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CHIGNIK SOCKEYE STUDIES
Annual Report - Anadromous Fish Project

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ABSTRACT

The results of research and analysis of Chignik salmon production are presented in three sections. Section I details the methods developed by FRI to forecast runs of sockeye salmon to the Chignik watershed. Multiple linear regression indicates that the sibling ratio, i.e., the ratio of the number of 2-ocean age fish returning in a given year to the number of 3-ocean age fish of the same brood returning in the following year, when adjusted for the effects of early ocean maturation (indexed by mean length of 2-ocean males) and parent escapement level accounts for about 92% of the variation in returns of 3-ocean age fish in the early run. However, this method indicates that only the sibling ratio is a significant predictor of 3-ocean age returns to the late run stock, and it accounts for about 68% of the variation in observed 3-ocean returns. The difference in accuracy between the two forecast models is attributed to the relatively high reliability of the early run data base and the low reliability of the late run data base.

Section II is an investigation of the suitability of catch per unit of effort in the late season sockeye fishery as an index of total abundance. Sockeye escapements are not enumerated after about 1 August, yet catches of sockeye after this date often remain significantly large. The method presented is intended to relate daily escapement level to daily catch level during late season after the counting weir has been removed via a relationship determined from daily catches and escapements during early season when the weir is in place. The components f (effort) and q (catchability) of the catch rate parameter, F, are examined for effects on the accuracy of predictions of total abundance from catch. Results indicate that catchability varies with effort in the fishery; that catchability may fluctuate on an annual basis due to differences in migratory behavior of the fish; and that catch rate, F, should be computed for individual years to estimate late season escapements because of inter-annual variation in the catchability coefficient.

Section III reviews the information on coho salmon in the Chignik watershed and provides a preliminary analysis of coho run dynamics. "Performance curves" of catch are developed to examine run timing and catch patterns, and some basic fishery statistics are calculated where data are sufficient to warrant it. Information on the early life history of coho is summarized and includes 1) growth rate and scale development; 2) food habits; and 3) predation on juvenile sockeye salmon.

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CHIGNIK SOCKEYE STUDIES

INTRODUCTION

Scope of the Report

This report summarizes research and analysis conducted by Fisheries Research Institute in the Chignik Watershed (Fig. 1) during the eighteenth year of Anadromous Fish Act (P.L. 89-304) support. Additional funds were provided by Columbia Wards Fisheries, Sea-Alaska Products, Inc., Chignik Boat Owner's Association, and the University of Washington.

Objectives of research in FY 1983 reflected the need to better describe the production dynamics of both sockeye and coho salmon in the watershed. This report is divided into three sections, the first of which details the forecast methods developed and refined since 1979 to predict annual returns of early and late run sockeye to Chignik. Section II presents a technique for estimating escapements of sockeye into Chignik River after the weir has been dismantled. The last section reviews the information base for Chignik coho salmon production, and provides some initial analyses of run statistics. An investigation of sockeye fry growth and prey availability in Chignik Lake is in progress and will be reported on at a later date.

Acknowledgments

As in previous years our research has been coordinated with biologists of the Alaska Department of Fish and Game. In particular, we would like to acknowledge the assistance of Bob Conrad of the Stock Biology division; Pete Probasco, ADF&G Area Management Biologist, and his fine staff; and FRI personnel Eric Volk, Alison Reak, and Jeff Fisher.

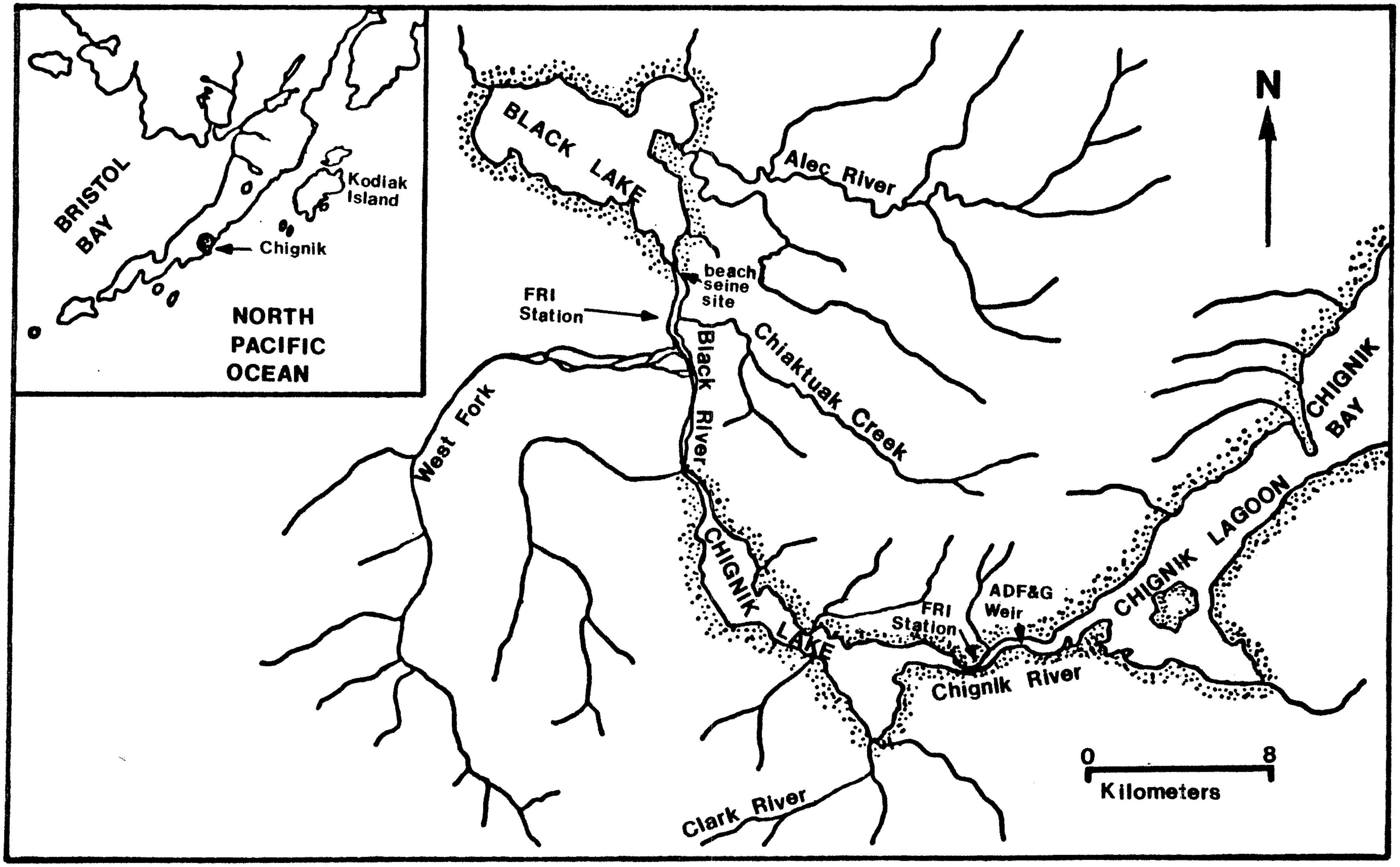

Figure 1. Map of the Chignik watershed with inset of western Alaska .

I. SOCKEYE SALMON FORECAST STUDIES

INTRODUCTION

Studies on the biology of sockeye salmon in the Chignik system were initiated by the Bureau of Commercial Fisheries in 1928 and continued until 1933. Fisheries Research Institute (FRI) began studies in 1955 at the request of the salmon canning industry in an effort to reverse the alarming decline in sockeye abundance during the early 1950's. By 1958 sufficient data had accumulated to consider as well the problem of forecasting annual sockeye runs to the system. The Alaska Department of Fish and Game (ADF&G) in 1961 joined FRI in forecast studies and by 1971 assumed responsibility for issuing annual forecasts.

Increasing dependence on pre-season sockeye forecasts, by both salmon processors planning their Alaska operating strategies and by ADF&G in managing the sensitive Cape Igvak interception fishery, has intensified the requirement for accuracy in predictions of expected run strength. Fisheries Research Institute resumed forecast studies in 1979 when it became apparent that patterns of stock production and recruitment no longer were adequately modelled by existing forecast methods. After several years of testing new models, FRI and ADF&G issued a joint forecast for the 1983 run. This section details the methods used in computing the 1983 and 1984 Chignik sockeye forecasts.

Background

The annual sockeye return to Chignik is composed of two runs that typically exhibit separate peaks of abundance in mid-June and mid-July. "Early run" fish are bound primarily for the Black Lake spawning/nursery complex high in the watershed (Fig. 2a) while "late run" fish are destined largely for the Black River/Chignik Lake complex (Fig. 2b). During much of the season the two stocks mix in the fishery in varying relative proportions as the predominance of early run fish in the catch and escapement gradually shifts to a predominance of late run fish. The transition from early to late run has been modelled since 1964 by an average time of entry (TOE) curve fit to data from tagging studies begun in 1962. Some features of the transition are consistent from year to year while others, such as the timing and rate at which transition occurs, may show significant annual variation (Conrad 1983).

The adult return often shows a characteristic pattern of freshwater age composition that coincides with the passage of each stock through the fishery and into the escapement. The early run of returning adults is composed primarily of age group 1.3, with ages 2.3, 1.2 and 2.2 less abundant. However, in some years, particularly those in which early runs are weak, the percentage of 2.3's may exceed that of 1.3's. Late run adults are mainly 2.3 and 2.2 at return, ages 1.3 and 1.2 rarely contributing more than 25% to the late run total[1] (Conrad 1983).

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[1] Alaska Department of Fish and Game. 1981. Chignik Area Management Report.

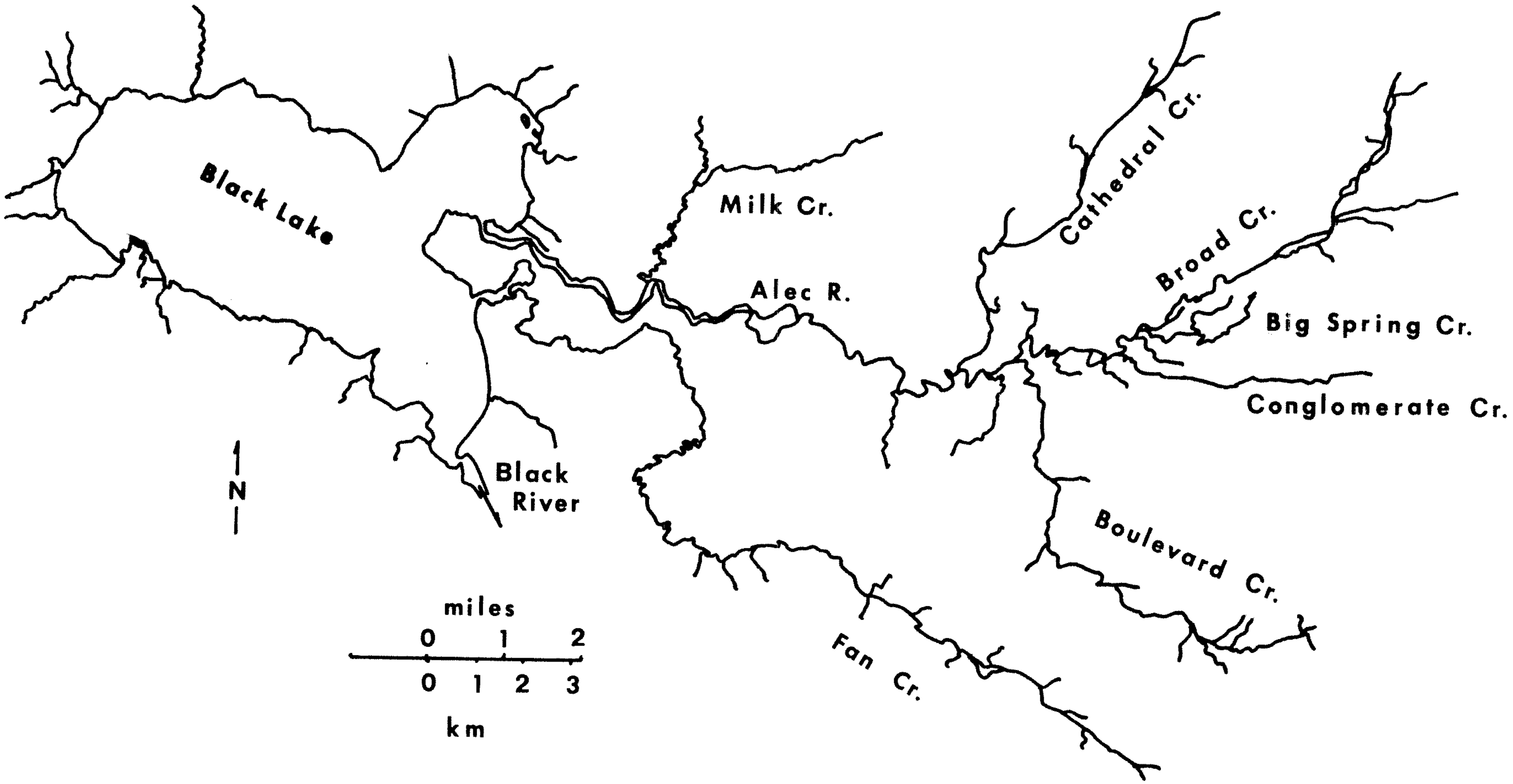

Figure 2a. Map of principal spawning tributaries and nursery area utilized by the Black Lake stock of sockeye in the Chignik watershed.

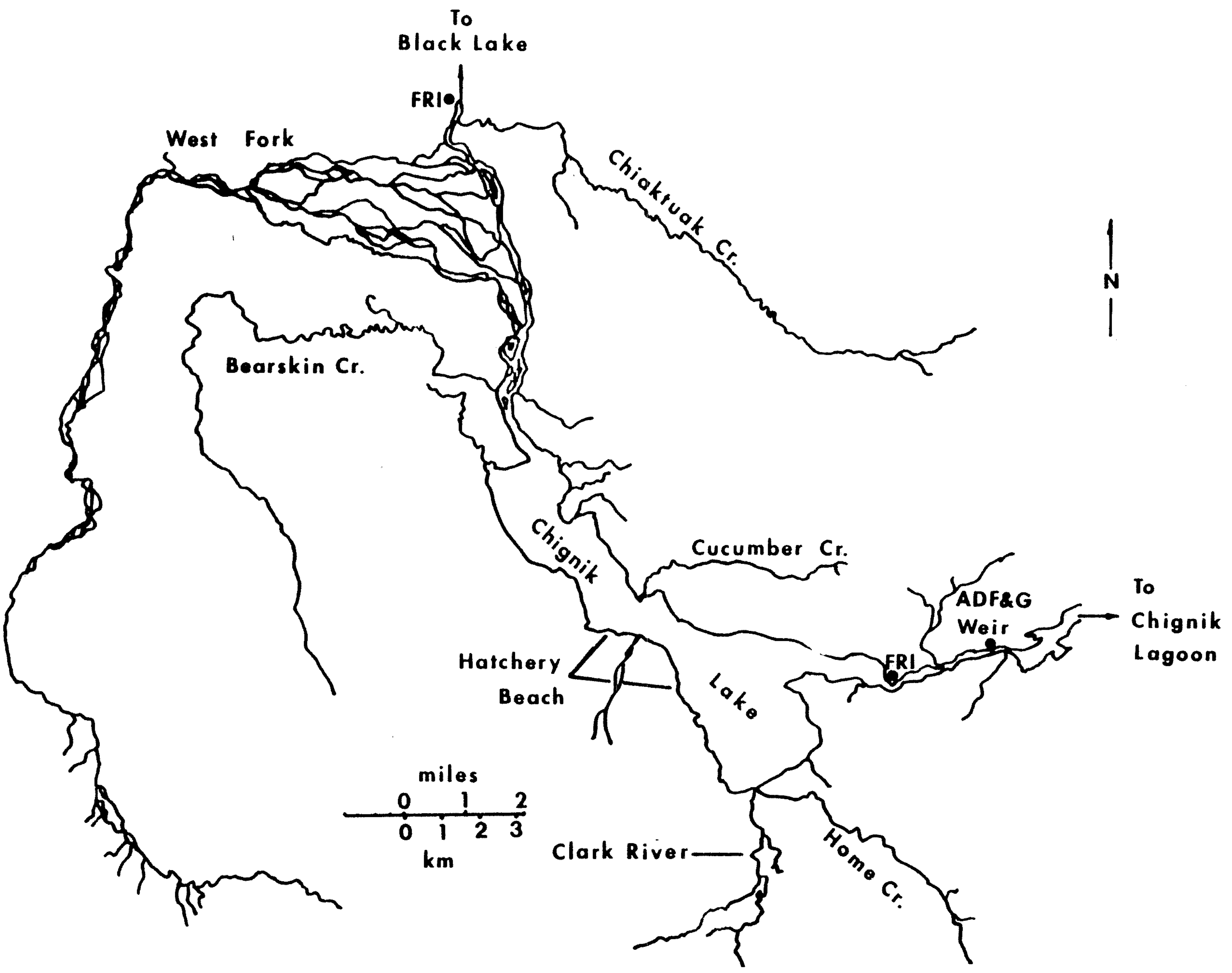

Figure 2b. Map of principal spawning and rearing areas utilized by the Chignik Lake stock of sockeye in the Chignik watershed.

Other age groups generally comprise less than 5% of the return of either stock. The stock-specific freshwater ages are caused by the different conditions for growth of juveniles. The two nursery lakes in the watershed are physically dissimilar (see Burgner, et al. 1969; Narver 1966 for details). Black Lake is extremely turbid and has a high surface area/ volume ratio (mean depth $\leq$ 3 m) which promotes rapid warming in spring and maintenance of relatively warmer temperatures throughout summer. High-quality prey such as emergent larvae and winged adult insects are principal diet components for sockeye fry in Black Lake (Narver 1966; Parr 1972). Chignik Lake is less turbid, has a low surface area/volume ratio, and consequently warms more slowly in spring and summer. Juvenile sockeye disperse to the limnetic area of Chignik Lake when they are about 30 mm and thereafter feed primarily on zooplankton. Studies on fish growth and age structure in the juvenile sockeye populations indicate that virtually no fish reside in Black Lake for more than 2 full summers, whereas age I and age II fingerlings are abundant in Chignik Lake. While quantitative data on age composition in the smolt migration are lacking, the freshwater age composition of returning adults typically shows that most survivors of the Black Lake stock migrated to sea as age I smolts and those from Chignik Lake were age II at seaward migration. This generalization is complicated by density-dependent mid-summer emigrations of age 0 fry from Black Lake into Chignik Lake (Roos 1958; Narver 1966). Presumably a fraction of Black Lake emigrants migrate from Chignik Lake as age I smolts and the rest migrate a year later at age II.

METHODS

The abundance of adult salmon in a given year i is the product of brood strength times the fraction of the brood maturing in year i summed across all broods contributing fish to the return in year i. The brood maturity index, relating the mean proportion of broods returning at age j-1 in year i-1 to the mean proportion returning at age j in year i, is widely used to predict returns of age j salmon and steelhead a year in advance. Where previous forecasts of Chignik sockeye employed linear regression analysis to quantify the ratio between returns of sibling 2-ocean and 3-ocean age fish in sequential years, we extended this form of analysis to consider a set of variables that index the expected strength and maturity rate of broods present in annual returns. Given the observed differences in population biology of the two stocks in the system, analyses were performed on separate data sets compiled for each stock from fishery statistics and brood production tables published in Chignik Area Management Reports, from FRI sampling records, and from NOAA air and water temperature records collected at Women's Bay, Kodiak Island. Much of the early run data consisted of statistics calculated from spawning ground data or data collected at the outlet of Black Lake. Late run statistics were taken directly as reported in Area Management Reports.

Data sets were submitted to a stepwise multiple regression computer program (BMDP2R[2]) which fit the data to the model:

$$\hat{Y} = a + b_1x_1 + b_2x_2 + \ldots b_ix_i + \varepsilon$$

where $\hat{Y}$ = predicted value of dependent variable
a = intercept of the regression
b_1, b_2, b_i = regression coefficients
x_1, x_2, x_i = independent (predictor) variables
ε = error term.

The dependent variable in each case was the total return of 3-ocean age fish in year i, which was the sum of 1.3 and 2.3 returns in each year. In general, independent variables were:

1. Escapement in year i-5 (ESCP5).
2. Escapement in year i-6 (ESCP6).
3. Number of 1.2 jacks returning in year i-1 (AGE12).
4. Number of 2.2 jacks returning in year i-1 (AGE22).
5. Number of 2-ocean fish returning in year i-1 (AGEX2).
6. Mean length of 1.2 males in year i-1 (ML12M).
7. Mean length of 2.2 males in year i-1 (ML22M).

Two additional variables were defined for the late run data base only:

8. Mean winter (Nov-Mar) air temperature at Kodiak in year i-6 (MAIRT).
9. Mean winter (Nov-Mar) sea surface temperature at Women's Bay in year i (SSTEM).

Variables entered the model sequentially until a pre-selected minimum significance level prevented further inclusion of variables. Eligibility was further limited to only variables that reduced error variance in the model by 5% or more.

The forecast of total returns of the major ages in year i was obtained by adding the predictions for 3-ocean and 2-ocean returns. Expected returns of 2-ocean age fish in year i were simply the geometric mean returns for all years in the data set. A prediction interval was established by pooling variances for the estimates of 3-ocean and 2-ocean returns, computing the standard deviation from the pooled variance, and multiplying this value by the appropriate "t" value for 80% confidence. Variances on predictions of 3-ocean returns were computed by the matrix inversion technique given in Draper and Smith (1966) for multiple linear regression techniques.

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[2] Biomedical Computer Programs, P-Series, 1979. Health Sciences Computing Facility, Department of Biomathematics, School of Medicine, UCLA.

RESULTS

Early Run Model

Multiple linear regression analysis of the early run data set indicated that returns of 3-ocean fish (coded name AGEX3) are predictable from estimates of three parameters of stock production (Table 1). The prediction equation resulting from stepwise variable selection was:

$$\mathrm{AGEX3} = 3304858.407 + 7.697(\mathrm{AGE12}) - 6703.503(\mathrm{ML12M}) + 1.052(\mathrm{ESCP5}).$$

The first significant variable in predicting AGEX3 was the return of 2-ocean jacks in the previous year (AGE12). This relationship suggests a reasonably constant maturity schedule, and it makes sound biological sense here as an index of expected total brood production. About 75% of yearly variability in returns of 3-ocean fish to the early run was accounted for by the return of 2-ocean fish in the previous year. The second variable to enter the regression model was mean length of 1.2 males in the previous year (ML12M). The sign of the regression coefficient was negative, supporting the hypothesis that larger body size for 2-ocean fish in year i-1 indicates that a larger fraction of the brood has matured as 2-ocean rather than as 3-ocean adults. The influence of ML12M therefore is to adjust the relationship between AGEX3 and AGE12 according to the effect of body size on the brood maturity schedule. These two variables together accounted for approximately 82% of the variability in AGEX3. The inclusion of escapement in year i-5 (ESCP5) completed model development and increased to roughly 92% the amount of variability in AGEX3 explained by the regression model.

Inclusion of ESCP5 is noteworthy in that it indexes the potential production of broods maturing primarily as 1.3 adults. The relative proportions of 1.3 and 2.3 adults in early run broods varies with brood strength, such that the 1.3 age group is a relatively smaller percentage of weak broods and a relativly larger component of strong broods (Fig. 3). Coupled with the observation that age I parr are virtually absent from Black Lake, the relation strongly suggests that variability in early run brood strength is determined largely by the production of smolts in this nursery lake.

Accuracy of the model in hindcasting returns of 3-ocean sockeye from previous years is shown in Fig. 4. Note that predictions are for the same years of data used in formulating the model. Prediction error (observed-predicted) exceeds 200,000 in only 1 case and 150,000 in 3 of 15 cases. Large errors in 1977 and 1978 are due in part to exceptionally large returns of 2.3's which apparently had emigrated to Chignik Lake and found good rearing conditions. Expressed as a percentage of the observed run, prediction error exceeds 40% in 1 case, 30% in 3 cases, and 20% in 5 of 15 cases. Average percentage error for the 15 years tested is 16.8%.

Table 1. Summary of regression analysis of early run data set.

Step no.	Variable entered	Regression coefficient	95% confidence limit on B	R^2	F-to-enter	Standard error of prediction
0	Intercept	3304858.407				
1	AGE12	7.697	±2.607	.7509	34.197	223954
2	ML12M	-6703.503	±3085.495	.8184	4.458	199040
3	ESCP5	1.052	±.5723	.9167	12.975	140817

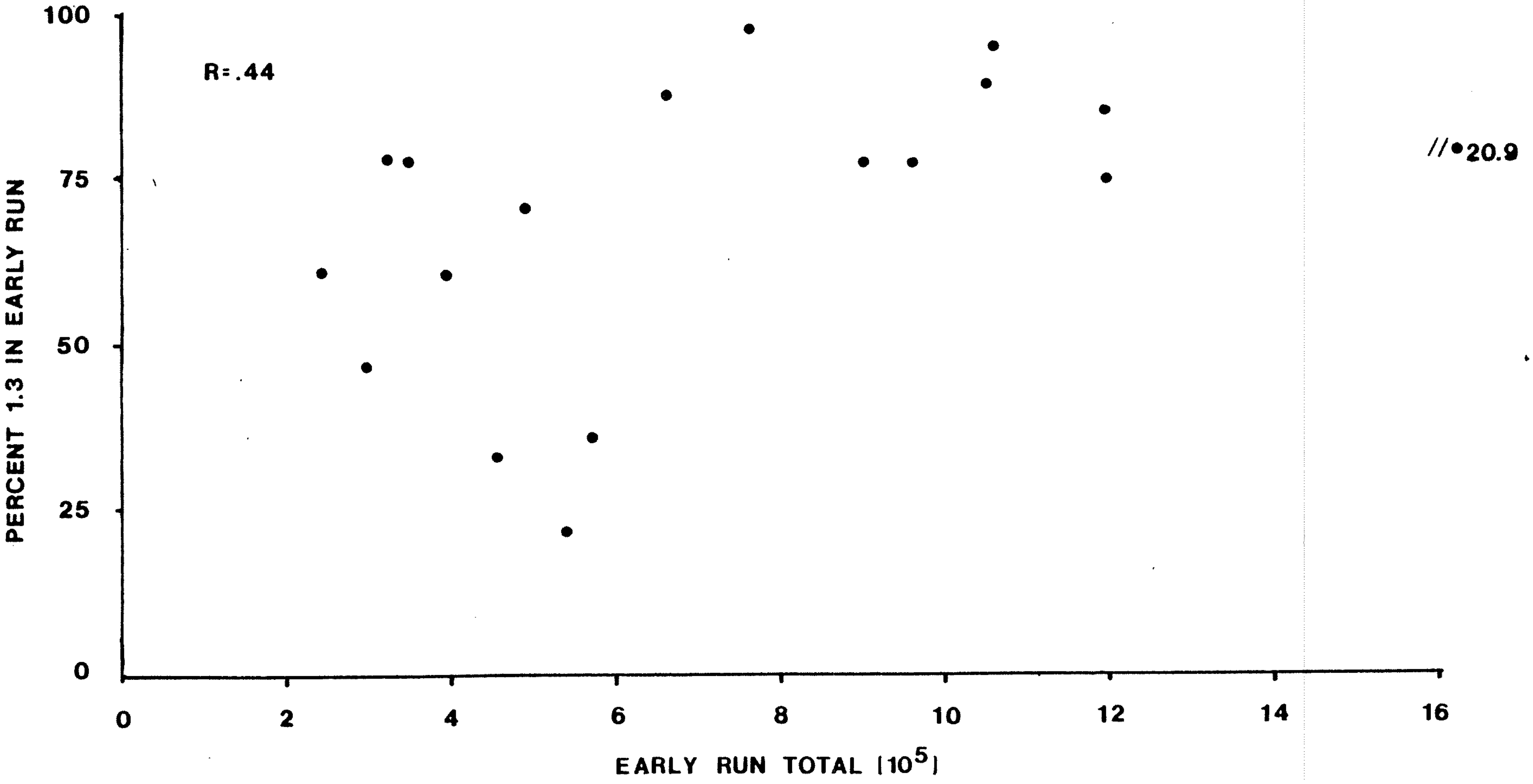


Figure 3. Correlation of total early run size with percentage of 1.3 adults in the early run of sockeye salmon to Chignik, illustrating the tendency for lower percentages to be associated with weaker runs.

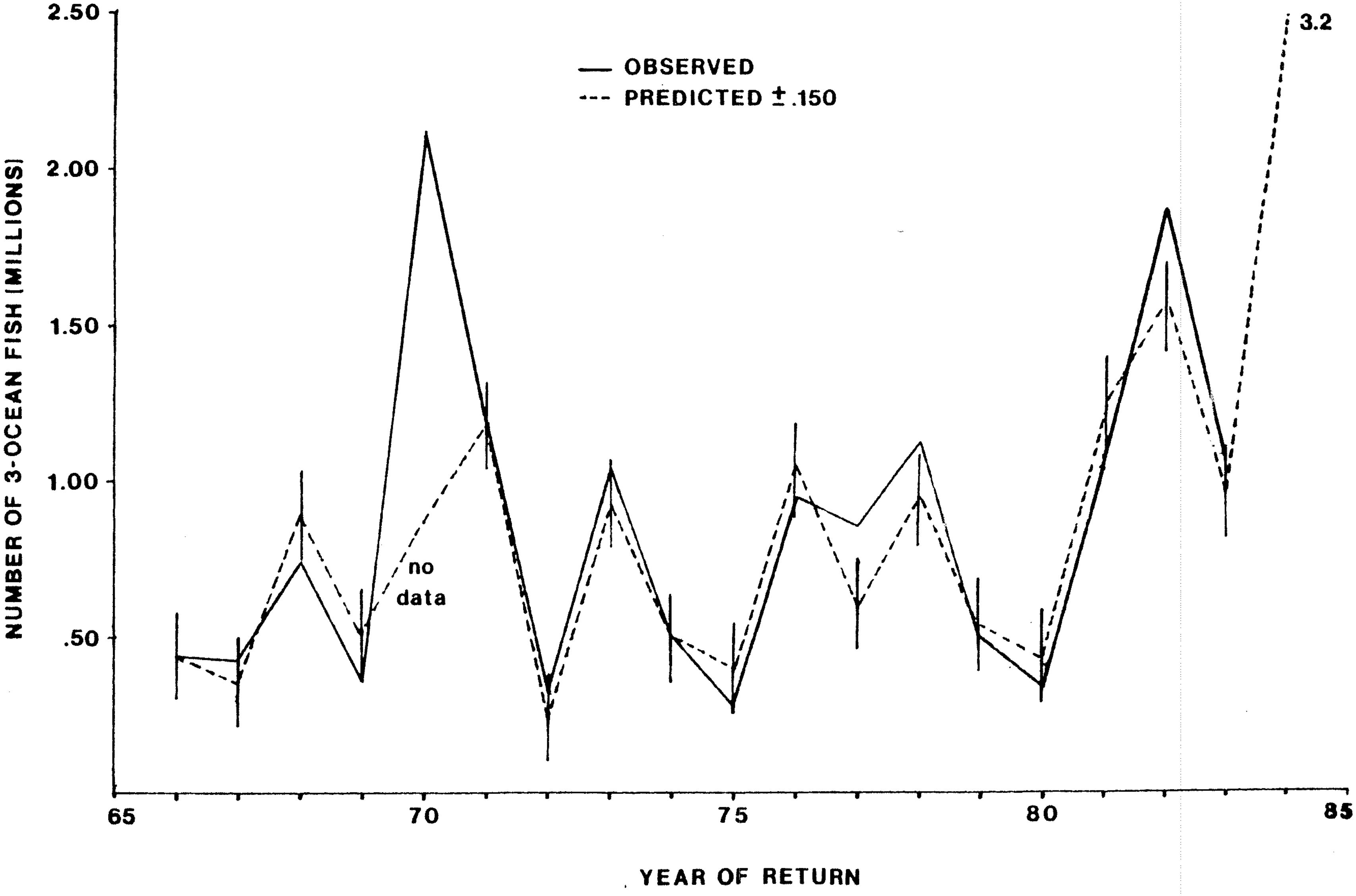


Figure 4. Performance of the early run forecast model in hindcasting sockeye returns to Chignik.

Late Run Model

Analysis of the late-run data provided no completely satisfactory forecast model. Although a model incorporating SSTEM and MAIRT accounted for approximately 68% of variation in returns of 3-ocean age fish, its performance in hindcasting returns was erratic. Moreover, forecasts cannot be prepared earlier than 1 April of the year of return because SSTEM requires data from Nov-Mar of the current year. This schedule is unacceptable to users who must plan operating strategies well in advance of the fishing season. A second model, derived from late run brood production data, indicated that only the return of 2-ocean age fish in the previous year (AGEX2) was significantly related to AGEX3 (Table 2). The resulting regression equation was;

$$\text{AGEX3} = 236499.868 + 2.639(\text{AGEX2}).$$

Approximately 50% of the variability in AGEX3 was explained by variability in AGEX2.

Performance of this model is shown graphically in Fig. 5. Prediction error exceeded 600,000 in 2 cases, 400,000 in 3 cases and 200,000 in 11 of 20 cases. Expressed as a percentage of the observed return of 3- ocean fish, error exceeded 100% in 2 cases, 50% in 6 cases, and 25% in 14 of 20 cases. Mean prediction error for the late run model was 46.6%.

DISCUSSION

Several major differences exist between the early and late run forecast models, not the least being the disparity in performance. We suggest that differences in accuracy between the models relate to the quality of data available for each stock. Statistics for the early run are calculated in this analysis from data obtained by routine sampling for age, length, and sex of spawners captured at the outlet of Black Lake prior to their movement onto the spawning grounds. These samples are reliably stock-specific as no mixing of stocks occurs at this location. Representative samples from the late run are not easily obtained because the majority of spawners are inaccessible in the deeper waters off lake beaches. Late run statistics consequently are calculated from data collected in the commercial fishery, but they cannot be considered as stock-specific because early and late run fish mix in the catch during the fishing season. Therefore, bias in stock production data probably is the major component of variability in the relationships from which the late run forecast model is developed.

Errors in stock production estimates arise primarily from two sources: 1) inaccuracy in stock abundance assessment; and 2) misallocation of ages within stocks. Both the early and late run data bases contain some error in stock abundance statistics which is attributable to yearly variations in timing of the sockeye run relative to the place-

Table 2. Summary of regression analysis of late run data set.

Step no.	Variable entered	Regression coefficient	95% confidence limit on	R^2	F-to-enter	Standard error of prediction
0	Intercept					
1	Age X 2	2.761	±1.53	.4410	14.20	319768

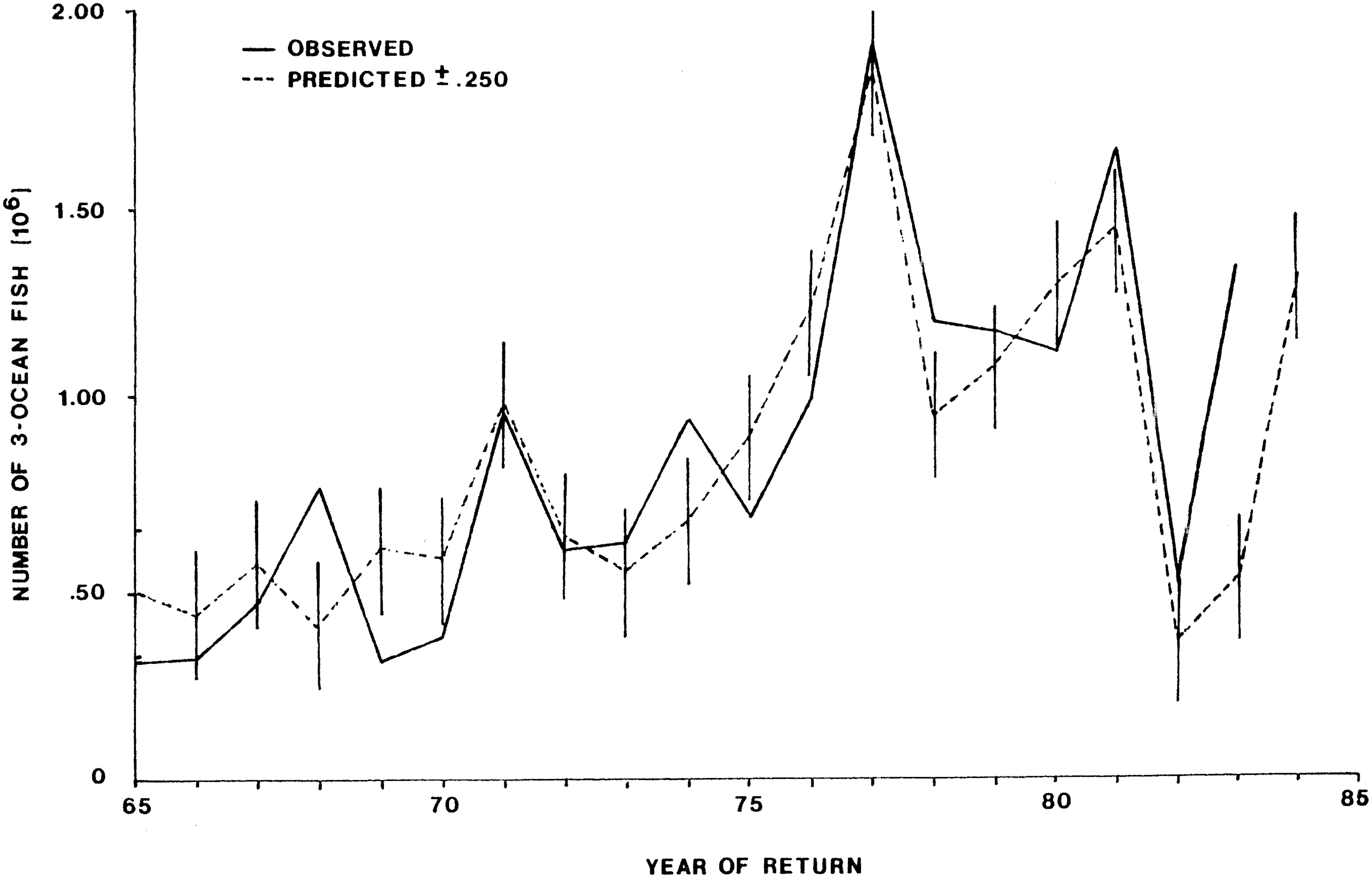


Figure 5. Performance of the late run forecast model in hindcasting sockeye returns to Chignik.

ment in time of the TOE curve. Errors of this sort are generated in estimates of stock abundance if the TOE curve is misplaced with respect to actual run timing. The frequency of occurrence, magnitude, and direction (to early run or to late run) of such errors in the statistics are indeterminate. However, assessment of late run stock size is further subject to a source of error which does not affect the early run. Late run sockeye typically return to the system in relatively low numbers well into October, but enumeration of daily run totals ceases in early August of each year when the weir on Chignik River is removed. The assumption is made that approximately 50,000 additional spawners pass into the escapement after 1 August, yet patterns of exploitation and catch per unit of effort in the commercial fishery after this date suggest that late season abundance of sockeye may be highly variable between years (Section II, this report). Undetected variability in late season run dynamics could account in part for the lack of significant stock production relationships in the late run data base.

Estimates of stock abundance in each year are apportioned to appropriate broods based on the age composition of the return. The accuracy of age composition statistics thus is a key factor in ascertaining overall brood production. As Burgner and Marshall (1974) point out, large discrepancies may exist between age composition estimates for each stock calculated from scale samples taken in the commercial fishery and from otoliths collected on the spawning grounds. Our use of age composition statistics for the early run calculated from data taken at Black Lake rather than from the fishery almost certainly improves the accuracy of brood production estimates, thus permitting a higher degree of accuracy in calculations based on brood production estimates. Unavailability of reliable stock-specific late run age data conversely must certainly impair the accuracy of brood production estimates for this stock.

The results clearly indicate a need for better determinations of basic population statistics for the late run. The lack of significant relationships among variables of stock production in the data base may result from 1) a real absence of such relationships in late run production dynamics; or 2) masking of such relationships by variability in the data. We suggest that (2) presently is the case, but the point is that (1) cannot be tested until (2) is resolved. Efforts are being undertaken to increase the reliability of late run data, including an in-season stock separation program based on scale pattern analysis, and estimation of late season escapements from CPUE in the commercial fishery.

PRELIMINARY FORECAST OF 1984 RETURN

	Early Run	Late Run
Point estimate:	3.2 million	1.2 million
80% prediction range:	2.6 to 3.7 million	760,000 to 1.64 million
Expected harvest:	2.2 to 3.3 million	510,000 to 1.39 million

Forecast Methods

Point estimates given above are sums of the predicted returns of 3-ocean and 2-ocean age sockeye in the respective runs.

A multiple linear regression equation predicts the return of 3-ocean age fish in the early run from data on the return of 1.2 age fish in the previous year, mean length of 1.2 males in the previous year, and size of the early run escapement 5 years earlier. The expected return of 2-ocean age fish in the early run is the geometric mean of 2-ocean returns since 1965, excluding 1969 and 1975.

A linear regression equation is used to predict the number of 3-ocean age fish in the late run based on the number of 2-ocean age fish in the previous year's run. The expected return of 2-ocean age fish in the late run is the geometric mean of 2-ocean returns since 1962.

Discussion of the 1984 Forecast

Early Run: The early run forecast indicates a return in 1984 much larger than in any recent year. The prediction is based mainly on an abnormally large return of 1.2 age fish in 1983 that was roughly three times the size of any 1.2 return since 1960. Values of the other two predictor variables were near average or slightly above.

A substantial degree of uncertainty is connected with the 1984 forecast for two principle reasons. First, an unknown effect of El Niño during the winter of 1982-83 may have disrupted the normal brood maturity schedule such that a larger fraction of the 1979 brood returned in 1983 at age 1.2 rather than at the normal age 1.3. However, there is no corroborative evidence that this has occurred in other sockeye systems. Second, the relationship between 2-ocean returns in one year and 3-ocean returns in the next is linear in the range of values currently on record, but the data base is inadequate to predict whether or not the relation remains linear at values far outside the established range.

Late Run: The predicted return of late run fish falls well within the range of past runs and is somewhat smaller than the average for years since 1975. While the relationship between 2-ocean and 3-ocean returns is quite variable in late run data, observed runs are within the prediction range in 14 of 20 hindcasts for years since 1962. We expect the 1984 late run to be reasonably close to forecasted size because there was nothing unusual about the return of 2-ocean fish in 1983.

II. ESTIMATION OF LATE SEASON SOCKEYE ESCAPEMENT

INTRODUCTION

Daily escapements into the Chignik watershed are enumerated at a weir located approximately 3 km from the mouth of Chignik River. From late May to early August, fish passage rates estimated daily at several gates in the weir are used to compute the total escapement per 24-hr period. Estimated daily totals are partitioned into early run and late run components to provide estimates of cumulative escapements to each stock by day. Decisions to open or close the commercial fishery are made by comparing cumulative escapements to date against escapement goals for each stock. This system continues until a late run escapement of 200,000 spawners is achieved, usually on or about 1 August of each year.

Escapements occurring over the remainder of the sockeye run are assumed to add about 50,000 to the late run spawning population. This is a semi-quantitative estimate and is assigned to the late escapement regardless of the magnitude of catches taken in Chignik Lagoon during this segment of the run. For example, catch totals for the months of August and September, hereafter referred to as "late season," were highly variable over the 10-yr period 1974-83, whereas escapements were not (Fig. 6). If catch is a linear function of total abundance and fishing effort (Ricker 1975), then fluctuations in catch per unit of effort imply changes in total abundance. Large annual variations in catch suggest that actual escapements from the late season sockeye fishery may be seriously misrepresented by escapements assumed to be constant at 50,000.

Failure to account for large discrepancies between actual and assumed escapements generates pervasive errors in late run statistics. Perhaps most important among these is the effect on calculations of return per spawner, wherein relatively small errors in estimated numbers of spawners can profoundly alter interpretations of stock productivity. This has significant implications for determining the optimum late run escapement level. It is noteworthy that the present goal of 250,000 spawners was suggested by Dahlberg (1968) from spawner-recruit analyses of the stock in years when late season escapements were quantitatively estimated from weir counts made through September (op. cit.). If present escapements actually are much different than 250,000, then possibly the late run stock is not being managed for maximum productivity. A derivative result of the uncertainty in late run escapement estimates was discussed in Section I of this report involving the annual Chignik sockeye forecast. Whereas the early run forecast model had strong relationships among variables of brood production and maturity, the late run data failed to produce significant relationships of this type, with the exception of a moderately constant brood maturity schedule. Whether or not consistent relationships actually exist among the production statistics of late run broods

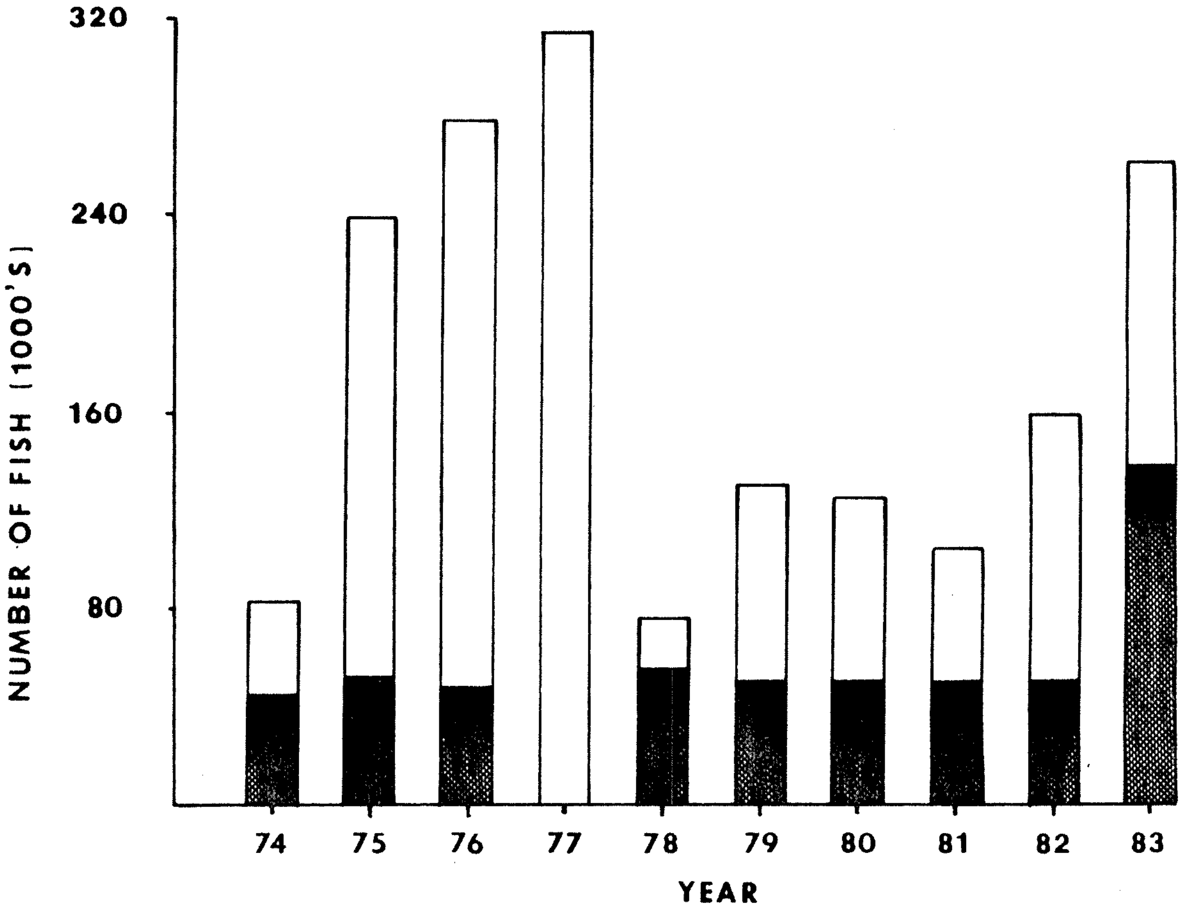


Figure 6. Comparison of late season catches with estimated late season escapement of Chignik sockeye.

presently cannot be determined because the reliability of the statistics is suspect.

Our objective is to resolve this uncertainty by providing quantitative estimates of late season escapements for the past 10 years. The relation of catch to total abundance is the logical basis for developing an escapement estimator, since escapement is simply the difference between the two parameters. Accordingly, the following section quantifies the relationship using fishery statistics for the period prior to weir removal in each of the available years of data 1974-83. The derived estimation procedure then is applied to late season catch data to calculate sockeye escapements after weir removal in those years. Late run escapements are recalculated to include the estimated late season component.

METHODS

Catch and effort data for years since 1974 were obtained from computerized summaries of ADF&G fish ticket collections, which for this case reported the data stratified by statistical sub-district, species, and date. Catch was given in numbers and pounds of sockeye landed, and effort was shown as numbers of boats and numbers of landings in each sub-district on each date. The database was limited to catch in numbers and effort in number of boats within statistical sub-district 274-10 for each day of fishing. Sub-district 274-10 includes all of Chignik Lagoon and the immediate surrounding waters of Chignik Bay. More than 80% of the total catch of sockeye in the Chignik District normally is taken within this area (Conrad 1983).

Escapement data were obtained from ADF&G Area Management Reports. Daily escapements at Chignik weir were lagged 1 day back to adjust for migration time between Chignik Lagoon and the weir. Although Dahlberg (1968) reported a skewed distribution of migration times for fish tagged in the Lagoon and used a modal value of 2 days for his time of entry studies, Conrad (1983) noted a stronger correlation between lagoon catch and escapement on the following day than for lagoon catch and escapement 2 days later. Therefore, total abundance in Chignik Lagoon for any date on which fishing occurred is the sum of the lagoon catch on that day and the escapement on the following day.

Analysis proceeded from the basic catch equation:

$$C = F\bar{N} \qquad (1)$$

wherein catch is some fraction of the average total abundance available to the fleet during a defined time interval. Prediction of N from the catch is possible by rearranging (1) to

$$N = \frac{C}{F}$$

If F, rate of fishing mortality, is approximately constant for all N, then this formulation is equivalent to linear regression of N on C where the intercept is 0 and slope is 1/F. Regression by the least squares method is preferred for this application because the technique is designed to minimize the sum of errors in predictions made from the regression line, and thus minimizes the likelihood of systematic over- or underestimates of total abundance. As we are concerned primarily with the accuracy of the sum of daily escapement estimates rather than with the accuracy of the daily estimates themselves, predictions of abundance from a least squares regression on catch should produce the highest reliability in the ultimate late season escapement total. While this is a convenient model for the prediction of N, it should be recognized that the accuracy of predictions is strictly dependent on the variability of F about its mean value. Therefore, the prediction of total abundance corresponding to a given level of catch essentially is a matter of defining the behavior of F with respect to N.

The instantaneous rate of fishing mortality (also called "rate of fishing" or "catch rate") is the product of fishing effort (f) and catchability (q) applied to the fishery, i.e.,

$$F_i = qf_i \qquad (2)$$

subscripted in time units i. In theory this relation holds only so long as effort is strictly additive, such that an increase in effort results in a linear increase in fishing rate (Ricker 1975). Note the absence of a subscript on q, emphasizing the assumption that each unit of effort catches a constant fraction of the stock (N) available at time i (Paloheimo and Dickie 1964). The concept of catchability in this sense is less a biological one than a mathematical one, as q is simply a proportionality constant relating the catch rate to the expenditure of effort (Gulland 1969).

The catchability coefficient is defined explicitly from eq. (2) as

$$q = \frac{F}{f}$$

and since F = C/N

$$q = \frac{C/N}{f}$$

or

$$q = \frac{C}{f} \cdot \frac{1}{N}$$
$$= \frac{C/F}{N}$$

In words, catchability is the catch per unit of effort (defined as 1 boat·day) divided by total stock abundance. Its value must be determined empirically for each application, since the term, q, is a simple numerical representation for the complex physical, biological, and environmental circumstances resulting in the catch of a specific fishery. In practice q may not be constant and must be modelled as a function of effort (Brannian 1982). Further, the degree to which q varies within a particular fishery will directly influence, and possibly limit through its effect on F, the usefulness of catch data to accurately index total abundance. Establishing the validity of the assumption of constant q using real data therefore is key to the estimation process.

Daily run statistics for the months prior to weir removal in each year were used to develop empirical relationships between the variables of catch and total abundance. The response of catchability to varying levels of effort was examined first by plotting q against f for all years pooled. Regression analysis was used to test the assumption of constant q, stated as the hypothesis that the slope of the regression line was not significantly different from 0. The relationship between catch and total abundance was quantified by linear regression as well. Total abundance by day prior to weir removal was regressed on catch for individual years to determine the variability of the relationship between years. Since prior analysis had shown that intercepts of these regression lines were not significantly different from 0 in 8 of the 10 years tested, regression lines for all years were constrained through the origin so that slope coefficients would be equivalent to 1/F in individual years.

Linear equations resulting from the analysis outlined above were applied to catches taken after the removal of Chignik weir. Predictions of daily total abundance in the late season sockeye fishery were produced for each day on which fishing occurred. Daily escapements were estimated as the difference between predicted total abundance and observed catch. Escapements for days closed to commercial fishing were estimated by linear interpolation of predicted total abundances on days adjacent to the closure.

RESULTS

Catchability

Gross inspection of pooled values of catchability plotted against effort clearly shows that catchability was highly variable at low levels of effort and much less variable with increasing effort (Fig. 7). When the data were stratified by levels of effort there was a significant reduction in variability when effort exceeded 10 units but little further reduction at levels of ≥ 30 or ≥ 40 units. The probable explanation for this is that catches associated with effort ≤ 10 boats are subsistence harvests of a fixed number of sockeye per boat during closed periods, rather than catches of a proportion of the stock available (pers. observation). Since these catches did not conform to the definition of catchability given above, they were dropped from the analysis.

Regression analysis of catchability on effort showed that q did not truly stabilize with increasing effort even when subsistence harvests were excluded (Table 3). Slopes of lines relating catchability

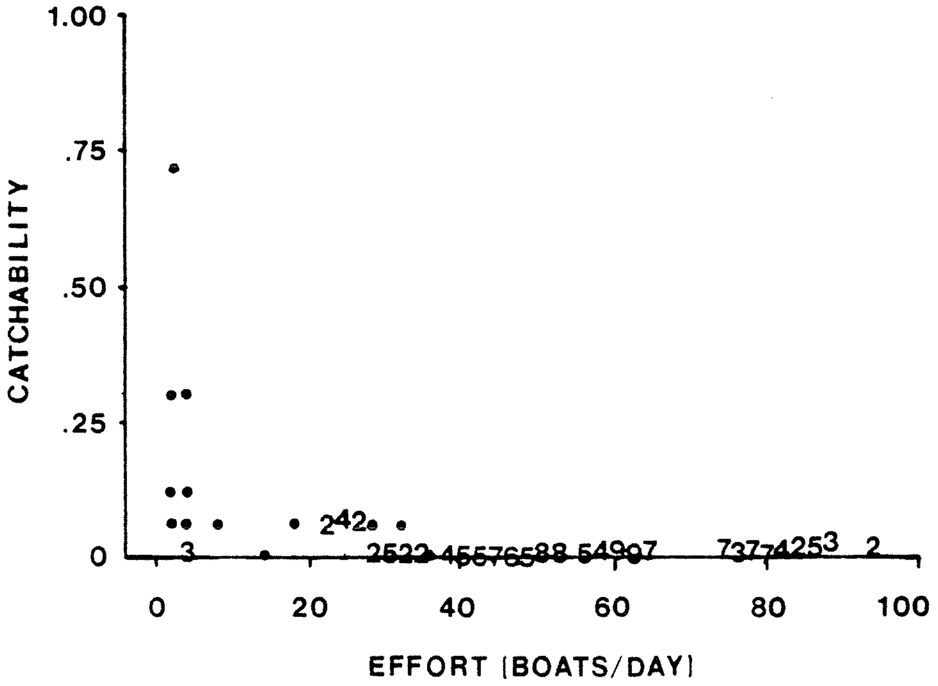


Figure 7. Relation of catchability to effort for pooled data from 1974-82. Numbers indicate number of occurrences at each data point.

Table 3. Regression analysis of the effect of varying minimum levels of effort on resulting estimates of catchability. Catchability is constant when the slope coefficient β is not significantly different from 0 at P = .05.

Minimum level of effort	$\hat{\beta}$	Var($\hat{\beta}$)	r^2	$\hat{\beta} = 0$	
				t-ratio	t-crit
>0	-8.3×10^{-4}	2.20×10^{-8}	0.118	5.61	1.96
>10	-3.2×10^{-4}	1.44×10^{-10}	0.776	26.75	1.96
≥30	-2.6×10^{-4}	9.93×10^{-11}	0.775	25.71	1.96
≥40	-2.3×10^{-4}	9.41×10^{-11}	0.755	23.40	1.96

to effort >10, ≥ 30, and ≥ 40 units were significantly different from 0 in each case, suggesting that q should not be taken as strictly constant. However, means of the values of q predicted from each of the regressions were not significantly different from each other (p = .05, Student's "t"), thus for simplicity q was considered to be approximately constant when effort >10 units. Note that while q is fixed in any given year, its value was permitted to vary between years in response to annual variation in the unmeasured factors affecting catchability.

Rate of Fishing Mortality

Slope coefficients, their reciprocals and standard deviations, and standard errors of estimation for year-specific regressions of total abundance on catch are shown in Table 4. Reciprocals are means of F for days on which fishing occurred, given as n in the table, and are not equivalent to the exploitation rate, u, which would include escapements on days when no fishing occurred. The values presented here represent the fraction of total stock abundance available on fishing day i that was actually harvested by the fleet, averaged over all fishing days i prior to weir removal in early August. Differences in F thus indicate differences in catch rate that are unrelated to total run size or harvest management decisions.

The application of catch rate as a predictor of abundance is directed by the degree of consistency in calculated values of $\bar{F}$. Results of analysis of covariance indicated that estimates of $\bar{F}$ were significantly different (Table 5), thus the assumption of a constant catch rate between years was rejected. The difference in slopes was not related to a trend in F over the past 10 yr (Fig. 8), suggesting that fishing power in the fleet was relatively stable and the variability in F was primarily in the components of catchability rather than in effort. As an example, the comparatively low F in 1983 probably resulted from anomalous behavior of early run sockeye migrating through Chignik Lagoon rather than differences in effort. Adults in 1983 quickly and quietly transited the principal fishing grounds and thereby reduced both the time and probability of detection by the commercial fleet.

The behavioral aspect of catchability also may be expressd as within-year variation in migration timing between Chignik Lagoon and Chignik weir. If the actual holding time of fish in the lagoon is highly variable or much different than the assumed 1-day lag time, then artifacts in the calculations of total daily abundance will bias the regression of abundance on catch. The consequence is seen as poor reliability in the predictive model and large standard errors of estimates. Annual variation in the components of catchability and associated effects appears to be the limiting factor in the use of catch data to estimate total abundance. Additional research on the components of variance in the catchability coefficient and estimation of lag time is necessary to refine within-year estimates of F.

Table 4. Summary of regression analysis of total stock abundance on catch by day prior to weir removal in the years indicated.

Year	Slope coefficient β =(1/F)	S.D.(1/F)	$\hat{F}$	S.D.(F)	SE $\hat{Y}$	n
1974	1.28095	0.03206	0.78067	0.01906	4116	20
1975	1.12649	0.03842	0.88771	0.02927	3005	9
1976	1.07081	0.01224	0.93387	0.01055	3665	26
1977	1.06388	0.00814	0.93996	0.00714	3929	19
1978	1.11157	0.01730	0.89963	0.01379	6293	32
1979	1.26993	0.05419	0.78744	0.03222	10467	22
1980	1.14749	0.01611	0.87147	0.01207	2577	20
1981	1.07939	0.01446	0.92645	0.01225	3738	39
1982	1.11232	0.00876	0.89902	0.00702	3370	20
1983	1.19960	0.04287	0.83361	0.02876	10278	36

Table 5. Analysis of covariance table of regression lines of total abundance on catch for the years 1974 to 1982.

Source	d.f.	SS	MS	F
Total	207	924552567129		
Regression	1	917019430056		
Residuals about common line	206	7533137073	36568627	
Residuals about individual lines	198	5408989203	27318127	8.64**
Difference	9	2124147870	236016430	

**Indicates rejection at .001 significance level.

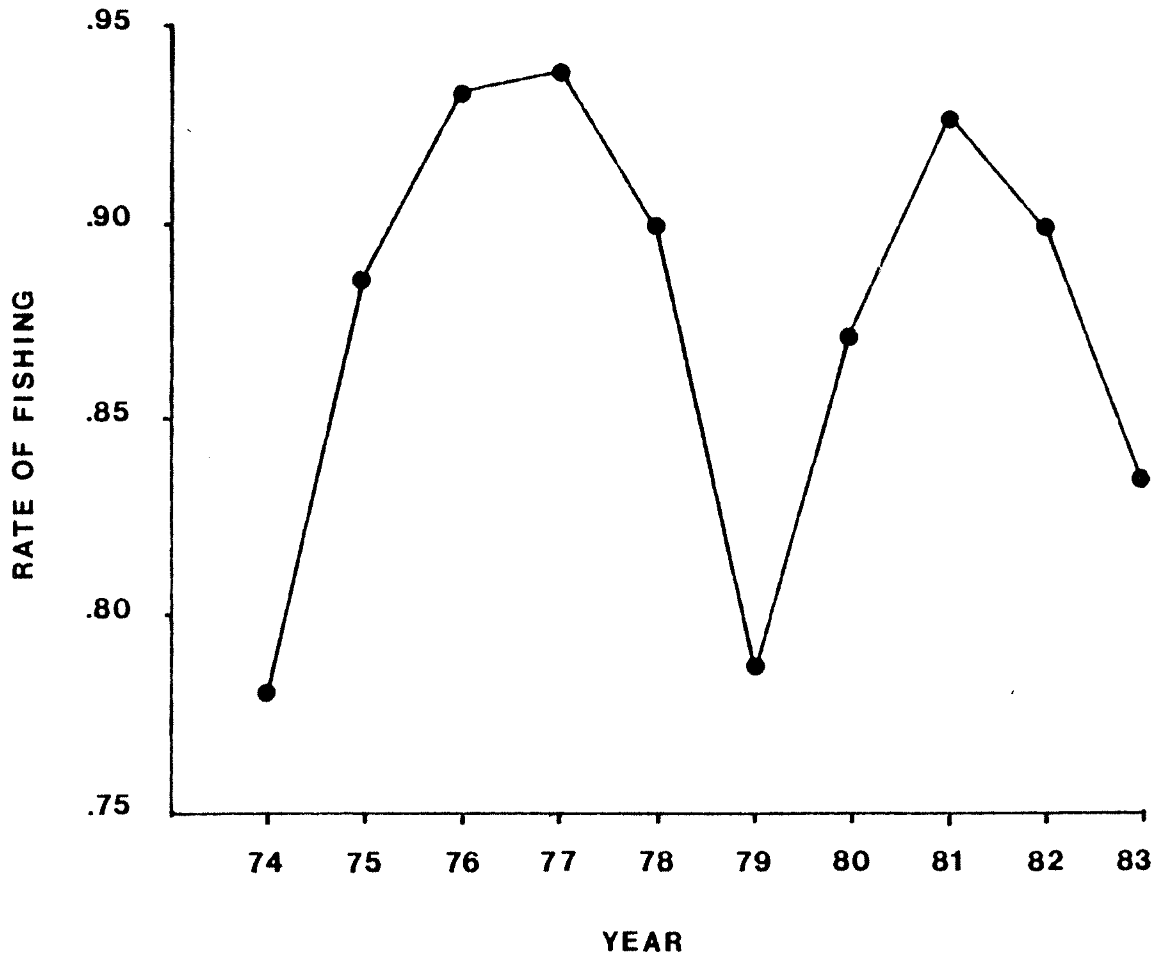


Figure 8. Fluctuation in rate of fishing, F, over the 10-year period of analysis, 1974 - 1983.

Estimation of Late Season Escapement

Results to be discussed in this section are summarized in Table 6. Details of the results are discussed for individual years below. Column headings in Table 6 require further explanation. Cumulative effort refers to the total number of boat•days expended in Chignik Lagoon during the season. Total fishing days indicates the number of days on which commercial fishing occurred during the season. Cumulative catch is the total number of sockeye taken in Chignik Lagoon on all days of commercial fishing. Cumulative escapement includes that enumerated at the weir prior to dismantling plus the late season escapement estimated from late season catch. The estimate of mean F is accompanied by 1 standard deviation. The sum of differences in observed and predicted escapements describes the direction of bias in predictions of abundance from the catch on days prior to weir removal. For example, the sum of -7119 in 1974 indicates that the total of predicted escapements for the 20 days of fishing prior to weir removal was 7119 less than the total of corresponding observed escapements. The next column is simply this difference expressed as a percentage of the observed escapement total given above. Late season effort is the expenditure in boat•days following weir removal. Fishing days refers to the number of days after weir removal on which fishing actually occurred. Note that this does not necessarily correspond to the number of days open to commercial fishing. Late season catch is the cumulative total taken in Chignik Lagoon after weir removal. Estimated late season escapement is calculated from the catch as described earlier. Revised late run escapement is the sum of the estimated late season escapement total added to the estimated late run escapement accumulated by the last day of weir operation. The next column is the difference between the revised late run escapement total and the figure published in the ADF&G Area Management Report, expressed in the following column as a percentage of the ADF&G figure. The final two columns present the excess late run escapement in numbers and as percentages of the late run escapement goal.

1974

The total catch of sockeye in Chignik Lagoon and adjacent waters was 539,246 and the total escapement, including the revised late season estimate, was 712,469. The sum of differences between predicted escapement and observed escapement on the 20 days of fishing prior to weir removal was -7,119, indicating a tendency for the regression model to slightly underestimate total abundance. Effort in the late season fishery totalled 666 boat•days and the resulting catch was 83,962. The cumulative predicted late season escapement was 72,617, or 40,367 more than the published figure. The revised late run escapement estimate was increased by about 12.5% to a total of 364,612. This represents a surplus escapement of 45.8% to the late run.

Table 6. Summary of data used in estimating late season escapements of sockeye, late season escapement totals, adjusted late run escapement estimates, and estimated surplus of late run spawners for the years indicated.

Year	Cumulative effort	Total fishing days	Cumulative catch	Cumulative escapement	$\bar{F}$ ± S.D.	Σ observed -predicted escapements	Percent error	Late season effort	Fishing days	Late season catch	Estimated late season escapement	Revised late run escapement	Revised estimate-published estimate	Percent difference	Revised estimate-escapement goal	Percent difference
1974	1914	49	539246	712469	.781±.019	-7119	-5.1	666	29	83962	72617	364612	40367	12.5	114612	45.8
1975	1700	48	387128	617514	.888±.029	-13583	-39.7	1176	39	238379	88850	314084	45350	16.9	64084	25.6
1976	1929	52	1112410	881094	.934±.011	-24658	-28.2	1052	26	276899	110688	341828	71828	26.6	91828	36.7
1977	1847	52	1851552	829253	.940±.007	-8900	-8.3	706	33	314484	148561	463561	148561	47.2	213561	85.4
1978	2279	49	1397805	671827	.900±.014	-59636	-27.2	558	17	76821	28759	263009	-2291	-1.1	13009	5.2
1979	2158	47	908450	796495	.787±.032	+37405	+21.9	714	25	129591	108676	317889	58673	22.6	67889	27.2
1980	2003	54	707793	689990	.871±.012	-3379	-4.3	874	31	124618	75931	279729	25928	10.2	29729	11.9
1981	2526	58	1347729	849636	.926±.012	-29137	-21.4	508	19	104378	71414	301092	21411	7.7	51092	20.4
1982	2373	63	1413720	921197	.899±.007	+5571	+4.4	1040	43	158670	133471	305193	83471	37.7	55193	22.1
1983	3456	70	1596391	864837	.834±.029	-39440	-12.9	1218	34	262379	170095	441561	32095	7.8	191561	76.6

1975

The 1975 catch of sockeye in Chignik Lagoon was 387,128 and the escapement was 617,514. A weak early run limited fishing to only 9 days prior to the dismantling of Chignik weir. The sum of differences between predicted and observed escapement on those 9 days of fishing totalled -13,583, again pointing to a conservative bias in the prediction model. Cumulative effort for all of 1975 was 1,700 boat•days, of which 1,176 were expended in the late season sockeye fishery. The intensity of effort during this period resulted in a comparatively high exploitation of the late-arriving adults and a low escapement estimate of 88,850. This is roughly twice the recorded late-season escapement and produced an adjustment of about 17% in the late run escapement statistic. The cumulative late run escapement of 314,084 represents an excess of 25.6% over the escapement goal.

1976

The distribution of fishing time over the 1976 season was much more uniform than it had been in 1975. The total catch in the lagoon of 1,112,410 was taken in 26 days of fishing before weir removal and 26 days subsequent to it. The total escapement was 881,094, of which 341,828 were allocated to the late run. The conservative bias in predictions of escapement is somewhat more pronounced in the 1976 model, as the sum of residuals totals -24,658. However, much of the error is contributed by a single residual of -16,913 that appears to be due to an inappropriate match-up of lag time for the catch and corresponding escapement. Of the late run escapement total, 110,688 is estimated to be the late season component. This is nearly three times the recorded late season estimate and accounts for an increase by 26.6% in the recorded late run escapement. The adjusted estimate is 36.7% in excess of the late run escapement goal.

1977

The sockeye run was quite strong in 1977, producing a total lagoon catch of 1,851,553 and total escapement of 829,253. Total effort for the season was 1,874 boat•days, of which 1,141 occurred in 19 days of fishing prior to removal of the weir and 706 boat•days in 33 days following. The sum of prediction errors on days of fishing prior to weir removal underestimated true escapements by 8,900, again showing a conservative bias in predictions of total abundance. The late season escapement estimate is 148,561 based on a catch of 314,484. The adjusted late run escapement of 463,561 is 47.2% higher than the recorded figure, and represents an excess of 85.4% over the escapement goal.

1978

A strong early run in 1978 resulted in 32 days of fishing prior to removal of the Chignik weir, during which 1,721 boat•days of effort harvested 1,397,805 sockeye. Total cumulative escapement for the season was 671,827 including 28,759 estimated to be the late season component. Accumulated prediction errors totaled -59,636 over the 32 days of fishing prior to weir removal. This comparatively large error is associated with low reliability of estimates made from the regression model compared with those for other years. However, the estimated late season escapement of 28,759, while probably less than the actual escapement, agrees well with the comparatively small late season catch of 76,821, suggesting that the estimated figure is approximately the correct magnitude. The estimated late season component of the late run escapement was essentially the same as the published figure and the estimated total late run escapement was very close to the escapement goal.

1979

The total catch of sockeye in Chignik Lagoon was 908,450 and the total escapement, including the estimated late season component, was approximately 796,495. Cumulative effort totalled 2,158 boat•days for 22 days prior to and 25 days subsequent to the dismantling of the Chignik weir, all but 714 boat•days being exerted in the 22-day early period. Prediction error is toward overestimation of abundance; the sum of residuals is +37,405, or roughly 20% of the sum of observed escapements on days for which predictions were made. The estimate of 108,676 late season spawners increased the late run escapement total by about 22.6% to 317,889, which is approximately 27.2% over the escapement goal.

1980

A weak showing of early run fish in 1980 delayed the first commercial opening to July 7. Fishing was permitted on 20 of the 22 days remaining before the Chignik weir was dismantled, thus the regression of abundance on catch was calibrated with data from a relatively short segment of the total run. The resulting model is moderately accurate and shows a relatively small conservative bias in estimates, as the sum of residuals of predictions on days prior to weir removal is -3,379. The early season catch of 583,175 sockeye was taken by 1,129 units of effort in 22 days and the late season catch of 124,618 was taken in 31 days with the expenditure of 874 units of effort. Total escapement for both runs combined, including the estimated late season component, was 689,990. The late run escapement was revised upward by about 10% to 279,729, or 11.9% above the escapement goal.

1981

Commercial fishing was distributed more uniformly over the early and late sockeye runs than was the case in 1980. A total of 1,347,729 sockeye were caught in Chignik Lagoon and 849,636, including the estimated late season component, evaded the fishery and passed into the escapement. Fishing was permitted on 39 days prior to weir removal and on 19 days following, accounting for a total expenditure of 2,526 boat•days of effort. A substantial conservative bias is apparent in the sum of residuals of predictions (-29,137), but over 17,000 of this accumulative error was contributed by a single underestimate. The late season catch of 104,378 was secured by 508 units of effort over 39 days of fishing. The corresponding late season escapement estimate was 71,414, or 42.8% more than the assumed figure. The total late run escapement is estimated to be about 20% higher than the late run escapement goal.

1982

The Chignik Lagoon catch totalled 1,413,720 sockeye taken by 1,333 units of effort distributed over 20 days of fishing prior to weir removal and 1,040 units of effort in 43 days following. Total cumulative escapement, including the estimated late season component, is 921,197. Prediction errors totalled +5,573, indicating a slight tendency toward overestimation of abundance. The estimated late season escapement is 133,471 based on a catch of 158,670 and represents an adjustment in the late run escapement total upward by 37.7% to 305,193. This figure is 22.1% higher than the escapement goal.

1983

A total of 1,596,391 sockeye were taken by 3,456 units of effort in 70 days of commercial fishing in the lagoon. Escapement totalled 864,837 inclusive of the estimated late season component. Prediction error was quite high for the 1983 model ($SE_{Y/X}$ = 10,278), thus it is not surprising that the sum of residuals was a relatively large (-39,440). It is presumed that much of the error in predictions stems from variance in the catchability coefficient attributable to unusual migratory behavior as mentioned previously. The resultant late season escapement estimate of 170,095 corresponds to a late season catch of 262,379, and is roughly comparable in size to the published figure of 138,000. The revised estimate of late run escapement is 441,561, or 76.6% in excess of the late run escapement goal.

Brood Production

Productivity of broods reared in Chignik Lake is examined for brood years 1974-77 in Table 7. Only these four broods have returns of all major age groups through 1983. Age composition data in Conrad (1983) were used for total returns from each brood, and revised estimates of late run escapement as given in Table 6 were applied to the return/spawner ratio. The results indicated that R/S ratios calculated with data produced by 1) scale pattern stock separation techniques and 2) quantitative estimation of late season escapements are substantially lower than those calculated with data supplied by the time-of-entry curve and fixed late season escapement estimates. The average R/S ratio for 1974-77 broods was 3.33 calculated with our data, compared to 4.57 from ADF&G Management Reports.

Table 7. Comparison of return/spawner ratios estimated by ADF&G from published late run escapement and brood production estimates, with those estimated from adjusted late run escapements and brood production data based on late run returns given in Conrad (1983).

Broodyear	Adjusted late run escapement	Brood return	R/S	Published R/S
1974	364,612	1,005,897	2.76	3.90
1975	314,084	1,194,940	3.80	5.22
1976	341,828	1,347,267	3.94	4.98
1977	463,561	1,312,603	2.84	4.17
		$\bar{X}$	3.33	4.57

SUMMARY AND CONCLUSIONS

1. The method developed here is an initial step in establishing a rational basis for estimating late season escapements of sockeye into the Chignik watershed. A relationship between catch and total abundance is quantified in-season when visual escapement counts at the weir provide accurate and reliable data. The resulting estimate of catch rate was applied to daily catches taken after the weir has been dismantled to estimate total daily abundances. Daily escapements during periods open to commercial fishing were calculated as the difference between total abundance and catch, and those occurring during closures were interpolated from total abundance on adjacent days of fishing. In contrast to the recent practice of adding a fixed number representing the late season component to the escapement total, this method permits late season escapements to reflect the annual variation in run strength apparent in late season catches.

2. Catch rates fluctuate between years sufficiently that year-specific estimates are preferable to an average years-pooled value. These fluctuations show no trend suggestive of a systematic change in the fishing power of a unit of effort, therefore we conclude that catchability is the more influential of the two parameters controlling the state of F. The ability of the commercial fleet to detect and exploit centers of abundance in the spatial and temporal distributions of sockeye controlled the rate of catch and was reflected as differences in catchability coefficients between years. Diversity in the migratory behavior of returning adults is the most readily observed source of variance in the catchability coefficient, but the relative influences of other complex and ill-defined factors was not investigated.

3. Predictions of stock abundance from the catch rely on the assumption that F is constant within a season. The validity of this assumption in any year is reflected in the prediction error associated with year-specific regression models; frequent violation results in large standard errors and conformance produces low standard errors. Variability in F within an individual season may be explained partly by change in the catchability coefficient over time, but we suggest that an equally likely source is simply error in the adjustment of daily escapements to correspond with catches in Chignik Lagoon. The assumed 1-day lag time between catch in the lagoon and escapement at the weir may be appropriate for some years or parts of some years while being totally inappropriate for others. Misalignment of catch and escapement occasionally produces bizarre estimates of the fraction of available stock abundance harvested by the commercial fleet.

4. The results of this analysis suggest that escapements occurring after weir removal may add significant numbers of fish to the late run spawning population. Aside from the loss of harvestable fish, large surplus escapements may stress the carrying capacity of Chignik Lake for sockeye fry. Burgner et al. (1969) and Narver (1966) noted that the spawner density in Chignik Lake was over twice that of all other

sockeye nursery lakes studied in southwestern Alaska, with the exception of Karluk Lake, during the period 1955-62. The mean escapement producing such high densities of sockeye, roughly 307,000, was determined to be too large by both Narver (1966) and Dahlberg (1968). Their suggested optimum of 250,000 late run spawners translates to a spawner density of 11,363 sockeye$\cdot$km^{-2}. The highest estimated late run escapement in this analysis is about 464,000, or roughly 21,100 sockeye$\cdot$km^{-2}, and the average is 339,255, or about 15,421$\cdot$km^{-2}. Return per spawner ratios for the Chignik Lake stock are shown to be significantly lower at these densities than previously assumed. Additional research should be directed to determine the capacity of forage base production in Chignik Lake to support large fry populations produced at high spawner densities.

III. STATUS OF THE COHO SALMON INFORMATION BASE

INTRODUCTION

The coho salmon resource at Chignik in some years is an important source of supplemental income for local fishermen. Although the commercial catch of coho usually is incidental to a directed fishery for late season sockeye, recent catches in excess of 50,000 demonstrate the potential economic value of the coho stock. The relatively late timing of the coho run may offer fishermen who have not done well on other species a chance to salvage a season by fishing the coho run intensively. While factors such as processor interest, vessel operating costs, catch and ex-vessel value of other species, and catch per unit effort also influence the expenditure of effort in the coho fishery, in general the commercial catch of coho has been increasing steadily in recent years (Fig. 9).

Rising interest in coho salmon within the fishing industry has not been matched by increased research or management interest. The trend in coho production in the Chignik watershed is not well documented. The commercial catch is not a reliable index of changes in coho abundance because yearly variability in fishing patterns and run timing weaken inferences of run size drawn from the catch statistic alone. Escapement estimates are incomplete because much of the coho escapement occurs after the weir for counting sockeye is removed. Spawner surveys are lacking because the coho spawn after sockeye spawning surveys are completed. It is, however, important to assess the production dynamics of the coho stock at Chignik, both from the standpoint of utilization of the stock and from the standpoint of the potential impact of juvenile coho as predators on juvenile sockeye.

Accordingly, the objective of this section is to compile and review the available information on coho salmon production in the Chignik watershed. The existing information base is evaluated in terms of the basic population and fishery statistics that are needed to formulate a management plan, with specific attention given to the availability of data to describe the dynamics of adult returns. As this review is an assessment of only the coho stock returning to the Chignik watershed, catch data has been limited to that part of the Chignik Management Area total taken in Chignik Lagoon.

A. DYNAMICS OF ADULT RETURNS

Background

Adequate descriptions of coho run strength can be pieced together for a number of years after 1922 when the weir on Chignik River was first erected. Coho escapements were enumerated in all years - except

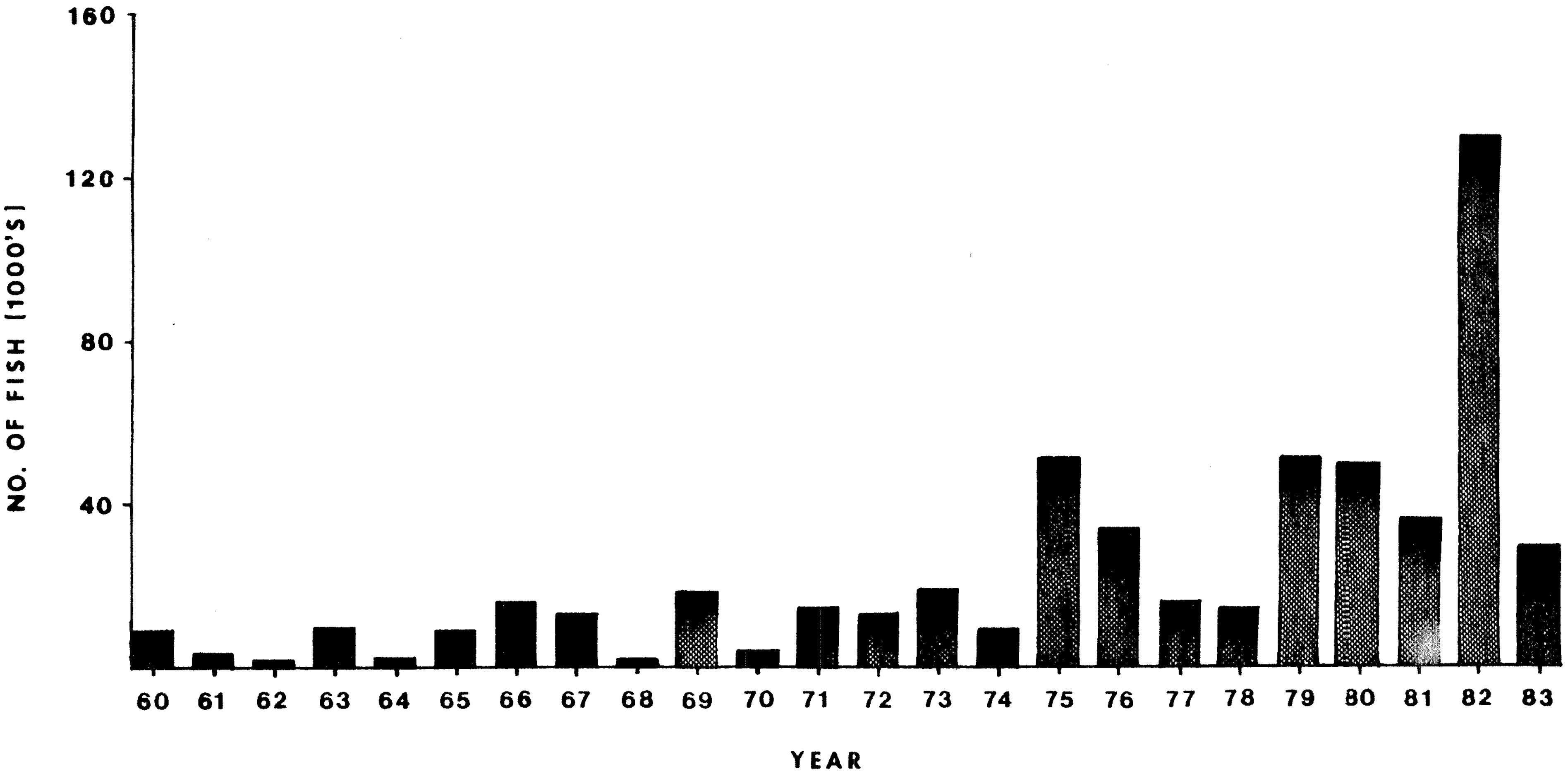


Figure 9. Trend in catches of coho salmon at Chignik since 1960.

when high water or world war precluded weir operation - until 1957. Rough guesses of the escapement were recorded until 1972, but the observer and the reliability of these estimates are unknown. The time series of catch of coho in Chignik Lagoon dates to 1893 and is shown in Fig. 10. Early catches of over 50,000 were taken by packing companies prospecting the Chignik area for profitable salmon runs. After several years of comparatively low catches, moderate catches of 10,000 to nearly 100,000 were again recorded between 1910 and 1927. The coho runs apparently generated little interest in the 25 years after 1932, even though they were of reasonably good size in a few years. There is some indication that this was a response to poor market conditions. Since 1955 catches of coho in Chignik Lagoon have trended upward to a maximum of over 130,000 in 1982.

Available data permit a limited analysis of the fluctuations in total abundance shown in Fig. 11. Variations in catch coincide very closely with variations in run size during the years 1922-28. The proportionality of catch to abundance suggests that effort was approximately constant in these years, and further implies that a directed fishery on coho operated at that time. Low catches in the following 3 decades probably reflect a low level of effort in late season after the main sockeye catch had been taken. Average exploitation rates in the two periods were 0.27 (1 SD = 0.12) and 0.04 (1 SD = 0.04), respectively.

Although the time series of total abundance is incomplete, major trends correspond approximately with the pattern of sockeye abundance in the Chignik system. Relatively large sockeye runs in the 1920's-1940's were followed by depressed runs in the 1950's and 1960's, with increasing production becoming apparent in the early 1970's and continuing to the present (Fig. 12). The coincidence of trends in abundance of the two species may result from major oscillations in the productivity of salmon stocks in general, correlated by Rogers (in press) to changes in the ocean environment, or it could result indirectly from interaction between the coho and sockeye stocks. Predation by coho juveniles on young sockeye salmon has been documented at Chignik by Roos (1960) and by Burgner and Marshall (1974). If coho are compensatory predators, then their productivity should be synchronous with the productivity of sockeye fry in the watershed.

Effect of Exploitation Patterns on Run Statistics

Catch is presently the only parameter of coho abundance that is routinely and reliably available. Catch (assuming constant effort) or catch per unit of effort may be considered as being proportional to total abundance if a given set of assumptions is satisfied. One assumption in particular requires that the catchability of coho remains constant at any level of stock abundance or fishing effort. As demonstrated in Section II of this report, catchability of salmon in the Chignik seine fishery in fact varies with effort, thus the distribution of effort in the coho fishery can have a profound effect on the proportionality between catch and total abundance.

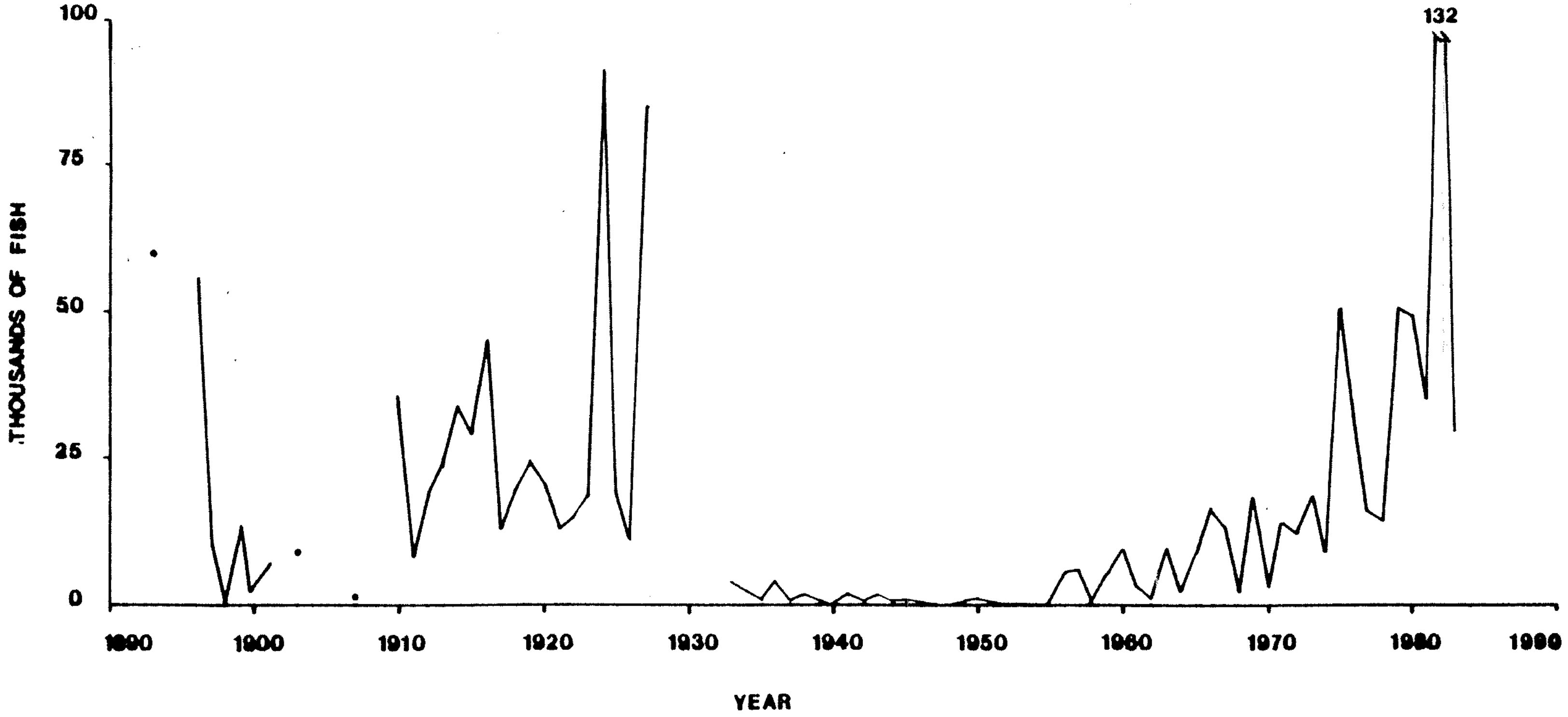


Figure 10. Time series of coho salmon catches in Chignik Lagoon, 1893-1983.

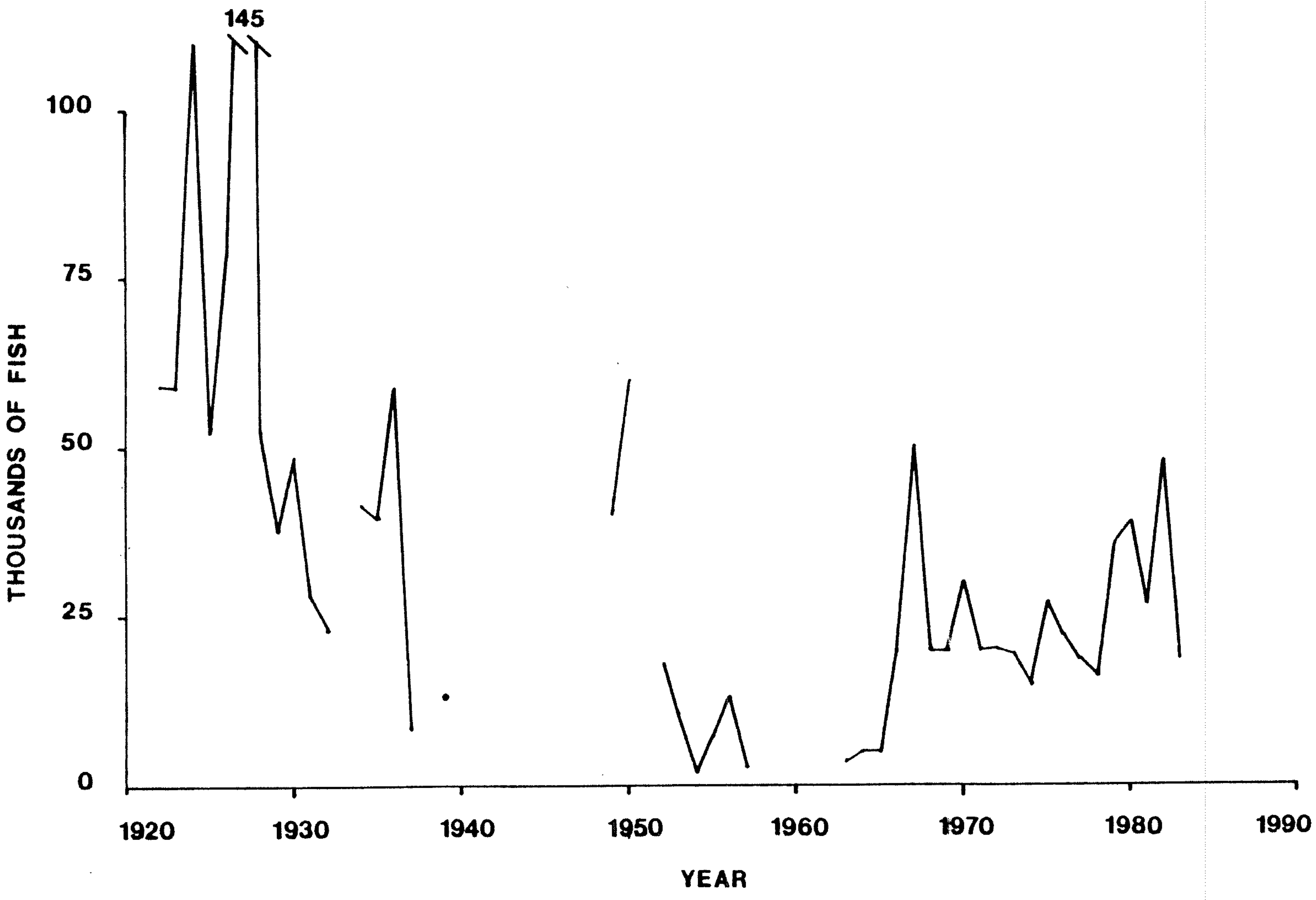


Figure 11. Time series of coho salmon abundance in the Chignik system, 1922-1983.

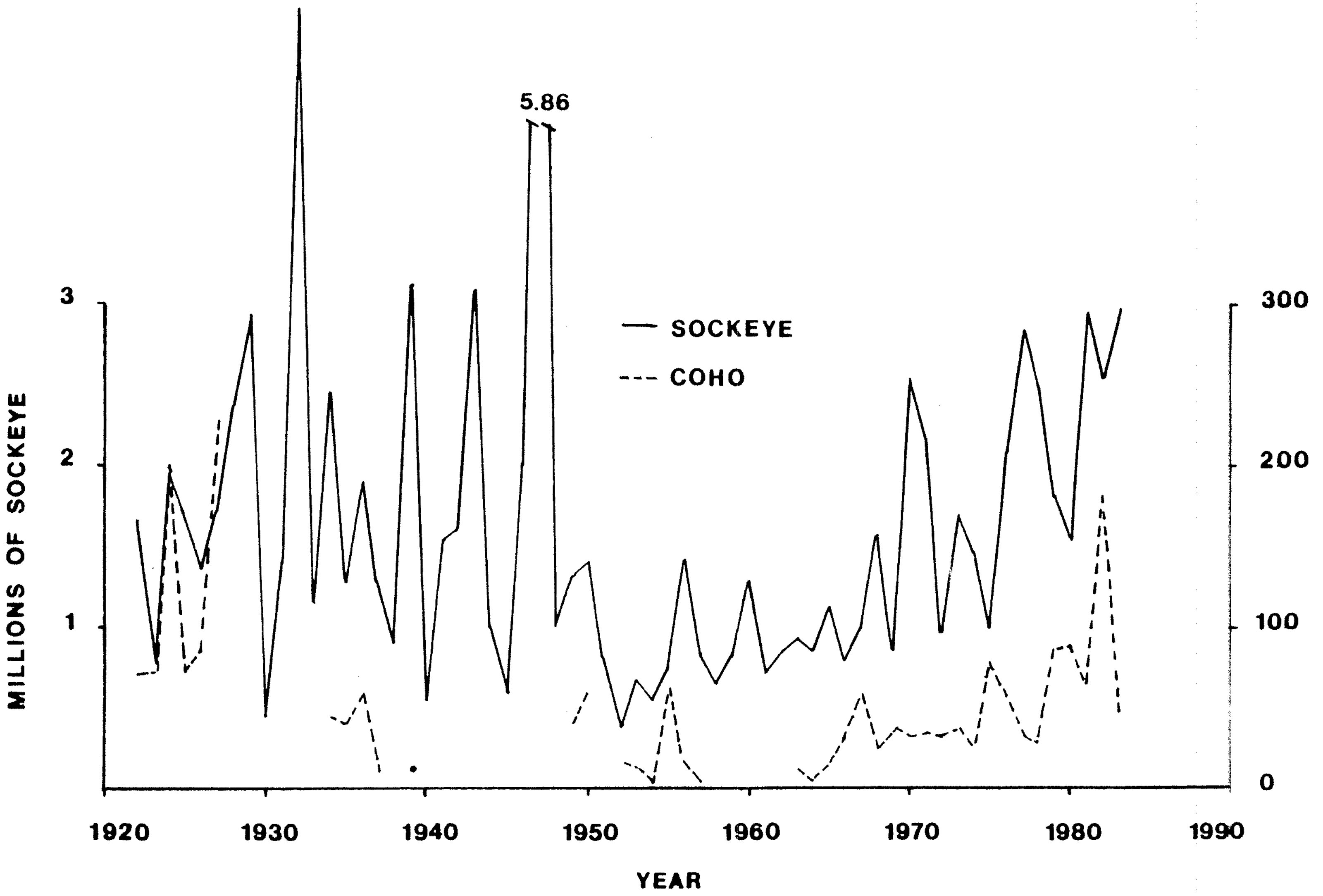


Figure 12. Comparison of trends in abundance of sockeye and coho salmon in the Chignik system, 1922-1983.

Participation in the late season coho fishery is highly variable within and between years and typically decreases while coho abundance is increasing, thus the time series of catch may be truncated with respect to the time density of coho abundance.

Variation in effort also results from long-term changes in gear type and associated effectiveness. A major redefinition of the unit of effort in Chignik salmon fisheries occurred in 1955 with restriction of the commercial fleet to the use of seines. The evolution of the present modified half-purse seine gear can be traced back to the beach seines in use at the inception of commercial fishing. The effect of progressive sophistication in gear and boat technology in recent years probably is expressed as an increasing trend in the fishing power of one unit of gear. It is likely that change in the fishing power of active gears, such as purse seines, is not insignificant to the calculation of effort if the area of influence of the gear increases or if the proportion of all fish within this area which are in fact caught increases as a result of gear modification (Gulland 1969). For this and other reasons, we have limited the analysis of coho run dynamics which follows to years after 1972.

Estimation of Run Timing and Total Abundance

Effective harvest control is the primary requirement of a management plan designed to maximize the productivity of a salmon stock. In addition to simply ensuring that designated escapement goals are met, harvest control ideally is implemented to ensure that the escapement is distributed evenly over all time segments of the run (Mundy 1982). However, the practice of allocating escapements from each time period places the management biologist in the position of discovering the size and timing of the run as it develops so that appropriate harvest decisions can be made. Use of the fishery as an indicator of run size is risky because variation in run timing may be misinterpreted as variation in run strength. For example, a small, early run could be devastated before its small size is detected by a fishery intended for a large run of average timing. Therefore, patterns of timing and abundance of past runs must be described and made available to the manager in a format that permits comparisons with incoming runs.

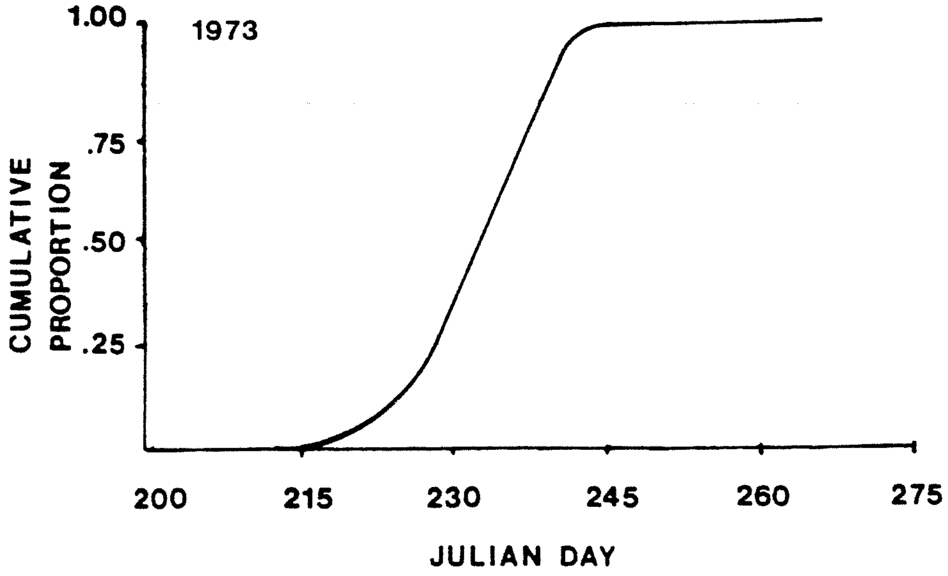
The temporal distribution of coho abundance was examined through analysis of "performance curves" (Mundy 1983) of the fishery for the years 1973-1983, exclusive of 1979 in which only weekly catch totals were available. The performance curve specifies the cumulative proportion of catch occurring by time interval at a fixed geographic reference point. It is a useful tool for integrating the factors producing the time series of catch - time/space distribution of fish abundance and time/space allocation of effort - into a tractable model of harvest dynamics. Comparisons of performance curves for a number of years permits an investigator to quantify annual variability in run timing and rate of catch. Given sufficient consistency in yearly patterns of harvest dynamics, a harvest control system is possible based on the expectation of cumulative catch as a function of time.

Performance curves for the coho fishery at Chignik are shown in Fig. 13a-j. Cumulative proportions of the catch by day are given in Appendix Table 1. Note that the curves are not symmetrical in many years which indicates that daily catch totals are not normally distributed in time about the peak day catch. Much of the asymmetry is probably due to loss of fishing effort soon after peak catches are made, which tends to truncate the time series of catch in late season. Other differences among the curves, such as timing and rate of catch, are displayed more clearly in Fig. 14. Considerable variability is seen in arrival timing of coho in the commercial catch. The date by which 5% of the cumulative catch has been harvested varies over a period of 19 days, from earliest on August 2 (Julian day 215) in 1980 to latest on August 22 (day 234) in 1983. The midpoint of the commercial harvest (not necessarily peak day catch) varies over 13 days from August 23 (day 235) in 1973 to September 5 (day 248) in 1983. However, comparison of catch proportions is not the optimal means for analyzing variation in migratory timing if variation in catch rate cannot be clearly distinguished from variation due to other effects, for example those of climate, that also influence the time of entry of the coho stock.

The rate at which catch accumulates showed marked inter-annual variability. The time interval between the dates when 5% and 50% of the cumulative catch is in ranged from 9 days in 1975 to 26 days in 1980. Part of this variability was assigned to effects of climate; the correlation of the above time interval with sea surface temperature in May prior to return was significant (r = .49, p = .05) and indicated that the temporal distribution of coho abundance was compressed in years of cold spring water temperatures and was relatively expanded in years of warm spring water temperatures. This relationship was detected also by Mundy (1982) in the timing of chinook salmon catches in the lower Yukon River. In years when migratory timing was early, variance about the mean date of catch was large; when timing was late, variance was much smaller. In general, cold spring temperatures are likely to coincide with coho runs that arrive in Chignik Lagoon relatively late and build in abundance quickly, whereas warm springs are likely to coincide with relatively early and prolonged arrivals of coho.

Variability in the timing and shape of individual curves is best perceived in reference to an average performance curve for the years 1973-83, exclusive of 1979 (Fig. 15). The 95% confidence band was calculated from the variance of dates on which specified cumulative proportions of the catch occurred. Data used to generate the curves are given in Appendix Table 1. On average, 5% of the coho catch was taken by August 14 (day 226) (± 5 days), 50% by August 29 (day 241) (± 3 days), and the harvest was 95% completed by September 3 (day 247) (± 4 days). Here again a slight asymmetry in the average performance curve was noted, as the interval of time from 5% to 50% of catch was 15 days and from 50% to 95% of catch it was 10 days.

Extension of the analysis of harvest dynamics to the dynamics of the total run was not done because estimates of total daily abundance



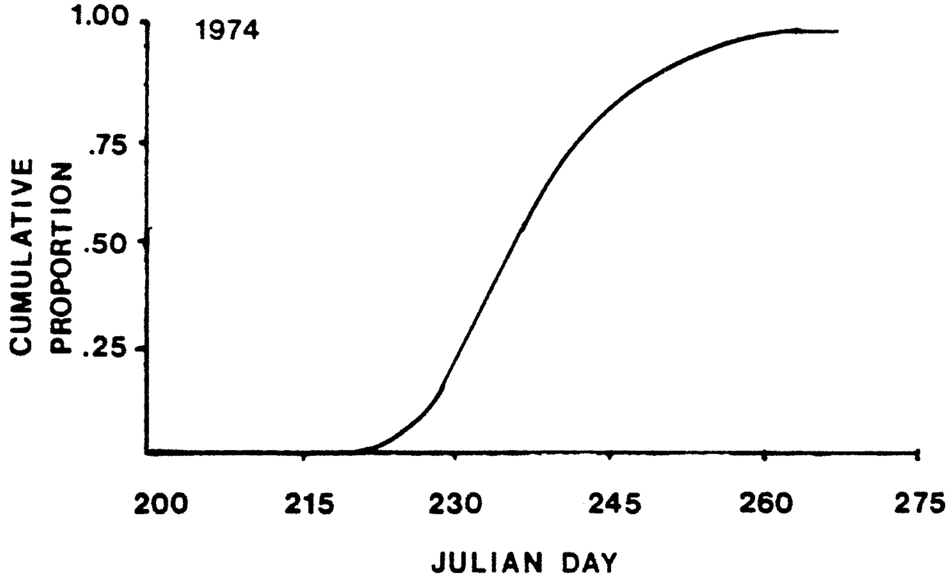
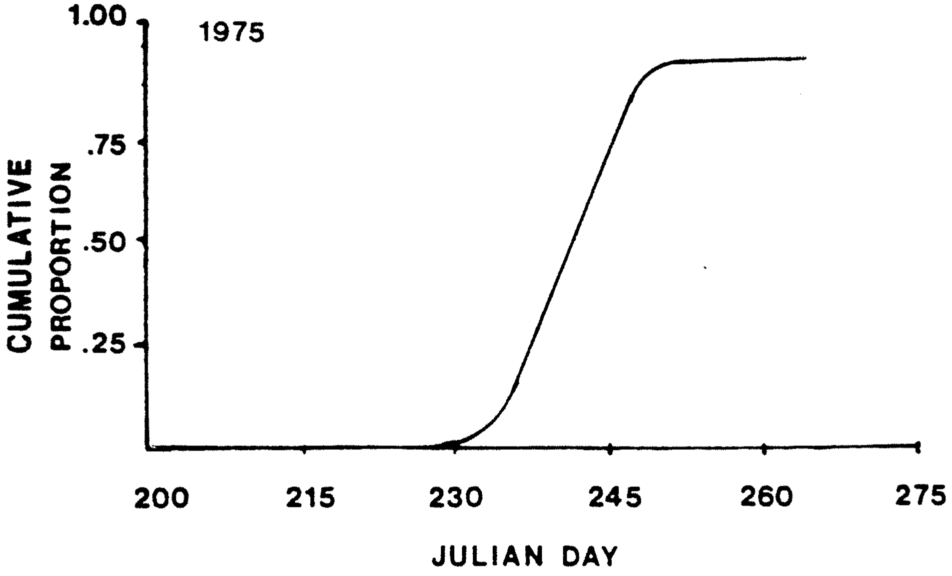
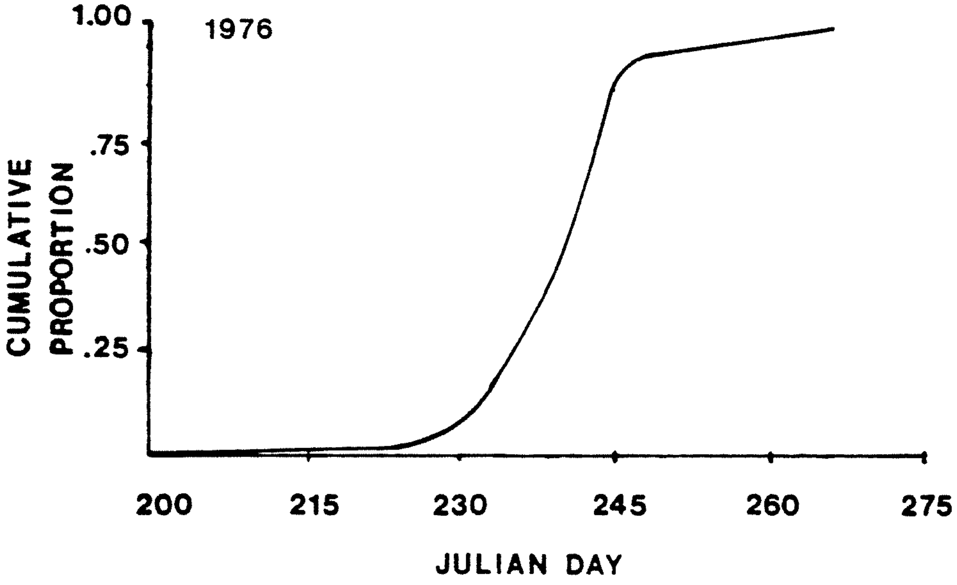


Figure 13a-j. Performance curves of catch for the Chignik coho fishery by julian date for individual years 1973-83, exclusive of 1979.





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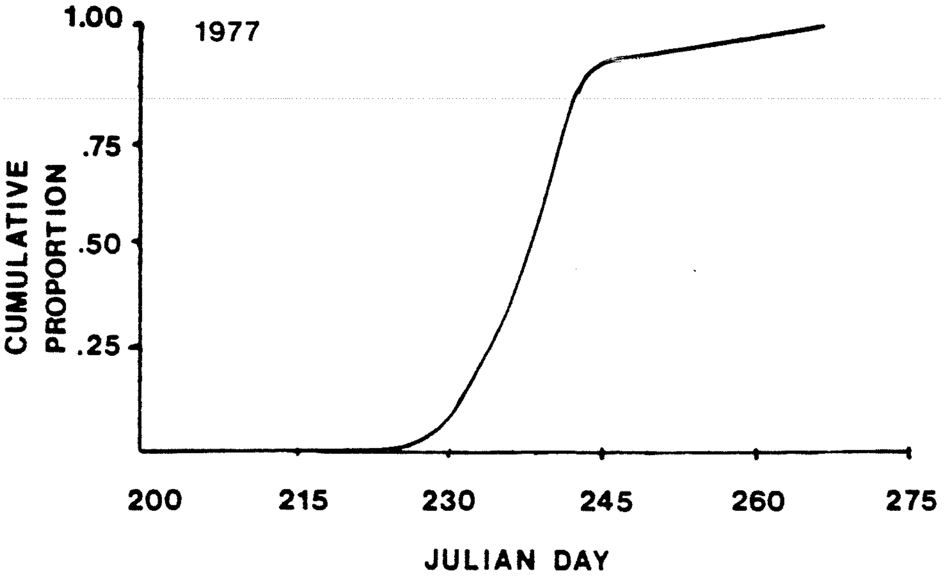

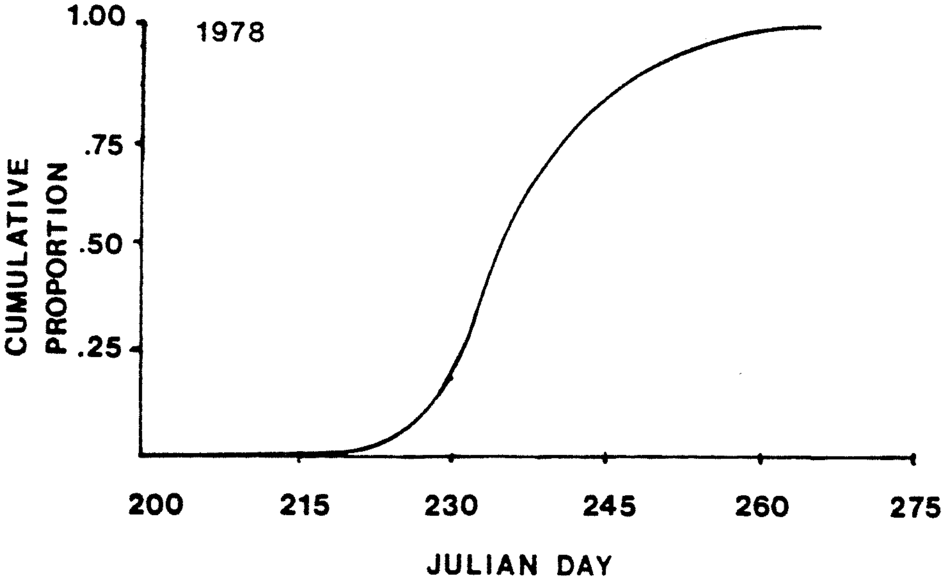

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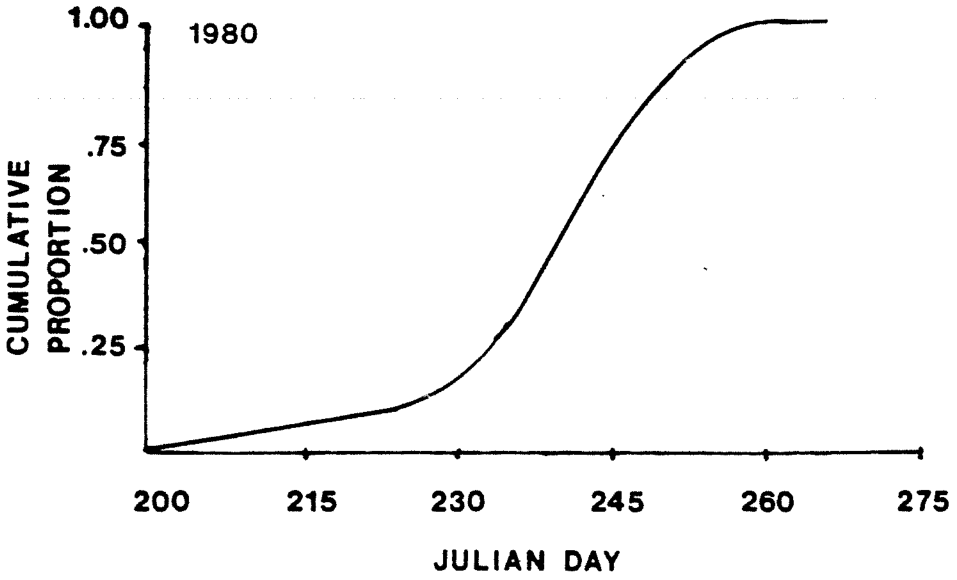

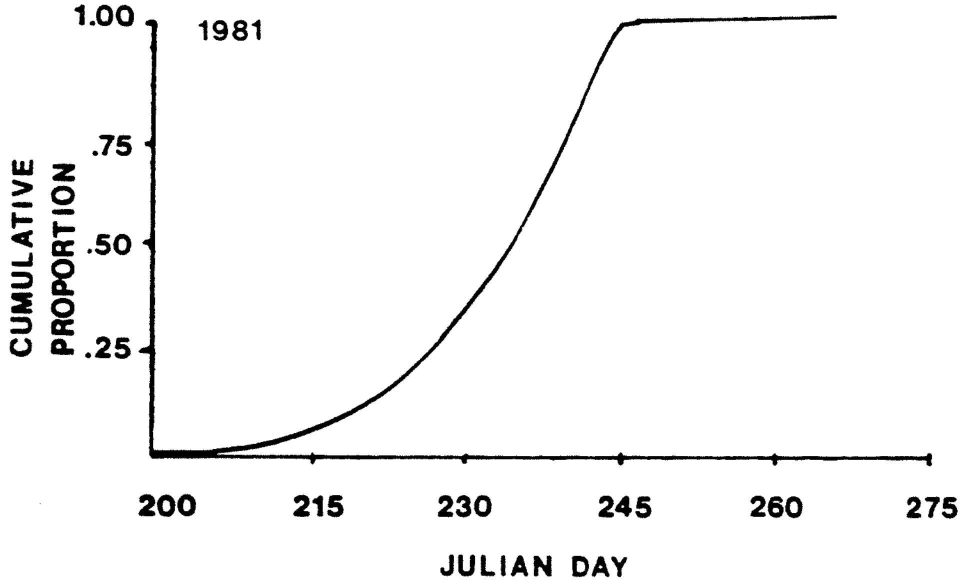

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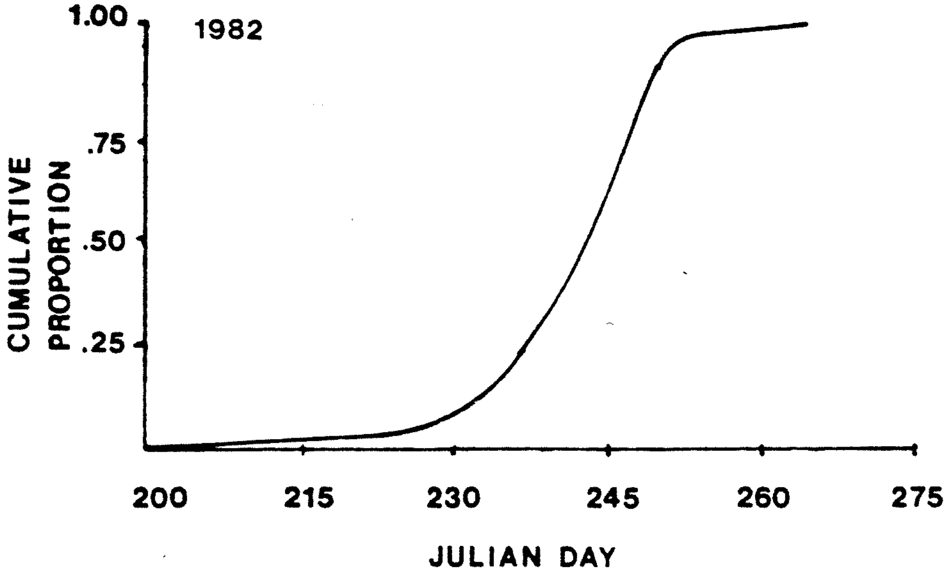

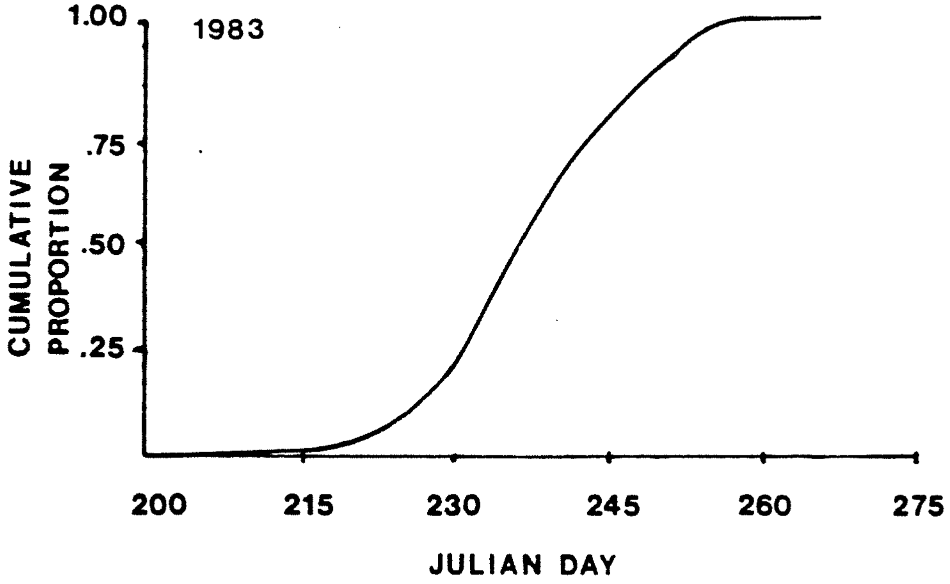

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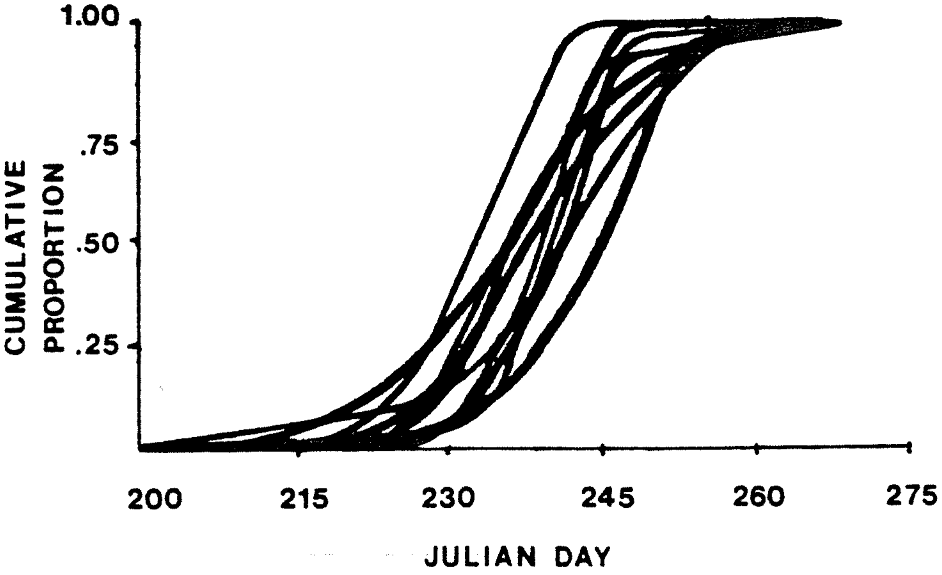

Figure 14. Comparison of performance curves of catch in the Chignik coho fishery 1973-83, exclusive of 1979.

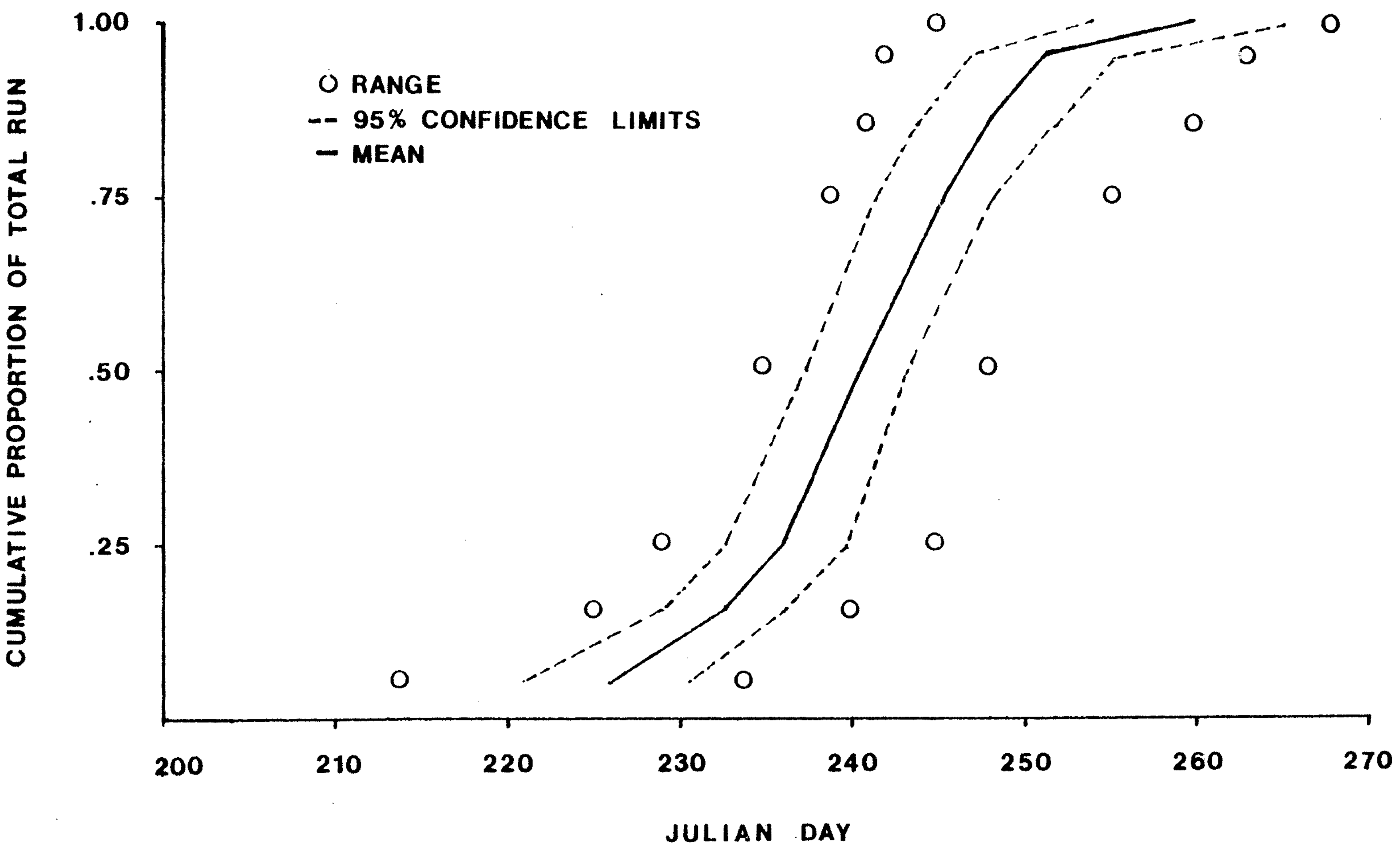

Figure 15. Average performance curve for coho salmon catches in Chignik Lagoon, 1973-83 exclusive of 1979.

and statistics based on total daily abundance were not verifiable in the absence of escapement data. However, since at least a provisional set of run statistics was needed to evaluate coho production, annual cumulative abundance was estimated from catch data by adaptation of the method developed in Section II of this report for estimating sockeye abundance after the Chignik weir is dismantled in early August.

Estimation of total run size was based on the equation:

$$N_i = \frac{C_i}{qf_i}$$

where N_i = total abundance on day i
C_i = catch on day i
q = catchability (assumed constant)
f_i = effort expended on day i

As mentioned in Section II, the proportionality between N_i and C_i/f_i is seen to vary as a function of effort because q is not constant for all f_i in Chignik Lagoon. Consequently, q was dimensioned in time as a power function of effort in the model:

$$q_i = af_i^b$$

The catch equation was recast as:

$$N_i = \frac{C_i}{[af_i^b(f_i)]}$$

where $a = 0.583$ and $b = -0.907$.

Since escapement is simply the difference of $N_i - C_i$,

$$E_i = \frac{C_i}{[af_i^b(f_i)]} - C_i$$

Daily abundance during closed periods was estimated from linear interpolation of abundance on adjacent dates when fishing occurred. Total accumulative abundance is the sum of estimated daily totals.

A summary of selected fishery statistics for Chignik coho salmon is presented in Table 8. Coho catches by day for the years 1973-83 exclusive of 1979, calculated daily run totals for the same period interpolated for days when no fishing occurred and daily totals smoothed by a moving average of 3 are given in Appendix Tables 2, 3 and 4, respectively. The run total for 1979 in Table 8 was estimated from an exploitation rate of .531 predicted by nonlinear regression of exploitation rate on effort (Fig. 16). Table 8 indicates that the coho fishery removed approximately 50-60% of each run. In general, elective participation in the fishery appears to have been an effective form of harvest control in the past 11 years as estimated exploitation rates are consistently near

Table 8. Summary of coho fishery statistics for the period 1973-1983, inclusive. Effort is the number of boat·days after 8/15.

Year	Effort (boat·days)	Catch	Estimated escapement	Estimated total	Mean catch/ boat·day	Exploitation rate
1973	240	18367	19314	37681	76.5	.487
1974	194	9496	14655	24151	48.9	.393
1975	737	51703	27393	79096	70.2	.654
1976	483	33450	22860	56310	69.3	.594
1977	256	16331	18301	34632	63.8	.472
1978	206	14467	15741	30208	70.2	.479
1979	335	52966	46742*	99708*	158.1	.531*
1980	502	49784	38615	88399	99.2	.563
1981	197	35580	27331	62911	180.6	.566
1982	832	132373	47236	179609	159.1	.737
1983	790	29507	18920	48427	37.4	.609

*Estimated by assuming exploitation rate = .531.

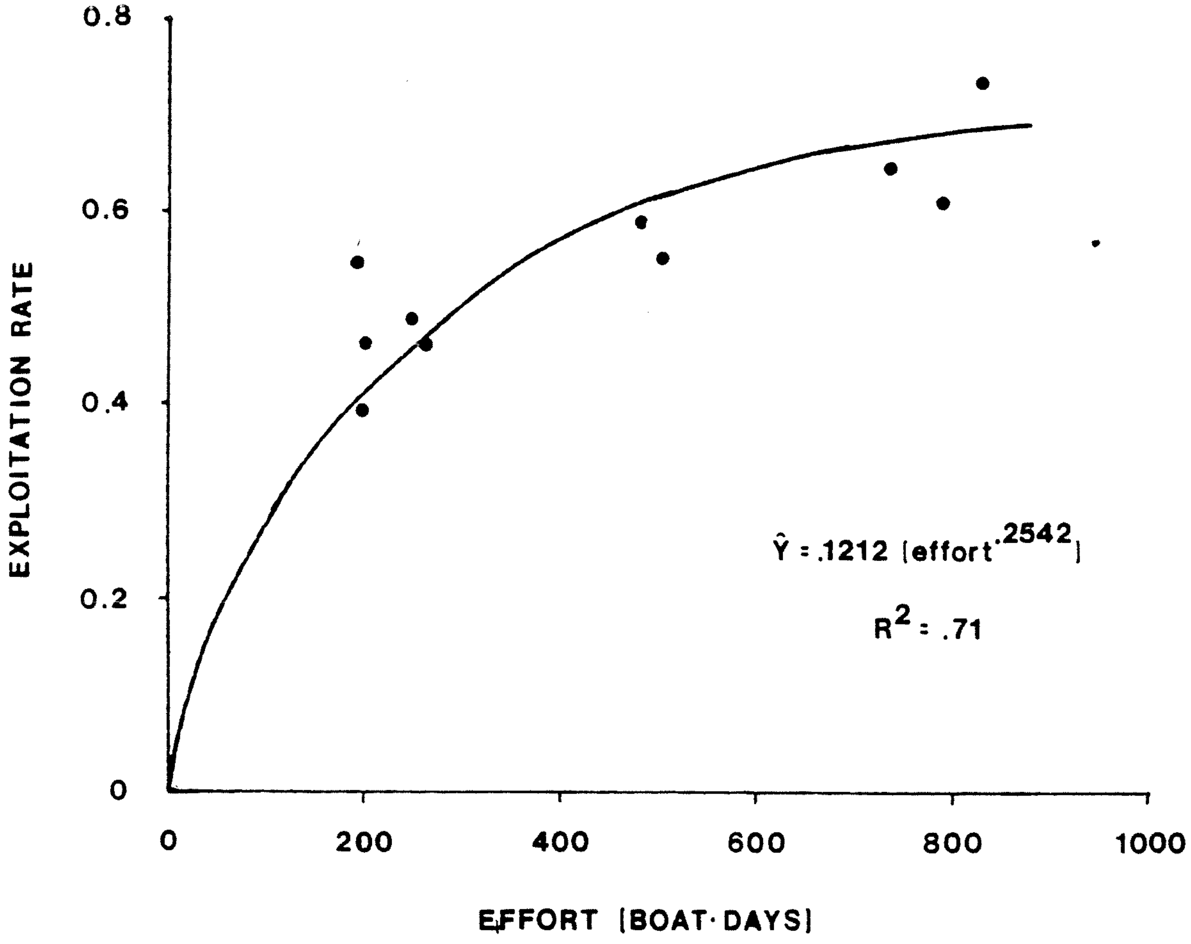

Figure 16. Function of exploitation rate with effort used to estimate exploitation rate for the 1979 coho fishery at Chignik. Curve is fit by inspection.

the mean ($\bar{x}$ = .553 ± 0.064). There was a tendency, however, to harvest less of a small run and more of a large run, and this suggests that boats drop out of the fishery sooner if the run is perceived to be small and, conversely, remain longer if the run appears large. Factors such as profitability of the catch of other species earlier in the season, processing limitations, expectation of catch, and relative abundance of sockeye will influence the minimum threshold catch per effort at which boats begin to drop out (pers. observation).

Age Composition

Age composition of coho runs since 1970, with the exception of those in 1979 and 1982 from which samples were not collected, is given in Table 9. Adult coho typically are age 2.1 at return, although the relative percentages of ages 2.1 and 1.1 in the catch may reverse in some years. Coho of age 1.2 or 3.1 are sampled occasionally but do not constitute important components of the catch. Jacks have never been reported from catch samples taken at Chignik. Israel (1933) found approximately 72% 2.1, 26% 1.1, and 2% 3.1 in the 1930 catch of coho in Chignik Lagoon.

The periodic reversals in freshwater age composition of returning adults is suggestive of large outmigrations of age I smolts in certain years but not in others. Since juvenile coho are known predators on sockeye juveniles (Roos 1960), age II coho which reside in the system longer and presumably attain larger size than age I coho probably exert a stronger predation pressure on the sockeye fry population. It is therefore of some interest to investigate the nature of age at outmigration of coho smolts.

It is clear from the literature that smoltification is related to fish size at some critical time in spring/early summer. We hypothesize that the percentage of age I smolts in a given coho brood relates to the growth rate or size attained by juveniles in their first summer. Necessary data for direct testing of the hypothesis are lacking, but an indirect approach is possible by postulating that fish growth is proportional to length of the summer growing season: i.e., growth is better in warmer, longer summers than it is in cold summers. Accordingly, the relative percentages of age I and II fish in each brood should show a strong relationship with some index of summer climate.

It turns out that the percentage of age I adults in brood years 1970-74 and 1977, for which such data are complete, is positively correlated (r = .89) with mean April air temperature at Kodiak in the year of fry emergence. The relationship appears to be nonlinear rather than linear and, if fit to a logistic curve, over 92% of the variation in freshwater age composition of the broods is explained by variation in April air temperature (Fig. 17). Although the underlying mechanism remains unresolved, early springs presumably denote above-average production and abundance of food organisms which, together with a longer

Table 9. Estimated age composition of the Chignik coho run by year of return.

Year	Age group 1.1	1.2	2.1	3.1	Total
1973	3,768		31,652	2,261	37,681
1974	3,864		20,287		24,151
1975	28,475		50,621		79,096
1976	9,010		45,611	1,689	56,310
1977	5,195		29,437		34,632
1978	4,833		24,468	906	30,208
1980	26,520		61,879		88,399
1981	47,183	2,516	13,211		62,911
1983	11,622	242	36,320	242	48,427

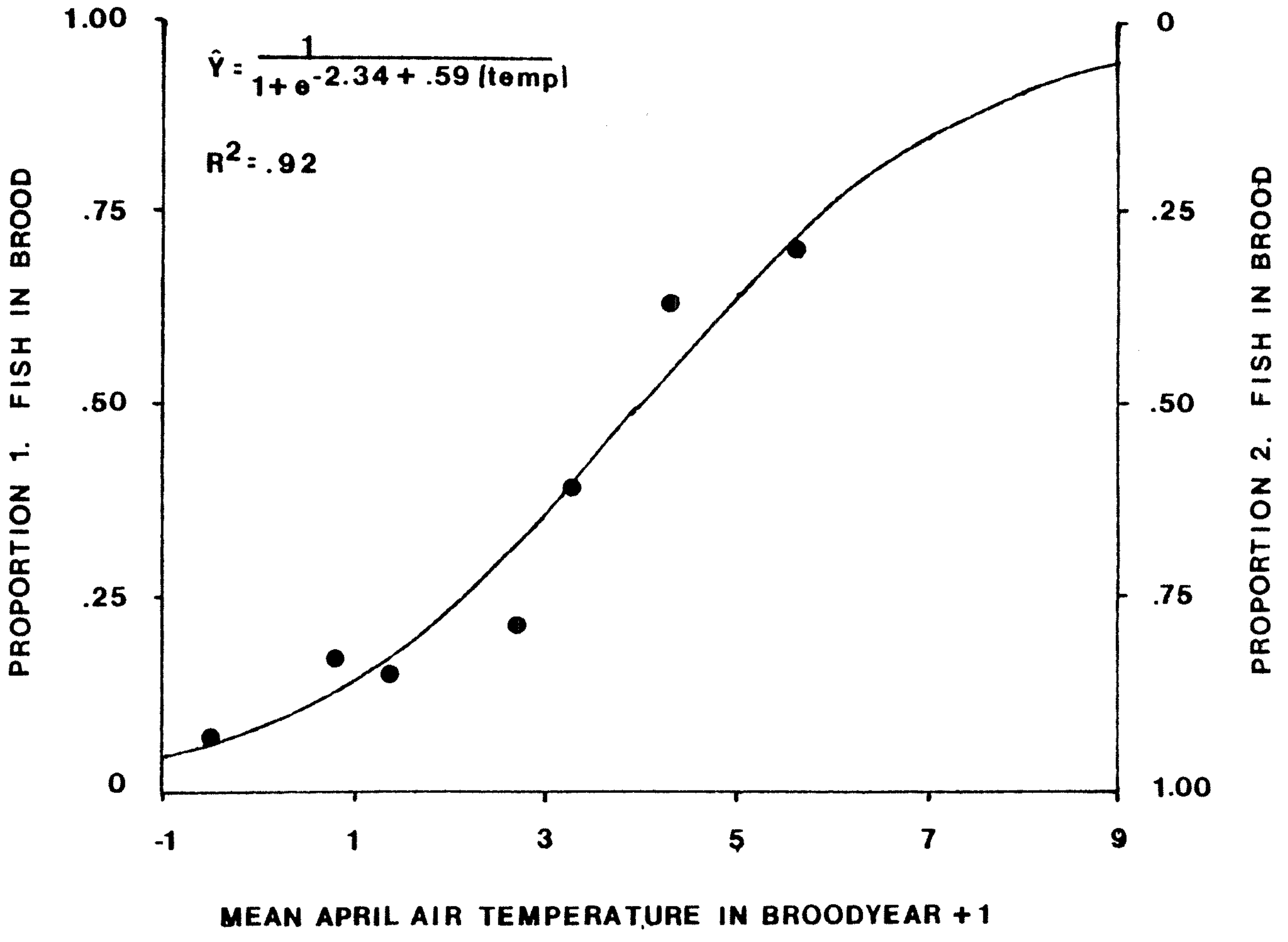

Figure 17. Logistic model of relative percentages of 1.1 and 2.1 age adults in coho brood returns as a function of spring air temperature in the year of emergence.

season, results in better foraging and growth. Attainment of some critical size for age 0 fingerlings by the end of the season then initiates smoltification in the following spring at age I. Unfortunately, the data permit no conclusive statements about the interrelation of temperature, growth, and freshwater age at smoltification of coho in the watershed.

Brood Production

Production of the Chignik stock of coho salmon cannot be estimated from available data. The short record of age composition, notably the absence of age data for 1979 and 1982, limits calculation of essentially complete brood returns to the years 1970-74 and 1977. All other years are incomplete because returns from a major age group cannot be computed. Returns in 1979 and 1982 were among the largest on record, thus the allocation of these runs among broods has significant, if not overriding, influence on resulting estimates of brood production. Predictions of age composition from the curve in Fig. 17 are not sufficient to fill in missing data because the age composition of the run in any particular year depends on both the age composition of broods in the run and the relative sizes of the broods. Neither of these essential statistics are reliably known for the brood years 1969, 1975, 1976, 1978, or 1979, thus even a very provisional analysis of brood production is not warranted.

Sex Ratio in the Coho Catch

The Chignik coho fishery is conducted with modified half-purse seines that are assumed to be non-selective of size or sex. Nevertheless, males usually predominate in samples taken aboard commercial tenders in late August (Table 10). It is possible that the skewed sex ratio from catch samples is an artifact of differential migratory timing of the sexes, as Israel (1933) found a tendency for males to predominate in samples taken nearer the peak of the run. This trend also was seen in samples taken over a period of three weeks prior to the approximate peak of the 1983 run. Since the fishery typically ceases soon after peak catches are made, early-arriving males may be harvested at a higher rate than females.

Spawning Time and Area

Spawning ground surveys were conducted in 1970 and 1971 to determine the distribution of spawners throughout the watershed. An aerial survey in late October of 1970 counted a total of only 1442 coho in the system. More than half of these were in the main Alec River. Eighty-five percent were counted in the Black Lake - Black River area. Cohos observed from the air and the very few captured had not begun spawning. The late November survey in 1971 was unsuccessful in locating any large concentrations of coho salmon. A few coho were observed in schools in the main Alec River, Fan Creek, and off the mouth of Chiaktuak Creek,

Table 10. Sex ratio in the commercial catch of coho salmon in the Chignik District for years in which data are available.

Year	Number males	Number females	Proportion males	95% confidence limit on ratio
1983	199	141	.585*	.533 - .637
1981	90	109	.452	.383 - .521
1980	30	20	.600	.464 - .736
1978	22	10	.688*	.527 - .849
1977	31	9	.775*	.646 - .904
1974	22	10	.688*	.527 - .849
1971	334	218	.605*	.564 - .646
1930	751	572	.568*	.541 - .595

*Indicates significant departure from 50/50 sex ratio at 95% confidence level.

but none appeared to be spawning. Examination of gonads in a few male and female cohos showed that spawning had not yet begun.

B. EARLY LIFE HISTORY

Growth of Juveniles

The sole published report on growth of juvenile coho in the Chignik system is a thesis submitted by Israel (1933) in fulfillment of the requirements for a Master's Degree from Stanford University. His findings are summarized in Table 11. Young coho were captured by beach seine in Chignik Lake and Chignik River during the summers of 1929 and 1930. Length (TS-FT) was measured to the nearest whole mm and age was determined from scale analysis. Particular attention was paid to scale development and circulus formation over the course of summer fish growth.

Young-of-the-year (age 0) coho were not abundant in spring and early summer samples, probably because they could pass through the mesh of the beach seine. Age 0 juveniles were first captured on 6/30 and averaged 42 mm in length. No scale formation had begun by this date. Later catches on 7/22, 8/29, and 9/10 showed that mean length progressed from 51 mm to 73 mm by the end of summer. Two distinctly different types of patterns were seen on scales of yearlings caught in spring and early summer, and these were designated age 2a and 2b for fish in their second summer of growth. These designations correspond to age I and age I+ in Table 11. Age I+ fish were uniformly larger than age I fish in all samples containing both types. The absence of age I+ juveniles in samples taken after 7/24 suggests that they were pre-smolt migrants captured en route to the ocean. Israel speculated that age I+ coho may have reared in Black Lake and so attained much larger size than their age I cohorts. Age I and age I+ juveniles were taken in earliest samples on 6/24, at which time they averaged 77 mm and 112 mm length, respectively. Age I coho grew an average of 20 mm in length between 6/24 and 9/10. Age I+ coho added an average of 22 mm in length before apparently migrating to sea. Note from Table 11 that in no sample did the range in lengths of age I coho overlap the range in lengths of age I+ coho. Age II coho juveniles were well represented in early samples but, like age I+ fish, were absent in samples taken after 7/24.

Differences in apparent growth rate between age groups are shown in Fig. 18. Age 0 fish grew an average of 0.4 mm/day between 6/24 and 9/10. Growth rate for age I fish is very much reduced relative to the other ages, averaging only 0.29 mm/day. This estimate could be artificially low if the largest age I fish outmigrated continuously during the period between the first and last sampling dates. Age I+ juveniles exhibited highest growth rate, averaging over 0.6 mm/day of spring growth. Growth of age II juveniles was roughly equivalent to that for

Table 11. Growth data for juvenile coho salmon sampled in Chignik Lake and Chignik River, 1930 (Adapted from Israel 1933).

Sample		Age							
date		0	# circuli	I	# circuli	I+	# circuli	II	# circuli
6/24/30	mean length			77 mm	0-3	112 mm	0-3	124 mm	0-5
	range			66-88	new rings	102-119	new rings	78-158	new rings
6/30	mean	42 mm	0	74 mm	0-6			126 mm	0-6
	range	39-47		50-119	new rings			96-218	new rings
7/11	mean			79 mm	2-6	120 mm	3-9	135 mm	2-8
	range			61-94	new rings	105-147	new rings	109-174	new rings
7/22	mean	51 mm	0 scales-	77 mm	1-4	124 mm		107 mm	
	range	45-61	platelets	65-98	new rings				
7/24	mean			88 mm	3-8	134 mm	5-9	140 mm	3-5
	range			65-113	new rings	126-142	new rings	133-152	new rings
8/29	mean	62 mm	4-10 scale	94 mm	5-10				
	range	51-70	rings	71-125	new rings				
9/10	mean	73 mm	7-12 scale	97 mm	6-10				
	range	65-76	rings	80-106	new rings				
Average rate of growth (mm·day^{-1})		0.40		0.29		0.61		0.56	

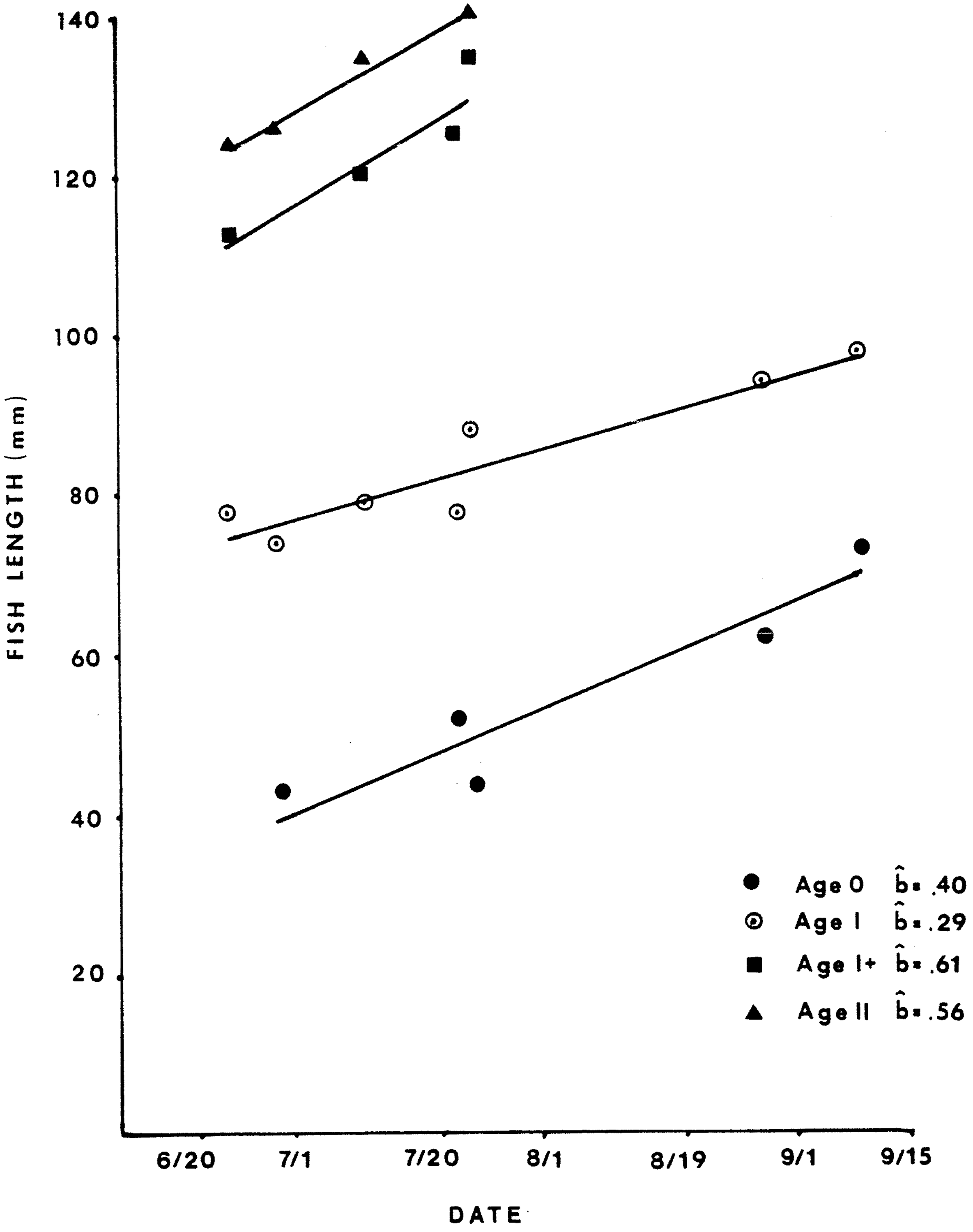

Figure 18. Growth of juvenile coho salmon in the Chignik system, from samples taken between 6/24/30 and 9/10/30 (redrawn from Israel 1933). Lines are fitted by least squares regression; coefficients are estimates of mean daily growth rate.

age I+, about 0.56 mm of length added per day prior to their disappearance from the system. Growth trajectories for age I+ and age II juveniles suggest that smoltification occurs at 120-140 mm for most coho in the system. Peak migration timing is difficult to pinpoint, but certainly most migration has occurred by mid-July.

Scale platelets first appeared on age 0 coho taken on 7/22 (mean length = 51 mm) and by 8/29, 4-10 ($\bar{x}$ = 7) circuli were visible on the scales (Table 11). Age 0 juveniles taken on 9/10 showed 7-12 ($\bar{x}$ = 10) circuli on the scales. Scales of age I and age I+ juveniles exhibited 0-3 ($\bar{x}$ = 2) new circuli in earliest samples (6/24), and by 9/10 there were 6-10 ($\bar{x}$ = 8) additional circuli on scales of age I coho. Age I+ coho added 5-9 ($\bar{x}$ = 7) circuli before apparently leaving the system sometime after 7/24. Scales of age II coho showed 0-5 new circuli in samples taken on 6/24 and about 3-5 ($\bar{x}$ = 4) additional circuli prior to their disappearance a month later.

The rate of circulus formation may decrease with increasing size of coho (Fig. 19). Age 0 juveniles on average formed one full circulus for every 2.3 mm of length added over 50 mm. Age I fish added a circulus for every 3.8 mm of length over about 77 mm, and age I+ fish added a circulus for every 4.8 mm of length over 112 mm. Age II juveniles formed a circulus for about every 10.5 mm of length over 124 mm. Obviously these are gross calculations complicated by outmigration of larger individuals of ages I+ and II, but the trend suggests that the periodicity of circulus formation slows in larger fish even though growth rate may be high. Assuming that scale growth in surface area is proportional to fish growth in length (Stohr and Parker 1982), the trend seen in Fig. 19 suggests that fewer, more widely-spaced circuli form in the scales of larger, faster-growing individuals.

Food Habits of Juvenile Coho

Reports by Roos (1960) and Burgner and Marshall (1974) are the only two sources of information on feeding habits of juvenile coho in the Chignik system. Their results indicate that nearly all coho were feeding at the time of capture in spring and summer months (97% and 91%, respectively). Table 12 summarizes the percent occurrence of food items in coho stomachs for both studies. Sockeye were found in over 30% of coho stomachs examined by Roos and nearly 19% of those reported by Burgner and Marshall. Insects were important food items for coho in both cases, in terms of frequency of occurrence in stomachs. However, there can be little doubt that sockeye are primary constituents of the coho diet when stomach content is expressed on a percent volume basis. Coho clearly rely most heavily on sockeye fry and fingerlings as food, at least during the period when samples were collected. Moreoever, larger coho (primarily ages I and II) rely more heavily on sockeye and consequently are perhaps the most important fish predator encountered by juvenile sockeye salmon in the Chignik system (Roos 1960).

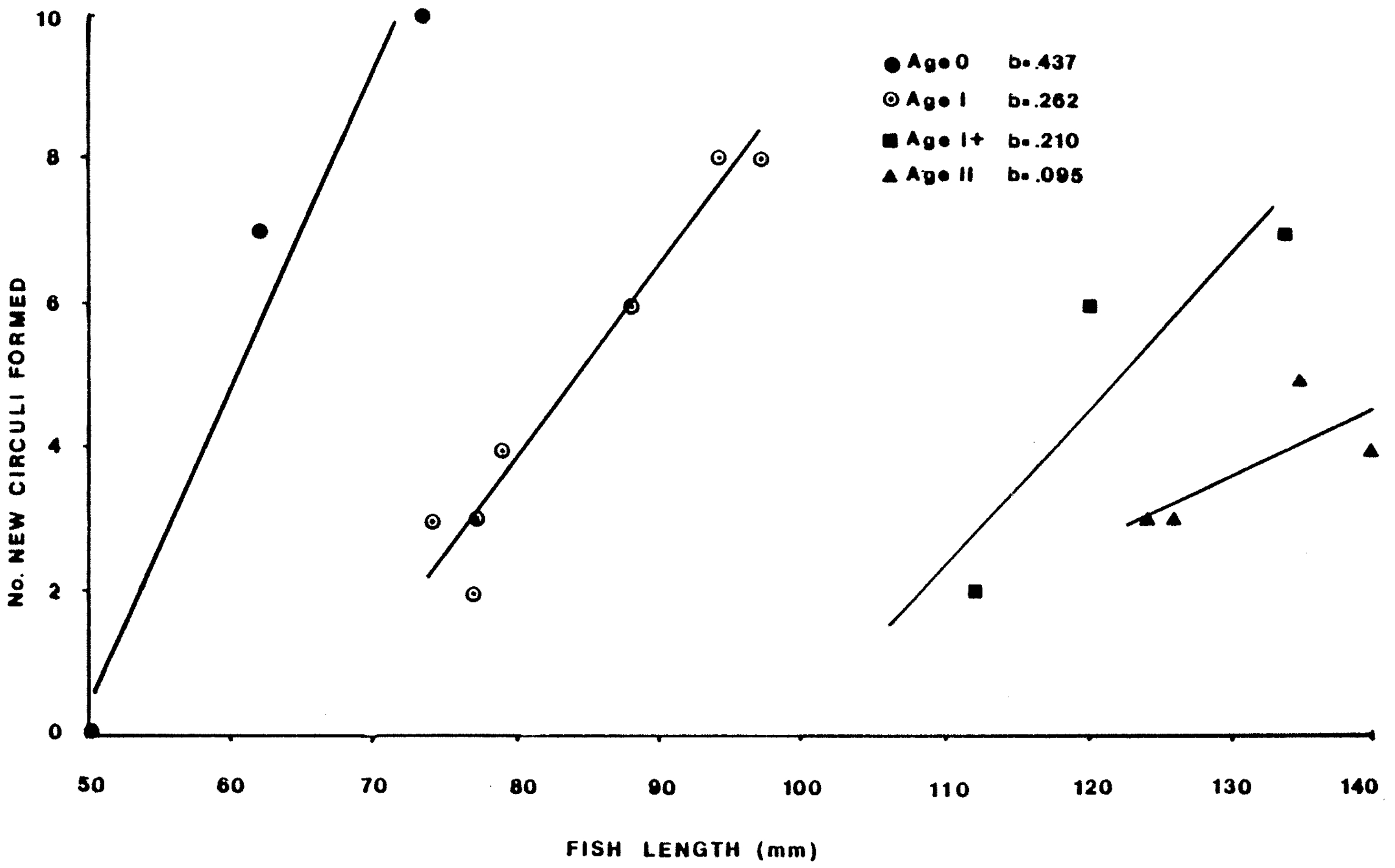

Figure 19. Rate of circulus formation in relation to fish length for juvenile coho salmon in the Chignik system sampled between 6/24/30 and 9/10/30 (drawn from data in Israel 1933). Lines are fitted by least squares regression; coefficients are estimates of the number of circuli formed per mm of fish growth for each age.

Table 12. Stomach contents of 182 juvenile coho salmon sampled at Chignik May-July 1956, 1957, and 1959 (Roos 1960) and of 397 coho sampled during the summers of 1970-71 (Burgner and Marshall 1974). (R = Roos, B = Burgner and Marshall).

Item	Percent occurrence in all coho		Percent occurence in feeding coho		Average number per stomach	
	R	B	R	B	R	B
Fish:						
Sockeye	29.7	17.2	30.5	18.9	0.7	0.21
Cottids		0.3		0.3		
Sticklebacks		0.3		0.3		
Fish material:						
Eggs		0.8		0.8		
U/I remains		22.4		24.7		
Insects	87.3	69.3	89.8	76.4		
Miscellaneous:	5.9					
Rocks		0.5		0.6		
Wood		0.5		0.6		
Worms/leeches		0.5		0.6		
Crustacea	10.9		11.3			
Number of empty stomachs	5	37				
Total examined	182	397				

Coho Predation on Juvenile Sockeye

Predation studies were initiated in the Chignik system in 1955 to obtain information on the relative significance of this mortality factor and the life history stage of sockeye in which it occurs. Early studies focused on predation by both Dolly Varden and coho juveniles on sockeye salmon fry and fingerlings. Dahlberg (1968) presented a summary evaluation of these studies and concluded that the higher incidence of predation by juvenile coho in freshwater established them as the more significant predator. Further, he considered (cf. Roos 1960) that if predation acted on the sockeye population in a depensatory manner, then a stable population of coho juveniles could exert an important population control on sockeye. In years of low sockeye escapements, coho predation would be relatively more intense and may in part explain the poor adult returns from low escapements of sockeye during the 1950′s and early 1960′s.

Juvenile coho reside in the Chignik system for 1, 2, or 3 years before migrating to sea. As Burgner and Marshall (1974) pointed out, the larger size attained by coho during extended freshwater residence, as well as the prolonged time period itself, together pose a greater threat to juvenile sockeye in the Chignik system than in most other sockeye salmon lake systems. They found a higher incidence of feeding on sockeye juveniles among larger cohos (Table 13). Coho larger than 100 mm were roughly 3.5 times more likely to contain sockeye than those 100 mm or smaller. Roos (1960) found a similar relation (Fig. 20), although the occurrence of sockeye in all coho stomachs examined was somewhat higher (29.7% vs 17%). Roos showed that predation on age 0 sockeye began in coho 60-64 mm in length and was most pronounced in those 105-115 mm in length.

The impact of juvenile coho predation on juvenile sockeye salmon in the nursery lakes is difficult to assess with available data. It is clear that the association of the two species is beneficial to the coho and detrimental to the sockeye. Detailed information on coho population size and distribution in the watershed, size-related predation rates on sockeye, the distribution of sizes in the coho population, and predation rates at other seasons of the year is needed to adequately describe the overall effect of coho predation on the sockeye population.

Predation on Coho by Other Species

There are no written accounts of predation on coho juveniles in the Chignik system, although a variety of potential predators exist in the watershed. Most important among these, in terms of numbers of coho taken, probably are avian predators such as mergansers, cormorants, gulls and terns. Fairly large populations of these birds seasonally inhabit the watershed and adjacent nearshore marine waters. Although juvenile sockeye undoubtedly are the main diet component because they are so abundant, coho fry and fingerlings likely are taken on some

Table 13. Percentages of Chignik coho salmon found feeding, by 100 mm size groups, and percentages found feeding on sockeye salmon (from Burgner and Marshall 1974).

	Length of coho (mm)	
	28-100	101-200
Percentage feeding	98	91
Percentage of feeders feeding on sockeye	9	34
Total fish examined*	165	159

*73 samples omitted because of overlap in length interval.

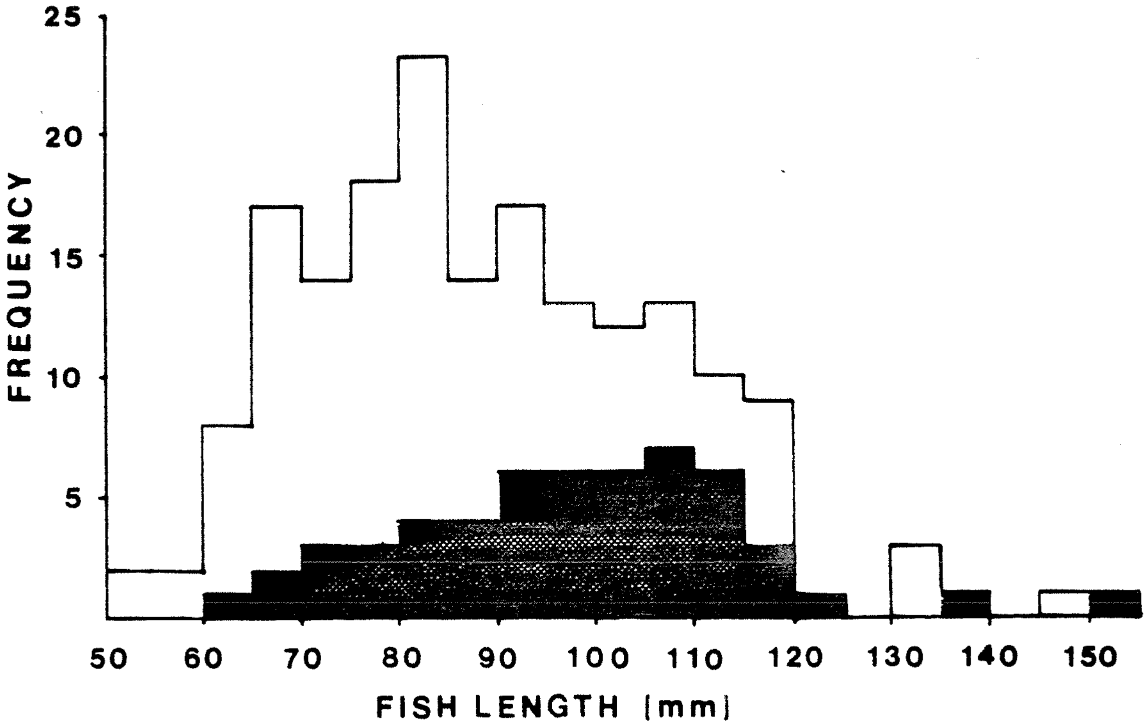

Figure 20. Size-frequency distributions of young Chignik coho salmon examined for stomach contents and those which ate sockeye fry.

fraction of predation attempts by birds. Possibly of lesser importance are other fish predators, for example, Dolly Varden, cottids, and large coho juveniles; harbor seals, a few of which are present in Chignik Lake and Chignik Lagoon; and assorted estuarine fish predators.

RECOMMENDATIONS

This review indicates that some of the essential data for estimating coho production are available, but not in a consistent or systematic format. The following recommendations are ordered by highest priority for developing a data base from which to formulate a coho management plan.

1. Routine sampling for age, sex and length data is mandatory for computing age composition statistics for coho runs. Sampling effort should be distributed over all time segments of the run to avoid bias due to differential migratory timing of sexes or age groups.

2. Weir operation should be extended to enumerate coho escapements, at least until peak coho abundance can be determined. This would provide reliable information on the pattern of coho abundance over time and, in addition, would permit testing of a catch estimator of total coho abundance. Providing coho can be distinguished from sockeye in the escapement (perhaps by ratio in the catch), determination of late season sockeye escapement is an attractive side benefit.

3. Determine time and location of coho spawning activity. It is anticipated that scale collections from spawning grounds will be needed to supplement scales taken in the commercial fishery in order to get an unbiased scale sample from all time segments of the run. Information on spawning sites is probably available from local inhabitants.

4. Assess the impact of coho predation on juvenile sockeye salmon. Obvious questions include:

    a) Predation rate on sockeye of various size classes by coho of various size classes.
    b) Distribution of juvenile coho relative to concentrations of sockeye fry.
    c) Effect of predation rate on coho growth and age at smoltification.

REFERENCES

Brannian, L. K. 1982. The estimation of daily escapement and total abundance from catch per unit effort of the sockeye salmon fishery in Togiak Bay, Alaska. M.S. Thesis, Univ. Washington, Seattle. 173 pp.

Burgner, R. L., and S. L. Marshall. 1974. Optimum escapement studies of Chignik sockeye salmon. Univ. Washington, Fish. Res. Inst., Final Rep FRI-UW-7401. 91 pp.

Burgner, R. L., C. J. DiCostanzo, R. J. Ellis, G. Y. Harry, Jr., W. L. Hartman, O. E. Kerns, 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. U.S. Fish. Wildl. Serv., Fish. Bull. 67(2):405-459.

Conrad, R. H. 1983. Management applications of scale pattern analysis methods for the sockeye salmon runs to Chignik, Alaska. M.S. Thesis, Univ. Washington, Seattle,. 232 pp.

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

Draper, N. and H. Smith. 1966. Applied Regression Analysis. Wiley and Sons, Inc., N.Y., p. 121.

Gulland, J. A. 1969. Manual of Methods for Fish Stock Assessment. Part 1. Fish Population Analysis. FAO Manuals in Fisheries Science No. 4., St. Paul's Press, Ltd., Malta, p. 44.

Israel, H. R. 1933. On the life history of the silver salmon, Oncorhynchus kisutch (Walbaum), of Chignik River, Alaska. M.S. Thesis, Stanford Univ., Palo Alto. 58 pp.

Mundy, P. R. 1982. Computation of migratory timing statistics for adult chinook salmon in the Yukon River, Alaska, and their relevance to fisheries management. North American Journal of Fisheries Management 4:359-370.

Mundy, P. R. 1983. Lecture Two: Theory and Practice; Shrimping in North Carolina. Proceedings of Sea Grant Seminar "Real-Time Fisheries Management," Univ. Washington, Seattle. 64 pp.

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

Paloheimo, J. E., and L. M. Dickie. 1964. Abundance and fishing success. Rapp. P.-V. Re′ un. Cons. Perm. int. Extor. Mer. 115:152-163.

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

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 pp.

Rogers, D. E. In press. Trends in abundance of northeastern Pacific stocks of salmon. Presentation workshop on influences of ocean conditions on the production of salmonids, 8-10 November 1983, Newport, Oregon. 30 pp.

Roos, J. F. 1958. Red salmon smolt studies at Chignik in 1958. Fish. Res. Inst., Univ. Washington, unpubl MS. 17 pp.

Roos, J. F. 1960a. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Trans. Am. Fish. Soc. 89(4):377-379.

Stohr, A. J., and S. S. Parker. 1982. Optimal size and time for release of coho salmon smolts into Yaquina Bay, Oregon. Univ. Washington, Fish. Res. Inst., Contract Completion Rep. FRI-UW-8217. 21 pp.

APPENDIX TABLES

Appendix Table 1. Cumulative proportions of coho catch by Julian day of the run.

Day	1973	1974	1975	1976	1977	1978	1980	1981	1982	1983
200				.00017	.00012		.01173	.00444	.00045	.00089
1				.00017	.00012		.01189	.00540	.00045	.00118
2				.00017	.00036		.01406	.00795	.00045	.00122
3		.00045	0.00000	.00017	.00036		.01498	.00860	.00045	.00177
4		.00045	.00006	.00061	.00036		.01802	.01082	.00101	.00177
5		.00127	.00006	.00061	.00036	0.00000	.02091	.01360	.00158	.00177
6		.00136	.00006	.00061	.00036	.00028	.02742	.01374	.00316	.00177
7		.00408	.00006	.00067	.00036	.00028	.02742	.01402	.00682	.00529
8		.00408	.00006	.00067	.00036	.00028	.02768	.02957	.00921	.00756
9		.00408	.00040	.00067	.00036	.00111	.03119	.03224	.00921	.00861
210		.00598	.00069	.00067	.00036	.00111	.04158	.03654	.00921	.01906
11		.00816	.00093	.00067	.00036	.00111	.04379	.04171	.00921	.01906
12		.01015	.00122	.00076	.00036	.00111	.04542	.04441	.00921	.01906
13	0.00000	.01115	.00183	.00076	.00036	.00297	.05038	.04441	.00921	.01942
14	.00193	.01278	.00183	.00076	.00036	.00304	.05076	.04441	.00921	.02116
15	.00193	.01278	.00183	.00381	.00036	.00374	.05076	.04607	.01052	.02284
16	.00193	.01278	.00221	.00677	.00054	.00408	.05345	.04890	.01291	.02560
17	.00193	.01632	.00239	.01232	.00065	.00408	.05452	.05222	.01398	.02623
18	.00930	.02239	.00351	.01427	.00065	.00408	.05470	.06332	.01442	.02623
19	.01268	.02529	.00458	.01520	.00065	.00643	.05558	.09865	.01442	.02623
220	.02850	.03082	.00488	.01520	.00113	.01114	.05680	.09865	.01442	.02889
21	.04409	.03689	.00498	.01595	.00268	.01259	.05640	.09865	.01607	.03004
22	.06176	.03689	.00498	.01706	.00405	.01439	.05680	.12695	.01806	.03609
23	.06176	.03689	.00551	.01769	.00666	.02096	.05845	.14157	.02015	.04637
24	.06176	.05847	.00771	.01839	.01166	.02096	.06197	.15863	.02017	.05488
25	.10239	.07206	.01015	.02281	.01166	.02096	.06793	.18665	0.2583	.05488
26	.13116	.09010	.01343	.02812	.01166	.04503	.08593	.21445	.02583	.05488
27	.17444	.11204	.01582	.02812	.02849	.08383	.11425	.21445	.02583	.07565
28	.22006	.14422	.01998	.05291	.04128	.11206	.11425	.21445	.03445	.09800
29	.29045	.14422	.01998	.07316	.07507	.14782	.11425	.27513	.04147	.13600
230	.29045	.14422	.02887	.09056	.10428	.18462	.14095	.31832	.04994	.17418
31	.29045	.20169	.03929	.10791	.13944	.18462	.16881	.37917	.04994	.23593
32	.39941	.25462	.04816	.12560	.13944	.18462	.20035	.39573	.04994	.23593
33	.46575	.29333	.06028	.15405	.13944	.28650	.22608	.42248	.04994	.23593
34	.51384	.35343	.08073	.15405	.22683	.32545	.24462	.42248	.04994	.26801
35	.59115	.41679	.11705	.21152	.27852	.39835	.24462	.42248	.09488	.36667
36	.65471	.41679	.11705	.25978	.34438	.48413	.24962	.55273	.12484	.42638
37	.70973	.41679	.19192	.30458	.41957	.61693	.34680	.61116	.16639	.50394
38	.70973	.57088	.23781	.34526	.53682	.61693	.42927	.64772	.19587	.54686
39	.80807	.66815	.30525	.40226	.53682	.61693	.49847	.71880	.22960	.54686
240	.86992	.69543	.39760	.48550	.53682	.70699	.58607	.74879	.23021	.54686
41	.93240	.71356	.47988	.48550	.75758	.81919	.67713	.74879	.23076	.62163
42	.98013	.77248	.54972	.59385	.76217	.85142	.67713	.74879	.31979	.69341
43	.98103	.77248	.54972	.67633	.82528	.85142	.67713	.80660	.38048	.73022
44	.00000	.77248	.67976	.74789	.91487	.87349	.74028	.85874	.45040	.76035
45		.86530	.75873	.84241	.97585	.87349	.79130	.90874	.48837	.80672

Appendix Table 1 - cont'd.

Day	1973	1974	1975	1976	1977	1978	1980	1981	1982	1983
246		.86920	.80875	.88230	.97585	.87349	.82673	.93617	.52589	.80672
47		.91996	.84538	.92388	.97585	.91291	.82673	1.00000	.61688	.80672
48		.91996	.86654	.92388	.98299	.92267	.82673		.66404	.81179
49		.94262	.88778	.97612	.98596	.95372	.82673		.71368	.85434
250		.95051	.88778	.97981	.98596	.95372	.82673		.76742	.89269
51		.97317	.92967	.99387	.98894	.96362	.88661		.82566	.92832
52		.97317	.94348	.99387	.98894	.97558	.93496		.87089	.94998
53		.99356	.95430	.99387	.99131	.97558	.97270		.90330	.97170
54		.99356	.97359	.99387	.99131	.97558	.98092		.92939	.98219
55		.99356	.98231	.99387	.99310	.98250	.99480		.93604	.98406
56		.99810	.98760	.99387	.99310	.98250	.99932		.94697	.99195
57		1.00000	.98760	.99387	.99488	.98250	1.00000		.96049	1.00000
58			.99046	.99387	.99488	1.00000			.96347	
59			.99046	.99387	.99881				.97212	
60			.99613	.99797	.99881				.97481	
61			.99613	1.00000	.99941				.97889	
62			.99908		.99941				.98580	
63			.99908		1.00000				.98993	
64			.99908						.99125	
65			.99931						.99408	
66			1.00000						.99723	
67									1.00000	

Appendix Table 2. Coho catches by day.

	Day	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
	200				6	2			(+584)	(+158)	(+58)	(+27)
7/20	201								8	34		9
	202					4			108	91		1
	203		6						46	23		17
	204			3	15				151	79	72	
	205		9						144	99	73	
	206		1				4		324	5	203	
	207		30		2					10	469	107
	208								13	553	306	69
	209			18			12		175	95		32
	210		24	13					110	184		
7/30	211											
	212		22	15	3				81	96		
	213		11	32			27		247			11
	214	43	18				1		19			53
	215				105		10			59	168	51
	216			20	102	3	5		134	101	307	84
	217		39	9	191	2			53	118	137	19
	218	164	67	59	67				9	395	57	
	219	75	32	56	32		34		44	1257		
	220	352	61	16		8	68		41			14
8/9	221	347	67	5	26	26	21				212	102
	222	393			38	23	26			1007	255	184
	223			28	22	44	95		102	520	268	313
	224		238	115	24	84			175	607	2	259
	225	904	150	128	152				297	997	727	
	226	640	199	172	183		348		896	989		
	227	963	242	125		283	561		1410			632
	228	1015	355	218	853	215	408				1106	680
	229	1566			697	568	518			2157	900	1172
	230			466	599	491	532		1329	1537	1087	1146
8/19	231		634	546	597	591			1387	2165		1879
	232	2424	584	465	609				1570	589		
	233	1476	427	635	979		1473		1281	952		
	234	1070	663	1072		1469	563		923			976
	235	1720	699	1903	1978	869	1054				5765	3002
	236	1414			1661	1107	1240		249	4634	3844	1817
	237	1224		3924	1542	1264	1920		4838	2079	5330	2360
	238		1700	2405	1400	1971			4106	1301	3782	1306
	239	2188	1073	3534	1962				3445	2529	4373	
	240	1376	301	4840	2865		1302		4361	1067	32	
8/29	241	1390	200	4312		3711	1622		4533		71	2275
	242	1062	650	3660	3729	77	466				11421	2184
	243	20			2839	1061				2057	7787	1120
	244	422		6815	2463	1506	319		3144	1855	8970	917
	245		1024	4139	3253	1025			2540	1779	4870	1411

Appendix Table 2. - cont'd.

	Day	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
	246		43	2621	1377				1764	976	4814	
	247		560	1920	1431		570			2271	11673	
	248			1109		120	141				6050	154
	249		250	1113	1798	50	449				6368	1295
	250		87		127						6895	1175
9/8	251		250	2195	484	50	143		2981		7471	1076
	252			724			173		2407		5803	659
	253		225	567		40			1879		4157	661
	254			1011					409		3348	319
	255			457		30	100		691		853	57
	256		50	277					225		1402	240
	257		21			30			34		1734	245
	258			150			253				382	
	259					66					1110	
	260			297	141						346	
9/18	261				70	10					523	
	262			155							886	
	263					10					530	
	264										169	
	265			12							363	
	266			36							405	
9/24	267										355	
TOTAL												

Appendix Table 3. **Estimated total runs of Chignik coho. Raw data with linear interpolation for closed periods (indicated by *).**

	Day	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
	200								+584	+158	+58	+27
7/20	201				10*	4*			9	39		10
	202				12*	5			126	108		1
	203		7		15*	5*			54	28		19
	204		9*	3	17*				187	97	115	45*
	205		10	7*	12*				179	119	117	70*
	206		1	10*	7*		5		392	6	230	96*
	207		34	14*	2		8*		206*	13	544	121
	208		31*	17*	2*		11*		20	691	350	79
	209		27*	21	2*		14		210	121	329*	36
	210		24	18	2*		19*		611	200	309*	357
7/30	211		28	16	2*		23*		131	236	288*	242*
	212		26	18	3		28*		96	120	267*	128*
	213		13	39	46*		32		279	104*	246*	13
	214	51	21	34*	89*		1		33	88*	226*	62
	215	87	29*	28*	132		13		96*	72	205	61
	216	123	37*	23	127		6		159	126	380	99
	217	159	46	11	239	2	18*		64	146	166	23
	218	195	78	69	82	4*	30*		12	483	91	22*
	219	94	38	68	39	7*	42		57	1505	146*	20*
	220	438	73	19	35*	9	84		50	1407*	201*	18
8/9	221	442	80	6	31	32	26		75*	1309*	256	120
	222	488	148*	20*	48	28	32		100*	1211	317	219
	223	*698	216*	33	30	56	116		125	643	337	376
	224	*907	284	138	33	106	219*		233	767	3	312
	225	1117	182	154	195	188*	322*		393	1255	1091	450*
	226	799	250	202	222	270*	425		1112	1240	1161*	588*
	227	1203	302	150	612*	352	680		1654	1700*	1240*	726
	228	1282	438	257	1001	274	490		1633*	2161*	1315	789
	229	1971	552*	403*	862	715	633		1612*	2621	1068	1367
	230	*2316	655*	548	730	628	646		1591	1950	1285	1355
8/19	231	*2662	779	649	738	768	1040*		1668	2653	2394*	2192
	232	*3007	732	554	779	1107*	1433*		1876	809	3502*	1882*
	233	1872	555	759	1196	1446*	1827		1553	1296	4611*	1568*
	234	1397	857	1270	1796*	1785	744		1134	2757*	5719*	1255
	235	2222	903	2245	2397	1090	1369		759*	4217*	6828	3447
	236	1827	1346*	3433*	2018	1430	1650		384	5678	4624	2175
	237	1618	1790*	4620	1884	1618	2494		5806	2597	6288	2790
	238	*2216	2233	2965	1769	2522	2244*		4976	1720	4539	1557
	239	2813	1438	4356	2451	3288*	1995*		4221	3222	5201	1946*
	240	1753	483	5851	3605	4054*	1745		5393	1393	59	2335*
8/29	241	1837	343	5254	4132*	4820	2229		5571	1824*	122	2724
	242	1446	1002	4413	4658	132	684		5033*	2255*	13500	2567
	243	32	1169*	6370*	3587	1490	572*		4495*	2686	9413	1376
	244	609	1337*	8327	3152	2114	460		3957	2397	10871	1142

Appendix Table 3. - cont'd.

Day		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
	245		1504	5135	4182	1479	586*		3184	2311	6022	1798
	246		74	3252	1803	1055*	711*		2364	1329	6082	1278*
	247		898	2469	1880	630*	83		2657*	3043	14262	758*
	248		664*	1497	2188*	206	242		2951*		7481	238
	249		429	1481	2496	86	720		3244*		7781	1643
	250		149	2174*	191	86*	483*		3538*		8526	1526
9/8	251		429	2866	688	86	245		3831		9402	1383
	252		408*	1045	638*	78*	297		3162		7331	877
	253		386	818	589*	69	255*		2483		5212	893
	254		286*	1403	539*	60*	213*		590		4348	443
	255		186*	660	490*	51	171		959		1253	88
	256		86	475	440*	51*	259*		386		2023	341
	257		36	366*	391*	51	346*		58		2405	354
	258			257	341*	79*	434				589	
	259			367*	292*	106					1630	
	260			476	242	62					519	
9/18	261			361*	112	17					768	
	262			249		17*					1250	
	263			173*		17					778	
	264			97*							261	
	265			21							533	
	266			62							608	
9/24	267										533	

Appendix Table 4. Daily coho run totals smoothed by moving average of three dates.

Day		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
					0	0			0			
					2	1			28	0		0
					6	2			31	13		3
	200		0		10	4			73	49		4
7/20	201		2	0	12	3			63	58	0	10
	202		5	1	15	2			122	78	38	22
	203		9	3	15	0			140	81	77	45
	204		7	7	12		2		253	74	154	70
	205		15	10	7		4		259	46	297	96
	206		22	14	4		8		206	237	375	99
	207		31	17	2		11		145	275	408	79
	208		27	19	2		15		280	337	329	157
	209		26	18	2		19		317	186	309	212
	210		26	17	2		23		279	185	288	242
7/30	211	0	22	24	17		28		169	153	274	128
	212	17	20	30	46		20		136	104	260	68
	213	46	21	34	89		15		136	88	246	45
	214	87	29	28	116	0	7		96	95	226	74
	215	123	37	21	166	1	12		106	115	270	61
	216	159	54	34	149	2	18		78	252	250	48
	217	149	54	49	120	4	30		44	711	212	22
	218	242	63	52	52	7	52		40	1132	134	20
	219	325	64	31	35	16	51		61	1407	146	53
	220	456	100	15	38	23	47		75	1309	201	119
8/9	221	543	148	20	36	39	58		100	1054	258	238
	222	698	216	64	37	63	122		153	874	303	302
	223	907	227	108	86	117	219		250	888	219	379
	224	941	239	165	150	188	322		579	1087	477	450
	225	1040	245	169	343	270	476		1053	1398	752	588
	226	1095	330	203	612	299	532		1466	1700	1164	701
	227	1485	431	270	825	447	601		1633	2161	1239	961
	228	1856	552	403	864	539	590		1612	2244	1208	1170
	229	2316	665	533	777	704	773		1624	2408	1223	1638
	230	2662	725	584	749	834	1040		1712	1804	1582	1810
8/19	231	2514	689	658	904	1107	1433		1699	1586	2394	1881
	232	2092	715	861	1257	1446	1335		1521	1621	3502	1568
	233	1830	772	1425	1796	1440	1313		1149	2757	4611	2090
	234	1815	1035	2316	2070	1435	1254		759	4217	5719	2292
	235	1889	1346	3433	2100	1379	1838		2316	4164	5724	2804
	236	1887	1790	3673	1890	1857	2129		3722	3332	5913	2174
	237	2216	1820	3980	2035	2476	2244		5001	2513	5150	2098
	238	2261	1385	4391	2608	2388	1995		4863	2112	5343	1946
	239	2134	755	5154	3396	4054	1990		5062	2146	3266	2335
	240	1679	609	5173	4132	3002	1553		5332	1824	1794	2542
8/29	241	1105	838	5346	4126	2147	1162		5033	2255	4650	222
	242	696	1169	6370	3799	1245	572		4495	2446	7678	1695

Appendix Table 4. - cont'd.

Day		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
	243	214	1337	6611	3640	1694	539		3879	2465	11261	1439
	244	71	972	5571	3046	1549	586		3168	2012	8769	1406
	245	0	825	3619	2622	1055	711		2735	2228	7658	1278
	246		545	2406	1957	630	597		2657	1457	8789	758
	247		664	1816	2188	307	600		2951	1014	9275	880
	248		414	1717	1625	126	482		3244	0	9841	1136
	249		336	2174	1125	86	483		3538		7929	1517
	250		329	2028	506	63	342		3510		8570	1262
9/8	251		408	1576	638	78	266		3159		8420	1051
	252		360	1089	589	69	255		2078		7315	738
	253		286	960	539	60	213		1344		5630	475
	254		186	846	490	54	214		645		3604	291
	255		103	500	440	51	259		468		2541	261
	256		41	366	341	60	346		148		1894	232
	257		12	330	341	79	260		19		1672	118
	258		0	367	292	82	145		0		1541	0
	259			401	215	62	0				913	
	260			362	118	32					972	
9/18	261			261	37	17					846	
	262			173	0	11					760	
	263			97		6					681	
	264			60		0					467	
	265			28							558	
	266			21							380	
	267			0							178	
	268										0	
	269											
	270											
9/28	271											