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Review of Salmon Escapement Goals in the Chignik Management Area

by

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and

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October 2005

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)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	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

In June 2004, a salmon escapement goal interdivisional review team, including staff from the Division of Commercial Fisheries and Sport Fish Division, was formed to review Pacific salmon *Oncorhynchus* spp. escapement goals in the Chignik Management Area (CMA; Area L). This report is the result of this review, 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).

This comprehensive review of the 13 existing salmon escapement goals in the CMA resulted in recommendations to leave the Chignik River Chinook salmon *O. tshawytscha* biological escapement goal (BEG) range unchanged and maintain the current numerical escapement goal ranges for the two sockeye salmon *O. nerka* stocks in the Chignik River watershed, but reclassify them from BEGs to sustainable escapement goals (SEGs). The team also recommended establishing two area-wide aggregate BEGs (odd- and even-years) replacing five district-wide pink salmon SEGs and establishing one area-wide SEG replacing five district-wide chum salmon *O. keta* SEGs.

The recommendation to maintain the current biological escapement goal (BEG range 1,300 to 2,700) for the Chignik River Chinook salmon stock was based on a Ricker spawner-recruit model that corroborated the current Chinook salmon goal established in 2002.

The team recommended that the Chignik River watershed early- and late-run sockeye salmon goals should not be changed, but should be designated as SEGs rather than BEGs. The early-run sockeye salmon escapement data did not exhibit enough contrast to perform a spawner-recruit analysis; therefore it was not possible to estimate the escapement that would produce maximum sustainable yield (S_{msy}). The late-run sockeye salmon escapement data had enough contrast to perform a spawner-recruit analysis; however, the model, which was significant, resulted in a wide range (201,000 to 455,000) that was not corroborated by other biological models considered in this review. The team did not feel that there was compelling evidence to change the current goals of 350,000 to 400,000 for the early run and 200,000 to 250,000 for the late run. Escapements have been sustainable and surplus production has been available while managing for the current goals.

Ricker spawner-recruit models indicated that separation of odd- and even-year pink salmon goals would be appropriate. The team recommended changing the five district-wide aggregate pink salmon SEGs to two area-wide aggregate BEGs. The team recommended a BEG of 327,000 to 737,000 fish for even years and a BEG of 541,000 to 1,177,000 fish for odd years. The team also recommended changing the five district-wide aggregate chum salmon SEGs to one area-wide aggregate SEG of 50,400 chum salmon based on risk analysis.

Key words: Pacific salmon, *Oncorhynchus*, escapement goal, Chignik, Area L, stock status.

INTRODUCTION

This report documents a review of the existing escapement goals for Chignik Management Area (CMA) salmon stocks 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 Alaska Board of Fisheries (BOF) adopted these policies into regulation in 2000 and 2001, respectively, to ensure that the state's salmon stocks would be conserved, managed and developed using the sustained yield principle.

Two important terms defined in the SSFP are:

1) "*biological escapement goal* (BEG): the escapement that provides the greatest potential for maximum sustained yield (MSY); …" and,
2) "*sustainable escapement goal* (SEG): 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 due to the absence of a stock specific catch estimate;…".

A report documenting the established escapement goals for stocks of five Pacific salmon species (Chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, coho *O. kisutch*, pink *O. gorbuscha*, and chum *O. keta* salmon) spawning in the Kodiak, Chignik, Alaska Peninsula and Aleutian Islands Management Areas of Alaska was prepared in 2001 (Nelson and Lloyd 2001). Most of the escapement goals documented in Nelson and Lloyd (2001) were based on average escapement estimates and spawning habitat availability, and were implemented in the late 1990s.

In June 2004, a salmon escapement goal interdivisional review team was formed to evaluate the existing CMA salmon escapement goals. The team included staff from the Division of Commercial Fisheries (CF) and Sport Fish Division (SF): Patricia Nelson (CF), Jim McCullough (CF), Mark Witteveen (CF), Ken Bouwens (CF), Heather Finkle (CF), Ivan Vining (CF), Jim Hasbrouck (SF), Bob Clark (SF), Dan Sharp (SF), Len Schwarz (SF), and Donn Tracy (SF).

The purpose of the team was to:

1) Determine the appropriate goal type (BEG or SEG) for each CMA salmon stock with an existing goal, based on the quality and quantity of available data,
2) Determine the most appropriate methods to evaluate the escapement goal ranges,
3) Estimate the escapement goal for each stock and compare these estimates with the current goal,
4) Determine if a goal could be developed for any stocks or stock-aggregates that currently have no goal, and,
5) Develop recommendations for each goal evaluated and present these recommendations to the Directors of Commercial Fisheries and Sport Fish Divisions for approval.

During the review process, escapement goals were evaluated for one Chinook and two sockeye salmon stocks (Table 1). In addition, five pink and five chum salmon stock-aggregate goal ranges were reviewed (Table 1). Formal meetings via teleconference, to discuss and develop recommendations, were held on June 10, June 16, August 2, September 2 and October 4, 2004. The team also communicated on a regular basis by telephone and email.

STUDY AREA

The CMA comprises all coastal waters and inland drainages on the south side of the Alaska Peninsula, bounded by a line extending 135° southeast for three miles from a point near Kilokak Rocks (57° 10.34’ N lat., 156° 20.22’ W long.) then due south, to a line extending 135° southeast for three miles from Kupreanof Point at 55° 33.98’ N lat., 159° 35.88’ W long. (Figure 1). The area is divided into five commercial fishing districts: Eastern, Central, Chignik Bay, Western, and Perryville Districts (Figure 1). These districts are further divided into 14 sections and 25 statistical reporting areas (Pappas et al. 2003).

BACKGROUND

The Chignik River is the largest Chinook salmon producing system on the south side of the Alaska Peninsula (Pappas et al. 2003). It is the only Chinook salmon system in the CMA with an established escapement goal (Hasbrouck and Clark *In prep*). Chinook salmon escapement levels at this system are currently enumerated via a weir outfitted with a video camera system, established mainly to account for sockeye salmon escapement. The weir is located on the Chignik River downstream of Chignik Lake (Figure 2). The current BEG, implemented in 2003, was based on the analysis of spawner-recruit data.

Two sockeye salmon stocks in the CMA have established BEGs. Both of these stocks are part of the Chignik River watershed consisting of two interconnecting lakes (Black Lake and Chignik Lake) with a single outlet river (Chignik River) that empties into a nearly enclosed estuary (Chignik Lagoon; Figure 2). The majority of the early run (Black Lake stock) enters the watershed from June through July and spawns in Black Lake and its tributaries (Pappas et al. 2003). The majority of the late run (Chignik Lake stock) enters the watershed in July and August and typically spawns in the Chignik Lake tributaries and the Chignik Lake shoal areas. Although the peak periods of passage for each stock are usually a few weeks apart, there is a period of overlap when both stocks are entering the watershed.

Sockeye salmon bound for Black and Chignik Lakes are enumerated through the use of a weir outfitted with a video camera system. In order to achieve escapement goals for these two runs (stocks) simultaneously, inseason estimates of the numbers of each stock in the daily escapement are required. These estimates have been determined using various methods over time. From 1980 through 2003, with the exception of 1982, stock separation was accomplished using scale pattern analysis (SPA; Witteveen and Botz 2004). Prior to 1980, time-of-entry relationships based on tagging studies and age groups were employed to divide the catch and escapement between the two runs (Dahlberg 1968). In 2004, an estimate of the total escapement of the Black Lake early run was based on weir counts through July 4. After July 4, the fish that passed upstream through the weir were assumed to be Chignik Lake late-run fish (Witteveen *unpublished memorandum*). This method was determined not to be significantly different ($P>0.05$) than the SPA method in estimating recruitment (Finkle *unpublished data*).

Due to the late season run timing of coho salmon returns to the CMA, there are no established coho salmon escapement goal ranges. Catches of coho salmon are generally incidental to the sockeye salmon fishery.

Pink salmon in the CMA are managed as aggregates of streams by district. A total of five district-wide (aggregate) pink salmon escapement goals have been established in the CMA (Table 1; Figure 1). These aggregate goals comprise the respective sums of aerial survey escapement management objectives (MO) for 49 individual index streams (Nelson and Lloyd 2001).

Similar to pink salmon in the CMA, five district-wide (aggregate) escapement goals have been established for chum salmon (Table 1; Figure 1). These aggregate goals comprise the respective sums of aerial survey escapement MOs for 42 individual index streams (Nelson and Lloyd 2001).

METHODS

Available escapement, harvest, and age data associated with each stock or combination of stocks to be examined were compiled from research reports, management reports, and unpublished historical databases. Limnological and spawning habitat data were compiled for each system when available. The team evaluated the type, quality, and amount of data for each stock according to criteria described in Bue and Hasbrouck (2001; Table 2). This evaluation was used to initially determine the appropriate type of escapement goal to apply to each stock, as defined in the SSFP and EGP.

Biological Escapement Goal Determination

If a sufficient time series of escapement and total return estimates were available, contrast in the escapement data (the ratio of the largest escapement to the smallest escapement) was sufficiently large (>4.0; CTC 1999), and estimates were sufficiently accurate and precise, then the data were considered sufficient to attempt to estimate the escapement level with the greatest potential to provide MSY. This level of spawning escapement is identified as S_{msy} (Hilborn and Walters 1992; CTC 1999; Quinn and Deriso 1999). Spawner-return data were analyzed using a mathematical stock recruitment model to estimate MSY, and the BEG range surrounding S_{msy}.

The Ricker spawner-recruit model (Ricker 1954) was the mathematical stock recruitment model fitted to available spawner-return data. Results were not used if the model fit the data poorly or if model assumptions were violated. Hilborn and Walters (1992), Quinn and Deriso (1999), and the Chinook Technical Committee (1999) provide good descriptions of the Ricker model and diagnostics to assess model fit. All Ricker models were tested and corrected for residual autocorrelation when necessary. A tabular stock-recruitment yield analysis was also used as a method to estimate S_{msy}, which was a modification of that presented in Hilborn and Walters (1992). This approach used spawner-return data to calculate the average surplus yield for a range of escapements. The average surplus yield was then compared for various ranges of escapement to determine the range where yield was maximized. A habitat based model (Parken *unpublished*) was also explored as a means to estimate S_{msy} for Chinook salmon. This approach relied on a meta-analysis of the relationship between drainage size and S_{msy} for systems along the North Pacific coast. When auxiliary data were available (e.g., light penetration, zooplankton, smolt abundance) additional limnological analyses were performed and compared to estimates of smolt and adult production. In cases where sufficient data existed but determining a scientifically defensible BEG was still not possible, other methods were used to establish an SEG.

Sustainable Escapement Goal Determination

If total return estimates were not available because harvest and/or age were not consistently measured, then the data were considered of fair to poor quality. These data would not provide an accurate estimate of S_{msy} and subsequent BEG. As a result, these data were evaluated using other methods to establish an SEG. Methods used to develop SEGs included the percentile approach, risk analysis, and limnological models.

The percentile approach followed the methods of Bue and Hasbrouck (2001) whereby the contrast of the escapement data and the exploitation rate of the stock were used to select the percentiles of observed annual escapements to be used for estimating the SEG. Low contrast (<4) implies that stock productivity is known for only a limited range of escapements. According to this approach, percentiles of the total range of observed annual escapements that are used to estimate an SEG for a stock with low contrast should be relatively wide, in an attempt to improve future knowledge of stock productivity. In cases where data contrast was less than 4 and the exploitation rate was low, the lower end of the SEG range was the 15^{th} percentile of the escapement data and the upper end of the range was the maximum escapement estimate. Alternately, in cases where contrast was larger, the percentiles of observed annual escapements used to estimate an SEG were narrowed. For stocks with high contrast and at least moderate exploitation, the lower end of the SEG range was increased from the 15^{th} to the 25^{th} percentile as a precautionary measure for stock protection.

The risk analysis (Bernard et al. *In press*) was used to establish an SEG, in the form of a precautionary reference point (PRP), from a time series of observed escapement estimates using probability distributions. This method is based on estimating the risk of management error and is particularly appropriate in situations where a particular stock (or stock aggregate) is not "targeted" and observed escapement estimates are the only reliable data available. In essence, this analysis begins with estimating the probability of detecting escapement falling below the SEG in a predetermined number of consecutive years (k). For example, if there is cause for concern when escapement falls below the SEG for 3 consecutive years, k would be equal to 3. Simultaneously, a second probability is estimated, that is the probability of taking action (e.g., closing a fishery to protect the stock) for three consecutive years when no action was needed. This analysis assumes that escapement observations follow a lognormal distribution and have a stationary mean (no temporal trend).

Two limnological models were used in this escapement goal review to corroborate spawner-recruit and stock-recruitment yield analyses, and to estimate SEGs. The euphotic volume (EV) model estimated adult escapement in part by determining the volume of lake water capable of primary production, which could sustain a rearing juvenile fish population (Koenings and Burkett 1987). The euphotic volume indicated a level of phytoplankton forage (primary production) available to zooplankton, and thus a level of zooplankton forage available for rearing juvenile fish. It was inferred from the model that shallower light penetration would also result in lower adult production compared to lakes with deeper light penetration because the shallower lakes would not have the primary production necessary to sustain a larger rearing population. The EV model assumed that the lake was deep enough to achieve 1% light penetration in the water column.

The second limnological model (i.e., zooplankton model), estimated smolt production based on the amount of available zooplankton biomass fed upon by smolt of a targeted threshold size, in a lake of known area (Koenings and Kyle 1997). The zooplankton model, like the EV model, relied upon the premise that the availability of forage to juvenile fish could impact their survival and subsequently, adult production. Adult production was calculated using species-specific fecundity and marine survival rate estimates. The zooplankton model further assumed that zooplankton were the only available forage.

CHINOOK SALMON

Chignik River Chinook salmon annual escapements were estimated by subtracting the estimates of recreational harvest from the inriver run. Inriver run estimates were made at a weir on the Chignik River by counting migrating Chinook salmon for a specified time interval and expanding the counts for intervals not sampled (Schwarz et al. 2002). Weir estimates were available from 1978 to 2003. Annual recreational harvests on this stock, which occur upstream of the weir were considered relatively minor because of their failure to appear in the Statewide Harvest Survey (Jennings et al. *In prep*). It was assumed that the average annual recreational harvest estimated from a creel survey conducted in 1988 and 1989 (Schwarz 1990) represented the annual recreational harvest for the remaining years.

For this analysis, it was assumed that all Chinook salmon harvested in Chignik Lagoon (statistical area 271-10) were bound for the Chignik River. The total annual runs of Chignik River Chinook salmon were estimated by adding commercial harvests and inriver run estimates.

Because there was no sampling trap at the weir, the commercial purse seine harvest in Chignik Lagoon was sampled to estimate the age composition of the run. Age composition data were only available for runs between 1993 and 2001. The age compositions of the 1993 through 2001 runs were assumed to represent the average age composition of the runs from 1978 through 1992.

A brood table was constructed from Chinook salmon run estimates by age class. Total run by age was estimated by multiplying total run and the age composition of Chinook salmon sampled from the commercial seine fishery. Age-specific returns were summed for each brood year to estimate total return by brood year. Return-per-spawner was then estimated as the total return from each brood year divided by the escapement for that brood year. These data were considered sufficient to estimate MSY (Hilborn and Walters 1992; CTC 1999; Quinn and Deriso 1999) and develop a BEG.

Spawner-Recruit Analysis

Spawner-recruit data were analyzed using a mathematical stock recruitment model (Ricker 1954) to estimate S_{msy} and the subsequent BEG range. If the analyses indicated there was significant autocorrelation ($\alpha = 0.05$) among the residuals of the model, the methods of Noakes et al. (1987) and Pankratz (1991) were used to alleviate bias in the parameter estimates. The BEG range was estimated using two approaches. The first approach was to multiply the escapement that provided MSY by 0.8 and 1.6 as suggested by Eggers (1993) who showed that, in general, this range of escapements produces average yields that are 90-100% of MSY. The second approach used parameter estimates directly from the Ricker model to estimate the two spawning escapements that would produce 90% of MSY.

Habitat-Based Model

Productivity of Chignik River Chinook salmon was estimated from a meta-analysis developed by Parken (*unpublished*). Parken compared and related estimates of carrying capacity (S_{eq}) and S_{msy} for 13 stream-type (age 1. and older smolt) and 12 ocean-type (age 0. smolt) Chinook salmon stocks along the North Pacific coast, including stocks from interior and southeast Alaska. The premise behind the meta-analysis was that physically larger drainages that contained Chinook salmon also tended to have proportionally larger populations than smaller drainages that contained Chinook salmon. The relationship between S_{eq} and watershed area was found to fit an allometric power (log-log) model very well, with R^2 values of 0.83 for ocean-type and 0.87 for stream-type Chinook with watersheds ranging from approximately 90 km^2 (King Salmon River in southeast Alaska) to over 130,000 km^2 (a portion of the Columbia River drainage). Similarly, the relationship between S_{msy} and watershed area fit an allometric power model equally well (R^2 = 0.82 for ocean-type and 0.88 for stream-type stocks). The Chignik River stock of Chinook salmon likely has a stream-type life history so the relationship developed for stream-type stocks was utilized in the analysis.

From Parken (*unpublished*), the relationship between watershed area and S_{eq} for the 13 stream-type stocks of Chinook salmon was

$$\ln\left(S_{eq}\right) = 0.684 \cdot \ln\left(\textit{watershed area}\right) + 3.90 \qquad (1)$$

The relationship for S_{msy} was

$$\ln\left(S_{msy}\right) = 0.698 \cdot \ln(\textit{watershed area}) + 2.81 \qquad (2)$$

Estimates of S_{eq} and S_{msy} were calculated from equations 1 and 2 using the area of the Chignik River watershed in square km.

SOCKEYE SALMON

From 1922 to 1960, the U. S. Fish and Wildlife service operated the Chignik River weir. The State of Alaska assumed control of the weir in 1961. Reliable escapement and harvest data were available from 1952 to the present. Dahlberg (1968) indicated that the quality of data between 1922 and 1951 was questionable as escapements were estimated and not counted for 16 of those years and many inconsistencies were found among processor, federal, and university data sources. Parker (1986) also indicated that errors existed in age composition statistics for the same data. Current data based on run reconstructions and SPA (from 1980 to 2003) were also subject to measurement and process error, however, these data do corroborate the results from past tagging studies and escapement trends.

The Black (early run) and Chignik (late run) Lake stocks are the only two sockeye salmon stocks in the CMA with BEGs. Escapement estimates used in the analyses for both runs were based mainly on weir counts and included postseason estimates for the Chignik late-run escapement following removal of the Chignik River weir. Individual sales receipts (fish tickets) documented sockeye salmon commercial harvest data for the CMA. Both catch and escapement data were obtained from the Westward Region CF salmon databases. Sport and subsistence harvests were not included in the total run estimates and were assumed to be minor. Available age data from the Westward Region CF salmon age database were also obtained. Brood tables for the early and late runs were developed based on the escapement, catch, and age data. In addition to catch and escapement data, sockeye salmon smolt outmigration, zooplankton, and water quality data were utilized to corroborate the existing BEGs.

Spawner-Recruit Analysis

Ricker spawner-recruit models (Ricker 1954) for the early, late, and combined sockeye salmon runs were analyzed with additive and multiplicative error structures (Quinn and Deriso 1999). The Ricker analyses performed with both error structures were divided into three temporal groups: from 1980 to 1997 when SPA was available for run reconstruction, 1965 to 1997 when production trends were similar to current production trends (Ruggerone et al. 1999), and 1952 to 1997 during which time there was continuous weir operation. Generalized Ricker models (Quinn and Deriso 1999) employing catch, escapement, and available sea surface temperature data from 1977 to 1997 were also run to address the influence of marine rearing conditions. Sea surface temperature data from the National Oceanic and Atmospheric Administration (NOAA) station 46003 (51° 49' 53" N, 155° 51' 01"W) were available from 1977 to the present. A Ricker analysis with a multiplicative error structure was performed for the early run using data from 1922-1945 and 1965-1996 (R. A. Clark, Alaska Department of Fish and Game, personal communication). This analysis was run for comparison to the models that employed more recent data.

If a significant ($P<0.05$) spawner-recruit model was found, S_{msy} was estimated along with the escapement ranges that would yield 90-100% of MSY. Model results were assessed using the criteria in Quinn and Deriso (1999) and the Chinook Technical Committee (1999). Escapement data contrast was considered since low data contrast (<4.0) can impart appreciable measurement error, and thus bias on estimated returns, with spawner-recruit models (CTC 1999).

Stock-Recruitment Yield Analysis

A tabular approach was used to examine stock-recruitment yield relationships for the early run of sockeye salmon from 1952-1997 and from 1965-1997. The analysis followed the Hilborn and

Walters (1992) Markov model. Escapements and returns were arranged into intervals based on size. The frequency that an escapement within a particular interval produced recruitment within a particular interval was calculated for all intervals. The relative proportion of recruitment in each escapement interval was also calculated. Average surplus yield (estimated as the recruitment minus parental spawning escapement) within each escapement interval was also calculated. Different intervals were specified and compared, due to changes in categorical yield that corresponded with changes in interval specification. The late run of sockeye salmon was not examined with a stock-recruitment yield analysis because of its significant Ricker relationship based on contemporary, reliable data.

Euphotic Volume Model

Euphotic volume (EV) data were available for 1991 and from 2000 to 2003. Annual average EV was estimated for each lake by

$$EV = EZD \cdot \text{Lake Area (km}^2) \quad (3)$$

where EZD was the euphotic zone depth in meters (Koenings et al. 1987). Adult production (AP) was estimated using

$$AP = EV \cdot 2{,}500 \text{ adults per EV unit} \quad (4)$$

from Koenings and Kyle (1997). Optimal escapement (OE) was estimated using

$$OE = EV \cdot 1{,}000 \text{ escaped adults per EV unit} \quad (5)$$

(Koenings and Kyle 1997). Optimal spring fry production (SF) was estimated by

$$SF = EV \cdot 110{,}000 \text{ spring fry/EV unit} \quad (6)$$

and total yearly smolt biomass production (SB), for each run separately, was determined by

$$SB = EV \cdot 107 \text{ kg/EV unit} \quad (7)$$

(Koenings and Kyle 1997). Escapement goal ranges were estimated by calculating values 25 percent higher and lower than the point estimates (i.e., 0.75 and 1.25 multiplied by the point estimate).

It should be noted that modifications were made to the EV model specific to the Chignik River watershed. Koenings and Burkett (1987) originally estimated SB to be 81 kg/EV unit based on their study of 22 sockeye salmon lakes among Alaska and Canada. The average threshold length of the sockeye salmon smolt from their study fell between 60 to 65 mm with an average length of 63 mm (Koenings and Burkett 1987). This was determined by the minimum size of outmigrating age 1. fish from their sockeye salmon smolt outmigration data (Koenings and Burkett 1987). From the log-linear length-weight relationship of their data, they estimated the threshold weight to fall between 2.0 and 2.5 g, with an average of 2.25 g (Koenings and Burkett 1987). For outmigrating Chignik juvenile sockeye salmon, the average weight could not be determined in the same manner as Koenings and Burkett (1987) due to the upstream migration of juvenile sockeye salmon from Chignik Lagoon and/or Chignik River to Chignik Lake. This prevented the determination of a threshold size for outmigrating juveniles as some of the smaller sized fish, which move downstream, might not necessarily leave the system. This could bias the threshold size estimate. Additionally, the significant log-linear length-weight relationship ($R = 0.91$, $P<0.05$) of the Chignik River watershed fish had a steeper slope than that for sockeye salmon smolt determined by Koenings and Burkett (1987). A threshold length of 66 mm for outmigrating Chignik sockeye salmon smolt was calculated from the mean length of outmigrating age 1. sockeye salmon from 1994 through 2003 (Bouwens and Newland 2004). The threshold weight for Chignik River watershed juvenile sockeye salmon was estimated to be 2.97 g by the log-linear length-weight relationship. The ratio between the two weights (2.97 g:2.25 g) was applied to the 81 kg/EV unit and used to estimate the 107 kg/EV unit.

Similarly, Black Lake fish had an average weight of 2.61 g, which was used to estimate a new smolt biomass of 94 kg/EV unit. The 94 kg/EV unit estimate was substituted into equation 7 for Black Lake calculations. For estimating production for both Chignik and Black Lakes combined, the system-wide EV was weighted based on the assumed four month rearing time (May through August) of fish in Black Lake. The EZD of Black Lake often exceeded the actual lake depth: the EZD at maximum lake depth (~4.0 m) was used to calculate EV. Using the EZD at maximum lake depth as opposed to average lake depth (~1.9 m) provided less biased estimates of smolt production compared to historic data.

Zooplankton Based Model

Zooplankton data were collected in 1991 (Kyle 1992) and 2000 through 2003 (Finkle 2005) from both Chignik and Black Lakes. Sockeye salmon smolt outmigration data were available from 1994 to 2003. Zooplankton samples were processed using methods outlined in Thomsen et al. (2002). The expected production of sockeye salmon smolt of a given size, based on zooplankton biomass in mg/m^2, was estimated by

$$S_G = \frac{2.11 \cdot ZB \cdot SA}{G} \tag{8}$$

where S_G was the smolt production of a given size, ZB was the zooplankton biomass, SA was the lake surface area in km^2, and G was the target smolt size in grams (Koenings and Kyle 1997). For the Chignik River watershed, the target size was estimated at 2.97 g, which was the weighted average mass of outmigrating Chignik River watershed sockeye smolt. Because of the availability of Black Lake juvenile sockeye salmon length and weight data (Bouwens and Finkle 2003), an average length of 2.61 g was calculated and used for the early run instead of the 2.97 g watershed estimate, which included age classes not present in Black Lake. The average fecundity of 3,000 eggs per spawning female sockeye salmon (Ramstad 1998), a one percent egg to smolt survival (Koenings and Burkett 1987), and a 50/50 sex ratio were assumed and used to estimate the optimal escapement based on S_G by

$$ESC_G = 2\left[\frac{S_G}{30}\right] \tag{9}$$

from Koenings and Burkett (1987). Adult sockeye salmon production ($PROD_G$) was calculated by

$$PROD_G = MS_G \cdot S_G \tag{10}$$

where MS_G was the size-specific smolt to adult marine survival of 12% from Koenings and Burkett (1987). These smolt size-specific estimates were used to describe the escapement goal ranges.

PINK SALMON

Pink salmon escapements in the CMA were enumerated by aerial survey. These data were available from 1962 to 2003. Escapements after 1984 were estimated using area-under-the-curve methodology assuming a 15-day stream life (Johnson and Barrett 1988) and were referred to as estimated total escapement. Achievement of the escapement goals was determined by the estimated total escapement. An investigation of the peak escapement counts versus the estimated total escapement revealed several inconsistencies in the database. In many cases, the estimated total escapement was lower than the peak count in a given stream due to inconsistencies in the calculation routine. Because the calculation inconsistencies resulted in unreliable estimates, all analyses for this review were performed using peak escapement counts. Subsequent fisheries management will rely on peak escapement counts to measure achievement of escapement goals.

No stock-specific harvest estimates were available for the CMA pink salmon fisheries. However, the team felt that it would be reasonable to aggregate district-wide pink salmon catches and escapements into a single brood table to estimate a spawner-recruit relationship.

Spawner-Recruit Analysis

District- and area-wide aggregate pink salmon spawner-recruit relationships were estimated for even-year returns, odd-year returns, and even- and odd- year returns combined. Spawning stock and recruitment data were analyzed using a Ricker spawner-recruit model (Ricker 1954), with both additive and multiplicative error structures considered (Quinn and Deriso 1999). If a Ricker spawner-recruit model was significant, then S_{msy} was estimated along with the range of escapements that would produce 90 to 100% of MSY.

CHUM SALMON

CMA chum salmon escapement was measured by peak aerial survey and total escapement was estimated using the area-under-the-curve method described in Johnson and Barrett (1988). Total estimated escapement estimates were used for inseason fishery management. As with Chignik pink salmon escapement estimates, there were many inconsistencies between the total estimated escapement calculations and the peak aerial survey counts, so peak aerial survey counts were used for these analyses. Future fisheries will be managed on the basis of peak escapement counts.

Stock-specific harvest estimates and age composition data were not available for chum salmon in the CMA. Chum salmon total peak escapement estimates were obtained from the ADF&G aerial survey database and SEGs were estimated using a risk analysis that followed Bernard et al. (*In press*). The percentile approach (Bue and Hasbrouck 2001) was also used to estimate district-wide chum salmon SEGs when the risk analysis was determined to be inappropriate.

Risk Analysis

District-wide chum salmon peak escapement time series were first log-transformed and tested for normality using a one-sample Kolmogorov-Smirnov test (Conover 1980) to determine whether escapement estimates followed a lognormal distribution ($P>0.15$). The log-transformed escapement time series were then tested for serial correlation using diagnostics in Chatfield (1984).

Based on the results, escapements were modeled as lognormally distributed variables. The number of consecutive years where escapement levels below the SEG (PRP) would cause a concern was set at three, the number of years between each regularly scheduled BOF meeting.

Risk of an unwarranted restriction due to a management concern (π_k) was estimated directly from the log transformed mean (μ), standard deviation (σ), and number of consecutive years to warrant a concern (k = 3) for various values of an SEG (X) as per Bernard et al. (*In press*):

$$\hat{\pi}_k = \left\{pr\left[(N : \hat{\mu}, \hat{\sigma}^2) \leq \ln X\right]\right\}^k \quad (11)$$

The risk of detecting a drop in mean escapement was estimated in the same way as risk of an unwarranted restriction, except that the risk of not detecting ($1 - \hat{\pi}_k$) was estimated and the mean escapement ($\hat{\mu}$) was changed by the desired percentage drop in the mean to be detected with the SEG:

$$1 - \hat{\pi}_k = \left\{pr\left[(N : \hat{\mu} + \Delta, \hat{\sigma}^2) \leq \ln X\right]\right\}^k \quad (12)$$

The desired percentage drop in the mean to be detected was estimated as the observed percent difference between the mean escapement and the minimum escapement greater than zero.

If the percent difference between the mean escapement and the minimum escapement produced an overly restrictive SEG, the risk was estimated for setting the SEG near the minimum observed escapement.

Percentile Approach

In cases where escapement estimates were normally distributed, risk analysis was considered inappropriate. The percentile approach (Bue and Hasbrouck 2001) was used as an alternative when assumptions required for the risk analysis were violated. Selection of the percentiles used in the calculation were based on escapement contrast and fishery exploitation of the stock (Bue and Hasbrouck 2001).

RESULTS

The comprehensive review of 13 existing CMA salmon escapement goals resulted in recommendations to change 10 of the goals. The team recommended leaving the current Chinook salmon BEG unchanged. They recommended reclassifying the two sockeye salmon BEGs as SEGs, with the same goal ranges. It was also recommended to establish one odd-year and one even-year CMA aggregate BEG for pink salmon, each composed of management objectives by district replacing the existing five district-wide SEGs. The team recommended replacing the five chum salmon SEGs with one area-wide aggregate SEG composed of management objectives by district. Appendices A through D provide a description of each stock, or stock aggregate, current escapement goal of each stock, escapement estimates, data used for analyses of escapement goals, and supplemental information used to evaluate each escapement goal.

CHINOOK SALMON

Chignik River watershed

Stock Status

During the 2001-2002 BOF meeting cycle, the Chignik River Chinook salmon BEG range of 1,450-2,700 spawners was changed to 1,300-2,700 spawners based on a Ricker analysis of spawner-recruit data (Hasbrouck and Clark *In prep*.; Appendix A1). This recommendation was based on multiplying the escapement that produced MSY by 0.8 and 1.6 as suggested by Eggers

(1993). Five of the past 26 years of escapements fell within the current BEG range, with most recent escapements above the range (Appendices A2 through A4).

Spawner-Recruit Analysis

For this review, the Chignik River Chinook salmon spawner-recruit data were reanalyzed with the addition of the 1995 and 1996 brood years (Appendices A1-A6). A significant ($P<0.001$) Ricker spawner-recruit relationship existed using the fully recruited brood years from 1978 to 1996. There was no significant ($P>0.05$) autocorrelation among residuals from the Ricker model (Appendix A6). Escapements have ranged from 669 fish in 1980 to about 6,030 fish in 2003 (data contrast of 9.3). The point estimate of escapement that produced MSY (S_{msy}) from the updated analysis was approximately 1,660 fish. Multiplying this escapement by 0.8 and 1.6 resulted in a computed range of 1,326-2,653 fish, which, when rounded, resulted in the same range recommended three years ago. The range computed directly from the model parameter estimates was 1,045-2,400 fish. The fitted Ricker curve crossed the replacement line (S_{eq}) at an escapement of approximately 4,960 fish.

Habitat-Based Model

Area of the Chignik River watershed measured 1,693 km^2. From watershed area, the estimate of S_{eq} from equation 1 was approximately 7,980 fish, about 1.5 times greater than that of the Ricker model. The estimate of S_{msy} from equation 2 was approximately 2,980, about 1.8 times greater than that of the Ricker model.

Escapement Goal Recommendation

The team recommended no change to the current escapement goal. The Ricker model with additional brood years of data provided very similar escapement goal ranges to those adopted in 2001-2002. The team believed the spawner-recruit data provided a more accurate estimate of stock productivity than the habitat-based model.

SOCKEYE SALMON

Chignik River watershed early run

Stock Status

An early and late run compose the two genetically distinct runs of sockeye salmon that return to the Chignik River watershed (Templin et al. 1999; Appendices B1-B5). The current early-run BEG is 350,000 to 400,000 sockeye salmon (Table 1; Appendix B1). This goal was established in 1968 (Dahlberg 1968) based on spawner-recruit relationships and by the carrying capacity of Black Lake, which was estimated in 1966 (Narver 1966). The upper range of the early-run BEG represented the maximum number of sockeye salmon that Black Lake could successfully sustain. Prior to implementing this goal, escapements fluctuated around and within the BEG range. Since then, the early run has exceeded the upper end of the BEG range in 20 of the past 52 years (Appendices B2 and B3).

Spawner-Recruit Analysis

Sockeye salmon escapements averaged about 390,000 (approximate range: 34,200 to 769,000) fish for the early run, from 1952 through 1997 (Appendices B1 through B3). Returns averaged about 1,100,000 sockeye salmon for the early run during these years. The contrast in the early-run escapement data for this time period was 22.5, above the recommended minimum contrast level of 4.0 (CTC 1999). It should be noted that the early-run contrast of 22.5 was driven by one data point from 1952 with an escapement estimate of 34,200 fish: without this data point the contrast would be reduced to 6.9.

From 1965 through 1997, sockeye salmon escapements averaged 455,000 (approximate range: 307,000 to 769,000) fish for the early run (Appendices B1-B3). Returns averaged about 1,400,000 sockeye salmon for the early run. The contrast in the early-run escapement data for these years was 2.5, below the recommended minimum contrast level of 4.0 (CTC 1999).

From 1980 through 1997, sockeye salmon escapements averaged 485,000 (approximate range: 361,000 to 769,000) fish for the early run (Appendices B1-B3). Returns averaged about 1,400,000 sockeye salmon for the early run during this period. The contrast in these early-run escapement data for these years was 2.1, well below the recommended minimum contrast level of 4.0 (CTC 1999).

Sockeye salmon escapements averaged 476,000 thousand (approximate range: 361,000 to 769,000) fish for the early run, from 1977 through 1997 (Appendices B1 through B3). Returns averaged 1,600,000 sockeye salmon for the early run during this period. The contrast in the early-run escapement data for these years was 2.1, which was well below the recommended minimum contrast level of 4.0 (CTC 1999).

The early run from 1922-1945 and 1965-1996 had an average sockeye salmon escapement of 461,000 fish, ranging between about 4,600 to 2,150,000 million fish. The contrast of these data was 463 for these years, well above the recommended minimum contrast level of 4.0 (CTC 1999).

Ricker spawner-recruit models were fit to the early-run fully recruited brood year spawner-recruit data for three different time periods 1952 to 1997, 1965 to 1997, and 1980 to 1997 (Appendices B6 and B7). No significant ($P>0.05$) spawner-recruit relationships were realized for any of the early run models despite accounting for additive and multiplicative error structures. A fourth spawner-recruit analysis using combined data from 1922 to 1945 and from 1965 to 1997 estimated S_{msy} at 409,000 fish with a range that produced 90-100% of S_{msy} between about 259,000 and 588,000 fish (R.A. Clark, Alaska Department of Fish and Game, personal communication). It should be noted that from 1922 to 1945, the weir was not installed for nine years and measurement and process errors were likely greater than in subsequent years. Despite their high contrast (463), data from 1922 to 1945 were not considered reliable, but were employed for comparison to the other Ricker models.

A generalized model, which incorporated sea surface temperature data, was run with fully recruited brood year spawner-recruit data from 1977 to 1997 for the early run. No significant relationship was found for that model ($P>0.05$; Appendix B6).

Stock-Recruitment Yield Analysis

Different intervals were considered for both early-run escapement and recruitment. The yield analysis tables had an escapement range from 1,000 to 800,000 fish, with intervals of 100,000 fish to create eight intervals. An escapement range was also assessed from 51,000 to 850,000 fish with intervals of 100,000 fish. Analyses for both interval ranges were performed with data sets from 1952 to 1997 and 1965 to 1997, for a total of four yield analyses. The escapement data from brood years 1952 through 1997 indicated lower productivity during 1952 through 1964, as suggested by Ruggerone et al. (1999).

For both time periods, the escapement intervals of 301,000 to 400,000 and 401,000 to 500,000 fish, had high average yields (>770,000 fish) for data in the 1,000 to 800,000 fish range. For the higher 51,000 to 850,000 fish range and both time periods, the escapement intervals of 351,000 to 450,000 and 451,000 to 550,000 fish also resulted in high average yields (>800,000 fish; Appendix B8). This suggested that the width of the interval range did not drastically affect the outcome of average yield, or return. It should be noted that results from the 51,000 to 850,000 fish range provided a point escapement estimate of 386,000 sockeye salmon (Appendix B8), which compared favorably to Ruggerone's 1999 early run S_{msy} of 382,000 sockeye salmon. Of all the time periods and intervals assessed, the uppermost escapement ranges produced the highest yields (>1,250,000 fish), however, only one data point was available for analysis in those escapement ranges. Similarly, intervals greater than 601,000 also had high average yields; however, due to the relatively few points per interval (< 5), these values should be viewed with caution. As with the spawner-recruit models, there was very little indication from the yield analysis that excessive escapement (>500,000 fish) would result in lower than average returns for the early run.

Euphotic Volume Analysis

Based on EV analyses, early-run adult production was estimated to be about 375,000 adult sockeye salmon annually, with an escapement goal range between 169,000 and 281,000 sockeye salmon (Appendices B6 and B9). It must be noted that early run EV sockeye salmon estimates, which were based on the euphotic zone depth (EZD), were questionable despite any corrections for the EZD in Black Lake due to the shallow lake depth.

Smolt Biomass as a Function of Zooplankton Biomass

Dependent upon smolt size, the zooplankton model provided an estimated escapement goal range of 342,000 to 513,000 sockeye salmon for the early run (Appendices B6 and B10). Adult production was estimated at approximately 770,000 sockeye salmon for the early run (Appendix B10). The zooplankton model may not be appropriate for Black Lake as its juvenile sockeye salmon are known to feed on insect larvae.

Chignik River watershed late run

Stock Status

The late run, which is the second genetically distinct component of the two sockeye salmon runs that return to the Chignik River watershed (Templin et al. 1999), has a BEG range of 200,000 to 250,000 sockeye salmon (Table 1; Appendix B1). This goal was established in 1968 (Dahlberg 1968) based on spawner-recruit relationships and by the carrying capacity of Chignik Lake, which was estimated in 1966 (Narver 1966). The upper range of the late-run BEG represented the maximum number of sockeye salmon that Chignik Lake could successfully sustain. In 1989, a management objective of 25,000 sockeye salmon after August 31 was added to the late-run escapement to meet the needs of subsistence and commercial fishermen. Prior to implementing the goals, escapements fluctuated around and within the BEG ranges. During this time frame, the late run has exceeded the BEG in 33 of the last 52 years (Appendices B2 and B4).

Spawner-Recruit Analysis

Sockeye salmon escapements averaged about 284,000 (approximate range: 120,000-557,000) fish for the late run, from 1952 through 1997 (Appendix B4). Returns averaged about 1,000,000 sockeye salmon for the late run during this period. The contrast in the late-run escapement data for this time period was 4.6, just above the recommended minimum contrast level of 4.0 (CTC 1999).

From 1965 through 1997, sockeye salmon escapements averaged 281,000 (approximate range: 120,000 to 557,000) fish for the late run (Appendix B4). Returns averaged about 1,100,000 sockeye salmon for the late run during this period. The contrast in these late-run escapement data was 4.6 for these years, just above the recommended minimum contrast level of 4.0 (CTC 1999).

From 1980 through 1997, sockeye salmon escapements averaged 325,000 (approximate range: 197,000 to 557,000) fish for the late run (Appendix B4). Returns averaged about 1,200,000 sockeye salmon for the late run during this period. The contrast in these late-run escapement data was 2.8 for these years, well below the recommended minimum contrast level of 4.0 (CTC 1999).

Sockeye salmon escapements averaged 319,000 (approximate range: 197,000 to 557,000) fish for the late run, from 1977 through 1997 run (Appendix B4). Returns averaged about 1,200,000 sockeye salmon for the late-run during this period. The contrast in these late-run escapement data was 2.8 for these years, which was well below the recommended minimum contrast level of 4.0 (CTC 1999).

Ricker spawner-recruit models were fit to the late-run fully recruited brood year spawner-recruit data for three different time periods 1952 to 1997, 1965 to 1997, and 1980 to 1997 (Appendix B6 and B7). A significant (P=0.0024) Ricker spawner-recruit relationship with multiplicative error was found for the late run, using the 1952 to 1997 brood year data (Appendix B6). Contrast for these data was 4.6. However, residual analysis indicated a non-stationary auto correlated error structure. Ruggerone et al. (1999) suggested that 1946 to 1964 was a time of low productivity, and data from this time period should be treated separately. A Ricker model with multiplicative error was fit for 1965 to 1997 data (Appendix B7) and was significant (P=0.0007), however no declining tail was observed in the spawner-recruit curve, which indicated results should be viewed with caution. The point estimate of S_{msy} was 317,000 fish with a computed 90-100% MSY range of about 201,000 to 455,000 fish (Appendix B6). The fitted Ricker spawner-recruit curve crossed the replacement line at an escapement (S_{eq}) of about 877,000 fish; however this was outside the range of known escapements. No significant relationships were found for the late run with the 1980 to 1997 data (P>0.05).

A generalized model, which incorporated sea surface temperature data, was run with fully recruited brood year spawner-recruit data from 1977 to 1997 for late run. No significant (P>0.05) relationship was found for that model.

Euphotic Volume Analysis

Based on the average EV, the adult production in Chignik Lake was estimated to be approximately 606,000 sockeye salmon annually. An escapement goal range of about 182,000 to 303,000 sockeye salmon was calculated based on the EV for the late run (Appendices B6 and B9).

Smolt Biomass as a Function of Zooplankton Biomass

Adult production was estimated at approximately 1,000,000 sockeye salmon based on the zooplankton model (Appendix B10). Dependent upon smolt size, the zooplankton model yielded estimated escapement goal ranges of 444,000 to 667,000 sockeye salmon for the late run (Appendices B6 and B10).

Chignik River watershed both runs combined

Stock Status

The combined BEG to the Chignik River watershed is 550,000 to 650,000 sockeye salmon (Table 1; Appendix B1). This goal ranges was established in 1968 (Dahlberg 1968) based on spawner-recruit relationships and the carrying capacity of the Chignik River watershed, which was estimated in 1966 (Narver 1966). The upper end of the watershed BEG range represented the maximum number of sockeye salmon that Chignik River watershed could successfully sustain. Prior to implementing the goals, escapements fluctuated around and within the BEG range. Since implementing the BEG, the total escapement to the watershed has generally increased and has exceeded the upper bound of the watershed BEG range for every year since 1976. During this time frame, both runs were overescaped in 1982, 1983, 1990, 1991, 1996, 1998, and 2001 (Appendices B2 and B5).

Spawner-Recruit Analysis

Sockeye salmon escapements averaged about 659,000 (approximate range: 295,000-1,040,000) fish for both runs combined, from 1952 through 1997 (Appendices B2 and B5). Returns averaged about 2,060,000 sockeye salmon for the combined runs during this period. The contrast in these combined run escapement data was 3.5 for this time period, which was below the recommended minimum contrast level of 4.0 (CTC 1999).

From 1965 through 1997, sockeye salmon escapements averaged about 737,000 (approximate range: 470,000 to 1,040,000) fish for both runs combined (Appendices B2 and B5). Returns averaged about 2,4800,000 sockeye salmon for the combined runs during this period. The contrast in these combined run escapement data maintained a contrast of 2.2 for this time period, well below the recommended minimum contrast level of 4.0 (CTC 1999).

From 1980 through 1997, sockeye salmon escapements averaged about 810,000 (approximate range: 664,000 to 1,040,000) fish for both runs combined (Appendices B2 and B5). Returns averaged about 2,660,000 sockeye salmon for the combined runs during this period. The contrast in these combined run escapement data was 1.6 for this time period, well below the recommended minimum contrast level of 4.0 (CTC 1999).

Sockeye salmon escapements averaged about 795,000 (approximate range: 664,000 to 1,040,000) fish for both runs combined, from 1977 through 1997 (Appendices B2 and B5). Returns averaged about 2,7500,000 sockeye salmon for the combined runs during this period. The contrast in these combined run escapement data was 1.6 for this time period, which was well below the recommended minimum contrast level of 4.0 (CTC 1999).

Ricker spawner-recruit models were fit to the combined runs fully recruited brood year spawner-recruit data for three different time periods 1952 to 1997, 1965 to 1997, and 1980 to 1997 (Appendix B6). No significant ($P>0.05$) spawner-recruit relationships were realized for any of the combined run models. A generalized model, which incorporated sea surface temperature data, was run with fully recruited brood year spawner-recruit data from 1977 to 1997 for both runs combined as the total run. No significant relationship was found for that model ($P>0.05$).

Euphotic Volume Analysis

Applying the EV model to both runs combined, adult production was estimated at approximately 1,320,000 sockeye salmon annually (Appendices B6 and B9). The escapement goal range for both runs combined was estimated to be between about 397,000 to 661,000 adult sockeye salmon. This range was not reliable because of the euphotic zone depth exceeded lake depth in Black Lake, which violated model assumptions.

Smolt Biomass as a Function of Zooplankton Biomass

Adult production was estimated at approximately 1,770,000 sockeye salmon with the zooplankton model (Appendices B6 and B10). The escapement goal range for both runs combined was 787,000 to 1,180,000 adult sockeye salmon based on the zooplankton model (Appendices B6 and B10). The zooplankton model might not provide reliable estimates for both runs combined because of the other available forage in Black Lake.

Escapement Goal Recommendation

The team felt that the results of these analyses did not warrant increasing or decreasing the current goals as they generally approximated the current goals. However, the team felt that the current goals should be designated as SEGs, instead of BEGs, because while sufficient data existed to attempt to estimate an early- and late-run BEG, scientifically defensible estimates of S_{msy} were still not possible. Additionally, despite the lack of an updated goal range, past run data have indicated that sustained sockeye salmon yields have occurred in excess of the five to 10 year period specified for SEGs in the SSFP. The lack of a significant spawner-recruit relationship with reliable data for the early run precluded the establishment of a system-wide escapement goal range. The yield analysis provided similar results to the spawner-recruit model; however the yield analysis did not indicate a downward trend in the spawner-recruit relationship. Both the EV and zooplankton models had very few data points to corroborate spawner-recruit relationships and could not robustly describe salmon stock productivity or data uncertainty. Run, light penetration, and zooplankton data, collected in the near future, will hopefully provide the necessary contrast and information to define stock productivity and data uncertainty relative to current rearing conditions for Chignik sockeye salmon. It should be noted that if a BEG were estimated with a spawner-recruit or habitat based model using current biological data for Chignik sockeye salmon, the escapement goal range would be wide (> 250,000 fish between the upper and lower goal ranges) as a function of the variance inherent in those data. However, current zooplankton data have indicated that the forage bases in both lakes have been overgrazed following escapements that have approached or exceeded the upper ranges of the escapement objectives. In an effort to reduce grazing pressure on the zooplankton forage bases and improve juvenile survival, narrower ranges were chosen to help avoid large escapement levels, which would subsequently increase juvenile competition and overgraze the zooplankton forge base. Current management practices in the CMA have enabled the achievement of escapement levels within these narrow ranges.

PINK SALMON

Eastern District

Stock Status

The current Eastern District pink salmon SEG of 488,000 was adopted in 1999 (Table 1; Appendix C1). Aerial survey estimates were summed from 23 index streams to estimate total district-wide escapement on an annual basis. Estimated total escapements were generally below the goal during the 1970s and through the mid 1980s, but have been above the goal during every year except one since 1988 and have achieved the goal in all of the past 10 years (Appendices C2 and C3). When escapement estimates relied on peak counts only, the same trend was evident with escapement estimates falling short of the goal in the 1970s and early 1980s and escapement improving in the mid 1980s; the goal was achieved in nine of the past 10 seasons (Appendices C2 and C3).

Spawner-Recruit Analysis

Ricker spawner-recruit models were fit to the Eastern District pink salmon data from brood years 1972-2001 (odd and even years combined) using additive and multiplicative error structures. There was a contrast in the data of 39.2, well above the recommended contrast level of 4.0 (CTC 1999; Appendix C1). The additive error model was significant (P=0.0027) and resulted in an estimate of S_{msy} of about 265,000 spawners with an escapement range of approximately 172,000 to 368,000 spawners, while the curve crossed the replacement line (S_{eq}) at an escapement of about 641,000 fish (Appendix C4). The multiplicative error model was also significant (P=0.0016) and resulted in an estimate of S_{msy} of about 260,000 spawners with an escapement range of approximately 171,000 to 359,000 spawners, while S_{eq} was estimated at about 609,000 pink salmon (Appendix C4). No autocorrelation was found in either models' residuals.

The even-year Eastern District pink salmon escapement data (1972-2000) had a contrast of 39.2, well above the recommended contrast level of 4.0 (CTC 1999; Appendix C1). The additive error model was significant (P=0.030) and resulted in an estimate of S_{msy} of about 251,000 spawners with an escapement range of approximately 161,000 to 356,000 spawners, while S_{eq} was estimated at about 659,000 pink salmon (Appendix C4). The multiplicative error model was also significant (P=0.0005) and resulted in an estimate of S_{msy} of about 268,000 spawners with an escapement range of approximately 174,000 to 374,000 spawners, while S_{eq} was estimated at about 661,000 pink salmon (Appendix C4). No autocorrelation was found in either models' residuals.

The odd-year Eastern District pink salmon escapement data (1973-2001) had a contrast of 31.7, well above the recommended contrast level of 4.0 (CTC 1999; Appendix C1). Neither the additive nor multiplicative error model were significant ($P>0.05$).

Central and Chignik Bay Districts Aggregate

Stock Status

The current Central District pink salmon SEG of 119,500 was adopted in 1999 (Table 1; Appendix C5). Aerial survey estimates were summed from eight index streams to estimate total escapement on an annual basis. Estimated total escapements were generally below the goal during 1970s and through the mid 1980s, but escapements improved in the mid 1980s and have been achieved in nine of the past 10 seasons (Appendix C6 and C7). The peak escapement counts also were generally below the SEG during the 1970s and early 1980s and have been above the goal nine of the past 10 seasons (Appendices C6 and C7).

The current Chignik Bay District pink salmon SEG of 6,500 was adopted in 1999 (Table 1; Appendix C8). Aerial survey estimates were summed from three index streams to estimate total escapement on an annual basis. Estimated total escapements were generally below the goal during 1970s and through the mid 1980s, but have been above the goal during every year except two since 1988 and have greatly exceeded the goal in many years (Appendices C9 and C10). The peak escapement counts also were generally below the SEG during the 1970s and early to mid 1980s, but have been above the goal seven of the past 10 seasons (Appendices C9 and C10).

Spawner-Recruit Analysis

Ricker spawner-recruit models were fit to the combined Central and Chignik Bay Districts pink salmon data from brood years (odd and even years combined) 1972-2001 using additive and multiplicative error structures. There was a contrast of 126.4 in peak escapement levels, from both districts combined, well above the recommended contrast level of 4.0 (CTC 1999). The additive error model was significant (P=0.0005) and resulted in an estimate of S_{msy} of about 155,000 spawners with an escapement range of approximately 99,000 to 222,000 spawners, while S_{eq} was estimated at about 422,000 pink salmon (Appendix C11). The multiplicative error model was also significant (P=0.0011) and resulted in an estimate of S_{msy} of about 125,000 spawners with an escapement range of approximately 79,000 to 179,000 spawners, while S_{eq} was estimated at about 350,000 pink salmon (Appendix C11). No autocorrelation was found in either models' residuals.

The even-year combined Central and Chignik Districts' data (1972-2000) had a contrast of 126.4, well above the recommended contrast level of 4.0 (CTC 1999). The additive error model was significant (P=0.0004) and resulted in an estimate of S_{msy} of about 131,000 spawners with an escapement range of approximately 83,000 to 187,000 spawners, while S_{eq} was estimated at about 360,000 pink salmon (Appendix C11). The multiplicative error model was also significant (P<0.0001) and resulted in an estimate of S_{msy} of about 101,000 spawners with an escapement range of approximately 63,000 to 147,000 spawners, while S_{eq} was estimated at about 309,000 pink salmon (Appendix C11). No autocorrelation was found in either models' residuals.

The odd-year combined Central and Chignik Districts' data (1973-2001) had a contrast of 10.3, well above the recommended contrast level of 4.0 (CTC 1999). The multiplicative error model was not significant (P>0.05). The additive error model was significant (P=0.015), however the model was not significantly (P>0.1) different from a linear model. No estimate for S_{msy} was calculated.

Western and Perryville Districts Aggregate

Stock Status

The current Western District pink salmon SEG of 61,500 was adopted in 1999 (Table 1; Appendix C12). Aerial survey estimates were summed from six index streams to estimate total district-wide escapement on an annual basis. Estimated total escapements were generally above the goal from the 1970s through the present with a time period during the mid 1980s through early 1990s when the goals were frequently not achieved (Appendices C13 and C14). Goals were achieved in all of the past 10 years when measured by estimated total escapement. Peak escapement counts followed a similar trend as the estimated total escapement and have achieved the goal in nine of the past 10 seasons (Appendices C13 and C14).

The current Perryville pink salmon SEG of 104,000 was adopted in 1999 (Table 1; Appendix C15). Aerial survey estimates were used from nine index streams to estimate total district-wide escapement on an annual basis. Total escapement estimates were often below the goal during 1970s and through the early 1980s, but have been generally above the goal since 1984 (Appendix C16 and C17). During the past 10 years, the goal has been achieved seven times. The peak escapement counts also were generally below the SEG during the 1970s and early 1980s and have been above the goal six of the past 10 seasons (Appendices C16 and C17).

Spawner-Recruit Analysis

Ricker spawner-recruit models were fit to the pink salmon data from brood 1972-2001 years (odd and even years combined) from both Western and Perryville Districts (combined) using additive and multiplicative error structures. There was a contrast in the escapement data of 7.7, which was above the recommended contrast level of 4.0 (CTC 1999). The additive error Ricker model was not significant (P>0.05). The multiplicative error Ricker model was significant (P=0.0079) and resulted in an estimate of S_{msy} of about 194,000 spawners with an escapement range of approximately 123,000 to 277,000 spawners, while S_{eq} was estimated at about 531,000 pink salmon (Appendix C18). No autocorrelation was found in the Ricker model residuals.

The even-year pink salmon data (1972-2000) from both Western and Perryville Districts (combined) had a contrast of 5.5, which was above the recommended contrast level of 4.0 (CTC 1999). The additive error Ricker model was not significant (P>0.05). The multiplicative error Ricker model was significant (P=0.0466) and resulted in an estimate of S_{msy} of about 186,000 spawners with an escapement range of approximately 118,000 to 265,000 spawners, while S_{eq} was estimated at about 503,000 pink salmon (Appendix C18). No autocorrelation was found in the Ricker model residuals.

The odd-year pink salmon data (1973-2001) from both Western and Perryville Districts (combined) had a contrast of 7.4, which was above the recommended contrast level of 4.0 (CTC 1999). Neither the additive nor multiplicative error Ricker models were significant (P>0.05).

Entire Chignik Management Area

Stock Status

The sum of the current district-wide pink salmon SEGs in the CMA is approximately 779,500 fish. (Table 1; Appendix C19). Aerial survey escapement estimates from 49 systems were summed as an index for the total escapement in the CMA on an annual basis. The estimated total escapements generally fell below the SEG during the 1970s and 1980s, but have reached the goal in all years since 1988 (Appendices C20 and C21). During the time period when peak escapement estimates were available (1972-2003), they generally fell below the SEG during the 1970s and 1980s, but have reached or exceeded the SEG during most years since the late 1980s (Appendices C20 and C21).

Spawner-Recruit Analysis

Aggregate (all districts) Ricker spawner-recruit models were fit to the Chignik pink salmon data from brood years (odd and even years combined) 1972-2001 using additive and multiplicative error structures. For the combined even- and odd-year data, there was a contrast of 14.0, well above the recommended contrast level of 4.0 (CTC 1999). The additive error Ricker model was significant (P=0.0020) and resulted in an estimate of S_{msy} of about 622,000 spawners with an escapement range of approximately 398,000 to 881,000 spawners, while S_{eq} was estimated at about 1,600,000 pink salmon (Appendix C22). The multiplicative error Ricker model was also significant (P=0.0019) and resulted in an estimate of S_{msy} of about 732,000 spawners with an escapement range of approximately 474,000 to 1,023,000 spawners, while S_{eq} was estimated at about 1,800,000 pink salmon (Appendix C22). No autocorrelation was found in the residuals of either Ricker model.

The even-year aggregate data (1972-2000) had a contrast of 12.1, well above the recommended contrast level of 4.0 (CTC 1999). The additive error Ricker model was significant (P=0.038) and resulted in an estimate of S_{msy} of about 515,000 spawners with an escapement range of approximately 327,000 to 737,000 spawners, while S_{eq} was estimated at about 1,400,000 pink salmon (Appendix C22). The multiplicative error Ricker model was also significant (P=0.0011) and resulted in an estimate of S_{msy} of about 584,000 spawners with an escapement range of approximately 375,000 to 825,000 spawners, while S_{eq} was estimated at about 1,500,000 pink salmon (Appendix C22). No autocorrelation was found in either Ricker model residuals.

The odd-year aggregate data (1973-2001) had a contrast of 9.9, above the recommended contrast level of 4.0 (CTC 1999). The additive error Ricker model was significant (P=0.012) and resulted in an estimate of S_{msy} of about 838,000 spawners with an escapement range of approximately 541,000 to 1,177,000 spawners, while S_{eq} was estimated at about 2,100,000 pink salmon (Appendix C22). No autocorrelation was found in the residuals. The multiplicative error Ricker model was not significant (P>0.05).

Escapement Goal Recommendation

Due to the lack of information on the stock specific harvest in any given district and the current lack of a substantial directed pink salmon fishery in the CMA, the team agreed that an area-wide goal for pink salmon would be recommended. The aggregate data were considered of BEG quality because of the availability of area-wide harvest data and the known age class composition of pink salmon. Spawner-recruit models with additive error structure were used to estimate BEGs separately for odd and even years, resulting in recommended BEGs of 327,000 to 737,000 during even years and 541,000 to 1,177,000 during odd years for pink salmon in the CMA.

The area-wide BEGs can be further divided into MOs by district. The management objectives for a specific district were estimated by multiplying an average of the proportion of the total CMA peak escapement estimates that occurred in that district by the area-wide BEG. Odd-year proportions for management objectives were calculated from odd-year peak escapements during 1985 through 2003 while even-year MOs were calculated from even-year peak escapements during 1984 through 2002. The management objectives for individual districts in some cases did not sum exactly to the area-wide goal due to number rounding.

Eastern District

The average proportion of estimated peak escapement that occurred in the Eastern District during even years (1984-2002) was 0.57. Multiplying this proportion by the area-wide additive even-year spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an even-year MO for the Eastern District of a peak aerial survey count of 186,000 to 418,000 pink salmon. The average proportion of peak escapement estimates that occurred in the Eastern District during odd years (1985-2003) was 0.51. Multiplying this proportion by the area-wide spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an odd-year MO for the Eastern District of a peak aerial survey count of 276,000 to 601,000 pink salmon.

Central District

The average proportion of estimated peak escapement that occurred in the Central District during even years (1984-2002) was 0.19. Multiplying this proportion by the area-wide additive even-year spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an even-year MO for the Central District of a peak aerial survey count of 62,000 to 140,000 pink salmon. The average proportion of peak escapement estimates that occurred in the Central District during odd years (1985-2003) was 0.16. Multiplying this proportion by the area-wide spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an odd-year MO for the Central District of a peak aerial survey count of 87,000 to 190,000 pink salmon.

Chignik Bay District

The average proportion of estimated peak escapement that occurred in the Chignik Bay District during even years (1984-2002) was 0.01. Multiplying this proportion by the area-wide additive even-year spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an even-year MO for the Chignik Bay District of a peak aerial survey count of 3,000 to 7,000 pink salmon. The average proportion of peak escapement estimates that occurred in the Chignik Bay District during odd years (1985-2003) was 0.01. Multiplying this proportion by the area-wide spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an odd-year MO for the Chignik Bay District of a peak aerial survey count of 8,000 to 17,000 pink salmon.

Western District

The average proportion of estimated peak escapement that occurred in the Western District during even years (1984-2002) was 0.09. Multiplying this proportion by the area-wide additive even-year spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an even-year MO for the Western District of a peak aerial survey count of 31,000 to 69,000 pink salmon. The average proportion of peak escapement estimates that occurred in the Western District during odd years (1985-2003) was 0.12. Multiplying this proportion by the area-wide spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an odd-year MO for the Western District of a peak aerial survey count of 65,000 to 141,000 pink salmon.

Perryville District

The average proportion of estimated peak escapement that occurred in the Perryville District during even years (1984-2002) was 0.14. Multiplying this proportion by the area-wide additive even-year spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an even-year MO for the Central District of a peak aerial survey count of 45,000 to 102,000 pink salmon. The average proportion of peak escapement estimates that occurred in the Perryville District during odd years (1985-2003) was 0.19. Multiplying this proportion by the area-wide spawner-recruit Ricker model estimates of 90% of S_{msy} resulted in an odd-year MO for the Perryville District of a peak aerial survey count of 105,000 to 228,000 pink salmon.

CHUM SALMON

Eastern District

Stock Status

The current Eastern District chum salmon SEG of 93,700 was adopted in 1999 (Table 1; Appendix D1). Aerial survey estimates were summed from 20 index streams to estimate district-wide total escapement on an annual basis. Estimated total escapements fell above and below the goal with similar frequency during the 1970s and early 1980s, but have generally been above the goal since 1988 (Appendices D2 and D3). Estimated total escapements have reached the goal during all of the past 10 years. When escapement was measured using peak counts only, the escapements generally fell below the goal throughout the time period that peak escapements were available; peak escapement estimates have fallen below the goals in six of the past 10 years (Appendices D2 and D3).

Percentile Approach

Since Eastern District chum salmon escapements were normally distributed, the risk analysis was considered inappropriate because the SEG estimates were unrealistically restrictive (greater than the mean of past escapements) for even high percent decreases in the mean (greater than 95% decrease). The goal was estimated according to the percentile algorithm using peak aerial survey estimates from 1972-2003. High contrast in the escapement estimates and low exploitation of this aggregate resulted in selection of the 15th and 75th percentiles to estimate the goal range (Bue and Hasbrouck 2001). Using the 15th and 75th percentiles resulted in a peak escapement goal range of 25,600 to 103,000.

Central District

Stock Status

The current Central District chum salmon SEG of 39,500 was adopted in 1999 (Table 1; Appendix D4). Aerial survey estimates were summed from six index streams to estimate district-wide total escapement on an annual basis. Total estimated escapement fell below the goal more frequently than above below the goal throughout the time that this district has been observed (Appendices D5 and D6). Escapement estimates have met the goal during four of the past 10 years. When escapement was measured using peak counts only, escapements were very low compared to the goal; escapements have reached the goal only two times since 1972 (Appendices D5 and D6).

Risk Analysis

A risk analysis for Central District chum salmon was performed using annual peak escapement data from 1972 through 2003. The peak escapement data were not auto correlated. The percent difference between the mean and minimum escapement was 94%. An escapement SEG of 5,900 resulted in a 2.6% risk of an unwarranted concern, with a 2.6% estimated risk that a drop in mean escapement of 94% would not be detected (Appendix D7).

Percentile Approach

An escapement goal range was estimated for the Central District according to the percentile algorithm using peak aerial survey estimates from 1972 through 2003. High contrast in the escapement estimates and low exploitation of this aggregate resulted in selection of the 15th and 75th percentiles to estimate the goal range (Bue and Hasbrouck 2001). Using the 15th and 75th percentiles resulted in a peak escapement goal range of 3,300 to 17,800.

Chignik Bay District

Stock Status

The current Chignik Bay District chum salmon SEG of 2,000 was adopted in 1999 (Table 1; Appendix D8). Aerial survey estimates were summed from three index streams to estimate district-wide total escapement on an annual basis. This area was surveyed sporadically through the mid 1980s and escapement estimates frequently fell below the SEG. Since the mid 1980s, this area was surveyed more regularly; however, escapement estimates still often fell below the goal (Appendices D9 and D10). However, escapement estimates have been above the goal in seven of the past 10 years. Peak count escapement estimates have generally been below the goal during the entire time that records are available; escapements were only estimated to have made the goal once in the past 10 years (Appendices D9 and D10).

Due to the sporadic surveys and lack of any further data, no analysis was performed to estimate an SEG for this area.

Western District

Stock Status

The current Western District chum salmon SEG of 12,500 was adopted in 1999 (Table 1; Appendix D11). Aerial survey estimates were summed from six index streams to estimate district-wide total escapement on an annual basis. Total estimated escapement exceeded the SEG during most years during the period that records are available and exceeded the goal in all of the past 10 seasons (Appendices D12 and D13). When escapement was measured using peak counts only, the escapements generally exceeded the goal during the 1970s and mid 1980s, but generally fell below the goal since the mid 1980s. Peak escapement counts were below the goal in eight of the past 10 years (Appendices D12 and D13).

Risk Analysis

A risk analysis for Western District chum salmon was performed using annual peak escapement data from 1972-2003. The peak escapement data were not auto correlated. The percent difference between the mean and minimum escapement was 84%. An escapement SEG of 9,600 resulted in a 2.6% risk of an unwarranted concern, with a 2.6% estimated risk that a drop in mean escapement of 84% would not be detected (Appendix D14).

Percentile Approach

An escapement goal range was estimated for the Western District according to the percentile algorithm using peak aerial survey estimates from 1973-2003. High contrast in the escapement estimates and low exploitation of this aggregate resulted in selection of the 15th and 75th percentiles to estimate the goal range (Bue and Hasbrouck 2001). Using the 15th and 75th percentiles resulted in a peak escapement goal range of 5,800 to 29,700.

Perryville District

Stock Status

The current Perryville District chum salmon SEG of 59,000 was adopted in 1999 (Table 1; Appendix D15). Aerial survey estimates were summed from seven index streams to estimate district-wide total escapement on an annual basis. Total escapement was estimated to be below the SEG during the most years in the 1970s and 1980s, but has generally met the goal since the early 1990s (Appendices D16 and D17). Escapements achieved the goal in eight of the past 10 years. Peak escapement counts follow a similar trend with escapement estimates falling below the goal until the early 1990s; however during the most recent five seasons, the goal has not been met (Appendices D16 and D17). During the past 10 years the goal has been met five times.

Risk Analysis

A risk analysis for Perryville District chum salmon was performed using annual peak escapement data from 1972 through 2003. The peak escapement data were not auto correlated. The percent difference between the mean and minimum escapement was 88%. An escapement SEG of 14,800 resulted in an 8.4% risk of an unwarranted concern, with an 8.4% estimated risk that a drop in mean escapement of 88% would not be detected (Appendix D18).

Percentile Approach

An escapement goal range was estimated for the Perryville District according to the percentile algorithm using peak aerial survey estimates from 1973 through 2003. High contrast in the escapement estimates and low exploitation of this aggregate resulted in selection of the 15th and 75th percentiles to estimate the goal range (Bue and Hasbrouck 2001). Using the 15th and 75th percentiles resulted in a peak escapement goal range of 6,000 to 39,400.

Entire Chignik Management Area

Stock Status

The current chum salmon SEG for the entire CMA is 206,700 fish. (Table 1; Appendix D19). Aerial survey escapement estimates from 42 systems were used as an index for the total escapement in the CMA. The estimated total escapements generally fell below the SEG during the 1980s, but have reached the goal in all years since 1990 (Appendices D20 and D21). During the time period that peak escapements were available (1973-2003), they generally fell below the SEG (Appendices D20 and D21).

Risk Analysis

A risk analysis was performed to estimate an area-wide chum salmon SEG using annual peak escapement data from 1972 through 2003. The peak escapement data were not auto correlated. The percent difference between the mean and minimum escapement was 78%. An escapement SEG of 95,900 resulted in a 5.6% risk of an unwarranted concern, with a 5.6% estimated risk that a drop in mean escapement of 78% would not be detected (Appendix D22).

An escapement SEG of 50,400 resulted in a 0.1% risk of an unwarranted concern, with a 0.1% estimated risk that a drop in mean escapement of 95% would not be detected (Appendix D22).

The escapement was below the SEG of 95,900 in three consecutive years only three times from 1972-2003, and only one time from 1976 to 2003. The escapement was below the SEG of 50,400 in three consecutive years only one time from 1972 to 2003, and only one time from 1976 to 2003.

Percentile Approach

An escapement goal range was estimated for the entire CMA according to the percentile algorithm using aerial survey estimates from 1973 through 2003. High contrast in the escapement estimates and low exploitation of this aggregate resulted in selection of the 15th and 75th percentiles to estimate the goal range (Bue and Hasbrouck 2001). Using the 15th and 75th percentiles resulted in a peak escapement goal range of 74,200 to 187,000.

Escapement Goal Recommendation

The CMA has been managed primarily on sockeye salmon escapement levels and secondarily on pink salmon escapement levels. There are currently no commercial fisheries consistently directed on chum salmon in this area and aerial survey effort has been limited. The team agreed that, because the chum salmon aerial survey data was not of BEG quality, primarily due to lack of age information, and the fact that directed fisheries have rarely occurred on chum salmon, an area-wide SEG estimated by risk analysis would be recommended. Using the 95% decrease in the mean results in an SEG of 50,400 chum salmon. The SEG was divided into MOs for each district. The management objective for a specific district was estimated by multiplying the average proportion of the total CMA peak escapement estimates that occurred in that district by the area-wide SEG. Proportions for MOs were calculated from peak escapements during 1984 through 2003. The individual district objectives may not sum to equal the area-wide goal due to rounding.

Eastern District

The average proportion of estimated peak escapement that occurred in the Eastern District during 1984 through 2003 was 0.50. Multiplying this proportion by the area-wide SEG resulted in a MO for the Eastern District of a peak aerial survey count of 25,200 chum salmon.

Central District

The average proportion of estimated peak escapement that occurred in the Central District during 1984 through 2003 was 0.13. Multiplying this proportion by the area-wide SEG resulted in a MO for the Central District of a peak aerial survey count of 6,700 chum salmon.

Chignik Bay District

The average proportion of estimated peak escapement that occurred in the Chignik Bay District during 1984 through 2003 was <0.01. Multiplying this proportion by the area-wide SEG resulted in a MO for the Chignik Bay District of a peak aerial survey count of 200 chum salmon.

Western District

The average proportion of estimated peak escapement that occurred in the Western District during 1984 through 2003 was 0.11. Multiplying this proportion by the area-wide SEG resulted in a MO for the Western District of a peak aerial survey count of 5,400 chum salmon.

Perryville District

The average proportion of estimated peak escapement that occurred in the Perryville District during 1984 through 2003 was 0.25. Multiplying this proportion by the area-wide SEG resulted in a MO for the Perryville District of a peak aerial survey count of 12,800 chum salmon.

DISCUSSION

Escapement goals should ideally be founded on ecological theory, principles of sustained yield, and empirical observations (Ricker 1954). Establishing prudent escapement goals is an evolving process, because each year provides more data, and the methods to determine such goals become more standardized and well documented. The SSFP and EGP are important steps in this evolution. The department formed an Escapement Goal Policy Implementation Team (EGPIT) in 2001 to provide recommendations on the estimation of escapement goals. EGPIT and other such groups will hopefully provide a more robust and efficient framework to estimate escapement goals, especially SEGs and Sustainable Escapement Targets (SETs), relative to available resources.

The methodologies used in this escapement goal evaluation were determined by the quality of the available data. Determining the contrast of the available escapement data was germane to the significance of spawner-recruit relationships. Low data contrast generally indicates that there is an insufficient range of data to describe the spawner-recruit relationship. In addition to poor data contrast, the availability stock specific data can also be problematic. In the CMA, stock specific catch data were available only for Chignik River Chinook and sockeye salmon. Further, because of the geographic location of the Chignik Management Area and the large number of stocks present throughout the commercial fishing season, it is likely that stock specific data will never be available for pink and chum salmon. Aerial survey escapement estimates for any species will always be relatively inaccurate and imprecise due to weather conditions, differences between observers, and logistical limitations. Therefore, while these estimates are valuable for assessing large-scale changes in production, it will probably never be possible to reliably estimate stock-specific production parameters from these data.

While it was not possible to calculate stock specific pink salmon harvest estimates, the team assessed aggregate spawner-recruit relationships, in an attempt to develop stock-aggregate BEGs. This technique provided the ability to estimate total production for the aggregate, which then allowed the estimation of S_{msy}. Obviously, this precluded the estimation of S_{msy} for individual systems, but did incorporate district-wide and area-wide harvest and escapement information that likely provided more accurate stock aggregate specific run data.

Because the percentile algorithm worked well in a previous escapement goal review of Upper Cook Inlet (Bue and Hasbrouck 2001), the team agreed that this approach should be attempted for chum systems which did not have BEG-quality data. However, CMA pink and chum salmon escapements have often been the result of management actions rather than stock productivity. In addition, the percentile method is probably not desirable for CMA stocks because of the inability to apportion harvests to stock-of-origin, despite greater data contrast.

The team concluded that the risk analysis approach would be appropriate for CMA chum salmon stocks since they have rarely had any fishery directed on them and will not have a directed fishery in the foreseeable future. The risk analysis provides an SEG that, if not met for three consecutive years, should raise concern among managers thereby reducing management emphasis on chum salmon stocks while still monitoring them for sustainability.

To corroborate spawner-recruit relationships, limnology data are often used to estimate sockeye salmon production for comparison. The utility of these data was limited by the lack of appropriate models to assess sockeye salmon production in “non-typical,” shallow lakes. The currently available sockeye salmon production models were based on limnological conditions in “typical” sockeye salmon lakes that are moderately sized, deep, and thermally stratified. In the CMA, Black Lake is unique in that it is shallow and continually mixed by persistent winds. This type of lake is generally much more productive in actuality than is estimated by the standard production models. Regardless, limnology data were used to gain insight into the potential production level of CMA sockeye salmon systems.

This comprehensive review of the 13 existing salmon escapement goals in the CMA resulted in recommendations to change 10 goals (five pink and five chum salmon), maintain the current numerical goal ranges for the two sockeye salmon stocks but reclassify them from BEGs to SEGs, and leave the one Chinook BEG range unchanged. The 10 goal changes included establishing two area-wide aggregate BEGs (odd- and even-years) replacing five district-wide pink salmon SEGs and establishing one area-wide SEG replacing five district-wide chum salmon SEGs.

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TABLES AND FIGURES

Table 1.–Current and recommended Chinook and sockeye salmon escapement goals by spawning system, and pink and chum salmon escapement goals by district, in the Chignik Management Area.

	Current Escapement Goal				Year	Recommended Escapement Goal				
System	Lower	Point	Upper	Type	Adopted	Lower	Point	Upper	Type [a]	Action
CHINOOK										
Chignik River	1,300	1,695	2,700	BEG	2002	1,300	1,695	2,700	BEG	none
SOCKEYE										
Chignik early run	350,000	375,000	400,000	BEG	1968	350,000	375,000	400,000	SEG	change
Chignik late run	200,000	225,000	250,000	BEG	1968	200,000	225,000	250,000	SEG	change
PINK										
Eastern District - even years		488,000		SEG	1999	186,000		418,000	MO	change
Eastern District - odd years		488,000		SEG	1999	276,000		601,000	MO	change
Central District - even years		119,500		SEG	1999	62,000		140,000	MO	change
Central District - odd years		119,500		SEG	1999	87,000		190,000	MO	change
Chignik Bay District - even years		6,500		SEG	1999	3,000		7,000	MO	change
Chignik Bay District - odd years		6,500		SEG	1999	8,000		17,000	MO	change
Western District - even years		61,500		SEG	1999	31,000		69,000	MO	change
Western District - odd years		61,500		SEG	1999	65,000		141,000	MO	change
Perryville District - even years		104,000		SEG	1999	45,000		102,000	MO	change
Perryville District - odd years		104,000		SEG	1999	105,000		228,000	MO	change
Entire Chignik Area - even years		779,500		SEG	1999	327,000	515,000	737,000	BEG	change
Entire Chignik Area - odd years		779,500		SEG	1999	541,000	838,000	1,177,000	BEG	change
CHUM										
Eastern District		93,700		SEG	1999	25,200			MO	change
Central District		39,500		SEG	1999	6,700			MO	change
Chignik Bay District		2,000		SEG	1999	200			MO	change
Western District		12,500		SEG	1999	5,400			MO	change
Perryville District		59,000		SEG	1999	12,800			MO	change
Entire Chignik Area		206,700		SEG	1999	50,400			SEG	change

[a] MO=Management objectives. The management objectives for each district may not add exactly to the escapement goal for the entire area due to rounding.

Table 2.–General criteria used to assess quality of data in estimating CMA salmon escapement goals.

Data Quality	**Criteria**
Excellent	Escapement, harvest, and age all estimated with relatively good accuracy and precision (i.e., escapement estimated by a weir or hydroacoustics, harvest estimated by Statewide Harvest Survey or Fish Tickets with harvest apportioned to stock of origin); escapement and return estimates can be derived for a sufficient time series to construct a brood table and estimate S_{msy}.
Good	Escapement, harvest, and age estimated with reasonably good accuracy and/or precision (i.e., escapement estimated by capture-recapture experiment or multiple foot/aerial surveys; harvest estimated by Statewide Harvest Survey or Fish Tickets); no age data or data of questionable accuracy and/or precision; data may allow construction of brood table; data time series relatively short to accurately estimate S_{msy}.
Fair	Escapement estimated or indexed and harvest estimated with reasonably good accuracy but precision lacking for one if not both; no age data; data insufficient to estimate total return and construct brood table.
Poor	Escapement indexed (i.e., single foot/aerial survey) such that the index provides only a fairly reliable measure of escapement; no harvest and age data.

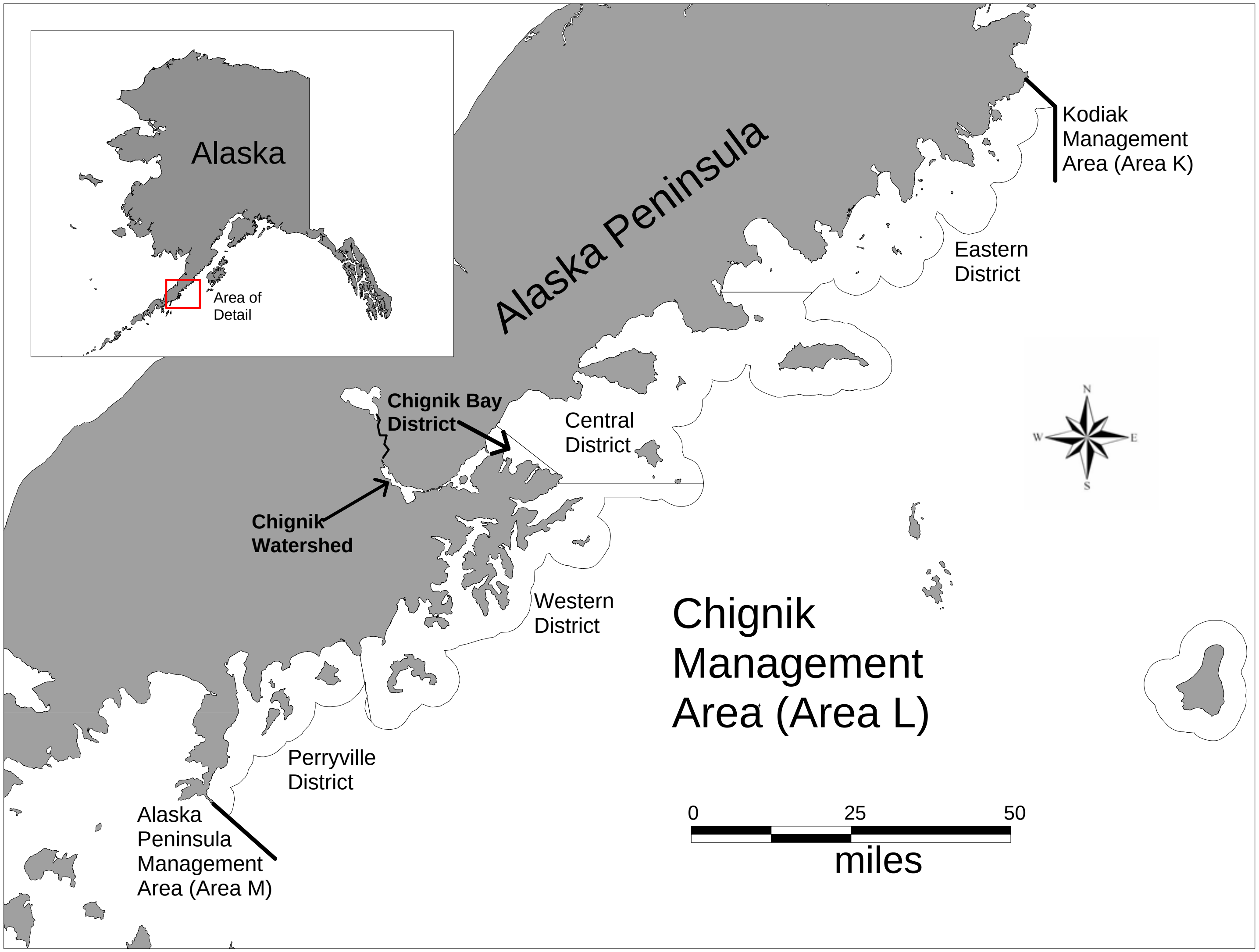


Figure 1.–The Chignik Management Area with the Eastern, Central, Chignik Bay, Western, and Perryville Districts depicted.

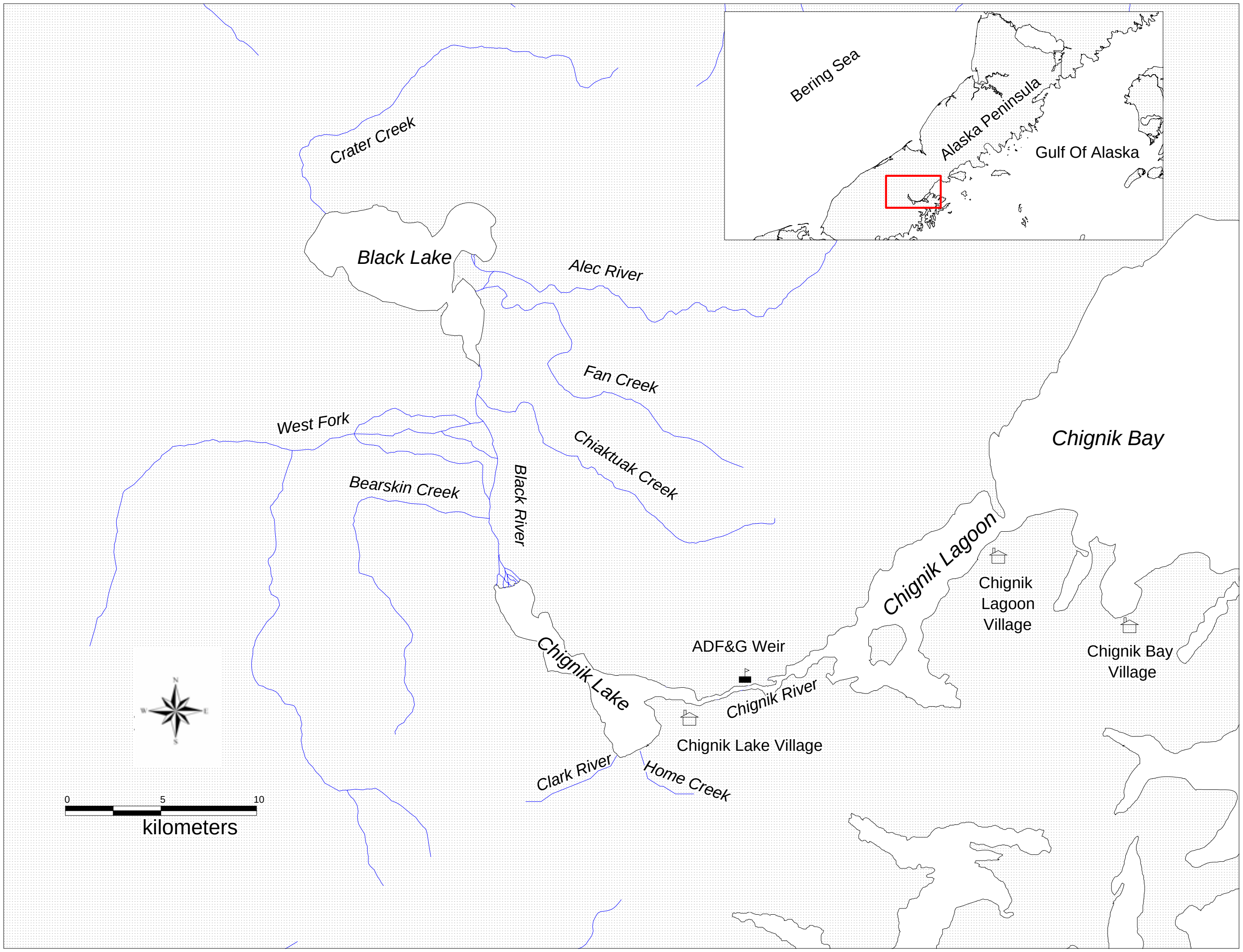


Figure 2.–The Chignik River watershed including Black and Chignik Lakes, Black and Chignik Rivers, and the Chignik Lagoon.

APPENDIX A: CHINOOK SALMON ESCAPEMENT GOAL REVIEW

Appendix A1.-Description of stock and escapement goals for Chignik River Chinook salmon.

System: Chignik River

Species: Chinook salmon

Description of stock and escapement goals.

Regulatory area:	Chignik Bay District, Chignik Lagoon
Management division:	Sport and Commercial Fisheries
Primary fishery:	Sport, Commercial, and Subsistence
Previous escapement goal:	BEG: 1,300-2,700 (2002)
Recommended escapement goal:	SEG: 1,300-2,700
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Weir counts, 1978 to present
Data summary:	
Data quality:	Good escapement, harvest and age data.
Data type:	Weir estimates, harvests, age compositions
Contrast:	9.3
Methodology:	Used Ricker model estimate of S_{msy} (0.8, 1.6)
Autocorrelation:	None.
Comments:	Although recreational harvests were based on two years of surveys only, it was assumed that recreational harvest was not significantly greater than 200 fish per year. Goal represents total spawner abundance. BEGs have been met the past five years.

Appendix A2.-Data available for analysis of Chinook salmon escapement goal by return year, Chignik River.

System: Chignik River

Species: Chinook salmon

Data available for analysis of escapement goals.

Return Year	Commercial Harvest[a] +	Subsistence Harvest +	Inriver Return[b] =	Total Return	Recreational Harvest[c]	Escapement[d]
1978	1,386	50	1,197	2,633	207	990
1979	856	14	1,050	1,920	207	843
1980	929	6	876	1,811	207	669
1981	2,006	0	1,603	3,609	207	1,396
1982	3,269	3	2,412	5,684	207	2,205
1983	3,560	0	1,943	5,503	207	1,736
1984	3,696	23	5,548	9,267	207	5,341
1985	1,810	1	3,144	4,955	207	2,937
1986	2,592	4	3,612	6,208	207	3,405
1987	1,931	10	2,624	4,565	207	2,417
1988	4,331	9	4,868	9,208	233	4,635
1989	3,532	24	3,316	6,872	181	3,135
1990	3,719	103	4,364	8,186	207	4,157
1991	1,993	42	4,545	6,580	207	4,338
1992	3,179	55	3,806	7,040	207	3,599
1993	5,240	122	1,946	7,308	207	1,739
1994	1,804	165	3,016	4,985	207	2,809
1995	3,008	98	4,288	7,394	207	4,081
1996	1,579	48	3,485	5,112	207	3,278
1997	1,289	28	3,824	5,141	207	3,617
1998	1,700	91	3,075	4,866	207	2,868
1999	2,101	243	3,728	6,072	207	3,521
2000	581	163	4,285	5,029	207	4,078
2001	1,142	171	2,992	4,305	207	2,785
2002	920	74	3,028	4,022	207	2,821
2003	2,834	0	6,412	9,246	207	6,205

[a] Commercial harvest is the commercial harvest of Chinook salmon from the Chignik Lagoon statistical area (statistical area 271-10).

[b] Inriver return is the estimated return to the weir.

[c] Recreational harvest in 1988 and 1989 was estimated from an onsite creel survey (Schwarz 1990). Recreational harvest in the remaining years is the average of 1988 and 1989.

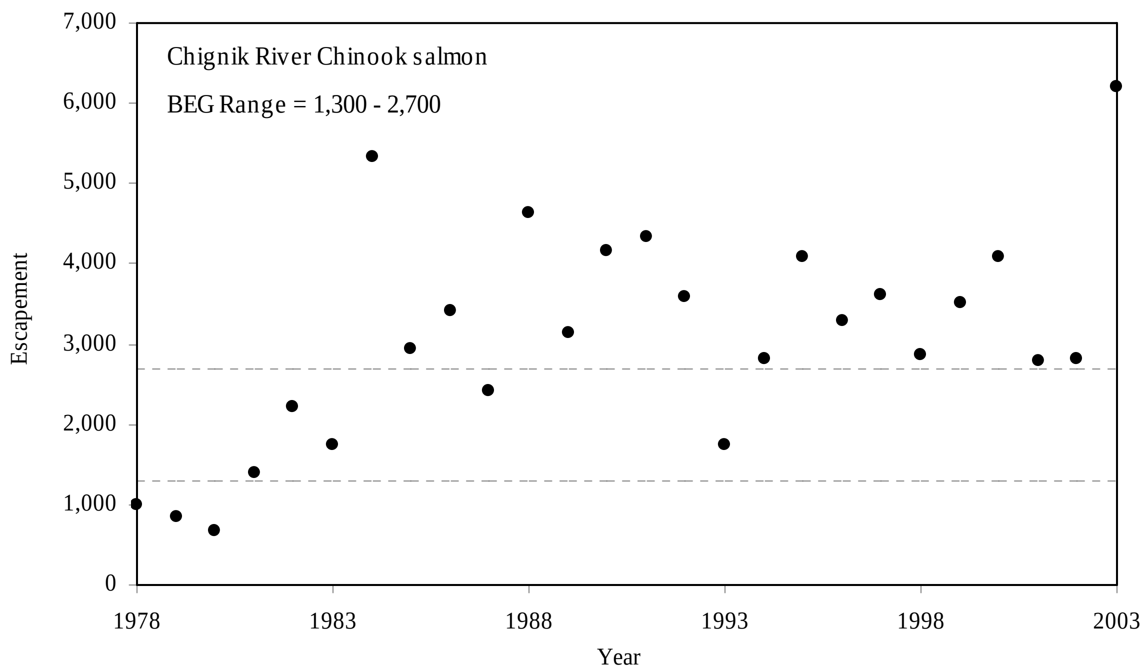
[d] Escapement is inriver return minus recreational harvest.

Appendix A3.-Estimated escapement of Chinook salmon in the Chignik River with existing escapement goals depicted.

System: **Chignik River**

Species: **Chinook salmon**

Data available for analysis of escapement goals.



Appendix A4.-Data available for analysis of Chinook salmon escapement goal by brood year, Chignik River.

System: **Chignik River**

Species **Chinook salmon**

Data available for analysis of escapement goals.

Brood Year	Escapement	Age 3 Return +	Age 4 Return +	Age 5 Return +	Age 6 Return +	Age 7 Return =	Total Return	Yield[a]	Return/ Spawner
1978	990	84	877	1,880	4,023	231	7,095	6,105	7.17
1979	843	133	849	3,165	2,151	289	6,588	5,745	7.81
1980	669	129	1,430	1,692	2,695	213	6,159	5,490	9.21
1981	1,396	217	765	2,120	1,982	429	5,513	4,117	3.95
1982	2,205	116	958	1,559	3,998	320	6,951	4,746	3.15
1983	1,736	145	704	3,145	2,983	382	7,360	5,624	4.24
1984	5,341	107	1,421	2,347	3,554	307	7,735	2,394	1.45
1985	2,937	215	1,060	2,796	2,857	328	7,256	4,319	2.47
1986	3,405	161	1,263	2,247	3,056	289	7,016	3,611	2.06
1987	2,417	191	1,015	2,405	3,869	144	7,623	5,206	3.15
1988	4,635	154	1,086	2,054	1,900	579	5,774	1,139	1.25
1989	3,135	165	1,007	2,475	4,677	682	9,005	5,870	2.87
1990	4,157	89	322	1,070	2,726	0	4,207	50	1.01
1991	4,338	144	890	1,266	2,196	0	4,496	158	1.04
1992	3,599	178	438	1,797	1,448	213	4,073	474	1.13
1993	1,739	0	1,098	2,224	1,791	287	5,400	3,661	3.11
1994	2,809	50	955	2,040	1,940	177	5,162	2,353	1.84
1995	4,081	239	1,822	2,083	1,425	188	5,756	1,675	1.41
1996	3,278	206	575	1,033	1,746	431	3,992	714	1.22
1997[b]	3,617	144	784	1,374	4,014				
1998[b]	2,868	891	621	3,158					
1999[b]	3,521	94	1,427						
2000[b]	4,078	216							
2001[b]	2,785								
2002[b]	2,821								
2003[b]	6,205								

a Yield is total return minus escapement.

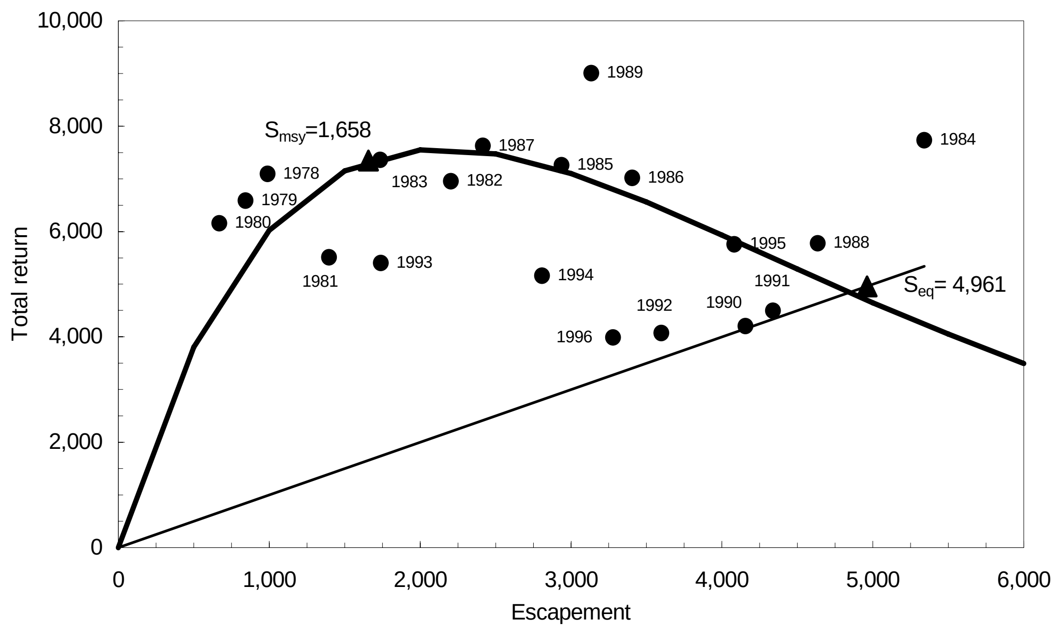
b Complete age data not yet available for all components of the run this year.

Appendix A5.-Fitted Ricker curve, line of replacement, and actual data for Chinook salmon, Chignik River.

System: Chignik River

Species: Chinook salmon

Ricker stock – recruitment relationship, 1978-1996 brood years. The solid curved line represents the multiplicative error Ricker curve and the solid straight line represents replacement.



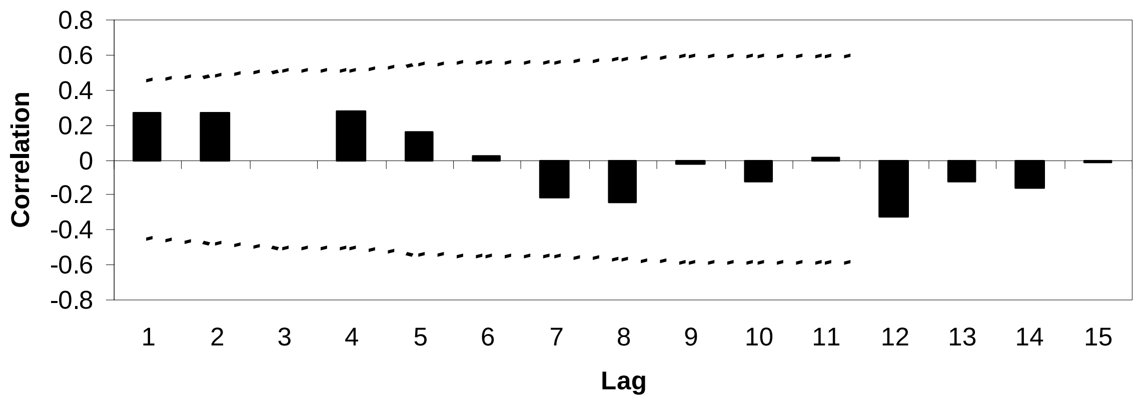
Appendix A6.-Autocorrelation function (ACF) and partial autocorrelation function (PACF) of the residuals of the Ricker model for Chinook salmon, Chignik River.

System: **Chignik River**

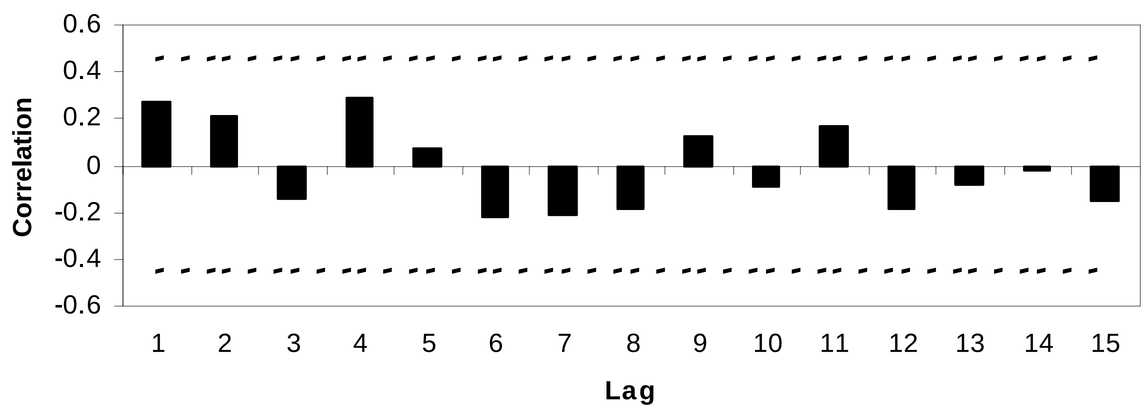
Species: **Chinook salmon**

Autocorrelation function (ACF) and partial autocorrelation function (PACF) of the residuals of the Ricker model.

ACF - Chignik River chinook salmon



PACF - Chignik River chinook salmon



APPENDIX B: SOCKEYE SALMON ESCAPEMENT GOAL REVIEW

Appendix B1.–Description of stocks and escapement goals for Chignik River watershed sockeye salmon.

System: **Chignik River watershed**

Species: **sockeye salmon**

Description of stock and escapement goals.

Regulatory area:	Chignik Management Area
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	BEG: Early run: 350,000 to 400,000 (1968)
	BEG: Late run: 200,000 to 250,000 (1968)
Recommended escapement goal:	SEG: Early run: 350,000 to 400,000
	SEG: Late run: 200,000 to 250,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Weir counts 1922, 1923, 1925 – 1930, 1932, 1933, 1935 – 1937, 1939, 1949 – 1950, 1952 to present
Data summary:	
Data quality:	Fair to Good
Data type:	Weir counts intermittently for 16 of the 29 years between 1922 and 1951 and from 1952 to present. Escapement age data available from 1955 to 1960, 1962 to 1969, and 1980 to 2003. Stock specific harvest information was available for 1962 to 1969 and 1980 to 2003.

-Continued-

Contrast:	1952-1997 : 3.5 (total run), 22.5 (early run), 4.6 (late run)
	1965-1997 : 2.2 (total run), 2.5 (early run), 4.6 (late run)
	1977-1997 : 1.6 (total run), 2.1 (early run), 2.8 (late run)
	1980-1997 : 1.6 (total run), 2.1 (early run), 2.8 (late run)
Methodology:	Ricker spawner-recruit model, Yield analysis, Euphotic volume analysis, Smolt biomass as a function of zooplankton biomass
Autocorrelation:	1952-1997: AR(3), but residuals non-stationary
Comments:	Ricker models were not significant for the current early-run sockeye salmon escapement goals. Yield analyses for the early run suggested escapement goal ranges similar to the current BEGs. A late-run Ricker model was significant for data between 1965 to 1997. A late-run Ricker model was also significant for data between 1952 to 1997, however regression diagnostics indicated a leverage issue and nonstationary auto correlated error. Limnological and smolt data from 1991 and 2000 to 2003. EV models indicated lowering the BEGs for both runs. Zooplankton models indicated no change to the early-run BEG and increasing the late-run BEG. Current goals recommended as a SEG.

Appendix B2.–Escapement data available for analysis for Chignik sockeye salmon.

System: Chignik River watershed

Species: sockeye salmon

Data available for analysis of escapement goals.

	Estimated Escapement		
Year	Early Run	Late Run	Total
1952	34,155	260,540	294,695
1953	168,375	221,408	389,783
1954	184,953	277,912	462,865
1955	256,757	201,409	458,166
1956	289,096	483,024	772,120
1957	192,479	328,779	521,258
1958	120,862	212,594	333,456
1959	112,226	308,645	420,871
1960	251,567	357,230	608,797
1961	140,714	254,970	395,684
1962	167,602	324,860	492,462
1963	332,536	200,314	532,850
1964	137,073	166,625	303,698
1965	307,192	163,151	470,343
1966	383,545	183,525	567,070
1967	328,000	189,000	517,000
1968	342,343	244,836	587,179
1969	366,589	132,055	498,644
1970	536,257	119,952	656,209
1971	671,668	232,501	904,169
1972	326,320	231,270	557,590
1973	538,462	243,729	782,191
1974	364,603	313,343	677,946
1975	319,890	257,508	577,398
1976	548,953	281,810	830,763
1977	364,557	328,916	693,473

-Continued-

System: **Chignik River watershed**

Species: **sockeye salmon**

Data available for analysis of escapement goals.

	Estimated Escapement		
Year	Early Run	Late Run	Total
1978	419,732	262,815	682,547
1979	491,467	246,349	737,816
1980	369,580	294,481	664,061
1981	570,210	261,239	831,449
1982	616,117	305,193	921,310
1983	426,178	428,034	854,212
1984	597,713	267,861	865,574
1985	373,040	372,798	745,838
1986	557,772	215,547	773,319
1987	589,299	214,444	803,743
1988	420,580	255,177	675,757
1989	384,001	557,174	941,175
1990	434,550	335,860	770,410
1991	662,660	377,438	1,040,098
1992	360,681	403,755	764,436
1993	364,261	333,116	697,377
1994	769,465	197,444	966,909
1995	366,495	373,425	739,920
1996	464,748	284,389	749,137
1997	396,668	378,950	775,618
1998	410,659	290,469	701,128
1999	457,424	258,542	715,966
2000	536,141	269,084	805,225
2001	744,013	392,905	1,136,918
2002	380,701	344,519	725,220
2003	350,004	334,141	684,145

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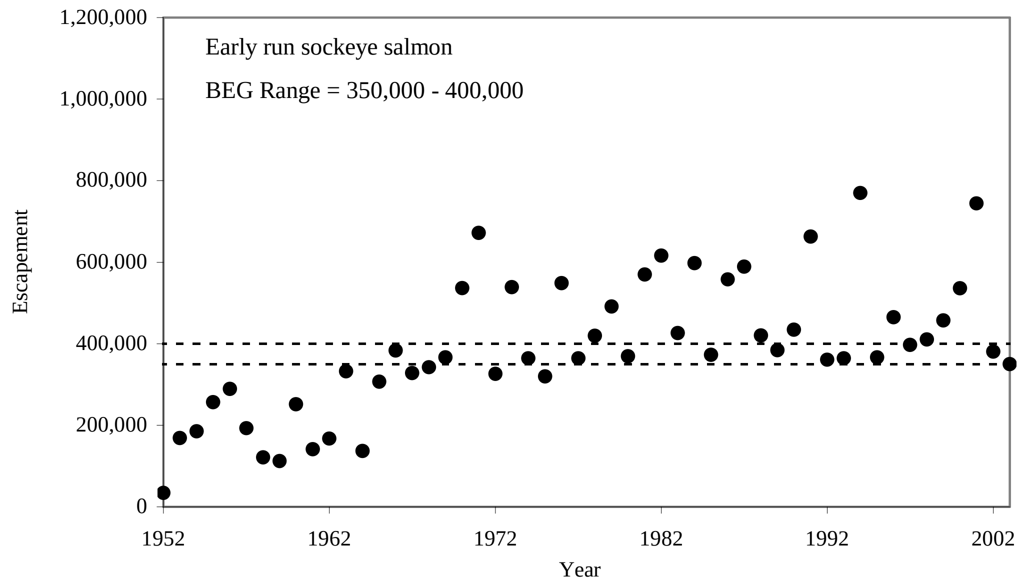
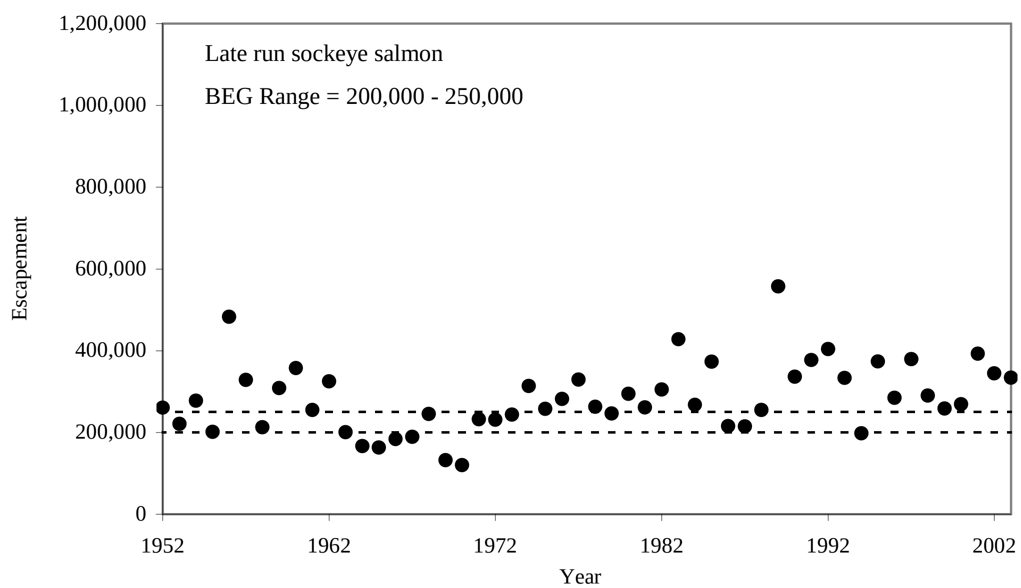
System: **Chignik River watershed**

Species: **sockeye salmon**

Observed escapement by year and current BEG range (dashed lines).





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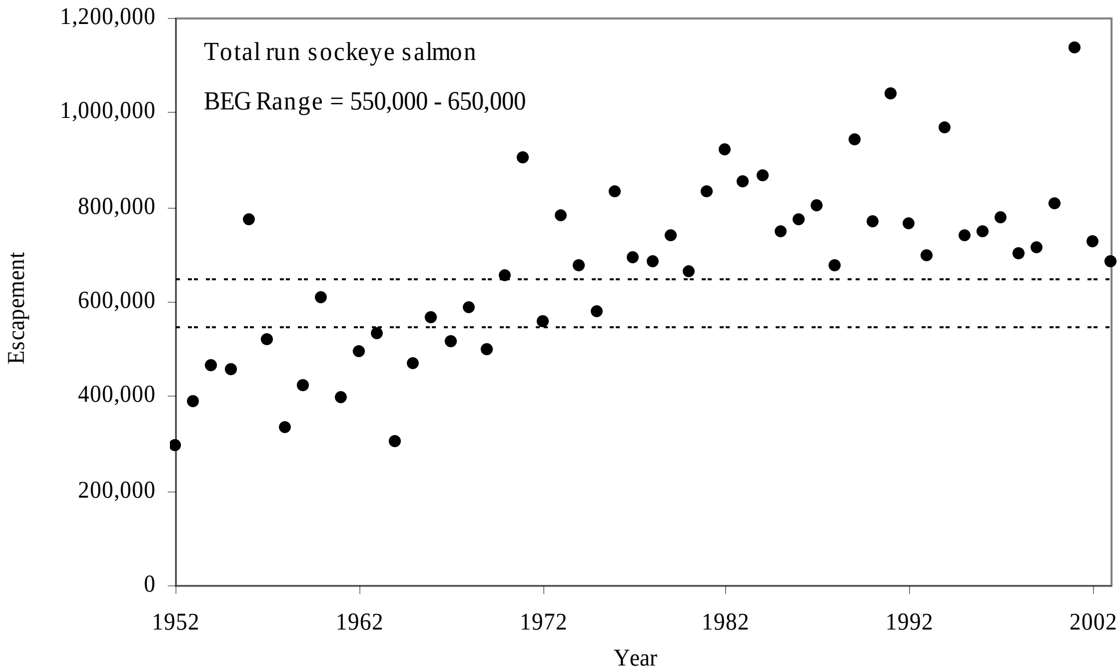
Appendix B2.–Page 4 of 4.

System: **Chignik River watershed**

Species: **sockeye salmon**

Observed escapement by year and current BEG range (dashed lines).



Appendix B3.–Chignik sockeye salmon early run brood table.

System: **Black Lake (early run)**

Species: **sockeye salmon**

Data available for analysis of escapement goals.

Chignik River Watershed Early Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1952	34,155	0	0	0	4,390	0	137,957	3,423	208	81,691	0	639	2,512	0	230,820	6.76
1953	168,375	0	0	0	1,024	32	154,589	17,848	1,625	180,887	252	0	1,350	0	357,607	2.12
1954	184,953	0	143	0	6,468	0	50,272	10,720	515	72,973	9	312	1,009	0	142,421	0.77
1955	256,757	0	783	0	30,302	0	430,793	3,476	339	88,693	109	0	0	0	554,495	2.16
1956	289,096	0	17	0	16,499	0	81,569	14,910	9	90,001	0	196	4,967	0	208,168	0.72
1957	192,479	0	0	0	6,559	161	117,979	10,507	52	210,686	3,641	21	906	0	350,512	1.82
1958	120,862	0	905	0	19,146	0	79,955	81,992	0	60,132	77	61	103	0	242,370	2.01
1959	112,226	0	1,522	0	31,039	142	148,403	13,872	402	144,581	874	58	54	0	340,946	3.04
1960	251,567	0	124	0	55,546	221	610,591	32,598	6,221	65,418	49	606	3,383	0	774,756	3.08
1961	140,714	0	276	0	14,301	1	387,053	3,483	536	164,278	486	1,020	209	0	571,645	4.06
1962	167,602	0	698	0	8,379	0	257,371	25,726	3,194	395,626	1,524	954	0	0	693,473	4.14
1963	332,536	0	0	0	29,538	173	448,298	17,628	905	199,104	0	2,506	551	0	698,703	2.10
1964	137,073	0	37	0	13,311	3,735	190,971	133,203	3,809	409,974	414	0	271	0	755,726	5.51
1965	307,192	0	394	0	102,570	421	1,535,858	80,851	3,332	201,220	271	497	22,731	0	1,948,144	6.34
1966	383,545	0	1,631	0	65,254	378	990,567	15,248	2,193	225,659	28	0	2,609	0	1,303,567	3.40
1967	328,000	0	2,728	0	16,157	163	99,357	6,078	13,965	100,663	1,601	0	0	0	240,712	0.73
1968	342,343	0	271	0	12,997	0	1,011,967	4,707	2,338	174,786	2,119	0	1,742	0	1,210,927	3.54
1969	366,589	0	0	0	13,279	160	302,109	68,392	1,375	88,106	509	0	2,351	0	476,282	1.30
1970	536,257	0	0	0	18,684	283	204,293	8,550	4,819	200,804	648	0	3,605	0	441,685	0.82
1971	671,668	0	615	0	23,187	0	836,146	70,487	3,775	442,621	375	235	6,015	0	1,383,455	2.06
1972	326,320	0	0	0	33,038	0	413,137	16,060	2,842	522,924	4,087	951	2,933	0	995,971	3.05
1973	538,462	0	0	0	19,133	0	670,530	107,814	0	371,174	1,630	472	1,675	0	1,172,428	2.18
1974	364,603	0	50	0	45,176	297	141,350	134,435	107	282,061	510	513	3,098	0	607,596	1.67
1975	319,890	0	0	0	22,848	2,088	66,316	51,249	1,148	508,045	1,200	405	35	2,492	655,827	2.05
1976	548,953	0	595	0	40,756	81	760,415	28,183	834	138,053	0	0	371	13,073	982,361	1.79
1977	364,557	0	95	0	67,262	442	1,725,603	12,985	7,759	374,386	0	3,161	1,498	40,594	2,233,783	6.13

-Continued-

System: **Black Lake (early run)**

Species: **sockeye salmon**

Data available for analysis of escapement goals.

Chignik River Watershed Early Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1978	419,732	0	267	0	56,354	3,129	497,590	68,525	6,032	321,208	0	0	208	14,987	968,298	2.31
1979	491,467	0	1,269	0	591,692	745	2,892,436	51,728	4,092	67,367	220	419	799	1,340	3,612,107	7.35
1980	369,580	0	283	108,988	90,497	1,074	635,271	150,063	1,492	736,108	2,082	940	1,110	4,833	1,732,741	4.69
1981	570,210	0	482	0	154,368	1,101	931,107	75,006	4,276	662,410	509	1,107	258	2,808	1,833,432	3.22
1982	616,117	0	120	0	171,708	2,006	1,622,919	134,083	2,124	390,096	0	393	0	193	2,323,643	3.77
1983	426,178	0	0	19,079	79,437	3,893	208,918	37,322	285	211,184	2	3,588	0	465	564,174	1.32
1984	597,713	476	2,273	1,220	45,960	2,185	324,482	42,024	2,599	210,441	1,213	704	2,463	0	636,040	1.06
1985	373,040	155	499	509	36,630	637	375,369	73,405	20,683	250,052	1,092	1,197	9,205	3,487	772,920	2.07
1986	557,772	384	1,515	6,370	341,300	0	1,894,843	55,308	2,967	202,442	11,104	5,792	1,147	45	2,523,215	4.52
1987	589,299	2,320	0	962	145,741	1,028	724,381	75,377	8,946	433,936	2,905	6,074	31,621	745	1,434,036	2.43
1988	420,580	0	1,468	667	69,885	1,878	492,058	122,713	5,446	961,409	1,426	804	447	258	1,658,460	3.94
1989	384,001	32	4,399	5,833	213,468	2,750	1,036,084	143,920	4,174	270,475	1,267	2,063	20,461	1,474	1,706,400	4.44
1990	434,550	1,004	557	34,094	137,472	5,126	461,400	180,724	5,707	689,768	23	3,314	7,077	579	1,526,844	3.51
1991	662,660	720	502	1,836	109,285	335	1,216,395	36,625	1,208	123,093	1,082	619	2,994	810	1,495,503	2.26
1992	360,681	1,843	449	114,749	52,151	10,551	370,948	67,340	1,387	294,451	10,197	0	5,091	603	929,759	2.58
1993	364,261	2,900	106	10,111	44,152	1,372	193,143	127,112	974	519,551	2,119	1,299	700	0	903,537	2.48
1994	769,465	234	653	0	89,104	1,091	1,191,546	219,496	14,117	521,350	54	601	97	567	2,038,909	2.65
1995	366,495	1,518	1,260	30,725	501,905	0	1,415,799	21,015	7,099	132,418	0	2,650	2,399	343	2,117,130	5.78
1996	464,748	7,202	567	78,280	58,023	0	1,092,142	14,877	12,799	302,104	1,115	812	2,456	0	1,570,375	3.38
1997[a]	396,668	1,359	0	7,166	50,504	839	488,972	49,781	3,277	174,087	193	0	0	0	776,179	1.96
1998	410,659	149	632	3,123	200,142	3	643,270	29,951								
1999	457,424	1,905	81	18,112	115,606	876										
2000	536,141	1,184	228													
2001	744,013															
2002	380,701															
2003	350,004															

[a] Brood year 1997 was considered fully recruited as the contribution of 7 year old fish to the spawner-recruit relationship was negligible.

Appendix B4.–Chignik sockeye salmon late run brood table.

System: Chignik Lake (late run)

Species: sockeye salmon

Data available for analysis of escapement goals.

Chignik River Watershed Late Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1952	260,540	0	0	0	22,213	0	258,747	30,836	986	229,563	0	3,932	8,403	0	554,680	2.13
1953	221,408	0	0	0	9,167	428	125,399	32,350	470	396,916	1,935	934	5,424	0	573,023	2.59
1954	277,912	0	547	0	2,848	0	39,658	75,361	771	418,442	804	1,661	5,069	0	545,161	1.96
1955	201,409	0	369	0	32,187	0	303,988	32,708	168	363,162	1,252	0	0	0	733,834	3.64
1956	483,024	0	1,330	0	12,515	0	106,327	36,113	435	221,169	0	1,349	4,781	0	384,019	0.80
1957	328,779	0	0	0	17,746	622	232,393	109,475	351	332,661	2,104	1,189	1,319	0	697,861	2.12
1958	212,594	0	1,459	0	50,630	0	23,204	139,797	0	419,109	980	93	432	0	635,704	2.99
1959	308,645	0	3,286	0	18,094	907	109,204	81,669	117	197,975	738	689	187	0	412,866	1.34
1960	357,230	0	146	0	24,455	491	122,278	8,273	1,314	210,883	141	1,618	12,824	0	382,423	1.07
1961	254,970	0	718	0	1,899	799	109,935	18,702	220	401,732	2,698	5,335	2,420	0	544,458	2.14
1962	324,860	0	123	0	4,312	0	44,074	69,811	998	692,188	1,074	1,109	0	0	813,689	2.50
1963	200,314	0	0	0	5,536	1,300	103,116	68,605	29	243,939	0	1,529	883	0	424,937	2.12
1964	166,625	0	88	0	6,607	4,550	24,880	65,639	713	140,826	960	194	5,776	0	250,233	1.50
1965	163,151	0	1,636	0	25,157	5,547	162,041	59,008	361	614,235	971	650	94,754	0	964,359	5.91
1966	183,525	0	1,715	0	14,784	942	284,131	28,590	455	407,967	2,419	0	16,843	0	757,845	4.13
1967	189,000	0	510	0	5,845	726	77,202	30,658	653	449,694	2,591	1,305	0	0	569,183	3.01
1968	244,836	0	863	0	3,781	0	107,955	19,044	619	567,425	15,173	2,470	27,620	0	744,949	3.04
1969	132,055	0	0	0	1,155	990	82,718	263,494	751	447,727	6,689	0	15,060	0	818,583	6.20
1970	119,952	0	0	0	17,731	11,703	25,375	138,675	1,187	415,418	10,992	0	17,763	0	638,845	5.33
1971	232,501	0	1,458	0	14,179	11,583	167,089	369,810	211	1,697,096	3,662	3,205	15,662	0	2,283,954	9.82
1972	231,270	0	0	0	27,096	2,202	107,848	85,981	111	810,308	34,712	250	3,456	0	1,071,963	4.64
1973	243,729	0	0	0	5,165	9,601	63,986	195,139	0	859,539	3,600	1,354	5,159	0	1,143,543	4.69
1974	313,343	0	3,951	0	21,748	3,117	98,583	184,079	55	735,042	2,209	2,188	8,748	2,553	1,062,274	3.39
1975	257,508	0	0	0	22,942	6,658	134,113	201,103	863	811,950	3,375	6,436	2,329	7,594	1,197,363	4.65
1976	281,810	0	1,031	0	64,277	875	732,795	89,113	2,479	498,558	0	2,730	9	4,452	1,396,318	4.95
1977	328,916	0	273	0	49,867	3,755	155,162	59,867	1,715	1,057,588	0	2,850	1,106	10,476	1,342,658	4.08

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Appendix B4.–Page 2 of 2.

System: Chignik Lake (late run)

Species: sockeye salmon

Data available for analysis of escapement goals.

Chignik River Watershed Late Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1978	262,815	0	399	0	16,722	5,810	227,692	279,023	961	390,267	687	1,668	168	228	923,623	3.51
1979	246,349	0	2,025	0	90,196	4,429	394,998	39,406	1,176	264,856	369	1,442	769	3,163	802,829	3.26
1980	294,481	0	1,571	11,611	18,519	8,491	149,295	305,514	620	439,791	3,038	756	974	1,082	941,262	3.20
1981	261,239	0	1,564	0	84,701	4,848	227,684	72,940	604	337,180	137	594	68	32	730,352	2.80
1982	305,193	0	2,420	0	50,521	3,139	177,018	98,754	677	533,173	146	1,269	0	276	867,394	2.84
1983	428,034	0	0	2,471	11,037	3,481	135,504	100,439	191	1,014,238	740	11,053	72	0	1,279,226	2.99
1984	267,861	109	832	505	27,815	9,809	137,789	297,259	2,359	1,558,686	1,658	8,876	6,550	547	2,052,793	7.66
1985	372,798	90	630	190	17,099	15,044	165,757	154,043	6,117	459,442	1,063	3,827	3,526	161	826,989	2.22
1986	215,547	94	2,518	12,421	170,342	305	316,570	161,091	1,707	463,238	7,247	11,927	1,988	573	1,150,022	5.34
1987	214,444	5,947	652	976	66,074	8,933	425,983	209,848	5,591	959,150	6,350	6,354	62,566	109	1,758,534	8.20
1988	255,177	0	2,225	1,038	53,583	3,095	273,248	101,364	1,846	179,809	3,556	9,433	7,838	1,129	638,164	2.50
1989	557,174	389	7,425	8,550	158,189	4,415	238,293	91,912	3,551	1,070,406	6,596	11,103	85,361	308	1,686,496	3.03
1990	335,860	413	409	5,271	22,662	1,151	326,230	166,352	1,873	446,003	1,731	2,016	15,270	827	990,206	2.95
1991	377,438	117	175	898	93,587	1,722	286,297	104,860	603	446,211	2,746	4,936	3,986	3,767	949,904	2.52
1992	403,755	559	986	21,610	17,908	12,056	203,800	190,144	2,232	524,930	57,442	1,069	20,705	379	1,053,820	2.61
1993	333,116	456	481	4,023	29,686	17,852	134,040	311,581	2,070	1,020,180	4,795	1,065	62	155	1,526,445	4.58
1994	197,444	79	886	0	55,525	7,069	451,141	292,046	3,212	401,872	248	2,258	1,921	226	1,216,483	6.16
1995	373,425	358	1,454	5,628	183,410	0	320,493	30,763	3,907	771,267	4,314	10,286	11,431	381	1,343,693	3.60
1996	284,389	979	55	41,569	42,153	105	740,974	40,140	7,531	503,462	3,569	3,847	7,301	0	1,391,684	4.89
1997[a]	378,950	2,829	155	3,189	35,303	1,848	211,832	94,455	1,984	659,784	2,426	0	0	0	1,013,805	2.68
1998	290,469	173	1,788	2,342	63,672	132	205,444	51,080								
1999	258,542	699	67	8,477	42,692	2,140										
2000	269,084	246	828													
2001	392,905															
2002	344,519															
2003	334,141															

[a] Brood year 1997 was considered fully recruited as the contribution of 7 year old fish to the spawner-recruit relationship was negligible.

Appendix B5.–Chignik sockeye salmon combined early- and late-run brood table.

System: **Chignik River watershed (combined early and late runs)**

Species: **sockeye salmon**

Data available for analysis of escapement goals.

Chignik River Watershed Combined Early and Late Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1952	294,695	0	0	0	26,603	0	396,704	34,259	1,194	311,254	0	4,571	10,915	0	785,500	2.67
1953	389,783	0	0	0	10,191	460	279,988	50,198	2,095	577,803	2,187	934	6,774	0	930,630	2.39
1954	462,865	0	690	0	9,316	0	89,930	86,081	1,286	491,415	813	1,973	6,078	0	687,582	1.49
1955	458,166	0	1,152	0	62,489	0	734,781	36,184	507	451,855	1,361	0	0	0	1,288,329	2.81
1956	772,120	0	1,347	0	29,014	0	187,896	51,023	444	311,170	0	1,545	9,748	0	592,187	0.77
1957	521,258	0	0	0	24,305	783	350,372	119,982	403	543,347	5,745	1,210	2,225	0	1,048,373	2.01
1958	333,456	0	2,364	0	69,776	0	103,159	221,789	0	479,241	1,057	154	535	0	878,074	2.63
1959	420,871	0	4,808	0	49,133	1,049	257,606	95,541	519	342,556	1,612	747	241	0	753,812	1.79
1960	608,797	0	270	0	80,000	712	732,869	40,871	7,535	276,301	190	2,224	16,207	0	1,157,179	1.90
1961	395,684	0	995	0	16,200	800	496,987	22,185	756	566,010	3,184	6,355	2,629	0	1,116,103	2.82
1962	492,462	0	821	0	12,691	0	301,445	95,537	4,192	1,087,814	2,598	2,063	0	0	1,507,162	3.06
1963	532,850	0	0	0	35,073	1,473	551,414	86,233	934	443,043	0	4,034	1,434	0	1,123,639	2.11
1964	303,698	0	125	0	19,918	8,285	215,851	198,842	4,522	550,800	1,375	194	6,047	0	1,005,959	3.31
1965	470,343	0	2,030	0	127,727	5,968	1,697,898	139,859	3,693	815,455	1,242	1,147	117,485	0	2,912,504	6.19
1966	567,070	0	3,346	0	80,038	1,320	1,274,698	43,838	2,648	633,626	2,447	0	19,451	0	2,061,412	3.64
1967	517,000	0	3,238	0	22,002	889	176,559	36,736	14,619	550,357	4,191	1,305	0	0	809,895	1.57
1968	587,179	0	1,134	0	16,778	0	1,119,922	23,751	2,957	742,210	17,292	2,470	29,362	0	1,955,876	3.33
1969	498,644	0	0	0	14,434	1,149	384,827	331,886	2,126	535,833	7,198	0	17,411	0	1,294,865	2.60
1970	656,209	0	0	0	36,415	11,986	229,667	147,226	6,006	616,222	11,640	0	21,368	0	1,080,530	1.65
1971	904,169	0	2,074	0	37,366	11,583	1,003,235	440,296	3,986	2,139,716	4,037	3,440	21,676	0	3,667,410	4.06
1972	557,590	0	0	0	60,134	2,202	520,985	102,041	2,952	1,333,232	38,799	1,200	6,389	0	2,067,934	3.71
1973	782,191	0	0	0	24,299	9,601	734,516	302,953	0	1,230,713	5,230	1,826	6,834	0	2,315,971	2.96
1974	677,946	0	4,001	0	66,924	3,414	239,934	318,514	162	1,017,103	2,718	2,700	11,846	2,553	1,669,870	2.46
1975	577,398	0	0	0	45,790	8,746	200,429	252,352	2,011	1,319,995	4,575	6,841	2,364	10,086	1,853,190	3.21
1976	830,763	0	1,625	0	105,034	957	1,493,210	117,296	3,313	636,610	0	2,730	379	17,525	2,378,679	2.86
1977	693,473	0	368	0	117,129	4,197	1,880,764	72,852	9,474	1,431,974	0	6,011	2,603	51,070	3,576,442	5.16

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System: **Chignik River watershed (combined early and late runs)**

Species: **sockeye salmon**

Data available for analysis of escapement goals.

Chignik River Watershed Combined Early and Late Run Sockeye Salmon Brood Table

		Return Ages														
Year	Escapement	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Other	Total	R/S
1978	682,547	0	665	0	73,076	8,939	725,282	347,548	6,993	711,475	687	1,668	375	15,214	1,891,921	2.77
1979	737,816	0	3,294	0	681,888	5,174	3,287,435	91,134	5,267	332,223	590	1,860	1,568	4,503	4,414,936	5.98
1980	664,061	0	1,854	120,599	109,016	9,565	784,566	455,577	2,112	1,175,899	5,120	1,696	2,084	5,915	2,674,003	4.03
1981	831,449	0	2,046	0	239,069	5,949	1,158,791	147,946	4,881	999,590	646	1,701	326	2,840	2,563,784	3.08
1982	921,310	0	2,540	0	222,230	5,145	1,799,936	232,838	2,801	923,269	146	1,662	0	469	3,191,037	3.46
1983	854,212	0	0	21,550	90,474	7,374	344,422	137,761	475	1,225,422	742	14,641	72	465	1,843,400	2.16
1984	865,574	585	3,105	1,725	73,775	11,994	462,271	339,283	4,958	1,769,127	2,871	9,579	9,014	547	2,688,833	3.11
1985	745,838	245	1,129	699	53,729	15,681	541,126	227,448	26,800	709,494	2,155	5,024	12,731	3,648	1,599,909	2.15
1986	773,319	478	4,033	18,791	511,642	305	2,211,413	216,399	4,673	665,680	18,351	17,719	3,135	618	3,673,237	4.75
1987	803,743	8,267	652	1,938	211,815	9,961	1,150,364	285,225	14,537	1,393,086	9,255	12,428	94,188	854	3,192,570	3.97
1988	675,757	0	3,693	1,705	123,468	4,973	765,306	224,077	7,292	1,141,218	4,983	10,237	8,285	1,387	2,296,623	3.40
1989	941,175	421	11,825	14,383	371,657	7,164	1,274,377	235,832	7,725	1,340,880	7,863	13,166	105,822	1,782	3,392,896	3.60
1990	770,410	1,418	966	39,365	160,133	6,277	787,630	347,075	7,580	1,135,771	1,755	5,329	22,346	1,406	2,517,050	3.27
1991	1,040,098	837	677	2,733	202,872	2,057	1,502,692	141,484	1,811	569,304	3,827	5,555	6,979	4,577	2,445,407	2.35
1992	764,436	2,402	1,435	136,359	70,059	22,607	574,747	257,484	3,619	819,382	67,639	1,069	25,796	982	1,983,580	2.59
1993	697,377	3,356	586	14,133	73,838	19,223	327,183	438,692	3,044	1,539,731	6,913	2,364	762	155	2,429,982	3.48
1994	966,909	313	1,539	0	144,629	8,161	1,642,687	511,542	17,329	923,222	302	2,858	2,018	793	3,255,393	3.37
1995	739,920	1,876	2,714	36,353	685,315	0	1,736,292	51,778	11,006	903,685	4,314	12,936	13,830	724	3,460,823	4.68
1996	749,137	8,180	622	119,849	100,175	105	1,833,116	55,016	20,330	805,566	4,684	4,659	9,757	0	2,962,059	3.95
1997[a]	775,618	4,188	155	10,355	85,807	2,686	700,805	144,235	5,261	833,871	2,619	0	0	0	1,789,966	2.31
1998	701,128	322	2,420	5,465	263,813	136	848,714	81,031								
1999	715,966	2,604	147	26,588	158,298	3,016										
2000	805,225	1,430	1,056													
2001	1,136,918															
2002	725,220															
2003	684,145															

[a] Brood year 1997 was considered fully recruited as the contribution of 7 year old fish to the spawner-recruit relationship was negligible.

Appendix B6.–Analysis results for Chignik sockeye salmon spawner-recruit, yield, EV, and zooplankton models.

System: Chignik River watershed

Species: sockeye salmon

Escapement goal review model summary.

	Early Run			Late Run			Total Run		
Method	Low	Point	High	Low	Point	High	Low	Point	High
Existing Goals	350,000	375,000	400,000	200,000	225,000	250,000	575,000	625,000	675,000
EV[a,b]	169,000	225,000	281,000	182,000	243,000	303,000	397,000	529,000	661,000
Zooplankton[b]	342,000	428,000	513,000	444,000	556,000	667,000	787,000	983,000	1,180,000
Spawner-recruit[c]									
1952 - 1997									
Additive error		NS			NS			n/a	
Multiplicative		NS			AC			n/a	
1965-1997									
Additive error		NS			NS			n/a	
Multiplicative		NS		201,000	317,000	455,000		n/a	
1980 -1997									
Additive error		NS			NS			NS	
Multiplicative		NS			NS			NS	
1977 - 1997									
Generalized[d]		NS			NS			NS	
1922-1945,1965-1996									
Multiplicative	259,000	409,000	588,000		n/a			n/a	
Yield Analysis[e]									
1952-1997									
1-800	301,000	356,000	400,000		n/a			n/a	
1-850	451,000	386,000	500,000		n/a			n/a	
1965-1997									
1-800	301,000	357,000	400,000		n/a			n/a	
1-850	451,000	386,000	500,000		n/a			n/a	
Actual Escapements[f,g]	350,000	477,000	769,000	197,000	318,000	557,000	664,000	795,000	1,137,000

[a] Low and high ranges were calculated as values 25% higher and lower than the point goals.

[b] Total run was estimated by summing early and late run values. Data from 1991, 2000 to 2003 (Kyle 1992; Bouwens and Newland 2003; Finkle 2005*)*. Values rounded from original analyses.

[c] NS =not significant (P>0.05), AC=autocorrelation present, n/a= data not available.

[d] Generalized R/S analyses based on data from 1977 to 2003, which is the span of available historic sea surface temperature data.

[e] Low and high ranges are based on interval ranges.

[f] Point estimates were the average of escapements between 1952 to 2003 for each run.

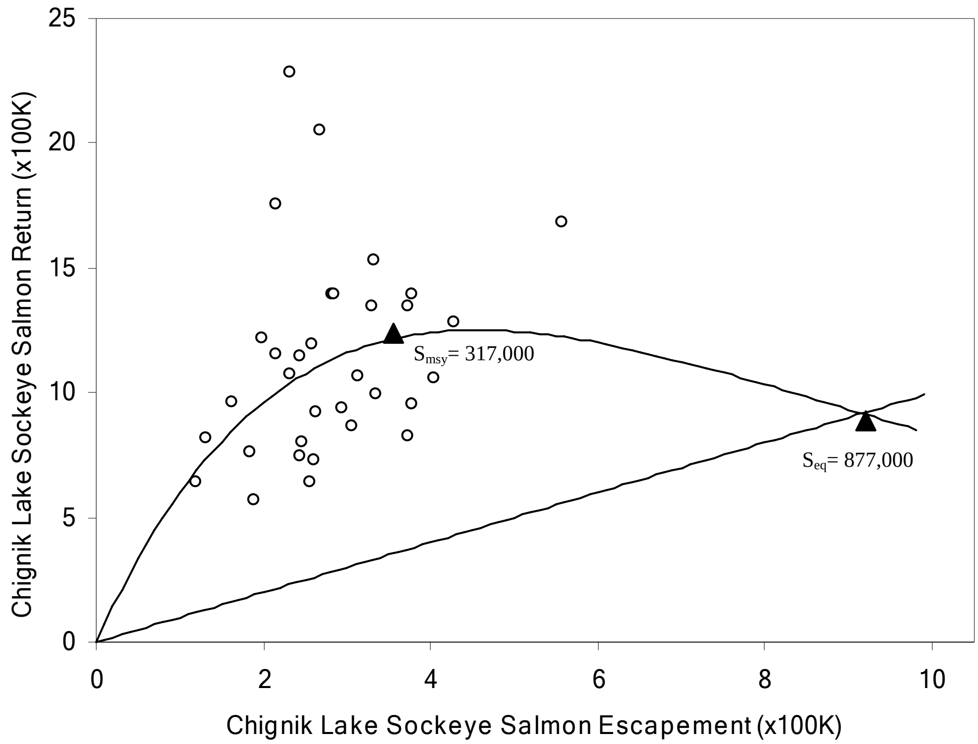
[g] The low and high ranges are the lowest and highest escapements since 1952.

Appendix B7.–Chignik sockeye salmon late run Ricker curve.

System: **Chignik Lake (late run)**

Species: **sockeye salmon**

Ricker stock – recruitment relationship, 1965-1997 brood years. The solid curved line represents the multiplicative error Ricker curve and the solid straight line represents replacement.



Appendix B8.–Chignik early run sockeye salmon spawner-recruit yield analysis.

System: **Black Lake (early run)**

Species: **sockeye salmon**

Yield analysis for 1952-1997 brood years. Escapement intervals have a range of 100,000 fish from 1,000 to 800,000 fish. Return intervals are shown as proportions of return range for given escapement intervals.

1952-1997	Escapement (thousands)							
Return (thousands)	1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800
1-200		0.1250						
201-400	1.0000	0.5000	0.3333	0.0588				
401-600		0.1250	0.3333	0.0588	0.1667	0.1429		
601-800		0.2500	0.3333	0.2941		0.1429		
801-1,000				0.1765	0.1667	0.1429		
1,001-1,200						0.1429		
1,201-1,400				0.1176			0.3333	
1,401-1,600					0.3333	0.1429	0.3333	
1,601-1,800				0.1176	0.1667			
1,801-2,000				0.0588		0.1429		
2,001-2,200				0.0588				1.0000
2,201-2,400				0.0588			0.3333	
2,401-2,600						0.1429		
3,601-3,800[a]					0.1667			
Number of Points	1	8	3	17	6	7	3	1
Average Yield	197	279	247	780	1,207	726	1,084	1,269
Average Return	231	432	512	1,136	1,650	1,289	1,734	2,039
Average Escapement	34	153	266	356	443	563	650	769

[a] Note that the return interval starts at 3,601 instead of 2,601.

-Continued-

System: **Black Lake (early run)**

Species: **sockeye salmon**

Yield analysis for 1965-1997 brood years. The escapement range is from 1,000 to 800,000 fish with 100,000 fish intervals. Return intervals are shown as proportions of return range for given escapement intervals.

1965-1997	Escapement (thousands)							
Return (thousands)	1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800
1-200								
201-400				0.0625				
401-600				0.0625	0.1667	0.1429		
601-800				0.2500		0.1429		
801-1,000				0.1875	0.1667	0.1429		
1,001-1,200						0.1429		
1,201-1,400				0.1250			0.3333	
1,401-1,600					0.3333	0.1429	0.3333	
1,601-1,800				0.1250	0.1667			
1,801-2,000				0.0625		0.1429		
2,001-2,200				0.0625				1.0000
2,201-2,400				0.0625			0.3333	
2,401-2,600						0.1429		
3,601-3,800[a]					0.1667			
Number of Points	0	0	0	16	6	7	3	1
Average Yield				806	1,207	726	1,084	1,269
Average Return				1,163	1,650	1,289	1,734	2,039
Average Escapement				357	443	563	650	769

[a] Note that the return interval starts at 3,601 instead of 2,601.

-Continued-

System: **Black Lake (early run)**

Species: **sockeye salmon**

Yield analysis for 1952-1997 brood years. The escapement range is from 51,000 to 850,000 fish with 100,000 fish intervals. Return intervals are shown as proportions of return range for given escapement intervals.

1952-1997	Escapement (thousands)								
Return (thousands)	1-50	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850
1-200			0.2500						
201-400	1.0000	0.5000	0.5000	0.2222					
401-600		0.2500		0.1111	0.1333	0.2000			
601-800		0.2500	0.2500	0.3333	0.2000		0.2000		
801-1,000				0.1111	0.2000	0.2000			
1,001-1,200						0.2000			
1,201-1,400				0.1111	0.0667			0.5000	
1,401-1,600					0.0667	0.2000	0.2000	0.5000	
1,601-1,800					0.2000				
1,801-2,000				0.1111			0.2000		
2,001-2,200					0.0667				1.0000
2,201-2,400					0.0667		0.2000		
2,401-2,600							0.2000		
3,601-3,800[a]						0.2000			
Number of Points	1	4	4	9	15	5	5	2	1
Average Yield	197	350	208	504	832	1,040	1,164	772	1,269
Average Return	231	478	386	810	1,219	1,556	1,750	1,439	2,039
Average Escapement	34	128	178	306	386	516	586	667	769

[a] Note that the return interval starts at 3,601 instead of 2,601.

-Continued-

System: **Black Lake**

Species: **sockeye salmon**

Yield analysis for 1965-1997 brood years. The escapement range is from 51,000 to 850,000 fish with 100,000 fish intervals. Return intervals are shown as proportions of return range for given escapement intervals.

1965-1997	Escapement (thousands)								
Return (thousands)	1-50	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850
1-200									
201-400				0.2000					
401-600					0.1333	0.2000			
601-800				0.2000	0.2000		0.2000		
801-1,000				0.2000	0.2000	0.2000			
1,001-1,200						0.2000			
1,201-1,400				0.2000	0.0667			0.5000	
1,401-1,600					0.0667	0.2000	0.2000	0.5000	
1,601-1,800					0.2000				
1,801-2,000				0.2000			0.2000		
2,001-2,200					0.0667				1.0000
2,201-2,400					0.0667		0.2000		
2,401-2,600							0.2000		
3,601-3,800[a]						0.2000			
Number of Points	0	0	0	5	15	5	5	2	1
Average Yield				686	832	1,040	1,164	772	1,269
Average Return				1,010	1,219	1,556	1,750	1,439	2,039
Average Escapement				325	386	516	586	667	769

[a] Note that the return interval starts at 3,601 instead of 2,601.

Appendix B9.–Chignik River watershed EV model analysis summary for sockeye salmon.

System: Chignik River watershed

Species: sockeye salmon

Euphotic volume model, 1991 and 2000-2003.

Location	Year	EZD (m)	EV (10^6 m^3)	Number of Spring Fry	Smolt Biomass (kg)	Number of Smolt	Adult Production (Number of Fish)	Adult Escapement (Number of Fish)
Black Lake[a]	1991	n/a	86.40	9,072,000	8,122	3,760,000	216,000	129,600
	2000	3.72	152.89	16,053,660	14,372	6,653,633	382,230	229,338
	2001	3.72	152.89	16,053,660	14,372	6,653,633	382,230	229,338
	2002	4.94	203.01	21,315,652	19,083	8,834,529	507,516	304,509
	2003	3.76	154.54	16,226,280	14,526	6,725,178	386,340	231,804
	Average	4.0	149.95	15,744,250	14,095	6,525,395	374,863	224,918
Chignik Lake[b]	1991	n/a	158.90	17,479,000	17,002	5,724,680	397,250	158,900
	2000	8.22	198.10	21,791,220	21,197	7,137,008	495,255	198,102
	2001	15.52	374.03	41,143,520	40,021	13,475,227	935,080	374,032
	2002	15.00	361.50	39,765,000	38,681	13,023,737	903,750	361,500
	2003	4.98	120.02	13,201,980	12,842	4,323,881	300,045	120,018
	Average	10.9	242.51	26,676,144	25,949	8,736,907	606,276	242,510
Both Lakes[b]	1991	n/a	245.00	26,950,000	26,215	8,826,599	612,500	245,000
	2000	7.10	462.59	50,885,340	49,498	16,665,844	1,156,485	462,594
	2001	12.57	819.56	90,152,040	87,693	29,526,380	2,048,910	819,564
	2002	12.48	814.01	89,541,208	87,099	29,326,321	2,035,027	814,011
	2003	4.68	304.81	33,529,100	32,615	10,981,370	762,025	304,810
	Average	9.2	529.20	58,211,538	56,624	19,065,303	1,322,989	529,196

[a] Number of Black Lake smolt based on an average weight of 2.61 g.

[b] Number of smolt for Chignik Lake and both lakes combined based on an average.

Appendix B10.–Chignik River watershed zooplankton model analysis summary for sockeye salmon.

System: Chignik River watershed

Species: sockeye salmon

Zooplankton model, 1991, 2000 – 2003.

Lake	Year	Zooplankton Biomass (mg/m^2)	Number of Smolt	Optimal Escapement	Lower Escapement Limit	Upper Escapement Limit	Size-specific Adult Production[c]
Black Lake[a]	1991	167.0	5,570,157	371,344	297,075	445,613	668,419
	2000	101.6	3,390,124	226,008	180,807	271,210	406,815
	2001	41.6	1,386,202	92,413	73,931	110,896	166,344
	2002	215.0	7,172,494	478,166	382,533	573,800	860,699
	2003	436.8	14,567,794	971,186	776,949	1,165,424	1,748,135
	Average	192.4	6,417,354	427,824	342,259	513,388	770,082
Chignik Lake[b]	1991	661.0	11,317,344	754,490	603,592	905,388	1,358,081
	2000	523.2	8,958,337	597,222	477,778	716,667	1,075,000
	2001	266.6	4,563,920	304,261	243,409	365,114	547,670
	2002	552.3	9,455,889	630,393	504,314	756,471	1,134,707
	2003	430.4	7,369,115	491,274	393,019	589,529	884,294
	Average	486.7	8,332,921	555,528	444,422	666,634	999,951
Both Lakes	1991	[d]	16,887,500	1,125,833	900,667	1,351,000	2,026,500
	2000		12,348,461	823,231	658,585	987,877	1,481,815
	2001		5,950,122	396,675	317,340	476,010	714,015
	2002		16,628,383	1,108,559	886,847	1,330,271	1,995,406
	2003		21,936,908	1,462,461	1,169,968	1,754,953	2,632,429
	Average		14,750,275	983,352	786,681	1,180,022	1,770,033

[a] Number of Black Lake smolt based on an average weight of 2.61 g.

[b] Number of smolt for Chignik Lake based on an average weight of 2.97 g.

[c] Size-specific adult production was estimated relative to smolt size for each rearing area.

[d] Combining density estimates from Black and Chignik Lakes would not accurately describe the collective zooplankton biomass density. The individual estimates of numbers of smolt and escapement levels from each lake are summed to generate estimates for both lakes combined.

APPENDIX C: PINK SALMON ESCAPEMENT GOAL REVIEW

Appendix C1.– Description of stocks and escapement goals for Eastern District pink salmon.

System: **Eastern District**

Species: **pink salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 488,000 (1999)
Recommended escapement goal:	MO: even years: 186,000 to 418,000
	MO: odd years: 276,000 to 601,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial Survey, 1962-2003

Data summary:

Data quality:	Fair.
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of 23 streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys, all years: 39.2
	Peak aerial surveys, even years: 39.2
	Peak aerial surveys, odd years: 31.7
	Estimated total escapement: 114.9

-Continued-

Methodology:	Ricker spawner-recruit model (Eastern District: all years additive error, all years multiplicative error, even years additive error, even years multiplicative error), proportion of the entire CMA BEG
Autocorrelation:	None
Comments:	Management objective estimated from a proportion of the area-wide BEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Eastern District.

Appendix C2.–Peak aerial surveys and total estimated escapement of pink salmon in the Eastern District.

System: Eastern District

Species: pink salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		401,700
1963		126,200
1964		605,700
1965		64,800
1966		302,200
1967		56,100
1968		390,300
1969		46,000
1970		201,700
1971		23,000
1972	21,555	15,900
1973	25,550	12,800
1974	89,901	76,200
1975	41,360	23,500
1976	172,870	228,800
1977	27,110	76,000
1978	256,250	309,300
1979	211,710	194,300
1980	470,300	425,500
1981	337,050	154,700
1982	322,650	301,500
1983	163,600	46,300
1984	460,300	486,500
1985	156,700	212,100
1986	358,600	580,700
1987	177,300	215,600
1988	699,300	1,005,400
1989	464,100	881,000
1990	504,800	811,400
1991	189,940	125,000
1992	845,340	1,318,100
1993	334,200	524,700
1994	587,500	863,300
1995	811,000	1,399,300
1996	541,400	1,059,600
1997	717,000	1,287,700
1998	667,100	1,273,200
1999	304,600	615,100
2000	704,300	810,700
2001	508,000	1,470,200
2002	609,900	777,710
2003	678,700	1,408,060

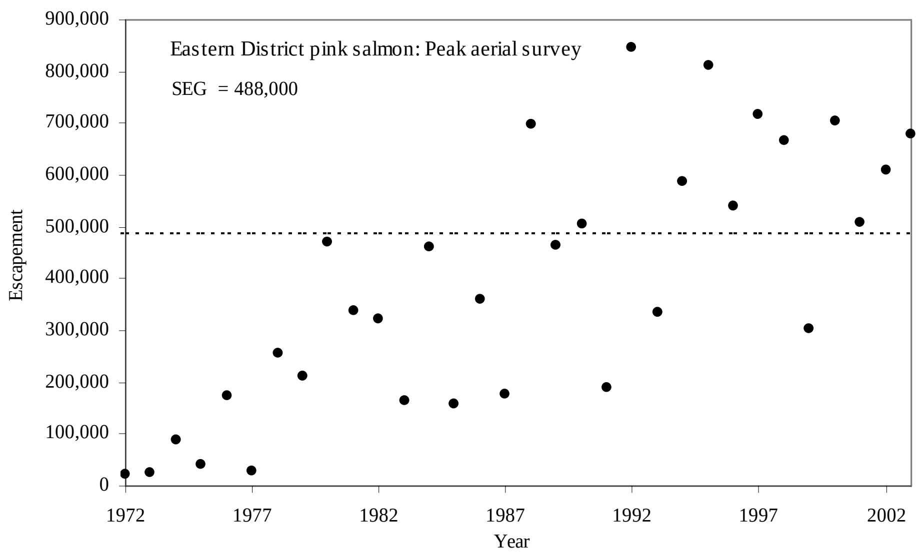
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

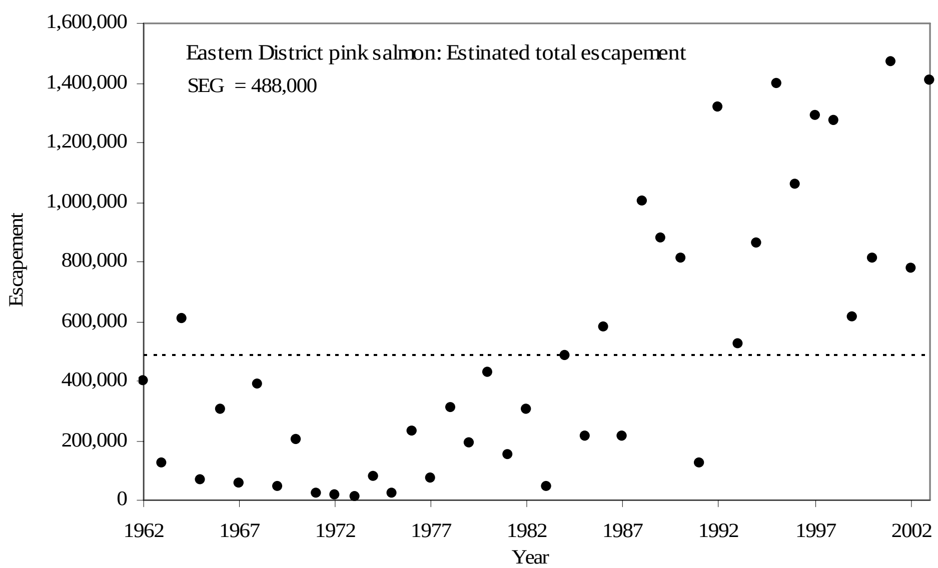
Appendix C3.–Peak aerial surveys and total estimated escapement of pink salmon in the Eastern District with existing escapement goals depicted.

System: **Eastern District**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



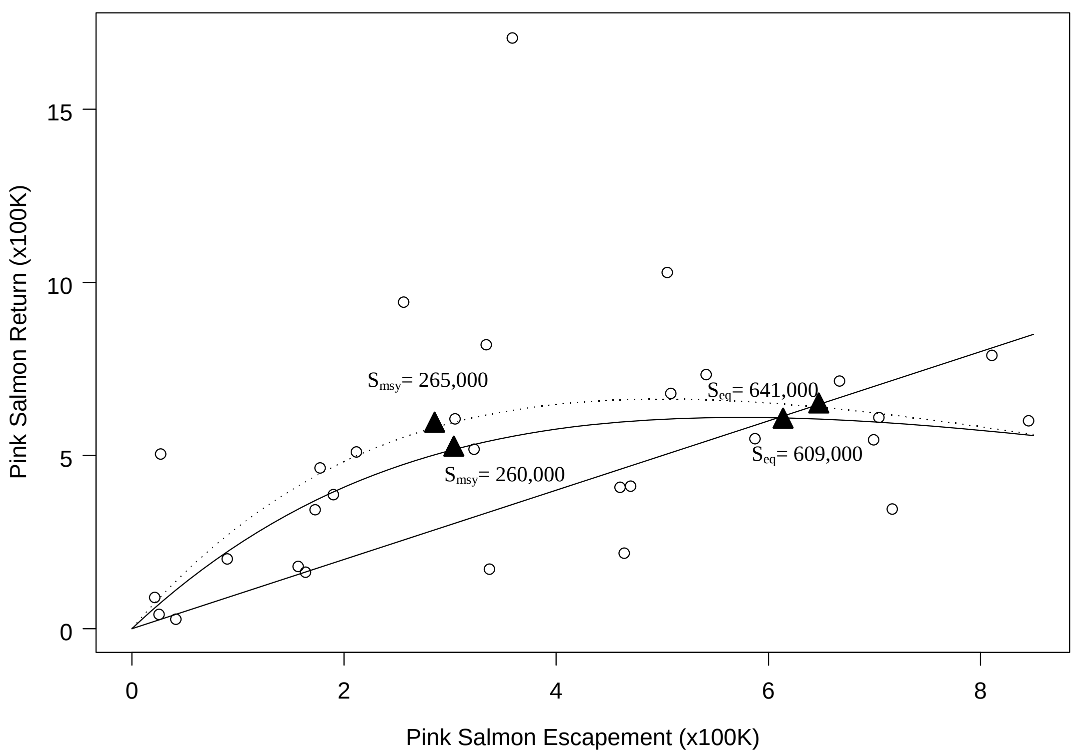


Appendix C4.–Ricker stock-recruitment curves for pink salmon in the Eastern District.

System: **Eastern District**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2001 all brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



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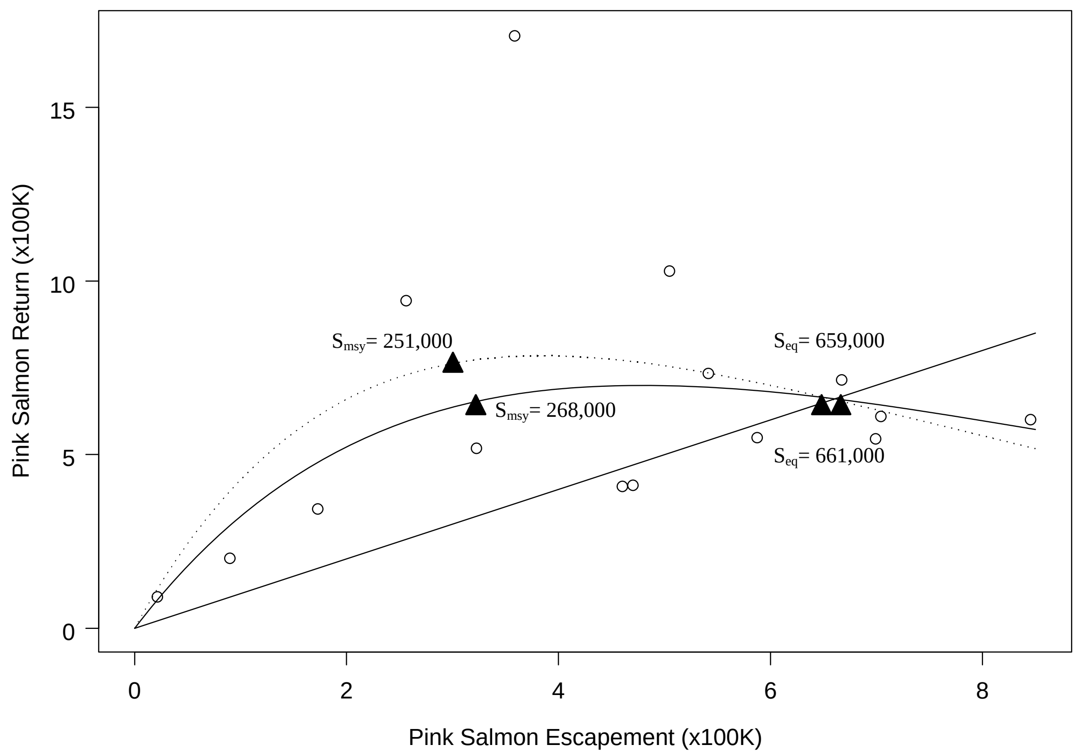
System: **Eastern District**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2000 even brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



Appendix C5.–Description of stocks and escapement goals for Central District pink salmon.

System: Central District

Species: pink salmon

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 119,500 (1999)
Recommended escapement goal:	MO: even years: 62,000 to 140,000
	MO: odd years: 87,000 to 190,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003.
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of eight streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 122.1
	Estimated total escapement: 230.8
Methodology:	Ricker spawner-recruit model (Central and Chignik Bay Districts aggregate: all years additive error, all years multiplicative error, even years additive error, even years multiplicative error), proportion of the entire CMA BEG
Autocorrelation:	None
Comments:	Management objective estimated from a proportion of the area-wide BEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Central District.

Appendix C6.–Peak aerial surveys and total estimated escapement of pink salmon in the Central District.

System: Central District

Species: pink salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		83,900
1963		92,600
1964		131,100
1965		65,800
1966		62,600
1967		18,500
1968		66,100
1969		69,600
1970		60,700
1971		74,800
1972	2,420	3,100
1973	31,350	50,200
1974	6,280	9,800
1975	21,060	26,400
1976	56,830	66,000
1977	165,000	199,900
1978	62,000	101,200
1979	198,500	297,000
1980	47,325	99,400
1981	110,090	76,500
1982	53,100	26,100
1983	22,800	11,000
1984	106,300	94,000
1985	54,100	7,400
1986	137,750	121,900
1987	80,250	65,700
1988	193,900	216,400
1989	78,600	215,000
1990	220,800	131,900
1991	100,200	201,100
1992	168,700	223,800
1993	137,100	160,900
1994	201,800	178,900
1995	152,100	715,500
1996	283,100	237,100
1997	218,000	594,600
1998	180,010	210,900
1999	71,650	374,300
2000	217,500	146,100
2001	149,000	460,400
2002	291,500	85,755
2003	295,500	576,510

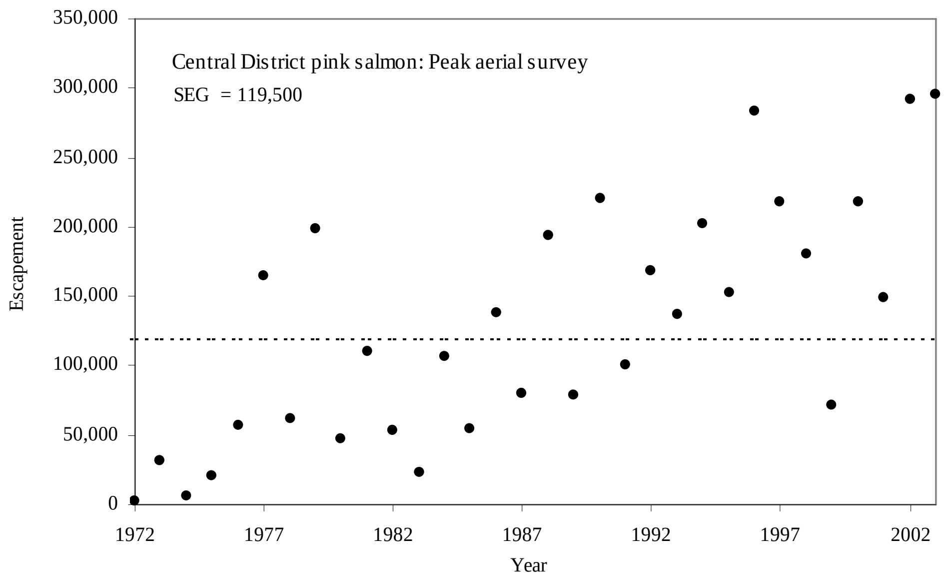
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

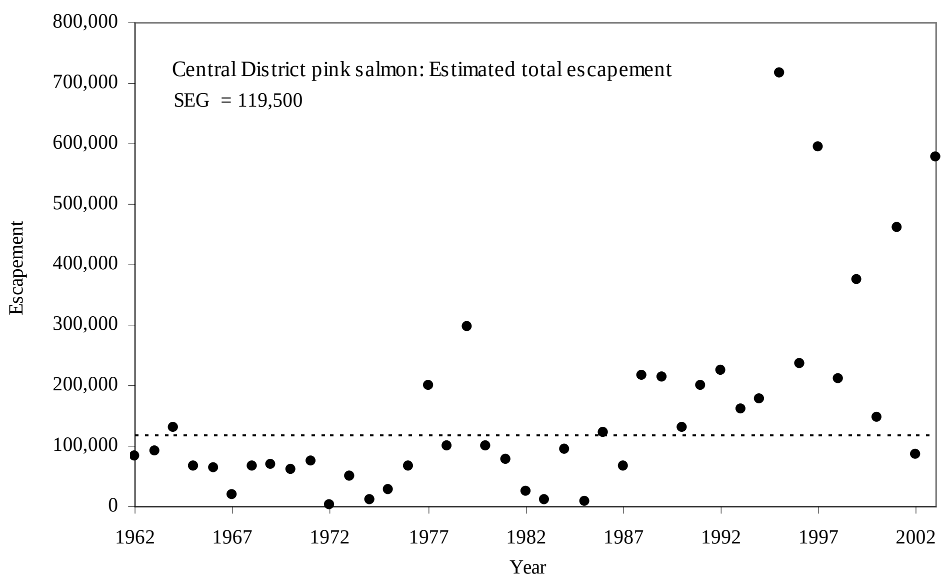
Appendix C7.–Peak aerial surveys and total estimated escapement of pink salmon in the Central District with existing escapement goals depicted.

System: **Central District**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).





Appendix C8.–Description of stocks and escapement goals for Chignik Bay District pink salmon**.**

System: Chignik Bay District

Species: pink salmon

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 6,500 (1999)
Recommended escapement goal:	MO: even years: 3,000 to 7,000
	MO: odd years: 8,000 to 17,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of three streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 427.3
	Estimated total escapement: 180.5
Methodology:	Ricker spawner-recruit model (Central and Chignik Bay Districts Aggregate: all years additive error, all years multiplicative error, even years additive error, even years multiplicative error), proportion of the entire CMA BEG
Autocorrelation:	None
Comments:	Management objective estimated from a proportion of the area-wide BEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Chignik Bay District.

Appendix C9.–Peak aerial surveys and total estimated escapement of pink salmon in the Chignik Bay District.

System: **Chignik Bay District**

Species: **pink salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		30,000
1963		20,700
1964		20,000
1965		11,000
1966		71,300
1967		5,700
1968		81,400
1969		11,700
1970		43,600
1971		5,500
1972	175	5,800
1973	500	2,200
1974	760	4,000
1975	110	1,200
1976	1,610	12,300
1977	940	3,000
1978	400	10,700
1979	500	1,200
1980	1,950	3,000
1981	800	1,400
1982	5,000	2,400
1983	1,040	1,000
1984	3,650	123,200
1985	2,000	0
1986	3,100	0
1987	25,340	0
1988	6,320	22,400
1989	13,000	13,500
1990	7,400	6,000
1991	7,200	12,200
1992	6,500	55,800
1993	7,000	2,000
1994	8,000	75,800
1995	47,000	180,500
1996	45,000	43,100
1997	1,075	59,400
1998	900	24,400
1999	800	37,300
2000	6,400	27,400
2001	8,000	19,700
2002	14,400	16,917
2003	8,000	143,897

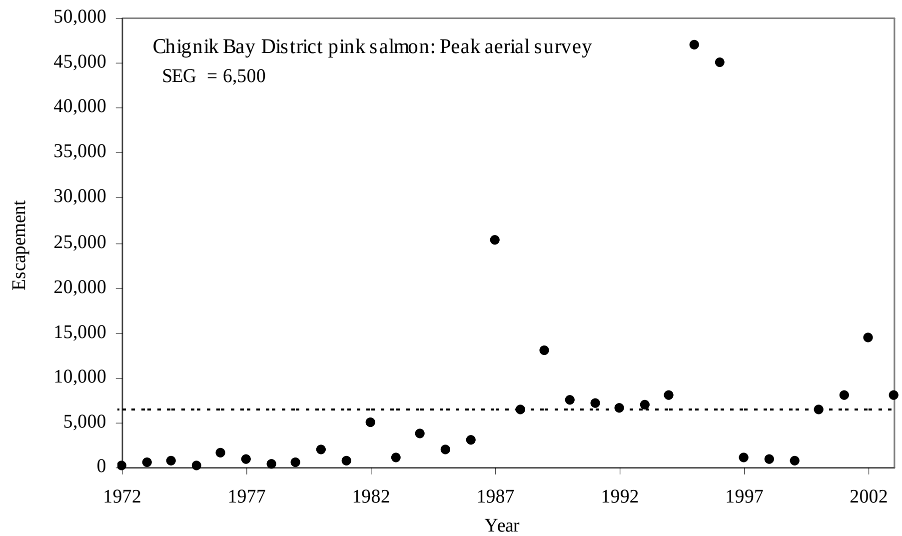
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

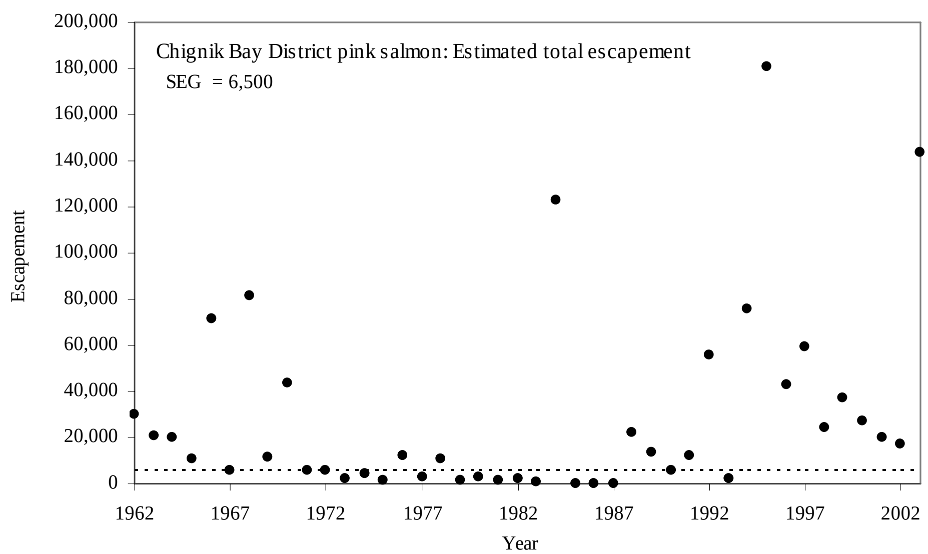
Appendix C10.–Peak aerial surveys and total estimated escapement of pink salmon in the Chignik Bay District with existing escapement goals depicted.

System: **Chignik Bay District**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



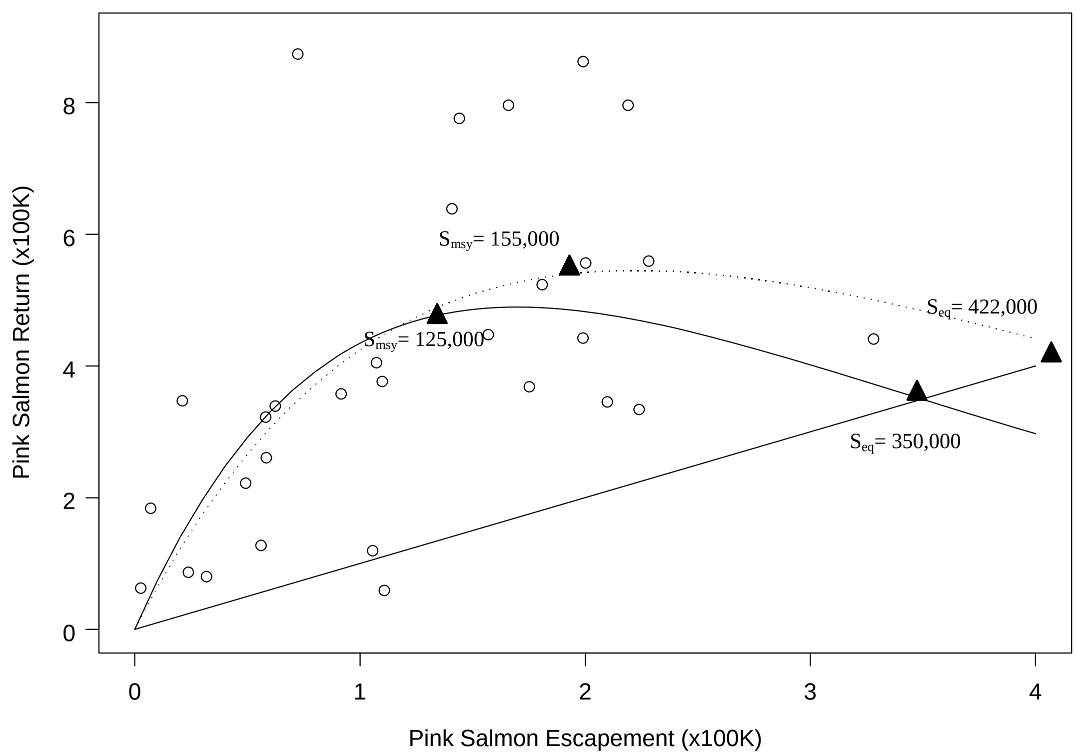


Appendix C11.–Ricker stock-recruitment curves for pink salmon in the Central and Chignik Bay Districts combined.

System: **Central and Chignik Districts combined**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2001 all brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



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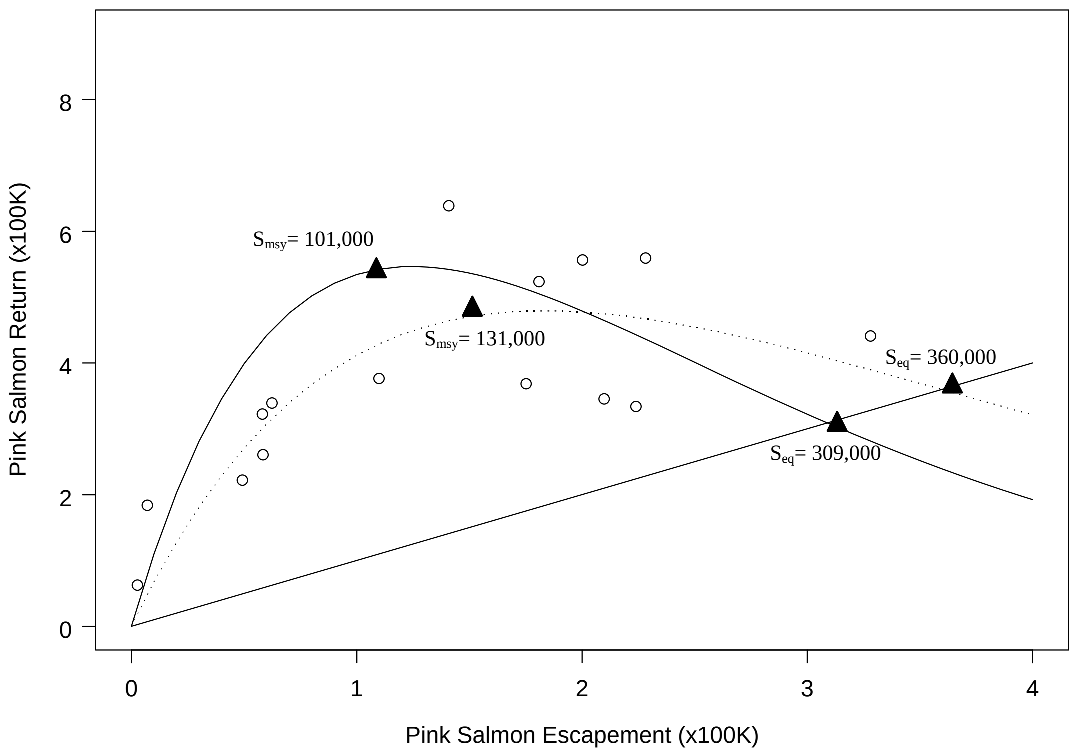
System: **Central and Chignik Districts combined**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2000 even brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



Appendix C12.–Description of stocks and escapement goals for Western District pink salmon.

System: Western District

Species: pink salmon

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 61,500 (1999)
Recommended escapement goal:	MO: even year: 31,000 to 69,000
	MO: odd year: 65,000 to 141,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003.
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003.A total of six streams are used as an index for district-wide escapement.
Contrast:	Peak aerial surveys: 8.2
	Estimated total escapement: 64.5
Methodology:	Ricker spawner-recruit model (Western and Perryville Districts aggregate: all years multiplicative error, even years additive error), proportion of the entire CMA BEG
Autocorrelation:	None
Comments:	Management objective estimated from a proportion of the area-wide BEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Western District.

Appendix C13.–Peak aerial surveys and total estimated escapement of pink salmon in the Western District.

System: Western District

Species: pink salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		242,000
1963		305,000
1964		165,000
1965		152,000
1966		179,300
1967		104,400
1968		151,300
1969		422,000
1970		202,000
1971		268,800
1972	52,065	8,600
1973	56,020	62,400
1974	102,000	77,400
1975	92,500	141,700
1976	268,700	114,200
1977	120,400	355,500
1978	159,100	333,400
1979	125,100	185,000
1980	132,200	139,500
1981	34,605	249,300
1982	52,920	45,900
1983	118,350	36,000
1984	72,350	188,000
1985	32,800	67,500
1986	123,400	43,800
1987	65,900	38,300
1988	50,900	232,400
1989	74,900	57,900
1990	45,200	44,300
1991	56,135	96,800
1992	46,600	38,800
1993	126,300	45,800
1994	200,500	111,600
1995	145,500	554,700
1996	131,000	220,800
1997	148,500	306,300
1998	36,000	150,400
1999	75,300	137,900
2000	102,500	130,100
2001	78,500	263,000
2002	157,000	85,501
2003	187,000	117,650

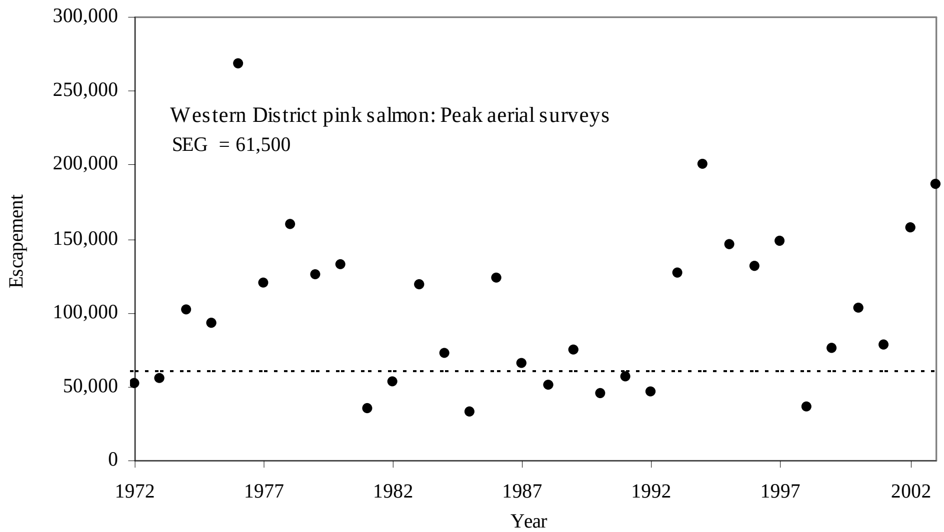
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

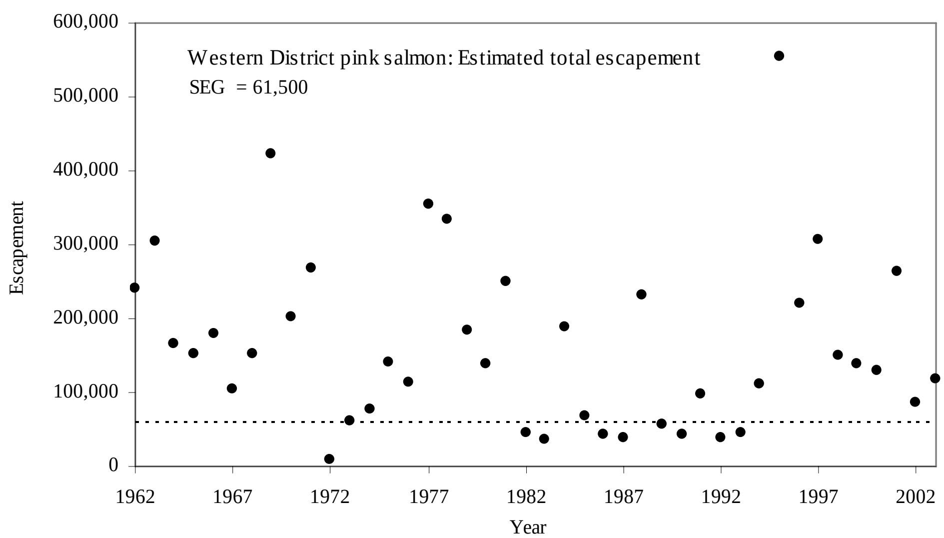
Appendix C14.–Peak aerial surveys and total estimated escapement of pink salmon in the Western District with existing escapement goals depicted.

System: **Western District**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG range (dashed lines).





Appendix C15.–Description of stocks and escapement goals for Perryville District pink salmon.

System: **Perryville District**

Species: **pink salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 104,000 (1999)
Recommended escapement goal:	MO: even year: 45,000 to 102,000
	MO: odd year: 105,000 to 228,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003.
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of nine streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 13.1
	Estimated total escapement: 74.6
Methodology:	Ricker spawner-recruit model (Western and Perryville Districts aggregate: all years multiplicative error, even years additive error), proportion of the entire CMA BEG
Autocorrelation:	None
Comments:	Management objective estimated from a proportion of the area-wide BEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Perryville District.

Appendix C16.–Peak aerial surveys and total estimated escapement of pink salmon in the Western District.

System: **Perryville District**

Species: **pink salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		155,500
1963		162,000
1964		72,000
1965		82,000
1966		90,000
1967		155,300
1968		128,700
1969		218,600
1970		72,600
1971		45,000
1972	23,960	7,800
1973	28,975	31,500
1974	33,030	60,200
1975	104,650	45,300
1976	66,050	89,300
1977	120,003	115,400
1978	71,350	157,500
1979	96,900	181,300
1980	36,900	74,800
1981	19,200	116,000
1982	46,550	13,400
1983	129,050	64,500
1984	167,900	109,800
1985	41,700	235,200
1986	71,200	180,500
1987	197,800	65,700
1988	239,300	181,300
1989	140,400	267,400
1990	122,815	88,400
1991	205,780	343,500
1992	145,470	190,400
1993	208,000	448,400
1994	215,520	153,900
1995	250,600	582,100
1996	78,500	395,700
1997	151,700	221,500
1998	151,700	222,800
1999	60,800	179,700
2000	75,600	98,700
2001	71,200	150,200
2002	193,300	62,170
2003	161,000	99,500

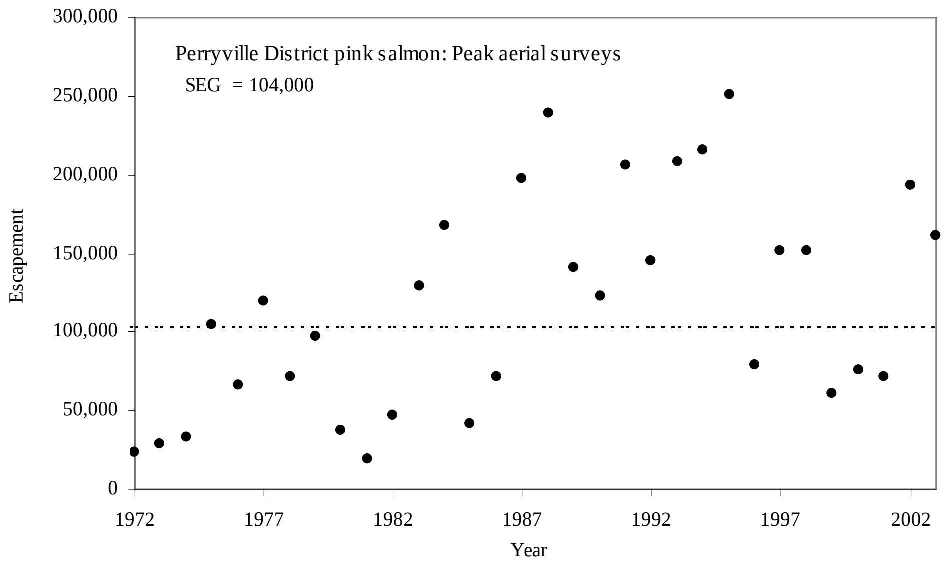
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

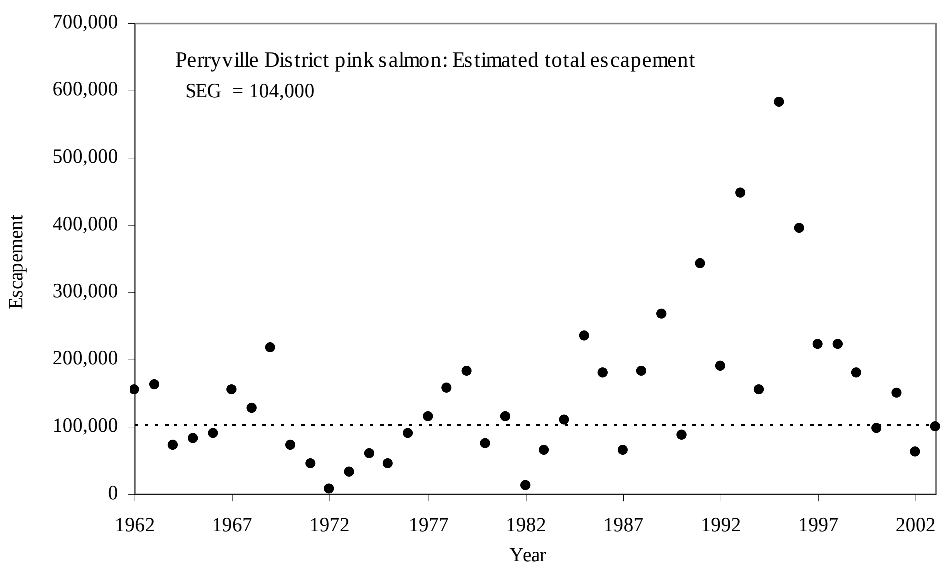
Appendix C17.–Peak aerial surveys and total estimated escapement of pink salmon in the Perryville District with existing escapement goals depicted.

System: **Perryville District**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG range (dashed lines).



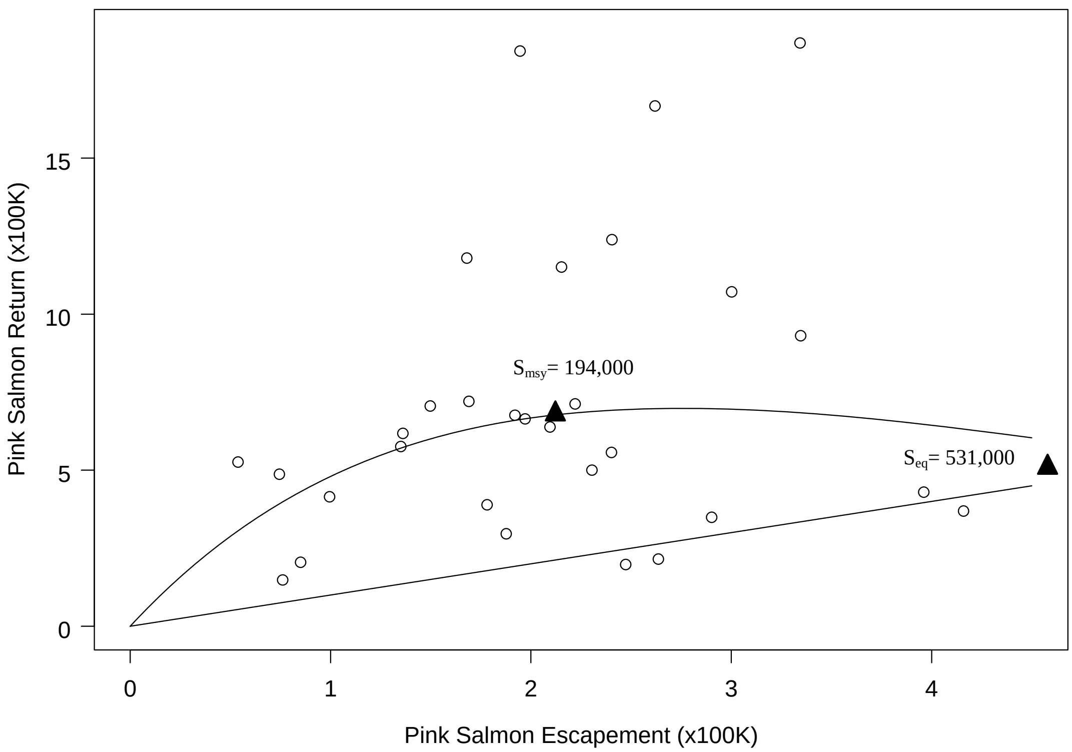


Appendix C18.–Ricker stock-recruitment curves for pink salmon in the Western and Perryville Districts combined.

System: **Western and Perryville Districts combined**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2001 all brood years. The solid line represents the multiplicative error Ricker curve and the solid straight line represents replacement.



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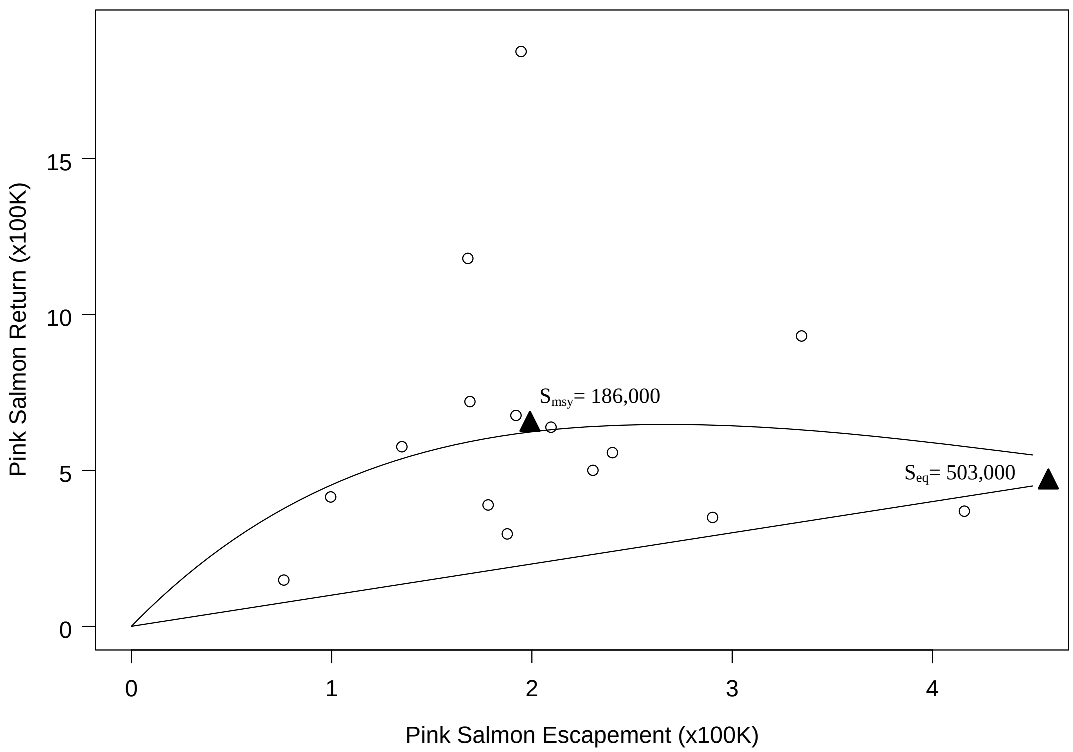
System: **Western and Perryville Districts combined**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2000 even brood years. The solid line represents the multiplicative error Ricker curve and the solid straight line represents replacement.



Appendix C19.–Description of stocks and escapement goals for pink salmon in the entire CMA.

System: **Entire CMA**

Species: **pink salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 779,500 (1999)
Recommended escapement goal:	BEG: even years: 327,000 to 737,000
	BEG: odd years: 541,000 to 1,177,000
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003.
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of 49 streams are used as an index for district-wide escapement.
Contrast:	Peak aerial surveys: 14.0
	Estimated total escapement: 83.3
Methodology:	Ricker spawner-recruit model (all years additive error, all years multiplicative error, even years additive error, even years multiplicative error, odd years additive error)
Autocorrelation:	None
Comments:	Ricker curves with additive error using 1972-2002 for even years and 1973-2003 for odd years were significant.

Appendix C20.–Peak aerial surveys and total estimated escapement of pink salmon in the entire CMA.

System: **Entire CMA**

Species: **pink salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		913,100
1963		706,500
1964		993,800
1965		375,600
1966		705,400
1967		340,000
1968		817,800
1969		767,900
1970		580,600
1971		417,100
1972	100,175	41,200
1973	142,395	159,100
1974	231,971	227,600
1975	259,680	238,100
1976	566,060	510,600
1977	433,453	749,800
1978	549,100	912,100
1979	632,710	858,800
1980	688,675	742,200
1981	501,745	597,900
1982	480,220	389,300
1983	434,840	158,800
1984	810,500	1,001,500
1985	287,300	522,200
1986	694,050	926,900
1987	546,590	385,300
1988	1,189,720	1,657,900
1989	771,000	1,434,800
1990	901,015	1,082,000
1991	559,255	778,600
1992	1,212,610	1,826,900
1993	812,600	1,181,800
1994	1,213,320	1,383,500
1995	1,406,200	3,432,100
1996	1,079,000	1,956,300
1997	1,236,275	2,469,500
1998	1,035,710	1,881,700
1999	513,150	1,344,300
2000	1,106,300	1,213,000
2001	814,700	2,363,500
2002	1,266,100	1,028,053
2003	1,330,200	2,345,617

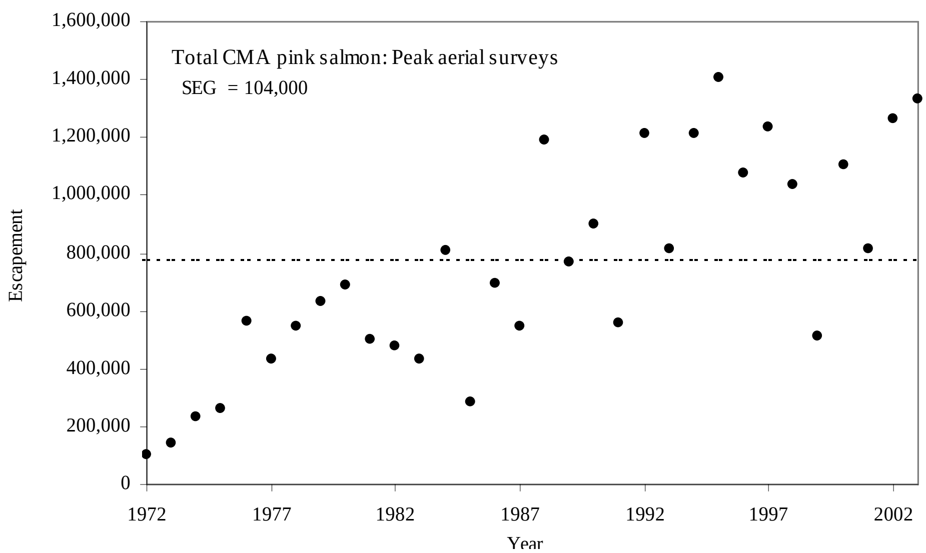
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

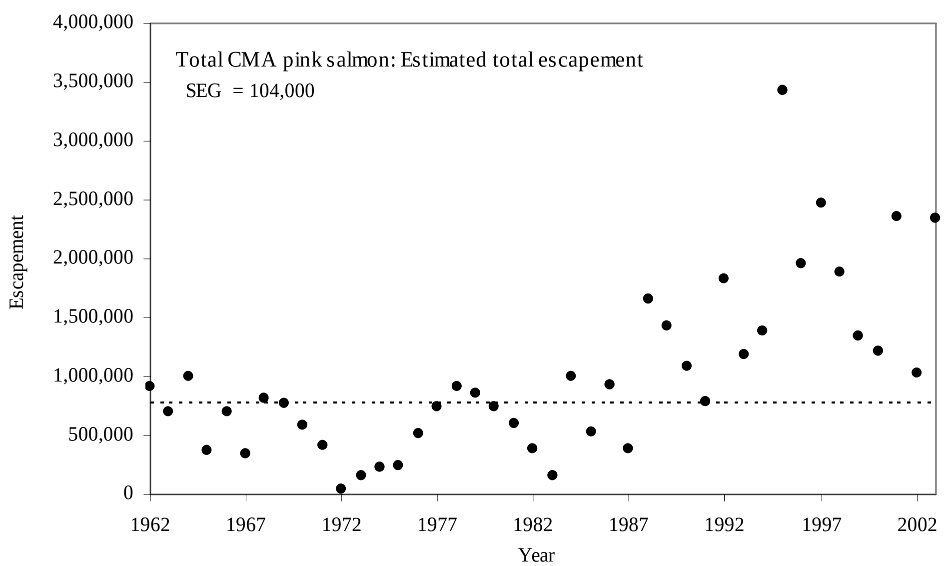
Appendix C21.–Peak aerial surveys and total estimated escapement of pink salmon in the entire CMA with existing escapement goals depicted.

System: **Entire CMA**

Species: **pink salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG range (dashed lines).



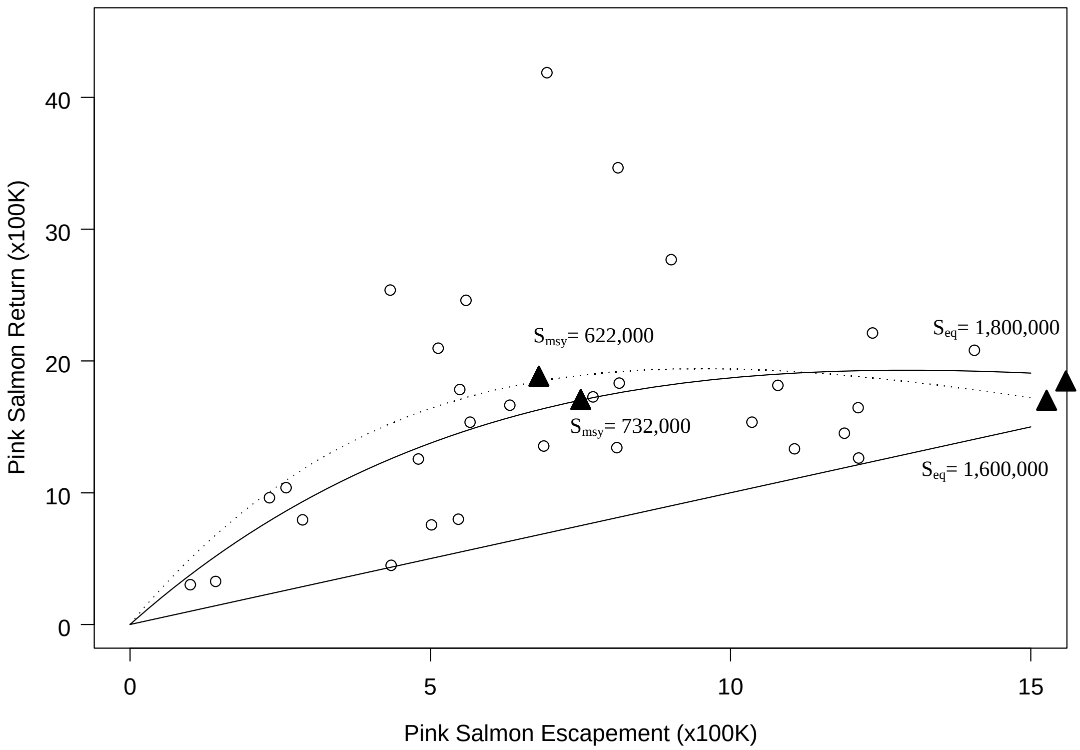


Appendix C22.–Ricker stock-recruitment curves for pink salmon in the entire CMA.

System: **Entire CMA**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2001 all brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



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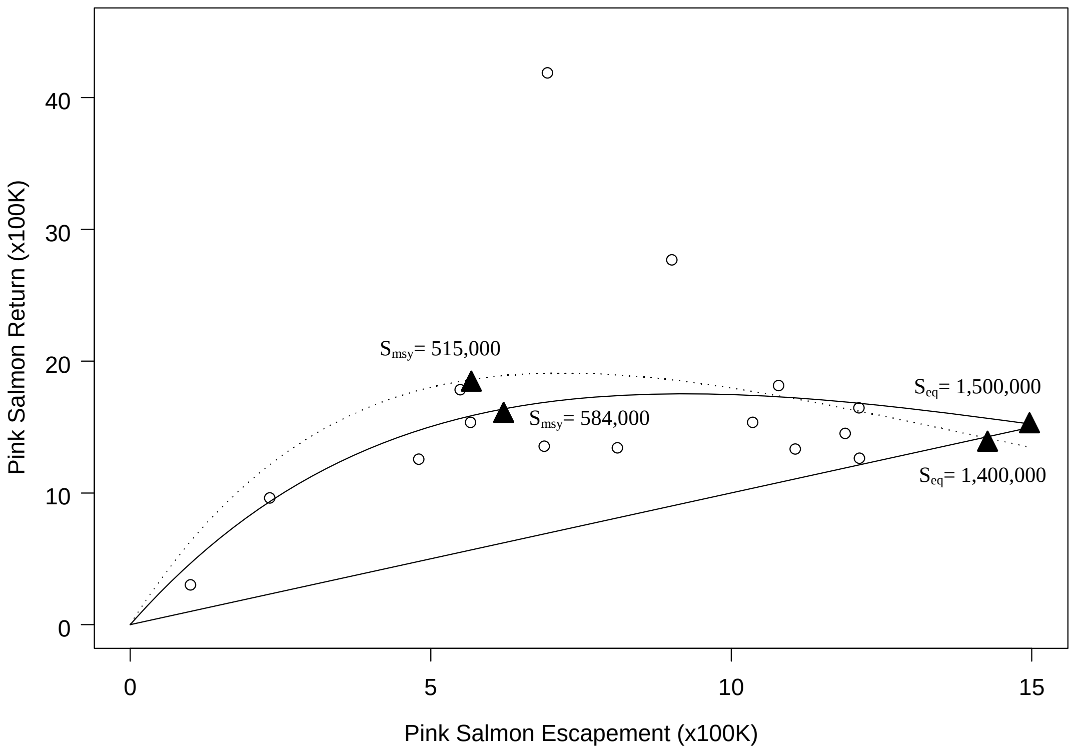
System: **Entire CMA**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1972 – 2000 even brood years. The dotted line represents the additive error Ricker curve, the solid line represents the multiplicative error Ricker curve, and the solid straight line represents replacement.



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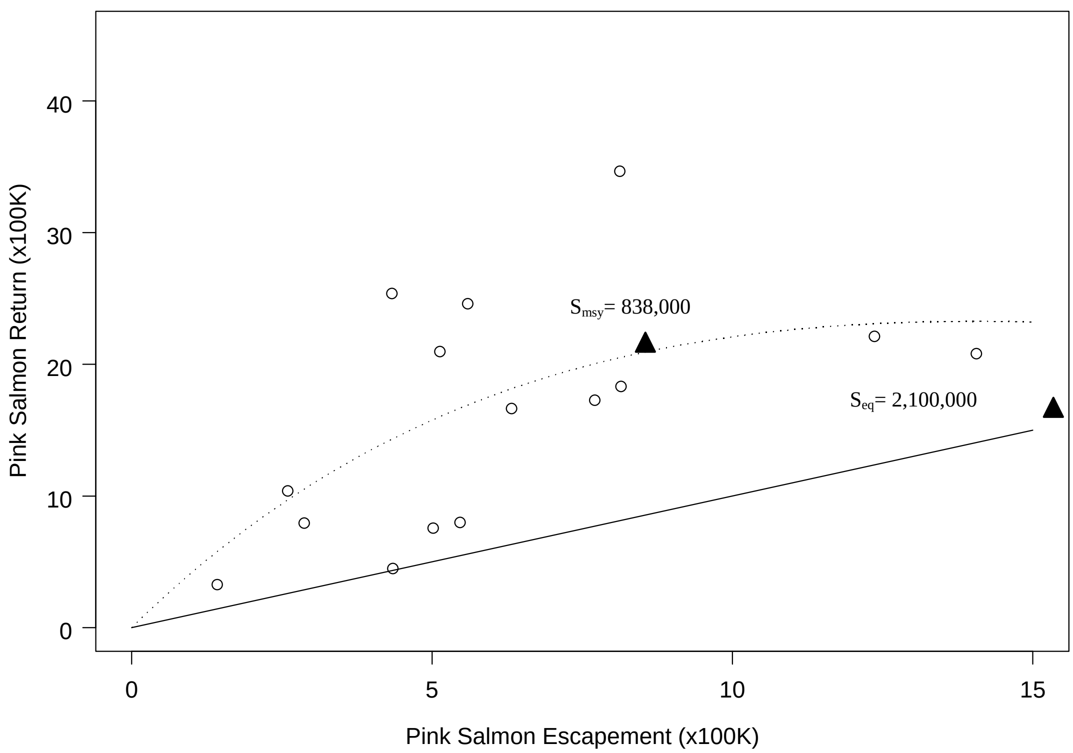
System: **Entire CMA**

Species: **pink salmon**

Ricker stock-recruitment relationship, 1973 – 2001 odd brood years. The dotted line represents the additive error Ricker curve and the solid straight line represents replacement.



APPENDIX D: CHUM SALMON ESCAPEMENT GOAL REVIEW

Appendix D1.-Description of stocks and escapement goals for Eastern District chum salmon.

System: **Eastern District**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 93,700 (1999)
Recommended escapement goal:	MO: 25,200
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of 20 streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 37.4
	Estimated total escapement: 83.0
Methodology:	Percentile approach, proportion of the entire CMA SEG
Comments:	Management objective estimated from a proportion of the area-wide SEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Eastern District.

Appendix D2.–Peak aerial surveys and total estimated escapement of chum salmon in the Eastern District.

System: Eastern District

Species: chum salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		79,600
1963		55,200
1964		165,400
1965		58,000
1966		58,000
1967		89,800
1968		63,000
1969		66,500
1970		126,000
1971		219,200
1972	74,350	107,400
1973	50,575	59,100
1974	48,980	76,300
1975	34,010	41,300
1976	93,600	122,300
1977	25,330	54,500
1978	88,150	55,800
1979	63,125	79,500
1980	86,900	107,000
1981	77,125	126,000
1982	130,150	145,400
1983	23,565	50,200
1984	135,850	214,700
1985	7,110	4,900
1986	5,200	8,500
1987	20,790	38,300
1988	124,000	221,900
1989	49,900	74,300
1990	102,700	139,700
1991	42,600	70,400
1992	194,235	306,900
1993	25,670	135,200
1994	113,800	129,200
1995	82,500	112,800
1996	87,000	130,500
1997	80,030	290,000
1998	67,350	97,700
1999	40,300	167,100
2000	127,310	216,000
2001	135,400	406,900
2002	102,450	174,850
2003	69,590	152,854

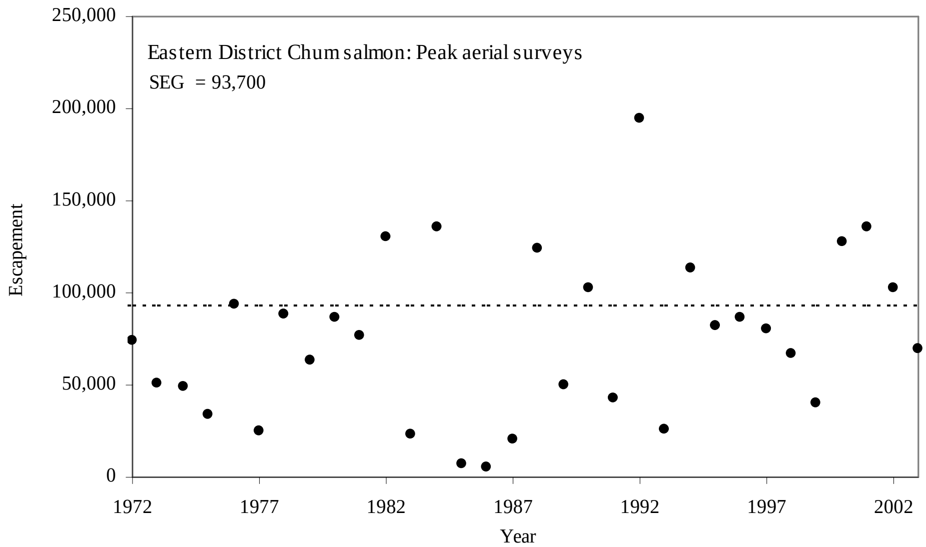
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

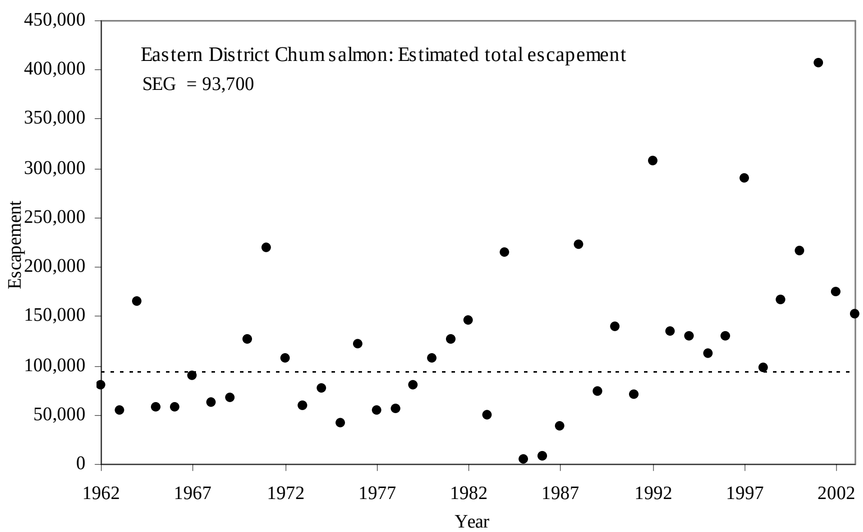
Appendix D3.–Peak aerial surveys and total estimated escapement of chum salmon in the Eastern District with existing escapement goals depicted.

System: **Eastern District**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).





Appendix D4.–Description of stocks and escapement goals for Central District chum salmon.

System: **Central District**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 39,500 (1999)
Recommended escapement goal:	MO: 6,700
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of six streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 112.1
	Estimated total escapement: 26.6
Methodology:	Risk analysis (Central District), percentile approach, proportion of the entire CMA SEG
Comments:	Management objective estimated from a proportion of the area-wide SEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Central District.

Appendix D5.–Peak aerial surveys and total estimated escapement of chum salmon in the Central District.

System: Central District

Species: chum salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		40,400
1963		34,000
1964		24,200
1965		19,200
1966		10,000
1967		17,200
1968		14,500
1969		6,500
1970		23,400
1971		29,100
1972	7,510	14,200
1973	2,430	12,200
1974	7,400	18,100
1975	4,350	18,800
1976	12,600	17,800
1977	2,600	9,300
1978	8,900	13,800
1979	8,400	44,800
1980	18,580	34,200
1981	15,575	26,100
1982	10,700	49,400
1983	900	17,000
1984	15,000	35,400
1985	7,509	9,600
1986	12,175	31,000
1987	3,700	17,500
1988	38,500	55,800
1989	5,300	34,700
1990	2,150	28,000
1991	28,100	18,000
1992	100,900	173,100
1993	15,700	39,400
1994	27,200	102,600
1995	17,500	44,500
1996	19,570	45,100
1997	10,200	65,700
1998	11,000	32,000
1999	22,020	32,400
2000	10,700	22,700
2001	2,400	36,500
2002	5,000	11,615
2003	40,010	43,191

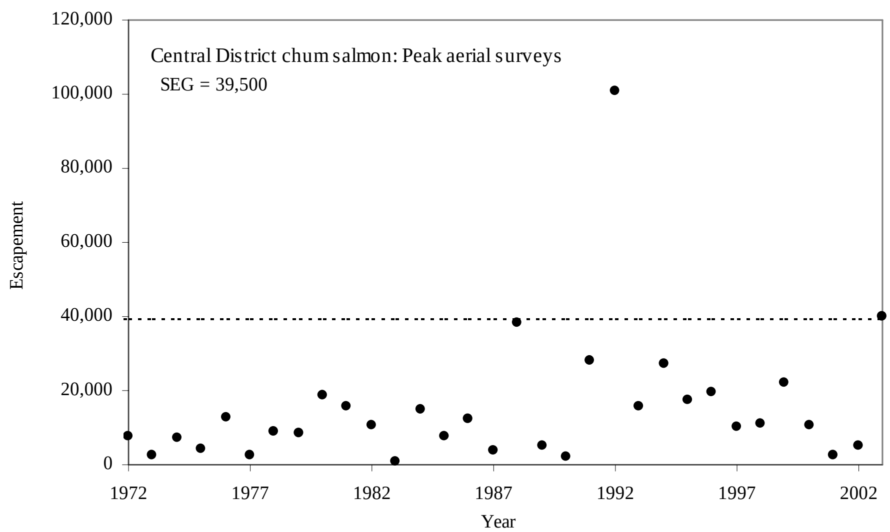
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

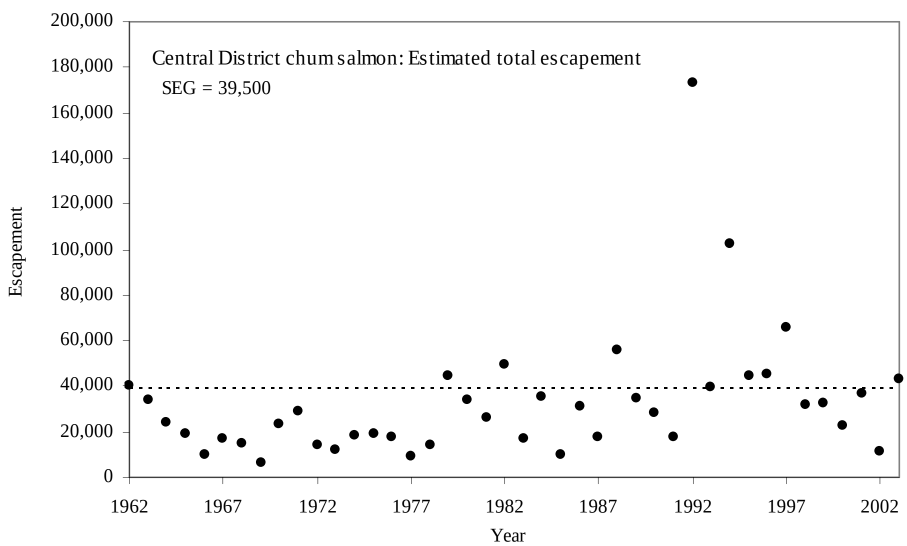
Appendix D6.–Peak aerial surveys and total estimated escapement of chum salmon in the Central District with existing escapement goals depicted.

System: **Central District**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



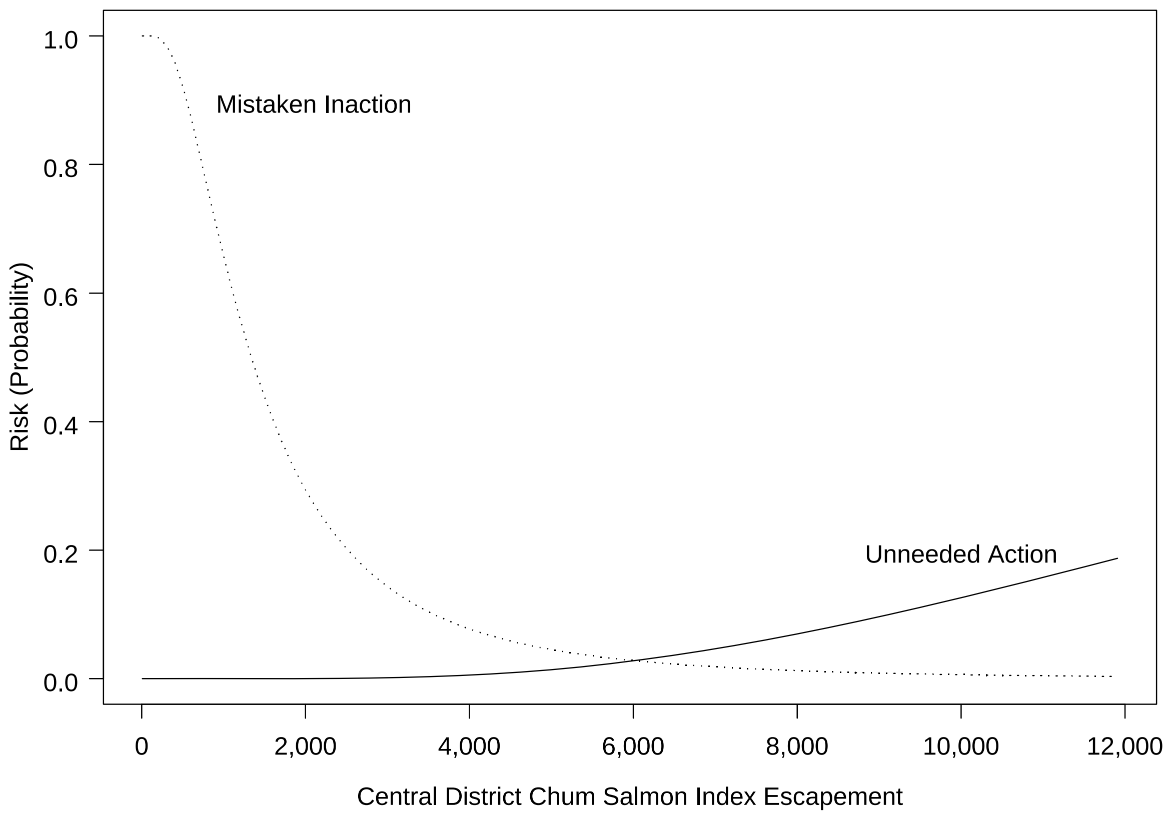


Appendix D7.–Risk analysis for chum salmon in the Central District.

System: **Central District**

Species: **chum salmon**

Central District chum salmon risk analysis



Appendix D8.–Description of stocks and escapement goals for Chignik Bay District chum salmon.

System: **Chignik Bay District**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 2,000 (1999)
Recommended escapement goal:	MO: 200
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1972 to 2003. A total of three streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial surveys: 1,500.0
	Estimated total escapement: 313.4
Methodology:	Proportion of the entire CMA SEG
Comments:	Management objective estimated from a proportion of the area-wide SEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Central District.

Appendix D9.–Peak aerial surveys and total estimated escapement of chum salmon in the Chignik Bay District.

System: **Chignik Bay District**

Species: **chum salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		6,700
1963		800
1964		2,500
1965		3,000
1966		4,500
1967		4,000
1968		1,000
1969		1,500
1970		21,000
1971		7,100
1972	2	3,300
1973	0	700
1974	0	2,100
1975	25	2,100
1976	0	2,400
1977	0	2,000
1978	0	2,100
1979	500	1,600
1980	0	300
1981	0	500
1982	500	1,400
1983	0	100
1984	0	300
1985	0	0
1986	0	0
1987	0	100
1988	2,400	15,300
1989	2,415	4,200
1990	1,500	1,500
1991	0	0
1992	0	100
1993	200	300
1994	500	1,500
1995	200	10,300
1996	3,000	16,400
1997	500	18,500
1998	0	4,500
1999	5	2,300
2000	0	100
2001	0	4,100
2002	0	67
2003	700	899

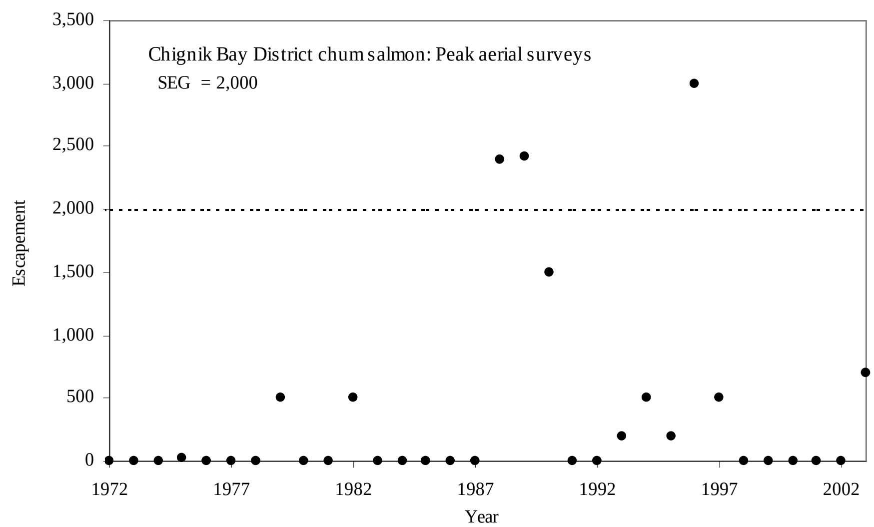
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

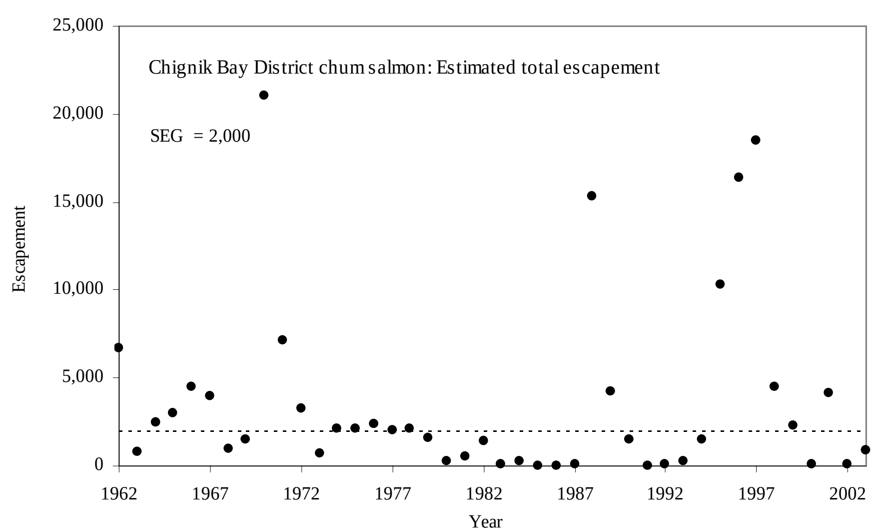
Appendix D10.–Peak aerial surveys and total estimated escapement of chum salmon in the Chignik Bay District with existing escapement goals depicted.

System: **Chignik Bay District**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).





Appendix D11.–Description of stocks and escapement goals for Western District chum salmon.

System: **Western District**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 12,500 (1999)
Recommended escapement goal:	MO: 5,400
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1973 to 2003. A total of six streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial survey: 14.1
	Estimated total escapement: 34.7
Methodology:	Risk analysis (Western District), percentile approach, proportion of the entire CMA SEG
Comments:	Management objective estimated from a proportion of the area-wide SEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Western District.

Appendix D12.–Peak aerial surveys and total estimated escapement of chum salmon in the Western District.

System: Western District

Species: chum salmon

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		83,100
1963		10,000
1964		37,000
1965		25,000
1966		12,000
1967		24,000
1968		9,600
1969		27,600
1970		49,700
1971		184,100
1972		59,000
1973	28,650	35,600
1974	29,330	39,400
1975	36,720	43,400
1976	25,200	55,000
1977	39,400	70,400
1978	16,750	27,300
1979	39,625	42,500
1980	43,500	56,500
1981	46,200	70,300
1982	28,350	35,400
1983	12,620	20,100
1984	48,100	73,800
1985	14,350	34,600
1986	6,500	5,300
1987	10,150	19,700
1988	20,920	27,400
1989	5,200	7,400
1990	9,350	28,800
1991	27,400	38,100
1992	43,465	53,300
1993	8,900	14,000
1994	14,500	23,000
1995	6,100	45,700
1996	9,800	44,500
1997	31,004	60,500
1998	9,100	30,600
1999	3,410	16,300
2000	5,300	12,700
2001	1,700	35,500
2002	9,200	17,082
2003	8,100	39,050

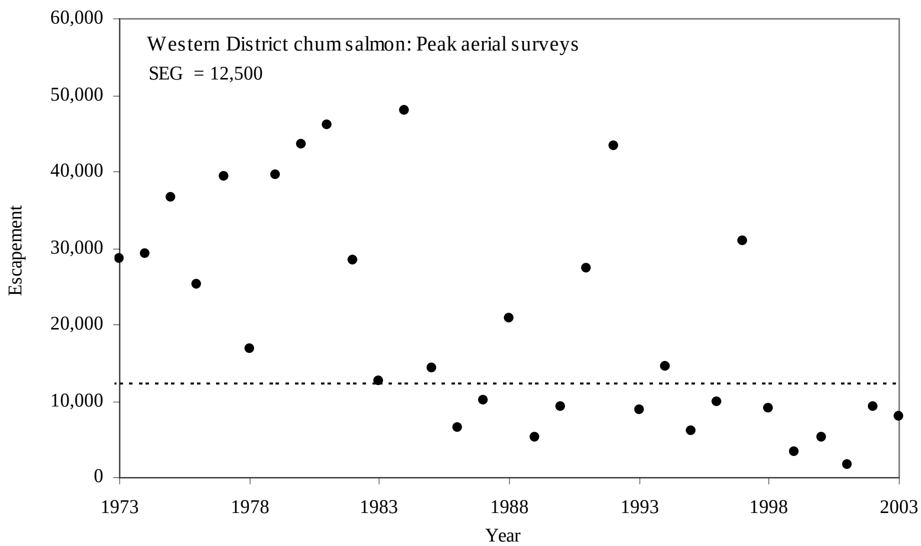
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

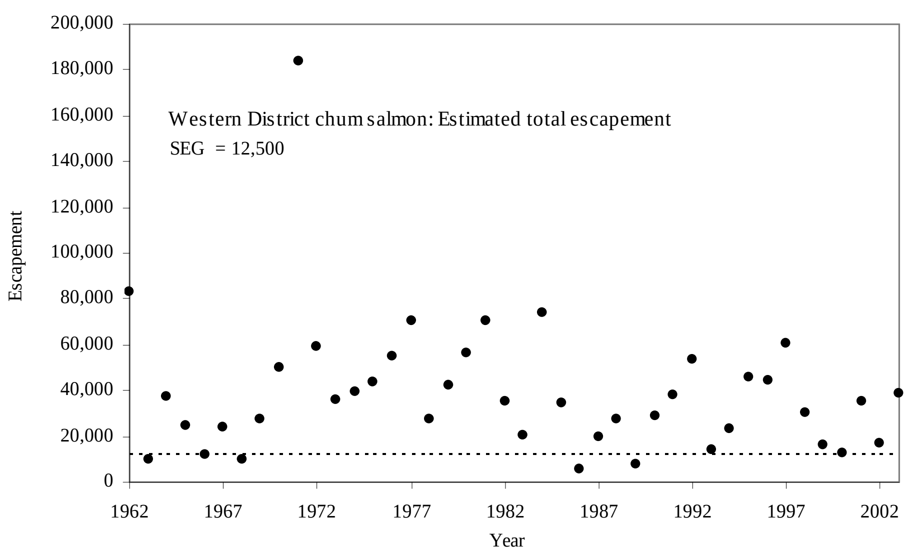
Appendix D13.–Peak aerial surveys and total estimated escapement of chum salmon in the Western District with existing escapement goals depicted.

System: **Western District**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



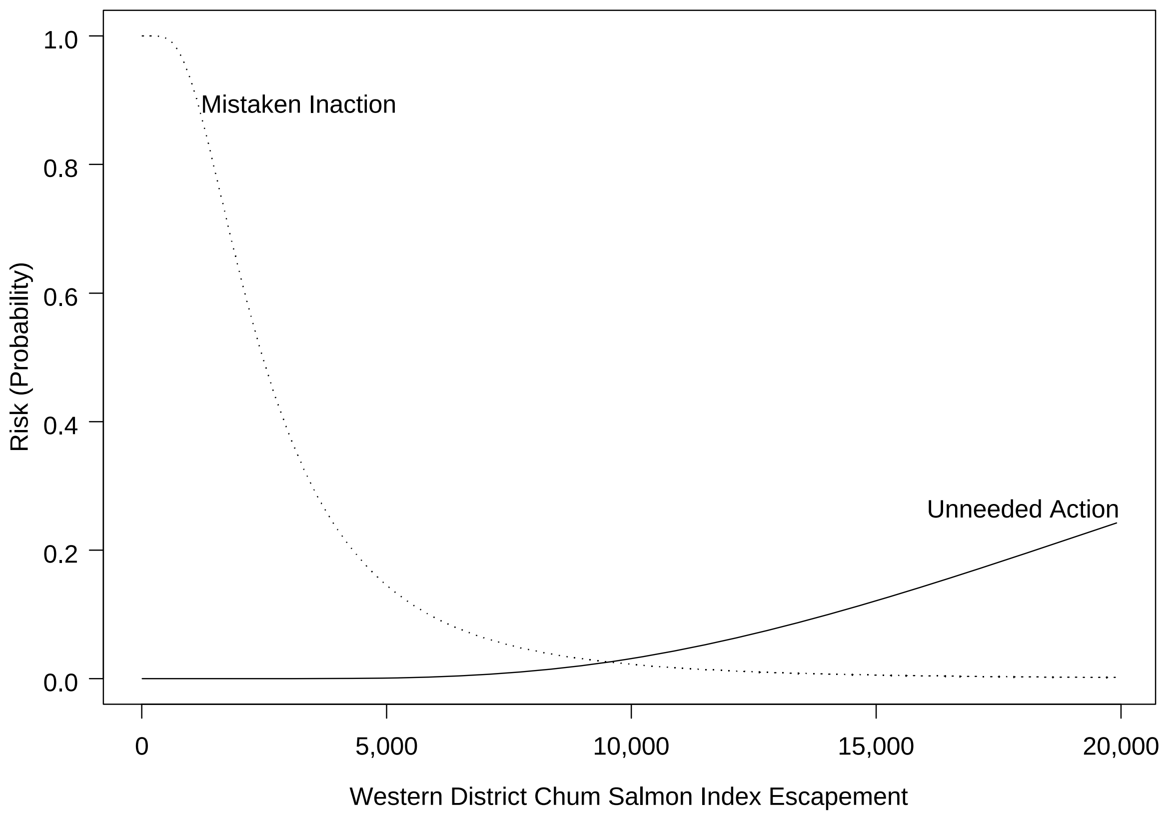


Appendix D14.–Risk analysis for chum salmon in the Western District.

System: **Western District**

Species: **chum salmon**

Western District chum salmon risk analysis.



Appendix D15.–Description of stocks and escapement goals for Perryville District chum salmon.

System: **Perryville District**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 59,000 (1999)
Recommended escapement goal:	MO: 12,800
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1973 to 2003. A total of seven streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial survey: 46.7
	Estimated total escapement: 343.2
Methodology:	Risk analysis (Perryville District), percentile approach, proportion of the entire CMA SEG
Comments:	Management objective estimated from a proportion of the area-wide SEG based on the proportion of peak aerial survey escapement estimates in the entire Chignik Management Area that occur in the Perryville District.

Appendix D16.–Peak aerial surveys and total estimated escapement of chum salmon in the Perryville District.

System: **Perryville District**

Species: **chum salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		10,500
1963		7,000
1964		26,000
1965		7,000
1966		20,400
1967		5,700
1968		1,800
1969		1,000
1970		13,000
1971		30,000
1972		11,500
1973	3,900	9,300
1974	6,160	12,500
1975	9,550	20,500
1976	7,100	8,900
1977	6,700	15,400
1978	3,800	5,300
1979	6,000	12,800
1980	13,800	29,100
1981	12,500	19,300
1982	17,100	23,600
1983	5,100	8,200
1984	39,700	46,000
1985	12,850	12,900
1986	6,700	7,700
1987	5,920	9,800
1988	24,220	41,400
1989	11,420	15,900
1990	21,275	55,800
1991	177,500	343,200
1992	25,885	40,300
1993	33,060	66,800
1994	70,700	126,000
1995	67,300	134,600
1996	67,055	132,000
1997	65,206	152,800
1998	68,225	214,500
1999	14,005	117,300
2000	7,031	51,900
2001	55,906	67,800
2002	13,320	32,020
2003	39,351	64,331

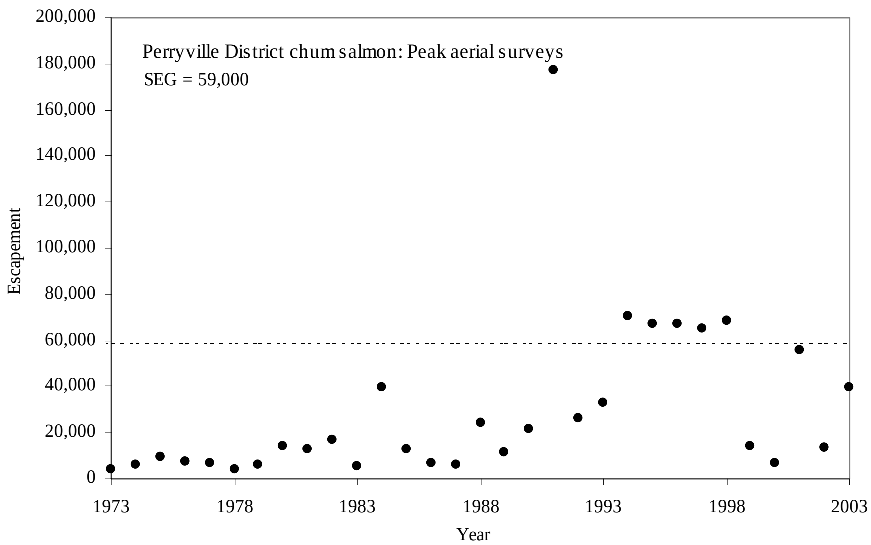
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

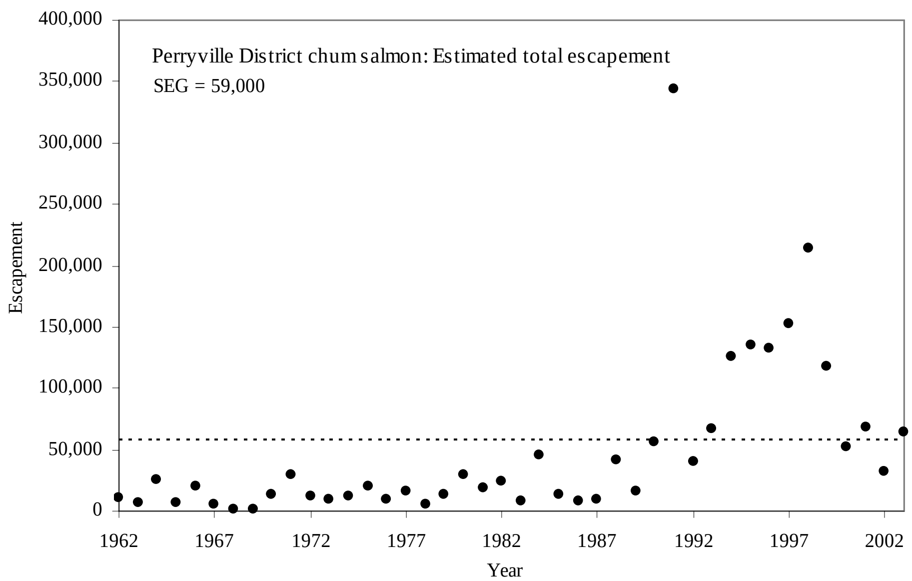
Appendix D17.–Peak aerial surveys and total estimated escapement of chum salmon in the Perryville District with existing escapement goals depicted.

System: **Perryville District**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



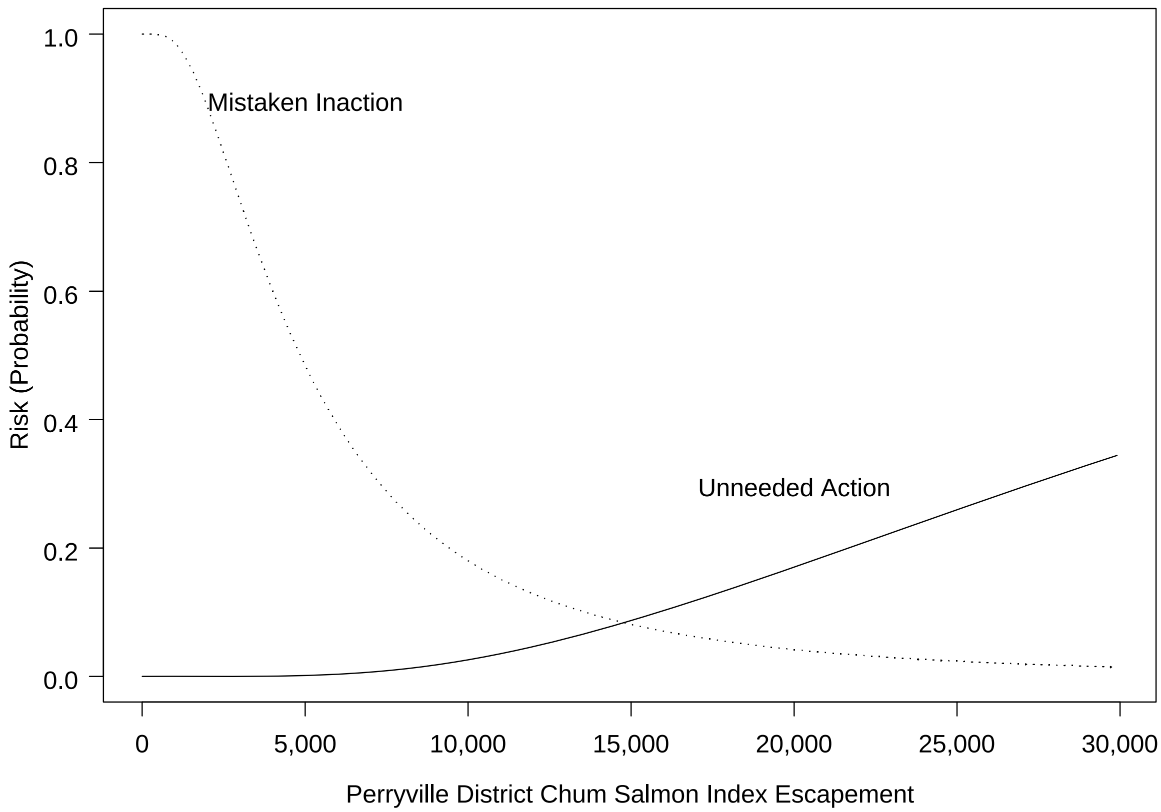


Appendix D18.–Risk analysis for chum salmon in the Perryville District.

System: **Perryville District**

Species: **chum salmon**

Perryville District chum salmon risk analysis.



Appendix D19.–Description of stocks and escapement goals for chum salmon in the entire CMA.

System: **Entire CMA**

Species: **chum salmon**

Description of stock and escapement goals.

Regulatory area	Chignik Management Area – Westward Region
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Previous escapement goal:	SEG: 206,700 (1999)
Recommended escapement goal:	SEG: 50,400
Optimal escapement goal:	none
Inriver goal:	none
Action points:	none
Escapement enumeration:	Aerial survey, 1962-2003
Data summary:	
Data quality:	Fair
Data type:	Fixed-wing aerial surveys with estimated total escapement from 1962 to 2003. Post 1984 estimated total escapement is computed by area-under-the-curve methodology using a 15 day stream life (Johnson and Barrett 1988). Peak surveys are available from 1973 to 2003. A total of 42 streams are used as an index for district-wide escapement. No stock specific harvest information is available.
Contrast:	Peak aerial survey: 11.9
	Estimated total escapement: 11.2
Methodology:	Risk Analysis
Comments:	Recommend adoption of risk analysis results.

Appendix D20.–Peak aerial surveys and total estimated escapement of chum salmon in the entire CMA.

System: **Entire CMA**

Species: **chum salmon**

Data available for analysis of escapement goals.

Year	Peak Aerial Survey	Estimated Total Escapement [a]
1962		220,300
1963		107,000
1964		255,100
1965		112,200
1966		104,900
1967		140,700
1968		89,900
1969		103,100
1970		233,100
1971		469,500
1972		195,400
1973	85,555	116,900
1974	91,870	148,400
1975	84,655	126,100
1976	138,500	206,400
1977	74,030	151,600
1978	117,600	104,300
1979	117,650	181,200
1980	162,780	227,100
1981	151,400	242,200
1982	186,800	255,200
1983	42,185	95,600
1984	238,650	370,200
1985	41,819	62,000
1986	30,575	52,500
1987	40,560	85,400
1988	210,040	361,800
1989	74,235	136,500
1990	136,975	253,800
1991	275,600	469,700
1992	364,485	573,700
1993	83,530	255,700
1994	226,700	382,300
1995	173,600	347,900
1996	186,425	368,500
1997	186,940	587,500
1998	155,675	379,300
1999	79,740	335,400
2000	150,341	303,400
2001	195,406	550,800
2002	129,970	235,634
2003	157,751	300,325

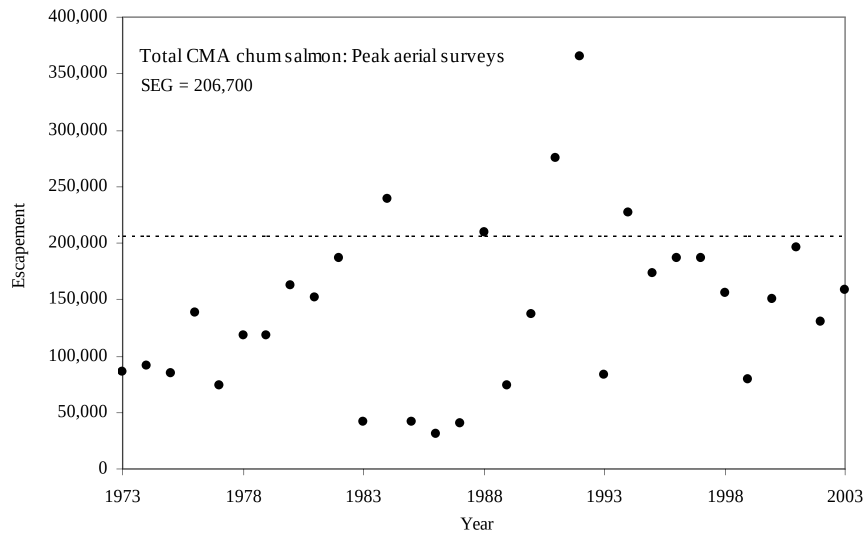
[a] Post 1984 escapement estimates computed by area-under-the-curve methodology using a 15.0 day average steam life (Johnson and Barrett 1988)

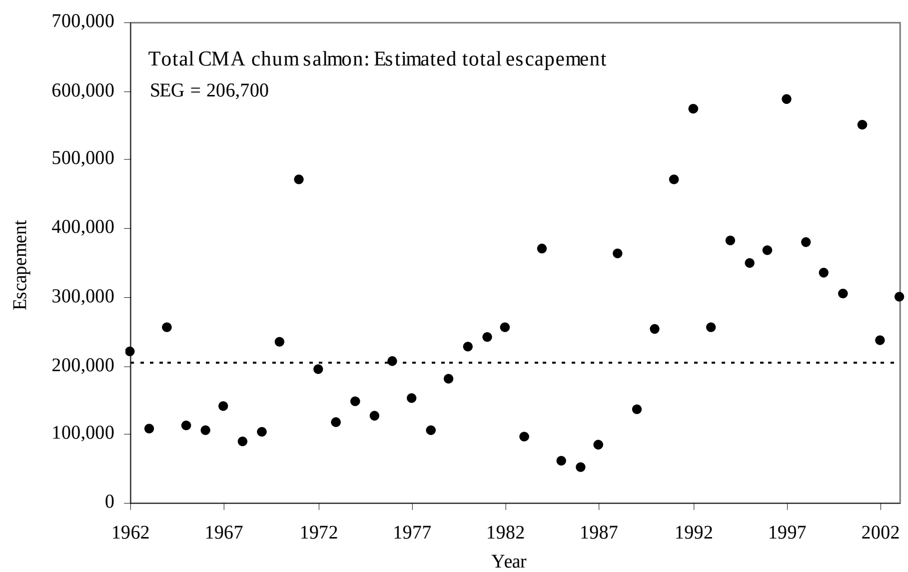
Appendix D21.–Peak aerial surveys and total estimated escapement of chum salmon in the entire CMA with existing escapement goals depicted.

System: **Entire CMA**

Species: **chum salmon**

Observed escapement by year (solid circles for aerial surveys) and current SEG (dashed lines).



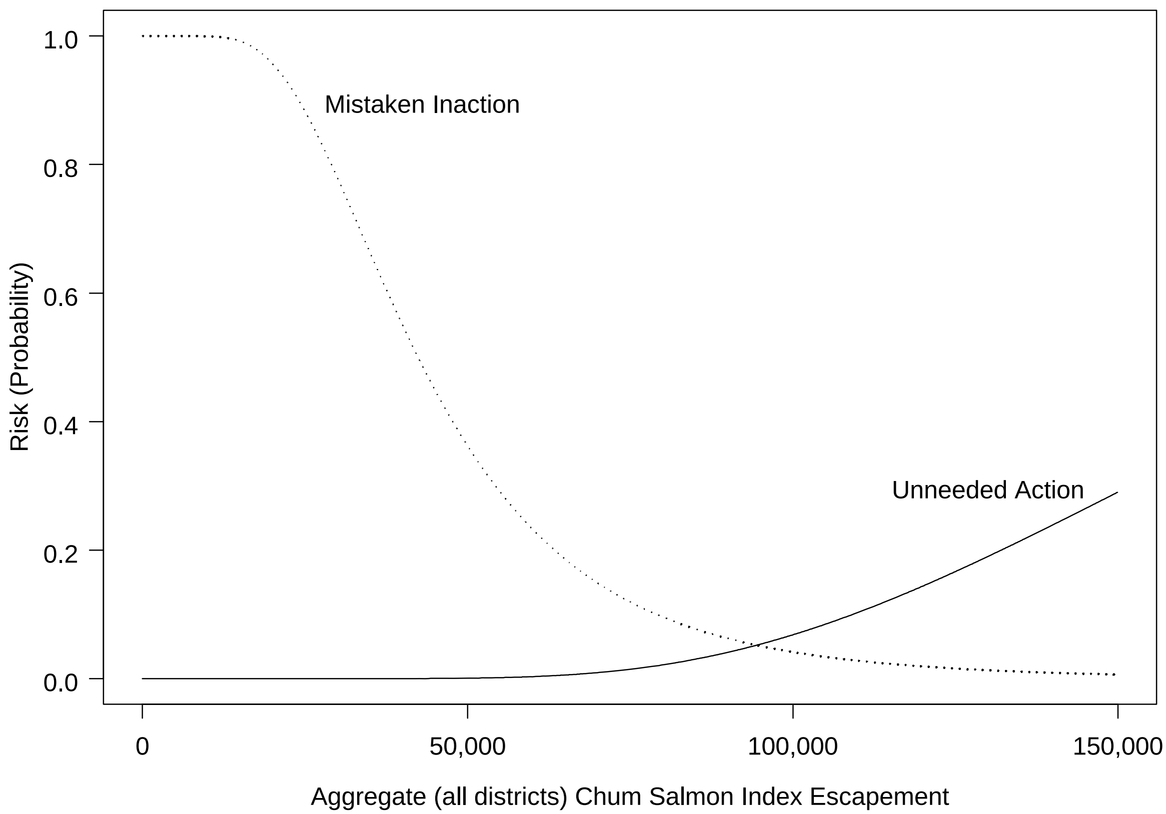


Appendix D22.–Risk analysis for chum salmon in the entire CMA.

System: **Entire CMA**

Species: **chum salmon**

Entire CMA chum salmon risk analysis using 78% decrease in mean.



-Continued-

System: **Entire CMA**

Species: **chum salmon**

Entire CMA chum salmon risk analysis using 95% decrease in mean.