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FORECAST OF THE 1976 PINK SALMON RETURNS TO SOUTHEASTERN ALASKA

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	i
LIST OF TABLES	i
LIST OF APPENDICES	ii
ABSTRACT	iii
INTRODUCTION	1
GEOGRAPHICAL AREA OF STUDY	1
DEFINITIONS	1
STATUS OF STOCKS	3
Historical Perspective	3
Northern Southeastern Alaska	5
Southern Southeastern Alaska	7
FORECAST SUCCESS	9
1976 FORECAST	12
1974 Escapement	12
Freshwater Mortality of the 1974 Brood	12
Pre-emergent Fry Sampling	14
Outmigration of Fry	14
Early Marine Mortality of the 1974 Brood	15
1976 FORECAST ANALYSIS	15
Southern Southeastern	16
Northern Southeastern	16

TABLE OF CONTENTS (Continued)

	Page
Return Distribution and Projected Harvest Levels	18
SUMMARY	19
Southern Southeastern	19
Northern Southeastern	21
ACKNOWLEDGMENTS	21
LITERATURE CITED	22
APPENDIX	24

LIST OF FIGURES

		Page
Figure 1.	Map of Southeastern Alaska showing regulatory districts and forecast units	2
Figure 2.	Annual commercial harvest of pink salmon in Southeastern Alaska since 1900	4
Figure 3a-c.	Northern Southeastern pink salmon commercial catch (3a), escapement (3b) and return per index spawner (3c)	6
Figure 4a-c.	Southern Southeastern pink salmon commercial catch (4a), escapement (4b) and return per index spawner (4c)	8
Figure 5.	Pink salmon escapement index attained in 1974 versus escapement index goals by district	13
Figure 6.	Percent of escapement index goals achieved in 1974 in 136 major spawning streams	13
Figure 7.	Observed and expected pink salmon returns to northern and southern Southeastern Alaska based on the 1976 predictive equations	17

LIST OF TABLES

Table 1.	Comparison of forecast and observed pink salmon returns in northern and southern Southeastern Alaska, 1967-1975	10
Table 2.	District pink salmon return forecasts, escapement index goals and estimated allowable harvest, Southeastern Alaska, 1976	20

LIST OF APPENDICES

		Page
Appendix Table 1.	Mean monthly precipitation at Juneau, Alaska during the incubation period of pink salmon broods from 1943 through 1975	25
Appendix Table 2.	Mean monthly precipitation at Ketchikan, Alaska during the incubation period of pink salmon broods from 1943 through 1975	26
Appendix 3.	Multiple regression analysis to determine point and range estimate of 1976 pink salmon returns to southern Southeastern Alaska	27
Appendix Table 4.	Number of live pink salmon alevins, sample size and annual fry indices, southern Southeastern, 1965-74 broods	32
Appendix 5.	Multiple regression analysis to determine point and range estimate of 1976 pink salmon returns to northern Southeastern Alaska	34
Appendix Table 6.	Number of live pink salmon alevins, sample size and district fry indices, northern Southeastern, 1965-74 brood years	39
Appendix Table 7.	Northern Southeastern adjusted pre-emergent densities weighted by effective spawning area . .	41
Appendix Table 8.	Northern Southeastern pre-emergent fry densities adjusted for the annual variation of escapement to sample streams	43

ABSTRACT

Southeastern pink salmon forecasts are based primarily upon an analysis of relationships between pre-emergent fry densities and subsequent adult returns. The pre-emergent fry abundance information is obtained each spring from an extensive sampling program covering over 100 Southeastern Alaska streams. Additionally, data on escapements, estuarine conditions, air temperature, precipitation and other factors are analyzed to improve forecast accuracy.

Pre-emergent sampling of the 1974 brood year (1976 return) pink salmon spawn was the most extensive in 13 years. Nearly 5,800 hydraulic samples were collected in 143 individual sections of 102 spawning streams throughout the region. Only 7% of the sample areas produced substantial numbers of live fry while 60% produced very few or no live fry at all. The low fry densities observed clearly point toward very poor pink salmon returns in both northern and southern Southeastern in 1976.

Several factors affected fry production:

1. Low escapements. Due to the generally poor returns the 1974 escapements in both northern and southern Southeastern were the lowest in an even year since 1960 and in most districts escapements were less than half of the desired goals.

2. Loss of spawn during high water. Heavy rainfall occurred throughout Southeastern during October, November and December 1974. For example, the October rainfall at Juneau was the most ever recorded there in any single month and the October rainfall at Ketchikan was 1.5 feet above normal. Some streams showed obvious signs of flooding the following spring and egg loss was probably widespread.

3. Freezing and desiccation of fry. Below normal temperatures were prevalent in Southeastern during February 1975 at a time when stream flows were low and snow cover was thin. Substantial numbers of dead fry were found during sampling in March and April.

4. Early outmigration. The possibility of early fry outmigration prior to stream sampling was examined. Trapping of outmig-

rant fry was conducted on a small scale in the southern area and records of similar studies were reviewed. The analysis indicated that early outmigration was not a significant factor in the low pre-emergent fry abundance observed in 1975.

5. Estuarine environment. In southern Southeastern the low fry production may have been partially offset by favorable estuarine conditions at the time fry were leaving the streams. At Ketchikan the sea water temperatures were above the average of the past few years. Northern Southeastern estuaries were colder than average and fry survival is not expected to be exceptional.

The forecast analysis indicated poor pink returns to both northern and southern sections of Southeast Alaska during 1976. In northern areas the point estimate of the return if 1.8 million with an upper range of 5.4 million. For southern Southeastern the point estimate of the return is 4.1 million with an upper range of 9.6 million. At the forecasted level little commercial harvest would be permissible and even if the returns approach the upper range there is little prospect for prolonged fishing in broad areas. There is also a very real possibility of extremely poor returns, especially in some areas, and achievement of well distributed escapement will be critically important in 1976.

		Return	Harvest
Southern Southeastern			
Point estimate	=	4.1 million	0.2 million
Range estimate	=	<1 - 9.6 million	0 - 3.6 million
Northern Southeastern			
Point estimate	=	1.8 million	0
Range estimate	=	<1 - 5.4 million	0 - 1.9 million

FORECAST OF 1976 PINK SALMON RETURNS TO SOUTHEASTERN ALASKA

INTRODUCTION

Southeastern Alaska pink salmon forecast research was begun in 1962. This report is the eleventh in a series concerning these studies (Noerenberg et al. 1964; Hoffman 1965, 1966; Smedley and Seibel 1967; Smedley et al. 1968; Valentine et al. 1970; Durley and Seibel 1972; Durley 1973a, 1973b; Kingsbury et al. 1975a). The purpose of this report is to describe the present condition of Southeastern pink salmon stocks, analyze the success of the 1975 Southeastern pink salmon forecast and present the 1976 forecast.

Annual pink salmon forecasts are of importance to salmon fishermen and processors for operational planning and to fishery managers for regulatory decision making. Forecast information contained in this report was presented at the December 1975 meeting of the Alaska Board of Fisheries and was published earlier in summary form (Waltemyer and Lindstrom, 1976).

GEOGRAPHICAL AREA OF STUDY

The major pink salmon producing area of Southeastern Alaska lies between Cape Fairweather and Dixon Entrance (Figure 1). For salmon management and forecast purposes this area is divided into southern and northern units; tagging studies have demonstrated that migration routes of pink salmon bound for the two units are sufficiently different that little mixing occurs in the catch (Nakatani et al. 1975). Southern Southeastern includes regulatory districts 1-8. Pink salmon enter through Dixon Entrance and Sumner Strait or approach the west coast of Prince of Wales Island directly from the Gulf of Alaska. The northern unit includes Districts 9-16. Pink salmon enter primarily through Icy Strait although small numbers pass through Peril Strait and lower Chatham Strait. Stocks bound for the west coast of Baranof and Chichagof islands approach from the north and may be intercepted by fisheries in Cross Sound or outer Icy Strait. The streams of Districts 4, 8, 15 and 16 produce relatively few pink salmon and are not considered in the forecasts.

DEFINITIONS

Because the terms escapement and return frequently occur throughout this report, it is important to briefly explain them as they are used in manage-

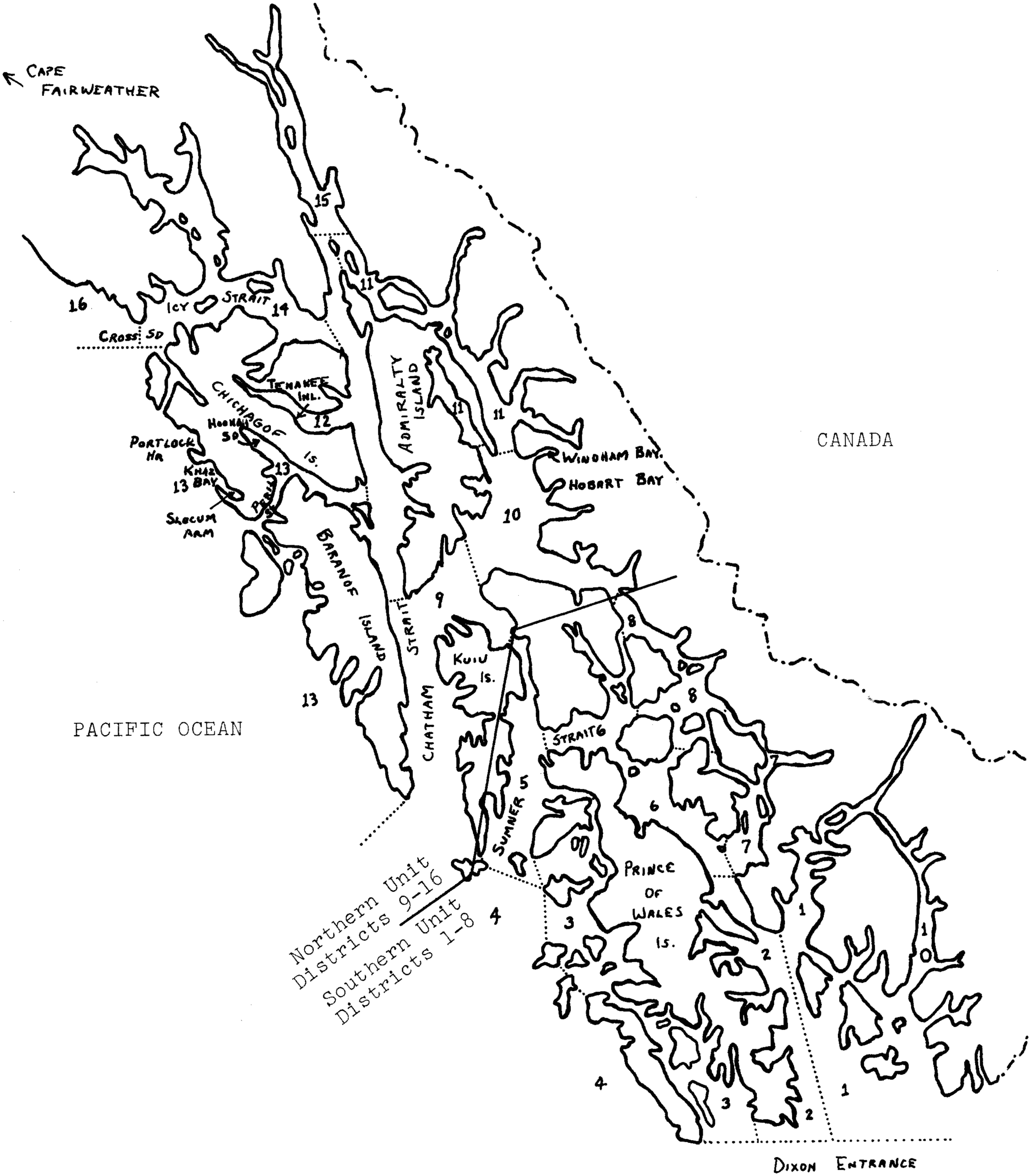

Figure 1. Map of Southeastern Alaska showning regulatory districts and forecast units.

ment of the Southeastern pink salmon. The term escapement refers to those salmon which survive natural and fishing mortalities and enter the spawning streams. Barring extreme predation, severe drought or drastic overcrowding a large proportion of these fish deposit the spawn to replenish the stocks. In this report "escapement" is used as an abbreviation for "escapement index". Since it is not now practical to accurately estimate the total number of pink salmon spawners in all the streams of Southeastern Alaska, an index or relative measure of escapement is obtained annually. The index is derived from annual peak counts from an extensive series of aerial and foot surveys and weir counts of pink salmon in the spawning streams. Provided that the relationship between total escapement and escapement index is constant, the escapement index can be substituted for total escapement for forecast and management purposes.

The term return refers to the adult salmon leaving the feeding grounds in the open ocean and entering inshore fishing grounds. Primary components of the return are the catch and the escapement. In this report the return is more precisely a "return index" because it represents the sum of the commercial catch and the escapement index.

STATUS OF THE STOCKS

Historical Perspective

The significance of the 1976 Southeastern pink salmon forecast can be properly discussed only in relation to longer term historical abundance levels of the stocks. Because data on escapement prior to 1960 are very limited, it is necessary to use annual commercial catch data as an indirect measure of annual run size in the discussion of historical patterns. The limitations of this approach as a result of variations in number and types of gear, fishing time, districts open to fishing and other factors must be recognized.

The commercial catch of Southeastern pink salmon did not reach significant proportions until after 1900. Annual commercial harvests from 1900 to present are shown in Figure 2. This figures suggests that, similar to other major Alaskan salmon fisheries, the Southeastern pink salmon fishery experienced four basic periods.

The first period, beginning with the commencement of commercial fishing and ending about 1917, could be called the period of development. During this period fishermen, fishing gear and processing facilities increased rapidly with a corresponding increase in catch from 4 million in 1900 to 41 million in 1917.

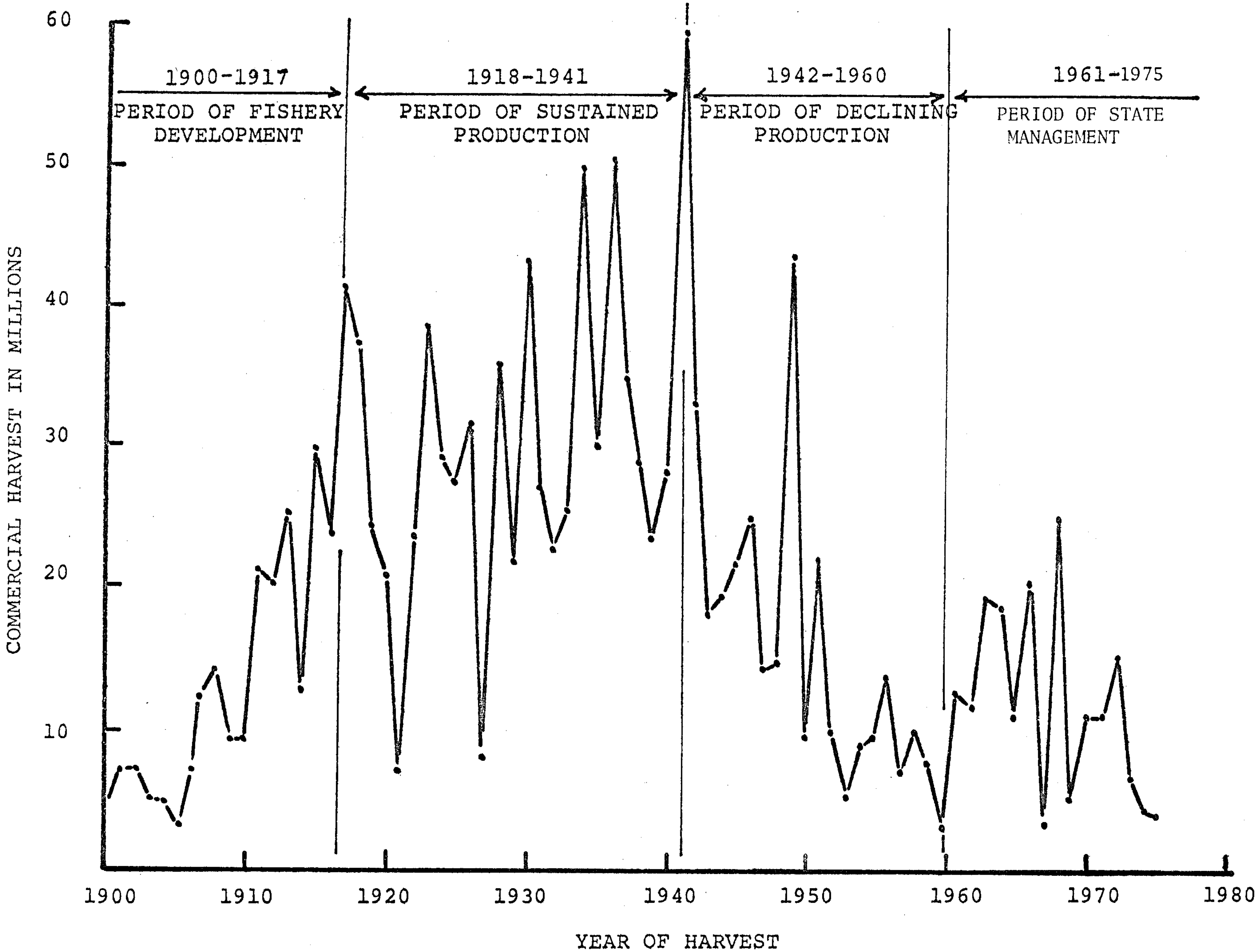

FIGURE 2. ANNUAL COMMERCIAL HARVEST OF PINK SALMON IN SOUTHEASTERN ALASKA SINCE 1900

The second period, from about 1918 to about 1941, could be referred to as a period of sustained production. Although large annual variations occurred, the catch appeared to have a relatively constant long term trend, neither increasing nor decreasing. The average annual pink salmon catch in Southeastern Alaska was 31 million fish; the peak annual catch of nearly 60 million pink salmon was attained in 1941.

During the third period, 1942-1960, a severe decline occurred in the catch of pink salmon from 33 million in 1942 to 3 million in 1960 with the exception of 1 year's recovery in 1949. The causes of the decline over nearly 20 years cannot be identified without more detailed study of the history of the fisheries, however, the most probable major cause was repeated overharvest with the subsequent reduction of spawning populations.

The fourth period, from 1961 to present, encompasses the span of state management during which the abundance of pink salmon initially responded well to more intensive management but recently has returned to very low levels. Average annual catch was approximately 11 million pink salmon with a maximum of 25 million in 1968. This period is particularly relevant to the discussion of the 1976 forecasts and it is useful to consider southern and northern units separately and in more detail.

Northern Southeastern Alaska

Pink salmon catches in northern Southeastern approached average historical levels in 1961 and 1963 but since then have declined rather steadily (Figure 3a). The catch of 9.9 million in 1968 was also comparatively high whereas the catch of about 520,000 in 1974 was the lowest since 1900. The 1975 catch (584,000 fish) was only marginally better.

Before 1972 fishery managers were quite effective in maintaining escapement levels (Figure 3b) through restriction of fishing time and waters open to fishing. However, an escapement index goal of 4 million for northern Southeastern established in 1972 has never been achieved. Since 1972 the escapement index has fallen lower each year. The bulk of the catch in 1975 came from Sitka Sound and Slocum Arm on the outside coast where escapement goals were met.

It appears that the decline of pink salmon catches in northern Southeastern Alaska since 1960 has been a reflection of progressively poorer survival conditions. The return per index spawner[a/] of northern Southeastern stocks

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a/ Return per index spawner for brood year n = $\frac{\text{return in year n+2}}{\text{escapement index in year n}}$

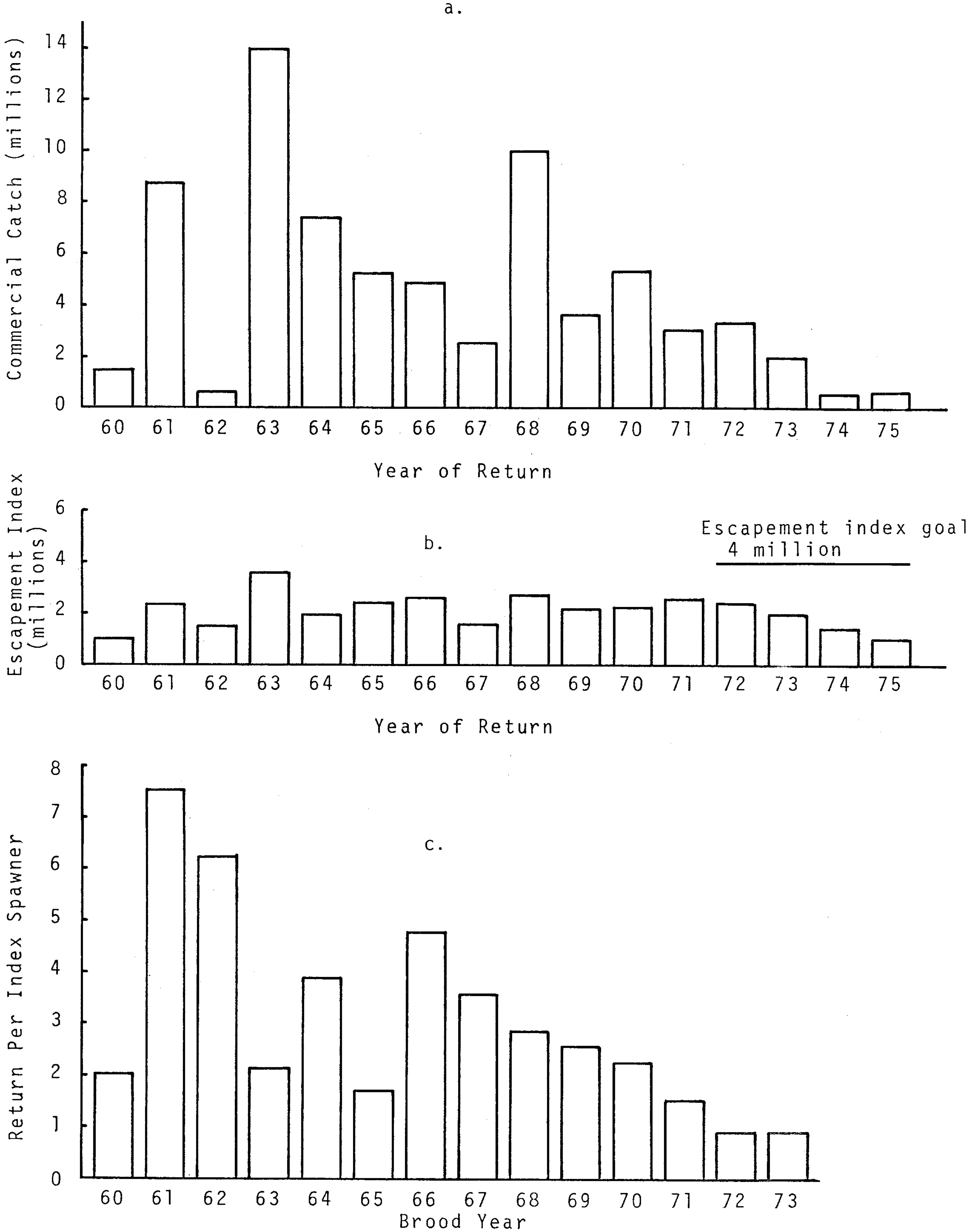


Figure 3a-c. Northern Southeastern pink salmon commercial catch (3a), escapement (3b) and return per index spawner (3c).

has declined rather steadily since 1961 (Figure 3c). The poor returns from the 1963 and 1965 broods was probably caused at least partially by severe drought during the spawning season which reduced stream flows to the point that many potential spawners died unspawned. Eggs already spawned may also have been adversely effected. The last two brood years (1972 and 1973) have returned less than one fish (in 1974 and 1975) for each fish in the escapement index. The northern Southeastern return per spawner ratio is a composite survival index of many stocks, some of which maintained their abundance and others which have declined drastically. The stocks from some areas are especially weak. These weak areas include Peril Strait, Hoonah Sound, Icy Strait, the lower west coast of Admiralty Island, the inner portion of Tenakee Inlet, northern Khaz Bay, Portlock Harbor, Hobart Bay and Windham Bay (Figure 1). Early-run stocks from inside waters have been effected more severely than middle- and late-run stocks and small streams have suffered more than larger streams.

The causes of the declining survival of northern Southeastern pink salmon are poorly understood but the observed trend toward lower ocean and air temperatures in recent winters may be involved. However, the severe winters of 1970-71 and 1971-72 did not seem to accelerate the decline of the survival rate which began at least as early as 1961 (Figure 3c). Some other Alaskan salmon stocks appear to have declined sharply as a result of those two winters (Waltemyer and Lindstrom 1976).

Regardless of the causes of the low survival it is obvious that it will require improved survival of the northern Southeastern pink salmon stocks to restore them enough to support significant commercial harvests. When abundance does increase the first priority must be the achievement of escapement goals so as to establish a "cushion" against years of poor survival and an opportunity to take full advantage of years of good survival. At present many pink salmon stocks in northern Southeastern Alaska are at extremely low levels of abundance.

Southern Southeastern Alaska

In southern Southeastern even-year pink salmon catches increased dramatically to over 15 million in 1966 and 1968 and then generally declined to a near-record low of 3.7 million in 1974 (Figure 4a). Odd-year catches remained at much lower levels reaching a maximum of 6.2 million in 1971 and then dropping to 3.2 million in 1975. Variations in escapement levels (Figure 4b) basically followed the variation in catches; even-year escapement index peaked in 1966 and 1968 and odd-year escapement index peaked in 1971. In 1975 the escapement index was increased above 1973 and 1974 levels through limitation of fishing time and open waters.

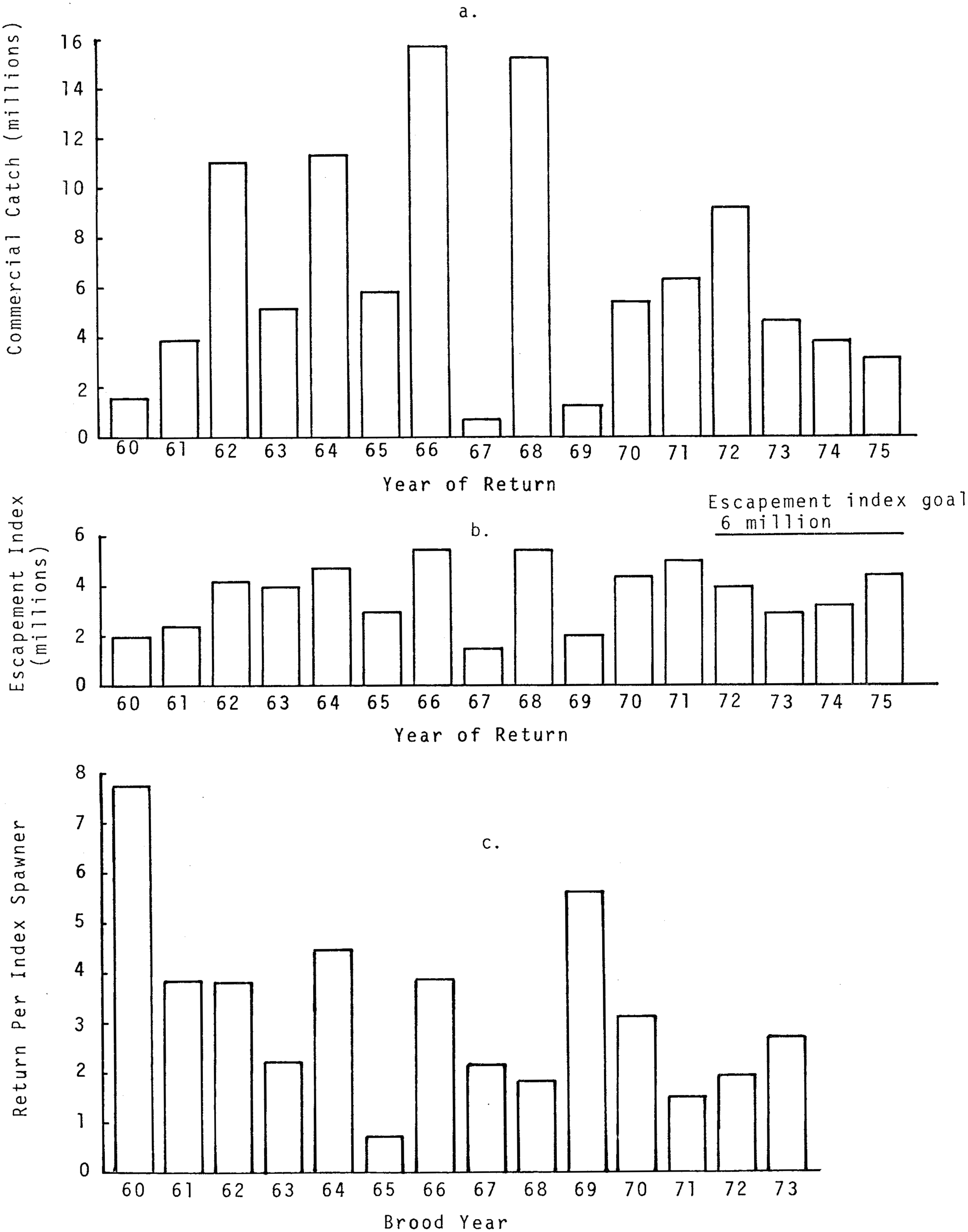


Figure 4a-c. Southern Southeastern pink salmon commercial catch (4a), escapement (4b) and return per index spawner (4c).

The return per index spawner (Figure 4c) of southern Southeastern pink salmon stocks has averaged only slightly higher than that of northern stocks but no obvious declining trend has occurred. Unusual climatic occurrences probably account for most years of poor pink salmon survival. Poor returns from the 1963 and 1965 broods were associated with extensive drought during the spawning seasons. Examination of weather records and stream survey reports indicate that the drought was longer, more severe and effected more streams in 1965 than in 1963. Consequently the return per index spawner of the 1965 brood was considerably lower than that of the 1963 brood. Poor returns from the 1968, 1971 and 1973 broods were associated with unusually cold winters during which water levels dropped and spawning beds froze. The low returns from the 1967 and 1972 broods cannot be readily explained by a single climatic event but several factors may have been responsible. Conversely the brood years of exceptionally high survival (1960 and 1969) were associated with average or slightly above average winter temperature and precipitation.

In sum, the magnitude of the pink salmon returns to southern Southeastern Alaska seem to be quite closely related to basic measures of the environment (temperature and precipitation) and the escapement index. Analysis of pre-emergent sampling results and other data to be discussed later indicates that the 1976 return (from the 1974 brood) will probably be very weak, however the general condition of the southern Southeastern pink salmon stocks appear to be good. The prospect of restoring those stocks to former levels of abundance is quite favorable.

FORECAST SUCCESS

The 1976 pink salmon return will be the tenth covered by the Southeastern forecast program. Forecast success has been variable with both good and poor forecasts for large, small and intermediate returns (Table 1). The problems experienced have been different in the two forecast units.

Southern Southeastern predictions have been reasonably accurate in terms of overall return strength for five of the nine previous returns. Even-year returns have been forecast more successfully (3 satisfactory out of 4) than have odd-year returns. We believe that current forecast techniques can be used to produce dependably accurate forecasts, particularly if this program is augmented with studies of estuarine or early marine survival of the pink salmon fry.

In northern Southeastern pink salmon returns in the last 6 years have been near or below the lower limit of the forecast range. In 1971, 1972 and 1974 returns were well below forecast levels which probably hindered rather

Table 1. Comparison of forecast and observed pink salmon returns in northern and southern Southeastern Alaska, 1967-1975 a/.

(Number of salmon in millions)

Return Year	Point Estimate	Range Estimate b/	Actual Return	Deviation from Point
		Southern Southeastern		
1967	4.8	4.2 - 5.4 e/	2.2	+2.6
1968	21.5	20.2 - 25.2	20.6	+0.9
1969	3.1	3.0 - 3.3	3.2	-0.1
1970	18.7	17.2 - 21.4	9.7	+9.0
1971	4.3	4.3 - 5.0	11.2	-6.9
1972	13.7	10.4 - 17.1	13.1	+0.6
1973	14.1	12.2 - 16.1	7.4	+6.7
1974	6.8	4.4 - 9.2	7.4 c/	-0.2
1975	2.1	0 - 4.1	7.4 d/	-5.3
		Northern Southeastern		
1967	4.9	4.9 e/	4.1	+0.8
1968	6.2	5.2 - 9.1	12.6	-6.4
1969	4.2	4.2 - 6.8	5.8	-1.8
1970	9.0	9.0 - 10.0	7.6	+1.4
1971	8.5	7.5 - 9.1	5.5	+3.0
1972	12.9	7.1 - 18.7	5.7	+7.2
1973	6.0	3.5 - 8.5	3.9	+2.1
1974	9.3	7.4 - 11.2	2.0 c/	+7.3
1975	4.8	1.6 - 8.0	1.7 d/	+3.1

a/ Return actually refers to return index, i.e., return index = catch + escapement index.

b/ Range estimates prior to 1972 were based on alternative forecast methods and were not intended as confidence limits.

c/ Return index revised slightly based on final catch statistics.

d/ Based on preliminary catch and escapement data.

e/ Pre-emergent fry indices alone indicated forecasts of 2.3 - 4.0 million for southern Southeastern and 4.0 - 5.1 for northern Southeastern in 1967.

than helped in management of the fisheries. The 1975 return was also weaker than predicted but in this case the forecast contributed to conservation of the stocks as will be explained below. The problem of repeated over-estimation of the northern runs is probably related to the declining return per spawner ratio discussed previously and we believe it has been dealt with in the 1976 forecast. However, it does appear that the development of thoroughly reliable forecasts of northern Southeastern pink salmon returns will require more intensive study and monitoring of both freshwater and estuarine environments. These studies are being initiated.

The forecast of the 1975 returns generally contributed to management of the pink salmon stocks, however some predictive errors were experienced. The predicted returns to both southern and northern units were very low. Southern Southeastern was expected to receive only 2.1 million fish which was only about one-third of the number required to meet the escapement index goals. The upper range of the forecast return was 4.1 million and the catch was not expected to exceed 300,000. Northern districts were expected to fare slightly better; the predicted return was 4.8 million including a harvest of 1.3 million, mostly from the Sitka area. In both southern and northern areas it was expected that early and middle runs would be especially weak and only the late runs, mostly produced by streams on the outside coasts would be sufficiently strong to allow fishing. Faced with the prediction for very weak returns, the Department's strategy was to hold back on intensive fishing until pink salmon began to appear in numbers in the usual inside schooling areas and bays.

In retrospect the 1975 pink salmon returns were generally poor and forecast accuracy was variable. Some areas experienced substantially stronger returns than was expected and some areas weaker. The southern unit return of 7.4 million exceeded the upper limit of the forecast range due to the strength of the middle run. It appears that the fry of the middle run of Districts 1, 2, 3, 6 and 7 experienced excellent estuarine survival in the spring of 1974 which partially compensated for the low fry input of the spawning streams. Fortunately the strength of the middle run was detected and that segment accounted for the bulk of the 1975 southern Southeastern catch. Early runs and some segments of the middle run were about as weak as expected while the late run was, if anything, weaker than expected. The returns to Anan Creek and Wilson River, both major early-run streams, were somewhat stronger than most other early runs as was anticipated from the forecast data.

In northern Southeastern the pink salmon returns to the inside districts were generally weaker than forecast and escapement indices declined in nearly every stream even though almost no fishing was allowed. Only about 45,600 pinks were caught in Districts 9-12, 14 and 15 which normally account for at least 80% of a substantial harvest. The forecast correctly indicated little or no harvestable surplus from these districts and in this case the forecast contributed to conservation of the essential spawning stock. Had normal fishing been allowed in these districts, many of the spawning streams could have been rendered totally barren. The runs in the Sitka Sound and Slocum Arm areas were actually about half of the expected magnitude, however, good escapement levels were achieved and the catch of about 539,000 pink salmon was the third highest since 1960.

1976 FORECAST

1974 Escapement

The downtrend of even-year pink salmon escapements since 1968 continued into 1974, the parent year or brood year of the 1976 return. In both northern and southern units escapement indices were below the average for even years since 1960 and far below escapement goals. In southern Southeastern the escapement index of 3.1 million was about 50% of the 6 million required while in northern Southeastern the 1974 escapement was only 37% of the goal of 4 million. None of the district escapement index goals were met in 1974 (Figure 5).

The distribution of pink salmon escapement among the numerous spawning streams is also very important because a super-abundance of spawners in one stream does not compensate for a scarcity of spawners in another. Figure 6 shows the percent of attainment of escapement index goals in 136 important Southeastern spawning streams in 1974. In 99 of the streams (73% of the total) less than 40% of the escapement goal was achieved. Goals were exceeded in 9 streams (7% of the total). These particular 136 streams were selected because a sufficient data base exists to establish reasonably valid escapement goals and they are considered representative of pink salmon spawning streams in the region. The analysis shows that insufficient numbers of spawners was the major problem in 1974 while distribution of escapement and excessive numbers of spawners was of lesser importance.

Freshwater Mortality of the 1974 Brood

Mortality of pink salmon during the incubation period in freshwater is highly variable; generally less than 10% of the eggs deposited survive to emergence in the spring. This results from a number of biological and climatological factors including superimposition of redds, disease, predation, scouring of spawn by floods, siltation, freezing and desiccation.

The 1974 pink salmon brood apparently experienced exceptionally high mortality in freshwater. Heavy rainfall occurred throughout Southeastern during

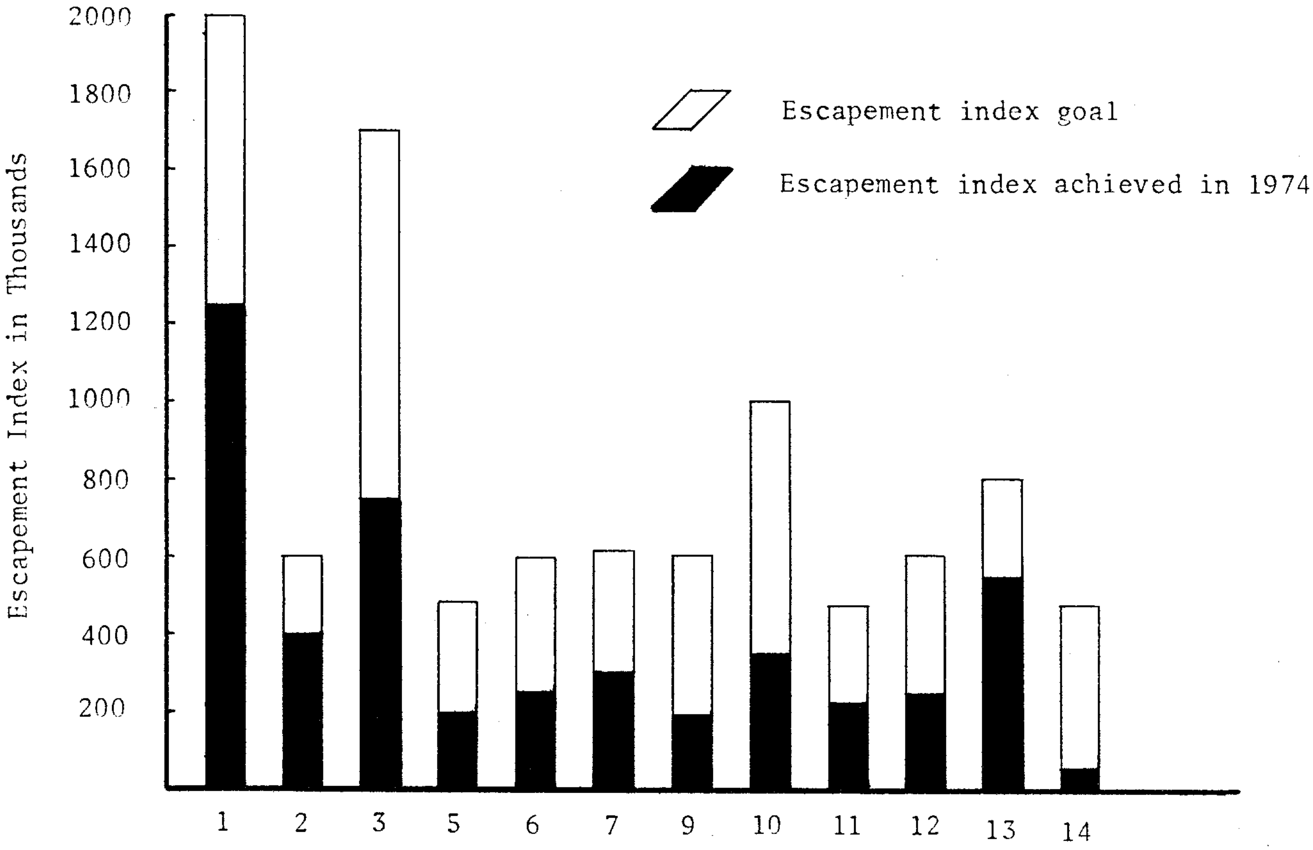


Figure 5. Pink salmon escapement index attained in 1974 versus escapement index goals by district.

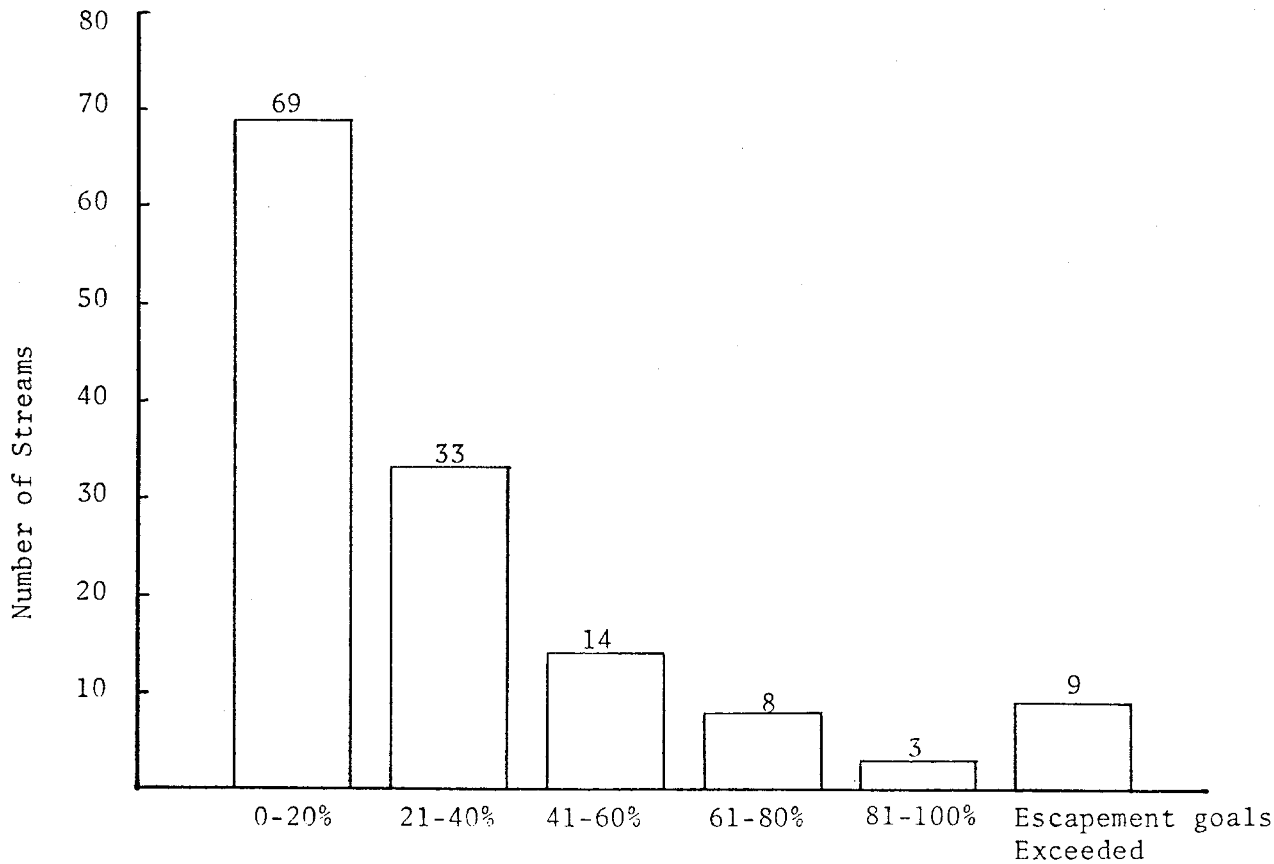


Figure 6. Percent of escapement index goals achieved in 1974 in 136 major spawning streams.

October, November and December 1974. October precipitation at Juneau of 15.25 inches was the highest recorded for any month (Appendix Table 1). Maximum precipitation in 24 hours was 1.47 inches. The October precipitation at Ketchikan was 18 inches above the monthly mean (Appendix Table 2) and the maximum 24 hour precipitation was 6.94 inches. Other stations reported similar precipitation extremes. Some streams showed obvious signs of flooding when visited the following spring and egg loss was probably widespread. In some streams hydraulic sampling of spawning grounds in the spring of 1975 yielded little evidence (dead eggs, fry or empty egg cases) of pink salmon spawn even though spawning had been noted the previous fall.

Mortality of the 1974 brood due to freezing and desiccation also occurred. Air temperatures during the first half of February throughout the region were below normal and most night-time temperatures were below freezing. This occurred when stream flows were low, snow cover was thin and spawning riffles were exposed to freezing. Substantial numbers of dead fry were found during sampling in March and April. In 22 of the 102 streams sampled we found at least 25% of the fry were dead and in 5 streams over 50% were dead. Regionwide the percentage of dead fry in 1975 was exceeded in only one year (1969) in 10 years of sampling.

Pre-emergent Fry Sampling

The Southeastern pink salmon forecast program utilizes portable hydraulic sampling equipment (McNeil 1964) to sample fry abundance in standard index sites in spawning streams throughout the region each year.

Ice cover, water levels and flying conditions during the 1975 pre-emergent fry sampling were ideal and the sampling effort was the most extensive since the start of the Southeastern forecast program. Nearly 5,800 hydraulic samples were collected in 144 sections of 102 major spawning streams throughout the region during February, March and April. In general the live fry densities were among the lowest observed (Appendix Tables 4 and 6). Only 7% of the sample areas produced substantial numbers of live fry while 60% of the areas produced very few or none at all. The average density of live fry in the southern unit was only 49 fry per square meter, the lowest fry index on record. The northern unit fry index of 108 fry per square meter was the second lowest.

Outmigration of Fry

The very low pink salmon densities found during the 1975 pre-emergent sampling prompted the consideration of early outmigration of fry. Trapping of outmigrant fry was conducted on a limited scale in the southern area and an extensive review of over 70 earlier outmigration studies on Southeastern Alaska streams was accomplished (Kingsbury et al. 1975b). The studies reviewed were conducted from 1941 to 1975 on 17 different streams throughout the region.

The analysis showed that very few pink salmon fry leave the spawning gravels prior to April 1. The majority of fry leave the streams in April and May. Fry that do leave earlier probably suffer greater mortality due to low food supply, slow growth, cold temperature and extended predation. Most of the pre-emergent sampling was completed prior to the April 1 date and only a few streams were sampled as late as mid-April. The results of the fry trapping and the information obtained in the review indicated that early outmigration of fry was an insignificant contributor to the low pre-emergent fry indices.

Early Marine Mortality of the 1974 Brood

The mortality of juvenile salmon in the estuaries and the ocean after their emigration from the spawning streams is quite variable. The weeks immediately following entry into marine waters are very important in determining the magnitude of the adult return. Sampling of pre-emergent fry does not account for this mortality, therefore, sea surface and air temperatures have been included in the forecast analysis as indicators of early marine mortality of pink salmon fry. The assumption was made that, within certain upper and lower limits, mortality of the fry decreases with increasing estuarine temperature. Temperature data were obtained from the National Oceanographic and Atmospheric Administration (NOAA) and from our own program of estuarine temperature and salinity sampling in the northern unit.

In southern Southeastern favorable estuarine temperatures were prevalent at the time the 1974 brood fry were leaving the streams. Ketchikan sea surface temperatures during March, April and May 1975 were about average for recent years and dense plankton blooms were observed. The low fry production of the spawning grounds may be partially offset by higher than average early marine survival but this effect is not expected to produce large pink salmon returns in the southern districts in 1976. In northern Southeastern the estuaries were colder than normal in the spring of 1975 and fry survival was probably not exceptional.

1976 FORECAST ANALYSIS

Southeastern pink salmon forecasts were based on relationships between pre-emergent fry abundance indices, temperature indicators of estuary conditions and subsequent adult returns. The relationship was mathematically described using multiple linear regression analysis. Calculations of the 1976 southern and northern unit forecasts are described in detail in Appendices 3-8 and are summarized below.

Southern Southeastern:

Multiple linear regression analysis of pre-emergent fry indices, Ketchikan March to May sea surface water temperatures and returns showed that these factors were associated with a total correlation coefficient (R) of 0.89 (Appendix 3). The standard error of estimate was 2.95 million pink salmon. The predictive equation was as follows:

$$Y = -13.43 + (0.107)(X_1) + (1.660)(X_2)$$

Where: Y = return in millions of pink salmon

X_1 = pre-emergent index fry value (no. live fry/m^2 - see Appendix Table 4)

X_2 = mean Ketchikan March-May surface seawater temperature (^oC).

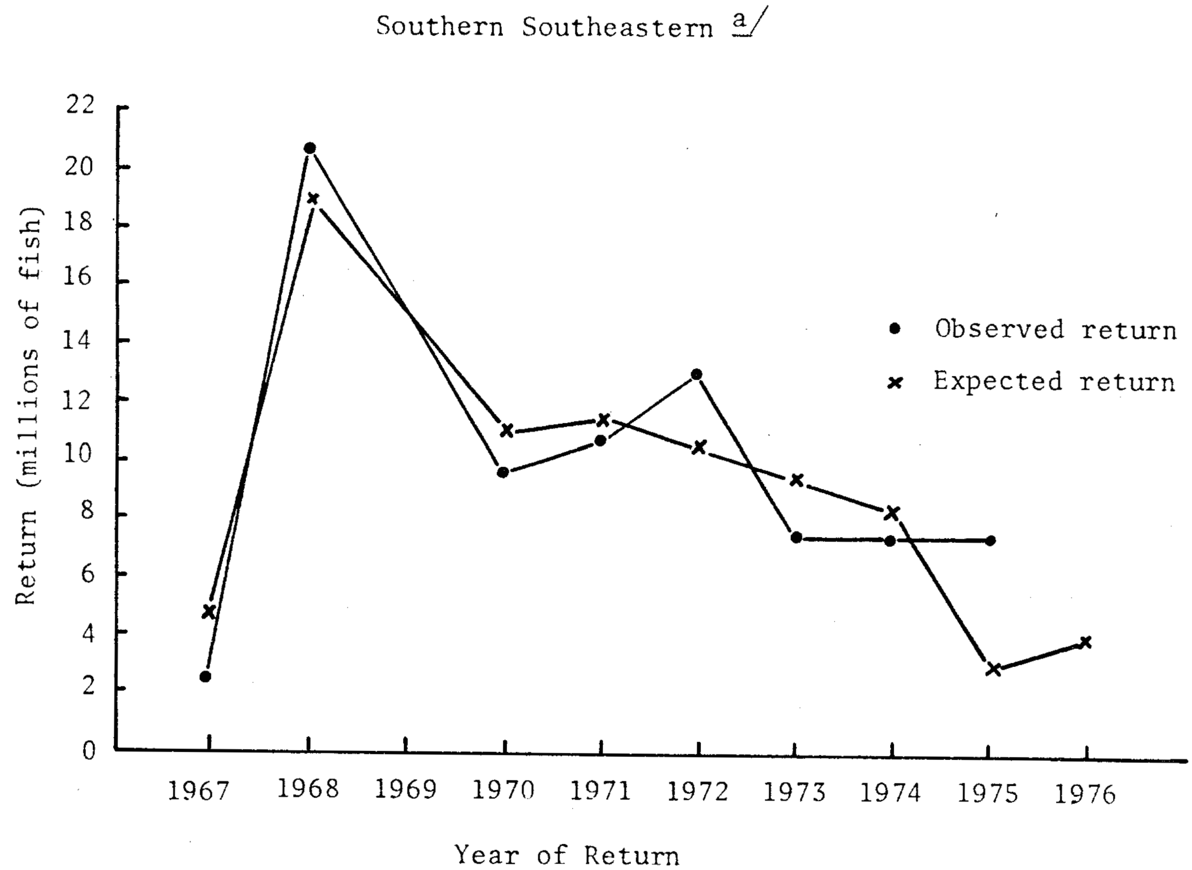
From the linear regression equation, returns were estimated for each year and compared with observed returns (Figure 7). This analysis showed the value of the multiple regression relationship for forecasting returns to southern Southeastern. The square of the correlation coefficient (R^2 = .79) indicated that 79% of the variance in return strengths to southern areas was accounted for by the multiple regression analysis.

The point estimate of the 1976 return to the southern unit is 4.1 million pink salmon with a range of about 1 million to 9.6 million. The range estimates are an 80% confidence interval about the predicted value. They are interpreted to mean that the return would be within the range eight out of ten times when estimated by the same methods, given identical conditions.

The return estimate of 4.1 million pink salmon indicates an expected return per index spawner from the 1974 brood of only 1.3. This is well below the average southern Southeastern return per spawner of over three pink salmon but within the range observed in the previous 14 years.

Northern Southeastern:

The 1976 northern Southeastern forecast is obtained from a multiple



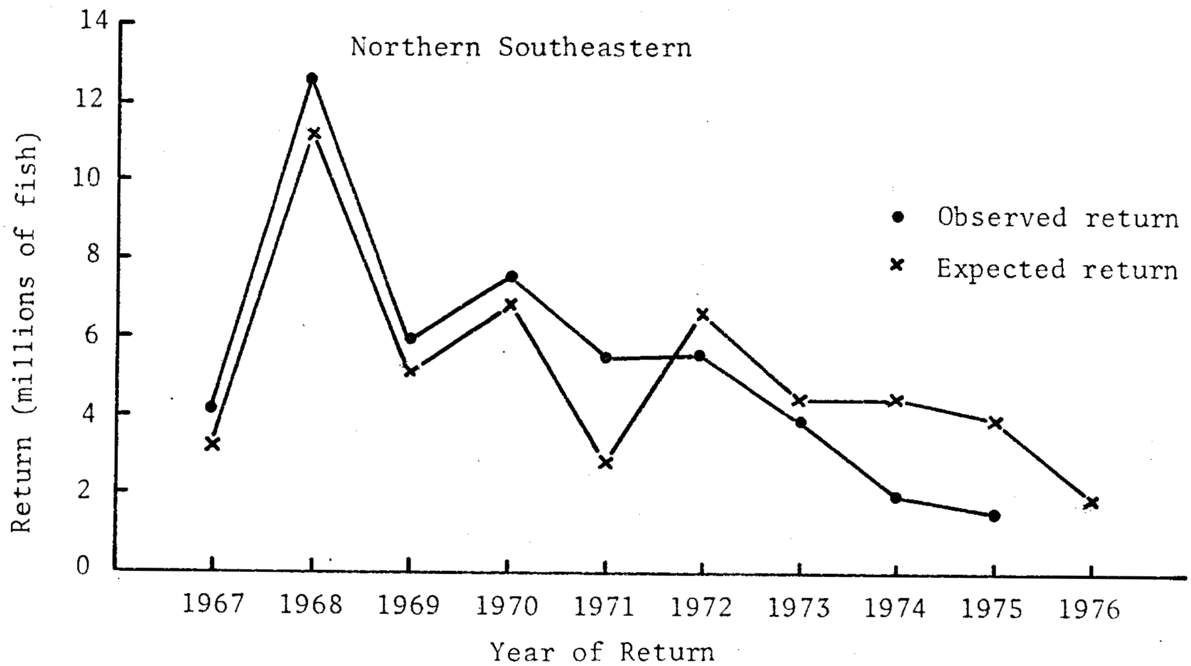


Figure 7. Observed and expected pink salmon returns to northern and southern Southeastern Alaska based on the 1976 predictive equations.

a/ The 1969 observed and expected returns for southern Southeastern were omitted because of lack of predictive data.

regression of fry indices, spring and summer air temperatures and returns (Appendix 5). Mean air temperatures from seven stations throughout northern Southeastern for the period April through August were chosen as an indication of post-emergent pink salmon survival. The same method was used for the 1975 forecast.

Analysis of the northern Southeastern pre-emergent indices, air temperatures and returns indicated they were related with a total correlation coefficient (R) of 0.81. The standard error of estimate was 3.30 million pink salmon. The multiple regression analysis indicated the best fit linear predictive equation to be as follows:

$$Y = -50.560 + (0.068) X_1 + (4.886) X_2$$

Where Y = return in millions of pink salmon

X_1 = pre-emergent index fry value (no. live fry/m^2 - see Appendix Tables 6-8)

X_2 = mean average April to August air temperature (°C) from seven stations

From the equation, return strengths were back calculated for each year and compared with the actual returns (Figure 7). The square of the correlation coefficient (R^2 = .67) indicated that 67% of the observed differences in returns to northern areas was accounted for by the index fry value and air temperature factors.

The point estimate for the 1976 return is 1.8 million pink salmon. The anticipated range of the estimate (at 80% confidence) is from about 1 million to 5.4 million. The point estimate indicates that only about one fish per brood year index spawner is expected to return in 1976. This is well below the average return per spawner of over three pink salmon per index spawner but nearly the same as that of the past 2 years.

Return Distribution and Projected Harvest Levels

Effective management of pink salmon stocks requires estimates of returns to geographic district and time segments. Forecasts for the important pink salmon spawning districts in Southeastern Alaska were obtained by partitioning the estimated returns to the northern and southern units based on district pre-emergent and escapement indices. First the escapement contribution of each district in the parent year (1974) was calculated as a percentage of the 1974 southern or northern unit escapement index. Each district escapement fraction was then weighted by the district pre-emergent index to obtain an estimate of the relative strength of the return to the districts. The estimates of relative district strengths were applied to the northern or southern unit forecasts to determine the district return estimates. In this manner both point and range estimates were obtained for all major districts (Table 2).

Escapement index goals for Southeastern regulatory districts were established in 1972. The escapement index goals are 6 million and 4 million for the southern and northern units respectively. Forecast of the 1976 pink salmon harvest for each district were calculated by subtracting district escapement index goals from the district return estimates described above. It should be understood that the district harvest estimates indicate the probable contribution of fish from each district to various intercepting fishing fleets. The actual district where the catch occurs is difficult to predict and it may be distant from the district of origin.

Forecasts of the timing of the pink salmon runs were computed in a manner similar to the forecasts of district returns. On the basis of past escapement surveys primarily since 1960 spawning streams were categorized as early-, middle- or late-run according to the following definitions:

Early - peak of spawning prior to August 10

Middle - peak of spawning August 10 to August 31

Late - peak of spawning September 1 or later.

Pre-emergent indices and escapement counts to representative streams in each category were used to partition the unit return estimates into early-, middle- and late-run forecasts. It must be recognized that the accuracy of these forecasts is affected by oceanographic factors and the location and intensity of intercepting fisheries at the time of the return in addition to all other factors affecting forecast accuracy.

The forecasts of the time segments and districts of the 1976 pink salmon returns to the southern and northern units are summarized below.

SUMMARY

Southern Southeastern

The 1976 pink salmon returns are expected to be weak in all southern districts. A return at the level of the point estimate of 4.1 million would probably allow a harvest of about 200,000 fish primarily from District 2. A return at

Table 2. District pink salmon return forecasts, escapement index goals and estimated allowable harvest, Southeastern Alaska, 1976[a].

(Number of salmon in millions)

District	Forecast Return: Point Estimate	Forecast Return: Range Estimate	Escapement Index Goals	Allowable Harvest: Point Estimate	Allowable Harvest: Range Estimate
		Southern Southeastern			
1	1.1	.1 - 2.6	2.0	0	0 - 0.6
2	0.8	.1 - 2.0	0.6	0.2	0 - 1.4
3	1.0	.1 - 2.3	1.7	0	0 - 0.6
5	0.4	.1 - 1.0	0.5	0	0 - 0.5
6	0.3	.1 - 0.6	0.6	0	0 - 0.0
7	0.5	.1 - 1.0	0.6	0	0 - 0.5
Subtotal	4.1	< 1 - 9.6	6.0	0.2	0 - 3.6
		Northern Southeastern			
9	0.2	.1 - 0.6	0.6	0	0 - 0
10	0.5	.1 - 1.4	1.0	0	0 - 0.4
11	0.5	.1 - 1.5	0.5	0	0 - 1.0
12	0.2	.1 - 0.7	0.6	0	0 - 0.1
13	0.4	.1 - 1.2	0.8	0	0 - 0.4
14	0.01	.01 - 0.03	0.5	0	0 - 0
Subtotal	1.8	< 1 - 5.4	4.0	0	0 - 1.9
Region total	5.9	< 1 - 15.0	10.0	0.2	0 - 5.5

a/ Return actually refers to return index, i.e., return index = catch + escapement index.

the upper forecast range would permit a harvest of about 3.6 million mostly from District 1-3. There is little prospect of prolonged fishing in broad areas. There is a possibility of a major failure of the return such as occurred in 1967 and 1969 and the lower range of the forecast is less than 1 million pink salmon.

Return timing is expected to be about 25% early, 30% middle and 45% late spawning. The timing pattern of the 1974 return may be repeated in which both early- and late-run streams were filled during the middle-run period.

Northern Southeastern

The pink salmon return to the northern unit is also expected to be very low. A return at the level of the point estimate of 1.8 million would not warrant any commercial harvest. A return at the upper range of 5.4 million might allow some fishing in Districts 10 and 11. These districts include mostly early- and middle-run streams. Overall the return is expected to be about 35% early-, 55% middle- and 10% late-run.

The spawning populations of District 14 (Icy Strait) streams are seriously depleted and complete protection of those runs is essential. Low returns are also expected throughout Districts 9, 12 and 13.

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LITERATURE CITED

Bureau of Commercial Fisheries Research Staff. 1959. Review of information on salmon migrations in Southeast Alaska, Juneau, Alaska. Unpublished Report.

Durley, Kenneth E. 1973a. Forecast of the 1973 pink salmon runs, Southeastern Alaska. Alaska Department of Fish and Game, Technical Data Report No. 10.

____________. 1973b. Forecast of the 1974 pink salmon runs, Southeastern Alaska. Alaska Department of Fish and Game, Technical Data Report No. 12.

____________ and Melvin C. Seibel. 1972. Forecast of 1972 pink salmon runs, Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 158.

Hoffman, Theodore C. 1965. Southeastern Alaska pink salmon forecast studies, pre-emergent fry program. Alaska Department of Fish and Game, Informational Leaflet No. 47.

____________. 1966. Southeastern Alaska pink salmon forecast studies, pre-emergent fry program. Alaska Department of Fish and Game, Informational Leaflet No. 88.

Kingsbury, Alan, Paul Larson and Gerry Downey. 1975a. Forecast of the 1975 pink salmon returns to Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 168.

____________. 1975b. Alevin abundance - pink salmon studies, Project No. AFC-50-1. Unpublished ADF&G Technical Report.

McNeil, William J. 1964. A method of measuring mortality of pink salmon eggs and larvae. Fishery Bulletin 63(3):575-588.

Nakatani, Roy E., Gerald J. Paulik and Richard Van Cleve. 1975. Pink salmon, Oncorhynchus gorbuscha, tagging experiments in Southeastern Alaska, 1938-42 and 1945. NOAA Technical Report NMFS SSRF-686.

Noerenberg, Wallace H., Robert S. Roys, Theodore C. Hoffman, Asa T. Wright and Allen S. Davis. 1964. Forecast research on 1964 Alaska pink salmon fisheries. Alaska Department of Fish and Game, Informational Leaflet No. 36.

Smedley, Stephen C. and Melvin C. Seibel. 1967. Forecast of 1967 pink salmon runs in Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 103.

____________________, Kenneth E. Durley and Michael J. McHugh. 1968. Forecast of 1968 pink salmon runs, Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 118.

Snedecor, George W. and William G. Cochran. 1973. Statistical methods. 6th Ed., Iowa State Univ. Press. 593 pp.

Valentine, John P., Louis A. Gwartney, Charles C. Larson and Gerry D. Downey. 1970. Forecast of the 1970 pink salmon runs, Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 142.

Waltemyer, David L. and Sandra C. Lindstrom (Editors). 1976. A summary of preliminary 1976 forecasts for Alaska salmon fisheries. Alaska Department of Fish and Game, Informational Leaflet No. 169.

APPENDIX

Appendix
Table 1. Mean monthly precipitation at Juneau, Alaska during the incubation period of pink salmon broods from 1943 through 1975[a].

Year	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
1943-44	6.65	5.66	11.24	9.26	6.50	9.86	4.55	1.76	5.75
1944-45	3.72	4.71	3.69	12.39	7.52	4.43	3.49	3.17	4.54
1945-46	7.76	4.17	7.31	11.05	2.43	2.57	4.24	2.03	3.50
1946-47	6.61	5.52	4.90	10.52	7.31	2.47	4.76	2.18	5.80
1947-48	2.01	8.47	11.09	4.89	4.89	4.36	6.77	1.14	4.16
1948-49	5.54	3.39	11.51	11.04	10.38	2.95	7.33	4.03	2.09
1949-50	3.97	3.52	7.80	8.50	9.22	2.35	0.94	2.22	1.29
1950-51	7.07	4.95	7.32	2.71	2.13	3.43	2.09	2.31	3.75
1951-52	2.67	2.76	3.85	3.65	4.70	2.30	3.50	2.85	3.32
1952-53	3.71	5.90	10.84	13.29	7.11	2.86	1.46	6.28	3.65
1953-54	2.95	5.45	6.17	12.33	2.72	5.02	2.01	4.22	1.49
1954-55	3.50	1.11	5.03	6.32	5.67	5.42	4.03	3.30	4.72
1955-56	2.37	6.53	5.39	7.47	2.65	2.86	2.83	4.05	4.69
1956-57	2.96	9.99	4.59	6.50	11.22	9.89	1.05	3.99	1.35
1957-58	2.83	1.50	5.61	3.94	8.55	3.76	4.90	2.00	1.20
1958-59	4.31	4.20	5.06	9.39	4.31	7.45	1.39	4.15	4.56
1959-60	7.39	5.39	5.51	6.04	6.82	5.88	3.86	2.05	4.84
1960-61	4.31	4.77	8.47	8.95	4.97	7.39	3.76	4.07	2.67
1961-62	6.04	12.31	7.01	10.20	6.12	4.04	6.99	0.96	5.00
1962-63	4.75	5.21	9.75	7.39	4.03	8.16	6.55	6.03	3.69
1963-64	5.22	1.20	8.05	7.78	3.91	4.56	3.19	8.48	4.38
1964-65	6.94	3.48	2.59	7.35	4.89	5.22	7.75	5.10	1.66
1965-66	2.26	4.17	2.34	7.99	1.46	4.26	4.34	3.13	6.36
1966-67	3.91	6.37	8.20	6.97	4.39	4.48	4.04	4.74	1.34
1967-68	4.26	5.46	8.53	5.71	5.81	3.25	3.25	5.30	3.85
1968-69	4.60	2.39	10.14	4.60	5.34	1.90	0.94	0.68	4.17
1969-70	7.88	7.54	5.44	3.77	8.69	4.36	2.37	3.35	4.08
1970-71	5.01	7.47	9.86	5.87	2.01	2.58	5.56	3.93	3.33
1971-72	1.67	6.89	5.36	5.80	4.38	3.23	3.73	2.71	4.19
1972-73	1.15	8.62	6.24	8.49	3.35	3.56	4.37	3.94	3.01
1973-74	3.65	6.64	4.95	6.07	1.63	2.30	2.37	6.23	1.15
1974-75	3.12	5.78	5.96	15.25	7.79	7.03	4.10	3.76	2.17
Record Mean	4.37	5.34	6.75	7.57	5.29	4.24	3.87	3.47	3.61

a/ Data from National Oceanographic and Atmospheric Administration climatological reports.

Appendix Table 2. Mean monthly precipitation at Ketchikan, Alaska during the incubation period of pink salmon broods from 1943 through 1975[a].

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
1943-44	14.95	11.23	15.00	12.25	24.56	18.91	18.89	4.95	18.69
1944-45	8.22	9.20	11.95	34.27	16.02	13.08	16.36	13.81	16.67
1945-46	9.12	2.00	17.15	24.90	9.62	9.19	17.53	9.85	16.67
1946-47	13.40	8.73	15.91	20.20	14.50	16.20	18.14	9.96	16.99
1947-48	6.68	13.37	18.73	22.26	12.41	18.00	21.08	7.14	6.77
1948-49	6.16	9.16	24.03	27.17	18.90	12.99	14.20	10.00	11.09
1949-50	9.47	11.31	28.07	37.23	24.81	6.56	1.65	16.58	10.19
1950-51	16.95	16.67	20.63	15.28	12.73	19.87	14.98	12.28	17.22
1951-52	5.82	7.86	7.65	17.73	12.89	13.47	17.93	12.04	13.25
1952-53	8.47	12.35	22.48	18.13	13.50	13.55	10.26	22.08	19.04
1953-54	8.82	7.73	19.60	28.67	21.42	24.22	11.12	25.60	6.05
1954-55	7.01	0.90	11.03	27.27	20.16	25.64	19.29	13.54	11.27
1955-56	2.68	20.83	12.72	26.76	12.31	4.94	5.34	10.25	10.90
1956-57	4.62	25.33	6.56	23.40	22.75	23.16	2.92	8.38	7.96
1957-58	8.00	7.75	8.62	14.81	22.02	16.54	20.01	9.66	3.94
1958-59	4.43	20.78	13.67	31.47	16.28	15.25	10.83	10.65	20.10
1959-60	9.83	11.67	13.62	25.83	22.80	30.63	9.31	4.12	8.24
1960-61	6.01	6.72	12.20	25.32	8.99	14.85	9.75	10.97	6.56
1961-62	5.75	12.61	7.07	26.87	13.57	11.17	31.28	1.11	12.04
1962-63	4.53	9.00	-	-	20.20	23.52	15.77	21.04	6.34
1963-64	6.69	.95	26.98	26.99	15.59	18.40	20.72	18.23	9.78
1964-65	10.97	19.54	11.18	31.10	16.71	9.53	18.48	20.23	4.85
1965-66	2.39	5.51	1.77	26.45	10.77	16.10	17.61	12.09	21.71
1966-67	3.80	11.24	19.50	22.70	10.13	14.37	13.70	23.69	2.75
1967-68	17.57	21.27	21.95	23.32	9.21	16.52	17.07	11.55	14.45
1968-69	7.42	13.18	21.51	30.62	23.12	6.66	4.94	5.48	5.37
1969-70	13.27	13.19	5.73	13.09	42.93	22.15	16.01	13.06	12.96
1970-71	11.18	15.80	21.59	23.58	2.80	11.33	8.29	16.44	14.01
1971-72	.93	13.00	9.91	23.92	20.92	9.67	12.64	15.88	18.46
1972-73	8.09	18.56	9.29	24.20	11.40	12.38	16.32	11.33	14.83
1973-74	11.65	8.29	23.05	21.42	6.24	16.76	9.36	19.08	3.94
1974-75	5.04	5.97	8.14	42.37	27.73	23.99	17.06	9.55	10.09
Record Mean	8.35	10.54	14.46	25.74	16.76	15.83	15.47	11.95	11.75

a/ Data from National Oceanographic and Atmospheric Administration climatological reports.

Appendix 3. Multiple regression analysis to determine point and range estimate of 1976 pink salmon returns to southern Southeastern Alaska [a].

Multiple Linear Regression

In the following analysis:

X_1 = southern Southeastern pre-emergent fry index expressed in fry per square meter

X_2 = average March-April-May sea surface temperature (°C) at Ketchikan

Y = southern Southeastern pink salmon return in millions of fish

Data used in the northern Southeastern multiple linear regression analysis:

Year of Return	X_1	X_2	Y
1967	67.3	6.7	2.2
1968	193.7	7.1	20.6
1969	85.0	N/A	3.2
1970	126.7	6.7	9.7
1971	115.2	7.8	11.2
1972	128.9	6.2	13.1
1973	134.4	5.4	7.4
1974	99.1	6.9	7.4
1975	57.7	6.3	7.4

The multiple linear regression equation to be solved is:

$$Y = a + b_1X_1 + b_2X_2$$

a/ The multiple linear regression was solved using a Hewlett-Packard (Model 65) program. Calculation of Sy.x, $S\hat{y}$, R and prediction interval were done by following methods of Snedecor and Cochran (1973).

Appendix 3 (cont.).

The terms a, b_1, and b_2 were determined using a Hewlett-Packard multiple regression program as follows:

$$b_2 = \frac{A - B}{\{n\Sigma X_1^2-(\Sigma X_1)^2\}\ \{n\Sigma X_2^2-(\Sigma X_2)^2\} - \{n\Sigma X_1 X_2 - (\Sigma X_1)(\Sigma X_2)\}^2}$$

where n = 8 a/

$$A = \{n\Sigma X_1^2 - (\Sigma X_1)^2\}\ \{n\Sigma X_2 Y-(\Sigma X_2)(\Sigma Y)\}$$

$$B = \{n\Sigma X_1 X_2-(\Sigma X_1)(\Sigma X_2)\}\ \{n\Sigma X_1 Y - (\Sigma X_1)\ (\Sigma Y)\}$$

$$b_1 = \frac{\{n\Sigma X_1 Y-(\Sigma X_1)(\Sigma Y)\} - b_2\{n\Sigma X_1 X_2-(\Sigma X_1)(\Sigma X_2)}{n\Sigma X_1^2 - (\Sigma X_1)^2}$$

$$a = \frac{1}{n}\ (\Sigma Y-b_2\ \Sigma X_2-b_1\Sigma X_1)$$

By solving the above, the prediction equation becomes:

$$Y = -13.43 + 0.107X_1 + 1.660X_2$$

The 1976 prediction is:

$$Y_{1976} = -13.43 + (0.107)(49.0) + (1.660)(7.4)$$

$$Y_{1976} = 4.1 \text{ million}$$

---

a/ The 1969 return and fry index data were omitted from the analysis because sea surface temperature data were not collected during 1968.

Appendix 3 (cont.).

Standard deviation from regression $Sy.x$:

Where: $\Sigma x_1 y = \Sigma X_1 Y - \frac{(\Sigma X_1)(\Sigma Y)}{n}$

$\Sigma x_2 y = \Sigma X_2 Y - \frac{(\Sigma X_2)(\Sigma Y)}{n}$

Σy^2 = total sum of squares = $\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$

$\Sigma \hat{y}^2$ = regression sum of squares

$= b_1 \Sigma x_1 y + b_2 \Sigma x_2 y$

$n = 8$

$k = 3$

$\Sigma d^2 = \Sigma y^2 - \Sigma \hat{y}^2$

$$Sy.x = \sqrt{\frac{\Sigma d^2}{n-k}}$$

$Sy.x_{1976}$ = 2.95

Correlation coefficient R

$$R = \sqrt{\frac{\Sigma \hat{y}^2}{\Sigma y^2}}$$

R_{1976} = 0.89

Appendix 3 (cont.).

Standard error of the prediction $S\hat{y}$

Where:

$$\Sigma x_1^2 = \Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n}$$

$$\Sigma x_2^2 = \Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n}$$

$$\Sigma x_1 x_2 = \Sigma X_1 X_2 - \frac{(\Sigma X_1)(\Sigma X_2)}{n}$$

$$D = (\Sigma x_1^2)(\Sigma x_2^2) - (\Sigma x_1 x_2)^2$$

$$c_{11} = \frac{\Sigma x_2^2}{D}$$

$$c_{12} = c_{21} = \frac{\Sigma x_1 x_2}{D}$$

$$c_{22} = \frac{\Sigma x_1^2}{D}$$

$$x_1 = X_1(1976) - \bar{X}_1$$

$$x_2 = X_2(1976) - \bar{X}_2$$

$\bar{X}_1$ and $\bar{X}_2$ are mean values

$$S\hat{y} = Sy.x\sqrt{1 + \frac{1}{n} + c_{11}x_1^2 + C_{22}x_2^2 + 2C_{12}x_1x_2}$$

$S\hat{y}(1976) = 3.73$

Appendix 3 (cont.).

Prediction interval at 80 percent confidence

Where: $t(5 d.f.) = 1.476$

$Y \pm t S\hat{y}$

$Y_{1976} \pm 5.5 = 4.1 \pm 5.5$

Appendix Table 4. Number of live pink salmon alevins, sample size and annual fry indices, southern Southeastern, 1965-74 broods.

District	1965 Brood Alevins No.	1965 Brood Digs No.	1965 Brood Index No/m²	1966 Brood Alevins No.	1966 Brood Digs No.	1966 Brood Index No/m²	1967 Brood Alevins No.	1967 Brood Digs No.	1967 Brood Index No/m²
1	2,587	201	64.4	5,453	241	113.1	10,905	913	59.7
2	4,723	126	187.4	3,454	150	115.1	4,081	264	77.3
3	4,324	309	70.0	31,546	610	258.6	14,445	779	92.7
5	482	80	30.1	1,488	61	122.0	4,786	223	107.3
6	1,033	230	22.5	8,367	210	199.2	5,717	372	76.8
7	2,804	240	58.4	10,525	290	181.5	8,970	326	137.6
Total/ Ave.	15,953	1,186	67.3	60,511	1,562	193.7	48,904	2,877	85.0

District	1968 Brood Alevins No.	1968 Brood Digs No.	1968 Brood Index No/m²	1969 Brood Alevins No.	1969 Brood Digs No.	1969 Brood Index No/m²	1970 Brood Alevins No.	1970 Brood Digs No.	1970 Brood Index No/m²
1	20,832	972	107.2	20,840	934	111.6	8,563	550	77.8
2	7,676	354	108.4	13,467	345	195.2	3,908	250	78.2
3	21,173	700	151.2	20,878	1,005	103.9	24,348	810	150.3
5	4,560	239	95.4	3,740	249	75.1	10,159	280	181.4
6	11,748	445	132.0	7,408	457	81.1	6,649	297	111.9
7	9,904	286	173.1	10,158	329	154.4	10,509	300	175.1
Total/ Ave.	75,893	2,996	126.7	76,491	3,319	115.2	64,136	2,487	128.9

Appendix Table 4. Number of live pink salmon alevins, sample size and annual fry indices, southern Southeastern, 1965-74 broods (cont.).

District	1971 Brood Alevins No.	1971 Brood Digs No.	1971 Brood Index No/m²	1972 Brood Alevins No.	1972 Brood Digs No.	1972 Brood Index No/m²
1	12,990	645	100.7	13,656	635	107.5
2	12,511	285	219.5	2,828	290	48.8
3	18,476	785	117.7	12,512	815	76.8
5	9,458	340	139.1	9,277	340	136.4
6	7,872	275	143.1	7,412	285	130.0
7	11,260	370	152.2	8,037	345	116.5
Total/ Ave.	72,567	2,700	134.4	53,722	2,710	99.1

District	1973 Brood Alevins No.	1973 Brood Digs No.	1973 Brood Index No/m²	1974 Brood Alevins No.	1974 Brood Digs No.	1974 Brood Index No/m²
1	3,707	645	28.7	3,879	625	31.0
2	2,071	295	35.1	4,076	270	75.5
3	10,399	825	63.0	7,401	825	44.9
5	6,603	342	96.5	5,025	342	73.5
6	3,370	290	58.1	2,366	290	40.8
7	5,795	370	78.3	3,924	370	53.0
Total/ Ave.	31,945	2,767	57.7	26,671	2,722	49.0

Appendix 5. Multiple regression analysis to determine point and range estimate of 1976 pink salmon returns to northern Southeastern Alaska. [a/]

Multiple Linear Regression

In the following analysis:

X_1 = northern Southeastern pre-emergent fry index expressed in fry per square meter (Appendix Tables 6-8).

X_2 = average April to August air temperature (°C) from the Angoon, Cape Spencer, Five Fingers, Glacier Bay, Juneau, Little Port Walter, Petersburg and Sitka weather stations

Y = northern Southeastern pink salmon return in millions of fish

Data used in the northern Southeastern multiple linear regression analysis:

Year of Return	X_1	X_2	Y
1967	114.1	9.4	4.1
1968	218.0	9.6	12.6
1969	94.2	10.1	5.8
1970	124.7	10.0	7.6
1971	137.0	9.0	5.5
1972	172.5	9.3	5.7
1973	168.6	8.9	3.9
1974	148.0	9.2	2.0
1975	127.5	9.4	1.6

The multiple linear regression equation to be solved is:

$$Y = a + b_1X_1 + b_2X_2$$

a/ The multiple linear regression was solved using a Hewlett-Packard (Model 65) program. Calculation of Sy.x, $S\hat{y}$, R and prediction interval were done by following methods of Snedecor and Cochran (1973).

The terms a, b_1, and b_2 were determined using a Hewlett-Packard multiple regression program as follows:

$$b_2 = \frac{A - B}{\{n\Sigma X_1^2-(\Sigma X_1)^2\}\{n\Sigma X_2^2-(\Sigma X_2)^2\} - \{n\Sigma X_1X_2 - (\Sigma X_1)(\Sigma X_2)\}^2}$$

where n = 8

$$A = \{n\Sigma X_1^2 - (\Sigma X_1)^2\}\{n\Sigma X_2Y-(\Sigma X_2)(\Sigma Y)\}$$

$$B = \{n\Sigma X_1X_2-(\Sigma X_1)(\Sigma X_2)\}\{n\Sigma X_1Y - (\Sigma X_1)(\Sigma Y)\}$$

$$b_1 = \frac{\{n\Sigma X_1Y-(\Sigma X_1)(\Sigma Y)\} - b_2\{n\Sigma X_1X_2-(\Sigma X_1)(\Sigma X_2)}{n\Sigma X_1^2 - (\Sigma X_1)^2}$$

$$a = \frac{1}{n}(\Sigma Y-b_2\ \Sigma X_2-b_1\Sigma X_1)$$

By solving the above, the prediction equation becomes:

$$Y = -50.560 + (0.068)X_1 + (4.866)X_2$$

The 1976 prediction is:

$$Y_{1976} = -50.560 + (0.068)(108.0) + (4.866)(9.2)$$

Y_{1976} = 1.8 million

Appendix 5 (cont.).

Standard deviation from regression $Sy.x$:

Where: $\Sigma x_1 y = \Sigma X_1 Y - \frac{(\Sigma X_1)(\Sigma Y)}{n}$

$\Sigma x_2 y = \Sigma X_2 Y - \frac{(\Sigma X_2)(\Sigma Y)}{n}$

Σy^2 = total sum of squares = $\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$

$\Sigma \hat{y}^2$ = regression sum of squares

$= b_1 \Sigma x_1 y + b_2 \Sigma x_2 y$

$n = 9$

$k = 3$

$\Sigma d^2 = \Sigma y^2 - \Sigma \hat{y}^2$

$$Sy.x = \sqrt{\frac{\Sigma d^2}{n-k}}$$

$Sy.x_{1976}$ = 2.21

Correlation coefficient R

$$R = \sqrt{\frac{\Sigma \hat{y}^2}{\Sigma y^2}}$$

R_{1976} = 0.81

Appendix 5 (cont.).

Standard error of the prediction $S\hat{y}$

Where:

$$\Sigma x_1^2 = \Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n}$$

$$\Sigma x_2^2 = \Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n}$$

$$\Sigma x_1 x_2 = \Sigma X_1 X_2 - \frac{(\Sigma X_1)(\Sigma X_2)}{n}$$

$$D = (\Sigma x_1^2)(\Sigma x_2^2) - (\Sigma x_1 x_2)^2$$

$$c_{11} = \frac{\Sigma x_2^2}{D}$$

$$c_{12} = c_{21} = \frac{\Sigma x_1 x_2}{D}$$

$$c_{22} = \frac{\Sigma x_1^2}{D}$$

$$x_1 = X_1 (1976) - \bar{X}_1$$

$$x_2 = X_2 (1976) - \bar{X}_2$$

$\bar{X}_1$ and $\bar{X}_2$ are mean values

$$S\hat{y} = Sy.x\sqrt{1 + \frac{1}{n} + c_{11} x_1^2 + C_{22} x_2^2 + 2C_{12} x_1 x_2}$$

$S\hat{y}(1976) = 2.50$

Appendix 5 (cont.).

Prediction interval at 80 percent confidence

Where: $t(6d.f.) = 1.44$

$Y \pm t\, S\hat{y}$

$Y\ 1976 \pm 3.6 = 1.8 \pm 3.6$

Appendix Table 6. Number of live pink salmon alevins, sample size and district fry indices, northern Southeastern, 1965-74 brood years.

District	1965 Brood Alevins No.	1965 Brood Digs No.	1965 Brood Index No/m^2	1966 Brood Alevins No.	1966 Brood Digs No.	1966 Brood Index No/m^2	1967 Brood Alevins No.	1967 Brood Digs No.	1967 Brood Index No/m^2
9	-	0	-	4,596	168	136.8	7,312	361	101.3
10	2,325	84	138.4	5,755	99	290.7	3,526	433	40.7
11	522	40	65.2	2,758	120	114.9	2,938	443	33.4
12	5,702	224	127.3	14,424	319	226.1	7,253	650	55.8
13	1,599	186	43.0	10,787	434	124.3	13,890	881	78.8
14	5,813	120	242.2	3,967	105	188.9	5,917	467	63.4
TOTALS	15,961	654		55,396	1,245		40,856	3,235	

District	1968 Brood Alevins No.	1968 Brood Digs No.	1968 Brood Index No/m^2	1969 Brood Alevins No.	1969 Brood Digs No.	1969 Brood Index No/m^2	1970 Brood Alevins No.	1970 Brood Digs No.	1970 Brood Index No/m^2
9	8,136	337	120.7	9,582	406	118.0	11,922	280	212.9
10	10,851	287	189.0	6,874	367	93.7	10,661	210	253.8
11	8,618	375	114.9	4,675	396	59.0	10,745	220	244.2
12	17,896	543	164.8	16,950	605	140.1	19,024	369	257.8
13	7,582	710	53.4	13,496	842	80.1	10,065	628	80.1
14	7,152	366	97.7	16,525	410	201.5	3,145	231	68.1
TOTALS	59,064	2,572		68,102	3,026		65,562	1,938	

Appendix Table 6. Number of live pink salmon alevins, sample size and district fry indices, northern Southeastern, 1965-74 brood years (cont.).

District	1971 Brood			1972 Brood		
	Alevins No.	Digs No.	Index No/m^2	Alevins No.	Digs No.	Index No/m^2
9	9,515	300	158.6	9,816	285	172.7
10	6,854	270	126.9	9,985	262	190.6
11	16,165	267	302.7	14,009	245	285.9
12	16,109	415	194.1	11,581	398	145.5
13	18,325	513	178.6	17,722	560	158.2
14	17,669	311	284.1	4,124	290	71.1
TOTALS	84,637	2,076		67,237	2,040	

District	1973 Brood			1974 Brood		
	Alevins No.	Digs No.	Index No/m^2	Alevins No.	Digs No.	Index No/m^2
9	7,445	285	130.6	5,622	329	85.4
10	6,387	250	127.7	8,738	260	168.0
11	2,564	180	71.2	11,133	270	206.2
12	6,050	384	78.8	6,382	378	84.4
13	14,695	513	143.2	6,938	494	70.2
14	11,119	310	179.3	1,113	280	19.9
TOTALS	48,260	1,922		39,926	2,011	

Appendix Table 7. Northern Southeastern adjusted pre-emergent densities weighted by effective spawning area [a].

	1965 Brood			1966 Brood		
	Adjusted fry value no/m^2	Effective spawning area in $m^2 \times 10^6$		Adjusted fry value no/m^2	Effective spawning area in $m^2 \times 10^6$	
District	A	B	AXB	A	B	AXB
9	--	--	--	176.4	0.817	144.1
10	127.0	0.607	77.1	388.9	0.607	236.1
11	65.1	0.391	25.5	100.2	0.391	39.2
12	133.9	1.068	143.0	262.9	1.068	280.8
13	43.2	0.960	41.5	115.3	0.960	110.7
14	172.9	0.987	170.7	245.1	0.987	241.9
Totals		4.013	457.8		4.830	1052.8
Weighted fry index		114.1			218.0	
	1967 Brood			1968 Brood		
9	264.1		215.8	83.1		67.9
10	44.4		27.0	226.6		137.5
11	54.1		21.2	102.4		40.0
12	58.2		62.2	178.2		190.3
13	80.4		77.2	33.8		32.4
14	52.1		51.4	136.1		134.3
Totals			454.8			602.4
Weighted fry index		94.2			124.7	
	1969 Brood			1970 Brood		
9	126.3		103.2	193.3		157.9
10	86.0		52.2	268.7		163.1
11	178.5		69.8	255.8		100.0
12	153.7		164.2	232.7		248.5
13	92.3		88.6	82.9		79.6
14	186.3		183.9	85.4		84.3
Totals			661.9			833.4
Weighted fry index		137.0			172.5	

(Continued)

Appendix Table 4. Northern Southeastern adjusted pre-emergent densities weighted by effective spawning area[a] (cont.).

District	1971 Brood: Adjusted fry value no/m^2 A	1971 Brood: Effective spawning area in $m^2 \times 10^6$ B	1971 Brood: AXB	1972 Brood: Adjusted fry value no/m^2 A	1972 Brood: Effective spawning area in $m^2 \times 10^6$ B	1972 Brood: AXB
9	131.9		107.8	188.7		154.2
10	112.2		68.1	156.5		95.0
11	206.3		80.7	194.1		75.9
12	166.2		177.5	154.8		165.3
13	198.6		190.7	125.1		120.1
14	191.8		189.3	105.7		104.3
Totals			814.1			714.8
Weighted fry index		168.6			148.0	

District	1973 Brood: A	1973 Brood: B	1973 Brood: AXB	1974 Brood: A	1974 Brood: B	1974 Brood: AXB
9	86.4		70.6	148.4		121.2
10	144.2		87.5	147.1		89.3
11	66.7		26.1	252.0		98.5
12	79.1		84.5	71.2		76.0
13	233.7		224.4	92.7		89.0
14	124.1		122.5	48.4		47.8
Totals			615.6			521.8
Weighted fry index		127.5			108.0	

a/ Weighted fry value = $\frac{AXB}{\Sigma B}$

Appendix Table 8. Northern Southeastern pre-emergent fry densities adjusted for the annual variation of escapement to sample streams[a].

District	1965 Brood Unweighted fry value no/m² F	1965 Brood Percent escapement to sample streams P	1965 Brood Adjusted fry value no/m²	1966 Brood Unweighted fry value no/m² F	1966 Brood Percent escapement to ssample streams P	1966 Brood Adjusted fry value no/m²
9	--	42.3	--	136.8	28.3	176.4
10	138.4	31.5	127.0	290.7	21.6	388.9
11	65.2	48.5	65.1	114.9	55.5	100.2
12	127.3	44.1	133.9	226.1	39.9	262.9
13	43.0	40.6	43.2	124.3	44.0	115.3
14	242.0	73.9	172.9	188.9	40.7	245.1
	1967 Brood			1968 Brood		
9	101.3	14.0	264.1	120.7	53.0	83.1
10	40.7	26.5	44.4	189.0	24.1	226.6
11	33.4	29.9	54.1	114.9	54.3	102.4
12	55.8	44.5	58.2	164.8	42.9	178.2
13	78.8	40.0	80.4	53.4	64.4	33.8
14	63.4	64.3	52.1	97.7	37.9	136.1
	1969 Brood			1970 Brood		
9	118.0	34.1	126.3	212.9	40.2	193.3
10	93.7	31.5	86.0	253.8	27.3	268.7
11	59.0	16.0	178.5	244.2	46.2	255.8
12	140.1	42.3	153.7	257.8	51.4	232.7
13	80.1	35.4	92.3	80.1	39.4	82.9
14	201.5	57.1	186.3	68.1	42.1	85.4
	1971 Brood			1972 Brood		
9	158.6	43.9	131.9	172.2	33.3	188.7
10	126.9	32.7	112.2	190.6	35.2	156.5
11	302.7	71.0	206.3	285.9	71.3	194.1
12	194.1	54.2	166.2	145.5	43.6	154.8
13	178.6	36.7	198.6	158.2	51.6	125.1
14	284.1	78.2	191.8	71.1	35.5	105.7

(Continued)

Appendix Table 8. Northern Southeastern pre-emergent fry densities adjusted for the annual variation of escapement to sample streams[a] (cont.).

	1973 Brood			1974 Brood		
District	Unweighted fry value no/m^2 F	Percent escapement to sample streams P	Adjusted fry value no/m^2	Unweighted fry value no/m^2 F	Percent escapement to sample streams P	Adjusted fry value no/m^2
9	130.6	55.2	86.4	85.4	21.0	148.4
10	127.7	25.6	144.2	168.0	33.0	147.1
11	71.2	51.7	66.7	206.2	39.6	252.0
12	78.8	46.2	79.1	84.4	55.0	71.2
13	143.2	25.0	233.7	70.2	30.9	92.7
14	179.3	76.3	124.1	19.9	21.7	48.4

District	Total percent escapement to sample streams	Average percent escapement to sample streams $\overline{P}$
9	365.3	36.5
10	289.0	28.9
11	484.0	48.4
12	464.1	46.4
13	408.0	40.8
14	527.7	52.8

a/ Adjusted fry value = $(\overline{P}/P) \times F$ where P = percent of district escapement index observed in sample streams, $\overline{P}$ = average P over for the 1965-1974 brood years and F = unweighted district fry index.