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A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON (Oncorhynchus nerka) RETURNING TO BRISTOL BAY IN 1985

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

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A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON *(Oncorhynchus nerka)* RETURNING TO BRISTOL BAY IN 1985

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

By

Stephen M. Fried

and

Henry J. Yuen

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

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ABSTRACT

This report reviews forecasts made by the Alaska Department of Fish and Game (ADF&G) of the return of sockeye salmon *(Oncorhynchus nerka)* to Bristol Bay, Alaska, in 1985. Forecasts for individual river systems by major age classes based upon spawner-recruit relationships (1979, 1980, and 1981 spawning escapements), return of sibling age classes in 1984, and estimates of smolt production and survival (1982 and 1983 smolt seaward migrations) were combined with forecasts for all of Bristol Bay by ocean age group, based upon information collected by Japanese research vessels, to yield a 1985 total return estimate of 35.0 million sockeye salmon. The final pooled forecast weighted results of the Standard ADF&G and Japanese Research Catches methods equally since their past performance has been similar. However, the Japanese Research Catches method produced a higher prediction of two-ocean sockeye salmon returns (4_2 and 5_3 age classes, 34.1 million) and a lower prediction of three-ocean returns (5_2 and 6_3 age classes, 7.8 million) than the Standard ADF&G method (12.4 million two-ocean; 12.9 million three-ocean returns). A great deal of uncertainty was associated with predicting returns to the Kvichak River system, which generally accounts for about 30% or more of the total return to Bristol Bay. Within the Standard ADF&G method, the spawner-recruit estimate for the dominant age class returning to the Kvichak system (5_3 sockeye salmon, 18.1 million) was eight times greater than the sibling returns estimate (2.3 million) and three times greater than the smolt production-survival estimate (5.7 million). Since smolt and sibling estimates were based on more recent information than was the spawner-recruit estimate, the spawner-recruit estimate for 5-year-old sockeye salmon returning to the Kvichak system was not used in calculating the final Standard ADF&G prediction. If the Japanese Research Catches two-ocean estimate for 1985 is more accurate than the Standard ADF&G estimate, actual returns to the Kvichak River could be twice as great as that indicated in the pooled forecast. Furthermore, actual returns to other systems would also be altered from those within the pooled forecast, probably resulting in lower than predicted returns to west side systems (Nushagak and Togiak Districts) and higher than predicted returns to east side systems (Egegik and Ugashik Districts, as well as Naknek-Kvichak District).

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

INTRODUCTION

The purpose of this report is to provide is to provide a final pre-season forecast for sockeye salmon *(Oncorhynchus nerka)* returns to Bristol Bay, Alaska, in 1985. Specific objectives are as follows: (1) to present results of the various methods used to forecast sockeye salmon returns to Bristol Bay in 1985, (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 production-survival estimates for individual age classes and river-lake systems. Forecasts obtained from this method, referred to as the Standard ADF&G method, have usually been within 47% of actual total run size. Other forecast methods have also been developed by ADF&G, 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. Although only 2 years of data are available for comparison, results of these attempts were promising since forecasts for both years were within about 25% of actual total run size. The 1985 pre-season forecast is for a total return of 35.3 million sockeye salmon, based upon the weighted mean of the results of two methods: (1) Standard ADF&G and (2) Japanese Research Catches.

METHODS

Standard ADF&G

The Standard ADF&G method provided forecasts for individual river-lake systems and major age classes. Ages 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): 4_2, 5_3, 5_2, and 6_3 (4-, 5-, and 6-year-old sockeye salmon which spent either 2 or 3 years within freshwater). Three components were included within the Standard ADF&G method: (1) spawner-recruit relationships, (2) sibling age class returns, and (3) smolt production-survival estimates. If more than one estimate was available within a component, these results were weighted equally and averaged to produce a single result for each component. Results of each of these three components, if available, were weighted equally and averaged for each system and age class. In some cases a result within or 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:

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

$$R = aEe^{-bE} \text{ , where}$$

R = total number of recruits returning in years n+4, n+5, and n+6 (i.e., returns four, five, and six years after spawning),

E = number of spawners in brood year n,

a and b = parameters which determine curve shape.

Predicted returns (number of recruits) for 1985 were based upon parental escapements (number of spawners) for 1979 (for 6_3 returns), 1980 (for 5_3 and 5_2 returns), and 1981 (for 4_2 returns). Predictions for each age class were calculated using the following general relationship:

$$R_i = M_i \; R = \text{ , where}$$

R_i = return of age class i (i.e., n+i years after spawning), and

M_i = mean proportion of age class i within past returns based upon either all years or only comparable cycle years (for Kvichak or Wood systems).

For example, the number of 5_3 sockeye salmon expected to return to a system in 1985 was based upon the spawning escapement to that system in 1980 multiplied by the mean proportion of the total return from past escapements which returned as age 5_3.

In cases where actual returns to date for a brood year were already greater than that expected from the spawner-recruit relationship, predictions for the 5_3 and 5_2 age classes were calculated using the following equation:

$$R = A \; / \; M_4 \text{ , where}$$

A = actual returns of 4_2 age class, and

M_4 = mean proportion of 4_2 age class within past returns;

while predictions for the 6_3 age class were calculated using the following equation:

$$R = A \; / \; (1\text{-}M_6) \text{ , where}$$

A = actual returns of 4_2, 5_3, and 5_2 age classes, and

M_6 = mean proportion of 6_3 age class within past returns.

Sibling Age Classes:

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

$$\ln [R_{iy}] = a + b \ln [R_{(i-1)y}] \text{ , where}$$

$\ln [R_{iy}]$ = 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,

a and b = intercept and slope of line, respectively.

The second was a ratio estimator with the general form:

$$R_{iy} = R_{(i-1)y} \sum_{j=n}^{(y-1)} [(R_{ij} / R_{(i-1)j})] / [(y-1)-n] \text{ , where}$$

n = first year of available data,

y-1 = year prior to forecasted return, and

[(y-1)-n] = total number of years of data available.

For example, the number of 5_3 salmon expected to return to a system in 1985 was based upon the number of 4_3 sockeye salmon that returned to that system in 1984. In the regression model, the natural logarithm of the number of 4_3 sockeye salmon that returned in 1984 was entered into an equation to predict the number of 5_3 salmon expected to return in 1985. In the ratio estimator, the number of 4_3 sockeye salmon that returned in 1984 was multiplied by the average ratio of 5_3 to 4_3 sockeye salmon recorded for past brood years.

Smolt Production-Survival:

Predicted returns from smolt studies were calculated only for Kvichak, Wood, and Nuyakuk River systems. Both Kvichak and Wood systems have a relatively extensive data base relating numbers of seaward migrating smolt to corresponding adult returns. Enumeration programs using sonar were initiated for these systems in 1971 and 1975, respectively. The Nuyakuk system program is relatively new; it has only been operated since 1983. However, attempts

were made to use Nuyakuk smolt information for a 1985 forecast since spawner-recruit estimates, based on record escapements, were considered unreliable, and data for sibling age classes was not available for two major age classes. Although smolt programs have been operated for Naknek and Egegik systems since 1982, and for Ugashik system since 1983, predictions of 1985 adult returns were not made since both spawner-recruit and sibling age classes estimates could be made.

Two methods were used to predict adult returns using smolt data. The first method was based upon estimates of mean survival and age of maturity and had the general equation:

$$R_{i_{(y+i)}} = S_k \times P_k \times Q_{ki} \text{ , where}$$

R_i = returns of age class i in year (y+i),

y = brood year (year of parental spawning),

S_k = number of age k smolt from brood year y (where k = age I or II, corresponding to smolt spending either two or three years in freshwater, respectively),

P_k = proportion of age k smolt which survive to maturity, and

Q_{ki} = proportion of age k smolt which return as age class i adults.

For example, the number of 5_3 sockeye salmon expected to return to a system in 1985 was based upon the number of age II smolt which migrated from that system in 1983 (i.e., progeny of 1980 spawning escapement) multiplied by the mean proportion of age II smolt which survive to maturity and the mean proportion of surviving age II smolt which mature at age 5_3.

The second method, used only for the Kvichak River system, included environmental effects upon smolt survival and maturity and had the general equation:

$$R_i = S_k \times Z \times H \text{ , where}$$

Z = proportion of smolt surviving and maturing to age i, and
H = a + bT, where T = mean June air temperature (°C) at Port Heiden during year of smolt migration, a and b = parameters which determine intercept (a) and slope (b) of line, respectively. For example, the number of 5_3 sockeye salmon expected to return to the Kvichak River system in 1985 was based upon the number of age II smolt which migrated from that system in 1983 (i.e., produced by the 1980 escapement) multiplied by the mean proportion of age II smolt which survive and mature at age 5_3 (estimated from the 1983 mean June air temperature at Port Heiden).

Japanese Research Catches

The Japanese Research Catches method provided a forecast of total sockeye salmon returns to Bristol Bay by two- (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 1984 (Takagi and Ito 1984) along with environmental effects within a multiple linear regression model:

$$R_m = a + b_1 G_{k-1} + b_2 L_k + b_3 C_k \text{ , where}$$

R_m = returns of ocean age group m,

G_{m-1} = geometric mean CPUE of ocean age group m-1,

L_{m-1} = mean fork length (mm) of ocean age group m-1, and

C_m = mean June Cold Bay air temperature(s) (°F) during year(s) of sockeye salmon ocean residence.

For example, the number of three-ocean (5_2 and 6_3) sockeye salmon expected to return to Bristol Bay in 1985 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 1984 and the sum of mean June Cold Bay air temperatures for 1983 and 1984.

In past years, this data was used to produce two separate forecasts, one based only upon geometric mean CPUE (Japanese High Seas Sampling method) and the other based upon both mean fork length and mean June Cold Bay air temperatures (Temperature-Length Model method) (Eggers, Meacham, and Yuen 1983 a and b). Combining all data into a single equation simplified the final pooling procedure and should not affect forecast accuracy.

Other Forecasting Techniques

Three other techniques have been used in past years to predict total returns of sockeye salmon to Bristol Bay (Eggers, Meacham, and Yuen 1983a and b): (1) Adak Purse Seine Catches, (2) Escapement-Temperature Model, and (3) Bay-Wide Sibling Returns methods. The first was based upon results of a University of Washington, Fisheries Research Institute, test fishing program in the Aleutians. However, this program has been discontinued. The second and third methods were not independent of results produced by the Standard ADF&G method, since predictions of total returns to Bristol Bay were made using combined spawning escapements, total returns, and sibling age class returns for each brood year for all of Bristol Bay. Since pooling results of these two methods with results of the Standard ADF&G method simply serves to give more weight to predictions based upon the spawner-recruit relationship and sibling age class returns, these two methods were not used in producing the 1985 forecast.

Pooling Forecast Results

Results of the Standard ADF&G and Japanese Research Catches methods were pooled based upon the past performance of each method in forecasting sockeye salmon returns to Bristol Bay (Tables 1 and 2). Past performance was estimated by fitting a linear regression model to observed and forecasted returns for each method and calculating standard errors (Table 3). A pooled forecast for each ocean age class was calculated from results of the Standard ADF&G and Japanese Research Catches methods using the inverse of their variances as weighting factors (Snedecor and Cochran 1969):

$$F_k = \frac{[F_{ADF\&G_k} \times (1/V_{ADF\&G_k})] + [F_{JRC_k} \times (1/V_{JRC_k})]}{(1/V_{ADF\&G_k}) + (1/V_{JRC_k})} \text{ , where}$$

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

$F_{ADF\&G_k}$ = Standard ADF&G forecast for returns of ocean age group k,

$V_{ADF\&G_k}$ = varance (standard error squared) of Standard ADF&G forecast of ocean age group k,

F_{JRC_k} = Japanese Research Catches forecast for returns of ocean age group k, and

V_{JRC_k} = variance of Japanese Research Catches forecast of ocean age group k.

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

$$V_k = \text{sqrt}[(V_{ADFG_k} + V_{JRC_k}) / 2] \text{ , where}$$

V_k = variance for pooled forecast of ocean age group k.

The standard error of the pooled total forecast was calculated as:

$$SE_t = \text{sqrt}[(V_2 + V_3) / 2] \text{ , where}$$

SE_t = standard error for pooled forecast of total returns.

Finally, the 80% confidence interval for the pooled forecast of total returns was estimated using the following relationship:

$$80\% \text{ C.I.} = t_{0.20[N-2]} \times SE_t] \text{ , where}$$

$t_{0.20\,[N-2]}$ = Student's t value with a probability of type I error of 0.20 and (N-2) degrees of freedom (a two-tailed test) = $t_{0.20[18]} = 1.33$.

Table 1. Comparisons of forecasts of total sockeye salmon returns to Bristol Bay, 1961-1984, made using three methods.

Year	Forecast (millions)			Actual Return (millions)		
					Total[4]	
	Standard ADF&G[1]	Japanese Research Catches[2]	Weighted Mean[3]	Inshore	All Age Classes	Only Major Age Classes
1961	43.6			18.1	24.2	
1962	19.6			10.4	11.4	
1963	8.6			6.9	7.9	
1964	17.4			10.9	11.2	
1965	27.8			53.1	60.1	
1966	31.3			17.5	19.4	
1967	13.7			10.3	11.2	
1968	10.4			8.0	8.9	
1969	21.3			19.0	21.1	
1970	55.8			39.4	43.4	
1971	15.2			15.8	17.9	
1972	9.7			5.4	6.7	
1973	6.2	7.1		2.4	3.3	3.0
1974	5.0	8.7		10.9	11.4	11.3
1975	12.0	13.7		24.2	25.6	25.2
1976	12.0	23.1		11.5	12.5	11.8
1977	8.4	29.4		9.7	10.4	10.2
1978	11.5	18.7		19.8	20.3	19.6
1979	22.7	34.5		39.8	40.1	39.6
1980	54.5	61.8		62.4	63.0	62.5
1981	26.7	27.5		34.5	35.3	35.2
1982	34.6	20.1		22.1	22.6	22.3
1983	27.1	40.7	33.4	45.8	46.1	45.6
1984	41.5	[5]	31.1	41.0	41.3	40.9
1985	25.3	41.9	35.0	?	?	?

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

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

[3] Forecast 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 high seas catch estimates.
Major age classes refer only to 4_2, 5_3, 5_2, and 6_3.

[5] No estimate made since research vessels fished in different area.

Table 2. Comparisons of forecasts of one- and two-ocean sockeye salmon returns to Bristol Bay, 1973-1984, made using two methods.

	Forecast (millions)					
	Standard ADF&G [1]		Japanese Research Catches [2]		Actual Return [3] (millions)	
Year	Two-ocean	Three-ocean	Two-ocean	Three-ocean	Two-ocean	Three-ocean
1973	2.7	3.5	2.0	2.4	0.5	2.5
1974	3.6	1.4	3.2	2.8	9.0	2.3
1975	9.0	3.0	7.0	4.2	19.3	5.9
1976	5.7	6.3	14.5	6.4	7.3	4.5
1977	4.1	4.3	21.2	6.1	4.7	5.5
1978	7.8	3.7	7.8	8.5	12.1	7.5
1979	17.0	5.7	22.0	10.6	32.1	7.5
1980	41.2	13.4	50.6	20.1	46.2	16.3
1981	12.9	13.8	15.7	9.7	16.0	19.2
1982	22.0	12.6	4.8	13.0	5.5	16.8
1983	18.8	8.3	30.9	8.1	37.4	8.2
1984	22.7	18.8	[4]	[4]	28.4	12.5
1985	12.4	12.9	34.1	7.8	?	?

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

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

[3] Included high seas catch estimates.
Major age classes refer only to 4_2, 5_3, 5_2, and 6_3.

[4] No estimate made since research vessels fished in different area.

Table 3. Accuracy of forecasts of sockeye salmon returns to Bristol Bay, 1961-1984, based upon linear regressions forecasted against actual returns.

Time Period	Age Classes Examined: Forecast	vs Actual	Standard Error of Regression (millions)
		Standard ADF&G	
1961-84	Major [1]	All [2]	11.36
1973-84	Major [1]	All [2]	9.30
1973-84	Major [1]	two-&three-ocean	9.25
1973-1984	two-ocean [3]	two-ocean	9.25
1973-1984	three-ocean [4]	three-ocean	3.27
		Japanese Research Catches	
1973-83	two-&three-ocean	All [2]	9.22
1973-83	two-&three-ocean	two-&three-ocean	9.23
1973-83	two-ocean	two-ocean	8.48
1973-83	three-ocean	three-ocean	3.85

[1] Includes returns of only 4_2, 5_3, 5_2, and 6_3 age classes.

[2] Includes returns of all age classes.

[3] Two-ocean returns are only for 4_2 and 5_3 age classes.

[4] Three-ocean returns are only for 5_2 and 6_3 age classes.

The pooled forecast of total run size was 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 25.3 and 41.9 million sockeye salmon, respectively (Table 1). The Japanese Research Catches method produced a higher two-ocean age group prediction (34.1 million) and a lower three-ocean age group prediction (7.8 million) than the Standard ADF&G method (12.4 and 12.9 million two- and three-ocean returns, respectively) (Table 2). Large 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 35.0 million sockeye salmon (Table 4), with an 80% confidence interval of 26.0 to 44.0 million (standard error of forecast, 6.76). Total projected harvest was 20.3 million sockeye salmon (Table 4), with an 80% confidence interval of 12.5 to 29.3 million (assuming the proportion of the total run returning to individual systems remained constant for total Bristol Bay runs ranging from 26.0 to 44.0 million).

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 except Kvichak River system 5_3 sockeye salmon), sibling age classes (used for all systems and age classes), and smolt production-survival (used for Kvichak, Wood, and Nuyakuk River systems only). Cases in which results of a component were 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. If more than one estimate was available within a single component, the unweighted mean was used as the component result.

Kvichak River

A total of 12.2 million sockeye salmon was forecasted to return to this system based upon the pooled results of the Standard ADF&G and Japanese Research Catches methods (Table 4). There was a great deal of uncertainty in calculating the Standard ADF&G method prediction for this system since spawner-recruit component results for 5-year-old sockeye salmon (primarily the 5_3 age class from the 1980 brood year spawning escapement) were much higher than results from either the sibling age classes or smolt production-survival components (Table 6). The Standard ADF&G method prediction for total returns to this system was 8.6 million sockeye salmon (Table 5). However, there was a large difference in estimated two-ocean returns to Bristol Bay between the Standard ADF&G and Japanese Research Catches methods.

Table 4. Forecasted returns of major age classes of sockeye salmon to Bristol Bay river-lake systems and commercial fishing districts in 1985 based upon pooled results of Standard ADF&G and Japanese Research Catches methods. Spawning escapement goals and resulting projected harvests are indicated.

	Numbers of sockeye salmon (thousands)						
	Forecasted Return by Age Class						
District: System	4 2	5 3	5 2	6 3	Total	Spawning Escapement Goal	Projected Harvest
Naknek-Kvichak:							
Kvichak	938	7,841	1,271	2,132	12,182	10,000	2,182
Branch	137	174	117	43	471	185	286
Naknek	1,094	1,972	1,022	780	4,868	1,000	3,868
Total	2,169	9,987	2,410	2,955	17,521		6,336
Egegik	287	4,138	704	1,461	6,590	1,000	5,590
Ugashik	881	3,391	824	525	5,621	700	4,921
Nushagak:							
Wood	950	474	835	75	2,334	1,000	1,334
Igushik	187	16	62	42	307	200	107
Nuyakuk	1,119	57	497	33	1,706	500	1,206
Total	2,256	547	1,394	150	4,347		2,647
Togiak	398	215	305	31	949	150	799
Total Bristol Bay [1]	5,991	18,278	5,637	5,122	35,028		20,293

[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 1985. (See Table 4 for actual pre-season forecast based upon pooled results of Standard ADF&G and Japanese Research Catches methods.)

	Numbers of sockeye salmon by age class (thousands)				
District:	4	5	5	6	
System	2	3	2	3	Total
Naknek-Kvichak District:					
Kvichak	481	4,021	1,521	2,552	8,575
Branch	70	89	140	52	351
Naknek	561	1,011	1,223	934	3,729
Total	1,112	5,121	2,884	3,538	12,655
Egegik District	147	2,122	842	1,749	4,860
Ugashik District	452	1,739	986	628	3,805
Nushagak District:					
Wood River	487	243	999	90	1,819
Igushik River	96	8	74	50	228
Nuyakuk River	574	29	595	40	1,238
Total	1,157	280	1,668	180	3,285
Togiak District	204	110	365	36	715
Total Bristol Bay[1]	3,072	9,372	6,745	6,132	25,321

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

Table 6. Forecasted returns of major age classes of sockeye salmon to Kvichak River system, Bristol Bay, in 1985 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	1,754	1.5847	0.2320	645
5_3	17,505[1]	1.9135	0.5404	18,101
5_2	17,505[1]	1.9135	0.1114	3,731
6_3	11,218	3.6519[2]	0.1041	4,265

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[3]	Predicted Return (thousands) Based on Ratio for Comparable Cycle Years
5_3	14 (4_3)	2,340 (0.70)	N/A
5_2	2,811 (4_2)	885 (0.76)	693
6_3	17,029 (5_3)	1,166 (0.56)	2,597

-Continued-

Table 6. Forecasted returns of major age classes of sockeye salmon to Kvichak River system, Bristol Bay, in 1985 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method (continued).

Smolt Component

Technique A (based upon mean survival and maturity:

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	6,549	0.0850	0.6359	354
5_3	76,245	0.1062	0.9422	7,630
5_2	122,928	0.0850	0.1875	1,960
6_3	81,113	0.1062	0.1267	1,091

Technique B (based upon environmental effects upon survival):

Age Class	Mean January Air Temp. in Year Smolt Enter Sea (°F)[4]	Smolt Production (thousands)	Estimated Survival of Age Class of Interest	Predicted Return (thousands)
4_2	24.6	6,549	0.0425	278
5_3	24.6	76,245	0.0495	3,774
5_2	29.8	122,928	0.0207	2,545
6_3	29.8	81,113	0.0238	1,930

[1] 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.

[2] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

[4] Mean January air temperatures at Cold Bay, Alaska.

If total two-ocean returns exceed those predicted by the pooled forecast, a large proportion of these sockeye salmon could return to the Kvichak system. This would result in an actual return to the Kvichak system that could be twice as high as that indicated by the pooled forecast. 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 1984. Therefore, the 4_2 age class forecast for this system was based upon results from spawner-recruit and mean smolt components which produced estimates of 0.6 to 0.3 million, respectively. This resulted in a Standard ADF&G predicted return of 0.5 million 4_2 sockeye salmon and a final pooled predicted return of 0.9 million.

5_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 because of a velocity barrier on the Newhalen River caused by extremely high water conditions (Poe and Mathisen 1980). Even when this loss was accounted for, an escapement of 17.5 million was estimated to produce a return of 18.1 million 5_3 sockeye salmon, based upon Ricker type spawner-recruit model using data from 1956-1978. This estimate was about eight times greater than the 2.3 million estimate based upon sibling age classes, and about three times greater than the 5.7 million estimate based upon the mean of the two smolt production-survival results. The spawner-recruit estimate was omitted from the final ADF&G method forecast for this system, resulting in a Standard ADF&G predicted return of 4.0 million 5_3 sockeye salmon and a final pooled predicted return of 7.9 million.

5_2:

The spawner-recruit component result of 3.7 million 5_2 sockeye salmon returns was about five times greater than the sibling age classes estimate of 0.8 million and about three times greater than the mean smolt production-survival estimate of 2.3 million. Although these disparities were not as great as those noted for 5_3 age class returns, the spawner-recruit estimate was omitted from the final ADF&G method forecast for this system to maintain consistency within this brood year. This resulted in a Standard ADF&G predicted return of 1.5 million 5_2 sockeye salmon and a final pooled predicted return of 1.3 million.

6_3:

Spawner-recruit, mean sibling age classes, and mean smolt-production survival components produced return estimates of 4.3, 1.9, and 1.5 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 2.6 million 6_3 sockeye salmon and a final pooled predicted return of 2.1 million. This would be the second largest return ever recorded for this age class. The largest 6_3 return was observed in 1966 (progeny of the 1960

spawning escapement of 14.6 million) when 6.3 million sockeye salmon were recorded. Only two other years have had 6_3 returns exceeding 1.0 million: 1962 (1956 brood year escapement of 14.6 million which produced 1.3 million 6_3 returns) and 1976 (1970 brood year escapement of 13.9 million which produced 1.2 million 6_3 returns).

Branch River

A total of 0.5 million sockeye salmon 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 0.4 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information were available for this system (Table 7). The range of spawning escapements which will produce 1985 returns to this system (1979-81 brood year escapements range from 82 thousand to 0.3 million) were well within the historical range of escapements used within the spawner-recruit model (1956-78 brood year escapements range from 36 thousand to 1.2 million). A discussion of results for each major age class follows.

4_2:

No. 3_2 sockeye salmon were obtained from samples collected in 1984. Therefore, the 4_2 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 70 thousand 4_2 sockeye salmon and a final pooled predicted return of 0.1 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 0.1 million and a final pooled predicted return of 0.2 million.

5_2:

Spawner-recruit and mean sibling age classes components both produced return estimates of about 0.1 million. This resulted in a Standard ADF&G predicted return of 0.1 million 5_2 sockeye salmon and a final pooled predicted return of 0.1 million.

6_3:

Spawner-recruit and mean sibling age classes components produced return estimates of 73 and 31 thousand sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 52 thousand 6_3 sockeye salmon and a final pooled predicted return of 43 thousand.

Naknek River

A total of 4.8 million sockeye salmon was forecasted to return to this

Table 7. Forecasted returns of major age classes of sockeye salmon to Branch River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	82	2.1009	0.4041	70
5_3	298	1.6351	0.1821	89
5_2	298	1.6351	0.3065	149
6_3	294	2.7857 [1]	0.0887	73

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression [2]	Predicted Return (thousands) Based on Ratio for All Years
5_2	98 (4_2)	88 (0.40)	172
6_3	31 (5_3)	18 (0.22)	44

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

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 3.7 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 8). A discussion of results for each major age class follows.

4_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.5 and 0.6 million sockeye salmon, respectively. Smolt data indicated possible returns of 0.7 to 1.1 million, which were similar to other estimates. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.6 million 4_2 sockeye salmon and a final pooled predicted return of 1.1 million.

5_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). Results of the spawner-recruit component for this age class, as well as the 5_2 age class (see below), were similar to results of the sibling age classes component; both produced 5_3 return estimates of 1.0 million. Smolt data indicated possible returns of 0.4 to 0.8 million, which were similar to other estimates. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 1.0 million and a final pooled predicted return of 2.0 million.

5_2:

Spawner-recruit and mean sibling age classes components produced return estimates of 1.1 and 1.3 million, respectively. Smolt data indicated possible returns of 4.0 to 8.1 million, which were much larger than the other estimates. A return of this size was considered to be very unlikely, even though the 1980 spawning escapement was the largest ever recorded (see previous section concerning 5_3 returns). The largest past return of 5_2 sockeye salmon was 3.9 million in 1981, and was produced by a spawning escapement of 1.3 million in 1976. Past escapements of 2.2 million (1959) and 2.0 million (1975) produced 5_2 returns of 0.3 and 1.7 million, respectively. The mean of spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 1.2 million 5_2 sockeye salmon and a final pooled predicted return of 1.0 million.

6_3:

Actual returns have already exceeded returns projected from a Ricker type spawner-recruit relationship. Past escapements of about 0.9 million sockeye salmon have produced returns-per-spawner ranging from only 2.0 to 4.5. Therefore, to predict 6_3 returns in 1985, estimated number of returns-per-spawner was increased from 4.3 (the actual number of returns-per-spawner to date) to 4.5 (the upper end of the range observed for past escapements). This

Table 8. Forecasted returns of major age classes of sockeye salmon to Naknek River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	1,796	1.8525	0.1423	473
5_3	2,645	1.3783	0.2855	1,041
5_2	2,645	1.3783	0.3033	1,106
6_3	925	4.5000[1]	0.2570	1,070

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
4_2	4 (3_2)	648 (0.30)	N/A
5_3	13 (4_3)	980 (0.37)	N/A
5_2	684 (4_2)	901 (0.39)	1,778
6_3	761 (5_3)	573 (0.20)	1,021

Smolt Component[3]

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	36,798	0.05-0.10	0.30	662-1,104
5_3	16,497	0.05-0.10	0.50	412- 824
5_2	115,624	0.05-0.10	0.70	4,047-8,094
6_3	12,898	0.05-0.10	0.50	325- 650

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

[3] Predictions not used in final forecast.

produced a spawner-recruit return estimate of 1.1 million sockeye salmon, which was only slightly greater than the mean sibling age classes return estimate of 0.8 million. Smolt data indicated possible returns of 0.3 to 0.7 million, which were similar to other estimates. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.9 million 6_3 sockeye salmon and a final pooled predicted return of 0.8 million.

Egegik River

A total of 6.6 million sockeye salmon 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 4.9 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). A discussion of results for each major age class follows.

4_2:

No 3_2 sockeye salmon were obtained from samples collected in 1984. Therefore, the 4_2 age class forecast for this system was based only upon the spawner-recruit component estimate of 0.1 million sockeye salmon. Smolt data indicated possible returns of 45 to 90 thousand, which were less than the spawner-recruit estimate. The spawner-recruit estimate resulted in a Standard ADF&G predicted return of 0.1 million 4_2 sockeye salmon and a final pooled predicted return of 0.3 million.

5_3:

Spawner-recruit and sibling age classes components produced 5_3 return estimates of 1.5 and 2.8 million sockeye salmon, respectively. Smolt data indicated possible returns of 0.6 to 1.2 million, which were more similar to the spawner-recruit estimate. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 2.1 million and a final pooled predicted return of 4.1 million. Only two past returns exceeding 4.0 million 5_3 sockeye salmon have been recorded: 4.4 million in 1965 and 5.7 million in 1983, from escapements of 1.8 (1960) and 0.9 (1978) million, respectively.

5_2:

Spawner-recruit and mean sibling age classes components produced return estimates of 0.4 and 1.3 million, respectively. Smolt data indicated possible returns of 1.5 to 3.0 million, which were greater than either of the other estimates but more similar to the sibling estimates. A return of this size was considered to be possible. The largest past return of 5_2 sockeye salmon was 3.2 million in 1961, and was produced by a spawning escapement equal in size to the 1980 brood year (1.1 million, 1956 brood year). The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.8 million 5_2 sockeye salmon and a

Table 9. Forecasted returns of major age classes of sockeye salmon to Egegik River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	695	3.0486	0.0693	147
5_3	1,061	2.9185	0.4772	1,478
5_2	1,061	2.9185	0.1130	350
6_3	1,032	5.7829[1]	0.2992	1,786

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
5_3	27 (4_3)	2,765 (0.57)	N/A
5_2	781 (4_2)	776 (0.71)	1,890
6_3	2,985 (5_3)	1,037 (0.37)	2,388

Smolt Component[3]

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	2,242	0.05-0.10	0.40	45- 90
5_3	16,524	0.05-0.10	0.70	578-1,156
5_2	49,457	0.05-0.10	0.60	1,484-2,968
6_3	14,287	0.05-0.10	0.30	214- 428

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

[3] Predictions not used in final forecast.

final pooled predicted return of 0.7 million. The actual return in 1985 may be greater.

6_3:

Actual returns have already exceeded returns projected from a Ricker type spawner-recruit relationship. Past escapements of about 1.0 million sockeye salmon have produced returns-per-spawner ranging from 1.6 to 6.3. Therefore, to predict 6_3 returns in 1985, estimated number of returns-per-spawner was increased from 2.8 (the actual number of returns-per-spawner to date) to 5.8 (based upon the mean production of 6_3 sockeye salmon produced by past escapements). This produced a spawner-recruit return estimate of 1.8 million sockeye salmon, which was similar to the mean sibling age classes return estimate of 1.7 million. Smolt data indicated possible returns of 0.2 to 0.4 million, which were less than the other estimates. The mean of the spawner-recruit and sibling estimates produced a Standard ADF&G predicted return of 1.7 million 6_3 sockeye salmon and a final pooled predicted return of 1.4 million.

Ugashik River

A total of 5.6 million sockeye salmon 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 3.8 million sockeye salmon (Table 5). Only spawner-recruit and sibling age classes information was 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). A discussion of results for each major age class follows.

4_2:

The 1981 spawning escapement of 1.3 million sockeye salmon was the fourth largest ever recorded. The 1979 and 1980 brood years were two of the three brood years with escapements larger than 1.3 million. Spawner-recruit and sibling age classes components produced 4_2 return estimates of 0.3 and 0.6 million sockeye salmon, respectively. Smolt data indicated possible returns of 0.8 to 1.6 million, which were greater than the other estimates. The mean of the spawner-recruit and sibling estimates resulted in a Standard ADF&G predicted return of 0.5 million 4_2 sockeye salmon and a final pooled predicted return of 0.9 million. The actual return in 1985 may be greater.

5_3:

The 1980 spawning escapement of 3.3 million sockeye salmon was the largest ever recorded. Only three previous spawning escapements have exceeded 1.0 million sockeye salmon: 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, to predict 5_3, as well as 5_2 returns in 1985, estimated number of returns-per-spawner was increased from 0.3 (the actual number of returns-per-spawner to date) to 1.2 (based upon the mean proportion of 4_2 sockeye salmon produced by past escape-

Table 10. Forecasted returns of major age classes of sockeye salmon to Ugashik River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	1,327	1.2274	0.1989	324
5_3	3,321	1.2039 [1]	0.4431	1,772
5_2	3,321	1.2039 [1]	0.2033	813
6_3	1,701	3.5497 [1]	0.1430	863

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
4_2	2 (3_2)	579 (0.61)	N/A
5_3	38 (4_3)	1,706 (0.64)	N/A
5_2	1,141 (4_2)	868 (0.87)	1,449
6_3	1,389 (5_3)	296 (0.59)	491 [3]

Smolt Component [4]

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	31,297	0.05-0.10	0.50	782-1,564
5_3	12,736	0.05-0.10	0.60	382- 764
5_2	not available			
6_3	not available			

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

[3] Data for 1973 excluded.

[4] Predictions not used in final forecast.

ments). This produced a spawner-recruit return estimate of 1.8 million sockeye salmon, which was similar to the sibling age classes return estimate of 1.7 million. Smolt data indicated possible returns of 0.4 to 0.8 million, which were lower than the other estimates. The mean of the spawner-recruit and sibling estimates produced a Standard ADF&G predicted return of 1.7 million 5_3 sockeye salmon and a final pooled predicted return of 3.4 million. Past returns of 5_3 sockeye salmon have never exceeded 1.6 million. However, returns of this magnitude have been produced by spawning escapements ranging from 0.4 to 2.3 million. Therefore, a return of 3.4 million would not be be unlikely.

5_2:

Spawner-recruit and mean sibling age classes components produced return estimates of 0.8 and 1.2 million, respectively. This resulted in a Standard ADF&G predicted return of 1.0 million 5_2 sockeye salmon and a final pooled predicted return of 0.8 million.

6_3:

The 1979 spawning escapement of 1.7 million sockeye salmon was the third largest ever recorded for this system (see previous section concerning 5_3 returns). Actual returns have already exceeded returns projected from a Ricker type spawner-recruit relationship. Great variability in past returns per spawner have occurred: the two largest past escapements for which complete returns have been documented produced returns-per-spawner of 0.5 (1965 spawning escapement, 1.0 million sockeye salmon) and 1.3 (1960, 2.3 million). To predict 6_3 returns in 1985, estimated number of returns-per-spawner was increased from 3.0 (the actual number of returns-per-spawner to date) to 3.5 (based upon the mean proportion of 6_3 sockeye salmon produced by past escapements). This produced a spawner-recruit estimate of 0.9 million sockeye salmon, which was about twice as great as the mean sibling age classes return estimate of 0.4 million. The mean of the results of both components produced a Standard ADF&G predicted return of 0.6 million 6_3 sockeye salmon and a final pooled predicted return of 0.5 million.

Wood River

A total of 2.3 million sockeye salmon 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& method prediction for total returns to this system was 1.8 million sockeye salmon (Table 5). Results of all three components were used whenever possible (Table 11). 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 1984. Therefore, the 4_2 age class forecast for this system was based upon results from spawner-recruit and smolt components which produced estimates of 0.6 and 0.4 million, respectively. This resulted in a Standard ADF&G predicted return of 0.5 million 4_2 sockeye salmon and a final pooled predicted return of 1.0 million.

Table 11. Forecasted returns of major age classes of sockeye salmon to Wood River system, Bristol Bay, in 1985 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	1,233	1.9449	0.2373	569
5_3	2,969	1.3123	0.0692	270
5_2	2,969	1.3123	0.4167	1,624
6_3	1,706	2.7198 [1]	0.0493	229

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression [2]	Predicted Return (thousands) Based on Ratio for Comparable Cycle Years
5_2	473 (4_2)	585 (0.15)	428
6_3	27 (5_3)	31 (0.33)	6

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	19,590	0.0594	0.3480	405
5_3	4,130	0.0576	0.9080	216
5_2	32,350	0.0594	0.4504	865
6_3	4,710	0.0576	0.0783	21

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

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 1984. Therefore, the 5_3 age class forecast for this system was based upon results from the spawner-recruit and smolt components. 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). These escapements produced returns-per-spawner of 0.8 and 1.3, respectively. Returns-per-spawner for the 1980 escapement, based upon a Ricker-type relationship, are predicted to be 1.3; actual returns-per-spawner to date have not exceeded this value. The forecast based upon the spawner-recruit component was 0.3 million sockeye salmon, which was similar to the smolt production-survival estimate of 0.2 million. This resulted in a Standard ADF&G predicted return of 0.2 million 5_3 sockeye salmon and a final pooled predicted return of 0.5 million.

5_2:

Spawner-recruit, mean sibling age classes, and smolt production-survival components produced return estimates of 1.6, 0.5, and 0.9 million sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 1.0 million 5_2 sockeye salmon and a final pooled predicted return of 0.8 million.

6_3:

Actual returns have already exceeded returns projected from a Ricker type spawner-recruit relationship. An escapement of 1.7 million sockeye salmon in 1974 produced returns-per-spawner of 2.9. To predict 6_3 returns in 1985, estimated number of returns-per-spawner was increased from 2.6 (the actual number of returns-per-spawner to date) to 2.7 (based upon the mean proportion of 6_3 sockeye salmon produced by past escapements). This produced a spawner-recruit return estimate of 0.2 million sockeye salmon, which was much greater than either the mean sibling age classes return estimate of 19 thousand or the smolt-production survival estimate of 21 thousand. This resulted in a Standard ADF&G predicted return of 90 thousand 6_3 sockeye salmon and a final pooled predicted return of 75 thousand. However, since results of the sibling and smolt components were so much lower than that of the spawner-recruit component, actual returns of this age class may be lower than that in the final forecast.

Igushik River

A total of 0.3 million sockeye salmon 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 12). A discussion of results for each major age class follows.

Table 12. Forecasted returns of major age classes of sockeye salmon to Igushik River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	591	0.7637	0.2136	96
5_3	1,988	0.0342 [1]	0.1232	8
5_2	1,988	0.0342 [1]	0.5576	38
6_3	860	0.9465 [1]	0.0970	79

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
5_2	19 (4_2)	129 (0.20)	92 [3]
6_3	15 (5_3)	22 (0.38)	20

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

[3] Data for 1969 excluded.

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 1984. Therefore, the 4_2 age class forecast for this system was only based upon results from spawner-recruit component which produced an estimate of 96 thousand sockeye salmon and a final pooled predicted return of 0.2 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 1984. Therefore, the 5_3, as well as the 5_2 age class forecast for this system was only based upon results from spawner-recruit component. 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 escapement of about 1.0 million or greater have been recorded. Previous escapements of 0.5 to 0.6 million have produced returns-per-spawner ranging from 0.6 to 1.0. Since actual returns from the 1980 escapement have already exceeded returns projected from a Ricker type spawner-recruit relationship, to predict 5_3, as well as 5_2, returns in 1985, estimated number of returns-per-spawner was increased from 0.01 (based upon a Ricker type spawner-recruit relationship) to 0.03 (based upon the mean proportion of 4_2 sockeye salmon produced by past escapements). This produced a spawner-recruit return estimate, as well as Standard ADF&G predicted return, of 8 thousand sockeye salmon, and a final pooled predicted return of 16 thousand.

5_2:

Spawner-recruit and mean sibling age classes components produced return estimates of 38 thousand and 0.1 million, respectively. This resulted in a Standard ADF&G predicted return of 74 thousand 5_2 sockeye salmon and a final pooled predicted return of 61 thousand.

6_3:

The 1979 spawning escapement of 0.9 million sockeye salmon was the second largest ever recorded for this system (see previous section concerning 5_3 returns). Actual returns have already exceeded returns projected from a Ricker type spawner-recruit relationship. To predict 6_3 returns in 1985, estimated number of returns-per-spawner was increased from 0.2 (the actual number of returns-per-spawner to date) to 0.9 (based upon the mean proportion of 6_3 sockeye salmon produced by past escapements). This produced a spawner-recruit return estimate of 79 thousand sockeye salmon, which was about four times larger than the mean sibling age classes return estimate of 21 thousand. The mean of the results of both components produced a Standard ADF&G predicted return of 50 thousand 6_3 sockeye salmon and a final pooled predicted return of 42 thousand.

Nuyakuk River

A total of 1.7 million sockeye salmon 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 1.2 million sockeye salmon (Table 5). The forecast of 5_3 returns was of particular concern, since a sibling age classes estimate could not be made, and the spawner-recruit estimate was based on a spawning escapement about three times greater than any previously documented escapement (Table 13). Therefore, smolt data were used to estimate returns, although no actual estimates of survival were available for Nuyakuk smolt. (This will be the first year smolt numbers can be compared with adult returns.) To produce a forecast using smolt data, it was assumed that survival of Nuyakuk smolt, which have the smallest size at the time of seaward migration, would be somewhat less than that for Wood River smolt. A discussion of results for each major age class follows.

4_2:

A prediction based upon sibling age classes could not be made since 3_2 sockeye salmon were obtained from samples collected in 1984. Therefore, the 4_2 age class forecast for this system was based upon results from the spawner-recruit and smolt components. 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. An escapement of 0.7 million in 1975 produced 7.8 returns-per-spawner. Returns-per-spawner for the 1980 escapement, based upon a Ricker-type relationship, are predicted to be 5.9. This produced a spawner-recruit estimate of 0.9 million 4_2 sockeye salmon, which was about four times greater than the smolt production-survival estimate of 0.2 million. This resulted in a Standard ADF&G predicted return of 0.6 million 4_2 sockeye salmon and a final pooled predicted return of 1.1 million. A return of this size would be about twice as great as the previous record return of 0.5 million in 1979, which was produced by an escapement of similar size (0.7 million, 1975 brood year).

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 1984. Therefore, the 5_3, as well as 5_2, age class forecast for this system was based upon results from the spawner-recruit and smolt components. The 1980 escapement of 3.0 million sockeye salmon was the largest ever recorded. A spawner-recruit prediction based upon a Ricker-type relationship was not used, since all other documented escapements have been less than 1.0 million. To predict 5_3 returns in 1985 returns-per-spawner were estimated to be 0.2 (based upon the mean proportion of 4_2 sockeye salmon produced by past escapements). This produced a spawner-recruit estimate of 31 thousand sockeye salmon, which was similar to the smolt production-survival estimate of 26 thousand. This resulted in a Standard ADF&G predicted return of 29 thousand 5_3 sockeye salmon and a final pooled predicted return of 57 thousand.

5_2:

Spawner-recruit and mean sibling age classes components produced return estimates of 0.4 and 0.7 million sockeye salmon, respectively. No smolt information was available for this age class. This resulted in a Standard

Table 13. Forecasted returns of major age classes of sockeye salmon to Nuyakuk River system, Bristol Bay, in 1985 based upon spawner-recruit, sibling returns, and smolt components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	834	5.8914	0.1842	905
5_3	3,027	0.2134 [1]	0.0482	31
5_2	3,027	0.2134 [1]	0.6844	442
6_3	360	3.8135	0.0420	58

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
5_2	120 (4_2)	452 (0.39)	1,044
6_3	10 (5_3)	14 (0.48)	28

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival of Age I or II Smolt	Estimated Proportion Maturing at Ocean Age of Interest	Predicted Return (thousands)
4_2	28,875	0.0500	0.1679	242
5_3	1,259	0.0500	0.4208	26
5_2	not available			
6_3	not available			

[1] Spawning escapement in 1980 much greater than any previously recorded. Therefore, assumed return-per-spawner calculated as: $R/S = A/(1-M)$.

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

ADF&G predicted return of 0.6 million 5_2 sockeye salmon and a final pooled predicted return of 0.7 million.

6_3:

Spawner-recruit and mean sibling age classes components produced return estimates of 58 and 21 thousand sockeye salmon, respectively. No smolt information was available for this age class. This resulted in a Standard ADF&G predicted return of 40 thousand 6_3 sockeye salmon and a final pooled predicted return of 33 thousand.

Togiak River

A total of 0.9 million sockeye salmon 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 0.7 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:

A prediction based upon sibling age classes could not be made since no 3_2 sockeye salmon were obtained from samples collected in 1984. Therefore, the 4_2 age class forecast for this system was only based upon results from the spawner-recruit component. 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 and produced 2.2 returns-per-spawner. To predict 4_2 returns in 1985 returns-per-spawner produced 2.2 returns-per-spawner. To predict 4_2 returns in 1985 returns-per-spawner were estimated to be 2.6 (based upon a Ricker-type relationship). This produced a spawner-recruit, as well as a Standard ADF&G, predicted return of 0.2 million 4_2 sockeye salmon and a final pooled predicted return of 0.4 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 1984. Therefore, the 5_3, as well as the 5_2 age class forecast for this system was only based upon results from spawner-recruit component. The 1980 spawning escapement of 0.5 million sockeye salmon was the largest ever recorded for this system (see previous section on 4_2 returns). To predict 5_3, as well as 5_2, returns in 1985 returns-per-spawner were estimated to be 2.1 (based upon a Ricker type spawner-recruit relationship). This produced a spawner-recruit, as well as a Standard ADF&G, predicted return of 0.1 million 5_3 sockeye salmon, and a final pooled predicted return was 0.2 million.

5_2:

Spawner-recruit and sibling age classes components produced return estimates of 0.6 and 0.2 million, respectively. This resulted in a Standard ADF&G predicted return of 0.4 million 5_2 sockeye salmon and a final pooled predicted return of 0.3 million

Table 14. Forecasted returns of major age classes of sockeye salmon to Togiak River system, Bristol Bay, in 1985 based upon spawner-recruit and sibling returns components of the Standard ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Estimated Return per Spawner	Mean Proportion of Age Class in Past Returns	Predicted Return (thousands)
4_2	307	2.5640	0.2597	204
5_3	527	2.0673	0.1011	110
5_2	527	2.0673	0.5273	574
6_3	198	3.5960[1]	0.0806	57

Sibling Returns Component

Age Class	Sibling Return in 1984 (thousands)	Predicted Return (thousands) Based on Linear Regression[2]	Predicted Return (thousands) Based on Ratio for All Years
5_2	44 (4_2)	157 (0.21)	N/A
6_3	13 (5_3)	16 (0.25)	15

[1] Actual return to date greater than that based upon Ricker relationship. Return-per-spawner calculated as:

$$R/S = A/(1-M)$$, where

R/S = return-per-spawner, A = actual return to date, and M = mean proportion of age class(es) in past returns.

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

6_3:

Spawner-recruit and mean sibling age classes components produced return estimates of 57 and 16 thousand sockeye salmon, respectively. This resulted in a Standard ADF&G predicted return of 36 thousand 6_3 sockeye salmon and a final pooled predicted return of 33 thousand.

SUMMARY

Large differences existed between the Standard ADF&G and Japanese Research Catches methods for 4_2, 5_3, and 6_3 predicted returns (Table 15).

The Standard ADF&G method predicted lower 4_2 and 5_3 returns and higher 6_3 returns than the Japanese Research Catches method. However, the past performance of both these methods has been similar (Tables 1-3). Therefore, although the final forecast was calculated by pooling results of both these methods, inconsistencies between the two component methods indicate that departures from the final forecast are likely. Table 16 is a summary of forecast results indicating how actual returns may deviate from the pooled forecast.

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Table 15. Comparison of total forecast returns of major age classes of sockeye salmon to Bristol Bay, 1985.

Age Class	Predicted Returns (Millions) Standard ADF&G	Japanese Research Catches	Weighted Mean
4_2	3.1 (12%)	10.2 (24%)	6.0 (17%)
5_3	9.4 (37%)	23.9 (57%)	18.3 (52%)
5_2	6.7 (27%)	6.2 (15%)	5.6 (16%)
6_3	6.1 (24%)	1.6 (4%)	5.1 (15%)
Total	25.3 (100%)	41.9 (100%)	35.0 (100%)

Table 16. Synopsis of forecasted returns of major age classes of sockeye salmon to Bristol Bay, 1985.

System	Age Class	Forecast (thousands)	Summary of Indicators	Possible Deviation
Kvichak	4_2	0.9	Low escapement; Low return per spawner; Low smolt; No 3_2 return in 1984; High two-ocean component in research catch	LOWER RETURN
	5_3	7.8	Second largest escapement; Low smolt; Low 4_3 return in 1984; High two-ocean component in research catch	HIGHER RETURN
	5_2	1.3	Second largest escapement; High smolt; Low 4_2 return in 1984; Low three-ocean component in research catch	UNKNOWN
	6_3	2.1	High return per spawner; Moderate smolt; Moderate 5_3 return in 1984; Low three-ocean component in research catch; Return would be second largest on record	LOWER RETURN
Branch	4_2	0.1	Moderate return per spawner; No 3_2 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_3	0.2	Moderate return per spawner; No 4_3 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_2	0.1	Moderate return per spawner; Moderate 4_2 return in 1984; 1984; Low three-ocean component in research catch	UNKNOWN
	6_3	0.04	High return per spawner; Moderate 5_3 return in 1984; Low three-ocean component in research catch	UNKNOWN

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Table 16. Synopsis of forecasted returns of major age classes of sockeye salmon to Bristol Bay, 1985 (continued).

System	Age Class	Forecast (thousands)	Summary of Indicators	Possible Deviation
Naknek	4_2	1.1	High escapement; Moderate return per spawner; High smolt; Moderately high 3_2 return in 1984; High two-component in research catch	UNKNOWN
	5_3	2.0	Record escapement; Moderate return per spawner assumed; Possible low smolt; Moderate 4_3 return in 1984; High two-ocean component in research catch	LOWER RETURN
	5_2	1.0	Record escapement; Moderate return per spawner assumed; Possible very high smolt; Moderate 4_2 return in 1984; Low three-ocean component in research catch	HIGHER RETURN
	6_3	0.8	High return per spawner; Possible low smolt; Moderate 5_3 return in 1984; Low three-ocean component in research catch	UNKNOWN
Egegik	4_2	0.3	Moderate return per spawner; Possible low smolt; No 3_2 return in 1984; High two-ocean component in research catch	LOWER RETURN
	5_3	4.1	Moderate return per spawner; Possible low smolt; High 4_3 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_2	0.7	Moderate return per spawner; Possible high smolt; High 4_2 return 1984; Low three-ocean component in research catch	HIGHER RETURN
	6_3	1.5	High return per spawner; Possible low smolt; High 5_3 return in 1984; Low three-ocean component in research catch	LOWER RETURN

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Table 16. Synopsis of forecasted return of major age classes of sockeye salmon to Bristol Bay, 1985 (continued).

System	Age Class	Forecast (thousands)	Summary of Indicators	Possible Deviation
Ugashik	4_2	0.9	High escapement; Moderate return per spawner assumed; Possible moderate smolt; Moderate 3_2 return in 1984; High two-ocean coomponent in research catches	HIGHER RETURN
	5_3	3.4	Record escapement; Moderate return per spawner assumed; Possible low smolt; High 4_3 return in 1984; High two-ocean component in research catch; 1985 5_3 return would be largest on record	LOWER RETURN
	5_2	0.8	Record escapement; Moderate return per spawner assumed; Moderate 4_2 return in 1984; Low two-ocean component in research catch	UNKNOWN
	6_3	0.5	High escapement; High return per spawner assumed; Moderate 5_3 return in 1984; Low two-ocean component in research catch	LOWER RETURN
Wood	4_2	1.0	Moderate return per spawner; Moderate smolt; No 3_2 return in 1984; High two-ocean component in research catch	LOWER RETURN
	5_3	0.5	Record escapement; Moderate smolt; No 4_3 return in in 1984; High two-ocean component in research catch	LOWER RETURN
	5_2	0.8	Record escapement; Moderate smolt; Moderate 4_2 return in 1984; Low three-ocean component in research catch	UNKNOWN
	6_3	0.1	High return per spawner; Low smolt; Low 5_3 return in 1984; Low three-ocean component in research catch	LOWER RETURN

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Table 16. Synopsis of forecasted return of major age classes of sockeye salmon to Bristol Bay, 1985 (continued).

System	Age Class	Forecast (thousands)	Summary of Indicators	Possible Deviation
Igushik	4_2	0.2	High escapement; Low return per spawner assumed; No 3_2 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_3	0.02	Record escapement; Very low return per spawner assumed; No 4_3 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_2	0.06	Record escapement; Very low return per spawner assumed; Low 4_2 return in 1984; Low three-ocean component in research catch	UNKNOWN
	6_3	0.04	High escapement; Low 5_3 return in 1984; Low three-ocean component in research catch	LOWER RETURN
Nuyakuk	4_2	1.1	High return per spawner; Low smolt; No 3_2 return in 1984; High two-ocean component in research catch	LOWER RETURN
	5_3	0.06	Record escapement; Low return per spawner assumed; Low smolt; No 4_3 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_2	0.5	Record escapement; Low return per spawner assumed; No 4_3 return in 1984; Low three-ocean component in research catch	UNKNOWN
	6_3	0.03	High return per spawner; Moderate 5_3 return in 1984; Low three-ocean component in research catch	UNKNOWN

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Table 16. Synopsis of forecasted return of major age classes of sockeye salmon to Bristol Bay, 1985 (continued).

System	Age Class	Forecast (thousands)	Summary of Indicators	Possible Deviation
Togiak	4_2	0.4	Second largest escapement; Moderate return per spawner; No 3_2 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_3	0.2	Record escapement; Moderate return per spawner assumed; No 4_3 return in 1984; High two-ocean component in research catch	UNKNOWN
	5_2	0.3	Record escapement; Moderate return per spawner assumed; Low 4_2 return in 1984; Low three-ocean component in research catch	LOWER RETURN
	6_3	0.03	High return per spawner; Low 5_3 return in 1984; Low three-ocean component in research catch	UNKNOWN

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