Fishery Manuscript No. 11–07

Escapement Goal Review of Copper and Bering Rivers, and Prince William Sound Pacific Salmon Stocks, 2011

by

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November 2011

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

FISHERY MANUSCRIPT NO. 11–07

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November 2011

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

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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 15 existing escapement goals, including 1 Chinook salmon stock, 5 chum salmon stocks, 2 coho salmon stocks, 2 pink salmon stocks (one goal for each even- and odd-year brood line), and 5 sockeye salmon stocks. All of the existing goals were adopted in 2002, 2005, or 2008, except for the 2 coho salmon goals that were adopted in 1991. The committee recommends no change to existing Chinook, chum, and coho salmon escapement goals. For pink salmon, it is recommended that the soundwide sustainable escapement goals (SEGs) for even- and odd-year brood lines change to district-specific SEGs. For sockeye salmon it is recommended that 3 goals change in range, but remain as SEGs: the Coghill Lake goal would change from 20,000–40,000 to 20,000–60,000, the Bering River District goal would change from 20,000–35,000 to 15,000–33,000, and the Upper Copper River goal would change from 300,000–500,000 to 360,000–750,000.

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 salmon harvested by the commercial fishery.

The 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 the spawning salmon stock, and is affected by a variety of factors including exploitation, predation, disease, and physical and biological changes in 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 (board) 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 board 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 the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements within the bounds of a BEG; and

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

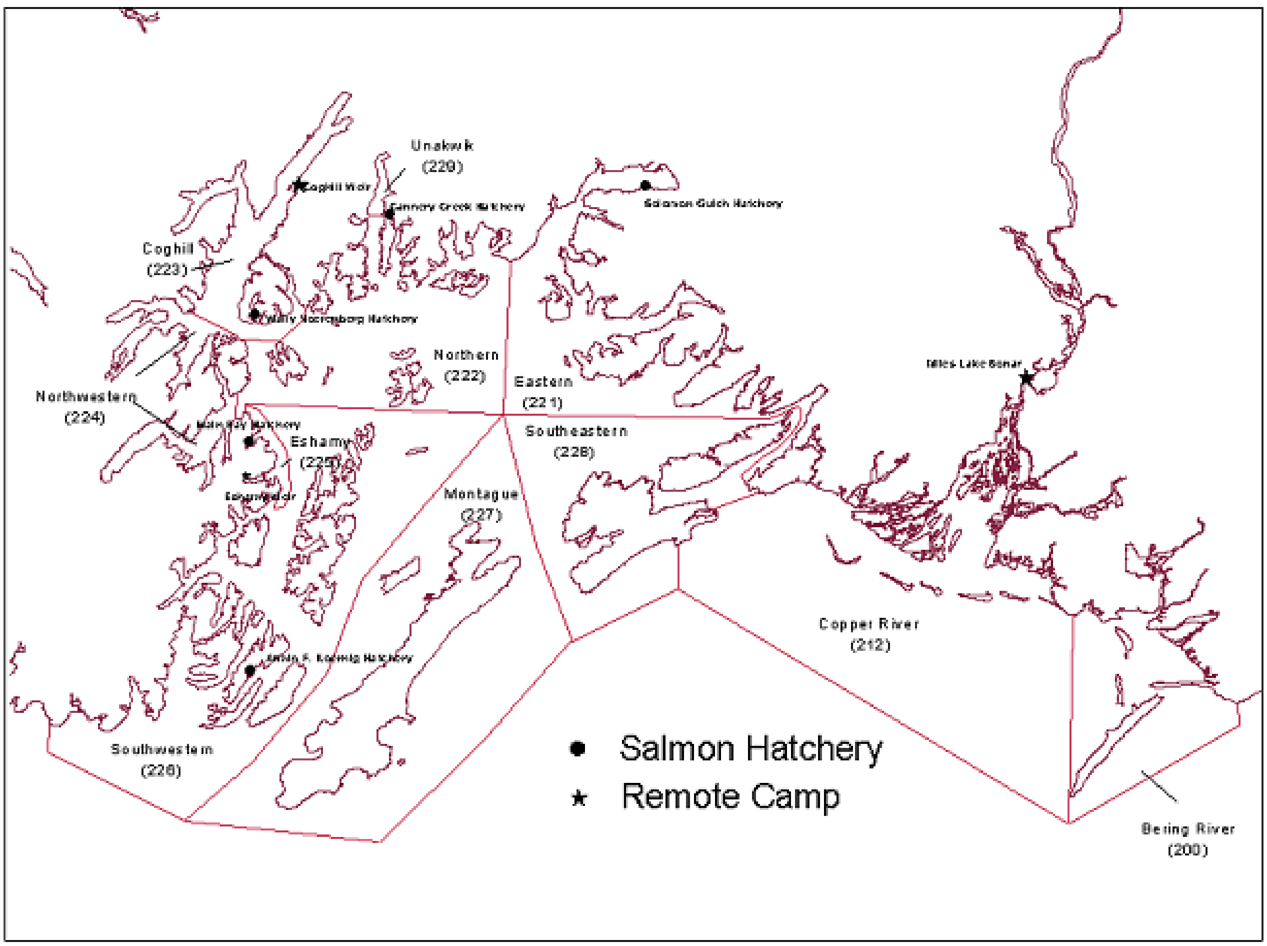


Figure 1.–Prince William Sound Management Area showing commercial fishing districts, salmon hatcheries, weir locations, and Miles Lake sonar camp.

Many salmon escapement goals in this area have been set and evaluated at regular intervals since statehood. This was the sixth time an interdivisional team reviewed escapement goals for stocks in this area. In 1994 and 1999, teams reviewed and recommended goals with guidance from the ADF&G 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), and Fair et al. (2008), this review only analyzed goals with recent (2008–2010) 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 Commercial Fisheries and Sport Fish divisions, held an initial meeting to discuss and develop recommendations on March 25, 2011. 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.

This report describes PWSMA salmon escapement goals reviewed in 2011 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 board and the public about the review of PWSMA salmon escapement goals and the committee's recommendations to the Commercial Fisheries and Sport Fish division directors.

During the 2011 review process, the committee evaluated escapement goals for various Chinook, chum, coho, pink, and sockeye salmon stocks:

- Chinook salmon: Copper River.
- Chum salmon: Coghill, Eastern, Northern/Unakwik, Northwestern, and Southeastern districts.
- Coho salmon: Bering River and Copper River Delta.
- Pink salmon: Even-year and odd-year soundwide brood lines.
- Sockeye salmon: Eshamy and Coghill lakes, Copper River Delta, and Bering and Upper Copper rivers.

OBJECTIVES

Objectives of the 2011 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 any new stocks for which there may be sufficient data to develop a goal; and,
4) Recommend new goals if appropriate.

METHODS

The team reviewed each of the existing escapement goals using updated escapement and harvest (if available) data collected since the 2008 review. Available escapement, catch, and age data for each stock originated from research reports, management reports, and unpublished historical databases. Escapement goals for salmon have typically been based on spawner-recruit relationships (e.g., Beverton and Holt 1957; Ricker 1954), which represent the productivity of the stock and estimated carrying capacity. However, specific methods to determine escapement goals vary in their technical complexity. 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). Differences in methods among years can affect the comparability and reliability of data. In the practical arena of salmon management, fishery biologists try to determine the amount of harvestable surplus and the number of spawners necessary to perpetuate the stock or run, known as the escapement goal.

Escapements of Copper River Chinook salmon, the only Chinook salmon stock in the PWSMA, have been monitored by mark–recapture projects since 1999. Escapements from 1980 to 1998 were indexed using aerial surveys, but total abundance estimates were not measured directly. The 1980–1998 abundances used, in part, to calculate the escapement goal were estimated using a catch-at-age model (Deriso et al. 1985; Savereide and Quinn 2004). Chinook salmon are primarily harvested commercially, but are also important for subsistence, personal use, and sport fishermen. 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 sport fishery from the annual Statewide Harvest Survey.

Chum salmon escapements were based on expanded counts from aerial surveys that have been conducted since 1965. Streams were flown multiple times each year with escapement estimated through area-under-the-curve calculations adjusted with estimates of stream life (17.5 days; Bue 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.

Escapements have been measured as peak index counts from fixed-wing aerial surveys for 2 coho salmon stocks. Although many streams have been surveyed for each coho salmon stock over the years, only surveys conducted annually over the same streams were used to evaluate and set escapement goals: 17 streams in the Copper River Delta surveyed back to 1981 and 7 streams in the Bering River Delta surveyed back to 1984. Coho salmon are primarily harvested commercially, but are also used 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 greater than 200 are surveyed annually. The 208 streams surveyed between 1960 and 1998 represent 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 1999, 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 a 17.5-day stream life (Bue et al. 1998). Hatchery-produced pink salmon have been returning to PWS since 1977 (Pirtle 1978). 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, all 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 Copper River Delta (CRD) aerial index 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 delta stocks to the Copper River harvests are unavailable. Escapement into Eshamy Lake has been visually counted through a weir since 1931 (Pirtle 1978), but reliable age composition data were unavailable until 1970; therefore, the spawner-recruit analysis used only complete brood years beginning with 1970 (Bue et al. 2002). Escapements to the Upper Copper River have 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 escapement, 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 (Upper Copper River vs. CRD vs. Bering River stocks); 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 and stock-specific harvest) for a stock. When “good” spawner-return data were available, escapement goals were estimated based on: (1) escapements producing average yields that were 90–100% of maximum sustained yield (MSY) from a stock-recruitment model, and (2) the Yield Analysis, explained below, which also estimates MSY with corresponding 90–100% yield range.

Stock–Recruitment Analysis

Complete spawner-return data exists for Eshamy and Coghill lakes sockeye salmon, and soundwide odd- and even-year pink salmon brood lines. Annual runs, the sum of escapements and harvests, were estimated and where quantifiable; sport and subsistence harvests were included in total return estimates.

We used Beverton-Holt (1957) and Ricker (1954) stock-recruitment models to estimate the escapement that produces maximum sustainable yield (S_{MSY}) and develop escapement goal ranges. Results were not used if the model fit the data poorly ($p \geq 0.20$) or if model assumptions were violated. Hilborn and Walters (1992), Quinn and Deriso (1999), and the Chinook Technical Committee (1999) provide clear descriptions of the Ricker model and diagnostics to assess model fit.

Ricker stock-recruitment models followed procedures outlined in Clark et al. (2009) where analyses were performed on each brood table using the linearized form of the Ricker relationship with multiplicative process error (Hilborn and Walters 1992) to estimate parameters and reference points. The Ricker α parameter was adjusted for log-normal process error (Hilborn 1985). Statistical uncertainty about the parameters and reference points was assessed with a bootstrap technique (Efron and Tibshirnai 1993); resampling the residuals of the linear regression with replacement, calculating all parameter estimates and reference points for each bootstrap replicate, and using percentiles of the bootstrap values to obtain interval estimates. The Beverton-Holt model (equation 7.5.1 of Hilborn and Walters 1992) was assessed using a maximum likelihood approach to fitting the observed escapement and subsequent return data using nonlinear regression with multiplicative process error. In this case, likelihood profiles were constructed for the parameters of interest. We tested all stock-recruitment models for serial correlation of residuals and corrected them when necessary (Quinn and Deriso 1999).

Yield Analysis

In previous PWSMA escapement goal reviews, a Markov yield table (Hilborn and Walters 1992) helped evaluate various (Coghill and Eshamy lakes sockeye and pink salmon) escapement goal ranges by partitioning escapement in overlapping intervals. The 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 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 an SEG developed using the percentile approach. In 2001 Bue and Hasbrouck[1] developed this 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, 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

[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*).

data is the maximum observed escapement divided by the minimum observed escapement. As contrast increases, meaning more information about the run size are known, 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 estimated SEG range was consistent with the current goal (i.e., a high degree of overlap), the committee recommended no change to the goal.

Risk Analysis

Risk Analysis method was used to develop PWS chum salmon SEG thresholds during the 2005 review. Six additional years of data since their inception did not warrant a reanalysis during this review. Evenson et al. (2008) fully describe the procedures employed to set these chum salmon goals following the methodology outlined in Bernard et al. (2009). In essence, recommended escapement thresholds were chosen 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.

RESULTS AND DISCUSSION

From this review, the majority of salmon escapement goals in PWSMA remain unchanged (Table 1). The committee recommended changes to both pink salmon SEGs and 3 of the 5 sockeye salmon SEGs. Details of the recommendations are provided below. Only stocks having goals that were modified, added, or deleted since the previous review are discussed in this section. The only exception is CRD sockeye salmon, in which the historical escapements were modified. These changes did not warrant a change to the goal, but were worth noting in the section below. Otherwise, any goals not discussed in the section below remained status quo. All of the data sets were updated (Appendix A) and most were reevaluated using the methodology originally used in their establishment. Munro and Volk (2011) provide a comprehensive review of goal performance from 2002 to 2010 (for 2008–2010, see Table 2).

Table 1.–Summary of recommended escapement goals for Prince William Sound Management Area salmon stocks, 2011.

System	Current Escapement Goal: Goal	Type	Year Adopted	Recommended Escapement Goal: Range	Escapement Data	Action
Chinook Salmon						
Copper River	> 24,000	SEG	2002	> 24,000	Mark–Recapture	No Change
Coho Salmon						
Bering River District	13,000–33,000	SEG	1991	13,000–33,000	Aerial Survey	No Change
Copper River Delta	32,000–67,000	SEG	1991	32,000–67,000	Aerial Survey	No Change
Sockeye Salmon						
Eshamy Lake	13,000–28,000	BEG	2008	13,000–28,000	Weir	No Change
Coghill Lake	20,000–40,000	SEG	2005	20,000–60,000	Weir	Change in Range
Bering River District	20,000–35,000	SEG	2002	15,000–33,000	Aerial Survey	Change in Range
Copper River Delta	55,000–130,000	SEG	2002	55,000–130,000	Aerial Survey	No Change
Upper Copper River	300,000–500,000	SEG	2002	360,000–750,000	Sonar	Change in Range
Pink Salmon						
Even-Year Brood Line (All Districts Combined)						
	1,250,000–2,750,000	SEG	2002	Discontinue	Aerial Survey	Change to District Goals[a]
Odd-Year Brood Line (All Districts Combined)						
	1,250,000–2,750,000	SEG	2002	Discontinue	Aerial Survey	Change to District Goals[b]
Chum Salmon (by District)						
Coghill	> 8,000	SEG	2005	> 8,000	Aerial Survey	No Change
Eastern	> 50,000	SEG	2005	> 50,000	Aerial Survey	No Change
Northern/Unakwik	> 20,000	SEG	2005	> 20,000	Aerial Survey	No Change
Northwestern	> 5,000	SEG	2005	> 5,000	Aerial Survey	No Change
Southeastern	> 8,000	SEG	2005	> 8,000	Aerial Survey	No Change

[a] Recommended district SEGs for even years: Eastern – 250,000 to 580,000; Northern – 140,000 to 210,000; Coghill – 60,000 to 150,000; Northwestern – 70,000 to 140,000; Eshamy – 3,000 to 11,000; Southwestern – 70,000 to 160,000; Montague – 50,000 to 140,000; Southeastern – 150,000 to 310,000.

[b] Recommended district SEGs for odd years: Eastern – 310,000 to 640,000; Northern – 90,000 to 180,000; Coghill – 60,000 to 250,000; Northwestern – 50,000 to 110,000; Eshamy – 4,000 to 11,000; Southwestern – 70,000 to 190,000; Montague – 140,000 to 280,000; Southeastern – 270,000 to 620,000.

Table 2.–Recommended escapement goals compared to escapements observed from 2008 through 2010 for Chinook, chum, coho, pink, and sockeye salmon stocks of the Prince William Sound Management Area.

		Recommended Escapement Goal				
		Type		Escapements		
System	Escapement Data	(BEG, SEG)	Range	2008	2009	2010
Chinook Salmon						
Copper River	Mark–Recapture	SEG	> 24,000	32,487	27,786	16,771
Chum Salmon						
Coghill	Aerial Survey	SEG	> 8,000	39,660	6,150	51,589
Eastern	Aerial Survey	SEG	> 50,000	74,740	100,309	91,514
Northern/Unakwik	Aerial Survey	SEG	> 20,000	38,791	22,063	38,207
Northwestern	Aerial Survey	SEG	> 5,000	28,051	30,074	30,074
Southeastern	Aerial Survey	SEG	> 8,000	21,614	106,284	85,138
Coho Salmon						
Bering River District	Aerial Survey	SEG	13,000–33,000	25,482	20,170	17,121
Copper River Delta	Aerial Survey	SEG	32,000–67,000	71,972	39,444	38,677
Pink Salmon [a]						
Even-Year Brood Line (All Districts Combined)						
	Aerial Survey	SEG	1,250,000–2,750,000	862,419		1,916,910
Odd-Year Brood Line (All Districts Combined)						
	Aerial Survey	SEG	1,250,000–2,750,000		1,829,623	
Sockeye Salmon						
Eshamy Lake	Weir	BEG	13,000–28,000	18,495	24,025	16,291
Coghill Lake	Weir	SEG	20,000–60,000	29,298	23,186	24,312
Bering River District	Aerial Survey	SEG	15,000–33,000	18,196	13,471	4,367
Copper River Delta	Aerial Survey	SEG	55,000–130,000	67,950	68,622	83,285
Upper Copper River	Sonar	SEG	360,000–750,000	477,953	469,123	491,300

[a] For pink salmon, the current goals are compared to recent escapements for the entire sound because previously there were only district-based management targets and not district-based escapement goals. Recommended goals are compared to previous escapements in Figures 4–5.

PINK SALMON

Even and Odd Years

The existing even- and odd-year pink salmon escapement goals cover all districts in PWSMA and are 1,250,000 to 2,750,000. ADF&G established these soundwide goals in 2002. Concurrently, they established "management targets" for each district (Bue et al. 2002; Table 3). ***In this review, we recommend converting the existing management targets to SEG ranges because each district is actively managed by district, not by overall returns to the sound.***

A close examination of the even-year management targets reveals that the historical median escapement is *below* the lower end of the proposed SEG for 7 of 8 districts, and barely above the lower goal for the other 1 (Figure 2). This strongly suggests that the management targets were set too high. The problem is likely related to the existing soundwide goal that was divided into district management targets based on their historical escapement proportions. An alternative explanation is that the goals are properly set, meaning that escapements have often been too low (below the goal) and harvest rates too high for much of the past 50 years. However, given the long time series of escapement data and their general stationary or increasing characteristics through time, it seems most plausible that the existing management targets are too high relative to the existing sustainable fishery.

The situation of median escapements being less than the lower-bound goal is less severe for the odd-year brood line (Figure 3); nonetheless, 1 district has the historical median below the lower end of the management target, while 7 others are only slightly above it.

An evaluation of the soundwide brood data for even and odd years with updated information did not warrant lowering the goal below 1,250,000. Hence, the committee believes the only viable option for setting district SEGs is to apply the percentile approach to each district (Figures 4–5; Table 3). The premise for choosing the percentile approach over previously-used techniques (Ricker model, Markov yield table) that utilized the 1960–1994 pre-emergence fry data or brood table yield data is that errors associated with these other approaches are causing the soundwide goal to be overestimated. Possible explanations for this include (a) high variability in productivity, largely driven by environmental forces that cause pink salmon stock-recruitment relationships to be less informative than other salmon species – as evidence of this poor relationship, Ricker stock-recruitment models using escapement and returns are not significant; and (b) poor relationships ($P>0.10$) between total return and fry data, and (c) poor fits between observed and predicted fry density ($P>0.35$). While the brood tables are not informative about S_{MSY}, they do indicate that the goal for even years should probably be lower than odd years, given the slightly higher productivity of the even-year brood line (Figure 6). Indeed, the soundwide sum of the recommended district SEGs for even years (793,000 to 1,701,000) is less than the sum of the recommended district SEGs for odd years (1,210,000 to 2,080,000; Table 3).

Applying the percentile approach decreases the lower bounds (compared to the current management targets) for each odd- and even-year district goal (Table 3). The same occurs for the upper bounds of each district, with the exception of Eshamy District, which increases from 10,000 to 11,000. ***To maintain future pink salmon stability in PWS, we recommend that each district be managed for its current long-term median value of escapement***.

Table 3.–Current management targets and recommended sustainable escapement goals by district and brood line for Prince William Sound pink salmon.

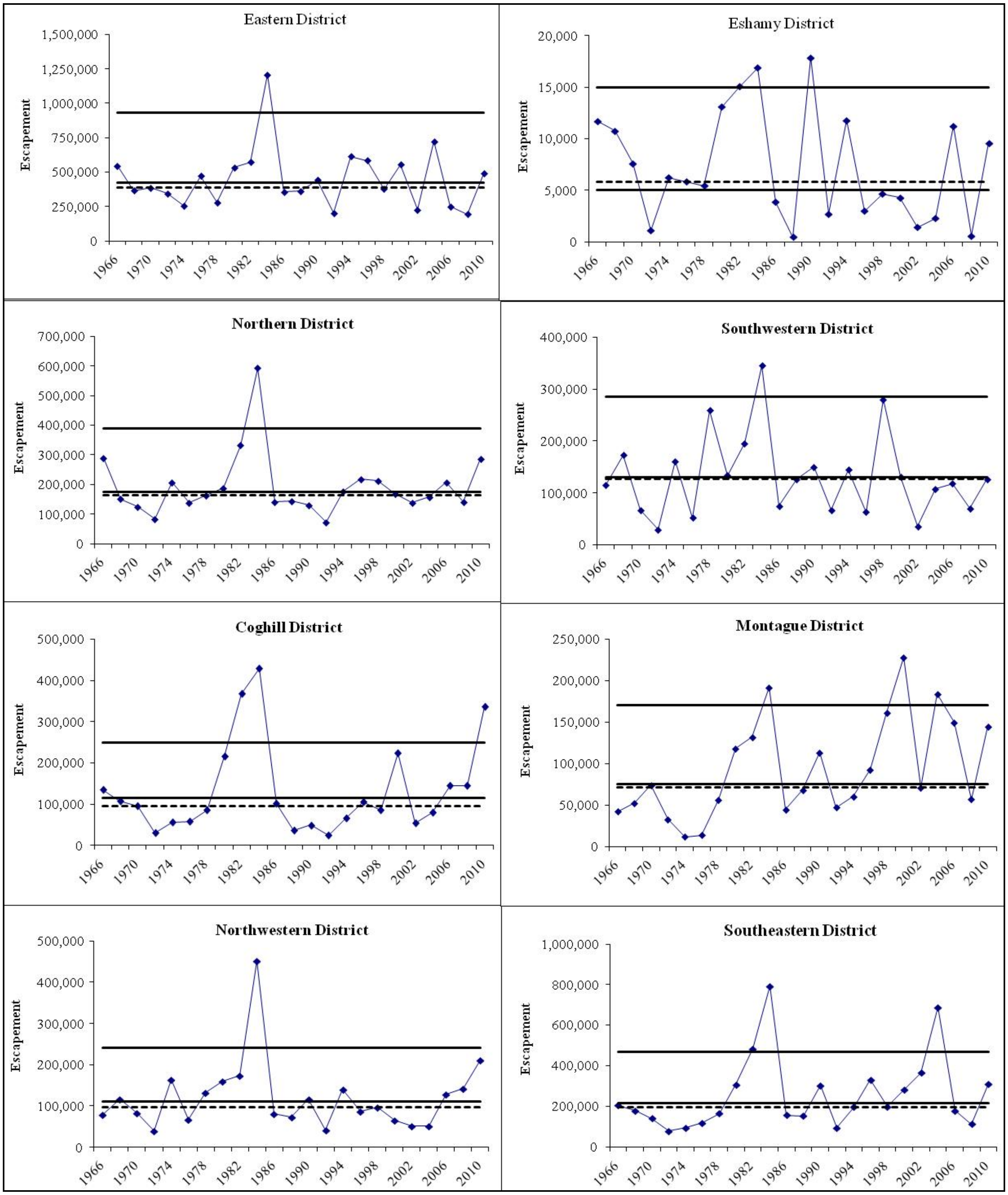
	Spawning escapement [a]								
Range Bound	Eastern	Northern/ Unakwik	Coghill	Northwestern	Eshamy	Southwestern	Montague	Southeastern	Total
Even Brood Line									
Current Goal [b]									
Lower	425,000	175,000	115,000	110,000	5,000	130,000	75,000	215,000	1,250,000
Upper	930,000	390,000	250,000	240,000	15,000	285,000	170,000	470,000	2,750,000
New Goal [c, d]									
Lower	250,000	140,000	60,000	70,000	3,000	70,000	50,000	150,000	793,000
1966–2010 Median	390,000	160,000	100,000	100,000	6,000	130,000	70,000	200,000	1,190,000
Upper	580,000	210,000	150,000	140,000	11,000	160,000	140,000	310,000	1,701,000
Odd Brood Line									
Current Goal [b]									
Lower	355,000	110,000	125,000	65,000	5,000	100,000	155,000	335,000	1,250,000
Upper	780,000	235,000	275,000	145,000	10,000	225,000	345,000	735,000	2,750,000
New Goal [c,d]									
Lower	310,000	90,000	60,000	50,000	4,000	70,000	140,000	270,000	1,210,000
1965–2009 Median	410,000	130,000	130,000	80,000	9,000	120,000	210,000	360,000	1,470,000
Upper	640,000	180,000	250,000	110,000	11,000	190,000	280,000	620,000	2,080,000

[a] Spawning escapement is indexed using area-under-the-curve of weekly aerial survey counts adjusted for stream life.

[b] Current goals (management targets) are reported in Bue et al. (2002).

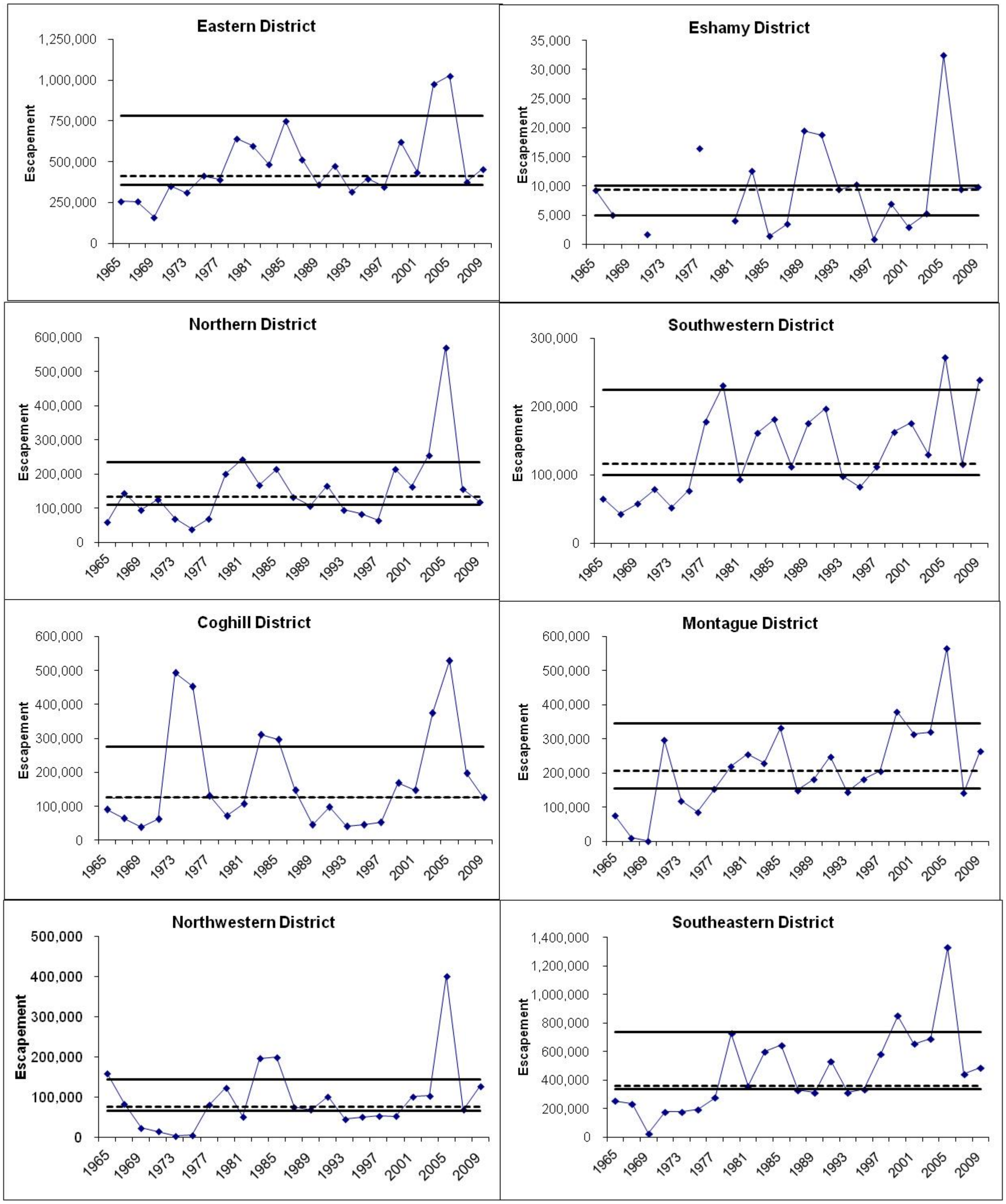
[c] Updated spawning escapement goal (SEG) ranges calculated by the percentile approach (1965–2010). Only years after the 1964 earthquake were used to calculate the escapement goals. Because of the lower contrast in the escapements for the Eastern District (even and odd brood lines) and the Southwestern District odd brood line, the 15th to 85th percentiles were used to calculate the bounds. All other bounds are the 25th and 75th percentiles.

[d] The goals are rounded to the nearest 10,000 fish for all districts except for Eshamy District, in which goals are rounded to the nearest 1,000.



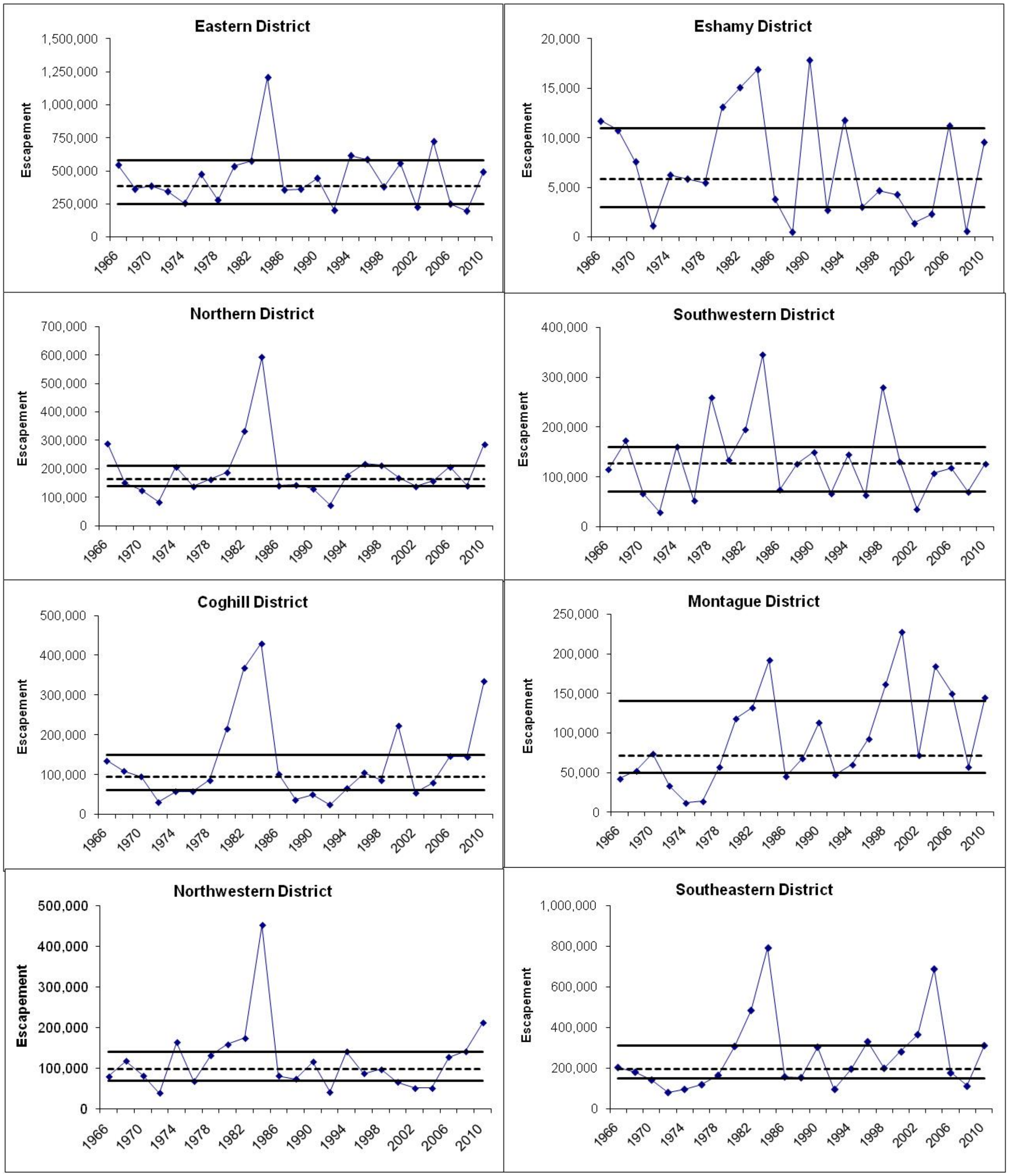
Note: Solid lines indicate bounds of the management targets established in 2002 (Bue et al. 2002). The dotted lines represent median values.

Figure 2.–Prince William Sound pink salmon current spawning management targets by district for EVEN years (1966–2010) and escapement indices.



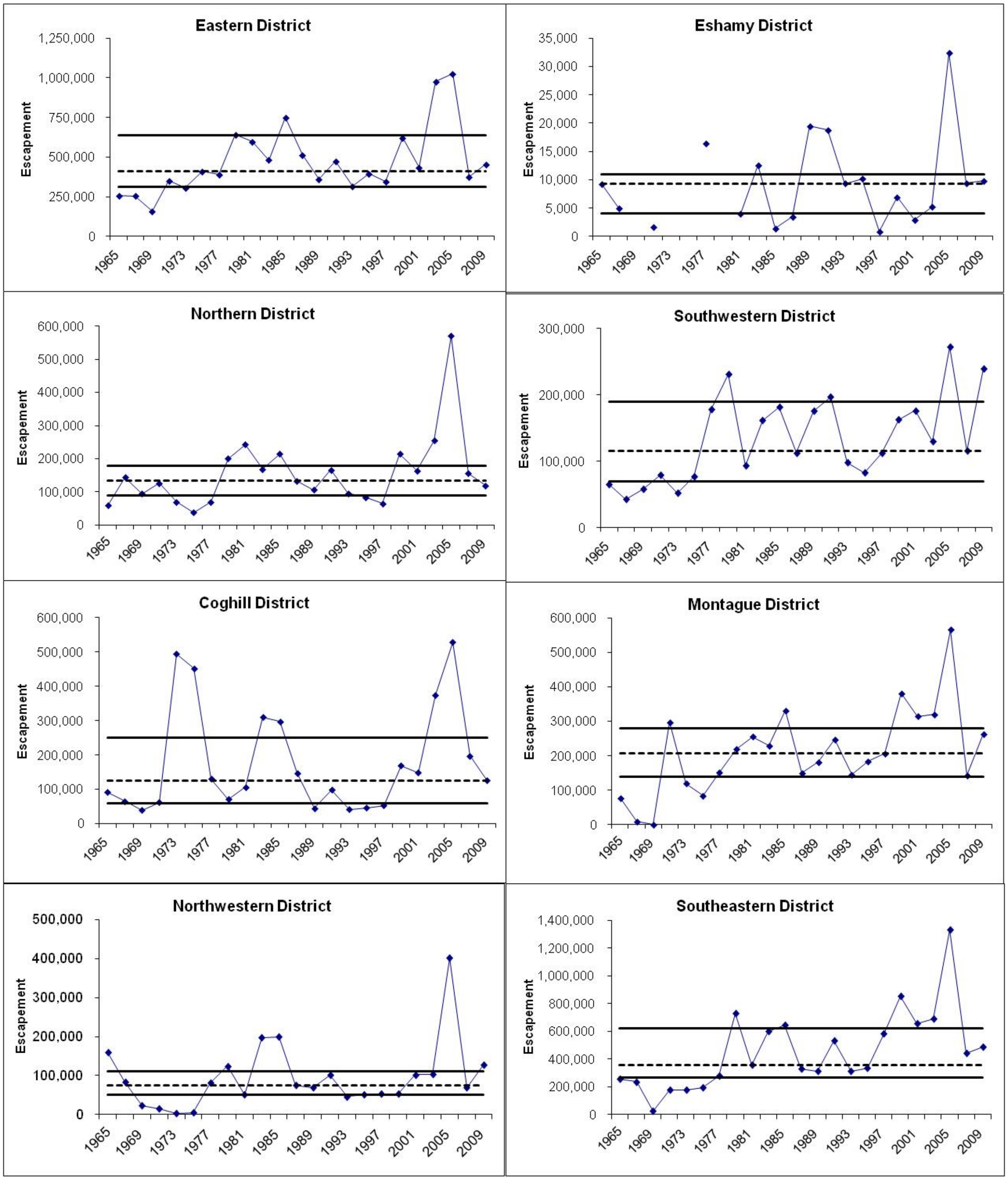
Note: Solid lines indicate bounds of the management targets established in 2002 (Bue et al. 2002). The dotted lines represent median values.

Figure 3.–Prince William Sound pink salmon current spawning management targets by district for ODD years (1965–2009) and escapement indices.



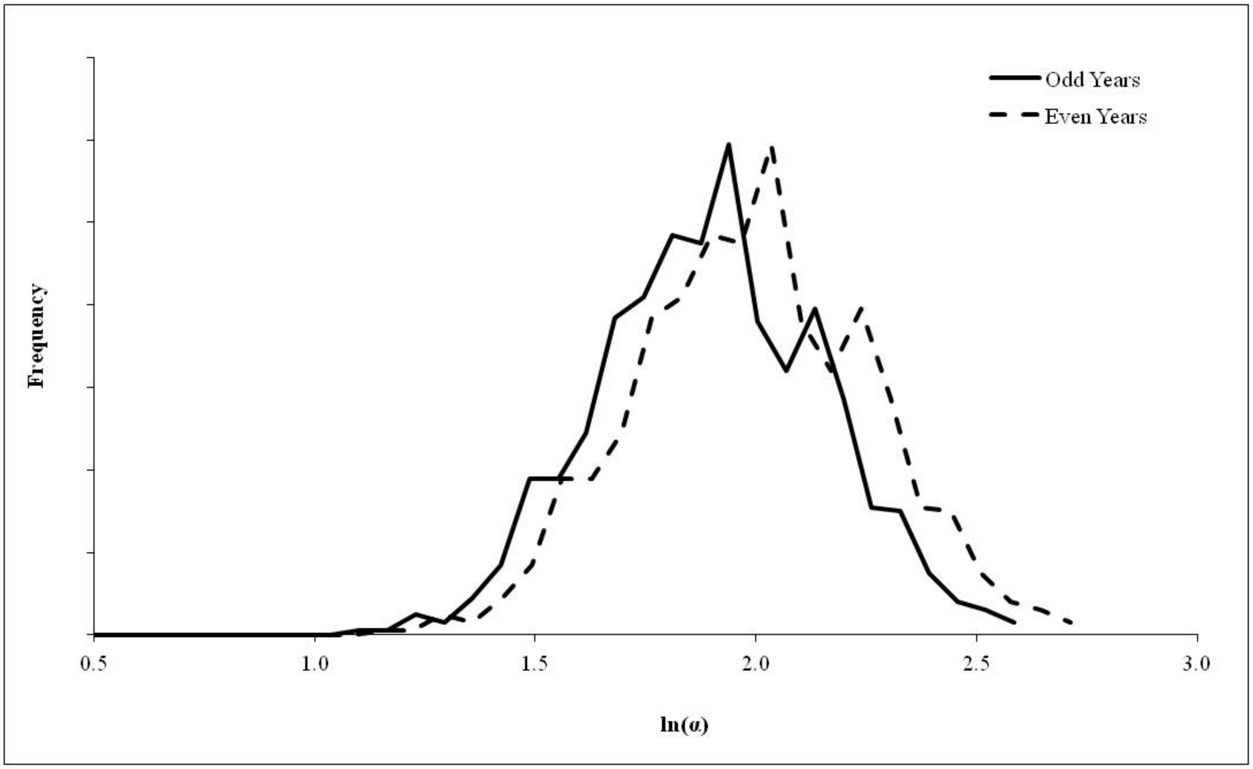
Note: The dotted lines represent median values.

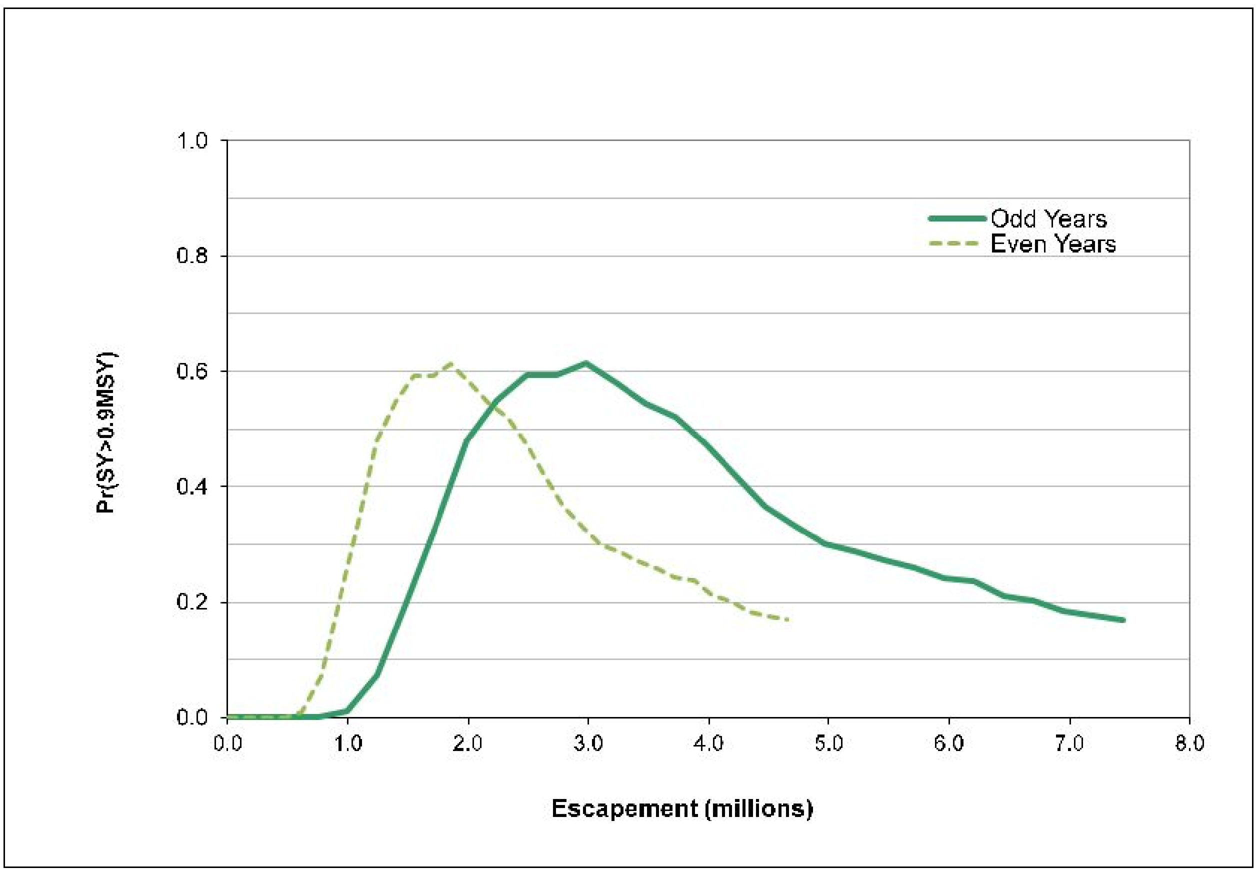
Figure 4.–Prince William Sound pink salmon recommended sustainable escapement goals (solid lines) by district for EVEN years (1966–2010) and escapement indices.



Note: The dotted lines represent median values.

Figure 5.–Prince William Sound pink salmon recommended sustainable escapement goals by district for ODD years (1965–2009) and escapement indices.





Note: The top figure shows bootstrap results for Ricker ln *α*. The bottom figure shows optimal yield profiles.

Figure 6.–Pink salmon productivity for soundwide even and odd years.

SOCKEYE SALMON

Bering River

The existing Bering River sockeye salmon SEG is 20,000 to 35,000 based on the percentile approach, established in 2002 using 1983–1995 data. Generally, a goal based on the percentile approach is left unchanged without good cause (e.g., change in harvest rates, change in assessment method). In this circumstance, when we checked historical escapement data for accuracy, numerous inconsistencies appeared, especially concerning the inclusion of Katalla River aerial counts. Katalla River is located west of the Bering River and in some years, was included in the Bering River sockeye salmon escapement data set, but in other years, it was not. Additionally, reviewers in 2002 (Bue et al. 2002) used the 25th and 75th percentiles to develop the escapement goal range when it should have been 15th and 85th percentiles (medium contrast), which would result in a goal of 20,000 to 43,000. They also could have used escapement data through 2001 similar to other systems in the 2002 review, rather than only through 1995.

We believe that Katalla River should be included in the escapement data set, essentially creating a Bering River District sockeye salmon SEG. The rationale for its inclusion is that some of the fish harvested in the Bering River District commercial fishery are destined for Katalla River and because this system has the potential to form a significant portion of the overall district escapement.

The act of altering historical escapements previously used to derive an existing goal is just cause for updating the goal. Katalla River counts began in 1988 and have occurred every year since (Appendix A7). The recommended new goal will use Bering River District escapements from 1988 through 2009. Escapement from 2010 was excluded because the commercial fishery was uncharacteristically closed to sockeye salmon harvest; therefore, it differs in representation from previous escapements. In 2010, the only sockeye salmon harvests (Table 4) occurred during periods open for coho salmon harvest. Also, poor weather conditions contributed to fewer aerial surveys. Using the percentile approach, contrast of the escapements is medium (6.3), so 15th and 85th percentiles were used to establish the SEG. ***The recommended goal is an SEG of 15,000 to 33,000***.

We also explored the possibility of using a provisional brood table for stock-recruitment modeling. Unfortunately, there are several shortcomings for developing a brood table for Bering River District sockeye salmon: 1) unaccounted harvest of Bering River fish caught in the Copper River District, 2) inaccurate reporting of Bering versus Copper River harvest, 3) peak counts from aerial surveys that occur mostly in drainages associated with Bering Lake; most other systems are glacial, making it difficult to visually observe fish, 4) inconsistent and sporadic age data from commercial harvests, and 5) no age data from Katalla River escapements. Given these potential problems, we decided not to use the brood table for evaluating an escapement goal.

Table 4.–Sockeye salmon commercial harvests for Bering River District, 1988–2010.

Year	Commercial Harvest
1988	7,152
1989	9,225
1990	8,332
1991	19,181
1992	19,721
1993	33,951
1994	27,926
1995	21,585
1996	37,712
1997	9,651
1998	8,439
1999	13,697
2000	1,279
2001	5,450
2002	235
2003	18,266
2004	13,165
2005	77,465
2006	36,867
2007	16,470
2008	1,175
2009	4,157
2010	51

Coghill Lake

The Coghill Lake sockeye salmon escapement goal has a long history that is relevant to our recommendations for this review:

> The current escapement goal is 20,000 to 40,000 spawners and was established in 2002 as a BEG and later modified to an SEG in 2005. From 1980 to 1982, a series of large escapements greater than 100,000 produced returns per spawner greater than 3.0 (Figure 7). However, escapements from brood years 1985 to 1989, which included escapements greater than 100,000 spawners in some years, did not replace themselves. Edmundson et al. (1992) suggested that poor production from the 1985 to 1989 brood years occurred from high densities of sockeye salmon fry grazing down the cyclopoid copepod population. Because of the apparent reduced productivity, the lake was fertilized (1993–1996) to increase zooplankton abundance. Additionally, the department collected smolt abundance data from 1989 to 1991 and 1993 to 1997. Although the mean number of smolt increased significantly after fertilization, their mean size remained less than 1.5 g, which is considered small and suboptimal for marine survival (Koenings and Burkett 1987; Koenings et al. 1993). Two studies suggest that the Ricker stock-recruitment model estimate of spawners required for S_{MSY} may be too high for the forage base (Edmundson et al. 1997; Koenings and Kyle 1997). Coghill Lake is an extremely harsh environment characterized by high inorganic turbidity, cold temperatures, short growing season, and a dense, anoxic saltwater mass that prevents metabolites, derived from the decomposition of organic material, from recirculating into the overlying oxygenated layers (Edmundson et al. 1992, 1997). Consequently, this lake may be more regulated by abiotic factors than biological interactions.

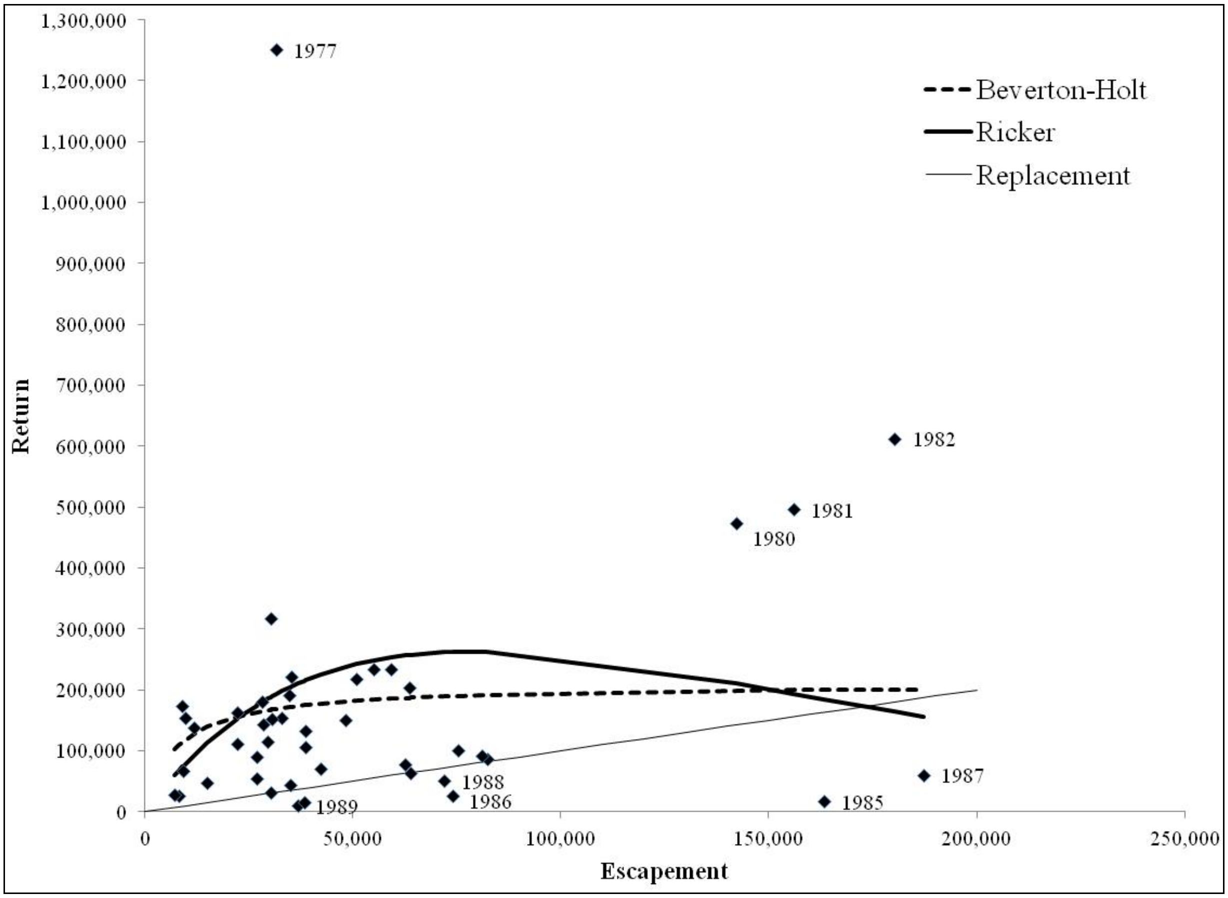


Figure 7.–Ricker and Beverton-Holt stock-recruitment models for Coghill Lake sockeye salmon, 1962–2005 brood years.

For this review, we revisited both the limnology data that is collected annually and the spawner-return data. Unfortunately, the limnological data did not lead to any firm conclusions about the relationship between escapement and corresponding effects on zooplankton abundance or composition given the observed high variability. Next, we revisited the Ricker model using spawner and return data. In the 2002 review, the Ricker model estimated S_{MSY} at about 59,000 using the full data set (1962–1995). In subsequent reviews, the spawner-return data set occasionally began with 1974 instead of 1962. From 1962 through 1973, a combination of towers and weirs composed the escapement estimate, whereas since then we have exclusively used a weir. In this review, because there was little difference in stock-recruitment results between the full and reduced data set, and without obvious reason to remove the earlier estimates, we used the full data set.

For the Ricker model, the estimate of S_{MSY} is similar to that estimated by Bue et al. (2002; Table 5). From the estimate of S_{MSY} the range that produces 90%–100% of MSY is 38,000 to 86,000. Obviously, the Ricker model tells us something much different than the existing goal of 20,000 to 40,000.

Because the Beverton-Holt stock-recruitment model is best for situations where rearing is limited, we also fit it to the spawner-return data. From the estimate of S_{MSY}, the range that produces 90%–100% of MSY is 15,000 to 63,000.

Table 5.–Ricker and Beverton-Holt stock-recruitment model estimates for Coghill Lake sockeye salmon, 1962–2005.

	Ricker			Beverton-Holt		
	L80	Point	U80	L80	Point	U80
ln α	1.37	1.67	1.95	2.10	3.32	4.55
β	8.2E-06	1.3E-05	1.7E-05	0	1.3E-04	3.3E-04
σ	0.86	1.04	1.16	0.83	0.97	1.10
S_{EQ}	138,427	172,917	242,315	133,325	201,490	269,655
S_{MSY}	46,366	59,677	86,485	7,657	32,192	56,727
U_{MSY}	0.69	0.76	0.81	0.69	0.81	0.93
MSY	144,379	194,477	260,127	98,406	137,105	175,804

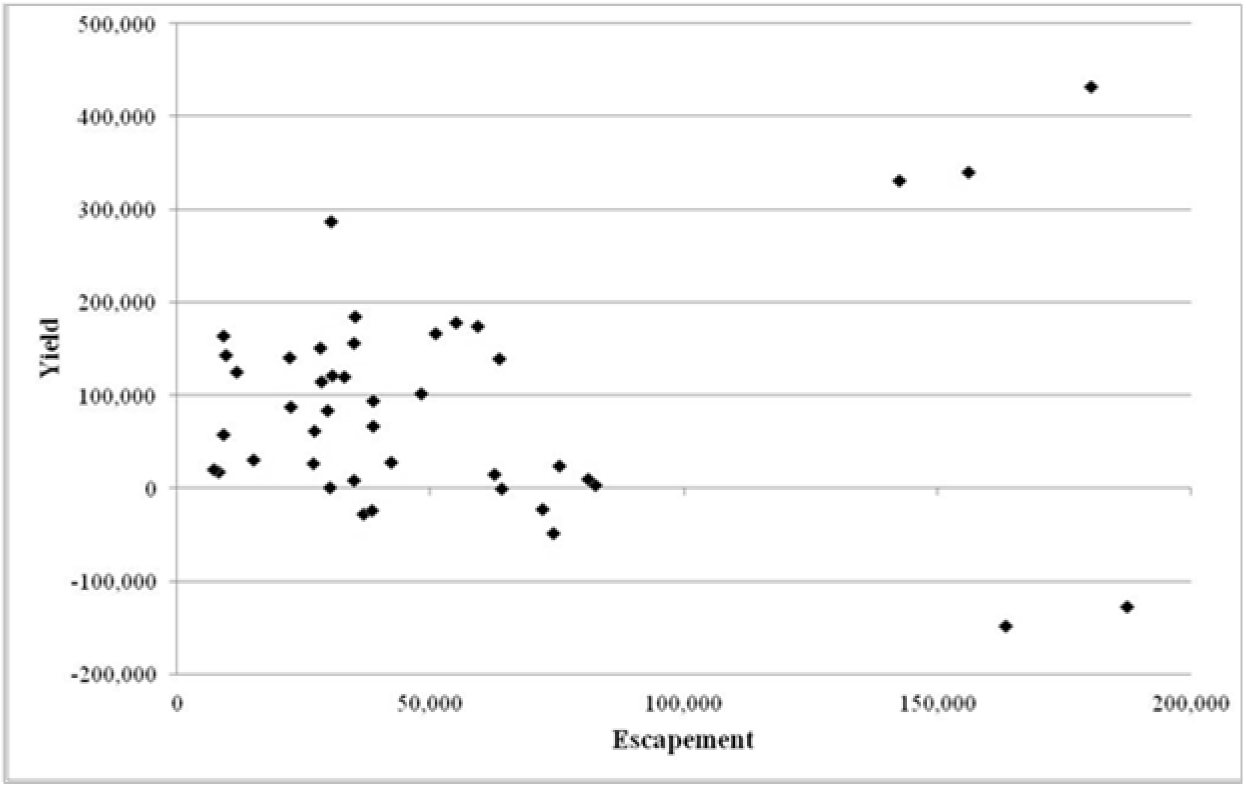
Note: Beverton-Holt estimates were recast as Ricker parameters for direct comparison.

Given the poor statistical (large σ) and visual fits (Figure 8) of the stock-recruitment models to the spawner and return data, we looked at the relationship between yield and escapement. This approach is similar to the Markov yield table approach, but without the subjectivity of escapement intervals (Figure 8). Notice that there is no apparent relationship (either dome shaped as expected, or otherwise) between yield and escapement. This lack of a relationship ties into statements from Edmundson et al. (1992, 1997) that the lake may be driven more by abiotic factors than biotic factors.

Four of the 10 escapements above 65,000 are below replacement, indicating that is too high. It would be desirable, however, to include the point estimates of S_{MSY} in the range of acceptable escapements. On the lower end, we do not advocate reducing the goal even though yields from escapements less than 20,000 have produced similar yields to those above. To further evaluate the current goal, we compared actual yields for (1) the original goal of 20,000 to 40,000; (2) the range suggested by the Ricker model of 38,000 to 86,000; and, (3) the range suggested by the Beverton-Holt model of 15,000 to 63,000 (Table 6). A goal range of 20,000 to 60,000 broadens the goal without decreasing expected yields and is best represented as a compromise between the current goal and the Beverton-Holt model. W***e recommend the new goal be an SEG of 20,000 to 60,000***.

Table 6.–A comparison of Coghill Lake sockeye salmon observed yields for the current goal, and ranges predicted by the Ricker and Beverton-Holt stock-recruitment models, 1962–2005.

Goal Based On	Escapement Range	Range of Observed Yields	Average Observed Yield	CV (Observed Yield)
Current	20,000–40,000	-27,471–1,219,486	151,830	1.78
Ricker Model	38,000–86,000	-47,217–178,688	57,304	1.33
Beverton-Holt Model	15,000–63,000	-27,471–1,219,486	137,830	1.69
Recommended	20,000–60,000	-27,471–1,219,486	147,362	1.63



Note: 1977 is not shown; escapement was 31,562 and yield was 1,219,486 in 1977.

Figure 8.–Relationship between actual yield and escapement for Coghill Lake sockeye salmon, 1962–2005.

Copper River Delta

The current CRD sockeye salmon SEG of 55,000 to 130,000 was developed from the percentile approach. After a thorough review of the historical escapement data set, several inconsistencies arose. We changed the estimates for 1971, 1974–1976, and 1980–1981 based on a review of past annual management report tables, and included the 2008–2010 data (Appendix A9). Changes to the historical escapement data set reduced the contrast from 7.1 to 6.0, changing the percentile values from the current goal to a range of 55,000 to 110,000.

The change to the upper end of the goal (130,000 to 110,000) is almost exclusively due to the inclusion of recent data (2002–2010), and not changes to the historical escapement data: percentile values for the old and revised data sets through 2001 are nearly identical. Because none of the recent escapements have been over 100,000, the upper bound has had little effect on the success of obtaining the goal. Practically speaking, the lower end of the goal is the only portion of the goal we can influence in most years. Given Gulkana Hatchery production, it is unlikely we will reduce the late-season effort such that we approach either 110,000 or 130,000. Frequently we find it necessary to update existing goals when data is corrected. In this case, however, we do not see the need for any change. Therefore, ***we do not recommend changing this goal***.

Upper Copper River

The existing SEG for Upper Copper River sockeye salmon is 300,000 to 500,000 based on the percentile approach established in 2002 (Bue et al. 2002). For this review, we updated the escapement data set through 2010 (Appendix A11) and converted past Bendix sonar estimates to those derived from DIDSON as demonstrated in Maxwell et al. (2011).

During the 2002 review, the reviewers used data from 1979 to 2001 to determine the data contrast (4.4), but used 1978 to 2001 to determine the percentiles. However, 1978 was the first year of sonar use on the Copper River and only utilized a transducer on 1 side of the river (south bank). Therefore, we chose to exclude it from the data set used to set the goal.

Because of the modification to historical escapements, there is justification for changing this goal. Using 1979 to 2010 escapement data, there is low contrast (3.0), leading to use of the 15th percentile to the maximum value: 357,347 to 750,557. Rounded to the nearest 10,000, ***the new recommended goal is an SEG of 360,000 to 750,000***. As shown in previous analyses there is no evidence to suggest that production (as measured by yield from combined upper and delta stocks) is reduced with higher escapements. ***We also recommend the fishery be managed for escapements that are dispersed throughout the range of the SEG to maintain the historical average of 450,000***.

The obvious question is why did the goal increase so much – was it from the conversion of Bendix to DIDSON, the removal of 1978, or the addition of years 2002–2010? The correction factor for converting Bendix counts to DIDSON counts was very small (about 1.00) for the south bank where most fish pass (greater than 90%) and much larger on the north bank (1.55) where few fish typically pass (Maxwell et al. 2011). Therefore, the change in sonar type had only a slight effect on the historical estimates of escapement: roughly 25% of the change for the lower goal and 10% of the change to the upper goal was due to the sonar change. The primary cause for the recommended increase in range (360,000 to 750,000) is the exclusion of data for 1978. Removing 1978 changes the data contrast, leading to a wider range of values in the percentile approach. When the reviewers developed the current goal in 2002, they did not include 1978 when calculating the contrast, but they did use it for calculating percentiles. Besides 1978 being the first year of sonar use and still in its infancy and with only one side of the river having a transducer, other evidence supports excluding 1978 as a valid estimate of overall escapement. For example, aerial survey indices in 1978 and 1979 are similar (the 1978 estimate is 77% of 1979; Roberson et al. 1983), in contrast to the large difference in sonar estimates (the 1978 estimate is 23% of 1979) for these 2 years. These aerial survey estimates appear to be a reliable index given that their relationship with subsistence catches from 1966 to 1980 is strongly correlated ($R^2 = 0.81$).

ACKNOWLEDGEMENTS

The authors thank other core members of the escapement goal committee: Rich Brenner, Bob Clark, Andrew Munro, Eric Volk, and Xinxian Zhang for their assistance and collaboration on estimating these escapement goals.

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

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		22,951	37,682
1981		17,895	42,458
1982		20,280	69,678
1983		22,066	84,204
1984		31,667	74,096
1985		8,481	56,541
1986		36,396	82,371
1987		28,054	74,827
1988		22,310	59,762
1989		45,747	79,020
1990		28,753	54,848
1991		28,346	72,264
1992		14,509	63,223
1993		17,517	59,240
1994		20,002	79,350
1995		14,115	94,101
1996		32,461	99,471
1997		49,761	115,090
1998		33,938	118,624
1999	16,157		95,951
2000	24,492		70,754
2001	28,208		81,155
2002	21,502		72,974
2003	34,034		94,505
2004	30,645		80,559
2005	21,528		66,357
2006	58,454		99,877
2007	34,565		87,770
2008	32,487		53,880
2009	27,787		43,006
2010	16,771		33,136

Note: Current goal is a lower-bound SEG >24,000 Chinook salmon and no changes to the goal are recommended.

[a] Estimated by mark–recapture project estimate 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
1965	69,180	20,980	20,768	18,907	
1966	75,690	24,870	10,540	5,770	
1967	74,570	23,270	7,450	1,670	
1968	48,960	10,620	8,780	800	
1969	58,690	17,340	8,410	780	
1970	34,430	4,020	11,880	2,720	7,950
1971	49,730	11,870	6,600	5,600	6,450
1972	112,950	70,760	28,160	22,980	26,990
1973	213,170	140,030	72,610	13,250	48,080
1974	72,010	55,510	29,280	6,580	3,200
1975	30,040	8,910	3,640	430	2,850
1976	16,260	29,430	25,670	8,300	770
1977	47,880	48,600	43,940	10,090	8,280
1978	90,250	27,480	18,160	12,940	6,550
1979	42,630	17,320	6,330	8,770	5,140
1980	26,720	27,880	23,340	3,060	6,710
1981	71,560	28,670	2,050	15,130	16,010
1982	146,120	68,580	22,130	21,880	25,260
1983	143,800	85,720	61,410	31,660	21,410
1984	129,190	59,080	19,690	7,920	8,650
1985	111,310	33,410	22,140	13,290	4,470
1986	126,690	50,740	13,140	17,420	8,830
1987	183,620	38,700	24,510	26,460	44,020
1988	258,560	75,420	39,240	40,780	66,930
1989	112,080	46,470	22,680	27,430	22,640
1990	115,100	112,480	26,020	37,020	7,275
1991	86,360	19,080	6,070	8,960	9,203
1992	48,804	12,903	10,003	11,072	3,881
1993	54,102	24,975	8,430	18,966	19,172
1994	40,476	23,942	14,176	12,992	4,057
1995	75,655	28,899	11,596	4,883	23,200
1996	137,908	55,568	19,669	24,405	47,334
1997	93,146	19,429	3,101	8,387	43,274
1998	86,227	28,867	22,764	7,553	52,103
1999	242,713	36,691	5,057	4,544	36,181
2000	196,253	23,655	20,488	10,150	34,969
2001	198,683	75,473	13,388	6,373	37,526
2002	94,046	30,531	7,430	16,194	104,906
2003	198,921	44,272	19,729	12,736	116,131
2004	108,833	42,456	9,685	10,371	42,344
2005	113,135	30,657	11,979	12,696	25,547
2006	109,403	52,069	15,900	25,860	26,739
2007	123,814	49,669	14,052	10,778	60,464
2008	74,740	38,791	39,660	28,051	21,614
2009	100,309	22,063	6,150	12,293	106,284
2010	91,514	38,207	51,589	30,074	85,138

Note: Current goals are district-specific lower-bound SEGs: Coghill >8,000; Eastern >50,000; Northern/Unakwik >20,000; 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 17.5 days 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]	Harvest Commercial [b]	Harvest Sport [c]	Total Run [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

[a] Calculated as peak aerial survey from the 7 primary index systems.

[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 Year	Wild Escapement [a]	Harvest [b] Commercial	Harvest [b] Sport [c]	Total Run [d]
1981	44,800	225,299		270,099
1982	40,175	310,154		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	14,443	447,987
2004	95,555	467,859	14,643	578,057
2005	95,892	263,465	10,240	369,597
2006	82,040	318,285	5,745	406,070
2007	50,715	117,182	7,823	175,720
2008	71,972	202,412	7,763	282,147
2009	39,444	207,776	14,420	261,640
2010	38,677	210,621	9,853	259,151

Note: Current goal is an SEG of 32,000–67,000 coho salmon and no changes to the goal are recommended.

[a] Calculated as peak aerial survey from the 17 primary index systems. Updated since the 2002 analysis to include peak numbers from the more recent Annual Management Reports. No estimates of Upper Copper River coho salmon escapements are available.

[b] Additional fisheries have an annual 1981–2007 harvest of about 2,500 coho salmon or < 1% of the total run. The commercial harvest includes both upriver and Copper River Delta stocks.

[c] From Statewide Harvest Survey. The sport harvest includes both upriver and Copper River Delta harvests.

[d] Escapement plus total harvest.

Appendix A5.–Supporting information for analysis of escapement goal for Prince William Sound pink salmon even-year brood line (all districts combined).

System:	Prince William Sound
Species:	pink salmon
Stock Unit:	even year

Data available for analysis of escapement goals.

Brood Year	Wild Escapement [a]	Intertidal Fry Density [b]	Yield [c]
1960	1,350,722		7,409,604
1962	2,018,010	146.74	4,030,566
1964	1,841,680	116.71	2,280,908
1966	1,423,170	80.98	2,185,508
1968	1,156,510	187.38	2,632,706
1970	979,220	123.10	(283,257)
1972	641,180	99.20	765,713
1974	958,120	157.30	2,987,135
1976	926,260	179.90	2,897,594
1978	1,145,010	237.23	13,067,293
1980	1,671,940	164.73	14,671,058
1982	2,274,570	327.37	19,571,165
1984	4,031,860	200.67	1,764,097
1986	960,220	221.61	906,716
1988	964,530	242.97	13,454,166
1990	1,325,852	176.72	862,358
1992	555,105	61.60	8,889,016
1994	1,413,184	221.24	6,240,973
1996	1,483,336		4,257,643
1998	1,420,105		6,086,528
2000	1,659,028		(393,986)
2002	943,177		3,957,586
2004	1,996,223		(129,990)
2006	1,187,595		1,098,403
2008	862,419		3,458,301
2010	1,916,910		

Note: Current goal is an SEG of 1,250,000–2,750,000 pink salmon. Recommendation is to drop this soundwide goal and replace with district-specific SEGs.

[a] The pink salmon escapement index is estimated from the area under the curve of weekly aerial survey counts adjusted for 17.5 days stream life.

[b] Intertidal fry density was measured as the number of live eggs and fry per m2 of intertidal stream bottom. Fry densities were last estimated in spring, 1995.

[c] Yield is total brood year return minus brood year escapement. Total wild pink salmon harvest was estimated by subtracting coded–wire tag (CWT) and thermally-marked otolith hatchery estimates from total Common Property Fishery harvest.

Appendix A6.–Supporting information for analysis of escapement goal for Prince William Sound pink salmon odd-year brood line (all districts combined).

District:	Prince William Sound
Species:	pink salmon
Stock Unit:	odd year

Data available for analysis of escapement goals.

Brood Year	Wild Escapement [a]	Intertidal Fry Density [b]	Yield [c]
1961	2,198,980	285.09	4,452,138
1963	1,355,740	251.38	2,080,687
1965	975,956	197.98	2,492,644
1967	842,260	136.81	4,390,889
1969	404,570	254.65	8,018,944
1971	1,112,550	118.07	2,169,338
1973	1,225,010	162.85	4,493,355
1975	1,265,560	311.24	4,120,507
1977	1,298,170	305.21	15,977,422
1979	2,217,280	356.67	18,009,653
1981	1,713,080	537.15	9,148,037
1983	2,163,100	364.75	18,051,533
1985	2,621,330	372.96	10,860,291
1987	1,466,240	285.81	5,338,102
1989 [d]	1,272,770	270.56	8,022,686
		330.00	
1991	1,837,165	212.54	1,029,203
1993	1,066,469	220.30	2,325,832
1995	1,190,184	242.75	3,199,402
1997	1,422,688		7,991,096
1999	2,462,871		6,364,497
2001	2,000,386		5,389,311
2003	2,857,289		14,434,592
2005	4,745,377		4,942,440
2007	1,509,133		1,315,606
2009	1,829,623		

Note: Current goal is an SEG of 1,250,000–2,750,000 pink salmon and the recommendation is to change the range to 15,000–33,000.

[a] The pink salmon escapement index is the area under the curve of weekly aerial survey counts adjusted for 17.5 days stream life.

[b] Intertidal fry density was measured as the number of live eggs and fry per m^2 of intertidal stream bottom. Fry densities were last estimated in spring, 1995.

[c] Yield is total brood year return minus brood year escapement. Total wild pink salmon harvest was estimated by subtracting coded–wire tag (CWT) and thermally-marked otolith hatchery estimates from total Common Property Fishery harvest.

[d] Two rounds of fry digs were completed due to the *Exxon Valdez* oil spill.

Appendix A7.–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

Note: Current goal is an SEG of 20,000–35,000 sockeye salmon and the recommendation is to change the range to 15,000–33,000.

[a] Calculated as peak aerial survey from the 6 primary index systems, including Katalla River.

[b] Wild escapement plus Common Property Fishery harvest.

Appendix A8.–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	23,479	NA	NA	NA
2007	70,001	NA	NA	NA
2008	29,298	NA	NA	NA
2009	23,186	NA	NA	NA
2010	24,312	NA	NA	NA

Note: Current goal is an SEG of 20,000–40,000 sockeye salmon and the recommendation is to change the range to 20,000–60,000.

[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.

Appendix A9.–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

Note: Current goal is an SEG of 55,000–130,000 sockeye salmon and the recommendation is no change to the goal.

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

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

System: Eshamy Lake
Species: sockeye salmon
Data available for analysis of escapement goals.

Brood Year	Wild Escapement	BY Total Return [a]	R/S	Yield [b]
1970	11,460	11,690	1.02	230
1971	954	6,667	6.99	5,713
1972	28,683	59,976	2.09	31,293
1973	10,202	34,411	3.37	24,209
1974	633	15,946	25.19	15,313
1975	1,724	31,355	18.19	29,631
1976	19,367	178,061	9.19	158,694
1977	11,746	38,453	3.27	26,707
1978	12,580	36,904	2.93	24,324
1979	12,169	39,724	3.26	27,555
1980	44,263	270,623	6.11	226,360
1981	23,048	30,841	1.34	7,793
1982	6,782	51,290	7.56	47,490
1983	10,348	51,162	4.94	43,355
1984	36,121	117,761	3.26	81,012
1985	26,178	58,163	2.22	31,960
1986	6,949	39,946	5.75	32,997
1987 [c]				
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]		91,903		
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	42,473	NA	NA	NA
2007	17,196	NA	NA	NA
2008	18,495	NA	NA	NA
2009	24,025	NA	NA	NA
2010	16,291	NA	NA	NA

Note: Current goal is an SEG of 13,000–28,000 sockeye salmon and the recommendation is no change to the goal.

[a] Total return was calculated as the wild escapement contribution estimates plus the Eshamy and Southwestern District 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 escapement.

[c] Eshamy Lake weir was not in place in 1987 and 1998.

Appendix A11.–Supporting information for analysis of escapement goal for Upper Copper River sockeye salmon.

System: Upper Copper River				
Species: sockeye salmon				
Data available for analysis of escapement goals.				
Brood	Wild	Harvest [b]		
Year	Escapement [a]	Sport	Sub/PU	Yield [c]
1978 [d]	56,661	1,606	28,061	1,226,115
1979	246,153	1,599	35,734	1,584,402
1980	283,059	2,109	33,984	898,192
1981	471,521	1,523	67,897	393,709
1982	383,603	3,343	108,611	1,401,450
1983	425,396	2,619	116,988	364,446
1984	509,662	3,267	76,177	799,759
1985	356,363	4,752	61,551	752,382
1986	357,876	4,137	68,495	1,282,377
1987	387,744	4,876	76,598	1,342,908
1988	329,707	3,038	71,525	1,330,488
1989	407,082	4,509	84,138	1,666,491
1990	438,006	3,569	98,197	1,365,446
1991	366,480	5,511	117,189	2,545,764
1992	373,950	4,560	131,956	2,566,560
1993	538,762	5,288	146,724	1,891,368
1994	465,125	6,533	162,302	1,192,879
1995	379,082	6,068	131,522	893,647
1996	573,173	11,851	147,059	973,087
1997	750,557	12,293	231,534	880,843
1998	487,612	11,184	201,624	1,222,498
1999	439,563	11,101	219,027	1,155,052
2000	346,183	12,361	167,353	1,561,087
2001	538,047	8,169	215,895	1,536,874
2002	582,230	7,761	145,343	2,046,444
2003	508,122	7,108	142,136	782,205
2004	448,639	6,464	181,741	777,274
2005	518,181	8,135	205,464	
2006	580,202	14,297	199,061	
2007	613,130	23,009	209,492	
2008	477,953	11,431	139,950	
2009	469,123	13,415	151,434	
2010	491,300	14,743	225,667	

Note: Current goal is an SEG of 300,000–500,000 sockeye salmon and the recommendation is to change the range to 360,000–750,000.

[a] Wild spawning escapements after 1977 were estimated as the adjusted Miles Lake sonar index (in DIDSON units) minus subsistence, personal use, and sport harvests in addition to the Gulkana Hatchery broodstock and excess brood escapement.

[b] The sport and subsistence/personal use harvests include both wild and hatchery stocks. Prior to 1995, no scanning for coded wire tags was completed in the Upper Copper River subsistence or personal use fisheries.

[c] Yield is total brood year return minus 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] The 1978 escapement data were excluded in calculating the SEG. This was the first year of sonar counting at Miles Lake and the project was of shorter duration and on only one bank.