A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON RETURNING TO BRISTOL BAY IN 1997

By

Beverly A. Cross

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AUTHOR

Beverly A. Cross is Region II Bristol Bay Research Project Leader for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Road, Anchorage, AK 99518.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS(Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

ABSTRACT

The total number of sockeye salmon *Oncorhynchus nerka* forecasted to return to Bristol Bay in 1997 is 35,841,000 (80% confidence interval: 21,173,000 - 50,509,000). Runs are expected to exceed spawning escapement goals for all systems. Total projected sockeye salmon harvest is expected to be 27,056,000. Most of this harvest will be taken within Bristol Bay inshore fishing districts (24,810,000), 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 = 2,246,000). The 1997 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 1997 forecast, estimates from spawner-return regressions were not used for Ugashik River because evaluations of past performance indicated that forecasts for Ugashik had similar levels of accuracy and bias if only sibling and smolt information were used. We also decided not to use spawner-return information for Ugashik River's forecast because numbers of spawners for the relevant brood years were some of the highest ever observed and we were concerned with the models' abilities to estimate returns from such high escapements. Based on performance evaluations, data prior to the 1978 return year were omitted from calculations for all rivers. To further correct under-forecasting errors, predictions for Branch and Ugashik Rivers were adjusted by their 1984-96 average percent forecast. Similar to last year, out of range sibling data were used in calculations for the 1997 forecast. The outlook for 1997-2000, 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 1997 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, sibling information, smolt.

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 1995), 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 19 of the last 23 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, there was still a tendency to under-forecast the run. Beginning in 1991 Cross et al. (1992, 1993, 1994) and Cross (1994, 1995, 1996) 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 1997 I continued to analyze bias correction factors, and found that trends in the forecast errors supported adjusting Branch and Ugashik Rivers forecasts in 1997.

The purpose of this report is to provide a final preseason forecast of sockeye salmon returning to Bristol Bay, Alaska, in 1997 with an outlook of abundance fluctuations through 2000. Specific objectives are to (1) document changes in methods used to forecast Bristol Bay sockeye salmon runs in 1997, (2) evaluate the relative accuracy of different forecasting methods, (3) forecast annual runs for all major river systems through 2000, 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 1956-95 are documented by Menard (1997). Estimates of numbers of smolt by year are taken from Crawford and Cross (1997).

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 all rivers except Nushagak River for 1997 were calculated using only data from the 1978 return year onward. The 1997 forecast for Nushagak River was calculated from spawner-recruit and sibling models built from 1982-96 escapement-return data. 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.

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):

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

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,

α, β= regression coefficients estimated by least square methods, and

ε = random error with mean, 0, and variance s^2.

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

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

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):

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

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 ($\rho > 0.25$). If a model was not significant for a river system age class, the 1978-96 mean return of that age class to that river system was used as the prediction. 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 1997.

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 1984-96 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

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 1991-96 predictions (Cross et al. 1992, 1993, 1994, and Cross 1994, 1995, 1996). Based on results from these investigations I limited my analysis for the 1997 forecast to looking at trends in forecast errors for predictions based on spawner-return data since 1978. Adjustment factors for the 1997 individual river predictions were estimated by taking the mean percent error from 1984-96. I also compared the performance of adjusting Kvichak River's predictions by the 1984-96 mean forecast error versus adjusting it by the mean error for peak-cycle (1984, 1985, 1989, 1990, 1994, 1995) and off-cycle (1986, 1987, 1988, 1991, 1992, 1993, 1996) years.

Confidence Intervals

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

$$80\%CI = F \pm t_{0.2}S_F \qquad 4$$

where:

F = forecasted total run of sockeye salmon to all of Bristol Bay (total of river system predictions) in 1997,

S_F = standard error of the forecasted total run of sockeye salmon to Bristol Bay in 1997, 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 1984-96 total run predictions using the same techniques as 1997:

$$S_F = \sqrt{MSE}, \qquad 5$$

$$MSE = \frac{\sum_{i=1}^{N}(F_i - A_i)^2}{N - 1} \qquad 6$$

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 (1984-96).

Outlook to 2000

Forecasts were made for 1998, 1999, and 2000 using only spawner-recruit data (Equation 1 or 2). These forecasts were not adjusted for historic forecast errors.

RESULTS

Forecast Data Base

Kvichak River's forecasts which included spawner-recruit estimates had similar levels of accuracy and precision than those which excluded the data (Table 1). The 1984-96 MPE and MAPE for Kvichak predictions which included spawner-recruit estimates were 10.3 and 58.0, compared to 8.3 and 59.8 for predictions with no spawner-recruit estimates (Table 1). I decided to include forecast estimates from spawner-recruit models in the 1997 predictions for Kvichak River because the levels of accuracy and precision were similar and the number of spawners four-, five-, and six-years ago were well within observed ranges.

Egegik predictions from 1984-96 which excluded spawner-recruit data were slightly more accurate (MAPE = 26.0) and precise (MPE = -21.8) than predictions which included the information (MAPE = 30.7, MPE = -27.4, Table 1). However, for the past three years, 1994-96, predictions which included spawner-return data were more accurate and precise (MAPE=21.3, MPE=9.4) than those which excluded spawner-return data (MAPE=23.4, MPE=18.7). Based on the recent trend and the fact that spawners four-and five-years ago were well within range of observed spawers, I decided to include estimates from spawner-recruit models in the 1997 predictions for Egegik River.

Ugashik River predictions which included spawner-recruit data had a 1984-96 MPE and MAPE of -12.2 and 32.4 compared to a MPE of -25.8 and a MAPE of 29.8 for predictions which excluded the data (Table 1). Ugashik River predictions which included spawner-recruit data had a similar accuracy to predictions which excluded the data, but were less biased. However, the number of spawners in Ugashik River in 1991 and 1992, parent years for the five-year and six-year-old returns, were the second greatest ever recorded, with the 1980 escapement of 3.3 million only being greater. Because the relationship of increasing spawners to returns has not been well described, and results from hindcasting indicated that spawner-recruit information did not greatly improve Ugashik River's forecast accuracy, I decided not to include spawner-recruit estimates in the 1997 Ugashik River predictions.

Out-Of-Range Data

Systems which had input variables (siblings or parent escapements) which were outside the data ranges used to build the model included Kvichak, Branch, Naknek, and Igushik Rivers. The number of age-1.2 returns to Kvichak River in 1996 which are the siblings to the age-1.3 returns in 1997 were less than previously recorded. The 1993 Branch River escapement or parent year for 1997 age-1.2 returns was greater than previously recorded. The 1991 Naknek River escapement, parent year for 1997 age-2.3 returns, was greater than previously recorded. The number of age-2.2 returns to Igushik River in 1996 which are the siblings to the age-2.3 returns in 1997 were less than previously recorded. 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.

River System Forecasts By Age

Kvichak River

Spawner-recruit, sibling, and smolt data bases were available for estimating Kvichak River run sizes in 1997.

Age 1.2. The age-1.2 forecast for this system was based upon spawner-recruit and smolt data (Appendix B.1). A prediction based on sibling data was not used because the regression model was not significant at the 25% level ($\rho > 0.25$). The spawner-recruit estimate of 2,162,000 was 54% less than the smolt estimate of 4,650,000. The average of the two estimates was 3,406,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix B.1). The spawner-recruit estimate of 4,458,000 was 338% greater than the smolt estimate of 1,018,000 which was 40% greater than the sibling estimate of 726,000. The average of the three estimates was 2,067,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix B.1). The spawner-recruit estimate of 1,857,000 was 203% greater than the sibling estimate of 613,000 and 36% greater than the smolt estimate of 1,367,000. The average of the three estimates was 1,279,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix B.1). The spawner-recruit estimate of 900,000 was about 48% greater than the smolt estimate of 607,000, and 181% greater than the sibling estimate of 320,000. The average of the three estimates was 609,000 sockeye salmon.

Branch River

Spawner-recruit and sibling data bases were available for estimating Branch River run sizes in 1997. 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 B.2). The spawner-recruit estimate of 165,000 was 27% less than the sibling estimate of 226,000. The average of the two estimates was 196,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based on the 1978-96 mean return of age-2.2 sockeye salmon (Appendix B.2). A prediction based on spawner-recruit data was not used because the regression model was not significant at the 25% level ($\rho > 0.25$). An estimate based on a sibling model was not made because no age-2.1 salmon returned to Branch River in 1996. The mean return estimate was 116,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based only upon spawner-recruit data (Appendix B.2). The prediction based on sibling data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The spawner-recruit estimate was 158,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based only upon sibling data (Appendix B.2). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The sibling estimate was 22,000 sockeye salmon.

Naknek River

Spawner-recruit, sibling, and smolt data bases were available for estimating Naknek River run sizes in 1997. 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 only on sibling data (Appendix B.3). A prediction based on spawner-recruit data was not used because the model was not significant at the 25% level. Smolt were not counted on the Naknek River in 1995. The sibling estimate was 389,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based on spawner-recruit and sibling data (Appendix B.3). Smolt information was not available. The spawner-recruit estimate was 781,000 sockeye salmon which was 53% greater than the sibling estimate of 511,000 salmon. The average of the two estimates was 646,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix B.3). Smolt information was not used because the model was not significant at the 25% level. The spawner-recruit estimate of 1,733,000 was 76% greater than the sibling estimate of 983,000 sockeye salmon. The average of the two estimates was 1,358,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based on spawner-recruit, sibling, and smolt data (Appendix B.3). The spawner-recruit estimate of 1,819,000 was 232% greater than the sibling estimate of 547,000, and 66% greater than the smolt estimate of 1,095,000. The average of the three estimates was 1,154,000 sockeye salmon.

Egegik River

Spawner-recruit, sibling, and smolt data bases were available for estimating 1997 Egegik River run sizes.

Age 1.2. The age-1.2 forecast was based on spawner-recruit, sibling, and smolt data (Appendix B.4). The spawner-recruit estimate of 640,000 sockeye salmon was similar to the smolt estimate of 629,000 and 31% less than the sibling estimate of 934,000. The average of the three estimates was 734,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based upon spawner-recruit, sibling and smolt data (Appendix B.4). The spawner-recruit estimate of 6,483,000 was similar to the smolt estimate of 6,654,000 which was 13% greater than the sibling estimate of 5,901,00 sockeye salmon. The average of the three estimates was 6,346,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit, sibling and smolt data (Appendix B.4). The smolt estimate of 3,262,000 was 117% greater than the spawner-recruit estimate of

1,503,000 and 531% greater than the sibling estimate of 517,000 sockeye salmon. The average of the three estimates was 1,761,000 sockeye salmon.

Age 2.3. The age-2.3 forecast for this system was based upon spawner-recruit, sibling and smolt data (Appendix B.4). The spawner-recruit estimate of 8,731,000 was 115% greater than the smolt estimate of 4,055,000 and 397% greater than the sibling estimate of 1,758,000 sockeye salmon. The average of the three estimates was 4,848,000 sockeye salmon.

Ugashik River

Spawner-recruit, sibling, and smolt data bases were available for estimating 1997 Ugashik River run sizes. However, spawner-recruit information was not used for the final 1997 Ugashik prediction. Evaluation of past forecast performance indicated that Ugashik predictions which omitted spawner-recruit information had similar average performances compared to those which included spawner-recruit data. In addition, Ugashik spawners in 1991 and 1992 were the second and third highest on record.

Age 1.2. The age-1.2 forecast was based only upon sibling data (Appendix B.5). The prediction based on smolt data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The sibling estimate was 778,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only upon sibling data (Appendix B.5). The prediction based on smolt data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The sibling estimate was 1,218,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon sibling and smolt data (Appendix B.5). The sibling estimate of 286,000 was 66% less than the smolt estimate of 848,000. The average of the two estimates was 567,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based only upon sibling data (Appendix B.5). The prediction based on smolt data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The sibling estimate was 371,000 sockeye salmon.

Wood River

Spawner-recruit and sibling data bases were available for estimating Wood River run sizes in 1997. 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 B.6). A sibling model was not used because no age-1.1 salmon returned to Wood River in 1996. The spawner-recruit estimate was 1,459,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based on the 1978-96 mean return of age-2.2 sockeye salmon to Wood River (Appendix B.6). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level ($\rho > 0.25$). A prediction based on sibling information was not made because no age-2.1 sockeye salmon were present in samples taken from Wood River in 1996. The mean return estimate was 125,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix B.6). The sibling estimate of 1,788,000 was 14% greater than the spawner-recruit estimate of 1,569,000. The average of the two estimates was 1,679,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based only upon sibling data (Appendix B.6). The prediction based on spawner-recruit data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The sibling estimate was 44,000 sockeye salmon.

Igushik River

Spawner-recruit and sibling data bases were available for estimating Igushik River run sizes in 1997. 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 B.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 1996. The spawner-recruit estimate was 248,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only on spawner-recruit data (Appendix B.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 1996. The spawner-recruit estimate was 41,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix B.7). The spawner-recruit estimate of 1,091,000 was 156% greater than the sibling estimate of 426,000. The average of the two estimates was 759,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix B.7). The spawner-recruit estimate of 52,000 was 420% greater than the sibling estimate of 10,000. The average of the two estimates was 31,000 sockeye salmon.

Nushagak River

Reliable age information for sockeye salmon returning to Nushagak River was available from 1982-96 return years. Spawner-recruit and sibling data bases from 1982-96 return years were used to predict Nushagak River run sizes in 1997.

Age 0.2. The age-0.2 forecast was based only upon spawner-recruit data (Appendix B.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 1996. The spawner-recruit estimate was 40,000 sockeye salmon.

Age 1.2. The age-1.2 forecast was based only upon results from spawner-recruit data (Appendix B.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 1996. The spawner-recruit estimate was 132,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only upon results from spawner-recruit data (Appendix B.8). 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 1996. The spawner-recruit estimate was 8,000 sockeye salmon.

Age 0.3. The age-0.3 forecast was based on spawner-recruit and sibling data bases (Appendix B.8). The spawner-recruit estimate of 502,000 was similar to the sibling estimate of 476,000. The average of the two estimates was 489,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix B.8). The sibling estimate of 991,000 was 14% greater than the spawner-recruit estimate of 865,000. The average of the two estimates was 928,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix B.8). The spawner-recruit estimate of 9,000 was similar to the sibling estimate of 8,000 sockeye salmon. The average of the two estimates was 9,000 sockeye salmon.

Age 0.4. The age-0.4 forecast was based on spawner-recruit and sibling data bases (Appendix B.8). The spawner-recruit estimate of 61,000 was similar to the sibling estimate of 64,000. The average of the two estimates was 62,000 sockeye salmon.

Togiak River

Spawner-recruit and sibling data bases were available for estimating Togiak River run sizes in 1997. 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 B.9). A prediction based on sibling data was not used because the model was not significant at the 25% level ($\rho > 0.25$). The spawner-recruit estimate was 127,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only on spawner-recruit data (Appendix B.9). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in 1996 Togiak River samples. The spawner-recruit estimate was 28,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix B.9). The spawner-recruit estimate of 414,000 was 75% greater than the sibling estimate of 236,000. The average of the two estimates was 325,000 sockeye salmon.

Age 2.3. The age-2.3 forecast for this system was based on spawner-recruit and sibling data (Appendix B.9). The spawner-recruit estimate of 34,000 was similar to the sibling estimate of 35,000 sockeye salmon. The average of the two estimates was 35,000 sockeye salmon.

1997 Individual Rivers' Forecast Adjustments

Kvichak River

Errors in Kvichak River forecasts varied considerably from 1984-96 (Figure 2). Predictions for pre-peak and peak cycle years (1984-85, 1989-90, 1994, 1995) under-forecasted the actual run, while predictions for off-cycle years (1986-87, 1991-93, 1996) did not show a consistent trend in their errors. Because the pre-peak and peak cycle years had a different error structure than the off-cycle years, I looked at adjustments based on cycle year average errors (average pre-peak and peak year error and an average off-cycle error). The average pre-peak and peak cycle error (1984-85, 1989-90, 1994-95) was -56.8%, while the average off-cycle error (1986-88, 1991-93, 1996) was only -3.6%. Based on the difference in the forecast errors among peak cycle and off-cycle years, I decided to evaluate an adjustment procedure which averaged the errors separately.

For the years we were able to evaluate, 1990-96, adjusting the original forecasts by the average cycle error improved all the pre-peak and peak years predictions (1990, 1994-95; Figure 2). Adjusted off-cycle predictions performed better than the original forecasts for two years (1991-92) and performed worse for two years (1993, 1996; Figure 2). An evaluation of Kvichak River's forecast errors indicated that pre-peak and peak year predictions should be adjusted upward to correct a consistent under-forecasting bias, while forecasts for off-cycle years did not warrant a bias correction factor. The 1997 unadjusted prediction for Kvichak River was 7.4 million and the estimated error based on average cycle year error was -0.3 million (Table 2). Because the trend in past errors did not support an adjustment for off-cycle years and the adjustment would have been so small, I did not adjust the 1997 Kvichak River forecast.

Branch River

Errors in Branch River forecasts showed a consistent trend of under-forecasting from 1989-96 (Figure 3). The 1997 unadjusted prediction for Branch River was 0.5 million. The estimated error for the 1997 prediction based on average errors was -0.1 million fish (Table 2). The 1987-96 mean error for Branch River forecasts was higher for unadjusted (-37%) compared to adjusted (-20%) forecasts (Figure 3). Adjusting Branch River's forecasts by the average error appeared to improve accuracy and precision, therefore I increased the 1997 prediction for Branch River by its' average error (-25.5%, -0.1 million).

Naknek River

Errors in Naknek River forecasts showed no consistent trends from 1984-96 (Figure 4). Naknek River forecasts from 1984-89 were either above or close to observed runs, while forecasts from

1990-93 were less than observed runs. The 1997 unadjusted prediction for Naknek River was 3.5 million. The estimated error for the 1997 prediction based on the 1984-96 average error was -0.8 million fish (Table 2). The 1987-96 average error for Naknek River forecasts were similar for unadjusted (-31%) compared to adjusted (-30%) forecasts (Figure 4). I decided not to adjust the 1997 Naknek River forecast because the overall accuracy and precision did not improve with the adjustment.

Egegik River

Egegik River forecasts showed a consistent trend of under-forecasting from 1984-1993 (Figure 5). The original forecast for Egegik River was close to the observed run in 1994 and was greater than the observed run in 1996. Forecasts for recent years have not shown a consistent under-forecasting bias like earlier years. The average Egegik forecast error from 1984-96 was -48.7%, while the average forecast error during the three most recent years (1994-96) was only -9.4%. Therefore adjusting the 1997 Egegik forecast by the longer term 1984-96 average error could easily result in a significant over-forecast in 1997. The 1997 unadjusted prediction for Egegik River was 13.7 million. The estimated error for the 1997 prediction based on 1984-96 average errors was -6.7 million fish (Table 2). Using average errors to adjust forecasts for Egegik River resulted in over-forecasts in 1987, 1988, 1991, 1994, and 1996 and under-forecasts in 1989, 1990, 1992, 1993, and 1995 (Figure 5). Because recent years forecasts have not shown a consistent trend of under-forecasting, I decided not to adjust the 1997 Egegik River forecast by the historical average error.

Ugashik River

Ugashik River forecasts were less than actual runs each year from 1984-96, except for 1987 and 1988 (Figure 6). Historic forecast errors indicated a consistent under-forecasting bias for Ugashik River, however errors during 1985 (-138%) and 1991 (-152%) were two to three times greater than other years. I was concerned about including these years in a simple historic average and applying the average error as an adjustment. I decided to trim the years included in the average by excluding the two highest errors (1985=-138%, 1991=-152%) and the two lowest errors (1987=17% and 1988=5%). The 1992-96 average error for original Ugashik River forecasts was -35.9% and this error was reduced -3.4% by adjusting previous forecasts by the trimmed average errors. The 1997 unadjusted prediction for Ugashik River was 2.9 million. The estimated error for the 1997 prediction based on the 1984-96 trimmed average was -1.2 million fish (Table 2). I decided to adjust the 1997 Ugashik River forecast by the trimmed average error because it improved accuracy and precision.

Wood River

Errors in Wood River forecasts were positive from 1984-86 (Figure 7). Errors from 1987-96 were not consistently positive or negative and were generally closer to the actual runs. Original forecasts performed better than those adjusted by the historic average error for 1987-96 (Figure 7). The 1997 unadjusted prediction for Wood River was 3.3 million. The estimated error for the 1997 prediction based on 1984-96 average errors was 0.1 million fish (Table 2). I did not adjust the 1997 Wood River forecast because the adjustment was relatively small and historic forecast performance was not improved with the adjustments.

Igushik River

Igushik River forecast errors were positive from 1984-88, however in recent years errors have been either negative or slightly positive (Figure 8). Adjusting the Igushik River forecast by the historic average forecast error did not improve forecast performance from 1987-1996. The 1997 unadjusted prediction for Igushik River was 1.1 million. The estimated error for the 1997 prediction based on the 1984-96 average error was 40 thousand fish (Table 2). I did not adjust the 1997 Igushik River forecast because the adjustment was relatively small and historic forecast performance was not improved with the adjustments.

Nushagak River

Errors in Nushagak River forecasts showed no clear trend from 1990-96 (Figure 9). Adjusting the Nushagak River forecast by the historic average forecast error did not improve forecast performance from 1993-1996. The 1997 unadjusted prediction for Nushagak River was 1.7 million. The estimated error for the 1997 prediction based on the 1990-96 average error was -0.2 million (Table 2). I did not adjust the 1997 Nushagak River forecast because historic forecast performance was not improved with the adjustments.

Togiak River

Errors in Togiak River forecasts showed no clear trend from 1984-96 (Figure 10). Adjusting the Togiak River forecast by the historic average forecast error did not improve forecast performance from 1987-1996. The 1997 unadjusted prediction for Togiak River was 0.5 million. The estimated error for the 1997 prediction based on the 1984-96 average errors was 15 thousand fish (Table 2). I did not adjust the 1997 Togiak River forecast because the adjustment was relatively small and historic forecast performance was not improved with the adjustments

1997 Forecast Adjustments

I used data from 1978 through 1996 to forecast all Bristol Bay systems. The only forecasts I adjusted by historic forecast errors were Branch and Ugashik Rivers. The 1997 Branch River forecast was increased by: 25.5% and the 1997 Ugashik River forecast was increased by 38.3%.

Final 1997 Total Bristol Bay Forecast

A total of 35,841,000 sockeye salmon (80% confidence interval: 21,173,000 - 50,509,000) are expected to return to Bristol Bay in 1997 (Table 3). A run of this size would be the seventeenth highest run since 1956, the first year of total run information. The 1997 prediction is 6% (2,490,000 sockeye salmon) less than the 20-year (1977-96) mean return of 38,331,000 (range: 10,671,000 - 66,293,000), and about 15% (6,523,000) less than the most recent 10-year (1987-96) mean return of 42,364,000 (range: 23,996,000 - 62,825,000).

Total projected sockeye salmon harvest is 27,056,000 (80% CI: 12,388,000 - 41,724,000; Table 3). Most (24,810,000) 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 = 2,246,000) 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 1995). 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 33,595,000 (Table 4). Runs should exceed spawning escapement goals for all river systems. The projected Bristol Bay combined fishing district harvest of 24,810,000 would be similar to the 20-year (1977-96) mean harvest of 25,094,000 (range: 4,878,000 - 44,427,000), and 15% (4,457,000) less than the 10-year (1987-96) mean harvest of 29,267,000 (range: 13,990,000 - 44,427,000).

Final 1997 River System Forecasts

Kvichak River

A total of 7,361,000 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 7,361,000 sockeye salmon to the Kvichak River system in 1997, an off-cycle year, would be 15% greater than the mean return of 6,376,000 sockeye salmon (range: 337,000-20,983,000) observed during past off-cycle years (1962-63, 1967-68, 1972-73, 1977-78, 1982-83, 1987-88, 1992-93). Age-1.2 sockeye salmon comprised 55% of the forecasted Kvichak River return (Table 3).

Branch River

A total of 617,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 6% greater than the mean return of 582,000 for 1987-1996 (range: 308,000 - 862,000), and about 15% greater than the mean return of 535,000 for 1977-1996 (range: 152,000 - 862,000). Age-1.2 and age-1.3 comprised 40% and 32% of the Branch River forecast (Table 3).

Naknek River

A total of 3,547,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 30% less than the mean return of 5,065,000 for 1987-96 (range: 1,796,000 - 10,353,000) and 23% less than the mean return of 4,583,000 for 1977-96 (range: 1,796,000 - 10,353,000). Age-1.3 and age-2.3 comprised 38% and 32% of the Naknek River forecast (Table 3).

Egegik River

A total of 13,689,000 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 13,371,000 for 1987-96 (range: 6,885,000 - 24,687,000), but about 48% greater than the mean return of 9,262,000 for 1977-96 (range: 2,229,000 - 24,687,000). The 1997 Egegik River forecast was 46% age-2.2 and 35% age-2.3 sockeye salmon (Table 3).

Ugashik River

A total of 4,058,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be about 15% less than the mean return of 4,769,000 for 1987-96 (range: 2,256,000 - 6,040,000) and similar to the mean return of 4,190,000 for 1977-96 (range: 95,000 - 7,875,000). Age-1.2 and age-2.2 sockeye salmon comprised 26% and 41% of the 1997 Ugashik River forecast (Table 3).

Wood River

A total of 3,307,000 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 3,271,000 for 1987-96 (range: 1,793,000 - 5,182,000) and similar to the mean return of 3,267,000 for 1977-96 (range: 929,000 - 5,182,000). The 1997 Wood River forecast was comprised of 44% age-1.2 and 51% age-1.3 sockeye salmon (Table 3).

Igushik River

A total of 1,079,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 20% less than the mean return of 1,354,000 for 1987-96 (range: 415,000 - 2,513,000) and 21% less than the mean return of 1,358,000 for 1977-96 (range: 164,000 - 3,276,000). Approximately 70% of the 1997 Igushik River forecast was comprised of age-1.3 sockeye salmon (Table 3).

Nushagak River

A total of 1,668 ,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 1,664,000 for 1989-96 (range: 792,000 - 2,330,000). The 1997 Nushagak River forecast was comprised of 56% age-1.3 and 35% zero freshwater aged sockeye salmon (Table 3).

Togiak River

A total of 515,000 sockeye salmon were forecasted to return to this system (Table 4). A total run of this size would be 19% less than the mean return of 634,000 for 1987-96 (range: 179,000 - 1,002,000), and 22% less than the mean return of 658,000 for 1977-96 (range: 179,000 - 1,173,000). About 63% of the sockeye salmon forecasted to return to Togiak River in 1997 were age 1.3 (Table 3).

Expected Forecast Performance

Our best estimate of 1997 sockeye run size was based on linear regression models using data from 1978-96, and subsequently, forecasts for Branch and Ugashik Rivers were increased by their 1984-

96 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 three areas:

River System	Most Probable Deviation from Forecasted Return	Reason for Probable Deviation
Kvichak	less than expected return of age-1.3 and age-2.2 sockeye salmon	Sibling-return relationships indicated lower returns of age-1.3 and age-2.2 fish than either spawner or smolt data bases.
Egegik	less than expected return of age-1.3 and age-2.3 sockeye salmon	Sibling-return relationships predicted lower returns of age-1.3 and age-2.3 fish than either spawner or smolt data.
Ugashik	less than expected runs of age-1.3 and age-2.3 sockeye	The spawner-return relationships were not used in 1997. Sibling relationships predicted lower runs than either spawner or smolt data bases.

Indicators that can be used to assess preseason forecast accuracy will not be available until June 1997 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 2000

Comparisons of 1997-2000 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 1997 and lowest in 1998 (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 which include and exclude spawner-recruit estimates, Kvichak, Egegik and Ugashik Rivers, 1984-96.

	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	-32.2	-20.9	-27.7	-27.7
1985	-29.6	-8.0	-43.9	-39.7	-49.1	-57.9
1986	287.6	335.6	-10.2	19.9	-15.7	-37.5
1987	-55.9	-67.7	-18.1	-12.7	59.2	20.2
1988	33.1	14.7	-26.8	-15.7	51.9	5.4
1989	-37.6	-54.8	-38.3	-30.0	-24.3	-32.4
1990	-47.5	-51.0	-49.3	-45.7	9.6	-16.0
1991	-25.6	-19.1	-19.7	-7.9	-50.2	-60.4
1992	-12.1	-17.6	-50.3	-47.1	-41.8	-32.7
1993	-4.7	-10.7	-55.4	-52.1	-33.2	-24.5
1994	-35.6	-38.4	-3.8	3.3	-20.0	-28.0
1995	-39.5	-33.6	-29.6	-38.7	-27.4	-29.8
1996	123.3	92.5	21.9	3.9	10.7	-14.7
84-96 MPE	10.3	8.3	-27.4	-21.8	-12.2	-25.8
84-96 MAPE	58.0	59.8	30.7	26.0	32.4	29.8

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

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

Table 2. Comparison of 1997 average forecasts based on regression models, estimated forecast errors, and adjusted forecasts based on individual rivers' forecast errors, Bristol Bay.

		Millions of Sockeye Salmon		
Data Base	Method of Modeling	Original 1997 Forecast	Estimated Error 1997[a]	Adjusted 1997 Forecast
Recent Data	84-96 Avg Error			
Kvichak		7.4	-0.3	Did Not Adjust
Branch		0.5	-0.1	0.6
Naknek		3.5	-0.8	Did Not Adjust
Egegik		13.7	-6.7	Did Not Adjust
Ugashik		2.9	-1.2	4.1
Wood		3.3	+0.1	Did Not Adjust
Igushik		1.1	+0.0	Did Not Adjust
Nushagak		1.7	-0.2	Did Not Adjust
Togiak		0.5	+0.0	Did Not Adjust

[a] Error = (predicted - actual).

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 1997.

District: River	Thousands of Sockeye Salmon							
	Forecasted Production by Age Class							
	1.2	2.2	1.3	2.3	Other[a]	Total	Spawning Goal	Total Harvest
NAKNEK-KVICHAK:								
Kvichak	3,406	2,067	1,279	609		7,361	4,000	3,361
Branch	245	146	198	28		617	185	432
Naknek	389	646	1,358	1,154		3,547	1,000	2,547
Total	4,040	2,859	2,835	1,791		11,525	5,185	6,340
EGEGIK	734	6,346	1,761	4,848		13,689	1,000	12,689
UGASHIK	1,076	1,685	784	513		4,058	700	3,358
NUSHAGAK:[b]								
Wood	1,459	125	1,679	44		3,307	1,000	2,307
Igushik	248	41	759	31		1,079	200	879
Nushagak	132	8	928	9	591	1,668	550	1,118
Total	1,839	174	3,366	84	591	6,054	1,750	4,304
TOGIAK[c]	127	28	325	35		515	150	365
BRISTOL BAY	7,816	11,092	9,071	7,271	591	35,841	8,785	27,056

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 (1986-1996 mean catch) to Togiak District harvest.

Table 4. Projected commercial harvests of sockeye salmon returning to Bristol Bay river systems in 1997.

District: River	Forecasted Total Production	Shumagin Islands- S. Unimak Harvest[a]	Bristol Bay Total Run	Bristol Bay Spawning Goal	Bristol Bay Harvest
NAKNEK-KVICHAK:					
Kvichak	7,361	461	6,900	4,000	2,900
Branch	617	39	578	185	393
Naknek	3,547	222	3,325	1,000	2,325
Total	11,525	722	10,803	5,185	5,618
EGEGIK	13,689	858	12,831	1,000	11,831
UGASHIK	4,058	254	3,804	700	3,104
NUSHAGAK:					
Wood	3,307	207	3,100	1,000	2,100
Igushik	1,079	68	1,011	200	811
Nushagak	1,668	105	1,563	550	1,013
Total	6,054	380	5,674	1,750	3,925
TOGIAK	515	32	483	150	333
BRISTOL BAY	35,841	2,246	33,595	8,785	24,810

Thousands of Sockeye Salmon.

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

Table 5. Preliminary forecasts of sockeye salmon returns to Bristol Bay, 1997-2000, based on spawner-recruit data only, and not adjusted for historic forecast errors.

DISTRICT: River	Thousands of Sockeye Salmon			
	1997	1998	1999	2000
NAKNEK-KVICHAK:				
Kvichak	9,377	9,557	15,200	15,314
Branch	453	426	484	406
Naknek	4,973	4,147	3,454	3,355
Total	14,803	14,130	19,138	19,075
EGEGIK	17,357	10,775	11,431	9,740
UGASHIK	6,663	5,142	4,337	4,305
NUSHAGAK:				
Wood	3,304	3,301	3,214	3,176
Igushik	1,432	1,482	1,487	1,489
Nushagak-Mulchatna	1,617	1,514	1,214	1,089
Total	6,353	6,297	5,915	5,754
TOGIAK	603	601	594	605
BRISTOL BAY	45,779	36,945	41,415	39,479

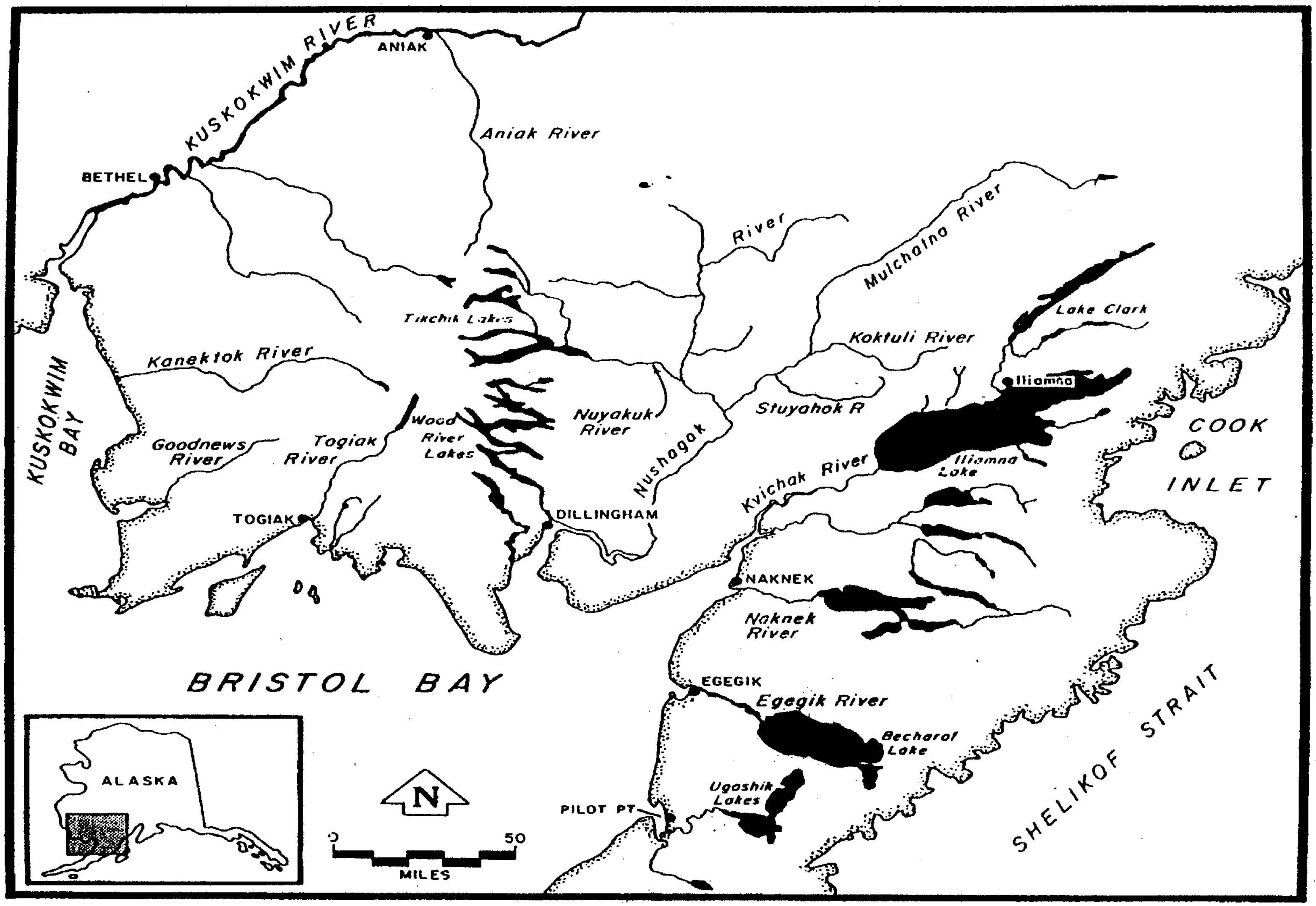
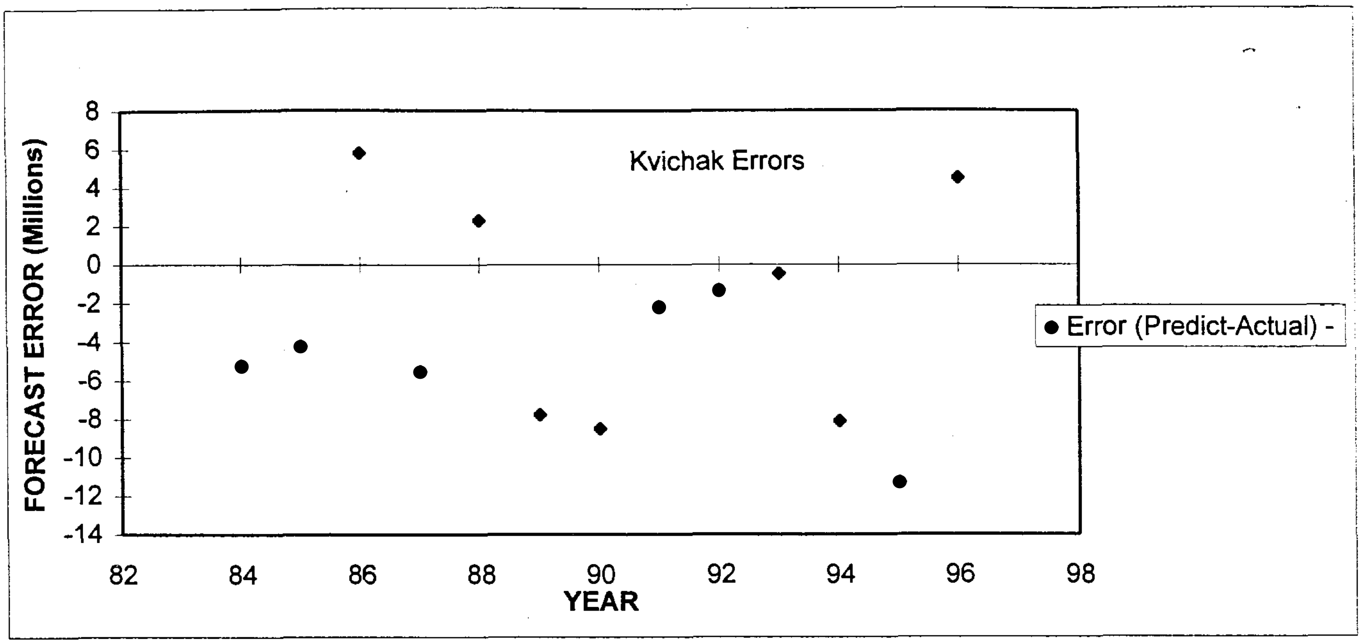


Figure 1. Map of Bristol Bay, Alaska showing major rivers.



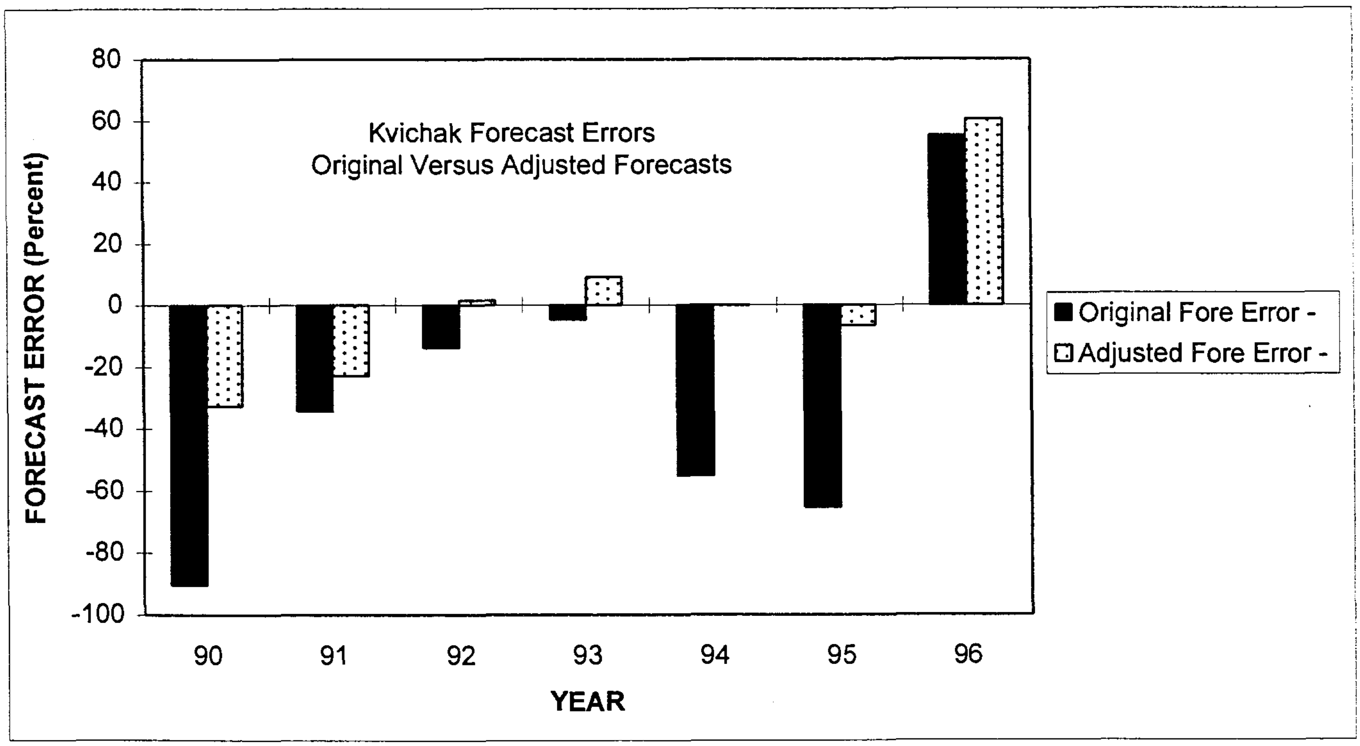
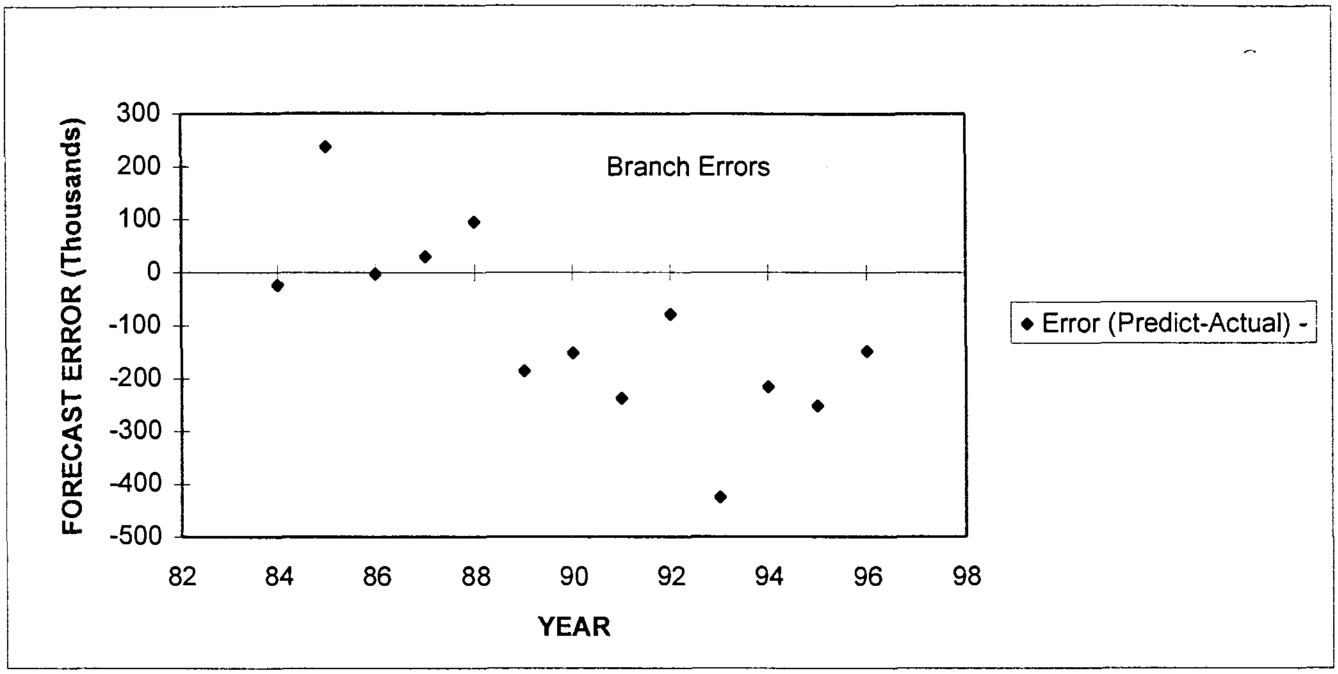


Figure 2. Errors (predicted run - actual run) of Kvichak River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1990-96 (bottom).



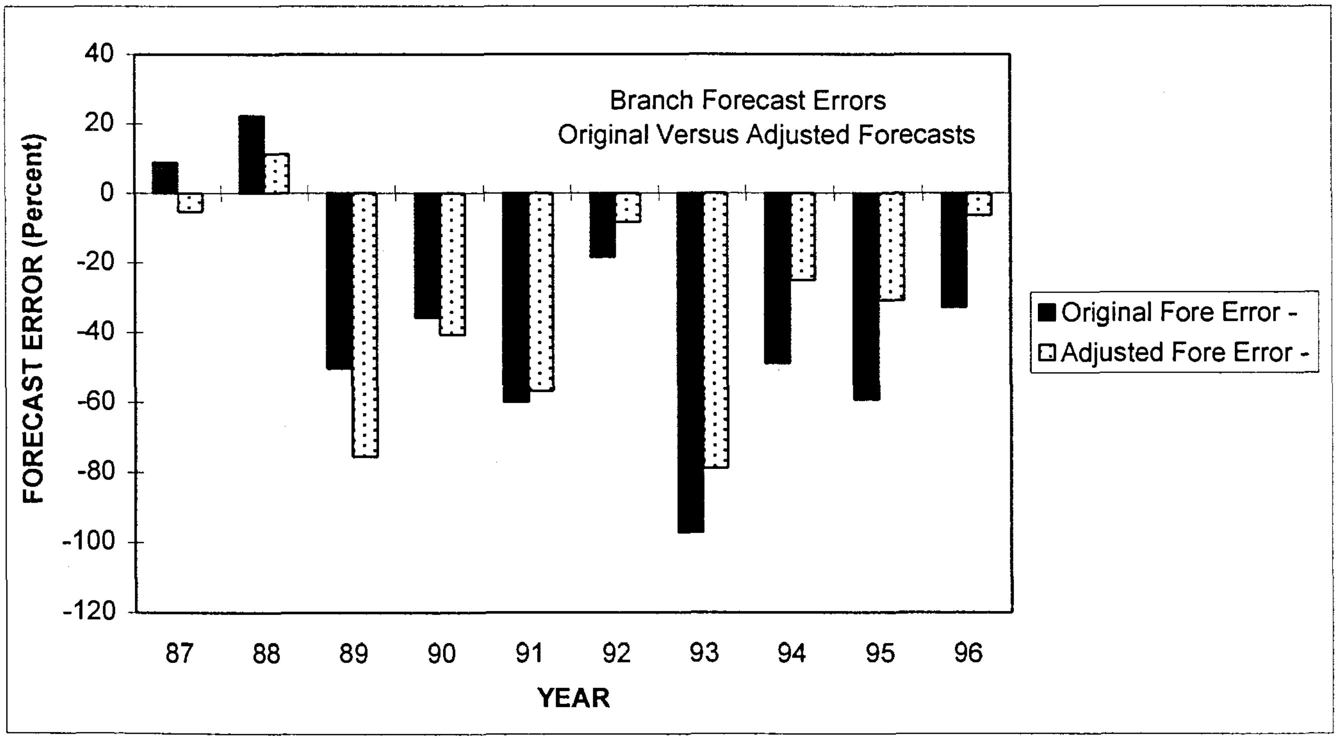
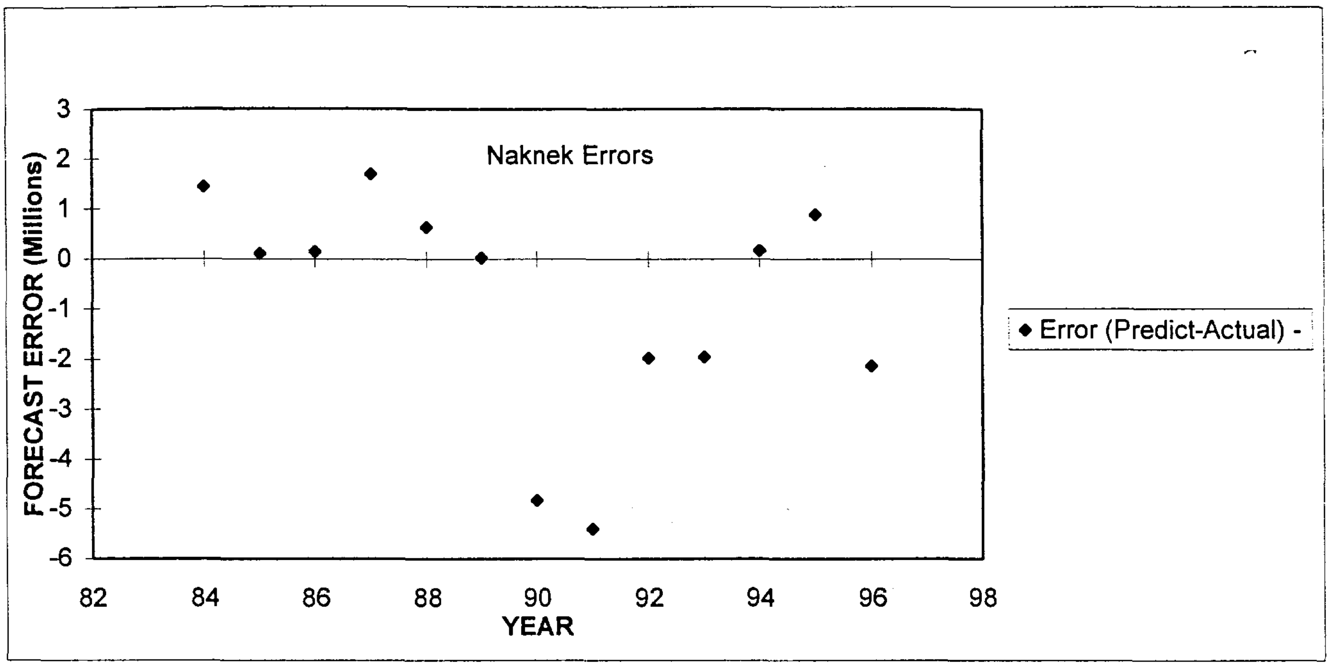


Figure 3. Errors (predicted run - actual run) of Branch River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).



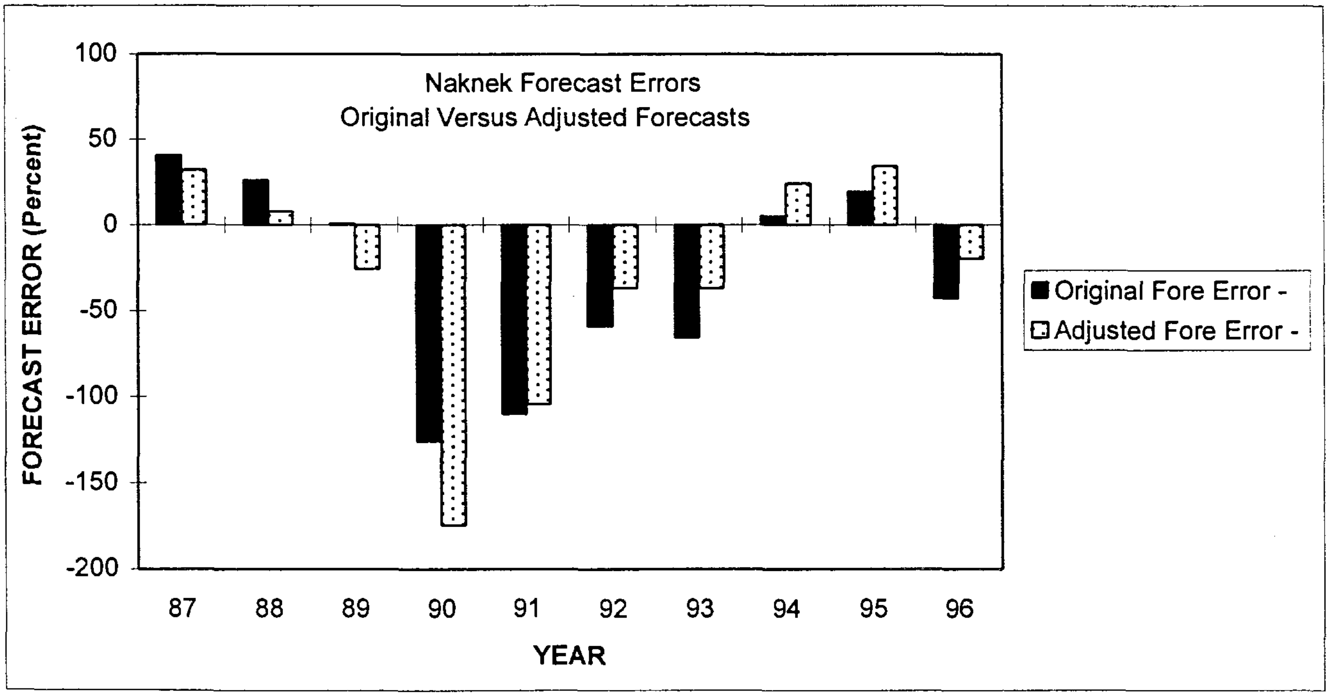
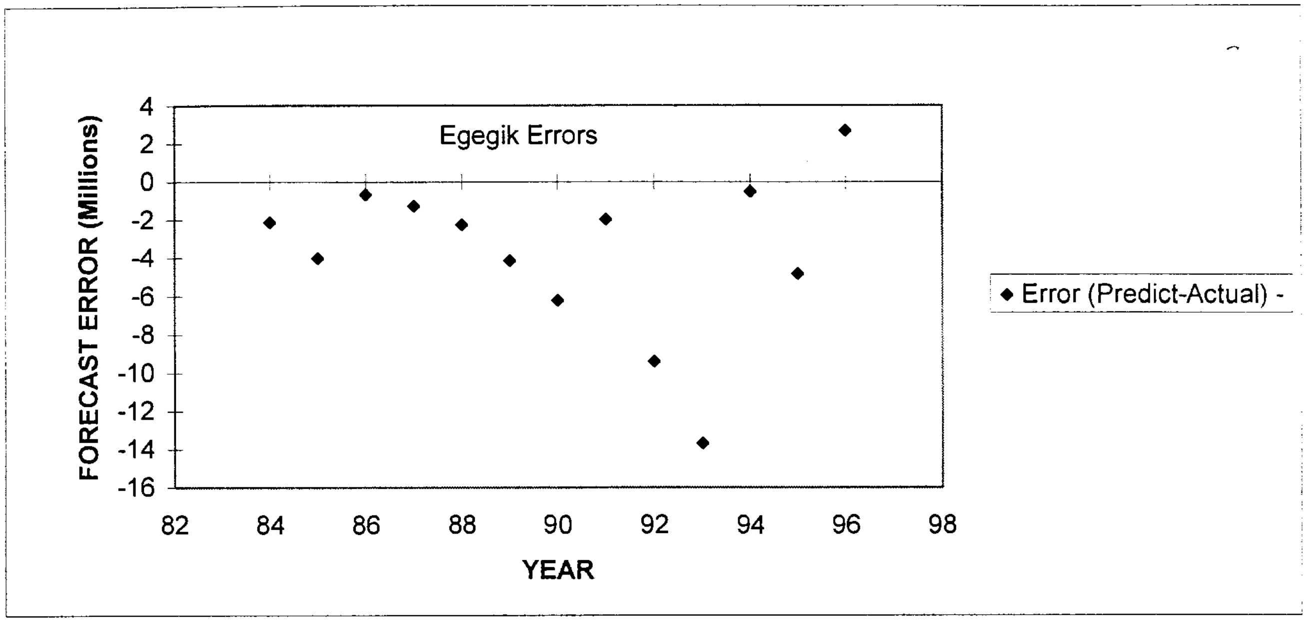


Figure 4. Errors (predicted run - actual run) of Naknek River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).



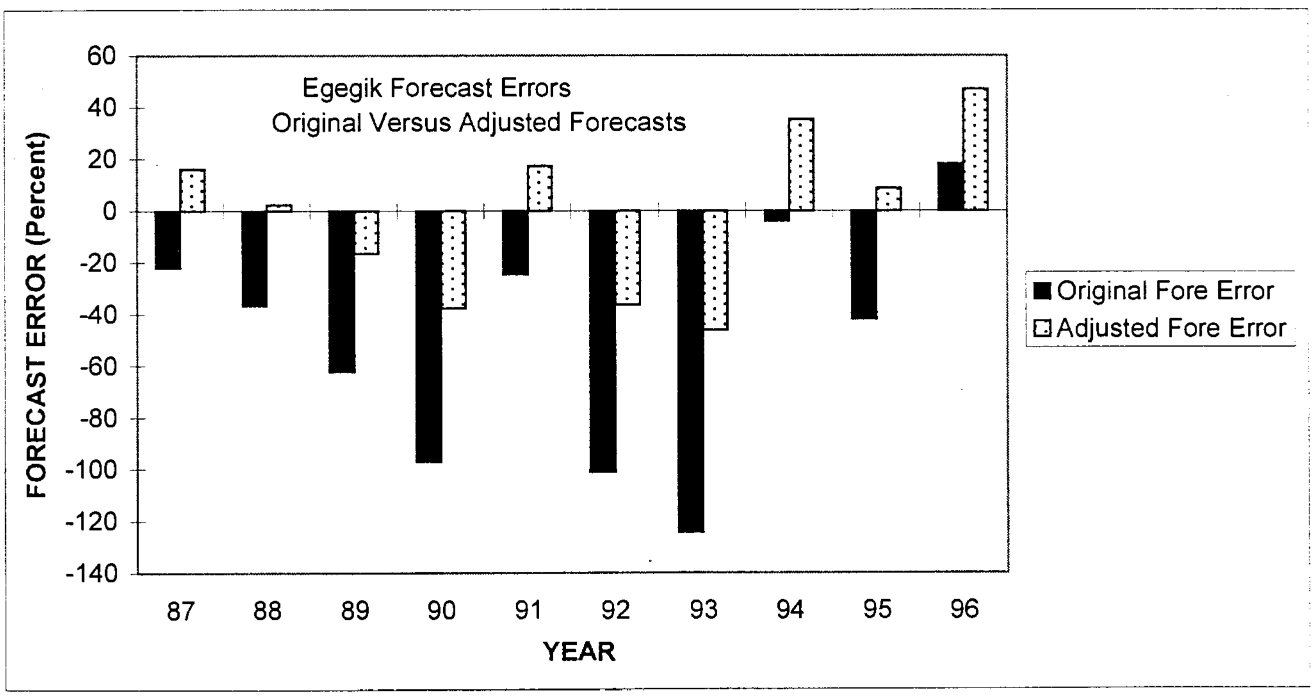
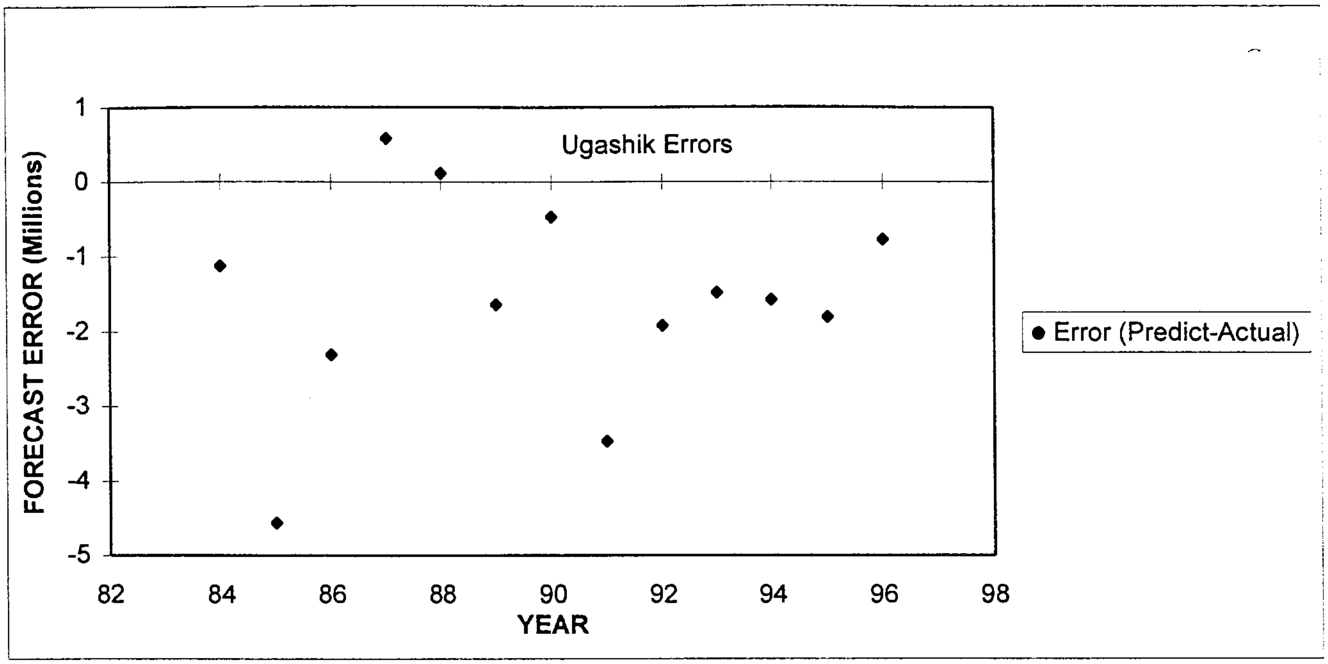


Figure 5. Errors (predicted run - actual run) of Egegik River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).



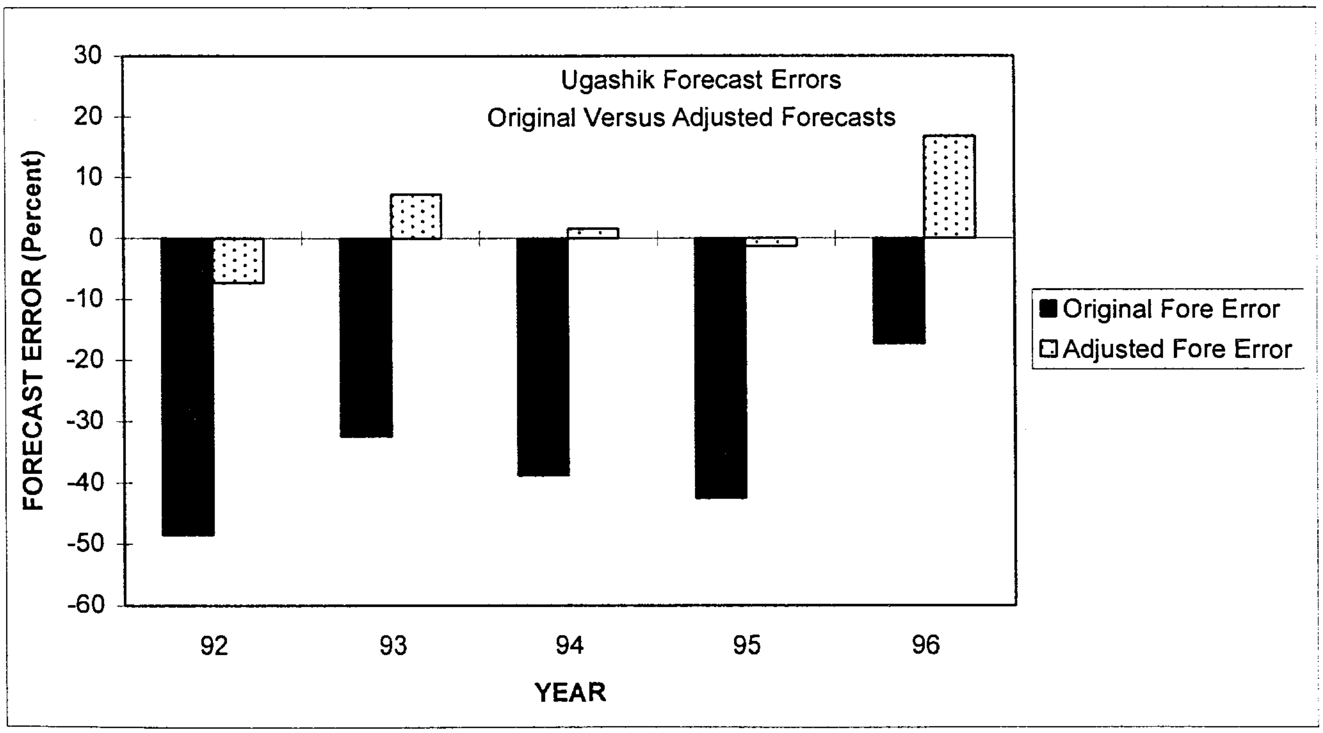
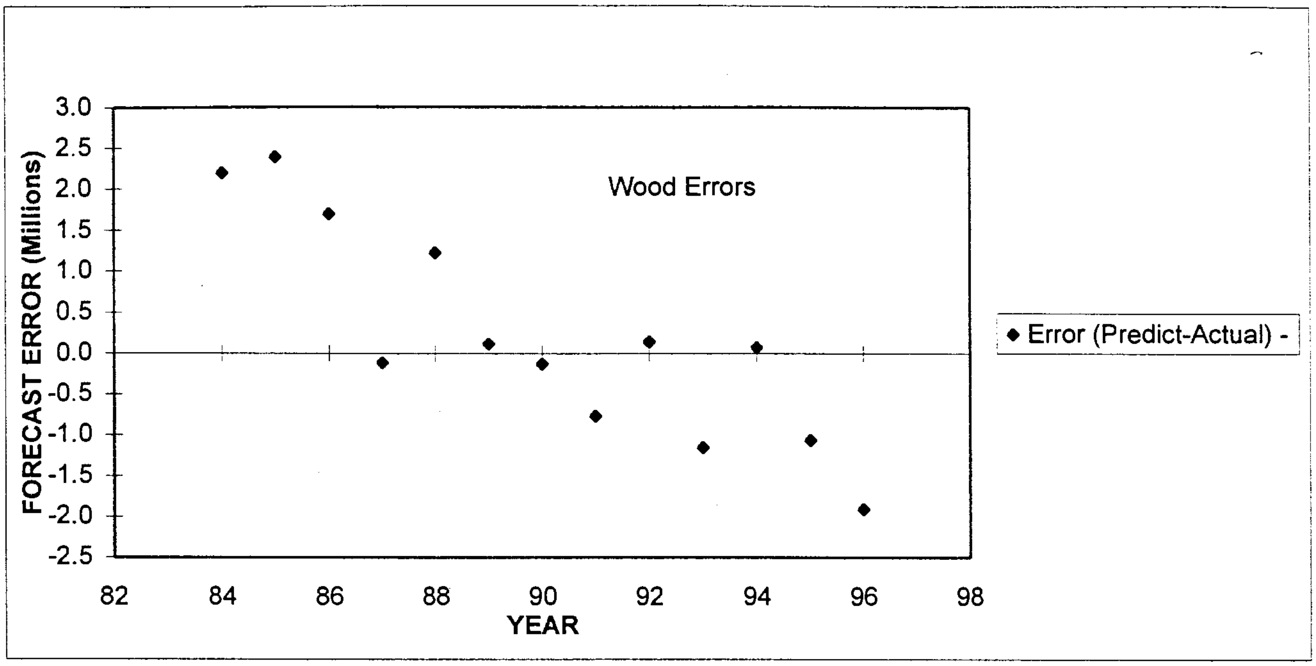


Figure 6. Errors (predicted run - actual run) of Ugashik River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1992-96 (bottom).



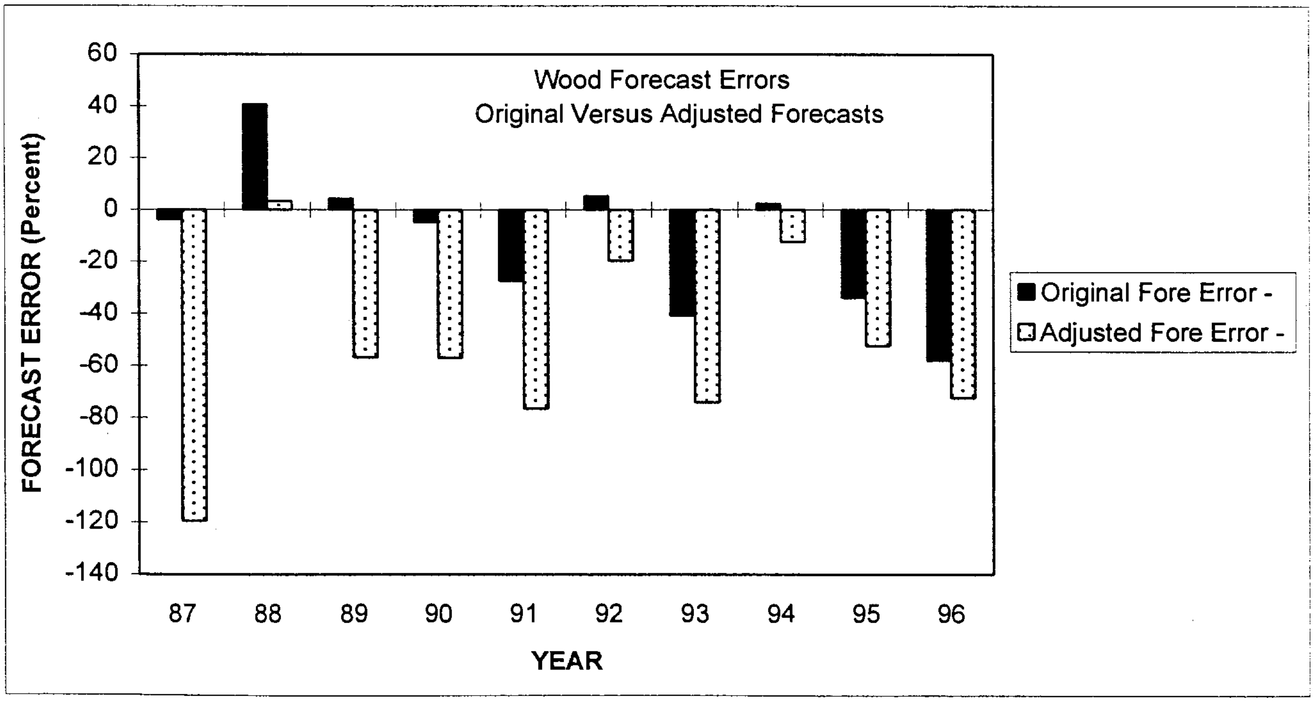
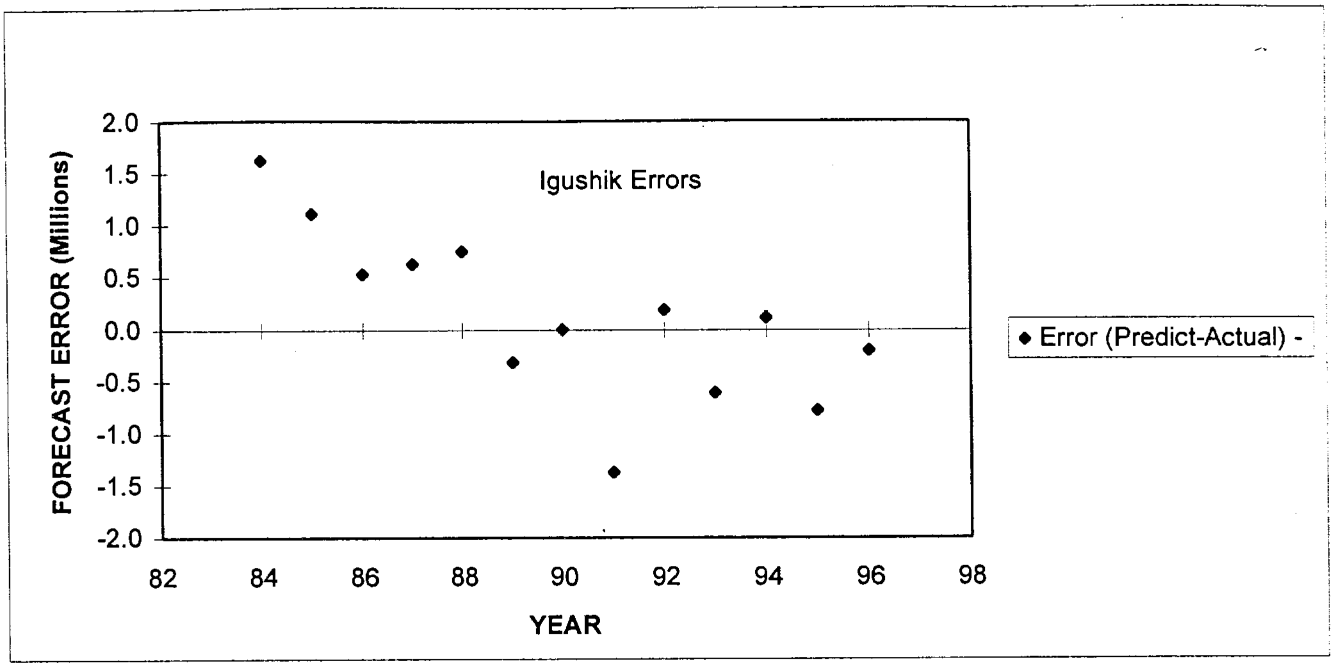


Figure 7. Errors (predicted run - actual run) of Wood River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).



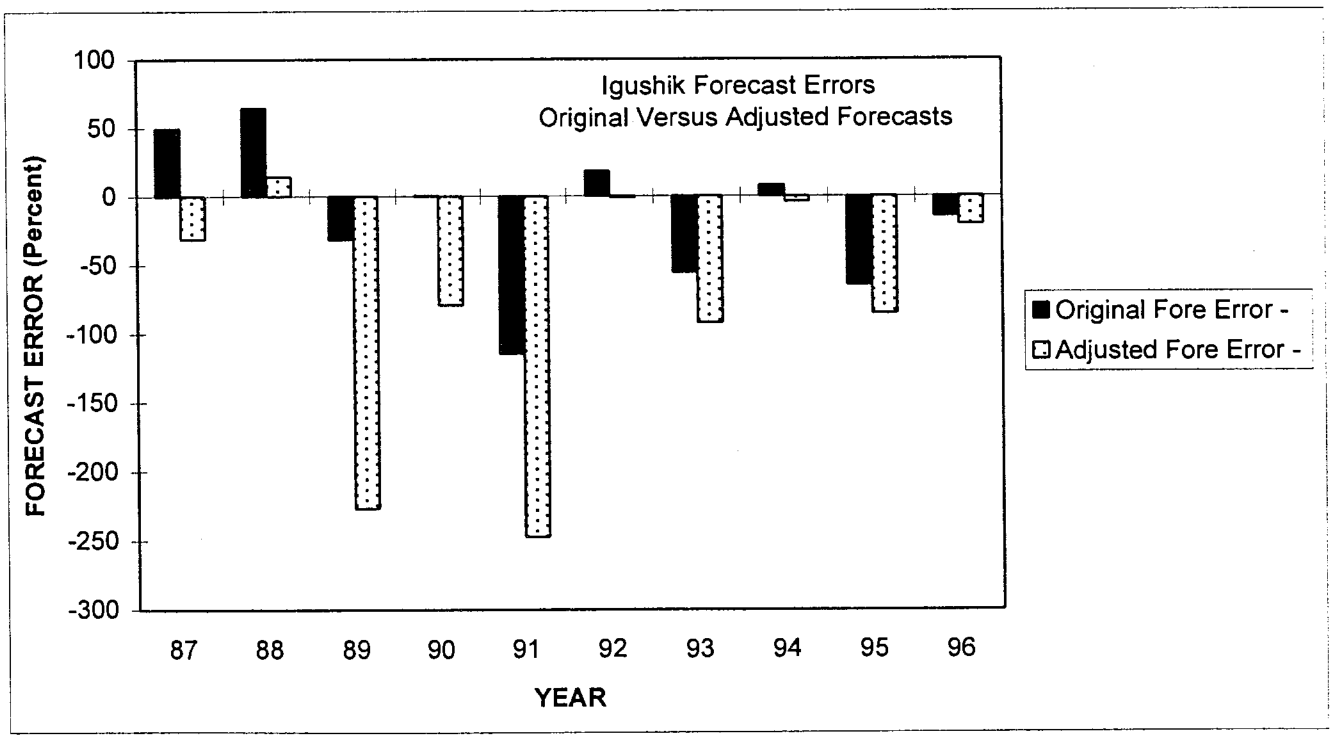
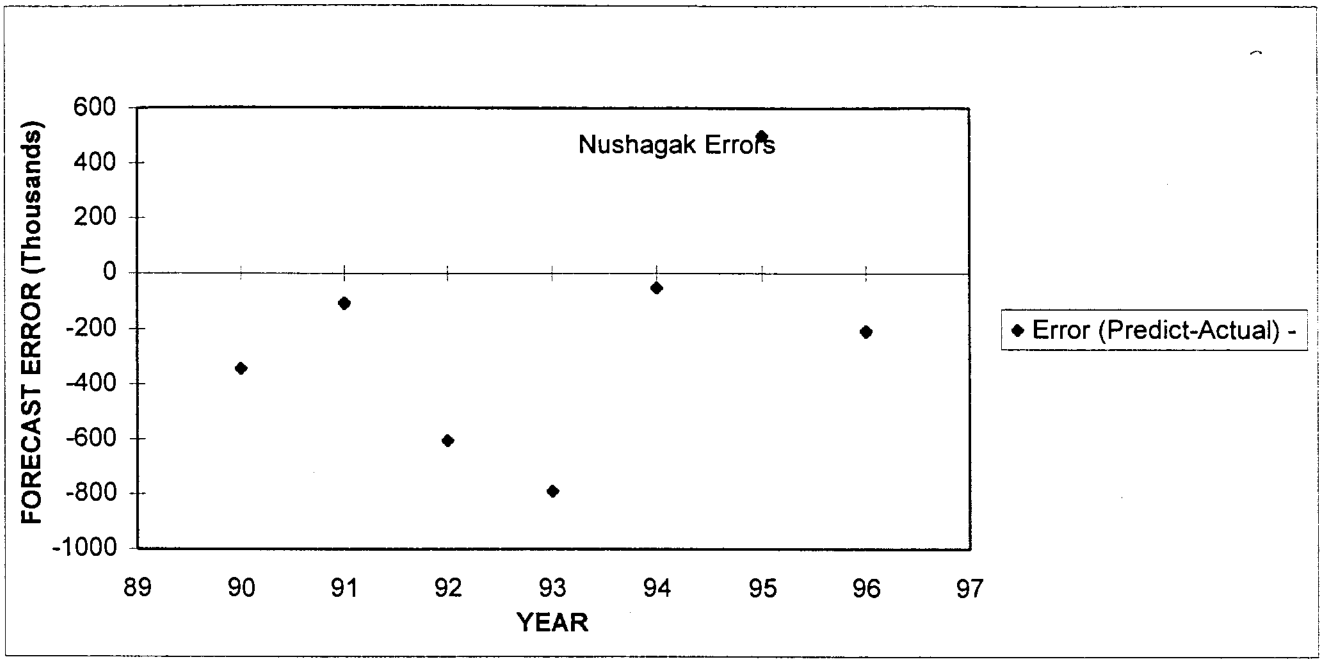


Figure 8. Errors (predicted run - actual run) of Igushik River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).



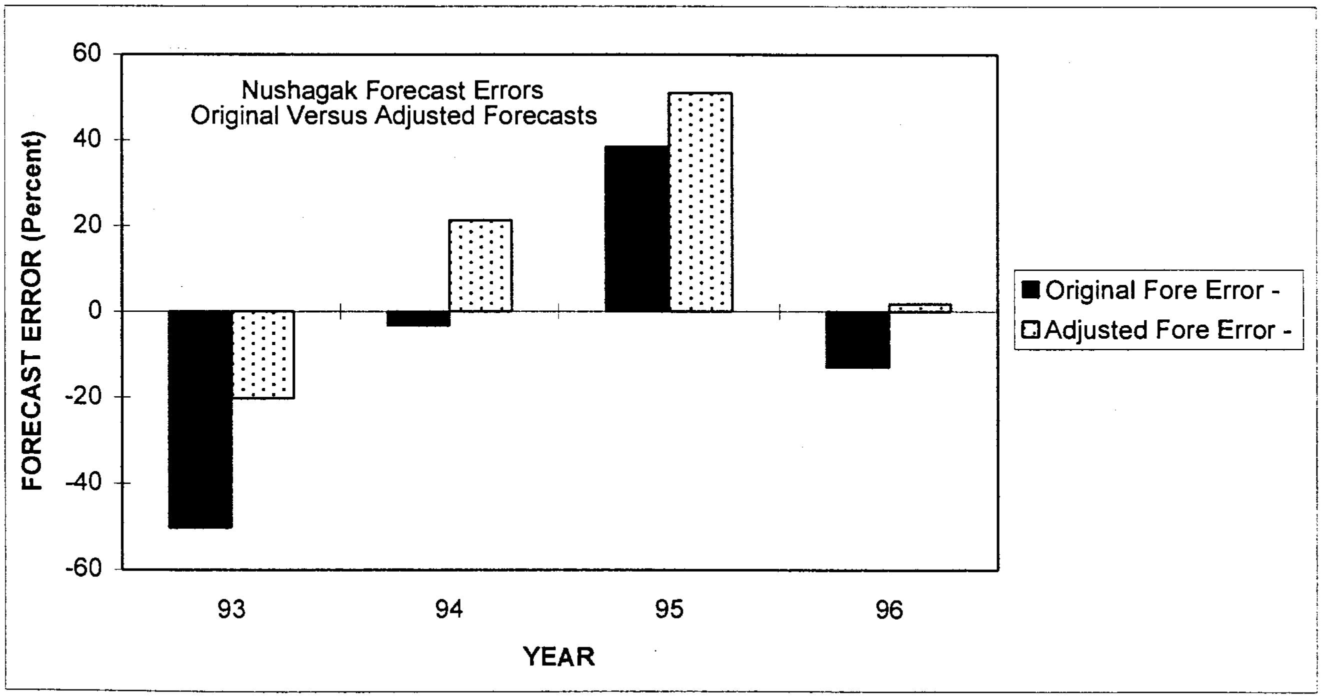
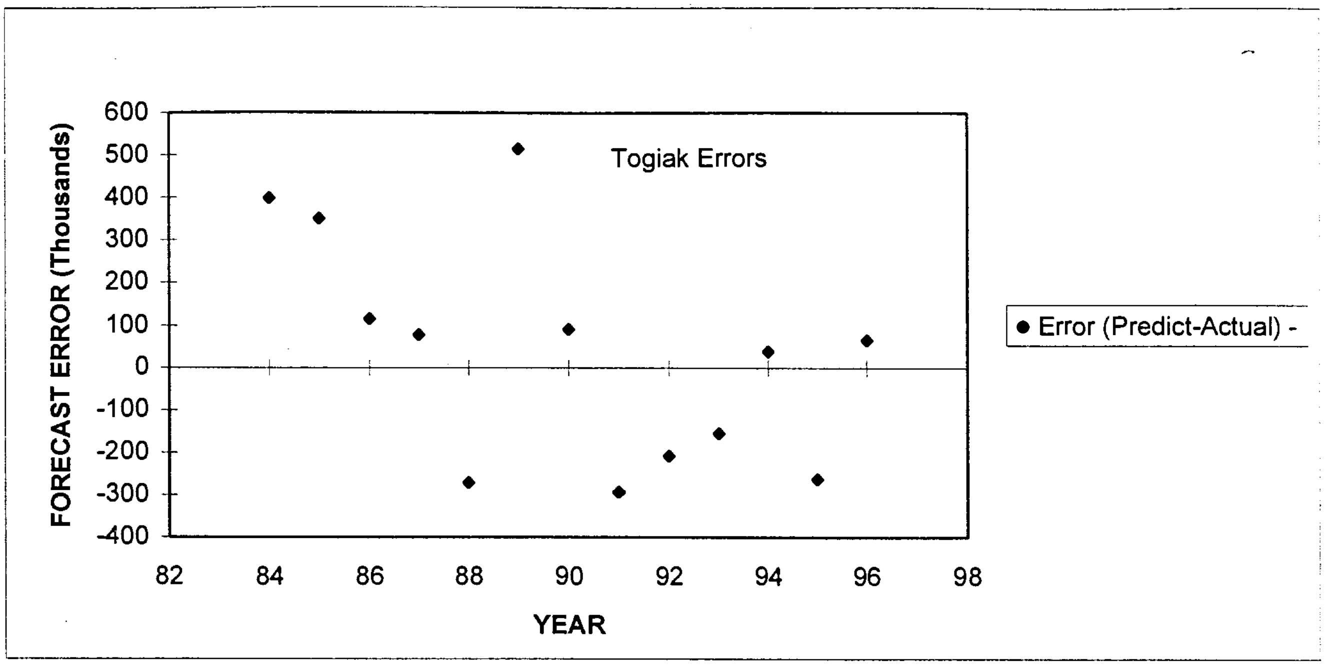


Figure 9. Errors (predicted run - actual run) of Nushagak River forecasts for 1990-96 (top) and a comparison between original and adjusted forecast errors, 1993-96 (bottom).



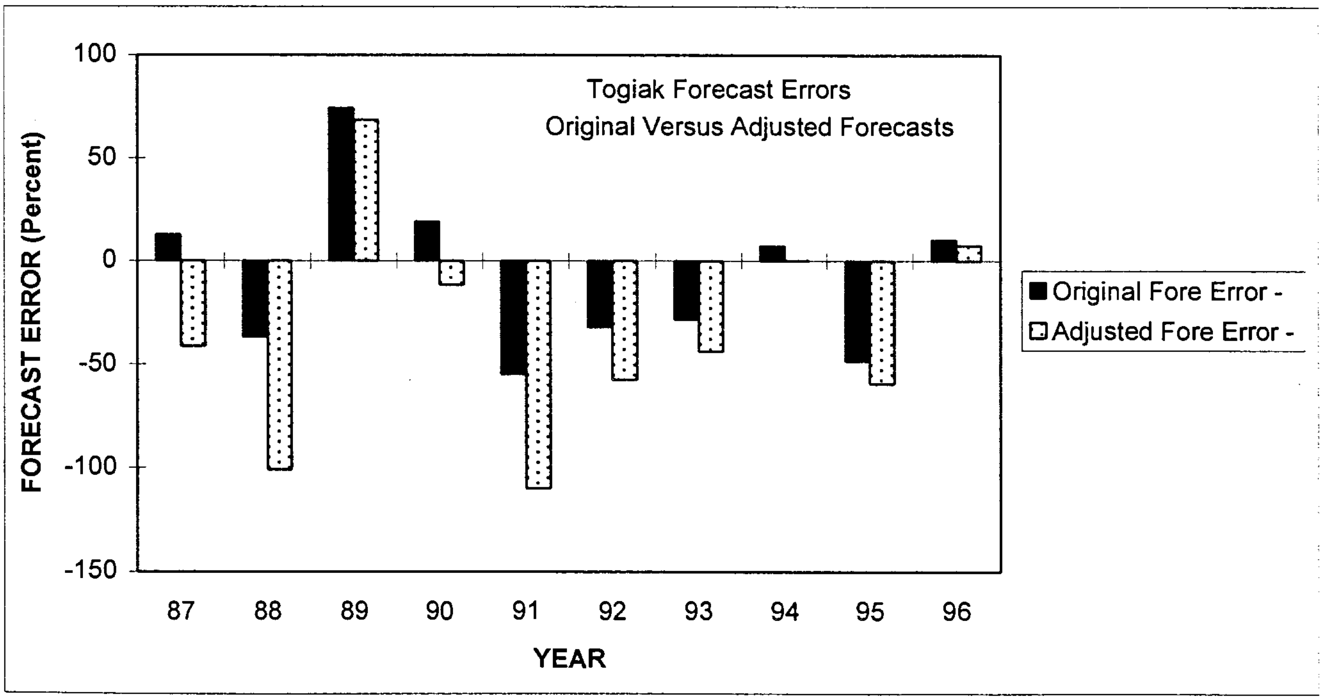


Figure 10. Errors (predicted run - actual run) of Togiak River forecasts for 1984-96 (top) and a comparison between original and adjusted forecast errors, 1987-96 (bottom).

APPENDIX A: HISTORIC SOCKEYE FORECASTS AND RETURNS

Appendix A.1. Preseason forecasts of sockeye salmon returns to Bristol Bay, 1961-1997 issued by the Alaska Department of Fish and Game.

Year	Forecast (millions)	Actual Return (millions) Inshore	Actual Return (millions) Total	Percent Error[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	15.2	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
1995	58.7	60.7	62.8	-6.5
1996	46.5	36.9	37.9	22.7
1997	35.8	18.9	20.5	74.6

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

APPENDIX B: UNADJUSTED RIVER SYSTEM FORECASTS

Appendix B.1. Forecasted returns of major age classes of sockeye salmon to the Kvichak River in 1997 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	4,025	2,162	5.0	19
2.2	4,726	4,458	0.1	19
1.3	4,726	1,857	0.1	19
2.3	4,223	900	2.5	19
	Total	9,377		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	2,950[a]	NS	12
2.2	2	726	0.1	16
1.3	422	613	1.0	18
2.3	704	320	1.0	18
	Total	4,609		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	209,857	4,650	5.0	19
2.2	11,034	1,018	0.1	19
1.3	53,638	1,367	5.0	18
2.3	30,207	607	5.0	18
	Total	7,642		

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

Appendix B.2. Forecasted returns of major age classes of sockeye salmon to the Branch River in 1997 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	348	165	5.0	19
2.2	225	60[a]	NS	18
1.3	225	158	1.0	19
2.3	278	13[a]	NS	18
	Total	396		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	4	226	10.0	16
2.2	0	[b]		
1.3	96	157[a]	NS	18
2.3	166	22	5.0	16
	Total	405		

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

[b] Estimate not made; no age-2.1 salmon returned to Branch River in 1996.

Appendix B.3. Forecasted returns of major age classes of sockeye salmon to the Naknek River in 1997 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	1,536	522[a]	NS	19
2.2	1,607	781	5.0	19
1.3	1,607	1,733	5.0	19
2.3	3,578	1,819	10.0	19
	Total	4,855		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	389	10.0	13
2.2	1	511	10.0	16
1.3	262	983	0.5	18
2.3	248	547	5.0	18
	Total	2,430		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	[b]			
2.2	[b]			
1.3	32,615	2,098[a]	NS	6
2.3	42,322	1,095	5.0	6
	Total	3,193		

[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 1995.

Appendix B.4. Forecasted returns of major age classes of sockeye salmon to the Egegik River in 1997 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	1,517	640	5.0	19
2.2	1,946	6,483	5.0	19
1.3	1,946	1,503	25.0	19
2.3	2,787	8,731	10.0	19
	Total	17,357		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	934	10.0	12
2.2	55	5,901	1.0	18
1.3	336	517	0.1	18
2.3	3,135	1,758	1.0	18
	Total	9,110		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	7,412	629	5.0	13
2.2	49,962	6,654	1.0	13
1.3	54,909	3,262	1.0	12
2.3	39,158	4,055	1.0	12
	Total	14,600		

Appendix B.5. Forecasted returns of major age classes of sockeye salmon to the Ugashik River in 1997 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	1,413	861	1.0	19
2.2	2,194	2,374	0.5	19
1.3	2,194	2,004	0.5	19
2.3	2,482	1,424	0.2	19
	Total	6,663		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	778	10.0	15
2.2	3	1,218	2.5	17
1.3	188	286	0.1	18
2.3	597	371	0.1	18
	Total	2,653		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	6,961	524[b]	NS	11
2.2	15,272	1,347[b]	NS	11
1.3	24,305	848	10.0	10
2.3	5,725	507[b]	NS	10
	Total	3,226		

[a] Spawner-recruit estimates were not used for the 1997 Ugashik River projection. Results from hindcasting indicated that forecasts had similar accuracies and precision levels using only sibling and smolt information.

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

Appendix B.6. Forecasted returns of major age classes of sockeye salmon to the Wood River in 1997 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	1,176	1,459	0.1	19
2.2	1,286	117[a]	NS	19
1.3	1,286	1,569	0.1	21
2.3	1,159	73[a]	NS	21
	Total	3,218		

		Sibling Data		
Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[b]		13
2.2	0	[b]		5
1.3	2,410	1,788	2.5	18
2.3	54	44	5.0	18
	Total	1,832		

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

[b] Estimate not made; no age-1.1 or age-2.1 salmon returned to Wood River in 1996.

Appendix B.7. Forecasted returns of major age classes of sockeye salmon to the Igushik River in 1997 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	405	248	0.1	19
2.2	305	41	2.5	19
1.3	305	1,091	0.1	19
2.3	756	52	2.5	19
	Total	1,432		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[a]		
2.2	0	[a]		
1.3	44	426	1.0	18
2.3	2	10	5.0	18
	Total	436		

[a] Estimates not made; no age-1.1 or age-2.1 *sockeye salmon* returned to Igushik River in 1996.

Appendix B.8. Forecasted returns of major age classes of sockeye salmon to the Nushagak River in 1997 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	509	40	1.5	15
1.2	715	132	1.5	15
2.2	695	8	6.0	14
0.3	715	502	1.0	15
1.3	695	865	0.1	15
2.3	492	9	3.0	15
0.4	695	61	10.0	15
	Total	1,617		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
0.2	0	[a]		
1.2	0	[a]		
2.2	0	[a]		
0.3	45	476	0.1	14
1.3	228	991	0.4	14
2.3	3	8	5.0	13
0.4	498	64	1.0	14
	Total	1,539		

[a] Estimates not made; no age-0.1, -1.1, or -2.1 sockeye salmon returned to Nushagak River in 1996.

Appendix B.9. Forecasted returns of major age classes of sockeye salmon to the Togiak River in 1997 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	193	127	1.0	19
2.2	215	28	10.0	19
1.3	215	414	0.5	19
2.3	278	34	2.5	19
	Total	603		

Sibling Data

Age Class	Sibling Return in 1996 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	183[a]	NS	5
2.2	0	[b]		
1.3	49	236	0.1	18
2.3	27	35	0.2	18
	Total	454		

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

[b] Estimate not made; no age-2.1 sockeye salmon returned to Togiak River in 1996