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Review of Salmon Escapement Goals in Bristol Bay, Alaska, 2009

by

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

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

The Alaska Department of Fish and Game interdivisional escapement goal review committee reviewed Pacific salmon *Oncorhynchus* spp. escapement goals for the major river systems in Bristol Bay. Spawner-return data were evaluated for sockeye salmon *O. nerka* in the Ugashik, Egegik, Naknek, Kvichak, Alagnak, Wood, Nushagak, Igushik, Togiak, and Kulukak Rivers; Chinook salmon *O. tshawytscha* in the Nushagak, Togiak, Alagnak, Naknek, and Egegik Rivers; and chum salmon *O. keta* in the Nushagak River. There are currently no escapement goals for coho salmon *O. kisutch* or pink salmon *O. gorbuscha* in any of the rivers in Bristol Bay. A total of 17 escapement goals were evaluated for 16 stocks in Bristol Bay. The committee recommended that the escapement goal for Togiak River sockeye salmon be defined as a Sustainable Escapement Goal (SEG) instead of a Biological Escapement Goal (BEG); however, the current escapement goal range would remain unchanged. The committee also recommended that the 2 escapement goals (off-cycle and pre-peak/peak) for sockeye salmon in the Kvichak River be combined into a single SEG escapement goal range of 2 million to 10 million with a recommended exploitation rate of 50% or less. The committee is also in the process of evaluating the effect that transitioning from Bendix sonar to dual frequency identification sonar (DIDSON) in the Nushagak River on current escapement goals for Chinook, chum, and sockeye salmon. The final step in the transition occurred in 2009. However, data from the 2 sonar systems has not been fully processed and analyzed at this time.

Key words: Pacific salmon, *Oncorhynchus*, sockeye salmon, *O. nerka*, Chinook salmon, *O. tshawytscha*, chum salmon, *O. keta*, coho salmon, *O. kisutch*, pink salmon, *O. gorbuscha*, Bristol Bay, Kvichak River, Alagnak River, Naknek River, Egegik River, Ugashik River, Wood River, Igushik River, Nushagak River, Kulukak River, Togiak River, spawning escapement goal, Ricker stock-recruitment model, smolt, Alaska Board of Fisheries.

INTRODUCTION

Bristol Bay, Alaska, supports some of the largest sockeye salmon *Oncorhynchus nerka* runs in the world. Combined sockeye salmon runs to Bristol Bay have averaged approximately 39.8 million fish for the last 20 years (1989–2008), with 9 major river systems producing more than 99% of the returning sockeye salmon (Ugashik, Egegik, Naknek, Kvichak, Alagnak, Wood, Nushagak, Igushik, and Togiak rivers; Table 1; Figure 1). Management of these sockeye salmon runs is based on achieving spawning escapements for each river within a specific escapement goal range. Individual escapement goals for sockeye salmon have been in place for the major river systems since the early 1960s (Burgner et al.1967; Fried 1994; Cross et al. 1997; Fair 2000, Fair et al. 2004; Baker et al. 2006). Bristol Bay also supports one of the largest runs of Chinook salmon *O. tshawytscha* in Alaska. The Chinook salmon run in the Nushagak River has averaged 150,000 since the 1990s. Smaller runs of chum *O. keta*, coho *O. kisutch*, and pink *O. gorbuscha* salmon are also found in the many rivers of Bristol Bay.

The purpose of this report is to inform the Alaska Board of Fisheries (board) and the public of our progress in reviewing and recommending escapement goals for salmon in Bristol Bay. Many salmon escapement goals in Bristol Bay have been set and evaluated at regular intervals since statehood. During the previous board cycle, 2006–2007, Bristol Bay escapement goals were reviewed, and recommended changes were made by the Alaska Department of Fish and Game (department; Baker et al. 2006).

Recent genetic techniques have greatly improved the ability to accurately determine sockeye salmon stock compositions of the harvest (Dann et al. 2009). In Bristol Bay, these data are currently available for the past 3 years. However, there is a study in progress that uses previous collected scale samples from harvests dating back to 1964 to isolate DNA and determine partial historical harvest stock compositions. Over the next few years, the data gathered from these

studies will be used to reconstruct brood tables for each sockeye salmon stock, and hence, greatly improve our understanding of stock productivity. Because of this imminent change to the brood tables upon which escapement goals are built, the escapement goal committee does not believe that major changes to existing goals should occur at this time. Nonetheless, it was the intention of this review to re-evaluate existing data sets using modern statistical and modeling techniques to estimate escapement levels at maximum sustained yield for comparison to current goals. Non-sockeye salmon escapement goals were evaluated, as necessary, in this review.

Escapement goals were reviewed based on the *Policy for the Management of Sustainable Salmon Fisheries* (SSFP; 5 AAC 39.222) and the *Policy for Statewide Salmon Escapement Goals* (EGP; 5 AAC 39.223). The board adopted these policies into regulation during the winter of 2000–2001 to ensure that the state's salmon stocks are conserved, managed, and developed using the sustained yield principle. Two important terms defined in the SSFP were:

"Biological Escapement Goal (BEG): the escapement that provides the greatest potential for maximum sustained yield (MSY)," and

"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."

The department reviews the escapement goals for Bristol Bay rivers on a schedule that corresponds to the board's 3-year cycle for considering area regulatory proposals. This report describes the Bristol Bay salmon escapement goals that were reviewed in 2009.

During the 2009 review process, escapement goals for the following stocks were evaluated:

- Sockeye salmon: Ugashik, Egegik, Naknek, Kvichak (pre-peak/peak and off-cycle), Alagnak, Wood, Nushagak, Igushik, Togiak, and Kulukak rivers;
- Chinook salmon: Alagnak, Egegik, Naknek, Nushagak, and Togiak rivers; and
- Chum salmon: Nushagak River.

During the spring of 2009, the department established an interdivisional escapement goal review committee (hereafter referred to as the committee). The committee consisted of 5 Division of Commercial Fisheries and 2 Division of Sport Fish personnel (Table 2). The committee was formed to provide an analysis for recommending an escapement goal for each stock of salmon.

The committee formally met 13 February, 2009 to review escapement goals and develop recommendations. The committee also communicated by email. All committee recommendations were reviewed by the department's regional and headquarters staff prior to being adopted as escapement goals per the SSFP and EGP (Table 2).

METHODS

Available escapement, catch, and age data for each stock were compiled from research reports, management reports, and unpublished historical databases. The committee evaluated the type, quality, and quantity of data for each stock. This evaluation was used to determine the appropriate type of escapement goal as defined in regulation. Generally speaking, an escapement goal for a stock should provide escapement that produces sustainable yields. An escapement goal for a stock was defined as a BEG if a sufficiently long time series of escapement, catch, and

age estimates were available; the estimates were sufficiently accurate and precise; and the data were considered sufficient to estimate MSY (as per rules and methods in Chinook Technical Committee 1999; Hilborn and Walters 1992; Quinn and Deriso 1999). An escapement goal for a stock was defined as an SEG if a sufficiently long time series of escapement estimates were available, but there was concern about the spawner-return data (lack of age composition estimates and/or concern with stock-specific catch allocation) or there was a lack of information on stock productivity.

The committee considered visual counts from towers as "good" estimates of escapement and sonar counts as "fair" estimates of escapement. Spawner-return data were considered "good" if the escapement quality was "good" and there were no concerns with estimates of stock-specific harvest. Spawner-return data were considered "fair" if the quality of the escapement data was "fair" or there were concerns with estimates of stock-specific harvest.

The majority of the large salmon stocks in Bristol Bay have "good" escapement and age data, and in some cases, smolt data. Sockeye salmon escapement was sampled by beach seine and visually counted using towers at Ugashik, Egegik, Naknek, Kvichak, Alagnak, Wood, Igushik, and Togiak rivers. Escapement was sampled by gillnet or beach seine and estimated using hydroacoustics (sonar) for Nushagak River salmon. Age data have been collected from both the escapement and harvest for all of these stocks. Harvest allocation for each stock was estimated by harvest location and age composition. Stock contributions for multi-stock fisheries (Naknek-Kvichak and Nushagak districts) were estimated based on age composition and run timing of each stock (West 2003). All other stocks (Kulukak Bay sockeye salmon; all Chinook salmon) whose escapements were estimated by aerial survey were not sampled for age composition, nor were their contributions to harvest.

ESCAPEMENT GOAL RECOMMENDATION

In previous reviews, escapement goals were evaluated for Bristol Bay stocks using the following methods: (1) Stock-Recruitment Analysis; (2) Yield Analysis; (3) Smolt Information; and (4) Risk Analysis. Spawner-return data were used to estimate escapement goals when the committee determined they were "good" estimates of total return (escapement and stock-specific harvest) for a stock. When "good" spawner-return data were available, escapement goals were estimated based on: (1) escapements producing average yields that were 90–100% of MSY from a stock-recruitment model, and 2) the Yield Analysis, described in Baker et al. (2006), which also estimates MSY with corresponding 90–100% yield range. Smolt information, when available, was used to aid in the estimation of escapement goals for stocks. When the harvest of a stock was deemed coincidental to harvests and management of primary stocks (e.g., chum harvests are coincidental to the directed harvests of sockeye and Chinook salmon in the Nushagak River), the risk analysis approach was used to determine SEG thresholds for these non-targeted stocks.

In this review, the purpose was not to fully re-evaluate all goals as previously explained, but rather to apply the most widely accepted method (stock-recruitment models) to estimate the spawning escapement at MSY, when applicable, for comparison to current goals. As such, only those methods used in this review are described below.

Stock-Recruitment Analysis

Stock-recruitment models were used to analyze salmon spawner-return data for all available brood years. For this analysis, spawners were analogous to stock and return analogous to

recruitment. Total returns were the sum of escapements and harvests. Methods used to estimate total return (harvest plus escapement) were described in Bernard (1983). Sport and subsistence harvests were only included in total return estimates for the Nushagak River Chinook salmon, and were considered minor components for the other stocks.

The most commonly used Stock-Recruitment (S-R) models are the Ricker (1954) and the Beverton-Holt (1957) models. These models are governed by the following equations, respectively:

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

$$R = \frac{\alpha S}{1 + \frac{\alpha}{\beta} S}$$

where α and β are parameters in these models. A Bayesian approach was used to estimate these parameters in the models. We used multiplicative error Bayesian analysis has been used for the stock-recruitment data analysis for Ricker (Rivot et al. 2001) and Beverton-Holt (McAllister et al. 2001) models. The department has also applied Bayesian approach to Ricker models in previous escapement goal studies (Der Hovanisian et al. *In prep.*). We assumed multiplicative error for both models. The analysis in this report was similar to the previous department studies, but it differs in three aspects. First, the serial correlation was not explicitly considered in the model. Autocorrelation can be a serious problem in a non-Bayesian analysis because autocorrelation leads to worse "time-series bias" (Walters 1985 and 1990). However, after Korman et al. (1995) examined sockeye stocks in Bristol Bay, Alaska, they concluded it was not worth applying a bias-correction method. Second, the parameter α was not corrected for the logarithm transformation bias using the formulas from Hilborn and Walters (1992). That correction was used for the mean of an estimated parameter (Hilborn and Mangel 1997). It was not appropriate to make the correction for the posterior distribution of a parameter within the Bayesian framework. Third, different uninformative priors (Meyer and Millar 2000) were applied. For the detail of the Bayesian models, refer to Appendix D.

Having estimates of α and β, the fishery management parameter, S_{msy} (the optimal stock size at MSY), was calculated based on the formulations from Hilborn and Walters (1992). To generate samples from the posterior distribution, a Markov Chain Monte Carlo (MCMC) chain was simulated, with 20,000 iterations. The first half of the sequence was discarded and convergence was checked. The analyses were done using WinBUGS (Bayesian Inference Using Gibbs Sampling) (Spiegelhalter et al. 1996).

Risk Analysis

For stocks that were passively managed and coincidentally harvested, SEG thresholds (Bernard et al. 2009) were estimated. The 6 goals previously developed using these procedures were: Kulukak River sockeye salmon; Alagnak, Egegik, Naknek, and Togiak rivers Chinook salmon; and Nushagak River chum salmon. The nature of the risk analysis approach does not lend itself to a necessary update with every 3 years of additional data; therefore, we did not re-analyze the data for this review.

RESULTS AND DISCUSSION

A total of 17 escapement goals were evaluated for 16 stocks in Bristol Bay. The committee recommended that the escapement goal for Togiak River sockeye salmon be defined as an (SEG) instead of a BEG; however, the current escapement goal range would remain unchanged from the 2000 review (Fair 2000; see also Table 3). The committee also recommended that the 2 escapement goals (off-cycle and pre-peak/peak) for sockeye salmon in the Kvichak River be combined into a single SEG escapement goal range of 2 million to 10 million with a recommended exploitation rate of 50% or less. The committee is also in the process of evaluating the effect that transitioning from Bendix sonar to DIDSON in the Nushagak River will have on current escapement goals for Chinook, chum, and sockeye salmon. The final step in the transition occurred in 2009. However, data from the 2 sonar systems have not been fully processed and analyzed at this time.

The committee recommended no change to the current SEG ranges for sockeye salmon in the Ugashik, Egegik, Naknek, Alagnak, Nushagak, Wood, and Igushik rivers (Table 3; Appendices A1–A9). The committee did not formally evaluate the escapement goals for sockeye salmon in these rivers. Non-targeted sockeye salmon stocks were identified in the commercial harvest in all the fishing districts in Bristol Bay based on genetic stock composition estimates (Dann et al. 2009). These genetic stock composition estimates will allow department to produce new estimates of total run and production (brood table) for sockeye salmon in each river. The department anticipates this will occur in 3–5 years and plans to re-evaluate escapement goals for sockeye salmon once new total run and brood tables are completed.

The recommendation for each escapement goal follows by species and river. The detailed information for each escapement goal can be found in the previous escapement goal reports (Baker et al. 2006; Fair et al. 2004). Recent and historical data used for each escapement goal analysis is located in Appendices A–C.

SOCKEYE SALMON

Ugashik River

No change was recommended to the current SEG range of 500,000 to 1,200,000 sockeye salmon for Ugashik River (Table 3; Appendix A1). Escapement was within the escapement goal range in 8 of the last 10 years (Appendix A1). Escapement averaged 853,000; total return averaged 2.758 million, and return per spawner (R/S) averaged 4.32 sockeye salmon annually from 1956−2002. The current SEG range is below the spawning escapement that produces Maximum Sustained Yield (S_{msy}) based on an analysis of S-R data (Table 4).

Egegik River

No change was recommended to the current SEG range of 800,000 to 1,400,000 sockeye salmon for Egegik River (Table 3; Appendix A2). Escapement was within the escapement goal range in 6 of the last 10 years (Appendix A2). Escapement averaged 1.097 million sockeye salmon, total return averaged 6.556 million, and R/S averaged 5.88 sockeye salmon annually from 1956–2002. The current SEG range is below S_{msy} based on an analysis of S-R data (Table 4).

Naknek River

No change was recommended to the current SEG range of 800,000 to 1,400,000 sockeye salmon for Naknek River (Table 3; Appendix A3). Escapement was within the escapement goal range in 2 of the last 10 years and within the optimum escapement goal range (800,000 to 2,000,000) 7 out of the last 10 years (Appendix A3). Escapement averaged 1.257 million, total return averaged 3.769 million, and R/S averaged 3.23 sockeye salmon annually from 1956–2002. The current SEG range is below S_{msy} based on an analysis of S-R data (Table 4).

Alagnak River

No change was recommended to the current minimum SEG threshold of 320,000 sockeye salmon for Alagnak River (Table 3; Appendix A4). The SEG threshold was exceeded in 10 of the last 10 years (Appendix A4). Escapement averaged 469,000, total return averaged 1.362 million, and R/S averaged 3.83 sockeye salmon annually from 1956–2002. The current SEG range is below S_{msy} based on an analysis of S-R data (Table 4).

This Alagnak River stock is passively managed and coincidentally harvested with the Kvichak River stock. Therefore, the department is not able to actively manage this stock and obtain an escapement goal range. It is for this reason that an SEG threshold was established for this stock and not an escapement goal range.

Historically, Alagnak River was not considered a large producer of sockeye salmon compared to the Kvichak River and some of the sockeye salmon stocks in Bristol Bay. However, since 2003 escapement to Alagnak River has averaged 3.286 million sockeye salmon. We do not yet know the total return from these large escapements. However, we should not be surprised by the recent production increase for Alagnak River. Schindler et al. (2006) used sediment cores to show that periods of high sockeye salmon abundance have occurred in Alagnak River approximately every 100 years for the last 5 centuries.

Kvichak River

The committee recommends a change to the Kvichak River sockeye salmon escapement goal. Currently, there are 2 goals: one for off-cycle years, and one for pre-peak and peak years. The current SEG for Kvichak River sockeye salmon is 2 million to 10 million for off-cycle years and 6 million to 10 million for pre-peak and peak years (Table 3; Appendix A5). Escapement was within the escapement goal range in 4 out of the last 7 off-cycle years (1999–2008) and 1 out of the last 3 pre-peak/peak years (1999–2008; Appendix A5). The pre-peak/peak escapement goal has not been met since 1999; 2005 was changed from a peak to off-cycle year. Escapement averaged 2.335 million, total return averaged 3.965 million, and R/S averaged 2.27 sockeye salmon annually during off-cycle years from 1956–2002. Escapement averaged 10.377 million, total return averaged 23.625 million, and R/S averaged 2.45 sockeye salmon annually during pre-peak and peak years from 1956–2002. Escapement averaged 5.243 million, total return averaged 11.076 million, and R/S averaged 2.34 sockeye salmon during all years from 1956–2002. The recommended SEG range of 2 million to 10 million for all years is below S_{msy} based on an analysis of S-R data (Table 4).

Setting an escapement goal for Kvichak River sockeye salmon run has proven difficult because of the perceived divergence in productivity between off-cycle and cycle (pre-peak and peak) years; poor density dependence found in the spawner-return data; and a subsequent lack of fit for stock-recruitment models. To help achieve escapements within the goal range and provide

harvest opportunity, a maximum exploitation rate of 50% was established for Kvichak River runs of 4 million to 20 million. For example, the management objective for an off-cycle year is 50% of the total inshore run, never to be less than 2 million or greater than 10 million. From 1996 through 2004, 7 of 9 years experienced escapements below the lower end of the escapement goal range (Figure 2). Since 2005, the lower end of the goal has been achieved each year.

In recent years, the ability to define a pre-peak or peak run was made increasingly difficult as the runs declined. A pre-peak/peak goal, largely composed of 5-year-old 2-ocean fish, was originally established in the 1960s (Rogers and Poe 1984) because it was believed that production differed from that of off-cycle years. Therefore, it was advantageous to separate them. However, with the new data available, we updated the analysis for comparing production between pre-peak/peak versus off-cycle years. Ricker S-R analyses were conducted separately for off-cycle and pre-peak/peak years. Alpha (α) parameters from the Ricker S-R analyses were used to compare the productivity between off-cycle and pre-peak/peak years (Figure 3). The results show similarity in the underlying productivity during off-cycle and pre-peak/peak years. In addition, we are no longer able to identify off-cycle and pre-peak/peak years. For instance, in 1983 (which was identified as an off-cycle year), the total run was large and looked more like a pre-peak or peak year than an off-cycle year. More recently, 2005 and 2009 (which were identified as peak and pre-peak years), the total runs were small and looked more like off-cycle years than a pre-peak or peak year. It was for these reasons the committee recommended that the pre-peak/peak goal of 6 million to 10 million be dropped and that the off-cycle goal of 2 million to 10 million expanded to include all years with a recommended 50% exploitation rate.

The recommended change of the escapement goal for Kvichak River sockeye salmon was also supported by an analysis completed by Ruggerone and Link (2006). Their analysis did not support the existing escapement goal policy of higher escapement levels (6 to 10 million fish) during peak and pre-peak return years compared to other return years (2 to 6 million). They concluded that maintenance of the Kvichak River sockeye salmon cycle through management actions does not appear necessary for high salmon productivity and harvestable surpluses. A similar conclusion was also reached by Rogers and Poe (1984).

Nushagak River

No change was recommended for the current SEG range of 340,000 to 760,000 sockeye salmon for Nushagak River (Table 3; Appendix A6). Escapement was within the escapement goal range in 7 of the last 10 years (Appendix A6). Escapement averaged 661,000, total return averaged 1.770 million, and R/S averaged 3.51 sockeye salmon annually from 1978–2002. The current SEG range is slightly below the spawning escapement that produces MSY (S_{msy}) based on an analysis of S-R data (Table 4).

The committee is also in the process of evaluating the effect that transitioning from Bendix sonar to DIDSON in the Nushagak River will have on the current escapement goal for sockeye salmon. The final step in the transition occurred in 2009. However, data from the 2 sonar systems have not been fully processed and analyzed at this time. Preliminary results *may* be available at the Bristol Bay board meeting in December 2009.

Wood River

No change was recommended to the current SEG range of 700,000 to 1,500,000 sockeye salmon for the Wood River (Table 3; Appendix A7). Escapement was within the escapement goal range

in 5 of the last 10 years (Appendix A7). Escapement averaged 1.148 million, total return averaged 3.163 million, and R/S averaged 2.88 sockeye salmon annually from 1956–2002. The current SEG range is below S_{msy} based on an analysis of S-R data (Table 4).

Igushik River

No change was recommended to the current SEG range of 150,000 to 300,000 sockeye salmon for Igushik River (Table 3; Appendix A8). Escapement was within the escapement goal range in 3 of the last 10 years (Appendix A8). Escapement averaged 346,000, total return averaged 976,000, and R/S averaged 4.49 sockeye salmon annually from 1956–2002. The current SEG range is below S_{msy} based on an analysis of S-R data (Table 4).

Togiak River

The committee recommended changing the escapement goal for sockeye salmon in Togiak River from a BEG to an SEG due to catch allocation issues within the Togiak District. Substantial numbers of non-Togiak stocks were identified in the commercial catch based on genetics stock composition estimates (Dann et al. 2009). Changing Togiak sockeye from a BEG to a SEG is similar to what was done for most sockeye salmon stocks in Bristol Bay in 2006 (Baker et al. 2006). Additionally, the committee recommends no change to the current escapement goal range of 120,000 to 270,000 (Table 3; Appendix A9) that was based on an escapement goal analysis for this stock that was completed in 2003 (Fair et al. 2004). The escapement goal range includes 100,000 to 250,000 tower counts and 20,000 expanded aerial survey counts that are considered additional to the Togiak towers counts (Baker et al. 2006; Fair et al. 2004).

Escapement was within the escapement goal range in 6 of the last 10 years (Appendix A9). Escapement averaged 182,000, total return averaged 559,000, and R/S averaged 3.48 sockeye salmon annually from 1956–2002. The current SEG range is close to S_{msy} based on an analysis of S-R data (Table 4).

Kulukak River

The committee was unable to evaluate the current escapement goal for sockeye salmon in Kulukak River because no aerial surveys were flown in the Kulukak River system from 2004–2008. The Kulukak River escapement goal is currently an SEG threshold of 8,000 aerial survey counts (Table 3; Appendix A10; Baker et al 2006; Fair et al. 2004). Escapement exceeded the SEG threshold in 5 out of 5 years from 1999–2003 (Appendix A10). The committee recommends that aerial surveys of the Kulukak River system be flown to evaluate this escapement goal in the future.

CHINOOK SALMON

Nushagak River

No change was recommended to the current SEG range of 40,000 to 80,000 Chinook salmon for Nushagak River (Table 3; Appendix B1). Escapement was within the escapement goal range in 4 of the last 10 years (Appendix B1). Escapement averaged 79,507 Chinook salmon from 1966–2002, producing an average total return of 165,329 with an average return per spawner of 2.61 annually.

The committee is also in the process of evaluating the effect that transitioning from Bendix sonar to DIDSON in Nushagak River will have on the current escapement goal for Chinook salmon.

Togiak River

The committee was unable to evaluate the current escapement goal for Chinook salmon in Togiak River because very few aerial surveys were flown in the Togiak River system for Chinook salmon from 2003–2008. The Togiak escapement goal is currently an SEG threshold of 9,300 aerial survey counts with no upper bounds (Table 3; Appendix B2). Escapement exceeded the SEG threshold in 4 out of 4 years (1999–2002). Escapement was not estimated in 2003-2008. The committee recommends that aerial surveys of the Togiak River system be flown to evaluate this escapement goal in the future.

Naknek River

No change was recommended to the current SEG threshold of 5,000 Chinook salmon (Table 3; Appendix B3). The escapement goal for Chinook salmon in the Naknek River was based on aerial survey estimates. The goal was estimated using the risk analysis approach with escapement data beginning in 1971 (Baker et al. 2006; Fair et al. 2004). Escapement has averaged 5,969 Chinook salmon from 1971–2008 (Appendix B3). Escapements exceeded the SEG threshold in 6 out the 7 years (2000–2004; 2007–2008). Escapement was not estimated in 1999 and 2005–2006.

Alagnak River

No change was recommended to the current SEG threshold of 2,700 Chinook salmon (Table 3; Appendix B4). The escapement goal for Chinook salmon in Alagnak River was based on aerial survey estimates. The goal was estimated using the risk analysis approach with escapement data beginning in 1970 (Baker et al. 2006; Fair et al. 2004). Escapement averaged 4,931 Chinook salmon from 1970–2008 (Appendix B4). Escapements exceeded the SEG threshold in 7 out of the last 10 years (1999–2008).

Egegik River

No change was recommended to the current SEG threshold of 450 Chinook salmon (Table 3; Appendix B5). The escapement goal for Chinook salmon in Egegik River was based on aerial survey estimates. The goal was estimated using the risk analysis approach with escapement data beginning in 1985 (Baker et al. 2006; Fair et al. 2004). Escapement estimates were the sum of aerial surveys from Gertrude, Kaye's, and Takayoto creeks only. Escapement has averaged 547 Chinook salmon from 1985–2008 (Appendix B5). Escapements exceeded the SEG threshold in 4 out of the last 10 years (1999–2008).

CHUM SALMON

Nushagak River

No change was recommended to the current SEG threshold of 190,000 Chum salmon (Table 3; Appendix C1). This escapement goal was based on sonar counts and established using the risk analysis approach (Baker et al. 2006; Fair et al. 2004). Escapement has averaged 308,945 chum salmon from 1980–2008 (Appendix C1). Escapements exceeded the SEG threshold in 8 out of the last 10 years (1999–2008).

COHO SALMON

There are currently no escapement goals for coho salmon in Bristol Bay. Coho salmon escapement goals for Nushagak, Togiak, and Kulukak rivers were dropped in 2006 (Baker et al. 2006). These goals were dropped because the department no longer estimates coho salmon escapement in these 3 rivers.

PINK SALMON

There are currently no escapement goals for pink salmon in Bristol Bay. The pink salmon escapement goal in the Nushagak River was dropped in 2006 (Baker et al. 2006). The Nushagak River pink salmon goal was dropped because the department no longer estimates pink salmon escapement in Nushagak River.

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TABLES AND FIGURES

Table 1.–Bristol Bay sockeye salmon runs by system, 1989–2008.

Year	Alagnak	Egegik	Igushik	Kvichak	Naknek	Nushagak	Togiak	Ugashik	Wood	Total
1989	1,456,715	10,982,191	1,253,349	20,546,578	3,303,545	1,260,160	178,897	5,050,591	2,600,575	46,632,601
1990	1,516,487	12,931,907	1,316,384	17,987,984	8,675,471	1,797,229	343,723	2,981,747	2,687,768	50,238,700
1991	1,653,055	9,938,490	2,513,393	8,329,427	10,285,373	1,800,479	804,953	5,628,628	3,425,986	44,379,784
1992	1,349,201	18,616,249	830,190	10,969,092	5,326,773	1,898,491	862,259	5,831,415	2,571,473	48,255,143
1993	2,257,608	24,482,294	1,661,902	9,901,802	4,905,544	2,330,448	697,395	5,912,728	3,936,201	56,085,922
1994	1,734,602	12,998,622	1,379,741	22,734,661	3,144,481	1,618,149	522,040	5,605,154	3,111,319	52,848,769
1995	1,780,539	16,200,744	1,989,745	28,330,238	3,700,260	792,229	771,293	6,040,598	4,191,837	63,797,483
1996	1,917,409	12,253,454	1,513,712	3,538,322	7,076,263	1,804,324	585,898	5,237,440	5,159,244	39,086,066
1997	681,409	9,363,087	313,691	1,828,355	1,514,787	929,880	264,240	2,238,765	3,631,149	20,765,363
1998	1,072,427	5,090,479	614,086	3,553,651	2,747,453	941,004	313,741	1,785,676	4,143,028	20,261,545
1999	2,843,135	9,406,998	1,626,796	13,307,746	3,969,933	991,826	565,234	4,059,544	6,160,257	42,931,469
2000	2,015,717	8,402,918	1,812,539	3,031,259	4,934,554	1,528,710	1,126,843	2,300,351	5,544,371	30,697,262
2001	1,106,307	3,867,625	1,324,241	1,435,570	6,683,792	2,126,312	1,109,256	1,356,025	4,014,038	23,023,166
2002	793,267	5,840,129	213,904	728,026	2,774,873	662,889	406,290	2,563,837	3,842,244	17,825,459
2003	3,789,818	3,502,937	1,035,722	1,750,692	5,183,655	2,273,681	897,566	2,582,872	5,744,224	26,761,167
2004	6,776,427	12,857,544	589,506	7,758,677	3,996,000	2,432,435	508,297	4,148,186	5,625,181	44,692,253
2005	5,301,016	9,625,859	1,878,030	2,877,518	7,806,032	3,442,172	565,478	3,001,814	4,770,667	39,268,586
2006	2,804,574	8,873,391	1,434,887	5,756,121	5,385,265	3,238,846	886,755	3,432,755	11,064,404	42,876,998
2007	4,277,498	7,928,408	1,762,291	4,230,592	8,736,347	2,579,855	1,086,227	7,625,801	6,523,544	44,750,563
2008	5,907,154	8,663,453	3,294,374	5,631,801	6,253,993	1,644,431	856,995	2,930,354	5,236,278	40,418,833
Mean	2,551,718	10,591,339	1,417,924	8,711,406	5,320,220	1,804,678	667,669	4,015,714	4,699,189	39,779,857
Median	1,848,974	9,516,429	1,407,314	5,693,961	5,059,105	1,798,854	641,647	3,746,150	4,167,433	42,904,234
Min	681,409	3,502,937	213,904	728,026	1,514,787	662,889	178,897	1,356,025	2,571,473	17,825,459
Max	6,776,427	24,482,294	3,294,374	28,330,238	10,285,373	3,442,172	1,126,843	7,625,801	11,064,404	63,797,483

Table 2.–List of members on the Alaska Department of Fish and Game (ADF&G) Bristol Bay salmon escapement goal committee and other participants who assisted with the escapement goal review.

Name	Position	Affiliation
Escapement Goal Committee:		
Timothy Baker	Area Research Biologist	ADF&G, Division of Commercial Fisheries
Lowell Fair	Regional Research Biologist	ADF&G, Division of Commercial Fisheries
Fred West	Asst. Area Research Biologist	ADF&G, Division of Commercial Fisheries
Greg Buck	Asst. Area Research Biologist	ADF&G, Division of Commercial Fisheries
Xinxian Zhang	Regional Biometrician	ADF&G, Division of Commercial Fisheries
Steve Fleischman	Fisheries Scientist	ADF&G, Division of Sport Fish
Jack Erickson	Regional Research Biologist	ADF&G, Division of Sport Fish
Other Participants:		
Erik Volk	Chief Fisheries Scientist	ADF&G, Division of Commercial Fisheries
Jeff Regnart	Regional Supervisor	ADF&G, Division of Commercial Fisheries
Dan Gray	Regional Management Biologist	ADF&G, Division of Commercial Fisheries
Slim Morstad	Area Management Biologist	ADF&G, Division of Commercial Fisheries
Tim Sands	Area Management Biologist	ADF&G, Division of Commercial Fisheries
Paul Salomone	Area Management Biologist	ADF&G, Division of Commercial Fisheries
Matt Jones	Asst. Area Management Biologist	ADF&G, Division of Commercial Fisheries
Jim Hasbrouck	Regional Supervisor	ADF&G, Division of Sport Fish
Matt Miller	Regional Management Biologist	ADF&G, Division of Sport Fish
Jason Dye	Area Management Biologist	ADF&G, Division of Sport Fish
Craig Schwanke	Asst. Area Management Biologist	ADF&G, Division of Sport Fish

Table 3.–Summary of current escapement goals and recommended escapement goals for salmon stocks in Bristol Bay, 2009.

	Current Escapement Goal				Recommended Escapement Goal		
System	Goal	Type	Year Adopted	Escapement Data	Action	Goal	Type
Sockeye Salmon							
Ugashik	500,000–1,200,000	SEG	1995; Changed to SEG in 2006	Tower	No Change		
Egegik	800,000–1,400,000	SEG	1995; Changed to SEG in 2006	Tower	No Change		
Naknek	800,000–1,400,000	SEG	1984; Changed to SEG in 2006	Tower	No Change		
Kvichak (off-cycle)	2,000,000–10,000,000	SEG	1997; Changed to SEG in 2006	Tower	Change to single goal	2,000,000–10,000,000	SEG
Kvichak (pre, peak)	6,000,000–10,000,000	SEG	1997; Changed to SEG in 2006	Tower	Change to single goal	2,000,000–10,000,000	SEG
Alagnak	320,000 minimum	SEG	2006	Tower	No Change		
Wood	700,000–1,500,000	SEG	2000; Changed to SEG in 2006	Tower	No Change		
Nushagak	340,000–760,000	SEG	1997; Changed to SEG in 2006	Sonar	No Change		
Igushik	150,000–300,000	SEG	2000; Changed to SEG in 2006	Tower	No Change		
Togiak	120,000–270,000	BEG	1997	Tower	Change to SEG	120,000–270,000	SEG
Kulukak Bay	8,000 minimum	SEG	2006	Aerial	No Change		
Chinook Salmon							
Nushagak	40,000–80,000	SEG	2006; Changed to SEG in 2006	Sonar	No Change		
Togiak	9,300 minimum	SEG	2006	Aerial	No Change		
Naknek	5,000 minimum	SEG	2006	Aerial	No Change		
Alagnak	2,700 minimum	SEG	2006	Aerial	No Change		
Egegik	450 minimum	SEG	2006	Aerial	No Change		
Chum Salmon							
Nushagak	190,000 minimum	SEG	2006	Sonar	No Change		

Table 4.–Current escapement goals and estimates of stock-recruitment parameters (α, β and Smsy) for sockeye salmon in Bristol Bay.

		Escapement Goal (x thousands)		Spawner-Return			α			β				S_{msy}		
	Goal							95% CI			95% CI				95% CI	
River	Type	Lower	Upper	Data	n	Model	Median	Lower	Upper	Median	Lower	Upper	1/β	Median	Lower	Upper
Ugashik	SEG	500	1,200	1956–2002	47	Ricker	3.36	2.33	5.19	0.0002	0.0000	0.0006	4,241	2,098	938	24,410
						Beverton-Holt	3.55	2.36	6.65	8,481	3,013	99,080		2,091	728	23,420
Egegik	SEG	800	1,400	1956–2002	47	Ricker	5.33	4.12	7.62	0.0001	0.0000	0.0004	9,804	6,226	1,819	132,200
						Beverton-Holt	5.49	4.16	9.83	36,370	9,452	811,600		8,871	2,077	201,900
Naknek	SEG	800	1,400	1956–2002	47	Ricker	4.02	2.90	5.71	0.0003	0.0001	0.0005	3,483	1,947	1,206	8,616
						Beverton-Holt	4.92	3.07	13.14	7,673	4,010	31,500		1,894	815	7,745
Alagnak	SEG	320		1956–2002	47	Ricker	3.27	2.29	5.06	0.0006	0.0001	0.0013	1,713	841	439	7,649
						Beverton-Holt	3.68	2.35	7.94	3,253	1,312	27,860		803	305	6,533
Kvichak	SEG	2,000	10,000	1956–2002	47	Ricker	1.85	1.39	2.54	0.0000	0.0000	0.0001	58,962	16,040	5,678	301,100
						Beverton-Holt	1.88	1.38	2.92	70,990	18,420	1,520,000		13,550	4,080	260,300
Nushagak	SEG	340	760	1978–2002	25	Ricker	5.08	3.82	6.82	0.0008	0.0005	0.0012	1,188	744	571	1,106
						Beverton-Holt	Model did not converge									
Wood	SEG	700	1,500	1956–2002	47	Ricker	3.64	2.63	5.28	0.0003	0.0001	0.0006	3,103	1,639	1,005	6,446
						Beverton-Holt	3.78	2.57	7.70	8,306	3,958	49,600		2,066	914	11,730
Igushik	SEG	150	300	1956–2002	47	Ricker	5.27	3.59	7.77	0.0019	0.0011	0.0028	514	328	251	509
						Beverton-Holt	Model did not converge									
Togiak	SEG	120	270	1956–2002	47	Ricker	5.53	3.94	7.66	0.0035	0.0018	0.0051	290	188	141	315
						Beverton-Holt	7.22	4.04	31.16	832	510	1,787		194	75	446
Bristol Bay	SEG	5,730	16,830	1956–2002	47	Ricker	3.21	2.54	4.32	0.0000	0.0000	0.0000	61,387	14,340	29,790	335,600
						Beverton-Holt	3.28	2.52	4.83	151,900	61,070	1,750,000		15,160	37,480	418,500

Note: A Bayesian analysis was used to estimate stock-recruitment parameters for Ricker and Beverton-Holt models. Multiplicative error was assumed for both models. Median parameter estimates were reported along with lower and upper 95% credible intervals (95% CI). Blank cells were that data which did not fit the models.

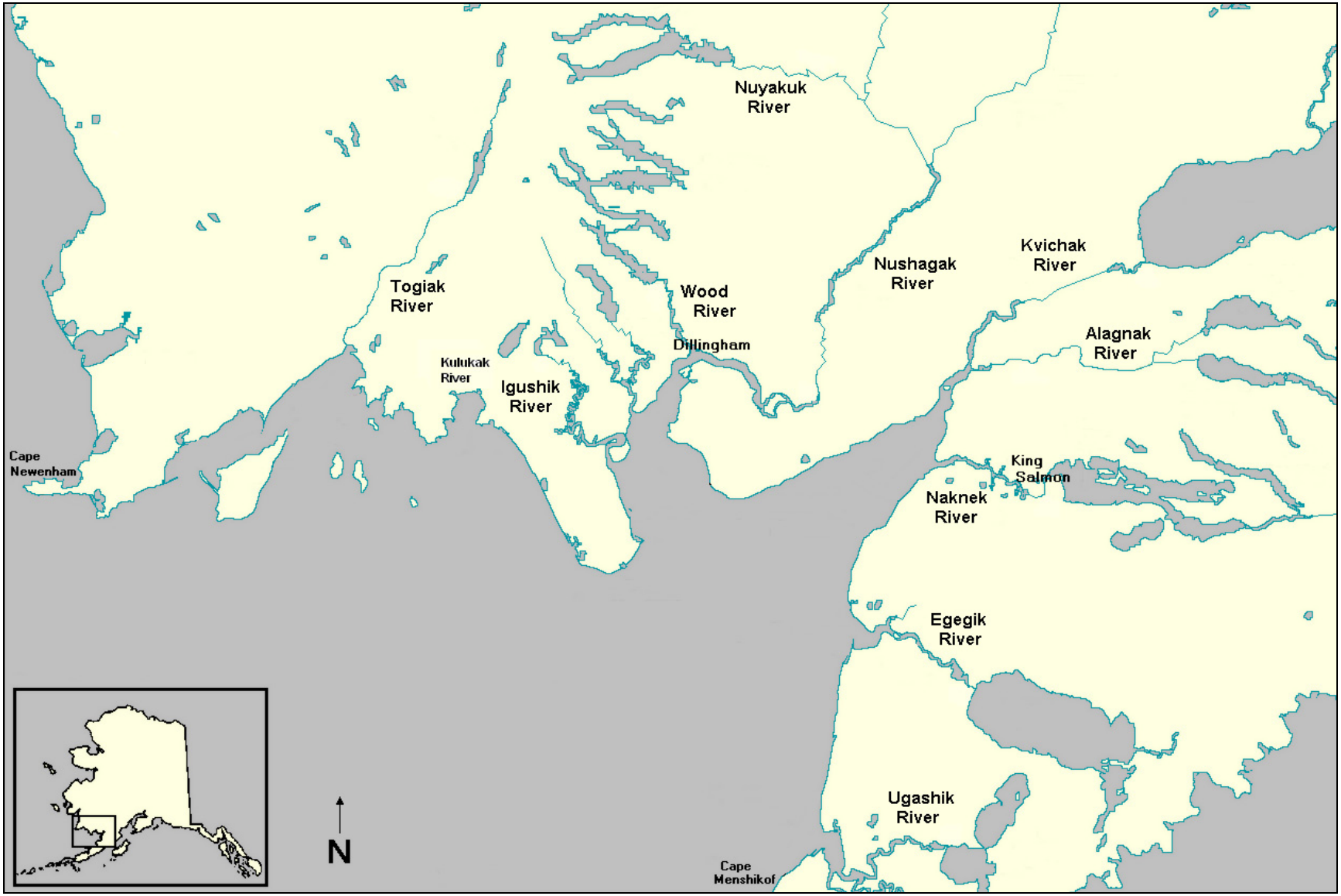

Figure 1.–Map of Bristol Bay showing major rivers.

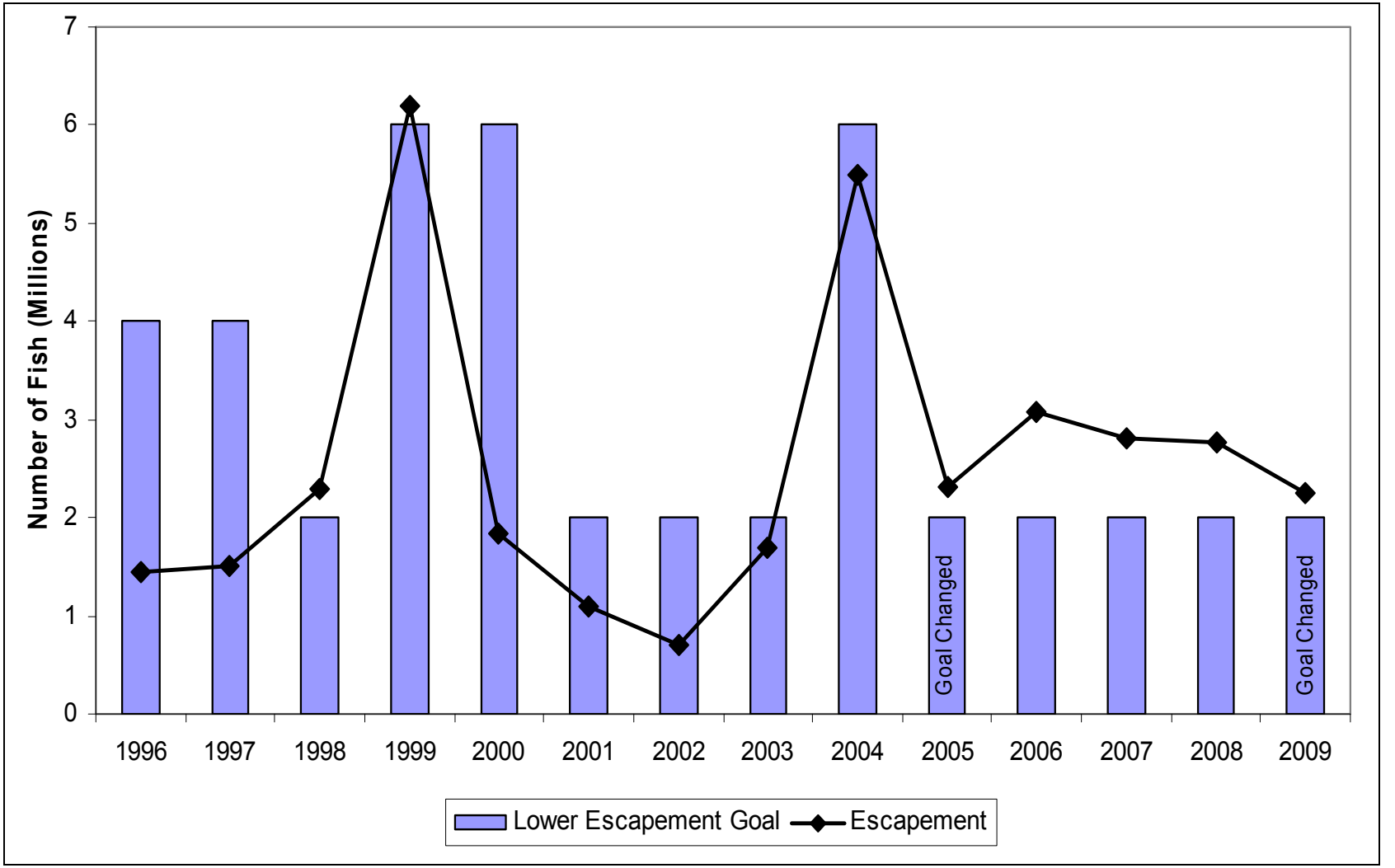

Figure 2.–Kvichak River sockeye salmon lower escapement goals and number of spawners, 1996–2009.

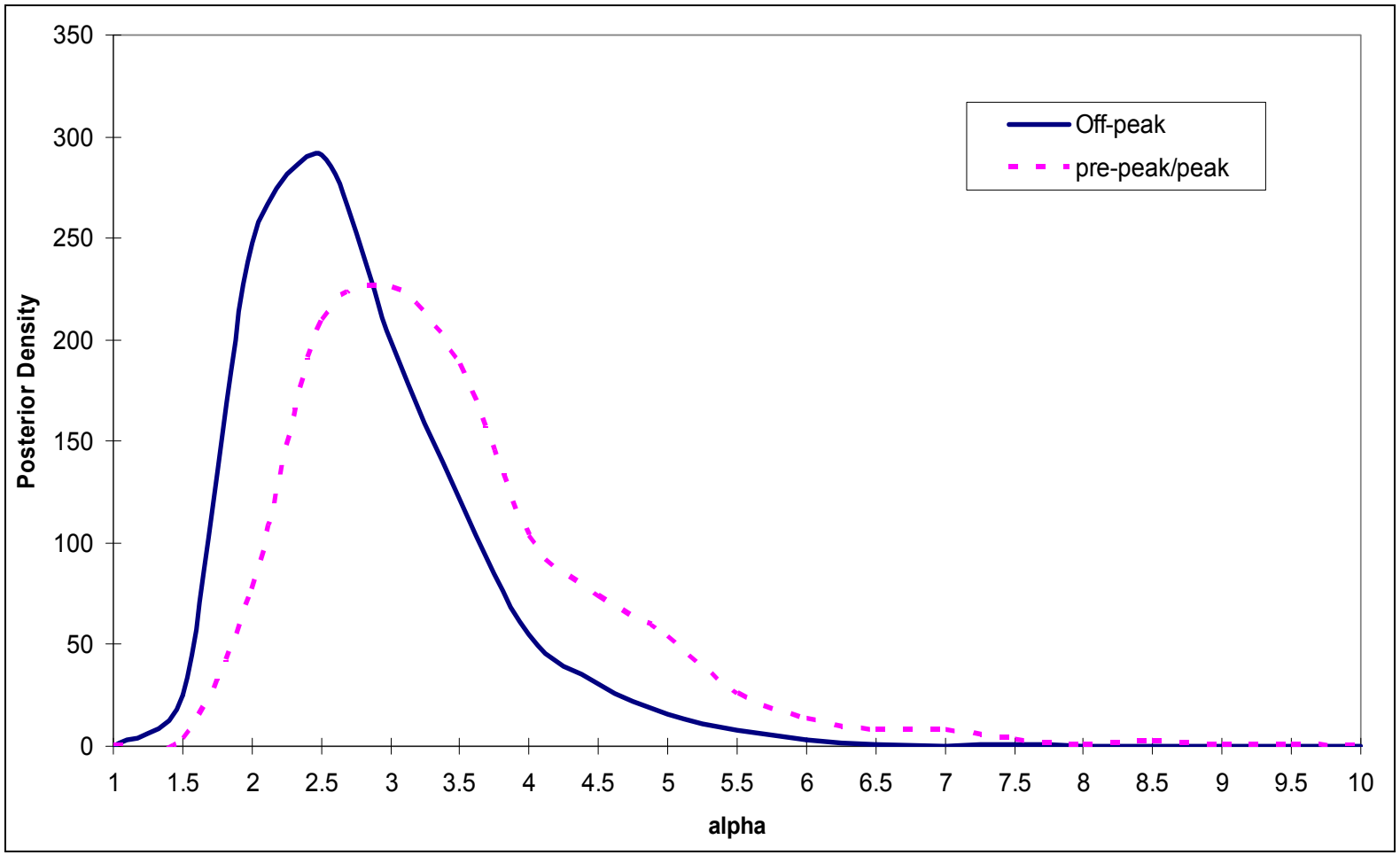

Figure 3.–Kernel density estimate of the posterior distribution of alpha parameter in Ricker stock-recruitment analysis of Kvichak River sockeye salmon during off-cycle and cycle (pre-peak/peak) years, 1956–2002, obtained from 10,000 iterations of the Gibbs sampler.

APPENDIX A. SOCKEYE SALMON

Appendix A1.–Escapement goal for Ugashik River sockeye salmon.

System: Ugashik River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	500,000–1,200,000 (1995)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	500,000–1,200,000
Escapement Goal Type:	Currently SEG. Change from BEG to SEG in 2006.
Escapement Estimation:	Tower counts from 1956 to present; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns about stock-specific harvest.
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment and yield analysis.
Autocorrelation	
Years within recommended goal	8 of last 10 years (1999–2008).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Ugashik River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement	Total Return	Return per Spawner
1949	0 [a]	2 [b]	
1950	0 [a]	49 [b]	
1951	0 [a]	343 [b]	
1952	0 [a]	1,189	
1953	0 [a]	1,108	
1954	0 [a]	511	
1955	0 [a]	178	
1956	425	4,132	9.72
1957	215	603	2.80
1958	280	678	2.42
1959	219	499	2.28
1960	2,304	3,031	1.32
1961	349	1,114	3.19
1962	255	423	1.66
1963	388	148	0.38
1964	473	322	0.68
1965	997	539	0.54
1966	704	2,315	3.29
1967	239	184	0.77
1968	71	39	0.55
1969	160	92	0.58
1970	735	295	0.40
1971	530	835	1.58
1972	79	258	3.27
1973	39	92	2.36
1974	62	725	11.69
1975	429	4,116	9.59
1976	356	5,309	14.91
1977	202	2,692	13.33
1978	82	2,065	25.18
1979	1,707	6,006	3.52
1980	3,335	7,781	2.33
1981	1,328	7,468	5.62
1982	1,186	2,508	2.11
1983	1,001	1,965	1.96
1984	1,270	5,464	4.30
1985	1,006	2,695	2.68
1986	1,016	6,696	6.59
1987	687	6,745	9.82
1988	654	5,650	8.64
1989	1,713	4,573	2.67
1990	749	4,611	6.16
1991	2,482	6,151	2.48
1992	2,195	2,703	1.23
1993	1,413	1,086	0.77
1994	1,095	1,660	1.52
1995	1,321	4,686	3.55
1996	692	1,388	2.01
1997	657	3,061	4.66
1998	925	1,349	1.46
1999	1,662	3,725	2.24
2000	638	4,179	6.55
2001	866	2,106	2.43
2002	892	4,875	5.47
2003	790	6,244 [b]	
2004	815	1,456 [b]	
2005	800	2 [b]	
2006	1,003	0 [b]	
2007	2,599	0 [b]	
2008	596	0 [b]	
1956–2002 Average	853	2,758	4.32
No. of Years	47	47	47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A2.–Escapement goal for Egegik River sockeye salmon.

System: Egegik River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	800,000–1,400,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	800,000–1,400,000
Escapement Goal Type:	Currently SEG. Changed from BEG to SEG in 2006.
Escapement Estimation:	Tower counts from 1956 to present; smolt data from 1983–2001; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns with stock-specific harvest.
Data Type	Tower counts; commercial harvest; smolt data; age data.
Methodology	Escapement goal based on Ricker stock-recruitment and yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1; smolt data had significant autoregressive correlation at lag-2.
Years within recommended goal	6 out of last 10 years (1999–2008).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Egegik River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement		Total Return		Return per Spawner
1949	0	[a]	14	[b]	
1950	0	[a]	371	[b]	
1951	0	[a]	2,653	[b]	
1952	0	[a]	1,632	[b]	
1953	0	[a]	1,105	[b]	
1954	0	[a]	1,992	[b]	
1955	0	[a]	1,265	[b]	
1956	1,104		6,846		6.20
1957	391		2,235		5.72
1958	246		1,261		5.13
1959	1,053		1,781		1.69
1960	1,799		7,911		4.40
1961	702		1,590		2.27
1962	1,027		1,474		1.44
1963	998		1,258		1.26
1964	850		1,983		2.33
1965	1,445		3,104		2.15
1966	804		2,511		3.12
1967	637		1,612		2.53
1968	339		459		1.35
1969	1,016		2,755		2.71
1970	920		1,240		1.35
1971	634		2,733		4.31
1972	546		2,959		5.42
1973	329		1,679		5.10
1974	1,276		3,025		2.37
1975	1,174		3,664		3.12
1976	509		5,317		10.45
1977	693		4,217		6.09
1978	896		9,208		10.28
1979	1,032		5,947		5.76
1980	1,061		8,575		8.08
1981	695		6,316		9.09
1982	1,035		6,339		6.12
1983	792		10,646		13.44
1984	1,165		13,528		11.61
1985	1,095		7,671		7.01
1986	1,152		14,331		12.44
1987	1,274		25,951		20.37
1988	1,599		18,885		11.81
1989	1,612		11,261		6.99
1990	2,192		15,739		7.18
1991	2,787		11,163		4.01
1992	1,946		9,701		4.99
1993	1,517		3,002		1.98
1994	1,898		8,758		4.61
1995	1,267		9,485		7.49
1996	1,076		4,617		4.29
1997	1,104		6,674		6.05
1998	1,111		1,637		1.47
1999	1,728		13,874		8.03
2000	1,032		12,387		12.00
2001	969		5,207		5.37
2002	1,036		5,595		5.40
2003	1,152		8,491	[b]	
2004	1,290		2,875	[b]	
2005	1,622		7	[b]	
2006	1,465		0	[b]	
2007	1,433		0	[b]	
2008	1,260		0	[b]	
1956–2002 Average	1,097		6,556		5.88
No. of Years	47		47		47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A3.–Escapement goal for Naknek River sockeye salmon.

System: Naknek River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	800,000–1,400,000 (1984)
Inriver Goal:	None
Optimal Escapement Goal:	2,000,000
Recommended Escapement Goal:	800,000–1,400,000
Escapement Goal Type:	Currently SEG. Changed from BEG to SEG in 2006.
Escapement Estimation:	Tower counts from 1956 to present; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns with stock-specific harvest.
Data Type	Tower counts; commercial harvest; age data.
Methodology	Escapement goal based on Ricker stock-recruitment, yield analysis.
Autocorrelation	No significant autocorrelation.
Years within recommended goal	2 out of last 10 years (1999–2008) within escapement goal range and 7 out of last 10 years within optimum escapement goal range (800,000 to 2,000,000).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Naknek River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement		Total Return		Return per Spawner
1950	0	[a]	1,100	[b]	
1951	0	[a]	3,234	[b]	
1952	0	[a]	1,572	[b]	
1953	0	[a]	589	[b]	
1954	0	[a]	3,138	[b]	
1955	0	[a]	1,851	[b]	
1956	1,773		2,499		1.41
1957	635		1,572		2.48
1958	278		1,039		3.74
1959	2,232		2,154		0.97
1960	828		4,022		4.86
1961	351		1,952		5.56
1962	723		1,074		1.49
1963	905		2,002		2.21
1964	1,350		2,060		1.53
1965	718		2,120		2.95
1966	1,016		3,839		3.78
1967	756		1,717		2.27
1968	1,023		745		0.73
1969	1,331		2,552		1.92
1970	733		2,718		3.71
1971	936		4,273		4.57
1972	587		1,264		2.15
1973	357		2,234		6.26
1974	1,241		2,284		1.84
1975	2,027		5,226		2.58
1976	1,321		8,255		6.25
1977	1,086		3,492		3.22
1978	813		3,695		4.55
1979	925		4,636		5.01
1980	2,645		4,275		1.62
1981	1,796		4,789		2.67
1982	1,156		2,043		1.77
1983	888		1,477		1.66
1984	1,242		4,477		3.60
1985	1,850		7,034		3.80
1986	1,978		13,665		6.91
1987	1,062		5,506		5.18
1988	1,038		2,184		2.10
1989	1,162		2,887		2.48
1990	2,093		4,375		2.09
1991	3,579		6,408		1.79
1992	1,607		1,484		0.92
1993	1,536		2,885		1.88
1994	991		2,251		2.27
1995	1,111		6,479		5.83
1996	1,078		7,013		6.51
1997	1,026		3,432		3.34
1998	1,202		4,032		3.35
1999	1,625		3,937		2.42
2000	1,375		8,387		6.10
2001	1,830		4,790		2.62
2002	1,264		5,924		4.69
2003	1,831		9,548	[b]	
2004	1,939		612	[b]	
2005	2,745		31	[b]	
2006	1,953		0	[b]	
2007	2,945		0	[b]	
2008	2,473		0	[b]	
1956–2002 Average	1,257		3,769		3.23
No. of Years	47		47		47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A4.–Escapement goal for Alagnak River sockeye salmon.

System: Alagnak River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	320,000 minimum (2006)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	
Escapement Goal Type:	Currently SEG.
Escapement Estimation:	Tower counts from 1956–1976; expanded aerial survey counts from 1977–2001. Tower counts from 2001–2008.
Summary:	
Data Quality	Fair to Good.
Data Type	Tower counts; aerial surveys; commercial harvest; age data.
Methodology	Escapement goal based on Ricker spawner-recruit analysis.
Autocorrelation	
Years within recommended goal	Escapement goal minimum has been met in 20 of out the last 20 years. This stock is passively managed and coincidentally harvested. Therefore, the department is not able to actively manage to obtain an escapement goal range.
Comments	Recommend no change to the current escapement goal range.

-continued-

System: Alagnak River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement	[ab]	Total Return		Return per Spawner
1950	0	[c]	262	[d]	
1951	0	[c]	680	[d]	
1952	0	[c]	925	[d]	
1953	0	[c]	80	[d]	
1954	0	[c]	660	[d]	
1955	0	[c]	1,095	[d]	
1956	784		2,390		3.05
1957	127		85		0.67
1958	95		148		1.56
1959	825		768		0.93
1960	1,241		456		0.37
1961	90		293		3.25
1962	91		262		2.88
1963	203		375		1.85
1964	249		336		1.35
1965	175		299		1.71
1966	174		580		3.33
1967	203		413		2.04
1968	194		180		0.93
1969	182		189		1.04
1970	177		152		0.86
1971	187		132		0.70
1972	151		152		1.00
1973	35		473		13.52
1974	215		1,141		5.31
1975	100		1,545		15.45
1976	82		1,804		22.00
1977	109		2,242		20.57
1978	584		928		1.59
1979	794		2,101		2.65
1980	804		881		1.10
1981	222		770		3.47
1982	646		855		1.32
1983	260		838		3.22
1984	581		982		1.69
1985	319		1,524		4.78
1986	621		2,148		3.46
1987	416		1,536		3.69
1988	525		1,636		3.12
1989	531		1,903		3.58
1990	456		2,529		5.55
1991	749		1,554		2.08
1992	612		639		1.04
1993	940		1,088		1.16
1994	655		1,360		2.08
1995	582		2,809		4.83
1996	828		1,934		2.34
1997	589		1,082		1.84
1998	681		2,749		4.04
1999	1,251		3,673		2.94
2000	1,218		8,756		7.19
2001	721		1,854		2.57
2002	767		3,456		4.51
2003	3,676		7,813	[d]	
2004	5,397		922	[d]	
2005	4,219		0	[d]	
2006	1,774		0	[d]	
2007	2,466		0	[d]	
2008	2,181		0	[d]	
1956–2002 Average	469		1,362		3.83
No. of Years	47		47		47

[a] The 1956–1976 and 2002–2008 escapements based on Alagnak tower count. The 1977–2001 escapements based on aerial survey.

[b] Brood table updated by Doug Eggers and John H Clark in spring of 2005. Aerial surveys expanded by 2.7 and catch added to Alagnak based on original allocation proportion between Kvichak, Naknek, and Alagnak (Clark 2005).

[c] Escapement not available.

[d] Incomplete returns from brood year escapement.

Appendix A5.–Escapement goal for Kvichak River sockeye salmon.

System: Kvichak River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	Off-cycle: 2,000,000–10,000,000 (1997)
	Pre-peak/Peak: 6,000,000–10,000,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Off-cycle: 2,000,000–10,000,000
	Pre-peak/Peak: 2,000,000–10,000,000
Escapement Goal Type:	Currently SEG. Changed from BEG to SEG in 2006.
Escapement Estimation:	Tower counts from 1956 to present; smolt data from 1971–2000; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns with stock-specific harvest.
Data Type	Tower counts; smolt data; commercial harvest; age data.
Methodology	Escapement goal based on Ricker stock-recruitment, yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	Off-cycle: 4 out of last 7 off-cycle years (1999–2008).
	Pre-peak/Peak: 1 of last 3 pre-peak/peak years (1999–2008). Have not met pre-peak/peak escapement goal since 1999. 2005 was changed from a peak to off-cycle year.
Comments	Recommend changing the escapement goal for Kvichak River sockeye salmon to a single goal of 2,000,000 to 10,000,000.

-continued-

System: Kvichak River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Type	Escapement	Total Return	Return per Spawner
1950		0 [a]	248 [b]	
1951		0 [a]	4,582 [b]	
1952		0 [a]	20,247 [b]	
1953		0 [a]	594 [b]	
1954		0 [a]	794 [b]	
1955		0 [a]	1,502 [b]	
1956	Peak	9,443	39,008	4.13
1957	Off-Cycle	2,843	4,091	1.44
1958	Off-Cycle	535	288	0.54
1959	Off-Cycle	674	547	0.81
1960	Peak	14,602	55,246	3.78
1961	Off-Cycle	3,706	3,496	0.94
1962	Off-Cycle	2,581	5,357	2.08
1963	Off-Cycle	339	1,119	3.30
1964	Off-Cycle	957	5,751	6.01
1965	Peak	24,326	45,026	1.85
1966	Off-Cycle	3,755	6,263	1.67
1967	Off-Cycle	3,216	1,526	0.47
1968	Off-Cycle	2,557	543	0.21
1969	Pre-Peak	8,394	5,304	0.63
1970	Peak	13,935	15,832	1.14
1971	Off-Cycle	2,387	2,829	1.19
1972	Off-Cycle	1,010	1,940	1.92
1973	Off-Cycle	227	2,458	10.83
1974	Pre-Peak	4,434	26,180	5.90
1975	Peak	13,140	38,087	2.90
1976	Off-Cycle	1,965	10,575	5.38
1977	Off-Cycle	1,341	3,239	2.42
1978	Off-Cycle	4,149	5,160	1.24
1979	Pre-Peak	11,218	42,142	3.76
1980	Peak	17,505 [c]	13,048	0.75
1981	Off-Cycle	1,754	2,130	1.21
1982	Off-Cycle	1,135	1,686	1.49
1983	Off-Cycle	3,570	13,391	3.75
1984	Pre-Peak	10,491	23,950	2.28
1985	Peak	7,211	17,421	2.42
1986	Off-Cycle	1,179	4,558	3.87
1987	Off-Cycle	6,066	12,045	1.99
1988	Off-Cycle	4,065	9,991	2.46
1989	Pre-Peak	8,318	26,203	3.15
1990	Peak	6,970	25,110	3.60
1991	Off-Cycle	4,223	4,802	1.14
1992	Off-Cycle	4,726	1,420	0.30
1993	Off-Cycle	4,025	2,955	0.73
1994	Pre-Peak	8,356	7,076	0.85
1995	Peak	10,039	10,244	1.02
1996	Off-Cycle	1,451	1,619	1.12
1997	Off-Cycle	1,504	582	0.39
1998	Off-Cycle	2,296	919	0.40
1999	Pre-Peak	6,197	7,426	1.20
2000	Peak	1,828	4,320	2.36
2001	Off-Cycle	1,095	4,081	3.73
2002	Off-Cycle	704	3,587	5.09
2003	Off-Cycle	1,687	4,318 [b]	
2004	Pre-Peak	5,500	4,297 [b]	
2005	Off-Cycle	2,320	2 [b]	
2006	Off-Cycle	3,068	0 [b]	
2007	Off-Cycle	2,810	0 [b]	
2008	Off-Cycle	2,758	0 [b]	
1956–2002				
Average		5,243	11,076	2.34
No. of Years		47	47	47
Pre-Peak/Peak		10,377	23,625	2.45
No. of Years		17	17	17
Off-Cycle		2,335	3,965	2.27
No. of Years		30	30	30

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

[c] The 1980 brood year escapement of 22.5 million was reduced to 17.5 million in the brood table to reflect the estimated 5 million sockeye salmon that did not spawn successfully because of the extreme velocity barrier at the falls on the Newhalen River.

Appendix A6.–Escapement goal for Nushagak River sockeye salmon.

System: Nushagak River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	340,000–760,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	235,000
Recommended Escapement Goal:	340,000–760,000
Escapement Goal Type:	Currently SEG. Changed from BEG to SEG in 2006.
Escapement Estimation:	Nuyakuk tower and expanded aerial survey counts from 1974–1979; sonar counts from 1980 to present; 25 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Tower, aerial survey, and sonar counts; commercial harvest; age data.
Methodology	Ricker stock-recruitment (standard brood table and Nushagak District aggregate brood table), yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1–Aggregate District model only
Years within recommended goal	7 out of last 20 years (1999–2008).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Nushagak River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement	[a]	Total Return		Return per Spawner
1974	185			[b]	
1975	752		1	[b]	
1976	470		319	[b]	
1977	553		2,162	[b]	
1978	664		1,491		2.24
1979	499		1,902		3.81
1980	3,317		1,284		0.39
1981	1,012		1,926		1.90
1982	601		1,563		2.60
1983	404		1,521		3.77
1984	593		912		1.54
1985	498		1,351		2.71
1986	990		1,999		2.02
1987	388		2,047		5.28
1988	483		2,457		5.09
1989	513		1,436		2.80
1990	680		1,247		1.83
1991	493		1,491		3.03
1992	695		1,551		2.23
1993	715		1,124		1.57
1994	509		872		1.71
1995	281		1,236		4.39
1996	504		2,374		4.71
1997	373		583		1.56
1998	459		2,286		4.98
1999	312		2,191		7.02
2000	404		3,719		9.21
2001	811		3,438		4.24
2002	316		2,250		7.12
2003	581		1,832	[b]	
2004	492		253	[b]	
2005	1,049		8	[b]	
2006	548		0	[b]	
2007	518		0	[b]	
2008	493		0	[b]	
1956–2002 Average	661		1,770		3.51
No. of Years	25		25		25

[a] Escapement for brood years 1974–1983 and 1985–1986 based on Nuyakuk tower plus aerial survey estimates. Escapement for brood years 1984 and 1987-present based on Nushagak sonar estimates.

[b] Incomplete returns from brood year escapement.

Appendix A7.–Escapement goal for Wood River sockeye salmon.

System: Wood River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	700,000–1,500,000 (1984)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	700,000–1,500,000
Escapement Goal Type:	Currently BEG. Recommended change to SEG.
Escapement Estimation:	Tower counts from 1956 to present; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns with regard to stock-specific harvest.
Data Type	Tower counts; commercial harvest; age data.
Methodology	Ricker stock-recruitment (standard brood table and Nushagak District aggregate brood table), yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1 (all Ricker models).
Years within recommended goal	5 out of last 10 years (1999–2008).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Wood River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement	Total Return	Return per Spawner
1950	0 [a]	58 [b]	
1951	0 [a]	804 [b]	
1952	0 [a]	1,313 [b]	
1953	0 [a]	808 [b]	
1954	0 [a]	2,529 [b]	
1955	0 [a]	3,789 [b]	
1956	773	1,473	1.91
1957	289	449	1.56
1958	960	2,643	2.75
1959	2,209	1,805	0.82
1960	1,016	2,734	2.69
1961	461	1,496	3.25
1962	874	1,503	1.72
1963	721	1,428	1.98
1964	1,076	1,220	1.13
1965	675	1,786	2.65
1966	1,209	2,121	1.75
1967	516	1,092	2.12
1968	649	1,108	1.71
1969	604	833	1.38
1970	1,162	2,800	2.41
1971	851	1,301	1.53
1972	431	1,514	3.51
1973	330	1,484	4.50
1974	1,709	5,164	3.02
1975	1,270	4,785	3.77
1976	817	5,720	7.00
1977	562	3,290	5.85
1978	2,267	3,288	1.45
1979	1,706	4,182	2.45
1980	2,969	1,605	0.54
1981	1,233	1,909	1.55
1982	976	1,438	1.47
1983	1,361	3,194	2.35
1984	1,003	1,998	1.99
1985	939	2,588	2.76
1986	819	3,330	4.07
1987	1,337	2,358	1.76
1988	867	3,193	3.68
1989	1,186	4,290	3.62
1990	1,069	2,794	2.61
1991	1,160	5,310	4.58
1992	1,286	4,282	3.33
1993	1,176	3,225	2.74
1994	1,472	5,292	3.59
1995	1,482	6,369	4.30
1996	1,650	6,454	3.91
1997	1,512	1,312	0.87
1998	1,756	6,729	3.83
1999	1,512	4,623	3.06
2000	1,300	6,099	4.69
2001	1,459	7,165	4.91
2002	1,284	7,864	6.12
2003	1,460	6,374 [b]	
2004	1,543	3,662 [b]	
2005	1,497	1 [b]	
2006	4,008	0 [b]	
2007	1,528	0 [b]	
2008	1,725	0 [b]	
1956–2002 Average	1,148	3,163	2.88
No. of Years	47	47	47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A8.–Escapement goal for Igushik River sockeye salmon.

System: Igushik River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	150,000–300,000 (2000)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	150,000–300,000
Escapement Goal Type:	Currently SEG. Changed from BEG to SEG in 2006.
Escapement Estimation:	Tower counts from 1956 to present; 47 years of complete return data available.
Summary:	
Data Quality	Good. Data quality would be excellent except for concerns with stock-specific harvest.
Data Type	Tower counts; commercial harvest; age data.
Methodology	Ricker stock-recruitment (standard brood and Nushagak District aggregate brood), yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1 (all Ricker models).
Years within recommended goal	3 out of last 10 years (1999–2008).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Igushik River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement		Total Return		Return per Spawner
1950	0	[a]	79	[b]	
1951	0	[a]	709	[b]	
1952	0	[a]	537	[b]	
1953	0	[a]	188	[b]	
1954	0	[a]	762	[b]	
1955	0	[a]	1,442	[b]	
1956	400		743		1.86
1957	130		76		0.58
1958	107		133		1.24
1959	644		371		0.58
1960	495		473		0.96
1961	294		436		1.48
1962	16		326		20.38
1963	92		508		5.52
1964	129		930		7.21
1965	181		1,090		6.02
1966	206		470		2.28
1967	282		175		0.62
1968	195		175		0.90
1969	512		538		1.05
1970	371		309		0.83
1971	211		303		1.44
1972	60		229		3.82
1973	60		725		12.08
1974	359		1,574		4.39
1975	241		3,981		16.52
1976	186		2,394		12.87
1977	96		2,015		20.99
1978	536		526		0.98
1979	860		846		0.98
1980	1,988		372		0.19
1981	591		1,025		1.73
1982	424		519		1.22
1983	180		544		3.02
1984	185		780		4.22
1985	212		1,633		7.70
1986	308		2,557		8.30
1987	169		806		4.77
1988	170		1,327		7.81
1989	462		1,761		3.81
1990	366		1,925		5.26
1991	756		1,661		2.20
1992	305		229		0.75
1993	406		506		1.25
1994	446		1,203		2.70
1995	473		2,301		4.86
1996	401		1,417		3.53
1997	128		178		1.39
1998	216		942		4.36
1999	446		891		2.00
2000	413		1,935		4.69
2001	410		1,130		2.76
2002	123		877		7.13
2003	194		3,825	[b]	
2004	110		853	[b]	
2005	366		0	[b]	
2006	305		0	[b]	
2007	415		0	[b]	
2008	1,055		0	[b]	
1956–2002					
Average	346		976		4.49
No. of Years	47		47		47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A9.–Escapement goal for Togiak River sockeye salmon.

System: Togiak River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	120,000–270,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	120,000–270,000
Escapement Goal Type:	Currently BEG. Recommend change to SEG.
Escapement Estimation:	Tower counts from 1956 to present; 47 years of complete return data available.
Summary:	
Data Quality	Good
Data Type	Tower counts; commercial harvest; age data.
Methodology	Ricker stock-recruitment, yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	7 out of last 10 years (1999–2008).
Comments	Recommend change from BEG to SEG due to catch allocation issues within the Togiak District. Non-Togiak stocks were identified in the commercial catch based on genetics stock composition estimates (Dann et al. 2009). Changing Togiak from a BEG to a SEG is similar to what was done for most of sockeye salmon stocks in Bristol Bay in 2006 (Baker et al. 2006).

-continued-

System: Togiak River

Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Year	Escapement		Total Return		Return per Spawner
1950	0	[a]	28	[b]	
1951	0	[a]	160	[b]	
1952	0	[a]	225	[b]	
1953	0	[a]	140	[b]	
1954	0	[a]	197	[b]	
1955	0	[a]	374	[b]	
1956	225		460		2.04
1957	25		182		7.29
1958	72		270		3.76
1959	210		296		1.41
1960	163		541		3.32
1961	122		340		2.79
1962	62		169		2.73
1963	116		152		1.31
1964	105		175		1.67
1965	96		405		4.22
1966	104		640		6.15
1967	81		181		2.23
1968	50		262		5.24
1969	117		216		1.85
1970	203		407		2.00
1971	200		558		2.79
1972	79		302		3.83
1973	107		654		6.11
1974	104		702		6.75
1975	181		1,199		6.62
1976	189		1,069		5.66
1977	163		886		5.44
1978	306		682		2.23
1979	198		584		2.95
1980	527		304		0.58
1981	307		343		1.12
1982	289		425		1.47
1983	213		1,247		5.86
1984	151		166		1.10
1985	153		350		2.29
1986	203		759		3.74
1987	278		892		3.21
1988	309		617		2.00
1989	104		546		5.25
1990	166		703		4.23
1991	254		691		2.72
1992	210		275		1.31
1993	189		322		1.71
1994	174		254		1.46
1995	211		1,441		6.83
1996	187		1,444		7.72
1997	152		463		3.05
1998	175		808		4.62
1999	196		518		2.64
2000	352		707		2.01
2001	303		637		2.10
2002	162		1,026		6.33
2003	232		999	[b]	
2004	136		113	[b]	
2005	156		1	[b]	
2006	312		0	[b]	
2007	270		0	[b]	
2008	206		0	[b]	
1956–2002					
Average	182		559		3.48
No. of Years	47		47		47

[a] Escapement not available.

[b] Incomplete returns from brood year escapement.

Appendix A10.–Escapement goal for Kulukak River sockeye salmon.

System: Kulukak River

Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	None
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	8,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts since 1961.
Summary:	
Data Quality	Poor
Data Type	Aerial survey; no age data.
Methodology	Risk analysis.
Autocorrelation	Significant autoregressive correlation at lag-1.
Years within recommended goal	5 out of last 5 years (1999–2003). We do not have escapement estimates from 2004–2008.
Comments	This escapement goal was not evaluated. We were unable to estimate the escapement for this stock because aerial survey estimates were not flown from 2004–2008 due to budget constraints. For stocks that are passively managed and coincidentally harvested, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

-continued-

System: Kulukak River

Species: sockeye salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)	Harvest
1961	5,200	8.56	3,373
1962	9,600	9.17	672
1963	11,400	9.34	554
1964	9,800	9.19	8,286
1965	16,300	9.7	3,265
1966	18,800	9.84	7,263
1967	10,000	9.21	24,379
1968	6,500	8.78	2,618
1969	8,400	9.04	3,411
1970	10,000	9.21	
1971	13,000	9.47	7,927
1972	3,400	8.13	17,244
1973	800	6.68	15,551
1974	4,900	8.5	13,615
1975	8,600	9.06	3,821
1976	11,200	9.32	4,822
1977	40,100	10.6	16,252
1978	33,900	10.43	29,668
1979	26,600	10.19	66,629
1980	45,700	10.73	42,811
1981	58,780	10.98	19,246
1982	52,750	10.87	13,952
1983	26,970	10.2	55,906
1984	49,800	10.82	96,709
1985	36,600	10.51	44,120
1986	42,800	10.66	100,466
1987	37,800	10.54	45,401
1988	31,700	10.36	143,112
1989	10,800	9.29	14,116
1990	49,600	10.81	27,311
1991	23,900	10.08	33,425
1992	26,400	10.18	108,358
1993	31,800	10.37	58,616
1994	29,700	10.30	76,781
1995	14,600	9.59	76,056
1996	19,000	9.85	76,833
1997	8,000	8.99	49,277
1998	13,000	9.47	76,332
1999	12,300	9.42	38,662
2000	22,400	10.02	67,612
2001	17,000	9.74	9,532
2002	8,500	9.05	19,032
2003	8,000	8.99	55,081
2004	[a]		80,487
2005	[a]		54,052
2006	[a]		51,813
2007	[a]		57,845
2008	[a]		24,523
Average	21,544	9.68	39,294
St. dev.	15,392	0.87	33,853
Median	16,300	9.70	29,668

[a] No aerial surveys were flown. Therefore, we do not have an estimate of escapement.

APPENDIX B. CHINOOK SALMON

Appendix B1.–Escapement goal for Nushagak River Chinook salmon.

System: Nushagak River

Species: Chinook salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	40,000–80,000 (2006)
Inriver Goal:	75,000
Optimal Escapement Goal:	None
Recommended Escapement Goal:	40,000–80,000
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts plus Nuyakuk tower from 1966–1979; sonar counts from 1980 to present; 31 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Aerial survey, tower, and sonar escapement estimates; sport, subsistence, and commercial harvests; age data.
Methodology	Ricker stock-recruitment, yield analysis.
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	4 out of last 10 years (Escapement goal range of 40,000–80,000 was set in 2006).
Comments	Recommend no change to current escapement goal range.

-continued-

System: Nushagak River

Species: Chinook salmon

Data available for analysis of escapement goals.

Year	Spawning Escapement	Total Return	Return per Spawner
1966	40,000	99,210	2.48
1967	65,000	99,885	1.54
1968	70,000	109,661	1.57
1969	35,000	49,038	1.40
1970	50,000	138,688	2.77
1971	40,000	174,720	4.37
1972	25,000	229,380	9.18
1973	35,000	203,196	5.81
1974	70,000	124,992	1.79
1975	70,000	400,440	5.72
1976	100,000	281,479	2.81
1977	65,000	475,536	7.32
1978	130,000	155,013	1.19
1979	95,000	219,538	2.31
1980	141,000	124,373	0.88
1981	150,000	171,420	1.14
1982	147,000	76,779	0.52
1983	161,730	86,156	0.53
1984	80,940	78,896	0.97
1985	115,720	106,832	0.92
1986	80,489	126,797	3.67
1987	46,065	168,082	2.15
1988	76,242	208,976	4.08
1989	73,875	220,399	2.98
1990	42,903	97,663	2.28
1991	97,466	192,486	1.97
1992	77,438	166,521	2.15
1993	91,419	221,450	2.42
1994	85,989	83,052	0.97
1995	80,489	91,302	1.13
1996	46,065	103,694	2.25
1997	76,242	110,881	1.45
1998	108,909	170,928	1.57
1999	56,426	231,815	4.11
2000	49,642	252,364	5.08
2001	84,665	146,907	1.74
2002	81,061	118,604	1.46
2003	72,420	0 [a]	
2004	107,683	0 [a]	
2005	163,506	0 [a]	
2006	117,364	0 [a]	
2007	53,344	0 [a]	
2008	88,758	0 [a]	
1966–2002 Average	79,507	165,329	2.61
No. of Years	37	37	37

[a] Incomplete returns from brood year escapement.

Appendix B2.–Escapement goal for Togiak River Chinook salmon.

System: Togiak River

Species: Chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	9,300 minimum (2006)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	9,300 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts since 1980.
Summary:	
Data Quality	Fair
Data Type	Aerial survey; harvest data; limited age data.
Methodology	Risk analysis.
Autocorrelation	Significant autoregressive at lag-1.
Years within recommended goal	4 out of last 4 years (1999–2002). We do not have any escapement estimates from 2003–2008.
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

-continued-

System: Togiak River

Species: Chinook salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)	Commercial Harvest	Subsistence Harvest	Sport Harvest
1980	8,045	8.99	10,858	900	34
1981	12,435	9.43	22,744	400	0
1982	6,800	8.82	33,607	400	231
1983	10,975	9.3	35,669	700	535
1984	19,085	9.86	19,958	600	46
1985	12,010	9.39	33,110	600	925
1986	[a]		16,267	700	618
1987	7,170	8.88	14,555	700	338
1988	6,390	8.76	13,205	429	0
1989	6,640	8.8	9,049	551	234
1990	6,475	8.78	9,651	480	445
1991	8,380	9.03	6,472	470	284
1992	7,410	8.91	11,764	1,361	271
1993	10,210	9.23	10,769	749	225
1994	15,115	9.62	9,492	904	663
1995	12,600	9.44	10,736	448	581
1996	8,299	9.02	8,281	471	790
1997	10,300	9.24	5,381	667	1,165
1998	9,856	9.2	12,878	782	763
1999	9,520	9.16	10,668	1,244	644
2000	11,813	9.38	7,254	1,116	470
2001	13,110	9.48	9,518	1,612	600
2002	9,515	9.16	2,654	703	600
2003	[a]			1,208	
2004	[a]			1,094	
2005	[a]			1,528	
2006	[a]			1,630	
2007	[a]			1,234	
2008	[a]			1,339	
1980–2008					
Average	10,098	9.18	14,110	863	455
St. dev.	3,168	0.30	9,063	389	308
Median	9,688	9.18	10,769	703	470
No. of Years	22	22	23	29	23

[a] Escapement not available.

Appendix B3.–Escapement goal for Naknek River Chinook salmon.

System: Naknek River

Species: Chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	5,000 minimum (2006)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	5,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Aerial survey counts since 1971
Summary:	
Data Quality	Fair
Data Type	Aerial survey and Big Creek weir; limited age data
Methodology	Risk analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	6 out of 7 years (2000–2004; 2007–2008). We do not have escapement estimates in 1999, and 2005–2006.
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

-continued-

System: Naknek River

Species: Chinook salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1971	2,885	7.97
1972	2,791	7.93
1973	2,536	7.84
1974	[a]	
1975	3,452	8.15
1976	7,131	8.87
1977	[a]	
1978	[a]	
1979	[a]	
1980	[a]	
1981	4,271	8.36
1982	8,610	9.06
1983	7,830	8.97
1984	4,995	8.52
1985	[a]	
1986	3,917	8.27
1987	4,450	8.40
1988	11,730	9.37
1989	2,710	7.90
1990	7,000	8.85
1991	4,391	8.39
1992	2,691	7.90
1993	8,016	8.99
1994	9,678	9.18
1995	4,960	8.51
1996	5,010	8.52
1997	10,453	9.25
1998	5,505	8.61
1999	[a]	
2000	3,233	8.08
2001	6,340	8.75
2002	7,503	8.92
2003	6,081	8.71
2004	12,878	9.46
2005	[a]	
2006	[a]	
2007	5,498	8.61
2008	6,559	8.79
1971–2008		
Average	5,969	8.59
St. dev.	2,781	0.47
Median	5,498	8.61
No. of Years	29	29

[a] Escapement not available.

Appendix B4.–Escapement goal for Alagnak River Chinook salmon.

System: Alagnak River

Species: Chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	2,700 minimum
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	2,700 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Aerial survey counts since 1970.
Summary:	
Data Quality	Fair
Data Type	Aerial survey; limited age data.
Methodology	Risk analysis.
Autocorrelation	Significant autoregressive at lag-1.
Years within recommended goal	7 out of last 10 years (1999–2008).
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

-continued-

System: Alagnak River

Species: Chinook salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1970	5,250	8.57
1971	1,475	7.30
1972	2,256	7.72
1973	824	6.71
1974	1,596	7.38
1975	6,620	8.80
1976	7,593	8.93
1977	9,425	9.15
1978	11,650	9.36
1979		
1980	2,930	7.98
1981	2,430	7.80
1982	3,400	8.13
1983	2,980	8.00
1984	6,090	8.71
1985	3,920	8.27
1986	3,090	8.04
1987	2,420	7.79
1988	4,600	8.43
1989	3,650	8.20
1990	1,720	7.45
1991	2,531	7.84
1992	3,042	8.02
1993	10,170	9.23
1994	8,480	9.05
1995	6,860	8.83
1996	9,885	9.20
1997	15,210	9.63
1998	4,148	8.33
1999	2,178	7.69
2000	2,220	7.71
2001	5,458	8.60
2002	3,675	8.21
2003	8,209	9.01
2004	6,755	8.82
2005	5,084	8.53
2006	4,278	8.36
2007	3,455	8.15
2008	1,825	7.51
1970–2008		
Average	4,931	8.30
St. dev.	3,247	0.66
Median	3,798	8.24
No. of Years	38	38

Appendix B5.–Escapement goal for Egegik River Chinook salmon.

System: Egegik River

Species: Chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	450 minimum (2006)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	450 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Combined aerial survey counts for Gertrude, Kaye's and Takayoto Creeks since 1985.
Summary:	
Data Quality	Poor.
Data Type	Aerial survey; no age data.
Methodology	Risk analysis.
Autocorrelation	No significant autocorrelation.
Years within recommended goal	4 out of last 10 years (1999–2008).
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

-continued-

System: Egegik River

Species: Chinook salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1985	805	6.69
1986	236	5.46
1987	924	6.83
1988	545	6.30
1989	730	6.59
1990	610	6.41
1991	295 [a]	5.69
1992	926	6.83
1993	720 [a]	6.58
1994	1,284 [a]	7.16
1995	834	6.73
1996	427	6.06
1997	807	6.69
1998	605	6.41
1999	286	5.66
2000	199	5.29
2001	389	5.96
2002	646	6.47
2003	790	6.67
2004	579	6.36
2005	335	5.81
2006	196	5.28
2007	458	6.13
2008	162	5.09
Mean	547	6.18
St. dev.	251	0.55
Median	579	6.36
No. of Years	21	21

[a] Escapement estimates not included in analysis due to timing of aerial surveys or poor aerial surveys condition.

APPENDIX C. CHUM SALMON

Appendix C1.–Escapement goal for Nushagak River chum salmon.

System: Nushagak River

Species: chum salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	190,000 minimum (2006)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	190,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Sonar counts through July 20 since 1980; 19 years of complete return data available
Summary:	
Data Quality	Good.
Data Type	Sonar escapement estimates; commercial harvest; age data.
Methodology	Risk analysis.
Autocorrelation	Not Significant.
Years within recommended goal	8 out of last 10 years (1999–2008).
Comments	For stocks that are passively managed and coincidentally harvested, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years. Escapement sonar counts are through July 20 when the project annually terminates.

-continued-

System: Nushagak River

Species: chum salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1980	969,000	13.78
1981	177,000	12.08
1982	256,000	12.45
1983	164,000	12.01
1984	362,000	12.80
1985	288,000	12.57
1986	200,300	12.21
1987	147,433	11.90
1988	186,418	12.14
1989	377,512	12.84
1990	329,793	12.71
1991	252,436	12.44
1992	302,678	12.62
1993	217,230	12.29
1994	378,928	12.85
1995	212,612	12.27
1996	225,029	12.32
1997	61,456	11.03
1998	299,215	12.61
1999	242,312	12.40
2000	141,324	11.86
2001	564,724	13.24
2002	419,964	12.95
2003	295,413	12.60
2004	283,811	12.56
2005	456,025	13.03
2006	661,002	13.40
2007	161,483	11.99
2008	326,300	12.70
Mean	308,945	12.50
St. dev.	180,388	0.53
Median	283,811	12.56
No. of Years	29	29

APPENDIX D. WINBUGS CODE

Appendix D1.–WINBUGS CODE

```
#Ricker model R=apha*S*exp(-beta*S)
Model ricker {
#sampling distribution (likelihood):
  for (i in 1:N) {
     y[i]<-log(R[i]/S[i])
     mu[i] <- log(alpha) - beta*S[i]
     y[i]~dnorm(mu[i], tau)
   }
#uninformative prior distribution of parameters:
  ialpha~dgamma(0.001, 0.001)
  alpha<-1/ialpha
  beta~dbeta(1, 1)
  tau~dgamma(1.0E-3, 1.0E-3)
#management parameter – optimal stock size:
  smsy<-log(alpha)/beta*(0.5-0.07*log(alpha))
}

#Beverton-Holt model R = a*S/(1+a/b *S)
Model bh{
#sampling distribution (likelihood):
  for (i in 1:N) {
     R[i] ~ dlnorm(log.mean[i], tau)
     log.mean[i] <- log((a*S[i])/(1 + (a/b)*S[i]))
  }
 #uninformative prior distribution of parameters:
   ia ~ dgamma(0.001, 0.001)
   a<-1/ia
   ib~dbeta(1, 1)
    b<-1/ib
    tau ~ dgamma(0.001, 0.001)
#management parameter – optimal stock size
  smsy<-b*sqrt(1/a)-b/a
}
```