SOUTHEAST ALASKA PINK AND CHUM SALMON INVESTIGATIONS, 1990-91

Final Report for the Period July 1, 1990 to June 30, 1991

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Forecast data collection, preparation, and analysis continued to be the primary activity of the Pink and Chum Salmon Investigations Project during the period July 1, 1990 through June 30, 1991. The 1990 pink salmon (*Oncorhynchus gorbuscha*) return to southern Southeast Alaska was 33.8 million, which was 13.1 million above the upper end of the forecast range. The northern Southeast return of 9.4 million was 2.6 million above the forecast midpoint, but well within the forecast range of 3.5 to 13.2 million. The 1991 forecast for southern Southeast Alaska is 72.7 million. Unlike past years, return is now being defined as catch plus escapement index times 2.5, instead of catch plus escapement index. The change was made to provide a more accurate representation of the spawner: recruit relationship. The northern Southeast prediction is for a return of 24.2 million. The return prediction for all of Southeast Alaska is 98,100,000, which is the largest forecast made since this program was initiated in 1963, and will be the largest return in history if it materializes.

Early marine studies continued in Tenakee Inlet, and were expanded to include additional sample areas in Peril Strait . The relationship between northern Southeast pink survival (return per index spawner) and fry size continues to provide the only reliable means of predicting the pink salmon return to northern Southeast Alaska.

INTRODUCTION

The Southeast Alaska pink salmon forecast research project was initiated in 1963. This report describes project activities during the period July 1, 1990 through June 30, 1991. The general scope of this project involves collection, analysis, and reporting of data useful for making preseason forecasts and evaluating escapement goals.

The primary objective of the forecast research project is to improve sampling and analytical techniques and to collect background data to provide accurate annual preseason estimates of pink salmon returns to northern and southern Southeast Alaska. Annual pink salmon forecasts are of importance to the fishing industry, both fishermen and processors, for operational planning, and to fisheries managers for regulatory decision making.

Pink salmon returns to Southeast Alaska have been forecast with variable success since 1967. The forecast was initially based on the abundance of fry in the gravel, just prior to out-migration, as measured by pre-emergent pumping. In 1965 pre-emergent fry sampling was initiated on selected streams region-wide. In 1970 the program was expanded to include 12 new sample areas in seven new streams. In 1984, the entire southern area pre-emergent program was deleted as a result of budget reductions and, in 1986, the entire northern area pre-emergent sampling program was deleted, also as a result of budget reductions.

Forecasts made since the elimination of the pre-emergent programs have been based on escapement estimates, fry size during their early marine residence, and environmental parameters thought to be reflecting freshwater and/or early marine survival. In southern Southeast Alaska numerous environmental parameters have been found which exhibit a correlation with survival as measured by return-per-index-spawner. These include: the average daily temperature over the November through February time period following spawning (colder temperatures result in lower survival); coldest 14 day moving average of minimum daily temperature over this same time period (again colder temperatures reduce survival); and the last day of the coldest 14 day temperature noted above (early season cold spells result in lower survival than equally cold periods later in the winter). Predictions to southern Southeast Alaska during the 1987 through 1990 time period were made by utilizing the environmental parameters which provided the highest overall correlation coefficient when combined with the brood year escapement index in a linear regression to predict return. Although this method provided reliable hindcasts between 1967 and 1986, it has not provided reliable forecasts between 1987 and 1990. The actual return of pink Salmon to southern Southeast Alaska has fallen outside of the 80% confidence interval for the last four consecutive years. Consequently, the 1991 prediction was based on a modified 3-parameter Ricker model.

In northern Southeast Alaska the relationship between environmental parameters and the brood year escapement index has never provided a reliable prediction. Consequently, returns to northern Southeastern are forecast utilizing the relationship between the size of fry collected during the early marine program in Tenakee Inlet and their subsequent adult return.

This report describes the 1990 return, presents the 1991 pink salmon forecast, and summarizes the data collected during the Early Marine program in the spring of 1990. Specific project objectives were to:

1. Continue adding to a historical database to be used for developing techniques for reliable forecasts of the pink salmon returns to the benefit of the resource, fishermen, processors, and fisheries managers.

2. Measure abundance, and growth of pink and chum salmon fry in marine nursery areas in Tenakee Inlet and Peril Strait and relate this data to abundance of returning adults.

PINK SALMON FORECASTS

Methods

Returns to the southern and northern areas of Southeast Alaska are forecast separately. Adult tagging studies (Verhoeven 1952, Hoffman et al. 1983) have shown little overlap in migration routes for returns to these two areas and production appears to vary independently. While there are differences in the odd and even year returns, all years were included in the forecast models because neither southern nor northern Southeast Alaska has ever exhibited a long term "odd" or "even" year cycle (Figure 1). The southern area encompasses Districts 101 through 108, and the northern area encompasses Districts 109 through 115.

Escapement estimates for northern and southern Southeast Alaska are obtained by summing the individual district escapement indices in each area. The district escapement indices are calculated by summing the highest escapement count made on each stream surveyed in the district and adjusting for the number of streams not surveyed within that district. The number of streams in each district is defined as the number of streams for which an escapement count is available at least once during the 1960 through 1990 time period. The number of streams not surveyed in each district is multiplied by the average escapement count to all streams within that district with a peak escapement count of under 10,000 pinks. Escapement index estimates for each district are recalculated for all years each year to insure that the expansion factor used to correct for unsurveyed streams is consistent between years. The majority of escapement counts are made by management biologists during routine aerial surveys. Weir counts are not included in the calculation since the data is only available for a few years, and the counts represent total escapements rather than index counts. The escapement index is multiplied by 2.5 to convert the index to an estimate of the total escapement. The expansion factor of 2.5 was obtained from a study by Dangel and Jones 1988, in which they determined that aerial observers were counting an average of 40% of the fish present in a stream. This is considered a minimum estimate since it does not include an expansion for stream life; consequently, fish which have died and drifted out of the river, and those which have not yet entered the stream on the date of the peak count, are not accounted for.

The southern Southeast Alaska forecast for 1991 was based on 24 years of data (1967 through 1990). We used a modified Ricker model of the form

$$R = \alpha E e^{-\beta E^{\gamma} + \delta_1 WT + \delta_2 PE + \epsilon}$$

where: R is the return

E is the escapement index

WT is the winter temperature index

PE is the sum of the previous 2 brood year escapement indices

ε is the error term

The 80% prediction interval was calculated as follows:

$$\hat{R} \pm z_{1-\frac{\alpha}{2}} * STDI$$

where α=.2, $z_{.9}$=1.28, and STDI is the standard error of the prediction from the model fit.

The northern Southeast Alaska forecast was based on multiple linear regression analysis with the size of fry in Tenakee Inlet and the brood year escapement as independent variables. The regression was run using log of the return and log of the escapement index because of a curvilinear component in the model.

Results and Discussion

The pink salmon return to southern Southeast Alaska in 1990 was 33.8 million fish (Table 1) which was 20.7 million above the forecast midpoint of 13.1 million (Hofmeister 1990). The escapement index in southern Southeast in 1990 was 7.1 million, which was within our goal range of 6.0 to 9.0 million (Figure 2) . The escapement was not well distributed, however, since streams in the Ketchikan management area (districts 101 through 103) were above goal levels while those in the Petersburg management area (districts 105 through 107) were below goal levels (Table 2). The northern Southeast Alaska return of 9.4 million (Table 1) was 2.6 million above the forecast midpoint, but within the 80% confidence range of 3.5 to 13.2 million (Hofmeister 1990). The 1990 escapement index in northern Southeast was 3.8 million (Table 3). The escapements in Districts 109 through 112 were very close to goal levels, while those in Districts 113 and 114 were only approximately half of the desired goal levels (Figure 3).

Southern Southeast Alaska 1990 Forecast Evaluation

This was the fourth consecutive year in which the return to southern Southeast Alaska came in well outside the forecast range. The returns in 1987 and 1988 were both overestimated, while the return in 1989 and 1990 were both underestimated. Figure 4 is a graph of the results of predicting the return to southern Southeast using escapement indices and winter temperatures as independent variables in a multiple linear regression. The graph show the results of including return years 1967 through 1986 into the regression model and predicting the returns from 1987 through 1990. It shows that while the model worked reasonably well over the first 20 years, it provides exceptionally poor predictions over the last four years. The total error (sign ignored) over the first 20 years was 97 million, for an average error of 4.8 million per year. The total error over the last four years was 171 million for an average error of 42.8 million per year.

The above problem was noted at the time of the 1990 prediction (Hofmeister 1990). A third variable (sum of the previous two brood year escapements) was proposed as a partial explanation for the large error in 1989. Including the sum of the previous two brood year escapement indices into the regression model reduced the underestimate of the 1989 return from 28 million to 17 million (Figure 4). The decision against using the new variable was based on the fact that it provided very little change in the prediction over the first 20 years, reducing the overall error (sign ignored) from 97 to 93 million. With the benefit of hindsight, it is apparent that the variable should have been included. The 1990 prediction, based only on the escapement index and winter temperatures, was 13.1 million. If the new variable had been included in the regression, the prediction would have increased to 30.5 million, which is much closer to the actual 1990 return of 33.8 million.

Figure 4 shows that even with the new variable, large errors still occur in the 1987 and 1988 predictions. The error in 1987 was not completely unexpected because the winter temperatures were well below average and the escapement index was the second highest of the study period. This was recognized at the time of the 1987 prediction and the official prediction was for a return of only 27 million (Eggers and Dean 1987) rather than the 65 million shown on Figure 4. The narrative section of the 1987 prediction publication (Eggers and Dean 1987) stated that "It is very possible that the regression analysis utilized for the 1987 prediction over-estimated the influence of escapements and underestimated the influence of environmental conditions. Consequently, if there is an error in the 1987 prediction it is expected to be in the direction of over-estimating the return." While environmentally induced, density independent mortality could account for the error in 1987; it can not explain the large error in 1988. The brood year escapement index was the highest of the study period and winter temperatures were above average.

Figure 5 is a graph of the spawner:recruit relationship for southern Southeastern. It shows that the two years with the largest escapements experienced very low survival. Figure 5 is not, however, a typical Ricker curve, since it is almost a straight line increase through escapement levels of 22 million followed by a steep drop when escapements exceeded 30 million. It will take additional years of data, with escapement levels above 22 but below 30 million to determine if overescapement was the cause of the poor returns in 1987 and 1988.

Northern Southeast Alaska 1990 Forecast Evaluation

The 1990 return forecast to northern Southeast Alaska was 6.8 million (Geiger 1990). The actual return came in at 9.4 million (Table 1), well within the forecast range of 3.5 to 13.2 million. The forecast for 1990 was the first to make use of the Tenakee Inlet fry size information. Fry size information is now available from the Tenakee Inlet Early Marine Program from 1979 through 1990. Figure 6 shows the relationship between Tenakee Inlet fry size, brood year escapements and returns. Unlike southern Southeast Alaska the northern Southeastern prediction model does not have any obvious outlier years.

Southern Southeast Alaska 1991 Forecast

The 1991 pink salmon forecast is 72.7 million with an 80% confidence range of 38.0 to 107.4. The relationships between brood year escapement indices, winter temperatures, and the sum of the previous two brood year escapement indices, provides a reasonably accurate prediction from 1967 through 1990 (R^2 = .79), provided that return years 1987 and 1988 are omitted from the model. When they are included in the linear regression model, the R^2 drops to .41. A desire to include all years of data (1967 through 1990) into the model resulted in attempting to fit the data to a Ricker model of the form:
where: R is the return index

$$R = \alpha E e^{-\beta E + \delta_1 WT + \delta_2 PE + \epsilon}$$

E is the escapement index
WT is the winter temperature index
PE is the previous brood year escapement index
ε is the error term

Inspection of a plot of the predicted return as a function of brood year escapement index revealed an unsatisfactory fit: the predicted curve underestimates the high returns and overestimates the low returns for the years 1987-88 when the brood year escapements were very high. Figure 7 shows a plot of observed and predicted returns as a function of brood year escapement index. Observed and predicted values are fit separately with a model-free smoothing spline to help aid the visualization of the underlying pattern. Figure 8 shows observed and predicted returns as a function of year.

Because of the poor fit, the standard Ricker model was modified to include another parameter, γ, and takes the form:

$$R = \alpha E e^{-\beta E^{\gamma} + \delta_1 WT + \delta_2 PE + \epsilon}$$

This modification was suggested by Paulik (1973). The parameter γ allows for greater flexibility in the model fit; in particular, it allows for a steeper descent of the "right arm" of the curve than does a standard Ricker model. Paulik interpreted this parameter as "an index of density dependence at mid to high stock levels".

The model was fit using variance-weighted non-linear regression. Because the nonlinear algorithm did not converge for the full model, γ was estimated by trying a range of integer values and then choosing the value that gave the best fit. This value turned out to be γ=6. Because we are interested in predictions rather than parameter estimates per se, we view this procedure as acceptable. Variance-weighting was deemed necessary because the residual plot showed extreme heterogeneity of variances. If we assume that ε is normally distributed, then e^{ε} will be log-normally distributed. This equates to a variance-weighting scheme where an observation is weighted by the inverse of the square of the expected value of that observation. Expected values are estimated as predicted values. The process is iterated as predicted values and hence the weighting changes (Carroll and Ruppert 1988).

The fit of this "generalized" Ricker model was appreciably better than for the standard model. Figure 9 shows observed and predicted returns as a function of brood year escapement index, while Figure 10 shows observed and predicted returns as a function of year. The residual plots were also satisfactory with no model defects evident. The predicted return index for 1991 was 72.7, with a standard prediction error of 27.1. An approximate 80% prediction interval is then given by:

$$\hat{R} \pm z_{1-\frac{\alpha}{2}} * STDI$$

where α=.2, STDI=27.1, and $z_{.1}$=1.28. Hence, an approximate 80% prediction interval is 72.7 ± 34.7 = (38.0, 107.4).

An alternative method of fitting a Ricker model is to log-transform both sides of the equation. This yields:

$$\log(R) = \alpha' + \log(E) - \beta E^{\gamma} + \delta_1 WT + \delta_2 PE + \epsilon$$

This can then be fit using multiple linear regression (finding γ as before; in this case γ=5 gave the best fit). The point prediction for this model was 69.5, with an approximate 80% prediction interval of 41.9 to 115.4.

The predictions and intervals are very similar for both methods. The results from the non-linear regression were chosen as the official prediction because of the slightly smaller prediction intervals.

Northern Southeast Alaska 1991 Forecast

The return forecast for northern Southeast Alaska is 24.2 million, with a 80% confidence range of 16.9 to 34.6 million. This will be the second year that fry length data from the Tenakee Inlet early marine program is being utilized for predictions. The correlation between fry length or weight during the May 16th through May 31 time period and apparent survival as measured by return per index spawner was noted in earlier years but not included in the official prediction because of the relatively small data base. We now have eleven years of comparative data, and the correlation continues to remain strong (R^2 = .76, 8 degrees of freedom). Because early marine fry data is being utilized, the number of years incorporated into the regression formula had to be reduced to 11 (return years 1980 through 1990), as comparative fry data is only available back to 1979.

Figure 6 is a graph of return predictions for northern Southeast Alaska using linear regression for the model: log of return as a function of log of brood year escapement and fry weight. The figure shows the predictions obtained when only one independent variable (fry weight) is used, and when two independent variables (fry weight and escapement indices) are included in the regression. The graph shows that the vast majority of the variation in return is explained by variation in fry weight; but including the escapement index into the regression does improve the R^2 from .64 to .83. Although brood year escapement index does not explain much of the variation in the subsequent return to northern Southeast (R^2 = .04), including the brood year escapement index into the regression analysis with fry size does explain a significant (p=.04) amount of additional variability. The average error (sign ignored) over the 11 year prediction period with just fry size in the model was 4.9 million. Including escapements into the model reduces the average error to 3.9 million per year.

EARLY MARINE SURVIVAL STUDIES

Tenakee Inlet

The 1990 early marine survival studies in northern Southeast Alaska was expanded to include Peril Strait in order to determine if the variation in fry size between years, noted in Tenakee Inlet, is present in other major estuaries of northern Southeastern. Peril Strait is a large body of water opening onto Chatham Strait, as is Tenakee Inlet. Pink and chum salmon were observed in large concentrations in the same types of habitat as in Tenakee Inlet.

Methods

Fry abundance in Tenakee Inlet was monitored once each week, weather permitting, by conducting visual surveys along the shoreline at Cannery Point and at three other sites in Tenakee Inlet. Three new sites were chosen on the north shore of Peril Strait within 3 miles of its confluence with Chatham Strait (Figure 11). Fry were counted by a person wearing polarized sun glasses and standing in the bow of a 4 meter skiff. The skiff was piloted along the shoreline in water as shallow as possible, at speeds less than 3 knots. Numbers and locations of fry were recorded directly in field note books at the time of observation. Fry samples for weight and length analysis were collected with a beach seine. The seine measured 38.5 m long by 1.8 m deep and had a uniform rectangular mesh of 3.2 x 6.4 mm. Fry samples collected for length-weight analysis were preserved in a 10% buffered (sodium borate) formalin solution.

Results and Discussion

The average length and weight of fry collected in Tenakee Inlet and Peril Strait, for the entire month of May, and by half month time period is presented in Table 4. This represents the total number of fry collected using all gear types (beach seine, purse seine, lampara seine, and dip net). Fry from the earliest years were collected primarily with dip nets, while those from the later years were collected mainly with beach seines.

The number of pink salmon observed at Cannery Point in Tenakee Inlet, and in Peril Strait, by statistical week, by year, is shown in Table 5. Peak and mean surveys for statistical weeks 18-22 were the highest for the study period in 1985. Both the peak survey count and the average count during statistical weeks 18 through 22 were below average in 1990. No correlation has been found between the number of fry observed and the number of pinks returning to Tenakee Inlet. The inability of observers to accurately estimate the number of fry present in large schools may be responsible for this lack of correlation.

Temperature and salinity data have been collected in Tenakee Inlet for most years at the same location near Hill Point at the outer entrance of the inlet. Table 6 lists the temperature, salinity and secchi disk measurements taken at that location. Temperature and salinity measurements at a 1 meter interval, for 1990 are listed in Table 7.

Pink salmon fry in Tenakee Inlet increased from an average length and weight of 34.9 mm and 303.4 mg, respectively, on May 2 to 45.4 mm and 801.0 mg on May 28, for an average growth rate of 0.39 mm per day in length and 18.4 mg per day in weight. In comparison, the 1989 fry grew at a rate of 0.26 mm and 11.5 mg per day. Pink salmon fry in Peril Strait increased from an average length and weight of 39.2 mm and 487.0 mg, on May 9 to 44.4 mm and 763.2 mg on May 30, for an average growth rate of 0.24 mm per day in length, and 12.6 mg per day in weight. The above are not true growth rate computations since newly outmigrating (small fry) are continually moving into the sample areas.

No useful relationships have been found between the number of fry counted during the early marine program and the subsequent adult pink salmon return. There is however, a strong relationship between fry size and return. Figure 6 shows the results of predicting pink salmon returns to northern Southeast by utilizing a linear regression analysis with the weight of pink salmon fry collected during the May 15 through May 31 time period as the independent variable. The relationship results in an r^2 value of 0.65. Utilizing fry length or weight as the independent variable in the regression makes little difference since the two are correlated with an R^2 value of 0.95. Figure 12 shows the relationship between the average weight of pink salmon fry collected from Tenakee Inlet over the May 16 through May 31 time period and the survival of pink salmon in northern Southeast as measured by return per index spawner.

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Table 1. Southern and northern Southeast Alaska harvest and escapement in thousands, and return per spawner, 1960-89.

	Southern Southeastern				Northern Southeastern			
	Harvest	Escapement	Return	RTN/SP	Harvest	Escapement	Return	RTN/SP
1960	1,440	2,235	3,675	1260	1,398	2,658		
1961	3,771	2,420	6,191	7624	2,763	10,387		
1962	10,740	4,320	15,060	6.7	489	1,933	2422	1.7
1963	5,136	3,881	9,017	3.7	13,901	4,007	17908	6.5
1964	11,258	4,836	16,094	3.7	7,281	2,739	10020	5.2
1965	5,710	3,491	9,201	2.4	5,159	2,891	8050	2.0
1966	15,562	5,156	20,718	4.3	4,786	3,095	7881	2.9
1967	641	1,856	2,497	0.7	2,429	1,986	4415	1.5
1968	15,194	4,891	20,085	3.9	9,871	3,167	13038	4.2
1969	1,197	2,006	3,203	1.7	3,608	2,420	6028	3.0
1970	5,412	4,152	9,564	2.0	5,240	2,507	7747	2.4
1971	6,250	4,961	11,211	5.6	3,012	2,834	5846	2.4
1972	9,153	4,032	13,185	3.2	3,242	2,859	6101	2.4
1973	4,555	3,379	7,934	1.6	1,880	2,224	4104	1.4
1974	4,221	3,698	7,919	2.0	661	1,880	2541	0.9
1975	3,330	4,683	8,013	2.4	615	1,549	2164	1.0
1976	5,157	5,330	10,487	2.8	139	1,373	1512	0.8
1977	11,242	6,172	17,414	3.7	2,521	4,132	6653	4.3
1978	18,424	5,455	23,879	4.5	2,758	2,984	5742	4.2
1979	6,952	4,745	11,697	1.9	3,750	4,987	8737	2.1
1980	12,892	6,240	19,132	3.5	1,393	2,580	3973	1.3
1981	13,497	5,900	19,397	4.1	5,328	3,904	9232	1.9
1982	12,945	5,932	18,877	3.0	11,233	4,170	15403	6.0
1983	31,445	8,127	39,572	6.7	6,053	4,228	10281	2.6
1984	19,676	8,992	28,668	4.8	4,974	3,905	8879	2.1
1985	30,708	12,457	43,165	5.3	21,211	8,516	29727	7.0
1986	45,003	14,287	59,290	6.6	1,143	2,852	3995	1.0
1987	4,623	5,632	10,255	0.8	5,628	4,206	9834	1.2
1988	9,047	4,386	13,433	0.9	2,014	2,833	4847	1.7
1989	45,762	8,758	54,520	9.7	13,638	4,505	18143	4.3
1990	26,681	7,133	33,814	7.7	5,659	3,694	9353	3.3

Table 2. Southern Southeast Alaska pink salmon escapement by district and year in thousands of fish.

	District							SSE
	101	102	103	105	106	107	108	Total
1960	733.7	69.1	931.5	156.1	69.1	239.3	36.0	2,234.8
1961	627.3	76.4	678.0	265.6	483.6	178.8	110.9	2,420.5
1962	1,244.6	354.3	1,253.7	468.5	518.2	421.0	59.4	4,319.7
1963	1,065.1	270.5	1,122.2	424.1	369.8	468.9	160.5	3,881.1
1964	1,273.5	525.7	1,254.0	548.0	663.4	453.2	118.7	4,836.4
1965	687.1	279.8	1,089.4	614.1	494.9	290.4	34.8	3,490.6
1966	1,496.9	663.7	1,315.4	537.2	647.7	495.0	0.0	5,155.9
1967	563.2	94.0	385.0	412.3	166.8	154.1	81.0	1,856.5
1968	1,837.2	544.3	1,095.1	499.3	433.6	388.8	92.7	4,891.0
1969	726.1	328.9	334.0	218.0	161.9	168.9	67.9	2,005.6
1970	1,508.6	264.8	1,478.2	229.5	248.9	348.7	73.9	4,152.4
1971	1,354.0	657.2	1,677.6	385.9	369.3	476.7	40.0	4,960.7
1972	1,651.1	393.2	916.0	286.4	229.4	442.2	113.8	4,032.2
1973	911.8	512.3	862.6	281.7	350.0	393.6	66.8	3,378.9
1974	1,293.9	480.4	1,156.0	201.1	201.4	325.1	39.8	3,697.7
1975	1,439.7	664.5	1,449.4	291.4	352.6	467.2	18.3	4,683.1
1976	1,528.7	728.3	1,580.9	154.7	635.4	685.7	15.8	5,329.6
1977	2,252.8	690.4	1,616.8	263.4	353.8	949.8	45.3	6,172.2
1978	2,157.5	569.3	1,685.6	292.6	289.1	439.4	21.1	5,454.5
1979	1,062.8	675.0	1,607.0	459.2	381.9	467.3	91.4	4,744.6
1980	2,358.9	686.1	2,506.6	147.8	155.5	358.8	26.6	6,240.2
1981	1,862.2	629.6	2,460.6	394.6	240.6	281.1	31.6	5,900.3
1982	2,191.1	568.9	2,069.3	244.4	335.7	452.5	69.7	5,931.6
1983	2,731.3	1,005.7	3,230.4	535.8	220.5	374.6	28.8	8,127.2
1984	3,685.2	956.2	3,334.1	266.4	313.1	409.2	28.2	8,992.3
1985	3,854.3	1,161.1	4,791.5	699.9	889.4	976.8	83.7	12,456.6
1986	4,534.0	1,761.5	5,841.1	677.0	842.5	590.3	40.8	14,287.1
1987	2,255.3	515.3	1,998.7	174.3	254.6	337.6	96.4	5,632.2
1988	1,567.1	509.9	1,493.0	171.1	278.5	300.4	65.5	4,385.5
1989	2,857.3	883.8	2,954.2	406.4	647.8	882.6	125.9	8,758.0
1990	2,171.7	1,107.6	2,324.0	397.3	587.2	431.2	113.8	7,132.8
Goal	2,000.0	600.0	1,700.0	500.0	600.0	600.0		6,000.0

Table 3. Northern Southeast Alaska pink salmon escapement by district and year in thousands of fish.

Year	District 109	110	110	112	113	114	115	NSE Total
1960	116.5	258.4	339.3	192.0	357.8	134.4	19.9	1,418.3
1961	473.1	382.5	465.4	515.0	711.8	215.2	72.4	2,835.3
1962	477.8	425.5	290.3	194.5	349.2	196.2	23.5	1,956.9
1963	545.6	319.7	436.4	844.9	1,311.4	549.3	25.7	4,033.0
1964	712.6	497.6	400.4	470.2	532.3	125.8	10.8	2,749.6
1965	670.9	238.0	334.8	472.5	768.3	406.7	0.0	2,891.2
1966	750.9	549.5	513.3	642.9	529.3	109.5	2.7	3,098.2
1967	436.8	196.1	260.4	335.4	577.9	179.4	15.3	2,001.4
1968	708.6	966.1	480.2	546.9	310.5	155.1	47.3	3,214.6
1969	397.4	289.0	241.6	465.7	770.7	255.3	22.9	2,442.7
1970	472.6	522.0	448.8	518.7	379.8	164.8	54.2	2,560.9
1971	518.1	576.5	303.3	494.2	549.7	392.1	0.0	2,834.0
1972	457.7	690.4	613.8	558.4	345.0	193.9	0.0	2,859.3
1973	309.5	285.9	281.3	487.9	600.9	258.2	71.6	2,295.2
1974	291.7	272.5	429.8	321.2	441.7	123.1	0.0	1,880.1
1975	211.1	74.0	151.2	296.6	669.5	146.8	29.8	1,579.1
1976	223.7	163.5	108.0	231.5	520.8	125.8	0.0	1,373.4
1977	568.6	248.0	351.3	644.7	2,082.4	237.3	50.2	4,182.6
1978	447.4	413.8	200.5	819.7	908.6	194.1	0.1	2,984.1
1979	813.7	729.2	485.6	717.2	2,001.6	239.7	72.0	5,059.1
1980	460.1	397.9	327.0	550.5	617.0	228.0	88.2	2,668.7
1981	427.7	370.1	299.9	612.1	1,960.0	234.1	45.4	3,949.3
1982	757.8	590.5	747.7	738.3	1,139.2	195.9	49.6	4,219.1
1983	577.4	358.4	430.1	687.3	1,913.1	261.6	62.5	4,290.4
1984	732.3	409.4	465.8	479.7	1,605.2	213.1	70.4	3,975.8
1985	1,135.5	1,050.7	1,827.1	1,168.3	2,759.4	575.4	282.8	8,799.1
1986	739.0	270.4	245.4	659.6	767.5	170.4	3.8	2,856.0
1987	604.3	1,085.9	889.3	517.4	948.4	160.5	82.9	4,288.6
1988	624.6	469.1	326.0	641.8	576.4	195.3	59.1	2,892.3
1989	809.3	991.8	632.3	787.5	1,091.9	192.7	71.8	4,577.3
1990	596.4	1,058.6	369.4	607.5	870.9	191.6	108.0	3,802.4
Goal	600.0	1,000.0	500.0	600.0	1,600.0	500.0		4,800.0

Table 4. Average length and weight of pink salmon fry captured in Tenakee Inlet and Peril Straits.

	May 1 through May 15			May 16 through May 31			May 1 through May 31		
Year	Length MM	Weight MG	Sample Size	Length MM	Weight MG	Sample Size	Length MM	Weight MG	Sample Size
Tenakee Inlet									
1979	36.2	380	845	38.1	448	861	37.2	415	1,706
1980	35.0	327	1,028	40.0	578	1,042	37.5	453	2,070
1981	37.5	438	1,006	46.0	873	763	41.2	625	1,769
1982	36.0	362	893	38.2	448	1,059	37.2	409	1,952
1983	38.0	415	3,542	44.0	653	2,449	40.5	512	5,991
1984	38.5	409	656	47.7	911	2,740	45.9	814	3,396
1985	35.7	295	3,628	38.8	431	1,920	36.7	342	5,548
1986	34.3	294	3,710	38.3	450	1,211	35.3	333	4,921
1987	34.9	323	2,815	41.0	582	3,749	38.4	471	6,564
1988	36.5	392	3,224	44.7	799	2,782	40.3	581	6,006
1989	35.4	342	2,282	41.1	641	1,715	37.8	470	3,997
1990	36.3	364	2,437	44.4	741	967	38.6	471	3,404
Peril Strait									
1990	39.2	487	286	41.8	612	1,422	41.3	591	1,708

Table 5. Tenakee Inlet early marine fry surveys at Cannery Point in thousands.

	Statistical Week											Peak	Weeks
Year	15	16	17	18	19	20	21	22	23	24	Mean	Survey	18-22
1980	3		5	127	59	86	23			127		73.8	
1981	2		7	42	81	8	8	13	8	2	81	30.4	
1982			10	20	500	400	200	25	31	15	500	229.0	
1983	9	2	16	48	130	141	155	120	155	118.8			
1984		185	185	58	221	74	221	117.7					
1985			123	756	1,036	516	1	1,036	486.4				
1986			39	188	221	95	319	145	319	172.4			
1987			51	45	166	43	37	166	47	166	91.4		
1988			171	103	41	75	278	278	97.5				
1989			232	206	64	745	83	68	745	233.2			
1990			211	298	286	78	140	298	202.6				
mean	4.7	62.3	63.3	95.7	224.6	306.9	132.5	100.1	101.8	8.5	357	173.7	

Table 5a. Peril Strait early marine fry surveys in thousands.

	Statistical Week											Peak	Weeks
Year	15	16	17	18	19	20	21	22	23	24	Mean	Survey	18-22
1990	Area #1				263	11	143	6			263		105.8
	Area #2				43	16	13	8			43		20.0
	Area #3				170	167	22	21			170		95.0

Table 6. Temperature salinity and secchi disk reading from Hill Point in Tenakee Inlet.

Date	Secchi in Meters	Temperature in C	Salinity in 0/00
05/03/83	4.5	6.9	30.8
05/06/83	6.5	7.6	30.7
05/09/83	7.5	8.6	29.1
05/14/83	8.5	10.1	28.6
05/17/83	5.5	8.3	30.0
05/19/83	9.0	7.4	31.2
05/23/83	13.0	8.1	28.1
05/26/83	14.0	7.6	29.4
05/31/83	4.5	9.1	27.9
mean	8.1	8.2	29.6
05/08/84	8.0	9.4	28.2
05/17/84	7.0	10.1	28.3
05/21/84	10.1	29.2	
05/31/84	20.0	8.5	29.8
mean	11.7	9.5	28.9
05/01/85	4.0	5.5	31.9
05/06/85	7.0	5.9	29.6
05/13/85	9.0	4.5	32.3
05/20/85	8.6	6.2	28.9
05/29/85	6.0	9.5	23.1
mean	6.9	6.3	29.2
05/07/86	5.5	10.8	22.9
05/14/86	7.2	7.3	28.4
05/21/86	4.5	7.3	30.1
05/27/86	5.5	9.1	28.7
mean	5.7	8.6	27.5
05/05/87	6.6	6.9	28.1
05/12/87	4.0	7.8	29.3
05/19/87	4.9	9.5	23.6
05/26/87	4.9	8.9	25.8
mean	5.1	8.3	26.7
05/03/88	4.0	6.9	29.2
05/11/88	8.0	9.8	28.1
05/17/88	7.5	10.1	23.3
05/24/88	7.5	9.1	24.9
mean	6.8	9.0	26.4
05/02/90	4.5	8.0	24.3
05/07/90	4.8	7.7	27.2
05/14/90	5.4	8.5	27.4
05/22/90	4.4	7.6	29.0
05/28/90	5.1	9.1	27.6
mean	4.8	8.0	27.0

Table 7. Temperatures and salinity reading at 1 meter intervals from Tenakee Inlet and Peril Straits.

Date	Location	Secchi in Feet	Temperature Salinity	Surface	1	2	3	4	5	6	7	8	9	10	Tenakee Inlet	Peril Strait
									Depth in Meters							
05/02/90	Tenakee	15.0	temperature	9.0	8.5	8.0	7.0	6.5	6.0	6.0	6.0	5.8	5.5	5.5	05/02/90	
			salinity	34.0	23.5	24.3	23.0	26.5	27.5	27.0	26.5	26.3	26.5	26.5		
05/07/90	Tenakee	16.0	temperature	8.0	7.8	7.7	7.5	7.5	7.0	6.3	6.0	5.8	5.6	5.6	05/07/90	
			salinity	26.1	27.0	27.2	27.2	27.5	28.9	29.0	29.7	30.0	30.1	30.1		
05/10/90	Peril Strait	10.0	temperature	7.8	7.4	7.2	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	05/10/90	
			salinity	28.5	28.9	29.2	29.4	29.4	29.3	29.3	29.3	29.5	29.5	29.5		
05/14/90	Tenakee	18.0	temperature	9.5	9.0	8.5	8.0	8.0	7.2	7.0	6.8	6.6	6.1	6.0	05/14/90	
			salinity	28.5	25.3	27.4	27.4	28.5	28.9	29.5	29.6	29.8	29.9	30.0		
05/17/90	Peril Strait	14.5	temperature	8.5	8.0	8.0	7.8	7.6	7.5	7.2	7.0	7.0	6.9	6.8		05/17/90
			salinity	23.5	23.0	29.0	29.1	29.2	29.4	29.7	29.8	29.8	29.9	30.0		
05/22/90	Tenakee	14.5	temperature	10.0	10.0	7.6	7.3	7.2	6.5	6.1	6.0	5.9	5.8	5.8	05/22/90	
			salinity	26.2	26.2	29.0	29.0	29.2	29.6	30.2	30.1	30.1	30.1	30.1		
05/24/90	Peril Strait	18.0	temperature	9.0	9.0	8.1	8.1	8.1	8.1	8.1	7.5	7.3	7.2	7.2		05/24/90
			salinity	28.6	28.6	28.3	29.0	29.0	29.0	29.0	29.5	29.8	29.9	29.9		
05/28/90	Tenakee	17.0	temperature	11.2	10.6	9.1	8.4	7.9	7.9	7.8	7.6	7.6	7.2	7.0	05/28/90	
			salinity	25.3	25.3	27.6	28.7	29.2	29.6	29.7	29.9	29.9	30.0	30.2		
05/30/90	Peril Strait	15.0	temperature	10.8	10.0	9.8	9.0	8.2	8.1	8.1	8.0	8.0	8.0	8.0		05/30/90
			salinity	28.9	31.5	29.8	29.8	30.2	30.3	30.3	30.3	30.4	30.3	30.3		

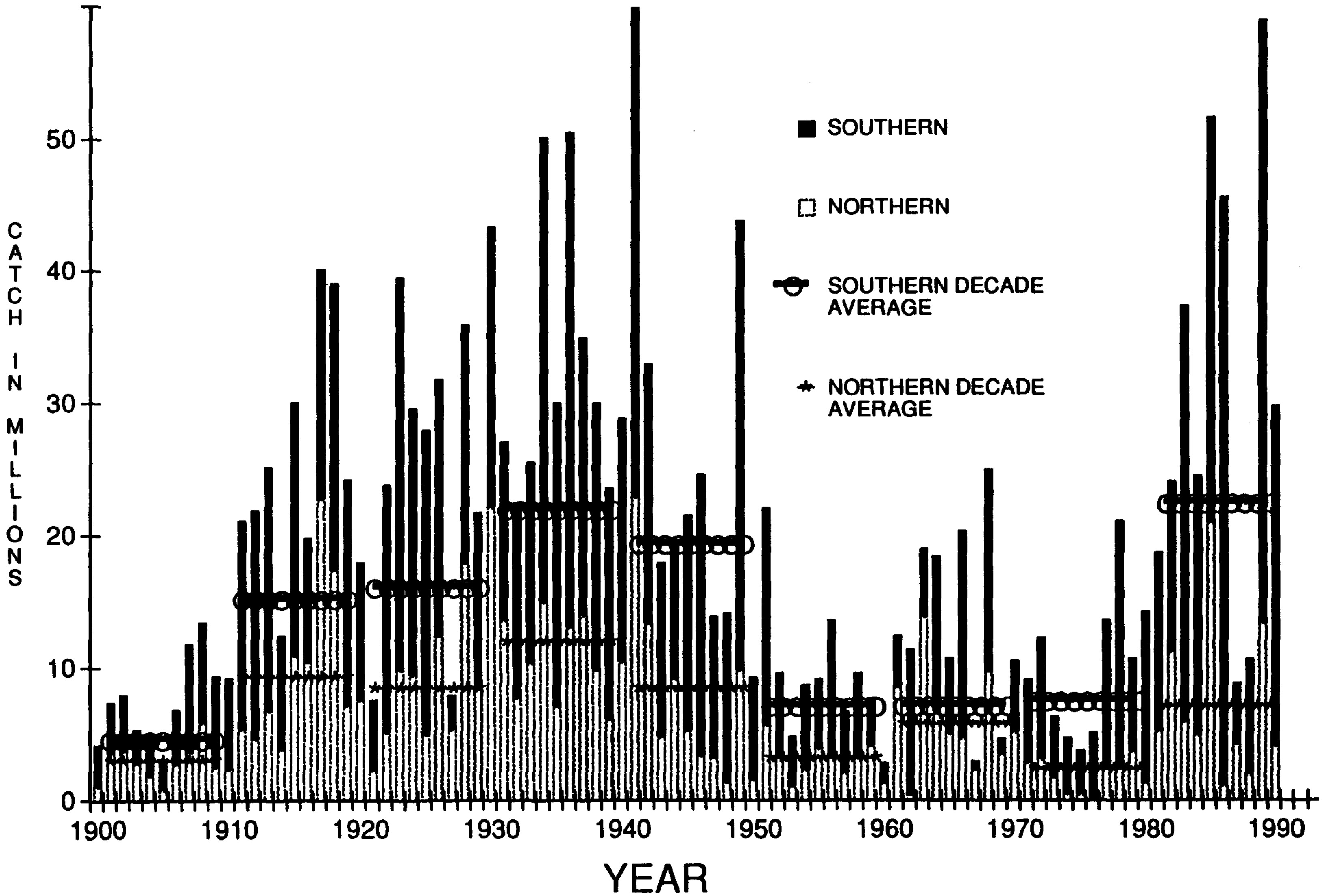

Figure 1. Northern and southern Southeast Alaska pink salmon catches with decade averages (1900-1990).

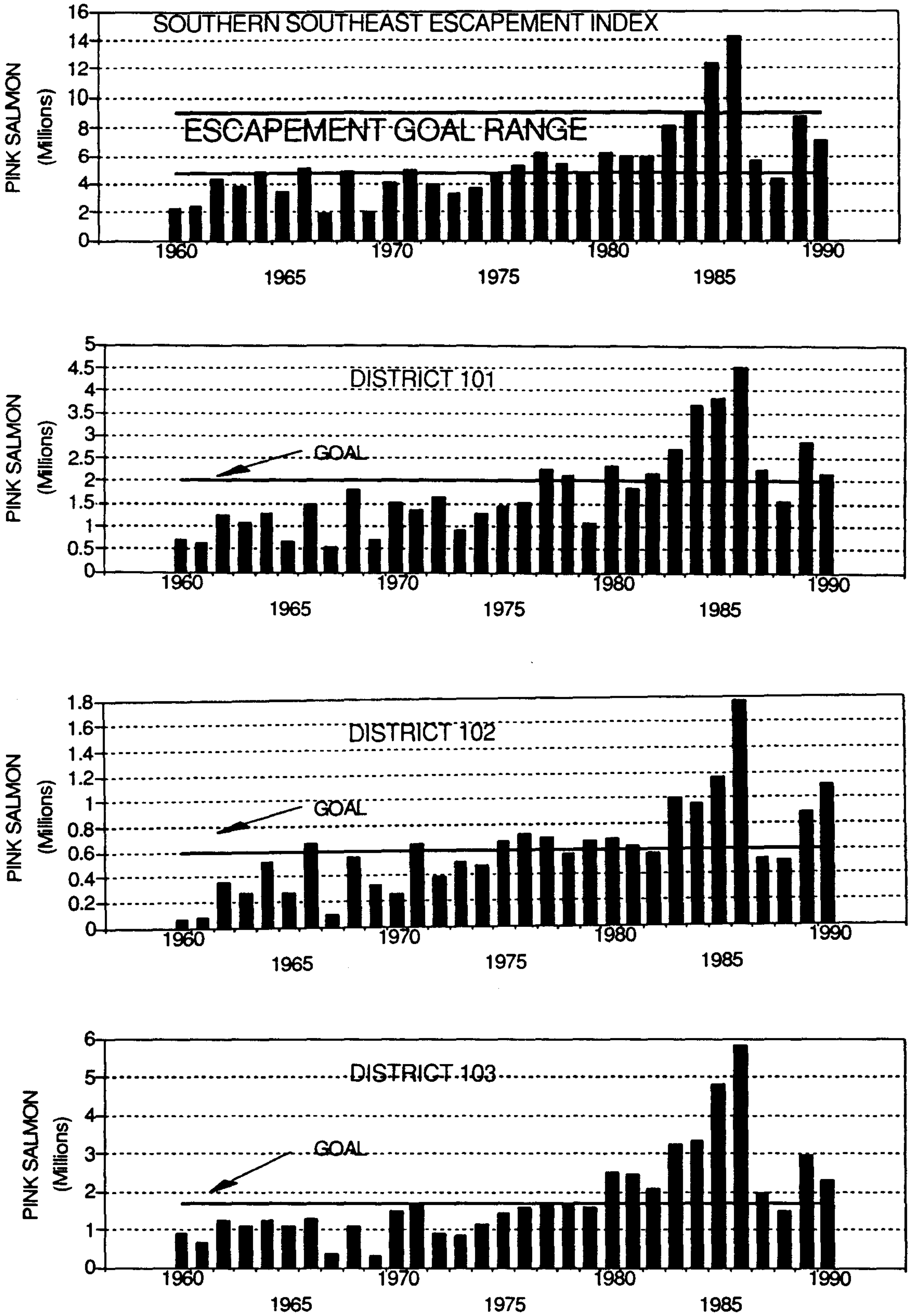

Figure 2. Southern Southeast Alaska pink salmon escapement index and escapement goals by district and year.

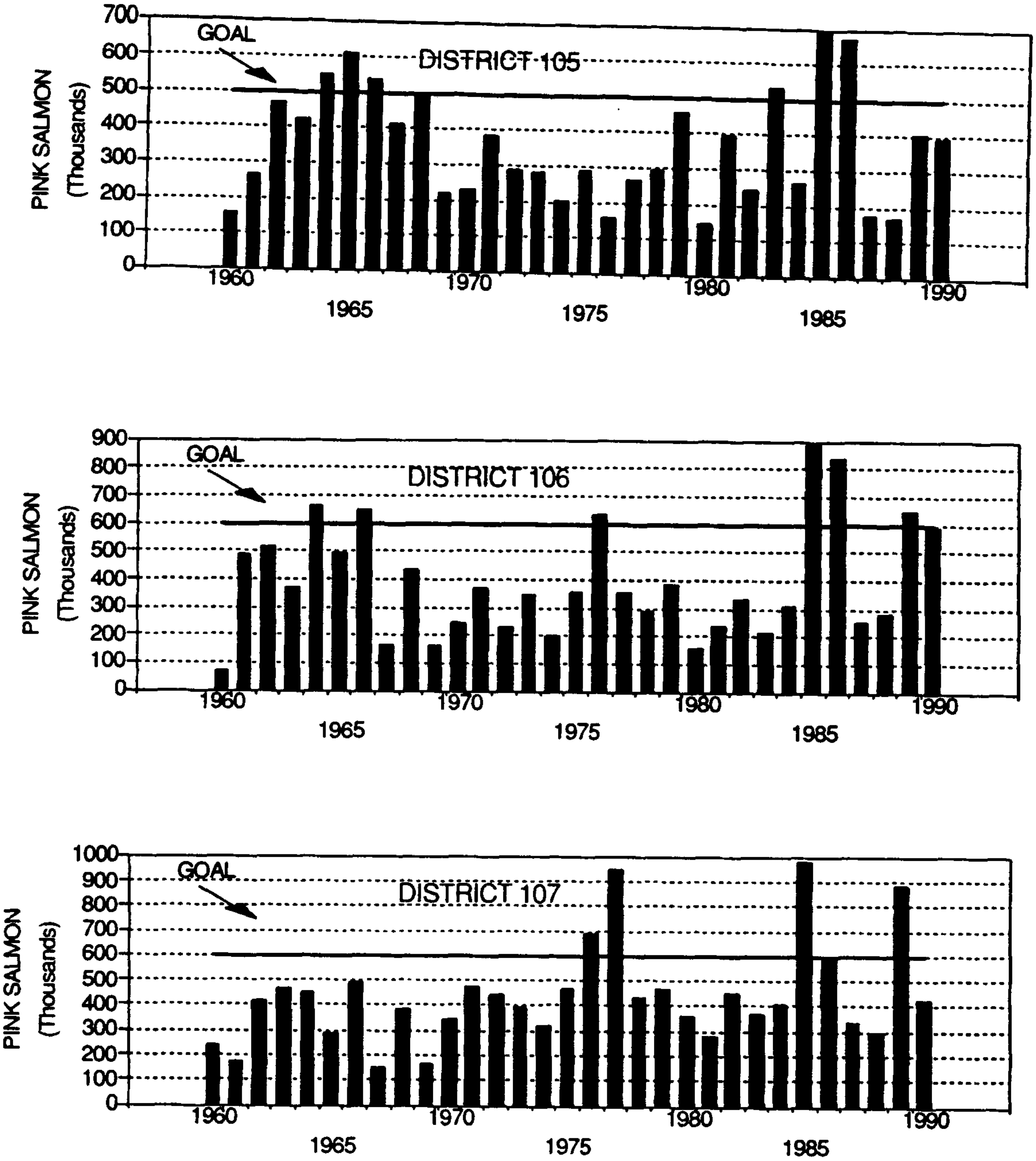

Figure 2. Page 2 of 2.

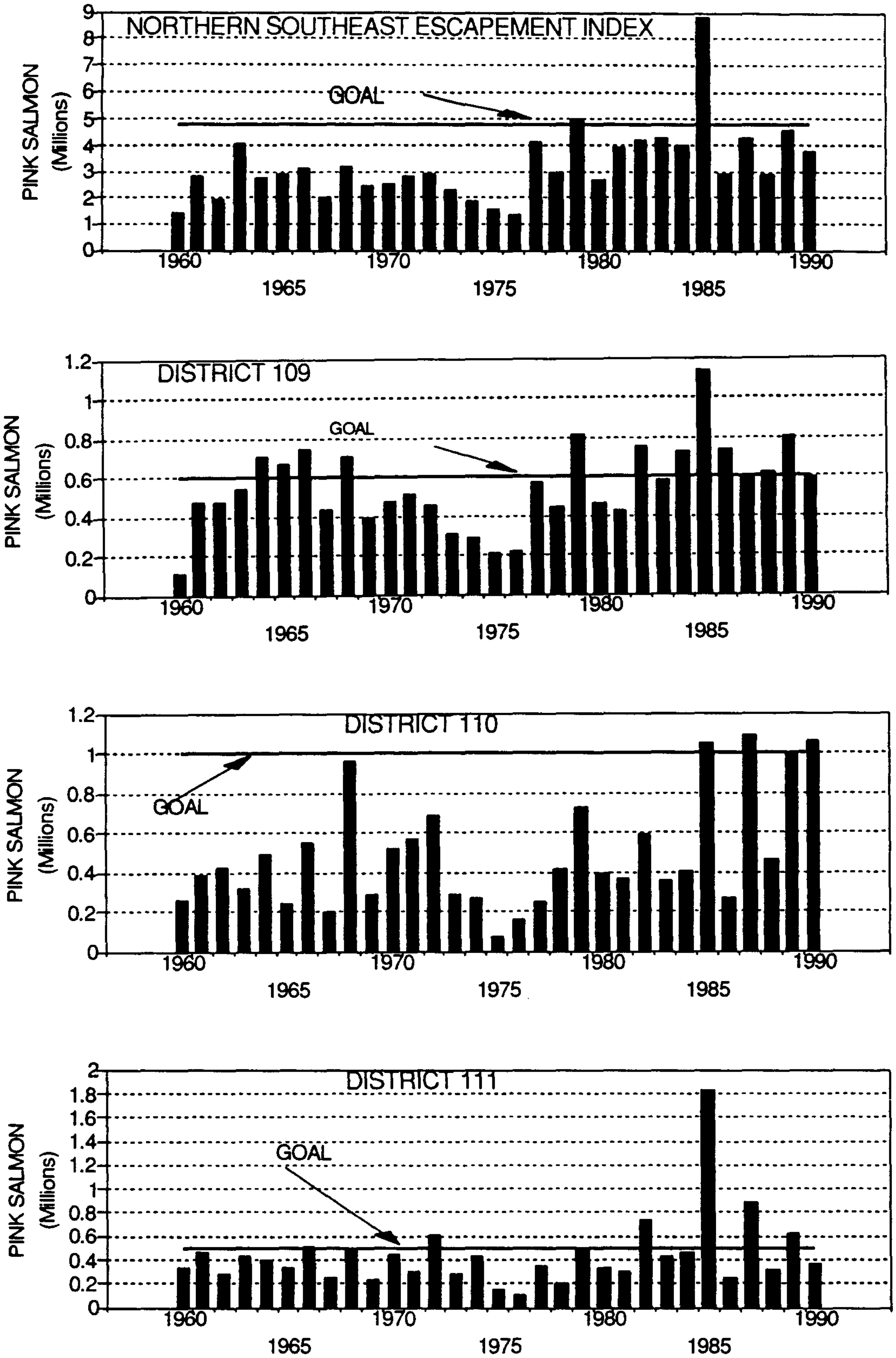

Figure 3. Northern Southeast Alaska pink salmon escapement index and escapement goals by district and year.

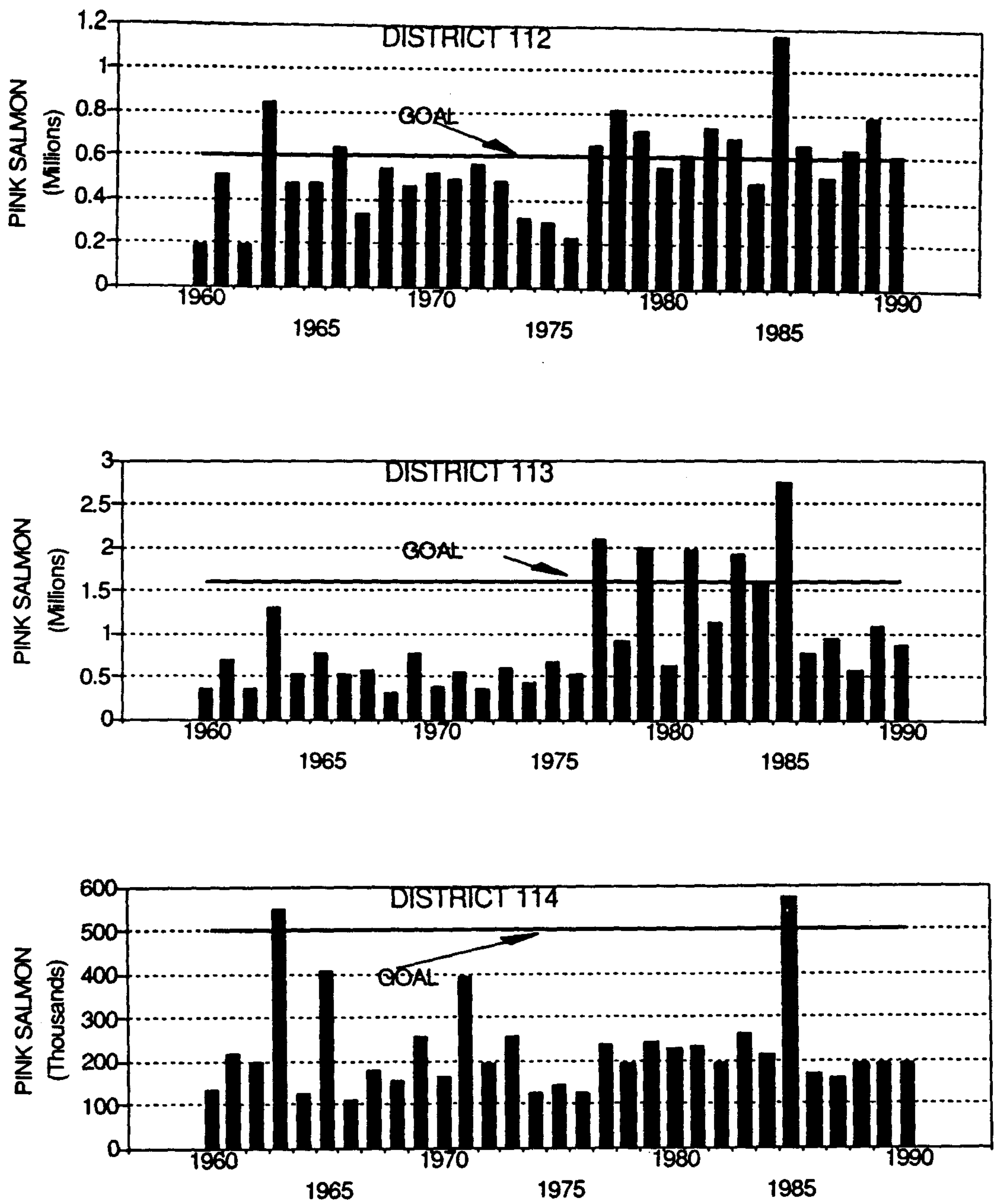

Figure 3. Page 2 of 2.

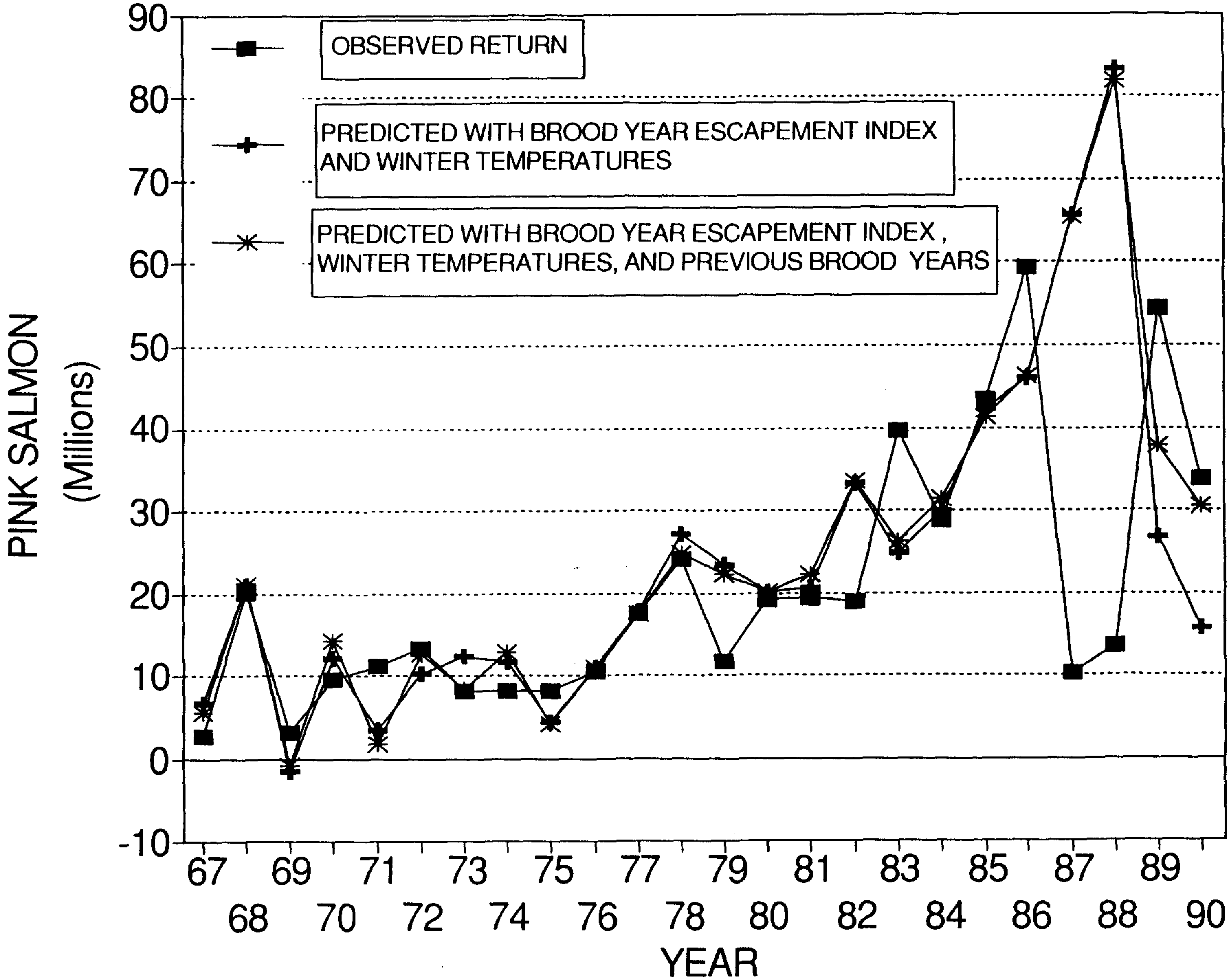

Figure 4. Observed and predicted return to southern Southeast Alaska with return year 1967 through 1986 in regression model.

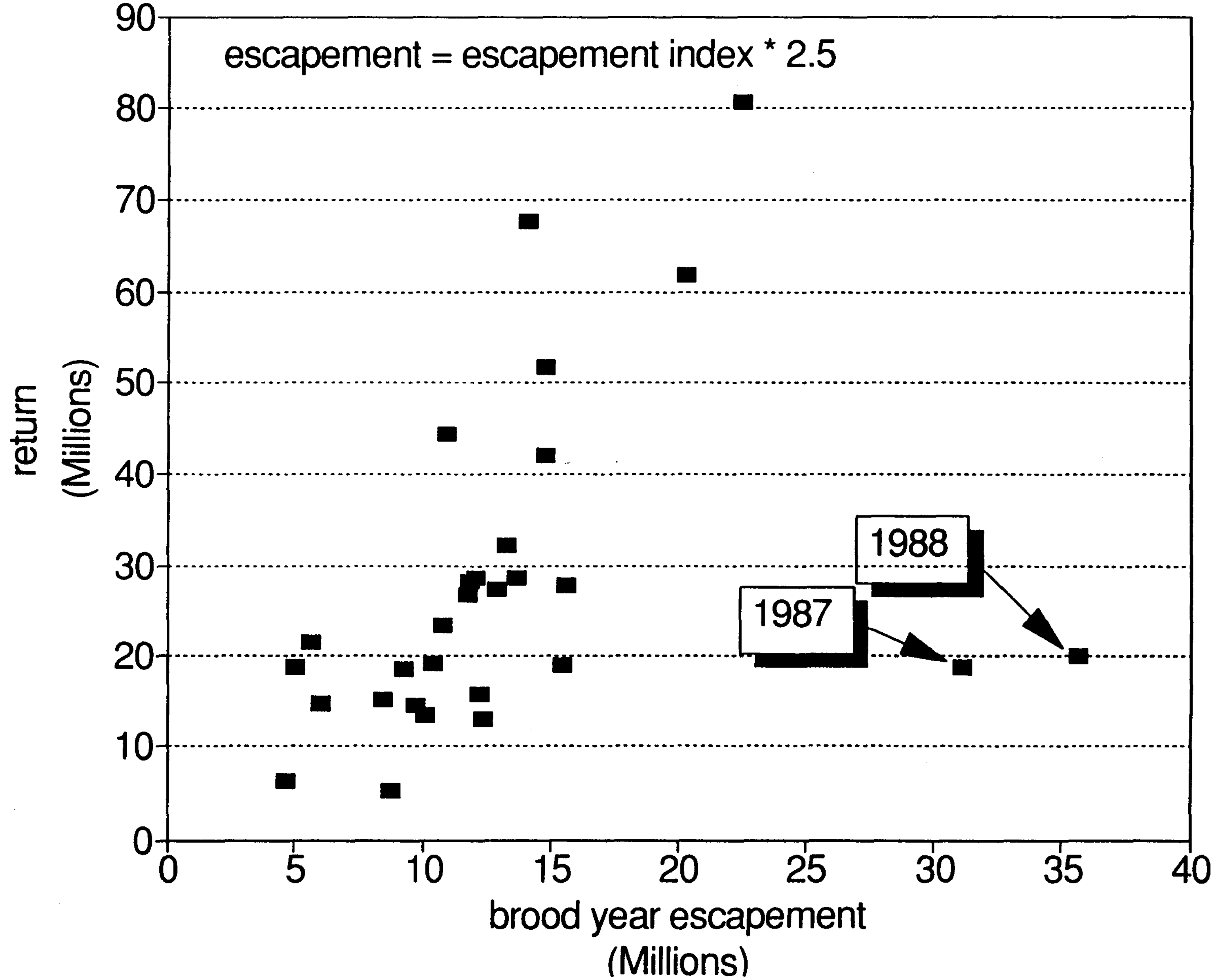

Figure 5. Spawner recruit relationship for pink salmon returning to southern Southeast Alaska.

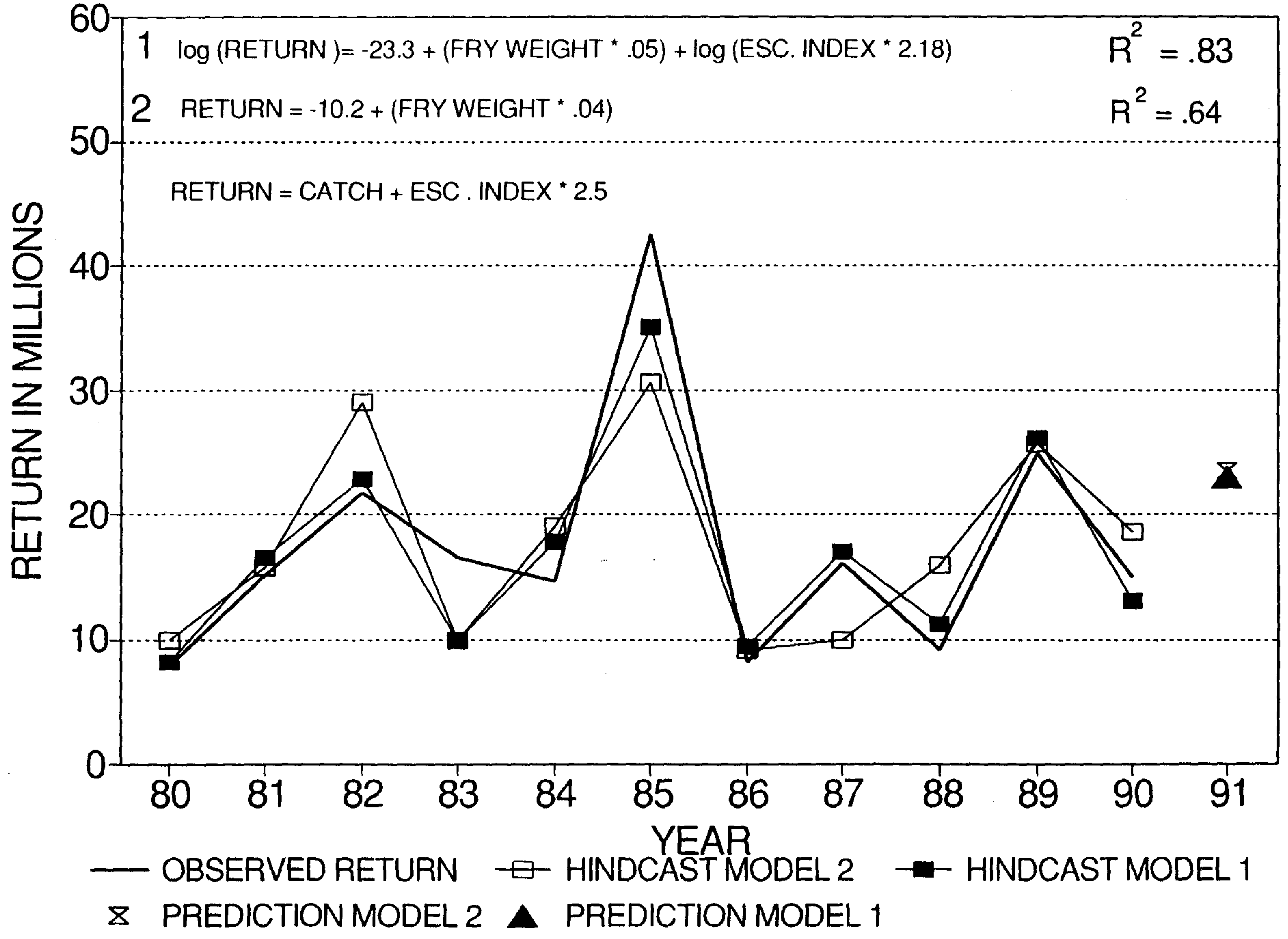

Figure 6. Observed and forecast returns to northern Southeast Alaska using fry weight and escapement.

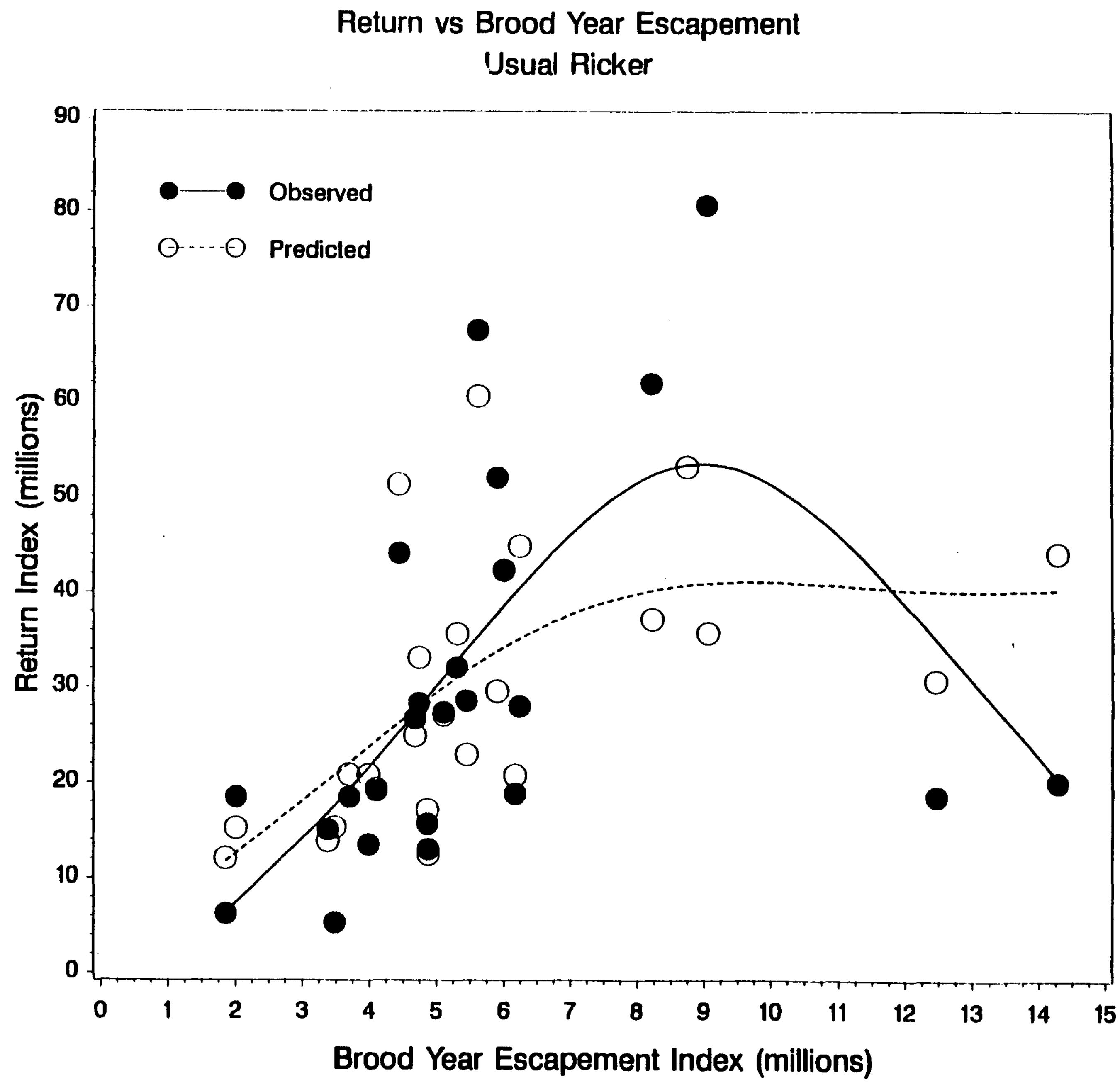

Figure 7. Ricker model predictions to southern Southeast Alaska as a function of Brood year escapement index.

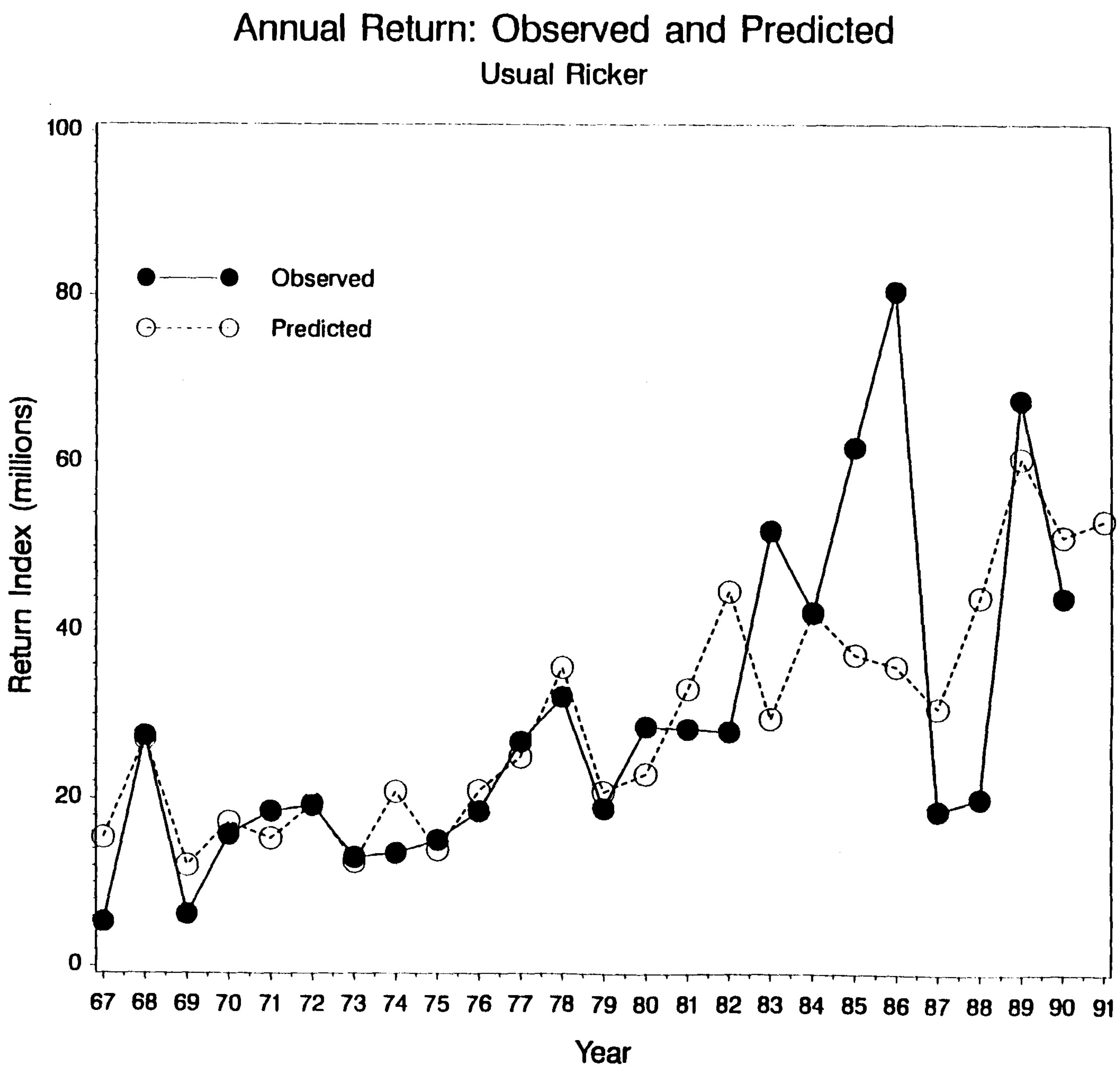

Figure 8. Ricker model predictions to southern Southeast Alaska as a function of year.

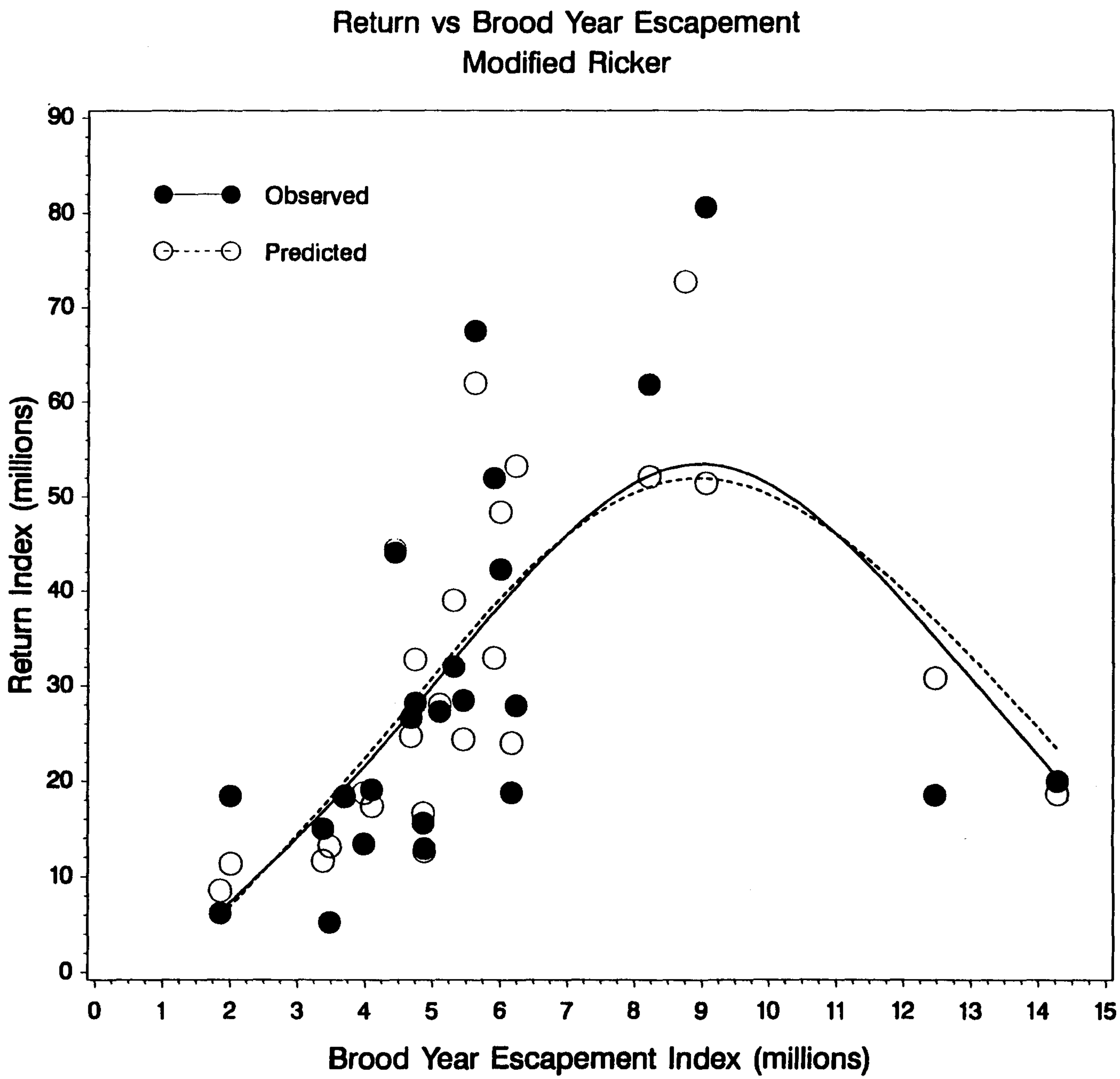

Figure 9. Modified Ricker model predictions to southern Southeast Alaska as a function of brood year escapement index.

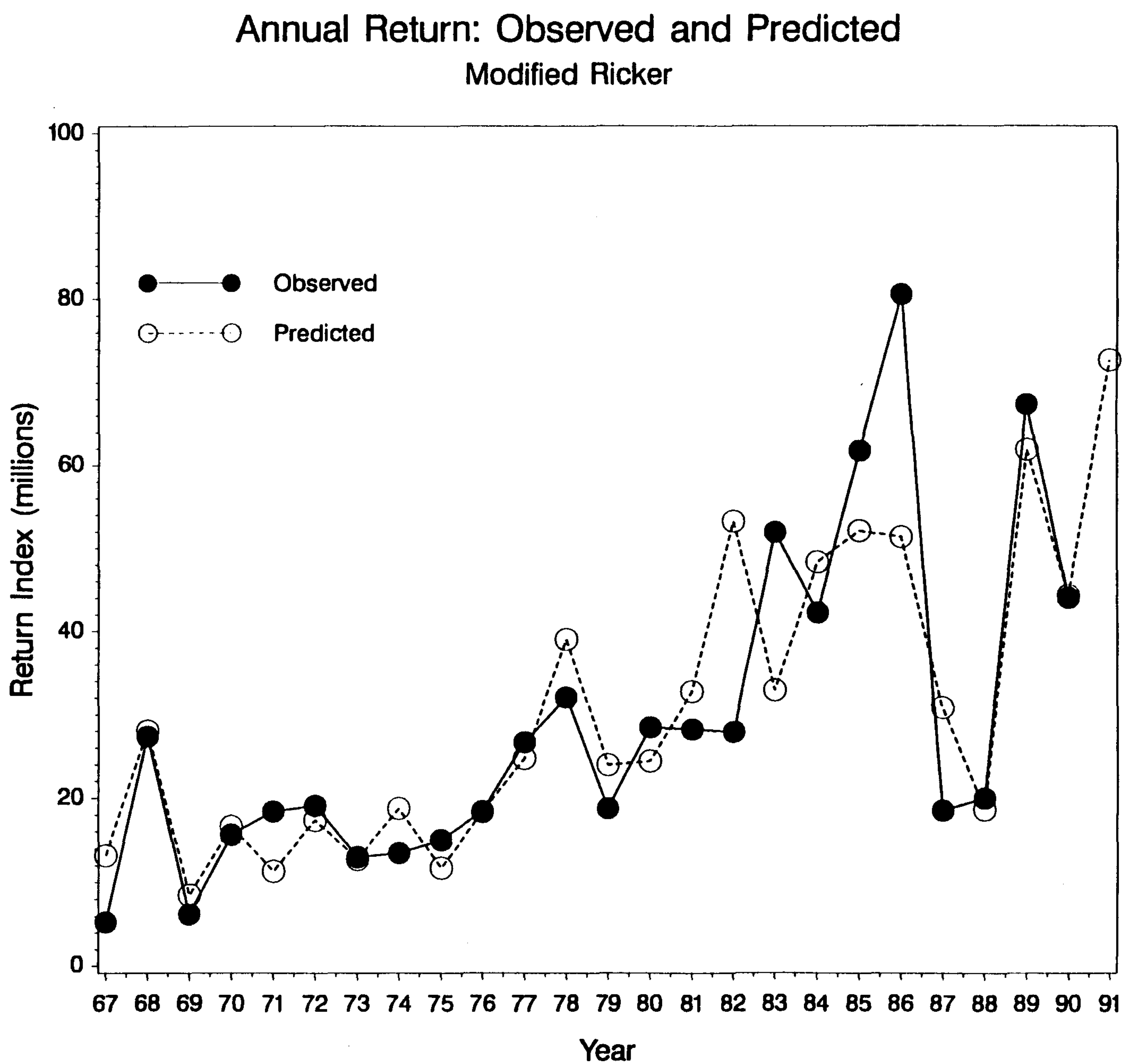

Figure 10. Modified Rick model predictions to southern Southeast Alaska as a function of year.

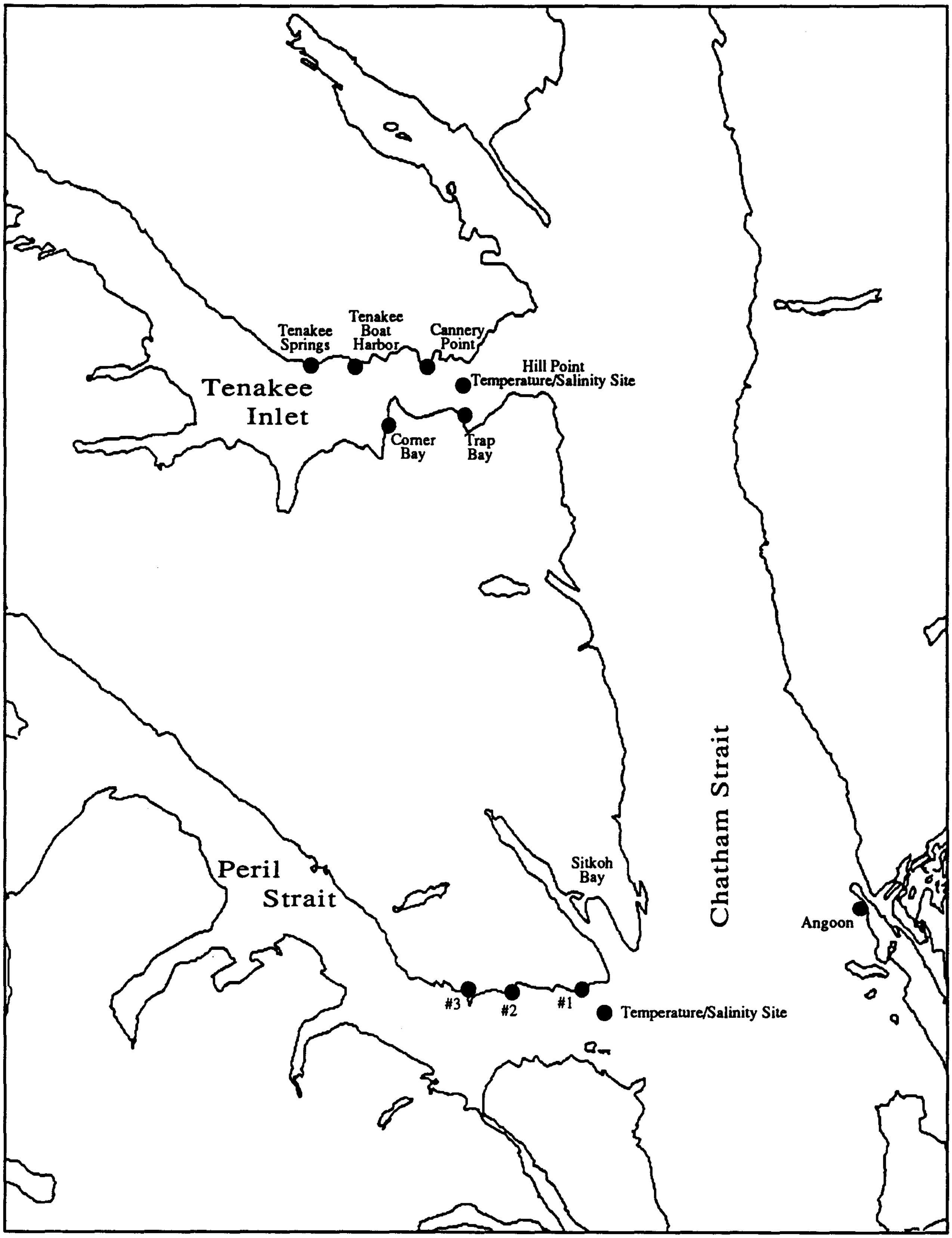

Figure 11. Major fry collection sites and oceanographic stations in Tenakee Inlet and Peril Strait in 1990.

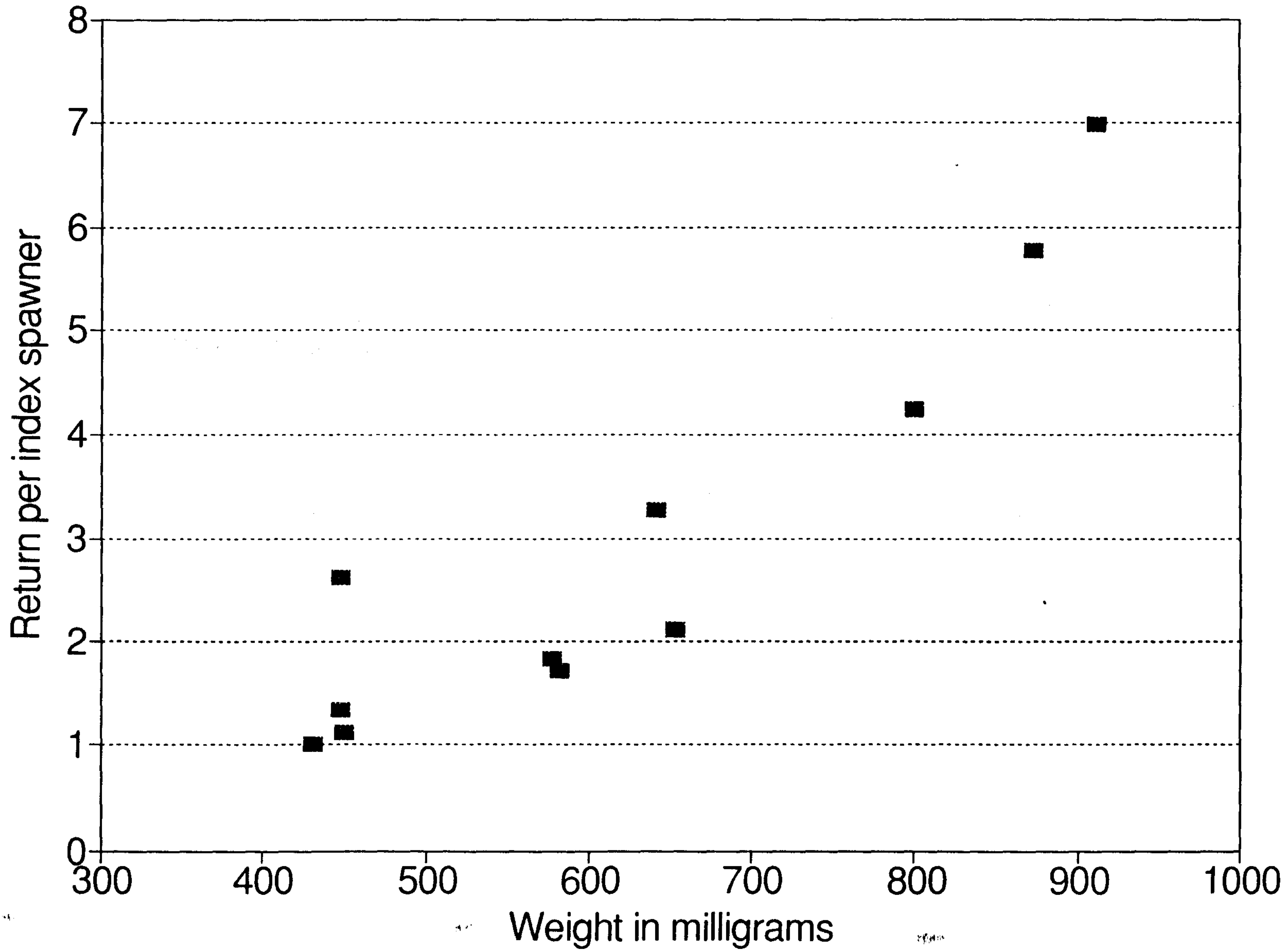

Figure 12. Size of pink salmon fry captured in Tenakee Inlet and subsequent return per index spawner.