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KENAI RIVER SOCKEYE SALMON BIOLOGICAL ESCAPEMENT GOAL REVIEW TEAM FINDINGS

by

Stephen M. Fried

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AUTHOR

Stephen M. Fried is the Regional Research Biologist for Prince William Sound, Cook Inlet and Bristol Bay 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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INTRODUCTION

A Kenai River Biological Escapement Goal (BEG) Interdivisional Review Team was formed in 1992 to evaluate sockeye salmon *Oncorhrynchus nerka* BEG's for the various stock management units within the Kenai River drainage (e.g. mainstem, early and late Russian River, Hidden Lake). The goal of the Team has been to determine whether existing BEG's needed to be modified and whether new goals needed to be established. This document summarizes the findings from the most recent meeting, convened in Anchorage on 29 November 1994, at which team members recommended maintaining the existing Kenai River spawning goal of 330,000 to 600,000 sockeye salmon which is enumerated by hydroacoustics at a site located about 19 miles from the Kenai River mouth. This spawning goal includes the mainstem Kenai River BEG of 300,000 to 570,000 sockeye salmon well as the late run Russian River BEG of 30,000 sockeye salmon. The meeting was attended by representatives from both the Commercial Fisheries Management and Development Division (CFMD; Linda Brannian, James Brady, Stan Carlson, Stephen Fried, John Hilsinger, Dana Schmidt, Kenneth Tarbox) and Sport Fish Division (SF; David Bernard, Steven Hammarstrom, Kelly Hepler, Douglas McBride). During the meeting we reviewed the history of existing BEG's for Kenai River system sockeye salmon populations, portions of the department's salmon spawning escapement goal policy relating to modification of existing BEG's, and results of analyses done by various team members to estimate Kenai River system sockeye salmon BEG's.

METHODS

Hilborn and Walters (1992) recently grouped potential approaches to describing stock-recruitment relationships into three categories: 1) rough and ready, 2) stock-recruitment curves with variances, and 3) tabular or Markov models (a more formal version of the rough-and-ready method). Interdivisional Review Team members were able to provide results based on a rough and ready approach and stock-recruitment curves, but were unable to use Markov models. Hilborn and Walters (1992) cautioned that without 30 to 50 data points, a tabular or Markov model should not be attempted, and only 22 years of stock-recruitment data were available for Kenai River sockeye salmon. Team members also discussed ancillary data that has been collected concerning rearing juvenile and migrating smolt survival and mortality.

The rough and ready approach is a qualitative method in which data are tabulated or plotted and examined for trends, patterns, or groupings that are useful in providing advice about stock and recruitment in a population. Stock-recruitment curves is a quantitative method in which various mathematical relationships are fit to available data. The most commonly used models were developed by Ricker (1954 and 1975) and Beverton and Holt (1957). Finally, tabular or Markov models is a very data intensive method which accommodates, but is not based on, any form of stock-recruitment curve and includes the variation seen in the data. This method is essentially a tabular representation of recruitment probabilities directly based on available data. Due to the large amounts of data needed for this method, few instances of it use in fisheries have been documented (e.g. Overholtz, Sissenwine and Clark 1986).

RESULTS AND DISCUSSION

Rough and Ready Approach

While a relatively wide range of spawning stock sizes has been documented in the Kenai River system, 51,000 to 1,407,000 sockeye salmon, the distribution of these data is strongly skewed towards smaller escapements (Table 1 and Figure 1). Thirteen data points have been obtained below a spawning stock size of about 400,000 sockeye salmon and only 3 data points have been obtained above a spawning stock size of about 700,000 sockeye salmon. A "rough-and-ready" description of these data is that there is a trend of increasing total returns, as well as increasing variability of total returns, with increasing spawning stock size. Total returns have been above replacement for all brood years, even at the greatest level of spawning stock observed, 1,407,000 sockeye salmon. Total returns greater than 1,000,000 sockeye salmon have not occurred at spawning stock sizes less than about 300,000 spawners. Increased total returns have not been obtained above spawning stock sizes of 500,00 to 600,000 sockeye salmon, but available data are too sparse to clearly define production at these spawning escapement levels. The greatest yield to date, 8,710,177 sockeye salmon, was the result of a spawning escapement of 571,000 sockeye salmon. The second greatest yield, 8,591,150 sockeye salmon, was the result of a spawning escapement of 1,407,000 sockeye salmon. The advice to be gathered from this data is that spawning escapements should be kept above 300,000 to 400,000 sockeye salmon to ensure high sustained yield, but that little or no increase in yield may occur at spawning escapements in excess of about 600,000 sockeye salmon (Table 2). Smoothed curves fit through the data, robust locally weighted smoothing (LOWESS) and distance weighted local smoothing (DWLS), also suggested that returns were generally greatest at a spawning stock size of about 600,000 sockeye salmon.

Stock-Recruitment Curves

Several stock recruitment curves and their variances were also examined, but classic models failed to fit the data well. While both Ricker (1954 and 1975) and Beverton-Holt (1957) models suggested BEG values of about 1,600,000, neither of these models provided a statistically significant fit to the data. The great amount of uncertainty entailed in estimating BEG from available data with stock recruitment curves was further illustrated by the variability in Ricker (1954 and 1975) model BEG estimates obtained from bootstrap interval estimates. This exercise was completed after the meeting, and the approximate 90% confidence interval for the BEG estimate of 1,560,000 spawners was 760,000 to 7,930,000 spawners (Stan Carlson, ADF&G, CFMD, Soldotna, personal communications;Table 2).

Production models based on conditions in freshwater nursery lakes were also examined. These models assume that year class strength is determined prior to the time juvenile sockeye salmon migrate to sea, and that the capacity of freshwater rearing systems to produce smolt is a good predictor of subsequent adult returns. A euphotic zone depth model suggested that BEG was 710,000 spawners, while a zooplankton standing crop biomass model estimated BEG to be 1,720,000 spawners (Table 2). However, comparisons of Skilak and Tustumena Lake data indicated that the zooplankton standing crop biomass model would not have been a good predictor of juvenile sockeye salmon production potential in Skilak Lake during the past seven years.

Ancillary Information

The most controversial item at the meeting concerned interpretation of Kenai River sockeye salmon juvenile and smolt data, much of which has been collected during Exxon Valdez Oil Spill Trustee Council studies examining effects of large spawning escapements on the Kenai River system. Although these studies are not yet complete, investigators are concerned that the carrying capacity of Skilak Lake for sockeye salmon juveniles may have been impacted by successive escapements in excess of 1,000,000 spawners (Schmidt 1994; Schmidt and Tarbox 1993). Some type of rearing capacity effect is suggested by reduced fry size, low lipid reserves in fry approaching winter, and reduced catches of smolt. Unfortunately, attempts to accurately estimate Kenai River smolt abundance using trap catches of marked and unmarked smolt have largely been unsuccessful (e.g. King, Brannian and Tarbox 1993 and 1994), and the project was discontinued in 1994. Without reasonably accurate and precise smolt estimates, it may not be possible to draw meaningful inferences about freshwater rearing capacity.

There was much debate on whether adult production is greatly influenced by fry and smolt size, and whether starvation is an important source of fry mortality during the winter months. If an average smolt size of about 60-65 mm and 2 g is critical for survival and smoltification, as has been suggested by Koenings and Burkette (1987), then the relationship between size of sockeye salmon fry collected during the fall in Skilak Lake and number of spawning females suggests that the BEG should be less than about 650,000 spawners (Table 2; Figure 2). However, while many investigators have felt there should be a link between smolt size and marine survival (e.g. Hyatt and Stockner 1985; McDonald et al. 1987; West and Larkin

1987; Koenings et al. 1993; Forbes and Peterman 1994), analyses of supporting data have been confounded by factors such as geographic location and marine effects. Also, little information appears to exist on the role starvation plays in winter mortality of sockeye salmon juveniles rearing in lakes. Bilton and Robins (1971) showed that sockeye salmon juveniles could be held under laboratory conditions without food for 20 to 30.5 weeks at a mean temperature of 4.95 C with relatively low mortality (1% and 15%, respectively). Since these juveniles were well fed prior to being deprived of food, while Skilak Lake fry did not appear to be well fed, starvation experiments using groups of juveniles having different levels of lipid reserves would help resolve this dilemma. Therefore, the Review Team was unable to reach a consensus on interpretation of this ancillary data and its use in identifying a sockeye salmon BEG for the Kenai River.

RECOMMENDATIONS

While some spawner-recruit models examined suggested that the BEG could be increased above the current level, most models fit available data poorly. Results of the rough and ready approach, as well as ancillary fry and smolt data, suggested it would be risky to increase the BEG at this time. Although we could not determine the level of spawning escapement that would produce maximum sustained yield, the current BEG has the potential to produce high sustained yields. Therefore, the Review Team recommended 1) the current BEG range for Kenai River mainstem and late run sockeye salmon to remain unchanged until concerns about freshwater production are more thoroughly explored and understood, and 2) results of an updated analysis, using data available after the 1995 field season, be made available at the January 1996 Board of Fisheries meeting.

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Table 1. Sockeye salmon production data, Kenai River, 19668-1989 brood years.

Brood Year	Escapement	Return	Yield	R/S	Escapement	Average		
					Range	Return	Yield	R/S
1969	51,000	411,577	360,577	8.07				
1970	72,000	526,214	454,214	7.31				
1968	82,000	925,616	843,616	11.29	less than 100	621,136	552,802	8.89
1975	128,000	859,379	731,379	6.71				
1974	144,000	686,266	542,266	4.77				
1979	245,000	1,037,066	792,066	4.23	100 to 250	860,904	688,570	5.24
1971	289,000	993,306	704,306	3.44				
1972	301,000	2,199,135	1,898,135	7.31				
1984	311,000	5,671,218	5,360,218	18.24				
1978	349,000	3,235,546	2,886,546	9.27	250 to 350	3,024,801	2,712,301	9.56
1976	353,000	1,182,768	829,768	3.35				
1973	358,000	1,989,670	1,631,670	5.56				
1981	369,000	2,216,034	1,847,034	6.01	350 to 400	1,796,157	1,436,157	4.97
1985	403,000	2,469,014	2,066,014	6.13				
1980	411,000	2,359,000	1,948,000	5.74				
1986	422,000	1,812,088	1,390,088	4.29	400 to 450	2,213,367	1,801,367	5.39
1983	566,000	6,178,243	5,612,243	10.92				
1982	571,000	9,281,177	8,710,177	16.25				
1977	663,000	2,700,730	2,037,730	4.07	450 to 700	6,053,383	5,453,383	10.41
1988	910,000	1,995,046	1,085,046	2.19				
1989	1,379,000	3,692,620	2,313,620	2.68				
1987	1,407,000	9,998,150	8,591,150	7.11	700 to 1500	5,228,605	3,996,605	3.99

Table 2. Sockeye salmon biological escapement goal estimates from various methods, Kenai River.

KENAI RIVER BIOLOGICAL ESCAPEMENT GOAL ESTIMATORS			
CURRENT BEG: 330,000 to 600,000 spawners above mile 19 sonar site (adopted 1987)			
Method	**BEG Estimate**	**Yield Estimate**	**Comments**
Spawners and Adult Returns			
[1] Rough and Ready	400,000 to 600,000	3,071,000	Yield is geometric mean of individual values within range
Maximum Yield	571,000	8,700,000	Past escapement which produced greatest yield
LOESS Fit	575,000	2,800,000	Smoothed using robust locally weighted regression
DWLS Fit	600,000	3,900,000	Smoothed using distance weighted polynomial regression
[2] Ricker Model	1,560,000	4,110,000	Bootstrapped 90% CI for BEG: 760,000 to 7,930,000
Freshwater Rearing Capacity			
Fall Fry Size	< 650,000	No estimate	Assumes mortality increases as fry size decreases resulting in fewer adult returns
Euphotic Zone Depth	710,000	1,960,000	Model estimates fw system capacity to produce smolt and maximize adult returns
[3] Zooplankton Biomass	1,720,000	4,750,000	Model estimates fw system capacity to produce smolt and maximize adult returns

[1] Hilborn and Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty. Chapman & Hall.

[2] Results from model fit by Stan Carlson (CFMD), p = 0.151, t-tailed test.

[3] Juvenile sockeye salmon production in Skilak Lake for the past seven years did not fit this model well.

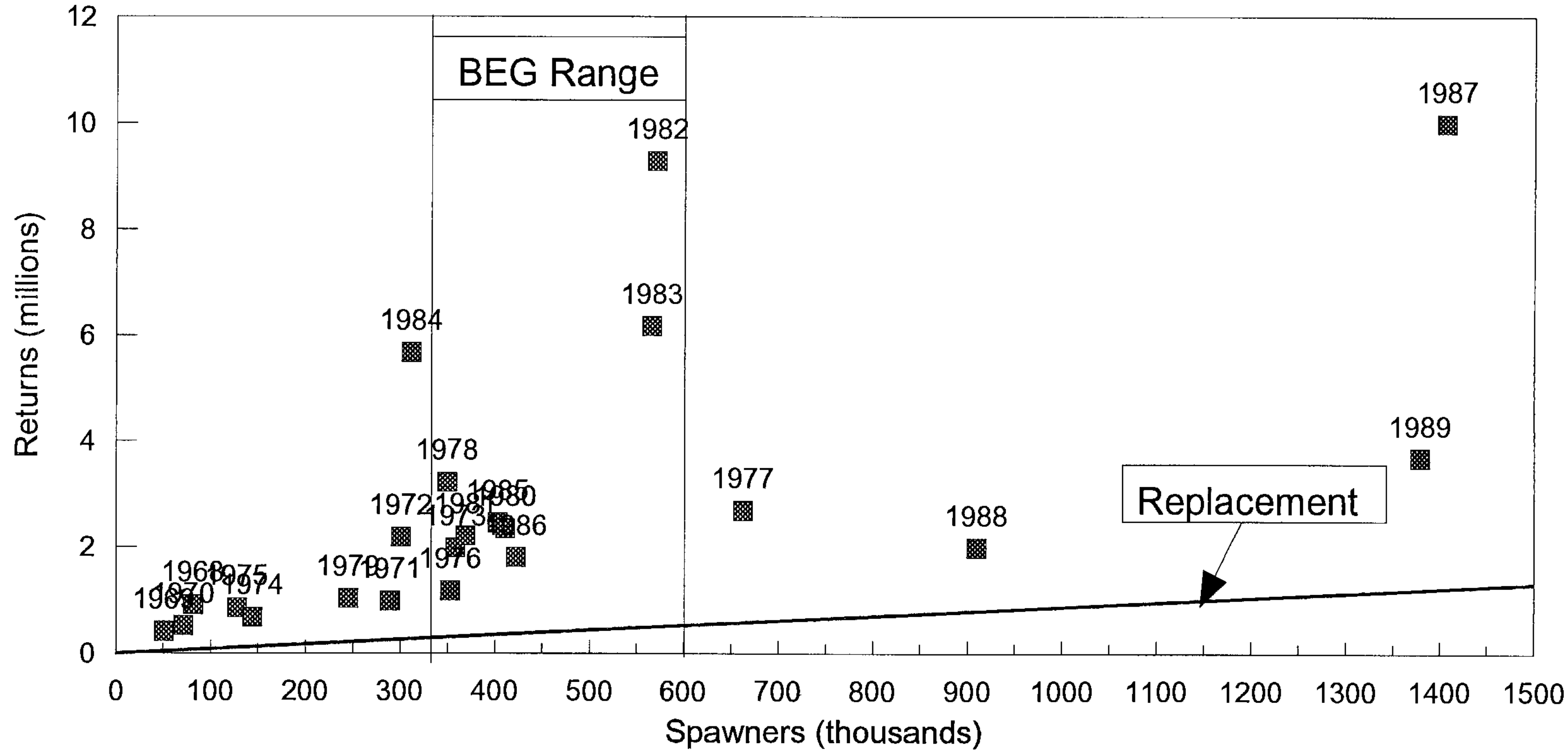

Figure 1. Sockeye salmon spawner and return data, Kenai River, 1968-1989 brood years.

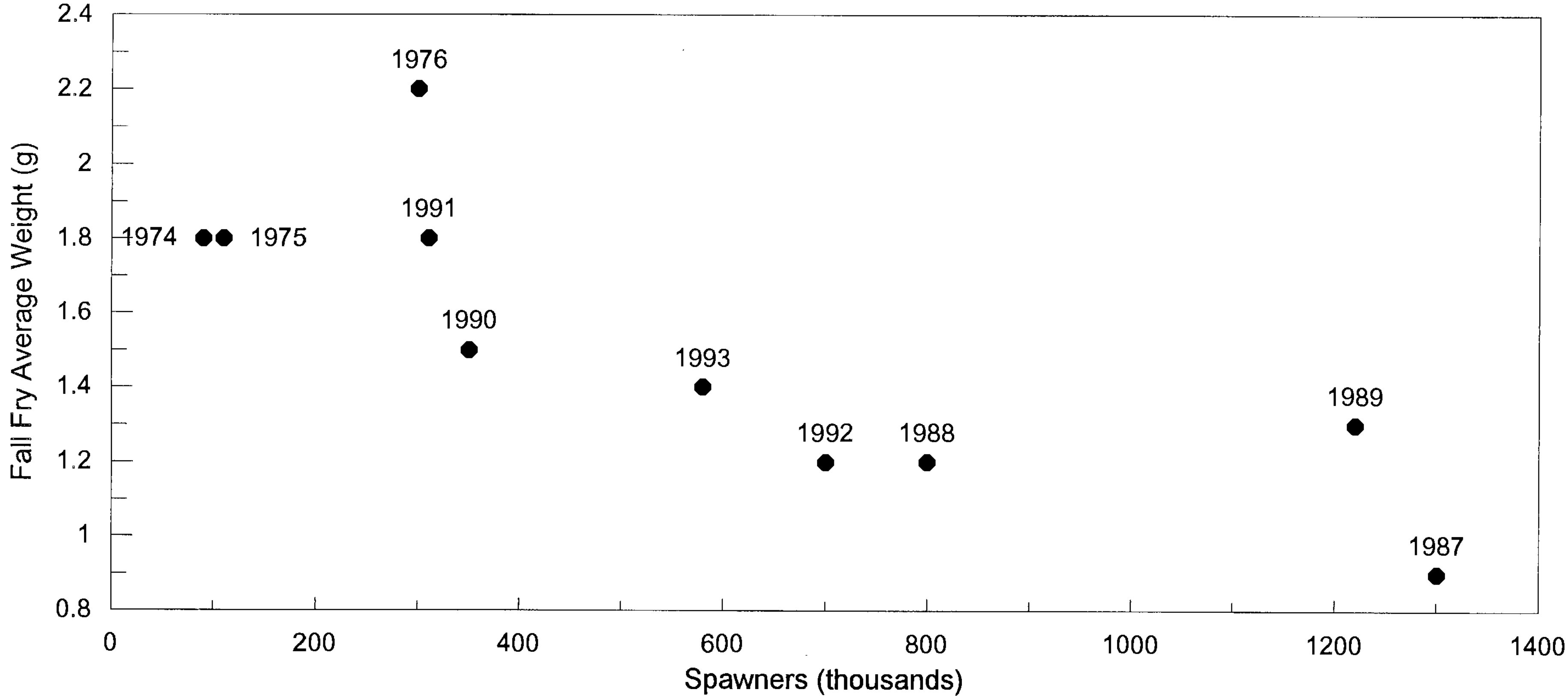

Figure 2. Sockeye salmon mainstem spawners and average weight of resulting age-0. fall fry collected in Skilak Lake, Kenai River, 1974-1976 and 1987-1993 brood years.