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Review of Salmon Escapement Goals in the Chignik Management Area, 2020

by

Heather Finkle

Kevin L. Schaberg

M. Birch Foster

and

Tyler Polum

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

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Weights and measures (metric)

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

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	′
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	″
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by

Heather Finkle
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

Kevin L. Schaberg
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

M. Birch Foster
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

and

Tyler Polum
Alaska Department of Fish and Game, Division of Sport Fish, Kodiak

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

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Heather Finkle, Kevin L. Schaberg, and M. Birch Foster
Alaska Department of Fish and Game, Division of Commercial Fisheries,
351 Research Court, Kodiak, Alaska 99615, USA

and

Tyler Polum
Alaska Department of Fish and Game, Division of Sport Fish,
351 Research Court, Kodiak, Alaska 99615, USA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In October 2020, an interdivisional team of staff from the Alaska Department of Fish and Game reviewed existing Pacific salmon *Oncorhynchus* escapement goals in the Chignik Management Area (CMA). The 6 CMA salmon escapement goals were last reviewed in 2018. Starting in 2020, the team reviewed recent data to determine whether substantial new information existed to warrant analyzing and updating the goals. The team determined Chignik sockeye salmon warranted further review. The team revised the early- and late-run sockeye salmon goals to a single biological escapement goal (BEG) of 450,000 to 800,000 fish to address overlaps and subsequent bottlenecks in freshwater rearing between the 2 major stocks. The early- and late-run sockeye salmon goals will be eliminated, and no new goals were added for systems currently without escapement goals.

Keywords: Pacific salmon, *Oncorhynchus*, escapement goal, Chignik, Chignik Management Area, Chignik Lake, Black Lake, stock status

INTRODUCTION

This report documents the 2020 review of salmon escapement goals in the Chignik Management Area (CMA) based on the Alaska Board of Fisheries' (BOF) *Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222) and the *Policy for Statewide Salmon Escapement Goals* (5 AAC 39.223). A summary of this review is provided to the directors of the divisions of Commercial Fisheries and Sport Fish of the Alaska Department of Fish and Game (ADF&G), and revisions are intended to take effect for salmon stocks returning in 2023. Salmon escapement goals in the CMA were last reviewed in 2018 (Schaberg et al. 2019).

Three important terms defined in the *Policy for the Management of Sustainable Salmon Fisheries* are as follows:

- *biological escapement goal* (BEG): the escapement that provides the greatest potential for maximum sustained yield (MSY),
- *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 or managed for, and
- *inriver run goal* (IRRG): a specific management objective for salmon stocks that are subject to harvest upstream of the point where escapement is estimated; the inriver run goal will be set in regulation by the BOF and is composed of the SEG, BEG, or optimal escapement goal (OEG), plus specific allocations to inriver fisheries.

Since the implementation of the *Policy for Statewide Salmon Escapement Goals* in 2001, escapement goals for the CMA have been reviewed 6 times (Witteveen et al. 2005, Witteveen et al. 2007, Nemeth et al. 2010, Sagalkin et al. 2013, Schaberg et al. 2015, Schaberg et al. 2019). These reviews correspond with area BOF meetings, which have historically been on a 3-year cycle; however, the CMA cycle was altered in 2014 and the review in 2015 only reflected 2 additional years of data (2013–2014). The 2018 escapement goal review proceeded as planned, but the 2020 CMA review cycle was delayed by the COVID-19 global pandemic, with the BOF meeting delayed until 2023.

In October 2020, the Salmon Escapement Goal Interdivisional Review Team (hereafter referred to as *the team*) was formed to review the existing CMA salmon escapement goals and recent escapements for stocks without escapement goals. The team included staff from the Division of Commercial Fisheries (CF) and the Division of Sport Fish (SF): Kevin Schaberg (CF), Tim McKinley (SF), Nicholas Sagalkin (CF), Heather Finkle (CF), M. Birch Foster (CF), Michelle Wattum (CF), Jeff Wadle (CF), Michelle Stratton (CF), Ross Renick (CF), Bob Murphy (CF), Lisa Fox (CF), Cassandra Whiteside (CF), Tyler Lawson (CF), Bill Templin (CF), Andrew Munro (CF), Rich Brenner (CF), Sarah Power (CF), Jim Hasbrouck (SF), Tom Vania (SF), Dan Bosch (SF), Mark Witteveen (SF), Adam St. Saviour (SF), Jason Dye (SF), and Tyler Polum (SF). The team met again in February 2022 to discuss the review.

For this review the team (1) reviewed recent escapements to all stocks with escapement goals; (2) determined 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; (3) determined the most appropriate methods to evaluate the escapement goal ranges; (4) estimated the escapement goal for each stock and compared these estimates with the current goal; (5) determined if a goal could be developed for any stocks or stock-aggregates that currently have no goal; and (6) presented findings from analyses for each goal evaluated to the directors of the divisions of Commercial Fisheries and Sport Fish.

MANAGEMENT AREA

The CMA, also designated as Area L, encompasses all coastal waters and inland drainages on the south side of the Alaska Peninsula, bounded by a line extending 135° southeast for 3 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 3 miles from Kupreanof Point at 55°33.98′ N lat, 159°35.88′ W long (Figure 1). The area is divided into 5 commercial fishing districts: Eastern, Central, Chignik Bay, Western, and Perryville Districts. These districts are further divided into 14 sections and 38 statistical reporting areas.

The Chignik watershed in the CMA consists of 2 interconnected lakes (Black and Chignik Lakes) with a single outlet river (the Chignik River) that empties into the Chignik Lagoon (Figure 2). All 5 species of Pacific salmon *Oncorhynchus* return to the Chignik River; sockeye salmon *O. nerka* returns consist of an early run and a late run, and Chinook salmon *O. tshawytscha* are only monitored in the Chignik River. Pink *O. gorbuscha*, chum *O. keta*, and coho *O. kisutch* salmon also return to other streams throughout the CMA.

BACKGROUND

One Chinook salmon stock in the CMA has an established BEG and is natal to the Chignik River (Appendix A). Reviews of the goal in 2013, 2015, and 2018 found no compelling evidence to support changing the goal. Chinook salmon escapement is enumerated through the Chignik River weir. Recent reductions in age samples of the escapement have probably affected the overall age composition estimate. Harvest occurs during directed sport and subsistence fisheries and incidentally in commercial fisheries targeting sockeye, pink, and chum salmon.

Two sockeye salmon stocks in the CMA have established escapement goals (Appendix B). Both of these stocks return to the Chignik River watershed (Figure 2). The majority of the early run (Black Lake stock) enters the watershed from June to 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 Chignik Lake tributaries and Chignik Lake shoal areas (Pappas et al. 2003). Although the peak periods of passage for each stock are usually a month apart, there is a period of overlap when both stocks are entering the watershed.

Sockeye salmon bound for Black and Chignik Lakes are harvested primarily in commercial and subsistence fisheries. Escapement of both stocks is enumerated as they transit Chignik River through a weir outfitted with a video camera system. Achievement of escapement goals for the early and late runs has relied on estimates of the numbers of each stock in the daily escapement. Stock apportionment has been determined using various methods over time. Prior to 1980, time-of-entry relationships based on tagging studies and age groups were employed to divide the catch and escapement between the 2 runs (Dahlberg 1968). From 1980 to 2003, except in 1982, stock separation was accomplished using scale pattern analysis (Witteveen and Botz 2004). Beginning in 2004, an estimate of the early-run escapement was based on weir counts through July 4. After July 4, the fish that passed upstream through the weir were assumed to be late-run fish.[1] Stock apportionment estimated by this method was not notably different than those from scale pattern analysis. Beginning in 2014, genetic stock identification was used to separate the early- and late-run stocks. In comparison to the transition date of July 4, logistic run timing during the overlap period suggested that using inseason genetic information resulted in more biologically sound escapement-based management (Anderson et al. 2013; Foster 2013). However, from 2014 through 2017, the inseason use of genetics to estimate early- and late-run stock proportions demonstrated the variable timing of entry into Chignik River and presented the department with the challenge of applying these proportions for management purposes. The genetic based inseason estimates did not provide effective inseason adaptive management tools because of the time-sensitive nature of fisheries management and the lag time between collecting samples and receiving genetics results. In 2020, as in 2018 and 2019, the central tendency of the genetic based logistic model was used to apportion escapement between the 2 runs inseason; however, genetic samples collected at the weir were used to inform postseason run reconstruction.[2]

Due to the late run timing of coho salmon returns to the CMA, there are no established coho salmon escapement goals. The vast majority of coho salmon escapement occurs in September after the Chignik River weir is pulled for the season and inclement fall weather precludes reliable aerial surveys for estimating escapement.

Pink salmon in the CMA are managed to achieve escapement goals based on the aggregates of index streams (Table 1; Appendix C). Separate areawide BEGs were established for odd and even years during the 2004 review (Witteveen et al. 2005) and amended to SEGs during the 2007 review (Witteveen et al. 2007). These aggregate goals were revised in 2015 and were composed of the respective sums of aerial survey escapement estimates for 8 individual index streams (Schaberg et al. 2015). The 2018 review did not indicate that the aggregate goal should change.

Chum salmon in the CMA are managed to achieve an escapement goal based on aggregates of index streams, similar to pink salmon (Table 1; Appendix D). This aggregate SEG was revised in 2015 and was composed of the respective sums of aerial survey escapement estimates for 6 individual index streams (Schaberg et al. 2015). The 2018 review did not indicate the aggregate goal should change.

METHODS

During the review process, 1 Chinook, 2 sockeye, 1 chum, and 2 pink salmon escapement goals were evaluated (Table 1). We conducted our review similarly to the 2018 review (Schaberg et al.

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[1] Witteveen, M. J. Chignik River inseason run apportionment. Alaska Department of Fish and Game, Kodiak memorandum addressed to Denby S. Lloyd, dated May 28, 2004.

[2] Foster, M. B., and D. M. Wilburn. Chignik inseason management 2018. Alaska Department of Fish and Game, Kodiak memorandum addressed to Nick Sagalkin, dated April 20, 2018.

2019), primarily examining recent (2018–2020) data and updating previous analyses. A formal meeting, via teleconference, to discuss review findings was held on October 26, 2020. The team also communicated on a regular basis by telephone and email, meeting again on February 4 and 9, 2022.

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 Table 2 and Clark et al. (2014). This evaluation was used to assist in determining the appropriate type of escapement goal to apply to each stock, as defined in the *Policy for the Management of Sustainable Salmon Fisheries* and the *Policy for Statewide Salmon Escapement Goals*.

ESCAPEMENT GOAL DETERMINATION

Biological Escapement Goal

In Alaska, most salmon BEGs are developed using Ricker (1954) spawner-recruit models (Munro and Brenner 2022). Data were fit to Ricker models using the Pacific salmon escapement analysis application (Hamazaki 2022) for this review. Bayesian Ricker models with and without time-varying α were used. The time-varying α Ricker model allows the α parameter of productivity to be assessed for annual and multiyear variability. BEG ranges, as defined in the *Policy for the Management of Sustainable Fisheries*, are estimates of the number of spawners that provide the greatest potential for maximum sustained yield, abbreviated as S_{MSY}. Only the Chignik River sockeye and Chinook salmon stocks have data sufficient for this type of analysis, and of these stocks, only the sockeye salmon stocks were identified for further review during this cycle.

Sustainable Escapement Goal

Sustainable escapement goals (SEGs) for Area L salmon stocks were determined using multiple methods: the Percentile Approach (Clark et al. 2014), the euphotic volume model (Koenings and Kyle 1997), and the zooplankton biomass models of Koenings and Burkett (1987).

The Percentile Approach is based on the principle that escapements of a stock within some range of percentiles observed over the time series of escapements and associated harvest from fishing represent a proxy for maintaining escapements within a range that encompasses S_{MSY} (Clark et al. 2014). The Percentile Approach takes into account the measurement error of the data collection method (i.e., weirs and towers have lower measurement error than aerial or foot surveys), contrast of the escapement data (i.e., the ratio of highest observed escapement to the lowest observed escapement), and the average harvest rate of the stock. Based on these criteria, Clark et al. (2014) outlined the following tiers to set an SEG range.

Tier	Escapement contrast	Measurement error	Harvest rate	SEG range
1	>8	High (aerial and foot surveys)	Low to moderate (< .40)	20th to 60th Percentile
2	>8	Low (weirs and towers)	Low to moderate (< .40)	15th to 65th Percentile
3	4–8	–	Low to moderate (< .40)	5th to 65th Percentile

The euphotic volume (EV) model (Koenings and Burkett 1987) includes a direct relationship between mean adult sockeye salmon production and the volume of photosynthetically active lake water capable of primary production using empirical observations. This relationship was corroborated by estimates of adult production based on rates of fry and smolt biomass per EV unit and estimated survival rates. The model assumes that shallower light penetration results in lower adult production compared to lakes with deeper light penetration because lakes with less light penetration would not have the primary (phytoplankton) and subsequent secondary (zooplankton) production necessary to sustain a larger sockeye salmon smolt rearing population. The EV model assumes that the sampled lake will be deep enough to allow the extinction of light, which increases with depth, to achieve a value of 1% the subsurface light irradiation. Escapement is estimated as a proportion of mean adult production.

The zooplankton biomass model, as described in Witteveen et al. (2005), estimates smolt production based on the biomass of available zooplankton forage able to sustain smolt of a targeted threshold size, in a lake of known area (Koenings and Kyle 1997). The zooplankton biomass model, like the EV model, assumes that the availability of forage could impact survival of juvenile fish and subsequent adult production. Adult production was calculated using species fecundity and marine survival rates. The zooplankton biomass model assumes zooplankton are the only available forage. Both EV and zooplankton biomass models apply solely to sockeye salmon.

CHINOOK SALMON

Escapement Goal Background and Previous Review

The Chignik River has the only Chinook salmon escapement goal established in the CMA (Table 1; Appendix A1). Chinook salmon escapement to the Chignik River is estimated using a weir outfitted with 2 video cameras (Anderson et al. 2013). The escapement goal was first established in 1992 (1,750 to 3,000 fish) and changed to a BEG (1,450 to 2,700 fish) using a spawner-recruit model in 1994 (Nelson and Lloyd 2001). The BEG was changed to an SEG for 1 year in 2001 (Nelson and Lloyd 2001), then revised back to a BEG of 1,300 to 2,700 fish in 2002 (Witteveen et al. 2005). Since 2002, the goal has remained unchanged (Appendix A1: Witteveen et al. 2005; Witteveen et al. 2007; Nemeth et al. 2010; Sagalkin et al. 2013; Schaberg et al. 2015, Schaberg et al. 2019).

Stock Status

Since the establishment of the current BEG of 1,300 to 2,700 fish in 2002, escapements of Chignik River Chinook salmon have been within or above the escapement goal range until recently with 2013, 2017, 2018, and 2020 not meeting the BEG (Appendices A2 and A3).

2020 Review

Following an extensive review in 2018 (Schaberg et al. 2019), the team decided an updated analysis and review of the Chignik River Chinook salmon run was not warranted despite recent escapements that failed to meet the lower bound of the escapement goal (Appendix A3).

SOCKEYE SALMON

Escapement Goal Background and Previous Review

Chignik River sockeye salmon are the only sockeye salmon stocks in the CMA with escapement goals (Table 1). Sockeye salmon also return to several smaller stream systems in the CMA (Albert Johnson Creek and Surprise Lake), but due to small run sizes and limited effort, escapement goals for these streams have not been established (Witteveen et. al. 2007). Although the peak periods of passage for Chignik River early- and late-run stocks are usually 1 month apart, the 2 runs overlap in late June and early July (Templin et al. 1999). Escapement estimates for both runs are based on weir estimates with the addition of post-weir estimates for the late run that were modeled after the weir was removed in late August or early September (Anderson et al. 2013).

Escapement goals for Chignik River sockeye salmon were originally established in 1968 and set at 350,000 to 400,000 fish for the early run and 200,000 to 250,000 fish for the late run (Dahlberg 1968). These initial escapement goals were developed using spawner-recruit relationships from periods of high (1922 to 1939) and low (1949 to 1960) productivity to rebuild declining Chignik runs (Dahlberg 1968). It is important to note that Dahlberg (1968) reduced his original estimate of escapement to Chignik Lake (340,000 fish) to account for early- and late-run stock interactions of rearing fry in Chignik Lake to facilitate restoring Black Lake productivity. In 1998, the BOF established a September 1–15 management objective of 25,000 fish, supplemental to the lower bound of the late-run goal, to accommodate subsistence fishers upstream of the Chignik weir. In 2004, the numerical ranges of the goals were left in place, but the goals were reclassified as SEGs because scientifically defensible estimates of S_{MSY} were not possible. Also in 2004, the BOF established an August management objective of 25,000 fish (in addition to the existing September management objective) to further provide subsistence opportunities upstream of the weir. In 2007, the late-run SEG was changed to 200,000 to 400,000 fish, and the two 25,000-fish management objectives were reclassified as inriver run goals (IRRG; Witteveen et al. 2007). Actual timing of adoption of the inriver goal is unclear from other documents because it was initially a management objective that was expanded over 2 cycles (1989 and 2004) but was adopted as a formal inriver goal in 2007. In 2013 the early-run goal was changed from an SEG to a BEG, the range was increased to 350,000–450,000 fish, and the IRRG was officially put into regulation (Sagalkin et al. 2013). In 2015 no changes were made to the Chignik River sockeye salmon escapement goals (Schaberg et al. 2015); however, the BOF increased the inriver run goal by 25,000 fish in September for a total IRRG of 75,000 fish. The 2019 BOF reduced the IRRG to 20,000 fish, with 10,000 fish required to pass the Chignik River weir during August and another 10,000 fish in September, with no changes made to either sockeye salmon goal.

Stock Status

The current Chignik River early-run escapement goal range (350,000 to 450,000) was established in 2013 and classified as a BEG. In the last 10 years, early-run escapements have been below the goal 3 times (2014, 2018, and 2020) and above the goal one time (2011; Appendices B2 and B3). The late-run escapements have generally fallen within the current SEG range (200,000 to 400,000) since implementation in 2008, except exceeding the goal in 2015 and not meeting the goal in 2020 (Appendices B2 and B4). Prior to 2019, the IRRGs were not met every year due to the time specific requirements and lack of weir operation when IRRGs are in effect. The August component has been achieved in 10 of the last 12 years (excluding 2011 and 2014). The September IRRG has not been met since the escapement goal was updated in 2016 and was only achieved in 3 of the 9 years 2007–2015 when it was September 1–15. The IRRG has been met each year following the 2019 BOF simplification of the IRRG.

2020 Review

Escapements for both runs in 2018–2020 were either below or within their SEG ranges (Table 1). Continued declines in Chignik sockeye salmon productivity prompted the team to analyze the goals in the 2020 review.

Similar to the approach of Dahlberg (1968), the team sought to identify and assess time periods of changing productivity to estimate the most biologically representative values of S_{MSY}. Juvenile sockeye salmon of Black Lake origin are known to rear throughout the watershed to varying extents in response to climatic conditions (Walsworth et al. 2020, Westley et al. 2010). Although Black Lake can provide growth advantages for juvenile sockeye salmon via warmer temperatures (Griffiths et al 2014, Walsworth et al. 2020, Westley et al. 2010), early-run fish that have reared in Black Lake can obtain notable growth rearing in Chignik Lake (Walsworth et al. 2015), although at a lesser rate than fish of Chignik Lake origin (Griffiths et al. 2013, Simmons et al. 2012). Knowing that both stocks share Chignik Lake as rearing habitat, the early and late runs were examined individually and as a total run to reflect any density-dependent effects.

Bayesian simple and time-varying α Ricker models were used to account for measurement error and serially correlated process error, providing a more realistic assessment of uncertainty than classical methods. Data from brood years 1983 to 2013 were used to explore changes in productivity coincidental to recent stabilization of the upper Chignik River, as reported by the US Army Corp of Engineers (USACOE) during the November 3–4, 2021, Black Lake Workshop hosted by the USACOE. Models drew multi-chain Monte Carlo (MCMC) samples from the joint probability distribution of unknowns in the model. For each of the 2 Markov chains, a 4,000-sample burn-in was discarded, after which each chain was iterated 29,000 times. A thinning factor of 10 was applied to the iterations. Trace plots were used to help identify convergence.

The time-varying α model indicated declining periods of productivity, more so for the late run than the early run, which may be the result of late-run juveniles competing with early-run juveniles in Chignik Lake (Figure 3). Because of the novelty and uncertainty surrounding the utility of the model and interpretation of the output, we did not use the time-varying α model to estimate S_{MSY}; however, it identified periods of relatively lower productivity (1998–2013). Considering these results and recent stabilization of the watershed in approximately 2000, the team felt justified in truncating the full data set to 1998–2013 to model periods of lower productivity and use the full data set to model periods of average productivity.

To account for density-dependent effects of both stocks interacting in Chignik Lake, S_{MSY} was estimated for the total Chignik sockeye salmon run using data from 1998 to 2013, during which time productivity was observed to be lower than in previous brood years. To assess periods of potentially low stock interactions and average to higher productivity, S_{MSY} was estimated for the total run using the full data set from 1983 to 2013.

Bayesian simple Ricker models were chosen to estimate S_{MSY} as indicated by lower deviance information criteria (DIC) values. Model output included values of S_{MSY} and their 70%, 80%, and 90% yield and recruitment profiles to estimate the probability of achieving S_{MSY} using data-generated or user-defined escapement goal range scenarios.

Other models used to estimate escapement goals were the euphotic volume and zooplankton biomass models using data from 2000 to 2020.

PINK SALMON

Escapement Goal Background and Previous Review

Pink salmon escapement goals in the CMA were originally established in 1999, with separate goals for each of the 5 commercial salmon fishing districts (Figure 1; Witteveen et al. 2005). Annual escapement estimates are based on aerial surveys of fish in as many as 49 streams throughout the area. Escapements from 1984 to 2004 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. During the 2004 escapement goal review, an investigation of the peak escapement counts versus the estimated total escapement revealed several inconsistencies in the database. Because the calculation inconsistencies resulted in unreliable estimates, the review in 2004 used peak escapement counts (Witteveen et al. 2005). Subsequently, fisheries management has relied on peak escapement counts to measure achievement of escapement goals, and all escapement goal reviews since 2004 have also used peak escapement counts.

Also in 2004, the goals for individual districts were removed and replaced with a single aggregate goal for the entire CMA developed using a stock-recruit analysis of peak aerial surveys for 49 streams throughout the 5 commercial fishing districts (Appendix C1). This aggregate goal was established as a BEG, with separate goal ranges for odd- and even-year returns of pink salmon (Witteveen et al. 2005). In 2007, the goals were reanalyzed using the yield analysis methods of Hilborn and Walters (1992). Due to lack of precision in aerial survey data, the goals were increased and reclassified as SEGs of 200,000 to 600,000 fish during even years and 500,000 to 800,000 fish for odd years (Witteveen et al. 2007). In the 2012 review, the team determined that the additional stock assessment data would not substantially affect the results of the previous escapement goal analyses. Thus, there was consensus to not reevaluate the goals in 2012, and there was no change to the even- and odd-year Chignik pink salmon SEGs (Witteveen et al. 2009; Sagalkin et al. 2013). During the 2015 review, a restrictive set of criteria were applied to the peak aerial survey counts to allow for more consistency in the aggregate index-based escapement goals. This resulted in a reduction of index streams from 49 to 8 (Schaberg et al. 2015). This also resulted in a reduction to the number of fish incorporated in the new indices, to which the Percentile Approach (Clark et al. 2014) was applied. The aggregate pink salmon SEG for odd years (260,000 to 450,000 fish) and for even years (170,000 to 280,000 fish) were adopted starting in the 2016 season (Appendix C1; Schaberg et al. 2015). For the 2018 review, the team felt an additional 2 years of data would not alter the goals and no review was warranted.

Stock Status

Even-year pink salmon escapements from 1980 to 2004 were consistently high, averaging around 255,000 pink salmon annually. Since 2010, even-year pink salmon escapements have been low. The lower bound of the even-year pink salmon SEG has not been met since its adoption in 2016 (Table 1; Appendices C2 and C3).

Odd-year pink salmon escapement estimates were relatively low in the early 1980s, with larger escapement observed beginning in 1989. Odd-year pink salmon escapement estimates were higher between 1995 and 2007. With the inception of the SEG in 2008, odd-year escapement based on districtwide peak aerial survey counts was within the goal range of 500,000–800,000 fish (Schaberg et al. 2015). After implementing the revised index-stream odd-year SEG in 2016, the goal was exceeded in 2017 (Table 1; Appendices C2 and C3).

2020 Review

Stock-specific harvest estimates for Chignik pink salmon are not available. In 2020, recent escapement data (Appendices C2–C3) were examined to determine if a change in the escapement goal was justified. The team determined that this stock did not warrant further review.

Chum Salmon

Escapement Goal Background and Previous Review

Chum salmon escapement goals in the CMA were originally established in 1999, with separate goals for each of the 5 commercial salmon fishing districts (Nelson and Lloyd 2001). Escapements from 1984 to 2004 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. During the 2004 escapement goal review, an examination of the peak escapement counts versus the estimated total escapement revealed several inconsistencies in the database. Because the calculation inconsistencies resulted in unreliable estimates, the review in 2004 used peak escapement counts (Witteveen et al. 2005). Subsequently, fisheries management has relied on peak escapement counts to measure achievement of escapement goals, and all escapement goal reviews since 2004 have also used peak escapement counts.

Chum salmon escapement goals were revised in 2004 to represent an aggregate goal for the entire CMA. This goal was developed using results of aerial surveys for 49 streams throughout the 5 commercial fishing districts (Figure 1; Appendix D1). This single aggregate goal in 2004 was developed using the Percentile Approach developed by Bue and Hasbrouck[3] and a risk analysis (Bernard et al. 2009) and was reclassified as a lower-bound SEG (Witteveen et al. 2005). In 2007, the aggregate lower-bound SEG was reanalyzed using a risk analysis and raised to 57,400 fish (Witteveen et al. 2007). In 2010 and 2013, the most recent escapements were reviewed and no change was made to the goal. During the 2015 review, a restrictive set of criteria were applied to the peak aerial survey count stream index to allow for more consistency in the aggregate index-based escapement goals. This resulted in a reduction of index streams from 49 to 6 (Schaberg et al. 2015). This also resulted in a reduction to the number of fish incorporated in the new indices to which the Percentile Approach (Clark et al. 2014) was applied. The aggregate chum salmon SEG range (45,000 to 110,000 fish) was adopted starting in the 2016 season (Table 1; Appendix D1; Schaberg et al. 2015).

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[3] Bue, B. G., and J. J. Hasbrouck. *Unpublished*. Escapement goal review of salmon stocks of Upper Cook Inlet. Report to the Alaska Board of Fisheries November 2001 (and February 2002). Alaska Department of Fish and Game, Anchorage.

Stock Status

With the revised SEG from 2016 and subsequent reduction in the number of streams included in the index, the chum salmon escapement in the CMA was within the SEG range since 2016, with the exception of 2020, which was below the lower bound of the goal (Table 1; Appendix D3).

2020 Review

Stock-specific harvest estimates for Chignik chum salmon were not available. Recent escapement data (Appendices D2–D3) were examined to determine if a change in the escapement goal was justified. The team determined that this stock did not warrant further review.

RESULTS

SOCKEYE SALMON

Escapement Goal Recommendation

The team discussed and advised discontinuing separate escapement goals for the early and late runs in favor of a single Chignik River sockeye salmon goal. Analyses of new information indicated notable changes to the rearing habitat of Chignik River sockeye salmon. Specifically, at the Black Lake Workshop, the USACOE revealed that the Chignik River watershed had stabilized around 2000. Studies initiated in 2011 identified that climate drives early-run juvenile sockeye salmon from Black Lake to rear throughout the watershed (Walsworth et al. 2015, Walsworth et al. 2020), with late-run juveniles outcompeting early-run juveniles in Chignik Lake (Griffiths et al. 2013). With watershed morphology stabilized and greater variability in recent climatic conditions, it is unlikely that the utilization of the entire watershed by early-run juvenile sockeye salmon will change. Through the course of this review, spawner-recruit relationships indicated increased density dependence (e.g., $\beta = 0.081$ for 1983 to 2013 and $\beta = 0.142$ for 1998 to 2013 for total run fitted to the Ricker without time-varying α; Table 3) for both runs since watershed stabilization (Figure 3), suggesting the adaptive rearing strategies of early-run juveniles may have increased intraspecific competition in Chignik Lake, and possibly throughout lower reaches of the watershed, systemically influencing productivity. Thus, the team determined a single Chignik River sockeye salmon goal more holistically and accurately reflects productivity affected by the broadscale habitat use of early-run juveniles and increased mixed-stock interactions by Chignik River sockeye salmon. Further, a single goal addresses the limited rearing capacity of Chignik Lake, which supports both early- and late-run juveniles.

Results from these analyses indicated S_{MSY} can be achieved by a single BEG of 450,000–800,000 fish for Chignik River sockeye salmon. Spawner-recruit models fitted with both time series of data were used for this escapement goal recommendation (Table 3; Figures 3 and 4). Using the 1983–2013 time series, the upper bound of 800,000 fish was estimated to provide a 90% probability of achieving 80% of MSY for the overall run (Figure 5). The recommended upper bound of 800,000 aligns with the S_{MSY} estimate of 782,000 fish using the entire 1983–2013 time series (Table 3 and Figure 4). This level of escapement also is known to provide replacement, where escapements that exceed this value have not consistently provided replacement. These brood years provide better insight into the overall variability of stock production and potential yield. Using the 1998–2013 time series, the lower bound of 450,000 fish is estimated to provide a 90% probability of achieving 80% of MSY for the overall run

(Figure 5) and is supported by the zooplankton biomass model lower bound (range 449,000 to 674,000 fish; Table 3) for Chignik Lake where juvenile early- and late-run fish rear together. The recommended lower bound of 450,000 fish is also based on the estimate of S_{MSY} of 500,700 fish using the 1998-2013 time series (Table 3 and Figure 4): these lower production years may be more indicative of conditions and production trends in the near future.

SUMMARY OF THE REVIEW

The team concluded that the 3 additional years of data since the 2018 review would not affect the existing escapement goals for the Chignik River Chinook, chum, and pink salmon stocks. There are no coho salmon escapement goals in the CMA because harvests are generally incidental to the directed sockeye salmon fishery and the late run timing of coho salmon prevents reliable estimates of escapement. The team elected to further analyze the early- and late-run sockeye salmon escapement goals.

The 2020 review team determined changes were warranted to the early- and late-run sockeye salmon goals in 2 ways. First, review of life-history data of Chignik River sockeye salmon supported going from separate goals for each run to a single Chignik River sockeye salmon BEG. The rationale behind a single goal was twofold: a single goal recognizes that juvenile early-run fish adapt to variable environmental conditions in Black Lake by utilizing diverse rearing habitats throughout the entire watershed to maintain survival and growth opportunities. The single goal also better addresses the bottleneck in rearing capacity of Chignik Lake because it provides a level of escapement that 1 lake can sustain for both stocks, as corroborated by both Ricker and zooplankton biomass models. Overall, a single goal targets sustainable levels of productivity for the watershed as opposed to solely for each run, which may fail to capture the impacts of stock interactions during life stages of sockeye salmon that are more susceptible to mortality.

Second, because the level of interactions between stocks is variable and unknown from year to year, 2 time series of data were used to reflect changes in productivity and stock interactions. The lower bound of 450,000 fish reflects S_{MSY} during periods of lower productivity in the watershed that coincided with the stabilization of the Chignik River. The upper bound of 800,000 fish was chosen because it approximates S_{MSY} encompassing periods of greater productivity and possibly minimal stock interaction. Additionally, the upper bound of 800,000 fish represents a level of escapement since 1998 that, if not exceeded, is known to yield sustainable levels of replacement. Both values of S_{MSY} used to define the upper and lower bounds of the goal are estimated to provide a 90% probability of achieving 80% of MSY for the total run. In recommending the single Chignik River sockeye salmon goal, the team also recommends discontinuing the early- and late-run sockeye salmon goals.

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TABLES AND FIGURES

Table 1.–Escapements, escapement goals, and 2020 recommendations for salmon stocks in the Chignik Management Area (CMA).

			Current escapement goal		Escapements										
Salmon species	System	Data type[a]	Type	Range	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Escapement goal recommendation
Chinook	Chignik River	WC	BEG	1,300–2,700	2,471	1,434	1,185	2,816	1,945	1,743	1,037	725	1,417	1,178	No change
Sockeye	Chignik River														
	Early run	WC	BEG	350,000–450,000	489,903	356,513	401,052	342,404	426,817	410,922	428,350	182,991	379,444	179,200	Single system wide BEG of 450,000–800,000
	Late run	WC	SEG	200,000–400,000[b]	263,913	355,878	355,050	309,206	697,082	362,253	364,211	356,707	302,555	151,777	
Pink[c]	CMA aggregate even yrs	PAS	SEG	260,000–450,000		111,000		87,240		68,100		NA[d]		118,675	No change
	CMA aggregate odd yrs	PAS	SEG	170,000–280,000	272,000		231,800		404,000		586,300		415,300		No change
Chum[c]	CMA aggregate	PAS	SEG	45,000–110,000	119,000	26,300	109,900	46,720	123,400	69,900	96,900	NA[e]	98,000	31,685	No change

[a] PAS = Peak Aerial Survey, WC = Weir Count.

[b] This lower bound does not include the inriver run goal of 20,000 fish.

[c] All counts are from index streams.

[d] Although an escapement of 42,000 pink salmon was observed, all 8 index streams could not be surveyed and are not included in this analysis.

[e] A total of 28,900 chum salmon were observed in only 3 of the 6 index streams.

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.

Table 3.–Summary of models evaluated for Chignik river sockeye salmon using data from 1983 to 2020.

Stock	Data set and analysis	Data range	ln α	β	Midpoint[a]	Lower[b]	Upper[b]
Early							
	Current goal				400,000	350,000	450,000
	Simple Ricker	1983 to 2013	1.548	0.141	427,272	284,768	787,477
		1998 to 2013	1.722	0.208	309,642	204,371	564,870
Late							
	Current goal				300,000	200,000	400,000
	Simple Ricker	1983 to 2013	1.794	0.215	311,507	205,635	582,558
		1998 to 2013	2.059	0.349	208,634	143,371	356,442
	Zooplankton biomass	2000 to 2020	NA	NA	560,120	449,453	674,179
	Euphotic volume	2000 to 2020	NA	NA	495,032	396,026	594,039
Total run							
	Simple Ricker	1983 to 2013	1.651	0.081	782,087	496,126	1,564,447
		1998 to 2013	1.982	0.142	500,668	333,300	900,651
	Time-varying α	1983 to 2013	1.675	0.082	784,960	509,180	1,600,208
		1998 to 2013	1.724	0.105	620,258	382,516	1,263,791

[a] Midpoints for simple Ricker and time varying alpha estimates are S_{MSY}.

[b] Lower and upper bounds for simple Ricker and time varying alpha estimates are 95% credibility intervals and for the zooplankton biomass and euphotic volume models are 80 and 120% of the model estimates.

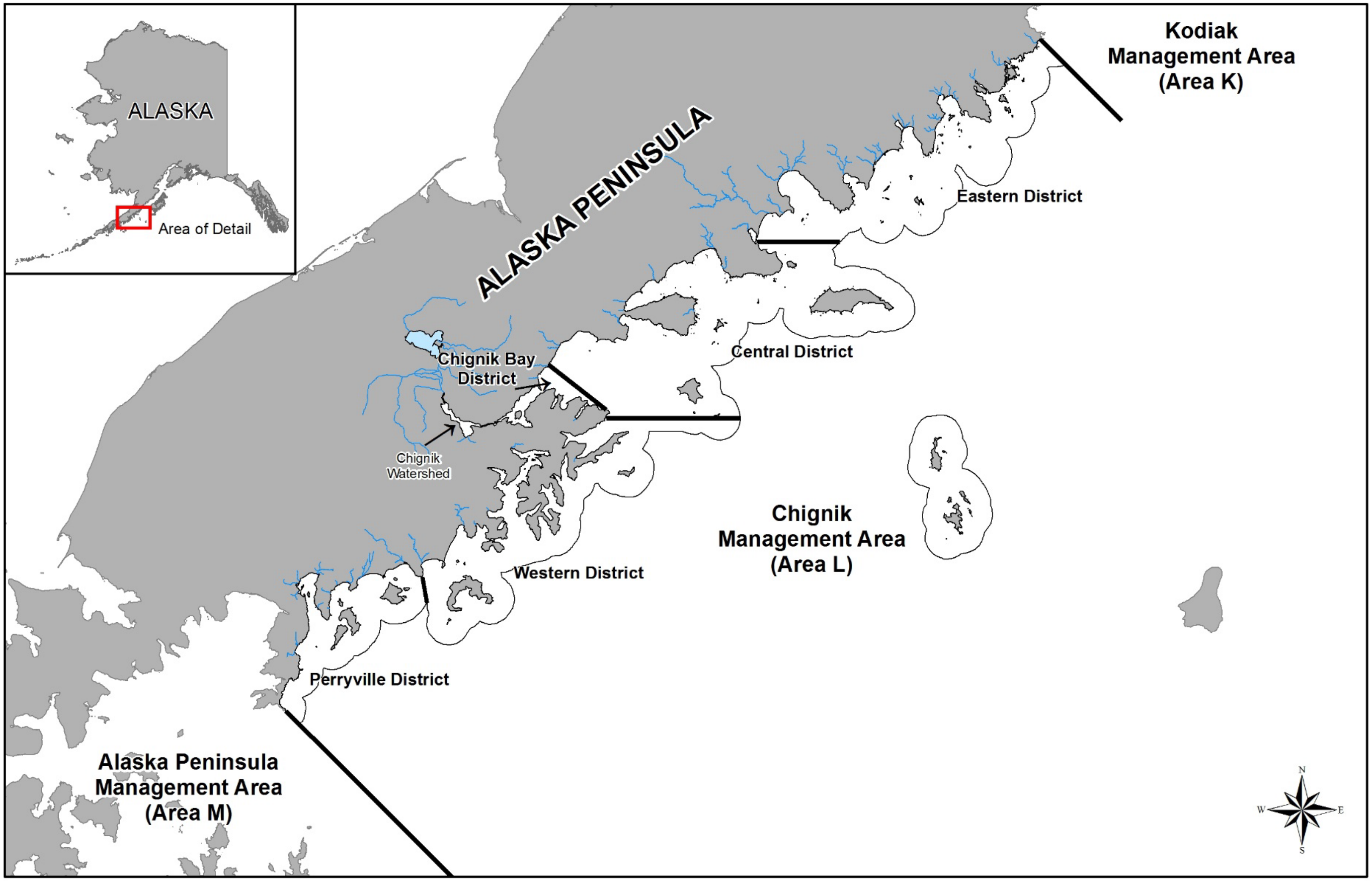


Figure 1.–The Chignik Management Area with the Eastern, Central, Chignik Bay, Western, and Perryville Districts depicted.

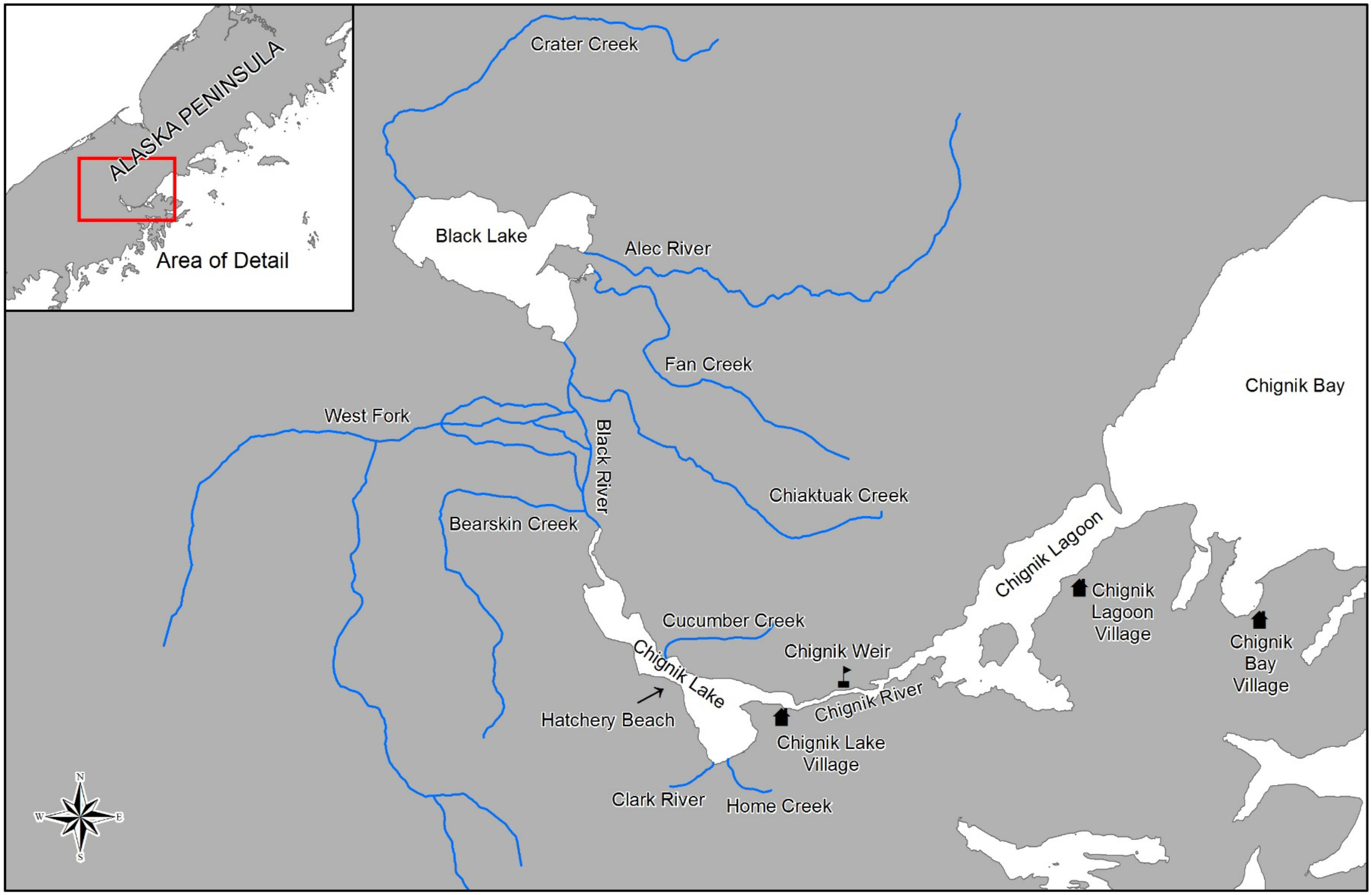


Figure 2.–The Chignik River watershed, showing Black and Chignik Lakes, Black and Chignik Rivers, and Chignik Lagoon.

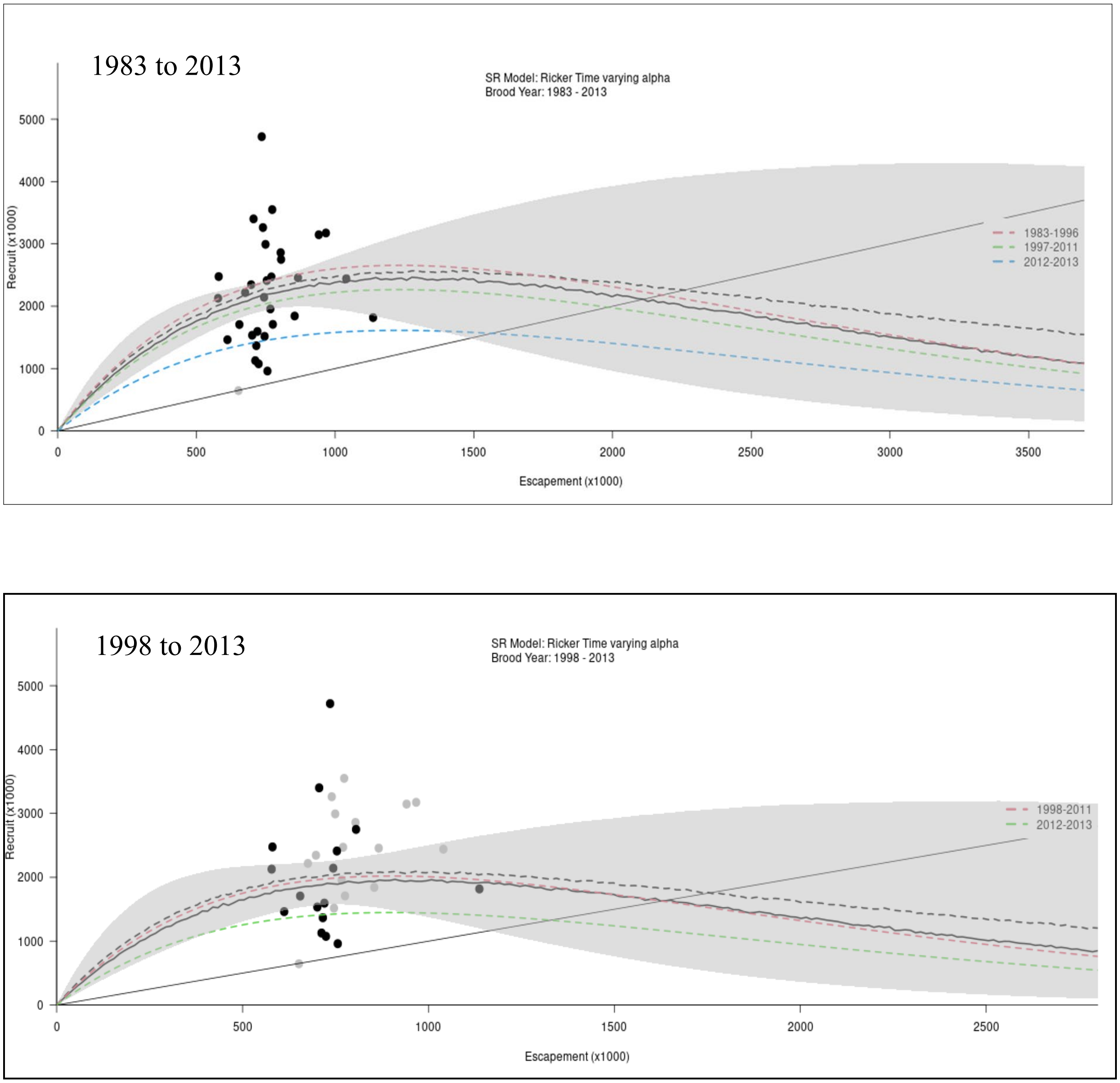
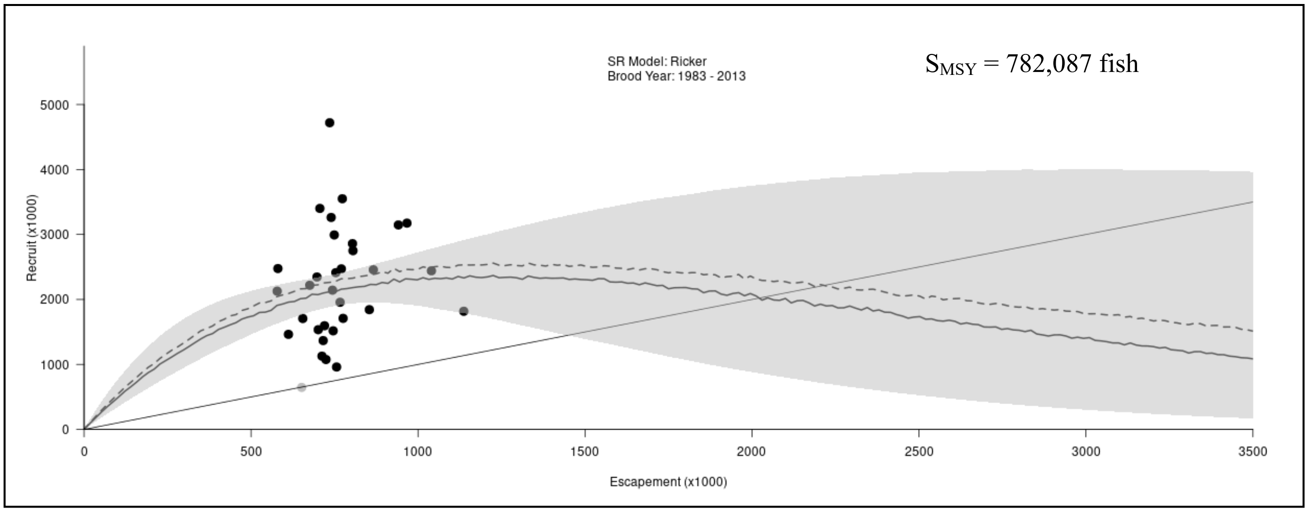


Figure 3.–Bayesian time-varying α Ricker curves for Chignik River sockeye salmon total run showing changes in productivity over different time periods as indicated by colored dashed lines using data between 1983 and 2013 and 1998 and 2013. Light grey dots are data points from 1983 to 1997 not included in the model fit.



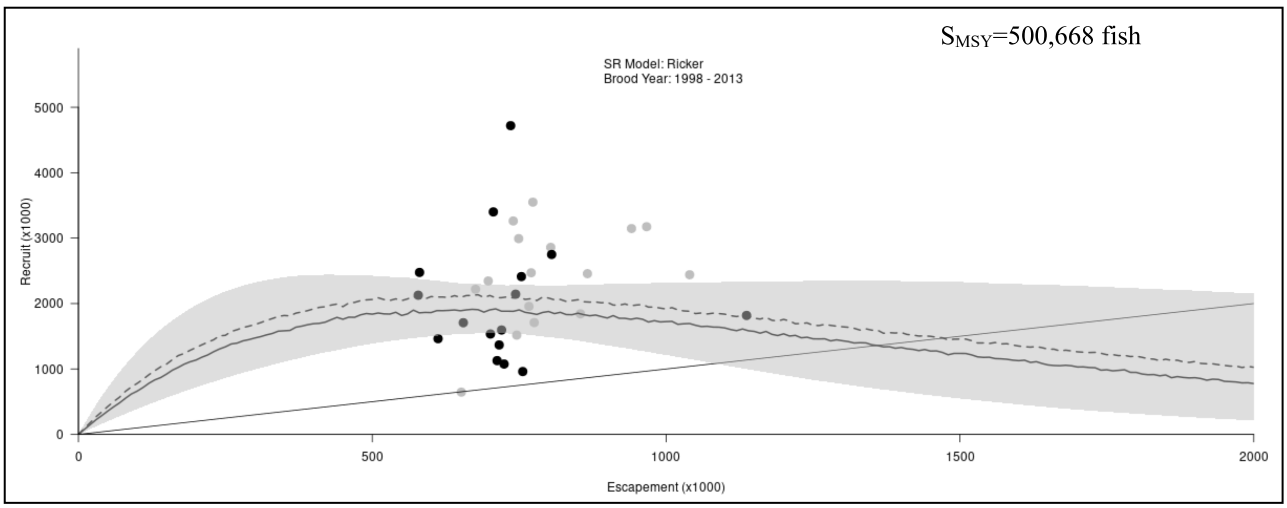


Figure 4.–Bayesian simple Ricker curves (solid line = median, dashed line = mean) for Chignik River sockeye salmon total runs using data from 1983 to 2013 (top panel) and 1998 to 2013 (bottom panel). Light grey dots are data points from 1983 to 1997 not included in the model fit.

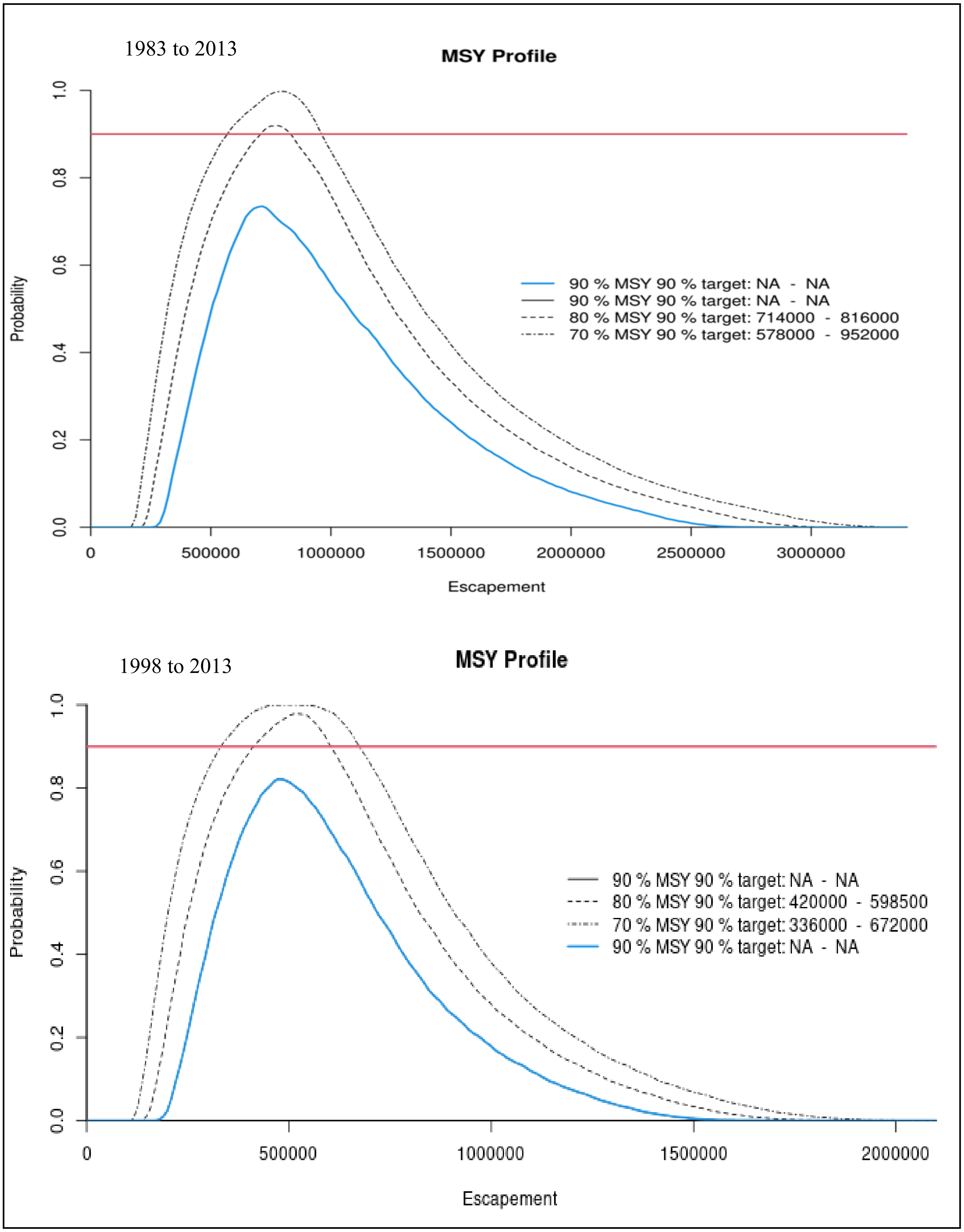


Figure 5.–Yield profiles for the Chignik River sockeye salmon total run using data from 1983 to 2013 (top panel) and 1998 to 2013 (bottom panel). Escapement goal ranges achieving specified proportions are indicated as appropriate.

APPENDIX A. SUPPORTING INFORMATION FOR THE CHIGNIK RIVER CHINOOK SALMON ESCAPEMENT GOAL

Appendix A1.–Description of stock and escapement goal for Chignik River Chinook salmon.

System: Chignik River
Species: Chinook salmon

Regulatory area:	Chignik Management Area
Management division(s):	Sport and Commercial
Primary fisheries:	Sport, Commercial, and Subsistence
Current escapement goal:	BEG: 1,300 to 2,700 fish (2002)
Review outcome:	No change
Optimal escapement goal:	None
Inriver goal:	None
Action points:	None
Escapement enumeration:	Weir, 1978 to present
Data summary:	
Data quality:	Good escapement and harvest data.
Data type:	Weir estimates, harvest estimates, age composition.
Data contrast:	1978 to 2020: 11.1
Comments:	BEG has been achieved 1 of the past 3 years (2019).

Appendix A2.–Chignik River Chinook salmon escapement and harvest information, 1978 to 2020.

Year	Comm harvest [a]	Subs harvest [b]	Weir count	Total run [c]	Sport harvest [d]	Sport harvest below weir [e]	Sport harvest above weir [e]	Escapement [f]
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
2004	2,337	0	7,840	10,177				7,840
2005	2,442	0	6,486	8,928			361	6,125
2006	1,941	0	3,535	5,476			245	3,290
2007	641	0	2,000	2,641			198	1,802
2008	208	0	1,730	1,948		10	55	1,675
2009	496	0	1,680	2,226		50	53	1,627
2010	1,480	0	3,679	5,195		36	179	3,500
2011	1,382	0	2,728	4,118		8	257	2,471
2012	303	37	1,449	1,835		46	15	1,434
2013	545	10	1,253	1,823		15	68	1,185
2014	353	34	2,895	3,291		9	79	2,816
2015	1,572	37	2,054	3,666		3	109	1,945
2016	664	1	1,843	2,508		[g]	100	1,743
2017	410	4	1,137	1,551			100	1,037
2018	0	1	825	826			100	725
2019	1,137	1	1,517	2,655			100	1,417
2020	0	13	1,278	1,291			100	1,178

Note: Blank cells indicate that this information was not collected during this year.

[a] Commercial harvest is the commercial harvest of Chinook salmon from the Chignik Lagoon statistical area (271-10). This does not include personal use or test fishery harvest.

[b] Subsistence harvest is from Chignik Lagoon as reported on subsistence permit reports.

[c] Sport harvests are only included in the total run 2008–2015 when harvest estimates from below the weir are available. During 1978–2004 sport harvest estimates are assumed to be above the weir and are subtracted from the weir count to estimate escapement.

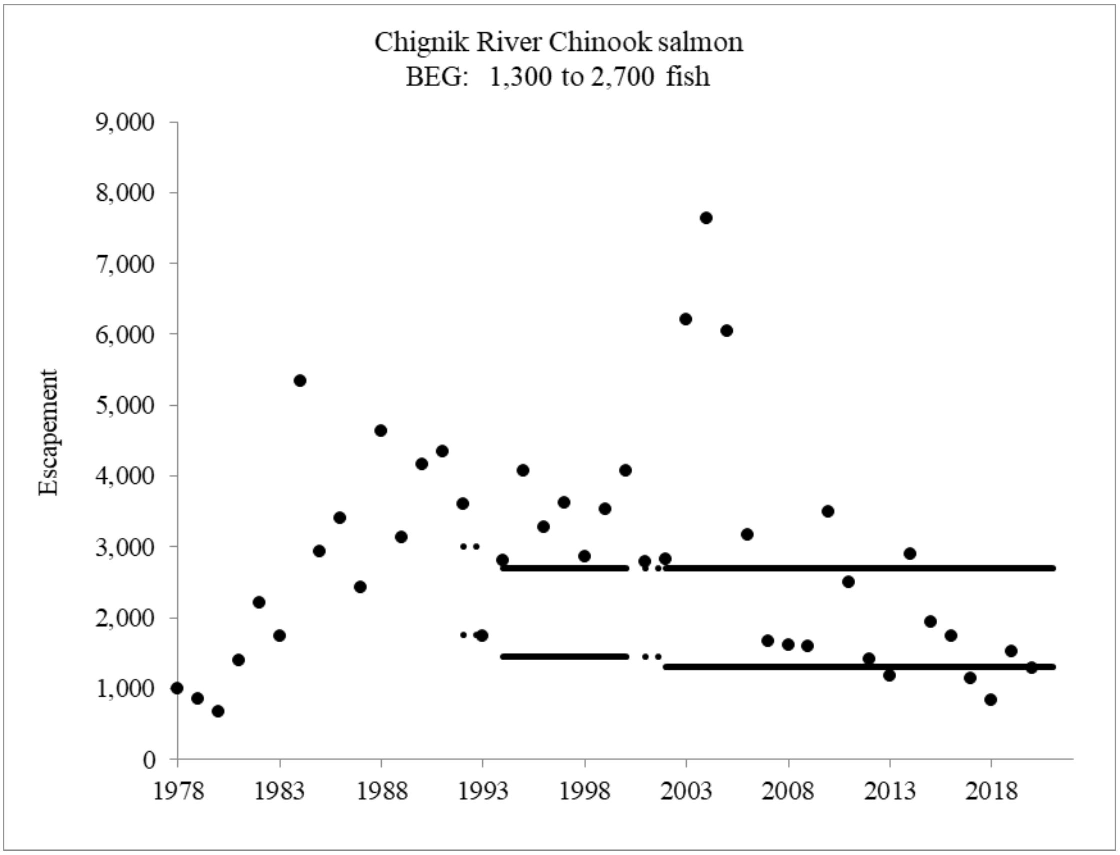
[d] Sport harvest in 1988 and 1989 was estimated from an onsite creel survey (Schwarz 1990). Recreational harvest in the remaining years is the average of 1988 and 1989.

[e] For 2005–2015, sport fish harvest is estimated through guide logbooks.

[f] Escapement is weir count minus sport harvest.

[g] Upriver sport harvests are unavailable through the Statewide Harvest Survey since 2015. Based on historical catches, 100 fish is used as a harvest estimate.

Appendix A3.–Annual escapements and escapement goals for Chignik River Chinook salmon, 1978 to present, with current and historical SEGs (dotted lines) and BEGs (solid lines).



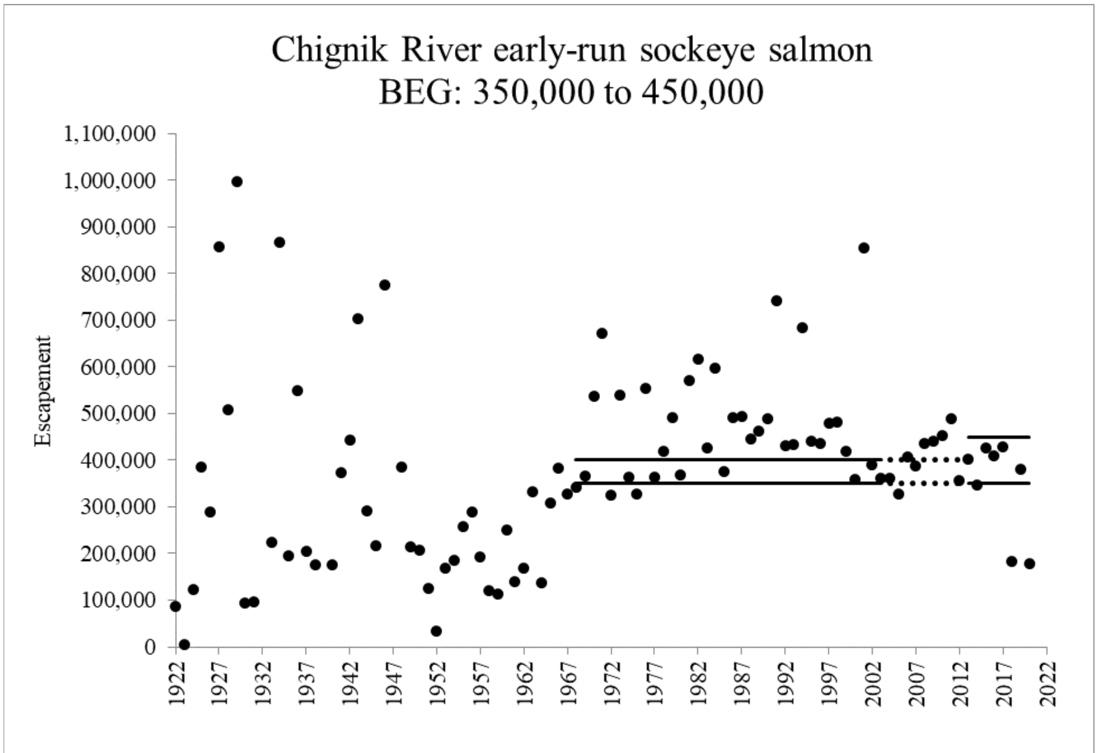
APPENDIX B. SUPPORTING INFORMATION FOR CHIGNIK RIVER SOCKEYE SALMON ESCAPEMENT GOALS

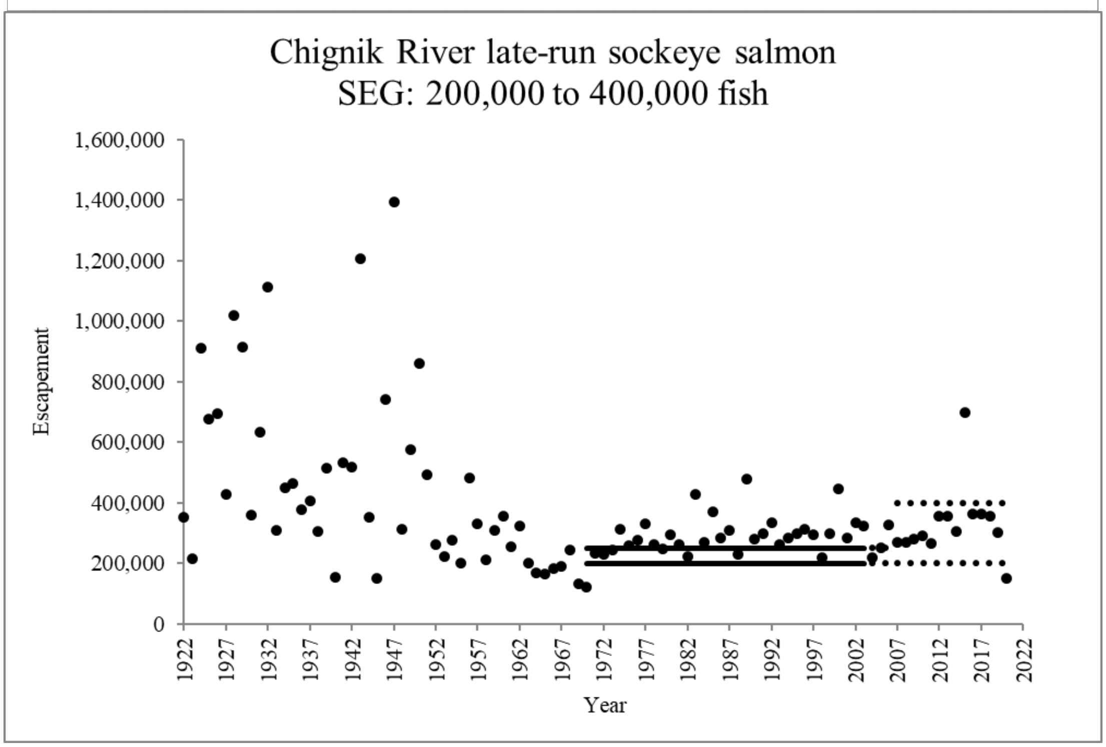
Appendix B1.–Description of stocks and escapement goals for Chignik River sockeye salmon.

System: Chignik River
Species: Sockeye salmon

Regulatory area:	Chignik Management Area
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Current escapement goal:	Early-run BEG: 350,000 to 450,000 fish (2013) Late-run SEG: 200,000 to 400,000 fish (2007)
Review outcome:	Total run BEG: 450,000 to 800,000 fish
Optimal escapement goal:	None
Inriver run goal:	1989: 25,000 management objective in addition to lower bound; 2004: In addition to the existing 25,000 August objective a 25,000 objective was added for September; 2008: The two management objectives were reclassified as inriver run goals but not added into regulation. 2016: An additional 25,000 fish were added to the August inriver run goal, for a total of 50,000 in August. 2019: The IRRG was reduced to 20,000 fish with 10,000 to pass the Chignik weir in August.
Action points:	None
Escapement enumeration:	Weir counts 1922, 1923, 1925–1930, 1932, 1933, 1935–1937,
Data summary	
Data quality:	Fair
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 2020. Stock-specific harvest information was available for 1962 to 1969 and 1980 to 2020. Smolt outmigration data from 1994 to 2016. Smolt grab sample data available from 2019 to present. Limnology data from 2000 to present.
Contrast:	1983–2020: 4.8 (early run) 1998–2020: 4.8 (early run) 1983–2020: 4.6 (late run) 1998–2020: 4.6 (late run)
Methodology:	Ricker stock-recruit model, yield analysis, euphotic volume model, zooplankton biomass model
Autocorrelation:	None detected

Appendix B2.–Annual escapements for Chignik River early- and late-run sockeye salmon, 1922 to 2020, with current and historical SEGs (dotted lines) and BEGs (solid lines).





Note: Escapement data for both runs from 1986 to 2020 were audited and updated.

Appendix B3.–Brood table for Chignik River early-run sockeye salmon.

Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	1.3	2.2	3.1	0.4	1.4	2.3	3.2	4.1	1.5	2.4	3.3	4.2	2.5	3.4	4.3	Total
1983	426,178	0	0	0	18,246	77,037	2,242	245,424	29,008	0	207	289	240,446	1	0	0	1,794	665	0	0	0	0	615,359
1984	597,713	0	577	1,731	1,365	49,624	1,236	409,258	51,388	0	0	2,337	261,938	600	0	0	567	2,074	0	0	0	0	782,694
1985	376,578	171	207	479	625	52,352	440	399,352	61,235	0	878	25,291	367,854	1,837	0	0	1,363	12,066	0	0	0	0	924,150
1986	489,566	414	458	1,681	4,859	396,722	0	2,107,278	60,402	6	6	3,561	281,476	16,435	0	0	5,369	1,122	0	0	0	0	2,879,788
1987	486,990	0	868	2,322	1,021	186,629	977	922,264	96,173	30	1,082	10,973	410,177	2,890	0	0	5,358	2,660	0	0	58	0	1,643,481
1988	444,907	0	0	1,904	766	96,606	2,129	586,231	129,848	327	0	3,686	755,550	1,379	0	0	427	164	0	0	0	0	1,579,015
1989	462,968	0	32	8,294	5,865	238,481	3,008	767,641	96,783	0	308	5,221	232,529	918	0	0	1,128	11,954	0	0	191	1	1,372,354
1990	489,087	0	1,516	636	34,963	136,900	3,365	585,423	218,972	0	837	5,993	590,615	1	0	0	4,170	8,331	0	0	0	0	1,591,721
1991	740,783	0	1,694	553	2,494	132,029	305	1,305,985	34,299	0	836	1,603	138,154	1,269	0	0	215	2,959	0	0	0	0	1,622,395
1992	429,736	0	2,717	625	128,392	54,266	1,947	471,555	73,271	6	546	1,316	191,108	2,173	0	0	0	3,382	0	0	0	0	931,302
1993	434,924	0	3,651	7	13,745	55,993	1,693	213,815	107,337	0	187	639	421,805	1,438	0	0	999	426	0	0	0	0	821,735
1994	682,447	0	358	855	0	101,622	749	1,093,433	175,991	0	0	8,773	298,848	0	0	0	495	48	0	0	0	0	1,681,172
1995	440,857	0	1,938	889	29,852	442,467	0	1,154,107	13,869	0	0	6,735	77,485	0	0	0	813	887	0	0	0	0	1,729,043
1996	435,298	0	7,691	411	60,195	46,028	0	1,330,990	11,803	0	707	12,397	261,454	539	0	0	575	1,217	0	0	0	0	1,734,007
1997	477,220	0	9	0	8,334	57,680	951	495,245	37,007	0	16	4,015	156,797	12	0	0	51	1,119	0	0	0	0	761,237
1998	481,516	0	225	969	2,928	208,162	0	638,991	42,551	0	0	3,364	127,356	1,420	0	0	0	0	0	0	0	0	1,025,967
1999	419,636	0	2,075	52	19,365	99,714	328	580,250	79,288	0	0	751	164,486	0	0	0	1,430	897	0	0	0	0	948,637
2000	359,544	0	1,571	15	14,617	247,436	689	992,475	43,620	0	0	10,689	213,580	0	0	0	5,994	2,844	0	0	0	0	1,533,531
2001	853,473	0	2,795	6	53,689	69,506	0	602,214	18,710	0	1,029	13,461	226,115	151	0	0	3,589	129	0	0	0	0	991,394
2002	390,094	0	0	0	8,613	40,746	0	265,983	7,831	0	553	3,740	69,341	0	0	0	0	0	0	0	0	0	396,808
2003	361,106	0	1,798	3	74,822	58,288	0	494,257	18,169	0	858	2,997	68,546	77	0	0	56	150	0	0	0	0	720,022
2004	360,330	0	7,375	133	122,189	45,422	0	732,956	35,556	0	844	2,267	148,286	0	0	0	2,499	348	0	0	0	0	1,097,875
2005	328,506	0	328	129	25,429	125,937	338	932,414	13,649	0	0	2,643	494,549	6,494	0	0	338	26,698	0	0	471	0	1,629,417
2006	408,233	0	1,136	1,162	15,269	217,976	807	2,278,713	115,723	0	0	37,132	606,404	0	0	0	4,414	8,149	0	0	0	0	3,286,885
2007	386,728	0	2,272	270	15,311	39,571	997	329,746	73,767	0	1,152	1,322	424,294	0	0	0	915	162	0	0	0	0	889,779
2008	433,841	0	323	22	10,872	438,138	1	1,962,724	3,524	0	0	4,741	58,317	0	0	0	0	1,430	0	0	0	0	2,480,093
2009	441,557	0	0	227	3,788	46,817	58	92,522	36,520	0	517	363	119,472	1,678	0	0	3	3,634	0	0	1,371	0	306,971
2010	452,191	0	0	1,062	0	167,481	806	375,272	73,029	0	0	871	318,946	871	0	0	2,606	5,099	0	0	0	0	946,042
2011	489,903	0	0	2,684	548	203,284	1,076	804,283	71,373	0	0	7,422	360,370	82	0	0	1,511	292	0	0	0	0	1,452,926
2012	356,513	0	0	1,669	335	113,906	401	640,782	28,298	0	0	3,057	18,657	0	0	0	848	427	0	0	0	0	808,379
2013	401,052	0	0	453	44,999	41,747	52	57,461	22,329	0	296	1,069	99,618	0	0	0	371	0	0				268,395
2014	342,404	0	4,336	572	10,721	50,416	0	120,979	10,916	0	711	1,323	31,056	154	0								
2015	426,817	0	17,909	342	129,551	43,779	174	89,237	29,807	0	361												
2016	410,922	0	1,517	1,084	558	22,795	1,498																

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Appendix B3.–Page 2 of 2.

		Return Ages																					
Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	1.3	2.2	3.1	0.4	1.4	2.3	3.2	4.1	1.5	2.4	3.3	4.2	2.5	3.4	4.3	Total
2017	428,350	0	887	1,153																			
2018	182,991	0																					
2019	379,444																						
2020	179,200																						

Appendix B4.–Brood table for Chignik River late-run sockeye salmon.

Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	1.3	2.2	3.1	0.4	1.4	2.3	3.2	4.1	1.5	2.4	3.3	4.2	2.5	3.4	4.3	Total
1983	428,034	0	0	0	2,686	11,007	3,453	102,010	93,420	0	80	1	1,003,347	737	0	0	10,201	8	0	206	0	0	1,227,156
1984	268,495	0	363	1,484	372	23,817	8,526	55,252	294,422	0	0	2,167	1,271,888	1,572	0	0	8,178	5,623	0	0	0	0	1,673,664
1985	369,260	117	80	501	11	6,730	13,584	121,092	136,566	0	522	772	308,862	797	0	0	2,759	381	0	0	0	0	592,772
1986	283,753	159	1	1,582	12,455	98,137	871	108,895	136,747	70	70	559	297,840	2,390	0	0	8,985	605	0	0	352	0	669,718
1987	316,753	0	5,730	113	721	33,530	7,749	194,183	154,879	186	73	3,842	723,745	3,191	0	0	6,136	81,406	0	0	88	0	1,215,574
1988	230,850	0	0	1,882	665	25,525	2,403	177,603	75,196	43	0	3,024	334,584	3,501	0	0	8,224	5,563	0	0	233	306	638,753
1989	478,207	0	486	4,895	5,936	108,754	3,048	431,063	118,585	385	725	1,865	996,795	6,122	0	0	10,778	84,279	131	0	29	0	1,773,875
1990	281,323	0	258	344	6,482	27,039	2,592	209,235	123,156	0	8	1,911	491,756	1,207	0	0	1,288	13,021	0	0	271	0	878,567
1991	299,315	0	123	268	667	68,817	1,801	232,540	100,305	0	122	285	401,231	2,568	0	0	5,237	3,983	0	0	0	0	817,948
1992	336,867	0	18	1,166	12,015	17,599	11,644	113,244	181,369	3,327	3	2,019	598,935	62,409	0	0	1,223	19,889	0	0	0	0	1,024,861
1993	262,453	0	118	582	1,593	19,018	16,302	108,923	310,843	0	3	2,005	1,057,764	4,781	0	0	1,245	177	0	0	0	0	1,523,355
1994	284,462	0	16	813	0	44,630	7,354	497,861	307,721	0	0	5,262	624,043	265	0	0	2,440	1,342	1,217	0	0	0	1,492,965
1995	299,063	0	42	2,195	6,078	211,571	0	526,292	44,556	162	0	2,678	700,149	13,561	67	0	12,647	12,723	0	0	0	0	1,532,721
1996	313,839	0	1,072	109	74,334	58,363	276	466,352	93,598	202	139	7,434	541,287	3,829	0	0	3,979	7,223	0	0	0	0	1,258,196
1997	298,398	0	3,728	162	1,842	23,959	2,063	193,698	109,060	0	426	1,874	601,008	2,479	0	0	4,042	2,979	0	0	219	0	947,540
1998	219,612	0	139	1,411	2,270	48,375	151	237,773	39,710	0	0	662	174,377	244	0	0	1,047	2,067	0	0	0	0	508,226
1999	296,330	0	619	83	9,182	55,116	2,627	139,443	44,235	0	0	2,800	161,337	110	0	0	2,030	637	0	0	0	0	418,219
2000	445,693	0	183	1,286	3,576	63,822	1,115	656,070	29,120	0	0	6,317	441,114	0	0	0	8,191	5,893	0	0	0	0	1,216,688
2001	283,445	0	17	351	14,760	21,099	2,166	296,865	47,270	0	1,202	15,890	419,422	558	0	0	6,695	167	0	0	0	0	826,463
2002	334,222	0	0	697	9,486	31,764	0	308,549	27,325	0	220	3,620	290,963	343	0	0	3,702	2,031	0	0	0	0	678,699
2003	250,883	0	1,218	340	39,313	50,783	257	243,741	44,133	0	47	3,291	353,880	227	0	0	3,053	2,413	0	0	0	0	742,696
2004	217,930	0	4,621	1,015	38,566	17,692	645	347,578	145,871	0	232	1,307	455,486	0	0	0	7,186	9,176	0	0	0	0	1,029,375
2005	251,951	0	546	0	12,451	57,234	1,148	369,728	48,566	0	0	2,310	288,594	32,332	0	0	3,163	24,500	0	0	5,505	0	846,077
2006	327,259	0	1,806	807	10,943	61,724	2,862	260,253	175,334	165	0	4,434	865,616	823	0	0	12,430	34,952	0	0	0	0	1,432,148
2007	268,245	0	2,273	1,158	11,803	14,290	877	67,153	92,071	0	22	2	621,023	0	0	0	4,758	1,257	0	0	0	0	816,686
2008	272,215	0	759	3,120	3,187	199,696	653	313,023	37,947	0	0	1,495	350,153	0	0	0	0	10,389	0	0	0	0	920,422
2009	278,505	0	0	1,186	192	31,344	2,993	108,644	195,683	0	2,197	1,556	932,901	6,981	0	0	589	3,937	0	0	138	0	1,288,340
2010	291,722	0	0	3,178	584	67,377	15,041	591,996	151,843	0	0	918	347,958	1,108	0	0	12,527	4,230	0	0	0	0	1,196,759
2011	263,913	0	0	6,665	731	125,211	12,590	426,758	58,766	0	0	5,334	320,218	221	0	0	2,225	456	0	0	0	0	959,176
2012	355,878	0	0	4,677	1,243	35,589	1,615	193,937	36,416	0	0	1,985	40,605	429	0	0	594	1,856	0	0	0	0	318,945
2013	355,050	0	420	933	7,739	48,021	4,199	100,113	113,005	0	1	829	415,519	0	0	0	915	0	0				691,694
2014	309,206	0	923	2,919	10,870	73,513	228	242,231	28,480	0	994	285	53,977	69	0								
2015	697,082	0	11,830	1,448	78,869	14,949	19,531	37,673	50,557	0	99	8											
2016	362,253	0	509	4,918	595	8,142	825																

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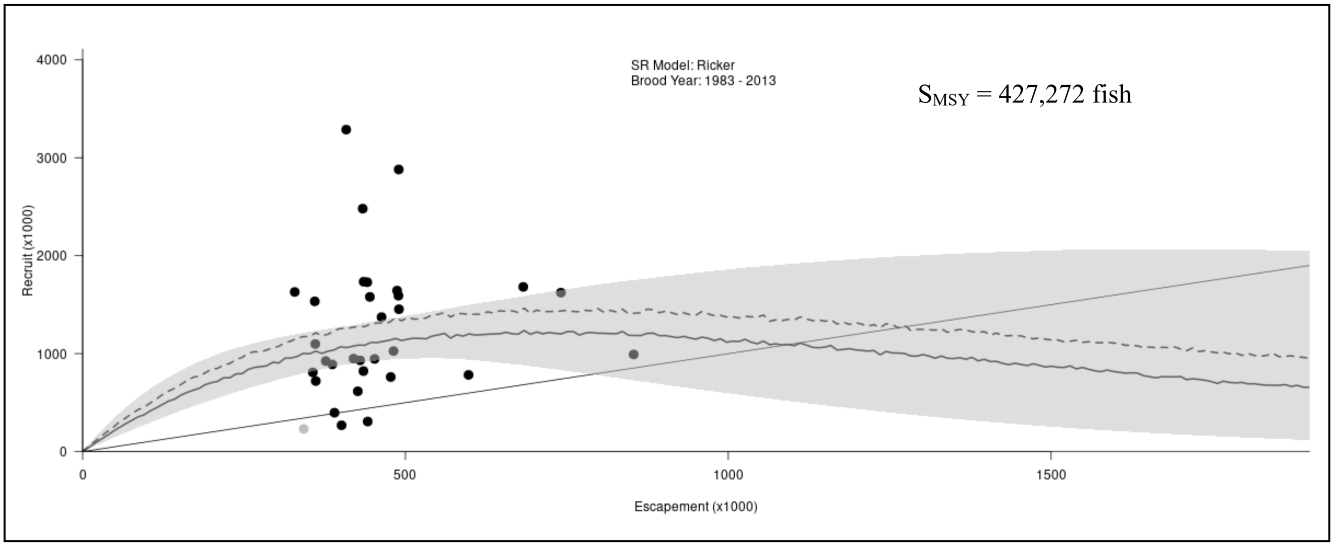
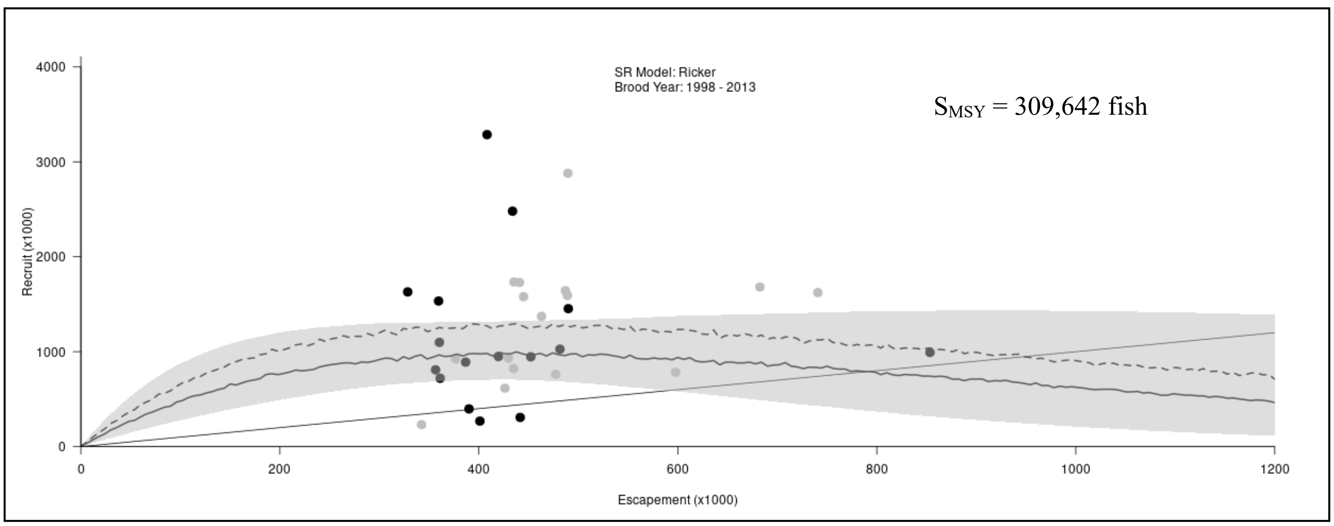
Appendix B4.–Page 2 of 2.

		Return Ages																					
Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	1.3	2.2	3.1	0.4	1.4	2.3	3.2	4.1	1.5	2.4	3.3	4.2	2.5	3.4	4.3	Total
2017	364,211	0	134	144																			
2018	356,707	0																					
2019	302,555																						
2020	151,777																						

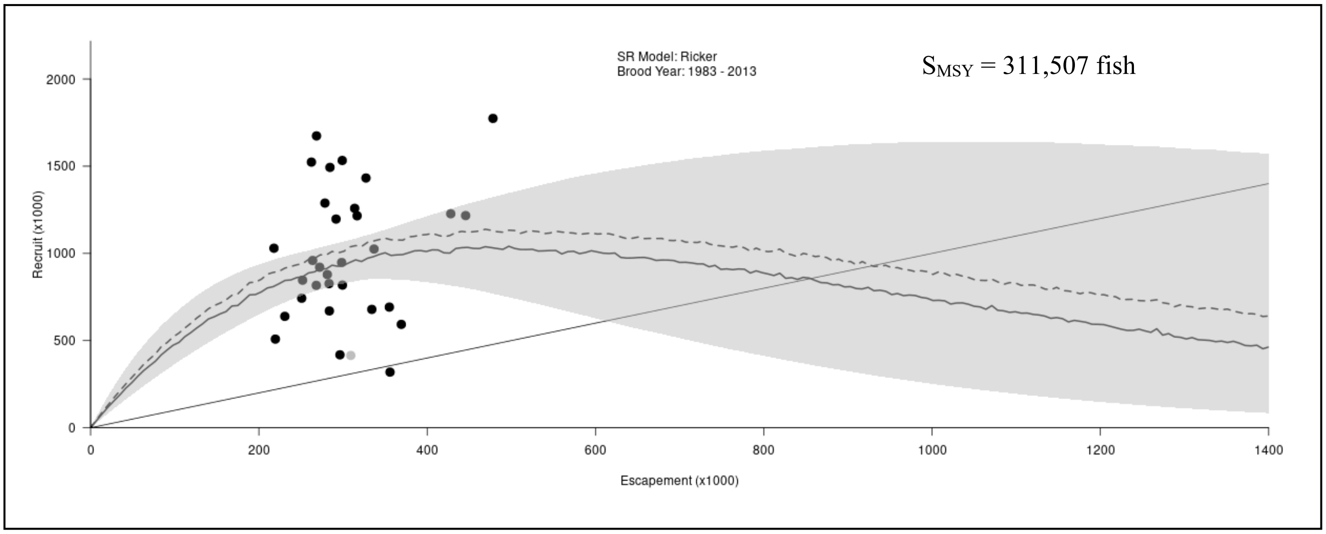
Appendix B5.–Chignik sockeye salmon early-run simple Ricker spawner recruit curves for 1983–2013 and 1998–2013.

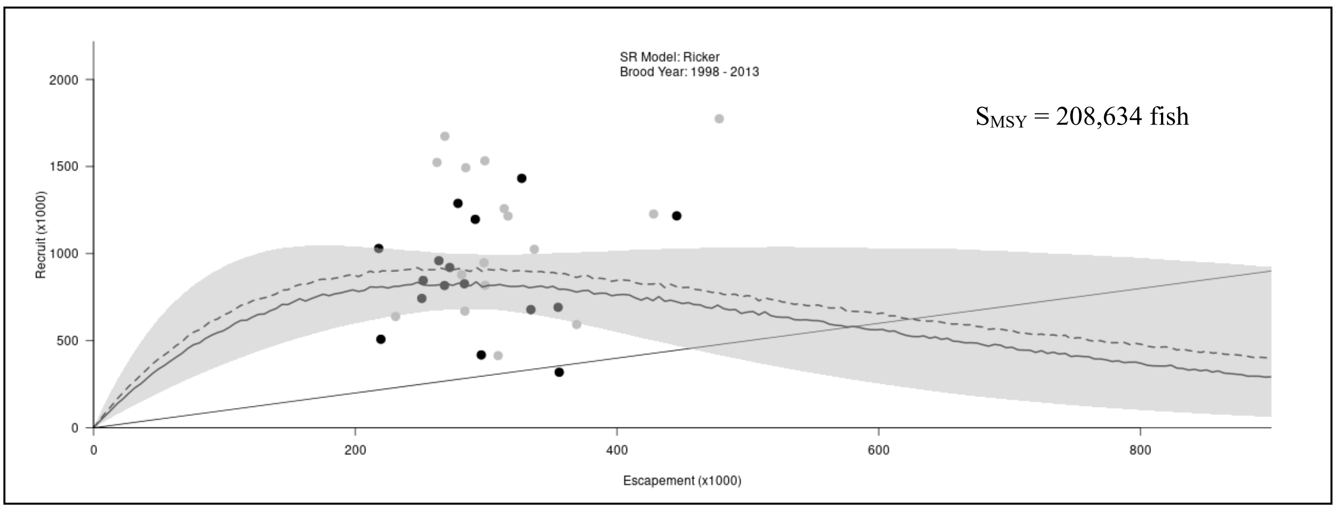




Note: Light grey dots are data points from 1983 to 1997 not included in the model fit.

Appendix B6.–Chignik sockeye salmon late-run simple Ricker spawner recruit curves for 1983–2013 and 1998–2013.





Note: Light grey dots are data points from 1983 to 1997 not included in the model fit.

APPENDIX C. SUPPORTING INFORMATION FOR CHIGNIK MANAGEMENT AREA PINK SALMON ESCAPEMENT GOALS

Appendix C1.–Description of stock and escapement goal for Chignik pink salmon.

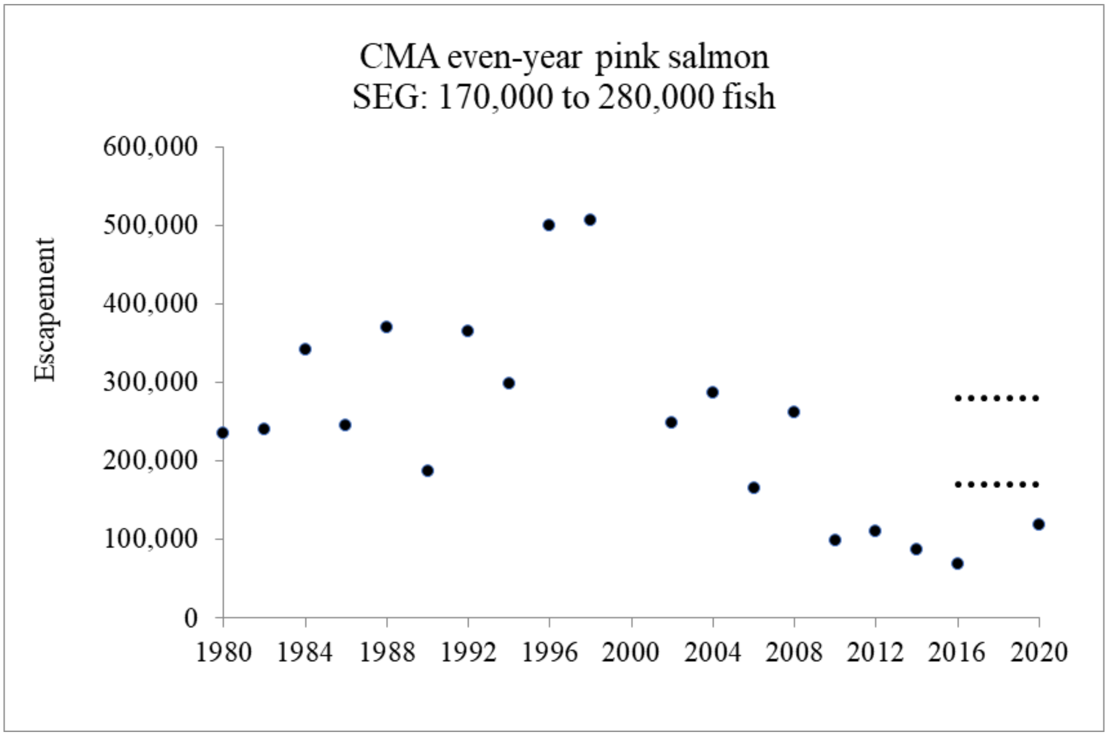
System: Entire CMA Species: Pink salmon	
Regulatory area	Chignik Management Area
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Current escapement goal:	SEG (even years): 170,000 to 280,000 (2016) SEG (odd years): 260,000 to 450,000 (2016)
Review outcome:	Even years: No change Odd years: No change
Optimal escapement goal:	None
Inriver goal:	None
Action points:	None
Escapement enumeration:	Aerial survey, 1980 to present
Data summary	
Data quality:	Poor
Data type:	Fixed-wing aerial surveys from 1980 to present. Data used in analysis represents indicator streams and years from each district with a complete survey dataset from 1980-present. No stock-specific harvest information is available.
Data Contrast:	Even years: 7.4; Odd years: 5.5
Methodology:	Percentile Approach
Criteria for SEG:	Moderate contrast, low exploitation
Percentiles:	20th to 60th
Comments:	Data from 1980–2021 were used from systems with complete survey histories, in years with a majority of systems surveyed, and indicator streams selected based on contribution to district and areawide escapement estimates. Eight areawide systems were chosen to represent an indexed escapement goal: Aniakchak River 272-605, Main Creek 272-702, Chiginagak Bay East 272-905, Kumlium Creek 272-501, North Fork River 272-514, Ivan River 273-722, Ivanof River 275-406, Humpback Creek 275-502.

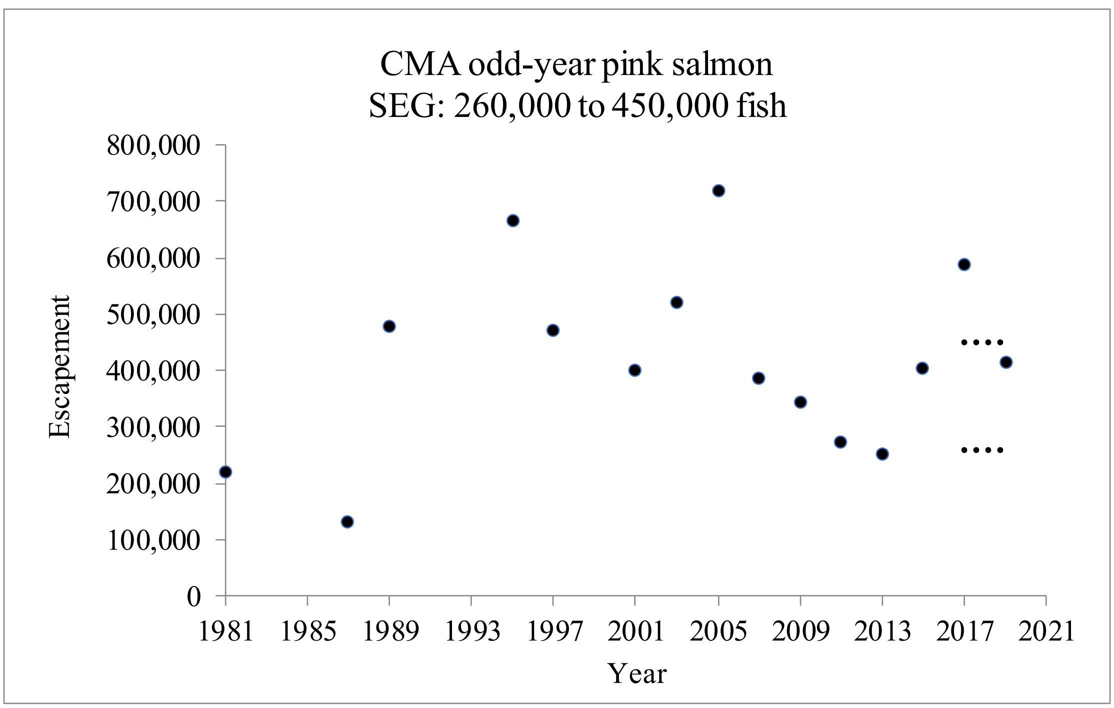
Appendix C2.–Chignik pink salmon peak aerial survey (PAS) counts, in selected indicator streams 1980–2020.

Year	Ivanof River	Humpback Creek	Ivan River	Kumlium Creek	North Fork River	Aniakchak River	Main Creek	Chiginagak Bay East	Index Total
1980	38,000	10,000	28,000	2,500	38,500	40,000	50,000	28,000	235,000
1981	18,000	39,000	80,000	35,000	14,000	2,700	5,800	25,000	219,500
1982	2,700	3,500	21,000	900	12,000	130,000	36,000	34,000	240,100
1983	20,000	8,500	12,000	–	–	1,000	9,000	3,100	IS
1984	61,000	15,000	98,000	3,000	25,000	28,400	8,500	102,000	340,900
1985	150,000	20,000	20,000	–	4,500	–	13,600	15,000	IS
1986	5,400	2,000	9,600	30,000	27,000	1,500	85,000	84,000	244,500
1987	16,900	15,500	12,800	46,900	5,500	2,500	11,100	20,000	131,200
1988	91,000	24,000	39,000	22,000	58,000	52,000	33,000	51,000	370,000
1989	161,000	51,000	32,000	63,000	23,000	5,000	53,000	89,000	477,000
1990	35,000	5,000	12,800	2,500	21,000	15,000	48,000	47,000	186,300
1991	150,300	96,300	42,200	115,300	–	–	–	5,700	IS
1992	43,110	25,290	31,400	9,800	38,300	96,600	25,600	95,140	365,240
1993	80,170	123,300	17,300	82,000	24,500	–	25,500	10,000	IS
1994	53,000	40,000	30,000	20,000	31,000	60,000	30,000	35,000	299,000
1995	145,000	100,000	120,000	114,000	45,000	70,000	66,000	7,000	667,000
1996	159,000	44,000	75,000	5,000	40,000	125,000	47,000	5,000	500,000
1997	35,000	46,000	92,000	125,000	33,000	68,000	70,000	3,500	472,500
1998	125,000	20,000	70,000	13,000	32,000	150,000	90,000	6,000	506,000
1999	130,000	14,000	14,000	107,000	45,000	1,000	31,900	–	IS
2000	25,000	12,000	51,000	–	27,000	197,000	28,000	23,000	IS
2001	32,000	24,000	71,000	150,000	20,000	41,000	12,000	52,000	402,000
2002	8,000	10,500	53,000	14,000	8,000	93,900	27,000	34,000	248,400
2003	38,000	19,000	20,000	117,000	52,000	102,000	30,000	144,000	522,000
2004	37,000	20,000	37,000	14,000	40,000	100,000	19,000	20,000	287,000
2005	72,000	82,300	150,000	175,000	27,500	140,400	69,000	1,100	717,300
2006	7,000	50,000	20,000	3,500	11,300	57,600	14,400	1,000	164,800
2007	100,000	35,000	56,000	37,000	54,000	29,500	64,000	9,000	384,500
2008	51,200	22,000	50,000	10,500	14,000	68,100	33,000	12,000	260,800
2009	65,550	24,200	89,100	51,300	15,300	44,300	32,200	22,300	344,250
2010	2,000	4,800	4,500	600	4,500	51,000	21,000	10,000	98,400
2011	37,000	42,000	30,000	52,000	22,000	31,000	29,000	29,000	272,000
2012	3,000	20,000	14,400	1,200	32,400	20,000	15,000	5,000	111,000
2013	10,000	18,900	37,600	75,000	6,700	38,000	18,600	47,000	231,800
2014	3,840	11,000	36,600	3,500	8,500	2,800	7,900	13,100	87,240
2015	53,600	21,200	39,200	136,000	15,700	65,300	37,000	36,000	404,000
2016	15,300	2,900	14,100	1,900	9,500	7,100	7,500	9,800	68,100
2017	106,000	44,200	76,900	153,100	81,300	44,100	57,700	23,000	586,300
2018	21,000	5,000	4,800	600	1,100	-	4,500	5,000	IS
2019	72,500	10,500	12,600	150,300	25,500	75,000	67,900	1,000	415,300
2020	23,000	9,450	37,600	8,100	6,675	4,000	23,430	6,420	118,675

Note: Systems not successfully surveyed in a survey year are indicated with a dash. If 1 or more systems in a survey year were not successfully surveyed, the Index Total was not calculated and is noted as “IS” for *incomplete survey*.

Appendix C3.–Chignik Management Area aggregate pink salmon PAS escapement, 1980–2020, with current escapement goals.





Note: Prior goals are not included due to a reduction in index streams used to estimate escapement.

APPENDIX D. SUPPORTING INFORMATION FOR THE CHIGNIK MANAGEMENT AREA CHUM SALMON ESCAPEMENT GOAL

Appendix D1.–Description of stocks and escapement goal for chum salmon in the entire CMA.

System: Entire CMA
Species: Chum salmon

Regulatory area	Chignik Management Area
Management division:	Commercial Fisheries
Primary fishery:	Commercial purse seine
Current escapement goal:	SEG: 45,000 to 110,000 (2016)
Review outcome:	No change
Optimal escapement goal:	None
Inriver goal:	None
Action points:	None
Escapement enumeration:	Aerial survey, 1981 to present
Data summary:	
Data quality:	Poor
Data type:	Fixed-wing aerial surveys from 1981 to present. Data used in analysis represents indicator streams and years from each district with a complete survey dataset from 1981 to present. No stock-specific harvest information is available.
Contrast:	10.1
Methodology:	Percentile Approach
Criteria for SEG:	High contrast, low exploitation
Percentiles:	20th to 60th
Comments:	Data from 1981 to 2021 were used from systems with complete survey histories, in years with a majority of systems surveyed, and indicator streams selected based on contribution to district and areawide escapement estimates. Six areawide systems were chosen to represent an indexed escapement goal; Aniakchak River 272-605, Small Nakalilok River 272-804, Chiginagak River 272-903a; Central District: North Fork River 272-514; Portage Creek 273-842; Ivanof River 275-406.

Appendix D2.–Chignik chum salmon peak aerial survey (PAS) counts for selected indicator streams 1981–2020.

Year	Small Nakalilok River	Aniakchak River	Chiginangak River	North Fork River	Portage Creek	Ivanof River	Total Index
1981	5,500	20,000	16,000	15,000	16,800	9,000	82,300
1982	–	47,000	8,500	2,000	6,000	6,100	IS
1983	3,200	2,665	8,700	–	5,500	4,000	IS
1984	32,000	42,000	34,850	10,500	12,600	38,000	169,950
1985	–	2,500	–	–	2,200	10,000	IS
1986	1,000	500	2,000	5,000	2,500	6,700	17,700
1987	2,500	1,700	15,700	3,700	6,400	4,745	34,745
1988	1,600	17,000	9,400	12,100	7,200	23,000	70,300
1989	4,100	2,500	3,400	1,200	1,600	4,000	16,800
1990	9,800	8,000	7,800	700	6,100	20,000	52,400
1991	4,100	5,600	–	2,900	18,700	167,500	IS
1992	11,160	50,100	4,300	54,000	3,120	14,000	136,680
1993	3,000	7,500	–	8,000	7,200	21,000	IS
1994	5,000	40,000	3,000	1,200	6,000	65,000	120,200
1995	400	50,000	2,000	15,000	5,000	65,000	137,400
1996	7,000	50,000	2,000	9,000	5,000	65,000	138,000
1997	12,000	7,500	30,000	5,000	15,000	56,000	125,500
1998	7,500	50,000	5,000	4,000	7,000	65,000	138,500
1999	15,000	6,900	3,000	2,000	1,600	6,000	34,500
2000	25,000	39,400	5,000	8,000	2,000	6,000	85,400
2001	10,000	46,000	31,000	2,000	600	53,000	142,600
2002	27,000	17,100	24,000	4,000	4,800	10,000	86,900
2003	7,000	15,000	4,000	13,000	1,500	28,000	68,500
2004	15,000	100,000	10,000	7,600	–	10,000	IS
2005	–	15,600	–	75,000	9,000	500	IS
2006	4,000	8,420	8,800	1,200	1,000	18,000	41,420
2007	8,700	10,500	4,200	2,000	14,500	100,000	139,900
2008	1,100	24,900	–	–	14,240	76,800	IS
2009	32,000	19,000	14,800	9,600	3,900	29,000	108,300
2010	12,000	3,500	19,125	4,000	2,000	62,000	102,625
2011	38,000	6,000	18,000	12,000	3,000	42,000	119,000
2012	5,000	5,000	3,000	3,600	2,200	7,500	26,300
2013	8,500	8,000	1,400	5,000	6,000	81,000	109,900
2014	1,100	6,300	1,720	1,000	8,600	28,000	46,720
2015	30,100	29,000	12,000	12,500	7,500	32,300	123,400
2016	8,500	6,400	19,600	4,000	5,400	26,000	69,900
2017	24,700	16,500	9,300	12,400	6,000	28,000	96,900
2018	–	–	–	3,200	5,200	20,500	IS
2019	18,700	24,000	17,400	12,400	4,700	20,800	98,000
2020	12,500	–	1,250	2,255	1,680	14,000	31,685

Note: Systems not successfully surveyed in a survey year are indicated with a dash. If 1 or more systems in a survey year were not successfully surveyed, the Index Total was not calculated and is noted as “IS” for *incomplete survey*.

Appendix D3.–Chignik Management Area chum salmon PAS escapement, 1981–2020, with current escapement goal.