Fishery Manuscript No. 17-10

Escapement Goal Review of Copper and Bering Rivers, and Prince William Sound Pacific Salmon Stocks, 2017

by

Stormy B. Haught

Richard E. Brenner

Jack W. Erickson

James W. Savereide

and

Timothy R. McKinley

November 2017

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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	ft^3/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 (negative log of)	pH
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)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, 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)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
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

FISHERY MANUSCRIPT NO. 17-10

ESCAPEMENT GOAL REVIEW OF COPPER AND BERING RIVERS, AND PRINCE WILLIAM SOUND PACIFIC SALMON STOCKS, 2017

by
Stormy B. Haught
Alaska Department of Fish and Game, Division of Commercial Fisheries, Cordova

Richard E. Brenner
Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau

Jack W. Erickson,
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

James W. Savereide
Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks

and
Timothy R. McKinley
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

November 2017

The Fishery Manuscript Series was established in 1987 by the Division of Sport Fish for the publication of technically oriented results of several years' work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. Fishery Manuscripts are intended for fishery and other technical professionals. Fishery Manuscripts are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Stormy B. Haught
Alaska Department of Fish and Game, Division of Commercial Fisheries,
401 Railroad Avenue, Cordova, AK 99574, USA

Richard E. Brenner
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1255 W. 8th Street, Juneau, AK 99802, USA

Jack W. Erickson
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, AK 99518, USA

James W. Savereide
Alaska Department of Fish and Game, Division of Sport Fish,
1300 College Road, Fairbanks AK, 99701, USA

and

Timothy R. McKinley
Alaska Department of Fish and Game, Division of Sport Fish
333 Raspberry Road, Anchorage, AK 99518, USA

This document should be cited as follows:
Haught, S. B., R. E. Brenner, J. W. Erickson, J. W. Savereide, and T. R. McKinley. 2017. Escapement goal review of Copper and Bering rivers, and Prince William Sound Pacific salmon stocks, 2017. Alaska Department of Fish and Game, Fishery Manuscript No. 17-10, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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. The escapement goal committee also reviewed escapement data for Gulkana River Chinook salmon, but decided not to consider establishing an escapement goal until a sufficient time series of data are available to better understand how well the current tower count project indexes escapement. 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 all Chinook, chum, and pink salmon escapement goals be updated. The escapement goal committee recommends no modifications be made to the existing coho and sockeye 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 that are 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 eighth 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 (2014–2016) 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 January 25, 2017. 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 April 26 and again on August 28 to review stock assessments and prepare escapement goal recommendations for the PWSMA and UCUSMA meeting in December 2017.

This report describes PWSMA and UCUSMA salmon escapement goals reviewed in 2017 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 2017 review process, the committee evaluated escapement goals (or potential goals) for various Chinook *Oncorhynchus tshawytscha*, chum *O. keta*, coho *O. kisutch*, pink *O. gorbuscha*, and sockeye *O. nerka* salmon stocks:

- Chinook salmon: Copper and Gulkana rivers;
- Chum salmon: Coghill, Eastern, Northern, Northwestern, and Southeastern districts;
- Coho salmon: Bering River and Copper River Delta;
- Pink salmon: Eastern, Northern, Coghill, Northwestern, Eshamy, Southwestern, Montague, and Southeastern (even-year and odd-year broodlines); and
- Sockeye salmon: Upper Copper River, Copper River Delta, Bering River, Coghill Lake, and Eshamy Lake.

OBJECTIVES

Objectives of the 2017 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 2014 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 (Savereide et al. *unpublished*[1]) 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.

Chum salmon escapement estimates were based on expanded counts from aerial surveys that have been conducted since 1963. Streams within each district were flown multiple times each year and escapement was estimated using area-under-the-curve (AUC) calculations adjusted with an estimate of stream life (12.6 days; Fried et al. 1998). Due to the lack of complete marking of hatchery fish, reliable estimates of hatchery contributions to commercial harvests of chum salmon are unavailable for 1986–2003. Instead, harvest estimates of wild chum salmon from that period rely on average harvests of wild chum salmon from 1970 to 1985. Since 2004, hatchery released chum salmon have been thermal-marked for identification. Due to the interception of wild chum bound for other districts, there are no reliable estimates of district of origin for wild stock chum salmon in the commercial harvest data.

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.

Since 1960, ADF&G has conducted aerial surveys of select pink salmon streams to index the spawning escapement in PWS. There are approximately 1,000 pink salmon spawning systems in PWSMA; historically, more than 200 streams have been surveyed annually. Between 1960 and 1989, an average of 266 streams were surveyed (range = 203 to 489). The 208 streams surveyed during 1989 represented approximately 20–25% of the anadromous streams in each district and 75–85% of the total spawning escapement (Fried 1994; Fried et al. 1998). Beginning in 1990, additional streams were surveyed in some districts to make the proportion flown similar to other districts and the survey total was updated to approximately 214 streams. However, due to recent budget reductions, in 2015 the number of streams surveyed was reduced to 134 streams. Indices of spawning escapement are estimated using area-under-the-curve methodology and appropriate stream-life values (Bue et al. 1998; Fried et al. 1998). Hatchery-produced pink salmon have been returning to PWS since 1977 (Pirtle 1979). Hatchery pink salmon returns have been estimated using wild stock exploitation rates (1977–1986) or mark–recapture methods that employed either coded wire tags or otolith thermal marks (1987–present; Brady et al. 1987; Joyce and Riffe 1998). Although studies have shown hatchery salmon strays throughout PWS, including some streams with high proportions of hatchery pink salmon (Brenner et al. 2012; Joyce and Evans 1999), these hatchery fish have not been accounted for in estimates of wild pink salmon escapement. Finally, because there are no methods to allocate commercial harvests to stream or

---

[1] 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 Savereide et al. *unpublished*.

district of origin, productivity and harvest rate have only been estimated for all of PWS and not for individual districts.

The inriver abundance of salmon in the Upper Copper River (UCR) has been monitored at Miles Lake since 1978 using sonar. Beginning in 2005 on the south bank, after a period of comparison, the Bendix side-scan sonar was replaced with dual-frequency identification sonar (DIDSON); this same replacement occurred in 2008 on the north bank (Maxwell et al. 2011). However, even with a reliable measure of inriver abundance, the contribution of the upriver stock to the commercial fishery is not known. Studies in the 1980s based on inherent differences in scale patterns attempted to estimate harvests by stock (UCR vs. CRD vs. Bering River stocks); however, these studies were discontinued because of imprecision in estimates (Marshall et al. 1987). 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 of sockeye salmon into Eshamy Lake has been visually counted through a weir since 1931 (Pirtle 1981), but reliable age composition data were unavailable until 1970; therefore, the spawner-recruitment analysis used only complete brood years beginning in 1970 (Bue et al. 2002). Due to reduced funding, the weir was replaced with a video system in 2012 and no additional age data are currently being collected.

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).

$$R = \alpha S e^{-\beta S} \tag{1}$$

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:

$$\ln(R/S) = \ln(\alpha) - \beta S \tag{2}$$

For this review, a Bayesian approach was used to describe the spawner-recruitment relationship and estimate the model parameters for Copper River Chinook salmon (Savereide 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).

Biological reference points MSY and S_{MSY} (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 S_{MSY}:

$$S_{MSY} \approx \frac{\ln(\alpha')}{\beta}\left[0.5 - 0.07\ln(\alpha')\right]. \tag{3}$$

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 S_{MSY}. Estimates of S_{MSY} 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] (*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 S_{MSY}. Escapements in the lower 60 to 65 percentiles were found to be optimal across a wide range of productivities and 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 all Chinook, chum, and pink 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 1–6 and Appendices A1–A10) and most were reevaluated using new methodologies. A comprehensive review of goal performance for all salmon stocks from 2008 to 2017 is found in Table 2.

CHINOOK SALMON

Copper River Chinook Salmon

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 achieved 24,000 or more salmon in 10 out of 14 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 keep escapements near the historical average, which were 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 S_{MSY} 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 is then derived by subtracting inriver harvest. There are only 18 escapement estimates available (1999–2016 mark–recapture estimates) and these estimates exhibit a 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). 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 2016 was completed (Savereide 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. The state-space model, similar to the catch-age model, estimates S_{MSY} to be lower than the current lower bound SEG. The estimated median

S_{MSY} from the state-space model is 18,595 fish. Optimal yield profiles indicate escapement of 18,595 Copper River Chinook salmon has an 85% probability of achieving 90% MSY and 33,000 fish has a 50% probability of achieving 70% of MSY (Figure 2; Savereide et al. *unpublished*). **Based on these results the committee recommends an SEG range of 18,500 to 33,000 Chinook salmon, which has a high probability of producing sustainable yields.**

Gulkana River Chinook Salmon

The committee reviewed Chinook salmon escapement data from the Gulkana River for consideration of an escapement goal. Escapements have been monitored in this system since 2002 with a counting tower project in the upper river and have ranged from 1,620 to 6,290 Chinook salmon. The relationship between escapement above the counting tower and Copper River total run is relatively strong (R^2 = 54%), which implies the counting tower provides a good indicator of overall Copper River run strength. However, the time series of data are relatively short, especially given the variability in the proportion of the Gulkana River Chinook salmon escapement enumerated at the tower, which ranged from 45–54% from 2013–2015 and 50–86% from 2002–2004. **The committee recommends continued monitoring of the system until a sufficient time series of data are available to better understand how well the tower count indexes escapement.**

CHUM SALMON

Escapement goals for chum salmon are currently based on counts from aerial surveys dating back to the 1960s. Streams were flown multiple times each year with escapement indexed using area-under-the-curve calculations adjusted for an estimate of stream life (Fried et al. 1998; Bue et al. 1998). Data from years when there were fewer than 150 of the current 214 index streams surveyed PWS-wide (1963–1971, 1974) were not used in the review of previous PWS wild chum salmon escapement goals. Additionally, the expanded count in the Northwestern District in 1975 was 0 fish and was not used in the calculations due to extreme effect on the results.

In 2005, all 5 escapement goals for PWS wild chum salmon were changed from SEG ranges to lower bound SEGs because they were thought to be harvested incidentally in the directed pink salmon fishery and their escapements could not be effectively managed to fall within a range (Evenson et al. 2008). Escapements from 1965 through 2004 were used in the development of these lower bound SEGs using a risk analysis (Bernard et al. 2009). District-specific escapement goals for this review were prompted by a:

(1) reduction in the overall number of aerial index streams flown throughout PWS due to departmental budget cuts: from more than 200 streams during 1989–2013 to a reduced subset of approximately 134 streams established during 2015;

(2) reassessment of the methods used to calculate annual stream escapements to only include streams with 3 or more surveys per year, which resulted in substantially lower estimates for some districts during some years; and

(3) review of the estimated annual harvest rate of wild chum salmon.

Methods

From the more than 200 streams flown since 1963, a reduced subset of 134 streams were selected from across PWS based on these streams having a high proportion of the overall escapement for pink and chum salmon. However, fewer than 70% of the 134 index streams were surveyed for 1 or more districts throughout most of the timespan 1963–1979 and 2016; thus, these years were excluded from this analysis.

We first evaluated the assumption that harvest should be considered "incidental" for wild chum salmon in PWS. To do this, we developed high and low estimates of annual harvest rates on this stock using aerial index stream data from 1980 to 2015 and assumed the actual harvest rate is within the high and low estimates. For estimates of harvest rate, we used data from the full set of 214 aerial index streams, not the newly established reduced subset established in 2015. Annual harvest rate is equal to the total harvest divided by the sum of harvest and escapement (run size). For the high estimate of harvest rate, we used PWS-wide adjusted-AUC (adjusted for stream life) as the estimate of escapement and did not expand this for observer efficiency or the proportion of overall escapement represented by aerial index streams. For the low estimate of harvest rate, we expanded PWS-wide adjusted-AUC escapements by dividing this by an observer efficiency correction factor of 0.436 and then by 0.80, to account for the proportion of overall escapement that is represented by the aerial index streams. These corrections were derived from the study by Fried et al. (1998) for PWS wild pink salmon, but are also thought to be a reasonable approximation for expanding PWS wild chum salmon escapements. Annual estimates of wild chum salmon harvest were distinguished from hatchery fish based on thermally marked otoliths of the hatchery component or, for Coghill and Eshamy districts between 1986 and 2003, based on average wild chum harvests in these districts prior to significant hatchery chum salmon production in in PWS (1970–1986).

Based on estimates of harvest (discussed below) and recent observations of commercial fishermen directing effort on wild chum salmon, we proceeded with the assumption that harvest of wild chum has not consistently been "incidental." Thus, we instead decided to use the percentile approach (Clark et al. 2014) to set escapement goals for individual districts using the adjusted-AUC values for the reduced subset of 134 aerial index streams in PWS established in 2015.

Results and Recommendations

Chum Salmon Harvest Rates and Percentiles

Abundance and harvest estimates for wild chum salmon in PWS have fluctuated considerably since the 1960s (Figure 3 and Table 3). In particular, estimates of total run size (and harvest) were substantially higher for the period 1981–1989 and have not returned to these levels. For the period 1980–2015, during which the number of aerial surveys were relatively consistent, low and high estimates of harvest of wild chum salmon in PWS averaged 36% and 56%, respectively (Appendix A2, Figure 3).

Estimates of harvest were at historically low levels during the mid-to-late 2000s; however, estimates of harvest increased substantially after 2011, related to increases in the exvessel price per pound of chum salmon (http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmoncatch_statewide). Based on the midpoint of possible low and high harvests since 1980, the long-term average harvest is approximately 40%, within the limit that allows the use of the percentile approach for setting escapement goals.

Based on recommendations from Clark et al. (2014) for escapements with high measurement error, such as those assessed using aerial surveys, we classified all PWS chum salmon escapement goals as "Tier 1" and used the 20th and 60th percentiles to inform the goals for all districts. The decision to use Tier 1 percentiles was also supported by contrast in escapements being classified as "high" (>8) for all but the Northern District, for which contrast was approximately 7.6. Due to high measurement error, lack of evidence that maximum yield can be easily attained given the complicated nature of management in this mixed-stock fishery, and lack of evidence that larger escapements have reduced productivity, we recommend that all PWS chum salmon goals be lower bound SEGs at the 20th percentiles. However, we also present the 60th percentiles (Appendix A2) for illustration purposes.

In the future, a run reconstruction using Bayesian methods could be employed to estimate harvest rates and district escapements for years that were excluded from the present analysis (e.g., 1960–1979 and 2016).

Eastern District Chum Salmon

For the Eastern District (221), escapements from 1980 to 2015 ranged from 20,198 to 313,522, a contrast that is >15 and considered high (Appendix A2, Figure 4). Average escapement during this timeframe was ~129,500. Escapements at the 20th percentile result in a lower bound of 79,000. During the past 10 years (2006–2015), no escapements have been lower than the proposed lower bound. **Based on these results, the committee recommends changing the current lower bound SEG of 50,000 for this stock to a lower bound SEG of 79,000.**

Northern District Chum Salmon

For the Northern District (222), escapements from 1980–2015 ranged from 15,189–116,265, a contrast of 7.6 and considered moderate (Appendix A2, Figure 4). Average escapement during this timeframe was ~47,500. Escapements at the 20th percentile would result in a lower bound of 28,000. Excluding 2016 when aerial survey conditions precluded an accurate measure of pink and chum salmon escapements, only 2 escapements during the past 10 years (2006–2015) have been lower than the proposed lower bound. **Based on these results, the committee recommends changing the current lower bound SEG of 20,000 for this stock to a lower bound SEG of 28,000.**

Coghill District Chum Salmon

For the Coghill District (223), escapements from 1980–2015 ranged from 1,000–84,752, a contrast of >84 and considered high (Appendix A2, Figure 4). Average escapement during this timeframe was ~20,000. Escapements at the 20th percentile would result in a lower bound of 10,000. Excluding 2016 when aerial survey conditions precluded an accurate measure of pink and chum salmon escapements, only 2 escapements during the past 10 years (2006–2015) have been lower than the proposed lower bound. **Based on these results, the committee recommends changing the current lower bound SEG of 8,000 for this stock to a lower bound SEG of 10,000.**

Northwestern District Chum Salmon

For the Northwestern District (224), escapements from 1980–2015 ranged from 1,419–54,072, a contrast of >38 and considered high (Appendix A2, Figure 3). Average escapement during this timeframe was ~16,500. Escapements at the 20th percentile would result in a lower bound of 7,000. Excluding 2016 when aerial survey conditions precluded an accurate measure of pink and chum salmon escapements, only 2 escapements during the past 10 years (2006–2015) have been lower than the proposed lower bound. **Based on these results, the committee recommends**

changing the current lower bound SEG of 5,000 for this stock to a lower bound SEG of 7,000.

Southeastern District Chum Salmon

For the Southeastern District (228), escapements from 1980–2015 ranged from 2,220–123,607, a contrast of >55 and considered high (Appendix A2, Figure 3). Average escapement during this timeframe was ~37,500. Escapements at the 20th percentile would result in a lower bound of 11,000. Excluding 2016 when aerial survey conditions precluded an accurate measure of pink and chum salmon escapements, no escapements during the past 10 years (2006–2015) have been lower than the proposed lower bound. **Based on these results, the committee recommends changing the current lower bound SEG of 8,000 for this stock to a lower bound SEG of 11,000.**

COHO SALMON

Bering River District and Copper River Delta Coho Salmon

Both goals were adopted in 2003 (Bue et al. 2002) and were developed using the percentile approach of Bue and Hasbrouck (*unpublished*). For this review these data sets were updated through 2016 (Appendices A3 and A4). Escapements observed in the past 3 years for both stocks provided no new information to warrant re-evaluation of current escapement goals. **The committee recommends the SEG of 13,000–33,000 spawners for Bering River District and the SEG of 32,000–67,000 spawners for Copper River Delta coho salmon remain unchanged.**

PINK SALMON

Even and Odd Years

Existing even- and odd-year pink salmon district-specific escapement goals for PWSMA were adopted in 2012 (Table 1). Prior to 2012, PWSMA had areawide escapement goals for the even- and odd-year runs. The goals were converted to district-specific goals because, in practice, inseason escapements and management was by district and not by returns to the entire sound. All existing goals were developed using the 4-tier percentile approach (Bue and Hasbrouck *unpublished*).

During recent years, budget cuts have resulted in ADF&G no longer having the resources to fly 214 individual streams multiple times throughout the entire run. These constraints forced ADF&G to select a subset of streams to index escapements and manage these fisheries. In addition, similar to wild chum salmon escapement goals, there were a suite of factors resulting in the escapement goal committee recommending a reevaluation of even- and odd-year wild pink salmon goals for PWS; these factors include the following:

(1) a reduction in the overall number of aerial index streams flown throughout PWS due to departmental budget cuts, from more than 200 streams during 1989–2013 to a reduced subset of approximately 134 streams set during 2015;

(2) a reassessment of the methods used to calculate annual stream escapements to only include streams with 3 or more surveys per year; and

(3) a review of the estimated annual harvest rate of wild pink salmon.

Methods

Similar to the assessment of wild chum salmon described above, we used the adjusted-AUC indices (Fried et al. 1998; Bue et al. 1998) for the reduced subset of 134 aerial index streams in PWS established in 2015 to reassess wild pink salmon escapement goals. We excluded the years 1963–1980 and 2016 from our analyses because fewer than 70% of the 134 index streams were surveyed for 1 or more districts in those years. Unlike the wild chum salmon assessment, 1980 was also excluded from this assessment due to fewer pink salmon streams flown during that year. Thus, 1982–2014 were used for the assessment of even-year pink salmon and 1981–2015 for the assessment of odd year pink salmon escapement goals.

As with wild chum salmon, we used adjusted-AUC indices from the full suite of 214 aerial index streams to estimate high and low estimates of annual harvest rates. Otherwise, our methods for estimating harvest rates are identical to that described above for wild chum salmon. Annual estimates of wild pink salmon were distinguished from hatchery fish in the harvest based on thermally marked otoliths, coded wire tags, or from historical estimates of proportions of wild pink salmon harvests before the advent of the large-scale marking program.

As described by Clark et al. (2014), we used contrasts in escapements for each district and estimates of PWS-wide harvest rates to inform our choice of percentiles used to set escapement goals for individual districts.

Results and Recommendations

Pink Salmon Harvest Rates and Percentiles

Similar to chum salmon, abundance and harvest estimates for even- and odd-year stocks of wild pink salmon in PWS have undergone considerable fluctuations since the 1960s (Figures 5–8). For even year pink salmon, harvests and estimates of total run size peaked during the 1980s; however, these are bimodal for odd-year pink salmon, with peaks during the 1980s and during recent years.

Average low and high estimates of harvest rates for even-year pink salmon during the period 1982–2014 were 45% and 68%, respectively (Table 4, Figure 5). However, harvest rates for even-year pink salmon decreased to 39% and 63% during the past 10 even years (1996–2014). For odd-year pink salmon, low and high estimates of harvest rates averaged 49% and 71% for 1981–2015 (Table 5, Figure 7), but were 44% and 67% during the past 10 odd-year (1997–2015).

When considering which percentiles to consider for pink salmon escapement goals, we placed more weight on the low estimates of harvest rates during the past 10 brood year returns. Results from the study by Fried et al. (1998) suggest that "true" escapement is more closely approximated by expanding adjusted-AUC for observer efficiency and the proportion of overall PWS escapement represented by the aerial index streams; these expansions are the basis for the low estimates of harvest rate. For the even year wild pink salmon stock, although the guidelines outlined in Clark et al. (2014) suggested not using this approach for harvest rates above 40%, given the lower harvest rate during recent brood years, relatively high contrast, and uncertainty in the aerial survey estimates, **we recommend a Tier 1 category for even brood year wild pink salmon and SEG with a lower bound at the 20th percentile and an upper bound at the 60th percentile.** Table 1 and Appendix A5 show these proposed escapement goals along with adjusted-AUC values by district for the 134 aerial index streams.

For the odd broodline of wild pink salmon in PWS, none of the average estimates of harvest rate were below 40%. Thus, in heeding the recommendations of Clark et al. (2014), **we recommend an SEG with a lower bound at the 25th percentile and an upper bound at the 75th percentile for the odd broodline of PWS pink salmon**. Table 1 and Appendix A6 show these proposed escapement goals along with adjusted AUC values by district for the 134 aerial index streams.

As is the case for PWS chum salmon, a run reconstruction using Bayesian methods could be employed to estimate district escapements for years that were excluded from the present analysis (e.g., 1963–1980 and 2016). Also, in light of the relatively high rate of harvest for both stocks of wild pink salmon in PWS, we suggest that other approaches for choosing escapement targets—including yield and spawner-recruitment analyses—be considered in the future.

SOCKEYE SALMON

Copper River and Copper River Delta Sockeye Salmon

The current SEGs for the Upper Copper River (UCR) and Copper River Delta (CRD) stocks were established using the percentile approach of Bue and Hasbrouck (*unpublished*); however, Clark et al. (2014) evaluated this approach and provided recommendations for when this method should not be used (See Percentile Approach in Escapement Goal Determination). Because harvest rates on these stocks average >40% and contrast in escapement data sets were low (<4), it was determined in the 2014 review that the percentile approach was not appropriate to use. Therefore, a thorough analysis using both a Markov yield table and a Bayesian Ricker stock-recruitment model was completed in 2014 (Moffitt et al. 2014). The stocks were combined for these analyses because there is no way to allocate the commercial harvest by stock. The results showed that good yields were being produced from escapements in the current SEG ranges and that a combined range would produce sustained yields at 90% or more of MSY (Moffitt et al. 2014); therefore, the SEGs for the 2 stocks were left unchanged.

For this review, the data sets for both stocks were updated through 2016 (Appendices A7 and A8). The committee determined that escapements observed in the past 3 years provided no new information to warrant re-evaluation of current escapement goals. **The committee recommends the SEG of 360,000–750,000 for the UCR stock and 55,000–130,000 for the CRD stock remain unchanged.**

Bering River District Sockeye Salmon

This goal 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 2016 (Appendix A9). The committee determined that escapements observed in the past 3 years provided no new information to warrant re-evaluation of the current SEG. **The committee recommends the SEG of 15,000–33,000 spawners for the Bering River District remain unchanged.**

Coghill Lake Sockeye Salmon

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 substantial risk of 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 2016 (Table 6; brood years 1962–2010 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. We also used a generalized additive model (GAM) to examine the relationship between escapement and the resulting yield. The use of a GAM is similar to the Markov yield table approach, but somewhat more flexible and without the subjectivity of choosing escapement intervals. The GAM was allowed considerable flexibility (knots = 10) to respond to changes in yield across historical escapements.

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 (Figure 9, Table 6). From our updated Ricker analysis (Figure 10, Table 7), the point estimate of escapement believed to result in maximum yield (S_{MSY} of ~61,000) 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 generally 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 S_{MSY}. Although the point estimate of S_{MSY} from our revised Ricker analysis is now slightly greater than the upper bound for this goal, we reiterate that estimates of Ricker model parameter and associated management reference points are relatively imprecise for this stock and in this respect our analysis mainly serves to show that updating spawner-recruit data has not changed parameter estimates since the assessments by Bue et al. (2002) and Fair et al. (2011). However, a recent study suggests productivity of wild sockeye for the Coghill and Eshamy stocks might be tied to a combination of interactions, including the density-dependence of adult or juvenile Coghill Lake sockeye salmon and competition from adult hatchery pink salmon in the marine environment (Ward et al. 2017). The authors of that study found that the performance (fit) of the Ricker model was significantly improved by adding a covariate for returning adult hatchery pink salmon during the year that sockeye salmon enter the marine environment.

Given the relative consistency of yield across a broad range of escapements and evidence that the parameters of the Ricker model have not changed appreciably since the last review (Fair et al.

2011), **the committee recommends the SEG of 20,000–60,000 spawners for Coghill Lake remain unchanged.** The committee also recommends that this stock be given a thorough reassessment during the next review to evaluate the possible influence of recent large escapements of sockeye salmon to Coghill Lake in 2011 and 2012 and large returns of pink salmon to PWS in 2013 and 2015.

Eshamy Lake Sockeye Salmon

This goal was established in 2008 (Fair et al. 2008) and was derived from the Ricker spawner-recruitment model. Escapements within the range of the current goal were determined to have a probability greater than 50% of producing returns of at least 90% of MSY. The Eshamy River weir, operated since the 1930s, was discontinued in 2012 due to budget reductions. Since 2013, a video weir system has been installed, but has only enumerated a portion of the escapement believed to enter Eshamy Lake in (Appendix A10). Thus, there is no additional escapement data to consider for the current review. **The committee recommends the BEG of 13,000–28,000 spawners for Eshamy Lake remain unchanged.**

ACKNOWLEDGEMENTS

The authors thank other core members of the escapement goal committee: Daniel Bosch, Jeremy Botz, Robert Clark, Steve Fleischman, James Hasbrouck, Bert Lewis, Andrew Munro, Charles Russell, Mark Somerville, Bill Templin, Matt Tyers, Tom Vania, Tim Viavant, and Xinxian Zhang for their assistance reviewing and establishing escapement goals recommendations.

REFERENCES CITED

Bernard, D. R., J. J. Hasbrouck, B. G. Bue, and R. A. Clark. 2009. Estimating risk of management error from precautionary reference points (PRPs) for non-targeted salmon stocks. Alaska Department of Fish and Game, Special Publication No. 09-09, Anchorage.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fisheries Investigation Series 2, Vol. 19 U.K. Ministry of Agriculture and Fisheries, London.

Bue, B. G., S. M. Fried, S. Sharr, D. G. Sharp, J. A. Wilcock, and H .J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: The Prince William Sound example. North Pacific Anadromous Fisheries Commission Bulletin 1:240–250.

Bue, B. G., J. J. Hasbrouck, and M. J. Evenson. 2002. Escapement goal review of Copper River and Bering Rivers, and Prince William Sound Pacific salmon stocks. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-35, Anchorage.

Brady, J. A., S. Sharr, K. Roberson, and F. M. Thompson. 1987. Prince William Sound area annual finfish management report, 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Cordova, Alaska.

Brenner, R. E., S. D. Moffitt, and W. S. Grant. 2012. Straying of hatchery salmon in Prince William Sound, Alaska. Environmental Biology of Fishes 94:179–195.

Clark, R. A., D. M. Eggers, A. R. Munro, S. J. Fleischman, B. G. Bue, and J. J. Hasbrouck. 2014. An evaluation of the percentile approach for establishing Sustainable Escapement Goals in lieu of stock productivity information. Alaska Department of Fish and Game, Fishery Manuscript No. 14-06, Anchorage.

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences 42:815–824.

Edmundson, J. A., G. B. Kyle, and T. M. Willette. 1992. Limnological and fisheries assessment of Coghill Lake relative to sockeye salmon (*Oncorhynchus nerka*) production and lake fertilization. Alaska Department of Fish and Game, Fisheries Rehabilitation Enhancement and Development Division Report 118, Juneau.

REFERENCES CITED (Continued)

Edmundson, J. A., G. B. Kyle, S. R. Carlson, and P. A. Shields. 1997. Trophic–level responses to nutrient treatment of meromictic and glacially influenced Coghill Lake. Alaska Fisheries Research Bulletin 4:136–153.

Evenson, M. J., J. J. Hasbrouck, S. D. Moffitt, and L. Fair. 2008. Escapement goal review for Copper River Bering River, and Prince William Sound salmon stocks. Alaska Department of Fish and Game, Fishery Manuscript No. 08-01, Anchorage.

Fair, L. F., S. D. Moffitt, M. J. Evenson, and J. W. Erickson. 2011. Escapement goal review of Copper and Bering rivers, and Prince William Sound Pacific salmon stocks, 2011. Alaska Department of Fish and Game, Fishery Manuscript No. 11-07, Anchorage.

Fair, L. F., S. D. Moffitt, M. J. Evenson, and J. Erickson. 2008. Escapement goal review of Copper and Bering rivers, and Prince William Sound Pacific salmon stocks, 2008. Alaska Department of Fish and Game, Fishery Manuscript No. 08-02, Anchorage.

Fleischman, S. J., and A. M. Reimer. 2017. Spawner-recruit analyses and escapement goal recommendations for Kenai River Chinook salmon. Alaska Department of Fish and Game, Fishery Manuscript Series No. 17-02, Anchorage.

Fleischman, S. J., M. J. Catalano, R. A. Clark, and D. R. Bernard. 2013. An age-structured state-space stock–recruit model for Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 70:401–414.

Fried, S. M. 1994. Pacific salmon spawning escapement goals for the Prince William Sound, Cook Inlet, and Bristol Bay areas of Alaska. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Special Publication No. 8, Juneau.

Fried, S. M., B.G. Bue, S. Sharp, and S. Sharr. 1998. Injury to spawning areas and evaluation of spawning escapement enumeration of pink salmon in Prince William Sound, Alaska, Exxon Valdez damage assessment (Fish/Shellfish NRDA Study 1) and restoration (restoration studies 9 and 60B) study final report, Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York, NY.

Joyce T. L., and D. G. Evans. 1999. Otolith marking of pink salmon in Prince William Sound salmon hatcheries, *Exxon Valdez* oil spill restoration final report (Restoration Project 99188). Alaska Department of Fish and Game, Division of Commercial Fisheries, Cordova and Anchorage, Alaska.

Joyce, T., and R. Riffe. 1998. Summary of Pacific salmon coded wire tag and thermal mark application and recovery, Prince William Sound, 1997. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development Division, Regional Information Report 2A98–06, Anchorage.

Koenings, J. P., and G. B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fisheries Research Bulletin 4:120–135.

Liermann, M. C., R. Sharma, C. K. Parken. 2010. Using accessible watershed size to predict management parameters for Chinook salmon *Oncorhynchus tshawytscha*, populations with little or no spawner-recruit data: A Bayesian hierarchical modeling approach. Fisheries Management and Ecology 17:40–51.

Marshall, S., D. Bernard, R. Conrad, B. Cross, D. McBride, A. McGregor, S. McPherson, G. Oliver, S. Sharr, and B. Van Alen. 1987. Application of scale patterns analysis to the management of Alaska's sockeye salmon (*Oncorhynchus nerka*) fisheries. Pages 307–326 [*In*] H. D. Smith, L. Margolis and C. C. Wood, editors. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Canadian Special Publication of Fisheries and Aquatic Science 96.

Maxwell, S. L., A. V. Faulkner, L. Fair, and X. Zhang. 2011. A comparison of estimates from 2 hydroacoustic systems used to assess sockeye salmon escapement in 5 Alaska Rivers. Alaska Department of Fish and Game, Fishery Manuscript Series No. 11-02, Anchorage.

REFERENCES CITED (Continued)

Moffitt, S. D., R. E. Brenner, J. W. Erickson, M. J. Evenson, R. A. Clark, and T. R. McKinley. 2014. Escapement goal review of Copper and Bering rivers, and Prince William Sound Pacific salmon stocks, 2014. Alaska Department of Fish and Game, Fishery Manuscript No. 14-05, Anchorage.

Pirtle, R. B. 1979. Annual management report 1978 Prince William Sound Area Region II. Alaska Department of Fish and Game, Division of Commercial Fisheries, Cordova, Alaska.

Pirtle, R. B. 1981. A compilation of historical sockeye salmon spawning escapement estimates from Prince William Sound. Alaska Department of Fish and Game, Division of Commercial Fisheries, Data Report No. 10, Cordova.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling.

Ricker, W. E. 1954. Stock and recruitment. Journal of the Fisheries Research Board of Canada 11:559–623.

Rivot, E., E. Prévost, and E. Parent. 2001. How robust are Bayesian posterior inferences based on a Ricker model with regards to measurement errors and prior assumptions about parameters? Canadian Journal of Fisheries and Aquatic Sciences 58:2284–2297.

Savereide, J. W. 2001. An age structured model for assessment and management of Copper River Chinook salmon. Master's Thesis, University of Alaska Fairbanks.

Savereide, J. W., and T. J. Quinn, II. 2004. An age structured assessment model for Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 61:974–985.

Staton, B. A., M. J. Catalano, and S. J. Fleischman. 2016. From sequential to integrated Bayesian analyses: Exploring the continuum with a Pacific salmon spawner-recruit model. Fisheries Research 186:237-247.

Ward E. J., R. E. Brenner, M. Adkison, J. Couture, S. C. Dressel, M. A. Litzow, S. Moffitt. 2017. Evaluating signals of oil spill impacts, climate, and species interactions in Pacific herring and Pacific salmon populations in Prince William Sound and Copper River, Alaska. PLoS ONE 12(3): e0172898. https://doi.org/10.1371/journal.pone.0172898

TABLES AND FIGURES

Table 1.–Summary of recommended escapement goals for Prince William Sound Management Area salmon stocks, 2017.

	Current escapement goal			Recommended escapement goal			
System	Goal	Type	Year adopted	Goal	Type	Data	Action
Chinook salmon							
Copper River	24,000	LB SEG	2003	18,500–33,000	SEG	Mark–recapture	Establish SEG range
Chum salmon							
Eastern District	50,000	LB SEG	2006	79,000	LB SEG	Aerial surveys	Change to LB SEG
Northern District	20,000	LB SEG	2006	28,000	LB SEG	Aerial surveys	Change to LB SEG
Coghill District	8,000	LB SEG	2006	10,000	LB SEG	Aerial surveys	Change to LB SEG
Northwestern District	5,000	LB SEG	2006	7,000	LB SEG	Aerial surveys	Change to LB SEG
Southeastern District	8,000	LB SEG	2006	11,000	LB SEG	Aerial surveys	Change to LB SEG
Coho salmon							
Copper River Delta	32,000–67,000	SEG	2003				No change
Bering River	13,000–33,000	SEG	2003				No change
Pink salmon							
Eastern District (even year)	250,000–580,000	SEG	2012	203,000–328,000	SEG	Aerial surveys	Change in range
Eastern District (odd year)	310,000–640,000	SEG	2012	346,000–863,000	SEG	Aerial surveys	Change in range
Northern District (even year)	140,000–210,000	SEG	2012	96,000–127,000	SEG	Aerial surveys	Change in range
Northern District (odd year)	90,000–180,000	SEG	2012	111,000–208,000	SEG	Aerial surveys	Change in range
Coghill District (even year)	60,000–150,000	SEG	2012	37,000–110,000	SEG	Aerial surveys	Change in range
Coghill District (odd year)	60,000–250,000	SEG	2012	54,000–233,000	SEG	Aerial surveys	Change in range
Northwestern District (even year)	70,000–140,000	SEG	2012	52,000–93,000	SEG	Aerial surveys	Change in range
Northwestern District (odd year)	50,000–110,000	SEG	2012	64,000–144,000	SEG	Aerial surveys	Change in range
Eshamy District (even year)	3,000–11,000	SEG	2012	1,000–4,000	SEG	Aerial surveys	Change in range
Eshamy District (odd year)	4,000–11,000	SEG	2012	5,000–31,000	SEG	Aerial surveys	Change in range
Southwestern District (even year)	70,000–160,000	SEG	2012	62,000–105,000	SEG	Aerial surveys	Change in range
Southwestern District (odd year)	70,000–190,000	SEG	2012	112,000–231,000	SEG	Aerial surveys	Change in range
Montague District (even year)	50,000–140,000	SEG	2012	36,000–72,000	SEG	Aerial surveys	Change in range
Montague District (odd year)	140,000–280,000	SEG	2012	143,000–330,000	SEG	Aerial surveys	Change in range
Southeastern District (even year)	150,000–310,000	SEG	2012	88,000–153,000	SEG	Aerial surveys	Change in range
Southeastern District (odd year)	270,000–620,000	SEG	2012	286,000–515,000	SEG	Aerial surveys	Change in range

-continued-

Table 1.–Page 2 of 2.

	Current escapement goal			Recommended escapement goal			
System	Goal	Type	Year adopted	Goal	Type	Data	Action
Sockeye salmon							
Upper Copper River	360,000–750,000	SEG	2012			Sonar	no change
Copper River Delta	55,000–130,000	SEG	2003			Aerial surveys	no change
Bering River	15,000–33,000	SEG	2012			Aerial surveys	no change
Coghill Lake	20,000–60,000	SEG	2012			Weir	no change
Eshamy Lake	13,000–28,000	BEG	2009			Weir	no change

Table 2.–Current escapement goals compared to escapements observed from 2008 through 2016 for Chinook, chum, coho, pink, and sockeye salmon stocks of the Prince William Sound Management Area.

Species/System	2017 goal range Lower	2017 goal range Upper	Type	Initial year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[a]
Chinook salmon														
Copper River	24,000		lower bound SEG	2003	32,485	27,781	16,771	27,993	27,911	28,727	20,840	26,607	12,534	
Chum salmon														
Eastern District	50,000		lower bound SEG	2006	82,068	150,051	146,613	240,321	97,362	150,044	93,491	112,142	131,168	
Northern District	20,000		lower bound SEG	2006	50,666	30,296	59,530	64,743	23,818	41,058	27,680	43,179	10,746	
Coghill District	8,000		lower bound SEG	2006	48,221	8,290	84,840	19,617	14,075	14,414	9,491	15,444	1,010	
Northwestern District	5,000		lower bound SEG	2006	34,107	15,826	34,300	11,951	9,360	4,995	5,041	7,321	4,100	
Southeastern District	8,000		lower bound SEG	2006	20,300	150,974	138,442	112,507	31,029	43,000	30,177	52,031	26,127	
Coho salmon														
Copper River Delta	32,000	67,000	SEG	2003	76,892	41,294	41,077	37,900	35,295	33,130	42,530	41,665	76,200	
Bering River	13,000	33,000	SEG	2003	28,932	22,141	21,311	18,890	15,605	18,820	26,475	15,550	26,150	
Pink salmon[b]														
Eastern District (even year)	250,000	580,000	SEG	2012					301,709		270,244		663,113	
Eastern District (odd year)	310,000	640,000	SEG	2012						1,371,111		1,605,058		
Northern District (even year)	140,000	210,000	SEG	2012					104,849		105,333		150,767	
Northern District (odd year)	90,000	180,000	SEG	2012						318,884		779,600		
Coghill District (even year)	60,000	150,000	SEG	2012					172,611		63,290		171,362	
Coghill District (odd year)	60,000	250,000	SEG	2012						640,414		801,201		
Northwestern District (even year)	70,000	140,000	SEG	2012					117,795		67,030		171,633	
Northwestern District (odd year)	50,000	110,000	SEG	2012						203,444		454,427		
Eshamy District (even year)	3,000	11,000	SEG	2012					1,052		12,400		NA[c]	
Eshamy District (odd year)	4,000	11,000	SEG	2012						12,145		70,068		
Southwestern District (even year)	70,000	160,000	SEG	2012					90,156		84,607		NA[c]	
Southwestern District (odd year)	70,000	190,000	SEG	2012						347,931		789,725		
Montague District (even year)	50,000	140,000	SEG	2012					77,756		NA[c]		NA[c]	
Montague District (odd year)	140,000	280,000	SEG	2012						411,373		649,144		
Southeastern District (even year)	150,000	310,000	SEG	2012					258,047		185,072		169,660	
Southeastern District (odd year)	270,000	620,000	SEG	2012						1,472,633		2,032,492		

-continued-

Table 2.–Page 2 of 2.

	2017 goal range			Initial										
Species/System	Lower	Upper	Type	year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[a]
Sockeye salmon														
Upper Copper River	360,000	750,000	SEG	2012	480,597	468,725	502,995	607,657	953,745	860,829	864,988	930,095	503,033	
Copper River Delta	55,000	130,000	SEG	2003	67,950	69,292	83,905	72,367	66,850	75,705	64,205	66,665	51,550	56,950
Bering River	15,000	33,000	SEG	2012	18,136	15,172	4,951	28,530	18,290	23,900	14,985	21,705	16,290	18,815
Coghill Lake	20,000	60,000	SEG	2012	29,298	23,186	24,312	102,359	74,978	17,231	21,836	13,684	8,708	50,312
Eshamy Lake	13,000	28,000	BEG	2009	18,495	24,025	16,291	24,129	NA	4,500[d]	7,453[d]	4,381[d]	5,817[d]	

Note: Shaded cells show years when escapement goals were not met.

[a] 2017 estimates are preliminary and incomplete for most stocks.

[b] Prior to 2012, pink salmon goals were soundwide goals within a brood line (even and odd years).

[c] Insufficient aerial survey coverage.

[d] A video weir was operated from 2013 to present. The numbers represent an unknown fraction of the total annual escapement.

Table 3.–Harvest, escapement, and total run size estimates used for high and low estimates of harvest rates of wild chum salmon in Prince William Sound, Alaska, 1980–2016.

Year	Harvest	Escapement	Max % harvest	Min % harvest	Min. total run	Max. total run
1980	412,948	76,309	84.4	65.4	489,257	631,724
1981	1,745,869	132,341	93	82.1	1,878,210	2,125,287
1982	1,335,368	242,634	84.6	65.7	1,578,002	2,030,993
1983	1,030,546	323,865	76.1	52.6	1,354,411	1,959,058
1984	1,196,785	191,112	86.2	68.6	1,387,897	1,744,698
1985	1,302,090	93,787	93.3	82.9	1,395,877	1,570,975
1986	1,662,366	266,265	86.2	68.5	1,928,631	2,425,740
1987	1,616,850	331,879	83	63	1,948,729	2,568,338
1988	1,265,442	626,566	66.9	41.3	1,892,008	3,061,789
1989	687,035	278,636	71.1	46.2	965,671	1,485,877
1990	411,611	316,263	56.5	31.2	727,874	1,318,328
1991	170,286	108,499	61.1	35.4	278,785	481,350
1992	179,741	91,411	66.3	40.7	271,152	441,814
1993	158,498	136,842	53.7	28.8	295,340	550,820
1994	227,404	114,512	66.5	40.9	341,916	555,707
1995	216,799	185,527	53.9	29	402,326	748,700
1996	221,625	368,937	37.5	17.3	590,562	1,279,357
1997	336,103	212,128	61.3	35.6	548,231	944,268
1998	296,630	183,999	61.7	36	480,629	824,150
1999	340,699	252,388	57.4	32	593,087	1,064,288
2000	463,210	397,492	53.8	28.9	860,702	1,602,809
2001	456,957	446,385	50.6	26.3	903,342	1,736,731
2002	180,304	292,597	38.1	17.7	472,901	1,019,172
2003	320,755	546,436	37	17	867,191	1,887,372
2004	213,848	289,742	42.5	20.5	503,590	1,044,530
2005	66,384	245,983	21.3	8.6	312,367	771,610
2006	150,464	304,695	33.1	14.7	455,159	1,024,016
2007	117,002	323,007	26.6	11.2	440,009	1,043,054
2008	182,016	245,644	42.6	20.5	427,660	886,271
2009	82,871	400,049	17.2	6.7	482,920	1,229,800
2010	91,872	498,041	15.6	6	589,913	1,519,742
2011	101,740	455,788	18.2	7.2	557,528	1,408,472
2012	211,798	179,308	54.2	29.2	391,106	725,869
2013	236,893	247,323	48.9	25	484,216	945,961
2014	227,078	166,670	57.7	32.2	393,748	704,916
2015	221,770	250,809	46.9	23.6	472,579	940,833
2016	97,281	173,150	36	16.4	270,431	593,697
Average	506,477	272,885	55.7	35.9	776,765	1,286,234
Median	232,149	251,599	55.4	30.2	525,911	1,054,410
Std. Dev	510,709	132,151	21.9	21.3	525,870	631,947

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the entire set of 214 aerial index streams. Max total run size uses expanded estimate of escapement to account for observer efficiency (0.436) and the proportion of total escapement represented by aerial index streams (0.80). Shaded values were not used in the estimation of descriptive statistics due to lower numbers of streams surveyed.

Table 4.–Harvest, escapement, and total run size estimates used for high and low estimates of harvest rates of even year wild pink salmon in Prince William Sound, Alaska, 1982–2016.

Year	Harvest	Escapement	Max % harvest	Min % harvest	Min. total run	Max. total run
1982	14,945,199	1,849,118	89	73.8	16,794,317	20,246,569
1984	17,631,675	3,569,838	83.2	63.3	21,201,513	27,866,302
1986	4,578,023	985,934	82.3	61.8	5,563,957	7,404,669
1988	795,772	971,164	45	22.2	1,766,936	3,580,072
1990	11,687,757	1,235,905	90.4	76.7	12,923,662	15,231,063
1992	862,846	542,537	61.4	35.7	1,405,383	2,418,285
1994	3,257,358	1,409,281	69.8	44.6	4,666,639	7,297,728
1996	3,016,749	1,483,336	67	41.5	4,500,085	7,269,432
1998	3,850,411	1,420,105	73.1	48.6	5,270,516	7,921,813
2000	5,730,913	1,659,028	77.6	54.6	7,389,941	10,487,301
2002	321,468	943,177	25.4	10.6	1,264,645	3,025,531
2004	2,938,308	2,001,123	59.5	33.9	4,939,431	8,675,473
2006	2,123,901	1,190,802	64.1	38.4	3,314,703	5,537,898
2008	1,428,273	862,419	62.4	36.6	2,290,692	3,900,805
2010	2,398,983	2,000,408	54.5	29.5	4,399,391	8,134,098
2012	3,302,575	1,125,692	74.6	50.6	4,428,267	6,529,903
2014	1,890,021	812,376	69.9	44.8	2,702,397	4,219,081
2016	2,182,452	1,326,535	62.2	36.5	3,508,987	5,985,591
Average	4,750,602	1,415,426	67.6	45.1	6,166,028	8,808,589
Median	3,016,749	1,235,905	69.8	44.6	4,500,085	7,297,728
Std. Dev	5,077,015	697,394	16.3	17.4	5,596,916	6,655,020

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the entire set of 214 aerial index streams. Max total run size uses expanded estimate of escapement to account for observer efficiency (0.436) and the proportion of total escapement represented by aerial index streams (0.80). Shaded values were not used in the estimation of descriptive statistics due to lower numbers of streams surveyed.

Table 5.–Harvest, escapement, and total run size estimates used for high and low estimates of harvest rates of odd year wild pink salmon in Prince William Sound, Alaska, 1981–2015.

Year	Harvest	Escapement	Max % harvest	Min % harvest	Min. total run	Max. total run
1981	17,402,547	2,166,319	88.9	73.7	19,568,866	23,613,324
1983	9,564,242	2,003,106	82.7	62.5	11,567,348	15,307,092
1985	17,590,108	2,347,997	88.2	72.3	19,938,105	24,321,751
1987	11,694,727	1,372,217	89.5	74.8	13,066,944	15,628,835
1989	3,510,074	1,233,676	74.0	49.8	4,743,750	7,046,989
1991	5,818,984	1,725,792	77.1	54.0	7,544,776	10,766,782
1993	477,302	1,065,640	30.9	13.5	1,542,942	3,532,463
1995	2,744,024	1,190,184	69.7	44.6	3,934,208	6,156,249
1997	1,163,052	1,422,688	45.0	22.2	2,585,740	5,241,859
1999	6,939,831	2,462,862	73.8	49.6	9,402,693	14,000,789
2001	6,854,291	2,000,386	77.4	54.4	8,854,677	12,589,343
2003	4,497,780	2,846,732	61.2	35.5	7,344,512	12,659,282
2005	12,296,372	4,736,116	72.2	47.5	17,032,488	25,874,686
2007	10,017,855	1,509,133	86.9	69.8	11,526,988	14,344,498
2009	994,708	1,829,623	35.2	15.9	2,824,331	6,240,187
2011	5,715,680	3,927,419	59.3	33.7	9,643,099	16,975,482
2013	17,281,214	4,684,239	78.7	56.3	21,965,453	30,710,798
2015	25,535,256	6,148,422	80.6	59.2	31,683,678	43,162,613
Average	8,894,336	2,481,808	70.6	49.4	11,376,144	16,009,612
Median	6,897,061	2,001,746	75.6	51.9	9,522,896	14,172,643
Std. Dev	6,958,306	1,449,258	17.8	19.0	8,009,283	10,235,206

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the entire set of 214 aerial index streams. Max total run size uses expanded estimate of escapement to account for observer efficiency (0.436) and the proportion of total escapement represented by aerial index streams (0.80).

Table 6.–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 recruits[a]	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 6.–Page 2 of 2.

Brood year	Escapement	Age at return in years: 3 1.1	4 1.2	5 1.3	5 2.2	6 2.3	BY recruits[a]	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	322	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	603	234,816	3.96	175,505
2000	28,446	419	55,977	86,862	169	422	143,849	5.06	115,403
2001	38,547	382	6,618	4,192	711	3,713	15,616	0.41	(22,931)
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	2,135	2,810	6,835	13,516	10,313	25,296	0.83	(5,017)
2006	23,479	2,697	37,325	50,252	1,254	3,005	91,527	3.9	141,016
2007	70,001	8,922	169,080	446,564	2,242	4,289	626,808	8.95	579,041
2008	29,298	91	114,660	49,673	855	130	165,279	5.64	135,981
2009	23,186	1,224	31,100	44,564	1,352	60	78,241	3.37	55,055
2010	24,312	280	59,294	41,178	176	35	100,928	4.15	76,616
2011[c]	102,359	91	169,080	50,252	1,254	10,313			
2012[c]	74,978	1,224	114,660	446,564	2,242	3,005			
2013[c]	17,231	280	31,100	49,673	855	4,289			
2014[c]	21,836	536	59,294	44,564	1,352	130			
2015[c]	13,684	10	31,857	41,178	176	60			
2016[c]	8,708	251	21,174	12,520	0	35			

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 7.–A comparison of Ricker stock-recruitment model estimates from Fair et al. (2011) and the current analysis that used spawner and recruitment data from brood years 1962–2010.

	Current analysis			Fair et al. 2011		
	2.50%	Median	97.50%	L80	Point	U80
ln α	1.23	1.68	2.12	1.37	1.67	1.95
β	5.50E-06	1.30E-05	1.90E-05	8.20E-06	1.30E-05	1.70E-05
σ	0.85	1.03	1.31	0.86	1.04	1.16
S_{EQ}	129,544	176,951	356,906	138,427	172,917	242,315
S_{MSY}	42,956	60,661	126,285	46,366	59,677	86,485
U_{MSY}	0.67	0.77	0.85	0.69	0.76	0.81
MSY	133,217	207,639	402,001	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.

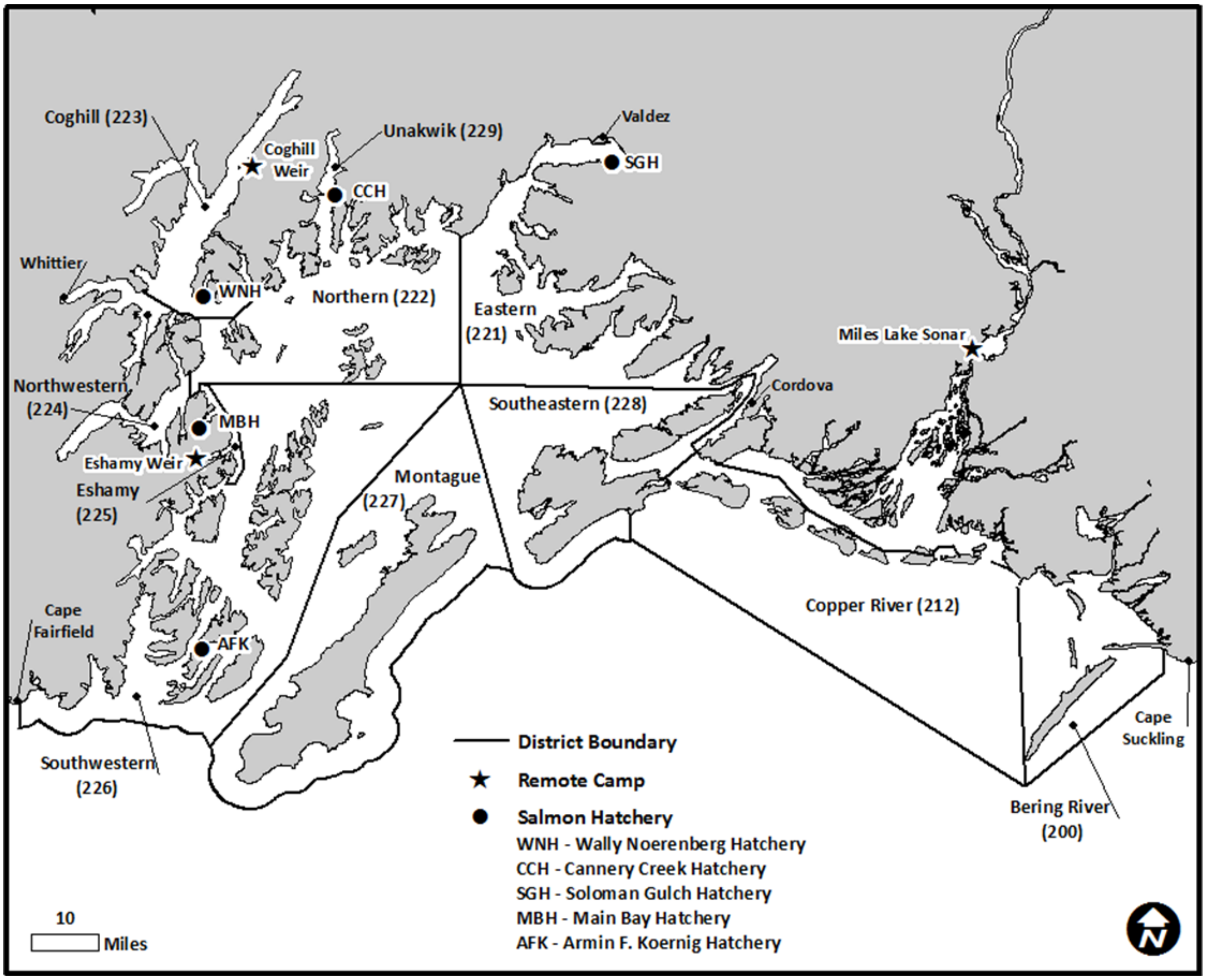


Figure 1.–Prince William Sound Management Area showing commercial fishing districts, salmon hatcheries, weir locations, and Miles Lake sonar camp.

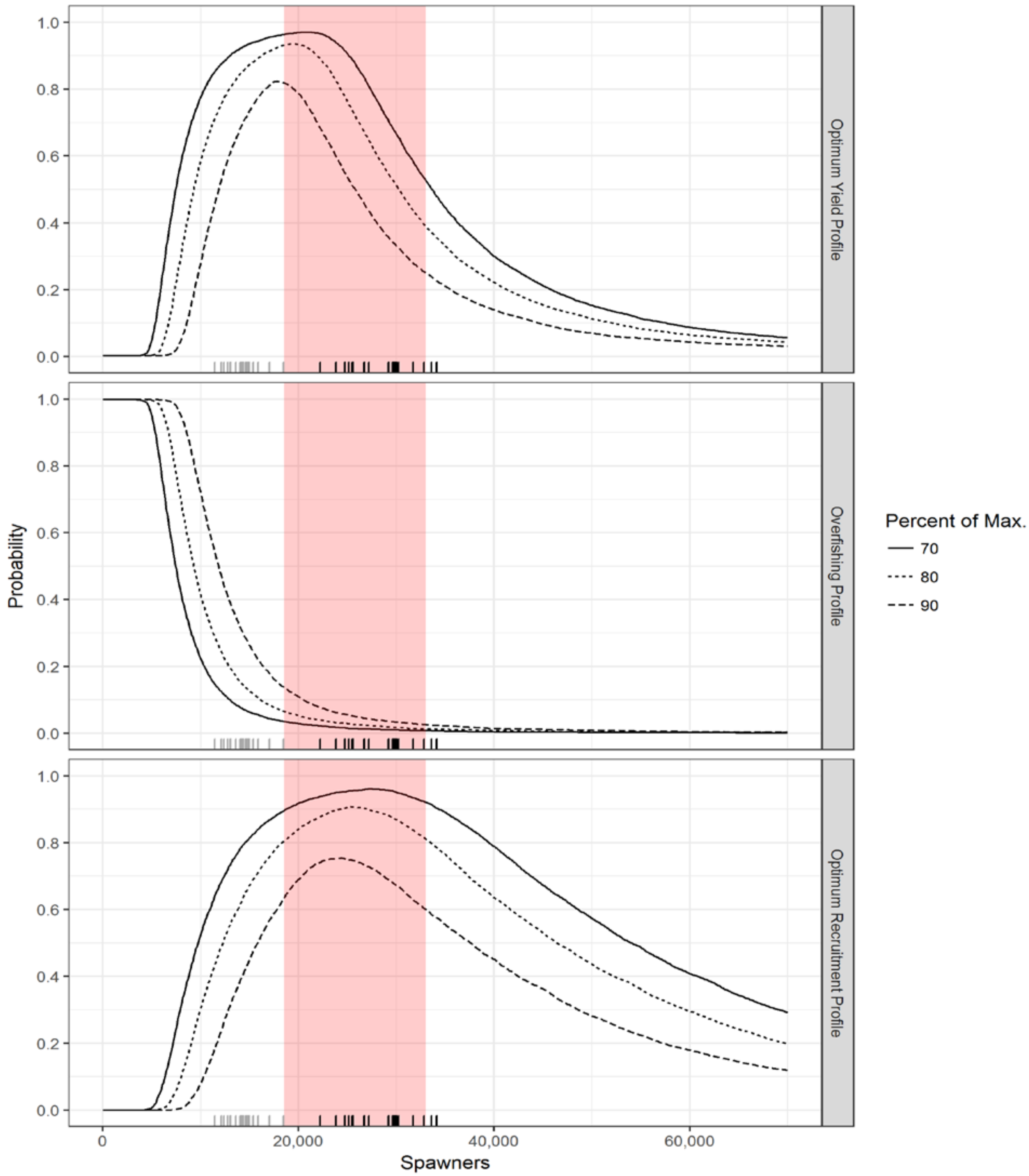


Figure 2.–Optimal yield profiles (OYPs), overfishing profiles (OFPs), and optimal recruitment profiles (ORPs) for Copper River Chinook salmon.

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 S_{MSY} ratios (see Savereide et al. *unpublished*).

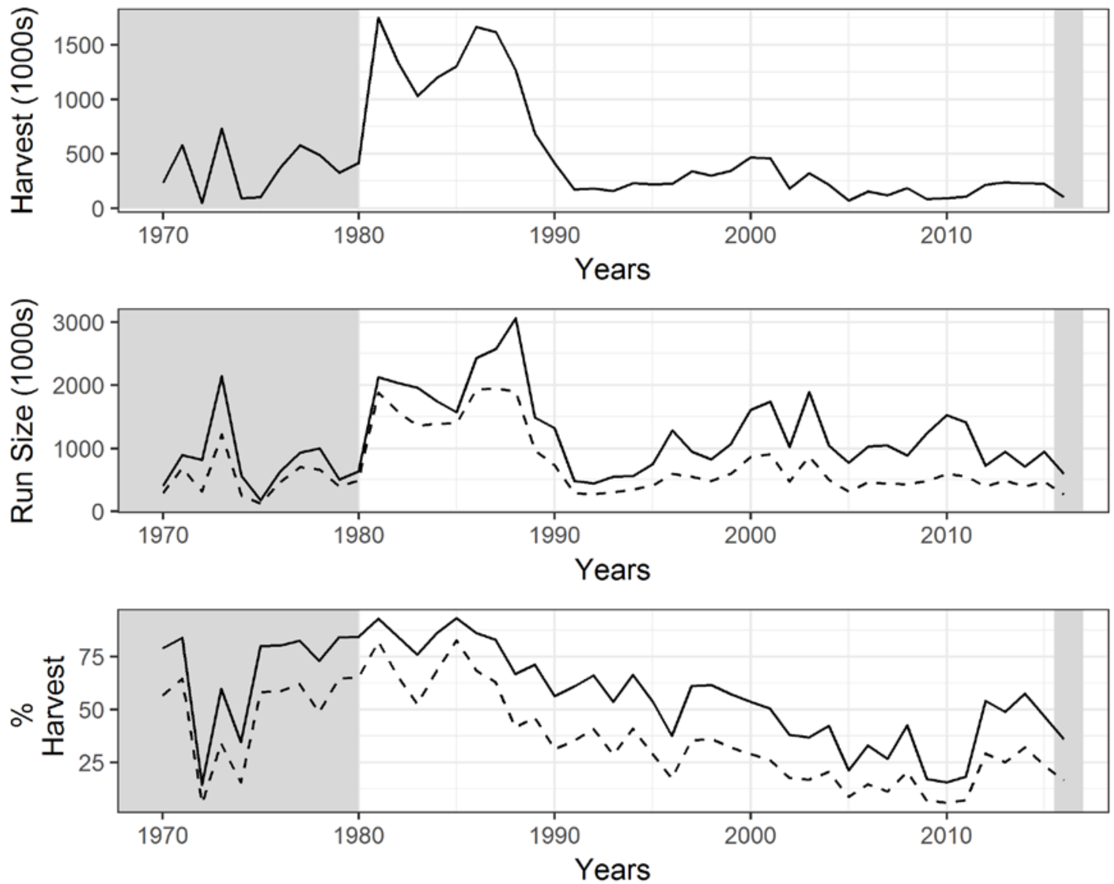


Figure 3.–Estimated harvest, high and low estimates of run size, and high and low estimates of harvest rate (% harvest of run) for PWS wild chum salmon.

Note: Run size = harvest + escapement. The high estimate of the run size using an expanded estimate of escapement to account for observer efficiency and the proportion of total escapement of the aerial index streams (adjusted AUC/0.436/0.80). For the low estimate of run sizes, escapement is only adjusted for stream life only (adjusted AUC). The high estimate of % harvest uses the low estimate of run size and vice versa. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

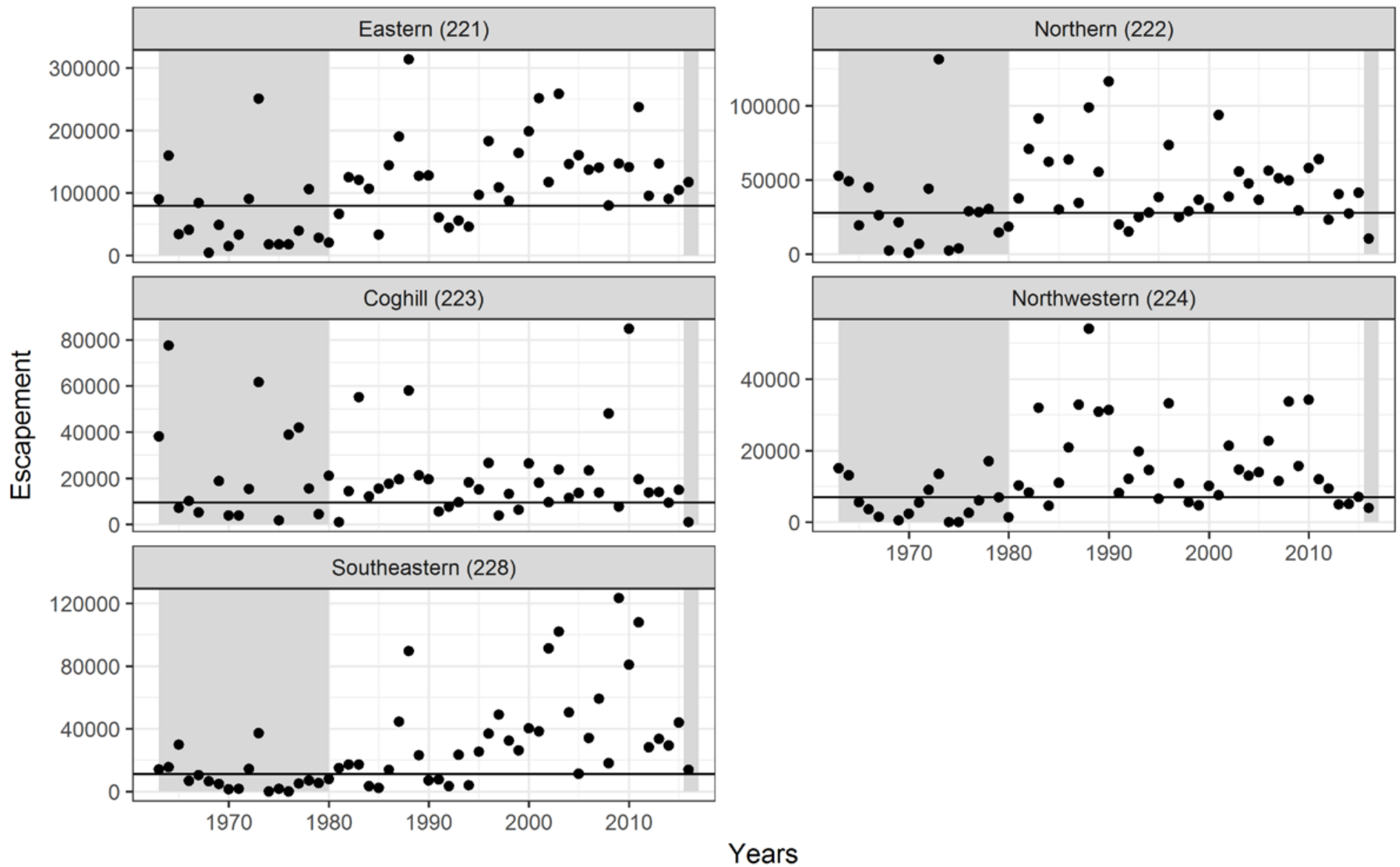


Figure 4.–Annual escapement estimates (dots) for PWS wild chum salmon and 20th percentile (line) of escapements (1963–2016) for districts; district numbers in parentheses.

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the reduced subset of ~134 aerial index streams set in 2015. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

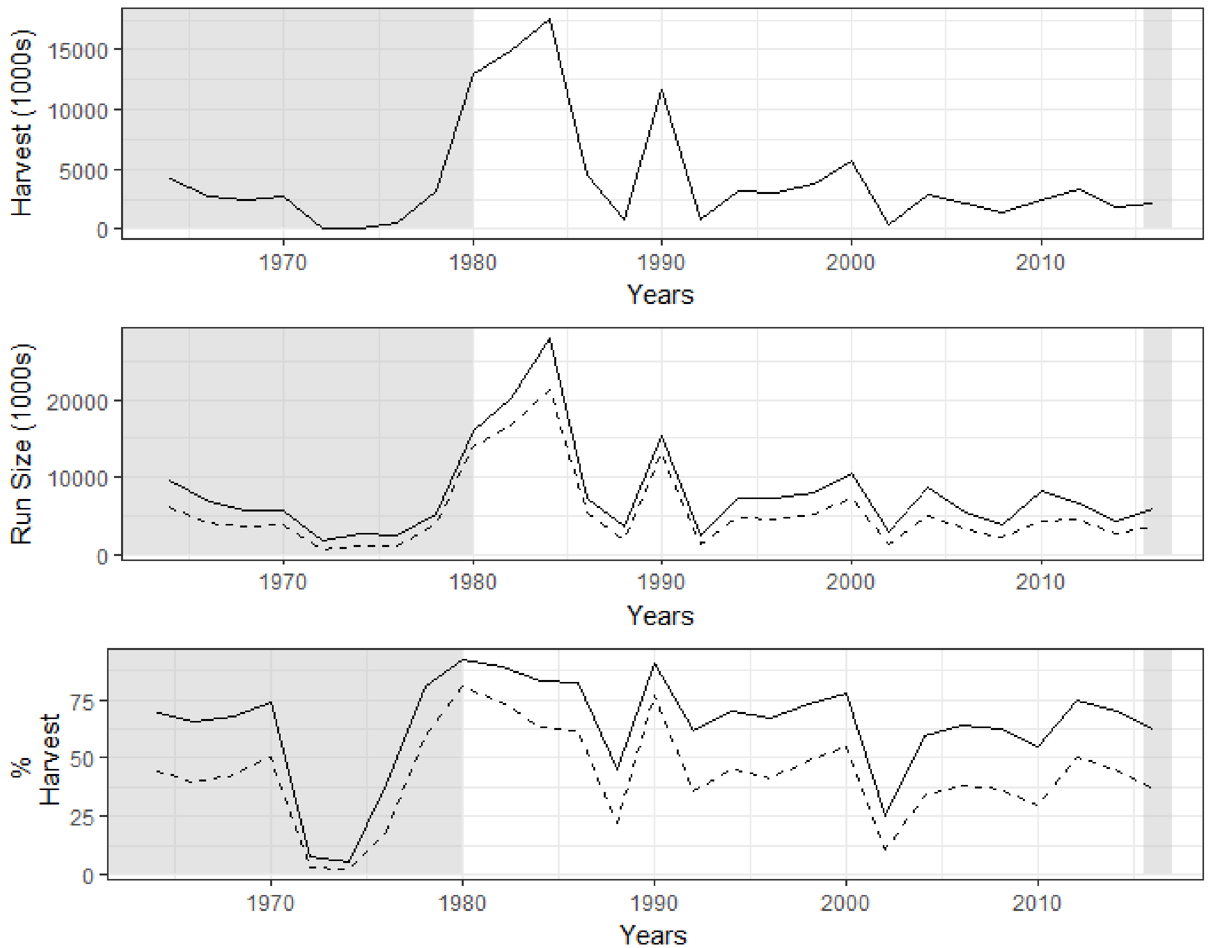


Figure 5.–Estimated harvest, high and low estimates of run size, and high and low estimates of harvest rate (% harvest of run) for even year wild pink salmon in PWS.

Note: Run size = harvest + escapement. The high estimate of the run size using an expanded estimate of escapement to account for observer efficiency and the proportion of total escapement of the aerial index streams (adjusted AUC/0.436/0.80). For the low estimate of run sizes, escapement is only adjusted for stream life only (adjusted AUC). The high estimate of % harvest uses the low estimate of run size and vice versa. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

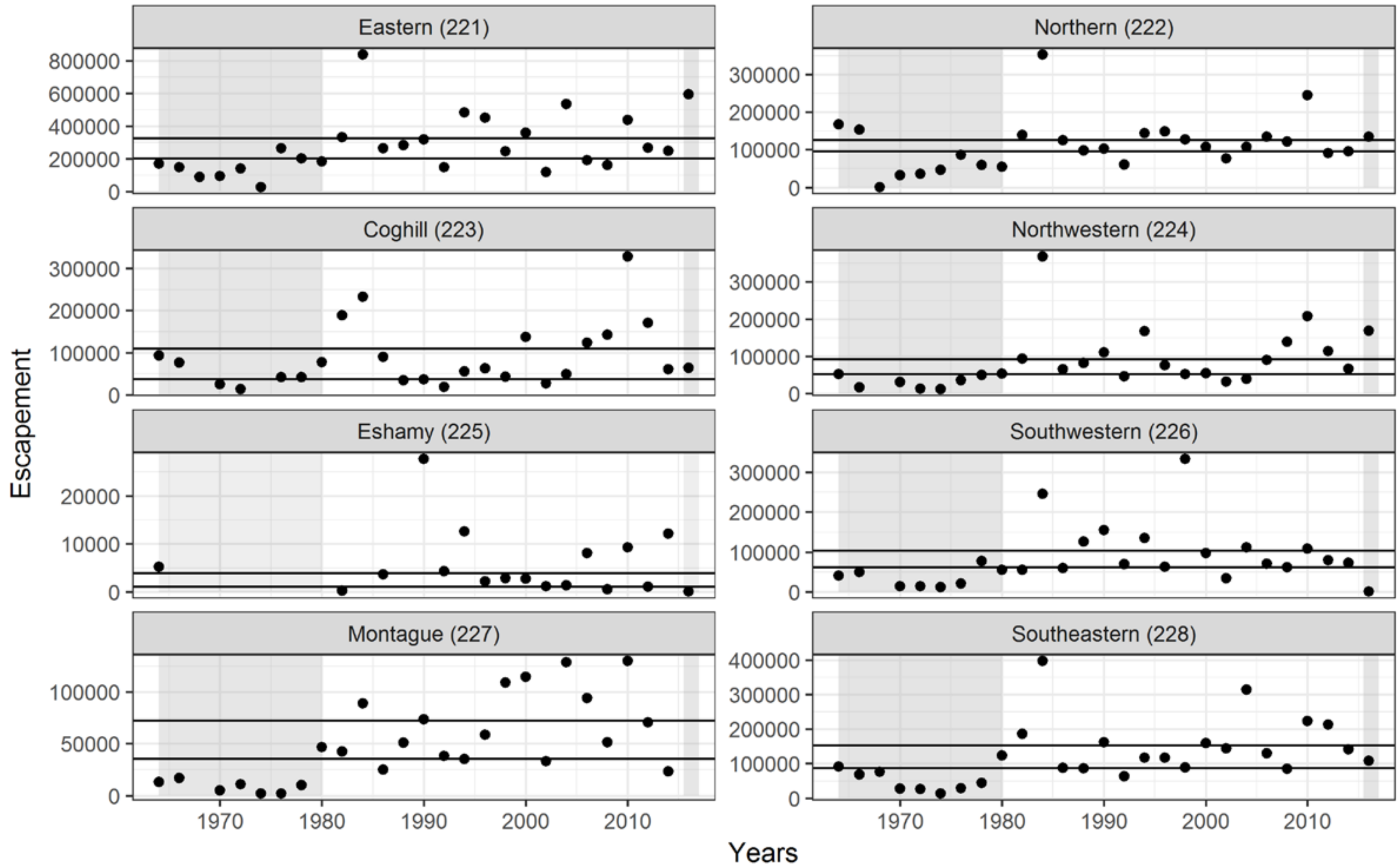


Figure 6.–Annual escapement estimates (dots) for PWS wild even-year pink salmon and 20th and 60th percentiles (lines) of escapements (1963–2016) for districts; district numbers in parentheses.

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the reduced subset of 134 aerial index streams set in 2015. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

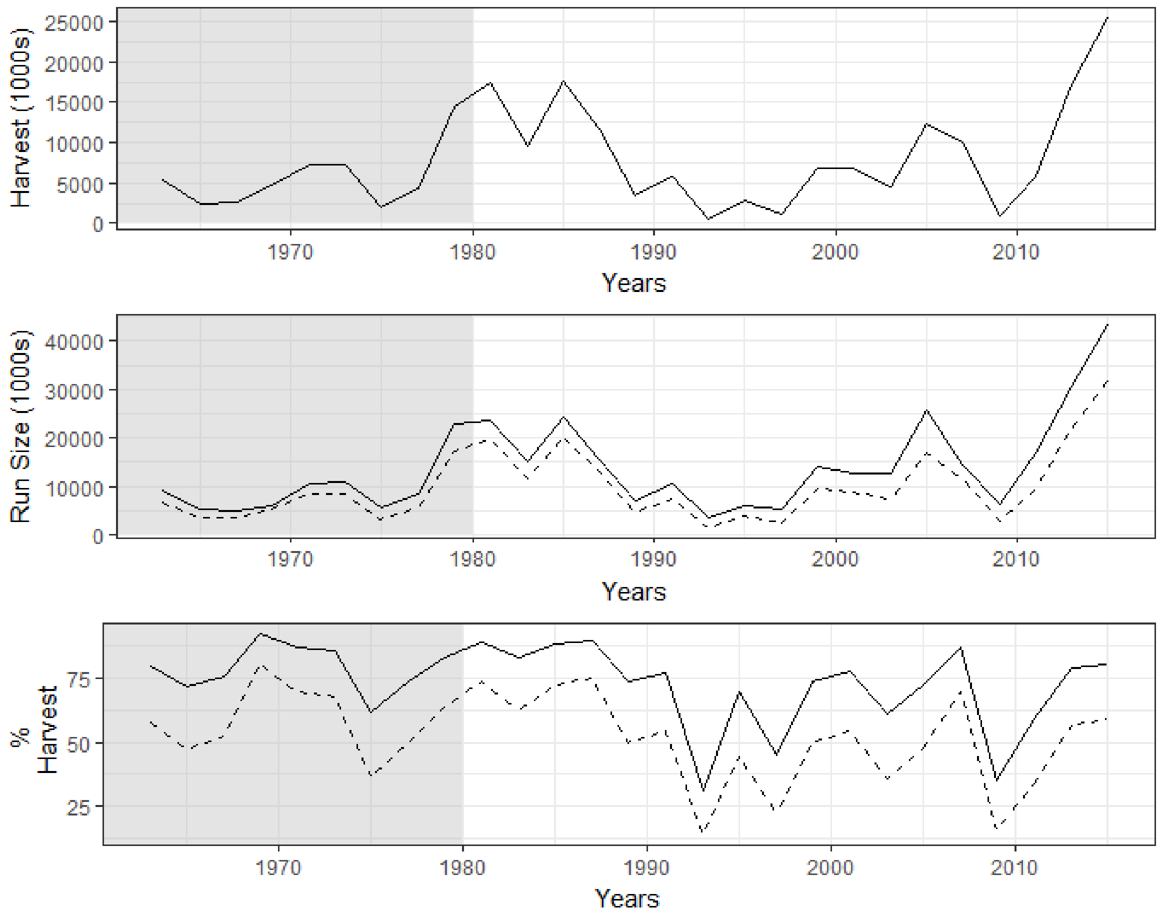


Figure 7.–Estimated harvest, high and low estimates of run size, and high and low estimates of harvest rate (% harvest of run) for <u>odd year</u> wild pink salmon in PWS.

Note: Run size = harvest + escapement. The high estimate of the total run size using an expanded estimate of escapement to account for observer efficiency and the proportion of total escapement of the aerial index streams (adjusted AUC/0.436/0.80). For the low estimate of run sizes, escapement is only adjusted for stream life (adjusted AUC). The high estimate of % harvest uses the low estimate of run size and vice versa. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

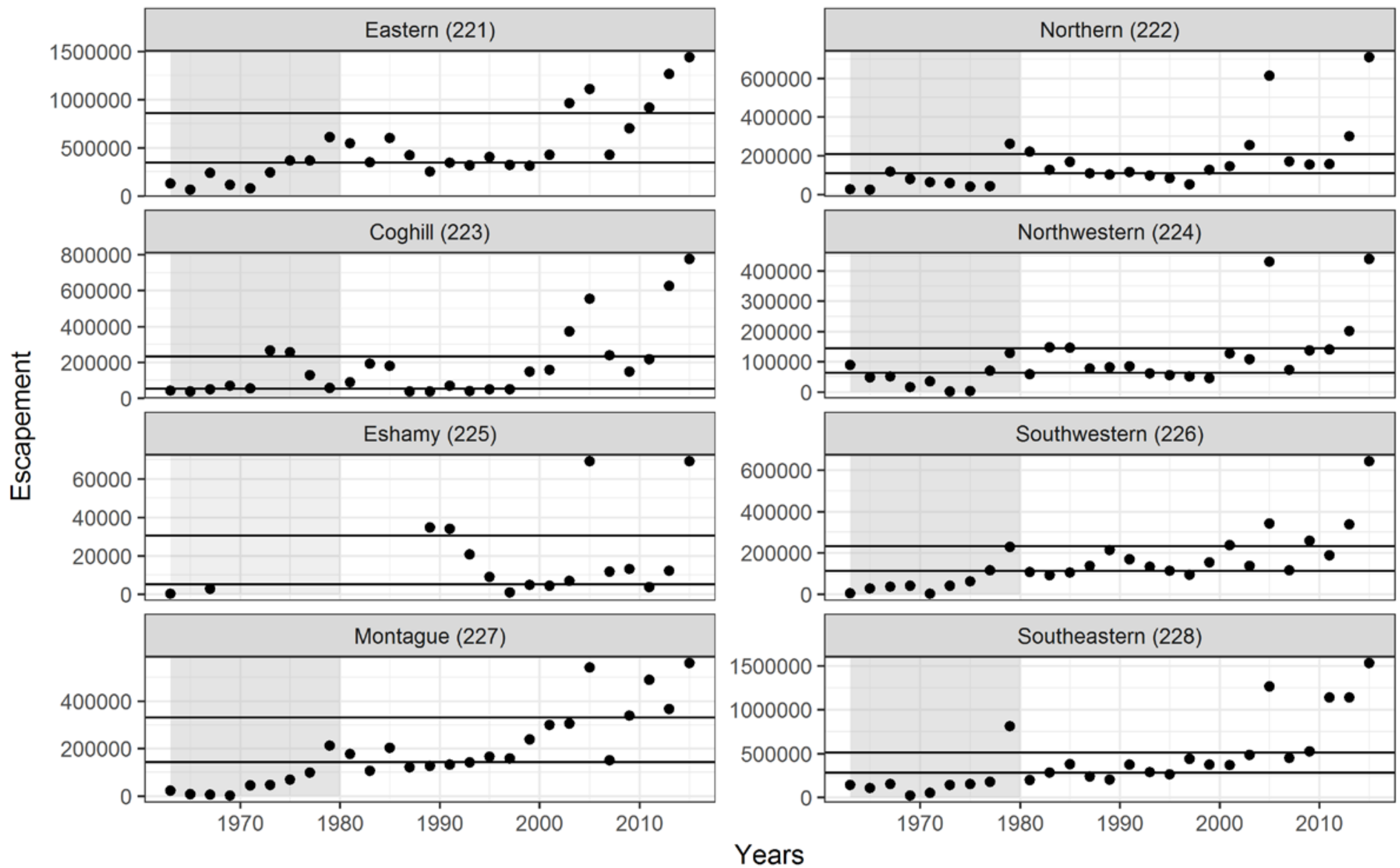


Figure 8.–Annual escapement estimates (dots) for odd-year wild PWS pink salmon and 25th and 75th percentiles (lines) of escapements (1963–2016) for districts; district numbers in parentheses.

Note: Escapement estimates are area-under-the-curve adjusted for stream life (adjusted-AUC) and based on the reduced subset of 134 aerial index streams set in 2015. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

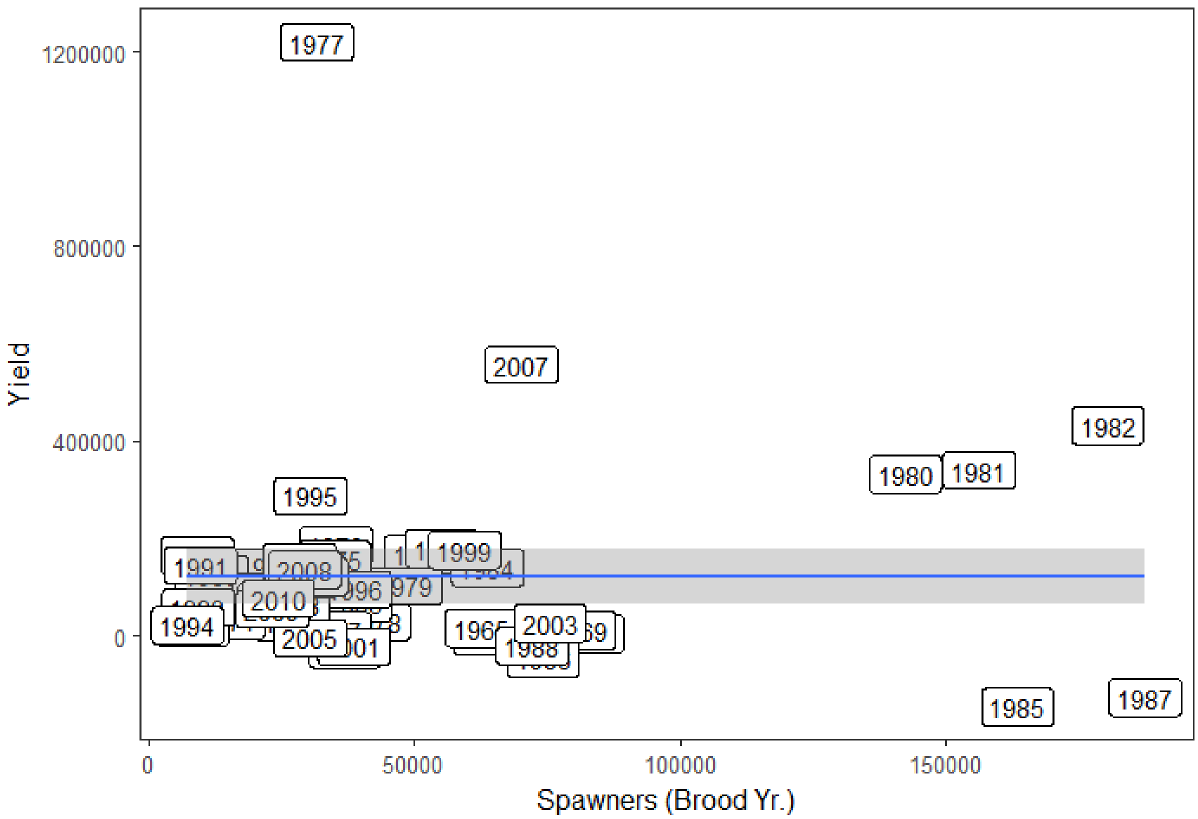


Figure 9.–Coghill Lake sockeye salmon yield (return minus spawners; y-axis) vs. brood-year spawning escapement (Spawners; x-axis).

Note: Data include sockeye salmon brood years 1962–2010. The best fit line from a generalized additive model (GAM) is shown in blue with 95% confidence interval in grey. The lack of inflection in the line indicates that yield is relatively constant across the entire range of spawners.

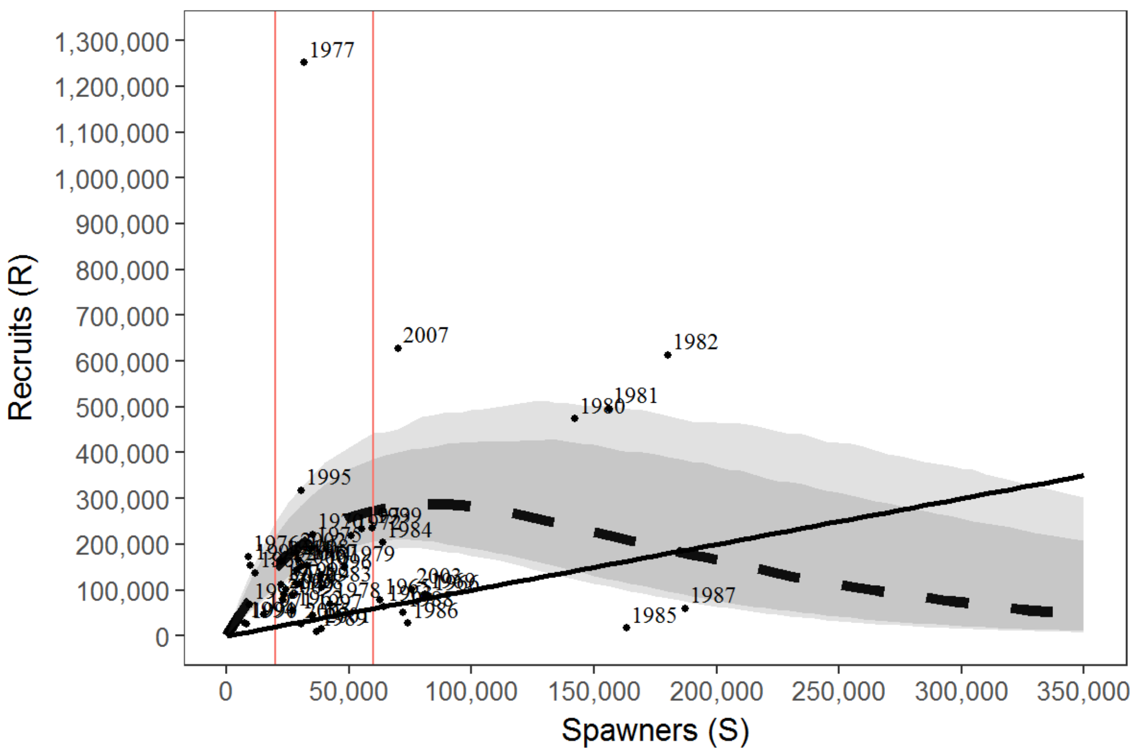


Figure 10.–Plausible spawner-recruit relationships for Coghill Lake sockeye salmon as derived from a Bayesian stock-recruit analysis for brood years 1962–2010.

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 20,000–60,000 spawners.

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

Appendix A1.–Supporting information for analysis of escapement goal for Copper River Chinook salmon.

System: Copper River

Species: Chinook salmon

Data available for analysis of escapement goals.

Brood year	Measured escapement[a]	Total run
1999	16,157	95,951
2000	24,492	70,754
2001	28,208	81,155
2002	21,502	72,974
2003	34,034	94,505
2004	30,645	80,559
2005	21,528	66,357
2006	58,454	99,877
2007	34,575	87,770
2008	32,485	53,880
2009	27,781	43,001
2010	16,771	33,181
2011	27,993	53,890
2012	27,911	44,312
2013	28,727	42,645
2014	20,840	35,453
2015	26,607	56,017
2016	12,534	29,634

Note: Current goal is a lower-bound sustainable escapement goal (SEG) of >24,000 Chinook salmon and a change to a range of 18,500–33,000 is recommended.

[a] Estimated by mark–recapture minus upriver harvests.

Appendix A2.–Supporting information for analysis of escapement goal for Prince William Sound chum salmon.

System: Prince William Sound

Species: chum salmon

Data available for analysis of escapement goals

	Wild escapements [a]									
Year	Eastern[b]	Eastern[c]	Northern[b]	Northern[c]	Coghill[b]	Coghill[c]	Northwestern[b]	Northwestern[c]	Southeastern[b]	Southeastern[c]
1980	21,936	20,198	19,409	18,544	22,066	21,165	1,419	1,419	8,444	7,829
1981	67,495	65,913	37,538	37,442	1,075	1,000	10,302	10,302	15,221	14,933
1982	129,714	124,757	71,708	70,698	14,368	14,368	8,345	8,345	17,312	17,262
1983	125,323	120,689	91,371	91,188	55,119	55,119	32,022	32,022	17,490	17,240
1984	106,972	106,352	63,824	62,128	12,094	12,094	4,645	4,645	3,577	3,577
1985	33,379	32,743	30,782	30,068	15,735	15,656	11,052	11,052	2,552	2,220
1986	146,366	143,518	64,899	63,518	17,670	17,604	20,902	20,878	14,108	13,909
1987	194,849	189,502	38,016	34,388	19,962	19,654	32,986	32,807	44,951	44,617
1988	321,022	313,522	100,841	98,884	58,605	57,921	54,155	54,072	89,588	89,549
1989	128,973	126,836	59,328	55,440	21,253	21,240	31,504	30,827	23,571	23,093
1990	131,099	127,676	118,933	116,265	22,823	19,588	31,955	31,340	7,501	7,181
1991	63,849	60,686	20,830	19,954	5,846	5,572	8,223	8,211	7,692	7,692
1992	47,992	43,953	15,424	15,189	8,264	7,677	12,123	12,107	3,626	3,559
1993	57,942	55,691	24,866	24,863	9,769	9,642	19,929	19,810	23,571	23,555
1994	47,409	45,947	28,199	27,949	18,274	18,178	14,791	14,633	4,307	4,108
1995	96,684	96,443	38,586	38,405	15,343	15,258	6,575	6,575	25,643	25,417
1996	182,767	182,383	75,829	73,362	26,703	26,703	33,179	33,143	42,619	36,971
1997	109,494	108,477	25,451	25,133	3,947	3,822	10,870	10,867	57,979	49,101
1998	88,713	87,383	29,264	28,855	13,380	13,278	5,683	5,552	35,808	32,365
1999	168,474	163,516	37,151	36,727	6,458	6,426	4,748	4,748	26,605	26,164
2000	205,680	198,132	31,198	31,074	26,682	26,540	10,214	10,145	44,278	40,448
2001	256,917	250,878	101,863	93,667	18,402	18,033	7,613	7,613	43,125	38,322
2002	120,070	116,992	39,837	38,763	9,574	9,560	21,497	21,427	97,910	91,469
2003	283,181	258,516	60,046	55,648	24,566	23,839	15,886	14,747	137,182	102,106

-continued-

Appendix A2.–Page 2 of 2.

System: Prince William Sound

Species: chum salmon

Data available for analysis of escapement goals

	Wild escapements [a]									
Year	Eastern[b]	Eastern[c]	Northern[b]	Northern[c]	Coghill[b]	Coghill[c]	Northwestern[b]	Northwestern[c]	Southeastern[b]	Southeastern[c]
2004	149,896	146,246	53,827	47,487	11,778	11,614	13,040	13,040	56,457	50,507
2005	161,276	160,064	39,444	36,641	14,911	13,571	15,482	13,994	12,141	11,471
2006	141,999	136,562	60,265	56,259	23,987	23,465	22,742	22,710	38,091	34,085
2007	144,941	140,595	54,709	51,168	14,738	13,757	12,570	11,499	71,595	59,199
2008	82,068	79,450	50,666	49,595	48,221	48,008	34,107	33,635	20,300	18,142
2009	150,051	146,577	30,296	29,464	8,290	7,763	15,826	15,730	150,974	123,607
2010	146,613	140,940	59,530	58,029	84,840	84,752	34,300	34,131	138,442	80,927
2011	240,321	237,372	64,743	63,876	19,617	19,614	11,951	11,951	112,507	107,857
2012	97,362	94,986	23,818	23,273	14,075	13,896	9,360	9,360	31,029	28,374
2013	150,044	146,349	41,058	40,475	14,414	14,086	4,995	4,995	43,000	33,678
2014	93,491	90,445	27,680	27,385	9,491	9,491	5,041	5,041	30,177	29,362
2015	112,142	104,437	43,179	41,253	15,444	14,929	7,321	7,060	52,031	44,095
2016	131,168	116,685	10,746	10,410		976	4,100	3,954	26,127	13,919
Mean	133,514	129,576	49,289	47,585	20,216	19,858	16,593	16,401	43,095	37,333
Median	129,343	125,797	40,447	39,619	15,393	15,094	12,346	12,029	30,603	28,868
Max	321,022	313,522	118,933	116,265	84,840	84,752	54,155	54,072	150,974	123,607
Min	21,936	20,198	15,424	15,189	1,075	1,000	1,419	1,419	2,552	2,220
Contrast	15	16	8	8	79	85	38	38	59	56
Q20	82,000	79,000	28,000	28,000	10,000	10,000	7,000	7,000	12,000	11,000
Q60	145,000	141,000	54,000	50,000	18,000	18,000	15,000	15,000	43,000	34,000

Note: Current goals are district-specific lower-bound sustainable escapement goals (SEG): Eastern >50,000; Northern/Unakwik >20,000; Coghill >8,000; Northwestern >5,000; Southeastern >8,000. Q20 and Q60 refer to the 20th and 60th quartiles (percentiles), respectively, rounded to the nearest 1,000. We recommend changing these goals to a lower bound SEG at the 20th percentile (Q20).

[a] The chum salmon escapement index is the area under the curve of weekly aerial survey counts adjusted for stream life (adjusted AUC). Only 1980–2015 data included in escapement goal analysis and summary statistics.

[b] Escapement indices calculated using 214 aerial index streams.

[c] Escapement indices calculated using 134 aerial index streams.

Appendix A3.–Supporting information for analysis of escapement goal for Copper River Delta coho salmon.

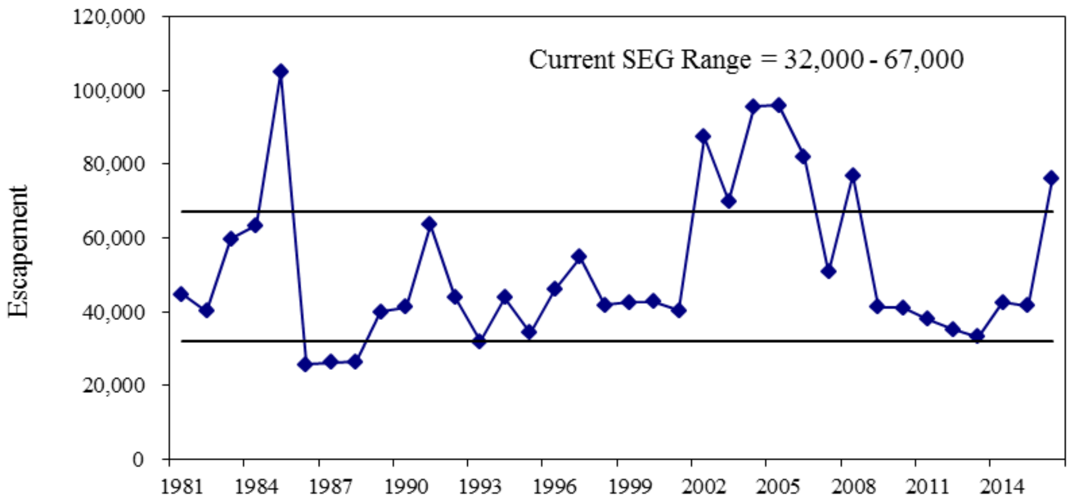
District: Copper River Delta
Species: coho salmon
Data available for analysis of escapement goals.

Return	Wild	Harvest	
year	escapement [a]	commercial [b]	Sport [c]
1981	44,800	225,299	
1982	40,175	310,154	
1983	59,700	454,763	84
1984	63,425	234,243	1,780
1985	104,910	382,432	649
1986	25,790	295,980	2,969
1987	26,215	111,599	1,010
1988	26,450	315,568	1,492
1989	39,895	194,454	2,118
1990	41,280	246,797	1,778
1991	63,650	385,086	1,941
1992	44,005	291,627	3,854
1993	31,870	281,469	4,139
1994	43,910	677,633	4,293
1995	34,380	542,658	2,543
1996	46,070	193,302	5,750
1997	54,740	18,656	2,825
1998	41,750	108,246	4,230
1999	42,505	132,797	6,978
2000	42,785	304,944	4,479
2001	40,286	256,638	12,144
2002	87,415	504,410	6,909
2003	70,055	363,489	14,443
2004	95,555	467,861	14,643
2005	95,892	263,584	9,799
2006	82,040	318,422	5,531
2007	50,715	117,522	6,749
2008	76,892	202,989	7,763
2009	41,294	208,493	14,420
2010	41,077	211,772	15,866
2011	37,900	128,054	14,304
2012	35,295	131,298	15,230
2013	33,130	245,234	17,053
2014	42,530	316,922	16,226
2015	41,665	138,404	16,170
2016	76,200	368,983	NA

[a] Escapement indices calculated as peak aerial survey from the 17 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-

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



Appendix A4.–Supporting information for analysis of escapement goal for Bering River District coho salmon.

District: Bering River

Species: coho salmon

Data available for analysis of escapement goals.

Return year	Wild escapement [a]	Commercial harvest [b,c]
1982	18,500	144,752
1983	11,900	117,669
1984	13,000	214,632
1985	66,500	419,276
1986	7,620	115,809
1987	3,985	15,864
1988	10,855	86,539
1989	14,600	26,952
1990	21,840	42,952
1991	27,300	110,951
1992	13,540	125,616
1993	25,650	115,833
1994	24,050	259,003
1995	22,950	282,045
1996	20,000	93,763
1997	34,400	97
1998	24,700	12,284
1999	28,290	9,954
2000	23,580	56,329
2001	27,107	2,715
2002	29,200	108,522
2003	22,475	59,481
2004	23,685	95,595
2005	32,442	43,030
2006	24,292	56,723
2007	27,452	9,305
2008	28,932	40,380
2009	22,141	45,542
2010	21,311	80,642
2011	18,890	19,966
2012	15,605	46,324
2013	18,020	46,959
2014	26,475	97,679
2015	15,550	12,116
2016	26,150	80,379

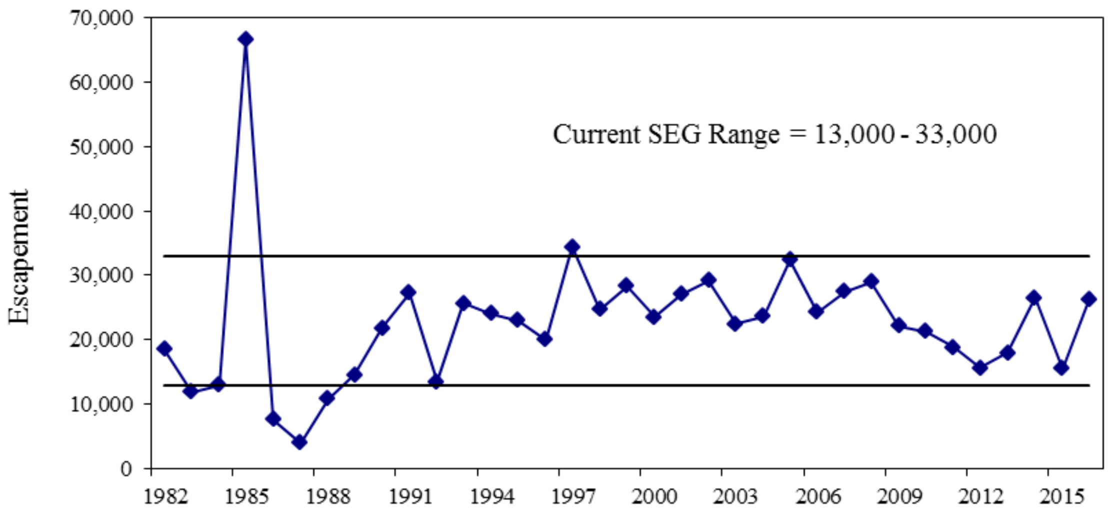
[a] Escapement indices calculated as peak aerial survey from the 7 primary index systems.

[b] The Kayak Island Subdistrict closed to commercial fishing in 1986.

[c] Harvest in the Bering River District, not stock specific.

-continued-

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



Appendix A5.–Supporting information for analysis of escapement goals for Prince William Sound even-year pink salmon.

District: Prince William Sound

Species: pink salmon

Stock unit: even year

Data available for analysis of escapement goals.

Brood year	Eastern[a]	Eastern[b]	Northern/Unakwik[a]	Northern/Unakwik[b]	Coghill[a]	Coghill[b]	Northwestern[a]	Northwestern[b]	Eshamy[a]	Eshamy[b]
1982	354,042	333,392	156,608	139,533	193,840	188,841	96,000	93,998	467	288
1984	892,860	839,339	409,956	353,175	263,469	232,592	376,235	367,782		
1986	281,759	266,051	133,557	125,507	92,576	89,825	67,128	65,328	3,690	3,690
1988	305,874	283,057	121,437	98,261	36,136	34,004	83,891	82,126		
1990	355,517	320,285	119,496	103,386	39,992	36,181	114,039	110,549	27,731	27,731
1992	158,390	150,193	66,839	61,195	19,689	18,324	47,378	46,766	4,310	4,310
1994	510,534	485,152	161,750	143,478	57,798	55,116	170,810	168,058	12,624	12,604
1996	481,669	450,974	169,817	148,585	65,756	63,240	78,116	76,696	2,207	2,207
1998	261,270	246,423	141,024	127,375	43,761	42,434	52,795	51,978	2,952	2,852
2000	401,677	360,133	120,609	107,466	138,376	137,665	54,871	54,523	2,772	2,772
2002	130,014	119,689	82,461	77,126	26,778	26,572	33,083	32,839	1,158	1,157
2004	575,573	534,679	120,575	107,478	51,747	49,050	41,837	39,153	1,414	1,364
2006	217,532	192,217	162,570	134,672	127,451	123,881	91,268	90,347	8,465	8,056
2008	193,844	161,710	141,527	121,502	145,177	142,733	141,787	138,968	579	579
2010	488,603	437,191	286,256	244,810	335,816	328,447	211,709	207,490	10,002	9,261
2012	301,709	268,432	104,872	91,211	172,611	170,752	117,795	114,518	1,052	1,052
2014	270,244	250,381	105,843	95,643	63,290	60,921	67,030	66,350	12,400	12,167
2016	617,999	594,778	137	135,037	63,986	63,986	168,272	168,272	100	100
Mean	363,595	335,253	153,247	134,141	110,251	105,916	108,575	106,322	6,122	6,006
Median	305,874	283,057	133,557	121,502	65,756	63,240	83,891	82,126	2,952	2,852
Max	892,860	839,339	409,956	353,175	335,816	328,447	376,235	367,782	27,731	27,731
Min	130,014	119,689	66,839	61,195	19,689	18,324	33,083	32,839	467	288
Contrast	7	7	6	6	17	18	11	11	59	96
Q20	226,000	203,000	109,000	96,000	41,000	37,000	53,000	52,000	1,000	1,000
Q60	355,000	328,000	141,000	127,000	114,000	110,000	94,000	93,000	4,000	4,000

-continued-

Appendix A5.–Page 2 of 3.

District: Prince William Sound

Species: pink salmon

Stock unit: even year

Data available for analysis of escapement goals.

Brood year	Southwestern[a]	Southwestern[b]	Montague[a]	Montague[b]	Southeastern[a]	Southeastern[b]	Total[a]	Total[b]
1982	78,292	55,611	57,444	42,506	239,639	186,455	1,176,332	1,040,624
1984	285,374	246,298	109,215	89,130	497,231	396,810	2,834,340	2,525,125
1986	62,888	59,630	27,303	24,939	102,331	87,771	771,231	722,741
1988	142,992	126,318	58,603	50,927	113,316	86,037	862,250	760,729
1990	207,706	155,093	80,358	73,511	248,607	162,204	1,193,445	988,938
1992	88,326	69,782	41,266	38,170	72,986	64,113	499,184	452,851
1994	152,409	135,104	39,997	35,114	148,049	116,949	1,253,970	1,151,575
1996	71,868	63,175	69,363	58,570	159,728	116,870	1,098,524	980,319
1998	383,392	333,787	131,553	109,016	123,093	88,655	1,139,839	1,002,519
2000	115,494	97,918	150,442	114,597	199,591	158,708	1,183,833	1,033,782
2002	36,627	33,847	38,658	33,121	180,203	143,375	528,982	467,726
2004	136,527	111,427	146,219	128,553	401,417	314,418	1,475,309	1,286,122
2006	81,301	70,426	109,597	94,143	154,501	129,858	952,686	843,600
2008	70,230	61,820	56,999	51,571	112,347	85,869	862,490	764,753
2010	126,421	109,012	143,362	129,968	310,676	223,178	1,912,844	1,689,357
2012	90,156	79,774	77,756	70,695	258,047	213,071	1,123,997	1,009,505
2014	84,607	73,104	24,917	23,136	185,072	141,845	813,402	723,548
2016	1,250	1,250			107,769	107,769		1,071,192
Mean	130,271	110,713	80,179	68,686	206,284	159,776	1,157,803	1,026,107
Median	90,156	79,774	69,363	58,570	180,203	141,845	1,123,997	988,938
Max	383,392	333,787	150,442	129,968	497,231	396,810	2,834,340	2,525,125
Min	36,627	33,847	24,917	23,136	72,986	64,113	499,184	452,851
Contrast	10	10	6	6	7	6	6	6
Q20	73,000	62,000	40,000	36,000	115,000	88,000	823,000	731,000
Q60	122,000	105,000	80,000	72,000	194,000	153,000	1,162,000	1,007,000

-continued-

Note: Escapement indices are area-under-the-curve adjusted for stream life for the reduced set of aerial index streams (134) set in 2015 due to state budget cuts. Escapement estimates were only collected for streams with 3 or more surveys per year. Hatchery strays are not accounted for in calculating these indices. Q20 and Q60 refer to the 20th and 60th quartiles (percentiles), respectively, rounded to the nearest 1,000. Current goals are district specific sustainable escapement goals (SEG) and a change in the goal to the 20th and 60th percentiles is recommended for all districts. Shaded areas indicate years not used in the calculation of percentiles due to low numbers of aerial surveys for 1 or more districts.

[a] Escapement indices calculated using 214 aerial index streams.

[b] Escapement indices calculated using 134 aerial index streams.

Appendix A6.–Supporting information for analysis of escapement goals for Prince William Sound odd-year pink salmon.

District: Prince William Sound

Species: pink salmon

Stock unit: odd year

Data available for analysis of escapement goals.

Brood year	Eastern[a]	Eastern[b]	Northern/Unakwik[a]	Northern/Unakwik[b]	Coghill[a]	Coghill[b]	Northwestern[a]	Northwestern[b]	Eshamy[a]	Eshamy[b]
1981	597,420	543,023	225,935	221,272	88,026	87,281	59,757	58,123		
1983	390,025	347,486	136,747	127,242	198,313	191,220	152,923	147,170		
1985	666,574	598,507	179,457	166,714	184,942	179,321	150,658	145,410		
1987	479,042	421,972	122,076	109,380	37,943	36,410	80,115	77,296		
1989	284,981	250,082	109,159	101,436	38,824	37,487	82,816	81,846	34,600	34,600
1991	395,868	345,169	123,061	114,718	72,708	68,899	85,051	83,940	33,941	33,941
1993	345,957	315,598	105,273	96,955	41,568	38,498	62,231	61,353	20,785	20,700
1995	449,011	402,264	92,699	84,312	50,330	49,310	55,338	54,656	9,000	8,990
1997	361,605	322,445	53,236	50,427	49,186	48,374	50,170	49,982	853	853
1999	349,095	310,051	134,277	126,575	148,308	147,845	45,887	45,282	4,805	4,795
2001	475,531	424,655	159,286	144,113	159,284	157,927	127,548	126,442	4,448	4,413
2003	1,099,747	964,355	269,533	253,962	374,275	370,688	123,514	108,073	7,039	6,954
2005	1,237,187	1,109,422	698,764	613,712	583,339	553,954	446,760	430,024	70,451	69,175
2007	469,875	424,938	192,345	169,596	252,441	238,770	78,010	72,040	12,184	11,727
2009	757,211	700,027	169,556	152,979	153,671	147,498	141,636	137,036	13,215	12,966
2011	982,215	916,690	163,306	156,362	220,777	217,560	140,534	139,334	3,643	3,643
2013	1,371,111	1,266,630	319,421	299,592	640,414	625,991	203,444	201,836	12,145	12,145
2015	1,457,403	1,440,254	713,639	708,920	775,488	775,488	438,944	438,944	68,988	68,988
Mean	676,103	616,865	220,432	205,459	226,102	220,696	140,296	136,599	21,150	20,992
Median	477,286	424,797	161,296	148,546	156,478	152,886	104,283	96,007	12,165	11,936
Max	1,457,403	1,440,254	713,639	708,920	775,488	775,488	446,760	438,944	70,451	69,175
Min	284,981	250,082	53,236	50,427	37,943	36,410	45,887	45,282	853	853
Contrast	5	6	13	14	20	21	10	10	83	81
Q25	391,000	346,000	122,000	111,000	56,000	54,000	66,000	64,000	5,000	5,000
Q75	926,000	863,000	218,000	208,000	245,000	233,000	148,000	144,000	31,000	31,000

-continued-

District: Prince William Sound
Species: pink salmon
Stock unit: odd year
Data available for analysis of escapement goals.

Brood year	Southwestern[a]	Southwestern[b]	Montague[a]	Montague[b]	Southeastern[a]	Southeastern[b]	Total[a]	Total[b]
1981	115,910	106,757	213,430	176,488	244,936	199,729	1,545,414	1,392,673
1983	111,222	91,123	123,340	105,172	416,817	284,749	1,529,388	1,294,162
1985	123,788	104,184	240,337	202,946	495,966	378,249	2,041,721	1,775,331
1987	156,951	137,040	141,204	120,511	311,699	239,862	1,329,030	1,142,471
1989	247,189	212,757	151,947	126,294	268,396	205,178	1,217,914	1,049,680
1991	213,095	169,162	172,242	132,545	499,015	373,277	1,594,981	1,321,651
1993	148,383	130,824	164,523	140,902	357,712	289,492	1,246,432	1,094,323
1995	130,599	111,495	185,437	165,572	358,928	261,894	1,331,342	1,138,494
1997	109,991	92,913	175,716	158,475	555,440	437,989	1,356,197	1,161,458
1999	166,561	153,763	263,194	237,219	475,700	372,836	1,587,826	1,398,366
2001	325,004	237,739	375,344	299,577	512,564	367,359	2,139,009	1,762,225
2003	169,521	136,902	336,766	304,685	625,766	485,550	3,006,161	2,631,169
2005	385,063	340,708	630,990	540,669	1,740,542	1,265,986	5,793,096	4,923,650
2007	139,824	115,112	179,368	149,881	596,225	448,990	1,920,273	1,631,054
2009	338,788	258,404	415,262	338,998	685,837	524,415	2,675,176	2,272,323
2011	224,472	188,475	562,331	489,313	1,535,537	1,138,410	3,832,815	3,249,789
2013	347,931	337,952	411,373	365,807	1,472,633	1,137,736	4,778,473	4,247,690
2015	644,158	644,158	559,994	559,994	1,529,543	1,529,543	6,188,157	6,166,289
Mean	227,692	198,304	294,600	256,392	704,625	552,291	2,506,300	2,202,933
Median	168,041	145,402	226,884	189,717	505,789	375,763	1,757,627	1,514,710
Max	644,158	644,158	630,990	559,994	1,740,542	1,529,543	6,188,157	6,166,289
Min	109,991	91,123	123,340	105,172	244,936	199,729	1,217,914	1,049,680
Contrast	6	7	5	5	7	8	5	6
Q25	133,000	112,000	173,000	143,000	373,000	286,000	1,399,000	1,195,000
Q75	306,000	231,000	402,000	330,000	671,000	515,000	2,923,000	2,541,000

-continued-

Note: Escapement indices are area-under-the-curve adjusted for stream life for the reduced set of aerial index streams (134) set in 2015 due to state budget cuts. Escapement estimates were only collected for streams with 3 or more surveys per year. Hatchery strays are not accounted for in calculating these indices. Q25 and Q75 refer to the 25th and 75th quartiles (percentiles), respectively, rounded to the nearest 1,000. Current goals are district specific sustainable escapement goals (SEG) and a change in the goal to the 25th and 75th percentiles is recommended for all districts.

[a] Escapement indices calculated using 214 aerial index streams.

[b] Escapement indices calculated using 134 aerial index streams.

Appendix A7.–Supporting information for analysis of escapement goal for Upper Copper River sockeye salmon.

System: Upper Copper River
Species: sockeye salmon
Data available for analysis of escapement goals.

Brood	Wild	Harvest [b]		
year [a]	escapement [a]	Commercial	sport	Sub/PU
1979	251,903	79,628	1,599	33,096
1980	295,346	18,558	2,109	31,041
1981	496,244	474,062	1,523	67,897
1982	395,719	1,174,032	3,343	108,611
1983	458,405	620,135	2,619	116,988
1984	499,792	894,725	3,267	76,177
1985	359,971	895,808	4,752	61,551
1986	361,591	750,066	4,137	68,495
1987	384,603	1,133,481	4,876	76,598
1988	389,150	484,654	3,038	71,525
1989	477,667	850,430	4,509	84,138
1990	472,978	780,569	3,569	98,197
1991	387,196	1,105,035	5,511	117,189
1992	406,255	883,839	4,560	131,956
1993	538,602	1,248,572	5,288	146,724
1994	461,315	1,059,460	6,533	162,302
1995	376,565	1,123,978	6,068	131,522
1996	546,131	2,042,064	11,851	147,059
1997	756,179	2,689,362	12,293	231,534
1998	462,396	819,761	11,184	201,624
1999	449,892	740,931	11,101	219,027
2000	343,691	516,133	12,361	167,353
2001	538,681	1,131,631	8,169	215,895
2002	581,717	915,572	7,761	145,343
2003	507,895	1,058,367	7,108	142,136
2004	448,534	989,588	6,464	181,741
2005	515,599	1,240,866	8,135	208,603
2006	579,552	1,336,612	14,297	200,866
2007	612,083	1,812,719	23,028	209,492
2008	480,597	303,537	11,431	139,950
2009	468,725	849,618	13,415	151,799
2010	502,995	442,458	14,743	225,664
2011	607,657	1,582,656	7,727	205,369
2012	953,745	1,536,018	23,404	220,951
2013	860,829	1,243,834	26,711	274,570
2014	864,988	1,606,930	18,005	257,530
2015	930,095	1,583,601	9,489	334,087
2016	503,033	1,000,670	18,068	232,142

-continued-

Note: Sub means subsistence fisheries, PU means personal use fisheries.

[a] Wild spawning escapements after 1978 were estimated as the adjusted Miles Lake sonar index (in DIDSON units) minus subsistence, personal use, and sport harvests and minus the Gulkana Hatchery broodstock and excess brood escapement.

[b] Sport and subsistence/personal use harvests include wild and hatchery stocks. Prior to 1995, no stock identification data were collected in subsistence or personal use fisheries. The 2016 sport harvest is estimated with the 2013–2015 average.

Appendix A8.–Supporting information for analysis of escapement goal for Copper River Delta sockeye salmon.

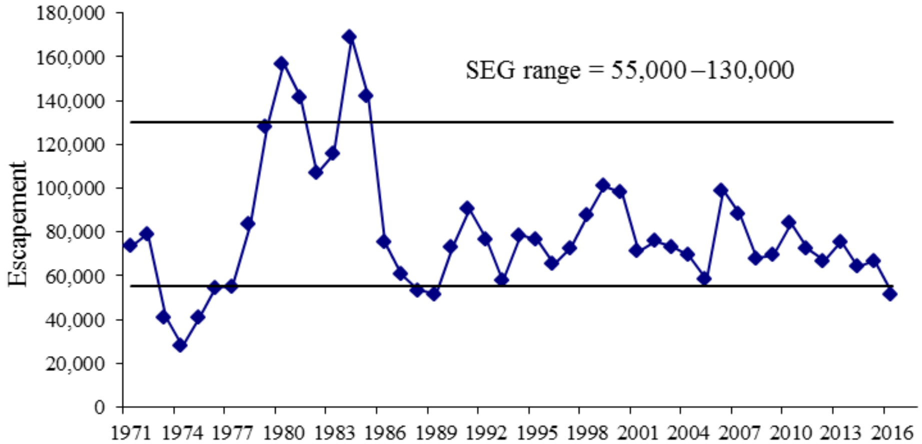
System:	Copper River Delta
Species:	sockeye salmon
Data available for analysis of escapement goals.	

Brood year	Escapement [a]
1971	73,587
1972	78,942
1973	40,970
1974	27,993
1975	40,910
1976	54,500
1977	55,144
1978	83,469
1979	127,900
1980	156,950
1981	141,550
1982	106,770
1983	115,750
1984	168,840
1985	142,050
1986	75,295
1987	60,698
1988	53,315
1989	51,700
1990	73,345
1991	90,500
1992	76,827
1993	57,720
1994	78,370
1995	76,370
1996	65,470
1997	72,563
1998	87,500
1999	100,925
2000	98,045
2001	71,065
2002	75,735
2003	73,150
2004	69,385
2005	58,406
2006	98,896
2007	88,285
2008	67,950
2009	69,292
2010	83,905
2011	72,367
2012	66,850
2013	75,705
2014	64,205
2015	66,665
2016	51,550

[a] Escapement indices calculated as the sum of peak aerial counts from 17 survey sites.

-continued-

System: Copper River Delta
Species: sockeye salmon
Observed escapement by year (blocked line) and current SEG range (solid line)



Appendix A9.–Supporting information for analysis of escapement goal for Bering River District sockeye salmon.

System: Bering River District

Species: sockeye salmon

Data available for analysis of escapement goals.

Brood year	Wild escapement [a]	Commercial 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	18,136	1,175
2009	15,172	4,157
2010	4,951	51
2011	28,530	6
2012	18,290	0
2013	23,900	3,321
2014	14,985	50
2015	21,705	2,137
2016	16,290	9,840

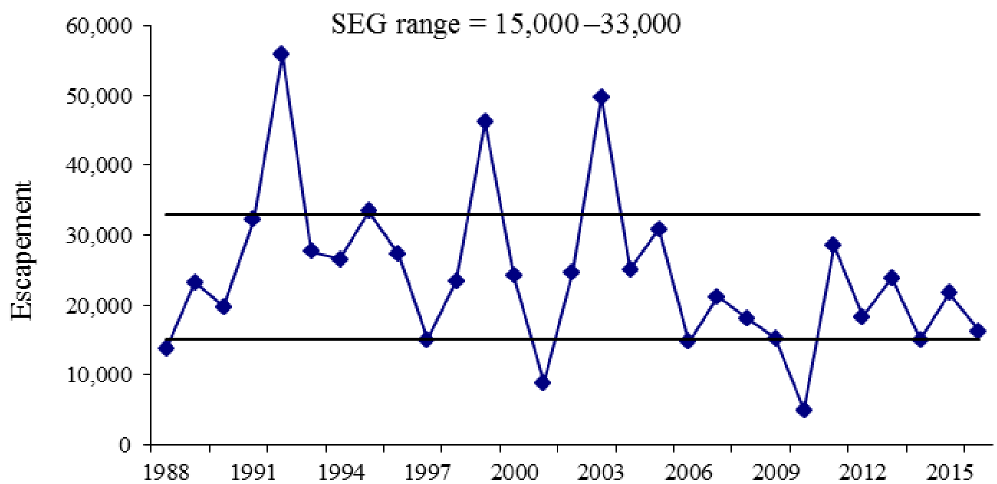
[a] Escapement indices calculated as the sum of peak aerial index counts from 6 primary index systems

[b] Bering River District harvest, not stock specific.

-continued-

System: Bering River
Species: sockeye salmon

Observed escapement by year (blocked line) and current SEG range (solid line).



Appendix A10.–Supporting information for analysis of escapement goal for Eshamy Lake sockeye salmon.

System: Eshamy Lake

Species: sockeye salmon

Data available for analysis of escapement goals.

Brood year	Wild escapement	BY total return [a]	R/S	Yield [b]
1970	11,460	11,690	1.02	230
1971	954	6,667	6.99	5,713
1972	28,683	59,976	2.09	31,293
1973	10,202	34,411	3.37	24,209
1974	633	15,946	25.19	15,313
1975	1,724	31,355	18.19	29,631
1976	19,367	178,061	9.19	158,694
1977	11,746	38,453	3.27	26,707
1978	12,580	36,904	2.93	24,324
1979	12,169	39,724	3.26	27,555
1980	44,263	270,623	6.11	226,360
1981	23,048	30,841	1.34	7,793
1982	6,782	51,290	7.56	47,490
1983	10,348	51,162	4.94	43,355
1984	36,121	117,761	3.26	81,012
1985	26,178	58,163	2.22	31,960
1986	6,949	39,946	5.75	32,997
1987 [c]	NA	NA	NA	NA
1988	31,747	93,876	3.0	62,129
1989	57,106	70,390	1.2	13,284
1990	14,191	58,447	4.1	44,256
1991	45,814	23,930	0.5	(21,884)
1992	30,627	24,468	0.8	(6,110)
1993	34,657	61,820	1.8	29,802
1994	23,910	54,750	2.3	33,382
1995	15,292	27,986	1.8	12,630
1996	5,271	65,804	12.5	60,533
1997	41,299	64,513	1.6	23,214
1998 [c]	NA	91,903	NA	NA
1999	27,057	40,521	1.5	13,464
2000	22,153	51,753	2.3	29,600
2001	55,187	50,750	0.9	(4,437)
2002	40,478	62,834	1.6	22,356

-continued-

System: Eshamy Lake

Species: sockeye salmon

Data available for analysis of escapement goals.

Brood year	Wild escapement	BY total return [a]	R/S	Yield [b]
2003	39,845	20,147	0.5	(19,698)
2004	13,443	53,477	4.0	40,034
2005	23,523	41,261	1.8	17,738
2006	42,473	62,674	1.5	20,201
2007[d]	17,196	NA	NA	NA
2008[d]	18,495	NA	NA	NA
2009[d]	24,025	NA	NA	NA
2010[d]	16,291	NA	NA	NA
2011[d]	24,129	NA	NA	NA
2012[c]	NA	NA	NA	NA
2013[d,e]	4,500	NA	NA	NA
2014[d,f]	7,453	NA	NA	NA
2015[d,g]	4,381	NA	NA	NA
2016[d,h]	5,817	NA	NA	NA

Note: Current goal is a biological escapement goal (BEG) of 13,000–28,000 sockeye salmon and no change to the goal is recommended. BY = brood year, R/S = return per spawner.

[a] Total return was calculated as the wild escapement contribution estimates plus the Eshamy and Southwestern districts Common Property Fishery harvests minus hatchery contribution estimates from sockeye salmon returning to Main Bay Hatchery and the estimate of Coghill Lake sockeye salmon in the harvest.

[b] Calculated as total return minus brood year escapement.

[c] Eshamy Lake weir was not in place in 1987, 1998, or 2012.

[d] Complete return data not available to calculate BY total return, R/S, or yield.

[e] Minimum video count for August 3 through October 1.

[f] Minimum video count for July 17 through October 1.

[g] Minimum video count for July 10 through October 6.

[h] Minimum video count for July 17 through September 8.

Appendix A11.–Links to repositories of code used in analysis of escapement goals for Prince William Sound pink and chum salmon, and Coghill Lake sockeye salmon.

https://github.com/commfish/PWS_Pink_Chum_EG

https://github.com/commfish/Coghill_sockeye