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**Escapement Goal Review of Copper and Bering Rivers, and Prince William Sound Pacific Salmon Stocks, 2020**

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**XXXX 2020**

**Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries**

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**Weights and measures (metric)**

centimeter cm

deciliter dL

gram g

hectare ha

kilogram kg

kilometer km

liter L

meter m

milliliter mL

millimeter mm

**Weights and measures (English)**

cubic feet per second ft3/s

foot ft

gallon gal

inch in

mile mi

nautical mile nmi

ounce oz

pound lb

quart qt

yard yd

**Time and temperature**

day d

degrees Celsius °C

degrees Fahrenheit °F

degrees kelvin K

hour h

minute min

second s

**Physics and chemistry**

all atomic symbols

alternating current AC

ampere A

calorie cal

direct current DC

hertz Hz

horsepower hp

hydrogen ion activity pH

(negative log of)

parts per million ppm

parts per thousand ppt,

‰

volts V

watts W

**General**

Alaska Administrative

Code AAC

all commonly accepted

abbreviations e.g., Mr., Mrs., AM, PM, etc.

all commonly accepted

professional titles e.g., Dr., Ph.D.,

R.N., etc.

at @

compass directions:

east E

north N

south S

west W

copyright ©

corporate suffixes:

Company Co.

Corporation Corp.

Incorporated Inc.

Limited Ltd.

District of Columbia D.C.

et alii (and others) et al.

et cetera (and so forth) etc.

exempli gratia

(for example) e.g.

Federal Information

Code FIC

id est (that is) i.e.

latitude or longitude lat. or long.

monetary symbols

(U.S.) $, ¢

months (tables and

figures): first three

letters Jan,...,Dec

registered trademark ®

trademark ™

United States

(adjective) U.S.

United States of

America (noun) USA

U.S.C. United States Code

U.S. state use two-letter abbreviations (e.g., AK, WA)

**Measures (fisheries)**

fork length FL

mideye-to-fork MEF

mideye-to-tail-fork METF

standard length SL

total length TL

**Mathematics, statistics**

*all standard mathematical*

*signs, symbols and*

*abbreviations*

alternate hypothesis HA

base of natural logarithm *e*

catch per unit effort CPUE

coefficient of variation CV

common test statistics (F, t, χ2, etc.)

confidence interval CI

correlation coefficient

(multiple) R

correlation coefficient

(simple) r

covariance cov

degree (angular ) °

degrees of freedom df

expected value *E*

greater than >

greater than or equal to ≥

harvest per unit effort HPUE

less than <

less than or equal to ≤

logarithm (natural) ln

logarithm (base 10) log

logarithm (specify base) log2, etc.

minute (angular) '

not significant NS

null hypothesis HO

percent %

probability P

probability of a type I error

(rejection of the null

hypothesis when true) α

probability of a type II error

(acceptance of the null

hypothesis when false) β

second (angular) "

standard deviation SD

standard error SE

variance

population Var

sample var

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**ESCAPEMENT GOAL REVIEW OF COPPER AND BERING RIVERS, AND PRINCE WILLIAM SOUND PACIFIC SALMON STOCKS, 2020**

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**TABLE OF CONTENTS**

**Page**

[LIST OF TABLES iii](#_Toc52200124)

[LIST OF FIGURES iii](#_Toc52200125)

[LIST OF APPENDICES iii](#_Toc52200126)

[ABSTRACT 1](#_Toc52200127)

[INTRODUCTION 1](#_Toc52200128)

[OBJECTIVES 3](#_Toc52200129)

[OVERVIEW OF STOCK ASSESSMENT METHODS 3](#_Toc52200130)

[Escapement and Harvest Data 3](#_Toc52200131)

[Escapement Goal Determination 5](#_Toc52200132)

[Spawner-recruitment Analysis 5](#_Toc52200133)

[Percentile Approach 6](#_Toc52200134)

[STOCK SPECIFIC METHODS, RESULTS AND RECOMMENDATIONS 7](#_Toc52200135)

[Chinook Salmon 7](#_Toc52200136)

[Copper River 7](#_Toc52200137)

[Coho Salmon 8](#_Toc52200138)

[Bering River 8](#_Toc52200139)

[Copper River Delta 8](#_Toc52200140)

[Sockeye Salmon 9](#_Toc52200141)

[Bering River 9](#_Toc52200142)

[Coghill Lake 9](#_Toc52200143)

[Methods and History 9](#_Toc52200144)

[Results and Recommendations 9](#_Toc52200145)

[ACKNOWLEDGEMENTS 10](#_Toc52200146)

[REFERENCES CITED 10](#_Toc52200147)

[TABLES AND FIGURES 14](#_Toc52200148)

[APPENDIX A: SUPPORTING INFORMATION FOR ESCAPEMENT GOALS FOR SALMON STOCKS IN THE COPPER RIVER, BERING RIVER, AND PRINCE WILLIAM SOUND AREAS 40](#_Toc52200149)

# LIST OF TABLES

**Table Page**

1. Summary of recommended escapement goals for Prince William Sound Management Area salmon stocks,

2017 15

2. Current escapement goals compared to escapements observed from 2010 through 2019 for Chinook, coho, and

sockeye salmon stocks of the Prince William Sound Management Area. 16

3. Total recruits of Coghill Lake sockeye salmon by age class that originated from brood years 1962 to 2016. 27

4. A comparison of Ricker stock-recruitment model estimates from Fair et al. (2011) and the current analysis that

used spawner and recruitment data for Coghill Lake sockeye salmon from brood years 1962–2014. 29

# LIST OF FIGURES

**Figure Page**

1. Prince William Sound Management Area showing commercial fishing districts, salmon hatcheries, weir

locations, and Miles Lake sonar camp. 30

2. Optimal yield profiles (OYPs), overfishing profiles (OFPs), and optimal recruitment profiles (ORPs) for

Copper RiverChinook salmon as derived from an age-structured state-space model fitted to abundance,

harvest, and age data for 1980–2018 (blue) and 1999–2018 (red). 31

3. Plausible spawner-recruit relationships for Coghill Lake sockeye salmon as derived from a Bayesian stock-

recruit analysis for brood years 1962–2014. 32

# LIST OF APPENDICES

**Appendix Page**

A 1. Supporting information for analysis of escapement goal for Copper River Chinook salmon. 34

A 2. Supporting information for analysis of escapement goal for Bering River District coho salmon. 35

A 3. Supporting information for analysis of escapement goal for Copper River Delta coho salmon. 37

A 4. Supporting information for analysis of escapement goal for Bering River District sockeye salmon. 39

A 5. Links to repositories of code used in analysis of escapement goals for Prince William Sound pink and chum

salmon, and Coghill Lake sockeye salmon. 41

# ABSTRACT

This report is a summary of escapement goal reviews and recommendations for major salmon stocks of the Upper Copper River and Prince William Sound Management Areas. Escapement goals were reviewed based on the *Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222) and the *Policy for Statewide Salmon Escapement Goals* (5 AAC 39.223) adopted by the Alaska Board of Fisheries into regulation in 2001. The escapement goal committee reviewed 29 existing escapement goals, including 1 Chinook *Oncorhynchus tshawytscha* , 5 chum *O. keta* , 2 coho *O. kisutch*, 16 pink *O. gorbuscha* (8 goals for each even- and odd-year brood line), and 5 sockeye *O. nerka* salmon stocks. All of the existing goals were adopted in 2002, 2005, 2008, or 2011 except for the 2 coho salmon goals that were adopted in 1991. The escapement goal committee recommends escapement goals be updated for 5 stocks; Copper River Chinook salmon, Copper River Delta and Bering River coho salmon, and Bering River and Coghill Lake sockeye salmon. The escapement goal committee recommends no modifications be made to the other existing salmon escapement goals, and that no goals are eliminated or created at this time.

Key words: Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, sockeye salmon *O. nerka*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, escapement goal, biological escapement goal, sustainable escapement goal, Copper River, Bering River, Prince William Sound

# INTRODUCTION

The Prince William Sound Management Area (PWSMA) and the Upper Copper/Upper Susitna Management Area (UCUSMA) encompass all coastal waters and inland drainages entering the north central Gulf of Alaska between Cape Suckling and Cape Fairfield (Figure 1). In addition to Prince William Sound (PWS), these management areas include the Bering and Copper river watersheds with a total adjacent land area of approximately 38,000 square miles. The PWSMA is divided into 11 commercial fishing districts that correspond to local geography and distribution of the 5 species of Pacific salmon *Oncorhynchus* spp. Saltwater subsistence fisheries are tied to commercial fishery openings by time and area, unless otherwise specified through emergency order. Copper River freshwater subsistence fisheries occur on the western Copper River Delta, and in the Chitina (federal subsistence) and Glennallen subdistricts of the Upper Copper River. Personal use fishing only occurs in the Chitina Subdistrict. Sport fisheries are broken out into Prince William Sound and Upper Copper/Upper Susitna management areas.

The primary management objective for all districts is to achieve spawning escapement goals for the major stocks while allowing for an orderly harvest of all fish surplus to spawning requirements and inriver goals. Escapement refers to the annual estimated size of a spawning salmon stock, and is affected by a variety of factors including harvest, predation, disease, and numerous physical and biological characteristics of the environment.

The Alaska Department of Fish and Game (ADF&G) reviews escapement goals for PWSMA and UCUSMA salmon stocks on a schedule corresponding to the Alaska Board of Fisheries (BOF) 3-year cycle for considering area regulatory proposals. Reviews are based on the *Policy for the Management of Sustainable Salmon Fisheries* (SSFP; 5 AAC 39.222) and the *Policy for Statewide Salmon Escapement Goals* (EGP; 5 AAC 39.223). The BOF adopted these policies into regulation during the 2000/2001 cycle to ensure Alaska’s salmon stocks are conserved, managed, and developed using the sustained yield principle. The EGP states that it is ADF&G’s responsibility to document existing salmon escapement goals for all salmon stocks currently managed for an escapement goal and to review existing, or propose new, escapement goals on a schedule that conforms to the BOF’s regular cycle of consideration of area regulatory proposals. For this review, there are 2 important terms defined in the SSFP:

5 AAC 39.222 (f)(3) *“biological escapement goal*” or “(BEG)” means the escapement that provides the greatest potential for maximum sustained yield; the BEG will be the primary management objective for the escapement unless an optimal escapement or inriver run goal has been adopted; the BEG will be developed from the best available biological information, and should be scientifically defensible on the basis of available biological information; the BEG will be determined by the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements within the bounds of a BEG; and

5 AAC 39.222 (f)(36) *“sustainable escapement goal*” or “(SEG)” means a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situations where a BEG cannot be estimated or managed for; the SEG is the primary management objective for the escapement, unless an optimal escapement or inriver run goal has been adopted by the board; the SEG will be developed from the best available biological information; and should be scientifically defensible on the basis of that information; the SEG will be determined by the department and will take into account data uncertainty and be stated as either an “SEG range” or “lower bound SEG”; the department will seek to maintain escapements within the bounds of the SEG range or above the level of a lower bound SEG.

Many salmon escapement goals in this area have been set and evaluated at regular intervals since statehood. This was the ninth time an interdivisional committee reviewed escapement goals for stocks in this area. In 1994 and 1999, committees reviewed and recommended goals with guidance from ADF&G’s *Salmon Escapement Goal Policy* adopted in 1992 (Fried 1994). Since the 2002 review, escapement goals have been compliant with the SSFP and EGP. Due to the comprehensive previous analyses in Bue et al. (2002), Evenson et al. (2008), Fair et al. (2008), Fair et al. (2011), and Moffitt et al. (2014), this review only analyzed goals with recent (2017–2019) data that might have resulted in a substantially different escapement goal from the last review, or those that should be eliminated or established. An interdivisional escapement goal committee (hereafter referred to as the committee), including staff from the Divisions of Commercial Fisheries and Sport Fish, held an initial meeting to discuss and develop recommendations on October 30, 2019. The committee recommended the appropriate type of escapement goal (BEG or SEG), based on the quality and quantity of available data and provided an analysis for recommending escapement goals. The committee met December 2019 to review stock assessments and prepare escapement goal recommendations for the PWSMA and UCUSMA meeting in December 2020.

This report describes PWSMA and UCUSMA salmon escapement goals reviewed in 2019 and 2020 and presents information from the previous 3 years in the context of these goals. All committee recommendations are reviewed by ADF&G regional and headquarters staff prior to adoption as escapement goals per the SSFP and EGP. The purpose of this report is to inform the BOF and the public about the review of PWSMA and UCUSMA salmon escapement goals and the committee’s recommendations to the Divisions of Commercial Fisheries and Sport Fish directors.

During the 2019–2020 review process, the committee evaluated escapement goals (or potential goals) for various Chinook *Oncorhynchus tshawytscha*, coho *O. kisutch*, and sockeye *O. nerka* salmon stocks:

* Chinook salmon: Copper River;
* Coho salmon: Bering River and Copper River Delta; and
* Sockeye salmon: Bering River and Coghill Lake.

# OBJECTIVES

Objectives of the 2019–2020 escapement goal review were as follows:

1. review existing goals to determine whether they are still appropriate given (a) new data collected since the last review, (b) current assessment techniques, and (c) current management practices;
2. review the methods used to establish the existing goals to determine whether alternative methods should be investigated;
3. consider additional stocks that may have sufficient data to develop a goal; and
4. recommend new goals if appropriate.

# OVERVIEW OF STOCK ASSESSMENT METHODS

The committee reviewed each of the existing escapement goals using updated escapement and harvest data (if available) collected since the 2017 review. Available escapement, harvest, and age data for each stock originated from research reports, management reports, and unpublished historical databases. Escapement goals for salmon are ideally based on spawner-recruitment relationships (e.g., Beverton and Holt 1957; Ricker 1954), which describe the productivity and carrying capacity of a stock. However, stock assessment data are often not suitable for describing a spawner-recruitment relationship (e.g., no stock-specific harvest data, short escapement time series, or inconsistent escapement monitoring). Therefore, other evaluation methods that use a smaller set of stock assessment data are necessary. Thus, escapement goals are evaluated and revised over time, as improved methods of assessment and goal setting are developed, and when new and better information becomes available.

## Escapement and Harvest Data

Estimates or indices of salmon escapement are obtained using a variety of methods such as aerial surveys, mark–recapture experiments, weir counts, and hydroacoustics (sonar). ADF&G estimates total annual harvests in various ways: commercial fishery from fish ticket receipts, personal use and subsistence fisheries from the return of fishery-specific harvest permits and household surveys; and sport fishery from the annual Statewide Harvest Survey (<http://www.adfg.alaska.gov/sf/sportfishingsurvey>).

Inriver abundance of Copper River Chinook salmon has been monitored by mark–recapture projects since 1999. Total drainage escapement is derived by subtracting inriver harvests from the inriver abundance estimate. Escapements from 1980 to 1998 were indexed in select spawning tributaries using aerial surveys, and these indices were integrated into a state-space age- structured model (Joy et al. *unpublished*[1](#_bookmark8)) to estimate total drainage escapement for the same years. Chinook salmon are primarily harvested commercially, but are also important for subsistence, personal use, and sport fisheries.

Coho salmon escapements to the Copper River Delta (CRD) and Bering River District have been measured as peak index counts from fixed-wing aerial surveys. Although many streams have been surveyed for each coho salmon stock over the years, only surveys conducted annually for the same streams were used to evaluate and set escapement goals: 17 streams in the CRD surveyed back to 1981 and 7 streams in the Bering River District surveyed back to 1984. Coho salmon are primarily harvested commercially, but also by subsistence, personal use, and sport fisheries.

1 Joy, P.J., Savereide, J. W., M. Tyers, and S. J. Fleischman. *Unpublished*. Run reconstruction, spawner-recruit analysis, and escapement goal recommendation for Chinook salmon in the Copper River. Alaska Department of Fish and Game, Anchorage. Subsequently referred to as Joy et al. *unpublished*.

The CRD aerial index of sockeye salmon is estimated as the sum of the peak aerial counts for 17 index streams (Fried 1994). No adjustments were made for area-under-the-curve or stream life. Estimates of contribution by the CRD stock to the Copper River harvests are unavailable. The Bering River District sockeye salmon aerial index is estimated as the sum of the peak aerial counts from 6 survey reaches. Sockeye salmon escapements into Coghill Lake have been visually counted since 1960. From 1960 to 1973, escapements were counted using a partial weir and tower with a full river weir coming into use in 1974. Age compositions from commercial harvests and escapements have been collected since 1962.

## Escapement Goal Determination

Escapement goals were evaluated for PWSMA and Upper Copper River stocks using the following methods: (1) Spawner-recruitment Analysis; and (2) Percentile Approach. Spawner and return data were used to estimate escapement goals when the committee determined it had “good” estimates of total return (escapement; age and stock-specific harvest) for a stock. When “good” spawner and return data were available, escapement goals were estimated based on: (1) escapements producing average yields that were 90–100% of maximum sustained yield (MSY) from a spawner-recruitment model, and (2) the Percentile Approach, explained below.

### Spawner-recruitment Analysis

The most commonly used stock-recruitment model, and the model used for these analyses, is described by Ricker (1954).

|  |  |
| --- | --- |
| *R*  *Se**S* | (1) |

where *α* and *β* are model parameters. After log-transforming both sides of the equation, the standard Ricker model was fit to the data using a linear regression equation:

|  |  |
| --- | --- |
| ln(*R* / *S* )  ln(** )  *S* | (2) |

For this review, a Bayesian approach was used to describe the spawner-recruitment relationship and estimate the model parameters for Copper River Chinook salmon (Joy et al. *unpublished*) and Coghill Lake sockeye salmon. State-space age-structured models have been previously used for Ricker stock-recruitment data analysis (Rivot et al. 2001; Fleischman et al.

2013), and ADF&G has applied the Bayesian approach to Ricker models in previous escapement goal studies (e.g., Fleischman and Reimer 2017; Savereide et al. 2018).

Biological reference points MSY and *SMSY* (the estimate of spawning escapement that produces MSY) represent quantities that maximize yield for the long-term.

We used approximate formulae given by Hilborn and Walters (1992) to estimate *SMSY*:

|  |  |
| --- | --- |
| *S*  ln(** ) 0.5  0.07 ln** .  *MSY * | (3) |

Analysis was performed using JAGS (Just Another Gibbs Sampler; Plummer 2003), which used Markov Chain Monte Carlo (MCMC) methods to sample from the joint posterior of the parameters and posteriors of MSY and *SMSY*. Estimates of *SMSY* to produce 90–100% of MSY came from the median posterior distributions of MSY generated at various escapement intervals.

### Percentile Approach

Many salmon stocks in PWSMA have a SEG developed using the percentile approach. In 2001 Bue and Hasbrouck[2](#_bookmark12) (*unpublished*) developed an algorithm using percentiles of observed escapements, whether estimates or indices, that incorporated contrast in the escapement data and assumed exploitation of the stock. Percentile ranking is the percent of all escapement values that fall below a particular value. To calculate percentiles, escapement data are ranked from the smallest to the largest value, with the smallest value the 0th percentile (i.e., none of the escapement values are less than the smallest). The percentile of all remaining escapement values is cumulative, or a summation, of 1/(*n*-1), where *n* is the number of escapement values. Contrast in the escapement data are the maximum observed escapement divided by the minimum observed escapement. As contrast in the escapements increases, the percentiles used to estimate the SEG are narrowed, primarily from the upper end, to better utilize the yields from the larger runs.

Clark et al. (2014) evaluated the Bue and Hasbrouck (*unpublished*) 4-tier percentile approach and recommended changes to the approach because the tiers are probably sub-optimal as proxies for determining a range of escapements around *SMSY*. Escapements in the lower 60 to 65 percentiles were found to be optimal across a wide range of productivities as well as serial correlation and measurement error in escapements (Clark et al. 2014). Based on this information Clark et al. (2014) recommend percentiles with the following 3 tiers for stocks with low to moderate (less than 0.40) average harvest rates:

Tier 1: high contrast (>8) and high measurement error (aerial and foot surveys) with low to moderate average harvest rates (<0.40), the 20th to 60th percentiles;

Tier 2: high contrast (>8) and low measurement error (weirs, towers) with low to moderate average harvest rates (<0.40), the 15th to 65th percentiles; and

Tier 3: low contrast (8 or less) and high or low measurement error with low to moderate average harvest rates (<0.40), the 5th to 65th percentiles;

2 Bue, B. G. and J. J. Hasbrouck. *Unpublished*. Escapement goal review of salmon stocks of Upper Cook Inlet. Alaska Department of Fish and Game, Report to the Alaska Board of Fisheries, November 2001 (and February 2002), Anchorage. Subsequently referred to as Bue and Hasbrouck u*npublished*.

Use of the Percentile Approach is not recommended for the following situations:

* average harvest rates of 0.40 and greater; and
* very low contrast (4 or less) and high measurement error (aerial or foot surveys)

# STOCK SPECIFIC METHODS, RESULTS AND RECOMMENDATIONS

From this review, the escapement goal committee recommended changes to 5 of the existing salmon escapement goals in PWSMA and UCUSMA (Table 1). The committee specifically reviewed all the recent escapements (Table 2) and current methodology to determine whether there was sufficient new information or methodology to warrant a review of the existing goal. Details for these updated analyses and recommendations are provided below. All data sets were updated (Tables 1–4 and Appendices A1–A4) and most were reevaluated using new methodologies. A comprehensive review of goal performance for all salmon stocks from 2008 to 2019 is found in Table 2.

## Chinook Salmon

### Copper River

The current lower bound SEG of 24,000 or more spawners was implemented in 2003 (Bue et al. 2002). Since the lower bound SEG was established Chinook salmon escapements have achieved 24,000 or more salmon in 11 out of 16 years (Appendix A1). The escapement goal was originally established with very few direct estimates of escapement, and was set as a lower bound SEG to maintain escapements near the historical average. This goal was estimated for 1980–1998 using a catch-age model (Deriso et al. 1985; Savereide and Quinn 2004). Multiple approaches were explored using the catch-age model and the approach that allowed for measurement error in the pooled catch-age data from all fisheries and brood-year return proportions to vary over time produced parameter estimates with high precision and low bias; estimates of *SMSY* from all 4 approaches of the catch-age model ranged from 14,388 to 19,711 (Savereide 2001). Since 1999, mark–recapture techniques have been used to estimate inriver abundance, and total drainage escapement was thus derived by subtracting inriver harvest. There are only 20 escapement estimates available (1999–2018 mark–recapture estimates) and these estimates exhibit low contrast (4.7), which provides limited information for estimating a stock-recruit relationship, and hence a BEG. This goal has been reviewed every BOF cycle since 2002 (Evenson et al. 2008; Fair et al. 2008, 2011; Moffitt et al. 2014; Savereide et al. 2018). During these reviews, the committee evaluated stock- recruit data, the percentile approach (Clark et. al 2014), and habitat-based models (Liermann et al. 2010) as means of setting an escapement goal. During this review a state-space model that simultaneously reconstructs runs and fits a spawner-recruit model to estimate total return, escapement, and recruitment of Copper River Chinook salmon from 1980 to 2018 was completed (Joy et al. *unpublished*). The model uses harvest, age composition, and relative and absolute measures of inriver run abundance to estimate parameters that describe the production relationship for this stock. Uncertainty from the run reconstruction is passed through to the spawner-recruit analysis and all relevant data are considered and weighted by their precision. The model accommodates missing data, measurement error in the data, absolute and relative abundance indices, and changes in age at maturity. Additionally, a similar state-state model was used on a subset of data from 1999 to 2018 that used only mark-recapture estimates of escapement (and excluded abundance indices used in the full data set) to determine how optimal values would differ when only considering more recent years and only high quality data. This second analysis is referred to as the ’99 analysis. The state-space model from the full analysis (1980–2018), similar to the catch- age model, estimates *SMSY* to be lower than the current lower bound SEG. The estimated median *SMSY* from the full state-space model is 22,844 fish and 26,951 from the ’99 analysis. Optimal yield profiles indicate an escapement of 22,844 Copper River Chinook salmon has a 64% probability of achieving 90% MSY in the full analysis and a 70% chance of achieving 90% MSY in the ’99 analysis. A 21,000 fish escapement has a 68% and 65% of achieving 90% of MSY in the full and ’99 analysis, respectively, while 31,000 fish has a 73% and 88% probability of achieving 70% of MSY in the full and ’99 analysis, respectively (Figure 2; Joy et al. *unpublished*). **Based on these results the committee recommends an SEG range of 21,000 to 31,000 Chinook salmon, which has a high probability of producing sustainable yields.**

## Coho Salmon

### Bering River

The current SEG (13,000–33,000) for this stock was adopted in 2003 and was developed using the percentile approach of Bue and Hasbrouck (*unpublished*) and peak aerial surveys from 7 index systems. For this review the data set was updated through 2018 and recommendations from Clark et al. (2014) and yield analysis were applied to determine escapements that provide sustained yield (Appendix A2). This stock is high contrast (14.4) with an average harvest rate likely greater than 40% and high measurement error (aerial surveys). A percentile approach is not recommended for stocks with average harvest rates of 0.4 or greater (Clarke et al. 2014).

We calculated yields from complete brood years (1982–2013) and generated Markov yield tables. Yield analysis indicated highest (>100,000) mean yields occur within an aerial escapement index range of 10,000–20,000, and that escapement indices from 5,000 to 25,000 produce average yields greater than 90,000. **Based on these results the committee recommends the Bering River coho salmon SEG be updated to 13,000–25,000.** Because only the upper bound of the goal range is being decreased, the change in this goal should not result in allocative implications to fisheries.

### Copper River Delta

The current SEG (32,000–67,000) for this stock was adopted in 2003 and was developed using the percentile approach of Bue and Hasbrouck (*unpublished*) and peak aerial escapement counts from 17 index systems. For this review the data set was updated through 2018, and an additional index system (Pleasant Creek), which has been flown consistently since 1982, was added. Recommendations from Clark et al. (2014) and yield analysis were applied to determine escapements that provide sustained yield (Appendix A3). This stock is low contrast (4.1) with an average harvest rate likely greater than 40% and high measurement error (aerial surveys). A percentile approach is not recommended for stocks with average harvest rates of 0.4 or greater (Clarke et al. 2014).

We calculated yields from complete brood years (1981–2013) and generated Markov yield tables. Yield analysis indicated highest mean yields (>350,000) occur within an aerial escapement index range of 40,000–50,000, and that escapement indices from 20,000 to 50,000 produce average yields greater than 218,000. **Based on these results the committee recommends the Copper River Delta coho salmon SEG be updated to a range of 32,000–50,000.** Because only the upper bound of the goal range is being decreased, the change in this goal should not result in allocative implications to fisheries.

## Sockeye Salmon

### Bering River

The current SEG (15,000–33,000) for this stock was adopted in 2012 (Fair et al. 2011) and was developed from peak aerial surveys using the percentile approach of Bue and Hasbrouck (*unpublished*). For this review the data set was updated through 2018 and the 3-tier percentile method was applied (Appendix A4). This method was used because the tiers from the Bue and Hasbrouck approach were deemed to provide less optimal proxies for determining the range of escapements around *SMSY* (Clark et al. 2014). This stock is high contrast (12.8), with a moderate average harvest rate (0.27) and high measurement error (aerial surveys), resulting in a tier 1 percentile recommendation (20th and 60th percentiles). **Based on these results the committee recommends the Bering River sockeye salmon SEG be updated to a range of 15,000–24,000.** Because only the upper bound of the goal range is being decreased, the change in this goal should not result in allocative implications to fisheries.

### Coghill Lake

### Methods and History

The current Coghill Lake sockeye salmon SEG was adopted in 2012 after extensive analyses that included comparisons of yield from the Ricker and Beverton-Holt models (Fair et al. 2011). In their analysis, the authors noted the absence of a clear trend in empirical estimates of yield (recruits minus brood-year spawners) across a wide range of spawning escapements. In establishing the new goal it was determined that broadening the SEG range (from the previous range of 20,000–40,000 spawners to a new range of 20,000–60,000 spawners) would allow for greater flexibility by fisheries managers without substantially risking a decrease in yields. It has been suggested that the productivity of Coghill Lake sockeye salmon might be influenced by abiotic factors that include a short ice-free period, cold temperatures, high inorganic turbidity, and meromictic characteristics that can also be disrupted by unpredictable stochastic processes (Edmundson et al. 1992, 1997). However, there was also some evidence of density-dependent effects at high levels of spawning escapement, which resulted in depleted zooplankton abundances for rearing juvenile sockeye salmon (Edmundson et al. 1997; Koenings and Kyle 1997).

For this escapement goal review, we updated escapement and return data through 2019 (Table 3; brood years 1962–2014 used) and reanalyzed the Ricker spawner-recruitment relationship in a Bayesian framework. See Fleischman and Reimer (2017), Fleischman et al. (2013), and Staton et al. (2016) for salmon stock assessments that used similar Bayesian approaches for estimating Ricker model parameter values and informing management reference points.

### Results and Recommendations

As was noted by Fair et al. (2011), measured yield of Coghill Lake wild sockeye salmon has been relatively constant across the entire range of historical escapements, suggesting that a large range of escapements could result in high or low yields (Haught et al. 2017). From our updated Ricker analysis (Figure 3, Table 4), the point estimate of escapement believed to result in maximum yield (*SMSY* of 56,568) was very close to the estimate of 59,000 from Bue et al. 2002 and 59,677 from Fair et al. (2011). Parameter estimates (alpha, beta, sigma) for the Bayesian Ricker model were also similar to those presented in Fair et al. (2011) and the confidence bounds of these parameter estimates were similarly large. Thus, updated spawner and return data since the 2002 and 2011 reviews has not appreciably changed model output or recommendations for *SMSY*. However, of note is that these estimates of SMSY are very close to the upper bound (60,000) of the existing goal.

Even though there is considerable uncertainty surrounding the estimates of *SMSY*, the estimates are robust across analyses and measured yields have remained relatively constant across the range of historical escapements. This suggests a large range of escapements can result in high or low yields. In addition, the yield and overfishing profiles from the latest SRA suggest that similar historical yields can be observed at higher levels of escapement with a much lower probability of overfishing. Increasing the upper bound to 75,000 would result in a ~90% probability of achieving at least 80% of MSY (and a 66% probability of achieving at least 90% of MSY). **Based on these results the committee recommends the Coghill Lake sockeye salmon SEG be updated to 20,000–75,000.** There is some evidence that multiple years of high spawning escapements into Coghill Lake may result in density-dependent effects including depleted zooplankton abundances for rearing juvenile sockeye salmon (Edmundson et al. 1997; Koenings and Kyle 1997) and we therefore suggest that consecutive escapements at the upper end of the goal be avoided. Because only the upper bound of the goal is being increased, the change in this goal should not result in allocative implications to fisheries.

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# TABLES AND FIGURES

Table .– Summary of recommended escapement goals for Prince William Sound Management Area salmon stocks 2020

20

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Current escapement goal | | | |  |  | Recommended escapement goa | | l |
| System | Goal | Type | Year adopted |  | Goal | Type | Data | Action |
| Chinook salmon |  |  |  |  |  |  |  |  |
| Copper River | 24,000 | LB SEG | 2003 |  | 21,000–31,000 | SEG | Mark–recapture | Establish SEG range |
| Coho salmon |  |  |  |  |  |  |  |  |
| Copper River Delta | 32,000–67,000 | SEG | 2003 |  | 32,000-50,000 | SEG | Aerial surveys | Lower the upper bound |
| Bering River | 13,000–33,000 | SEG | 2003 |  | 13,000-25,000 | SEG | Aerial surveys | Lower the upper bound |
| Sockeye salmon |  |  |  |  |  |  |  |  |
| Bering River | 15,000–33,000 | SEG | 2012 |  | 15,000–24,000 |  | Aerial Surveys | Lower the upper bound |
| Coghill Lake | 20,000–60,000 | SEG | 2012 |  | 20,000–75,000 |  | Weir | Raise the upper bound |

Table .–Current escapement goals compared to escapements observed from 2010 through 2019 for Chinook, coho, and sockeye salmon stocks of the Prince William Sound Management Area.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Current Goal** | |  | Initial | Escapement | | | | | | | | | |
| System | Lower | Upper | Type | Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| **KING SALMON** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Prince William Sound* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Copper River | 24,000 |  | LB SEG | 2003 | **16,746** | **27,936** | **27,846** | **29,013** | **20,689** | **26,751** | **12,430** | **33,644** | **42,678** | 35,138 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **CHUM SALMON** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Prince William Sound* a,b |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eastern District | 79,000 |  | LB SEG | 2018 | 140,940 | 237,372 | 94,986 | 146,349 | 90,445 | 104,437 | 116,685 | 76,836 | 109,598 | 56,846 |
| Northern District | 28,000 |  | LB SEG | 2018 | 58,029 | 63,876 | 23,273 | 40,475 | 27,385 | 41,253 | 10,410 | 33,437 | 18,407 | 11,690 |
| Coghill District | 10,000 |  | LB SEG | 2018 | 84,752 | 19,614 | 13,896 | 14,086 | 9,491 | 14,929 | 976 | 13,210 | 13,617 | 3,437 |
| Northwestern District | 7,000 |  | LB SEG | 2018 | 34,131 | 11,951 | 9,360 | 4,995 | 5,041 | 7,060 | 3,954 | 7,118 | 15,563 | 3,258 |
| Southeastern District | 11,000 |  | LB SEG | 2018 | 80,927 | 107,857 | 28,374 | 33,678 | 29,362 | 44,095 | 13,919 | 26,330 | 10,164 | 19,451 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **COHO SALMON** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Prince William Sound* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Copper River Delta | 32,000 | 67,000 | SEG | 2003 | **40,377** | **38,145** | **36,735** | **34,630** | **44,040** | **42,065** | **76,200** | **43,760** | **53,800** | 36,420 |
| Bering River | 13,000 | 33,000 | SEG | 2003 | 21,311 | 18,890 | 15,605 | 18,820 | 26,475 | 15,550 | 26,150 | 30,650 | 26,525 | 10,015 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **PINK SALMON** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Prince William Sound* a,c |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eastern District (even year) | 203,000 | 328,000 | SEG | 2018 |  |  | 268,432 |  | 250,381 |  | 594,778 |  | 309,325 |  |
| Eastern District (odd year) | 346,000 | 863,000 | SEG | 2018 |  |  |  | 1,266,630 |  | 1,440,254 |  | 557,545 |  | 445,075 |
| Northern District (even year) | 96,000 | 127,000 | SEG | 2018 |  |  | 91,187 |  | 95,134 |  | 133,460 |  | 111,174 |  |
| Northern District (odd year) | 111,000 | 208,000 | SEG | 2018 |  |  |  | 299,054 |  | 708,920 |  | 395,437 |  | 195,169 |
| Coghill District (even year) | 37,000 | 110,000 | SEG | 2018 |  |  | 170,752 |  | 60,921 |  | 63,986 |  | 70,881 |  |
| Coghill District (odd year) | 54,000 | 233,000 | SEG | 2018 |  |  |  | 625,991 |  | 775,488 |  | 181,153 |  | 153,129 |
| Northwestern District (even year) | 52,000 | 93,000 | SEG | 2018 |  |  | 114,518 |  | 66,350 |  | 168,272 |  | 111,194 |  |
| Northwestern District (odd year) | 64,000 | 144,000 | SEG | 2018 |  |  |  | 201,836 |  | 438,944 |  | 250,989 |  | 91,267 |
| Eshamy District (even year) | 1,000 | 4,000 | SEG | 2018 |  |  | 1,052 |  | 12,167 |  | NAd |  | 16,594 |  |
| Eshamy District (odd year) | 5,000 | 31,000 | SEG | 2018 |  |  |  | 12,145 |  | 68,988 |  | 2,836 |  | 1,402 |
| Southwestern District (even year) | 62,000 | 105,000 | SEG | 2018 |  |  | 79,774 |  | 73,104 |  | NAd |  | 81,100 |  |
| Southwestern District (odd year) | 112,000 | 231,000 | SEG | 2018 |  |  |  | 337,952 |  | 644,158 |  | 172,930 |  | 33,340 |
| Montague District (even year) | 36,000 | 72,000 | SEG | 2018 |  |  | 70,695 |  | 23,136 |  | NAd |  | 135,208 |  |
| Montague District (odd year) | 143,000 | 330,000 | SEG | 2018 |  |  |  | 365,807 |  | 559,994 |  | 205,252 |  | 25,385 |
| Southeastern District (even year) | 88,000 | 153,000 | SEG | 2018 |  |  | 213,071 |  | 141,845 |  | 107,769 |  | 293,275 |  |
| Southeastern District (odd year) | 286,000 | 515,000 | SEG | 2018 |  |  |  | 1,137,736 |  | 1,529,543 |  | 372,960 |  | 290,452 |

Table 2. Page 2 of 2.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SOCKEYE SALMON** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Prince William Sound* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Upper Copper River | 360,000 | 750,000 | SEG | 2012 | **502,445** | **607,140** | **954,010** | **860,253** | **864,169** | **930,145** | **513,143** | **460,295** | **495,779** | 719,526 |
| Copper River Delta | 55,000 | 130,000 | SEG | 2003 | **83,905** | 72,367 | 66,850 | 75,705 | 64,205 | **66,665** | 51,550 | **56,950** | 58,470 | 61,825 |
| Bering River | 15,000 | 33,000 | SEG | 2012 | 4,367 | 28,530 | 18,290 | 23,900 | **14,885** | **22,705** | **16,390** | 19,115 | 13,300 | 17,630 |
| Coghill Lake | 20,000 | 60,000 | SEG | 2012 | 24,312 | 102,359 | **74,978** | 17,231 | 21,836 | 13,684 | 8,708 | **50,462** | 62,295 | 32,247 |
| Eshamy Lake e | 13,000 | 28,000 | BEG | 2009 | 16,291 | 24,129 | NA | NA | NA | NA | NA | NA | NA | NA |
| *Notes*: NA = data not available; NC = no count; NS = no survey; LB SEG = lower-bound SEG. | | | | | | | | |  |  |  |  |  |  |  |  |
| Bold highlights indicate changes due to harvest updates since the previous escapement goal review cycle; gray shadings were below the lower bound of the escapement goal. | | | | | | | | | | | | | | | |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| a All PWS chum and pink salmon goals were revised in 2017 using a different index approach than previously used. Escapement values presented here use the new index based on a reduced set of survey streams. Values prior to 2018 should not be read relative to the previous goal. | | | | | | | | | | | | | | |  |  |
| b No estimates for chum salmon escapements are included for the Unakwik, Eshamy, Southwestern, or Montague districts because there are no escapement goals for those districts. | | | | | | | | | | | | | | | | |
| c The estimates for pink salmon (odd year) do not include Unakwik District escapements, due to absence of an escapement goal and an average escapement estimate of a few thousand fish. | | | | | | | | | | | | | | | | |
| d Fewer than 3 surveys were flown for almost all the index streams in the Eshamy, Southwestern, and Montague districts in 2016, so they were not used in calculating the area under the curve index. | | | | | | | | | | | | | | | | |
| e Eshamy River weir was not operated in 2012-2019. A pilot project to assess the use of video for monitoring in 2013–2016 did not provide a comparable total escapement estimate. | | | | | | | | | | | | | | |  |  |

Table .–Total recruits of Coghill Lake sockeye salmon by age class that originated from brood years 1962 to 2016.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age at return in years | | | | | | | | | |
|  | 3 | | 4 | 5 | 5 | 6 |  |  |  |
| Brood year | Escapement | 1.1 | 1.2 | 1.3 | 2.2 | 2.3 | BY recruitsa | R/S | Yield b |
| 1962 b | 26,866 | 0 | 17,815 | 34,021 | 2,195 | 489 | 54,520 | 2.03 | 27,654 |
| 1963 b | 63,984 | 159 | 4,391 | 53,756 | 318 | 5,325 | 63,949 | 1 | (35) |
| 1964 b | 22,200 | 0 | 32,538 | 124,343 | 4,154 | 2,095 | 163,130 | 7.35 | 140,930 |
| 1965 b | 62,500 | 224 | 25,199 | 48,915 | 1,634 | 1,694 | 77,666 | 1.24 | 15,166 |
| 1966 b | 82,500 | 267 | 9,913 | 54,766 | 303 | 20,909 | 86,158 | 1.04 | 3,658 |
| 1967 b | 33,000 | 0 | 3,751 | 140,138 | 1,396 | 8,047 | 153,332 | 4.65 | 120,332 |
| 1968 b | 11,800 | 0 | 22,526 | 108,120 | 3,219 | 3,643 | 137,508 | 11.65 | 125,708 |
| 1969 b | 81,000 | 0 | 12,896 | 60,811 | 7,908 | 10,133 | 91,748 | 1.13 | 10,748 |
| 1970 b | 35,200 | 0 | 49,280 | 158,164 | 8,803 | 4,619 | 220,866 | 6.27 | 185,666 |
| 1971 b | 15,000 | 115 | 5,604 | 32,566 | 2,782 | 5,661 | 46,728 | 3.12 | 31,728 |
| 1972 b | 51,000 | 0 | 29,452 | 164,079 | 6,691 | 18,346 | 218,568 | 4.29 | 167,568 |
| 1973 b | 55,000 | 0 | 25,454 | 203,097 | 3,332 | 1,805 | 233,688 | 4.25 | 178,688 |
| 1974 | 22,334 | 455 | 21,031 | 76,250 | 10,499 | 2,590 | 110,825 | 4.96 | 88,491 |
| 1975 | 34,855 | 0 | 38,347 | 136,670 | 7,713 | 8,799 | 191,528 | 5.5 | 156,673 |
| 1976 | 9,056 | 90 | 52,434 | 99,913 | 12,717 | 8,377 | 173,531 | 19.16 | 164,475 |
| 1977 | 31,562 | 1,981 | 137,083 | 1,108,256 | 1,773 | 1,956 | 1,251,048 | 39.64 | 1,219,486 |
| 1978 | 42,284 | 656 | 8,799 | 51,329 | 2,139 | 7,381 | 70,303 | 1.66 | 28,019 |
| 1979 | 48,281 | 270 | 17,439 | 105,297 | 6,351 | 21,049 | 150,407 | 3.12 | 102,126 |
| 1980 | 142,253 | 162 | 37,780 | 344,020 | 51,572 | 40,122 | 473,656 | 3.33 | 331,403 |
| 1981 | 156,112 | 436 | 92,478 | 355,917 | 14,590 | 32,817 | 496,238 | 3.18 | 340,126 |
| 1982 | 180,314 | 155 | 58,604 | 546,985 | 5,829 | 586 | 612,159 | 3.39 | 431,845 |
| 1983 | 38,783 | 71 | 11,755 | 86,810 | 448 | 7,213 | 106,297 | 2.74 | 67,514 |
| 1984 | 63,622 | 1,347 | 64,775 | 133,744 | 2,112 | 1,108 | 203,086 | 3.19 | 139,464 |
| 1985 | 163,342 | 31 | 1,682 | 12,951 | 1,170 | 764 | 16,598 | 0.1 | (146,744) |
| 1986 | 74,135 | 34 | 4,372 | 17,266 | 83 | 5,164 | 26,918 | 0.36 | (47,217) |
| 1987 | 187,263 | 20 | 2,169 | 53,697 | 1,419 | 2,749 | 60,053 | 0.32 | (127,210) |
| 1988 | 72,023 | 21 | 6,913 | 41,717 | 1,246 | 598 | 50,495 | 0.7 | (21,528) |
| 1989 | 36,881 | 11 | 2,596 | 4,662 | 406 | 1,735 | 9,410 | 0.26 | (27,471) |

-continued-

Table 3.–Page 2 of 2.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age at return in years | | | | | | | | | |
|  | 3 | | 4 | 5 | 5 | 6 |  |  |  |
| Brood year | Escapement | 1.1 | 1.2 | 1.3 | 2.2 | 2.3 | BY recruitsa | R/S | Yield b |
| 1990 | 8,250 | 49 | 3,519 | 19,808 | 1,018 | 1,733 | 26,127 | 3.17 | 17,877 |
| 1991 | 9,701 | 106 | 38,575 | 113,543 | 942 | 643 | 153,809 | 15.85 | 144,108 |
| 1992 | 29,642 | 160 | 14,841 | 97,317 | 321,531 | 1,488 | 114,127 | 3.85 | 84,485 |
| 1993 | 9,232 | 122 | 8,467 | 58,365 | 230 | 282 | 67,466 | 7.31 | 58,234 |
| 1994 | 7,264 | 0 | 2,313 | 9,645 | 3,999 | 11,982 | 27,939 | 3.85 | 20,675 |
| 1995 | 30,382 | 974 | 133,941 | 177,124 | 2,379 | 3,090 | 317,508 | 10.45 | 287,126 |
| 1996 | 38,693 | 244 | 22,428 | 108,519 | 1,697 | 583 | 133,471 | 3.45 | 94,778 |
| 1997 | 35,010 | 4 | 12,566 | 30,255 | 318 | 1,593 | 44,736 | 1.28 | 9,726 |
| 1998 | 27,050 | 154 | 21,013 | 67,785 | 347 | 191 | 89,490 | 3.31 | 62,440 |
| 1999 | 59,311 | 419 | 99,869 | 132,588 | 1,337 | 592 | 234,805 | 3.96 | 175,494 |
| 2000 | 28,446 | 419 | 55,977 | 81,462 | 126 | 422 | 138,406 | 4.87 | 109,960 |
| 2001 | 38,547 | 382 | 1,473 | 4,192 | 711 | 3,713 | 10,471 | 0.27 | (28,076) |
| 2002 | 28,323 | 30 | 27,264 | 149,002 | 1,047 | 2,989 | 180,332 | 6.37 | 152,009 |
| 2003 | 75,427 | 281 | 29,262 | 66,271 | 3,193 | 1,762 | 100,769 | 1.34 | 25,342 |
| 2004 | 30,569 | 1 | 45,985 | 105,257 | 514 | 195 | 151,952 | 4.97 | 121,383 |
| 2005 | 30,313 | 508 | 2,810 | 6,835 | 13,516 | 6,280 | 29,949 | 0.99 | (364) |
| 2006 | 23,479 | 2,697 | 37,325 | 122,276 | 552 | 3,802 | 166,652 | 7.10 | 143,173 |
| 2007 | 70,001 | 3,117 | 104,874 | 535,148 | 2,851 | 3,052 | 649,042 | 9.27 | 579,041 |
| 2008 | 29,298 | 40 | 30,185 | 40,675 | 838 | 46 | 71,784 | 2.45 | 42,486 |
| 2009 | 23,186 | 1,952 | 35,330 | 83,113 | 509 | 60 | 120,964 | 5.22 | 97,778 |
| 2010 | 24,312 | 49 | 20,985 | 64,145 | 1595 | 0 | 86,774 | 3.57 | 62,462 |
| 2011c | 102,359 | 199 | 17,183 | 23,706 | 0 | 313 | 41,401 | 0.40 | (60,958) |
| 2012 c | 74,978 | 10 | 8,544 | 38,654 | 390 | 0 | 47,598 | 0.63 | (27,380) |
| 2013 c | 17,231 | 963 | 44,975 | 26,430 | 4315 | 1,746 | 78,429 | 4.55 | 61,198 |
| 2014 c | 21,836 | 7,473 | 206,588 | 334,798 | 1,011 |  |  |  |  |
| 2015 c | 13,684 | 0 | 15,394 |  |  |  |  |  |  |
| 2016 c | 8,708 | 11,427 |  |  |  |  |  |  |  |
| 2017 | 50,462 |  |  |  |  |  |  |  |  |
| 2018 | 62,295 |  |  |  |  |  |  |  |  |
| 2019 | 32,247 |  |  |  |  |  |  |  |  |

*Note*: Recruits include fish from commercial, sport harvests, and escapements. Current goal is a sustainable escapement goal (SEG) of 20,000–60,000 sockeye salmon and no change to the goal is recommended. BY = brood year, R/S = return per spawner.

a Total return was calculated as Coghill Lake weir escapement plus total Coghill District Common Property Fishery harvest wild contributions plus sockeye salmon harvested in the Eshamy and Southwestern districts prior to the timing of Eshamy Lake wild sockeye salmon.

b A partial weir and tower were used to enumerate sockeye salmon escapement into Coghill Lake.

c Complete return data not yet available to calculate BY total return, R/S, or yield.

Table .–A comparison of Ricker stock-recruitment model estimates from Fair et al. (2011) and the current analysis that used spawner and recruitment data for Coghill Lake sockeye salmon from brood years 1962–2014.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Current analysis | | |  | Fair et al. 2011 | |  | |
|  | 2.50% | Median | 97.50% | L80 | Point | | U80 |
| ln α | 1.21 | 1.75 | 2.29 | 1.37 | 1.67 | | 1.95 |
| β | 6.80-06 | 1.39E-05 | 2.08-05 | 8.20E-06 | 1.30E-05 | | 1.70E-05 |
| σ | 0.88 | 1.05 | 1.31 | 0.86 | 1.04 | | 1.16 |
| SEQ | 123,587 | 170,042 | 315,477 | 138,427 | 172,917 | | 242,315 |
| *SMSY* | 40,042 | 56,364 | 107,101 | 46,366 | 59,677 | | 86,485 |
| *UMSY* | 0.68 | 0.79 | 0.87 | 0.69 | 0.76 | | 0.81 |
| MSY | 128,019 | 222,006 | 494,633 | 144,379 | 194,477 | | 260,127 |

*Note*: Fair et al. used data from brood years 1962–2005 and shows lower and upper 80% prediction intervals, and the current analysis shows 2.5% and 97.5% Bayesian credible intervals.

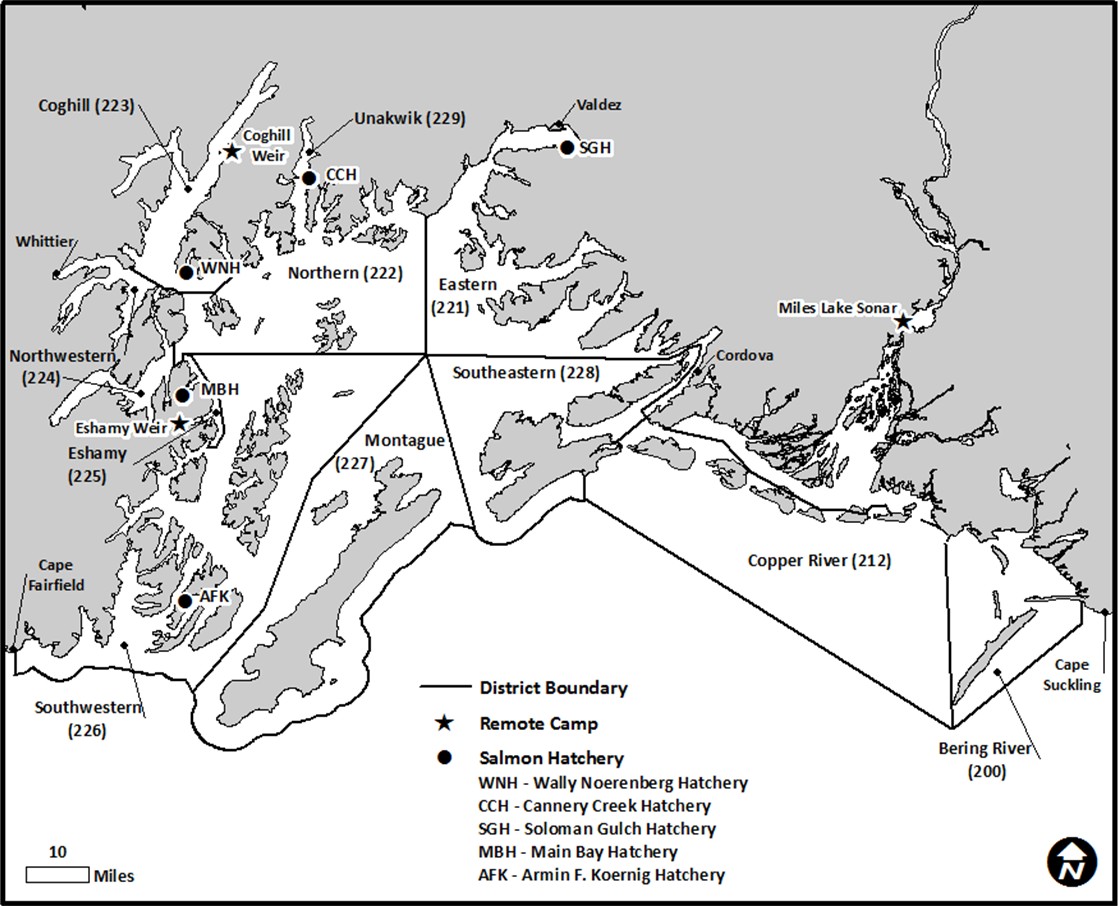


Figure .–Prince William Sound Management Area showing commercial fishing districts, salmon hatcheries, weir locations, and Miles Lake sonar camp.

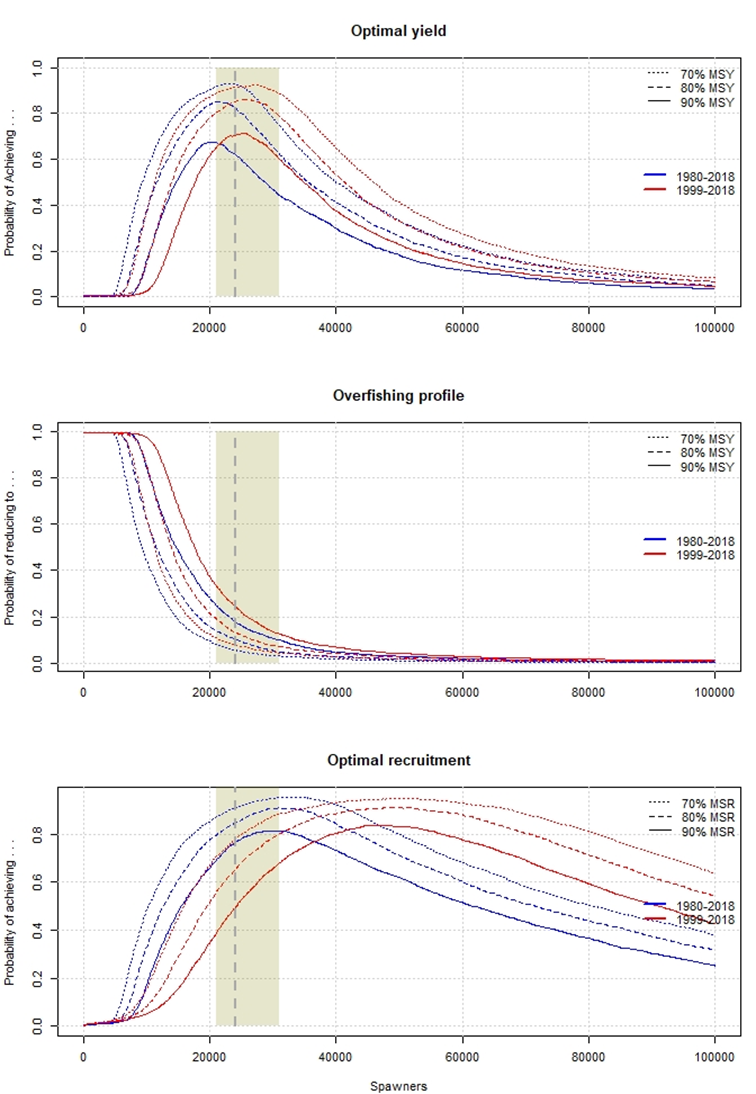


Figure – Optimal yield profiles (OYPs), overfishing profiles (OFPs), and optimal recruitment profiles (ORPs) for Copper RiverChinook salmon as derived from an age-structured state-space model fitted to abundance, harvest, and age data for 1980–2018 (blue) and 1999–2018 (red).

*Note*: OYPs and ORPs show probability that a specified spawning abundance will result in specified fractions (70%, 80%, and 90% line) of maximum sustained yield or maximum recruitment. OFPs show probability that reducing escapement to a specified spawning abundance will result in less than specified fractions of maximum sustained yield. Shaded areas bracket the recommended goal ranges; grey and black marks along the *x*-axis show comparable lower and upper bounds for other Alaskan Chinook salmon stocks scaled by *SMSY* ratios (see Savereide et al. 2018).

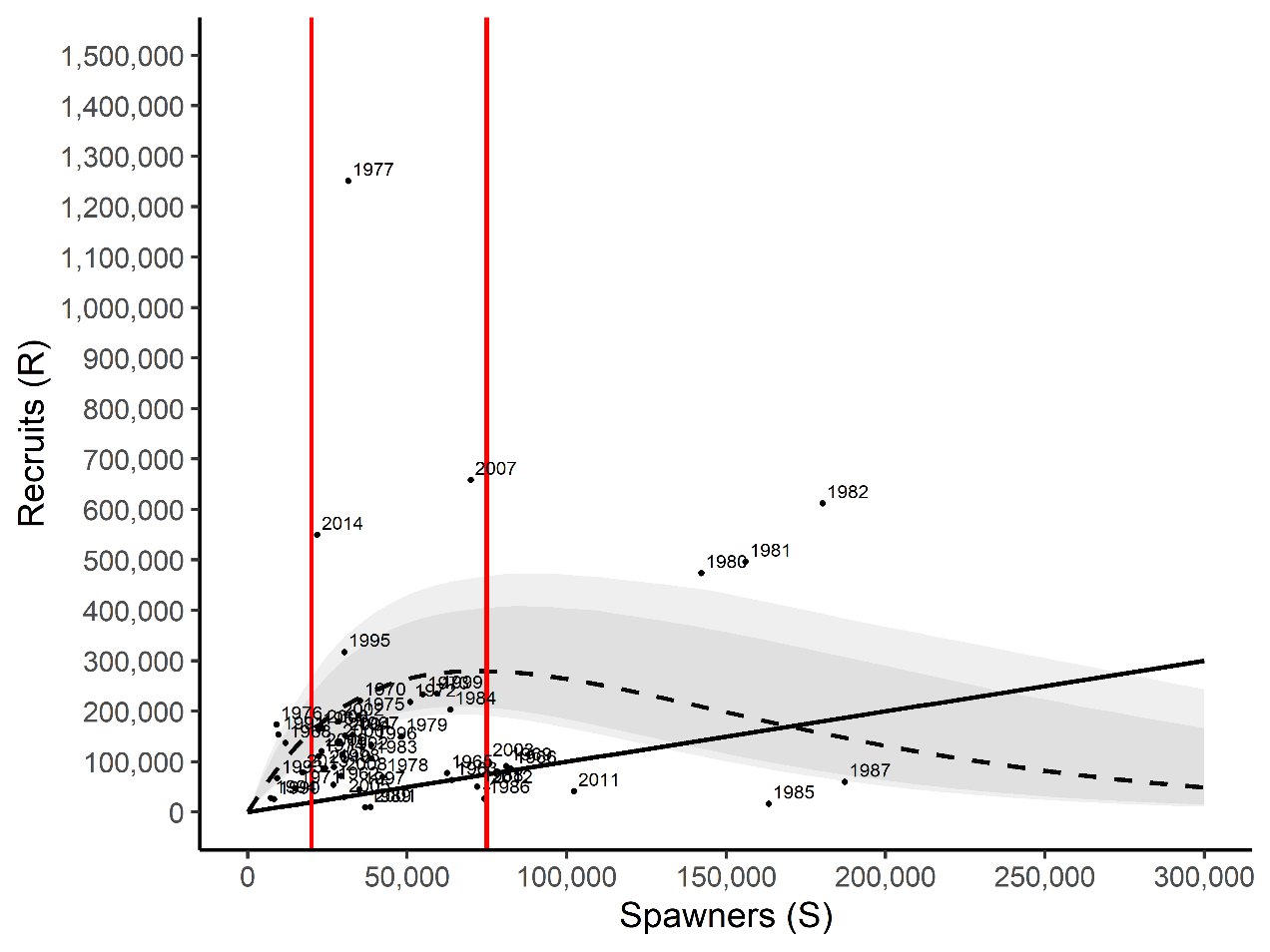


Figure .–Plausible spawner-recruit relationships for Coghill Lake sockeye salmon as derived from a Bayesian stock-recruit analysis for brood years 1962–2014.

*Note*: Posterior medians of *R* and *S* are plotted as brood year labels. The heavy dashed line is the Ricker relationship constructed from ln(*α*) and *β* posterior medians with 90% and 95% credibility intervals (shaded areas). Recruits equal spawners on the solid diagonal “replacement” line. The 2 vertical lines show the current SEG range of 20,000–75,000 spawners.

# APPENDIX A: SUPPORTING INFORMATION FOR ESCAPEMENT GOALS FOR SALMON STOCKS IN THE COPPER RIVER, BERING RIVER, AND PRINCE WILLIAM SOUND AREAS

Appendix A .–Supporting information for analysis of the escapement goal for Copper River Chinook salmon.

|  |  |  |
| --- | --- | --- |
| System: Copper River | | |
| Species: Chinook salmon | | |
| Data available for analysis of escapement goals. | | |
| Brood | Measured | Total |
| year | a  escapement | run |
| 1999 | 16,157 | 95,951 |
| 2000 | 24,492 | 70,754 |
| 2001 | 28,208 | 81,139 |
| 2002 | 21,354 | 72,974 |
| 2003 | 33,919 | 94,555 |
| 2004 | 30,473 | 80,566 |
| 2005 | 21,556 | 66,357 |
| 2006 | 58,425 | 99,877 |
| 2007 | 34,562 | 87,771 |
| 2008 | 32,453 | 53,893 |
| 2009 | 27,749 | 43,007 |
| 2010 | 16,746 | 33,184 |
| 2011 | 27,936 | 53,890 |
| 2012 | 27,846 | 44,313 |
| 2013 | 29,013 | 42,902 |
| 2014 | 20,689 | 35,322 |
| 2015 | 26,751 | 56,187 |
| 2016 | 12,430 | 29,295 |
| 2017 | 33,644 | 56,167 |
| 2018 | 42,678 | 61,631 |

*Note*: Current goal is a lower-bound sustainable escapement goal (SEG) of >24,000 Chinook salmon and a change to a SEG range of 21,000–31,000 is recommended.

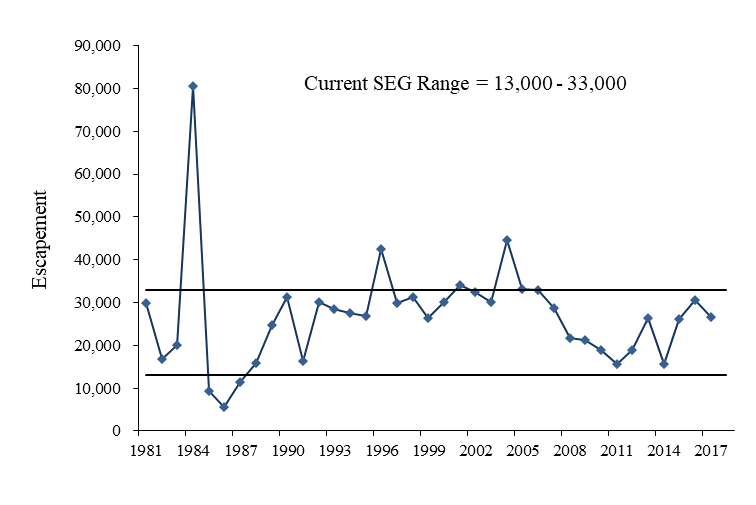
a Estimated by mark–recapture minus upriver harvests.

Appendix A .–Supporting information for analysis of the escapement goal for Bering River District coho salmon.

|  |  |  |  |
| --- | --- | --- | --- |
| **District: Bering River Delta** | |  |  |
| **Species: coho salmon** | |  |  |
| **Data available for analysis of escapement goals.** | | | |
| Return | Wild |  | Commercial |
| Year | Escapement a |  | Harvest b |
| 1982 | 30,000 |  | 144,752 |
| 1983 | 16,700 |  | 117,669 |
| 1984 | 20,000 |  | 214,632 |
| 1985 | 80,500 |  | 419,276 |
| 1986 | 9,420 |  | 115,809 |
| 1987 | 5,585 |  | 15,864 |
| 1988 | 11,415 |  | 86,539 |
| 1989 | 15,820 |  | 26,952 |
| 1990 | 24,800 |  | 42,952 |
| 1991 | 31,300 |  | 110,951 |
| 1992 | 16,300 |  | 125,616 |
| 1993 | 30,050 |  | 115,833 |
| 1994 | 28,550 |  | 259,003 |
| 1995 | 27,450 |  | 282,045 |
| 1996 | 26,800 |  | 93,763 |
| 1997 | 42,400 |  | 97 |
| 1998 | 29,800 |  | 12,284 |
| 1999 | 31,290 |  | 9,852 |
| 2000 | 26,380 |  | 56,329 |
| 2001 | 30,007 |  | 2,715 |
| 2002 | 34,200 |  | 108,522 |
| 2003 | 32,475 |  | 59,481 |
| 2004 | 30,185 |  | 95,595 |
| 2005 | 44,542 |  | 43,030 |
| 2006 | 33,192 |  | 56,713 |
| 2007 | 32,962 |  | 9,305 |
| 2008 | 28,822 |  | 40,380 |
| 2009 | 21,760 |  | 45,522 |
| 2010 | 21,311 |  | 80,560 |
| 2011 | 18,890 |  | 19,956 |
| 2012 | 15,605 |  | 46,169 |
| 2013 | 18,820 |  | 46,959 |
| 2014 | 26,475 |  | 97,637 |
| 2015 | 15,550 |  | 12,106 |
| 2016 | 26,150 |  | 80,094 |
| 2017 | 30,650 |  | 119,090 |
| 2018 | 26,525 |  | 120,774 |
| a Escapement indices calculated as peak aerial survey from the 18 primary index systems. | | | |
| b Copper River District harvest, not stock specific. | | | |
|  | | | |
|  | | | |
|  | | | |

Appendix A2.–Page 2 of 2.

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| --- |
|  |



Appendix A .–Supporting information for analysis of the escapement goal for Copper River Delta coho salmon.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| District: Copper River Delta | |  |  |  |
| Species: coho salmon | |  |  |  |
| Data available for analysis of escapement goals. | | | |  |
| Return | Wild |  | Harvest |  |
| Year | Escapement a |  | Commercial b | Sport c |
| 1981 | 44,800 |  | 310,154 | 0 |
| 1982 | 40,575 |  | 454,763 | 398 |
| 1983 | 60,050 |  | 234,243 | 84 |
| 1984 | 64,525 |  | 382,432 | 1,780 |
| 1985 | 106,410 |  | 587,990 | 649 |
| 1986 | 25,790 |  | 295,980 | 2,969 |
| 1987 | 26,465 |  | 111,599 | 1,010 |
| 1988 | 26,560 |  | 315,568 | 1,492 |
| 1989 | 40,856 |  | 194,454 | 2,118 |
| 1990 | 41,281 |  | 246,797 | 1,778 |
| 1991 | 63,656 |  | 385,086 | 1,941 |
| 1992 | 44,013 |  | 291,627 | 3,854 |
| 1993 | 31,870 |  | 281,469 | 4,139 |
| 1994 | 43,955 |  | 677,633 | 4,293 |
| 1995 | 34,480 |  | 542,658 | 2,543 |
| 1996 | 46,110 |  | 193,042 | 6,364 |
| 1997 | 55,360 |  | 18,656 | 2,825 |
| 1998 | 42,200 |  | 108,232 | 4,230 |
| 1999 | 43,725 |  | 153,061 | 6,978 |
| 2000 | 42,830 |  | 304,944 | 4,479 |
| 2001 | 40,496 |  | 251,473 | 12,144 |
| 2002 | 87,415 |  | 504,223 | 6,909 |
| 2003 | 72,055 |  | 363,489 | 14,443 |
| 2004 | 99,505 |  | 467,859 | 14,643 |
| 2005 | 99,682 |  | 263,465 | 9,799 |
| 2006 | 89,070 |  | 318,285 | 5,531 |
| 2007 | 51,215 |  | 117,182 | 6,749 |
| 2008 | 74,772 |  | 202,621 | 7,763 |
| 2009 | 40,124 |  | 207,776 | 14,420 |
| 2010 | 40,377 |  | 210,621 | 15,866 |
| 2011 | 38,145 |  | 127,511 | 14,304 |
| 2012 | 36,735 |  | 130,261 | 15,230 |
| 2013 | 34,630 |  | 244,985 | 17,053 |
| 2014 | 44,040 |  | 315,776 | 16,226 |
| 2015 | 42,065 |  | 136,981 | 24,515 |
| 2016 | 76,200 |  | 367,630 | 13,094 |
| 2017 | 43,760 |  | 306,287 | 9,582 |
| 2018 | 53,800 |  | 303,957 | 12,117 |

a Escapement indices calculated as peak aerial survey from the 18 primary index systems.

b Copper River District harvest, not stock specific.

c From statewide harvest survey. The sport harvest includes both upriver and Copper River Delta harvests.

-continued-

Appendix A3.**–**Page 2 of 2.

|  |
| --- |
| District: Copper River Delta |
| Species: coho salmon |
| Observed escapement by year (blocked line) and current SEG range (solid line). |

Appendix A .–Supporting information for analysis of the escapement goal for Bering River District sockeye salmon.

|  |  |  |
| --- | --- | --- |
| System: | Bering River District | |
| Species: | sockeye salmon | |
| Data available for analysis of escapement goals. | | |
|  |  |  |
| Brood | Wild | Commercial |
| Year | Escapement a | Harvest b |
| 1988 | 13,680 | 7,152 |
| 1989 | 23,300 | 9,225 |
| 1990 | 19,741 | 8,332 |
| 1991 | 32,220 | 19,181 |
| 1992 | 55,895 | 19,721 |
| 1993 | 27,725 | 33,951 |
| 1994 | 26,550 | 27,926 |
| 1995 | 33,450 | 21,585 |
| 1996 | 27,310 | 37,712 |
| 1997 | 15,065 | 9,651 |
| 1998 | 23,450 | 8,439 |
| 1999 | 46,195 | 13,697 |
| 2000 | 24,220 | 1,279 |
| 2001 | 8,823 | 5,450 |
| 2002 | 24,715 | 235 |
| 2003 | 49,840 | 18,266 |
| 2004 | 25,135 | 13,165 |
| 2005 | 30,890 | 77,465 |
| 2006 | 14,671 | 36,867 |
| 2007 | 21,170 | 16,470 |
| 2008 | 18,196 | 1,175 |
| 2009 | 13,471 | 4,157 |
| 2010 | 4,367 | 51 |
| 2011 | 28,530 | 6 |
| 2012 | 18,290 | 0 |
| 2013 | 23,900 | 3,321 |
| 2014 | 14,885 | 50 |
| 2015 | 22,705 | 2,137 |
| 2016 | 16,390 | 9,840 |
| 2017 | 19,115 | 2,578 |
| 2018 | 13,300 | 33 |

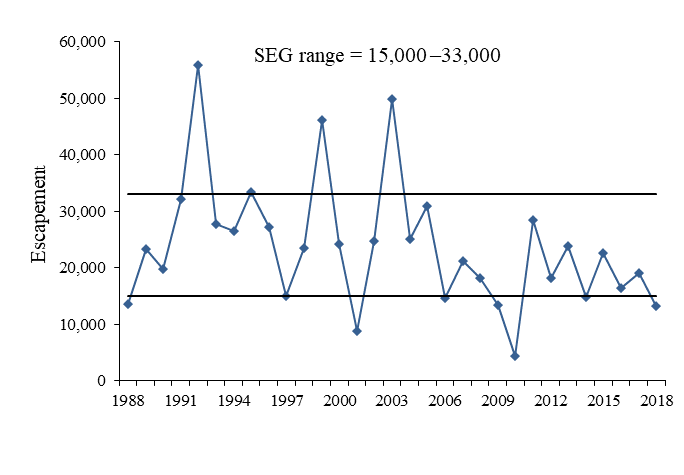
a Escapement indices calculated as the sum of peak aerial index counts from 6 primary index systems

b Bering River District harvest, not stock specific.

-continued-

Appendix A4.**–**Page 2 of 2.

|  |  |
| --- | --- |
| System: | Bering River |
| Species: | sockeye salmon |
| Observed escapement by year (blocked line) and current SEG range (solid line). | |



Appendix A .– Links to repositories of code used in analysis of escapement goals for Coghill Lake sockeye salmon.

<https://github.com/commfish/Coghill_sockeye>