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Escapement Goal Review of Copper and Bering Rivers, and Prince William Sound Pacific Salmon Stocks, 2014

by

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

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	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

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ABSTRACT

This report is a summary of escapement goal reviews and recommendations for major salmon stocks of the Copper River, Bering River, and Prince William Sound Management Area. 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*, 5 sockeye *O. nerka*, and 16 pink *O. gorbuscha* salmon stocks (8 goals for each even- and odd-year brood line). The committee also reviewed escapement data for Gulkana River Chinook salmon but decided not to consider establishing an escapement goal until an ongoing radiotelemetry evaluation of the escapement monitoring program is completed. 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 committee recommends no change to the existing escapement goals and no new goals be created at this time.

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

INTRODUCTION

The Prince William Sound Management Area (PWSMA), also known as Area E, encompasses 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), the management area includes the Bering and Copper rivers and has a total adjacent land area of approximately 38,000 square miles. The management area is divided into 11 commercial fishing districts that correspond to local geography and distribution of the 5 species of Pacific salmon *Oncorhynchus* spp. harvested by the commercial fishery.

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 exploitation, 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 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 that the state'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 board'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; BEG will be the primary management objective for the escapement unless an optimal escapement or inriver run goal has been adopted; BEG will be developed from the best available biological information, and should be scientifically defensible on the basis of available biological information; BEG will be determined by ADF&G 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 seventh 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), and Fair et al. (2011), this review only analyzed goals with recent (2011–2013) 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 on February 28, 2014, to discuss and develop recommendations. 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 June 24 and again on August 14 to review stock assessments and prepare escapement goal recommendations for the upcoming Prince William Sound and Upper Copper/Upper Susitna Finfish Alaska Board of Fisheries meeting in December 2014.

This report describes PWSMA salmon escapement goals reviewed in 2014 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 salmon escapement goals and the committee's recommendations to the Divisions of Commercial Fisheries and Sport Fish directors.

During the 2014 review process, the committee evaluated escapement goals for various Chinook *O. tshawytscha*, chum *O. keta*, coho *O. kisutch*, sockeye *O. nerka*, and pink *O. gorbuscha* 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/Unakwik, Coghill, Northwestern, Eshamy, Southwestern, Montague, and Southeastern (even-year and odd-year broodlines); and
- Sockeye salmon: Eshamy and Coghill lakes, Copper River Delta, and Bering and Upper Copper rivers.

OBJECTIVES

Objectives of the 2014 review were to

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 2011 review. Available escapement, catch, 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 utilize 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 with 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 from the return of fishery-specific harvest permits and household surveys; and sport fishery from the annual *Statewide Harvest Survey*.

Inriver abundance of Copper River Chinook salmon, the only Chinook salmon spawning stock in the PWSMA, 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 catch-at-age model (Deriso et al. 1985; Savereide and Quinn 2004) 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 fishermen.

Chum salmon escapements were based on expanded counts from aerial surveys that have been conducted since 1963. Numerous streams within each district were flown multiple times each year with escapement estimated through area-under-the-curve calculations adjusted with an estimate of stream life (12.6 days; Fried et al. 1998). Catches of most chum salmon have been incidental to harvest of pink salmon throughout PWS except in terminal areas for returns to hatcheries. Reliable estimates of hatchery contributions to commercial harvests of chum salmon are unavailable before 2003. Likewise, there are no reliable estimates of district of origin for wild stock chum salmon with the possible exceptions of the Eastern and Southeastern districts.

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 fishermen.

Since 1960, ADF&G has conducted aerial surveys of selected pink salmon streams to index the spawning escapement in PWS. There are approximately 1,000 pink salmon spawning systems in PWSMA, of which more than 200 are surveyed annually. Between 1960 and 1989, an average of 266 streams were surveyed (range = 203–489). 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 is now 214 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). Because there are no methods to allocate commercial harvests to stream or even district of origin, most analyses were completed on the soundwide wild return by brood line.

The Bering River District sockeye salmon aerial index is estimated as the sum of the peak aerial counts from 6 survey sites. 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. 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. 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 with 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. The inriver abundance of salmon in the Upper Copper River (UCR) has been monitored at Miles Lake since 1978 with sonar. Beginning in 2005 on the south bank, after a period of comparison, the traditional 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 reliably 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).

ESCAPEMENT GOAL DETERMINATION

Escapement goals were evaluated for PWS stocks using the following methods: (1) Stock–Recruitment Analysis; (2) Yield Analysis; (3) Percentile Approach; and (4) Risk Analysis. Spawner-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-return data were available, escapement goals were estimated based on the following: (1) escapements producing average yields that were 90–100% of maximum sustained yield (MSY) from a stock-recruitment model, and (2) the Yield Analysis, explained below, which selects an escapement goal range that produces large observed yields.

Stock–Recruitment Analysis

Complete spawner-return data exists for Eshamy and Coghill lakes sockeye salmon, soundwide odd- and even-year pink salmon brood lines, and combined UCR and CRD sockeye salmon. Annual runs, the sum of escapements and harvests, were estimated and where quantifiable; sport and subsistence harvests from permit returns were included in total return estimates. Age composition from the escapements and harvests were also estimated and were applied to annual estimates of escapement and harvest in order to calculate total return (sum of age-specific returns) from a particular escapement.

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:

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

In previous PWSMA escapement goal reviews, classical statistical approaches were used in stock-recruitment analyses for PWS pink salmon and Eshamy and Coghill sockeye salmon. For this review a Bayesian approach was used to describe the spawner-recruitment relationship and estimate the model parameters (Appendix B1). Multiplicative-error Bayesian analysis has been previously used for Ricker stock-recruitment data analysis (Rivot et al. 2001), and ADF&G has applied the Bayesian approach to Ricker models in previous escapement goal studies (e.g., Fleischman et al. 2011). This analysis was similar to Fleischman et al. (2011), except for the following two aspects: First, serial correlation was not explicitly considered in the model. Autocorrelation can be a serious problem in a non-Bayesian analysis because autocorrelation leads to more "time-series bias" (Walters 1985 and 1990). However, after Korman et al. (1995) examined Pacific salmon stocks in Bristol Bay, Alaska, they concluded it was not necessary to apply a bias-correction method. Also, bias is not an issue under the Bayesian framework because the entire posterior distribution for a parameter is provided. Second, the parameter α was not corrected for logarithm transformation bias using the formulas from Hilborn and Walters (1992) because that correction was used for the mean of an estimated parameter (Hilborn and Mangel 1997). Using a Bayesian approach, this type of transformation bias is resolved by taking the exponent of the entire posterior distribution of the parameter, not just its mean (Stow et al. 2006).

The management parameters MSY, the maximum sustainable yield, and S_{msy}, the estimate of spawning escapement that produces MSY, represent quantities that optimize for the long-term median.

We used approximate formulas given by Hilborn and Walters (1992) to estimate the fishery management parameters S_{msy} and MSY:

$$S_{msy} \approx \frac{\ln(\alpha)}{\beta}\left(0.5 - 0.07\ln(\alpha)\right),$$
$$MSY = \alpha S_{msy} e^{-\beta S_{msy}} - S_{msy} \tag{3}$$

Analysis was performed using WinBUGS (Bayesian Inference Using Gibbs Sampling; Spiegelhalter et al. 1996), which used Markov Chain Monte Carlo (MCMC) to sample from the joint posterior of the parameters and posteriors of the fishery management parameters. After a burn-in of 10,000 iterations, we generated another 10,000 cycles of the MCMC and thinned the chain by taking every 30th sample yielding a final chain of length 334. We performed 3 Markov chains and a total of 1,002 samples from those posteriors. Estimates of S_{msy} to produce 90–100% of MSY came from the median of the posterior distributions of MSY generated at various escapement intervals.

Yield Analysis

In previous PWSMA escapement goal reviews, a Markov yield table (Hilborn and Walters 1992) was used to evaluate various (Coghill and Eshamy lakes sockeye and PWS pink salmon) escapement goal ranges by partitioning escapement into overlapping intervals. Mean numbers of spawners, mean returns, mean return per spawner, mean yield, and the range of yields were calculated for each interval of spawner abundance. For this review, we also employed a more simplistic approach that examined a plot of the relationship between yield and spawners, looking for a range of escapements that, on average, produce the highest yields.

Percentile Approach

Many salmon stocks in PWSMA have a SEG developed using the percentile approach. In 2001 Bue and Hasbrouck[1] developed an algorithm using percentiles of observed escapements, whether estimates or indices, that incorporated contrast in the escapement data and 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,

[1] 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 (*Unpublished*).

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 is 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. For exploited stocks with high contrast, the lower end of the SEG range is increased to the 25th percentile as a precautionary measure for stock protection:

Escapement Contrast and Exploitation	SEG Range
Low Contrast (<4)	15th Percentile to maximum observation
Medium Contrast (4 to 8)	15th to 85th Percentile
High Contrast (>8); Low Exploitation	15th to 75th Percentile
High Contrast (>8); Exploited Population	25th to 75th Percentile

For this review, the SEG ranges of all stocks with existing percentile-based goals were reevaluated using the percentile approach with updated or revised escapement data. If the calculated SEG range approximated the current goal (i.e., a high degree of overlap), the committee recommended no change to the goal.

Risk Analysis

A risk analysis method was used to develop PWS chum salmon lower bound SEGs during the 2005 review. Evenson et al. (2008) and this report fully describe the procedures employed to set these chum salmon goals following the methodology outlined in Bernard et al. (2009). In essence, recommended lower bound SEGs were chosen based on minimizing risk for triggering an unwarranted concern and an approximately equal risk of failing to detect a substantial percentage drop (e.g., 80–95%) in mean escapement.

STOCK-SPECIFIC METHODS, RESULTS, AND RECOMMENDATIONS

From this review, the escapement goal committee recommended all salmon escapement goals in PWSMA remain unchanged (Table 1). The committee specifically reviewed all the recent escapements (Table 2) to determine whether there was sufficient new information to warrant a review of the existing goal. Details for these updated analyses and recommendations are provided below. All data sets were updated (Appendix A) and most were reevaluated using the methodology originally used in their establishment. Munro and Volk (2014) provide a comprehensive review of goal performance from 2005 to 2013 (for 2011–2013, see Table 2).

PRINCE WILLIAM SOUND CHUM SALMON

In 2005, all 5 escapement goals for PWS chum salmon were changed from SEG ranges to lower bound SEGs because they are generally harvested incidentally in the directed pink salmon fishery and their escapements cannot 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). The detailed review of these escapement goals for this BOF meeting was prompted by a reanalysis of past aerial survey data in PWS that resulted in re-estimation of expanded counts of chum salmon for all PWS. There were also eleven additional years (1963, 1964, 2005–2013) of realized escapements to fold into the review.

Escapement goals for chum salmon are based on expanded counts from aerial surveys dating back to the 1960s. Streams are 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 where there were fewer than 150 of the current 214 index streams surveyed PWS-wide (1964–1971, 1974) were not used in the review of escapement goals (Table 3). Additionally, the expanded count in the Northwestern District during 1975 was 0 fish and was not used in the calculations due to extreme effect on the results.

Methods

Escapement time series were first log-transformed and tested for normality using a one-sample Kolmogorov-Smirnov test. All 5 stocks followed a log-normal distribution ($P > 0.40$; Table 3). The log-transformed escapement time series were then tested for serial correlation using diagnostics in Abraham and Ledolter (1983). Time series were restricted to the 1977–2013 time frame solely for these tests, to avoid the effects of interpolation for missing values in the 1963–2013 time series. There was a significant ($\alpha = 0.05$) lag-1 serial correlation in escapements of chum salmon in the Eastern and Southeastern districts; escapements in the Northern, Coghill, and Northwestern districts showed no significant lag-1 correlation (Figures 2–6). Escapements of Northern, Coghill, and Northwestern districts chum salmon were modeled as log-normally distributed variables; escapements of chum salmon in the Eastern and Southeastern districts were modeled with a lag-1 autoregressive term (Table 4). Residuals of the autoregressive models had no significant serial correlation, so no further modeling was necessary. The number of consecutive years that would cause a concern (k) was set at 3, the number of years between each regularly scheduled BOF meeting.

The log-normal model for estimating risk of an unwarranted restriction due to a management concern was estimated directly from the Student's t-distribution of the log-transformed mean, sample standard deviation, number of years in the time series, and number of consecutive years to warrant a concern for various values of an escapement threshold (Table 4) as per Bernard et al. (2009, equations 1 through 8).

The lag-1 autoregressive model for estimating risk of an unwarranted restriction due to a management concern cannot be calculated directly, so parametric simulation as per Bernard et al. (2009, equations 9 through 13) was conducted. One thousand lag-1 serially correlated escapements were generated. The mean and standard deviation parameters of each model were adjusted slightly so that the average of the 1,000 simulated escapements closely matched that of the time series of observed escapements (Table 4).

Risk of detecting a drop in mean escapement was calculated in the same way as risk of an unwarranted restriction, except that the risk of not detecting (1 - risk) was estimated and the mean escapement was changed by the desired percentage drop in mean to be detected with the threshold. Risk was estimated for drops in mean escapement of 80% to 95% for each stock. This range in percentage drops in mean escapement was based on the observed percent difference between the mean escapement and the minimum escapement for each stock (86% for Eastern, 92% for Northern, 95% for Coghill, 91% for Northwestern, and 95% for Southeastern chum salmon). Lower bound escapement thresholds were compared against existing SEGs based on minimizing risk for triggering an unwarranted concern and an approximately equal risk of failing to detect the maximum percentage drop in mean escapement as noted above.

Results and Recommendations

Eastern District Chum Salmon

Estimated risk for the current lower bound SEG (50,000) was 2% (once in 50 years) for an unwarranted concern, with an 11% (once in 9 years) estimated risk that a consistent drop in mean escapement of 85% (from a mean of approximately 127,700 to the minimum observed escapement of 17,500) would not be detected (Figure 7). However, estimated risk of not detecting a 90% drop in mean escapement decreases to 4% (once in 25 years).

Alternatives to the current SEG were also contemplated by the committee. For example, a lower bound escapement of 56,000 balances a 3% risk of an unwarranted concern with a 3% risk of not detecting a 90% drop from the mean escapement. Similarly, a lower bound escapement of 40,000 balances a 1% risk of an unwarranted concern with a 1% risk of not detecting a 95% drop from the mean escapement. These alternatives were rejected in favor of the current escapement goal. Three consecutive escapements of less than 50,000 have never occurred in 37 years of consecutive chum salmon escapements (1977–2013) so that observed risk must be less than 3% (Figure 8). **Based on these results, the committee recommends no change to the current lower bound SEG of 50,000 for this stock.**

Northern District Chum Salmon

Estimated risk for the current lower bound SEG (20,000) was 1% (once in 100 years) for an unwarranted concern, with a 3% (once in 33 years) estimated risk that a consistent drop in mean escapement of 90% (from a mean of approximately 49,000 to the minimum observed escapement of 3,800) would not be detected (Figure 9). However, estimated risk of not detecting a 95% drop in mean escapement decreases to 1% (once in 100 years). Three consecutive escapements of less than 20,000 have never occurred in 37 years of consecutive chum salmon escapements (1977–2013) so that observed risk must be less than 3% (Figure 10). **Based on these results, the committee recommends no change to the current lower bound SEG of 20,000 for this stock.**

Coghill District Chum Salmon

Estimated risk for the current lower bound SEG (8,000) was 1% (once in 100 years) for an unwarranted concern, with a 2% (once in 50 years) estimated risk that a consistent drop in mean escapement of 95% (from a mean of approximately 21,500 to the minimum observed escapement of 1,075) would not be detected (Figure 11). Three consecutive escapements of less than 8,000 have never occurred in 37 years of consecutive chum salmon escapements (1977–2013) so that observed risk must be less than 3% (Figure 12). **Based on these results, the committee recommends no change to the current lower bound SEG of 8,000 for this stock.**

Northwestern District Chum Salmon

Estimated risk for the current lower bound SEG (5,000) was 1% (once in 100 years) for an unwarranted concern, with an 11% (once in 9 years) estimated risk that a consistent drop in mean escapement of 90% (from a mean of approximately 16,300 to the minimum observed escapement of 1,419) would not be detected (Figure 13). However, estimated risk of not detecting a 95% drop in mean escapement decreases to 1% (once in 100 years). Three consecutive escapements of less than 5,000 have never occurred in 37 years of consecutive chum salmon escapements

(1977–2013) so that observed risk must be less than 3% (Figure 14). **Based on these results, the committee recommends no change to the current lower bound SEG of 5,000 for this stock.**

Southeastern District Chum Salmon

Estimated risk for the current lower bound SEG (8,000) was 6% (once in 17 years) for an unwarranted concern, with a 10% (once in 10 years) estimated risk that a consistent drop in mean escapement of 95% (from a mean of approximately 38,000 to the minimum observed escapement of 2,011) would not be detected (Figure 15).

Alternatives to the current SEG were also contemplated by the committee. One example considered was a lower bound escapement of 9,500 that balances a 7% risk of an unwarranted concern with a 7% risk of not detecting a 95% drop from the mean escapement. This was rejected in favor of the current escapement goal. Three consecutive escapements of less than 8,000 have occurred twice in 37 years of consecutive chum salmon escapements (1977–2013) so that observed risk is 5% (Figure 16). **Based on these results, the committee recommends no change to the current lower bound SEG of 8,000 for this stock.**

COPPER RIVER CHINOOK SALMON

The lower bound SEG of 24,000 or more spawners was established in 2002 (Bue et al. 2002). The 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 at that time were estimated for 1980–1998 using a catch-age model (Deriso et al. 1985; Savereide and Quinn 2004). Since 1999, mark–recapture techniques have been used to estimate inriver abundance, and total drainage escapement is derived by subtracting inriver harvest. This goal has been reviewed every BOF cycle since 2002 (Evenson et al. 2008; Fair et al. 2008, 2011). During these reviews, the EG committee has evaluated stock-recruit data, the percentile approach (Bue and Hasbrouck), and habitat-based models (Liermann et al. 2010) as means of setting an escapement goal. There are only 15 escapement estimates available (1999–2013 mark-recapture estimates) and these estimates exhibit a low contrast (3.6) and therefore provide limited information for estimating a stock-recruit relationship, and hence a BEG. Results from all 3 of the above analyses indicated the current lower bound SEG of 24,000 is a reasonable goal for ensuring high sustained yields and low risk of overfishing. No new information on production by this stock will be forthcoming until escapements greater than observed in the recent past are realized. Most estimates of escapement since 1980 have been less than 40,000 Chinook salmon. Recent measured estimates have ranged from 16,000 to 58,000 Chinook salmon and escapements exceeded 24,000 in 11 of 15 years since 1999 (Appendix A1). The lower bound SEG was chosen to keep future escapements near the historical average without precluding the possibility that exceptionally large returns will provide new information on productivity associated with higher escapements. The EG committee viewed this threshold as a minimum escapement to be met and not a consistent management target. Because there was no information available regarding production from large escapements, no meaningful upper bound could be set for the SEG. **Based on these results, the committee recommends no change to the current lower bound SEG of 24,000 for this stock.**

Gulkana River

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 6,090 Chinook salmon. Because some spawning occurs downstream of the counting tower and there is potential for year-to-year variation in spawning distribution within the Gulkana River, escapement counts at the counting tower represent an unknown and perhaps variable fraction of the total escapement in the Gulkana River. Currently, ADF&G is in the second year of a 3-year radiotelemetry project designed to estimate the fraction of the escapement that spawns upstream of the counting tower**.** Based on these considerations, **the committee recommends consideration of an escapement goal for the Gulkana River be tabled until the next cycle when the results of the radiotelemetry project and 3 more years of escapement estimates are available.**

PINK SALMON

Even and Odd Years

Existing even- and odd-year pink salmon district-specific escapement goals (Table 1) for PWSMA were established in 2011. Prior to 2012, PWSMA had areawide escapement goals for the even- and odd-year runs. The goals were converted to district-specific goals in 2011 because management is by district and not by overall returns to the sound (Appendix A5). All existing goals were developed using the percentile approach (Bue and Hasbrouck) and have been in effect 1 year (odd broodline) and 2 years (even broodline).

During this review process it became apparent that the likelihood of having the ability to fly 214 individual streams multiple times throughout the entire run and producing estimates of escapement using the area-under-the-curve methodology may no longer be an option for assessing these stocks. Reduced budgets and the inability to locate a pilot able and willing to fly these low-level surveys in the same manner will probably require ADF&G to select a subset of streams to index these escapements and manage these fisheries in the near future. **The escapement goal review committee recommends no changes be made to the existing escapement goals for PSWMA pink salmon** and that research staff focus their efforts to

- Review the historical database of aerial surveys for accuracy and completeness;
- Update all historical indices of escapement using variable residency times when applying the area-under-the-curve methodology; and
- Develop new escapement goals from a smaller, representative number of streams that accurately reflect historical escapement patterns.

COPPER RIVER SOCKEYE SALMON

The following is an examination of wild Copper River sockeye salmon for brood years 1961–2013. Current sockeye salmon SEGs for the Copper River are 360,000–750,000 sockeye salmon for the upper Copper River stock, adopted in 2011, and 55,000–130,000 for the Copper River Delta stock, adopted in 2002 (Fair et al. 2011). Both goals were developed using the percentile approach of Bue and Hasbrouck.

Prior to the start of the Miles Lake sonar operation in 1978, estimates of UCR escapement were made using mark–recapture methods and expansion of upriver aerial indices. Beginning in 1978, upriver wild spawners were estimated as adjusted Miles Lake sonar total count minus upriver subsistence, personal use, and sport harvests; and minus the Gulkana Hatchery broodstock and excess. No species apportionment is conducted for the Miles Lake sonar project. Therefore, total sonar counts were adjusted to approximate sockeye salmon passage by assuming the proportion counted by the sonar was the same as the proportion in the subsistence and personal use fisheries (1961–1998), or by subtracting the Chinook salmon mark–recapture estimate of inriver abundance (1999–present).

CRD aerial indices were calculated as the sum of peak counts for 17 index systems (Appendix A8). Peak counts were adjusted for an observer efficiency of 0.5 (expansion of 2.0) unless otherwise noted. This adjustment was made based on weir and aerial survey count comparisons conducted on a limited number of systems in the late 1970s and early 1980s; however, no documentation of the observer efficiency calculations is available. No adjustments were made for sockeye salmon stream or lake life because no estimates of spawner life are available.

UCR and CRD stocks were combined for the analyses because we currently cannot allocate the commercial harvest to specific stock or stock group (Tables 5; Figure 17). Studies of scale growth pattern differences in the 1980s attempted to allocate to area of origin (Marshall et al. 1987) but had low accuracy in some years and were discontinued.

Contrast in the combined UCR and CRD escapement index is 7.1 for brood years 1961–2013 and 2.2 for brood years 1979–2013 (Table 5). Wild spawners were estimated separately for upriver and delta for brood years 1961–2013 (Table 5). Contrast for brood years 1979–2013 was estimated as 3.8 for upriver and 3.3 for delta escapements. The first year of upriver sonar counts (1978) was excluded because the project started late, ended early, had sonar on only the south bank, and did not have a substrate to aim the transducer.

Methods

Percentile approach

Current Copper River sockeye salmon goals are SEGs based on the percentile approach of Bue and Hasbrouck. Current SEGs were calculated with escapement indices from 1979–2001 (UCR) and 1971–2001 (CRD). Escapements since 2001 were added to the time series and the percentiles recalculated (Table 2; Table 5 and 6). For the CRD stock, the updated range has an identical lower bound as the existing goal (55,000), but the updated upper bound (105,000) is less than the current (130,000). For the UCR stock, the updated percentile range was 375,000–955,000 which was larger on both bounds than the existing SEG range of 360,000–760,000.

Markov table yield approach

Copper River sockeye salmon data were examined for patterns in yield for brood years with complete returns (1961–2008). Overlapping escapement intervals of 200,000 spawners (1961–2008) and 150,000 spawners (1979–2008) were examined and both interval ranges showed good average yields between 400,000 and 800,000 spawners (Table 7; Figure 18). This indicates that our current combined upriver and delta escapement range (470,000–1,000,000) covers the range of escapements that has produced good yields.

Next we examined the relationship between geographic location of the escapements and total yield because the escapement indices for brood years 1979–2013 were only weakly correlated ($r = -0.37$). These data did not show an obvious relationship between UCR escapement, CRD spawning escapement indices, or Copper River total escapement and total yield (Figure 19).

Stock-Recruitment analysis

Bayesian Ricker stock-recruitment models were used to analyze Copper River sockeye salmon data for brood years with complete returns, 1961–2008 (Table 5). For this analysis, spawners were analogous to stock and brood return of adults analogous to recruitment. Total brood returns were the sum of the combined UCR and CRD escapements and all harvests summed over all ages of the return.

The model produced a median estimate of S_{msy} (~700,000; Table 8) that is within the current UCR and CRD combined SEG range of 470,000–1,000,000 and near the 1979–2013 average of 664,000. Escapement goal bounds from stock-recruitment analyses are usually set at 90% of S_{msy} or 470,000–1,000,000 for this analysis (Figure 20). This range is the same as our existing SEG range for both UCR and CRD stocks combined. Bayesian analysis indicates that escapements anywhere within the bounds of the range would have a ~50% probability of achieving >90% of MSY (Figure 21).

Results and Recommendations

Copper River sockeye salmon spawning escapements were combined UCR and CRD for the Markov-table yield and stock–recruitment analyses due to our inability to allocate the commercial harvests to stock or area of origin. Escapement data for both UCR and CRD systems are only indices of abundance. Current goals produce sustained yields, but because we are unable to allocate harvest by stock, we are unable to develop stock-specific stock-recruitment analyses to determine the spawner abundance required for maximum sustained yield for either UCR or CRD stocks.

Therefore, both stock-recruitment and Markov-table yield analyses require combining UCR and CRD escapement and harvest data. However, the 2 stock groups are evaluated and managed with different tools (sonar and aerial surveys) that require separate goals or management targets. If either stock-recruitment or Markov-table yield analysis were used to produce a total Copper River escapement goal, it would have to be allocated to the UCR and CRD using some additional method (e.g., average historical escapement proportions).

The current SEGs for both the UCR and CRD stocks were established using the percentile approach (Bue and Hasbrouck). However, a recent analysis of the percentile approach by Clark et al.[2] provided criteria for when the percentile approach is not recommended: e.g., when the harvest rate is >0.40 or for stocks with low escapement contrast (4 or less) and high measurement error. The 2004–2013 average harvest rate is estimated at 0.65 (0.44 to 0.75) and the 1979–2013 escapement contrast is <4.00 (Table 5). This suggests the percentile approach of Bue and Hasbrouck may not be appropriate for setting escapement goals for Copper River sockeye salmon, so that other methods should be considered.

Markov-table yields indicated that good yields are being produced from escapements in our current SEG range (Table 7; Figure 18). The Bayesian Ricker stock-recruitment analysis indicated our current combined SEG ranges would produce sustained yields at 90% or more of MSY (Figure 20). The Bayesian Ricker model would provide a combined goal that must be allocated to UCR and CRD to be useful for management. One method to allocate the combined

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[2] Clark, R. A., D. M. Eggers, A. R. Munro, S. J. Fleischman, B. G. Bue, and J. J. Hasbrouck. Draft. An evaluation of the percentile approach for establishing sustainable escapement goals in lieu of stock productivity information. Alaska Department of Fish and Game, Special Publication, Anchorage.

goal is to use the average historical escapement proportions of the escapements from Table 5 (1961–2013 = 73.85% UCR and 26.15% CRD). These proportions and the bounds that would produce sustained yields of ≥90% MSY (470,000–1,000,000) would produce management targets very similar to the existing SEGs (345,000–740,000 vs. existing SEG of 360,000–750,000 for the UCR and 62,500–130,000[3] vs. existing SEG of 55,000–130,000 for the CRD).

Based on the information available, the committee recommends no changes to the existing Copper River sockeye salmon sustainable escapement goals at this time.

BERING RIVER DISTRICT AND COPPER RIVER DELTA COHO SALMON

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 CRD remain unchanged. Both goals were established in 1991 (Fried 1994) and adopted as an SEG in 2002 (Bue et al. 2002). With updated information through 2013 (Appendices A3–A4) and using the traditional percentile approach, the Bering River District percentile range is similar (18,000–32,000) to the existing SEG. Likewise, the updated Copper River Delta percentile range is similar (32,000–64,000) to the existing SEG. Lack of stock-specific harvest information and indices of escapement (peak aerial survey counts) preclude development of a spawner-recruitment relationship and hence a BEG.

BERING RIVER DISTRICT SOCKEYE SALMON

The committee recommends the SEG of 15,000–33,000 spawners for the Bering River District remain unchanged. This goal was established in 2011 (Fair et al. 2011) and was derived using the percentile approach with medium contrast (6.3) and the 15th and 85th percentiles. The goal was changed in 2011 because 1) historical inconsistencies in the aerial index counts were corrected, 2) aerial index counts from the Katalla River, which had been flown since 1988, were officially included in the escapement goal and, 3) an error in the percentiles used to calculate the previous goal was corrected (from 25th–75th to 15th–85th percentiles). An examination of updated information through 2013 (Appendix A6) did not indicate cause to recalculate this goal for the current review.

COGHILL LAKE SOCKEYE SALMON

The committee recommends the SEG of 20,000–60,000 spawners for Coghill Lake remain unchanged. This goal was established in 2011 (Fair et al. 2011) after extensive analyses that included comparisons of yield from the Ricker and Beverton-Holt models. In establishing this goal it was determined that broadening the SEG range (from the previous goal of 20,000–40,000) would allow for greater flexibility by fisheries managers without substantial risk of a decrease in yields. Updated escapement and yield data through 2013 (Appendix A7) did not provide justification for changing the goal for the current review.

ESHAMY LAKE SOCKEYE SALMON

The committee recommends the BEG of 13,000–28,000 spawners for Eshamy Lake remain unchanged. This goal was established in 2008 (Fair et al. 2008) and was derived from the Ricker stock-recruitment model. Escapements within the range of the current goal were determined to

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[3] Copper River Delta escapement goal bounds need to be adjusted to values used by management. Escapement indices were adjusted for an observer efficiency of 0.5 for use in the stock-recruit model and output results must be divided by 2 to bring back to aerial index units used for management.

have a probability greater than 50% of producing returns at least 90% of MSY. Since the 2011 review, budget cuts have resulted in the replacement of the Eshamy Lake weir with a video monitoring system. Unfortunately, the video system was not operational in 2012 and only collected a portion of the escapement believed to enter Eshamy Lake in 2013 (Appendix A9). Thus, there is little additional escapement data to consider for the current review.

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TABLES AND FIGURES

Table 1.–Summary of recommended escapement goals for Prince William Sound Management Area salmon stocks, 2014.

System	Goal	Long-term target	Year adopted	Assessment method	Recommended action
Chinook salmon					
Copper River	> 24,000	27,000	2002	Mark–Recapture	No Change
Coho salmon					
Bering River District	13,000–33,000	–	1991	Aerial Survey	No Change
Copper River Delta	32,000–67,000	–	1991	Aerial Survey	No Change
Sockeye salmon					
Eshamy Lake	13,000–28,000	–	2008	Weir	No Change
Coghill Lake	20,000–60,000	–	2011	Weir	No Change
Bering River District	15,000–33,000	–	2011	Aerial Survey	No Change
Copper River Delta	55,000–130,000	84,500	2002	Aerial Survey	No Change
Upper Copper River	360,000–750,000	450,000	2011	Sonar	No Change
Pink salmon (broodline year)					
Coghill (even)	60,000–150,000	100,000	2011	Aerial Survey	No Change
Coghill (odd)	60,000–250,000	130,000	2011	Aerial Survey	No Change
Eastern (even)	250,000–580,000	390,000	2011	Aerial Survey	No Change
Eastern (odd)	310,000–640,000	410,000	2011	Aerial Survey	No Change
Eshamy (even)	3,000–11,000	6,000	2011	Aerial Survey	No Change
Eshamy (odd)	4,000–11,000	9,000	2011	Aerial Survey	No Change
Montague (even)	50,000–140,000	70,000	2011	Aerial Survey	No Change
Montague (odd)	140,000–280,000	210,000	2011	Aerial Survey	No Change
Northern/Unakwik (even)	140,000–210,000	160,000	2011	Aerial Survey	No Change
Northern/Unakwik (odd)	90,000–180,000	130,000	2011	Aerial Survey	No Change
Northwestern (even)	70,000–140,000	100,000	2011	Aerial Survey	No Change
Northwestern (odd)	50,000–110,000	80,000	2011	Aerial Survey	No Change
Southeastern (even)	150,000–310,000	200,000	2011	Aerial Survey	No Change
Southeastern (odd)	270,000–620,000	360,000	2011	Aerial Survey	No Change
Southwestern (even)	70,000–160,000	130,000	2011	Aerial Survey	No Change
Southwestern (odd)	70,000–190,000	120,000	2011	Aerial Survey	No Change
Chum salmon					
Coghill	> 8,000	18,750	2005	Aerial Survey	No Change
Eastern	> 50,000	103,100	2005	Aerial Survey	No Change
Northern/Unakwik	> 20,000	40,100	2005	Aerial Survey	No Change
Northwestern	> 5,000	13,000	2005	Aerial Survey	No Change
Southeastern	> 8,000	25,000	2005	Aerial Survey	No Change

Note: Chinook and chum salmon goals are lower bound sustainable escapement goals (SEG) and Eshamy Lake sockeye salmon is a biological escapement goal (BEG). All other goals are SEG ranges.

Table 2.–Current escapement goals compared to escapements observed from 2011 through 2013 for Chinook, chum, coho, pink, and sockeye salmon stocks of the Prince William Sound Management Area.

	Current escapement goal		Escapements		
System	Escapement data	Range	2011	2012	2013
Chinook salmon					
Copper River	Mark–Recapture	> 24,000	27,994	27,835	29,012
Chum salmon					
Coghill	Aerial Survey	> 8,000	19,617	14,075	14,414
Eastern	Aerial Survey	> 50,000	240,321	97,362	140,806
Northern	Aerial Survey	> 20,000	64,743	23,818	41,058
Northwestern	Aerial Survey	> 5,000	11,951	9,360	4,995
Southeastern	Aerial Survey	> 8,000	112,507	31,029	43,000
Coho salmon					
Bering River District	Aerial Survey	13,000–33,000	18,890	15,605	18,820
Copper River Delta	Aerial Survey	32,000–67,000	38,495	37,010	34,680
Pink salmon [a]					
Coghill (even year)	Aerial Survey	60,000–150,000		172,611	
Coghill (odd year)	Aerial Survey	60,000–250,000	257,020		640,414
Eastern (even year)	Aerial Survey	250,000–580,000		301,709	
Eastern (odd year)	Aerial Survey	310,000–640,000	982,837		1,266,783
Eshamy (even year)	Aerial Survey	3,000–11,000		1,052	
Eshamy (odd year)	Aerial Survey	4,000–11,000	4,368		12,145
Montague (even year)	Aerial Survey	50,000–140,000		77,756	
Montague (odd year)	Aerial Survey	140,000–280,000	598,918		411,373
Northern/Unakwik (even year)	Aerial Survey	140,000–210,000		106,568	
Northern/Unakwik (odd year)	Aerial Survey	90,000–180,000	167,408		329,434
Northwestern (even year)	Aerial Survey	70,000–140,000		117,795	
Northwestern (odd year)	Aerial Survey	50,000–110,000	147,128		203,444
Southeastern (even year)	Aerial Survey	150,000–310,000		258,047	
Southeastern (odd year)	Aerial Survey	270,000–620,000	1,537,438		1,472,633
Southwestern (even year)	Aerial Survey	70,000–160,000		90,156	
Southwestern (odd year)	Aerial Survey	70,000–190,000	232,302		348,012
Sockeye salmon					
Eshamy Lake[b]	Weir	13,000–28,000	24,129	ND	4,500
Coghill Lake	Weir	20,000–60,000	102,359	73,978	17,231
Bering River District	Aerial Survey	15,000–33,000	28,530	18,290	23,900
Copper River Delta	Aerial Survey	55,000–130,000	72,367	66,850	75,705
Upper Copper River	Sonar	360,000–750,000	607,657	953,756	864,152

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

[b] No weir at Eshamy Lake in 2012 or 2013; video assessment project provided a minimum estimate of 4,500 in 2013.

Table 3.–Escapements (Esc) and natural log of escapements [ln(Esc)] of chum salmon stocks assessed in 5 fishing districts of Prince William Sound, Alaska (1963–2013).

	Eastern		Northern		Coghill		Northwestern		Southeastern	
Year	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc))	Esc	ln(Esc))
1963	99,451	11.51	53,253	10.88	38,507	10.56	15,042	9.62	17,328	9.76
1964	177,740	12.09	49,627	10.81	77,479	11.26	13,067	9.48	16,303	9.70
1965	34,097	10.44	19,750	9.89	7,302	8.90	5,545	8.62	31,008	10.34
1966	40,609	10.61	44,875	10.71	10,277	9.24	3,934	8.28	7,008	8.85
1967	85,712	11.36	26,255	10.18	5,313	8.58	1,564	7.36	10,366	9.25
1968	3,710	8.22	2,503	7.83	ND	ND	ND	ND	6,694	8.81
1969	49,359	10.81	21,442	9.97	18,777	9.84	596	6.39	5,121	8.54
1970	14,366	9.57	784	6.66	4,002	8.29	2,350	7.76	1,500	7.31
1971	34,656	10.45	7,175	8.88	3,853	8.26	5,505	8.61	1,942	7.57
1972	91,057	11.42	45,760	10.73	15,442	9.64	9,243	9.13	14,541	9.58
1973	257,342	12.46	131,588	11.79	61,688	11.03	13,421	9.50	38,807	10.57
1974	19,147	9.86	2,497	7.82	0	ND	0	ND	0	ND
1975	17,375	9.76	3,800	8.24	1,827	7.51	0	ND	2,011	7.61
1976	17,769	9.79	31,142	10.35	38,800	10.57	2,684	7.90	50	3.91
1977	40,202	10.60	28,390	10.25	41,963	10.64	6,030	8.70	5,189	8.55
1978	107,274	11.58	31,006	10.34	15,833	9.67	17,024	9.74	7,375	8.91
1979	29,475	10.29	14,552	9.59	4,565	8.43	6,985	8.85	5,437	8.60
1980	21,936	10.00	19,409	9.87	22,066	10.00	1,419	7.26	8,444	9.04
1981	67,495	11.12	37,538	10.53	1,075	6.98	10,302	9.24	15,221	9.63
1982	129,714	11.77	71,708	11.18	14,368	9.57	8,345	9.03	17,312	9.76
1983	125,323	11.74	91,371	11.42	55,119	10.92	32,022	10.37	17,490	9.77
1984	106,972	11.58	63,824	11.06	12,094	9.40	4,645	8.44	3,577	8.18
1985	33,379	10.42	30,782	10.33	15,735	9.66	11,052	9.31	2,552	7.84
1986	146,366	11.89	64,899	11.08	17,670	9.78	20,902	9.95	14,108	9.55
1987	194,849	12.18	38,016	10.55	19,962	9.90	32,986	10.40	44,951	10.71
1988	321,022	12.68	100,841	11.52	58,605	10.98	54,155	10.90	89,588	11.40
1989	128,973	11.77	59,328	10.99	21,253	9.96	31,504	10.36	23,571	10.07
1990	131,099	11.78	118,933	11.69	22,823	10.04	31,955	10.37	7,501	8.92
1991	63,849	11.06	20,830	9.94	5,846	8.67	8,223	9.01	7,692	8.95
1992	47,992	10.78	15,424	9.64	8,264	9.02	12,123	9.40	3,626	8.20
1993	57,942	10.97	24,866	10.12	9,769	9.19	19,929	9.90	23,571	10.07
1994	47,409	10.77	28,199	10.25	18,274	9.81	14,791	9.60	4,307	8.37
1995	96,684	11.48	38,586	10.56	15,343	9.64	6,575	8.79	25,643	10.15
1996	182,767	12.12	75,829	11.24	26,703	10.19	33,179	10.41	42,619	10.66
1997	109,494	11.60	25,451	10.14	3,947	8.28	10,870	9.29	57,979	10.97
1998	88,713	11.39	29,264	10.28	13,380	9.50	5,683	8.65	35,808	10.49
1999	168,474	12.03	37,151	10.52	6,458	8.77	4,748	8.47	26,605	10.19
2000	205,680	12.23	31,198	10.35	26,682	10.19	10,214	9.23	44,278	10.70
2001	256,917	12.46	101,863	11.53	18,402	9.82	7,613	8.94	43,125	10.67
2002	120,070	11.70	39,837	10.59	9,574	9.17	21,497	9.98	97,910	11.49
2003	283,181	12.55	60,046	11.00	24,566	10.11	15,886	9.67	137,182	11.83
2004	149,896	11.92	53,827	10.89	11,778	9.37	13,040	9.48	56,457	10.94
2005	161,276	11.99	39,444	10.58	14,911	9.61	15,482	9.65	12,141	9.40

-continued-

Table 3.–Page 2 of 2.

	Eastern		Northern		Coghill		Northwestern		Southeastern	
Year	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)
2006	141,999	11.86	60,265	11.01	23,987	10.09	22,742	10.03	38,091	10.55
2007	144,941	11.88	54,709	10.91	14,738	9.60	12,570	9.44	71,595	11.18
2008	82,068	11.32	50,666	10.83	48,221	10.78	34,107	10.44	20,300	9.92
2009	150,051	11.92	30,296	10.32	8,290	9.02	15,826	9.67	150,974	11.92
2010	146,613	11.90	59,530	10.99	84,840	11.35	34,300	10.44	138,442	11.84
2011	240,321	12.39	64,743	11.08	19,617	9.88	11,951	9.39	112,507	11.63
2012	97,362	11.49	23,818	10.08	14,075	9.55	9,360	9.14	31,029	10.34
2013	140,806	11.86	41,058	10.62	14,414	9.58	4,995	8.52	43,000	10.67
t[a]	41		41		41		40		41	
Mean	127,654	11.57	49,071	10.62	21,529	9.66	16,318	9.47	38,046	9.99
Min	17,375	9.76	3,800	8.24	1,075	6.98	1,419	7.26	2,011	7.61
Max	321,022	12.68	131,588	11.79	84,840	11.35	54,155	10.90	150,974	11.92
SD	72,514	0.68	28,550	0.65	17,890	0.88	11,310	0.72	39,693	1.15
CV	56.8%	5.9%	58.2%	6.2%	83.1%	9.1%	69.3%	7.6%	104.3%	11.5%
Median	125,323	11.74	39,837	10.59	15.735	9.66	12,805	9.46	23,571	10.07
Q25[b]	82,068	11.32	29,264	10.28	11,778	9.37	8,315	9.03	8,444	9.04
Q75[b]	150,051	11.92	60,265	11.01	23,987	10.09	21,051	9.95	44,278	10.70
MaxDif[c]		0.13		0.09		0.14		0.09		0.08
P		0.49		0.91		0.44		0.89		0.95

Note: Shaded values were not used in the estimation of descriptive statistics or risk-based reference points.

[a] Refers to length of time series.

[b] Refers to 25th and 75th quartiles.

[c] MaxDif is the test statistic of the one-sample Kolmogorov-Smirnov test.

Table 4.–Risk analysis results for chum salmon for 5 districts with sustained escapement goals in Prince William Sound.

Stock	t	$\hat{\mu}$	$\hat{\phi}_1$	$\hat{\sigma}$	k
Eastern District	41	11.62	0.45	0.58	3 years
Northern District	41	10.62	NA	0.65	3 years
Coghill District	41	9.66	NA	0.88	3 years
Northwestern District	40	9.47	NA	0.72	3 years
Southeastern District	41	10.10	0.59	0.88	3 years

Note: t = length of time series of escapements, $\hat{\mu}$ = log-transformed mean escapement, $\hat{\phi}_1$ = lag-1 autoregressive term for Eastern and Southeastern districts chum salmon, $\hat{\sigma}$ = standard deviation of log-transformed escapement, k = number of consecutive years to warrant a concern of chum salmon stocks. NA = not applicable.

Table 5.–Copper River sockeye salmon spawner-recruitment data, brood years 1961–2013.

	Spawning Escapement							
Brood year	UCR[a]	CRD index[b]	Adjusted CRD index[c]	Total UCR & CRD Esc.	Total BY return	Yield	R/S	ln(R/S)
1961	312,646	15,247	30,494	343,140	1,466,177	1,123,036	4.27	0.63
1962	316,333	49,880	99,760	416,093	767,186	351,093	1.84	0.27
1963	183,347	43,830	87,660	271,007	630,732	359,725	2.33	0.37
1964	162,650	35,670	71,340	233,990	1,187,843	953,852	5.08	0.71
1965	244,383	64,590	129,180	373,563	1,790,511	1,416,948	4.79	0.68
1966	315,573	29,550	59,100	374,673	1,492,946	1,118,273	3.98	0.60
1967	132,678	9,920	19,840	152,518	871,347	718,829	5.71	0.76
1968	211,982	11,360	22,720	234,702	844,271	609,569	3.60	0.56
1969	465,622	31,100	62,200	527,822	919,052	391,229	1.74	0.24
1970	256,305	36,712	73,424	329,729	515,510	185,781	1.56	0.19
1971	438,228	73,587	147,174	585,402	1,097,016	511,614	1.87	0.27
1972	250,465	78,942	157,884	408,349	1,041,188	632,839	2.55	0.41
1973	350,305	40,970	81,940	432,245	460,440	28,195	1.07	0.03
1974	153,848	27,993	55,986	209,834	663,791	453,957	3.16	0.50
1975	90,766	40,910	81,820	172,586	586,099	413,513	3.40	0.53
1976	139,496	54,500	109,000	248,496	1,169,542	921,046	4.71	0.67
1977	246,808	55,144	110,288	357,096	1,872,961	1,515,864	5.24	0.72
1978	67,456	83,469	166,938	234,394	1,527,655	1,293,262	6.52	0.81
1979	251,903	127,900	255,800	507,703	1,894,936	1,387,233	3.73	0.57
1980	295,346	156,950	313,900	609,246	1,645,535	1,036,289	2.70	0.43
1981	496,244	141,550	283,100	779,344	1,044,003	264,659	1.34	0.13
1982	395,719	106,770	213,540	609,259	1,845,251	1,235,992	3.03	0.48
1983	458,405	115,750	231,500	689,905	1,114,613	424,708	1.62	0.21
1984	499,792	168,840	337,680	837,472	1,546,523	709,051	1.85	0.27
1985	359,971	142,050	284,100	644,071	1,315,175	671,104	2.04	0.31
1986	361,591	75,295	150,590	512,181	1,714,760	1,202,579	3.35	0.52
1987	384,603	60,698	121,396	505,999	1,786,394	1,280,395	3.53	0.55
1988	389,150	53,315	106,630	495,780	1,621,033	1,125,253	3.27	0.51
1989	477,667	51,700	103,400	581,067	2,065,443	1,484,376	3.55	0.55
1990	472,978	73,345	146,690	619,668	1,797,244	1,177,576	2.90	0.46
1991	387,196	90,500	181,000	568,196	2,772,351	2,204,155	4.88	0.69
1992	406,255	76,827	153,654	559,909	3,041,416	2,481,507	5.43	0.73
1993	538,602	57,720	115,440	654,042	2,540,496	1,886,454	3.88	0.59
1994	461,315	78,370	156,740	618,055	1,820,341	1,202,286	2.95	0.47
1995	376,565	76,370	152,740	529,305	1,437,847	908,542	2.72	0.43
1996	546,131	65,470	130,940	677,071	1,695,273	1,018,201	2.50	0.40
1997	756,179	72,563	145,125	901,305	1,794,129	892,824	1.99	0.30
1998	462,396	87,500	175,000	637,396	1,904,862	1,267,467	2.99	0.48
1999	449,892	100,925	201,850	651,742	1,810,548	1,158,806	2.78	0.44
2000	343,691	98,045	196,090	539,781	2,121,297	1,581,516	3.93	0.59
2001	538,681	71,065	142,130	680,811	2,233,813	1,553,002	3.28	0.52
2002	581,717	75,735	151,470	733,187	2,786,123	2,052,936	3.80	0.58

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Table 5.–Page 2 of 2.

Brood Year	Spawning Escapement UCR[a]	CRD Index[b]	Adjusted CRD index[c]	Total UCR & CRD Esc.	Total BY return	Yield	R/S	ln(R/S)
2003	507,895	73,150	146,300	654,195	1,452,741	798,546	2.22	0.35
2004	448,534	69,385	138,770	587,304	1,390,962	803,658	2.37	0.37
2005	515,599	58,406	116,812	632,411	1,108,378	475,966	1.75	0.24
2006	579,552	98,896	197,792	777,344	2,328,103	1,550,759	2.99	0.48
2007	612,083	88,285	176,570	788,653	2,731,862	1,943,209	3.46	0.54
2008	480,597	67,950	135,900	616,497	2,110,400	1,493,903	3.42	0.53
2009 [d]	468,725	68,622	137,244	605,969				
2010 [d]	502,995	83,285	166,570	669,565				
2011 [d]	607,657	76,507	153,014	760,671				
2012 [d]	953,756	66,850	133,700	1,087,456				
2013 [d]	864,152	73,505	147,010	1,011,162				
<u>1961–2008</u>								
Count	48	48	48	48	48	48	48	48
Minimum	67,456	9,920	19,840	152,518	460,440	28,195	1.07	0.03
Maximum	756,179	168,840	337,680	901,305	3,041,416	2,481,507	6.52	0.81
Contrast	11.21	17.02	17.02	5.91				
<u>1979–2008</u>								
Count	30	30	30	30	30	30	30	30
Minimum	251,903	51,700	103,400	495,780	1,044,003	264,659	1.34	0.13
Maximum	756,179	168,840	337,680	901,305	3,041,416	2,481,507	5.43	0.73
Contrast	3.00	3.27	3.27	1.82				

Note: Complete brood year returns are available through 2008. UCR = Upper Copper River; CRD = Copper River Delta; BY = brood year; and R/S = return per spawner.

[a] Upper Copper River escapement was estimated with mark–recapture methods or expansion of upriver aerial surveys (1961–1977) or calculated as adjusted Miles Lake sonar indices (DIDSON equivalent) minus upriver harvests and minus Gulkana Hatchery broodstock and excess fish (1978–2013).

[b] Copper River Delta escapement indices were calculated as the sum of the peak counts of 17 index systems from approximately weekly aerial surveys.

[c] Copper River Delta adjusted escapement indices were calculated as the sum of the peak counts of 17 index systems from approximately weekly aerial surveys divided by an observer efficiency of 0.5.

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

Table 6.–Current escapement goals and updated percentile-approach range for Copper River sockeye salmon.

	Years	Contrast	Percentiles	Range		
<u>Upper Copper River</u>						
Current SEG	1979–2010	3.00	15th to Max	360,000	–	760,000
Updated Percentile	1979–2013	3.79	15th to Max	375,000	–	955,000
<u>Copper River Delta</u>						
Current SEG	1971–2001	6.03	15th to 85th	55,000	–	130,000
Updated Percentile	1971–2013	6.03	15th to 85th	55,000	–	105,000

Note: SEG = sustainable escapement goal.

Table 7.–Markov yield tables for Copper River sockeye salmon with overlapping escapement intervals of 200,000 fish (top panel) and 150,000 fish (bottom panel).

Brood Years 1961-2008

Escapement, return, yield, and standard deviation of yield numbers in millions

Escapement Interval			*n*	Mean				Standard Deviation
				Escapement	Returns	R/S	Yield	Yield
	<	0.20	2	0.16	0.73	4.55	0.57	0.22
0.1	–	0.30	8	0.22	0.94	4.31	0.72	0.32
0.20	–	0.40	11	0.29	1.20	4.11	0.90	0.45
0.30	–	0.50	9	0.39	1.23	3.18	0.83	0.52
0.40	–	0.60	15	0.52	1.61	3.06	1.09	0.69
0.50	–	0.70	25	0.60	1.79	3.01	1.19	0.51
0.60	–	0.80	18	0.67	1.85	2.76	1.18	0.51
	>	0.7	6	0.80	1.50	3.29	1.02	0.72

Brood Years 1979–2008

Escapement, return, yield, and standard deviation of yield numbers in millions

Escapement Interval			*n*	Mean				Standard Deviation
				Escapement	Returns	R/S	Yield	Yield
	<	0.150	0					
0.075	–	0.225	0					
0.150	–	0.300	0					
0.225	–	0.375	0					
0.300	–	0.450	0					
0.375	–	0.525	4	0.51	1.75	3.47	1.25	0.28
0.450	–	0.600	10	0.54	1.98	3.68	1.45	0.55
0.525	–	0.675	17	0.61	1.89	3.15	1.29	0.53
0.600	–	0.750	15	0.65	1.81	2.79	1.16	0.46
0.675	–	0.825	7	0.73	1.99	2.71	1.26	0.71
0.750	–	0.900	4	0.80	1.91	2.41	1.12	0.77
0.825	–	0.975	2	0.87	1.67	1.92	0.80	0.13
	>	0.90	1	0.90	1.79	1.99	0.89	

Note: The top panel includes brood years 1961–2008, and the bottom panel includes only brood years 1979–2008. Miles Lake sonar started operation in 1978 and provided a significant improvement in our estimate of escapement and total return; however, 1978 is not included in the bottom analysis because only one bank had sonar, the project started late and ended early, and there was no substrate to aim the transducer. R/S = return per spawner. Empty cells have no data ($n = 0$).

Table 8.–Posterior percentiles from a Bayesian stock-recruitment analysis of Copper River sockeye salmon data, brood years 1961–2008.

Node	Mean	SD	Monte Carlo error	2.50%	Median	97.50%
MSY	1,243,000	831,800	27,190	922,300	1,130,000	2,073,000
S.msy	859,000	908,400	28,680	469,300	713,200	1,892,000
alpha	4.73	0.80	0.03	3.43	4.66	6.49
beta	0.00000085	0.00000030	0.00000001	0.00000027	0.00000084	0.00000146
deviance	42.18	2.533	0.08823	39.32	41.55	48.75
sigma	0.3803	0.0409	0.0013	0.3067	0.3771	0.4664

Note: This analysis combined Upper Copper River and Copper River Delta stocks because we do not have a commercial harvest allocation program. MSY = maximum sustained yield; *S.msy* = estimate of spawning escapement that produces MSY.

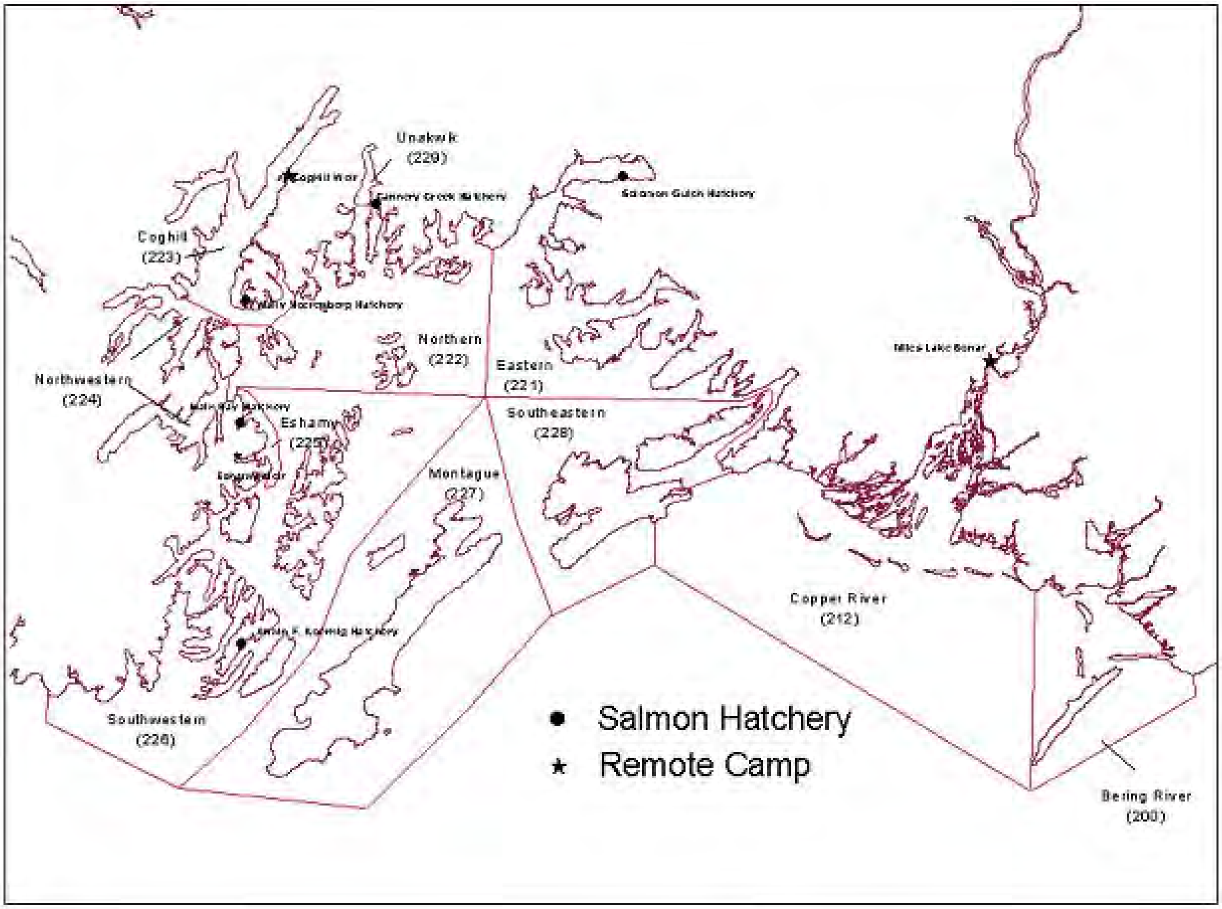
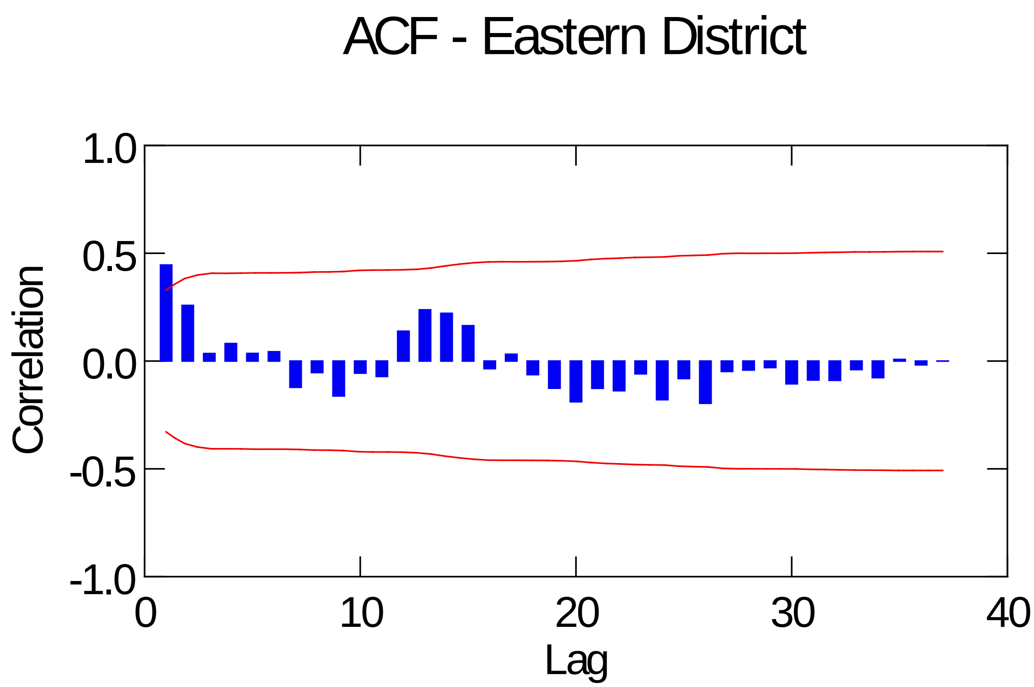


Figure 1.–Prince William Sound Management Area showing commercial fishing districts, salmon hatcheries, weir locations, and Miles Lake sonar camp.



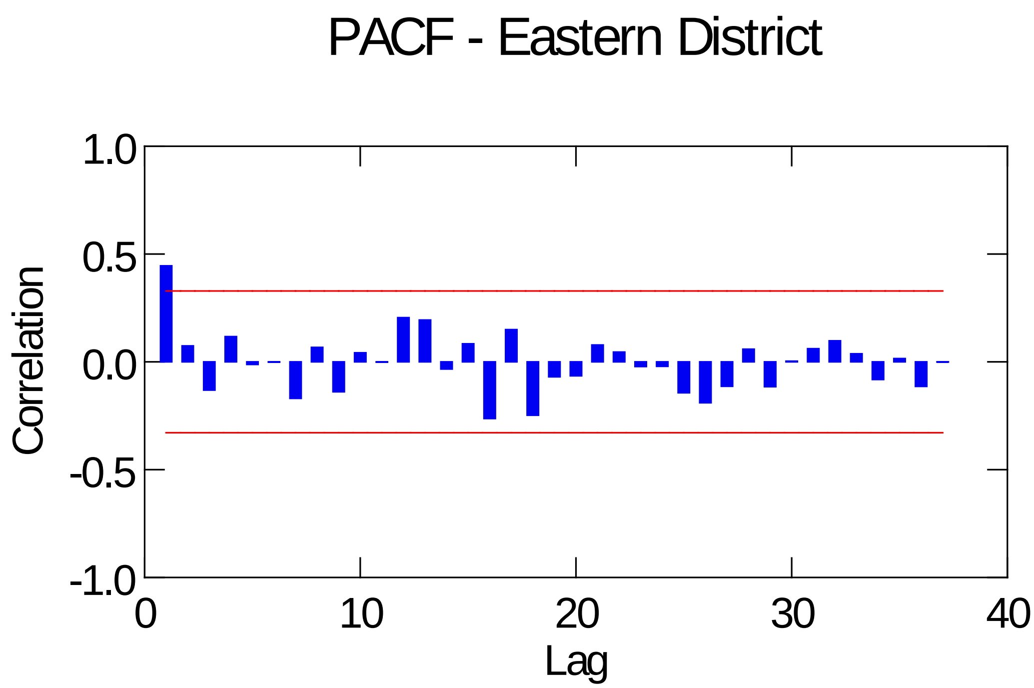
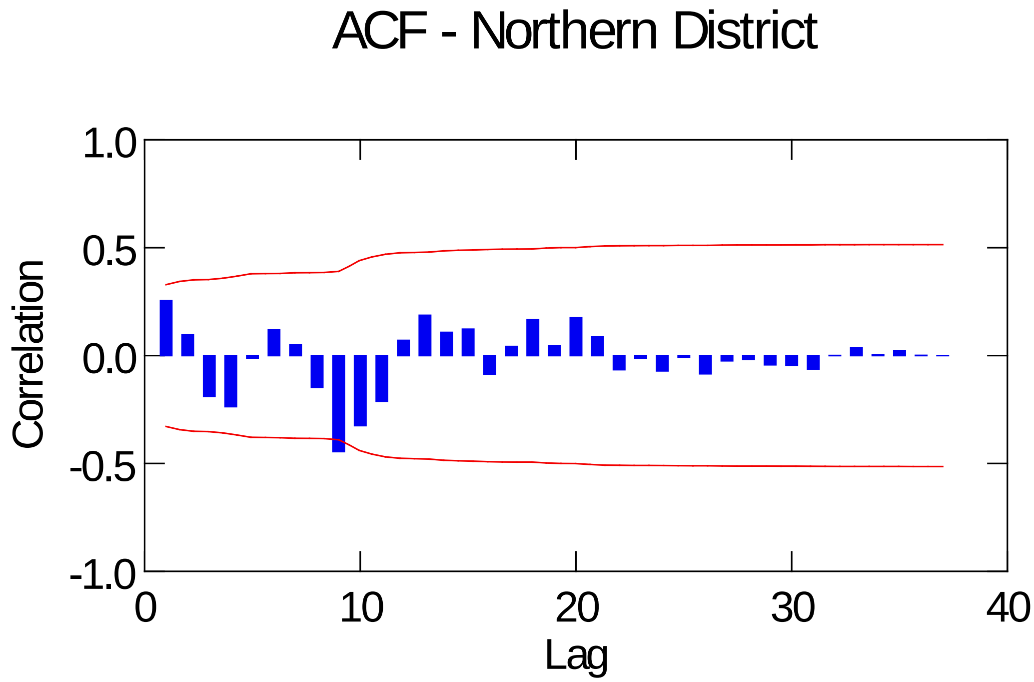


Figure 2.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Eastern District of Prince William Sound (1977–2013).



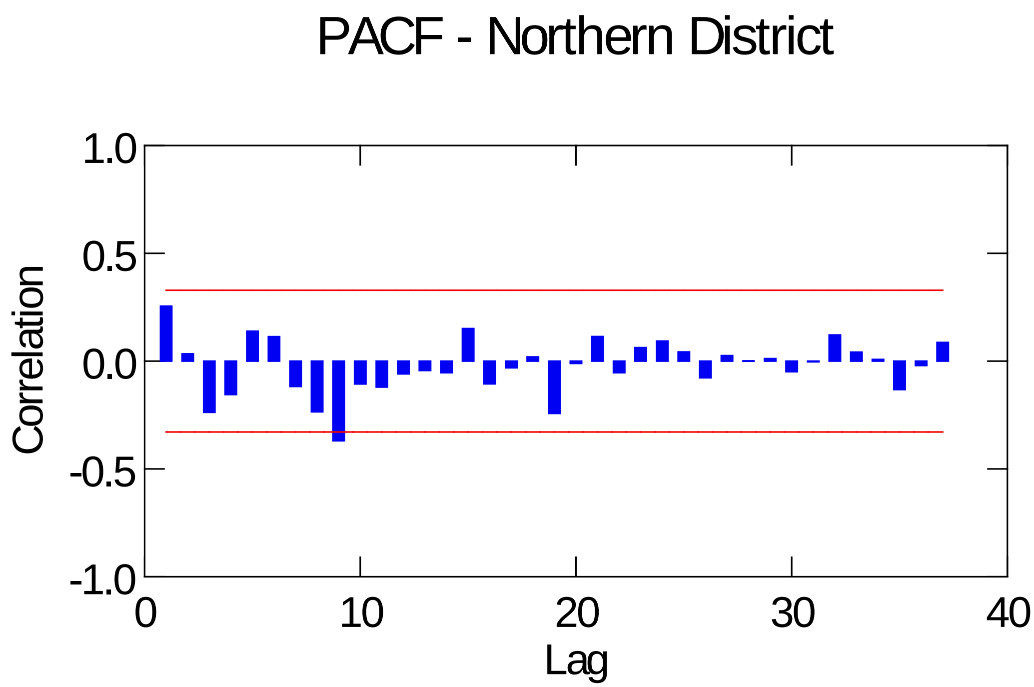
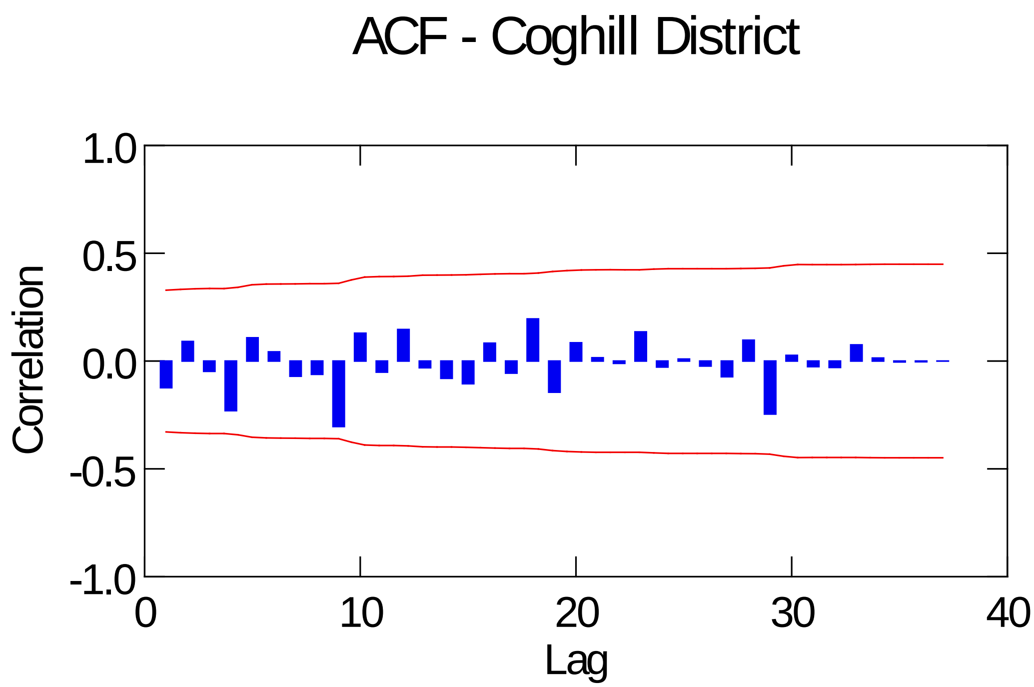


Figure 3.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Northern District of Prince William Sound (1977–2013).



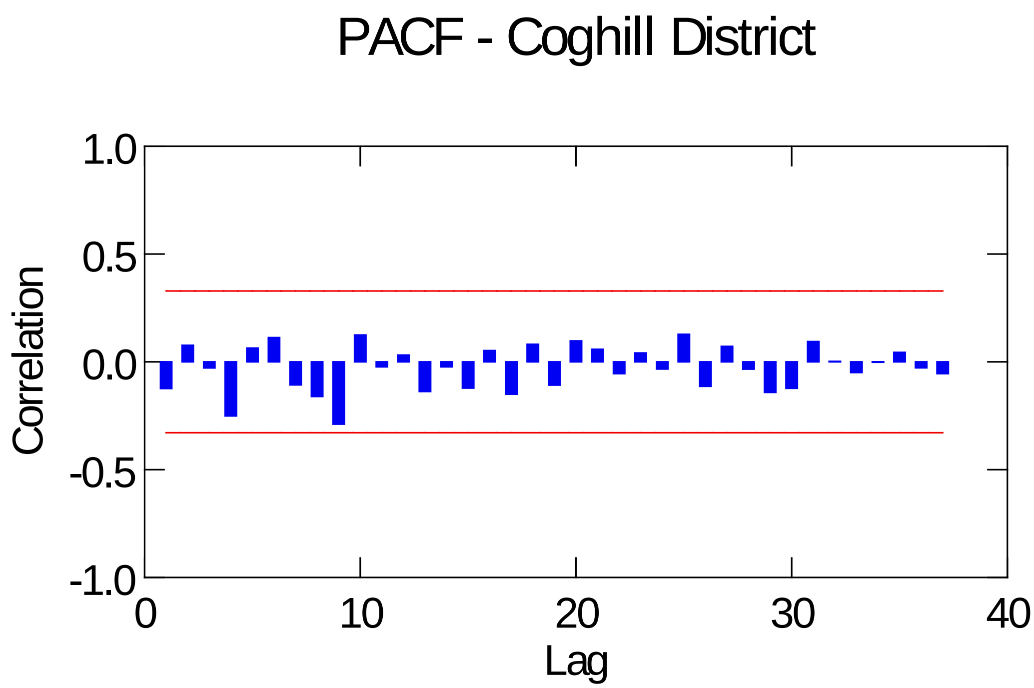


Figure 4.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Coghill District of Prince William Sound (1977–2013).

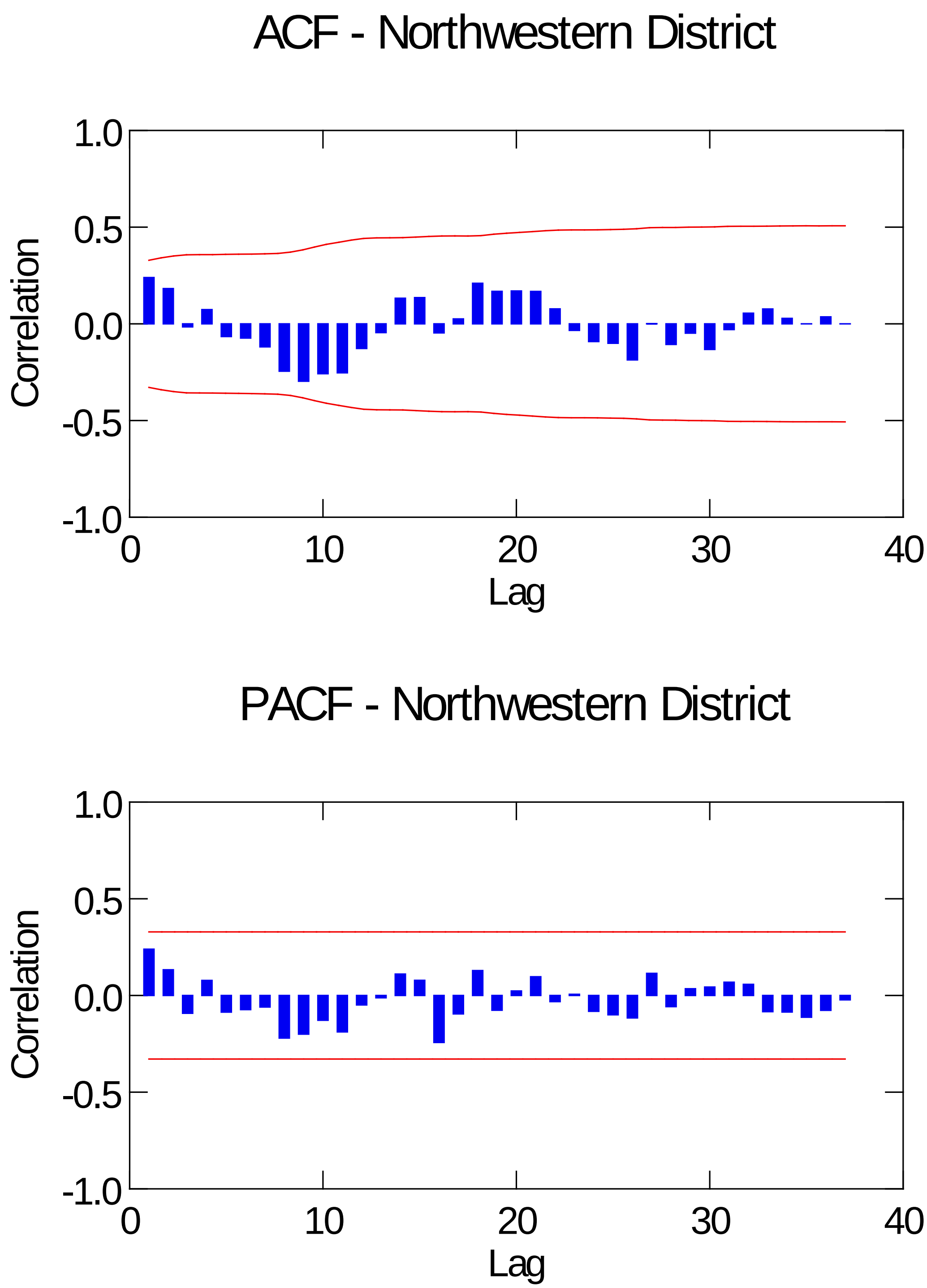


Figure 5.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Northwestern District of Prince William Sound (1977–2013).

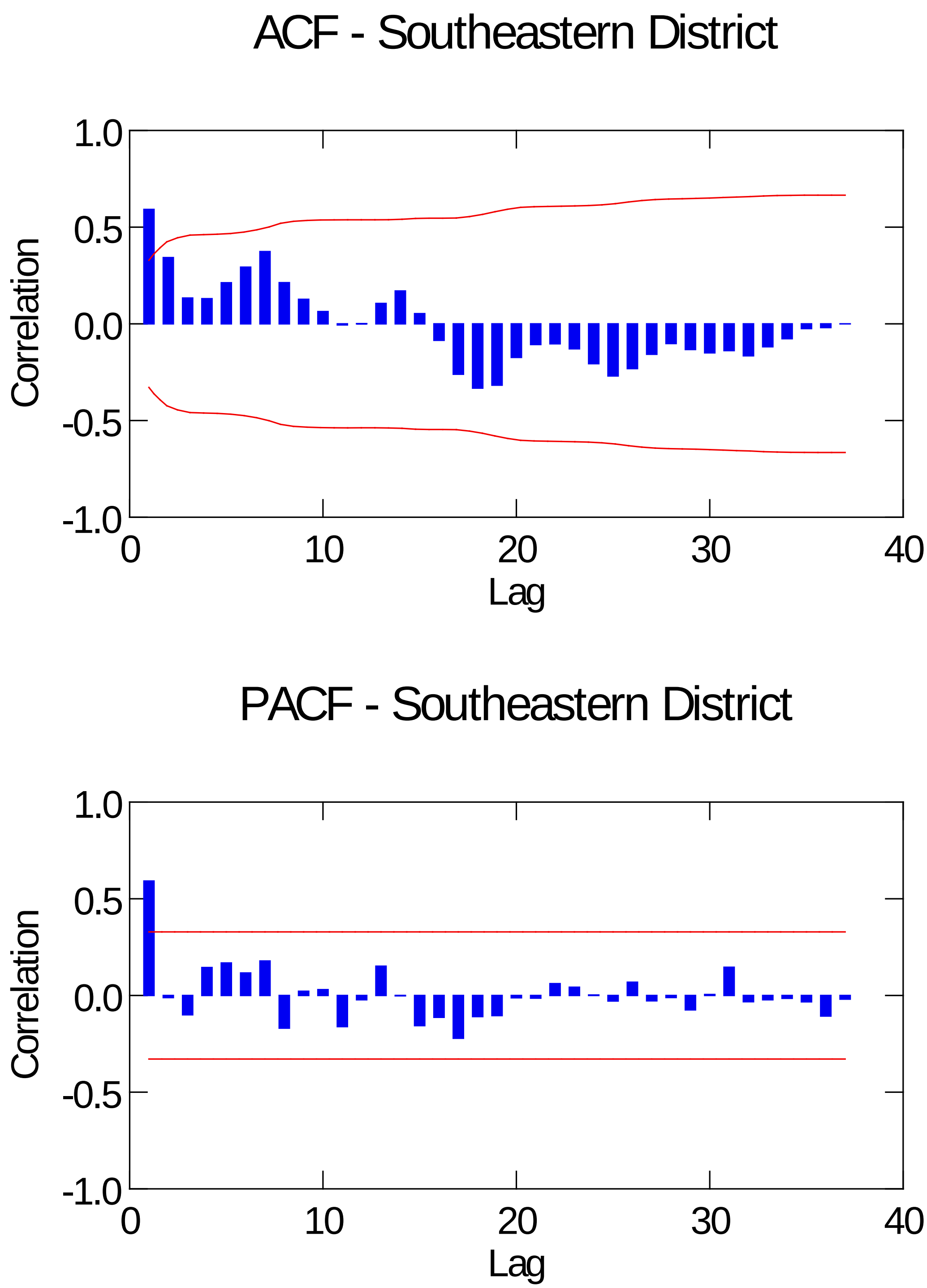


Figure 6.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Southeastern District of Prince William Sound (1977–2013).

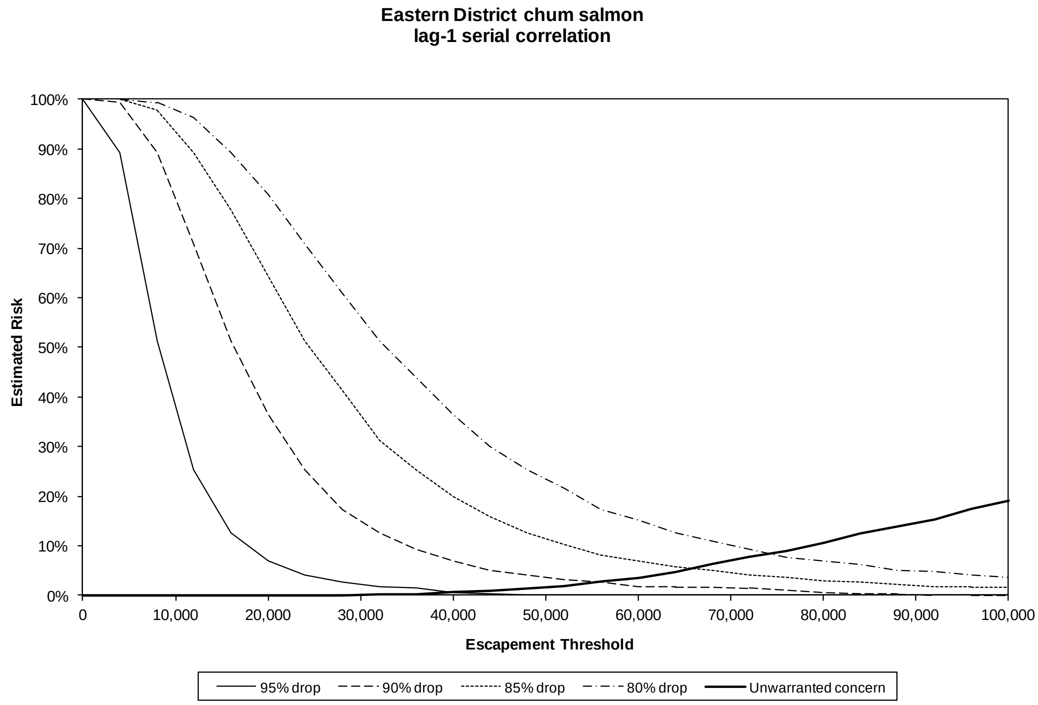


Figure 7.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Eastern District chum salmon.

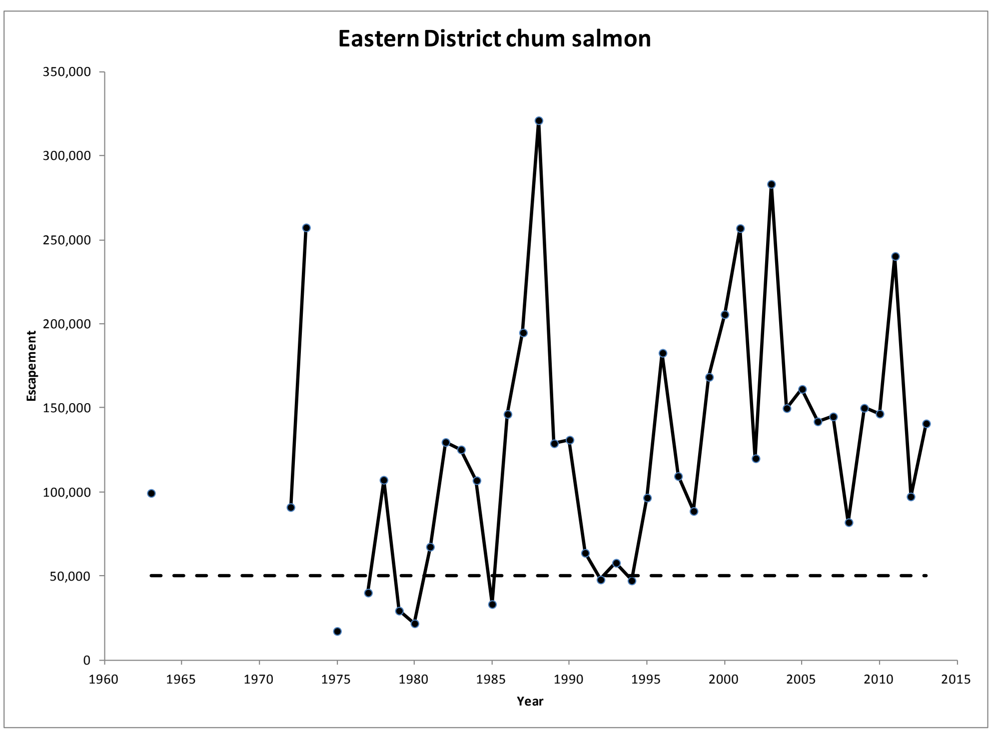


Figure 8.–Escapement of chum salmon in the Eastern District (1963–2013; solid line) and the recommended lower bound sustainable escapement goal (SEG; dashed line).

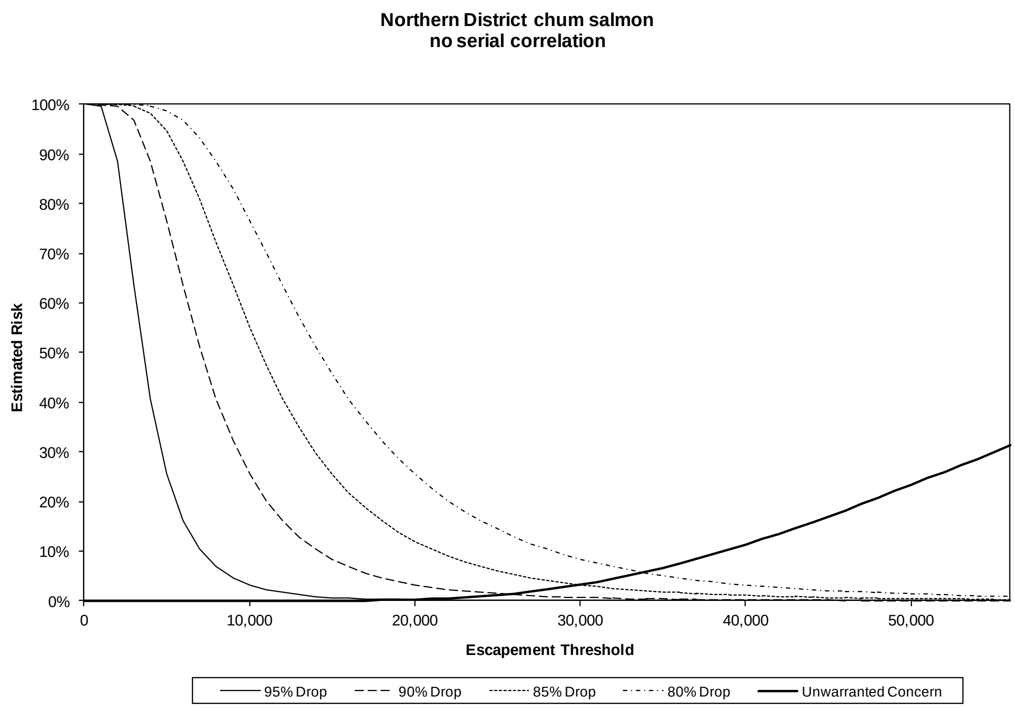


Figure 9.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Northern District chum salmon.

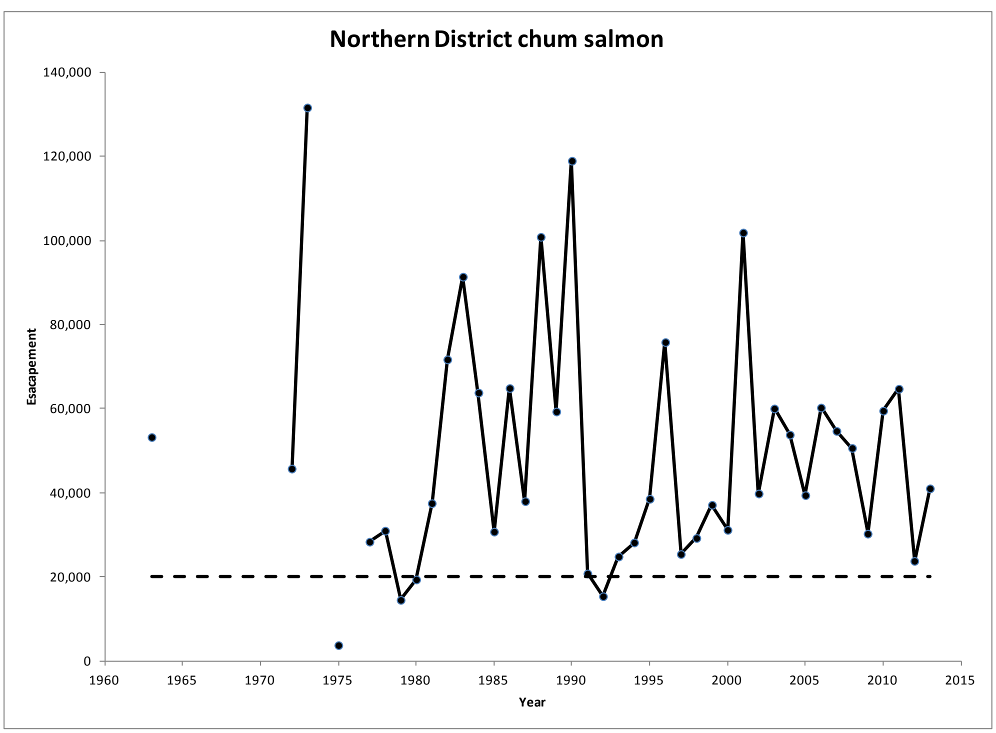


Figure 10.–Escapement of chum salmon in the Northern District (1963–2013; solid line) and the recommended lower bound sustainable escapement goal (SEG; dashed line).

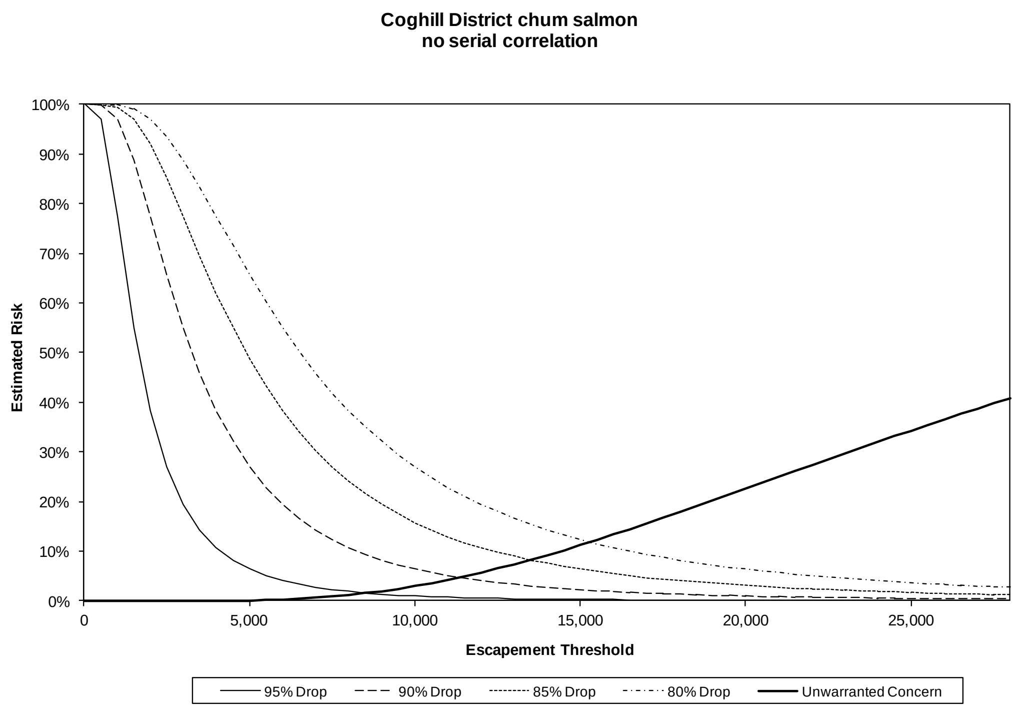


Figure 11.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Coghill District chum salmon.

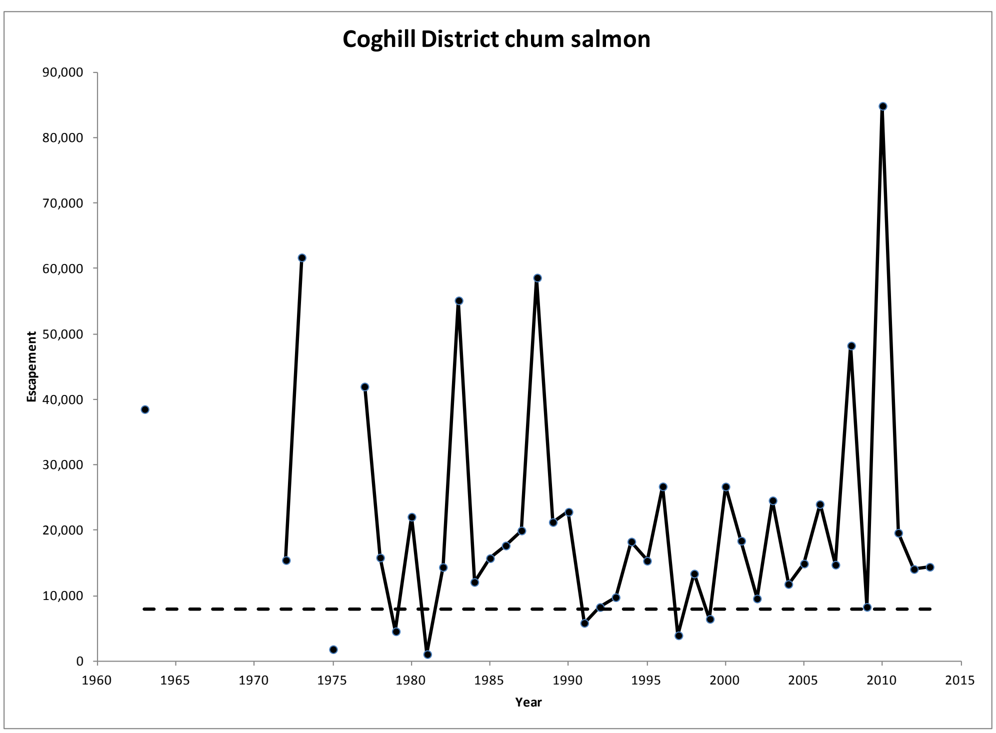


Figure 12.–Escapement of chum salmon in the Coghill District (1963–2013; solid line) and the recommended lower bound sustainable escapement goal (SEG; dashed line).

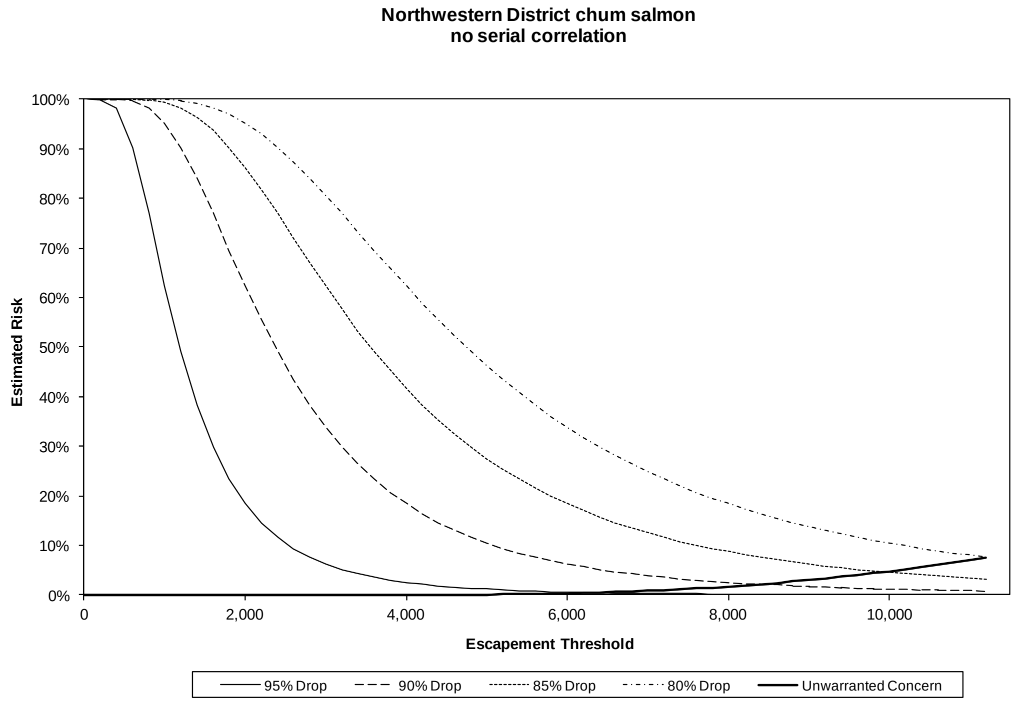


Figure 13.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Northwestern District chum salmon.

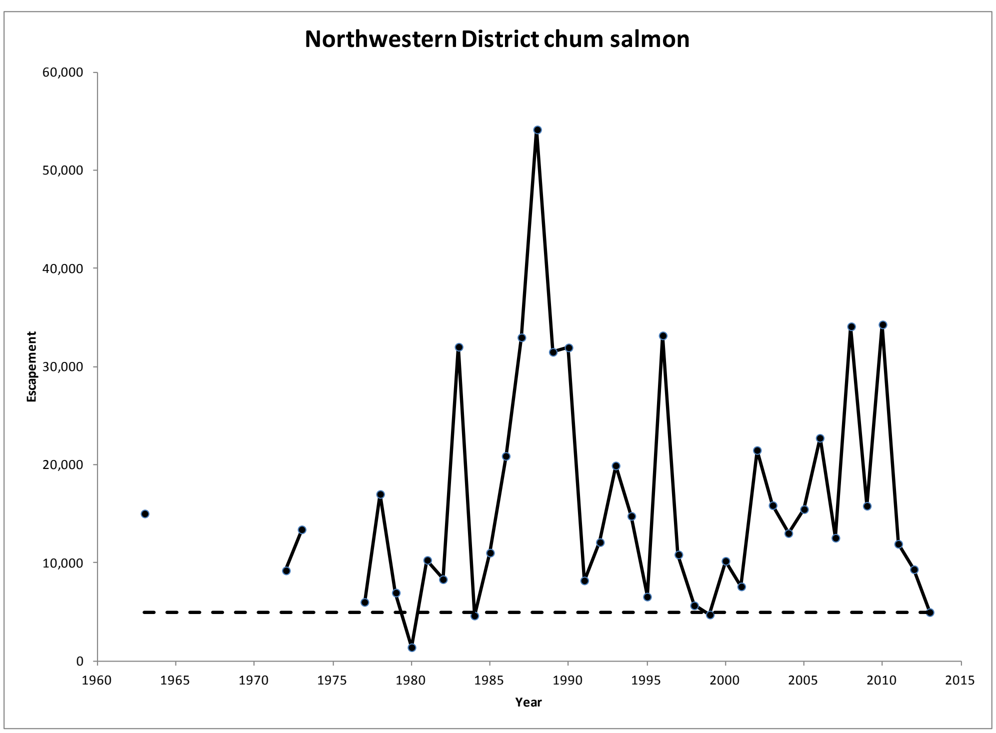


Figure 14.–Escapement of chum salmon in the Northwestern District (1963–2013; solid line) and the recommended lower bound SEG (dashed line).

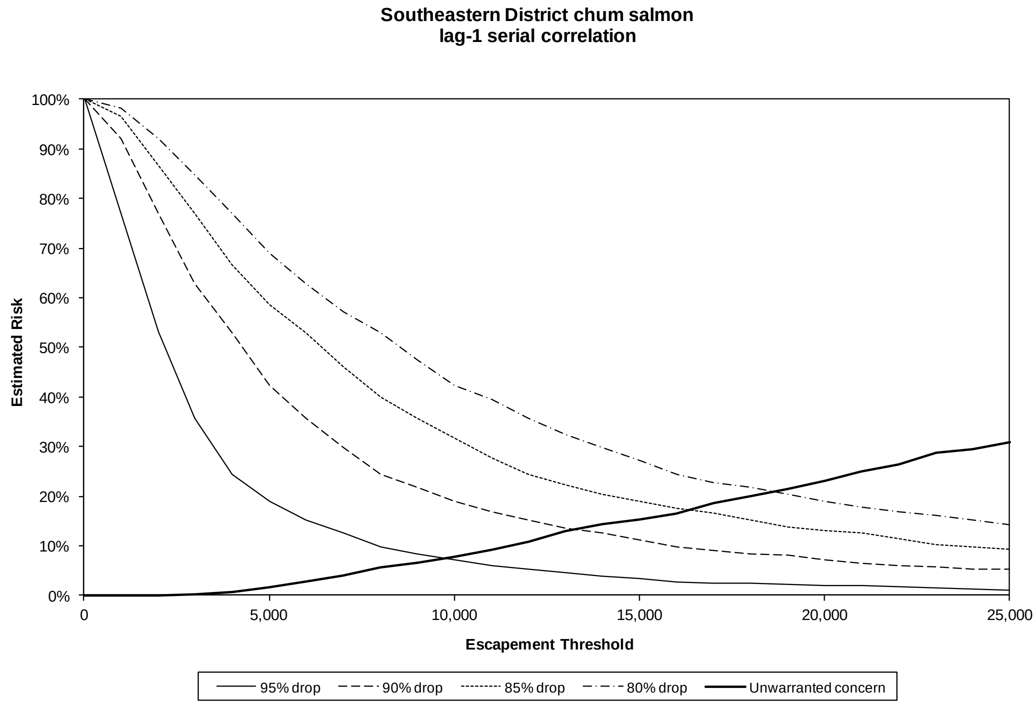


Figure 15.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Southeastern District chum salmon.

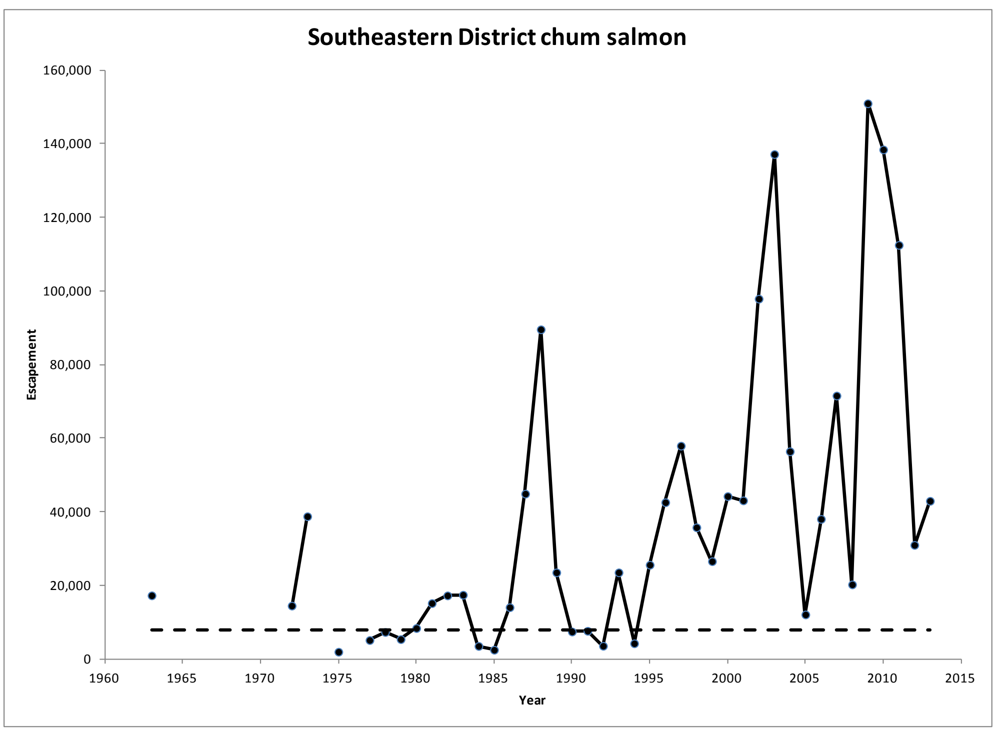
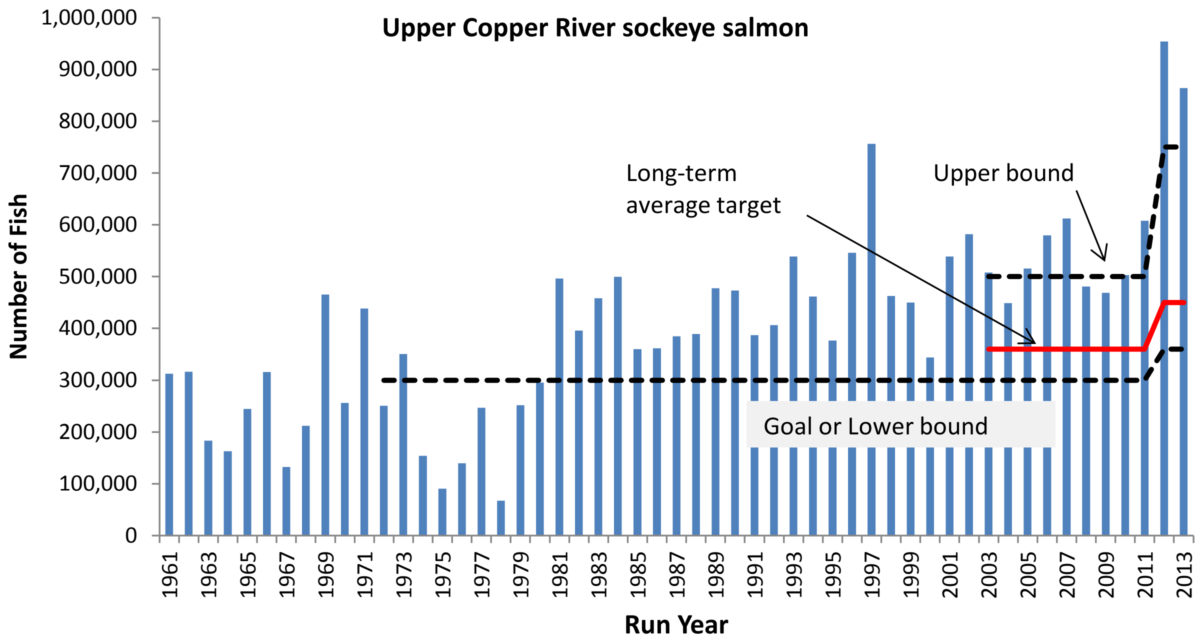


Figure 16.–Escapement of chum salmon in the Southeastern District (1963–2013; solid line) and the recommended lower bound sustainable escapement goal (SEG; dashed line).



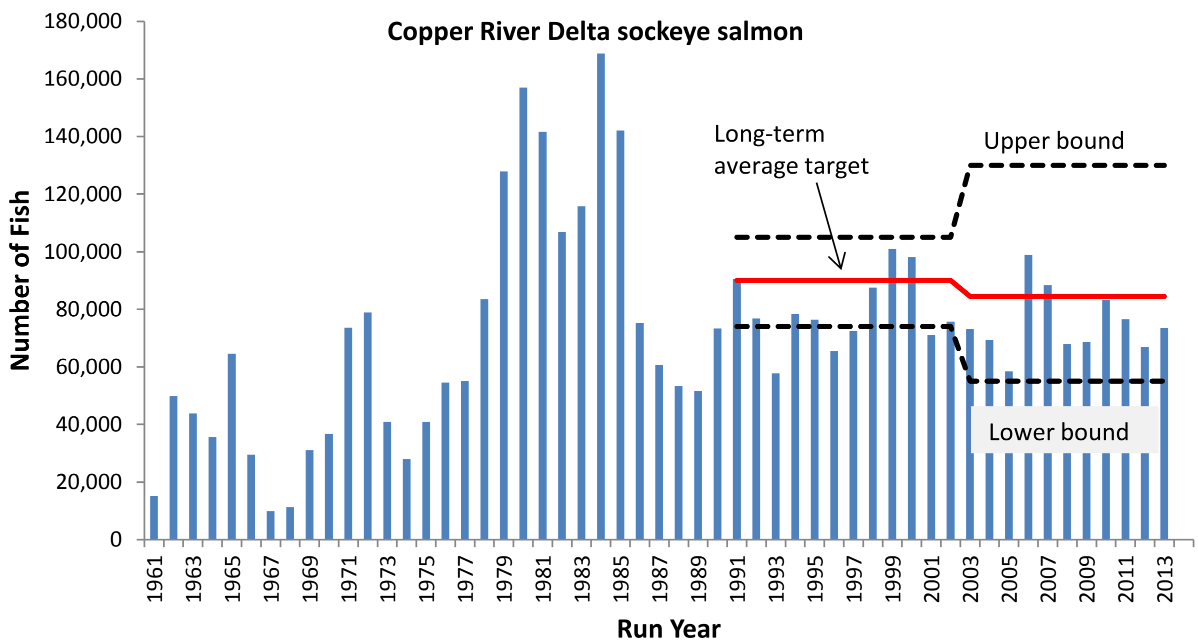
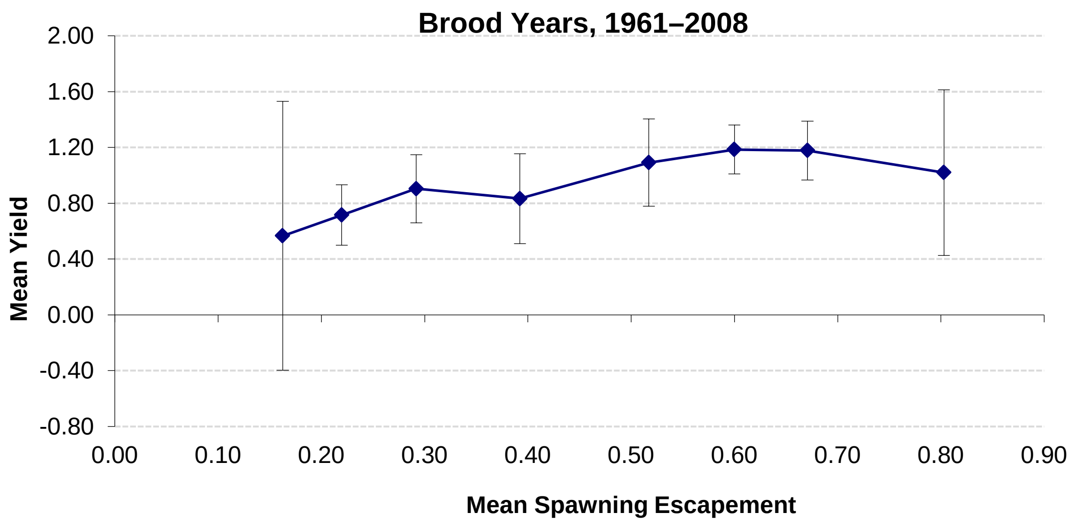


Figure 17.–Copper River sockeye salmon spawning escapement counts and historical escapement goals.

Top graphic includes Upper Copper River escapements calculated as inriver abundance indices minus upriver harvests and Gulkana Hatchery broodstock and excess. Inriver abundance was calculated from mark-recapture and expanded aerial surveys counts (1961–1977) and DIDSON equivalent sonar counts (1978–2013). Bottom graphic shows Copper River Delta escapement calculated as the peak count from approximately weekly aerial surveys in 17 index areas.



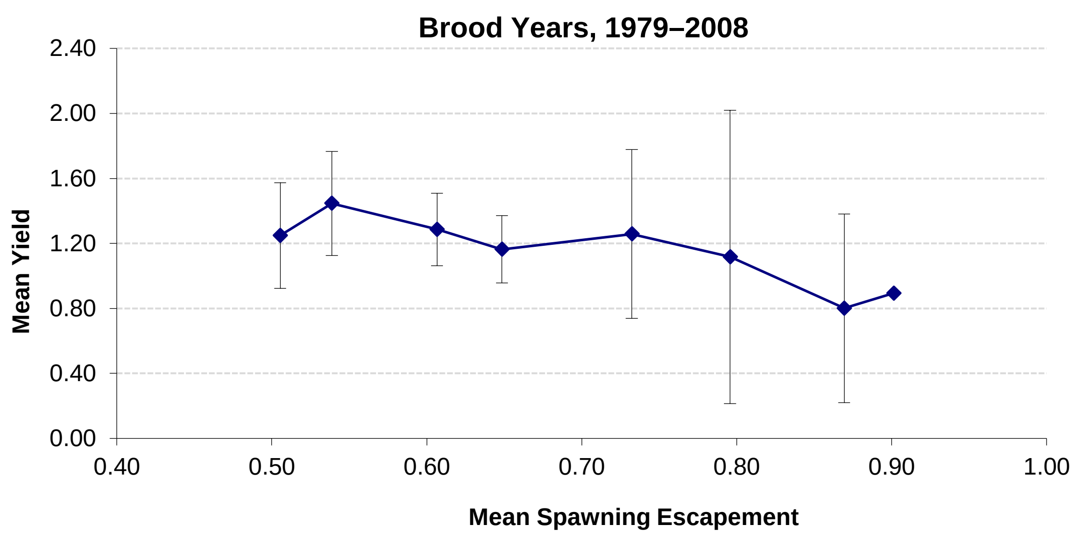


Figure 18.–Mean yield of Copper River sockeye salmon at overlapping 200,000 spawner intervals for brood years 1961–2008 (top figure) and 150,000 spawner intervals for brood years 1979–2008 (bottom figure). Vertical bars represent the 90% confidence intervals of the yield.

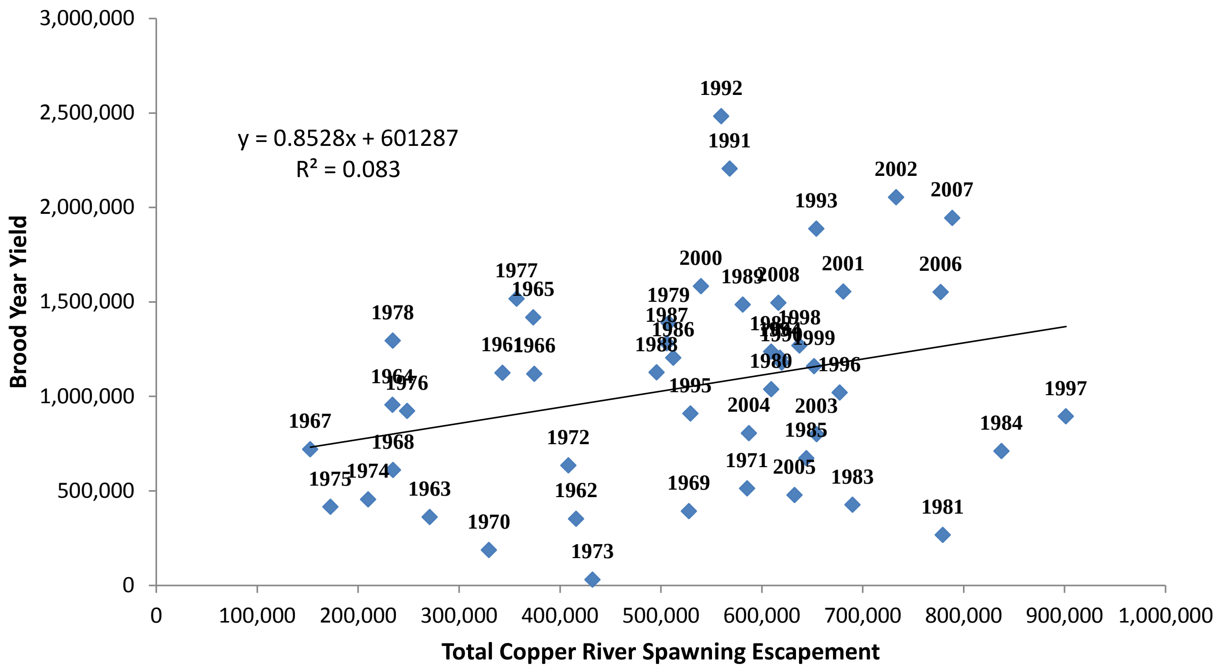


Figure 19.–Total Copper River sockeye salmon spawning escapement (Upper Copper River and Copper River Delta) and total Copper River yield by brood year, 1961–2008.

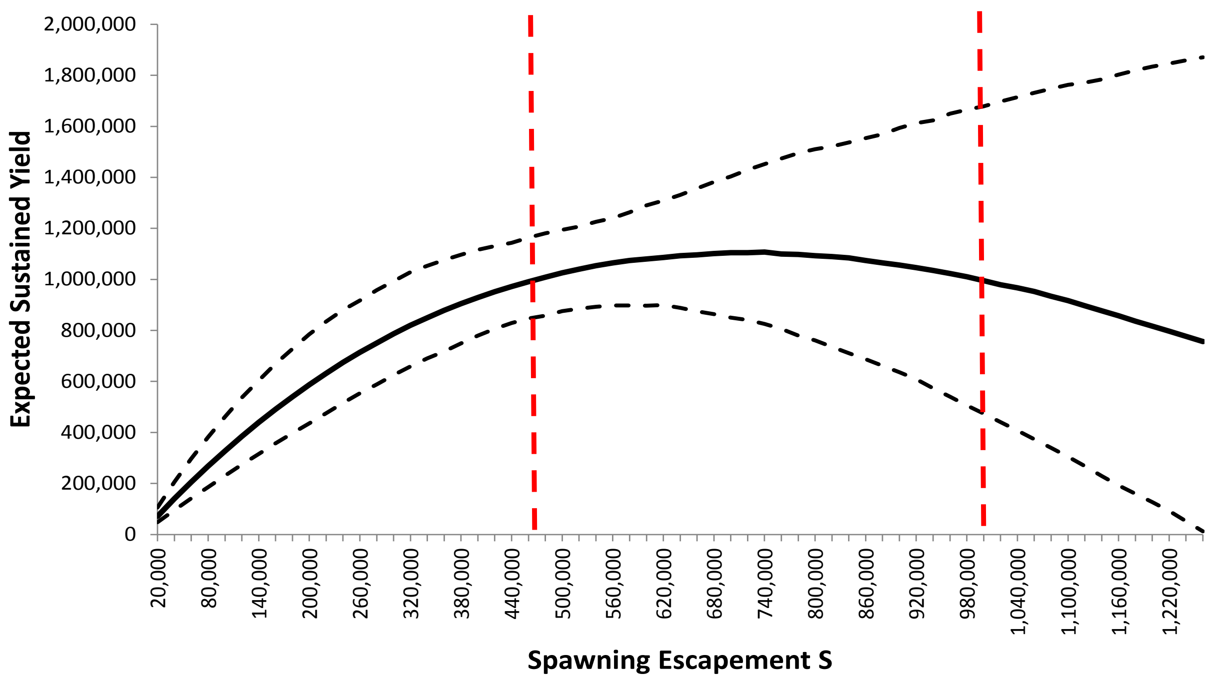


Figure 20.–Expected sustained yield (solid black line) and 95% interval (dashed black lines) versus sockeye salmon spawning escapement for the combined Upper Copper River and Copper River Delta, brood years 1961–2008. Red vertical lines bracket spawning escapement that would produce 90% of the median value of maximum sustained yield (MSY).

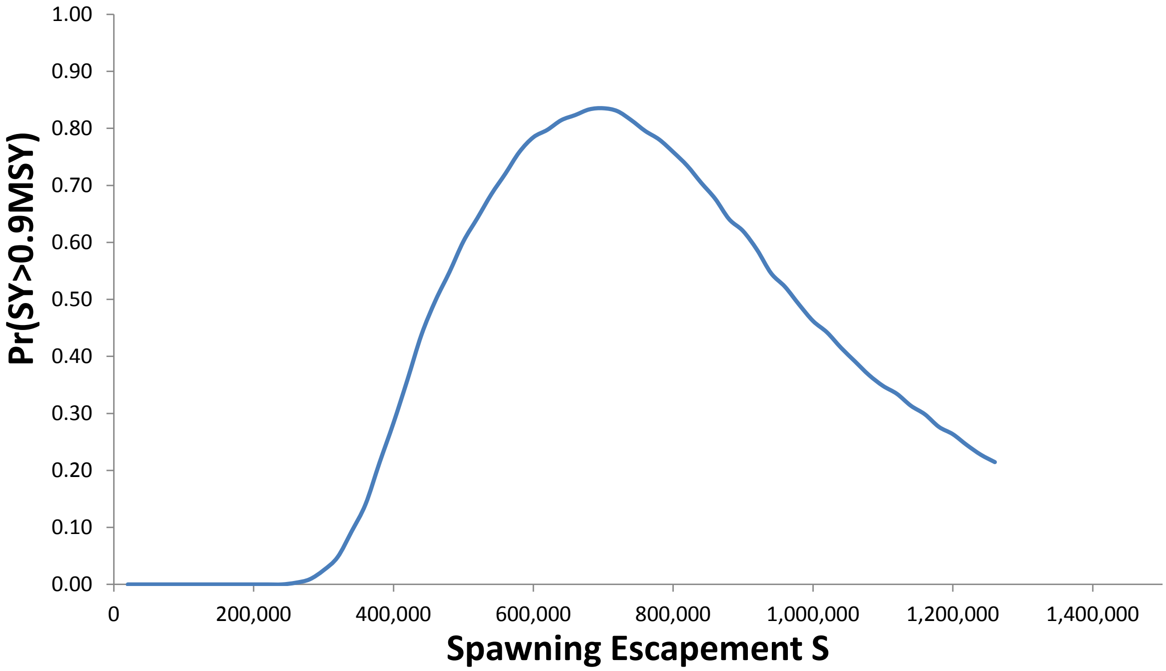


Figure 21.–Probability of achieving 90% of maximum sustained yield (MSY) for given values of combined Upper Copper River and Copper River Delta spawning escapement for brood years 1961–2008.

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]	Modeled escapement [b]	Total return [c]
1980	ND	22,951	37,682
1981	ND	17,895	42,458
1982	ND	20,280	69,678
1983	ND	22,066	84,204
1984	ND	31,667	74,096
1985	ND	8,481	56,541
1986	ND	36,396	82,371
1987	ND	28,054	74,827
1988	ND	22,310	59,762
1989	ND	45,747	79,020
1990	ND	28,753	54,848
1991	ND	28,346	72,264
1992	ND	14,509	63,223
1993	ND	17,517	59,240
1994	ND	20,002	79,350
1995	ND	14,115	94,101
1996	ND	32,461	99,471
1997	ND	49,761	115,090
1998	ND	33,938	118,624
1999	16,157	ND	95,951
2000	24,492	ND	70,754
2001	28,208	ND	81,155
2002	21,502	ND	72,974
2003	34,034	ND	94,505
2004	30,645	ND	80,559
2005	21,528	ND	66,357
2006	58,454	ND	99,877
2007	34,575	ND	87,770
2008	32,487	ND	53,880
2009	27,787	ND	43,007
2010	16,771	ND	33,181
2011	27,994	ND	53,889
2012	27,835	ND	44,312
2013	29,012	ND	42,880

Note: Current goal is a lower-bound sustainable escapement goal (SEG) of >24,000 Chinook salmon and no change to the goal is recommended.

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

[b] From age-structured model (Savereide and Quinn 2004).

[c] Total return estimated by age-structured model from 1980 to 1998 and from mark–recapture estimates of escapement and subsistence, sport, and commercial harvest information since 1999.

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	Northern	Coghill	Northwestern	Southeastern
1963	99,451	53,253	38,507	15,042	17,328
1964	177,740	49,627	77,479	13,067	16,303
1965	34,097	19,750	7,302	5,545	31,008
1966	40,609	44,875	10,277	3,934	7,008
1967	85,712	26,255	5,313	1,564	10,366
1968	3,710	2,503	ND	ND	6,694
1969	49,359	21,442	18,777	596	5,121
1970	14,366	784	4,002	2,350	1,500
1971	34,656	7,175	3,853	5,505	1,942
1972	91,057	45,760	15,442	9,243	14,541
1973	257,342	131,588	61,688	13,421	38,807
1974	19,147	2,497	0	0	0
1975	17,375	3,800	1,827	0	2,011
1976	17,769	31,142	38,800	2,684	50
1977	40,202	28,390	41,963	6,030	5,189
1978	107,274	31,006	15,833	17,024	7,375
1979	29,475	14,552	4,565	6,985	5,437
1980	21,936	19,409	22,066	1,419	8,444
1981	67,495	37,538	1,075	10,302	15,221
1982	129,714	71,708	14,368	8,345	17,312
1983	125,323	91,371	55,119	32,022	17,490
1984	106,972	63,824	12,094	4,645	3,577
1985	33,379	30,782	15,735	11,052	2,552
1986	146,366	64,899	17,670	20,902	14,108
1987	194,849	38,016	19,962	32,986	44,951
1988	321,022	100,841	58,605	54,155	89,588
1989	128,973	59,328	21,253	31,504	23,571
1990	131,099	118,933	22,823	31,955	7,501
1991	63,849	20,830	5,846	8,223	7,692
1992	47,992	15,424	8,264	12,123	3,626
1993	57,942	24,866	9,769	19,929	23,571
1994	47,409	28,199	18,274	14,791	4,307
1995	96,684	38,586	15,343	6,575	25,643
1996	182,767	75,829	26,703	33,179	42,619
1997	109,494	25,451	3,947	10,870	57,979
1998	88,713	29,264	13,380	5,683	35,808
1999	168,474	37,151	6,458	4,748	26,605
2000	205,680	31,198	26,682	10,214	44,278
2001	256,917	101,863	18,402	7,613	43,125
2002	120,070	39,837	9,574	21,497	97,910
2003	283,181	60,046	24,566	15,886	137,182
2004	149,896	53,827	11,778	13,040	56,457
2005	161,276	39,444	14,911	15,482	12,141
2006	141,999	60,265	23,987	22,742	38,091
2007	144,941	54,709	14,738	12,570	71,595
2008	82,068	50,666	48,221	34,107	20,300

-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	Northern	Coghill	Northwestern	Southeastern
2009	150,051	30,296	8,290	15,826	150,974
2010	146,613	59,530	84,840	34,300	138,442
2011	240,321	64,743	19,617	11,951	112,507
2012	97,362	23,818	14,075	9,360	31,029
2013	140,806	41,058	14,414	4,995	43,000

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. No changes to any of the goals are recommended.

[a] The chum salmon escapement index is the area under the curve of weekly aerial survey counts adjusted for stream life.

Appendix A3.–Supporting information for analysis of escapement goal for Bering River District coho salmon.

System: Bering River District
Species: coho salmon

Data available for analysis of escapement goals.

Return Year	Wild escapement[a]	Commercial Harvest[b]	Total run[c,d]
1982	18,500	144,752	163,252
1983	16,700	117,669	134,369
1984	20,000	214,632	234,632
1985	80,500	419,276	499,776
1986	9,420	115,809	125,229
1987	5,585	15,864	21,449
1988	11,415	86,539	97,954
1989	15,820	26,952	42,772
1990	24,800	42,952	67,752
1991	31,300	110,951	142,251
1992	16,300	125,616	141,916
1993	30,050	115,833	145,883
1994	28,550	259,003	287,553
1995	27,450	282,045	309,495
1996	26,800	93,763	120,563
1997	42,400	97	42,497
1998	29,800	12,284	42,084
1999	31,290	9,852	41,142
2000	26,380	56,329	82,709
2001	30,007	2,715	32,722
2002	34,200	108,522	142,722
2003	32,475	59,481	91,956
2004	30,185	95,595	125,780
2005	44,542	43,030	87,572
2006	33,192	56,713	89,905
2007	32,962	9,305	42,267
2008	28,822	40,380	69,202
2009	21,760	45,522	67,282
2010	21,311	80,560	101,871
2011	18,890	19,956	38,846
2012	15,605	46,169	61,774
2013	18,820	46,959	65,779

Note: Current goal is a sustainable escapement goal (SEG) of 13,000–33,000 and no change to the goal is recommended.

[a] Calculated as the sum of peak aerial index counts from 9 sites.

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

[c] There are no sport fish harvest estimates for the Bering River District systems.

[d] Escapement plus total harvest.

Appendix A4.–Supporting information for analysis of escapement goal for Copper River Delta coho salmon.

System: Copper River Delta
Species: coho salmon

Data available for analysis of escapement goals.

Return		Harvest [a]		Total
year	Wild escapement [b]	Commercial	Sport/PU/Sub [c]	run [d]
1981	44,800	225,299	ND	270,099
1982	40,175	310,154	ND	350,329
1983	59,700	454,763	84	514,547
1984	63,425	234,243	1,780	299,448
1985	104,910	382,432	649	487,991
1986	25,790	295,980	2,969	324,739
1987	26,215	111,599	1,010	138,824
1988	26,450	315,568	1,492	343,510
1989	39,895	194,454	2,118	236,467
1990	41,280	246,797	1,778	289,855
1991	63,650	385,086	1,941	450,677
1992	44,005	291,627	3,854	339,486
1993	31,870	281,469	4,139	317,478
1994	43,910	677,633	4,293	725,836
1995	34,380	542,658	2,543	579,581
1996	46,070	193,042	5,750	244,862
1997	54,740	18,656	2,825	76,221
1998	41,750	108,232	4,230	154,212
1999	42,505	153,061	6,978	202,544
2000	42,785	304,944	4,479	352,208
2001	40,286	251,473	12,144	303,903
2002	87,415	504,223	6,909	598,547
2003	70,055	363,489	17,549	451,093
2004	95,555	467,859	18,296	581,710
2005	95,892	263,465	12,104	371,461
2006	82,040	318,285	8,607	408,932
2007	50,715	117,182	8,910	176,807
2008	71,972	202,412	11,468	285,852
2009	39,444	207,776	16,633	263,853
2010	38,677	210,621	18,378	267,676
2011	37,900	127,511	17,226	182,637
2012	35,295	130,261	17,523	183,079
2013	34,680	244,985	16,414	296,079

Note: Current goal is a sustainable escapement goal (SEG) of 32,000–67,000 coho salmon and no change to the goal is recommended.

[a] Commercial harvest includes both Upper Copper River and Copper River Delta stocks.

[b] Calculated as the sum of peak aerial index counts from 21 sites.

[c] Sport harvest from statewide harvest survey; data available beginning in 1983. Sport harvest includes both Upper Copper River and Copper River Delta harvests. Data in table from personal use (PU) and subsistence (Sub) begins in 2003.

[d] Escapement plus total harvest.

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

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

	Natural stock escapement indices [a]								
Brood year	Eastern	Northern/ Unakwik	Coghill	Northwestern	Eshamy	Southwestern	Montague	Southeastern	Total
1966	544,980	288,710	135,440	79,960	11,720	115,570	42,220	204,570	1,423,170
1968	364,930	151,120	108,020	117,430	10,770	172,770	52,350	179,120	1,156,510
1970	387,090	125,360	95,170	82,660	7,610	66,790	73,880	140,660	979,220
1972	344,470	83,900	30,960	39,020	1,100	29,530	33,140	79,060	641,180
1974	256,880	206,750	56,940	163,930	6,240	160,980	11,750	94,650	958,120
1976	472,080	139,600	57,090	68,150	5,840	52,120	13,790	117,590	926,260
1978	279,120	163,010	85,450	132,300	5,430	258,980	56,690	164,030	1,145,010
1980	535,960	189,140	214,930	159,260	13,100	133,470	118,400	307,680	1,671,940
1982	573,070	332,560	368,380	174,290	15,080	195,950	132,380	482,860	2,274,570
1984	1,209,740	593,310	429,450	452,370	16,860	345,760	191,810	792,560	4,031,860
1986	356,380	141,420	101,600	81,490	3,840	74,980	44,680	155,830	960,220
1988	362,370	143,850	37,070	73,780	490	126,440	67,990	152,540	964,530
1990	443,660	131,580	49,110	115,870	17,870	150,100	113,572	304,090	1,325,852
1992	204,383	72,915	23,611	42,308	2,709	66,953	47,156	95,070	555,105
1994	615,240	178,151	65,648	141,290	11,799	144,594	60,084	196,378	1,413,184
1996	584,236	218,022	104,781	86,709	3,000	63,337	92,966	330,285	1,483,336
1998	377,700	213,288	85,968	97,485	4,644	280,335	161,275	199,410	1,420,105
2000	554,984	168,247	223,646	66,078	4,286	131,648	227,881	282,258	1,659,028
2002	226,068	138,204	54,882	50,981	1,397	35,554	71,461	364,630	943,177
2004	724,663	158,958	79,010	51,306	2,300	108,192	183,891	687,903	1,996,223
2006	248,592	208,397	145,511	127,836	11,247	118,205	149,798	178,009	1,187,595
2008	193,844	141,396	145,177	141,787	579	70,291	56,999	112,347	862,419
2010	490,952	287,570	335,108	211,709	9,585	126,489	144,821	310,676	1,916,910
2012	301,709	106,568	172,611	117,795	1,052	90,156	77,756	258,047	1,125,693

-continued-

Appendix A5.–Page 2 of 2.

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

	Natural stock escapement indices [a]								
Brood year	Eastern	Northern/ Unakwik	Coghill	Northwestern	Eshamy	Southwestern	Montague	Southeastern	Total
1965	257,853	59,820	91,584	159,011	9,340	65,380	77,042	255,926	975,956
1967	255,240	144,200	65,240	82,980	5,020	42,950	10,020	236,610	842,260
1969	160,600	94,770	39,020	23,830	ND	57,890	1,550	26,910	404,570
1971	352,800	126,210	62,160	14,320	1,710	79,140	296,730	179,480	1,112,550
1973	309,040	69,660	493,780	2,910	ND	52,320	119,520	177,780	1,225,010
1975	412,560	38,260	452,430	4,990	ND	77,270	85,380	194,670	1,265,560
1977	390,930	69,980	130,510	80,890	16,450	178,670	152,960	277,780	1,298,170
1979	642,220	200,730	70,980	124,020	ND	231,300	219,400	728,630	2,217,280
1981	599,340	243,170	106,450	51,210	3,990	93,630	255,420	359,870	1,713,080
1983	481,950	168,410	310,330	196,630	12,610	161,290	230,200	601,680	2,163,100
1985	750,530	214,210	296,970	199,190	1,410	181,270	332,240	645,510	2,621,330
1987	514,570	132,960	147,060	75,390	3,450	112,920	149,260	330,630	1,466,240
1989	359,730	106,530	45,510	68,540	19,470	176,230	181,760	315,000	1,272,770
1991	474,380	165,930	98,580	101,320	18,800	197,095	247,890	533,170	1,837,165
1993	315,209	95,614	41,837	46,011	9,348	98,573	144,784	315,093	1,066,469
1995	396,696	84,447	46,029	50,582	10,182	82,490	183,448	336,310	1,190,184
1997	345,725	65,260	52,961	53,740	914	112,010	206,943	585,135	1,422,688
1999	622,502	214,732	168,816	52,340	6,900	163,347	381,054	853,180	2,462,871
2001	436,585	163,573	148,665	102,294	2,963	176,503	314,323	655,480	2,000,386
2003	975,327	255,059	375,147	103,931	5,206	130,356	320,494	691,769	2,857,289
2005	1,025,756	570,079	528,264	401,640	32,396	272,572	566,002	1,330,407	4,727,116
2007	374,723	156,063	197,405	68,667	9,461	116,130	142,769	443,914	1,509,133
2009	454,960	119,747	125,907	127,261	9,790	239,357	263,770	488,831	1,829,623
2011	982,837	167,408	257,020	147,128	4,368	232,302	598,918	1,537,438	3,927,419
2013	1,266,783	329,434	640,414	203,444	12,145	348,012	411,373	1,472,633	4,684,239

Note: Current goals are district specific sustainable escapement goals (SEG) and no changes to the goals are recommended.

[a] Pink salmon escapement index is calculated as the area under the curve of weekly aerial survey counts adjusted for stream life. Hatchery strays are not accounted for in calculating these indices.

Appendix A6.–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.

Return year	Wild escapement [a]	CPF harvest	Total run [b]
1988	13,680	7,152	20,832
1989	23,300	9,225	32,525
1990	19,741	8,332	28,073
1991	32,220	19,181	51,401
1992	55,895	19,721	75,616
1993	27,725	33,951	61,676
1994	26,550	27,926	54,476
1995	33,450	21,585	55,035
1996	27,310	37,712	65,022
1997	15,065	9,651	24,716
1998	23,450	8,439	31,889
1999	46,195	13,697	59,892
2000	24,220	1,279	25,499
2001	8,823	5,450	14,273
2002	24,715	235	24,950
2003	49,840	18,266	68,106
2004	25,135	13,165	38,300
2005	30,890	77,465	108,355
2006	14,671	36,867	51,538
2007	21,170	16,470	37,640
2008	18,196	1,175	19,371
2009	13,471	4,157	17,628
2010	4,367	51	4,418
2011	28,530	6	28,536
2012	18,290	0	18,290
2013	23,900	3,286	27,186

Note: Current goal is a sustainable escapement goal (SEG) of 15,000–33,000 sockeye salmon and no change to the goal is recommended. CPF = common property fishery.

[a] Calculated as the sum of peak aerial index counts from the 6 stream systems, including Katalla River.

[b] Wild escapement plus common property fishery harvest.

Appendix A7.–Supporting information for analysis of escapement goal for Coghill Lake sockeye salmon.

System:	Coghill Lake
Species:	sockeye salmon

Data available for analysis of escapement goals.

Brood year	Wild escapement	BY total return [a]	R/S	Yield [b]
1962 [c]	26,866	54,521	2.0	27,655
1963 [c]	63,984	63,949	1.0	(35)
1964 [c]	22,200	163,131	7.3	140,931
1965 [c]	62,500	77,666	1.2	15,166
1966 [c]	82,500	86,158	1.0	3,658
1967 [c]	33,000	153,333	4.6	120,333
1968 [c]	11,800	137,509	11.7	125,709
1969 [c]	81,000	91,749	1.1	10,749
1970 [c]	35,200	220,867	6.3	185,667
1971 [c]	15,000	46,728	3.1	31,728
1972 [c]	51,000	218,569	4.3	167,569
1973 [c]	55,000	233,689	4.2	178,689
1974	22,334	110,825	5.0	88,491
1975	34,855	191,529	5.5	156,674
1976	9,056	173,531	19.2	164,475
1977	31,562	1,251,048	39.6	1,219,486
1978	42,284	70,303	1.7	28,019
1979	48,281	150,407	3.1	102,126
1980	142,253	473,656	3.3	331,403
1981	156,112	496,238	3.2	340,126
1982	180,314	612,159	3.4	431,845
1983	38,783	106,297	2.7	67,514
1984	63,622	203,086	3.2	139,464
1985	163,342	16,598	0.1	(146,744)
1986	74,135	26,918	0.4	(47,217)
1987	187,263	60,053	0.3	(127,210)
1988	72,023	50,495	0.7	(21,528)
1989	36,881	9,410	0.3	(27,471)
1990	8,250	26,127	3.2	17,877
1991	9,701	153,809	15.9	144,108
1992	29,642	114,128	3.9	84,486
1993	9,232	67,501	7.3	58,269
1994	7,264	27,940	3.8	20,676
1995	30,382	317,501	10.5	287,119
1996	38,693	133,377	3.4	94,684
1997	35,010	44,736	1.3	9,726
1998	27,050	89,490	3.3	62,440
1999	59,311	234,831	4.0	175,520
2000	28,446	143,849	5.1	115,403
2001	38,547	15,616	0.4	(22,931)
2002	28,323	180,332	6.4	152,009
2003	75,427	100,769	1.3	25,342
2004	30,569	151,952	5.0	121,383
2005	30,313	25,296	0.8	(5,017)
2006 [d]	23,479			
2007 [d]	70,001			

-continued-

System:	Coghill Lake
Species:	sockeye salmon

Data available for analysis of escapement goals.

Brood year	Wild escapement	BY total return [a]	R/S	Yield [b]
2008 [d]	29,298			
2009 [d]	23,186			
2010 [d]	24,312			
2011 [d]	102,359			
2012 [d]	73,978			
2013 [d]	17,231			

Note: 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 District prior to the timing of Eshamy Lake wild sockeye salmon.

[b] Yield is total brood year return minus brood year escapement.

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

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

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	68,622
2010	83,285
2011	72,367
2012	66,850
2013	75,705

Note: Current goal is a sustainable escapement goal (SEG) of 55,000–130,000 sockeye salmon and no change to the goal is recommended.

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

Appendix A9.–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]	ND	ND	ND	ND
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]	ND	91,903	ND	ND
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
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[d]	42,473			
2007[d]	17,196			
2008[d]	18,495			

-continued-

Appendix A9.–Page 2 of 2.

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]
2009[d]	24,025			
2010[d]	16,291			
2011[d]	24,129			
2012[d,e]	ND	ND	ND	ND
2013[e,f]	4,500			

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 2012–2014.

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

[e] No escapement data are available. There was no funding for the weir and the video assessment project collected minimal data.

[f] Minimum video count for 8/3 through 10/1.

Appendix A10.–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 year	Wild escapement [b]	Harvest [a] Sport	Sub/PU	Yield [c]
1979	251,903	1,599	33,096	1,407,524
1980	295,346	2,109	31,041	1,044,278
1981	496,244	1,523	67,897	392,181
1982	395,719	3,343	108,611	1,242,610
1983	458,405	2,619	116,988	427,247
1984	499,792	3,267	76,177	712,829
1985	359,971	4,752	61,551	675,496
1986	361,591	4,137	68,495	1,206,711
1987	384,603	4,876	76,598	1,285,260
1988	389,150	3,038	71,525	1,128,729
1989	477,667	4,509	84,138	1,489,288
1990	472,978	3,569	98,197	1,180,841
1991	387,196	5,511	117,189	2,211,333
1992	406,255	4,560	131,956	2,487,676
1993	538,602	5,288	146,724	1,894,621
1994	461,315	6,533	162,302	1,212,313
1995	376,565	6,068	131,522	915,343
1996	546,131	11,851	147,059	1,031,514
1997	756,179	12,293	231,534	903,491
1998	462,396	11,184	201,624	1,280,264
1999	449,892	11,101	219,027	1,174,122
2000	343,691	12,361	167,353	1,597,786
2001	538,681	8,169	215,895	1,564,882
2002	581,717	7,761	145,343	2,062,959
2003	507,895	7,108	142,136	809,655
2004	448,534	6,464	181,741	811,651
2005	515,599	8,135	208,603	484,076
2006	579,552	14,297	200,866	1,565,862
2007	612,083	23,028	209,492	2,093,918
2008[d]	480,597	11,431	139,950	
2009[d]	468,725	13,415	151,799	
2010[d]	502,995	14,743	225,664	
2011[d]	607,657	7,727	205,360	
2012[d]	953,756	23,393	220,850	
2013[d]	864,152	15,288	273,703	

Note: Current goal is a sustainable escapement goal (SEG) of 360,000–750,000 sockeye salmon; no change to the goal is recommended. Sub = subsistence fisheries, PU = personal use fisheries.

[a] 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 2013 sport harvest is estimated with the 2010–2012 average.

[b] 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.

[c] Yield is total brood year return minus the brood year escapement. Shown is the total yield for both upper Copper River and the Copper River delta because we currently have no method to separate the stock groups in the commercial harvest.

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

APPENDIX B: WINBUGS CODE FOR COPPER RIVER STOCK-RECRUITMENT MODEL

Appendix B1.–WinBUGS code used for Copper River sockeye salmon stock-recruitment analysis.

```
#Ricker model for stock-recruitment analysis
model Ricker{

 lnalpha ~ dunif(0, 10)
 beta ~ dunif(0, 10)
 phi <- 0
 sigma.white ~ dunif(0,10)
 resid.red.0 ~ dnorm(0,tau.red)

 for(y in 1:n) {lnRS[y] ~ dnorm(mean2.lnRS[y],tau.white) }

 mean2.lnRS[1]     <- mean1.lnRS[1] + phi * resid.red.0
 for (y in 2:n) { mean2.lnRS[y] <- mean1.lnRS[y] + phi * resid.red[y-1] }

 for(y in 1:n) {  mean1.lnRS[y] <- lnalpha - beta * S[y]  }
 for(y in 1:n) {  resid.red[y]     <- lnRS[y] - mean1.lnRS[y]  }
 for(y in 1:n) {  resid.white[y] <- lnRS[y] - mean2.lnRS[y]  }

 tau.white <- 1 / sigma.white / sigma.white
 tau.red <- tau.white * (1-phi*phi)
 sigma.red <- 1 / sqrt(tau.red)
 sigma<-sigma.red

#lnalpha.c <- lnalpha + (sigma.red * sigma.red / 2)
 lnalpha.c <- lnalpha
 alpha<-exp(lnalpha.c)
 S.max <- 1 / beta
 S.eq <- S.max * lnalpha.c
 S.msy <- S.eq * (0.5 - 0.07*lnalpha.c)
 U.msy <- lnalpha.c * (0.5 - 0.07*lnalpha.c)
 R.msy <- S.msy * exp(lnalpha.c - beta * S.msy)
 MSY <- R.msy - S.msy

 start<-0
 end<-5000000
 step<-(end-start)/1000
 S.star[1]<-0
 for (i in 2:1002) {                    #LOOP TO FIND Pr(SY>90%MSY)
   S.star[i] <- S.star[i-1]+step
   R.star[i] <- S.star[i] * exp(lnalpha.c - beta * S.star[i])
   SY[i] <- R.star[i] - S.star[i]
   I90[i] <- step(SY[i] - 0.9 * MSY)
   }
```