation in the trends of the two sets of data are apparent after June 13 with about a one day lag between Chignik River weir counts and Black River sonar counts. The sonar apparatus appears to have fairly consistently over-estimated the escapement to Black Lake.

We believe that the lack of precision obtained with the multiple transducer sonar system precludes its usefulness.

### Time-of-Entry Curves

In Fig. 4 we show three time-of-entry curves, the average curve for the years 1961-1969, the shifted average curve of Shaul (1978) and our year-specific curve based on scale pattern recognition of age 2.3 fish. Prior to comparing these curves we will present some supporting data for our scale pattern curve.

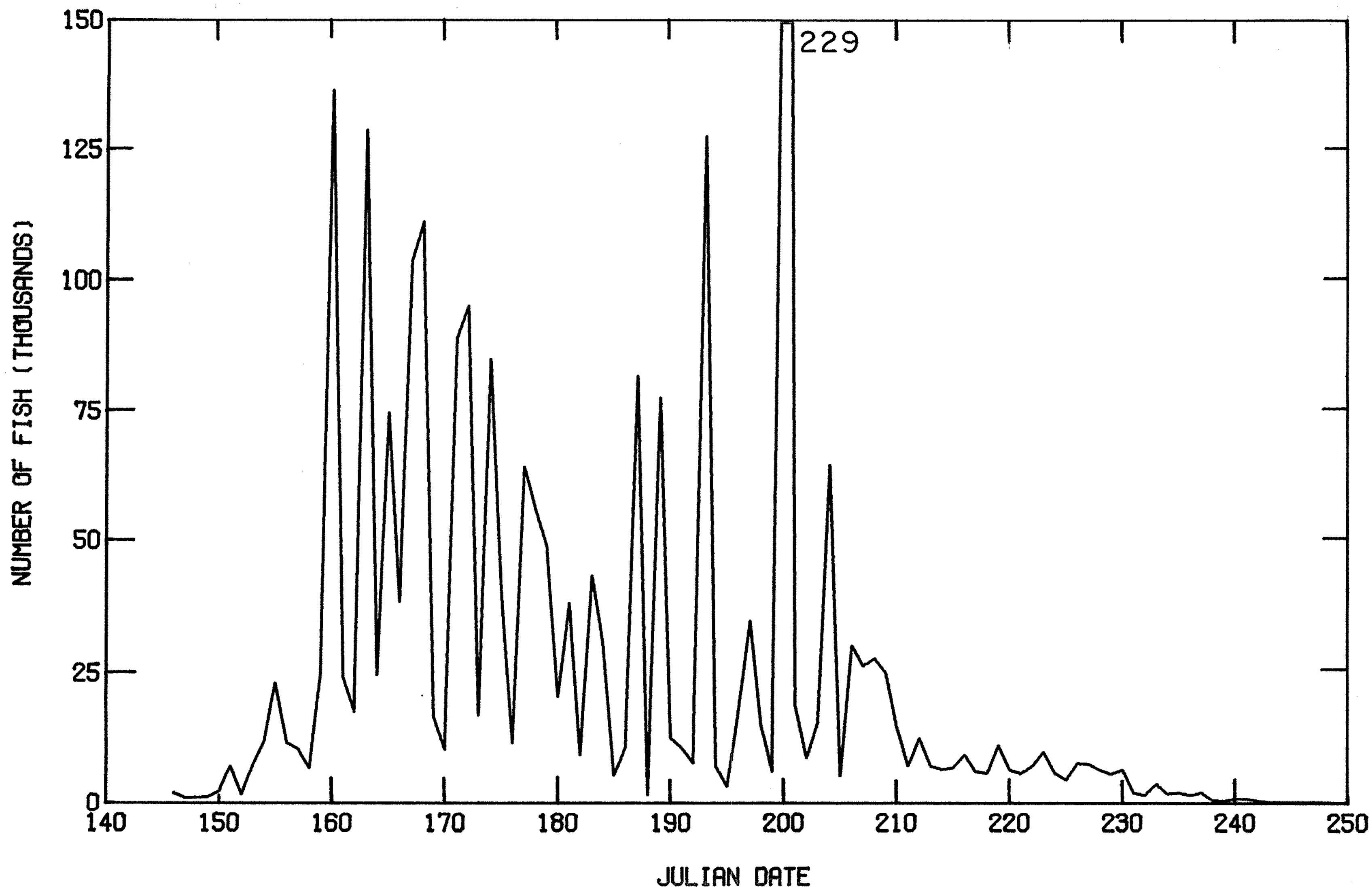


Fig. 2. Run strength by adjusted (Lagoon) date, 1978.

Table 3. Daily and cumulative sonar counts from the Black River site.

| Date | North | South | Total | Cum. | % Total |
|---|---|---|---|---|---|
| June 6 | 2733 | | 2733 | | 0.4 |
| 7 | 2323 | 12903 | 15226 | 17959 | 2.4 |
| 8 | 995 | 18900 | 19895 | 37854 | 3.1 |
| 9 | 1603 | 15935 | 17538 | 55392 | 2.8 |
| 10 | 3624 | 23607 | 27231 | 82623 | 4.3 |
| 11 | 4739 | 28908 | 33647 | 116270 | 5.3 |
| 12 | 3495 | 30432 | 33927 | 150197 | 5.3 |
| 13 | 3220 | 31594 | 34814 | 185011 | 5.5 |
| 14 | 2269 | 22192 | 24461 | 209472 | 3.8 |
| 15 | 1787 | 28378 | 30165 | 239637 | 4.7 |
| 16 | 5432 | 48011 | 53443 | 293080 | 8.4 |
| 17 | 4461 | 16079 | 20540 | 313620 | 3.2 |
| 18 | 4199 | 16601 | 20800 | 334420 | 3.3 |
| 19 | 4992 | 39969 | 44961 | 379381 | 7.1 |
| 20 | 6328 | 53380 | 59708 | 439089 | 9.4 |
| 21 | 8712 | 33097 | 41809 | 480898 | 6.6 |
| 22 | 4104 | 16837 | 20941 | 501839 | 3.3 |
| 23 | 3496 | 5521 | 9017 | 510856 | 1.4 |
| 24 | 6491 | 14482 | 20973 | 531829 | 3.3 |
| 25 | 2796 | 7967 | 10763 | 542592 | 1.7 |
| 26 | 4663 | 5551 | 10214 | 552806 | 1.6 |
| 27 | 4083 | 5471 | 9554 | 562360 | 1.5 |
| 28 | 4973 | 2433 | 7406 | 569766 | 1.2 |
| 29 | 2979 | 8543 | 11522 | 581288 | 1.8 |
| 30 | 1605 | 4451 | 6056 | 587344 | 1.0 |
| July 1 | 1039 | 6758 | 7797 | 595141 | 1.2 |
| 2 | 1640 | 4686 | 6326 | 601467 | 1.0 |
| 3 | 1256 | 2738 | 3994 | 605461 | 0.6 |
| 4 | 811 | 1987 | 2798 | 608259 | 0.4 |
| 5 | 889 | 1498 | 2387 | 610646 | 0.4 |
| 6 | 1107 | 1482 | 2589 | 613235 | 0.4 |
| 7 | 1334 | 1603 | 2937 | 616172 | 0.5 |
| 8 | 3653 | 3212 | 6865 | 623037 | 1.1 |
| 9 | 2908 | 2084 | 4992 | 628029 | 0.8 |
| 10 | 1921 | 2524 | 4475 | 632504 | 0.7 |
| 11 | 2291 | 1281 | 3572 | 636076 | 0.6 |
| 12 | | 567 | 567 | 636643 | <0.1 |
| Total | 14951 | 521692 | 636643 | | |

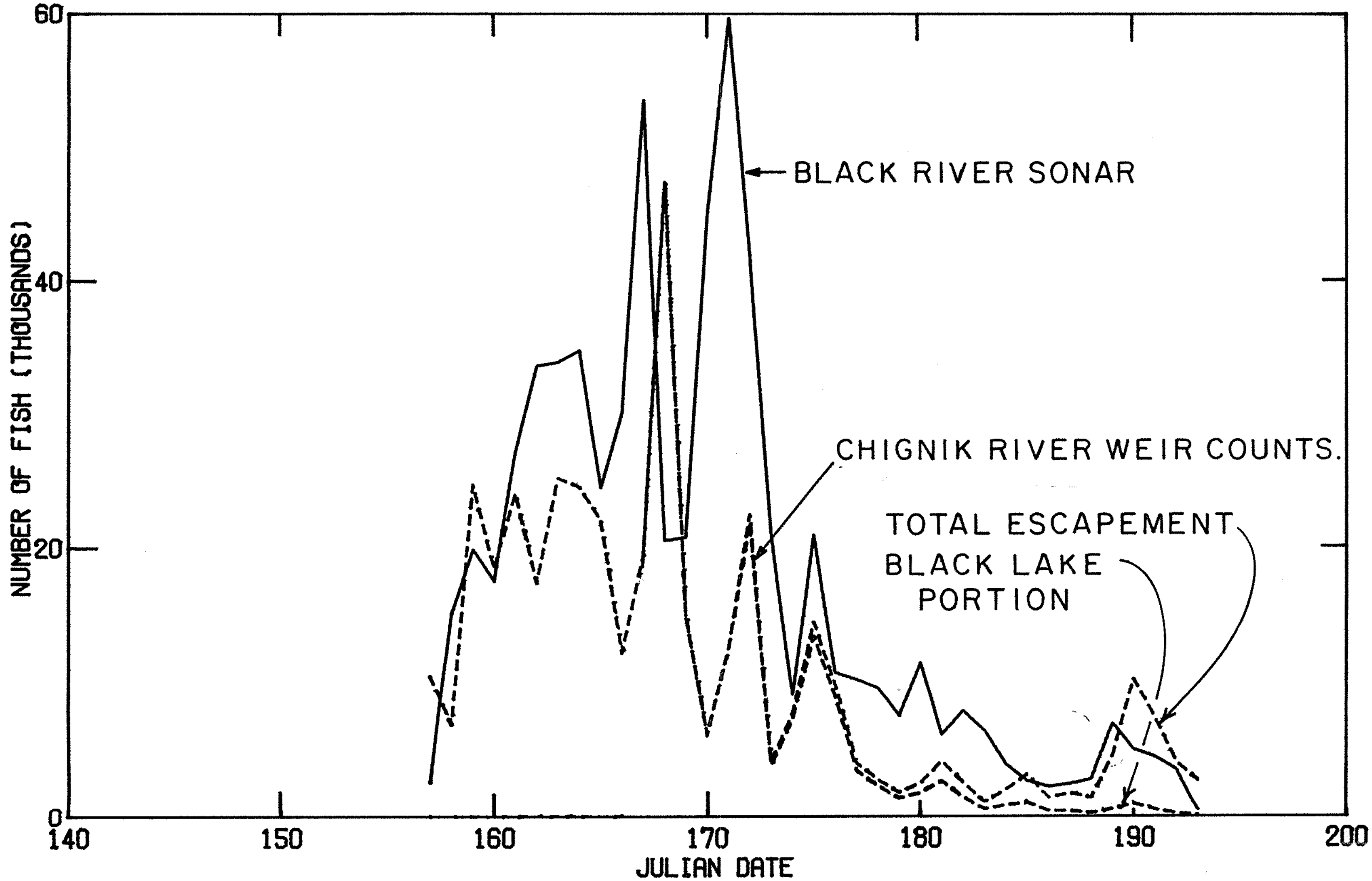


Fig. 3. Daily early run escapement as estimated by weir counts and scale pattern time-of-entry curve and by sonar enumerature. Sonar estimates do not include fish bound for West Fork.

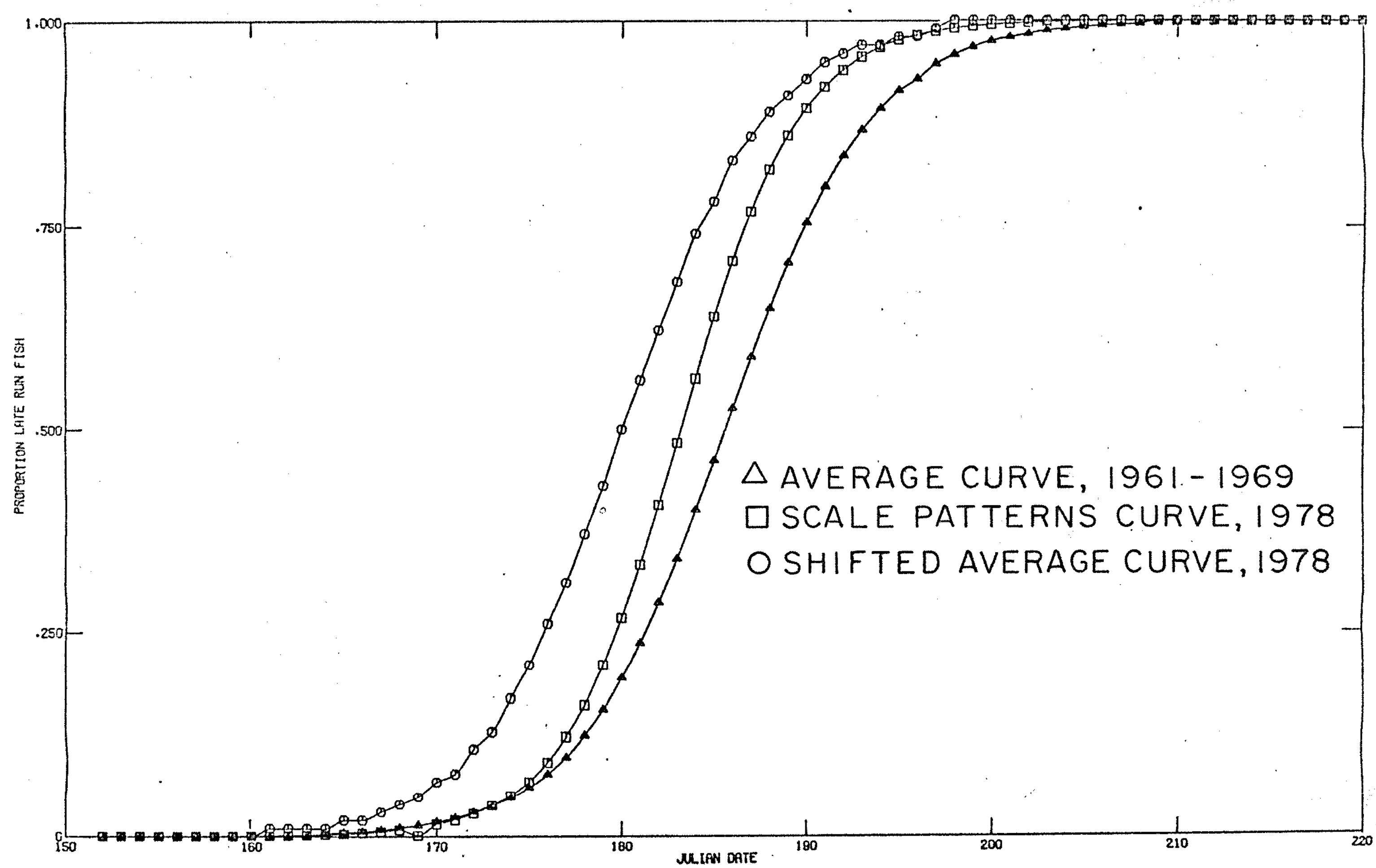


Fig. 4. Time-of-entry curves for the 1978 sockeye salmon run in relation to the average (1961-1969) time-of-entry curve.

Selection of variables to be used in this separation was accomplished using a stepwise procedure. The results of ranking variables and sequentially entering them into the discriminant function are presented in Table 4. These data show that increasing the number of variables above three was not warranted. We therefore used three variables (size of the first freshwater zone, size of the second freshwater zone, and the distance from the focus to the sixth circulus) to classify fish of unknown origin sampled in the fishery during the period of overlap in time-of-entry according to lake of origin.

The classification matrix was calculated using a second group of fish of known origin (Table 5). Classification accuracy was estimated at 82% using this set of data. The results of classifying unknown samples and the proportions of each stock present by date are summarized in Table 6.

In Fig. 5 we show a plot of the transformed data and the least squares regression line which was fitted to the data. The estimate for the slope (b) is 0.32 and for the intercept (a) it is -57.75. These values were substituted back into equation (1) and the equation was solved for the percent late run fish by date. The resulting curve is shown in Fig. 4.

Comparison of the curves in Fig. 4 shows that the transition between early- and late-run fish occurred earlier than average. The data of Shaul (1978) show that this earliness was perceived; however it was overcompensated. Furthermore, the average and shifted average curves have a slope of 0.25 in the linear form whereas the scale patterns curve in 1978 has a slope of 0.32. This means there was a more rapid transition from early- to late-run fish in 1978 than average.

Each of these curves was used to estimate the catch and escapement for the early run (Black Lake and Black River tributaries) and late run (Chignik Lake), Table 7a. Differences in allocation exist primarily in catch because the current harvest strategy stresses harvest during the period of overlap in time of entry.

Dahlberg (1968) believed that the Black River segment of the early run should be included with the late run for the purposes of evaluating spawner/recruit relationships and setting optimum escapements because these fry rear in Chignik Lake (Narver 1963, 1966). Annual run statistics for recent years (Shaul 1978) do not take this into account. We used an estimate of 6.3% (Shaul 1978) for the contribution of the Black River stock to the early run. This estimate assumes an equal exploitation rate for the Black River tributary and Black Lake stocks which is not valid. This is discussed in more detail later. This problem notwithstanding, we calculated catch and

Table 4. Classification accuracy as a function of variables used, age 2.3 sockeye salmon, 1978.

| Number of variables | Variable Code Number[1/] | Percent correctly classified[2/] |
|---|---|---|
| 2 | 2, 4 | 81.7 |
| 3 | 2, 4, 6 | 83.0 |
| 4 | 2, 4, 6, 3 | 81.7 |
| 5 | 2, 4, 6, 3, 5 | 80.4 |
| 6 | 2, 4, 6, 3, 5, 7 | 81.7 |
| 7 | 2, 4, 6, 3, 5, 7, 1 | 80.9 |

[1/] Variable codes:
1 = Number of circuli in first freshwater zone.
2 = Size of first freshwater zone.
3 = Number of circuli in second freshwater zone.
4 = Size of second freshwater zone.
5 = Distance from focus to third circulus.
6 = Distance from focus to sixth circulus.
7 = Distance from focus to ninth circulus.

[2/] Based on learning samples.

Table 5. Classification array for age 2.3 sockeye salmon in 1978.

| | Correct decision | |
|---|---|---|
| Calculated decision | Black Lake | Chignik Lake |
| Black Lake | 84(.84) | 16(.16) |
| Chignik Lake | 20(.20) | 80(.80) |

Table 6. Results of classifying unknown age 2.3 sockeye salmon sampled in the fishery by date.

| Calendar Date | Julian Date | Number by stock | | Uncorrected proportion by stock | | Corrected proportion by stock | |
|---|---|---|---|---|---|---|---|
| | | Black | Chignik | Black | Chignik | Black | Chignik |
| June 17 | 168 | 30 | 12 | .7143 | .2857 | .8640 | .1360 |
| June 20 | 171 | 36 | 9 | .8000 | .2000 | 1.000 | 0.0 |
| June 23 | 174 | 33 | 12 | .7333 | .2667 | .8942 | .1058 |
| June 27 | 178 | 44 | 24 | .6471 | .3529 | .7573 | .2427 |
| June 30 | 181 | 22 | 32 | .4074 | .5926 | .3769 | .6231 |
| July 3 | 184 | 20 | 39 | .3390 | .6610 | .2683 | .7317 |
| July 6 | 187 | 35 | 68 | .3398 | .6602 | .2696 | .7304 |
| July 8 | 189 | 21 | 74 | .2211 | .7789 | .0812 | .9188 |
| July 12 | 193 | 27 | 79 | .2547 | .7453 | .1345 | .8655 |

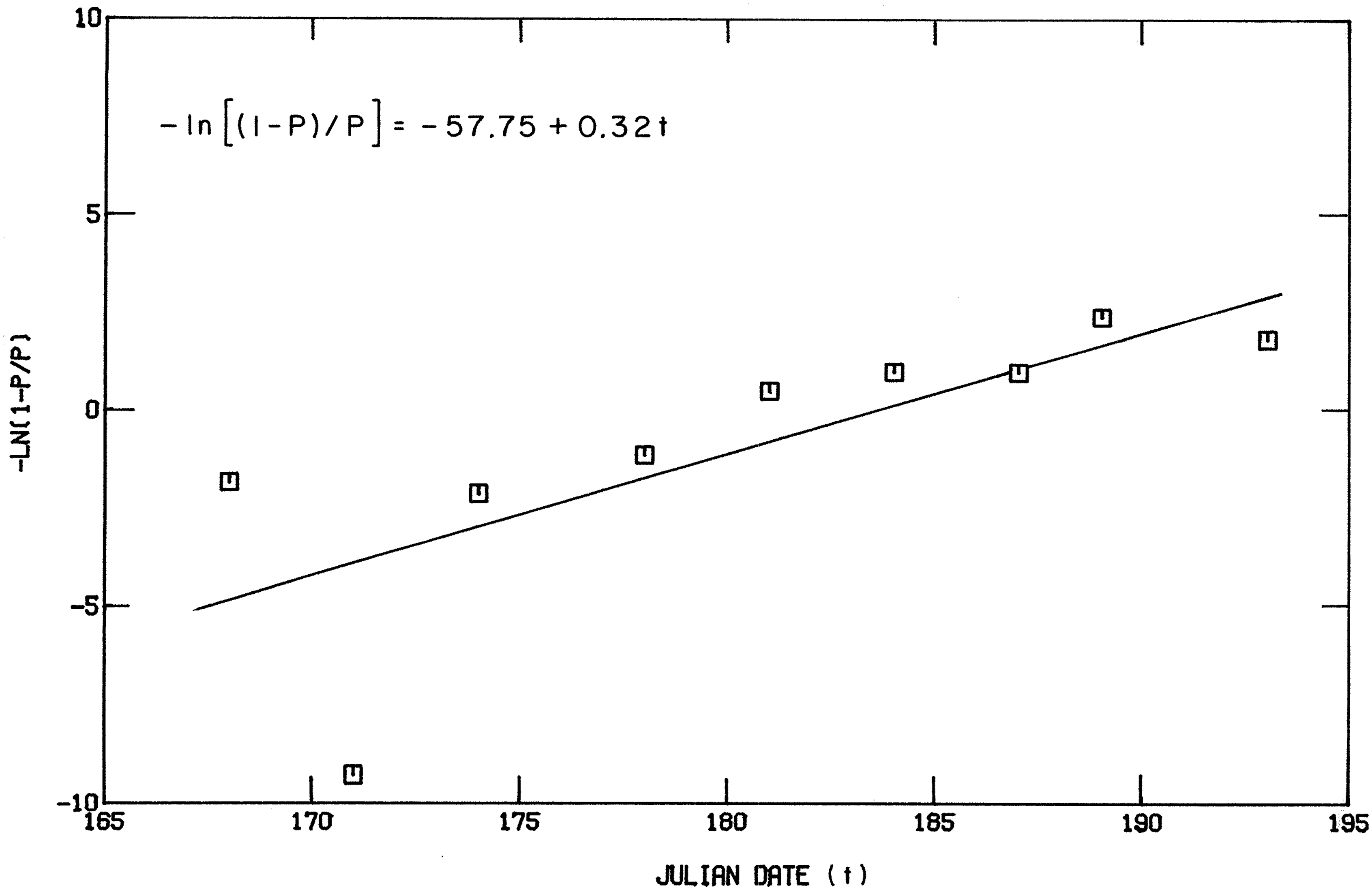


Fig. 5. Regression of $-LN[\frac{1-P}{P}]$ on Julian date used to estimate a and b in the scale patterns time-of-entry curve.

Table 7a. Catch, escapement and total return by run and combined runs as determined by different time-of-entry curves.

| Method | EARLY RUN[1/] [3/] | | | LATE RUN | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Catch | Escapement | Total | Catch | Escapement | Total | Catch | Escapement | Total |
| Average T-O-E curve | 1,023,361 | 444,183 | 1,467,544 | 792,520 | 238,364 | 1,030,884 | 1,815,881 | 682,547 | 2,498,428 |
| Shifted T-O-E curve | 851,154 | 414,640 | 1,265,79 | 964,727 | 267,907 | 1,232,634 | 1,815,881 | 682,547 | 2,498,428 |
| Scale patterns T-O-E curve | 956,845 | 433,184 | 1,390,029 | 859,036 | 249,363 | 1,108,399 | 1,815,881 | 682,547 | 2,498,428 |

.ncludes Black River

Table 7b. Catch, escapement, and total return by nursery lake and for both lakes combined as determined by different time-of-entry curves.

| Method | BLACK LAKE | | | CHIGNIK LAKE[2/] [3/] | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Catch | Escapement | Total | Catch | Escapement | Total | Catch | Escapement | Total |
| Average T-O-E curve | 958,889 | 416,199 | 1,375,088 | 856,992 | 266,348 | 1,123,340 | 1,815,881 | 682,545 | 2,498,428 |
| Shifted T-O-E curve | 797,531 | 388,518 | 1,186,049 | 1,018,350 | 294,029 | 1,312,379 | 1,815,881 | 682,547 | 2,498,428 |
| Scale patterns T-O-E curve | 896,564 | 405,894 | 1,302,458 | 919,317 | 276,653 | 1,195,970 | 1,815,881 | 682,547 | 2,498,428 |

[2/]Includes Black River

[3/]Black River contribution is 6.3% of total early run. Exploitation rates of Black River and Black Lake stocks are assumed to be equal.

escapements by nursery lake and these are shown in Table 7b. The same trends are present in Table 7a as in Table 7b.

In summary, the scale pattern time-of-entry curve estimated significantly more early-run fish than the shifted time-of-entry curve and significantly fewer early-run fish than the average time-of-entry curve. For the late run the opposite occurred. These same trends were apparent when data were adjusted to account for nursery lake of fry. It should be noted however, that the attempt to compensate for the perceived earliness of the run actually resulted in a greater error (though in a different direction) than would have resulted from using just the average curve. For the early run the difference in number of fish between the scale pattern time-of-entry curve estimate and the shifted average time-of-entry curve estimate is -124,236 or -8.92%. The difference in number of fish between the scale pattern time-of-entry curve estimate and the average time-of-entry curve estimate for the early run is 77,515 or 5.61%.

## Age Composition

Age composition information for 1978 is summarized in Tables 8a-8d by location and date of sampling. These data are reproduced from Shaul (1978).

### Total Return

The age composition of the total return by date is expressed as percentages and shown in Fig. 6. Age 1.3 fish predominated early in the run. However, this age class exhibits a steady decrease in relative abundance from the beginning of sampling on day 158 (June 7) to day 189 (July 8). After day 189, age 1.3 fish composed 5% or less of the run. Age 2.3 fish composed 30 to 35% of the run through day 168 (June 17) then began to increase in relative abundance to a peak representation of about 80% from day 189 (July 8) through day 197 (July 16). The decreasing abundance of this group from day 197 (July 16) through day 209 (July 28) and its subsequent increase and leveling off throughout the remainder of the season is directly related to the increase and subsequent decrease in the representation of age 2.2 and 3.2 fish. The percent of age 2.2 fish showed two modes, one on about day 178 (June 27) and one on day 209 (July 28). Age 3.2 fish first appeared late in June, with peak representation in samples on day 206 (July 25).

### Age Composition by Run and Stock

In Table 9, we present the results of allocating the total return using the method of Dahlberg (1968). Burgner and Marshall

Table 8a. Age composition from samples collected in the fishery, by date, 1978.

| Date | Age Class 1.1 | 2.1 | 1.2 | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | 1.4 | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/7 Number | | | | | | 78 | 30 | | | | 108 |
| Percent | | | | | | 72.5 | 27.5 | | | | |
| 6/9 | | | 1 | 5 | | 111 | 82 | | | 3 | 202 |
| | | | 0.5 | 2.4 | | 55.0 | 40.6 | | | 1.5 | |
| 6/12 | | | | 10 | | 88 | 30 | | | 1 | 129 |
| | | | | 7.7 | | 68.2 | 23.3 | | | 0.8 | |
| 6/17 | | | 1 | 10 | | 65 | 45 | | | | 121 |
| | | | 0.8 | 8.3 | | 53.7 | 37.2 | | | | |
| 6/20 | | | 2 | 8 | | 68 | 51 | | | | 129 |
| | | | 1.6 | 6.2 | | 52.7 | 39.5 | | | | |
| 6/23 | | | 3 | 30 | | 47 | 47 | | | | 127 |
| | | | 2.4 | 23.6 | | 37.0 | 37.0 | | | | |
| 6/27 | | | 1 | 17 | 2 | 27 | 71 | 2 | | | 120 |
| | | | 0.8 | 14.2 | 1.7 | 22.5 | 59.1 | 1.7 | | | |
| 6/30 | | | | 8 | | 20 | 57 | 1 | | | 86 |
| | | | | 9.3 | | 23.3 | 66.3 | 1.1 | | | |
| 7/3 | 1 | 1 | 4 | 12 | 1 | 14 | 72 | 3 | | | 108 |
| | 0.9 | 0.9 | 3.7 | 11.1 | 0.9 | 13.0 | 66.7 | 2.8 | | | |
| 7/6 | | | 1 | 14 | 3 | 4 | 106 | 3 | | | 131 |
| | | | 0.8 | 10.7 | 2.3 | 3.0 | 80.9 | 2.3 | | | |
| 7/8 | | | | 5 | | 8 | 94 | 7 | | | 114 |
| | | | | 44 | | 7.0 | 82.5 | 6.1 | | | |
| 7/12 | | | | 9 | 6 | 2 | 107 | 4 | | | 128 |
| | | | | 7.0 | 4.7 | 1.6 | 83.6 | 3.1 | | | |
| 7/16 | | | 2 | 4 | 3 | 3 | 74 | 6 | 1 | | 93 |
| | | | 2.1 | 4.3 | 3.2 | 3.2 | 79.6 | 6.5 | 1.1 | | |
| 7/19 | | | | 14 | 7 | | 104 | 3 | | | 128 |
| | | | | 10.9 | 5.5 | | 81.3 | 2.3 | | | |
| 7/23 | | | | 23 | 23 | 1 | 69 | 2 | | | 118 |
| | | | | 19.5 | 19.5 | 0.8 | 58.5 | 1.7 | | | |

Table 8a. Age composition from samples collected in the fishery, by date, 1978. (continued)

| Date | | AGE CLASS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.1 | 2.1 | 1.2 | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | 1.4 | n |
| 7/25 | Number | | 1 | | 36 | 20 | 3 | 55 | 2 | | | 117 |
| | Percent | | 0.8 | | 30.8 | 17.1 | 2.6 | 47.0 | 1.7 | | | |
| 7/28 | | | 1 | | 27 | 15 | 2 | 60 | 2 | | | 107 |
| | | | 0.9 | | 25.2 | 14.0 | 1.9 | 56.1 | 1.9 | | | |
| 8/1 | | | 1 | | 30 | 19 | 6 | 53 | 2 | | 2 | 113 |
| | | | 0.9 | | 26.5 | 16.8 | 5.3 | 46.9 | 1.8 | | 1.8 | |
| 8/7 | | | | 1 | 29 | 6 | 9 | 77 | 3 | | 4 | 129 |
| | | | | 0.8 | 22.5 | 4.6 | 7.0 | 59.7 | 2.3 | | 3.1 | |
| 8/15 | | | 1 | | 4 | 4 | 1 | 47 | 8 | | | 65 |
| | | | 1.5 | | 6.2 | 6.2 | 1.5 | 72.3 | 12.3 | | | |
| 8/20 | | | | | 4 | 8 | | 21 | 7 | | | 41 |
| | | | | | 9.8 | 19.5 | | 51.2 | 17.2 | | | |
| 8/23 | | | | | 4 | 10 | 1 | 33 | 10 | | | 58 |
| | | | | | 6.9 | 17.2 | 1.8 | 56.9 | 17.2 | | | |

Table 8b. Age composition from samples collected at the outlet of Black Lake, by date, 1978.

| Date | Age Class 1.2 | 2.2 | 1.3 | 2.3 | 3.3 | 1.4 | n |
|---|---|---|---|---|---|---|---|
| June 12 Number | 2 | 6 | 112 | 58 | 1 | | 179 |
| Percent | 1.1 | 3.4 | 62.6 | 32.4 | 0.6 | | |
| June 15 | | 3 | 100 | 45 | | | 148 |
| | | 2.0 | 67.6 | 30.4 | | | |
| June 17 | 5 | 12 | 104 | 49 | | | 170 |
| | 2.9 | 7.1 | 61.2 | 28.8 | | | |
| June 19 | 5 | 7 | 168 | 43 | | | 223 |
| | 2.2 | 3.1 | 75.3 | 19.3 | | | |
| June 21 | 4 | 5 | 115 | 56 | | 1 | 181 |
| | 2.2 | 2.8 | 63.5 | 30.9 | | 0.6 | |
| June 23 | 1 | 8 | 129 | 34 | | 1 | 173 |
| | 0.6 | 4.6 | 74.6 | 19.6 | | 0.6 | |
| June 25 & 27 | 7 | 14 | 115 | 37 | | | 173 |
| | 4.0 | 8.1 | 66.5 | 21.4 | | | |
| July 1 | 2 | 15 | 129 | 75 | | | 221 |
| | 0.9 | 6.8 | 58.4 | 33.9 | | | |
| July 5 | 1 | 2 | 89 | 38 | | | 130 |
| | 0.8 | 1.5 | 68.5 | 29.2 | | | |

Table 8c. Age composition from samples collected in Chiaktuak Creek.

| | Age Class | | |
|---|---|---|---|
| | 2.2 | 1.3 | 2.3 |
| Number | 3 | 31 | 217 |
| Percent | 1.2 | 12.3 | 86.5 |

Table 8d. Age composition from samples collected from late run spawning grounds.

| Location | | Age Class | | | | | | n |
|---|---|---|---|---|---|---|---|---|
| | | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | |
| North Hatchery Beach | Number | 14 | 11 | 0 | 189 | 10 | 1 | 225 |
| | Percent | 6.2 | 4.9 | 0 | 84.0 | 4.5 | 0.4 | |
| South Hatchery Beach | Number | 4 | 3 | 0 | 121 | 9 | 1 | 138 |
| | Percent | 2.9 | 2.2 | 0 | 87.7 | 6.5 | 0.7 | |
| Cliff Bay | Number | 9 | 3 | 0 | 22 | 2 | 0 | 36 |
| | Percent | 25.0 | 8.3 | 0 | 61.1 | 5.6 | 0 | |
| Clarks River | Number | 36 | 1 | 1 | 51 | 1 | 0 | 90 |
| | Percent | 40.0 | 1.1 | 1.1 | 56.7 | 1.1 | 0 | |
| Late Run Total | Number | 63 | 18 | 1 | 383 | 22 | 2 | 489 |
| | Percent | 12.9 | 3.7 | 0.2 | 78.3 | 4.5 | 0.4 | |

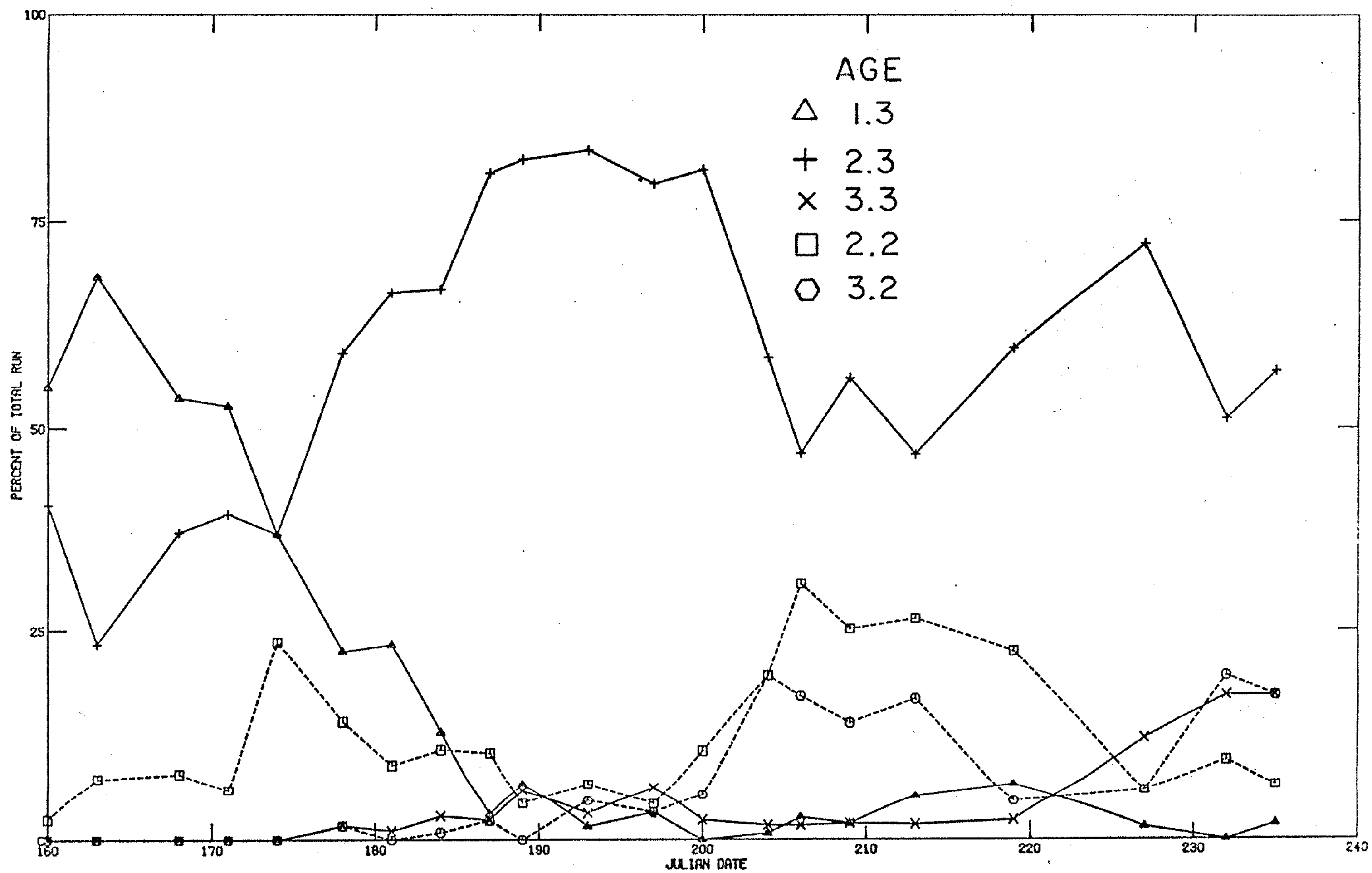


Fig. 6. Daily age composition of the 1978 run expressed as percentages. Curves have been smoothed by a moving average of three sampling dates.

Table 9. Age composition by run (early vs. late) and by stock in 1978 as determined by allocating the total return using the method of Dahlberg (1968) and the time-of-entry curve estimated by scale patterns recognition. Equal exploitation rates of Black Lake and Black River stocks is assumed.

| Group | Age Class 1.1 | 2.1 | 1.2 | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | 1.4 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Return[1] | | | | | | | | | | | |
| Numbers | 661 | 3,326 | 18,890 | 269,828 | 89,139 | 735,929 | 1,328,335 | 45,798 | 732 | 5,790 | 2,498,428 |
| Percent | <0.1 | 0.1 | 0.8 | 10.8 | 3.6 | 29.5 | 53.2 | 1.8 | <0.1 | 0.2 | |
| Early Run[1] | | | | | | | | | | | |
| Number | 210 | 341 | 11,992 | 121,388 | 3,734 | 681,634 | 560,454 | 5,814 | 8 | 4,354 | 1,390,029 |
| Percent | <0.1 | <0.1 | 0.9 | 8.7 | 0.3 | 49.0 | 40.3 | 0.4 | <0.1 | 0.3 | |
| Black River[2] | | | | | | | | | | | |
| Numbers | | | 1,051 | | | 10,771 | 75,749 | | | | 87,571 |
| Percent | | | 1.2 | | | 12.3 | 86.5 | | | | 100.0 |
| Black Lake | | | | | | | | | | | |
| Numbers | 310 | 341 | 10,941 | 121,388 | 3,734 | 670,863 | 484,705 | 5,814 | 8 | 4,354 | 1,302,458 |
| Percent | <0.1 | <0.1 | 0.8 | 9.3 | 0.3 | 51.5 | 37.2 | 0.5 | <0.1 | 0.3 | |
| Late Run[1] | | | | | | | | | | | |
| Numbers | 351 | 2,985 | 6,898 | 148,440 | 85,405 | 54,295 | 767,881 | 39,984 | 724 | 1,436 | 1,108,399 |
| Percent | <0.1 | 0.3 | 0.6 | 13.4 | 7.7 | 4.9 | 69.3 | 3.6 | 0.1 | 0.1 | |
| Chignik Lake | | | | | | | | | | | |
| Numbers | 351 | 2,985 | 7,949 | 148,440 | 85,405 | 65,066 | 843,630 | 39,984 | 724 | 1,436 | 1,195,970 |
| Percent | <0.1 | 0.3 | 0.7 | 12.4 | 7.1 | 5.4 | 70.5 | 3.3 | 0.1 | 0.1 | |

[1] Based on fishery samples.

[2] Based on spawning ground samples.

(1974) emphasized that this method fails to account for differences in age composition between the early and late runs during the period of overlap in time-of-entry. The significance of this problem is underscored by comparing the percent age composition data for the Black Lake stock calculated with this method and that calculated from sampling conducted at the outlet of Black Lake (Table 8b). The method of Dahlberg (1968) seriously underestimated the percent of age 1.3 fish (51.5 vs. 66.4) and seriously overestimated the percent of age 2.3 fish (37.2 vs. 27.2). The method also underestimated the percent of 1.2 age fish (0.8 vs. 1.7) and overestimated the percent of 2.2 fish (9.3 vs. 4.5) in the Black Lake stock.

In Table 10, we present the results of allocating the total return by the method of Burgner and Marshall (1974). We used Shaul's (1978) estimate of 0.063 for the proportion of Black River tributary fish in the early run. Estimates of the number of age 1.2 and 1.3 fish returning in the early run turned out to be 4,173 and 139,544 greater than estimates for the total number of fish of these age classes returning to the entire system. The 95% confidence interval for the proportion of age 1.2 fish in the early run is 0.0169 $\pm$ 0.0063. When the upper and lower limits of this range are multiplied by the total estimated Black Lake return, the range of values is 13,806 to 30,217. Clearly, the discrepancy in age 1.2 fish estimates could be explained simply by variation in our estimate of the proportion of age 1.2 fish. A similar exercise for the proportion of age 1.3 fish in the early run produces a 95% confidence interval of 0.6640 $\pm$ 0.0218. This corresponds to a range of 834,615 to 895,049 fish. We cannot attribute the observed discrepancy between early run and total run abundance for this age group to uncertainty in our estimate of the proportion of the age group present.

We developed a hypothesis to explain this anomaly in the age composition statistics based on two observations: 1) the percent of age 1.3 fish from samples collected in the fishery dropped below the 66.4% observed at the outlet of Black Lake by June 9. This decrease was coupled with an increase in the percent of age 2.3 fish in the fishery samples (Fig. 6). These changes in age composition occurred much too early to be explained by the transition of early- to late-run fish (Fig. 4); 2) the Black River tributary stocks of the early run exhibited an age composition quite different than the Black Lake stocks, with about 12.3% age 1.3's, 86.5% age 2.3's, and 1.2% age 1.2's.

These facts suggested to us that if the total early run to Black River tributaries was proportionately more abundant than the 6.3% estimated from aerial surveys of the spawning grounds, then we might be able to account for the anomaly. This hypothesis carries with it two corollaries. First, because of the difference in age composition between stocks and the observed trends in age composition in the fishery, the Black River tributary fish must have entered during the

Table 10. Age composition by run (early vs. late) and by stock in 1978 as determined by the subtraction method of Marshall & Burgner (1977). The scale patterns time-of-entry curve was used to estimate the number of early and late run fish. Equal exploitation rates for Black Lake and Black River stocks is assumed.

| Group | Age class 1.1 | 2.1 | 1.2 | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | 1.4 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Return[1/] | | | | | | | | | | | |
| Numbers | 661 | 3,326 | 18,890 | 269,828 | 89,139 | 735,929 | 1,328,335 | 45,798 | 732 | 5,790 | 2,498,428 |
| Percent | <0.1 | 0.1 | 0.8 | 10.8 | 3.6 | 29.5 | 53.2 | 1.8 | <0.1 | 0.2 | |
| Black Lake[2/] | | | | | | | | | | | |
| Number | | | 22,012 | 58,741 | | 864,702 | 354,529 | 781 | | 1,693 | 1,302,458 |
| Percent | | | 1.7 | 4.5 | | 66.4 | 27.2 | 0.06 | | 0.1 | |
| Black River[3/] | | | | | | | | | | | |
| Number | | | 1,051 | | | 10,771 | 75,749 | | | | 87,571 |
| Percent | | | 1.2 | | | 13.4 | 86.5 | | | | 100.0 |
| Early Run | | | | | | | | | | | |
| Number | | | 23,063 | 58,741 | | 875,473 | 430,278 | 781 | | 1,693 | 1,390,029 |
| Percent | | | | | | | | | | | |
| Late Run | | | | | | | | | | | |
| Number | 661 | 3,326 | -4,173 | 211,087 | 89,139 | -139,544 | 898,057 | 45,017 | 732 | 4,097 | 1,108,399 |
| Percent | | | | | | | | | | | |
| Chignik Lake | | | | | | | | | | | |
| Number | 661 | 3,326 | -3,122 | 211,087 | 89,139 | -128,773 | 973,806 | 45,017 | 732 | 4,079 | 1,195,952 |
| Percent | | | | | | | | | | | |

1/ Based on fishery samples.

2/ Based on beach seine samples collected at the outlet of Black Lake.

3/ Based on spawning ground samples.

latter portion of the early run, i.e., there must be some temporal segregation in timing of Black Lake and early Black River sockeye runs. Secondly, because of this temporal segregation and the management strategy which emphasizes harvest of runs during the period of overlap between early- and late- run fish, the exploitation rate for the Black River tributary stocks must have been considerably greater than that for the Black Lake stock.

The first set of supporting data for the above hypothesis was derived by allocating the early run into Black River tributary and Black Lake segments using the age composition method of Fredin and Worlund (1974). Point estimates (with 95% confidence intervals) were made for the contribution by stock on days when sampling was conducted in the fishery (Table 11). We then fitted a third order polynomial to these data (Table 12, Fig. 7). The resulting model was used to estimate the proportion of each stock present by day, to allocate catch and escapement, and to calculate exploitation rates. This method produced the following estimates of catch and escapement for the two stocks.

| | Catch | Escapement | Total |
|---|---|---|---|
| Black Lake | 664,489 | 366,648 | 1,031,137 |
| Black River | 292,356 | 66,536 | 358,892 |
| Total Early Run | 956,845 | 433,184 | 1,390,029 |

A second line of supportive evidence for this hypothesis of higher exploitation rate for Black River tributary stocks is based on escapement-return relationships. Shaul (1978) estimated the return per spawner of Chignik Lake age 2.3 fish from the 1972 brood year to be 5.22. We used this figure to estimate Black River early run returns of 2.3 fish in 1978 because fry of Black River tributary origin rear in Chignik Lake (Narver 1966). The early run escapement to Black River tributaries in 1972 was about 64,937 (Shaul 1978). These data produce an estimated return to Black River tributaries of 338,971 age 2.3 fish in 1978. Since age 2.3's represented 86.5% of the Black River tributary returns, we expanded the figure to account for returns of age 1.3 and 1.2. The resulting estimate is 391,874. Using the 1978 estimated Black River tributary escapement figures of Shaul (1978) we calculated estimates of catch and escapement by stock for 1978.

Table 11. Estimates of the proportion (and 95% confidence intervals) of Black Lake and Black River tributary fish in the early run, by day, 1978.

| Julian Date | Black Lake | Black River |
|---|---|---|
| 158 | 1.00 | 0.00 |
| 160 | 0.99 ± .12 | 0.01 ± .12 |
| 163 | 0.88 ± .16 | 0.12 ± .16 |
| 168 | 0.87 ± .16 | 0.13 ± .16 |
| 171 | 0.69 ± .16 | 0.31 ± .16 |
| 174 | 0.51 ± .16 | 0.49 ± .16 |
| 178 | 0.39 ± .16 | 0.61 ± .16 |
| 181 | 0.33 ± .18 | 0.67 ± .18 |
| 184 | 0.34 ± .16 | 0.66 ± .16 |
| 187 | 0.32 ± .15 | 0.67 ± .15 |
| 189 | 0.14 ± .14 | 0.86 ± .14 |
| 193 | 0.36 ± .15 | 0.64 ± .15 |

Table 12. Analysis of variance for the polynomial regression of the proportion of Black River tributary fish in the early run on Julian date.

| Source | Degrees of freedom | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Total | 12 | .99489 | | |
| Reduction to linear | 1 | .88533 | .88533 | |
| Deviations from linear | 11 | .10956 | .01096 | 80.8** |
| Reduction to quadratic | 1 | .03313 | | |
| Deviations from quadratic | 10 | .07643 | .00764 | 4.33 NS |
| Reduction to cubic | 1 | .03772 | | |
| Deviations from cubic | 9 | .03872 | .00430 | 8.77** |

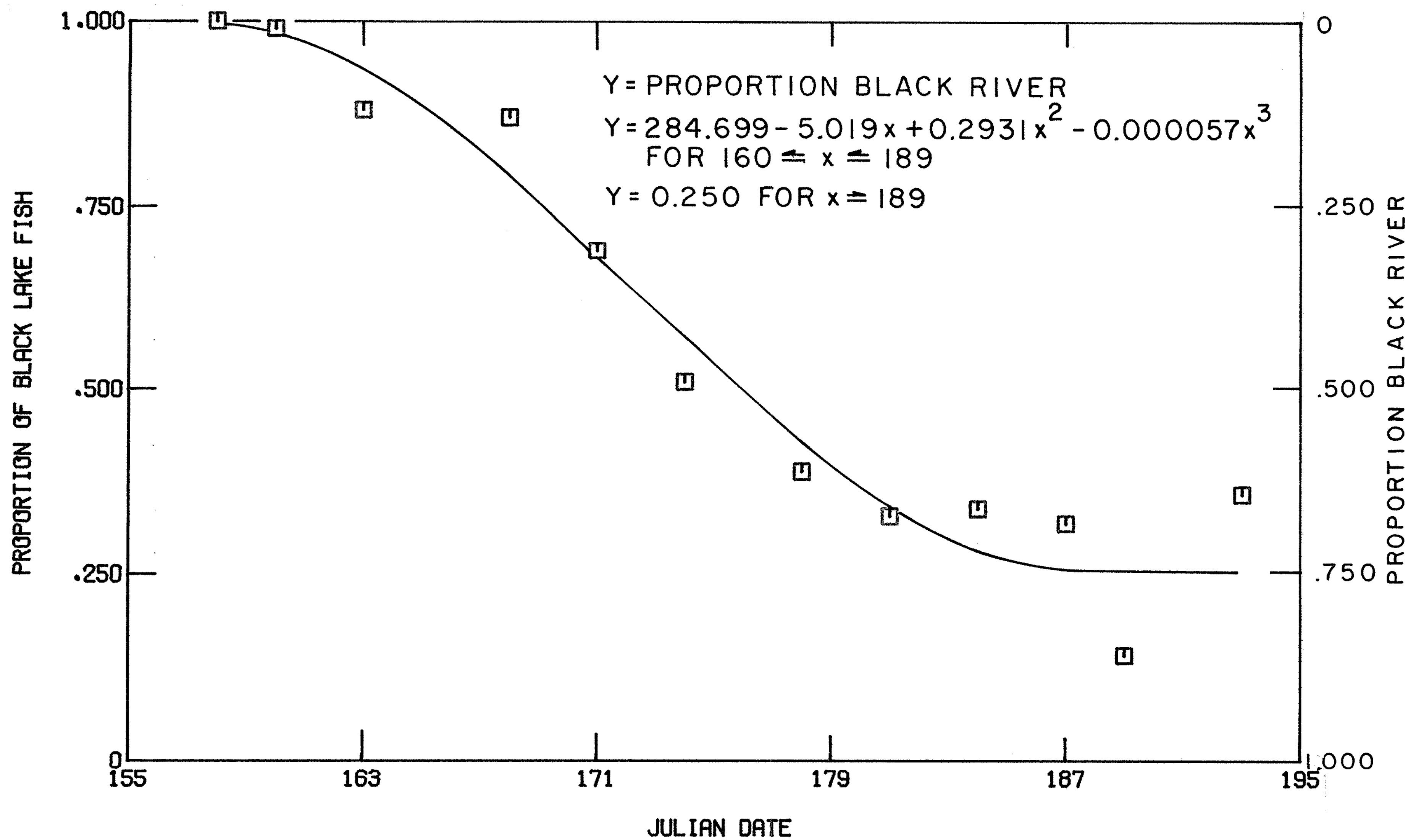


Fig. 7. Third order polynomial regression of the proportion of Black River fish in the early run on Julian date.

| | Catch | Escapement | Total |
|---|---|---|---|
| Black Lake | 592,261 | 405,894 | 998,155 |
| Black River | 364,584 | 27,290 | 391,874 |
| Total Early Run | 956,845 | 433,184 | 1,390,029 |

Because each method of allocating the early run into component stocks produced independent yet quite similar results, we believe that in fact Black River tributary fish were much more abundant in the early run than previously thought. In order to rectify the differences in the two estimates of abundance we simply took their average, and in Table 13 we present our estimates of the catch and escapement by run, stock, and nursery lake. In Table 14, we present the return by age class. In these data the anomaly in the age composition statistics has vanished.

## Exploitation Pattern

The harvest management strategy of the Alaska Department of Fish and Game for the Chignik sockeye run is based on optimizing nursery lake carrying capacity by ensuring proper escapements to the major spawning grounds. Timing is the mechanism upon which daily escapement goals for each run (early vs. late) are based. The escapement goals take into consideration that some fry of Black River spawners rear in Chignik Lake. They do not account for any differences in time of entry for Black River tributary vs. Black Lake fish because these differences were previously unmeasured.

The following strategy has evolved based on these considerations. A set of cumulative daily escapement goals for the early and late run is calculated from the average entry pattern (see Fig. 5). The daily goals are typically shifted over the time domain to account for perceived earliness or lateness of the run in a year. These goals are conservative by design so that if the cumulative escapement goal is met on a day then fishing will be permitted two days hence. If the total early run escapement goal is reached prior to or during the period of overlap in time of entry for the early vs. late run, then extensive fishing is permitted in order to harvest the last of the early-run fish. Once the late run dominates, a new set of cumulative daily escapement goals is used to regulate the harvest. When the final late run goal is assumed, then fishing is usually allowed on a 5- or 6- day-a-week basis.

In Fig. 8a, we show the temporal distribution of catch and escapement for the entire run in 1978. Day 183 is the approximate

Table 13. Final estimates of the catch, escapement and total return of sockeye salmon to Chignik in 1978 by run, stock and nursery lake of fry.

| | Catch | Escapement | Total |
|---|---|---|---|
| Black Lake | 628,375 | 386,271 | 1,014,646 |
| Black River tributaries | 328,470 | 46,913 | 395,383 |
| Early Run[1/] | 956,845 | 433,184 | 1,390,029 |
| Late Run | 859,036 | 249,363 | 1,108,399 |
| Chignik Lake[2/] | 1,187,506 | 296,276 | 1,483,782 |
| Total Return | 1,815,881 | 682,547 | 2,498,428 |

1/ Early run includes Black Lake and Black River tributary early spawning stocks.

2/ Chignik Lake includes late run and Black River tributary late spawning stocks.

Table 14. Final estimates of the age composition by run (early vs. late) and by stock in 1978 as determined by the subtraction method of Marshall & Burgner (1977). The scale patterns time-of-entry curve was used to estimate the number of early and late run fish. Age composition data were used to estimate the number of Black Lake and Black River fish in the early run.

| Group | 1.1 | 2.1 | 1.2 | 2.2 | 3.2 | 1.3 | 2.3 | 3.3 | 4.3 | 1.4 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Return | | | | | | | | | | | |
| Numbers | 661 | 3,326 | 18,890 | 269,828 | 89,139 | 735,929 | 1,328,335 | 45,798 | 732 | 5,790 | 2,498,428 |
| Percent | <0.1 | 0.1 | 0.8 | 10.8 | 3.6 | 29.5 | 53.2 | 1.8 | <0.1 | 0.2 | |
| Black Lake | | | | | | | | | | | |
| Numbers | | | 17,148 | 45,761 | | 673,622 | 276,187 | 609 | | 1,319 | 1,014,646 |
| Percent | | | 1.69 | 4.51 | | 66.39 | 27.22 | .06 | | 0.13 | |
| Black River | | | | | | | | | | | |
| Numbers | | | 4,505 | | | 46,172 | 324,706 | | | | 375,383 |
| Percent | | | 1.2 | | | 12.3 | 86.5 | | | | |
| Early Run | | | | | | | | | | | |
| Numbers | 0 | 0 | 18,890 | 45,761 | | 719,794 | 600,893 | 609 | | 1,319 | 1,387,266 1/ |
| Percent | | | 1.36 | 3.30 | | 51.89 | 43.31 | 0.04 | | 0.10 | |
| Late Run | | | | | | | | | | | |
| Numbers | 661 | 3,326 | 0 | 224,067 | 89,139 | 16,135 | 727,442 | 45,189 | 732 | 4,471 | 1,111,162 1/ |
| Percent | 0.06 | 0.30 | 0 | 20.17 | 8.02 | 1.45 | 65.47 | 4.07 | 0.07 | 0.40 | |
| Chignik Lake | | | | | | | | | | | |
| Numbers | 661 | 3,326 | 4,505 | 224,067 | 89,139 | 62,307 | 1,052,148 | 45,189 | 732 | 4,471 | 1,486,545 1/ |
| Percent | 0.04 | 0.22 | 0.30 | 15.07 | 6.00 | 4.19 | 70.78 | 3.04 | 0.05 | 0.30 | |

1/ The total early run of age 1.2 was estimated at 21,653 which is 2763 more than the 18,890 age 1.2 fish which we estimated to have returned to the entire system. We used the smaller estimate and therefore the early run total is 2763 fish fewer than the sum of the Black River and Black Lake stocks and the late run is comensurately larger.

50% point in the time-of-entry curve (see Fig. 5). The heavy exploitation during the period of overlap in time-of-entry is apparent. In Figs. 8b and c we show the pattern of exploitation for each run (early and late) and the heavy exploitation during the period of overlap is easily seen. Further resolution is provided for the early run in Figs. 9a and b. The distribution of the catch for the Black Lake stock was such that approximately 73% of the catch occurred after the median run date of 165.5 (June 14). The estimated exploitation rate was 0.614. For the Black River tributary stocks (Fig. 9b), approximately 57% of the catch occurred after the median run date of 175.5 (June 24). The estimated exploitation rate for the Black River tributary stocks was 0.875. The late estimated run exploitation rate was 0.775 and approximately 58% of the harvest occurred after the median run date of 199.5 (July 18).

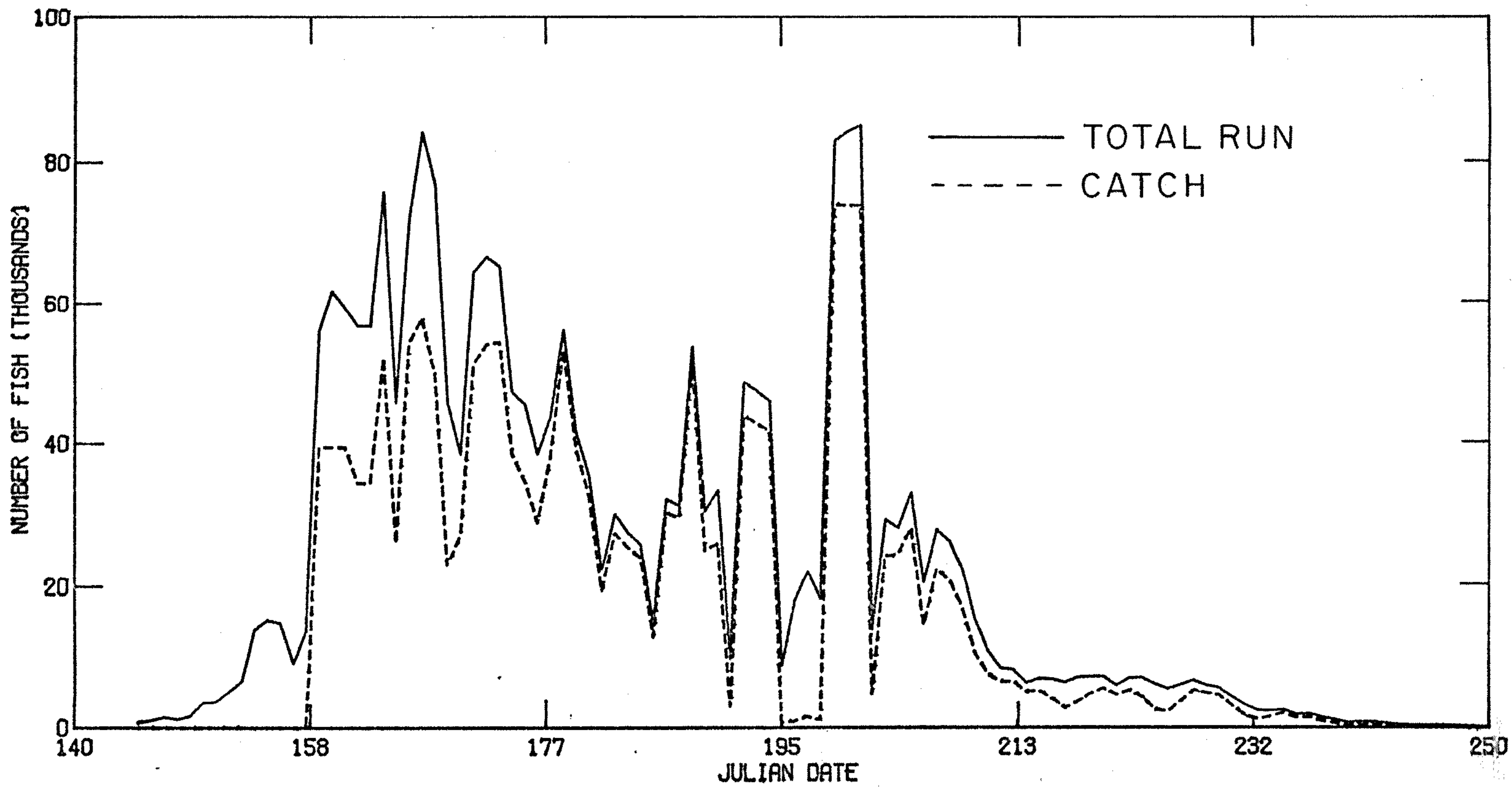


Fig. 8a. Temporal exploitation pattern of the 1978 sockeye run. Curves smoothed by a moving average of three sampling dates.

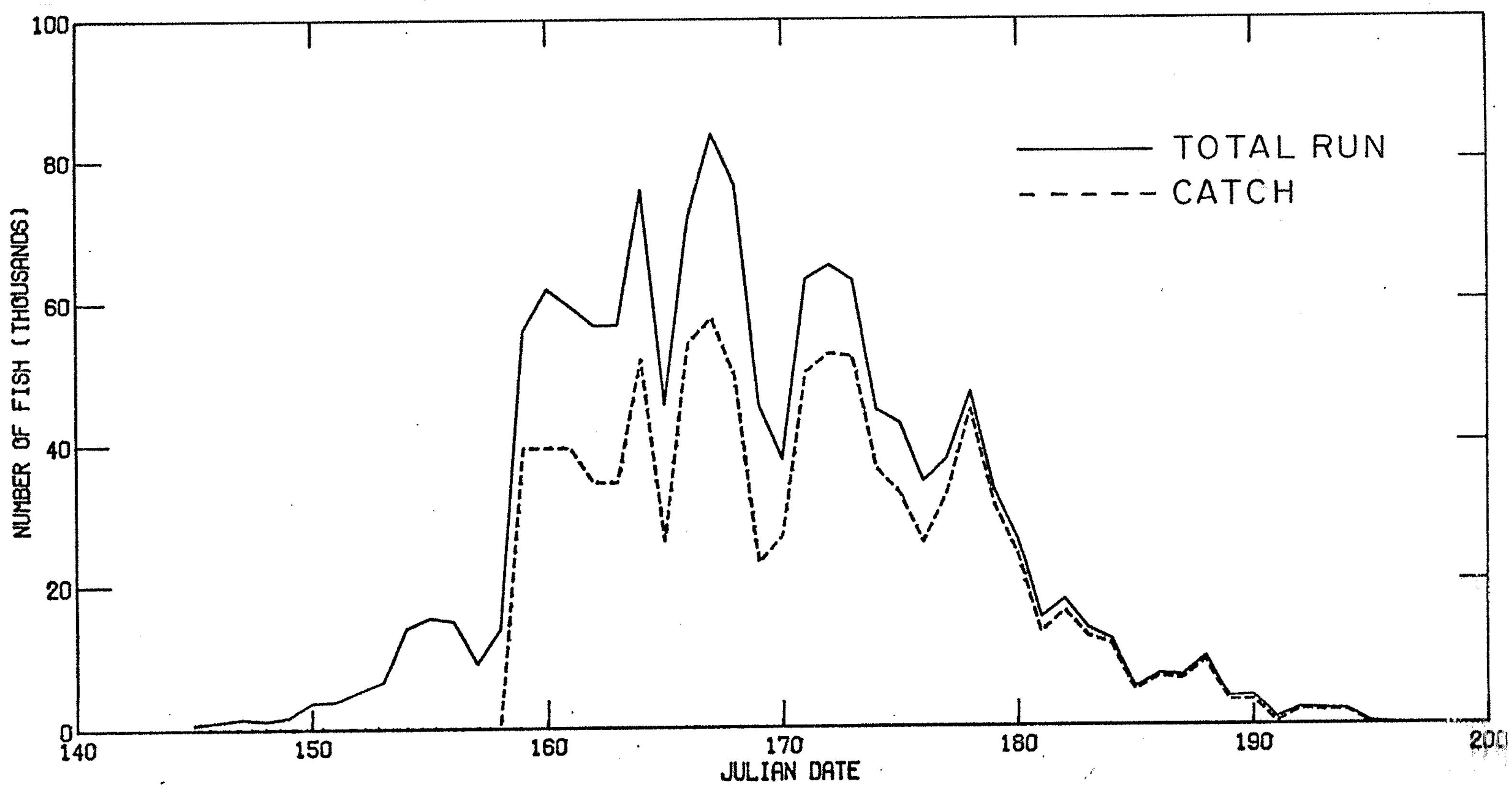


Fig. 8b. Temporal exploitation pattern of the early (Black Lake) run, 1978. Curves are smoothed by a moving average of three sampling dates.

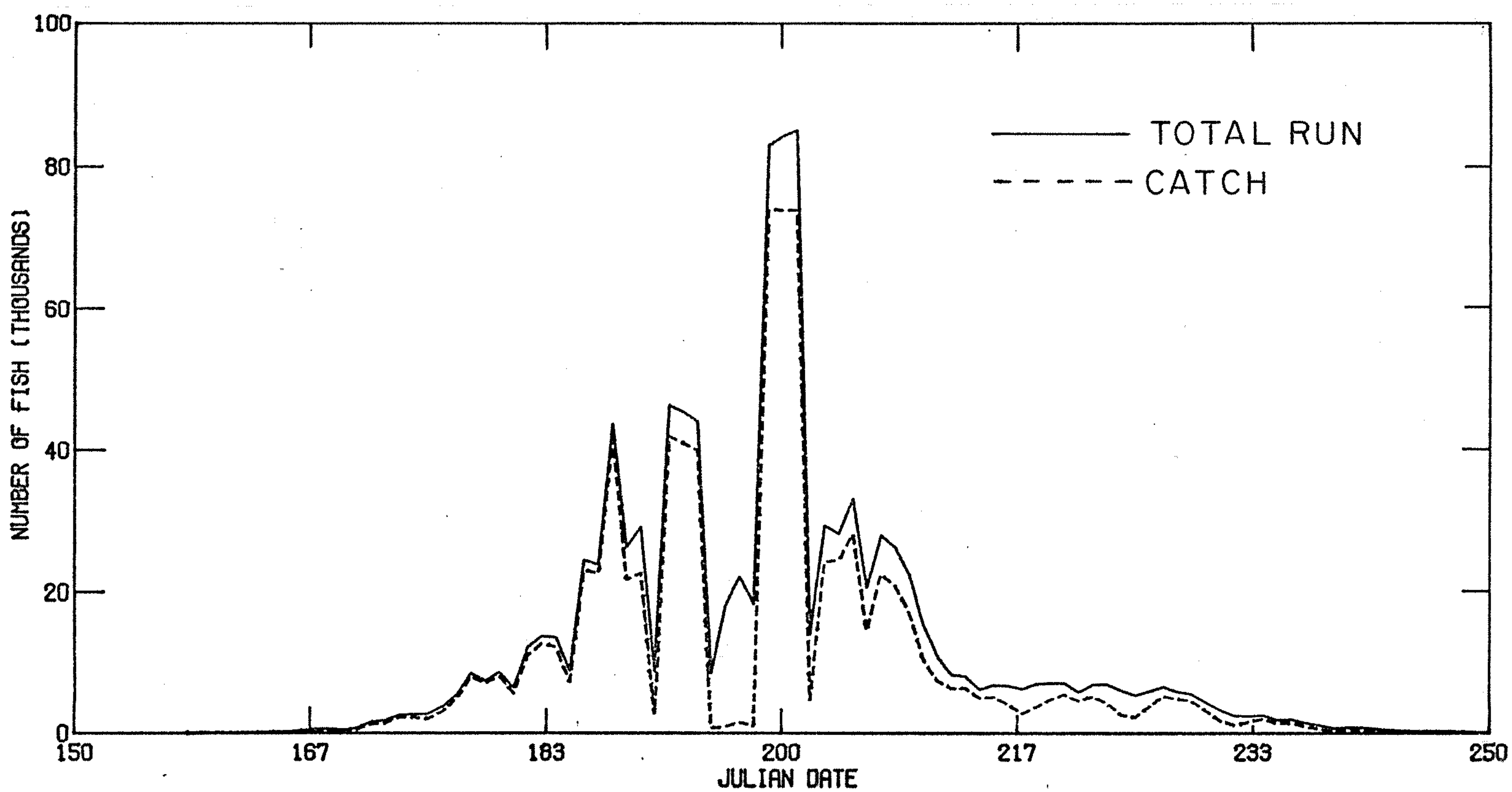


Fig. 8c. Temporal exploitation pattern of the late (Chignik Lake) run, 1978. Curves smoothed by a moving average of three sampling dates.

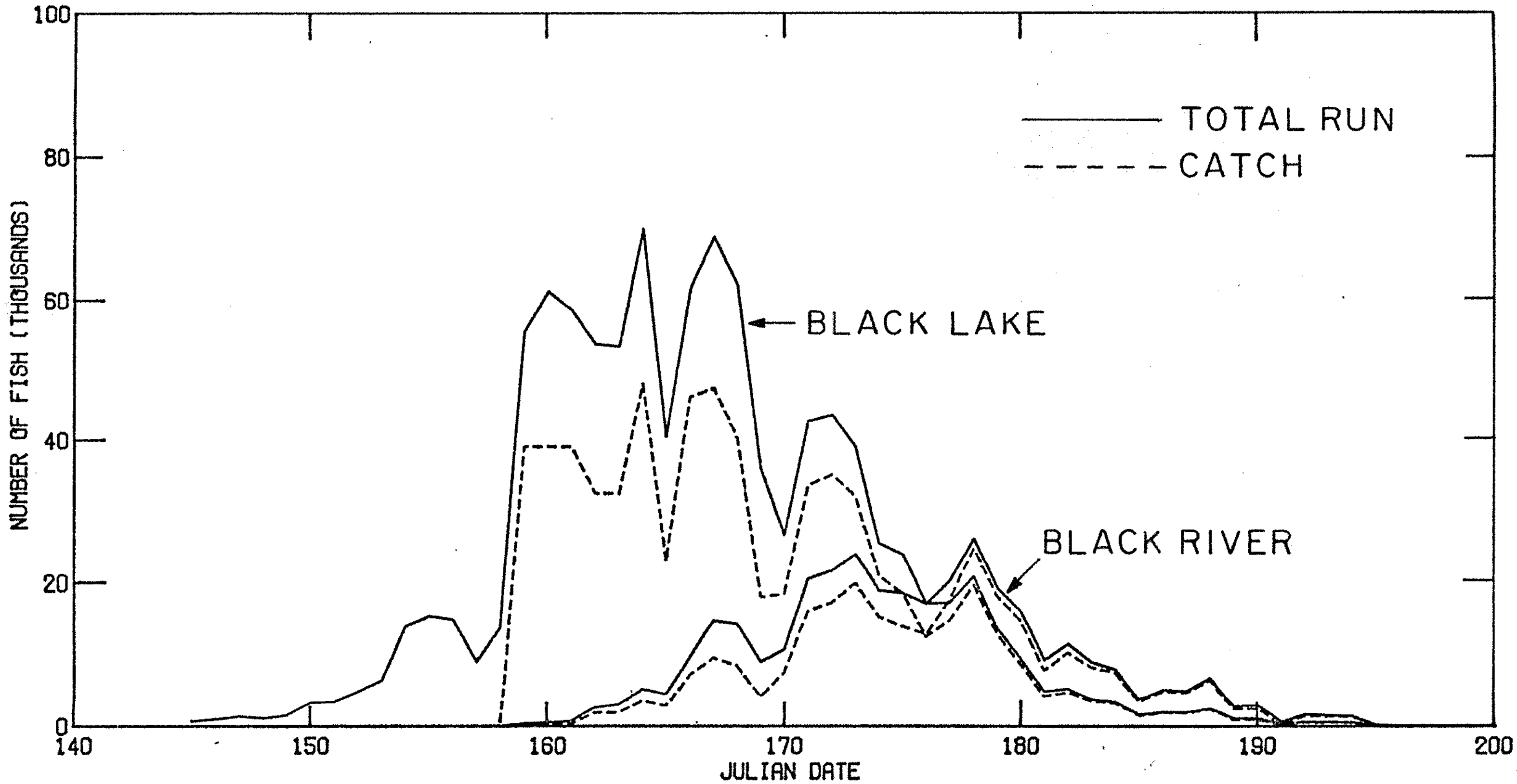


Fig. 9a. Temporal exploitation patterns and overlap of entry time of Black Lake and Black River stocks, 1978. Curves smoothed by a moving average of three sampling dates.

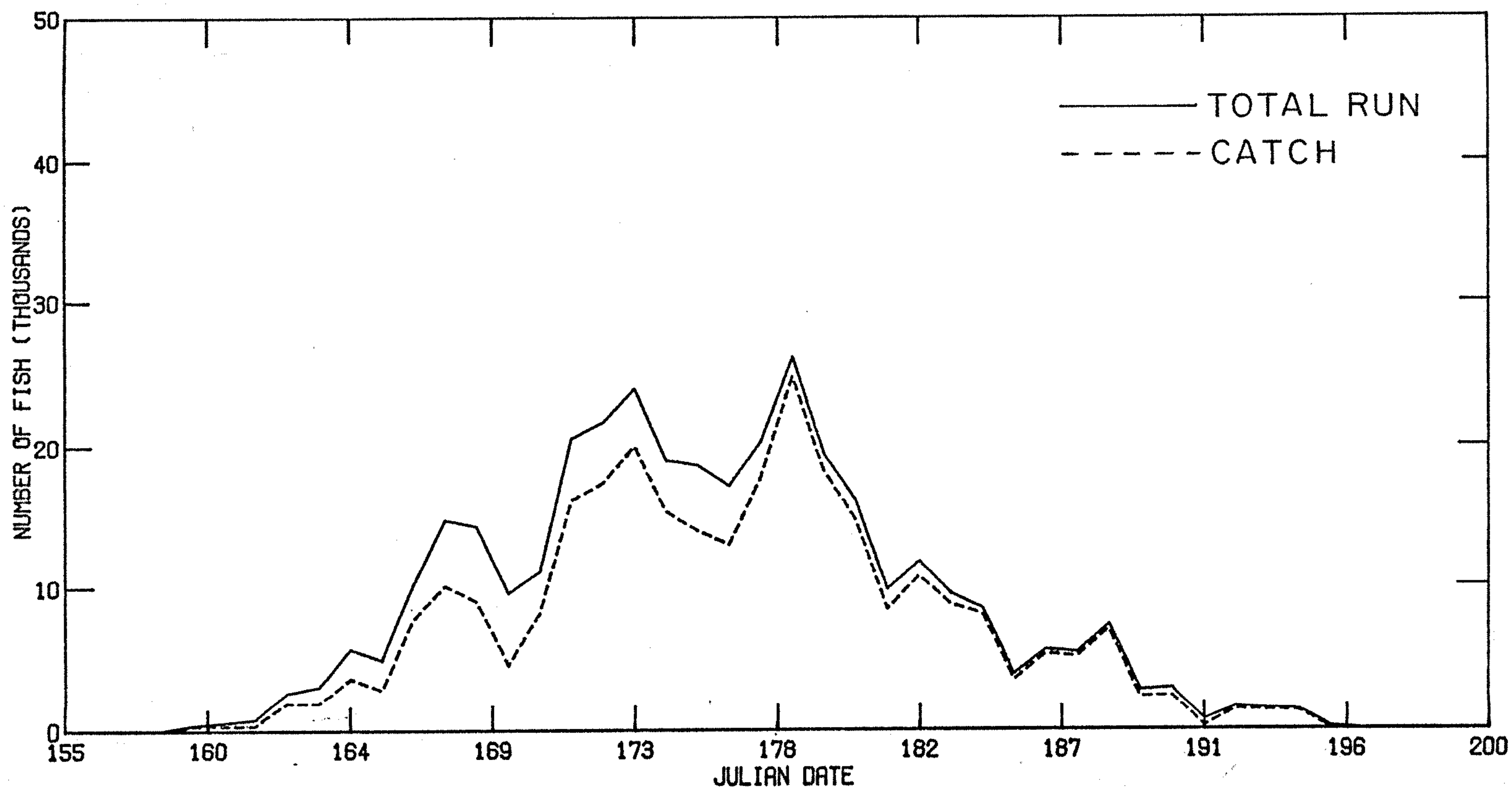


Fig. 9b. Temporal exploitation pattern of the Black River stock, 1978. Curves smoothed by moving average of three sampling dates.

## RECOMMENDATIONS

1) The use of average and shifted average time-of-entry curves should be abandoned in favor of year-specific curves. Scale patterns recognition techniques appear to offer the best approach to this goal.

2) Time-of-entry curves based on scale patterns recognition techniques should be calculated for the other major age classes (1.2, 2.2, and 1.3) to test for significant differences in migration timing of year class.

3) Scale patterns recognition techniques should be used to estimate time-of-entry curves for years in which tagging was not done. The use of years-pooled functions should be explored in this regard in order to minimize the number of standards which need to be developed.

4) Age composition statistics need to be recomputed in order to remove errors resulting from use of average time-of-entry curves, and from use of the fishery-scale method.

5) In future years, routine sampling schemes should include provisions for obtaining estimates of the contribution of Black River stocks in the early run. This would include scale samples from the spawning grounds to attempt separation by scale patterns analysis because in some years age compositions of the two stocks are quite similar.

6) In years where age compositions of the Black Lake and Black River tributary stocks are sufficiently different, the proportions of each in the early run should be estimated. This will allow evaluation of the importance of Black River tributary spawners to the early run and conceivably could alter significantly the escapement goals for each stock.

7) The current management strategy which emphasizes harvest during the period of overlap in time-of-entry should be altered in order to ensure adequate escapement into Black River tributaries. The level which is adequate is uncertain at this time. The high variability in levels observed since 1960 (2,350 to 66,000) is clearly undesirable given the apparent high productivity of this stock. An interim goal of perhaps 40,000 does not seem unrealistic. Special care should be taken in 1980 and 1981 to protect fish maturing after 5 and 6 years returning from the very low escapement of 5,065 in 1975.

8) Efforts should begin immediately to develop in-season stock separation capabilities.

9) While this report does not consider error in the annual run statistics resulting from misinterpretation of age readings from scales, we believe that efforts should continue on this front.

10) In view of the magnitude of the proposed projects in this section we see an immediate need to create a computer data bank of the adult fish data.

11) Lastly, we know little of the stocks of fish in the late run. It may prove valuable to search for characteristic time-of-entry patterns in this run as well.

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# APPENDIX

Appendix Table 1. Adjusted daily catch, escapement, and daily run of sockeye salmon in 1978.

| | | Catch | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day (i) | Escapement (i-2) | Lagoon (i) | Hook Bay (i+2) | Aniakchak (i+3) | Imuya (i+6) | Igvak (i+6) | Puale (i+8) | Beaver-Balboa (i+7) | Stepovak (i+6) | Total | Daily Run |
| Prior to 147 | 2,000 | | | | | | | | | | 2,000 |
| 147 | 1,008 | | | | | | | | | | 1,008 |
| 148 | 1,152 | | | | | | | | | | 1,152 |
| 149 | 1,200 | | | | | | | | | | 1,200 |
| 150 | 2,369 | | | | | | | | | | 2,369 |
| 151 | 7,200 | | | | | | | | | | 7,200 |
| (June 1) 152 | 1,680 | | | | | | | | | | 1,680 |
| 153 | 7,435 | | | | | | | | | | 7,435 |
| 154 | 11,929 | | | | | | | | | | 11,929 |
| 155 | 23,094 | | | | | | | | | | 23,094 |
| 156 | 11,577 | | | | | | | | | | 11,577 |
| 157 | 10,435 | | | | | | | | | | 10,435 |
| 158 | 6,720 | | | | | | | | | | 6,720 |
| 159 | 24,700 | | | | | | | | | | 24,700 |
| 160 | 18,426 | 118,402 | | | | | | | | 118,402 | 136,828 |
| 161 | 24,036 | | | | | | | | | | 24,036 |
| 162 | 17,382 | | | | | | | | | | 17,382 |
| 163 | 25,166 | 102,170 | | 1,554 | | | | | | 103,724 | 128,880 |
| 164 | 24,524 | | | | | | | | | | 24,524 |
| 165 | 22,056 | 52,645 | | | | | | | | 52,645 | 74,701 |
| 166 | 12,265 | | | 4,145 | 8,322 | 13,654 | | | | 26,121 | 38,386 |
| 167 | 19,526 | 84,229 | | | | | | | | 84,229 | 103,755 |
| 168 | 47,496 | 63,530 | | 146 | | | | | | 63,676 | 111,172 |
| 169 | 15,146 | | | | | | | | 1,367 | 1,367 | 16,513 |
| 170 | 6,045 | | | 2,332 | | | | | 1,848 | 4,180 | 10,225 |
| 171 | 12,659 | 69,822 | | 5,267 | | | | 394 | 1,094 | 76,577 | 89,236 |
| 172 | 22,514 | 52,396 | | | 2,766 | 16,736 | | 942 | | 72,940 | 95,454 |
| 173 | 4,048 | | 3,000 | | 5,288 | 4,471 | | | | 12,759 | 16,807 |

Appendix Table 1. Adjusted daily catch, escapement, and daily run of sockeye salmon in 1978 - continued.

| | | Catch | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day (i) | Escapement (i-2) | Lagoon (i) | Hook Bay (i+2) | Aniakchak (i+3) | Imuya (i+6) | Igvak (i+6) | Puale (i+8) | Beaver-Balboa (i+7) | Stepovak (i+6) | Total | Daily Run |
| 174 | 7,615 | 45,979 | 1,613 | 2,654 | 2,924 | 24,455 | | | | 77,625 | 85,240 |
| 175 | 14,596 | 23,544 | | 1,825 | | | | | | 25,369 | 39,965 |
| 176 | 9,842 | | 525 | | | | | | 1,064 | 1,589 | 11,431 |
| 177 | 4,034 | 35,280 | 5,891 | | 2,730 | 15,850 | | | 399 | 60,150 | 64,184 |
| 178 | 2,935 | 19,974 | | 1,392 | 14,098 | 16,760 | | 24 | 707 | 52,955 | 55,890 |
| 179 | 1,947 | 31,045 | 4,241 | | 960 | 10,393 | | 180 | | 46,819 | 48,766 |
| 180 | 2,673 | 14,840 | 2,529 | 260 | | | | | | 17,629 | 20,302 |
| 181 | 4,195 | 28,204 | 2,174 | 1,224 | | 2,488 | | | | 34,090 | 38,285 |
| (July 1) 182 | 2,724 | | 1,176 | 5,306 | | | | | | 6,482 | 9,206 |
| 183 | 1,224 | 37,623 | 1,375 | 3,204 | | | | | | 42,202 | 43,426 |
| 184 | 2,172 | 24,650 | | 2,629 | | | | | 958 | 28,237 | 30,409 |
| 185 | 3,258 | | | | | | | 311 | 1,729 | 2,040 | 5,298 |
| 186 | 1,578 | | 5,891 | 36 | | | | 148 | 3,123 | 9,198 | 10,776 |
| 187 | 1,914 | 78,604 | | 1,172 | | | | 255 | | 80,031 | 81,945 |
| 188 | 1,554 | | | | | | | | | | 1,554 |
| 189 | 4,542 | 71,677 | 1,564 | | | | | | | 73,241 | 77,783 |
| 190 | 10,260 | | | 2,238 | | | | | | 2,238 | 12,498 |
| 191 | 7,266 | | 501 | | | | | 178 | 2,570 | 3,249 | 10,515 |
| 192 | 4,092 | | | 1,639 | | | | 529 | 1,398 | 3,566 | 7,658 |
| 193 | 2,862 | 124,898 | | | | | | 75 | | 124,973 | 127,835 |
| 194 | 6,978 | | | | | | | | | | 6,978 |
| 195 | 2,934 | | 194 | | | | | 62 | | 256 | 3,190 |
| 196 | 15,846 | | | 1,545 | | | 102 | | | 1,647 | 17,493 |
| 197 | 34,303 | | | | | | | | 617 | 617 | 34,920 |
| 198 | 12,654 | | | | | | 2,088 | 139 | | 2,227 | 14,481 |
| 199 | 5,972 | | | | | | 107 | | | 107 | 6,079 |
| 200 | 8,412 | 217,467 | 102 | | | | 122 | | 3,421 | 221,112 | 229,525 |
| 201 | 16,569 | | 1,714 | | | | | 306 | | 2,020 | 18,589 |
| 202 | 8,520 | | | 107 | | | | | | 107 | 8,627 |

Appendix Table 1. Adjusted daily catch, escapement, and daily run of sockeye salmon in 1978 - continued.

| Day (i) | Escapement (i-2) | Catch | | | | | | | | | Daily Run |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lagoon (i) | Hook Bay (i+2) | Aniakchak (i+3) | Imuya (i+6) | Igvak (i+6) | Puale (i+8) | Beaver-Balboa (i+7) | Stepovak (i+6) | Total | |
| 203 | 2,376 | | 385 | 342 | 1,683 | 10,731 | | | | 13,141 | 15,517 |
| 204 | 4,314 | 53,404 | 2,396 | 1,787 | | 2,643 | | | | 60,230 | 64,544 |
| 205 | 4,362 | | 221 | 572 | | | | | | 793 | 5,155 |
| 206 | 6,240 | 21,941 | | 1,811 | | | | 197 | 114 | 24,063 | 30,303 |
| 207 | 6,894 | | 1,238 | 326 | 5,394 | 12,561 | | | | 19,519 | 26,413 |
| 208 | 3,954 | | | 422 | 7,560 | 15,923 | | | | 23,905 | 27,859 |
| 209 | 5,856 | 12,054 | 411 | 956 | 1,014 | 4,795 | | | | 19,230 | 25,086 |
| 210 | 5,450 | | 226 | 419 | 4,960 | 3,021 | | | | 9,126 | 14,576 |
| 211 | 2,520 | | | 2,224 | 1,200 | 1,211 | | | | 4,635 | 7,155 |
| 212 | 1,932 | 7,643 | | 2,249 | | 538 | | | 36 | 10,466 | 12,398 |
| (Aug. 1) 213 | 1,278 | 5,770 | | | | | | 54 | | 5,824 | 7,104 |
| 214 | 1,800 | 4,603 | | | | | | 77 | | 4,680 | 6,480 |
| 215 | 972 | 4,160 | 67 | 1,392 | | | | 22 | 256 | 5,897 | 6,869 |
| 216 | 2,832 | 5,046 | | 1,132 | | | | 303 | | 6,481 | 9,313 |
| 217 | 5,124 | | | 883 | | | | | | 883 | 6,007 |
| 218 | 4,386 | | 2 | 1,232 | | 1 | | | | 1,235 | 5,621 |
| 219 | 1,662 | 7,476 | | 955 | | 1 | | 608 | 422 | 9,462 | 11,124 |
| 220 | 1,596 | 4,704 | | | | 4 | | 114 | | 4,822 | 6,418 |
| 221 | 1,800 | 3,860 | | | | | | | | 3,860 | 5,660 |
| 222 | 1,000 | 5,174 | 4 | 987 | | | | | | 6,165 | 7,165 |
| 223 | 2,800 | 4,997 | 148 | 1,829 | | | | 39 | | 7,013 | 9,813 |
| 224 | 5,100 | | 51 | 541 | | | | 18 | | 610 | 5,710 |
| 225 | 4,400 | | | | | | | 40 | | | 4,440 |
| 226 | 1,700 | 5,814 | | | | | | 178 | | 5,992 | 7,692 |
| 227 | 1,600 | 5,889 | | | | | | | | 5,889 | 7,489 |
| 228 | 1,000 | 5,306 | 58 | | | | | | | 5,364 | 6,364 |
| 229 | 1,000 | 4,515 | | | | | | 7 | | 4,522 | 5,522 |
| 230 | 1,500 | 4,902 | | | | 10 | | | | 4,912 | 6,412 |
| 231 | 2,000 | | | | | | | | | | 2,000 |

Appendix Table 1. Adjusted daily catch, escapement, and daily run of sockeye salmon in 1978 - continued.

| | | Catch | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day (i) | Escapement (i-2) | Lagoon (i) | Hook Bay (i+2) | Aniakchak (i+3) | Imuya (i+6) | Igvak (i+6) | Puale (i+8) | Beaver-Balboa (i+7) | Stepovak (i+6) | Total | Daily Run |
| 232 | 1,500 | | | | | | | | 74 | 74 | 1,574 |
| 233 | 500 | 3,168 | | | | | | | | 3,168 | 3,668 |
| 234 | 500 | 1,350 | | | | | | | | 1,350 | 1,850 |
| 235 | 500 | 1,511 | | | | | | | | 1,511 | 2,011 |
| 236 | 500 | 986 | | | | | | 78 | | 1,064 | 1,564 |
| 237 | 500 | 1,572 | | | | | | | | 1,572 | 2,072 |
| 238 | 500 | | | | | | | | 26 | 26 | 526 |
| 239 | 500 | | | | | | | | | | 500 |
| 240 | 250 | 664 | | | | | | | | 664 | 914 |
| 241 | 250 | 587 | | | | | | | | 587 | 837 |
| 242 | 250 | 213 | | | | | | | | 213 | 463 |
| 243 | 250 | | | | | | | | | | 250 |
| (Sept 1) 244 | 250 | 62 | | | | | | | | | 312 |
| 245 | 250 | | | | | | | | | | 250 |
| 246 | 250 | | | | | | | | | | 250 |
| 247 | 100 | 209 | | | | | | | | | 309 |
| 248 | 100 | 61 | | | | | | | | | 161 |
| 249 | 100 | 47 | | | | | | | | | 147 |
| 250 | 100 | | | | | | | | | | 100 |
| 251 | 100 | 6 | | | | | | 13 | | | 119 |
| 252 | 100 | | | | | | | | | | 100 |
| 253 | 100 | | | | | | | | | | 100 |
| 254 | 100 | | | | | | | 2 | 12 | | 114 |
| 255 | 100 | | | | | | | 16 | 131 | | 247 |
| 256 | 100 | | | | | | | | 135 | | 235 |
| 257 | 100 | | | | | | | | 126 | | 226 |
| 258 | | | | | | | | | | | |
| 259 | | | | | | | | | | | |
| 260 | | | | | | | | | | | |

Appendix Table 1. Adjusted daily catch, escapement, and daily run of sockeye salmon in 1978 - continued.

| Day (i) | Escapement (i-2) | Catch | | | | | | | | | Daily Run |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lagoon (i) | Hook Bay (i+2) | Aniakchak (i+3) | Imuya (i+6) | Igvak (i+6) | Puale (i+8) | Beaver-Balboa (i+7) | Stepovak (i+6) | Total | |
| 261 | | | | | | | | | 108 | 108 | 108 |
| 262 | | | | | | | | 6 | | 6 | 6 |
| 263 | | | | | | | | | 22 | 22 | 22 |
| 264 | | | | | | | | | 34 | 34 | 34 |
| 265 | | | | | | | | | | | |
| 266 | | | | | | | | | | | |
| 267 | | | | | | | | | | | |
| 268 | | | | | | | | | | | |
| 269 | | | | | | | | | | | |
| 270 | | | | | | | | | | | |
| TOTAL | 682,547 | 1,474,673 | 37,697 | 59,234 | 58,899 | 156,346 | 2,419 | 5,315 | 21,791 | 1,815,897 | 2,498,918 |