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Alaska Department of Fish and Game
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A Synopsis and Critique of Forecasts of Sockeye Salmon Returning to Bristol Bay, Alaska in 1988

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State of Alaska Steve Cowper, Governor

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ABSTRACT

The total number of sockeye salmon (*Oncorhynchus nerka*) forecasted to return to Bristol Bay in 1988 is 28.3 million (80% confidence interval: 14.7 to 42.1 million). Returns are expected to exceed spawning escapement goals for all systems, and the total harvest is projected to be 18.6 million sockeye salmon (80% confidence interval: 5.5 to 32.4 million). This forecast was based on a modified ADF&G method which omitted data prior to the 1978 return year from calculations using spawner-recruit, sibling, and smolt data. To compare the performance of the modified ADF&G method with past methods, a hindcasting procedure was used to calculate modified ADF&G method forecasts for 1984-87. Modified ADF&G method forecasts had a lower mean percent error (a measure of bias) and a lower mean absolute percent error (a measure of accuracy) than forecasts based on the old ADF&G method (which used all available data), the Japanese Research Vessel Catch (JRVC) method (which used data on immature sockeye salmon captured during July near the Aleutian Islands in conjunction with air temperature data), and the composite of these methods. For 1988, the old ADF&G method, the JRVC method, and the composite of these methods produced total return forecasts of 18.1, 15.1, and 16.7 million sockeye salmon, respectively. However, a total return of less than 20 million sockeye salmon has not been observed since 1977. The outlook for 1988-91, based only on the spawner-recruit component of the modified ADF&G method, is for the total number of sockeye salmon returning to Bristol Bay to be greatest in 1989 (39.1 million) and least in 1991 (27.9 million), mostly due to variations in returns to the Kvichak River system.

KEY WORDS: Salmon forecast, sockeye salmon, *Oncorhynchus nerka*, Bristol Bay, spawner-recruit, environmental indicators

INTRODUCTION

Preseason forecasts of the number of sockeye salmon (*Oncorhynchus nerka*) returning to Bristol Bay, Alaska, have been made by the Alaska Department of Fish and Game (ADF&G) since 1961 (ADF&G 1961). These forecasts are used by ADF&G staff to estimate commercial harvests; to set quotas for the Shumagin Island-South Peninsula June fishery; and to determine which stocks might be in low abundance and need protection against possible overharvesting. Seafood buyers and processors use forecasts to estimate the supply of raw fish which will be available for various uses; to determine staff and equipment needed for production of fresh, frozen, and canned products; and to plan deployment of tenders and processing vessels. Commercial fishermen use forecasts to decide which areas might provide them with the best fishing opportunities and to assist in decisions involving future investments for equipment and gear.

Until 1983, annual preseason forecasts made by ADF&G were usually calculated as the mean of estimates obtained from models using either spawner-recruit, sibling, or smolt data. Forecasts from this method, referred to as the ADF&G method, had a mean absolute error (MAPE) of 37% of the actual total run size for 1961-1982 (MAPE range: 3 to 78%) (Fried and Yuen 1987; Fried et al. 1987). Beginning in 1983 attempts were made to improve forecast accuracy by combining results from the ADF&G method with those from other methods (Eggers et al. 1983a, 1983b). For the past 3 years only results from two forecasting methods, the ADF&G and Japanese Research Vessel Catch (JRVC) methods, have been combined to produce the preseason forecast (Fried and Yuen 1985, 1986, and 1987). However, these composite forecasts have generally not been more accurate than forecasts based solely on the ADF&G method (MAPE, 1983-1987: 23%, composite; 26%, ADF&G) and have not corrected the tendency of forecasts to under-estimate total run size (published forecasts for 13 of the last 14 years have been less than postseason abundance estimates).

To correct these problems, we modified the methods used to calculate run size predictions for 1988. The most important change made was to omit data prior to the 1978 return year from all calculations. We felt that models based on more recent data would more accurately reflect current trends in sockeye salmon production. Most Bristol Bay river systems have shown a dramatic increase in the number of returning sockeye salmon adults produced by each spawner since 1978, coincident with: (1) decreased interception of maturing sockeye salmon on the high seas, (2) the onset of more favorable climatic conditions, and (3) improvements in ADF&G's ability to determine and attain spawning escapement goals for most major Bristol Bay systems (Eggers et al. 1984).

The purpose of this report is to provide a final preseason forecast of the number of sockeye salmon returning to Bristol Bay, Alaska, in 1988 with an outlook of abundance through 1991. Specific objectives are: (1) to describe models currently used to forecast sockeye salmon returns to Bristol Bay, (2) to determine relative accuracies of different forecasting methods, (3) to indicate where actual returns are most likely to depart from preseason expectations, and (4) to forecast total annual returns through 1991.

METHODS

Age Designation

Sockeye salmon ages were expressed according to modified European system designations (Koo 1962), wherein the number of annular (winter) scale checks formed in fresh and salt water are indicated to the left and right of a decimal point, respectively. Four age classes account for about 98% of total returns: 1.2 (28%), 2.2 (31%), 1.3 (28%), and 2.3 (11%). These four age classes are equivalent to the following Gilbert and Rich (1927) designations: 4_2, 5_3, 5_2, and 6_3, which are dated from the time of egg deposition and show both total age (first digit) as well as the year of life in which seaward migration occurred (subscript).

Smolt ages were expressed as either age-I or -II, corresponding to sockeye salmon that migrated seaward in either their second or third year of life, respectively.

ADF&G Method Forecast

The ADF&G method forecast has been used to predict the number of sockeye salmon, by major age class, returning to nine river systems that account for about 98% of Bristol Bay sockeye salmon production; these are: the Kvichak, Branch, Naknek, Egegik, Ugashik, Wood, Igushik, Nuyakuk, and Togiak Rivers. Forecasts for each system and age class have been calculated by averaging results of several models which used either (1) spawner-recruit, (2) sibling, or (3) smolt data. Prior to 1986 predictions for each data component were calculated by averaging results from two or more models (e.g. linear regression, ratio estimator, mean proportion) (Eggers et al. 1983a, 1983b). Beginning in 1986 only results from a single model were used to calculate forecasts for each data component (Fried and Yuen 1986 and 1987). For the 1988 forecast only results from a single linear regression model was used to calculate the forecast for each data component, and all data prior to the 1978 return year were excluded from analyses.

Predicted returns from spawner-recruit data were based on a linear form of the Ricker (1954) curve constructed for age-specific returns (Brannian et al. 1982):

$$\ln[R_{a,r,y} / E_{r,y}] = \ln[\alpha] + \beta E_{r,y}$$

where $R_{a,r,y}$ = number of age-*a* sockeye salmon returning to river system *r* from spawning during brood year *y*; $E_{r,y}$ = total number of spawners in river system *r* during brood year *y*; α and β = parameters which determine the y-axis intercept and slope of the line, respectively.

In cases where the Ricker relationship was not significant at the 75% level (F-test, H_0: $\beta = 0$; Snedecor and Cochran 1969), a linear regression model based on natural logarithm transformed data was used:

$$\ln[R_{a,r,y}] = \alpha + \beta \ln[E_{r,y}] \ .$$

Predicted returns from sibling (younger age classes from the same brood year) and smolt data were also based upon linear regression models using natural logarithm transformed data, as suggested by Peterman (1982a, 1982b):

$$\ln[R_{a,r,y}] = \alpha + \beta \ln[S_{j,r,y}]$$

where $S_{j,r,y}$ = either the number of age-j smolt (where j = age-I or -II) migrating from river system r which were progeny of spawning in brood year y, or the number of age-j adults (where j = [a-1]) returning to river system r from spawning in brood year y.

Since at least 3 years of smolt production estimates and subsequent adult returns are needed to fit linear regression models, forecasts using smolt data could only be calculated for all age classes for the Kvichak, Wood, Naknek, and Egegik River systems. Smolt enumeration programs using sonar equipment were begun, respectively, in those systems in 1971 (Russell 1972), 1975 (Krasnowski 1976), 1982 (Huttunen 1984), and 1982 (Bue 1984). Smolt enumeration programs were initiated on the Ugashik (Fried et al. 1987) and Nuyakuk (Minard and Frederickson 1987) River systems in 1983, so models for these systems could only be developed to predict returns of age-1.2 and -2.2 sockeye salmon.

Only spawner-recruit model results were available for the 1988 Nuyakuk River forecast, since severe flooding made it impossible to obtain visual counts of spawners from counting towers and to collect samples to estimate the age composition of the spawning population during 1987. Total returns to this system in 1987 have not yet been estimated from other available data (i.e. sonar project counts and age composition samples; aerial survey counts), so forecasts based on sibling returns could not be calculated and insufficient data were available to build smolt models for age-1.2 and -2.2 adult returns.

Results from models were excluded from final forecast calculations if the fit of the model was not significant at the 75% level or the value of the input variable ($E_{r,y}$ or $S_{j,r,y}$) was outside the range of data used to build the model. If results from spawner-recruit, sibling and smolt models did not meet these criteria for a river system age class, the mean return of that age class to that river system for the past 10 years was used as the prediction.

Japanese Research Vessel Catch Forecast

The Japanese Research Vessel Catch (JRVC) method forecast has been used to provide estimates of total returns of sockeye salmon which had remained at sea for either 2 (1.2 and 2.2) or 3 (1.3 and 2.3) years (hereafter referred to as age-.2 and age-.3 sockeye salmon, respectively). These estimates 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 1987 (K. Takagi and S. Ito 1987) along with Cold Bay, Alaska, air temperatures (Climatological Data Publications, U.S. Department of Commerce, National Climatic Data Center, Asheville, North Carolina) within a multiple linear regression model:

$$R_{o,z} = a + b_1\ G_{(o-1),(z-1)} + b_2\ L_{(o-1),(z-1)} + b_3\ C_{(z-1)\&(z-2)}$$

where $R_{o,z}$ = total number of ocean-age-*o* sockeye salmon returning in year *z*; $G_{(o-1),(z-1)}$ = geometric mean CPUE of ocean-age-*(o-1)* sockeye salmon in year *(z-1)*; $L_{(o-1),(z-1)}$ = mean fork length (mm) of ocean-age-*(o-1)* sockeye salmon in year *(z-1)*; $C_{(z-1)\&(z-2)}$ = mean June air temperature (^oF) at Cold Bay during year *(z-1)*, or the sum of mean June air temperatures during years *(z-1)* and *(z-2)* for ocean-age-2 and 3 sockeye salmon, respectively.

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 homoscedacticity (Fried and Yuen 1985). We also combined temperature, length and geometric mean CPUE data as independent variables within a single model, since the accuracy of forecasts produced by this model, based on results of a hindcasting procedure, did not differ greatly from those produced from the two previously used models. (Fried and Yuen 1986). For the 1988 forecast, all data prior to the 1978 return year were excluded from analyses.

Results from the models used within the JRVC method were excluded from final forecast calculations if the fit of the model was not significant at the 75% level or the value of any input variables ($G_{(o-1),(z-1)}$, $L_{(o-1),(z-1)}$, $C_{(z-1)\&(z-2)}$) was outside the range of data used to build the model. When data prior to 1978 were omitted from calculations, the JRVC model for age-.3 sockeye salmon returns was not statistically significant at the 75% level, and the input value for CPUE (0.11) needed for the JRVC model for age-.2 sockeye salmon returns was outside the range of data used to build that model (CPUE range for 1978-1987, 0.18 to 1.33). Therefore, results from the JRVC method were not used for the 1988 forecast.

Confidence Intervals and Forecast Performance

Standard errors and 80% confidence intervals for each age specific forecast were calculated using linear regression analysis to describe the relationship between past forecasts (independent variable) and actual returns (dependent variable):

$$80\%\ C.I. = P_a \pm t_{0.2} s_{\hat{p}}$$

where P_a = forecasted total return of age-*a* sockeye salmon in 1988; $t_{0.2}$ = Student's t value with a probability of type I error of *0.20*; $s_{\hat{p}}$ = standard error of the forecasted total return of age-a sockeye salmon in 1988:

$$s_{\hat{p}} = s_{d.p} \sqrt{1/n + [(P_{i,a} - \bar{P}_a)^2 / \Sigma(P_{i,a} - \bar{P}_a)^2]}$$

where $P_{i,a}$ = forecasted total return of age-*a* sockeye salmon in year *i*; $\bar{P}_a$ = mean forecasted total return of age-*a* sockeye salmon; n = number of past years for which predictions available; $s_{d.p}$ = the standard error from regression of past ADF&G forecasts and actual returns of age-*a* sockeye salmon:

$$s_{d.p} = \sqrt{\Sigma(D_{i,a} - \hat{D}_{i,a})^2] / (n-2)}$$

where $\hat{D}_{i,a}$ = estimated total return of age-*a* sockeye salmon in year *i* based on regression of forecasted and actual returns. $D_{i,a}$ = actual total return of age-*a* sockeye salmon in year *i*.

Since the ADF&G method used for the 1988 forecast was different from the one used for past forecasts, a hindcasting procedure was used to simulate its past performance. Due to the limited amount of data available (i.e. all data prior to the 1978 return year were omitted from analyses), modified ADF&G method hindcasts could be calculated for only four years, 1984-87. We were unable to calculate hindcasts prior to 1984 because most models were not significant at the 75% level and many of the input data were out of range of values used for models.

Hindcasts made with the modified ADF&G method were compared with published forecasts (Eggers 1983b; Fried and Yuen 1985, 1986, and 1987) to determine whether the new method could be expected to produce more accurate and less biased forecasts. Three statistics were used for comparisons, percent error (a measure of annual performance):

$$PE = 100 \times ([P_{i,a} - D_{i,a}] / D_{i,a}) ;$$

mean percent error (a measure of bias):

$$MPE = \Sigma (100 \times ([P_{i,a} - D_{i,a}] / D_{i,a})) / i ;$$

and mean absolute percent error (a measure of overall accuracy which treats under- and over-forecasting errors similarly):

$$MAPE = \Sigma |(100 \times ([P_{i,a} - D_{i,a}] / D_{i,a}))| / i .$$

Outlook to 1991

Using only spawner-recruit data, forecasts were also made for the years 1989, 1990, and 1991. To determine whether forecasts for these years were reasonable, past trends in sockeye salmon production and environmental conditions were examined for 1965-1987. Annual return per spawner values were calculated as the weighted sums of total escapements 4, 5, and 6 years prior to each annual return. The mean June air temperature associated with each annual return was calculated as the weighted mean of average June air temperatures recorded at Cold Bay, Alaska, 1, 2, and 3 years prior to each annual return. Deviations from the mean return per spawner value were calculated for actual returns in 1965-87 and for forecasted returns in 1988-91. Deviations from the mean Cold Bay air temperature in June associated with each annual return were calculated for 1965-88. The correlation coefficient (Snedecor and Cochran 1969) between annual deviations from the mean return per spawner value and annual deviations from the mean June air temperature was calculated for 1965-87 data, and a plot was made of all deviations for 1965-91.

RESULTS AND DISCUSSION

Total Bristol Bay Forecast

Based on the results of the modified ADF&G method, total production for Bristol Bay in 1988 is expected to be 28.3 million sockeye salmon (80% C.I., 14.7 to 42.1 million) (Tables 1 and 2). This level of production would only be about 5% (1.4 million sockeye salmon) greater than the 20-year (1968-87) mean (26.9 million; range: 3.5 to 66.3 million), but about 24% (6.5 million) less than the most recent 10-year (1978-87) mean (37.2 million, range 20.8 to 66.3 million).

Table 1. Forecasts of sockeye salmon returns to Bristol Bay, Alaska, 1961-88, based on results of several methods.

	Forecast (millions)				Actual Return (millions)	
	ADF&G					
Year	Modified	Old	JRVC	Composite	Inshore	Total[a]
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[b]		9.7	10.7
1978		11.5	2.9[b]		19.8	20.8
1979		22.7	9.1[b]		39.8	40.9
1980		54.5	49.6[b]		62.4	66.2
1981		26.7	17.0[b]		34.5	37.1
1982		34.6	15.0[b]		22.1	24.7
1983		27.1	53.9[b]	33.4[c]	45.8	48.0
1984	35.1[b]	41.5	13.8[b]	31.1[d]	41.0	42.6
1985	29.6[b]	25.3	44.2	35.0[e]	36.6	38.5
1986	29.1[b]	23.7	19.1	22.5[e]	23.7	24.4
1987	25.1[b]	15.6	17.5	16.5[e]	27.4	28.3
1988	28.3	18.1	15.1	16.7[e]	?	?

[a] Included foreign high seas and domestic Shumagin Islands-False Pass catches for 1961-87.

[b] Hindcasted estimates, using data only prior to the year for which estimate was made (JRVC estimates: Fried and Yuen 1986).

[c] Weighted mean of old ADF&G, Japanese Gill Net CPUE, and Escapement-Temperature models (Eggers et al. 1983a).

[d] Weighted mean of old ADF&G, Japanese Gill Net CPUE, Temperature-Length, Escapement-Temperature, and Bay-wide Sibling Return models (Eggers et al. 1983b).

[e] Weighted mean of old ADF&G and JRVC models (Fried and Yuen 1985, 1986, and 1987).

Table 2. Forecasted production, spawning escapement goals, and total projected harvests of major age classes of sockeye salmon returning to Bristol Bay, Alaska, river systems in 1988, based on results of the modified ADF&G method.

	Numbers of sockeye salmon (thousands)						
	Forecasted Production by Age Class						
District: System	1.2	2.2	1.3	2.3	Total	Spawning Goal	Total Harvest
NAKNEK-KVICHAK:							
Kvichak	4,817	2,915	1,275	299	9,306	5,000	4,306
Branch	171	21	211	24	427	185	242
Naknek	289	800	702	659	2,450	1,000	1,450
Total	5,276	3,736	2,188	982	12,182	6,185	5,997
EGEGIK	609	2,191	2,195	949	5,944	1,000	4,944
UGASHIK	760	1,291	943	428	3,422	700	2,722
NUSHAGAK:[a]							
Wood	1,116	190	1,639	77	3,021	1,000	2,021
Igushik	247	40	824	55	1,166	200	966
Nuyakuk	273	11	1,472	78	1,834	500	1,334
Total	1,636	241	3,935	210	6,021	1,700	4,321
TOGIAK[b]	239	28	448	18	733	150	583
TOTAL BRISTOL BAY	8,520	7,487	9,708	2,587	28,302	9,735	18,567

[a] Forecasts for Nushagak-Mulchatna and Snake River systems were not included. However, since Nushagak District catches have not been allocated to either of these systems in past years, additional returns would only be seen as spawning escapements (mean total escapement, 1978-87, 140 thousand).

[b] Forecasts for Kulukak, Kanik, Osviak, and Matogak River systems were not included. These systems may contribute an additional 106 thousand (mean total return, 1978-87) sockeye salmon to the total Togiak District return.

Total projected sockeye salmon harvest is expected to be 18.6 million with an 80% C.I. of 5.5 to 32.4 million (Table 2). While most of this harvest will be taken within Bristol Bay inshore fishing districts (16.8 million), some has been allocated to the Shumagin Islands and South Unimak fisheries under an existing management plan (8.3% of total Bristol Bay harvest: 1.5 million), while the remainder will be taken by the high seas Japanese mothership fishery (mean harvest, 1983-87, 0.3 million) (Table 3).

The total number of sockeye salmon expected to return to Bristol Bay, after high seas, Shumagin Islands, and South Unimak fisheries have occurred, is 26.5 million (Table 3). Returns should exceed spawning escapement goals for all river systems. The projected Bristol Bay combined fishing district harvest of 16.8 million would be about 24% (3.2 million) more than the 20-year (1968-87) mean harvest of 13.6 million (range: 0.7 to 37.3 million), but about 21% (4.5 million) less than the 10-year (1978-87) mean harvest of 21.3 million (range: 4.9 to 37.3 million).

River System Forecasts

Results from models were excluded from final river system forecast calculations if the fit of the model was not significant at the 75% level or the value of the input variable ($E_{r,y}$ or $S_{j,r,y}$) was outside the range of data used to build the model. If results from spawner-recruit, sibling and smolt models did not meet these criteria for a river system age class, the mean return of that age class to that river system for the past 10 years was used as the prediction.

Kvichak River

A total of 9,306,000 sockeye salmon (80% C.I.: 4,520,000 to 14,121,000) was forecasted to return to this system (Table 2). Sockeye salmon production within the Kvichak River system has followed a 5-year abundance cycle (Mathisen and Poe 1981). A return of 9,306,000 sockeye salmon to the Kvichak River system in 1988 would be 38% greater than the mean return of 6,743,000 sockeye salmon (range: 337,000 to 20,981,000) observed during equivalent "low cycle" years (1963, 1968, 1973, 1978, 1983).

Age-1.2. A prediction based on sibling data could not be made since no age-1.1 sockeye salmon were obtained from samples collected in 1987 (Table 4). Therefore, the age-1.2 forecast for this system was based upon spawner-recruit and smolt data. The spawner-recruit estimate of 5,894,000 was about 58% greater than the smolt estimate of 3,739,000. The final ADF&G method predicted return was 4,817,000 (80% C.I.: 2,358,000 to 7,275,000).

Age-2.2. The age-2.2 forecast for this system was based upon the spawner-recruit, sibling, and smolt data (Table 4). The smolt estimate of 4,877,000 was 62% greater than the spawner-recruit estimate of 3,013,000 and 470% greater than the sibling estimate of 856,000. The final ADF&G method predicted return was 2,915,000 (80% C.I.: 1,174,000 to 4,657,000).

Table 3. Projected commercial harvests of sockeye salmon returning to Bristol Bay, Alaska, river systems in 1988, based on results of the modified ADF&G method.

	Numbers of sockeye salmon (thousands)					
		High Seas	Shumagin	Bristol Bay		
District: System	Forecasted Total Production	Japanese Mothership Harvest	Islands-S. Unimak Harvest	Harvest	Spawning Goal	Total Return
NAKNEK-KVICHAK:						
Kvichak	9,306	88	499	3,718	5,000	8,718
Branch	427	4	23	215	185	400
Naknek	2,450	23	131	1,295	1,000	2,295
Total	12,182	115	654	5,228	6,185	11,413
EGEGIK	5,944	56	319	4,568	1,000	5,568
UGASHIK	3,422	32	184	2,506	700	3,206
NUSHAGAK:						
Wood	3,021	29	162	1,830	1,000	2,830
Igushik	1,166	11	63	892	200	1,092
Nuyakuk	1,834	17	98	1,218	500	1,718
Total	6,021	57	323	3,941	1,700	5,641
TOGIAK	733	7	39	537	150	687
TOTAL BRISTOL BAY	28,302	268[a]	1,519[b]	16,758	9,735	26,515

[a]Mean high seas Japanese mothership catch for 1983-87. Numbers were apportioned among river systems based on proportions in the forecast of total production.

[b]Guideline harvest calculated as 8.3% of projected Bristol Bay harvest. Numbers were apportioned among river systems based on proportions in the forecast of total production.

Table 4. Forecasted returns of major age classes of sockeye salmon to the Kvichak River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	10,490	5,894	90.0	10
2.2	3,569	3,013	97.5	10
1.3	3,569	1,562	99.5	10
2.3	1,134	315	95.0	10
	Total	10,784		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	0	[a]		6
2.2	3	856	99.5	8
1.3	8,321	1,696	99.0	9
2.3	552	283	90.0	9
	Total	2,835		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	83,470	3,739	75.0	10
2.2	53,260	4,877	99.5	10
1.3	23,590	566	99.5	9
2.3	1,937	[b]		9
	Total	9,182		

[a] Estimate not made; no siblings returned previous year.

[b] Estimate not made; smolt production less than values used for model.

Age-1.3. The age-1.3 forecast for this system was based upon spawner-recruit, sibling, and smolt data (Table 4). The spawner-recruit and sibling components produced similar estimates of 1,562,000 and 1,696,000, respectively. The smolt estimate of 566,000 was 176% less than the spawner-recruit estimate and 200% less than the sibling estimate. The final ADF&G predicted return was 1,275,000 (80% C.I.: 989,000 to 1,560,000).

Age-2.3. A prediction based on smolt data could not be made since age-II smolt production from the 1982 spawning escapement was less than the nine smolt production estimates used to build the model (Table 4). Therefore, the age-2.3 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit and sibling components produced similar predictions of 315,000 and 283,000, respectively. The final ADF&G method predicted return was 299,000 (80% C.I.: 0 to 628,000).

Branch River

A total of 427,000 sockeye salmon (80% C.I.: 256,000 to 600,000) was forecasted to return to this system (Table 2). A total return of 427,000 sockeye salmon to the Branch River in 1988 would be 14% less than the mean return of 497,000 for 1978-87 (range: 280,000 to 859,000), but 11% greater than the mean return of 383,000 for 1968-87 (range: 129,000 to 859,000). No smolt data were available for this system.

Age-1.2. The age-1.2 forecast for this system was based upon spawner-recruit and sibling data (Table 5). The spawner-recruit estimate of 200,000 was 42% greater than the sibling estimate of 141,000 sockeye salmon. The final ADF&G predicted return was 171,000 (80% C.I.:83,000 to 258,000).

Age-2.2. A prediction based on sibling data could not be made since no age-2.1 sockeye salmon were obtained from samples collected in 1987 (Table 5). Therefore, the age-2.2 forecast for this system was based only upon spawner-recruit data. The final ADF&G predicted return was 21,000 (80% C.I.: 8,000 to 34,000).

Age-1.3. The prediction based on sibling data was not used since the model was not significant at the 75% level (Table 5). Therefore, the age-1.3 forecast for this system was based only upon spawner-recruit data. The final ADF&G predicted return was 211,000 (80% C.I.: 164,000 to 258,000).

Age-2.3. Predictions based on spawner-recruit and sibling data were not used since neither model was significant at the 75% level (Table 5). The final ADF&G predicted return, based on the mean return of age-2.3 sockeye salmon for 1978-87, was 24,000 (80% C.I.: 0 to 50,000).

Naknek River

A total of 2,450,000 sockeye salmon (80% C.I.: 1,008,000 to 3,959,000) was forecasted to return to this system (Table 2). A total return of this size would be 40% less than the mean return of 4,086,000 for 1978-87 (range: 2,006,000 to 7,914,000) and 24% less than the mean return of 3,214,000 for 1968-87 (range: 724,000 to 7,914,000 million).

Table 5. Forecasted returns of major age classes of sockeye salmon to the Branch River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	215	200	90.0	10
2.2	96	21	75.0	9
1.3	96	211	95.0	10
2.3	239	12[a]	n.s.	10
	Total	444		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	< 1	141	75.0	8
2.2	0	[b]		3
1.3	143	158[a]	n.s.	9
2.3	4	3[a]	n.s.	8
	Total	302		

[a] Estimate not used; significance level greater than 75.0%.

[b] Estimate not made; no siblings returned previous year.

Age-1.2. Predictions based on spawner-recruit and sibling data were not used since neither model was significant at the 75% level (Table 6). Therefore, the age-1.2 forecast for this system was based only upon smolt data. The final ADF&G predicted return was 289,000 (80% C.I.: 141,000 to 437,000).

Age-2.2. Predictions based on spawner-recruit, sibling, and smolt data were not used since none of the models were significant at the 75% level (Table 6). The final ADF&G predicted return, based on the mean return of age-2.2 sockeye salmon for 1978-87, was 800,000 (80% C.I.: 322,000 to 1,278,000).

Age-1.3. Predictions based on spawner-recruit and smolt data were not used since the spawner-recruit model was not significant at the 75% level, and age-I smolt production from the 1983 spawning escapement was less than the four smolt production estimates used to build the smolt model (Table 6). Therefore, the age-1.3 forecast for this system was based only on sibling data. The final ADF&G predicted return was 702,000 (80% C.I.: 545,000 to 859,000).

Age-2.3. The prediction based on smolt data was not used since the model was not significant at the 75% level (Table 6). Therefore, the age-2.3 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 785,000 was 47% greater than the sibling estimate of 533,000. The final ADF&G predicted return was 659,000 (80% C.I.: 0 to 1,385,000).

Egegik River

A total of 5,944,000 sockeye salmon (80% C.I.: 2,883,000 to 9,101,000) was forecasted to return to this system (Table 2). A total return of this size would be similar to the mean return of 5,591,000 for 1978-87 (range: 2,229,000 to 9,016,000), but 57% greater than the mean return of 3,782,00 for 1968-87 (range: 790,000 to 9,016,000).

Age-1.2. The prediction based on sibling data was not used since the model was not significant at the 75% level (Table 7). Therefore, the age-1.2 forecast for this system was based upon spawner-recruit and smolt data. The smolt estimate of 881,000 was 262% greater than the spawner-recruit estimate of 337,000. The final ADF&G predicted return was 609,000 (80% C.I.: 298,000 to 920,000).

Age-2.2. The prediction based on smolt data was not used since the model was not significant at the 75% level (Table 7). Therefore, the age-2.2 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 2,201,000 was similar to the sibling estimate of 2,180,000. The final ADF&G predicted return was 2,191,000 (80% C.I.: 882,000 to 3,499,000).

Table 6. Forecasted returns of major age classes of sockeye salmon to the Naknek River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	1,242	496[a]	n.s.	10
2.2	888	571[a]	n.s.	10
1.3	888	1,095[a]	n.s.	10
2.3	1,155	785	90.0	10
	Total	2,947		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	< 1	409[a]	n.s.	8
2.2	6	999[a]	n.s.	7
1.3	140	702	75.0	9
2.3	216	533	75.0	9
	Total	2,653		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	22,144	289	75.0	4
2.2	19,148	557[a]	n.s.	3
1.3	6,307	b		4
2.3	13,370	524[a]	n.s.	3
	Total	1,370		

[a] Estimate not used; significance level greater than 75.0%.

[b] Estimate not made; smolt production less than values used for model.

Table 7. Forecasted returns of major age classes of sockeye salmon to the Egegik River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	1,165	337	97.5	10
2.2	792	2,201	75.0	10
1.3	792	656	75.0	10
2.3	1,034	990	97.5	10
	Total	4,184		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	1	842[a]	n.s.	6
2.2	7	2,180	75.0	9
1.3	1,753	3,734	99.5	9
2.3	1,794	908	75.0	9
	Total	7,664		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	14,016	881	75.0	4
2.2	29,984	3,868[a]	n.s.	4
1.3	54,586	b		3
2.3	11,435	c		3
	Total	4,749		

[a] Estimate not used; significance level greater than 75.0%.

[b] Estimate not made; smolt production greater than values used for model.

[c] Estimate not made; smolt production less than values used for model.

Age-1.3. A prediction based on smolt data was not made since age-I smolt production from the 1983 spawning escapement was greater than the three smolt production estimates used to build the smolt model (Table 7). Therefore, the age-1.3 forecast for this system was based upon spawner-recruit and sibling data. The sibling estimate of 3,734,000 was 569% greater than the spawner-recruit estimate of 656,000. The final ADF&G predicted return was 2,195,000 (80% C.I.: 1,703,000 to 2,687,000).

Age-2.3. A prediction based on smolt data was not made since age-II smolt production from the 1982 spawning escapement was less than the three smolt production estimates used to build the smolt model (Table 7). Therefore, the age-2.3 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 990,000 was only 9% greater than the sibling estimate of 908,000. The final ADF&G predicted return was 949,000 (80% C.I.: 0 to 1,995,000).

Ugashik River

A total of 3,422,000 sockeye salmon (80% C.I.: 1,623,00 to 5,264,000) was forecasted to return to this system (Table 2). A total return of this size would be only 11% less than the mean return of 3,838,000 for 1978-87 (range: 83,000 to 7,743,000), but 58% greater than the mean return of 2,169,000 for 1968-87 (range: 60,000 to 7,743,000).

Age-1.2. The prediction based on smolt data was not used since the model was not significant at the 75% level (Table 8). Therefore, the age-1.2 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 1,267,000 was 501% greater than the sibling estimate of 253,000. The final ADF&G predicted return was 760,000 (80% C.I.: 372,000 to 1,148,000).

Age-2.2. The prediction based on smolt data was not used since the model was not significant at the 75% level (Table 8). Therefore, the age-2.2 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 1,416,000 was 21% greater than the sibling estimate of 1,166,000. The final ADF&G predicted return was 1,291,000 (80% C.I.: 520,000 to 2,062,000).

Age-1.3. A prediction based on smolt data was not made since only two years of age-I smolt production and subsequent adult return data were available (Table 8). Therefore, the age-1.3 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 1,207,000 was 78% greater than the sibling estimate of 679,000. The final ADF&G predicted return was 943,000 (80% C.I.: 732,000 to 1,154,000).

Age-2.3. A prediction based on smolt data was not made since only two years of age-II smolt production and subsequent adult return data were available (Table 8). Therefore, the age-2.3 forecast for this system was based upon spawner-recruit and sibling data. The spawner-recruit estimate of 579,000 was 109% greater than the sibling estimate of 277,000. The final ADF&G predicted return was 428,000 (80% C.I.: 0 to 900,000).

Table 8. Forecasted returns of major age classes of sockeye salmon to the Ugashik River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	1,241	1,267	95.0	10
2.2	1,000	1,416	97.5	10
1.3	1,000	1,207	99.0	10
2.3	1,157	579	99.0	10
	Total	4,469		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	< 1	253	75.0	6
2.2	5	1,166	75.0	8
1.3	609	679	99.5	9
2.3	602	277	99.5	9
	Total	2,375		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	37,890	706[a]	n.s.	3
2.2	15,186	1,619[a]	n.s.	3
1.3	12,694	b		2
2.3	21,408	b		2
	Total	2,325		

[a]Estimate not used; significance level greater than 75.0%.

[b]Estimate not made; sample size too small for regression analysis.

Wood River

A total of 3,021,000 sockeye salmon (80% C.I.: 1,894,000 to 4,156,000) was forecasted to return to this system (Table 2). A total return of this size would be 15% less than the mean return of 3,569,000 for 1978-87 (range: 1,830,000 to 4,925,000), but 20% greater than the mean return of 2,529,000 for 1968-87 (range: 716,000 to 4,925,000).

Age-1.2. The prediction based on sibling data was not used since the model was not significant at the 75% level (Table 9). Therefore, the age-1.2 forecast for this system was based upon spawner-recruit and smolt data. The spawner-recruit estimate of 1,418,000 was 74% greater than the smolt estimate of 813,000. The final ADF&G predicted return was 1,116,000 (80% C.I.: 546,000 to 1,685,000).

Age-2.2. Predictions based on sibling and smolt data could not be made since no age-2.1 sockeye salmon were obtained from samples collected in 1987, and age-II smolt production from the 1983 spawning escapement was less than the 10 smolt production estimates used to build the smolt model (Table 9). Therefore, the age-2.2 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 190,000 (80% C.I.: 76,000 to 304,000).

Age-1.3. The age-1.3 forecast for this system was based upon spawner-recruit, sibling, and smolt data (Table 9). The spawner-recruit estimate of 1,792,000 was similar to the sibling estimate of 1,812,000 and 37% greater than the smolt estimate of 1,312,000. The final ADF&G predicted return was 1,639,000 (80% C.I.: 1,271,000 to 2,006,000).

Age-2.3. Predictions based on spawner-recruit and smolt data were not used since neither model was significant at the 75% level (Table 9). Therefore, the forecast was based only on sibling data. The final ADF&G predicted return was 77,000 (80% C.I.: 0 to 162,000).

Igushik River

A total of 1,166,000 sockeye salmon (80% C.I.: 776,000 to 1,561,000) was forecasted to return to this system (Table 2). A total return of this size would be 22% less than the mean return of 1,428,000 million for 1978-87 (range: 415,000 to 3,276,000), but 24% greater than the mean return of 938,000 for 1968-87 (range: 133,000 to 3,276,000). No smolt data were available for this system.

Age-1.2. A prediction based on sibling data was not made since no age-1.1 sockeye salmon were obtained from samples collected in 1987 and only two years of data were available to build the model (Table 10). Therefore, the age-1.2 forecast was based only upon results from spawner-recruit data. The final ADF&G predicted return was 247,000 (80% C.I.: 121,000 to 373,000).

Age-2.2. A prediction based on sibling data was not made since no age-2.1 sockeye salmon were obtained from samples collected in 1987 (Table 10).

Table 9. Forecasted returns of major age classes of sockeye salmon to the Wood River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	1,002	1,418	95.0	10
2.2	1,360	190	75.0	10
1.3	1,360	1,792	99.5	10
2.3	976	88[a]	n.s.	10
	Total	3,488		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	< 1	866[a]	n.s.	7
2.2	0	[b]		5
1.3	1,953	1,812	95.0	9
2.3	133	77	97.5	9
	Total	2,755		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	27,466	813	97.5	10
2.2	597	[c]		10
1.3	31,950	1,312	95.0	10
2.3	4,690	75[a]	n.s.	10
	Total	2,200		

[a] Estimate not used; significance level greater than 75.0%.

[b] Estimate not made; no siblings returned previous year.

[c] Estimate not made; smolt production less than values used for model.

Table 10. Forecasted returns of major age classes of sockeye salmon to the Igushik River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	184	247	99.5	10
2.2	180	40	95.0	10
1.3	180	948	99.5	10
2.3	423	55	75.0	10
	Total	1,290		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	0	[a,b]		2
2.2	0	[a]		3
1.3	150	700	97.5	9
2.3	9	18[c]	n.s.	9
	Total	718		

[a] Estimate not made; no siblings returned previous year.

[b] Estimate not made; sample size too small for regression analysis.

[c] Estimate not used; significance level greater than 75.0%.

Therefore, the age-2.2 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 40,000 (80% C.I.: 16,000 to 64,000).

Age-1.3. The age-1.3 forecast for this system was based upon spawner-recruit and sibling data (Table 10). The spawner-recruit estimate of 948,000 was 35% greater than the sibling estimate of 700,000. The final ADF&G predicted return was 824,000 (80% C.I.: 639,000 to 1,009,000).

Age-2.3. The prediction based on sibling data was not used since the model was not significant at the 75% level (Table 10). Therefore, the age-2.3 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 55,000 (80% C.I.: 0 to 116,000).

Nuyakuk River

A total of 1,834,000 sockeye salmon (80% C.I.: 1,280,000 to 2,396,000) was forecasted to return to this system (Table 2). A total return of this size would be 11% less than the mean return of 2,072,000 for 1978-87 (range: 792,000 to 5,053,000 million), but 45% greater than the mean return of 1,268,000 for 1968-87 (range: 93,000 to 5,053,000). The 1988 forecasts for all age classes were based only on spawner-recruit data (Table 11).

Age-1.2. The final ADF&G predicted return was 273,000 (80% C.I.: 134,000 to 412,000).

Age-2.2. The final ADF&G predicted return was 11,000 (80% C.I.: 4,000 to 18,000).

Age-1.3. The final ADF&G predicted return was 1,472,000 (80% C.I.: 1,142,000 to 1,802,000).

Age-2.3. The final ADF&G predicted return was 78,000 (80% C.I.: 0 to 164,000).

Togiak River

A total of 733,000 sockeye salmon (80% C.I.: 476,000 to 992,000) was forecasted to return to this system (Table 2). A total return of this size would be similar to the mean return of 697,000 for 1978-87 (range: 296,000 to 1,173,000), but 42% greater than the mean return of 518,000 for 1968-87 (range: 137,000 to 1,173,000). No smolt data were available for this system.

Age-1.2. A prediction based on sibling data was not made since no age-1.1 sockeye salmon were obtained from samples collected in 1987 (Table 12). Therefore, the age-1.2 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 239,000 (80% C.I.: 117,000 to 361,000).

Age-2.2. A prediction based on sibling data was not made since no age-2.1 sockeye salmon have ever been obtained from samples (Table 12). Therefore, the age-2.2 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 28,000 (80% C.I.: 11,000 to 45,000).

Table 11. Forecasted returns of major age classes of sockeye salmon to the Nuyakuk River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit data.

		Spawner-Recruit Data		
Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	472	273	99.0	9
2.2	318	11	90.0	9
1.3	318	1,472	99.5	9
2.3	537	37[a]	n.s.	8
	Total	1,793		

[a] Estimate not used; significance level greater than 75.0%.

Table 12. Forecasted returns of major age classes of sockeye salmon to the Togiak River system, Bristol Bay, Alaska, in 1988 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	150	239	99.5	10
2.2	212	28	95.0	10
1.3	212	448	99.5	10
2.3	288	22	95.0	10
	Total	737		

Sibling Data

Age Class	Sibling Return in 1987 (thousands)	Predicted Return (thousands)	Significance Level (%)	Sample Size
1.2	0	[a]		4
2.2	0	[a,b]		0
1.3	285	[c]		9
2.3	14	14	97.5	9
	Total	14		

[a] Estimate not made; no siblings returned previous year.

[b] Estimate not made; sample size too small for regression analysis.

[c] Estimate not made; siblings return in 1987 greater than values used for model.

Age-1.3. A prediction based on sibling data was not made since age-1.2 sockeye salmon returns in 1987 were greater than any of the nine values used to build the model (Table 12). Therefore, the age-1.3 forecast was based only on spawner-recruit data. The final ADF&G predicted return was 448,000 (80% C.I.: 348,000 to 548,000).

Age-2.3. The age-2.3 forecast for this system was based upon spawner-recruit and sibling data (Table 12). The spawner-recruit estimate of 22,000 was 57% greater than the sibling estimate of 14,000. The final ADF&G estimate was 18,000 (80% C.I.: 0 to 38,000).

Expected Forecast Performance

Modified ADF&G method hindcasts were less biased (i.e., MPE was closest to zero: -8.2) and had a smaller mean error (MAPE: 17.8) than predictions based on the other three methods for the 4 years that could be examined (Table 13). Annual performance, however, was quite variable. Modified ADF&G method hindcasts were more accurate than JRVC method forecasts in 3 out of 4 years but were more accurate than either old ADF&G method or composite forecast only in 2 out of 4 years.

While we selected the forecast based on the modified ADF&G method as our best estimate of sockeye salmon run size for 1988, the large differences among the four forecasting methods examined suggested that the most likely deviations from our forecast would be less than expected returns for all age classes returning to all systems. Sockeye salmon run size predictions based on results from the old ADF&G method (18.1 million), the JRVC method (15.1 million), and the composite of these two methods (16.7 million), were 36, 47, and 41% less, respectively, than that based on the modified ADF&G method (28.3 million) (Table 1). However, a total sockeye salmon return less than 20.0 million has not been recorded since 1977, and published forecasts (based on either the past ADF&G method or a composite of methods) for 13 of the last 14 years have been less than total run size.

Outlook to 1991

Forecasts for 1989-91 based on spawner-recruit data, when compared to spawner-recruit estimates used for the 1988 forecast, suggested that the total number of sockeye salmon returning to Bristol Bay will be greatest in 1989 and least 1991, mostly due to variations in returns to the Kvichak River system (Table 14). Declining returns were indicated for both the Egegik and Ugashik River systems after 1989, but returns to most other systems will be fairly stable.

Fried and Yuen (1987) had previously suggested that sockeye salmon production for 1987-90 might be adversely affected by what appeared to be the advent of less favorable environmental conditions: cooler than average June air temperatures during the 3 years each brood year spent at sea (Figure 1). At that time we noted a strong positive correlation (r=0.635, significant at the 99% level) between deviations from the mean number of sockeye salmon adults

Table 13. Annual percent errors, mean percent errors (MPE), and mean absolute percent errors (MAPE) for forecasts of total sockeye salmon returns to Bristol Bay, Alaska, 1984-87, based on results of several methods.

	Forecast Method			
	ADF&G			
Year	Old	Modified	JRVC	Composite
1984	-2.6	-17.6[a]	-67.6[a]	-27.0[b]
1985	-34.3	-23.1[a]	14.8	-9.1[c]
1986	-2.9	19.3[a]	-29.5	-7.8[c]
1987	-44.9	-11.3[a]	-38.2	-41.7[c]
MPE	-21.2	-8.2	-30.1	-21.4
MAPE	21.2	17.8	37.5	21.4

[a] Based on hindcasted estimates, using data only prior to the year for which the estimate was made (JRVC: Fried and Yuen 1986).

[b] Based on weighted mean of old ADF&G, Japanese Gill Net CPUE, Temperature-Length, Escapement-Temperature, and Bay-wide Sibling Return models (Eggers et al. 1983b).

[c] Based on weighted mean of old ADF&G and JRVC models (1984-87 results from Fried and Yuen 1985, 1986, and 1987).

Table 14. Preliminary forecasts of sockeye salmon returns to Bristol Bay, Alaska, 1988-91, based only on spawner-recruit data.

DISTRICT: River System	Number of Sockeye Salmon (thousands) 1988	1989	1990	1991
NAKNEK-KVICHAK:				
Kvichak	10,784	17,313	11,029	6,699
Branch	456	376	457	383
Naknek	3,785	3,685	3,815	4,001
Total	15,025	21,374	15,301	11,083
EGEGIK	4,184	5,213	4,820	4,909
UGASHIK	4,469	4,744	4,284	3,917
NUSHAGAK:				
Wood	3,541	3,552	3,479	3,530
Igushik	1,290	1,299	1,397	1,506
Nuyakuk	1,834	2,166	2,153	2,323
Total	6,665	7,017	7,029	7,359
TOGIAK	737	749	710	655
TOTAL BRISTOL BAY	31,080	39,097	32,144	27,923

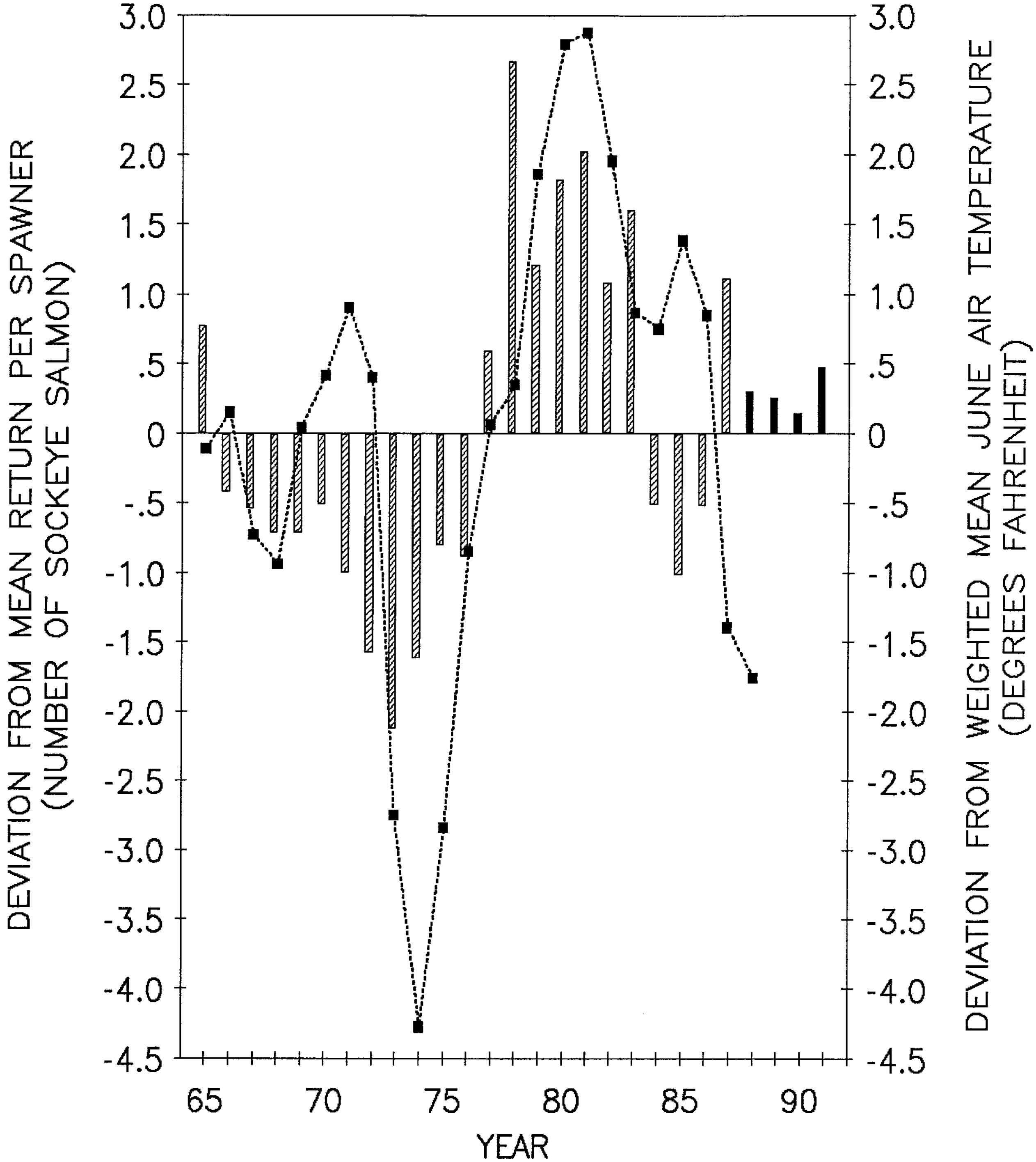

Figure 1. Annual deviations from the mean number of returning Bristol Bay, Alaska, sockeye salmon produced per spawner (bar chart) and mean Cold Bay, Alaska, June air temperature (line chart), 1965-87. Deviations from forecasted return per spawner values are shown for 1988-91 (solid bars).

produced per spawner (RPS) and deviations from the mean June air temperature index for the period 1965-86. However, the RPS value for brood years contributing to 1987 returns (3.6) was much greater than average (mean, 1965-87: 2.5), even though the temperature index was much less than average. While the addition of this data pair did not affect the statistical significance of the correlation (r=0.578, significant at the 99% level), there have been other departures from the expected relationship in recent years (e.g. the occurrence of below average RPS values for the 1984 and 1985 return years during a period when air temperature indices were above average). These occurrences suggested that the strong relationship observed between RPS values and air temperature indices may be deteriorating.

While we do not expect production to fall to the levels observed prior to 1978 (mean RPS, 1965-77: 1.5; range: 0.3-3.1), when large numbers of sockeye salmon were captured on the high seas by foreign vessels, we also do not anticipate sockeye salmon production to attain the extremely high levels observed during 1978-83 (mean RPS: 4.2; range: 3.6-5.1). Rather, we think that sockeye salmon production from brood years contributing to returns in 1988-91 (mean RPS: 2.8; range: 2.6-2.9) will be slightly greater than the long-term, 1966-87, average (mean RPS: 2.5). This level of production would be better than that realized for the last three return years (mean RPS, 1984-86: 1.8; range: 1.4-2.0).

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