INFORMATIONAL LEAFLET NO. 255

A SYNOPSIS AND CRITIQUE OF FORECASTS OF
SOCKEYE SALMON (*Oncorhynchus nerka*) RETURNING TO
BRISTOL BAY IN 1986

By
Stephen M. Fried
and
Henry J. Yuen

STATE OF ALASKA
Bill Sheffield, Governor
DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner
P.O. Box 3-2000, Juneau 99802

April 1986

A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON *(Oncorhynchus nerka)* RETURNING TO BRISTOL BAY IN 1986

Individual forecasts for Kvichak, Naknek, Egegik, Ugashik
Wood, Igushik, Nuyakuk, and Togiak systems

By

Stephen M. Fried

and

Henry J. Yuen

Alaska Department of Fish and Game
Division of Commercial Fisheries
Anchorage, Alaska

April 1986

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

ABSTRACT

This report is a review of techniques used by the Alaska Department of Fish and Game (ADF&G) to forecast returns of sockeye salmon *(Oncorhynchus nerka)* to Bristol Bay, Alaska, in 1986. The final forecast, based on the weighted mean of two independent forecasting methods (Standard ADF&G and analyses of Japanese Research Catches), was for a total return of 22.5 million (80% confidence range, 15.1 to 29.9 million) and a commercial harvest of 13.3 million (80% confidence range, 7.5 to 20.2 million) sockeye salmon. Standard ADF&G predictions, made for individual river systems by major age classes (4_2, 5_2, 5_3, and 6_3), were based upon spawner-recruit relationships (estimated returns from the 1980, 1981, and 1982 spawning escapements), return of sibling age classes in 1985, and estimates of smolt-to-adult returns (estimate returns from smolt migrating to sea in 1983 and 1984). Japanese Research Catches predictions, made for all of Bristol Bay by two- (4_2 and 5_3) and three-ocean (5_2 and 6_3) age classes, were based upon mean catch per unit of effort and length of immature sockeye salmon reported by Japanese research vessels fishing south of the Aleutian Islands in July 1985. Differences in predictions between the two methods, as well as among component estimators within the Standard ADF&G method, suggested that most likely deviations from the pooled forecast would be greater than predicted two-ocean returns and less than predicted three-ocean returns.

KEY WORDS: sockeye salmon, salmon forecasts, population dynamics, Bristol Bay.

INTRODUCTION

The purpose of this report is to provide a final pre-season forecast for sockeye salmon *(Oncorhynchus nerka)* returns to Bristol Bay, Alaska, in 1986. Specific objectives are (1) to present results of the various methods used to forecast sockeye salmon returns to Bristol Bay, (2) to document the performance of these various methods, and (3) to indicate where actual returns are most likely to depart from pre-season expectations.

Until 1983, the annual pre-season forecast used by the Alaska Department of Fish and Game (ADF&G) was calculated as the unweighted average of estimates obtained from spawner-recruit relationships, sibling age class returns, and smolt-to-adult returns for individual age classes and river-lake systems. Forecasts obtained from this method, referred to as the Standard ADF&G method, had a mean error within 36% of actual total run size for the period 1973-1985. Other forecasting methods have also been examined, but, while average performance of some of these has been better than the Standard ADF&G method, year to year reliability has been inconsistent. Beginning in 1983, attempts were made to improve forecast reliability by pooling results from the Standard ADF&G method with results from some of the other available forecast methods (Eggers 1983a and b, Fried and Yuen 1985). Although only three years of data are available for comparison, results have been encouraging; mean forecast accuracy has been within 22% of actual total run size.

The 1986 pre-season forecast is for a total return of 22.5 million sockeye salmon, based upon the weighted mean of the results of two methods: 1) Standard ADF&G and 2) Japanese Research Catches.

METHODS

Age Designation

Adult agees were expressed according to Gilbert and Rich (1927) designations, where total age in years is indicated as well as total time in years spent within freshwater (subscript). Four age classes account for about 98% of total returns: 4_2, 5_3, 5_2, and 6_3 (4-, 5-, and 6-year-old sockeye salmon which spent either two or three years within freshwater). These ages are equivalent to the following European-style (Koo 1962) designations: 1.2, 2.2, 1.3, and 2.3, respectively.

Smolt ages were expressed as Roman numerals corresponding to the number of annular marks on their scales. Two age classes account for about 98% of smolt populations: I (2_2 or 0.2) and II (3_3 or 0.3) (i.e., sockeye salmon that remained either two or three years, respectively, in freshwater prior to migrating seaward).

Standard ADF&G Forecast

The forecast based upon the Standard ADF&G method provided estimates of sockeye salmon returns for individual river-lake systems and major age classes. Three components were included within the Standard ADF&G method: 1) spawner-recruit relationships, 2) sibling age class returns, and 3) smolt-to-adult returns. Each of these three components, if available, were weighted equally and averaged for each system and age class. In some cases a result from a component was excluded from final calculations. The rationale for each exclusion can be found within the appropriate portion of the Results and Discussion section.

Spawner-Recruit Estimators:

Predicted returns from spawner-recruit relationships were based upon dome-shaped, Ricker (1954) curves having the general equation:

$$R_{i,y} = aE_y e^{-bE_y},$$

where

$R_{i,y}$ = number of returning sockeye salmon (recruits) from brood year y;

E_y = number of spawners of all ages in brood year y;

a and b = parameters which determine curve shape.

Age-specific spawner-recruit (i.e., regressing $R_{i,y}$ against E_y) models (Brannian et al. 1982) were used to make this year's forecast for each system rather than the total return models which were used in past years (e.g., Fried and Yuen 1985). This eliminated errors due to age class apportionment, which were difficult to quantify, and produced hindcast at least as accurate as the previously used, two-tier method.

In cases where actual returns to date for a brood year were already much greater or less than those predicted from Ricker spawner-recruit relationships, forecasts were calculated using the following general equation:

$$R_{i,y} = M_i (T_y / C),$$

where

M_i = mean proportion of age class i within past brood year returns;

T_y = total returns to date from brood year y;

C = mean proportion of younger age classes (i.e., 1 to i-1) in the returns by brood year.

$$C = \sum_{y=1}^{Y} \sum_{k=1}^{i-1} R_{k,y}$$

where

Y = total number of brood years that complete return data is available.

This was referred to as the mean proportion method of the spawner-recruit component.

Sibling Age Classes Estimators:

Predicted returns from sibling age classes (younger age classes from the same brood year) were based upon a linear regression model with the general equation:

$$\ln[R_{i,y}] = c + d \ln[R_{(i-1),y}] ,$$

where

$\ln[R_{i,y}]$ = natural logarithm of return of age class i from brood year y;

$\ln[R_{(i-1),y}]$ = natural logarithm of return of age class (i-1) from brood year y;

c and d = intercept and slope of line, respectively.

Smolt Production-Survival Estimators:

Two methods were used to predict adult returns from smolt data. The first was a linear regression model with the general equation:

$$\ln[R_{i,y}] = f + g \ln[S_{k,y}] ,$$

where

$\ln[S_{k,y}]$ = natural logarithm of number of age k smolt produced from brood year y (where k = age I or II);

f and g = intercept and slope of line, respectively.

The second was based upon estimates of both mean survival and age of maturity and had the general equation:

$$R_{i,y} = (S_{k,y})(P_k)(M_{k,i}) ,$$

where

P_k = proportion of all age k smolt which survive to maturity;

$M_{k,i}$ = proportion of age k smolt which return as age class i adults.

The first method could only be used for Kvichak and Wood River systems, since these were the only two systems with enough data relating smolt numbers and subsequent adult returns for regression analysis. Smolt enumeration programs using sonar were begun in 1971 for the Kvichak River and in 1974 for the Wood River system.

The second method was used for the Naknek, Egegik, Ugashik, and Nuyakuk systems, since not enough data were available for regression analysis. Smolt enumeration programs using sonar were begun in 1982 for the Naknek and Egegik Rivers and in 1983 for the Ugashik and Nuyakuk Rivers. However, due to the limited amount of data available, estimates of smolt survival and maturity had to be based on mean values observed for Kvichak and Wood River system smolt. Therefore, estimates based upon smolt data for Naknek, Egegik, Ugashik, and Nuyakuk systems were only used as indicators of how actual returns might deviate from the final forecast.

Forecast Based on Japanese Research Catches

The forecast method based upon the Japanese Research Catches provided estimates of total sockeye salmon returns to Bristol Bay by two-ocean (4_2 and 5_3) and three-ocean (5_2 and 6_3) age groups. Predictions were made using data on catch per unit of effort (CPUE) and mean length of immature sockeye salmon captured by Japanese research vessels fishing south of the Aleutian Islands during July 1985 (Takagi and Ito 1985) along with Bristol Bay air temperatures (Climatological Data Publications, U.S. Department of Commerce, National Climatic Data Center, Asheville, North Carolina) within a multiple linear regression model:

$$\ln[R_{m,t}] = h + n_1 \ln[L_{m-1,\ t-1}] + n_2 [J_{t-1} + J_{t-2}] + n_3 G_{m-1,\ t-1}$$

where

$R_{m,t}$ = returns of ocean age group m in year t;

$L_{m-1,\ t-1}$ = mean length of ocean age group m-1 in Japanese research gill net sample in summer preceding return year (i.e., t-1);

J_{t-1}, J_{t-2} = mean June Cold Bay air temperature in the year and two years preceding the return year t, respectively;

$G_{m-1,\ t-1}$ = geometric mean CPUE of ocean age group m-1 in Japanese research gill net sampling the year preceding the return year;

h, n_1, n_2, and n_3 = constants.

For example, the number of three-ocean (5_2 and 6_3) sockeye salmon expected to return to Bristol Bay in 1986 was based upon geometric mean CPUE and fork length of two-ocean immature sockeye salmon captured by Japanese research vessels fishing south of the Aleutian Islands during July 1985 and the sum of mean June Cold Bay air temperatures for 1984 and 1985.

Prior to 1985, these data were used to produce three separate forecasts: one based only upon geometric mean CPUE, another based only upon arithmetic mean CPUE, and a third based upon both mean fork length and mean June Cold Bay air temperatures (Eggers et al. 1983a and b). In 1985 use of arithmetic mean CPUE data was discontinued since we felt that geometric mean CPUE data would best meet regression assumptions of normality and homoscedasticity. We also combined temperature, length, and geometric mean CPUE data as independent variables within a single model. Since Japanese Research Catches method has only been used since 1985, past performance was simulated with a "hindcasting" procedure in which predicted returns for each year were calculated using data only from the years prior to the year of interest. The earliest year for which a hindcast could be calculated was 1977, since Japanese research vessel catch data were first available for the summer of 1972 and a minimum of five years of data were needed to fit a multiple regression model having three independent variables. To determine how forecast accuracy might be affected by using temperature, length, and CPUE data within a single model, hindcasts from the Japanese Research Catches model were compared with hindcasts from a model using only CPUE data and a model using only length and temperature data.

A jackknife procedure was used in 1985 to assess accuracy of models without a past history of published results (Fried and Yuen 1985). For this procedure, predictions for past years were made with a model using data from all years except that for which the prediction was made. However, we felt that a hindcasting procedure better simulated past performance and thus produced measures of accuracy more comparable with published ADF&G forecasts.

<u>Pooling Forecast Results</u>

Pooled forecasts for each ocean age class were calculated from results of: (1) Standard ADF&G and Japanese Research Catches methods and (2) Standard ADF&G, Temperature-Length, and Geometric CPUE methods. Results of independent methods were pooled based upon the past performance of each method in forecasting sockeye salmon returns to Bristol Bay. The inverse variance of the regression of forecasted (independent variable) versus actual (dependent variable) returns for each method was used as the weighting factor in calculating pooled forecasts (Snedecor and Cochran 1969):

$$F_k = \frac{\sum_{j=1}^{n} F_{j,k} \, (1 / V_{j,k})}{\sum_{j=1}^{n} 1 / V_{j,k}}$$

where

F_k = weighted mean forecast of returns for ocean age group k;

$F_{j,k}$ = method j forecast for returns of ocean age group k;

$V_{j,k}$ = variance (standard error squared) of method j forecast for ocean age group k.

Variance estimates for each pooled ocean age forecast were calculated using the following formula for samples of equal size (Snedecor and Cochran 1969):

$$VP_k = \sum_{j=1}^{n} \left[\frac{1/V_{j,k}}{\sum_{j=1}^{n} 1/V_{j,k}} \right]^2 V_{j,k} ,$$

where

VP_k = variance estimate for pooled forecast of ocean age group k.

The standard error or each pooled ocean age forecast was calculated as:

$$SE_k = [\ VP_k]^{1/2} ,$$

where

SE_k = standard error for pooled forecast of ocean age group k.

Finally, 80% confidence limits for each pooled ocean age group forecast was estimated using the following relationship:

$$80\%\ C.L. = F_k \mp [t_{0.20[df]} \times SE_k] ,$$

where

$t_{0.20[df]}$ = Student's t value with a probability of type I error of 0.20 and df, degrees of freedom;

df = sum of degrees of freedom of variance terms = n(N-1), where N = number of years examined for each of the n methods used in the pooled forecast.

Pooled two-ocean and three-ocean age forecasts of total run size (including estimates of upper and lower 80% confidence limits) were apportioned among individual river-lake systems by major age classes based upon proportions within the original Standard ADF&G forecast.

RESULTS AND DISCUSSION

Total Bristol Bay Forecast

The Standard ADF&G and Japanese Research Catches methods produced total Bristol Bay forecasts of 23.7 and 19.1 million sockeye salmon, respectively (Table 1). The Japanese Research Catches method produced a slightly greater two-ocean age group prediction (13.7 million) and a much lesser three-ocean age group prediction (5.4 million) than the Standard ADF&G method (11.9 and 11.8 million two-ocean and three-ocean returns, respectively, Table 2).

Differences in total and ocean age group predictions between the Standard ADF&G and Japanese Research Catches methods were difficult to reconcile since the past performance of both methods, indicated by their standard errors, was similar (Table 3). The final weighted pooled forecast of total returns was 22.5 million sockeye salmon (Table 4), with an 80% confidence interval of 15.1 to 29.9 million. Total projected harvest was 13.3 million sockeye salmon (Table 4), with an 80% confidence interval of 7.5 to 20.2 million (assuming the proportion of the total run returning to individual systems remained constant for total run sizes within the 80% confidence interval).

Comparison of Japanese Research Vessel Data Models

Comparison of hindcast results of the three models using Japanese research vessel catch data indicated that the Japanese Research Catches model was most accurate for two-ocean returns and least accurate for three-ocean returns (Table 3). However, these performance differences were small and all three models produced similar total forecasts for 1986 (Table 2). Pooling Standard ADF&G results with those obtained from the Temperature-Length and Geometric Mean CPUE models produced a total return estimate of 21.9 million (80% confidence range, 14.6 to 29.3 million) and a projected harvest of 12.5 million (80% confidence range, 6.7 to 19.5 million). These estimates were very similar to those produced by pooling Standard ADF&G with Japanese Research Catches estimates. These results were in accord with the assumption that combining temperature, length, and CPUE data into a single model (i.e., Japanese Research Catches model) would not affect forecasting performance.

River-Lake System Forecasts

Final forecasts for each system and major age class (Table 4) were based upon the distribution of returns within the Standard ADF&G forecast (Table 5). The Standard ADF&G forecast for each system and major age class was calculated as the unweighted mean of results from three components: spawner-recruit (used for all systems and age classes), sibling age classes (used for all systems and age classes whenever possible), and smolt (used for Kvichak and Wood River systems only). Cases in which results of a component were

Table 1. Comparisons of forecasts of sockeye salmon returns to Bristol Bay, Alaska, 1961-1985, made using three methods.

Year	Forecast (millions) Standard ADF&G[1]	Japanese Research Catches[2]	Weighted Mean[3]	Actual Return (millions) Inshore	Total[4]
1961	43.6			18.1	24.5
1962	19.6			10.4	11.7
1963	8.6			6.9	8.0
1964	17.4			10.9	11.5
1965	27.8			53.1	60.8
1966	31.3			17.5	20.0
1967	13.7			10.3	11.5
1968	10.4			8.0	9.4
1969	21.3			19.0	21.9
1970	55.8			39.4	45.0
1971	15.2			15.8	18.3
1972	9.7			5.4	7.2
1973	6.2			2.4	3.5
1974	5.0			10.9	11.5
1975	12.0			24.2	25.8
1976	12.0			11.5	12.8
1977	8.4	26.2		9.7	10.7
1978	11.5	2.9		19.8	20.8
1979	22.7	9.1		39.8	40.9
1980	54.5	49.6		62.4	66.2
1981	26.7	17.0		34.5	37.1
1982	34.6	15.0		22.1	24.7
1983	27.1	53.9	33.4	45.8	48.0
1984	41.5	13.8	31.1	41.0	42.6
1985	25.3	44.2	35.0	36.6	38.5
1986	23.7	19.1	22.5	?	?

[1] Published Standard ADF&G forecasts for past years.

[2] Hindcasted Japanese Research Catches forecast estimates (using data only from years prior to the year for which estimate was made).

[3] Published pooled forecast for past years calculated as mean, weighted by inverse of variance, of several methods (1983: Standard ADF&G, Japanese Gill Net CPUE, and Escapement-Temperature Model; 1984: Standard ADF&G, Japanese Gill Net CPUE, Temperature-Length Model, Escapement-Temperature Model, and Bay-wide Sibling Returns; 1985: Standard ADF&G and Japanese Research Catches).

[4] Included foreign high seas and domestic False Pass-Shumagin Islands catch estimates.

Table 2. Comparisons of forecasts of one-ocean and two-ocean sockeye salmon returns to Bristol Bay, Alaska, 1977-1985, made using four methods.

	Forecast (millions)								Actual Return[3] (millions)	
			Japanese Research Vessel Data							
	Standard ADF&G[1]		Japanese Research Catches[2]		Temperature-Length Model[2]		Geometric Mean CPUE Model[2]			
Year	Two-ocean	Three-ocean	Two-ocean	Three-ocean	Two-ocean	Three-ocean	Two-ocean	Three-ocean	Two-ocean	Three-ocean
1977	4.1	4.3	0.3	25.9	0.2	5.1	16.2	6.8	4.9	5.7
1978	7.8	3.7	2.4	0.5	3.8	7.0	7.6	8.4	12.4	7.8
1979	17.0	5.7	0.5	8.6	0.5	8.6	12.1	7.3	32.9	7.7
1980	41.2	13.4	42.3	7.3	12.3	8.8	49.2	39.9	49.2	16.6
1981	12.9	13.8	9.0	8.0	21.6	9.4	12.9	39.1	17.0	20.0
1982	22.0	12.6	4.4	10.6	5.0	8.3	22.0	40.8	6.1	18.3
1983	18.8	8.3	30.6	8.3	17.9	9.1	18.8	12.3	39.1	8.5
1984	22.7	18.8	4.6	9.2	6.1	9.1	22.7	11.0	29.5	12.9
1985	12.4	12.9	34.5	9.7	28.5	12.6	12.4	8.7	22.9	15.4
1986	11.9	11.8	11.8	5.4	14.9	6.2	17.0	5.0	?	?

1 Published forecasts for past years.

2 Hindcasted estimates (using data only from years prior to the year for which estimate was made).

3 Included foreign high seas and domestic False Pass-Shumagin Islands catch estimates.

Table 3. Accuracy of forecasts of sockeye salmon returns to Bristol Bay, Alaska, 1977-1985, based upon linear regressions of forecasted (independent variable) versus actual (dependent variable) returns.

	Standard Error of Regression (millions of sockeye)	
Forecast Method	Two-ocean	Three-ocean
Standard ADF&G	10.95	3.65
Japanese Research Vessel Data:		
Japanese Research Catches	11.86	5.45
Temperature-Length Model	15.65	4.72
Geometric CPUE Model	11.91	3.12

Table 4. Forecasted returns of major age classes of sockeye salmon returning to Bristol Bay river-lake systems and commercial fishing districts in 1986 based upon pooled results of Standard ADF&G and Japanese Research Catches methods. Spawning goals and resulting projected harvests are indicated.

District: System	Numbers of sockeye salmon (thousands): Forecasted Return by Age Class 4_2	5_3	5_2	6_3	Total	Spawning Goal	Projected Harvest
Naknek-Kvichak:							
Kvichak	1,226	2,257	241	739	4,463	5,000	0
Branch	127	18	66	15	226	185	41
Naknek	558	960	935	725	3,178	1,000	2,178
Total	1,911	3,235	1,242	1,479	7,867		2,219
Egegik	304	2,867	388	1,857	5,416	1,000	4,416
Ugashik	454	2,378	1,342	722	4,896	700	4,196
Nushagak:							
Wood	799	86	774	42	1,701	1,000	701
Igushik	136	88	456	23	703	200	503
Nuyakuk	176	68	1,157	36	1,437	500	937
Total	1,111	242	2,387	101	3,841		2,141
Togiak	143	61	299	18	521	150	371
Total Bristol Bay[1]	3,923	8,783	5,658	4,177	22,541		13,343

[1] Sockeye salmon of minor age classes and systems not considered within forecast calculations may increase the total return by 1 to 2 %.

Table 5. Summary of results of Standard ADF&G method, showing estimated returns of sockeye salmon to Bristol Bay river-lake systems and commercial fishing districts in 1986. (See Table 4 for actual pre-season forecast based upon pooled results of Standard ADF&G and Japanese Research Catches methods.)

District: System	Numbers of sockeye salmon by age class (thousands)				
	4_2	5_3	5_2	6_3	Total
Naknek-Kvichak District:					
Kvichak	1,149	2,114	289	887	4,438
Branch	119	17	80	18	233
Naknek	523	899	1,122	870	3,413
Total	1,790	3,030	1,490	1,774	8,084
Egegik District	285	2,685	466	2,228	5,664
Ugashik District	426	2,228	1,610	866	5,130
Nushagak District:					
Wood River	748	81	929	51	1,809
Igushik River	127	82	547	28	784
Nuyakuk River	165	64	1,389	43	1,661
Total	1,040	227	2,865	122	4,254
Togiak District	134	57	359	22	572
Total Bristol Bay[1]	3,675	8,227	6,790	5,012	23,704

[1] Sockeye salmon of minor age classes and systems not considered within forecast calculations may increase the total return by 1 to 2%.

excluded from final calculations, as well as problem areas where inconsistencies in results among components were encountered, are identified and discussed under the appropriate sections.

Kvichak River

A total of 4.5 million sockeye salmon (80% confidence range, 2.9 to 6.0 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 4.4 million sockeye salmon (Table 5). Predictions from the smolt component were greater than results from either the spawner-recruit or sibling age classes components for two-ocean returns, but less than results from the other components for three-ocean returns (Table 6). If actual returns follow the pattern indicated by smolt component results, total return to the Kvichak system would be at the upper end of the 80% confidence range (i.e., about 5.6 million).

4_2:

A prediction based upon sibling age classes could not be made since no 3_2 sockeye salmon were obtained from samples collected in 1985. Therefore, the 4_2 age class forecast for this system was based upon results from spawner-recruit and smolt components which produced estimates of 0.372 million and 1.926 million, respectively. This results in a Standard ADF&G predicted return of 1.149 million 4_2 sockeye salmon and a final pooled predicted return pf 1.226 million (80% confidence range, 0.791 to 1.663 (million).

5_3:

A prediction based upon sibling age classes could not be made since no 4_3 sockeye salmon were obtained from samples collected in 1985. Therefore, the 5_3 age class forecast for this system was based upon results from spawner-recruit and smolt components which produced estimates of 1.337 and 2.890 million, respectively. This results in a Standard ADF&G prediction return of 2.114 million 5_3 sockeye salmon and a final pooled predicted return of 2.257 million (80% confidence range, 1.454 to 3.059 million).

5_2:

All three components indicated that returns of 5_2 sockeye salmon would be less than 0.5 million. The smolt component produced the lowest prediction of 0.150 million, while spawner-recruit and sibling components produced predictions of 0.309 and 0.408 million, respectively. This resulted in a Standard ADF&G predicted return of 0.289 million 5_2 sockeye salmon and a final pooled predicted return of 0.241 million (80% confidence range, 0.170 to 0.311 million).

6_3:

The 1980 escapement was the second largest ever recorded (1980, 22.5 million; 1965, 24.3 million). However, about 5.0 million sockeye salmon within the escapement probably died prior to spawning due to a velocity barrier on the

Table 6. Forecasted returns of major age classes of sockeye salmon to the Kvichak River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1,134	372 (0.06)
5_3	1,754	1,337 (0.01)
5_2	1,754	309 (0.24)
6_3	17,505[2]	1,174 (0.11)

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
5_2	961 (4_2)	408 (0.77)
6_3	7,981 (5_3)	826 (0.59)

Smolt Component

Age Class	Smolt Production (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	51,893	1,926 (0.57)
5_3	37,595	2,890 (0.88)
5_2	6,549	150 (0.87)
6_3	76,244	660 (0.85)

[1] Coefficient of determination (R^2) shown in parentheses.

[2] Actual 1980 escapement was 22.505 million, however, five million sockeye salmon were assumed to have died before spawning due to a velocity barrier on the Newhalen River.

Newhalen River caused by extremely high water conditions (Poe and Mathisen 1980). When this loss was accounted for, an escapement of 17.5 million was estimated to produce a return of 1.174 million 6_3 sockeye salmon. This estimate was 50% greater than the 0.826 million estimated based upon sibling age classes and 70% greater than the 0.660 million estimate based upon smolt. This resulted in a Standard ADF&G predicted return of 0.887 million 6_3 sockeye salmon and a final pooled predicted return of 0.739 million (80% confidence range, 0.523 to 0.955 million).

Branch River

A total of 0.2 million sockeye salmon (80% confidence range, 0.2 to 0.3 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 0.2 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were available for this system (Table 7). A discussion of results for each major age class follows.

4_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.153 and 0.084 million, respectively. This resulted in a Standard ADF&G predicted return of 0.119 million 4_2 sockeye salmon and a final pooled predicted return of 0.127 million (80% confidence range, 0.082 to 0.172 million).

5_3:

No 4_3 sockeye salmon were obtained from samples collected in 1984. Therefore, the 5_3 age class forecast for this system was based only upon results from the spawner-recruit component. This resulted in a Standard ADF&G predicted return of 0.017 million and a final pooled predicted return of 0.018 million (80% confidence range, 0.012 to 0.025 million).

5_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.043 and 0.077 million, respectively. This resulted in a Standard ADF&G predicted return of 0.080 million 5_2 sockeye salmon and a final pooled predicted return of 0.066 million (80% confidence range, 0.047 to 0.086 million).

6_3:

Spawner-recruit and sibling age classes components produced return estimates of 0.024 and 0.011 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 0.018 million 6_3 sockeye salmon and a final pooled predicted return of 0.015 mllion (80% confidence range, 0.010 to 0.019 million).

Naknek River

A total of 3.2 million sockeye salmon (80% confidence range, 2.2 to 4.2 million) was forecasted to return to this system based upon the pooled results of the

Table 7. Forecasted returns of major age classes of sockeye salmon to the Branch River system, Bristol Bay, in 1986 based upon spawner-recruit and sibling return components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	239	153 (0.01)
5_3	82	17 (0.02)
5_2	82	43 (0.02)
6_3	297	24 (0.17)

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	<1 (3_2)	84 (0.20)
5_2	67 (4_2)	77 (0.39)
6_3	12 (5_3)	11 (0.20)

[1] Coefficient of determination (R^2) shown in parentheses.

Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 3.4 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were used to calculate the Standard ADF&G prediction for this system, although smolt information was examined to determine whether similar trends in returns were indicated (Table 8). Predictions from the smolt component were similar to or greater than results from both the spawner-recruit and sibling age classes components for all major age classes. If actual returns follow the pattern indicated by smolt component results, total returns to the Naknek system could be well above the upper end of the 80% confidence range; possibly as great as 7.0 million (greatest total return previously recorded was 7.9 million in 1981). A discussion of results for each major age class follows.

4_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.403 and 0.642 million sockeye salmon, respectively. Smolt data indicated possible returns of 1.041 million, about twice as great as the other estimates. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.523 million 4_2 sockeye salmon and a final pooled predicted return of 0.558 million (80% confidence range, 0.360 to 0.756 million).

5_3:

Spawner-recruit and sibling age classes components produced similar estimates of 0.868 and 0.930 million, respectively. Smolt data indicated possible returns of 2.871 million, about three times as great as the other estimates. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.899 million and a final pooled predicted return of 0.960 million (80% confidence range, 0.619 to 1.301 million).

5_2:

Spawner-recruit and sibling age classes components produced similar return estimates of 1.132 and 1.111 million, respectively. Smolt data indicated a much greater return of 2.120 million. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 1.122 million 5_2 sockeye salmon and a final pooled predicted return of 0.935 million (80% confidence range, 0.661 to 1.208 million).

6_3:

The 1980 spawning escapement of 2.6 million sockeye salmon was the largest ever recorded (past range, 1956-78, 0.3 to 2.2 million). Actual returns have been much less than those based upon a Ricker-type spawner-recruit relationship. Therefore, estimated returns for the spawner-recruit component for this age class were estimated with the mean proportion method. This produced an estimate of 1.099 million which was still much greater than the 0.641 million estimate obtained from the sibling age classes component. However, smolt data also suggested that returns of 1.010 million might be expected. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.870 million and a final pooled predicted return of 0.725 million (80% confidence range, 0.513 to 0.937 million).

Table 8. Forecasted returns of major age classes of sockeye salmon to the Naknek River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1,155	403 (0.06)
5_3	1,796	868 (0.02)
5_2	1,796	1,132 (0.02)
6_3	2,644[2]	1,099 [3]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	3 (3_2)	642 (0.33)
5_3	10 (4_3)	930 (0.39)
5_2	950 (4_2)	1,111 (0.40)
6_3	1,177 (5_3)	641 (0.19)

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival[4]	Proportion Maturing	Predicted Return (thousands)
4_2	32,140	0.09	0.36	1,041
5_3	48,825	0.12	0.49	2,871
5_2	36,798	0.09	0.64	2,120
6_3	16,497	0.12	0.51	1,010

[1] Coefficient of determination (R^2) shown in parentheses.

[2] Spawning escapement in 1980 largest ever recorded.

[3] Actual return to date has been much less than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

[4] Insufficient data available to estimate average survivals for Naknek River smolt. Estimates used were mean survivals for Kvichak River smolt.

Egegik River

A total of 5.4 million sockeye salmon (80% confidence range, 3.6 to 7.2 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 5.7 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were used to calculate the Standard ADF&G prediction for this system, although smolt information was examined to determine whether similar trends in returns were indicated (Table 9). Predictions from the smolt component were less than results from both the spawner-recruit and sibling age classes components for all major age classes except the 4_2. If actual returns follow the pattern indicated by smolt component results, total returns to the Egegik system could be at the lower end of the 80% confidence range (possibly as low as 3.8 million). A discussion of results for each major age class follows.

4_2:

The spawner-recruit estimate of 0.165 million was only about half that of the sibling age classes estimate of 0.405 million sockeye salmon. Smolt data indicated that returns could be 0.574 million, even higher than those predicted by the sibling age classes component. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.285 million and a final pooled predicted return of 0.304 million (80% confidence range, 0.196 to 0.412 million).

5_3:

Spawner-recruit and sibling age classes produced widely divergent estimates for this age class also, 1.068 and 4.302 million sockeye salmon, respectively. Smolt data indicated possible returns of 2.360 million, intermediate to the two other component estimates. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 2.685 million and a final pooled predicted return of 2.867 million (80% confidence range, 1.848 to 3.886 million).

5_2:

The sibling age classes component again produced a much higher estimate than the spawner-recruit components, 0.745 and 0.187 million, respectively. Smolt data indicated possible returns of only 0.127 million, less than even the spawner-recruit component. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.466 million 5_2 sockeye salmon and a final pooled predicted return of 0.388 million (80% confidence range, 0.275 to 0.502 million).

6_3:

Actual returns have already exceeded returns projected from a Ricker-type spawner-recruit relationship. Therefore, to predict 6_3 returns in 1986, estimated returns for the spawner-recruit component were estimated based

Table 9. Forecasted returns of major age classes of sockeye salmon to the Egegik River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1,034	165 (0.07)
5_3	694	1,068 (0.01)
5_2	694	187 (0.06)
6_3	1,060	3,124 [2]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1 (3_2)	405 (0.38)
5_3	72 (4_3)	4,302 (0.62)
5_2	646 (4_2)	745 (0.73)
6_3	4,470 (5_3)	1,332 (0.41)

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival[3]	Proportion Maturing	Predicted Return (thousands)
4_2	17,234	0.09	0.37	574
5_3	32,236	0.12	0.61	2,360
5_2	2,242	0.09	0.63	127
6_3	16,525	0.12	0.39	773

1 Coefficient of determination (R^2) shown in parentheses.

2 Actual return to date has been much greater than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

3 Insufficient data available to estimate average survivals for Egegik River smolt. Estimates used were mean survivals for Kvichak River smolt.

upon the mean proportion model. This produced an estimate of 3.124 million which was much greater than the 1.332 million estimate obtained from the sibling age classes component. Smolt data indicated possible returns of only 0.773 million, less than either of the other estimates. The mean of the spawner-recruit and sibling estimates produced a Standard ADF&G predicted return of 2.228 million 6_3 sockeye salmon and a final pooled predicted return of 1.857 million (80% confidence range, 1.313 to 2.400 million).

Ugashik River

A total of 4.9 million sockeye salmon (80% confidence range, 3.3 to 6.5 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches method (Table 4). The Standard ADF&G method prediction for total returns to this system was 5.1 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes data were used to calculate the Standard ADF&G prediction for this system, although smolt information was examined to determine whether similar trends in returns were indicated (Table 10). Predictions from the smolt component were much greater than results from either the spawner-recruit or sibling age classes components for two-ocean returns, but less than or similar to results from the other components for three-ocean returns (Table 10). If actual returns follow the pattern indicated by smolt component results, total returns to the Ugashik system could be well above the upper end of the 80% confidence range; possibly as great as 12.3 million. However, since the greatest total return previously recorded was 7.9 million in 1985, a return of over 12.0 million is considered very unlikely. A discussion of results for each major age class follows.

4_2:

Spawner-recruit and sibling age classes components produced similar 4_2 return estimates of about 0.408 and 0.443 million sockeye salmon, respectively. Smolt data indicated possible returns of 3.397 million, much greater than the other estimates. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.426 million 4_2 sockeye salmon and a final pooled predicted return of 0.454 million (80% confidence range, 0.293 to 0.616 million).

5_3:

The 1981 spawning escapement of 1.3 million sockeye salmon was the fourth largest ever recorded. Actual returns have already exceeded returns projected from a Ricker-type spawner-recruit relationship. Therefore, to predict 5_3, as well as 5_2, returns in 1986, estimated returns for the spawner-recruit component were estimated based upon the mean proportion method. This produced an estimate of 3.907 million which was about seven times greater than the sibling age classes component estimate of 0.548 million. Smolt data indicated possible returns of 7.340 million, almost two times greater than even the spawner-recruit estimate. The mean the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 2.228 million 5_3 sockeye salmon and a final pooled predicted return of 2.378 million (80% confidence range, 1.533 to 3.224 million).

Table 10. Forecasted returns of major age classes of sockeye salmon to the Ugashik River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1,157	408 (0.01)
5_3	1,326	3,907 [2]
5_2	1,326	1,742 [2]
6_3	3,321[3]	1,079 [2]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1 (3_2)	443 (0.60)
5_3	4 (4_3)	548 (0.69)
5_2	1,882 (4_2)	1,478 (0.87)
6_3	3,267 (5_3)	653 (0.63)

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival[4]	Proportion Maturing	Predicted Return (thousands)
4_2	75,491	0.09	0.50	3,397
5_3	82,657	0.12	0.74	7,340
5_2	12,736	0.09	0.50	573
6_3	31,297	0.12	0.26	976

[1] Coefficient of determination (R^2) shown in parentheses.

[2] Actual return to date has been much greater than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

[3] Spawning escapement in 1980 largest ever recorded.

[4] Insufficient data available to estimate average survivals for Ugashik River smolt. Estimates used were mean survivals for Kvichak River smolt.

5_2:

Since actual returns have already exceeded returns projected from a Ricker-type spawner-recruit relationship, the mean proportion method was used. The spawner-recruit component produced an estimate of 1.742 million, which was about 20% greater than the sibling age classes component estimate of 1.478 million. Smolt data indicated returns of 0.573 million, much less than either of the other estimates. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 1.610 million 5_2 sockeye salmon and a final pooled predicted return of 1.342 million (80% confidence range, 0.949 to 1.734 million).

6_3:

The 1980 spawning escapement of 3.3 million sockeye salmon was the largest ever recorded. Only four previous spawning escapements have exceeded 1.0 million sockeye salmon: 1982 (1.2 million), 1981 (1.3 million), 1979 (1.7 million) and 1960 (2.3 million). Actual returns have already exceeded returns projected from a Ricker-type spawner-recruit relationship. Therefore, the mean proportion method was used to predict 6_3 returns in 1986. This produced an estimate of 1.079 million, which was almost two times greater than the sibling age class component estimate of 0.653 million. Smolt data indicated possible returns of 0.976 million, similar to the spawner-recruit estimate. The mean of the spawner-recruit and sibling estimates produced a Standard ADF&G predicted return of 0.866 million 6_3 sockeye salmon and a final pooled predicted return of 0.722 million (80% confidence range, 0.510 to 0.933 million).

Wood River

A total of 1.7 million sockeye salmon (80% confidence range, 1.1 to 2.3 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 1.8 million sockeye salmon (Table 5). Results of all three Standard ADF&G components were used whenever possible (Table 11). A discussion of results for each major age class follows.

4_2:

Spawner-recruit, sibling age classes, and smolt components produced estimates of 0.794, 1.006, and 0.444 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 0.748 million 4_2 sockeye salmon and a final pooled predicted return of 0.799 million (80% confidence range, 0.515 to 1.083 million).

5_3:

A prediction based upon sibling age classes could not be made since no 4_3 sockeye salmon were obtained from samples collected in 1985. Therefore, the 5_3 age class forecast for this system was based upon results from the spawner-recruit and smolt components, which produced estimates of 0.131 and 0.031

Table 11. Forecasted returns of major age classes of sockeye salmon to the Wood River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	976	794 (0.01)
5_3	1,233	131 (0.16)
5_2	1,233	1,054 (0.02)
6_3	2,969[2]	62[3]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	3 (3_2)	1,006 (0.38)
5_2	770 (4_2)	704 (0.14)
6_3	82 (5_3)	47 (0.37)

Smolt Component

Age Class	Smolt Production (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	22,330	444 (0.56)
5_3	1,380	31 (0.39)
5_2	19,590	1,029 (0.32)
6_3	4,130	43 (0.21)

[1] Coefficient of determination (R^2) shown in parentheses

[2] Spawning escapement in 1980 largest ever recorded.

[3] Actual return to date has been much less than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 0.081 million 5_3 sockeye salmon and a final pooled predicted return of 0.086 million (80% confidence range, 0.056 to 0.117 million).

5_2:

Spawner-recruit, sibling age classes, and smolt components produced return estimates of 1.054, 0.704, and 1.029 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 0.929 million 5_2 sockeye salmon and a final pooled predicted return of 0.774 million (80% confidence range, 0.570 to 1.001 million). A return of this size would be well below the range of 1.1 to 2.4 million observed for this age class during the past eight years (1977-1985).

6_3:

The 1980 escapement of 3.0 million sockeye salmon was the largest ever recorded. Only two other escapements have ever exceeded 2.0 million: 1959 (2.2 million) and 1978 (2.3 million). Since actual returns have been much less than those projected from a Ricker-type spawner-recruit relationship, the mean proportion method was used. This produced a spawner-recruit return estimate of 0.062 million sockeye salmon, which was greater than both the sibling age classes estimate of 0.047 million and the smolt estimate of 0.043 million. This mean of these components resulted in a Standard ADF&G predicted return of 0.051 million 6_3 sockeye salmon and a final pooled predicted return of 0.042 million (80% confidence range, 0.030 to 0.055 million).

Igushik River

A total of 0.7 million sockeye salmon (80% confidence range, 0.5 to 0.9 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 0.8 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were available for this system (Table 12). A discussion of results for each major age class follows.

4_2:

A prediction based upon sibling age classes could not be made since no 3_2 sockeye salmon were obtained from samples collected in 1985. Therefore, the 4_2 age class forecast for this system was only based upon results from spawner-recruit component which produced a Standard ADF&G predicted return of 0.127 million sockeye salmon and a final pooled predicted return of 0.136 million (80% confidence range, 0.087 to 0.184 million).

5_3:

A prediction based upon sibling age classes could not be made since no 4_3 sockeye salmon were obtained from samples collected in 1985. Therefore, the 5_3 age class forecast for this system was only based upon results from spawner-recruit component which produced a Standard ADF&G predicted return

Table 12. Forecasted returns of major age classes of sockeye salmon to the Igushik River system, Bristol Bay, in 1986 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	423	127 (0.04)
5_3	591	82 (0.09)
5_2	591	769 (0.002)
6_3	1,987[2]	31 [3]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
5_2	153 (4_2)	325 (0.20)
6_3	21 (5_3)	25 (0.38)

1 Coefficient of determination (R^2) shown in parentheses.

2 Spawning escapement in 1980 largest ever recorded.

3 Actual return to date has been much less than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

of 0.082 million sockeye salmon and a final pooled predicted return of 0.088 million (80% confidence range, 0.056 to 0.119 million).

5_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.769 and 0.325 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 0.547 million 5_2 sockeye salmon and a final pooled predicted return of 0.456 million (80% confidence range, 0.322 to 0.589 million).

6_3:

The 1980 spawning escapement of 2.0 million sockeye salmon was the largest ever recorded for this system. Except for the 1979 escapement of 0.9 million, no other escapements of about 1.0 million or greater have been recorded. Since actual returns from the 1980 escapement have been much less than returns projected from a Ricker-type spawner-recruit relationship, the mean proportion method was used to predict 6_3 returns in 1986. This produced a spawner-recruit return estimate of 0.031 million, which was similar to the sibling age classes estimate of 0.025. This resulted in a Standard ADF&G predicted return of 0.028 million 6_3 sockeye salmon and a final pooled predicted return of 0.023 million (80% confidence range, 0.017 to 0.030 million).

Nuyakuk River

A total of 1.4 million sockeye salmon (80% confidence range, 1.0 to 1.9 million) was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 1.7 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were used to calculate the Standard ADF&G prediction for this system, although smolt information was examined to determine whether similar trends in returns were indicated (Table 13). Smolt component results were generally in good agreement with results from the other components and indicated total returns would be 1.6 million. A discussion of results for each major age class folows.

4_2:

Spawner-recruit and sibling age classes produced return estimates of 0.199 and 0.130 million sockeye salmon, respectively. Smolt data suggested that returns would be 0.075 million, lower than both other estimates. The mean of spawner-recruit and sibling age classes estimates resulted in a Standard ADF&G predicted return of 0.165 million 4_2 sockeye salmon and a final pooled predicted return of 0.176 million (80% confidence range, 0.113 to 0.238 million).

5_3:

The 1981 spawning escapement of 0.8 million sockeye salmon was the second highest ever recorded, only exceeded by the 1980 escapement of 3.0 million, and produced a return estimate of about 0.064 million sockeye salmon. A

Table 13. Forecasted returns of major age classes of sockeye salmon to the Nuyakuk River system, Bristol Bay, in 1986 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	537	199 (0.05)
5_3	834	64 (0.02)
5_2	834	1,858 (0.003)
6_3	3,026[3]	28[2]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	1 (3_2)	130 (0.47)
5_2	309 (4_2)	920 (0.40)
6_3	78 (5_3)	58 (0.46)

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival[4]	Proportion Maturing	Predicted Return (thousands)
4_2	6,294	0.06	0.20	75
5_3	90	0.16	0.51	7
5_2	28,875	0.06	0.80	1,386
6_3	1,259	0.16	0.49	99

1 Coefficient of determination (R^2) shown in parentheses.

2 Spawning escapement in 1980 largest ever recorded.

3 Actual return to date has been much less than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

4 Insufficient data available to estimate average survivals for Nuyakuk River smolt. Estimates used were mean survivals for Wood River smolt.

prediction based upon sibling age classes could not be made since no 4_3 sockeye salmon were obtained from samples collected in 1985. Smolt data indicated returns of only 0.007 million, much less than those predicted by the spawner-recruit component. Due to the minor contribution this age class will make to the total return to this system, only the spawner-recruit estimate was for the final forecast. This resulted in a Standard ADF&G predicted return of 0.064 million 5_3 sockeye salmon and a final pooled predicted return of 0.068 million (80% confidence range, 0.044 to 0.093 million).

5_2:

As was previously noted, the 1981 spawning escapement of 0.8 million sockeye salmon was the second highest ever recorded. The spawner-recruit component produced a return estimate of 1.858 million, which was about two times greater than the sibling age classes estimate of 0.920 million. Smolt data indicated returns of 1.386 million, only slightly less than the sibling age classes estimate. The mean of the spawner-recruit and sibling age classes components resulted in a Standard ADF&G predicted return of 1.389 million 5_2 sockeye salmon and a final pooled predicted return of 1.157 million (80% confidence range, 0.819 to 1.496 million).

6_3:

The 1980 spawning escapement of 3.0 million was the largest ever recorded. Since actual returns to date have been much less than those based upon a Ricker-type spawner-recruit relationship, the mean proportion method was used to predict 6_3 returns in 1986. This produced a spawner-recruit return estimate of 0.028 million, which was about half that of the sibling age classes estimate of 0.058 million. Smolt data indicated returns of 0.099 million, greater than both spawner-recruit and sibling age classes estimates. The mean of the spawner-recruit and sibling age classes estimates resulted in a Standard ADF&G predicted return of 0.043 million 6_3 sockeye salmon and a final pooled predicted return of 0.036 million (80% confidence range, 0.025 to 0.046 million).

Togiak River

A total of 0.5 million sockeye salmon (80% confidence range, 0.4 to 0.7 million) was forecasted to return to this system based upon the pooled results of Standard ADF&G and Japanese Research Catches methods (Table 4). The Standard ADF&G method prediction for total returns to this system was 0.6 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were available for this system (Table 14). A discussion of results for each major age class follows.

4_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.179 and 0.088 million, respectively. This resulted in a Standard ADF&G predicted return of 0.134 million 4_2 sockeye salmon and a final pooled predicted return of 0.143 million (80% confidence range, 0.092 to 0.193 million).

Table 14. Forecasted returns of major age classes of sockeye salmon to the Togiak River system, Bristol Bay, in 1986 based upon spawner-recruit and sibling returns components to the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	288	179 (0.01)
5_3	307	57 (0.13)
5_2	307	525 (0.02)
6_3	526[2]	29 [3]

Sibling Returns Component

Age Class	Sibling Return in 1985 (thousands)	Predicted Return Based on Linear Regression (thousands)[1]
4_2	153 (3_2)	88 (0.01)
5_2	73 (4_2)	193 (0.20)
6_3	12 (5_3)	15 (0.26)

1 Coefficient of determination (R^2) shown in parentheses.

2 Spawning escapement in 1980 largest ever recorded.

3 Actual return to date has been much less than that based upon Ricker relationship. Return calculated with mean proportion method (see Methods section).

5_3:

The 1981 spawning escapement of 0.3 million was the second highest ever recorded, and was exceeded only by the 1980 escapement of 0.5 million. (Another escapement of 0.3 million occurred in 1978). A prediction based upon sibling age classes could not be made since no 4_3 sockeye salmon were obtained from samples collected in 1985. Therefore, the 5_3 age class forecast for this system was only based upon results from the spawner-recruit component. This produced a Standard ADF&G predicted return of 0.057 million 5_3 sockeye salmon and a final pooled predicted return of 0.061 million (80% confidence range, 0.039 to 0.082 million).

5_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.525 and 0.193 million, respectively. This resulted in a Standard ADF&G predicted return of 0.359 million 5_2 sockeye salmon and a final pooled predicted return of 0.299 million (80% confidence range, 0.212 to 0.387 million).

6_3:

The 1980 spawning escapement of 0.5 million sockeye salmon was the greatest ever recorded. Since actual returns to date have been much less than that based upon a Ricker-type spawner-recruit relationship, the mean proportion method was used to predict 6_3 returns in 1986. This produced a spawner-recruit return estimate of 0.029 million, which was only about half that of the sibling age classes estimate of 0.015 million. This resulted in a Standard ADF&G predicted return of 0.022 million 6_3 sockeye salmon and a final pooled predicted return of 0.018 million (80% confidence range, 0.013 to 0.024 million).

SUMMARY

The total forecast based upon the Standard ADF&G method was only 24% greater than that based upon the Japanese Research Catches method (Table 1). The greatest difference between the two methods was found for three-ocean return predictions: the Standard ADF&G estimate was about twice the estimate based on Japanese Research Catches (Table 15). Since past performance of the Standard ADF&G method has been somewhat better than that of the Japanese Research Catches method (Tables 2 and 3), the pooled forecast most closely resembled the Standard ADF&G estimate (Table 15). Inconsistencies between the two methods, as well as among component models within the Standard ADF&G method, indicate that the most likely deviations from the pooled forecast for most systems would be greater than predicted two-ocean returns and less than predicted three-ocean returns (Table 16).

ACKNOWLEDGMENTS

Although the entire Bristol Bay staff of the Commercial Fisheries Division, ADF&G, assisted in collecting data upon which 1986 predictions were based,

Table 15. Comparison of total forecasted returns of major age classes of sockeye salmon to Bristol Bay, Alaska, in 1986.

	Forecast (millions)		
Age Class	Standard ADF&G	Japanese Research Catches	Weighted Mean
4_2	3.7 (16%)	4.2 (22%)	3.9 (17%)
5_3	8.2 (34%)	9.5 (50%)	8.8 (39%)
two-ocean	11.9 (50%)	13.7 (72%)	12.7 (56%)
5_2	6.8 (29%)	3.1 (16%)	5.6 (25%)
6_3	5.0 (21%)	2.3 (12%)	4.2 (19%)
three-ocean	11.8 (50%)	5.4 (28%)	9.8 (44%)
Total	23.7 (100%)	19.1 (100%)	22.5 (100%)

Table 16. Synopsis of sockeye salmon returns to Bristol Bay, Alaska, river-lake systems for age classes in which deviations of forecasted from actual returns are most likely to occur in 1986.

System	Age Class	Forecast (millions)	Summary of Indicators	Possible Deviation
Kvichak	4_2	1.226 (0.791-1.663)	No 3_2 return in 1985, but smolt prediction five times greater than spawner-recruit prediction and two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (upper 80% CI)
	5_3	2.257 (1.454-3.059)	No 4_3 return in 1985, but smolt prediction two times greater than spawner-recruit prediction and two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (upper 80% CI)
Naknek	4_2	0.558 (0.360-0.756)	Smolt prediction about two times greater than spawner-recruit and sibling age classes predictions; two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (upper 80% CI)
	5_3	0.960 (0.619-1.301)	Smolt prediction about three times greater than spawner-recruit and sibling age classes predictions; two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (above upper 80% CI)

-Continued-

Table 16. Synopsis of sockeye salmon returns to Bristol Bay, Alaska, river-lake systems for age classes in which deviations of forecasted from actual returns are most likely to occur in 1986 (continued).

System	Age Class	Forecast (millions)	Summary of Indicators	Possible Deviation
Egegik	6_3	1.857 (1.313-2.400)	Smolt prediction four times less than spawner-recruit and almost two times less than sibling age classes prediction; three-ocean component of Japanese Research Catches prediction much less than that in Standard ADF&G	LESSER RETURN (below lower 80% CI)
Ugashik	4_2	0.454 (0.293-0.616)	Smolt prediction almost eight times greater than spawner-recruit and sibling age classes predictions; two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (above upper 80% CI)
	5_3	2.378 (1.533-3.224)	Smolt prediction about two times greater than spawner-recruit and thirteen times greater than sibling age classes predictions; two-ocean returns in Japanese Research Catches prediction greater than that in Standard ADF&G	GREATER RETURN (above upper 80% CI)
	5_2	1.342 (0.949-1.734)	Smolt prediction about three times less than spawner-recruit and sibling age classes predictions; three-ocean returns in Japanese Research Catches prediction much less than that in Standard ADF&G	LESSER RETURN (below lower 80% CI)

-Continued-

Table 16. Synopsis of sockeye salmon returns to Bristol Bay, Alaska, river-lake systems for age classes in which deviations of forecasted from actual returns are most likely to occur in 1986 (continued).

System	Age Class	Forecast (millions)	Summary of Indicators	Possible Deviation
Ugashik	6_3	0.722 (0.510-0.933)	This would be greatest 6_3 return ever observed, previous record 0.533 million in 1985; all Standard ADF&G component predictions greater than 0.653 million, but three-ocean returns in Japanese Research Catches prediction much less than that in Standard ADF&G	LESSER RETURN (lower 80% CI)
Wood	5_2	0.774 (0.547-1.001)	Low 5_2 return when compared with range of 1.1 to 2.4 million for previous eight years; spawner-recruit and smolt predictions both about 1.0 million, sibling age classes prediction about 0.7 million; three-ocean returns in Japanese Research Catches prediction much less than that in Standard ADF&G	GREATER RETURN (upper 80% CI)
Igushik	5_2	0.456 (0.322-0.589)	Spawner-recruit prediction over two times greater than sibling age classes prediction; three-ocean returns in Japanese Research Catches prediction much less than that in Standard ADF&G	LESSER RETURN (lower 80% CI)
Togiak	5_2	0.299 (0.212-0.387)	Sibling age classes prediction almost three times less than spawner-recruit prediction; three-ocean returns in Japanese Research Catches prediction much less than that in Standard ADF&G	LESSER RETURN (lower 80%CI)

and provided many useful suggestions during the long process of formulating the 1986 forecast, we would especially like to thank the following staff members for their review of and discussions on the final forecast: Charles Meacham (Region II Research Supervisor), Michael Nelson (Bristol Bay Senior Area Management Biologist), and Donald Bill (Naknek-Kvichak District Area Management Biologist).

LITERATURE CITED

Brannian, L.K., O.A. Mathisen, and D.A. McCaughran. 1982. Variance estimates of sockeye salmon predictions with reference to the Egegik River system of Bristol Bay, Alaska. Final Report for the period January 1, 1982 - June 30, 1982 to Alaska Department of Fish and Game. Contract No. 82-0769. University of Washington, Fisheries Research Institute, Seattle. 105 pp.

Eggers, D.M., C.P. Meacham, and H. Yuen. 1983a. Synopsis and critique of the available forecasts of sockeye salmon returning to Bristol Bay in 1983. Informational Leaflet No. 207. Alaska Department of Fish and Game, Juneau, Alaska. 24 pp.

Eggers, D.M., C.P. Meacham, and H. Yuen. 1983b. Synopsis and critique of the available forecasts of sockeye salmon *(Oncorhynchus nerka)* returning to Bristol Bay in 1984. Informational Leaflet No. 228. Alaska Department of Fish and Game, Juneau, Alaska. 26 pp.

Fried, S.M. and H.J. Yuen. 1985. A synopsis and critique of forecasts of sockeye salmon *(Oncorhynchus nerka)* returning to Bristol Bay in 1985. Informational Leaflet No. 247. Alaska Department of Fish and Game, Juneau, Alaska. 40 pp.

Gilbert, C.H. and W.H. Rich. 1927. Investigations concerning the red salmon runs to the Karluk River, Alaska. Bulletin of the United States Bureau of Fisheries. 43 (Part 2): 1-89.

Koo, T.S.Y. 1962. Age designation in salmon, p. 37-48. In T.S.Y. Koo [ed.]. Studies of Alaska red salmon. University of Washington Publications in Fisheries, New Series, Volume I.

Poe, P.H. and O.A. Mathisen. 1980. The 1979 and 1980 enumeration of sockeye salmon to the Newhalen River-Lake Clark system. Preliminary Report (November 20, 1980). Fisheries Research Institute, University of Washington. Seattle.

Ricker, W.E. 1954. Stock and recruitment. Journal of the Fisheries Research Board of Canada. 11: 559-623.

Snedecor, G.W. and W.G. Cochran. 1969. Statistical Methods. Sixth Edition. Iowa State University Press, Ames. 593 pp.

Takagi, K. and S. Ito. 1985. Abundance and biological information of immature sockeye salmon in waters south of the Aleutian Islands in 1985 July. International North Pacific Fisheries Commission, Document 2897. Fisheries Agency of Japan, Tokyo, Japan. 5 pp.