# A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON RETURNING TO BRISTOL BAY IN 1995

by

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**ABSTRACT**

The total number of sockeye salmon *Oncorhynchus nerka* forecasted to return to Bristol Bay in 1995 is 58,716,000 (80% confidence interval: 44,544,000 - 72,888,000). Runs are expected to exceed spawning escapement goals for all systems. Total projected sockeye salmon harvest is expected to be 43,931,000. Most of this harvest will be taken within Bristol Bay inshore fishing districts (40,285,000), but some have been allocated to June fisheries occurring in the vicinity of the Shumagin Islands and South Unimak under an existing management plan (8.3% of total Bristol Bay projected harvest= 3,646,000). The 1995 forecast was based on the ADF&G method which averaged results from three linear regression models based on the relationship between returns and either spawner, sibling, or smolt data. However, for the 1995 forecast estimates from spawner-return regressions were not used for Egegik River because evaluations of past performance indicated that Egegik forecasts were more accurate and less biased if only sibling and smolt information were used. Also, based on performance evaluations of the ADF&G method, data prior to the 1978 return year were omitted from calculations for all rivers. To further correct under-forecasting errors, predictions for eastside rivers (Kvichak, Branch, Naknek, Egegik and Ugashik) were adjusted by the 1984-94 average percent forecast error of the corresponding systems. Similar to last year, out of range data were used in calculations for the 1995 forecast. The number of spawners in 1991 and the number of age-1.1 returns in 1994 were greater than previously recorded for the Naknek River. Because these data are greater than those included in the regression models, I have less confidence in the accuracy of the prediction for Naknek River. The outlook for 1995-98, based only on the spawner-recruit component of the forecast and not adjusted for average historic forecast errors, is for the total sockeye salmon run to Bristol Bay to be highest in 1995 and lowest in 1998. For all years examined, runs to all river systems are expected to exceed spawning goal requirements.

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

## INTRODUCTION

Preseason forecasts of sockeye salmon *Oncorhynchus nerka* runs to Bristol Bay, Alaska, have been made by the Alaska Department of Fish and Game (ADF&G) since 1961 (ADF&G 1961; Appendix A.1). ADF&G biologists use forecasts to (1) estimate commercial harvests, (2) set quotas for the Shumagin Islands-South Unimak June fishery (ADF&G 1992), and (3) determine which stocks may need protection against possible overharvesting. Seafood buyers and processors use forecasts to (1) estimate the supply of raw fish available for various uses, (2) determine staff and equipment needed for production of fresh, frozen, and canned products, and (3) 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.

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 percent error (MAPE) of 37.0 for 1961-82 (MAPE range= 2.7 - 78.0; Fried and Yuen 1987; Fried et al. 1988). 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; Fried and Yuen 1985, 1986, 1987). However, these forecasts did not prove to be more accurate than forecasts based solely on the ADF&G method and did not correct the tendency of published forecasts to under-estimate total run size for 18 of the last 20 years (Fried et al. 1988; Appendix A.1).

Methods used to calculate run size predictions were modified again in 1988 in an attempt to remedy these problems (Fried et al. 1988; Fried and Cross 1988, 1990). The omission of data prior to the 1978 return year from all calculations was the most important change in forecast methods. It was felt that models based on 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 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).

Although forecasts based on only recent data decreased under-forecasting errors for river systems on the east side of Bristol Bay, there was still a tendency to under-forecast the run (eight out of the last ten years). Since 1991 Cross et al. (1992, 1993, 1994) and Cross (1994) adjusted the forecast to correct the continuing bias of under-forecasting. Several bias correction factors were evaluated in search of the most accurate forecast (Cross et al. 1993). The goal was an unbiased forecast without any tendency to over- or under-forecast. In 1995 I continued to analyze bias correction factors, and methods used were similar to those for the 1992-94 forecasts.

The purpose of this report is to provide a final preseason forecast of sockeye salmon returning to Bristol Bay, Alaska, in 1995 with an outlook of abundance fluctuations through 1998. Specific objectives are to (1) document changes in methods used to forecast Bristol Bay sockeye salmon runs in 1995, (2) evaluate the relative accuracy of different forecasting methods, (3) forecast annual runs for all major river systems through 1998, and (4) indicate where actual runs are most likely to depart from preseason expectations.

## METHODS

### *Age Designation*

Sockeye salmon ages were expressed according to European system designations (Koo 1962), wherein the number of annuli formed in fresh and saltwater are indicated to the left and right of a decimal point. Historically, four age classes account for about 99% of total returns: 23% were age 1.2, 43% were age 2.2, 21% were age 1.3, and 12% were age 2.3. Smolt ages were expressed as either age 1. or 2., corresponding to sockeye salmon that migrated seaward in either their second or third year of life.

### *Forecast Data Base and Techniques*

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: Kvichak, Branch, Naknek, Egegik, Ugashik, Wood, Igushik, Nushagak, and Togiak Rivers (Figure 1). 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. Estimates of numbers of spawners and recruits by age for brood years 1956-94 are documented in the 1994 Bristol Bay annual management report (ADF&G 1995). Estimates of numbers of smolt by year are taken from Crawford and Cross 1994.

Predictions for the Nushagak River drainage have only been made since 1992. Prior to 1992, forecasts were made for Nuyakuk River, a major tributary of the Nushagak River. A sonar project to count adult salmon entering the Nushagak River mainstem has operated since 1979. The 1995 forecast for Nushagak River was calculated from spawner-recruit and sibling models built from 1982-94 escapement return 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 per component (spawner-recruit, sibling, or smolt) were calculated and averaged for the forecast (Fried and Yuen 1986, 1987).

Forecasts for 1995 were first calculated using all available data (referred to as the All Data ADF&G method) and then recalculated with all data prior to the 1978 return year excluded from calculations (referred to as the Recent Data ADF&G method).

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):

$$\ln\left(\frac{R_{a,r,y}}{E_{r,y}}\right) = \ln(\alpha) + \beta E_{r,y} + \epsilon \qquad (1)$$

where:

$R_{a,r,y}$ = number of age-*a* sockeye salmon returning to river system *r* from brood year *y*,

$E_{r,y}$ = total number of spawners in river system *r* during brood year *y*,

$\alpha$, $\beta$ = regression coefficients estimated by least square methods, and

$\varepsilon$ = random error with mean, 0, and variance $\sigma^2$.

In cases where the Ricker relationship was not significant at the 25% level (F-test, Ho: $\beta = 0$, $P > 0.25$; Snedecor and Cochran 1969), a linear regression model based on natural logarithm transformed data was used:

$$\ln(R_{a,r,y}) = \alpha + \beta \ln(E_{r,y}) + \epsilon. \qquad (2)$$

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):

$$\ln(R_{a,r,y}) = \alpha + \beta \ln(S_{j,r,y}) + \epsilon \qquad (3)$$

where:

$S_{j,r,y}$ = either the number of age-*j* smolt (where *j* = age 1. or 2.) migrating from river system *r* which were progeny of 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*.

Smolt data were available for four of the nine forecasted river systems. Smolt enumeration programs using sonar equipment were begun in 1971 for Kvichak (Russell 1972), 1982 for Egegik (Bue 1984), and 1983 for Ugashik (Fried et al. 1987) River systems. A smolt sonar project operated on the Naknek River from 1982-86 and 1993-94 (Crawford and Cross 1995).

Results from models were excluded from final forecast calculations if the model was not significant at the 25% level ($P > 0.25$). If a model was not significant for a river system age class, the mean return of that age class to that river system was used as the prediction. For All Data ADF&G method forecasts, mean returns for all past years (1956-94) were used. For Recent Data ADF&G method forecasts, mean returns for the past 17 years 1978-94, were used. In past years, results from models were also excluded if the input variable ($E_{r,y}$ or $S_{j,r,y}$) was outside the range of data used to build the model. However, results from regression models in which the input data were out-of-range were used in 1995.

Because spawners are the most removed in time from returns, I decided to investigate whether predictions would be more accurate by not including spawner-return predictions for rivers in which I had sibling and smolt information (Kvichak, Egegik, and Ugashik). The accuracies of hindcasts for 1984-94 which averaged estimates from spawner-return, sibling-return, and smolt-return models were compared to those which only included estimates from sibling-return and smolt-return models.

## *Evaluation of Forecast Performance*

### Comparison of Recent and All Data Forecasts

Since the Recent Data ADF&G method was first used for the 1988 forecast, a hindcasting procedure in which only data prior to the year of interest were used to build models was used to simulate past performance for several years. Due to the limited amount of data available (all data prior to the 1978 return year were omitted from analyses), Recent Data ADF&G method hindcasts could be calculated for only 11 years, 1984-94. Hindcasts prior to 1984 could not be calculated because models were not significant at the 25% level ($P > 0.25$).

Recent Data ADF&G method hindcasts for 1984-94 were compared with All Data ADF&G method hindcasts for the same period to determine which method could be expected to produce less biased and more accurate forecasts. Three statistics were used for comparisons: percent error (PE), mean percent error (MPE), and mean absolute percent error (MAPE). PE is a measure of annual performance:

$$PE = 100\left(\frac{F_{i,r} - A_{i,r}}{A_{i,r}}\right) \tag{4}$$

where:

$F_{i,r}$ = forecasted total return of sockeye salmon for year *i* and river system *r*, and

$A_{i,r}$ = actual total return of sockeye salmon for year *i* and river system *r*.

MPE is a measure of bias:

$$MPE = \frac{\sum_{i=1}^{N} 100\left(\frac{F_{i,r} - A_{i,r}}{A_{i,r}}\right)}{N} \tag{5}$$

where:

N = number of years.

MAPE is measure of overall accuracy which treats under- and over-forecasting errors similarly:

$$MAPE = \frac{\sum_{i=1}^{N} 100\left(\frac{|F_{i,r} - A_{i,r}|}{A_{i,r}}\right)}{N}. \tag{6}$$

**Modeling Historic Forecast Errors**

In an effort to reduce the tendency to under-forecast Bristol Bay runs, I looked at ways to model historic forecast errors and develop bias adjustment factors for the 1991-94 predictions (Cross et al. 1992, 1993, 1994, and Cross 1994). Based on results from these investigations I limited my analysis for the 1995 forecast to looking at trends in forecast errors for predictions based on Recent Data. Adjustment factors for the 1995 individual river predictions were estimated by taking the mean percent error from 1984-94. I decided to adjust each individual river's forecast by its own average forecast error because the errors have varied considerably among rivers. I was concerned that using one adjustment for the entire eastside of Bristol Bay would result in overforecasting some systems (Kvichak River) while under forecasting other systems (Egegik River).

I also compared the performance of adjusting Kvichak River's predictions by the 1984-94 mean forecast error versus adjusting it by the mean error for peak-cycle (1984, 1985, 1989, 1990, 1994) and off-cycle (1986, 1987, 1988, 1991, 1992, 1993) years.

### *Confidence Intervals*

The 80% confidence interval (80% CI) for the total run forecast was calculated as:

$$80\%\ CI = F \pm t_{0.2} s_F \qquad (7)$$

where:

F = forecasted total run of sockeye salmon to all of Bristol Bay (total of river system predictions) in 1995,

$s_F$ = standard error of the forecasted total run of sockeye salmon to Bristol Bay in 1995, and

$t_{0.2}$ = Student's t value with a probability of type I error of 0.20, and N-1 df.

Estimation of ($s_F$) was based on the mean squared error (MSE) calculated from 1984-94 total run predictions using the same techniques as 1995:

$$s_{\hat{x}} = \sqrt{MSE} \, , \tag{8}$$

$$MSE = \frac{\sum_{i=1}^{N} (F_i - A_i)^2}{N - 1} \tag{9}$$

where:

$F_i$ = forecasted total return of sockeye salmon for year *i*,

$A_i$ = actual total return of sockeye salmon for year *i*, and

N = number of years (1984-94).

### *Outlook to 1998*

Forecasts were made for 1996, 1997, and 1998 using only spawner-recruit data (Equation 1 or 2). These forecasts were not adjusted for historic forecast errors.

## RESULTS

### *Forecast Data Base*

Kvichak and Ugashik River's forecasts which included spawner-recruit estimates had similar or better accuracies and precision than those which excluded the data, but not so for Egegik River. The 1984-94 MPE and MAPE for Kvichak predictions which included spawner-recruit estimates were 4.6 and 53.7, compared to 4.6 and 59.2 for predictions with no spawner-recruit estimates (Table 1). Ugashik River predictions which included spawner-recruit data had a 1984-94 MPE and MAPE of -12.8 and 34.8 compared to a MPE of -26.5 and a MAPE of 31.2 for predictions which excluded the data. Egegik predictions which excluded spawner-recruit data were more accurate (MAPE=26.8) and precise (MPE=-22.6) than predictions which included the information

(MAPE=38.8, MPE=-38.8). Additionally, the number of spawners in Egegik River in 1990 and 1991, parent years for the five-year and four-year-old returns, were greater than previously recorded. Because the relationship of increasing spawners to returns has not been well described, and results from hindcasting indicated that spawner-recruit information had not improved Egegik River's forecast performance, I decided not to include spawner-recruit estimates in the 1995 Egegik River prediction. I did include spawner-recruit estimates for the 1995 Kvichak and Ugashik predictions based on the fact that forecast performance had been enhanced in the past by its inclusion and parent year spawners were within historic ranges.

### *Performance of Recent and All Data Forecasts*

Justification for use of the Recent Data ADF&G method was based on the observation that the number of returning adults produced per spawner has increased dramatically since 1978 (Fried et al. 1988). It was hoped that use of only recent data would provide a more accurate estimate of total sockeye salmon returns and would help correct the past under-forecasting bias of annual runs. If results for 1984-94 are representative of future performance, then forecasts of total sockeye salmon returns to Bristol Bay based on the Recent Data ADF&G method should be less biased (MPE=-17.4) and more accurate (MAPE=25.2) than forecasts based on the All Data ADF&G method (MPE=-42.5; MAPE=42.5; Appendix B.1).

Unfortunately, the All Data method was more accurate than the Recent Data method for Wood, Igushik, Nuyakuk/Nushagak, and Togiak Rivers based on the 1984-94 average errors (Appendix B.1). However, the All Data method performed better than the Recent Data method for westside systems only during the earlier years (1984-86); while Recent Data forecasts were more accurate and less biased during 1987-94. The 1987-94 MPE and MAPE for combined westside systems was 7.2 and 24.7 for the Recent Data method and -30.8 and 30.8 for the All Data method. Because the Recent Data method performed better for the more recent years, I decided to use only Recent Data in our 1995 projections for all Bristol Bay rivers.

### *Out-Of-Range Data*

Naknek River was the only system which had input variables (parent escapement and sibling) which were outside the data ranges used to build the model. These variables were: (1) the 1991 escapement or parent year for 1995 age-1.2 returns; and (2) the 1994 return of age-1.1 sockeye salmon which are siblings to age-1.2 returns in 1995. Although there is a high degree of uncertainty when a model is used to predict an outcome outside its existing values, I felt that using the out-of-range input variables in the regression models was preferable to excluding the information.

## *Unadjusted River System Forecasts*

### Kvichak River

Spawner-recruit, sibling, and smolt data bases were available for estimating Kvichak River run sizes in 1995.

*Age 1.2*. The age-1.2 forecast for this system was based upon spawner-recruit and smolt data (Appendix C.1). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from the Kvichak River in 1994. The spawner-recruit estimate of 2,829,000 was 68% greater than the smolt estimate of 1,679,000. The average of the two estimates was 2,254,000 sockeye salmon.

*Age 2.2.* The age-2.2 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The smolt estimate of 18,296,000 was 49% greater than the sibling estimate of 12,239,000 which was 69% greater than the spawner-recruit estimate of 7,217,000. The average of the three estimates was 12,584,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The spawner-recruit estimate of 2,173,000 was 106% greater than the sibling estimate of 1,055,000 and 135% greater than the smolt estimate of 924,000. The average of the three estimates was 1,384,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The sibling estimate of 1,217,000 was about 14% greater than the spawner-recruit estimate of 1,071,000, and 68% greater than the smolt estimate of 722,000. The average of the three estimates was 1,003,000 sockeye salmon.

### Branch River

Spawner-recruit and sibling data bases were available for estimating Branch River run sizes in 1995. There has never been a smolt project on the Branch River.

*Age 1.2*. The age-1.2 forecast was based upon spawner-recruit and sibling data (Appendix C.2). The spawner-recruit estimate of 206,000 was 50% greater than the sibling estimate of 137,000. The average of the two estimates was 172,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based only upon spawner-recruit data (Appendix C.2). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in samples collected from the Branch River in 1994. The spawner-recruit estimate was 48,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based only upon spawner-recruit data (Appendix C.2). The prediction based on sibling data was not used because the model was not significant at the 25% level (P > 0.25). The spawner-recruit estimate was 180,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based only upon sibling data (Appendix C.2). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level (P > 0.25). The sibling estimate was 25,000 sockeye salmon.

### Naknek River

Spawner-recruit, sibling, and smolt data bases were available for estimating Naknek River run sizes in 1995. The smolt project on the Naknek River operated from 1982-86 and again in 1993-94.

*Age 1.2*. The age-1.2 forecast was based spawner-recruit, sibling, and smolt data (Appendix C.3). The sibling estimate of 1,218,000 was 22% greater than the spawner-recruit estimate of 1,002,000 and 248% greater than the smolt estimate of 350,000. The average of the three estimates was 856,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based only upon spawner-recruit data (Appendix C.3). Predictions based on sibling and smolt data were not used because models were not significant at the 25% level (P > 0.25). The spawner-recruit estimate was 964,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix C.3). Smolt information was not available. The spawner-recruit estimate of 2,232,000 was 79% greater than the sibling estimate of 1,246,000. The average of the two estimates was 1,739,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based on spawner-recruit and sibling data (Appendix C.3). The spawner-recruit estimate of 884,000 was 25% less than the sibling estimate of 1,181,000. The average of the two estimates was 1,033,000 sockeye salmon.

### Egegik River

Spawner-recruit, sibling, and smolt data bases were available for estimating 1995 Egegik River run sizes. However, spawner-recruit information was not used for the final 1995 Egegik prediction. Evaluation of past forecast performance indicated that Egegik predictions were more accurate and less bias if spawner-recruit data were not incorporated.

*Age 1.2*. The age-1.2 forecast was based on sibling and smolt data (Appendix C.4). The sibling estimate of 758,000 was 12% less than the smolt estimate of 864,000. The average of the two estimates was 811,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based upon sibling and smolt data (Appendix C.4). The sibling estimate of 6,098,000 was 7% greater than the smolt estimate of 5,712,000. The average of the two estimates was 5,905,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon sibling and smolt data (Appendix C.4). The sibling estimate of 634,000 was 46% less than the smolt estimate of 1,166,000. The average of the two estimates was 900,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast for this system was based upon sibling and smolt data (Appendix C.4). The sibling estimate of 2,909,000 was 65% greater than the smolt estimate of 1,766,000. The average of the two estimates was 2,338,000 sockeye salmon.

**Ugashik River**

Spawner-recruit and sibling data bases were available for estimating all age groups of 1995 Ugashik River run sizes. Only age-1.2 and age-2.2 sockeye salmon returning to Ugashik River could be predicted from smolt data because the smolt project did not operate in 1992.

*Age 1.2*. The age-1.2 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The prediction based on smolt data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate of 1,468,000 was 28% greater than the sibling estimate of 1,148,000. The average of the two estimates was 1,308,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The prediction based on smolt data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate of 1,263,000 was 25% less than the sibling estimate of 1,680,000. The average of the two estimates was 1,472,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The spawner-recruit estimate of 717,000 was 57% greater than the sibling estimate of 456,000. The average of the two estimates was 587,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The spawner-recruit estimate of 1,061,000 was 14% greater than the sibling estimate of 932,000. The average of the two estimates was 997,000 sockeye salmon.

### Wood River

Spawner-recruit and sibling data bases were available for estimating Wood River run sizes in 1995. Smolt emigrating from the Wood River were last counted in 1990.

*Age 1.2*. The age-1.2 forecast was based only upon spawner-recruit data (Appendix C.6). The prediction based on sibling data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate was 1,364,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based only upon sibling data (Appendix C.6). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level ($P > 0.25$). The sibling estimate was 270,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.6). The spawner-recruit estimate of 1,589,000 was 18% greater than the sibling estimate of 1,348,000. The average of the two estimates was 1,469,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based only upon sibling data (Appendix C.6). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level ($P > 0.25$). The sibling estimate was 18,000 sockeye salmon.

### Igushik River

Spawner-recruit and sibling data bases were available for estimating Igushik River run sizes in 1995. There has never been a smolt project on the Igushik River.

*Age 1.2*. The age-1.2 forecast was based only upon results from spawner-recruit data (Appendix C.7). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Igushik River in 1994. The spawner-recruit estimate was 198,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based only on spawner-recruit data (Appendix C.7). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in samples collected from Igushik River in 1994. The spawner-recruit estimate was 46,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.7). The spawner-recruit estimate of 1,102,000 was 55% greater than the sibling estimate of 709,000. The average of the two estimates was 906,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix C.7). The spawner-recruit estimate of 51,000 was similar to the sibling estimate of 46,000. The average of the two estimates was 49,000 sockeye salmon.

**Nushagak River**

Reliable age information for sockeye salmon returning to Nushagak River was available from 1982-94 return years. Spawner-recruit and sibling data bases from 1982-94 return years were used to predict Nushagak River run sizes in 1995.

*Age 0.2*. The age-0.2 forecast was based only upon spawner-recruit data (Appendix C.8). A prediction based on sibling data could not be made because no age-0.1 sockeye salmon were present in samples collected from Nushagak River in 1994. The spawner-recruit estimate was 43,000 sockeye salmon.

*Age 1.2*. The age-1.2 forecast was based only upon results from spawner-recruit data (Appendix C.8). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Nushagak River in 1994. The spawner-recruit estimate was 100,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based on the 1982-94 mean returns of age-2.2 sockeye salmon to Nushagak River (Appendix C.8). A prediction based on spawner-recruit was not used because the model was not significant at the 25% level ($P > 0.25$). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in samples collected from Nushagak River in 1994. The mean return of age-2.2 sockeye salmon was 20,000 sockeye salmon.

*Age 0.3*. The age-0.3 forecast was based on spawner-recruit and sibling data bases (Appendix C.8). The spawner-recruit estimate of 447,000 was 94% greater than the sibling estimate of 230,000. The average of the two estimates was 338,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.8). The spawner-recruit estimate of 921,000 was 92% greater than the sibling estimate of 480,000. The average of the two estimates was 701,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast was based only upon sibling data (Appendix C.8). A prediction based on spawner-recruit was not used because the model was not significant at the 25% level ($P > 0.25$). The sibling estimate was 4,000 sockeye salmon.

*Age 0.4*. The age-0.4 forecast was based on spawner-recruit and sibling data bases (Appendix C.8). The spawner-recruit estimate of 68,000 was 38% less than the sibling estimate of 110,000. The average of the two estimates was 89,000 sockeye salmon.

**Togiak River**

Spawner-recruit and sibling data bases were available for estimating Togiak River run sizes in 1995. A smolt project was operated on Togiak River only in 1988.

*Age 1.2*. The age-1.2 forecast was based only on spawner-recruit data (Appendix C.9). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Togiak River in 1994. The spawner-recruit estimate was 114,000 sockeye salmon.

*Age 2.2*. The age-2.2 forecast was based only on spawner-recruit data (Appendix C.9). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in 1994 Togiak River samples. The spawner-recruit estimate was 26,000 sockeye salmon.

*Age 1.3*. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix C.9). The spawner-recruit estimate of 408,000 was 20% greater than the sibling estimate of 341,000. The average of the two estimates was 375,000 sockeye salmon.

*Age 2.3*. The age-2.3 forecast for this system was based on spawner-recruit and sibling data (Appendix C.9). The spawner-recruit estimate of 33,000 was 136% greater than the sibling estimate of 14,000. The average of the two estimates was 24,000 sockeye salmon.

## *Recent Data Forecast Errors and 1995 Forecast Adjustments*

**Eastside Forecast Errors**

Errors of eastside forecasts based on Recent Data were generally negative (forecasted run less than actual run), and showed a slight trend of being increasingly negative through the years from 1984-93 (Figure 2). Because there were limited years of Recent Data, an average of the errors was calculated rather than using other modeling techniques. The 1984-94 average error of -37% was used as an estimate of the 1995 prediction error. The 1995 prediction for combined eastside systems based on Recent Data was 38.0 million fish. The estimated error for the 1995 eastside prediction based on average errors was -14.0 million fish (Table 2). Using the average error to adjust Recent Data forecasts for eastside systems resulted in under-forecasts in 1989-93 and over-forecasts for 1987-88 and 1994 (Figure 2). The 1987-94 average error for Recent Data eastside forecasts was reduced from -44% to -16% by adjusting for previous years average error. I decided to adjust eastside forecasts by their individual errors rather than adjust the combined eastside forecast because forecast errors have varied among rivers.

**Westside Forecast Errors**

Errors of westside (Wood, Igushik, Togiak) forecasts based on Recent Data were generally positive (forecasted run more than actual run), and errors decreased through time for 1984-94 (Figure 3). The 1984-94 average error (+11%) was used as an estimate of the 1995 prediction error. The 1995 prediction for combined westside systems (Wood, Igushik, Togiak) based on Recent Data was 4.9 million fish. The estimated error for the 1995 westside prediction based on average errors was +0.5 million fish (Table 2). Using the average error to adjust Recent Data forecasts for westside systems resulted in under-forecasts for 1987-94 (Figure 3). The 1987-94 average error for Recent Data westside forecasts was increased from +4.4% to -56% by adjusting for previous years average error. Because errors of Recent Data westside forecasts decreased through time, correcting by a simple average decreased rather than improved the accuracy of the more recent years' predictions.

**Individual Rivers Forecast Errors**

***Kvichak River.*** Errors in Kvichak River forecasts based on Recent Data varied considerably from 1984-94 (Figure 4). Predictions for pre-peak and peak cycle years (1984-85, 1989-90, 1994) generally under-forecasted the actual run more than predictions for off-cycle years (1986-87, 1991-93). I compared adjustments based on the 1984-94 average error to an adjustment based on cycle year errors (average pre-peak and peak year error and an average off-cycle error). Predictions adjusted by the 1984-94 error had an 1990-94 average error of -6% and an average absolute error of 22%, while predictions adjusted by cycle years errors had a 1990-94 average error of -9% and an average absolute error of 13%. Although the precision of the cycle year adjusted forecasts was slightly (3%) lower than that of the average error adjusted forecasts, I decided to use the cycle error adjustment because the accuracy was higher (9%).

The 1995 Recent Data prediction for Kvichak River was 17.2 million. The estimated error for the 1995 prediction based on cycle year errors was -9.5 million fish (Table 2). Using cycle year errors to adjust Recent Data forecasts for Kvichak River improved the forecast performance for all years tested (1990-94) except during 1993 (Figure 4). The 1990-94 average error for Recent Data Kvichak River forecasts was reduced from -40% to -9% by adjusting for previous cycle years average error.

***Branch River.*** Errors in Branch River forecasts based on Recent Data showed a trend of being increasingly negative from 1984-94 (Figure 5). The 1995 Recent Data prediction for Branch River was 0.4 million. The estimated error for the 1995 prediction based on average errors was -0.1 million fish (Table 2). The 1987-94 mean error for Recent Data Branch River forecasts was similar for unadjusted (-35%) and adjusted (-35%) forecasts (Figure 5). Although the 1987-94 average error was similar for adjusted forecasts, errors for all years except 1989 and 1990 were reduced.

*Naknek River.* Errors in Naknek River forecasts based on Recent Data showed no trend from 1984-94 (Figure 6). The 1995 Recent Data prediction for Naknek River was 4.6 million. The estimated error for the 1995 prediction based on average errors was -1.0 million fish (Table 2). The 1987-94 average error for Recent Data Naknek River forecasts was increased from -36% to -39% by adjusting for previous years average error (Figure 6). Although the 1987-94 average error increased slightly, errors for 1987-88 and 1991-93 were reduced significantly. I decided to adjust the 1995 Naknek River forecast because the 1987-94 mean absolute error was less for adjusted forecasts (49%) compared to original forecasts (55%).

*Egegik River.* Egegik River forecasts based on Recent Data and no escapement-return data were less than observed runs for all years except 1986 and 1994 (Figure 7). The 1995 Recent Data prediction for Egegik River was 9.9 million. The estimated error for the 1995 prediction based on average errors was -4.0 million fish (Table 2). Using average errors to adjust Recent Data forecasts for Egegik River resulted in over-forecasts in 1987, 1988, 1991 and 1994 and under-forecasts in 1989-90 and 1992-93 (Figure 7). The 1987-94 average error for Recent Data Egegik River forecasts was reduced from -45% to -12% by adjusting for previous years average error.

*Ugashik River.* Errors in Ugashik River forecasts based on Recent Data showed no trend from 1984-94 (Figure 8). The 1995 Recent Data prediction for Ugashik River was 4.4 million. The estimated error for the 1995 prediction based on average errors was -1.4 million fish (Table 2). The 1987-94 average error for Recent Data Ugashik River forecasts was reduced from -25% to -1% by adjusting for previous years average error (Figure 8).

*Wood River.* Errors in Wood River forecasts based on Recent Data were positive from 1984-86, however the magnitude of the errors has been reduced in recent years (Figure 9). The 1995 Recent Data prediction for Wood River was 3.1 million. The estimated error for the 1995 prediction based on average errors was +0.4 million fish (Table 2). I did not adjust the 1995 Wood River forecast because the 1987-94 average error of the Recent Data forecasts was only 4%, while errors for adjusted forecasts averaged -52% (Figure 9).

*Igushik River.* Igushik River forecast errors based on Recent Data were positive from 1984-88, however the magnitude of the errors has been reduced in recent years (Figure 10). The 1995 Recent Data prediction for Igushik River was 1.2 million. The estimated error for the 1995 prediction based on average errors was 0.1 million fish (Table 2). I did not adjust the 1995 Igushik River forecast because the 1987-94 average error of the Recent Data forecasts was only 8%, while errors for adjusted forecasts averaged -84% (Figure 10).

*Togiak River.* Errors in Togiak River forecasts based on Recent Data showed no clear trend from 1984-94 (Figure 11). The 1995 Recent Data prediction for Togiak River was 0.5 million. The estimated error for the 1995 prediction based on average errors was 0.03 million fish (Table 2). I did not adjust the 1995 Togiak River forecast because the 1987-94 average error of the Recent Data forecasts was only -5%, while errors for adjusted forecasts averaged -37% (Figure 11).

**1995 Forecast Adjustment**

I used only Recent Data (1978-94) to forecast all Bristol Bay systems. I also adjusted individual eastside rivers forecasts by their average forecast errors, but did not adjust forecasts for westside systems. The 1995 Recent Data forecasts by eastside river were increased by: 55.1% for Kvichak, 21.7% for Branch, 22.7% for Naknek, 39.9% for Egegik, and 32.1% for Ugashik River.

### *Adjusted Total Bristol Bay Forecast*

Based on results of the Recent Data method adjusted by individual rivers 1984-94 average percent error, a total of 58,716,000 sockeye salmon (80% CI: 44,544,000 - 72,888,000) are expected to return to Bristol Bay in 1995 (Table 3). A run of this size would be the third highest run since 1956, the first year of total run information. The 1995 prediction is 59% (21,809,000 sockeye salmon) greater than the 20-year (1975-94) mean return of 36,907,000 (range: 10,671,000 to 66,293,000), and about 44% (17,888,000) greater than the most recent 10-year (1985-94) mean return of 40,828,000 (range: 23,996,000 - 55,026,000).

Total projected sockeye salmon harvest is 43,931,000 (80% CI: 29,759,000 - 58,103,000; Table 3). Most (40,285,000) of this harvest will be taken within Bristol Bay inshore fishing districts (Table 4). The remainder of the sockeye harvest (8.3% of total Bristol Bay harvest = 3,646,000) has been allocated to fisheries occurring in June in the vicinity of Shumagin Islands and South Unimak under an existing management plan (regulation 5AAC 09.365, ADF&G 1992). No estimate is available of the number of Bristol Bay sockeye salmon expected to be harvested by foreign or domestic high seas fisheries.

The total number of sockeye salmon expected to return to Bristol Bay, after the Shumagin Islands and South Unimak fisheries have occurred is 55,070,000 (Table 4). Runs should exceed spawning escapement goals for all river systems. The projected Bristol Bay combined fishing district harvest of 40,285,000 would be 141% (23,594,000) greater than the 20-year (1975-94) mean harvest of 16,691,000 (range: 4,878,000 - 40,462,000), and 55% (14,290,000) greater than the 10-year (1985-94) mean harvest of 25,995,000 (range: 13,990,000 - 40,462,000).

## *Adjusted River System Forecasts*

**Kvichak River**

A total of 26,719,000 sockeye salmon were forecasted to return to this system (Table 4). Sockeye salmon production within Kvichak River has followed a five-year abundance cycle (Mathisen and Poe 1981). A return of 26,719,000 sockeye salmon to the Kvichak River system in 1995, a peak-cycle year, would be similar to the mean return of 27,458,000 sockeye salmon (range: 14,060,000 - 47,656,000) observed during past "peak" years (1960, 1965, 1970, 1975, 1980, 1985, 1990). Age-2.2 sockeye salmon comprised 73% of the forecasted Kvichak River return (Table 3).

**Branch River**

A total of 516,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be similar to the mean return of 511,000 for 1985-1994 (range: 283,000 - 862,000), and about 8% greater than the mean return of 478,000 for 1975-1994 (range: 129,000 - 862,000). Age-1.2 and age-1.3 comprised 40% and 42% of the Branch River forecast (Table 3).

**Naknek River**

A total of 5,633,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 18% greater than the mean return of 4,791,000 for 1985-94 (range: 1,796,000 - 10,353,000) and 29% greater than the mean return of 4,368,000 for 1975-94 (range: 1,796,000 - 10,353,000). Age-1.3 and age-2.3 comprised 38% and 22% of the Naknek River forecast (Table 3).

**Egegik River**

A total of 13,926,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be about 16% greater than the mean return of 12,046,000 for 1985-94 (range: 6,175,000 - 24,687,000), but about 73% greater than the mean return of 8,055,000 for 1975-94 (range: 2,031,000 - 24,687,000). The 1995 Egegik River forecast was 59% age-2.2 and 23% age-2.3 sockeye salmon (Table 3).

**Ugashik River**

A total of 5,763,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be about 14% greater than the mean return of 5,053,000 for 1985-94 (range: 2,256,000 - 7,875,000) and about 57% greater than the mean return of 3,680,000 for 1975-94 (range: 95,000 - 7,875,000). Age-1.2 and age-2.2 sockeye salmon comprised 30% and 34% of the 1995 Ugashik River forecast (Table 3).

**Wood River**

A total of 3,121,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 16% greater than the mean return of 2,686,000 for 1985-94 (range: 1,694,000 - 3,970,000) and similar to the mean return of 2,971,000 for 1975-94 (range: 929,000 - 4,925,000). The 1995 Wood River forecast was comprised of 44% age-1.2 and 47% age-1.3 sockeye salmon (Table 3).

**Igushik River**

A total of 1,199,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be similar to the mean return of 1,151,000 for 1985-94 (range: 415,000 - 2,573,000) and also similar to the mean return of 1,225,000 for 1975-94 (range: 164,000 - 3,276,000). Approximately 76% of the 1995 Igushik River forecast was comprised of age-1.3 sockeye salmon (Table 3).

**Nushagak River**

A total of 1,300,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of his size would be 21% less than the mean return of 1,637,000 for 1985-94 (range: 964,000 - 2,362,000). The 1995 Nushagak River forecast was comprised of 54% age-1.3 and 37% zero freshwater aged sockeye salmon (Table 3).

**Togiak River**

A total of 539,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be similar to the mean return of 576,000 for 1985-94 (range: 179,000 -

1,002,000), and 16% less than the mean return of 641,000 for 1975-94 (range: 179,000 - 1,173,000). About 70% of the sockeye salmon forecasted to return to Togiak River in 1995 were age 1.3 (Table 3).

### *Expected Forecast Performance*

Our best estimate of 1995 sockeye run size was based on the Recent Data method. Subsequently, forecasts for individual eastside river systems were increased by their 1984-94 average percent error. Although this forecast is our best estimate of returning run size, differences among the various forecasting components and methods suggested that deviations would be most likely to occur in two areas:

| River System | Most Probable Deviation from Forecasted Return | Reason for Probable Deviation |
|---|---|---|
| Kvichak | less than expected return of age-2.2 sockeye salmon | Spawner-return, and sibling forecasts indicated lower returns of age-2.2 fish than smolt forecasts. |
| Egegik | greater than expected return of age-2.2 sockeye salmon. | The spawner-return relationship was not used in 1995, but it predicted more age-2.2 fish than either sibling or smolt forecasts. |

This is the fifth year ADF&G adjusted the forecast based on historic forecast errors. If the 1995 run is similar to runs occurring in the past eleven years, the forecast should be close to the actual run. If the 1995 run is below average, similar to 1986 and 1988 runs, the 1995 forecast will be too high. Other indicators that can be used to assess preseason forecast accuracy will not be available until June 1995 when the Shumagin Islands-South Unimak commercial fishery and the Port Moller offshore test fishery (operated by Fisheries Research Institute, University of Washington) take place. Catch, effort, and age composition data collected from these fisheries have been used in past years with varying degrees of success to modify preseason expectations (Eggers and Shaul 1987; Fried and Hilborn 1988; Yuen and Fried 1985).

## *Outlook to 1998*

Comparisons of 1995-98 forecasts based only on spawner-recruit data not adjusted for historic errors suggested that the total number of sockeye salmon returning to Bristol Bay would be highest in 1995 and similar in 1996-98 (Table 5). Runs to all river systems are not only expected to exceed escapement goals, but also produce high catches similar to the past five years. The reader is cautioned that these long-term predictions are based only on spawner-recruit data and will undoubtedly change as smolt and sibling information become available.

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Table 1. Annual percent errors, mean percent errors (MPE), and mean absolute percent errors (MAPE) for hindcasts of sockeye salmon based on Recent Data which include and exclude spawner-recruit estimates, Kvichak, Egegik and Ugashik Rivers, 1984-94.

| | Percent Errors[a] | | | | | |
|---|---|---|---|---|---|---|
| | Kvichak | | Egegik | | Ugashik | |
| Year | Include S/R[b] | Omit S/R | Include S/R | Omit S/R | Include S/R | Omit S/R |
| 1984 | -21.7 | -33.8 | -34.0 | -20.9 | -27.7 | -27.7 |
| 1985 | -29.6 | -8.0 | -44.0 | -39.7 | -49.1 | -57.9 |
| 1986 | 287.6 | 335.6 | -36.1 | 19.9 | -15.7 | -37.5 |
| 1987 | -55.9 | -67.7 | -27.4 | -12.7 | 59.2 | 20.2 |
| 1988 | 33.1 | 14.9 | -28.5 | -15.7 | 51.9 | 5.4 |
| 1989 | -37.6 | -54.8 | -44.0 | -30.0 | -24.3 | -32.4 |
| 1990 | -47.5 | -51.0 | -53.4 | -45.7 | 9.6 | -16.0 |
| 1991 | -25.6 | -19.1 | -33.2 | -7.9 | -50.2 | -60.4 |
| 1992 | -12.1 | -17.6 | -54.8 | -47.1 | -41.8 | -32.7 |
| 1993 | -4.5 | -10.7 | -67.3 | -52.1 | -33.2 | -24.5 |
| 1994 | -35.6 | -38.4 | -3.8 | 3.3 | -20.0 | -28.0 |
| 84-94 MPE | 4.6 | 4.6 | -38.8 | -22.6 | -12.8 | -26.5 |
| 84-94 MAPE | 53.7 | 59.2 | 38.8 | 26.8 | 34.8 | 31.2 |

[a] Percent error calculated as:
(forecast - actual return) / actual return x 100

[b] S/R stands for spawner-recruit estimates.

Table 2. Comparison of 1995 preliminary forecasts, estimated forecast errors, and adjusted forecasts based on Recent Data for combined eastside, combined westside, and individual Bristol Bay rivers.

| | | Millions of Sockeye Salmon | | |
|---|---|---|---|---|
| Data Base | Method of Modeling | Original 1995 Forecast | Estimated Error 1995[a] | Adjusted 1995 Forecast |
| Eastside[b] - Recent Data | 84-94 Avg Error | 38.0 | -14.0 | 52.0 |
| Westside[c] - Recent Data | 84-94 Avg Error | 4.9 | +0.5 | 4.4 |
| Individual Rivers - Recent Data | 84-94 Avg Error | | | |
| Kvichak | | 17.2 | -9.5 | 26.7 |
| Branch | | 0.4 | -0.1 | 0.5 |
| Naknek | | 4.6 | -1.0 | 5.6 |
| Egegik | | 9.9 | -4.0 | 13.9 |
| Ugashik | | 4.4 | -1.4 | 5.8 |
| Wood | | 3.1 | +0.4 | Did Not Adjust |
| Igushik | | 1.2 | +0.1 | Did Not Adjust |
| Nushagak | | 1.3 | No Estimate | Did Not Adjust |
| Togiak | | 0.5 | +0.0 | Did Not Adjust |

[a] Error = (predicted - actual).
[b] Eastside includes Kvichak, Naknek, Egegik, and Ugashik Rivers.
[c] Westside includes Wood, Igushik, and Togiak Rivers.

Table 3. Forecasted production, spawning escapement goals, and total projected harvests of major age classes of sockeye salmon returning to Bristol Bay river systems in 1995 based on results of the Recent Data method adjusted by individual rivers 1984-94 average percent error.

| | Thousands of Sockeye Salmon | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forecasted Production by Age Class | | | | | | | |
| District: River | 1.2 | 2.2 | 1.3 | 2.3 | Other[a] | Total | Spawning Goal | Total Harvest |
| NAKNEK-KVICHAK: | | | | | | | | |
| Kvichak | 3,496 | 19,520 | 2,147 | 1,556 | | 26,719 | 10,000 | 16,719 |
| Branch | 209 | 58 | 219 | 30 | | 516 | 185 | 331 |
| Naknek | 1,050 | 1,183 | 2,133 | 1,267 | | 5,633 | 1,000 | 4,633 |
| Total | 4,755 | 20,761 | 4,499 | 2,853 | | 32,868 | 11,185 | 21,683 |
| EGEGIK | 1,135 | 8,261 | 1,259 | 3,271 | | 13,926 | 1,000 | 12,926 |
| UGASHIK | 1,727 | 1,944 | 775 | 1,317 | | 5,763 | 700 | 5,063 |
| NUSHAGAK:[b] | | | | | | | | |
| Wood | 1,364 | 270 | 1,469 | 18 | | 3,121 | 1,000 | 2,121 |
| Igushik | 198 | 46 | 906 | 49 | | 1,199 | 200 | 999 |
| Nushagak | 99 | 20 | 701 | 4 | 476 | 1,300 | 550 | 750 |
| Total | 1,661 | 336 | 3,076 | 71 | 476 | 5,620 | 1,750 | 3,870 |
| TOGIAK[c] | 114 | 26 | 375 | 24 | | 539 | 150 | 389 |
| BRISTOL BAY | 9,392 | 31,328 | 9,984 | 7,536 | 476 | 58,716 | 14,785 | 43,931 |

[a] Other includes zero freshwater ages (0.2, 0.3, 0.4) which are only forecasted for Nushagak River.

[b] Forecast for Snake River system was not included (1971-1991 average escapement was 18,000).

[c] Forecasts for Kulukak, Kanik, Osviak, and Matogak River systems were not included. These systems may contribute an additional 76,000 (1985-1994 mean catch) to Togiak District harvest.

cted commercial harvests of sockeye salmon returning to
ol Bay river systems in 1995 based on results of
ecent Data method adjusted by individual rivers 1984-94
ge percent error.

| Thousands of Sockeye Salmon | | | | |
|---|---|---|---|---|
| | | Bristol Bay | | |
| Forecasted Total Production | Shumagin Islands- S. Unimak Harvest[a] | Total Run | Spawning Goal | Harvest |
| 26,719 | 1,659 | 25,060 | 10,000 | 15,060 |
| 516 | 32 | 484 | 185 | 299 |
| 5,633 | 350 | 5,283 | 1,000 | 4,283 |
| 32,868 | 2,041 | 30,827 | 11,185 | 19,642 |
| 13,926 | 865 | 13,061 | 1,000 | 12,061 |
| 5,763 | 358 | 5,405 | 700 | 4,705 |
| 3,121 | 194 | 2,927 | 1,000 | 1,927 |
| 1,199 | 74 | 1,125 | 200 | 925 |
| 1,300 | 81 | 1,219 | 550 | 669 |
| 5,620 | 349 | 5,271 | 1,750 | 3,521 |
| 539 | 33 | 506 | 150 | 356 |
| 58,716 | 3,646 | 55,070 | 14,785 | 40,285 |

ırvest calculated as 8.3% of projected Bristol Bay
umbers were apportioned among river systems based on
in the forecast of total production.

Table 5. Preliminary forecasts of sockeye salmon returns to Bristol Bay, 1995-1998, based on spawner-recruit data only, and not adjusted for historic forecast errors.

| DISTRICT: River | Thousands of Sockeye Salmon | | | |
|---|---|---|---|---|
| | 1995 | 1996 | 1997 | 1998 |
| NAKNEK-KVICHAK: | | | | |
| Kvichak | 13,290 | 9,972 | 10,144 | 10,481 |
| Branch | 434 | 407 | 408 | 363 |
| Naknek | 5,082 | 6,828 | 4,957 | 3,962 |
| Total | 18,806 | 17,207 | 15,509 | 14,806 |
| EGEGIK | 14,998 | 10,536 | 10,732 | 12,634 |
| UGASHIK | 4,509 | 7,119 | 7,041 | 5,365 |
| NUSHAGAK: | | | | |
| Wood | 3,235 | 3,223 | 3,191 | 3,209 |
| Igushik | 1,397 | 1,262 | 1,419 | 1,467 |
| Nushagak-Mulchatna | 1,666 | 1,629 | 1,768 | 1,630 |
| Total | 6,298 | 6,114 | 6,378 | 6,306 |
| TOGIAK | 581 | 586 | 602 | 604 |
| BRISTOL BAY | 45,192 | 41,562 | 40,262 | 39,715 |

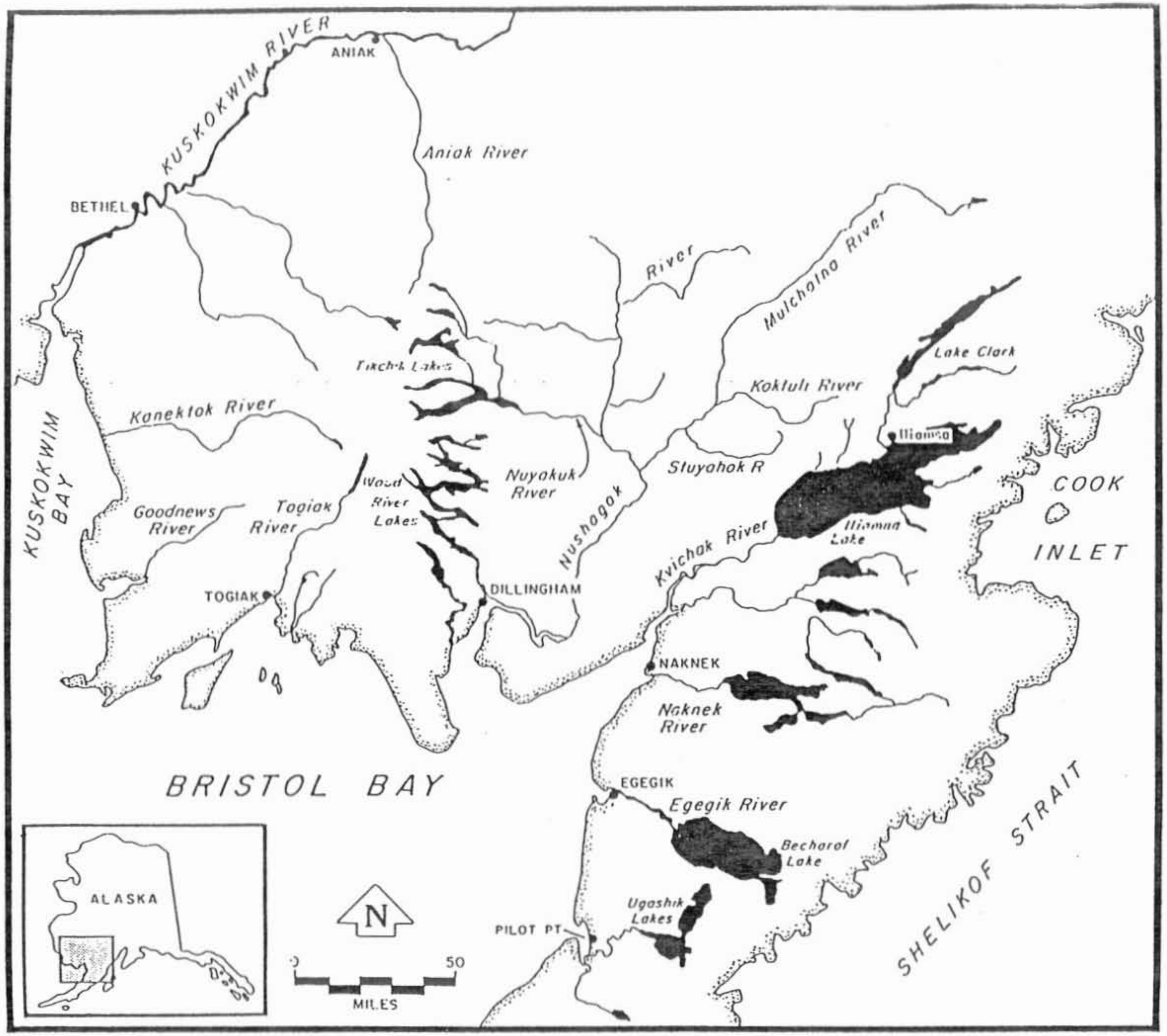



Figure 1. Map of Bristol Bay, Alaska showing major rivers.

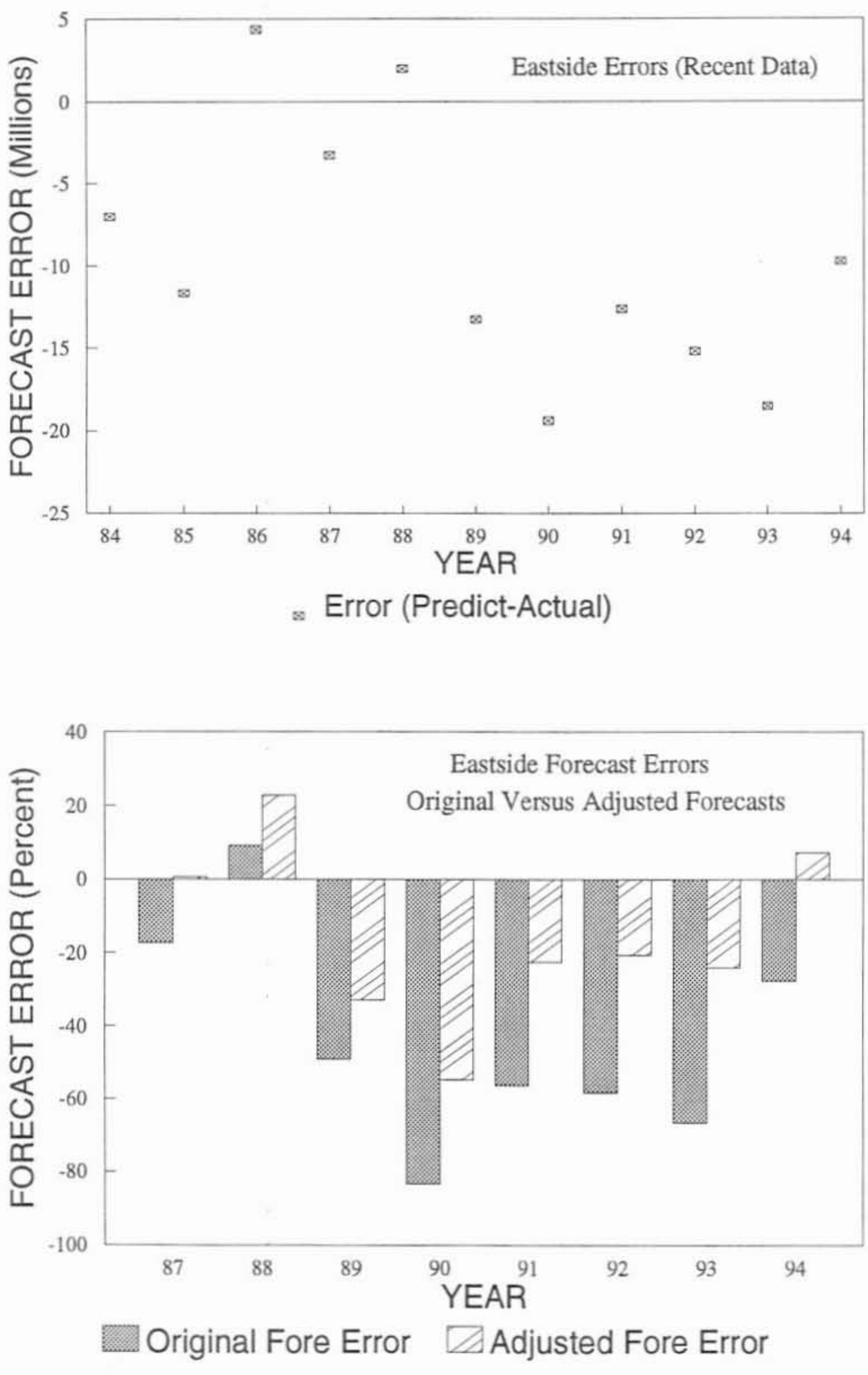
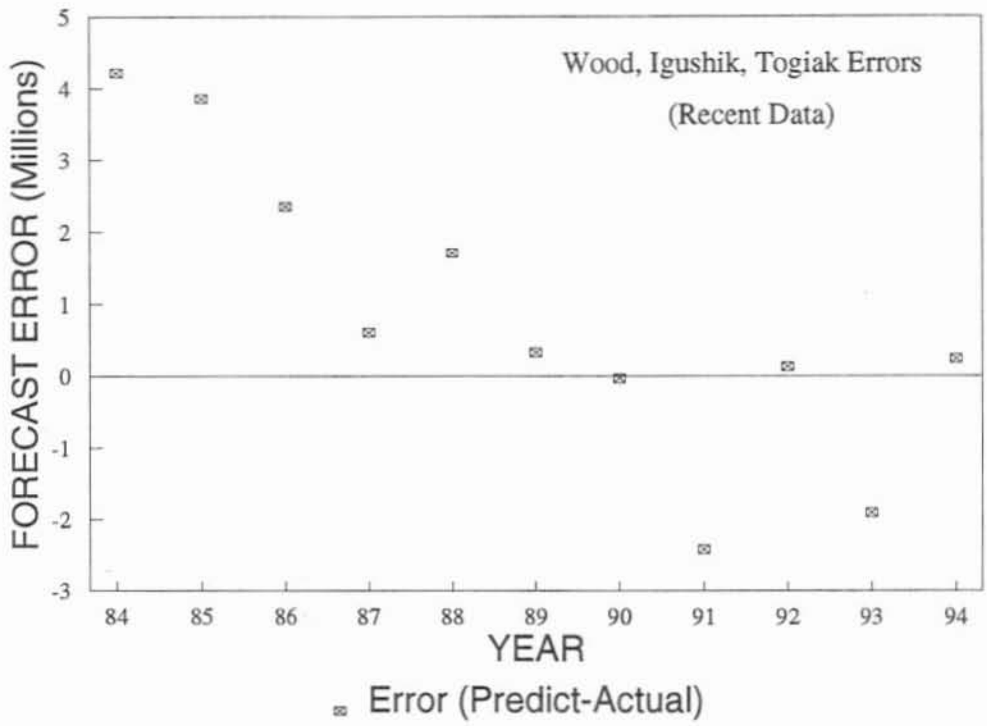



Figure 2. Errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).



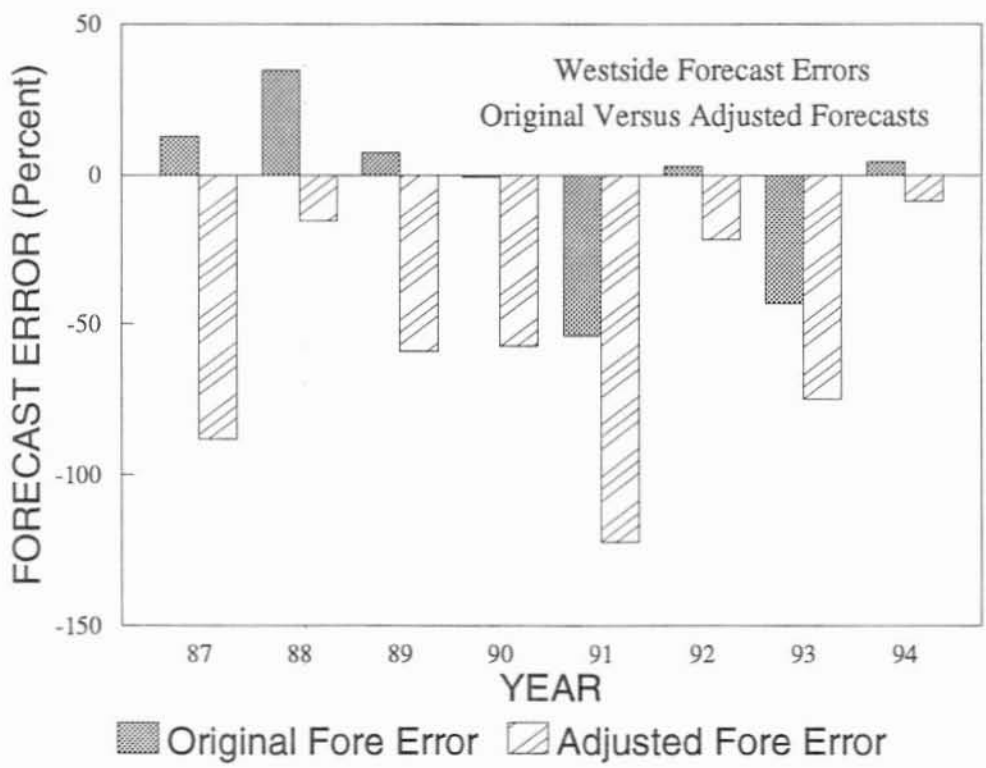
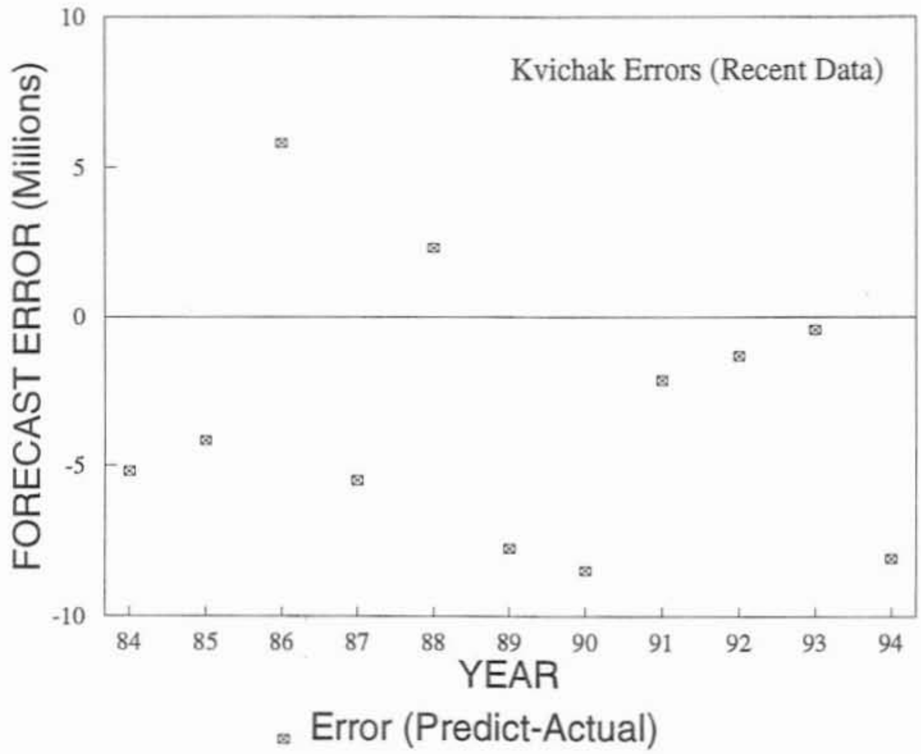




Figure 3. Errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).



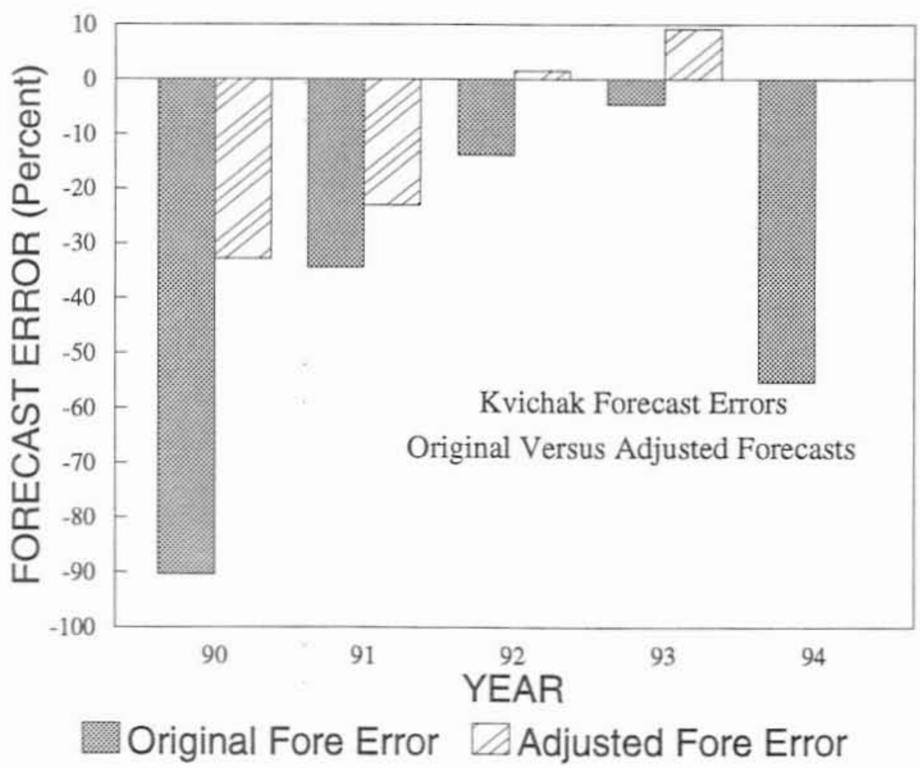
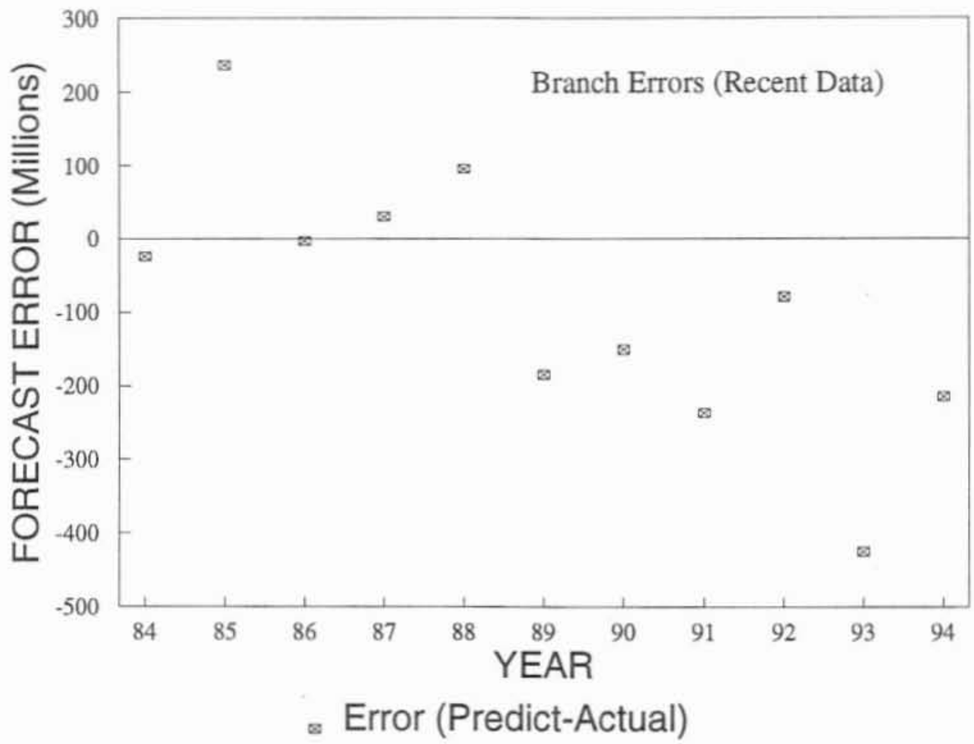




Figure 4. Errors (predicted run - actual run) of Kvichak River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1990-94 (bottom).



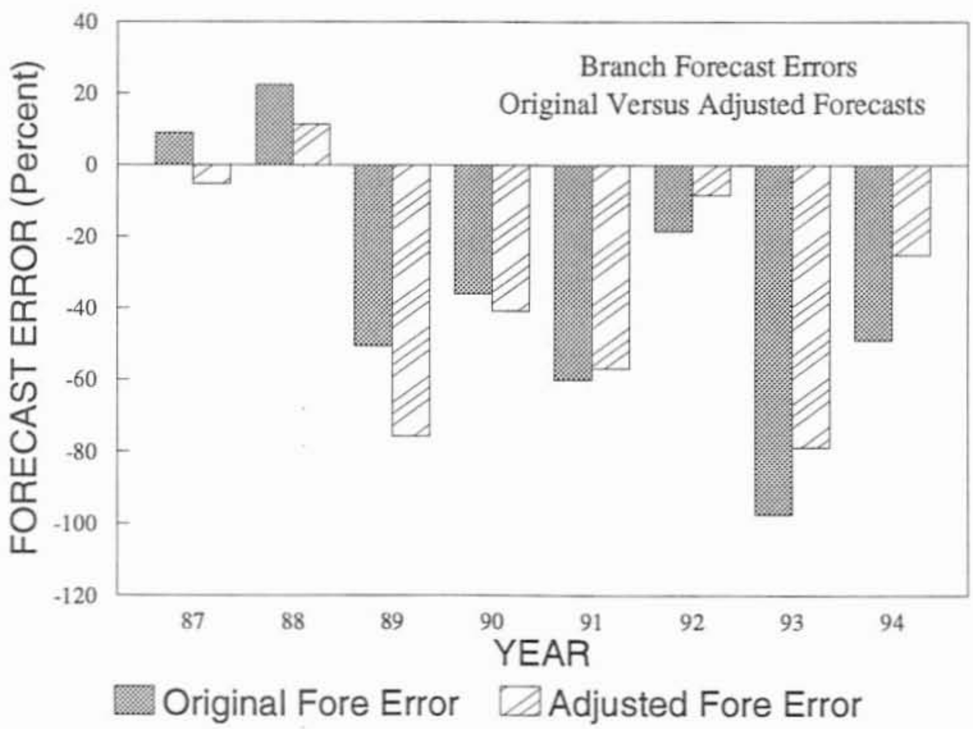




Figure 5. Errors (predicted run - actual run) of Branch River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).

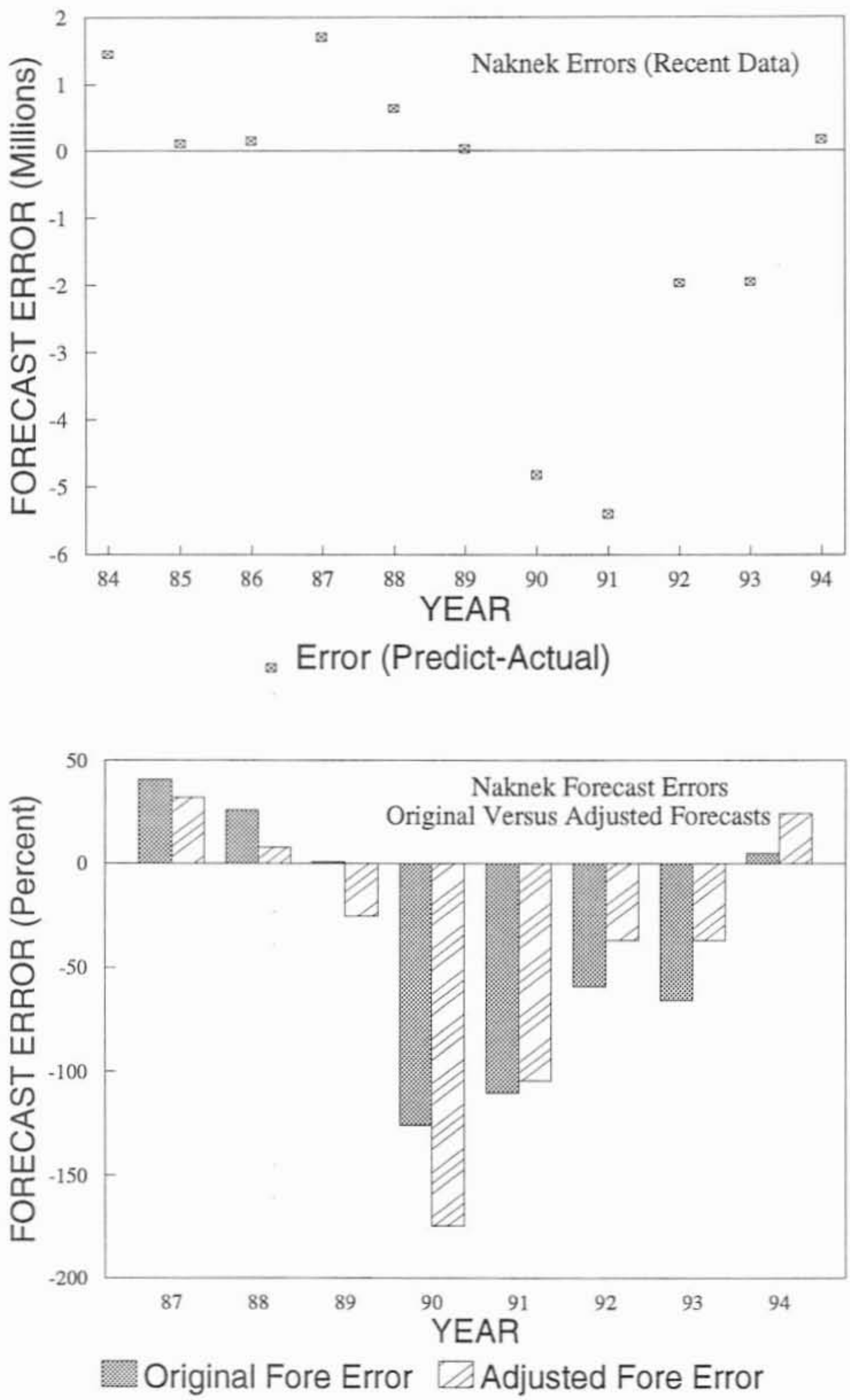
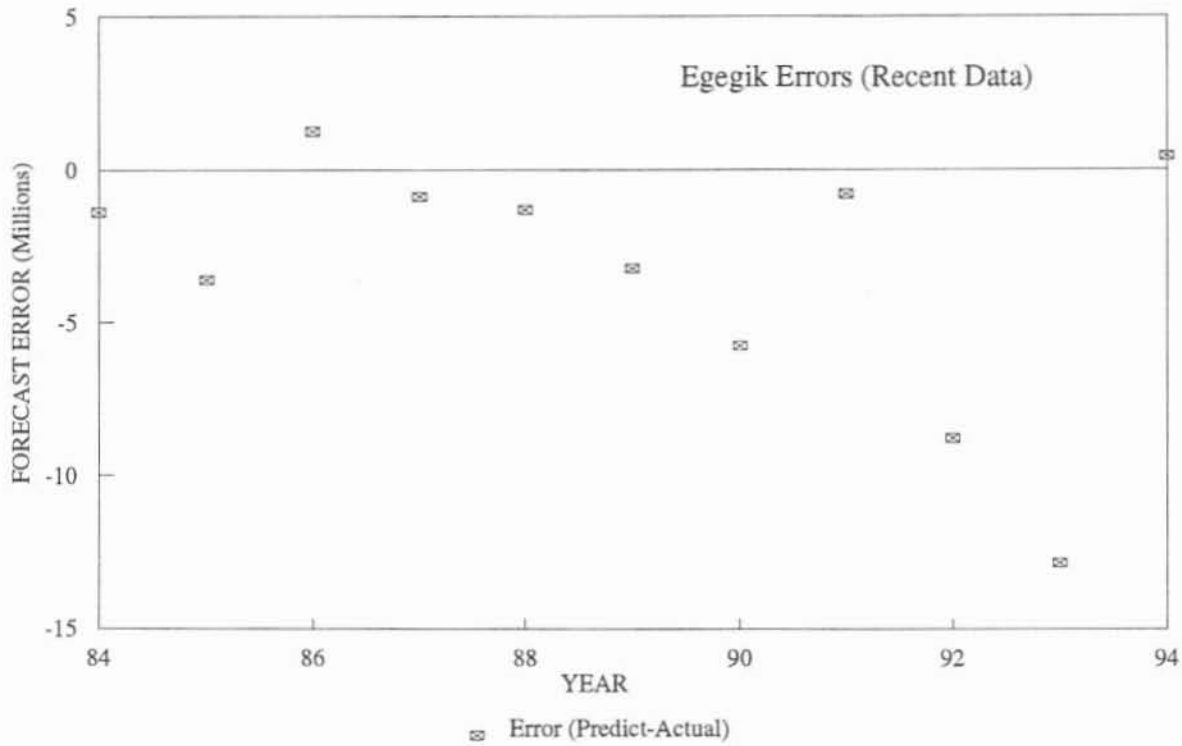



Figure 6. Errors (predicted run - actual run) of Naknek River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).



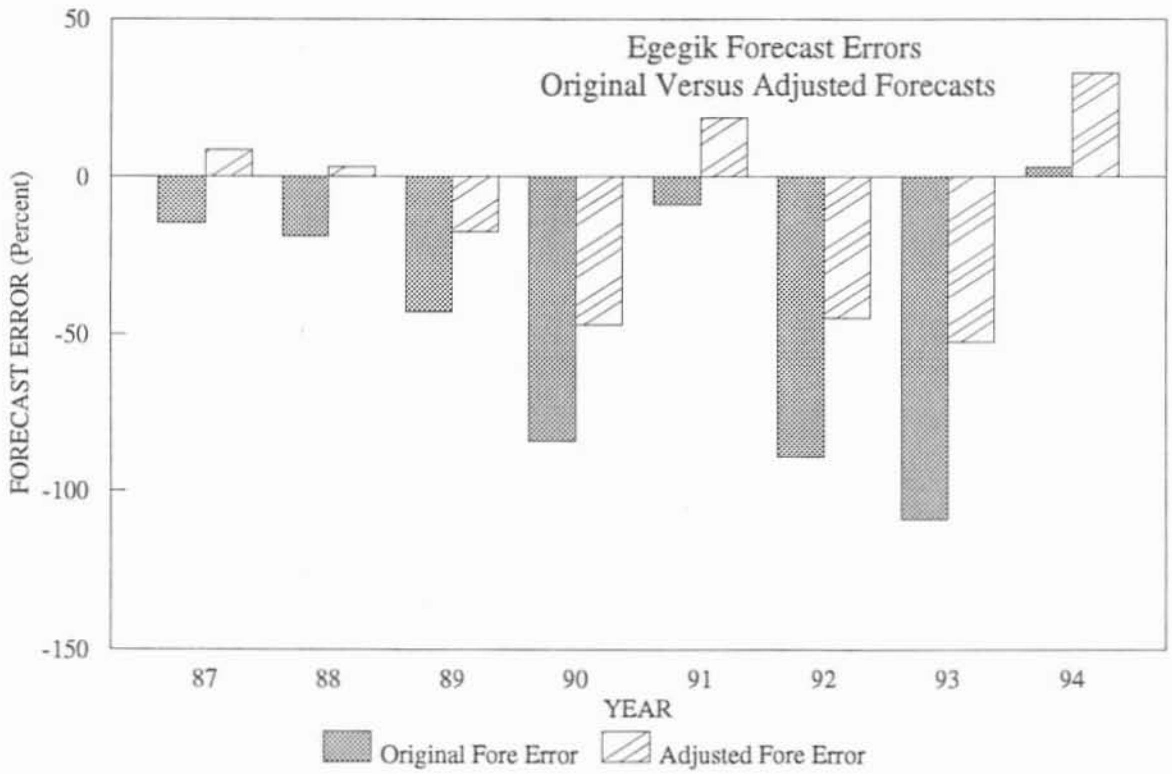
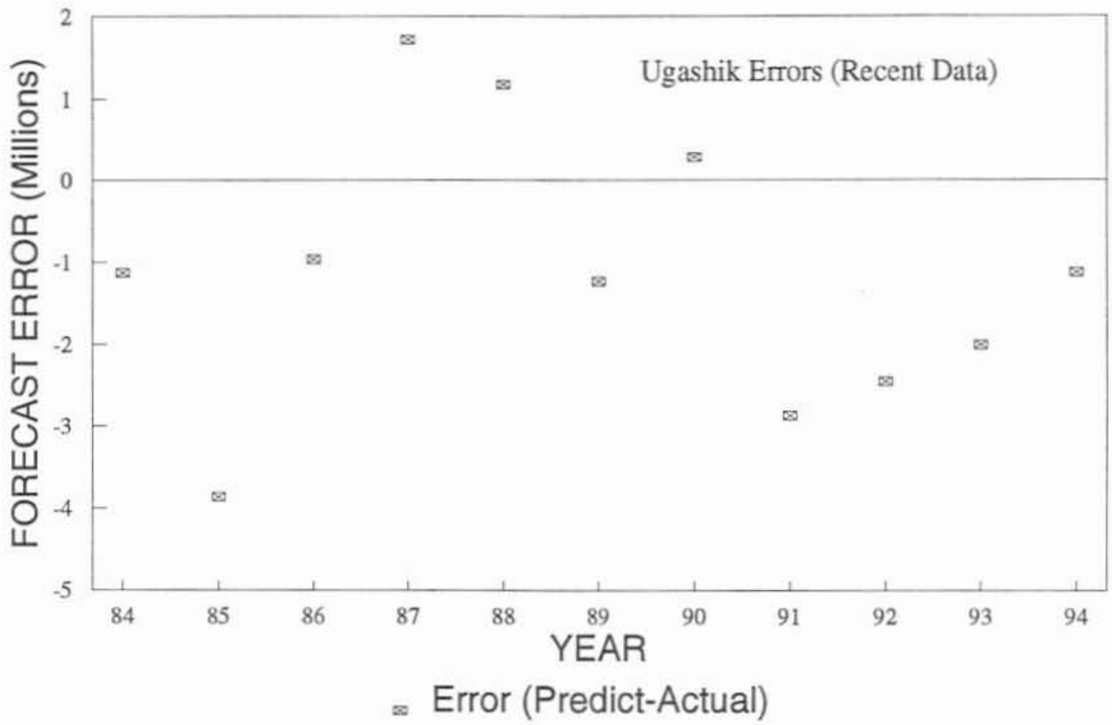




Figure 7. Errors (predicted run - actual run) of Egegik River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).



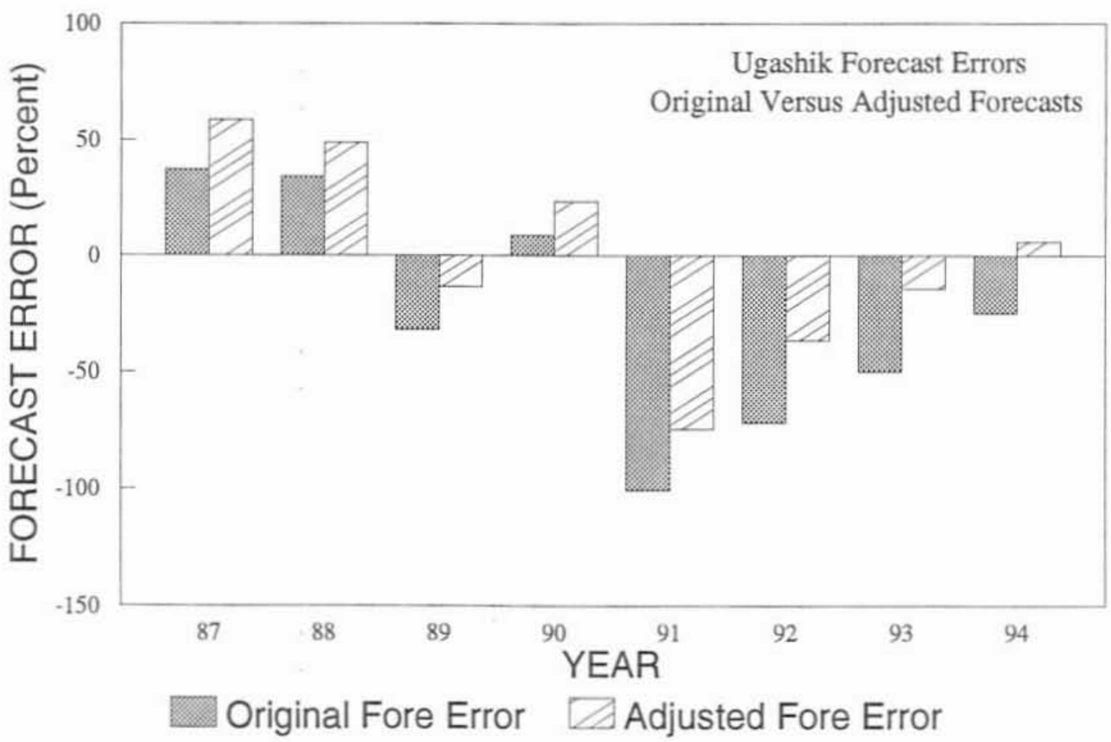
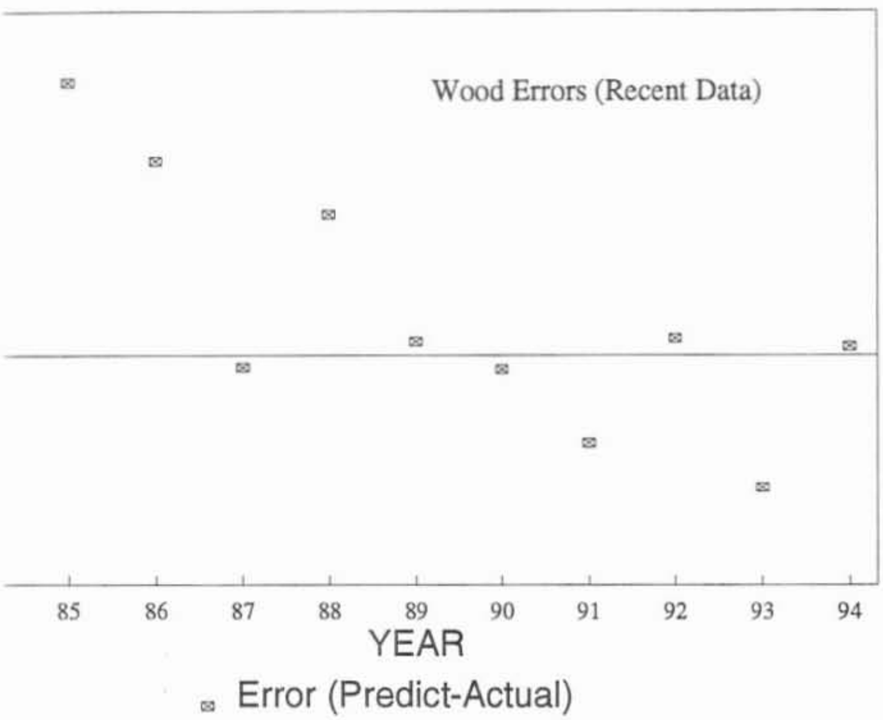
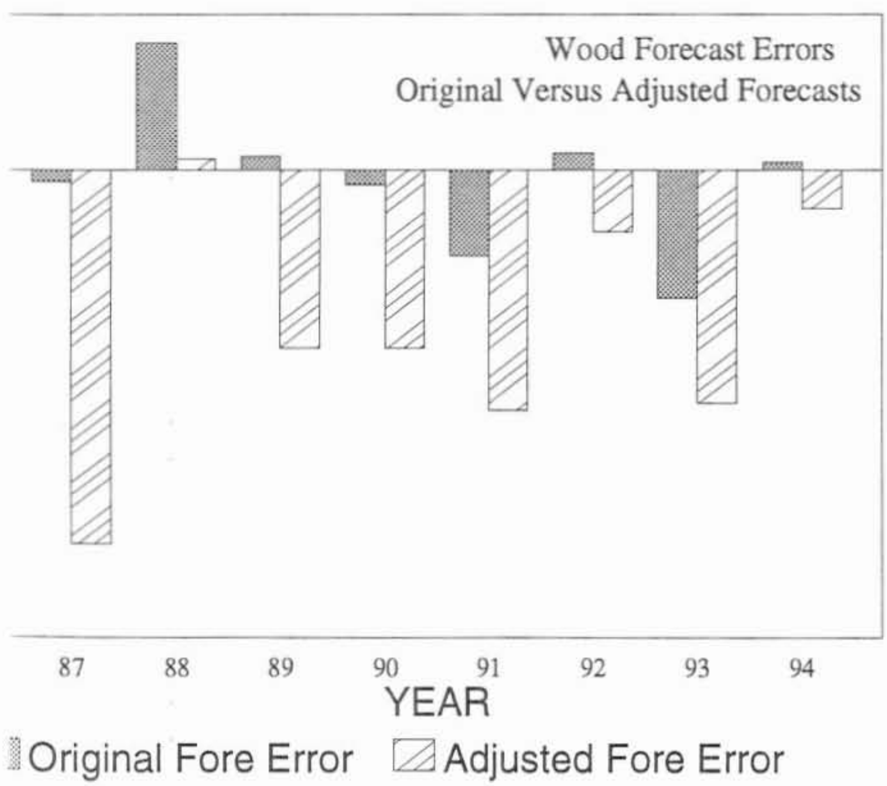
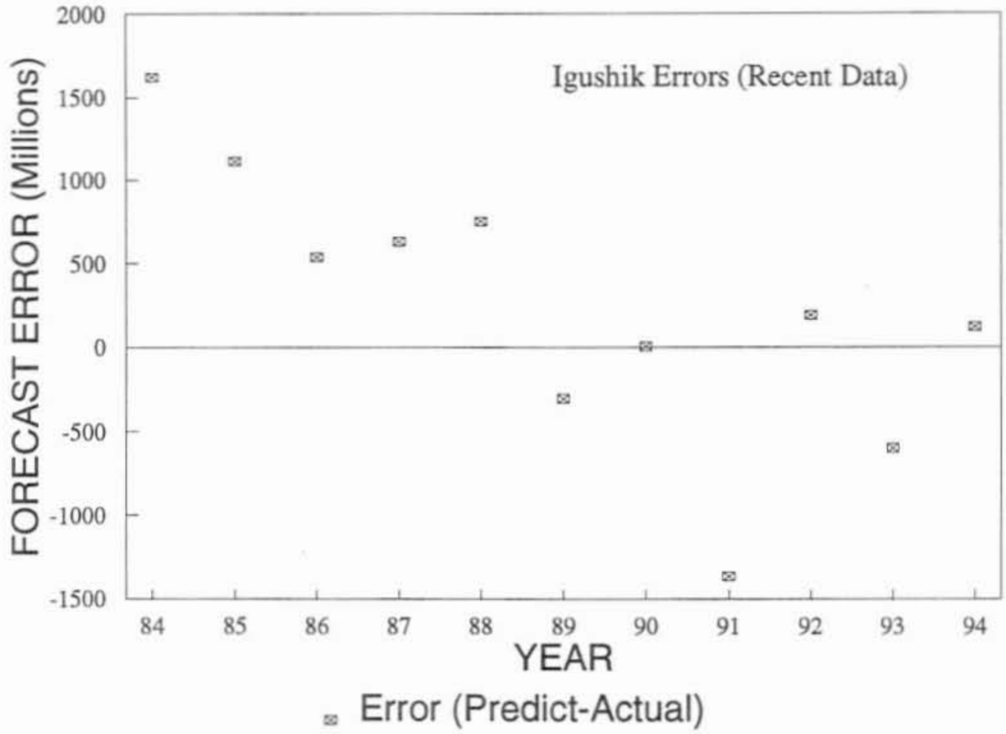




Figure 8. Errors (predicted run - actual run) of Ugashik River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).




ɔrs (predicted run - actual run) of Wood River forecasts made
Recent Data for 1984-94 (top) and a comparison between
ıal and adjusted forecast errors, 1987-94 (bottom).



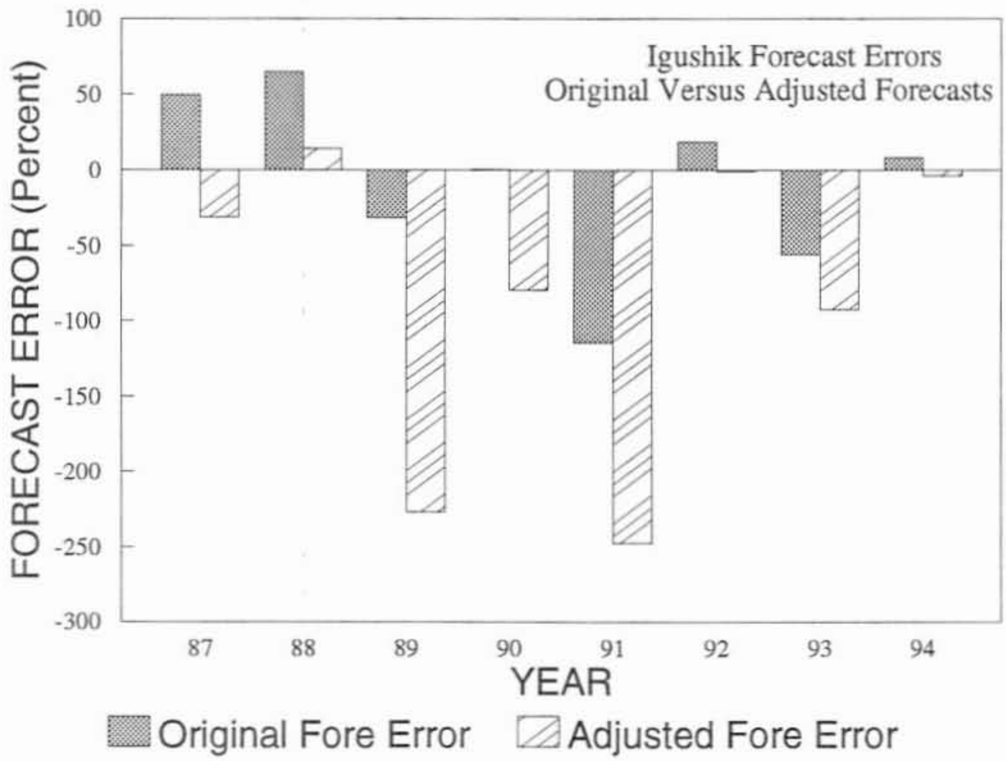
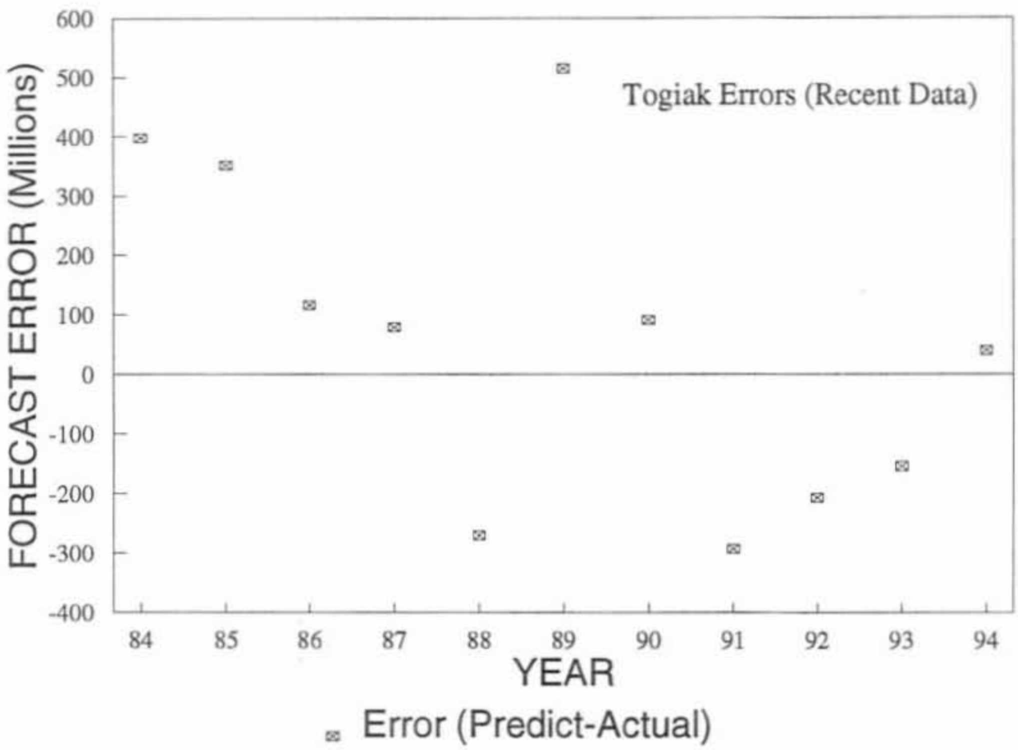




Figure 10. Errors (predicted run - actual run) of Igushik River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).



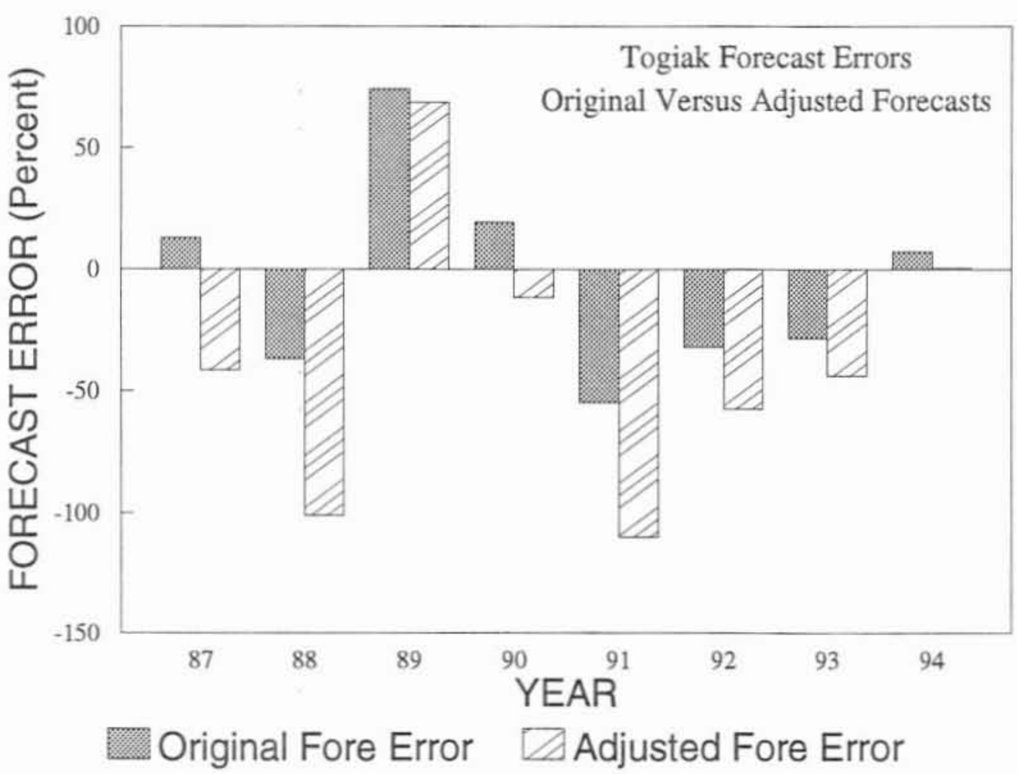




Figure 11. Errors (predicted run - actual run) of Togiak River forecasts made with Recent Data for 1984-94 (top) and a comparison between original and adjusted forecast errors, 1987-94 (bottom).

## APPENDIX A: HISTORIC SOCKEYE FORECASTS AND RETURNS

Appendix A.1. Preseason forecasts of sockeye salmon returns to Bristol Bay, 1961-1994, issued by the Alaska Department of Fish and Game.

| Year | Forecast (millions) | Actual Return (millions) | | Percent Error[b] |
|---|---|---|---|---|
| | | Inshore | Total[a] | |
| 1961 | 43.6 | 18.1 | 24.5 | 78.0 |
| 1962 | 19.6 | 10.4 | 11.7 | 67.5 |
| 1963 | 8.6 | 6.9 | 8.0 | 7.5 |
| 1964 | 17.4 | 10.9 | 11.5 | 51.3 |
| 1965 | 27.8 | 53.1 | 60.8 | -54.3 |
| 1966 | 31.3 | 17.5 | 20.0 | 56.5 |
| 1967 | 13.7 | 10.3 | 11.5 | 19.1 |
| 1968 | 10.4 | 8.0 | 9.4 | 10.6 |
| 1969 | 21.3 | 19.0 | 21.9 | -2.7 |
| 1970 | 62.7 | 39.4 | 45.0 | 39.3 |
| 1971 | 1.2 | 15.8 | 18.3 | -16.9 |
| 1972 | 9.7 | 5.4 | 7.2 | 34.7 |
| 1973 | 6.2 | 2.4 | 3.5 | 77.1 |
| 1974 | 5.0 | 10.9 | 11.5 | -56.5 |
| 1975 | 12.0 | 24.2 | 25.8 | -53.5 |
| 1976 | 12.0 | 11.5 | 12.8 | -6.3 |
| 1977 | 8.4 | 9.7 | 10.7 | -21.5 |
| 1978 | 11.5 | 19.8 | 20.8 | -44.7 |
| 1979 | 22.7 | 39.8 | 40.9 | -44.5 |
| 1980 | 54.5 | 62.4 | 66.2 | -17.7 |
| 1981 | 26.7 | 34.5 | 37.1 | -28.0 |
| 1982 | 34.6 | 22.1 | 24.7 | 40.1 |
| 1983 | 33.4 | 45.8 | 48.0 | -30.4 |
| 1984 | 31.1 | 41.0 | 42.6 | -27.0 |
| 1985 | 35.0 | 36.6 | 38.5 | -9.1 |
| 1986 | 22.5 | 23.7 | 24.4 | -7.8 |
| 1987 | 16.5 | 27.3 | 28.3 | -41.7 |
| 1988 | 28.8 | 23.2 | 24.0 | 20.0 |
| 1989 | 30.4 | 43.9 | 45.7 | -33.5 |
| 1990 | 26.7 | 47.6 | 49.0 | -45.5 |
| 1991 | 31.9 | 42.2 | 43.8 | -27.2 |
| 1992 | 39.6 | 45.1 | 47.5 | -16.6 |
| 1993 | 44.7 | 52.1 | 55.0 | -18.7 |
| 1994 | 56.0 | 50.3 | 51.8 | 8.1 |

[a] Includes foreign high seas and domestic Shumagin Islands-South Unimak catches.

[b] Percent error calculated as: (forecast - actual total return) / actual total return x 100.

APPENDIX B: HINDCAST ERRORS

Appendix B.1. Annual percent errors, mean percent errors (MPE), and mean absolute percent errors (MAPE) for hindcasts of total sockeye salmon returns to Bristol Bay river systems, 1984-94, based on All Data (1956-94) or Recent Data (1978-94).

| | Percent Errors[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Kvichak | Branch | Naknek | Egegik | Ugashik | Wood | Igushik | Nuyakuk/ Nushagak[b] | Togiak | Combined East | Combined West | Total |
| | | | | | ALL DATA FORECASTS | | | | | | | |
| 1984 | -40.0 | -32.7 | -29.4 | -49.1 | -44.4 | -12.2 | 73.5 | 23.9 | 0.4 | -41.1 | 7.8 | -36.5 |
| 1985 | 1.3 | -9.5 | -21.0 | -58.9 | -56.9 | 5.1 | -33.5 | -4.6 | -20.5 | -29.8 | -5.7 | -27.7 |
| 1986 | 126.3 | -52.6 | -32.0 | -54.7 | -67.8 | -3.5 | -36.2 | -26.8 | -4.4 | -34.7 | -18.1 | -31.3 |
| 1987 | -78.4 | -13.4 | -15.5 | -43.0 | -47.8 | -35.0 | -18.9 | 37.7 | -24.0 | -55.7 | -22.0 | -49.8 |
| 1988 | -9.5 | -13.0 | 13.5 | -54.5 | -17.0 | 9.9 | 13.5 | 42.3 | -56.0 | -27.3 | -1.3 | -23.0 |
| 1989 | -48.5 | -48.0 | -18.4 | -61.4 | -47.4 | -24.6 | -64.5 | -37.0 | 81.0 | -49.4 | -33.5 | -47.5 |
| 1990 | -55.6 | -47.6 | -65.1 | -61.5 | -50.2 | -29.6 | -51.1 | -52.2 | -11.9 | -58.8 | -39.6 | -56.3 |
| 1991 | -49.1 | -49.2 | -68.1 | -41.1 | -75.9 | -38.0 | -75.9 | -34.8 | -52.3 | -56.8 | -49.7 | -55.4 |
| 1992 | -27.3 | -42.4 | -53.5 | -65.7 | -62.8 | -23.3 | -37.8 | -23.5 | -45.4 | -53.3 | -28.4 | -50.0 |
| 1993 | -31.8 | -61.9 | -49.1 | -73.2 | -42.6 | -44.6 | -65.4 | -27.9 | -36.7 | -57.7 | -43.4 | -55.4 |
| 1994 | -45.8 | -45.3 | -19.3 | -17.1 | -46.3 | -36.6 | -41.5 | -3.2 | -23.6 | -35.7 | -28.4 | -34.8 |
| 84-94 MPE | -23.5 | -37.8 | -32.6 | -52.7 | -50.8 | -21.1 | -30.7 | -9.7 | -17.6 | -45.5 | -23.8 | -42.5 |
| 84-94 MAPE | 46.7 | 37.8 | 42.8 | 52.7 | 50.8 | 23.8 | 46.5 | 28.5 | 32.4 | 45.5 | 25.3 | 42.5 |
| 87-94 MPE | -43.3 | -40.1 | -34.5 | -52.2 | -48.8 | -27.7 | -42.7 | -12.3 | -21.1 | -49.3 | -30.8 | -46.5 |
| 87-94 MAPE | 43.3 | 40.1 | 37.8 | 52.2 | 48.8 | 30.2 | 46.1 | 32.3 | 41.4 | 49.3 | 30.8 | 46.5 |
| | | | | | RECENT DATA FORECASTS | | | | | | | |
| 1984 | -21.7 | -4.1 | 47.4 | -34.0 | -27.7 | 105.7 | 355.7 | 196.4 | 80.2 | -18.7 | 152.9 | -2.5 |
| 1985 | -29.6 | 83.7 | 2.9 | -44.0 | -49.1 | 141.0 | 227.6 | 34.8 | 92.4 | -33.2 | 124.4 | -19.6 |
| 1986 | 287.6 | -0.7 | 3.7 | -36.1 | -15.7 | 93.1 | 59.1 | 23.5 | 28.5 | 14.3 | 56.0 | 23.0 |
| 1987 | -55.9 | 9.8 | 68.9 | -27.4 | 59.2 | -3.7 | 98.1 | 248.4 | 14.6 | -17.5 | 45.2 | -6.6 |
| 1988 | 33.1 | 28.6 | 35.4 | -28.5 | 51.9 | 68.4 | 181.0 | 177.0 | -26.9 | 9.4 | 74.3 | 20.1 |
| 1989 | -37.6 | -33.5 | 0.9 | -44.0 | -24.3 | 4.4 | -24.1 | -2.3 | 287.7 | -34.4 | 5.5 | -29.7 |
| 1990 | -47.5 | -26.4 | -55.7 | -53.4 | 9.6 | -4.6 | 0.5 | -16.1 | 23.6 | -46.7 | -5.1 | -41.3 |
| 1991 | -25.6 | -37.5 | -52.4 | -33.2 | -50.2 | -21.6 | -53.4 | -12.8 | -35.4 | -39.9 | -30.3 | -38.0 |
| 1992 | -12.1 | -15.6 | -37.1 | -54.8 | -41.8 | 5.6 | 22.4 | -23.5 | -24.2 | -38.9 | -5.2 | -34.4 |
| 1993 | -4.5 | -49.3 | -39.7 | -67.3 | -33.2 | -29.0 | -35.8 | -27.9 | -22.1 | -46.2 | -29.4 | -43.6 |
| 1994 | -35.6 | -32.8 | 5.4 | -3.8 | -20.0 | 2.4 | 8.6 | -3.2 | 7.9 | -21.6 | 2.7 | -18.4 |
| 84-94 MPE | 4.6 | -7.1 | -1.8 | -38.8 | -12.8 | 32.9 | 76.3 | 54.0 | 38.8 | -24.8 | 35.5 | -17.4 |
| 84-94 MAPE | 53.7 | 29.3 | 31.8 | 38.8 | 34.8 | 43.6 | 96.9 | 69.6 | 58.5 | 29.2 | 48.3 | 25.2 |
| 87-94 MPE | -23.2 | -19.6 | -9.3 | -39.0 | -6.1 | 2.7 | 24.7 | 42.4 | 28.1 | -29.5 | 7.2 | -24.0 |
| 87-94 MAPE | 31.5 | 29.2 | 36.9 | 39.0 | 36.3 | 17.5 | 53.0 | 63.9 | 55.3 | 31.8 | 24.7 | 29.0 |

[a] Percent error calculated as:
(forecast - actual total return) / actual total return x 100.

[b] Hindcasts 1984-91 were for Nuyakuk River, 1992-94 hindcasts were for total Nushagak River.

DIX C: UNADJUSTED RIVER SYSTEM FORECASTS

dix C.1. Forecasted returns of major age classes of sockeye salmon to the Kvichak River in 1995 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

| Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|
| 4,222 | 2,829 | 5.0 | 17 |
| 6,970 | 7,217 | 0.1 | 17 |
| 6,970 | 2,173 | 0.1 | 17 |
| 8,317 | 1,071 | 2.5 | 17 |
| | Total 13,290 | | |

Sibling Data

| Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|
| 0 | [a] | | |
| 83 | 12,239 | 0.1 | 14 |
| 1,540 | 1,055 | 1.0 | 16 |
| 18,795 | 1,217 | 1.0 | 16 |
| | Total 14,511 | | |

Smolt Data

| Smolt Production (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|
| 21,781 | 1,679 | 5.0 | 17 |
| 204,626 | 18,296 | 0.1 | 17 |
| 18,172 | 924 | 5.0 | 16 |
| 61,317 | 722 | 5.0 | 16 |
| | Total 21,621 | | |

:imate not made; no age-1.1 sockeye salmon returned to Kvichak ver in 1994

Appendix C.2. Forecasted returns of major age classes of sockeye salmon to the Branch River in 1995 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 277 | 206 | 5.0 | 17 |
| 2.2 | 168 | 48 | 25.0 | 16 |
| 1.3 | 168 | 180 | 1.0 | 17 |
| 2.3 | 196 | 13[a] | NS | 17 |
| | Total | 447 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 1 | 137 | 10.0 | 14 |
| 2.2 | 0 | [b] | | |
| 1.3 | 262 | 215[a] | NS | 16 |
| 2.3 | 178 | 25 | 5.0 | 15 |
| | Total | 377 | | |

[a] Estimate not used; regression model not significant at 25% level (P>0.25).

[b] Estimate not made; no age-2.1 sockeye salmon returned to Branch River in 1994

Appendix C.3. Forecasted returns of major age classes of sockeye salmon to the Naknek River in 1995 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 3,578 | 1,002 | 25.0 | 17 |
| 2.2 | 2,092 | 964 | 25.0 | 17 |
| 1.3 | 2,092 | 2,232 | 5.0 | 17 |
| 2.3 | 1,161 | 884 | 10.0 | 17 |
| | Total | 5,082 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 12 | 1,218 | 25.0 | 12 |
| 2.2 | 46 | 944[a] | NS | 14 |
| 1.3 | 405 | 1,246 | 2.5 | 16 |
| 2.3 | 1,152 | 1,181 | 2.5 | 16 |
| | Total | 4,589 | | |

Smolt Data

| Age Class | Smolt Production (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 24,184 | 350 | 25.0 | 5 |
| 2.2 | 28,839 | 489[a] | NS | 5 |
| 1.3 | [b] | | | |
| 2.3 | [b] | | | |
| | Total | 839 | | |

[a] Estimate not used; regression model not significant at 25% level (P>0.25).

[b] Estimate not made; smolt were not counted in Naknek River in 1992.

Appendix C.4. Forecasted returns of major age classes of sockeye salmon to the Egegik River in 1995 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data[a]

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 2,786 | 170 | 2.5 | 17 |
| 2.2 | 2,191 | 10,304 | 2.5 | 17 |
| 1.3 | 2,191 | 869[b] | NS | 17 |
| 2.3 | 1,611 | 3,011 | 10.0 | 17 |
| | | Total 14,354 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 1 | 758 | 25.0 | 10 |
| 2.2 | 65 | 6,098 | 1.0 | 16 |
| 1.3 | 405 | 634 | 0.1 | 16 |
| 2.3 | 6,087 | 2,909 | 1.0 | 16 |
| | | Total 10,399 | | |

Smolt Data

| Age Class | Smolt Production (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 20,203 | 864 | 1.0 | 11 |
| 2.2 | 37,719 | 5,712 | 1.0 | 11 |
| 1.3 | 6,048 | 1,166 | 1.0 | 10 |
| 2.3 | 17,338 | 1,766 | 1.0 | 10 |
| | | Total 9,508 | | |

[a] Spawner-return estimates were not used for the 1995 Egegik River projection. Results from hindcasting indicated that forecasts were more accurate and less bias using only sibling and smolt information.

[b] Estimate not used; regression model not significant at the 25% level (P>0.25).

Appendix C.5. Forecasted returns of major age classes of sockeye salmon to the Ugashik River in 1995 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 2,482 | 1,468 | 1.0 | 17 |
| 2.2 | 750 | 1,263 | 0.5 | 17 |
| 1.3 | 750 | 717 | 0.5 | 17 |
| 2.3 | 1,713 | 1,061 | 0.2 | 17 |
| | Total | 4,509 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 6 | 1,148 | 5.0 | 13 |
| 2.2 | 14 | 1,680 | 10.0 | 15 |
| 1.3 | 347 | 456 | 0.1 | 16 |
| 2.3 | 2,470 | 932 | 0.1 | 16 |
| | Total | 4,216 | | |

Smolt Data

| Age Class | Smolt Production (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 58,331 | 681[a] | NS | 9 |
| 2.2 | 12,415 | 1,882[a] | NS | 9 |
| 1.3 | [b] | | | |
| 2.3 | [b] | | | |
| | Total | 2,563 | | |

[a] Estimate not used; regression model not significant at the 25% level (P>0.25).

[b] Estimate not made; smolt were not counted in Ugashik River in 1992.

Appendix C.6. Forecasted returns of major age classes of sockeye salmon to the Wood River in 1995 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 1,159 | 1,364 | 0.1 | 17 |
| 2.2 | 1,069 | 125[a] | NS | 17 |
| 1.3 | 1,069 | 1,589 | 0.1 | 17 |
| 2.3 | 1,159 | 95[a] | NS | 17 |
| | Total | 3,173 | | |

Sibling Data

| Age Class | Sibling Return in 1995 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 11 | 1,528[a] | NS | 12 |
| 2.2 | 1 | 270 | 0.5 | 5 |
| 1.3 | 1,111 | 1,348 | 0.5 | 16 |
| 2.3 | 13 | 18 | 10.0 | 16 |
| | Total | 3,164 | | |

[a] Estimate not used; regression model not significant at the 25% level (P>0.25).

Appendix C.7. Forecasted returns of major age classes of sockeye salmon to the Igushik River in 1995 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 756 | 198 | 0.1 | 17 |
| 2.2 | 365 | 46 | 2.5 | 17 |
| 1.3 | 365 | 1,102 | 0.1 | 17 |
| 2.3 | 461 | 51 | 2.5 | 19 |
| | Total | 1,397 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 0 | [a] | | |
| 2.2 | 0 | [a] | | |
| 1.3 | 159 | 709 | 1.0 | 16 |
| 2.3 | 59 | 46 | 5.0 | 16 |
| | Total | 755 | | |

[a] Estimates not made; no age-1.1 or age-2.1 sockeye salmon returned to Igushik River in 1994.

Appendix C.8. Forecasted returns of major age classes of sockeye salmon to the Nushagak River in 1995 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 0.2 | 695 | 43 | 2.5 | 13 |
| 1.2 | 495 | 100 | 2.5 | 13 |
| 2.2 | 675 | 7[a] | NS | 13 |
| 0.3 | 495 | 447 | 1.0 | 13 |
| 1.3 | 675 | 921 | 0.1 | 13 |
| 2.3 | 513 | 12[a] | NS | 13 |
| 0.4 | 675 | 68 | 10.0 | 13 |
| | Total | 1,598 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 0.2 | 0 | [b] | | |
| 1.2 | 0 | [b] | | |
| 2.2 | 0 | [b] | | |
| 0.3 | 10 | 230 | 0.1 | 12 |
| 1.3 | 36 | 480 | 5.0 | 12 |
| 2.3 | 1 | 4 | 10.0 | 11 |
| 0.4 | 776 | 110 | 2.5 | 12 |
| | Total | 824 | | |

[a] Estimate not used; regression model not significant at 25% level ($P>0.25$).

[b] Estimates not made; no age-0.1, -1.1, or -2.1 sockeye salmon returned to Nushagak River in 1994.

Appendix Table C.9. Forecasted returns of major age classes of sockeye salmon to the Togiak River in 1995 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

| Age Class | Spawning Escapement (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 278 | 114 | 1.0 | 17 |
| 2.2 | 189 | 26 | 10.0 | 17 |
| 1.3 | 189 | 408 | 0.5 | 17 |
| 2.3 | 104 | 33 | 2.5 | 17 |
| | Total | 581 | | |

Sibling Data

| Age Class | Sibling Return in 1994 (thousands) | Predicted Return (thousands) | Approximate Significance Level (%) | Sample Size |
|---|---|---|---|---|
| 1.2 | 3 | [a] | NS | 1 |
| 2.2 | 0 | [b] | | |
| 1.3 | 101 | 341 | 0.1 | 16 |
| 2.3 | 7 | 14 | 0.2 | 16 |
| | Total | 309 | | |

[a] Estimate not made; insufficient historical returns of age-1.1 fish returning to Togiak River to calculate a regression model.

[b] Estimate not made; no age-2.1 sockeye salmon returned to Togiak River in 1994