FRI-UW 8129
December 1981

CHIGNIK SOCKEYE STUDIES

by

Steven S. Parker, Ward Johnson,
and Donald E. Rogers

Annual Report

for the period July 1, 1980 - June 30, 1981

Project No. AFC65

Grant No. 81ABDUW8A

This project was funded in part by P.L. 89-304 (Anadromous Fish Act)
through the National Marine Fisheries Service.

Approved

Submitted March 4, 1982

Robert L Burgner
Director

FRI-UW 8129
December 1981

CHIGNIK SOCKEYE STUDIES

by

Steven S. Parker, Ward Johnson,
and Donald E. Rogers

Annual Report

for the period July 1, 1980 - June 30, 1981

Project No. AFC65

Grant No. 81ABDUW8A

This project was funded in part by P.L. 89-304 (Anadromous Fish Act) through the National Marine Fisheries Service.

Approved

Submitted March 4, 1982

Robert L Burgner
Director

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The Alaska Department of Fish and Game provided assistance of two kinds during the 1981 field season. The minicomputer-based scale digitizing equipment was provided by Scott Marshall through the ADF&G Stock Separation Office. Larry Nicholson and his staff at the ADF&G weir on Chignik River provided assistance which was greatly appreciated.

Robert Conrad programmed the mini-computer and performed the scale pattern analysis in the field. Peter Cummings assisted with scale collections.

This project was supported by: The National Marine Fisheries Service, Columbia Wards Fisheries, Alaska Packers Association, and private contributions from several Chignik vessel owners.

ABSTRACT

The development and execution of an in-season stock separation program at Chignik suggests that scale pattern analysis using a two-class linear discriminant function is a viable and important supplement to the present management system. Details of the program methodology are given with an evaluation of its efficiency and effectiveness. Results of allocating the sockeye run into its two component stocks indicates that the 1981 run was approximately 10 days earlier than the average time-of-entry (TOE) curve predicts, and supports the decision made early in the run by ADF&G to shift the curve forward in time by 10 days.

The scale pattern stock separation concept is inadequate as a complete substitute for the present management system. The controlled escapement plan is based on the assumption that stock composition is predictable over the duration of the sockeye run, whereas scale pattern analysis produces new estimates of stock composition with each input of new data. It is suggested that the optimum management system is a combination of the average TOE curve verified for accuracy by intensive in-season scale sampling and discriminant function analysis.

1.0 INTRODUCTION

The production of sockeye salmon in the Chignik lakes has been studied extensively by the Fisheries Research Institute (FRI), in cooperation with the Alaska Department of Fish and Game (ADF&G), since 1952. Two major investigations conducted in the system sought to: 1) identify ecological factors limiting the production of sockeye in the lakes (see Narver 1966); and 2) evaluate historical stock production data (see Dahlberg 1968) in order to recommend optimum escapement levels for rebuilding each of the two principal stocks composing the total run. These studies suggested that the decline in sockeye production in the Chignik watershed was not related to a loss of potential spawning area, but rather to density dependent competitive interactions between sockeye fry and fish populations resident in the nursery lakes. From their results, Narver (1966) and Dahlberg (1968) recommended the present escapement goals as being those that would maximize the production of sockeye fry in each nursery lake.

Optimum escapements are approached by regulating the commercial harvest. Decisions to open or close the fishery are based on historical entry patterns of the early and late runs, escapement goals, and escapement to date during the season. A primary feature of this controlled escapement system is the logistic time-of-entry (TOE) curve (Dahlberg 1968) which is used to estimate the relative proportions of each stock present in the catch and escapement on a daily basis. The Dahlberg curve is the result of an eight-year tagging program at Chignik. Fish tagged in Chignik Lagoon were monitored through the ADF&G weir on Chignik River and ultimately to their spawning grounds. The curve currently used by ADF&G in regulating the harvest is an average of the eight year-specific curves derived from the tagging studies (Fig. 1).

Although the average TOE curve evidently has been an effective run separation tool since 1964, two properties of the method are recognized as potential sources of error in apportioning daily runs into the component stocks. As an average curve, small variations in run timing between years may not be compensated for, although in some years the midpoint of the curve arbitrarily has been advanced 7-10 days in response to notably early runs. However, Marshall, et al (1980) point out that in years of large returns, small variations in run timing may result in substantial misappropriations of catch and escapement to the major stocks. The other recognized problem is that the logistic run separation curve is appropriate for assigning catch and escapement to each stock only when the stocks return in approximately equal magnitudes (Pedersen and Petersen 1971). When this condition is not met, significant overallocation to the stock in low abundance occurs.

Recent applications of discriminant function analysis (Fisher 1936; Lachenbruch 1975) to problems of mixed-stock fishery management (Anas and Murai 1969; Parsons 1972; Cook and Lord 1978; Pella and Robertson 1979) have shown great promise for estimating the relative proportions of stocks present in a mixed-stock fishery. The advantage of a stock

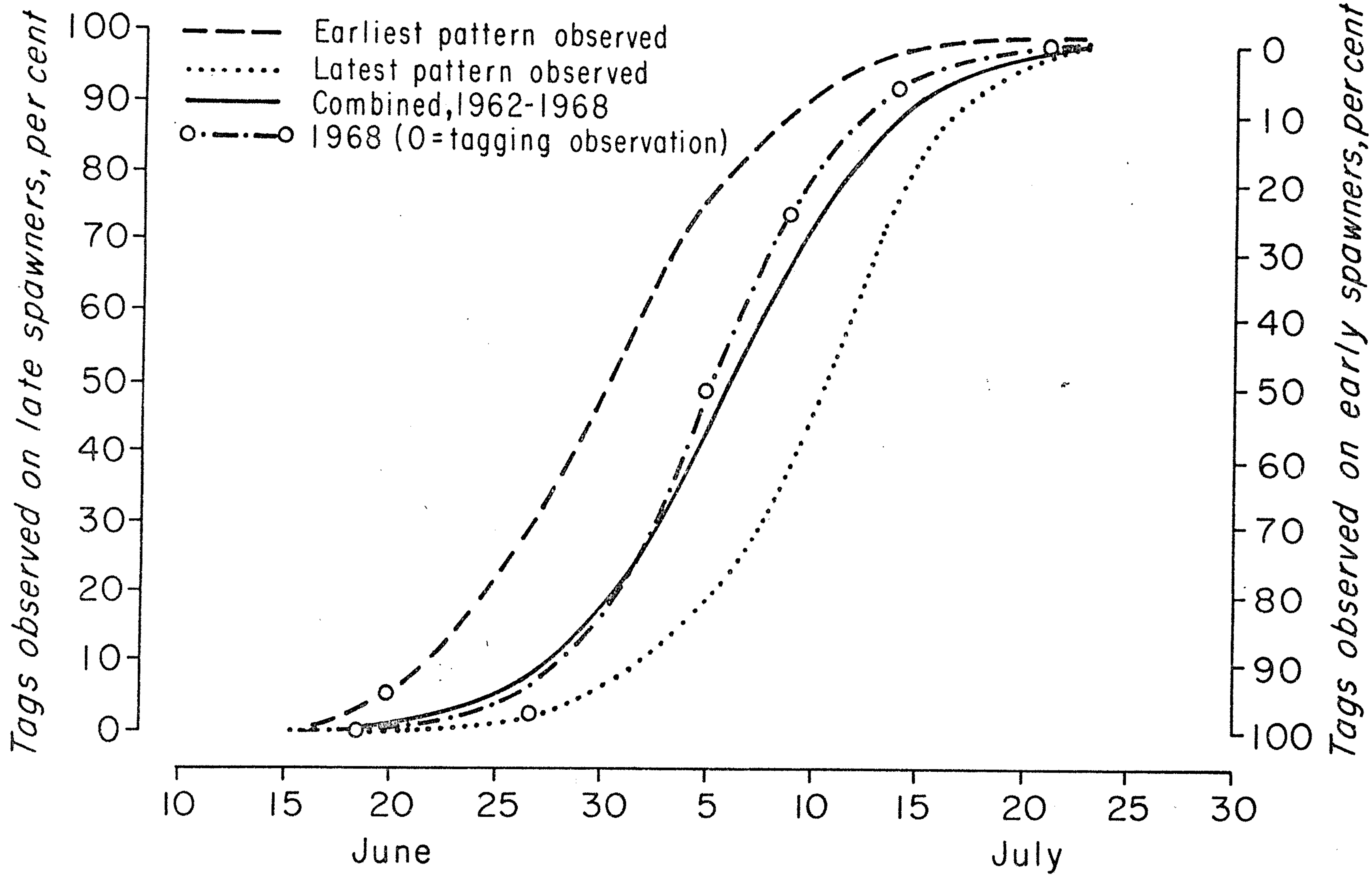

Fig. 1. Pattern of time-of-entry for Black Lake (early) and Chignik Lake (late) stocks, 1962-1968 (from Parr and Pedersen 1969).

separation method based on discriminant function analysis is that information on the stock composition of a fishery may be continuously updated with direct evidence taken from the commercial catch. This ability circumvents problems associated with tagging and theoretical modelling of run dynamics.

Marshall et al. (1980) employed discriminant function analysis in allocating the 1978 Chignik sockeye run into component stocks. In their view, stock separation using scale pattern recognition techniques is superior to the continued use of the average TOE curve because a TOE curve based on scale data is independent of both yearly variations in run timing and differences in the magnitude of the early and late runs. Because the scale pattern technique provides direct evidence of the relative proportions of each stock in the catch and escapement at each sampling date, a test is possible of the assumption that the entry pattern of the two stocks follows that predicted by the average TOE curve. The scale pattern method thus provides: 1) a daily evaluation of the status of the run in terms of catch and escapement by stock; and 2) a measure of the reliability of the average TOE curve in accurately modelling the transition from early run to late run through the season. On the basis of their results, they recommended that further studies be carried out at Chignik to better evaluate the potential of scale pattern analysis for improved fishery management. Moreover, since the potential usefulness of the pattern recognition technique as a management tool is not fully exploited in post-season analyses of the run, it was suggested that an in-season stock separation program be initiated.

We report herein the results of the first of a two-year in-season stock separation program at Chignik. The objectives of the report are to:

1. Present the stock separation methodology developed for in-season use at Chignik in 1981. All phases of the procedure are discussed, with emphasis on problems encountered in sample collection and allocating catch and escapement in season by alternative methods.

2. Estimate the numbers of fish of each principal stock in the daily catch and escapement by age group. Comparisons are made between the numbers obtained from each of two different analytical treatments of the scale pattern data.

1.1 Description of the Study Area

The Chignik watershed lies at the westerly inflection of the Alaska Peninsula approximately 400 km southwest of King Salmon (Fig. 2). Black Lake has a surface area of about 41.1 km^2 and an early summer mean depth of 3 m. The lake may lose possibly one-third of its volume by late summer. Alec River tributaries and Fan Creek provide most of the spawning grounds for sockeye which utilize Black Lake as a nursery area. Black

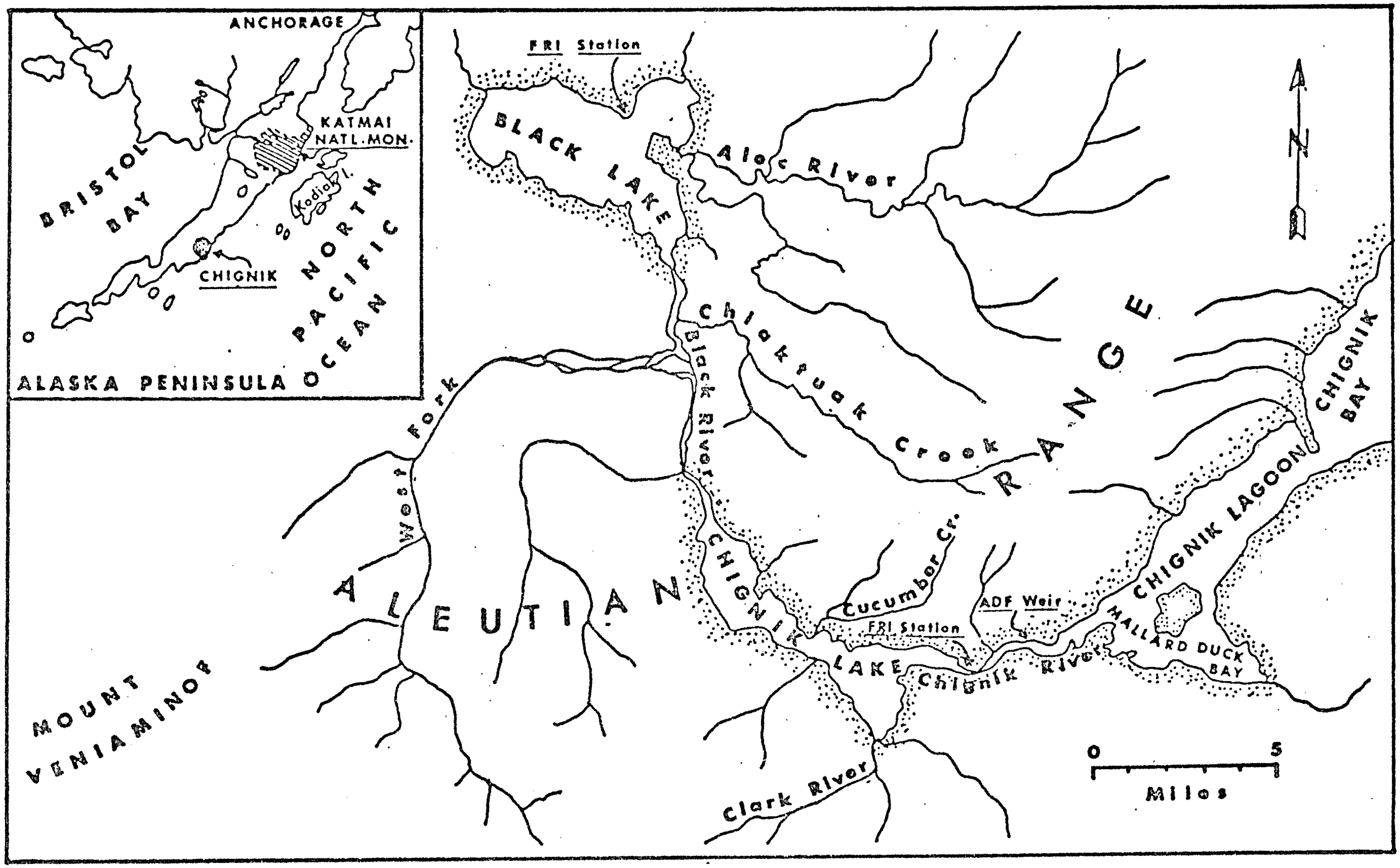

Fig. 2. Map of the Chignik River watershed with inset of western Alaska.

River (12 km long) connects Black Lake and Chignik Lake. Two major spawning streams, Chiaktuak and West Fork, flow into Black River. Progeny of spawners in these tributaries migrate downstream at emergence. Chignik Lake has roughly one-half the surface area and over six times the volume of Black Lake. Most spawning activity occurs along Hatchery Beach and in Clark River tributaries. The Chignik River (7.2 km) drains Chignik Lake into Chignik Lagoon. A seasonal weir maintained by the Alaska Department of Fish and Game (ADF&G) is located about 3 km from the river mouth.

A survey of 26 sockeye salmon nursery lakes in the Bristol Bay/ Alaska Peninsula region characterized the Chignik system as high in number of spawners per unit of surface area (second overall), productivity and standing crop of phytoplankton (first overall), and total dissolved solids (second overall) (Burgner, et al. 1969). Details of the survey specific to the Chignik system are given in Narver (1966).

1.2 Review of Pertinent Literature

The existence of distinct early and late segments of the sockeye run to Chignik was detected early in the history of the fishery, but Narver (1963) first detailed the relationship between timing of entry and geographical distribution of spawners within the watershed. Eight major and three minor spawning groups were identified on the basis of lacustrine scale pattern and age, time of entry of the returning adults, and time and location of spawning. Table 1 summarizes these groups and their identifying characteristics. Returning sockeye bound for the tributaries of Black Lake or the upper reaches of Chiaktuak Creek and West Fork enter the system from early June through early July, while those bound for the lower reaches of Chiaktuak, West Fork, and Chignik Lake tributaries enter from late June through September. The two distinct runs observed in the fishery since its inception therefore are conglomerates of several spawning groups which sequentially "load" the watershed.

Holmes[1] first reported the variability in scale patterns between sockeye which reared in Black Lake and those which reared in Chignik Lake. He noted that the scales of juvenile sockeye collected in Black River in June showed considerably more growth of the year than scales sampled from juveniles in Chignik River. Similarly, Roos[2] analyzed the lacustrine portion of scales taken from adults on the spawning

---

[1]Letter from Harlan Holmes to Dr. Willis H. Rich, July 26, 1928. In Univ. Washington Fish. Res. Inst. Archives.

[2]Roos, John F. 1960. Life history of red salmon *Oncorhynchus nerka* (Walbaum) at Chignik, Alaska. Univ. Washington Fish. Res. Inst. 56 pp. (unpublished manuscript).

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

grounds and reported that the mean number of circuli and size of the freshwater zone was greater for Black Lake spawners of age I and age II than for Chignik Lake spawners of these ages. He attributed the differences to more favorable growing conditions in Black Lake.

Narver (1966) verified that conditions for fry growth were more favorable in Black Lake than in Chignik Lake. His conclusion was supported primarily by 1) the growth rate of fry in Black Lake, which was essentially linear and rapid relative to that of fry rearing in Chignik Lake; and 2) the virtual absence of age II fry in Black Lake in midsummer compared to the apparent abundance of age II juveniles in Chignik Lake. On the basis of calculated carrying capacities of the nursery lakes for sockeye fry, Narver (1966) suggested escapements of 411,000 to Black Lake and 256,000 to Chignik Lake spawning grounds.

It remained for Dahlberg (1968) to develop an independent estimate of optimum escapement levels and to devise some method for allocating the total run into its principal components in order to achieve desired escapements. Tagging studies performed in the years 1962-69 provided the data necessary to model the transition from early to late run during the period of unknown stock composition. This logistic time-of-entry curve was used to apportion historical Chignik runs into component stocks for spawner-recruit analysis. Results indicated that the maximum return per spawner during the years of high sockeye production in Chignik (1922-33) occurred at estimated escapements of 383,000 to Black Lake and 395,000 to Chignik Lake. The recommended escapement level for Chignik Lake was revised to 256,000 to allow for fry emigrations from Black Lake. The logistic TOE curve has been used since 1964 for in-season allocation of the catch and escapement to the early and late runs.

Marshall et al. (1980) developed a logistic TOE curve for the 1978 sockeye run from data produced by discriminant function analysis of scales taken in the commercial catch. Their post-season evaluation of the catch and escapement by age group showed that pattern recognition methods could be very effective for separating early run and late run fish in mixed fishery samples. This capability allowed somewhat more flexibility in apportioning the daily run, because the timing of entry, arrival rates, and relative proportions of the two major stocks were estimated directly from samples taken during the run rather than from the rigid schedule provided by the average TOE curve. The advantages to a year-specific separation curve were emphasized. Continued studies of stock separation using scale pattern analysis, and establishment of an in-season capability, were recommended.

1.3 Scale Pattern Analysis

Discriminant function analysis of stock-specific scale characters is based on the assumption that stocks of fish which are genetically or geographically isolated reflect differences of life history in the circular patterns on their scales. The analysis is straightforward in concept but rather more complex in application. Briefly, selected characters on scales from fish of known stocks are measured in units of distance (resolution = 0.001") and number (e.g., circuli produced in the first year in freshwater). A sample ideally in excess of 200 scales is taken from each known stock to construct statistically a mathematical representation of the "standard" or average scale pattern for each stock. Scales from fish of unknown origin then may be processed in identical fashion and allocated to either known stock on the basis of how closely their scale patterns coincide. Since the growth rates and lacustrine residence times of sockeye fry are dissimilar between the two nursery lakes of the Chignik system (Narver 1963, 1966; Parr 1972; Marshall 1977), scale patterns formed during freshwater residence should be distinguishable between stocks. The presence of characteristic patterns on the scales of returning adults theoretically allows for a high degree of accuracy in separating by discriminant function analysis the commercial catch and escapement into component stocks.

2.0 METHODS

2.1 Scale Collection

In applying pattern recognition techniques to scale pattern analysis it is imperative that artificial sources of variation in scale measurements be minimized so that natural differences in scale growth between stocks are emphasized. Consistency in all phases of the methodology is essential, but it is perhaps most important in the collection of scales for the analysis. Most scales collected for this study were either "preferred scales" or were from the "preferred area" on the fish (Clutter and Whitesel 1956). In the event no scales remained in the preferred area (as sometimes occurs in commercial catch sampling), a scale was taken from the identical scale row and diagonal on the right side of the fish or the fish was not sampled. All scales taken from the right side were noted as "not preferred scale" in further analyses.

2.1.1 Early Run Standards

Scales used as early run standards were removed from spawners at the outlet of Black Lake. Routine sampling at this site provides age composition, sex ratio, and length-at-age data for the Black Lake stock. We assumed that no mixing of stocks occurs at the outlet of Black Lake since it is reasonably well removed from the nearest Black River tributary spawning ground. It is possible that some early-returning adults which spawn far up Chiaktuak Creek (Fig. 2 and Table 1) may temporarily mix with Black Lake fish at the sampling site before dropping back to the mouth of Chiaktuak. However, we consider this possibility remote and feel that the potential for variance in the early run standard added by such behavior is insignificant.

Six separate sampling events between June 9 and June 22 produced 1233 scales from the early run escapement. Because the proportion of 2.3 age fish in the early run was unexpectedly low (see Age Composition, Section 3.1), only 140 of these scales were suitable as 2.3 age early run standards. Although a standard sample of 200 scales generally is desirable, the statistical methods employed in this study (see Data Analysis, Section 2.3) permit smaller sample sizes when necessary.

2.1.2 Late Run Standards

In-season acquisition of scales for the late run standard is not feasible because pure samples of scales from late run fish cannot be obtained until well after the period of transition from early to late run. Alternative methods for developing late run standards were investigated in anticipation of the 1981 field season. These were:

1. The use of scales from precocious fish of a year class as late-run standards for the following year. Marshall et al. (1980) indicated that only the freshwater portion of Chignik sockeye scales is

useful in the discriminant analysis. We hypothesized that the relevant growth patterns on 2-ocean age scales should be identical to or, at least, proportional to those of 3-ocean scales taken from fish of the same year class. Initial tests of the hypothesis showed that substituting 2.2 age scales from the 1979 late run as the 1980 2.3 age late-run standard provided a classification accuracy of nearly 78% in separating early-run 2.3's from late-run 2.3's in the 1980 scale collection. This compares favorably with a classification accuracy of about 82% obtained with the optimum set of data.

2. Pooling late-run scales of appropriate age groups from previous years to serve as late-run standards for the current year. This method assumes that long-term differences in fry growth rates between lakes are significantly greater than short-term differences in growth rates between years in Chignik Lake. The hypothesis was tested using pooled 3-ocean scales from the 1978 and 1979 late runs as late run standards in comparison with 3-ocean late run scales from the 1980 run. In order for this method to be successful, the variances about specific scale characters from years-pooled samples must be small enough to allow a clear separation of scale patterns unique to each stock.

Our tests indicated that the "years pooled" method was not adequate, hence we used as late run standards 200 scales from 2.2 age fish sampled from the 1980 late run. Only scales taken after July 21, 1980 were used as we felt that the possibility of contaminating the late run standard with early run scales was unacceptably high in samples taken prior to this date.

2.1.3 Unknowns

Sockeye of unknown origin were sampled at 2-, 3-, or occasionally, 4-day intervals as permitted by the accessibility of fish in the commercial catch. All sampling was conducted within Chignik Lagoon, and attempts were made to ascertain the place of capture of all fish sampled. Time constraints of 2 hr above and below high slack water allowed sampling of about 320 fish on each occasion.

2.2 Age Composition

Scales which had been pressed into acetate cards were projected 10x to the screen of a microfiche reader during the early part of the season (prior to 7/3) and 43x thereafter. All scales were aged using criteria established by Marshall (1977) for aging Chignik sockeye. The relatively low magnification at 10x often made aging the freshwater portion of scales difficult. In fact, a review at 43x of scales aged before 7/3 revealed a substantial bias toward misclassifying 1.3 age fish as 2.3's (Table 2). However, all scales selected for the discriminant function

Table 2. Comparison of age composition estimates by viewing scale images at 10x and 43x. All scales taken after 7/1 were aged at 43x.

	10x		43x	
Date	% 1.3	% 2.3	% 1.3	% 2.3
6/3	90.6	5.1	88.3	7.1
6/8	80.8	9.4	79.9	4.0
6/11	70.5	19.8	78.2	12.1
6/15	60.5	30.5	77.3	13.6
6/17	57.9	26.6	68.1	16.7
6/19	65.1	26.4	74.2	17.1
6/22	64.3	25.3	69.8	19.4
6/24	50.8	41.1	63.7	28.0
6/28	45.5	50.0	54.7	41.3
7/01	44.4	50.0	40.6	53.1
7/03			39.6	56.2
7/06			26.5	70.7
7/09			18.4	74.8
7/12			18.5	76.0

analysis were projected 100x to a digitizer screen and thereby verified before measurement.

We calculated the age composition for each stock separately using the subtraction method of Marshall and Burgner (1977). This method uses the age composition of the total run (numbers by age group) as determined by fishery scale samples and subtracts the numbers by age group calculated for the early run to estimate the numbers by age group in the late run.

2.3 Data Analysis

A minicomputer-based scale digitizing system was used to record, store, and edit raw data. Biological information accompanying each measured scale was compiled on a pre-formatted CRT display along with other identifying data. Scale images projected at 100x onto the surface of an electronic digitizer were measured by moving a hand-operated cursor across the projected image. Measurements initialized at the scale focus recorded the distance and number of circuli from the focus to the end of lacustrine scale growth and the number of circuli within each annulus. The scale radius from which these measurements were made was selected in a manner described by Narver (1963) and is considered to be standard practice. A FORTRAN computer program was written to compile, interpret, and store data. Biological data and other identifiers, scale characters measured, their card-image format, and a brief explanation of codes are presented in Table 3.

Thirteen variables measured or counted from the scales in each standard sample and 21 variables added by transformation of scale measurements were analytically reduced to the fewest that significantly contributed to the separating power of the discriminant function. A FORTRAN program designed to be used on Vector Graphics minicomputers provided an initial set of "best" variables for inclusion in the procedure. Program FSTAT (Conrad and Burgner 1981) was used to calculate an F-statistic for each variable. Larger F-values indicate a greater distance between variable group centroids.

Variables selected by FSTAT were entered into program DSCRM 2 (Conrad and Burgner 1981) to estimate classification accuracy of the two-group linear discriminant function. A key advantage to DSCRM 2 is the leaving-one-out approach (Lachenbruch and Mickey 1968) to estimating classification accuracy. This feature allows for much smaller standard sample sizes because each scale in the standard is classified by all other scales in the sample, rather than one-half of the sample being used to classify the other half of the sample.

Finally, program CLASS (Conrad and Burgner 1981) was used to estimate the relative proportions of early and late run fish in samples taken in the fishery between June 11 and July 12. This program adjusts

Table 3. Biological data and other identifiers, scale characters measured, their format on key-punched cards, and explanations of coded data for sockeye scales.

Identifier	Card Column	Explanation
Fish number	1-2	Refers to position of scale on card
Sample number	3-6	Scale card number
Date	7-8 9-10 11-12	Year of sample Month Day
Location	13	1 = Chignik Lagoon 2 = Chignik River 3 = Chignik Lake 4 = Black Lake
Stock	14	1 = Black Lake 2 = Chignik Lake 3 = Unknown
Age	15-16	Column 15 refers to freshwater (FW) age, 16 refers to oceans age
V1	17-18	Number of circuli in fist FW zone
V1	19-22	Size of first FW zone
V3	23-24	The number of the first circulus of the widest pair in the first FW zone
V4	25-28	Distance between the pair of circuli in V3
V5	29-30	Number of circuli in the second FW zone
V6	31-34	Size of the second FW zone
V7	35-36	The number of the first circulus of the widest pair in the second FW zone
V8	37-40	Distance between the pair of circuli in V7
V9-V13	41-60	Five fields of four digits recording the distance from the scale focus to the outer edge of every third circulus in the freshwater growth zone

proportional estimates for classification error using the procedure of Cook and Lord (1978).

2.3.1 Allocation of Daily Catch and Escapement

Estimation of run magnitude on a daily basis was computed by adjusting the dates of catch and escapement to account for migration time (Appendix Table I). The numbers of fish in the catch and escapement were provided by ADF&G (Nicholson per. comm.). We adjusted all catches to coincide with the dates of escapements at the ADF&G weir on Chignik River. We assumed a 2-day lag time between catches in Chignik Lagoon and appearance at the weir of fish which had avoided capture (Dahlberg 1968). For the distant fisheries we used a migration rate of 20 miles per day (Dahlberg 1968; French, et al. 1976). The estimated travel time between the ADF&G weir and the distant fisheries is: Cape Igvak, 8 days; Chiginagak, 7 days; Aniakchak, 5 days; Kujulik, 4 days; Hook Bay, 3 days. The Cape Igvak catch of Chignik-bound sockeye was estimated as 80% of the total Cape Igvak catch (Nicholson pers. comm.). Catches in the Western and Perryville districts (total = 21,168) were not included.

We chose to evaluate two alternative methods for allocating catch and escapement. We felt a comparison of catch and escapement statistics produced by 1) corrected proportional estimates smoothed to fit a logistic TOE curve (SPE) and 2) unsmoothed corrected proportional estimates (CPE) by sampling date would be of value in light of certain compromises which must be met when allocating the daily run using either method. Briefly, prior experience in using the SPE method indicated that the shape and inflection point of the logistic form of the curve is extremely sensitive to fitting the proportional estimates obtained by discriminant analysis. Consequently, inaccuracy of proportional estimates resulting from bias in scale sampling, measurement error, or classification error may be magnified by the curve fitting procedure.

However, the alternative CPE method is not without drawbacks. In a similar exercise using scales sampled during the 1979 sockeye run to Chignik, the estimated relative proportions by day were shown to be quite variable between sampling dates prior to and subsequent to the transition from early to late run (Table 4). This variability makes questionable the interpolation of relative proportions of early and late fish in daily runs on intervening dates and undoubtedly contributes some uncertainty to the allocation of catch and escapement.

2.3.1.1 Smoothed Proportional Estimates (SPE)

In this method, estimated proportions of each stock in the catch by sampling date are fitted to a logistic curve of the form

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

where:

Table 4. Proportional estimates from a two-class discriminant function analysis of 2.3 age sockeye in the 1979 Chignik run.

Date	Corrected proportions (early)	Corrected proportions (late)	Smoothed proportions (early)	Smoothed proportions (late)
6/21	.752	.248	.914	.086
6/23	.854	.146	.843	.157
6/27	.595	.405	.575	.425
6/28	.880	.120	.490	.510
7/1	.492	.508	.255	.745
7/3	.120	.880	.147	.853
7/7	.104	.896	.042	.958
7/8	.001	.999	.030	.970
7/10	.001	.999	.015	.985
7/12	.196	.804	.008	.992

p = proportion of late run fish
e = base of Naperian logarithms
t = time (in Julian dates)
a, b = constants

Values of "a" and "b" in equation (1) are obtained via the smoothing function:

$$a + bt = -\ln \frac{1-p}{p} \qquad (2)$$

where "p" again is the proportion of late run fish on day t estimated from discriminant function analysis. In this linearized form of equation (1) "a" is the intercept of the regression and "b" is the slope. Two properties of the smoothing function must be recognized during its use: 1) it is extremely sensitive to the values of $\log_e$-transformed proportional estimates; and 2) the $\log_e$-transform of 0.000 or 1.000 is a complex number. Therefore, any sample classified by the discriminant function as 0% or 100% late run was assigned a proportional estimate of 0.001 or 0.999, respectively. Furthermore, since the number of decimal places in the proportional estimates alters the resultant $\log_e$-transformed value (e.g., 0.01 = -4.60517; 0.001 = -6.90776; 0.0001 = -9.21034), and hence, the slope and intercept of the regression line, we arbitrarily chose three decimals for proportional estimates. Finally, because the values of "a" and "b" from the regression are computed in $\log_e$-scale, their estimated values were carried to five decimal places for insertion in equation 1.

2.3.1.2 Corrected Proportional Estimates (CPE)

Proportional estimates for days on which no sampling occurred were obtained by linear interpolation between proportional estimates for dates on which sampling occurred. For estimating proportions of late fish in the run prior to the first sampling date (6/11, p = .667) and after the last sampling date (7/12, p = .970) we arbitrarily assigned values of .001 to 6/5 and .999 to 7/15. These dates are ± 20 days of the calculated midpoint of the transition period (6/25, p = .495).

3.0 RESULTS AND DISCUSSION

3.1 Age Composition

Table 5 summarizes the age composition data for the 1981 sockeye return. Figure 3 illustrates the trends in age composition expressed as percentages of the total run by day. The early phase of the return was composed primarily of 1.3 age fish, with the other ages constituting a relatively small fraction until 6/22. The increasing abundance of 2.3's in the commercial catch samples was mirrored by a decline in abundance of 1.3's, and roughly followed by about 5 days the transition from early run to late run (Fig. 4). The correlation of age composition with stock composition in the commercial catch is consistent with past observations that the early (Black Lake) stock produces mainly 1-check smolts and the late (Chignik Lake) stock produces primarily 2-check smolts. It is this observed stock-specific freshwater age characteristic that forms the basis for Marshall and Burgner's (1977) contention that the use of fishery age composition statistics may generate misleading estimates of the early run age composition in some years.

Age composition estimates for the Black Lake escapement are given in Table 6. Trends in age composition over time are apparent but statistically not significant (Students' "t"; 95%). Differences in numbers of fish allocated to each age group using an average age composition as opposed to following the observed trends in calculating the age composition of the early run are surprisingly minor:

	Age Group					
	0.2	1.2	2.2	0.3	1.3	2.3
Average age comp	1,293	128,039	16,425	9,959	968,701	169,037
Age comp by day	1,175	123,223	15,603	8,755	972,223	172,476
Percent difference	9.1	3.8	5.0	12.1	0.4	2.0

We computed absolute numbers of early run fish by age group using the unweighted average age composition. The numbers of early run fish by age group were subtracted from the estimated numbers of fish of each age in the total return to obtain an estimate of the numbers of late run fish by age group.

Table 5. Age composition of the 1981 Chignik sockeye run from samples collected in the fishery.

Date		Age group												n
		1.1	2.1	0.2	1.2	2.2	3.2	0.3	1.3	2.3	3.3	1.4	2.4	
6/3	Number				10	1			234	19				265
	Percent				3.8	0.4			88.3	7.1				
6/8					20	4		8	230	26				288
					6.9	1.4		2.8	79.9	9.0				
6/11				1	21	2	1	3	226	35				289
				0.3	7.3	0.7	0.3	1.1	78.2	12.1				
6/15				1	10	10		2	205	36		1		265
				0.4	3.8	3.8		0.7	77.3	13.6		0.4		
6/17		1			20	15		2	175	43		1		257
		0.4			7.8	5.8		0.8	68.1	167		0.4		
6/19					21	4		1	221	51				298
					7.1	1.3		0.3	74.2	17.1				
6/22					21	2		3	180	50	1	1		258
					8.1	0.8		1.1	69.8	19.4	0.4	0.4		
6/24					18	2		2	177	78	1			278
					6.5	0.7		0.7	63.7	28.0	0.4			
6/28					7	2		1	139	105				254
					2.8	0.8		0.4	54.7	41.3				

Table 5. Age composition of the 1981 Chignik sockeye run from samples collected in the fishery - continued.

Date		Age group 1.1	2.1	0.2	1.2	2.2	3.2	0.3	1.3	2.3	3.3	1.4	2.4	n
7/1	Number				9	3	1		97	127	1	1		239
	Percent				3.8	1.3	0.4		40.6	53.1	0.4	0.4		
7/3					7	3		1	105	149				265
					2.7	1.1		0.4	39.6	56.2				
7/6					1	5		1	67	179				253
					0.4	2.0		0.4	26.5	70.7				
7/9					3	9	1		43	175	3			234
					1.3	3.8	0.4		18.4	74.8	1.3			
7/12			1		3	8			47	193	1		1	254
			0.4		1.2	3.1			18.5	76.0	0.4		0.4	

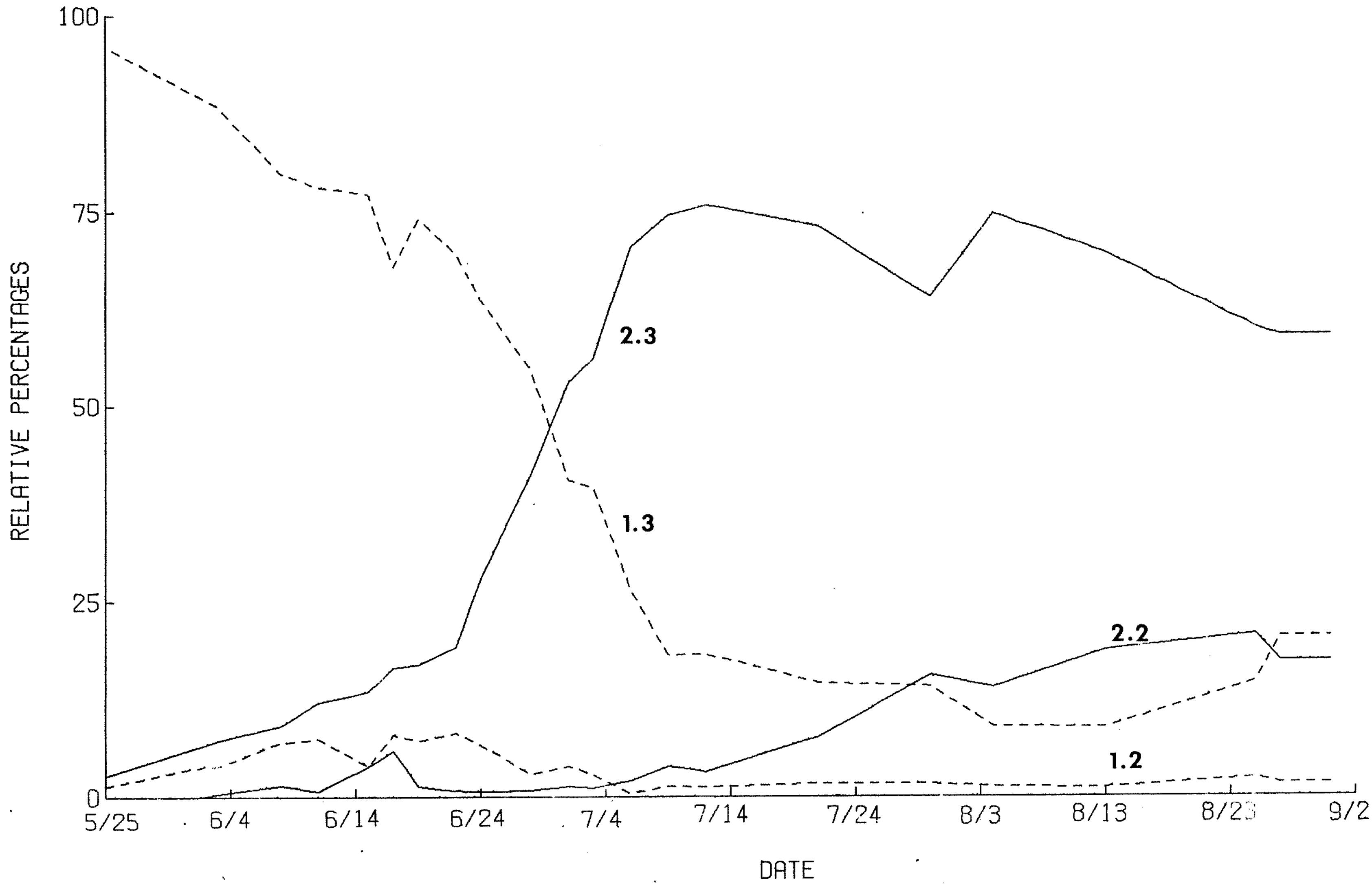

Fig. 3. Daily age composition of the 1981 sockeye run expressed as percentages. Minor age groups are not shown.

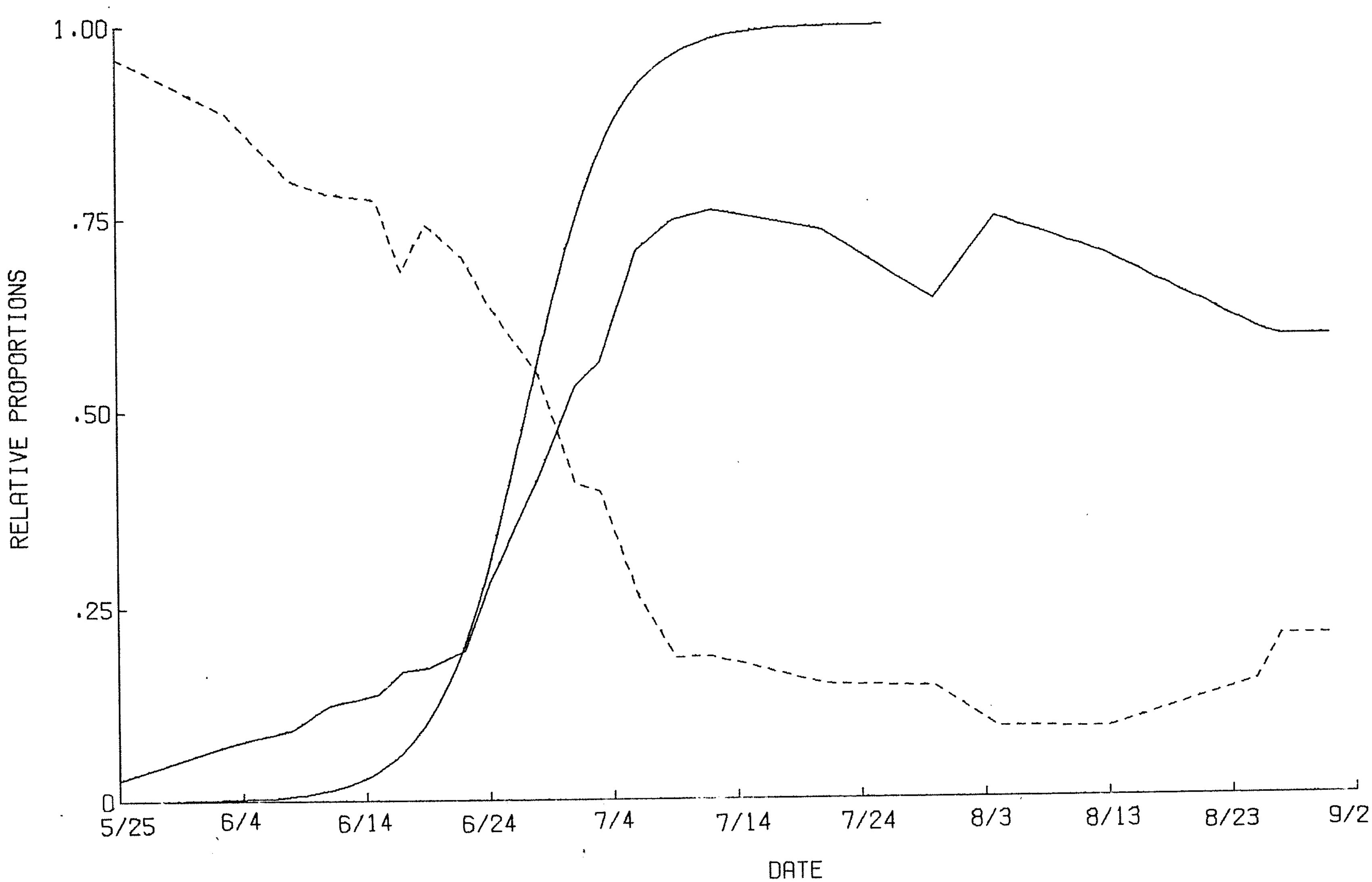

Fig. 4. Timing of the transition in age and stock composition of samples taken in the commercial fishery.

Table 6. Age composition of the early run from samples collected at the outlet of Black Lake, 1981.

Date		Age group 0.2	1.2	2.2	0.3	1.3	2.3	n
6/9	Number		11	1	2	100	14	128
	Percent		8.6	0.8	1.6	78.1	10.9	
6/10		1	36	4	2	159	20	222
		0.5	16.2	1.8	0.9	71.6	9.0	
6/12			13	5	2	143	30	193
			6.7	2.6	1.0	74.1	15.6	
6/13			24	1	2	132	22	181
			13.3	0.6	1.1	72.8	12.2	
6/21			12	3		133	34	182
			6.6	1.6		73.1	18.7	
6/22			11			144	22	177
			6.2			81.4	12.4	
Total		1	107	14	8	811	142	1083
		0.1	9.9	1.3	0.7	74.9	13.1	

3.2 Estimation of Relative Proportions

From the results of program FSTAT and the sequential entering of ranked variables into the discriminant function, we found that the following three variables provided maximum classification accuracy:

1) Total number of circuli in the freshwater growth zone.
2) Total size of the freshwater growth zone, excluding plus growth.
3) The ratio of the size of the first freshwater growth zone to the size of the total freshwater growth zone, excluding plus growth.

Because identification of plus growth on scales was often equivocal, we excluded this feature from analyses.

The classification matrix calculated using the "leaving-one-out" method is presented in Table 7. Although classification accuracy was

Table 7. Classification matrix for 2.3 age sockeye in the 1981 return.

	Decisions	
Stock	Percent correct	Percent incorrect
Black Lake	68.0	32.0
Chignik Lake	65.0	35.0
Mean classification accuracy = 66.5%		

somewhat lower than expected, we believe the resultant proportional estimates computed for each sample provide a reasonable reflection of the actual mixing proportions of the two stocks in the fishery. The source(s) of error causing the reduced classification accuracy presently eludes us, but two possibilities are likely. First, the use of scales from 2.2 age Chignik Lake fish from the 1980 return as the 1981 2.3 Chignik Lake standard may have contributed to a reduction in segregating power of the discriminant function. Some evidence suggests that the early growth of precocious fish is rapid relative to others of a cohort. Since the separation of Black from Chignik Lake fish is based on the presumed fast freshwater growth of Black Lake fish compared to Chignik Lake fish, the hypothesized rapid growth of precocious Chignik Lake fish used for the 1981 standard may have diminished the natural variation in the scale patterns between stocks. A second potential factor involves the measurement and analysis of individual scales. Scales composing the late run standard were measured in the lab at 200x prior to leaving for the field season. All computer software was programmed in the lab for scale measurements taken at 200x. However, logistical problems precluded the use of a 200x lens in the field, hence all scale measurements taken in-season at 100x were transformed to 200x by the minicomputer to be compatible with prewritten programs and the existing late run standard. Any measurement error occuring at 100x consequently was doubled during transformation.

3.2.1 Run Allocation

The relative proportions of early and late run fish present in the fishery on each sampling date, as estimated by discriminant function analysis, are given in Table 8. A logistic TOE curve has been fit to the data in Fig. 5a. Figures 5b-c illustrate the differences in total run allocation using the SPE method (Fig. 5b) and the CPE method (Fig. 5c). It is apparent from the figures that the SPE method allocated significantly more fish to the early run than did the CPE method. This is attributable primarily to the estimate of relative proportions in the sample taken on 6/11 ($p = 0.667$) during the period of large daily returns. The SPE curve minimized the impact of that single sample by allocating to the late run less than 5% of any daily total prior to 6/17, whereas the CPE method maximized its impact because proportional estimates for dates prior to 6/11 and between 6/11 and 6/15 were derived from linear interpolation. The SPE schedule allocated 16,813 fish to the late run during the period 6/6 to 6/15, while the CPE schedule allocated 211,408. The difference of 194,595 was partially offset by differences in the two methods over the remainder of the run; however, the late run total as estimated by CPE was 168,531 greater than that estimated by SPE. Of this total, 43,062 was the difference in estimated late run escapements and 125,469 was the difference in catch (Table 9). Estimates of daily catch and escapement by run using SPE and CPE are presented in Appendix Tables II and III, respectively.

The inflection point of the logistic curve --that point where theoretically each stock is equally abundant in the run-- falls on 6/25, fully 10 days earlier than the average date observed during the tagging studies in 1962-69. The ADF&G detected the earliness of the run early in the season and arbitrarily shifted their management schedule forward by 10 days to compensate. Nonetheless, the point must be made that yearly run timing may be highly variable and in some years not sufficiently pronounced to be detectable. In years of large returns this may produce significant errors in partitioning the run, while in years of low or unequal returns to both stocks the placement in time of the TOE curve early in the season, when actual run strength is not yet known, can be extremely confusing and ambiguous.

3.3 Age Composition by Run

In Table 10 we compare age composition estimates for each run calculated using the alternative run allocation methods in conjunction with the subtraction method of Marshall and Burgner (1977). Of immediate interest is the apparent overestimation by both allocation methods

Table 8. Proportional estimates derived from the two-class discriminant function analysis of unknown 2.3 age sockeye in the fishery by sampling date, 1981.

		Smoothed proportions (SPE)		Corrected proportions (CPE)	
Date	N	Black	Chignik	Black	Chignik
6/11	50	.987	.013	.333	.667
6/15	46	.963	.037	1.000	.000
6/17	50	.939	.061	.697	.303
6/19	50	.899	.101	.939	.061
6/22	49	.798	.202	.980	.020
6/24	75	.697	.303	.636	.364
6/28	75	.438	.562	.111	.889
7/1	75	.257	.743	.030	.970
7/3	75	.168	.832	.232	.768
7/6	75	.082	.918	.192	.808
7/9	75	.038	.962	.000	1.000
7/12	75	.017	.983	.030	.970

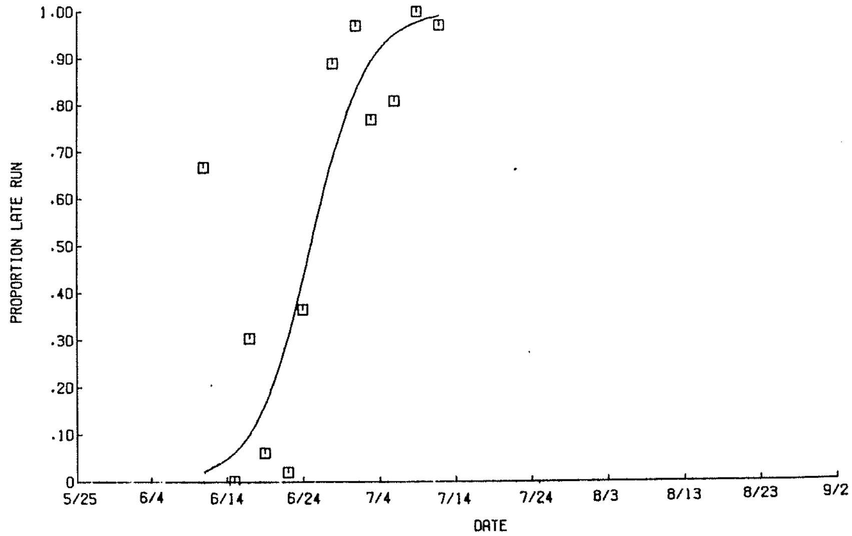

Fig. 5a. Corrected proportional estimates (CPE) and the smoothed (SPE) scale pattern TOE curve for the 1981 sockeye run.

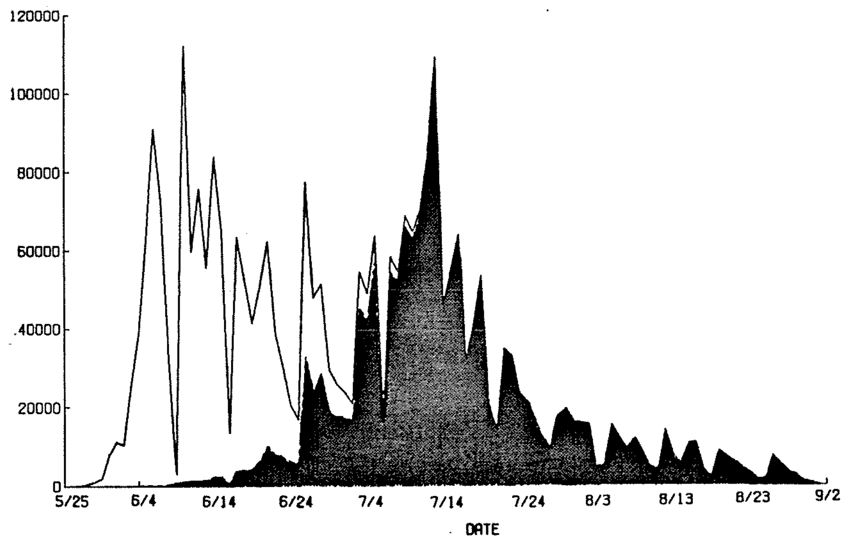

Fig. 5b. Daily totals for the 1981 sockeye run partitioned into early and late components by the SPE method.

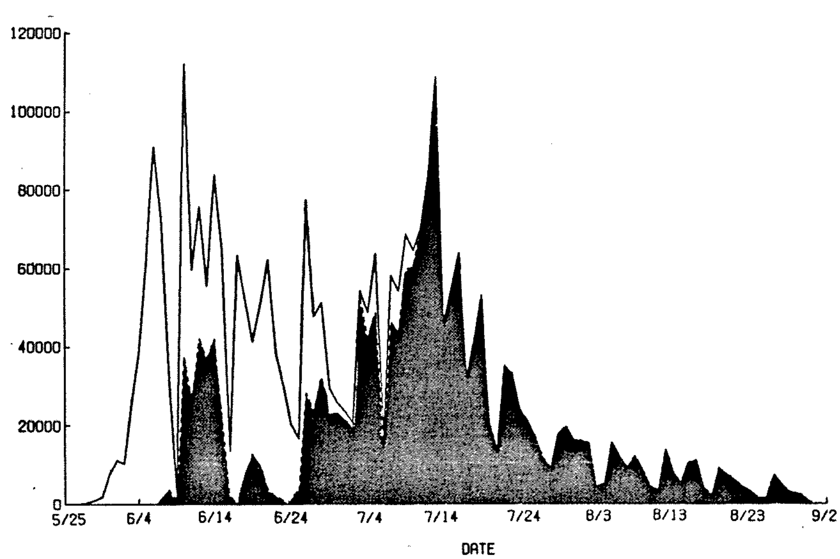

Fig. 5c. Daily totals for the 1981 sockeye run partitioned into early and late components by the CPE method.

Table 9. Summary of catch and escapement by stock calculated using smoothed proportional estimates and corrected proportional estimates.

Method	Escapement	Early escapement	Late escapement	Catch*	Early catch	Late catch	Total	Early total	Late total
SPE	832,944	565,640	267,304	2,089,724	727,815	1,361,909	2,922,668	1,293,455	1,629,213
CPE	832,944	527,733	305,211	2,089,724	591,984	1,497,740	2,922,668	1,119,717	1,802,951

*Does not include Stepovak, Beaver/Balboa, Perryville and Western District catches.

of the numbers of 1.2 age fish in the early run. However, this is probably an artefact of the subtraction method and may be partially explained by either or both of the following factors:

1. Variance in estimates of the percentage of 1.2 age fish in samples collected at the outlet of Black Lake. The 95% confidence interval on our estimate of the number of 1.2's in the early run ranges from 80,970 to 167,373.

2. The presence of an indeterminate number of Black River spawners in the early and late runs. Marshall et al. (1980) resolved a similar allocation problem by showing that fish bound for Black River tributaries constituted a much larger fraction of the total run than previously thought.

We were unable to distinguish the return of Black River adults by discriminant function analysis because scales of these fish are virtually identical to those of Chignik Lake spawners and are classified into a composite late run category. The age composition stock separation method of Fredin and Worland (1974) could not be used because necessary data were unavailable. Consequently, we cannot estimate the magnitude or age composition of the Black River adult return with sufficient confidence to help explain the negative estimates of the number of 1.2 age fish in the late run obtained using the subtraction method. The most parsimonious solution is to acknowledge an unmeasured influence from the Black River component of the early run, and to attribute the discrepancy in the age composition statistics to uncertainty in our estimate of the number of 1.2 age fish in the Black Lake escapement.

3.4 Evaluation of the Methodology

This appraisal of the in-season stock separation method based on scale pattern analysis is limited to aspects of day-to-day operation of the program that were noted during initial field tests. We assume that the theoretical underpinnings of discriminant function analysis are secure, and that adaptation of the technology to fisheries problems is appropriate. Our concern in this section centers mainly on identifying sources of potential error contributed by methods of collection and interpretation of data.

3.4.1 Sample Collection

As mentioned previously, careful collection and measurement of scales for the analysis is imperative. Consistency during scale measurement is not a serious problem because a single technician measures all the scales analyzed during the season. Significant problems may arise during collection of scales from the commercial catch.

The allocation of daily catch and escapement using proportional estimates from scale samples taken in the fishery is based on the

Table 10. Estimates of age composition by run as determined by the subtraction method of Marshall and Burgner (1977). The SPE method was used to apportion the runs in Part A and the CPE method provided numbers used in Part B. Age composition statistics were computed from fishery samples and Black Lake samples.

	Age group												
	1.1	2.1	0.2	1.2	2.2	3.2	0.3	1.3	2.3	3.3	1.4	2.4	Total
Part A													
Total return													
Numbers	646	5,127	1,423	104,807	122,801	4,086	15,451	1,341,374	1,309,857	12,031	1,809	3,351	2,922,668
Percent	0.02	0.18	0.05	3.59	4.20	0.14	0.53	45.89	44.82	0.41	0.06	0.12	
Early run													
Numbers			1,293	128,039	16,425		9,959	968,798	169,037				1,293,455
Percent			0.10	9.90	1.27		0.77	74.90	13.07				
Late run													
Numbers	646	5,127	130	-23,232	106,376	4,086	5,492	372,576	1,140,820	12,031	1,809	3,351	1,629,213
Percent	0.04	0.32	0.01	0.00	6.53	0.25	0.34	22.87	70.02	0.74	0.11	0.21	
Part B													
Total return													
Numbers	646	5,127	1,423	104,807	122,801	4,086	15,451	1,341,374	1,309,857	12,031	1,809	3,351	2,922,668
Percent	0.02	0.18	0.05	3.59	4.20	0.14	0.53	45.89	44.82	0.41	0.06	0.12	
Early run													
Numbers			1,120	110,852	14,556		7,838	838,668	146,683				1,119,717
Percent			0.10	9.90	1.27		0.77	74.90	13.07				
Late run													
Numbers	646	5,127	303	-6,045	108,245	4,086	7,613	502,706	1,163,174	12,031	1,809	3,351	1,802,951
Percent	0.03	0.28	0.02	0	6.00	0.23	0.42	27.88	64.52	0.67	0.10	0.19	

assumptions that 1) scale samples are representative of the entire sockeye population in Chignik Lagoon; and 2) the relative proportions of each stock present in the commercial catch will apply to the escapement at the weir two days later. These assumptions may be routinely violated by collecting scales aboard commercial tenders in Chignik Lagoon. To illustrate how this occurs, it is convenient to conceptualize the sockeye run as daily arrivals and departures of discrete groups of fish into and out of the Lagoon. Each of these groups has a unique stock composition, later-arriving groups having higher proportions of late run fish than early-arriving groups. Since the currency of the model is time, the spatial distribution of groups is important as it relates to the timing of their movements into and out of the Lagoon.

Although we generally sampled only the catch from a single fishing boat and attempted to ascertain the time and location of capture, the nature of the fishery and fishing grounds unavoidably introduces the chance of bias in scale collections. The commercial tenders inside the Lagoon service boats which may have fished from inside the mouth of Chignik River throughout the Lagoon to just outside its mouth. Fish caught in Chignik River are presumed to be actively migrating upstream and will likely pass the weir with the next high tide, whereas fish taken within the Lagoon may not pass the weir for two days on average. Migration time for fish caught outside the Lagoon is uncertain. In the hypothetical case, if a sample of scales represents fish distributed across these locations, then the obtained proportional estimates may not accurately represent the true mixing proportions in the escapement two days later.

The problem is aggravated by a behavior characteristic of salmon preparing to migrate into home streams. Sockeye commonly are observed to congregate in Chignik Lagoon for variable periods of time before moving into Chignik River. Dahlberg (1968) found an average of two days between release of tagged fish in the Lagoon and their subsequent appearance at the weir, but others (Nicholson, pers. comm.) have noted delays of up to 10 days. Consider a case wherein the presence of large numbers of fish in the Lagoon is known although escapements at the weir remain low. Fish entering the Lagoon each day are, as our time-of-entry model predicts, increasingly likely to be late run fish. Their entry into the Lagoon effectively dilutes the proportion of early run fish congregated there relative to those departing upstream each day. Samples taken from the commercial catch during such a period overrepresent the proportion of late run fish in the escapement two days later.

The error in proportional estimates attributable to biased scale samples undoubtedly was a small fraction of the total. Classification accuracy during the season was such that relatively small variations in run timing could not significantly have influenced calculations of the proportional estimates. It is nonetheless desireable to acknowledge the potential for bias in scale collections, since eliminating inconsistencies in scale collection and processing enhances the intrinsic variation in stock-specific scale characteristics. In future applications of the method, when classification accuracy is sufficiently high that small-scale variance components are detectable, the effect of bias in scale samples can be more rigorously evaluated.

3.4.2 Choice of Allocation Method

From previous experience with the scale pattern stock separation technique, (Marshall et al. 1980; unpub. data), we anticipated some of the confusing aspects of using it on an in-season basis. These essentially concerned the relative merits of fitting the estimates of stock composition in each sample to a logistic TOE curve (SPE) as opposed to using the proportional estimates directly with no attempt to fit them to a curve (CPE). What we discovered while attempting to implement the scale pattern technique during the season is that it does not by itself meet requirements imposed by the controlled escapement management concept.

The controlled escapement plan used at Chignik to regulate the commercial harvest is based on a simple information feedback loop wherein cumulative escapements to each stock are compared against escapement goals for each stock by day. So long as escapements meet daily escapement goals, surplus fish may be harvested. The daily escapement goals have been computed for each stock on the assumption that the values of "a" and "b" in the logistic TOE curve remain constant over the season, i.e. the relative proportions of each stock in the escapement on day i can be predicted from the relative proportions of each stock present on day i-n, $n < i$. The feasibility of the controlled escapement scheme thus hinges on the ability to predict the stock composition of future escapements. In contrast, the SPE stock separation method produces new estimates of "a" and "b" with each input of new data and, consequently, new estimates of stock composition on all days prior to the latest sampling date (Table 11). Although future stock compositions can be predicted with the SPE method by virtue of the curve-fitting procedure, changes in the slope and intercept of the curve with new data alter predicted values. This necessarily changes the status of the cumulative escapements to each stock vis-a-vis their escapement goals and forces the management biologist to regulate the harvest somewhat in retrospect.

Even though the SPE and CPE stock separation techniques do not offer complete alternatives to the existing method, we must emphasize that the failure of the scale pattern method to fit the controlled-escapement plan at Chignik should not over-shadow the positive aspects of the scale pattern stock separation concept. The scale pattern approach is most effective in detecting yearly variations in run timing and monitoring the transition from early to late run on a day-to-day basis. Furthermore, allocation of daily runs to each stock is independent of the relative magnitudes of the early and late runs. Gross errors associated with proportioning unequal quantities are avoided by partitioning daily returns on the basis of stock compositions measured directly from fishery scale samples. These characteristics undoubtedly contribute to a more accurate and reliable representation of the actual

Table 11. Summary of proportional estimates by sampling date, their $\log_e$-transformed values, and estimates of "a", "b", and the projected midpoint in the transition from early to late run based on new data at each sampling date.

Date	Proportion Early (1-p)	Proportion Late (p)	$-\ln \frac{1-p}{p}$	a	b	Calculated Run Midpoint (date)
6/11	0.333	0.667	0.69465			
6/15	0.999	0.001	-6.90675	310.4520	-1.90035	6/12
6/17	0.697	0.303	-0.83305	79.10860	-0.48972	6/11
6/19	0.939	0.061	-2.73394	47.76175	-0.29974	6/9
6/22	0.980	0.020	-3.89182	41.46679	-0.26185	6/8
6/24	0.636	0.364	-0.55804	5.15512	-0.04427	4/26
6/28	0.111	0.889	2.08057	-30.52318	0.16793	7/1
7/1	0.030	0.970	3.47610	-48.28342	0.27303	6/25
7/3	0.232	0.768	1.19705	-44.05972	0.24813	6/26
7/6	0.192	0.808	1.43707	-40.10897	0.22497	6/27
7/9	0.001	0.999	6.90675	-51.79159	0.29305	6/25
7/12	0.030	0.970	3.47610	-47.90675	0.27054	6/25

sockeye run dynamics than that described by the average TOE curve in any year.

Our conclusion from the perspective of efficient in-season sockeye run management at Chignik is that the scale pattern stock separation method is not yet sufficiently developed that a complete dismantling of the present management system is warranted. Rather, the strength of the scale pattern concept should be exploited as an in-season reference for 1) checking the placement in time of the average TOE curve, and 2) monitoring the rate of transition from early to late run. We therefore recommend that the optimum in-season management design consists of the current ADF&G harvest plan verified by intensive scale sampling and discriminant function analysis.

4.0 LITERATURE CITED

Anas, R.E. and S. Murai. 1969. Use of scale characters and a discriminant function for classifying sockeye salmon (Oncorhynchus nerka) by continent of origin. Int. North Pac. Fish. Comm., Bull. 26:157-192.

Burgner, R.L., C.J. DiCostanzo, R.J. Ellis, G.Y. Harry, Jr., W.L. Hartman, O.E. Kerns, Jr., O.A. Mathisen, and W.F. Royce. 1969. Biological studies and estimates of optimum escapements of sockeye salmon in the major river systems in southwestern Alaska. USFWS Fish. Bull. 67(2):405-459.

Conrad, R.H. and R.L. Burgner. 1981. Chignik sockeye stock separation studies. Univ. of Washington, Fish. Res. Inst. Interim Rep. 25 pp.

Cook, R.C. and G.E. Lord. 1978. Identification of stocks of Bristol Bay sockeye salmon, Oncorhynchus nerka, by evaluating scale patterns with a polynomial discriminant method. Fish. Bull. 76(2):415-423.

Clutter, R.I. and L.E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Int. Pac. Salmon Fish. Comm., Bull. 9. 159 pp.

Dahlberg, M.L. 1968. Analysis of the dynamics of sockeye salmon returns to the Chignik Lakes, Alaska. Ph.D. Dissertation, Univ. of Washington, Seattle, 337 pp.

Fisher, R. 1936. The use of multiple measurements in taxonomic problems. Ann. Eugen. 7:179-188.

Fredin, R. and D. Worlund. 1974. Catches of sockeye salmon of Bristol Bay origin by the Japanese mothership salmon fishery. 1956-1970. Int. North Pac. Fish. Comm. Bull. 30:1-80.

French, R., H. Bilton, M. Osaka, and A. Hartt. 1976. Distribution and origin of sockeye salmon (Oncorhynchus nerka) in offshore waters of the north Pacific Ocean. Int. North Pac. Fish. Comm. Bull. 34:57-60.

Lachenbruch, P.A. 1975. Discriminant analysis. Hafner Press, New York, N.Y. 128 pp.

Lachenbruch, P.A. and M.R. Mickey. 1968. Estimation of error rates in discriminant analysis. Technometrics 10:1-11.

Marshall, S.L. 1977. Lacustrine scale patterns of sockeye salmon of the Chignik Lakes, Alaska. M.S. thesis, Univ. Washington, Seattle, 137 pp.

Marshall, S.L. and R.L. Burgner. 1977. Chignik sockeye studies. Univ. of Washington, Fish. Res. Inst. Final Rep. FRI-UW-7733. 156 pp.

Marshall, S.L., S.S. Parker, and R.L. Burgner. 1980. Chignik sockeye studies. Univ. of Washington, Fish. Res. Inst., Annual Report. FRI-UW-8005. 54pp.

Narver, D.W. 1963. Identification of adult red salmon groups by lacustrine scale measurements, time-of-entry and spawning characteristics. M.S. Thesis, Univ. of Washington, Seattle, 96 pp.

Narver, D.W. 1966. Pelagial ecology and carrying capacity of sockeye salmon in the Chignik Lakes, Alaska. Ph.D. Dissertation, Univ. of Washington, Seattle. 348 pp.

Parr, W. 1972. Interaction between sockeye salmon and lake resident fish in the Chignik Lakes, Alaska. M.S. Thesis, Univ. of Washington, Seattle, 103 pp.

Parsons, L.S. 1972. Use of meristic characters and a discriminant function for classifying spring- and autumn-spawning Atlantic herring. Int. Comm. Northwest Atl. Fish. Res. Bull. 9:5-9.

Pedersen, P.C. and D. Petersen. 1971. Forecast of the 1971 Chignik system red salmon run. Alaska Dept. Fish and Game, Informational Leaflet #151. 13 pp.

5.0 APPENDIX

Appendix Table 1. Adjusted catch, escapement, and total run by day.

Date	i	i+2	i+3	i+4	i+5	i+7	i+8	Total run	Total catch
	Escapement	Lagoon catch	Hook Bay	Kujulik	Aniakchak	Chiginagak	Iguak		
5/25	36							36	
5/26	0							0	
5/27	54							54	
5/28	318							318	
5/29	911							911	
5/30	1,834							1,834	
5/31	7,773							7,773	
6/1	11,207							11,207	
6/2	10,409							10,409	
6/3	25,358							25,358	
6/4	38,460							38,460	
6/5	61,204							61,204	
6/6	90,963							90,963	
6/7	72,937							72,937	
6/8	31,832	438						32,270	438
6/9	3,055							3,055	
6/10	5,926	106,260						112,186	106,260
6/11	3,386	56,508						59,894	56,508
6/12	1,993	64,258	9,385					15,636	73,643
6/13	2,882	47,797	2,050		3,101			55,830	52,948
6/14	23,332	44,932	6,913		8,457			83,634	60,302
6/15	50,423	520	4,691		9,474			65,108	14,685
6/16	5,698	603	1,317	944	5,061			13,623	7,925
6/17	817	51,337			11,041			63,195	62,378
6/18	751	37,820	5,191		8,581			52,343	51,592
6/19	4,320	27,263	7,232		2,768			41,584	37,264
6/20	4,374	29,484	11,725	693	4,510			50,786	46,412
6/21	12,992	19,953	9,506		2,978		16,772	62,201	49,209
6/22	18,758		3,018		6,119		10,931	38,826	20,068

Appendix Table 1. Adjusted catch, escapement, and total run by day - continued.

Date	i Escapement	i+2 Lagoon catch	i+3 Hook Bay	i+4 Kujulik	i+5 Aniakchak	i+7 Chiginagak	i+8 Iguak	Total run	Total catch
6/23	26,765				3,338			30,103	3,338
6/24	8,162						12,229	20,391	12,229
6/25	1,332		604				15,027	16,963	15,631
6/26	7,187	50,766					19,430	77,383	70,196
6/27	22,805		5,885				19,252	47,942	25,137
6/28	25,828						25,596	51,424	25,596
6/29	19,876				9,923		25,596	29,799	9,923
6/30	25,489	360						25,849	360
7/1	23,822							23,822	
7/2	20,826							20,826	
7/3	7,713	46,814						54,527	46,814
7/4	6,978	35,343	6,588					48,909	41,931
7/5	17,196	44,816	1,611					63,623	46,427
7/6	8,580		5,011		4,590			18,181	9,601
7/7	2,646	54,263		311	1,170			58,390	55,744
7/8	1,745	39,733	9,207		3,827			54,512	52,767
7/9	1,507	45,641	4,783				16,794	68,725	67,218
7/10	1,630	40,276	3,008	86	3,356		16,350	64,706	63,076
7/11	1,790	43,662	3,996	2,782	4,641		13,365	70,236	68,446
7/12	2,439	41,354	7,054	1,230	4,444		27,708	84,229	81,790
7/13	1,530	32,309	11,344	5,831	3,086		65,930	109,030	107,500
7/14	1,374	22,874	15,115	2,533	4,606			46,502	45,128
7/15	1,962	30,343	14,378	8,881				55,564	53,602
7/16	3,963	38,184	16,087	2,937	2,754			63,925	59,962
7/17	2,632	17,771	7,310		4,949			32,662	30,030
7/18	2,476	23,360	3,206	9,466	3,281			41,789	39,313
7/19	9,177	17,170	16,313	5,547				53,258	44,081
7/20	9,174		5,501	1,038	5,328			21,041	11,867
7/21	1,824	4,501			3,974		3,902	14,201	12,377
7/22	2,454	22,485	411		741		8,920	35,011	32,557

Appendix Table 1. Adjusted catch, escapement, and total run by day - continued.

	i	i+2	i+3	i+4	i+5	i+7	i+8		
Date	Escapement	Lagoon catch	Hook Bay	Kujulik	Aniakchak	Chiginagak	Iguak	Total run	Total catch
7/23	3,006	12,836	7,346				9,960	33,148	30,142
7/24	2,928	11,960	5,501		464		2,977	23,830	20,902
7/25	1,410	7,917	4,152		4,540		3,394	21,413	20,003
7/26	1,365	6,923	3,288		5,678			17,254	15,889
7/27	1,932	6,822	2,012	89	1,330			12,185	10,253
7/28	1,632	5,128	1,771		972			9,503	7,871
7/29	2,304	9,117	3,183		748	213	2,331	17,896	15,592
7/30	2,424	10,711	1,680		3,439		1,468	19,722	17,298
7/31	1,558	9,953	2,245		1,236	21	1,209	16,222	14,664
8/1	2,000	10,468	2,091		1,573	26	134	16,292	14,292
8/2	2,000	8,269	2,226		1,734	366	1,002	15,597	13,597
8/3	2,000		1,056		1,649			4,705	2,705
8/4	2,000				3,324			5,324	3,324
8/5	2,000	10,285			3,357			15,642	13,642
8/6	2,000	9,046	1,168					12,214	10,214
8/7	2,000	6,852	622	9				9,483	7,483
8/8	2,000	6,813	286		2,967			12,066	10,066
8/9	2,000	6,489	424		26			8,939	6,939
8/10	2,000		500		2,191			4,691	2,691
8/11	2,000				1,562	59		3,621	1,621
8/12	2,000	10,250			1,173	137	5	13,565	11,565
8/13	2,000	5,140	285			702		8,127	6,127
8/14	2,000	3,565	84			27		5,676	3,676
8/15	1,500	6,550	1,169		1,243			10,462	8,962
8/16	1,500	8,307	1,166					10,973	9,473
8/17	1,500		1,636		1,108	14		4,258	2,758
8/18	1,500				734	9		2,243	743
8/19	1,500	7,070			347	6	16	8,939	7,439

Appendix Table 1. Adjusted catch, escapement, and total run by day - continued.

	i	i+2	i+3	i+4	i+5	i+7	i+8		
Date	Escapement	Lagoon catch	Hook Bay	Kujulik	Aniakchak	Chiginagak	Iguak	Total run	Total catch
8/20	1,500	4,745	1,022			19		7,286	5,786
8/21	1,500	4,072	384				16	5,972	4,472
8/22	1,500	1,440	1,356		138			4,434	2,934
8/23	1,500	1,628	4		122			3,254	1,754
8/24	1,500				63			1,563	63
8/25	1,500							1,500	
8/26	1,500	5,598						7,098	5,598
8/27	1,500	3,251	385					5,136	3,636
8/28	1,500	1,704						3,204	1,704
8/29	1,000	1,573						2,573	1,513
8/30	1,000							1,000	
8/31	500							500	
Totals	832,944	1,343,680	245,483	42,377	172,868	1,599	283,718	2,922,668	2,089,724

Appendix Table 2. Daily run allocation using the smoothed proportional estimates (SPE) method.

CALENDAR DATE		JULIAN DATE	ALPHA (SMOOTH)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
MAY	25	145.	0.000	36.0	0.0	36.0	0.	0.	0.	36.	0.
	26	146.	0.000	0.0	0.0	0.0	0.	0.	0.	0.	0.
	27	147.	0.000	54.0	0.0	54.0	0.	0.	0.	54.	0.
	28	148.	0.000	318.0	0.0	318.0	0.	0.	0.	318.	0.
	29	149.	0.000	911.0	0.0	911.0	0.	0.	0.	911.	0.
	30	150.	0.000	1834.0	0.0	1834.0	0.	0.	0.	1834.	0.
	31	151.	.001	7765.0	8.0	7773.0	0.	0.	0.	7765.	8.
JUNE	1	152.	.001	11196.0	11.0	11207.0	0.	0.	0.	11196.	11.
	2	153.	.001	10399.0	10.0	10409.0	0.	0.	0.	10399.	10.
	3	154.	.002	25307.0	51.0	25358.0	0.	0.	0.	25307.	51.
	4	155.	.002	38383.0	77.0	38460.0	0.	0.	0.	38383.	77.
	5	156.	.003	61020.0	184.0	61204.0	0.	0.	0.	61020.	184.
	6	157.	.003	90690.0	273.0	90963.0	0.	0.	0.	90690.	273.
	7	158.	.004	72645.0	292.0	72937.0	0.	0.	0.	72645.	292.
	8	159.	.006	31641.0	191.0	31832.0	435.	3.	438.	32076.	194.
	9	160.	.007	3034.0	21.0	3055.0	0.	0.	0.	3034.	21.
	10	161.	.010	5867.0	59.0	5926.0	105197.	1063.	106260.	111064.	1122.
	11	162.	.013	3342.0	44.0	3386.0	55773.	735.	56508.	59115.	779.
	12	163.	.017	1959.0	34.0	1993.0	72391.	1252.	73643.	74350.	1286.
	13	164.	.022	2819.0	63.0	2882.0	51783.	1165.	52948.	54602.	1228.
	14	165.	.028	22679.0	653.0	23332.0	58614.	1688.	60302.	81293.	2341.
	15	166.	.037	48557.0	1866.0	50423.0	14142.	543.	14685.	62699.	2409.
	16	167.	.048	5424.0	274.0	5698.0	7545.	380.	7925.	12969.	654.
	17	168.	.061	767.0	50.0	817.0	58573.	3805.	62378.	59340.	3855.
	18	169.	.079	692.0	59.0	751.0	47516.	4076.	51592.	48208.	4135.
	19	170.	.101	3884.0	436.0	4320.0	33500.	3764.	37264.	37384.	4200.
	20	171.	.128	3814.0	560.0	4374.0	40471.	5941.	46412.	44285.	6501.
	21	172.	.162	10887.0	2105.0	12992.0	41237.	7972.	49209.	52124.	10077.
	22	173.	.202	14969.0	3789.0	18758.0	16014.	4054.	20068.	30983.	7843.
	23	174.	.249	20101.0	6664.0	26765.0	2507.	831.	3338.	22608.	7495.
	24	175.	.303	5689.0	2473.0	8162.0	8524.	3705.	12229.	14213.	6178.
	25	176.	.363	848.0	484.0	1332.0	9957.	5674.	15631.	10805.	6158.
	26	177.	.428	4111.0	3076.0	7187.0	40152.	30044.	70196.	44263.	33120.
	27	178.	.495	11517.0	11288.0	22805.0	12694.	12443.	25137.	24211.	23731.

Appendix Table 2. Daily run allocation using the smoothed proportional estimates (SPE) method - continued.

CALENDAR DATE	JULIAN DATE	ALPHA (SMOOTH)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
JUNE 28	179.	.562	11313.0	14515.0	25828.0	11211.	14385.	25596.	22524.	28900.
29	180.	.627	7414.0	12462.0	19876.0	3701.	6222.	9923.	11115.	18684.
30	181.	.688	7953.0	17536.0	25489.0	112.	248.	360.	8065.	17784.
JULY 1	182.	.743	6122.0	17700.0	23822.0	0.	0.	0.	6122.	17700.
2	183.	.791	4353.0	16473.0	20826.0	0.	0.	0.	4353.	16473.
3	184.	.832	1296.0	6417.0	7713.0	7865.	38949.	46814.	9161.	45366.
4	185.	.867	928.0	6050.0	6978.0	5577.	36354.	41931.	6505.	42404.
5	186.	.895	1806.0	15390.0	17196.0	4875.	41552.	46427.	6681.	56942.
6	187.	.918	704.0	7876.0	8580.0	787.	8814.	9601.	1491.	16690.
7	188.	.936	169.0	2477.0	2646.0	3568.	52176.	55744.	3737.	54653.
8	189.	.951	86.0	1659.0	1745.0	2586.	50181.	52767.	2672.	51840.
9	190.	.962	57.0	1450.0	1507.0	2554.	64664.	67218.	2611.	66114.
10	191.	.971	47.0	1583.0	1630.0	1829.	61247.	63076.	1876.	62830.
11	192.	.977	41.0	1749.0	1790.0	1574.	66872.	68446.	1615.	68621.
12	193.	.983	41.0	2398.0	2439.0	1390.	80400.	81790.	1431.	82798.
13	194.	.987	20.0	1510.0	1530.0	1398.	106102.	107500.	1418.	107612.
14	195.	.990	14.0	1360.0	1374.0	451.	44677.	45128.	465.	46037.
15	196.	.992	16.0	1946.0	1962.0	429.	53173.	53602.	445.	55119.
16	197.	.994	24.0	3939.0	3963.0	360.	59602.	59962.	384.	63541.
17	198.	.996	11.0	2621.0	2632.0	120.	29910.	30030.	131.	32531.
18	199.	.997	7.0	2469.0	2476.0	118.	39195.	39313.	125.	41664.
19	200.	.997	28.0	9149.0	9177.0	132.	43949.	44081.	160.	53098.
20	201.	.998	18.0	9156.0	9174.0	24.	11843.	11867.	42.	20999.
21	202.	.998	4.0	1820.0	1824.0	25.	12352.	12377.	29.	14172.
22	203.	.999	2.0	2452.0	2454.0	33.	32524.	32557.	35.	34976.
23	204.	.999	3.0	3003.0	3006.0	30.	30112.	30142.	33.	33115.
24	205.	.999	3.0	2925.0	2928.0	21.	20881.	20902.	24.	23806.
25	206.	.999	1.0	1409.0	1410.0	20.	19983.	20003.	21.	21392.
26	207.	1.000	0.0	1365.0	1365.0	0.	15889.	15889.	0.	17254.
27	208.	1.000	0.0	1932.0	1932.0	0.	10253.	10253.	0.	12185.
28	209.	1.000	0.0	1632.0	1632.0	0.	7871.	7871.	0.	9503.
29	210.	1.000	0.0	2304.0	2304.0	0.	15592.	15592.	0.	17896.
30	211.	1.000	0.0	2424.0	2424.0	0.	17298.	17298.	0.	19722.
31	212.	1.000	0.0	1558.0	1558.0	0.	14664.	14664.	0.	16222.

Appendix Table 2. Daily run allocation using the smoothed proportional estimates (SPE) method - continued.

CALENDAR DATE	JULIAN DATE	ALPHA (SMOOTH)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
AUG 1	213.	1.000	0.0	2000.0	2000.0	0.	14292.	14292.	0.	16292.
2	214.	1.000	0.0	2000.0	2000.0	0.	13597.	13597.	0.	15597.
3	215.	1.000	0.0	2000.0	2000.0	0.	2705.	2705.	0.	4705.
4	216.	1.000	0.0	2000.0	2000.0	0.	3324.	3324.	0.	5324.
5	217.	1.000	0.0	2000.0	2000.0	0.	13642.	13642.	0.	15642.
6	218.	1.000	0.0	2000.0	2000.0	0.	10214.	10214.	0.	12214.
7	219.	1.000	0.0	2000.0	2000.0	0.	7483.	7483.	0.	9483.
8	220.	1.000	0.0	2000.0	2000.0	0.	10066.	10066.	0.	12066.
9	221.	1.000	0.0	2000.0	2000.0	0.	6939.	6939.	0.	8939.
10	222.	1.000	0.0	2000.0	2000.0	0.	2691.	2691.	0.	4691.
11	223.	1.000	0.0	2000.0	2000.0	0.	1621.	1621.	0.	3621.
12	224.	1.000	0.0	2000.0	2000.0	0.	11565.	11565.	0.	13565.
13	225.	1.000	0.0	2000.0	2000.0	0.	6127.	6127.	0.	8127.
14	226.	1.000	0.0	2000.0	2000.0	0.	3676.	3676.	0.	5676.
15	227.	1.000	0.0	1500.0	1500.0	0.	8962.	8962.	0.	10462.
16	228.	1.000	0.0	1500.0	1500.0	0.	9473.	9473.	0.	10973.
17	229.	1.000	0.0	1500.0	1500.0	0.	2758.	2758.	0.	4258.
18	230.	1.000	0.0	1500.0	1500.0	0.	743.	743.	0.	2243.
19	231.	1.000	0.0	1500.0	1500.0	0.	7439.	7439.	0.	8939.
20	232.	1.000	0.0	1500.0	1500.0	0.	5786.	5786.	0.	7286.
21	233.	1.000	0.0	1500.0	1500.0	0.	4472.	4472.	0.	5972.
22	234.	1.000	0.0	1500.0	1500.0	0.	2934.	2934.	0.	4434.
23	235.	1.000	0.0	1500.0	1500.0	0.	1754.	1754.	0.	3254.
24	236.	1.000	0.0	1500.0	1500.0	0.	63.	63.	0.	1563.
25	237.	1.000	0.0	1500.0	1500.0	0.	0.	0.	0.	1500.
26	238.	1.000	0.0	1500.0	1500.0	0.	5598.	5598.	0.	7098.
27	239.	1.000	0.0	1500.0	1500.0	0.	3636.	3636.	0.	5136.
28	240.	1.000	0.0	1500.0	1500.0	0.	1704.	1704.	0.	3204.
29	241.	1.000	0.0	1000.0	1000.0	0.	1573.	1573.	0.	2573.
30	242.	1.000	0.0	1000.0	1000.0	0.	0.	0.	0.	1000.
31	243.	1.000	0.0	500.0	500.0	0.	0.	0.	0.	500.
			565640	267304	832944	727815	1361909	2089724	1293455	1629213

Appendix Table 3. Daily run allocation using the corrected proportional estimates (CPE) method.

CALENDAR DATE	JULIAN DATE	ALPHA (RAW)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
MAY 25	145.	0.000	36.0	0.0	36.0	0.0	0.	0.	36.0	0.
26	146.	0.000	0.0	0.0	0.0	0.0	0.	0.	0.0	0.
27	147.	0.000	54.0	0.0	54.0	0.0	0.	0.	54.0	0.
28	148.	0.000	318.0	0.0	318.0	0.0	0.	0.	318.0	0.
29	149.	0.000	911.0	0.0	911.0	0.0	0.	0.	911.0	0.
30	150.	0.000	1834.0	0.0	1834.0	0.0	0.	0.	1834.0	0.
31	151.	0.000	7773.0	0.0	7773.0	0.0	0.	0.	7773.0	0.
JUNE 1	152.	0.000	11207.0	0.0	11207.0	0.0	0.	0.	11207.0	0.
2	153.	0.000	10409.0	0.0	10409.0	0.0	0.	0.	10409.0	0.
3	154.	0.000	25358.0	0.0	25358.0	0.0	0.	0.	25358.0	0.
4	155.	0.000	38460.0	0.0	38460.0	0.0	0.	0.	38460.0	0.
5	156.	0.000	61204.0	0.0	61204.0	0.0	0.	0.	61204.0	0.
6	157.	0.000	90963.0	0.0	90963.0	0.0	0.	0.	90963.0	0.
7	158.	0.000	72937.0	0.0	72937.0	0.0	0.	0.	72937.0	0.
8	159.	.111	28299.0	3533.0	31832.0	389.0	49.	438.	28688.0	3582.
9	160.	.222	2377.0	678.0	3055.0	0.0	0.	0.	2377.0	678.
10	161.	.334	3947.0	1979.0	5926.0	70769.0	35491.	106260.	74716.0	37470.
11	162.	.445	1879.0	1507.0	3386.0	31362.0	25146.	56508.	33241.0	26653.
12	163.	.556	885.0	1108.0	1993.0	32697.0	40946.	73643.	33582.0	42054.
13	164.	.667	960.0	1922.0	2882.0	17632.0	35316.	52948.	18592.0	37238.
14	165.	.501	11643.0	11689.0	23332.0	30091.0	30211.	60302.	41734.0	41900.
15	166.	.334	33582.0	16841.0	50423.0	9780.0	4905.	14685.	43362.0	21746.
16	167.	.168	4741.0	957.0	5698.0	6594.0	1331.	7925.	11335.0	2288.
17	168.	.001	816.0	1.0	817.0	62316.0	62.	62378.	63132.0	63.
18	169.	.152	637.0	114.0	751.0	43750.0	7842.	51592.	44387.0	7956.
19	170.	.303	3011.0	1309.0	4320.0	25973.0	11291.	37264.	28984.0	12600.
20	171.	.182	3578.0	796.0	4374.0	37965.0	8447.	46412.	41543.0	9243.
21	172.	.061	12199.0	793.0	12992.0	46207.0	3002.	49209.	58406.0	3795.
22	173.	.047	17876.0	882.0	18758.0	19125.0	943.	20068.	37001.0	1825.
23	174.	.034	25855.0	910.0	26765.0	3225.0	113.	3338.	29080.0	1023.
24	175.	.020	7999.0	163.0	8162.0	11984.0	245.	12229.	19983.0	408.
25	176.	.192	1076.0	256.0	1332.0	12630.0	3001.	15631.	13706.0	3257.
26	177.	.364	4571.0	2616.0	7187.0	44645.0	25551.	70196.	49216.0	28167.
27	178.	.495	11517.0	11288.0	22805.0	12694.0	12443.	25137.	24211.0	23731.

Appendix Table 3. Daily run allocation using the corrected proportional estimates (CPE) method - continued.

CALENDAR DATE	JULIAN DATE	ALPHA (RAW)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
JUNE 28	179.	.62700	9634.0	16194.0	25828.0	9547.0	16049.	25596.	25828.0	25596.
29	180.	.75800	4810.0	15066.0	19876.0	2401.0	7522.	9923.	19876.0	9923.
30	181.	.88900	2829.0	22660.0	25489.0	40.0	320.	360.	25489.0	360.
JULY 1	182.	.91600	2001.0	21821.0	23822.0	0.0	0.	0.	23822.0	0.
2	183.	.94300	1187.0	19639.0	20826.0	0.0	0.	0.	20826.0	0.
3	184.	.97000	231.0	7482.0	7713.0	1404.0	45410.	46814.	7713.0	46814.
4	185.	.86900	914.0	6064.0	6978.0	5493.0	36438.	41931.	6978.0	41931.
5	186.	.76800	3989.0	13207.0	17196.0	10771.0	35656.	46427.	17196.0	46427.
6	187.	.78200	1870.0	6710.0	8580.0	2093.0	7508.	9601.	8580.0	9601.
7	188.	.79500	542.0	2104.0	2646.0	11428.0	44316.	55744.	2646.0	55744.
8	189.	.80800	335.0	1410.0	1745.0	10131.0	42636.	52767.	1745.0	52767.
9	190.	.87200	193.0	1314.0	1507.0	8604.0	58614.	67218.	1507.0	67218.
10	191.	.93500	106.0	1524.0	1630.0	4100.0	58976.	63076.	1630.0	63076.
11	192.	.99900	2.0	1788.0	1790.0	68.0	68378.	68446.	1790.0	68446.
12	193.	.98900	27.0	2412.0	2439.0	900.0	80890.	81790.	2439.0	81790.
13	194.	.98000	31.0	1499.0	1530.0	2150.0	105350.	107500.	1530.0	107500.
14	195.	.97000	41.0	1333.0	1374.0	1354.0	43774.	45128.	1374.0	45128.
15	196.	.98000	39.0	1923.0	1962.0	1072.0	52530.	53602.	1962.0	53602.
16	197.	.99000	40.0	3923.0	3963.0	600.0	59362.	59962.	3963.0	59962.
17	198.	1.00000	0.0	2632.0	2632.0	0.0	30030.	30030.	2632.0	30030.
18	199.	1.00000	0.0	2476.0	2476.0	0.0	39313.	39313.	2476.0	39313.
19	200.	1.00000	0.0	9177.0	9177.0	0.0	44081.	44081.	9177.0	44081.
20	201.	1.00000	0.0	9174.0	9174.0	0.0	11867.	11867.	9174.0	11867.
21	202.	1.00000	0.0	1824.0	1824.0	0.0	12377.	12377.	1824.0	12377.
22	203.	1.00000	0.0	2454.0	2454.0	0.0	32557.	32557.	2454.0	32557.
23	204.	1.00000	0.0	3006.0	3006.0	0.0	30142.	30142.	3006.0	30142.
24	205.	1.00000	0.0	2928.0	2928.0	0.0	20902.	20902.	2928.0	20902.
25	206.	1.00000	0.0	1410.0	1410.0	0.0	20003.	20003.	1410.0	20003.
26	207.	1.00000	0.0	1365.0	1365.0	0.0	15889.	15889.	1365.0	15889.
27	208.	1.00000	0.0	1932.0	1932.0	0.0	10253.	10253.	1932.0	10253.
28	209.	1.00000	0.0	1632.0	1632.0	0.0	7871.	7871.	1632.0	7871.
29	210.	1.00000	0.0	2304.0	2304.0	0.0	15592.	15592.	2304.0	15592.
30	211.	1.00000	0.0	2424.0	2424.0	0.0	17298.	17298.	2424.0	17298.
31	212.	1.00000	0.0	1558.0	1558.0	0.0	14664.	14664.	1558.0	14664.

Appendix Table 3. Daily run allocation using the corrected proportional estimates (CPE) method - continued.

CALENDAR DATE	JULIAN DATE	ALPHA (RAW)	EARLY ESCAPMENT	LATE ESCAPMENT	TOTAL ESCAPMENT	EARLY CATCH	LATE CATCH	TOTAL CATCH	EARLY RUN	LATE RUN
AUG 1	213.	1.000	0.0	2000.0	2000.0	0.0	14292.	14292.	0.0	16292.
2	214.	1.000	0.0	2000.0	2000.0	0.0	13597.	13597.	0.0	15597.
3	215.	1.000	0.0	2000.0	2000.0	0.0	2705.	2705.	0.0	4705.
4	216.	1.000	0.0	2000.0	2000.0	0.0	3324.	3324.	0.0	5324.
5	217.	1.000	0.0	2000.0	2000.0	0.0	13642.	13642.	0.0	15642.
6	218.	1.000	0.0	2000.0	2000.0	0.0	10214.	10214.	0.0	12214.
7	219.	1.000	0.0	2000.0	2000.0	0.0	7483.	7483.	0.0	9483.
8	220.	1.000	0.0	2000.0	2000.0	0.0	10066.	10066.	0.0	12066.
9	221.	1.000	0.0	2000.0	2000.0	0.0	6939.	6939.	0.0	8939.
10	222.	1.000	0.0	2000.0	2000.0	0.0	2691.	2691.	0.0	4691.
11	223.	1.000	0.0	2000.0	2000.0	0.0	1621.	1621.	0.0	3621.
12	224.	1.000	0.0	2000.0	2000.0	0.0	11565.	11565.	0.0	13565.
13	225.	1.000	0.0	2000.0	2000.0	0.0	6127.	6127.	0.0	8127.
14	226.	1.000	0.0	2000.0	2000.0	0.0	3676.	3676.	0.0	5676.
15	227.	1.000	0.0	1500.0	1500.0	0.0	8962.	8962.	0.0	10462.
16	228.	1.000	0.0	1500.0	1500.0	0.0	9473.	9473.	0.0	10973.
17	229.	1.000	0.0	1500.0	1500.0	0.0	2758.	2758.	0.0	4258.
18	230.	1.000	0.0	1500.0	1500.0	0.0	743.	743.	0.0	2243.
19	231.	1.000	0.0	1500.0	1500.0	0.0	7439.	7439.	0.0	8939.
20	232.	1.000	0.0	1500.0	1500.0	0.0	5786.	5786.	0.0	7286.
21	233.	1.000	0.0	1500.0	1500.0	0.0	4472.	4472.	0.0	5972.
22	234.	1.000	0.0	1500.0	1500.0	0.0	2934.	2934.	0.0	4434.
23	235.	1.000	0.0	1500.0	1500.0	0.0	1754.	1754.	0.0	3254.
24	236.	1.000	0.0	1500.0	1500.0	0.0	63.	63.	0.0	1563.
25	237.	1.000	0.0	1500.0	1500.0	0.0	0.	0.	0.0	1500.
26	238.	1.000	0.0	1500.0	1500.0	0.0	5598.	5598.	0.0	7098.
27	239.	1.000	0.0	1500.0	1500.0	0.0	3636.	3636.	0.0	5136.
28	240.	1.000	0.0	1500.0	1500.0	0.0	1704.	1704.	0.0	3204.
29	241.	1.000	0.0	1000.0	1000.0	0.0	1573.	1573.	0.0	2573.
30	242.	1.000	0.0	1000.0	1000.0	0.0	0.	0.	0.0	1000.
31	243.	1.000	0.0	500.0	500.0	0.0	0.	0.	0.0	500.
			527733	305211	832944	591984	1497740	2089724	1119717	1802951