Fishery Manuscript No. 07-04

A Review of Escapement Goals for Salmon Stocks in Lower Cook Inlet, Alaska, 2007

by

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and

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October 2007

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

Symbols and Abbreviations

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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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October 2007

The Division of Sport Fish Special Publications series was established in 1991 for the publication of techniques and procedures manuals, informational pamphlets, special subject reports to decision-making bodies, symposia and workshop proceedings, application software documentation, in-house lectures, and other documents that do not fit in another publication series of the Division of Sport Fish. Since 2004, the Division of Commercial Fisheries has also used the same Special Publication series. Special Publications are intended for fishery and other technical professionals. Special Publications are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm. This publication has undergone editorial and peer review.

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This document should be cited as:
Otis, E. O., and N. J. Szarzi. 2007. A review of escapement goals for salmon stocks in Lower Cook Inlet, Alaska, 2007. Alaska Department of Fish and Game, Fishery Manuscript No. 07-04, Anchorage.

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ABSTRACT

Following the Alaska Board of Fisheries adoption of two policies in 2000–2001 that affect development of escapement goals, the Alaska Department of Fish and Game (ADF&G) revised all salmon escapement goals in Lower Cook Inlet. Salmon escapements are primarily monitored by single or multiple aerial and/or foot surveys of stream reaches that can be monitored, except for Anchor River Chinook salmon *Oncorhynchus tshawytscha*, monitored by sonar and weir, and Ninilchik River Chinook salmon, monitored by a weir operated during only a portion of the run. The resulting escapement indices do not provide absolute abundance estimates suitable for estimating biological escapement goals. Consequently, ADF&G developed an algorithm to estimate sustainable escapement goals for each of the 3 Chinook salmon, 12 chum salmon *O. keta*, 21 pink salmon *O. gorbuscha*, and 8 sockeye salmon *O. nerka* stocks ADF&G monitors in Lower Cook Inlet. Escapement performance relative to these new goals has been good during the past 4 years, with harvestable surpluses available in 83–97% of the streams during most years. With the exception of 3 streams, ADF&G does not recommend making any changes to the current escapement goals. ADF&G recommends increasing the goal for McNeil River chum salmon to 24,000-48,000 fish, effectively restoring the previous, long-standing goal. Justification for this change was provided by a radiotelemetry study and retrospective analysis of historical escapements that suggests adequately seeding spawning areas upstream of McNeil Falls is the key to restoring McNeil River chum salmon production to levels observed during the 1970s–1980s. The Ninilchik River Chinook salmon sustainable escapement goal should be changed to 550–1,300 based on a longer period of weir operation to more accurately index the true escapement to that system. The development of a new SEG threshold of 5,000 Anchor River Chinook salmon is based on information from full enumeration of the escapement with sonar and weir and is described in a separate report.

Key words: Lower Cook Inlet, sustainable escapement goals, Chinook salmon, *Oncorhynchus tshawytscha*, chum salmon, *O. keta*, pink salmon, *O. gorbuscha*, sockeye salmon, *O. nerka*, escapement, Southern District, Outer District, Eastern District, Kamishak District, Alaska Board of Fisheries, BOF.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G; department) reviews the escapement goals for Lower Cook Inlet (LCI) salmon stocks on a schedule that corresponds to the Alaska Board of Fisheries 3-year cycle for considering area regulatory proposals. This report describes the Lower Cook Inlet salmon escapement goals that were reviewed in 2004 and presents information from the subsequent 3 years in the context of these goals. Our objective is to provide historical and current information on LCI salmon escapements and to evaluate the appropriateness of the current and recommended escapement goals for LCI salmon stocks. A brief summary of LCI stock assessment and management methods is also provided, along with a review of the methods used in 2001 to develop the current escapement goals.

Following the adoption of the Alaska Department of Fish and Game's Salmon Escapement Goal Policy in 1992, Fried (1994) documented all the existing escapement goals for LCI. Under this policy, escapement goals were categorized as biological escapement goals, optimal escapement goals, or inriver goals. At that time all escapement goals in LCI, including 3 Chinook salmon *Oncorhynchus tshawytscha*, 13 chum salmon *O. keta*, 31 pink salmon *O. gorbuscha*, and 8 sockeye salmon *O. nerka*, were considered biological escapement goals.

During 2000 and 2001, the Alaska Board of Fisheries (BOF) adopted two policies that currently govern escapement goals: the Policy for the Management of Sustainable Salmon Fisheries (sustainable salmon fisheries policy; SSFP) (5 AAC 39.222) and the Policy for Statewide Salmon Escapement Goals (escapement goal policy; EGP) (5 AAC 39.223). Under these policies sustainable escapement goals were added to those goals previously mentioned. Under sections (b) (2) and (3) of the escapement goal policy, ADF&G is to:

> "(2) establish biological escapement goals (BEG) for salmon stocks for which the department can reliably enumerate salmon escapement levels, as well as total annual returns"; and
>
> "(3) establish sustainable escapement goals (SEG) for salmon stocks for which the department can reliably estimate escapement levels when there is not sufficient information to enumerate total annual returns and the range of escapements that are used to develop a BEG."

Section (f) of the sustainable fisheries policy provides definitions that are more detailed, as follows:

> "(3) "biological escapement goal" or "(BEG)" means the escapement that provides the greatest potential for maximum sustained yield; BEG will be the primary management objective for the escapement unless an optimal escapement or inriver run goal has been adopted; BEG will be developed from the best available biological information and should be scientifically defensible on the basis of available biological information; BEG will be determined by the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements within the bounds of a BEG"; and
>
> "(36) "sustainable escapement goal" or "(SEG)" means a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situations where a BEG cannot be estimated due to the absence of stock specific catch estimate; the SEG is the primary management objective for the escapement, unless an optimal escapement or inriver run goal has been adopted by the board, and will be developed from the best available biological information; the SEG will be determined by the department and will be stated as a range that takes into account data uncertainty; the department will seek to maintain escapements within the bounds of the SEG."

Salmon management in LCI, to the extent possible, has focused on terminal fishing areas associated with individual streams. Consequently, escapement goals in LCI were developed for each one of the 47 stocks (3 Chinook salmon, 12 chum salmon, 24 pink salmon, and 8 sockeye salmon) that have historically received fishing pressure. The escapement goal of each of these stocks was reviewed in 2001 under the two BOF policies, resulting in the establishment of 47 new sustainable escapement goals (Bue and Hasbrouck *Unpublished*; Otis 2001). Area review of Lower Cook Inlet escapement goals in 2004 (Otis and Hasbrouck 2004) resulted in ADF&G recommendations for, and the BOF adoption of, changes to 4 streams. The escapement goal for Anchor River Chinook salmon was removed because a sonar and weir project begun in 2003 indicated historical aerial surveys did not accurately index total escapement. It was anticipated that continuation of the sonar/weir project would provide sufficient data to conduct more comprehensive analyses and recommend a new goal during the 2007 review (Otis and Hasbrouck 2004). In 2004, ADF&G removed the escapement goals for Little and Big Kamishak river pink salmon because no fishery currently targets these stocks and escapement monitoring is inconsistent. Additionally, ADF&G replaced the individual goals for pink salmon in Bear and

Salmon creeks in Resurrection Bay with a single sustainable escapement goal representing both streams.

During the 2007 review process, escapement goals for the following stocks were evaluated:

- Chinook salmon: Deep Creek; and Anchor and Ninilchik rivers.
- Chum salmon: Iniskin Bay; Ursus Cove; Cottonwood, Island, and Port Dick creeks; Dogfish Lagoon; and Port Graham, Rocky, Big Kamishak, Little Kamishak, McNeil, and Bruin rivers.
- Pink salmon: Port Chatham; Humpy, China Poot, Tutka, Barabara, Seldovia, Windy (right), Windy (left), Port Dick, Island, S. Nuka Island, Desire Lake, Bear and Salmon, Tonsina, Sunday, and Brown's Peak creeks; Thumb and Humpy coves; and Port Graham, Rocky, and Bruin rivers.
- Sockeye salmon: English Bay; Amakdedori Creek; and Delight, Desire, Bear, Aialik, Mikfik, and Chenik lakes.

During spring of 2007, ADF&G established an escapement goal review committee (hereafter referred to as the committee), consisting of Divisions of Commercial Fisheries and Sport Fish personnel. The committee formally met 16 January 2007 to review escapement goals and develop recommendations. The committee also communicated by email. All committee recommendations were reviewed by ADF&G regional and headquarters staff prior to being adopted by ADF&G as escapement goals per the SSFP and EGP.

METHODS

ASSESSING ESCAPEMENT AND HARVEST

The LCI commercial salmon fishery management area is comprised of all waters west of the longitude of Cape Fairfield, north of the latitude of Cape Douglas, and south of the latitude of Anchor Point, and is divided into 5 fishing districts (Figure 1). Barren Islands District is the only non-fishing district, with the remaining 4 districts (Southern, Outer, Eastern, and Kamishak Bay) separated into approximately 30 subdistricts and sections to facilitate commercial management of discrete stocks of salmon (Hammarstrom and Dickson 2007). The LCI sport fisheries management area also includes the Anchor and Ninilchik rivers and Deep Creek, which flow into Cook Inlet along the west side of the lower Kenai Peninsula, and adjacent marine sport fisheries. Salmon streams in the management areas (Figure 1) primarily produce pink and chum salmon, but also support smaller and less numerous runs of sockeye, coho *O. kisutch*, and Chinook salmon.

Escapements for most systems in LCI have been monitored by foot survey, aerial survey, or a combination of the two. Such surveys provide only an index of escapement due to the lack of supporting data such as accurate estimates of stream life and observer efficiency. The indices are a measurement on a numeric scale that provides information only about the relative level of the escapement. These measurements provide a ranking of escapement magnitude across years but in and of themselves provide no information on the total number of fish in the escapement. Escapement indices for stocks of pink and chum salmon are calculated by applying the area-under-the-curve method (Bue et al. 1998; Neilson and Geen 1981), which accounts for multiple sightings of the same fish during consecutive surveys by applying an average stream life factor.

Consistent weir data exist only for Ninilchik River Chinook salmon and Bear Lake sockeye salmon. Weir data provide a count or an estimate of the total number of fish in the escapement (i.e., total fish in the spawning population), expressed in units that are comparable to the estimates of total fish harvested for the same stock. Weir data exist for some other species-year-system combinations, but are not complete or consistent. LCI staff have also been developing and testing a digital time-lapse video recording system to remotely census fish returns in some small, clear streams (Otis and Dickson 2002). This technology may eventually allow replacement of aerial survey indices on select streams with escapement estimates more appropriate for developing and evaluating biological escapement goals. Dual Frequency Identification Sonar (DIDSON) has been operated in conjunction with a weir to count total Chinook salmon escapement in the Anchor River since 2003. The development of a new escapement goal for the Anchor River based on sonar and weir data is addressed in Szarzi et al. (*In prep*.)

Commercial harvest data are obtained from tallies from the fish ticket database. Estimates of sport harvest are from the postal survey conducted annually by the Division of Sport Fish (Jennings et al. 2007).

HISTORIC DEVELOPMENT OF ESCAPEMENT GOALS

Chinook salmon escapements have been monitored since 1962 using a combination of foot and aerial surveys. Starting in 1976, single helicopter surveys were used to index Chinook salmon escapements. Escapement goals for Deep Creek and Ninilchik and Anchor river stocks were first adopted in 1993 and were the average of the escapement indices in each system (Fried 1994). In 1999 the point goals were changed to ranges by multiplying the respective point goal by 0.8 and 1.6, similar to the method used to estimate the escapement range that produces 90% or more of the maximum sustained yield (MSY; Eggers 1993).

Chum salmon escapement surveys began in the early 1970s. Escapement goals were established from these indices beginning in 1979. Many of the original goals were based on a subjective assessment of the quality of available spawning habitat and the level of commercial harvests resulting from various levels of escapement (Fried 1994). In the case of McNeil River chum salmon, management for an escapement near the upper end of the escapement goal range occurred during years when higher abundances of fish reached the plentiful, high-quality spawning habitat available upstream of McNeil Falls.

Pink salmon escapement surveys began during the 1960s with many starting in either 1960 or 1962. Pink salmon escapement goals for some systems were first established in 1970, while goals for many other systems were established in either 1976 or 1982. Origins of these goals are not well documented. Those in the Outer and Eastern districts were based on quantitative estimates of available spawning areas, assuming an optimal density of 1.5–2.0 spawners per square meter (Fried 1994).

Aerial surveys to monitor sockeye salmon escapement indices began in LCI in 1960. In the case of Bear Lake, a complete count or estimate of escapements has been monitored through a weir since 1960. Although escapement goals were first established for sockeye salmon in 1982, goals for additional systems were added throughout the 1980s. Methods and rationales for setting these goals were generally not well documented.

DEVELOPMENT OF CURRENT ESCAPEMENT GOALS

Virtually all escapement goals in LCI are based on foot or aerial surveys. The surveys typically cover less than 100% of the stream due to practical constraints (e.g., dense riparian areas, etc.) and different people have conducted the surveys over the years under a wide variety of conditions. While the commercial fisheries in LCI primarily occur in terminal areas, stock mixing sometimes does take place, especially in areas such as Port Dick and Resurrection Bay. Lack of stock identification data prevents allocating commercial harvest to specific stocks. Also, a lack of annual age composition data for many stocks precludes construction of accurate brood tables and adds to the uncertainty in determining total return for many stocks. In 2001, with the definitions of escapement goals adopted into policy by the BOF and the uncertainties in estimating escapements and stock-specific commercial harvests, ADF&G recommended all goals of LCI stocks be changed to sustainable escapement goals (SEGs).

In 2001 the SEG for each stock within the management area was developed using percentiles of observed escapement estimates or indices that also incorporated contrast in the escapement data (Bue and Hasbrouck *Unpublished*; Otis 2001; Otis and Hasbrouck 2004). To calculate the percentiles, the escapement data were first ranked from the smallest to the largest value; with the smallest value representing the 0th percentile (i.e., none of the escapement values are less than the smallest). The percentile of all remaining escapement values is a summation of 1/(n-1), where n is the number of escapement values. Contrast in the escapement data is simply the maximum observed value divided by the minimum observed value. As contrast increased, the percentiles used to estimate the SEG range were narrowed, primarily from the upper range, to allow the SEG to include a wide range of escapements. For exploited stocks with a high contrast, the lower end of the SEG range was increased to the 25th percentile as a precautionary measure for stock protection. The percentiles used at different levels of contrast were as follows:

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

All resulting SEG ranges were rounded to the nearest 50 fish. Percentiles were calculated for nearly all stocks using aerial and foot survey escapement indices from 1976 through 2001 (through 2000 for Chinook salmon stocks). Aerial and foot survey data prior to 1976 were excluded due to inconsistencies in data collection methods. Survey data since 1976 were not used for 3 stocks: Ninilchik River Chinook salmon, Tutka Creek pink salmon, and Bear Lake sockeye salmon.

The Ninilchik River Chinook salmon SEG was based on the weir count of naturally produced Chinook salmon observed between 8–24 July from 1994–2000. This river has been stocked since the early 1990s with hatchery produced Chinook salmon from Ninilchik River brood stock. Hatchery stocked fish have been marked with an adipose fin clip and coded wire tag. Early in the stocking program only a portion of each release group was marked, but beginning in 1995 all stocked fish were marked. During 1994–2000 a weir was consistently in place for use in collecting brood stock. All fish that were passed through the weir were counted and examined for a missing adipose fin. Based on the marking and mark recovery data, the number of hatchery-stocked fish that passed through the weir could be estimated. The number of naturally produced fish was then estimated by subtracting the estimated number of hatchery fish from the total number of fish observed. Wild fish killed during egg takes were not subtracted from the count used to develop the SEG. The Ninilchik weir count is still considered an index because it does not account for all Chinook salmon in the escapement. Weir data were used because it was considered more reliable than the aerial surveys.

For Tutka Creek pink salmon, survey data from 1959 to 1975 were used to exclude years with hatchery supplementation, which began in 1976 and continued until 2005. For Bear Lake sockeye salmon, weir data from 1985 to 2001 were used because prior to 1985 the lake was managed to limit sockeye salmon production in favor of coho salmon.

RESULTS AND DISCUSSION

We recommend changing the SEG for Ninilchik River Chinook salmon from 400–800 to 550-1,300 by extending the number of days of weir counts annually that the goal is based upon from 17 (July 8–24) to 29 (July 3–31) and subtracting the wild fish killed for egg takes during the period to better represent the total escapement to the system. We also recommend increasing the SEG for McNeil River chum salmon from 13,750–25,750 to 24,000–48,000 to encourage more production from upriver spawning areas, which have been very lightly utilized during this recent 18-year era of poor adult returns to McNeil River. The following provides additional details on these recommendations and a review of recent salmon escapements relative to the goals developed in 2001.

CHINOOK SALMON

ADF&G recommends the current SEG range of 400–850 for the Ninilchik River (Table 1), based upon wild Chinook salmon counts to the weir operated during the part of the spawning migration between July 8–24, be changed to an SEG range of 550–1,300 wild adult Chinook salmon, based upon live Chinook salmon counts that escape to spawn upstream of the weir from July 3–31 during 1999–2007, to represent a greater proportion of the wild escapement.

From 1999 to 2005, the Ninilchik River Chinook salmon weir was operated throughout the Chinook salmon spawning migration starting in mid-May and ending in early August. During 2003 and 2004, the midpoint of the wild Chinook salmon run was July 4 compared to midpoints between July 11 and 16 for the years 1999–2002 and 2005. In 1999–2005, an average of 36% of the escapement above the weir was counted each year during July 8–24 with a range of 20–48% compared to an average of 65% with a range of 46–81% during July 3–31. Extending the SEG period for the Ninilchik River will encompass more of the variability in run timing and reduce the likelihood of mistaking a low escapement count for late run timing.

The egg take weir operating dates included the period of July 8–24 each year beginning in 1994. After 1999, the egg take weir operation included the period July 3–31, therefore the new SEG is based upon index weir counts from 1999–2007. Although the dates of weir operation encompass the midpoint of the Chinook salmon migration, weir operation is skewed toward the latter part of the return because more ripe Chinook salmon are available for egg-takes later in July.

ADF&G recommends an SEG threshold of 5,000 adult Chinook salmon in the Anchor River based on a full probability spawner recruit model that uses 31 years (1977–2007) of aerial survey escapement indices and inriver recreational harvest estimates, plus 5 years (2003–2007) of weir/sonar estimates of escapement and age composition. The recommended threshold is based on the point estimate (posterior median) of S_{MSY} from the full probability model.

Continued collection and analysis of stock assessment data for Anchor River Chinook salmon is necessary to evaluate the performance of the recommended S_{MSY} because there are no empirical production data from escapements at or near our estimate of S_{MSY} for this stock. Based on our spawner-recruit analyses, the Anchor River Chinook salmon stock can support more harvest. The difference between the average escapement from 2004–2006 and our proposed escapement threshold is 5,685 fish. Changes to the fishery should be implemented gradually, allowing time for their impact to be evaluated and for more production data to be collected. Szarzi et al. (*In prep*), provides a complete description of the escapement goal analyses conducted for the Anchor River Chinook salmon stock.

Recent Chinook salmon escapements at Deep Creek have been within or above the SEG (Table 1). The 2007 escapement of Deep Creek Chinook salmon was within the SEG.

CHUM SALMON

ADF&G recommends changing only one of the 12 chum salmon goals in Lower Cook Inlet (Table 2). Recent escapements have been sufficient, relative to the current SEGs, to provide a harvestable surplus for most LCI chum salmon stocks. During 2004–2007, only 17% of LCI chum stocks had escapements below the current SEG range, while 52% of chum stocks had escapements above the current SEG range (Figure 2). Low prices, relatively modest returns, and lack of tender service have all contributed to diminished commercial fishing effort, particularly in the Kamishak Bay District. This in turn has contributed to many chum salmon systems realizing escapements above their existing SEG range.

The exception to this general trend is McNeil River. Although McNeil River chum salmon have met or exceeded at least the low end of the current escapement goal range during 3 of the past 5 years and 13 of the past 19 years, it has exceeded the upper end of the range only three times since 1988, despite the lack of commercial fishing effort (Figure 3). Because this contrasts with chum salmon production from other west side Cook Inlet drainages, it suggests a freshwater cause rather than prevailing ocean conditions.

Several hypotheses have been developed to explain the low chum salmon production from McNeil River in recent years, relative to the 1970s–1980s. Principal among them are factors associated with the high seasonal abundance of brown bears (*Ursus arctos*) at McNeil Falls (Figure 4) and their potential to impede chum salmon from reaching quality spawning areas upstream of the falls. McNeil River is a unique system in that it is effectively bisected into two distinct stream reaches by a series of large, step falls created by a fault line through a bedrock section of the river just 2.0 km upstream from the ocean (Figure 5). McNeil Falls represent a difficult obstacle for the upstream migration of chum salmon, making them relatively easy prey for the high density of brown bears that annually frequent the area (Figure 6). Approximately 10 kilometers of spawning habitat exists upstream of McNeil Falls (Figure 7), including two heavily braided sections with abundant upwelling sites that chum salmon favor (Figures 7 and 8; Geist et al. 2002; Maclean 2003). In contrast, less than 2.0 km of river are available to chum salmon downstream of McNeil Falls, not all of which is suitable for spawning (Figure 9). In order for McNeil River to realize its productive capacity for chum salmon, favorable spawning habitats upstream of McNeil Falls need to be consistently reseeded by spawners.

While chum salmon are not as adept as sockeye salmon at leaping vertical barriers, aerial surveys over the past 30 years indicate substantial numbers of fish successfully ascended McNeil Falls in some years. The median number of spawners above McNeil Falls during 1976–1988, an era with sufficient production to provide consistent commercial fishing opportunities was 2,847 (Figure 10). In contrast, the median number of spawners successfully ascending McNeil Falls during 1989–2007, an era with poor production and virtually no harvest opportunities, was 510 (Figure 10). At least three factors likely contribute to the number of Above-Falls (AF) spawners in any given year: 1) fish density below McNeil Falls, 2) river discharge, and 3) the abundance of brown bears at McNeil Falls.

Spawning distribution with pink and chum salmon appears to be at least partially density dependent; higher densities of spawners in the lower river typically encourage more fish to seek less densely occupied spawning areas upstream. This tenet is corroborated each time fish have been observed spawning further upstream in drainages during years with abundant escapements. River discharge may also play a significant role in determining AF escapement, particularly for chum salmon, which are not well known for their ability to ascend challenging vertical and/or velocity barriers. It is likely that chum salmon have a very difficult time successfully ascending McNeil Falls during extremely high flows (velocity barrier) or extremely low flows (vertical barrier). Finally, it is reasonable to assume that the variable abundance of bears at McNeil Falls also plays a role in influencing AF escapement. High concentrations of bears can impede upstream migration of chum salmon by directly killing fish attempting to ascend the Falls and by "chasing" fish back down from holding areas midway up the Falls.

These three variables, and especially the last two, probably interact with one another. Fish are likely to be more vulnerable to bears at very low discharge; when fewer pathways through the falls are open, the fish are more concentrated. Although vulnerability to bears may diminish at very high discharges, the physical barrier created by high velocity flows may impede or completely preclude upstream movement. Fish density below the falls also interacts with discharge and bear abundance. High densities below the falls may cue more fish to attempt to ascend the falls, but if bear densities are high and/or discharge conditions are unfavorable, few fish may make it through. Likewise, lower densities of fish below the falls may not cue fish to attempt to ascend the falls, despite a lack of bears and favorable discharge conditions.

Of the three interacting variables that likely influence AF escapement, we only have the ability to manipulate one, escapement below McNeil Falls. When returns are strong, we can affect inriver escapement via openings and closures to the commercial fishery (e.g., see 1976–1988 in Figure 3). When returns are weak, as in the current era, the commercial fishery is closed and all returning fish are allowed to escape to the river (e.g., see 1989–2007 in Figure 3). Therefore, the McNeil River chum salmon stock will have to recover from its current low production on its own. This is most likely a natural cycle that has occurred throughout history prior to humans being here to observe or influence the peaks and valleys of annual salmon returns or bear densities. The relevant question is, once the run does recover, can we encourage more consistent "seeding" of upriver spawning areas to boost stream-wide production, thereby avoiding lengthy recovery periods in the future? Our historical time series of escapement indices above and below McNeil Falls (Figure 10) suggests that achieving higher AF escapements may require higher inriver escapements than our current SEG (13,750–25,750) recommends. As part of the retrospective analysis conducted to evaluate the McNeil River chum salmon escapement goal, we determined that the average escapement index during 1977–1988, an era with higher AF escapement and sufficient production to provide consistent commercial fishing opportunities, was 30,000 fish. In contrast, the average escapement since 1988, an era with low AF escapement, poor production, and virtually no harvest opportunities, was 18,000 fish. While not conclusive by themselves, these observations corroborate the hypothesis that greater escapement below McNeil Falls encourages greater use of high quality spawning habitats above McNeil Falls, and that more upriver spawning contributes to increased stream-wide production and harvest opportunities.

The missing ingredients to this simple observational analysis are stream discharge and bear abundance data. Unfortunately, we were unable to evaluate the degree to which stream discharge influences escapement above McNeil Falls. Discharge data do not exist for McNeil River and we were unable to find an appropriate proxy dataset. To remedy this, ADF&G recently purchased a remote water level and temperature data logger and deployed it at McNeil Falls in 2007, so the lengthy time series necessary to facilitate discharge analysis is forthcoming.

McNeil River State Game Sanctuary (MRSGS) staff has been recording bear densities at McNeil Falls for over 30 years (ADF&G 2007). Their data show a clear trend of increasing numbers of bears using both the Sanctuary as a whole, and McNeil Falls specifically, until about the mid-late 1990s when bear densities began dropping (Figure 4). Comparing the long-term trends in bear and salmon abundance at McNeil River (Figures 3 and 4) indicate that the decline in chum salmon occurred around the same time the number of bears using the MRSGS reached about 100–120 animals, which might suggest a cause and effect relationship since bears are at MRSGS, in large part, to prey on salmon. However, broadening our perspective to include other west-side Cook Inlet chum salmon stocks, we see that several systems experienced a similar decline in adult returns that began around 1989 (Figure 11). This area-wide phenomenon suggests that prevailing ocean conditions were at least part of the cause for the initial decline in adult chum salmon returns at McNeil River, and not bears alone. Figure 11 also illustrates how most Kamishak area chum stocks recovered and again began experiencing strong returns in about 2000, suggesting ocean conditions returned to those favorable to juvenile chum salmon survival. Because McNeil River chum salmon did not experience increased returns, it suggests a freshwater influence is involved in stalling its recovery. There is strong suspect that the lack of use of abundant upriver spawning areas in the past 19 years is a major cause for the continued low production from McNeil River.

In an effort to better understand factors affecting the freshwater production of chum salmon in McNeil River, ADF&G initiated a cooperative project between the Divisions of Wildlife Conservation and Commercial Fisheries in 2005. Josh Peirce, a graduate student at the University of Alaska Fairbanks (UAF) was hired to implement a 2-year radiotelemetry project to investigate chum salmon streamlife (SL: a key parameter in the area-under-the-curve (AUC) method used to estimate total spawning escapement from periodic aerial surveys), spawning distribution, and bear-induced mortality on pre-spawning fish. A detailed description of the methods and results associated with that study can be found in Peirce (2007). Select project results include: the average streamlife estimate for McNeil River chum salmon was reduced from 17.5 to 13.8 d; on average less than 10% of the total inriver escapement occurred above McNeil Falls, however, >90% of the above falls fish lived long enough to spawn; and >90% of the total escapement was confined below McNeil Falls where half of the fish were killed by bears before they spawned.

These data were used in a retrospective analysis of the 31 year time series of catch and escapement data available for McNeil River chum salmon. Historical aerial survey maps were reviewed to apportion the observed escapements to stream section (above and below McNeil Falls). The AUC model was re-run using the revised SL estimate and an observer efficiency parameter was introduced to convert the escapement index into an abundance estimate. Because some aerial survey years were truncated prior to the end of the run, a run-timing curve was developed from historical catch and escapement data and a model was developed to expand truncated escapement estimates accordingly. Finally, a predation model was developed to estimate the number of pre-spawning fish that were killed by bears stream wide at given escapement levels. The model was based on a combination of 16 years of observations where MRSGS staff recorded hourly counts of salmon removed by bears at McNeil Falls, and our 2-year telemetry study that investigated predation stream-wide. The predation model was used to subtract the number of pre-spawning fish killed by bears from the total inriver escapement estimates derived by aerial survey (using AUC) and estimated the number of actual spawners for each year. These values, along with the total return produced by each parent year, were fed into a Ricker (1975) stock-recruitment model to estimate the number of spawners that produce maximum sustained yield (S_{MSY}). Because we only had age composition data for 8 of the 25 return years in our time series, our brood table was built using the historical average age composition for years in which no age data were available.

After completing the run-timing and predation modeling exercises necessary to conduct a spawner-recruit analysis, S_{MSY} for McNeil River chum salmon was determined to be approximately 27,100 fish. The predation model was then used to determine what inriver escapement level was needed to assure 27,000 spawners. We found that the estimated inriver escapement target of 43,700 fish was virtually identical to the midpoint of the current SEG range (45,000 fish) once the current EG range had been rescaled (23,000–66,000) to account for the new SL and observer efficiency values used in the retrospective analysis. On the surface, this appears to be valid justification to maintain status quo. When applied retroactively, the lower end of the current SEG range has been met 13 of the past 19 years and nearly met 4 of the remaining 6 years (Figure 3). However, despite the acceptable escapement performance relative to the current SEG, seeding of upstream spawning areas has remained inconsistent and total returns have been insufficient for commercial harvest opportunities over this same period (Figures 10 and 3, respectively). Hence, the current SEG is not likely to promote sufficient production from McNeil River to maintain commercial viability once the chum salmon stock recovers on its own and fishing resumes.

We conclude that the “noise” in our data (e.g., observer bias associated with aerial survey estimates, incomplete age composition data to build accurate brood tables, error associated with predation models used to estimate actual spawner abundance, inability to quantify the influence above-falls spawners have on stream-wide production, etc.) makes it very difficult to use a traditional spawner-recruit analysis to estimate S_{MSY} for McNeil River chum salmon at this time. We therefore recommend a simplified approach, a return to the previous, long-standing escapement goal range (20,000–40,000) that was in place prior to adopting the current SEG based on the percentile methodology (Bue and Hasbrouck *Unpublished*). Because that goal was in place while aerial assessments employed outdated AUC methods and SL estimates, we recommend re-scaling the historic goal to account for the new SL factor and AUC model that will be used in future escapement monitoring for McNeil River chum salmon. However, we currently recommend against rescaling the goal to account for observer efficiency until more data are available to improve the estimates of that parameter, and the measurement error associated with it. Thus, the new goal of 24,000–48,000 fish represents an aerial survey based index of total inriver escapement rather than an estimate of spawning escapement. In the future, as more data become available to evaluate the effect discharge and bear predation have on escapement above McNeil Falls and stream-wide production, we plan to revise the goal accordingly.

PINK SALMON

ADF&G recommends no changes to the 21 pink salmon goals (Table 3). Recent pink salmon escapements have been sufficient, relative to the new SEGs, to provide a harvestable surplus for most stocks. During 2004–2007, only 3% of LCI pink salmon stocks had escapements below the current SEG range, while 61% of pink salmon stocks had escapements above the current SEG range (Figure 12). Low prices, relatively modest returns, and lack of tender service have all contributed to diminished commercial fishing effort for pink salmon, particularly in the Kamishak Bay District. This in turn has contributed to many pink salmon systems realizing escapements above the existing SEG range.

SOCKEYE SALMON

ADF&G recommends no changes to the 8 sockeye salmon goals (Table 4). Recent sockeye salmon escapements have been sufficient, relative to the new SEGs, to provide a harvestable surplus for most stocks. During 2004–2007, only 6% of LCI sockeye stocks had escapements below the current SEG range, while 60% of sockeye stocks had escapements above the current SEG range (Figure 13). Sockeye salmon runs in Lower Cook Inlet are modest in size compared to Upper Cook Inlet, largely due to LCI's limited number and size of accessible lakes, which juvenile sockeye require for rearing. As such, only a few of the larger systems receive consistent commercial fishing effort. Thus, some of the smaller systems entire return escapes into the respective lakes to spawn.

ACKNOWLEDGMENTS

We thank all ADF&G staff who routinely conducted the aerial and ground surveys necessary to collect the escapement data used in this report, most recently Lee Hammarstrom, Mark Dickson, Ethan Ford, Greg Demers, Sigfus (Tom) Sigurdsson, Joseph Loboy, Carol Kerkvliet and Michael Booz. A draft of this report benefited from review comments provided by Lee Hammarstrom and Ethan Ford (ADF&G, LCI Area and Assistant Area Finfish Management Biologists, respectively) Lowell Fair (Regional Research Supervisor, Central Region Commercial Fisheries), Tracy Lingnau (Regional Management Coordinator, Central Region Commercial Fisheries), James Hasbrouck (Regional Supervisor, Central Region Sport Fish), and Robert Clark (Senior Fisheries Scientist, ADF&G Sport Fish). Special thanks go to Scott Raborn (Biometrician, Central Region Commercial Fisheries), who assisted with the modeling exercises needed to conduct the McNeil River chum salmon escapement goal analysis, and to Josh Peirce (ADF&G Wildlife Conservation, McGrath), who conducted the radiotelemetry project at McNeil River while pursuing his Master's of Science degree at the University of Alaska at Fairbanks. Additional support for the McNeil River chum salmon telemetry project was provided by MRSGS staff.

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TABLES AND FIGURES

Table 1.–Current escapement goals, escapements observed from 2004 through 2007, and escapement goal recommendations in 2007 for 3 Chinook salmon stocks in Lower Cook Inlet.

System	Escapement Data	Escapement Goal Type (BEG, SEG)	Escapement Goal Range	Escapements 2004	2005	2006	2007	Recommendation
Chinook Salmon								
Anchor River	Sonar/weir	SEG	5,000	12,016	11,095	8,945	9,622	Threshold
Deep Creek	SAS[a]	SEG	350–800	1,075	1,076	507	553	NC
Ninilchik River[b]	Weir	SEG	400–850	416	814	764	532	Increase EG to 550–1,300

Note: NC = no change.

[a] SAS = Single Aerial Survey.

[b] Escapement of naturally produced fish through the weir between 8–24 July is basis for current SEG.

Table 2.–Current escapement goals, escapements observed from 2004 through 2007, and escapement goal recommendations in 2007 for 12 chum salmon stocks in Lower Cook Inlet, Alaska.

		Escapement Goal		Escapements				
System	Escapement Data[a]	Type (BEG, SEG)	Range	2004	2005	2006	2007	Recommendation[b]
Port Graham River	MFS	SEG	1,450–4,800	1,177	743	2,231	1,882	NC
Dogfish Lagoon	MFS	SEG	3,350–9,150	3,617	2,746	5,394	4,919	NC
Rocky River	MFS	SEG	1,200–5,400	17,159	6,060	11,200	1,600	NC
Port Dick Creek	MAS or MFS	SEG	1,900–4,450	8,620	4,848	2,786	2,753	NC
Island Creek	MAS or MFS	SEG	6,400–15,600	15,135	20,666	5,615	3,092	NC
Big Kamishak River	MAS	SEG	9,350–24,000	57,897	25,717	58,173	14,787	NC
Little Kamishak River	MAS	SEG	6,550–23,800	45,342	12,066	42,929	15,569	NC
McNeil River	MAS	SEG	13,750–25,750	11,203	17,411	28,176	13,590	Increase EG to 24,000–48,000
Bruin River	MAS	SEG	6,000–10,250	15,886	21,208	7,000	3,055	NC
Ursus Cove	MAS	SEG	6,050–9,850	15,988	12,176	15,663	20,897	NC
Cottonwood Creek	MAS	SEG	5,750–12,000	16,277	17,914	13,243	12,522	NC
Iniskin Bay	MAS	SEG	7,850–13,700	22,044	16,461	15,640	5,340	NC

[a] MAS = Multiple Aerial Survey, MFS = Multiple Foot Survey.

[b] NC = No Change.

Table 3.–Current escapement goals, escapements observed from 2004 through 2007, and escapement goal recommendations in 2007 for 21 pink salmon stocks in Lower Cook Inlet, Alaska.

System	Escapement Data[a]	Escapement Goal Type (BEG, SEG)	Escapement Goal Range	Escapements 2004	Escapements 2005	Escapements 2006	Escapements 2007	Recommendation[b]
Humpy Creek	MFS	SEG	21,650–85,550	28,945	93,756	48,368	53,989	NC
China Poot Creek	MFS	SEG	2,900–8,200	3,335	9,223	7,242	6,235	NC
Tutka Creek	MFS	SEG	6,500–17,000	17,846	133,600	25,824	5,664	NC
Barabara Creek	MFS	SEG	1,900–8,950	5,395	14,440	3,554	25,168	NC
Seldovia Creek	MFS	SEG	19,050–38,950	56,763	98,602	70,045	69,405	NC
Port Graham River	MFS	SEG	7,700–19,850	44,010	69,095	31,173	25,595	NC
Port Chatham	MFS	SEG	7,800–21,000	26,375	44,389	24,210	14,451	NC
Windy Creek Right	MFS	SEG	3,350–10,950	11,974	22,174	17,146	32,297	NC
Windy Creek Left	MFS	SEG	3,650–29,950	23,286	72,031	65,155	18,339	NC
Rocky River	MFS	SEG	9,350–54,250	53,760	198,671	67,840	189,992	NC
Port Dick Creek	MAS or MFS	SEG	18,550–58,300	13,323	122,236	51,500	44,170	NC
Island Creek	MAS or MFS	SEG	7,200–28,300	33,573	26,404	107,683	87,235	NC
S. Nuka Island Creek	MAS or MFS	SEG	2,700–14,250	6,432	11,199	5,100	6,645	NC
Desire Lake Creek	MAS	SEG	1,900–20,200	24,258	45,980	74,774	11,820	NC
Bear & Salmon Creeks	MFS	SEG	5,000–23,500	1,236	34,452	9,033	NA	NC
Thumb Cove	MFS	SEG	2,350–8,850	4,250	8,668	5,205	NA	NC
Humpy Cove	MFS	SEG	900–3,200	990	14,586	1,905	NA	NC
Tonsina Creek	MFS	SEG	500–5,850	3,450	9,922	6,453	NA	NC
Bruin River	MAS	SEG	18,650–155,750	66,494	98,346	515,114	350,420	NC
Sunday Creek	MAS	SEG	4,850–28,850	31,497	116,170	70,037	394,797	NC
Brown's Peak Creek	MAS	SEG	2,450–18,800	18,100	60,983	35,703	249,383	NC

[a] MAS = Multiple Aerial Survey, MFS = Multiple Foot Survey.

[b] NC = No Change.

Table 4.–Current escapement goals, escapements observed from 2004 through 2007, and escapement goal recommendations in 2007 for 8 sockeye salmon stocks in Lower Cook Inlet, Alaska.

		Escapement Goal		Escapements				
System	Escapement Data[a]	Type (BEG, SEG)	Range	2004	2005	2006	2007	Recommendation[b]
English Bay[c]	PAS, Weir	SEG	6,000–13,500	15,310	8,188	15,454	16,487	NC
Delight Lake	PAS, Weir	SEG	5,950–12,550	7,262	15,200	10,929	43,963	NC
Desire Lake	PAS, Weir	SEG	8,800–15,200	10,700	4,820	18,600	10,000	NC
Bear Lake[c]	Weir	SEG	700–8,300	8,061	10,285	8,338	8,421	NC
Aialik Lake	PAS	SEG	3,700–8,000	10,100	5,250	4,760	5,370	NC
Mikfik Lake	PAS	SEG	6,300–12,150	14,020	5,970	17,700	11,190	NC
Chenik Lake	PAS, Weir	SEG	1,880–9,300	17,006	14,507	13,868	18,288	NC
Amakdedori Creek	PAS	SEG	1,250–2,600	7,200	1,710	300	3,830	NC

[a] PAS = Peak Aerial Survey.

[b] NC = No Change.

[c] Bear Lake and English Bay Lake escapements include only those fish allowed past the weir to spawn naturally in the lake, not those removed for broodstock.

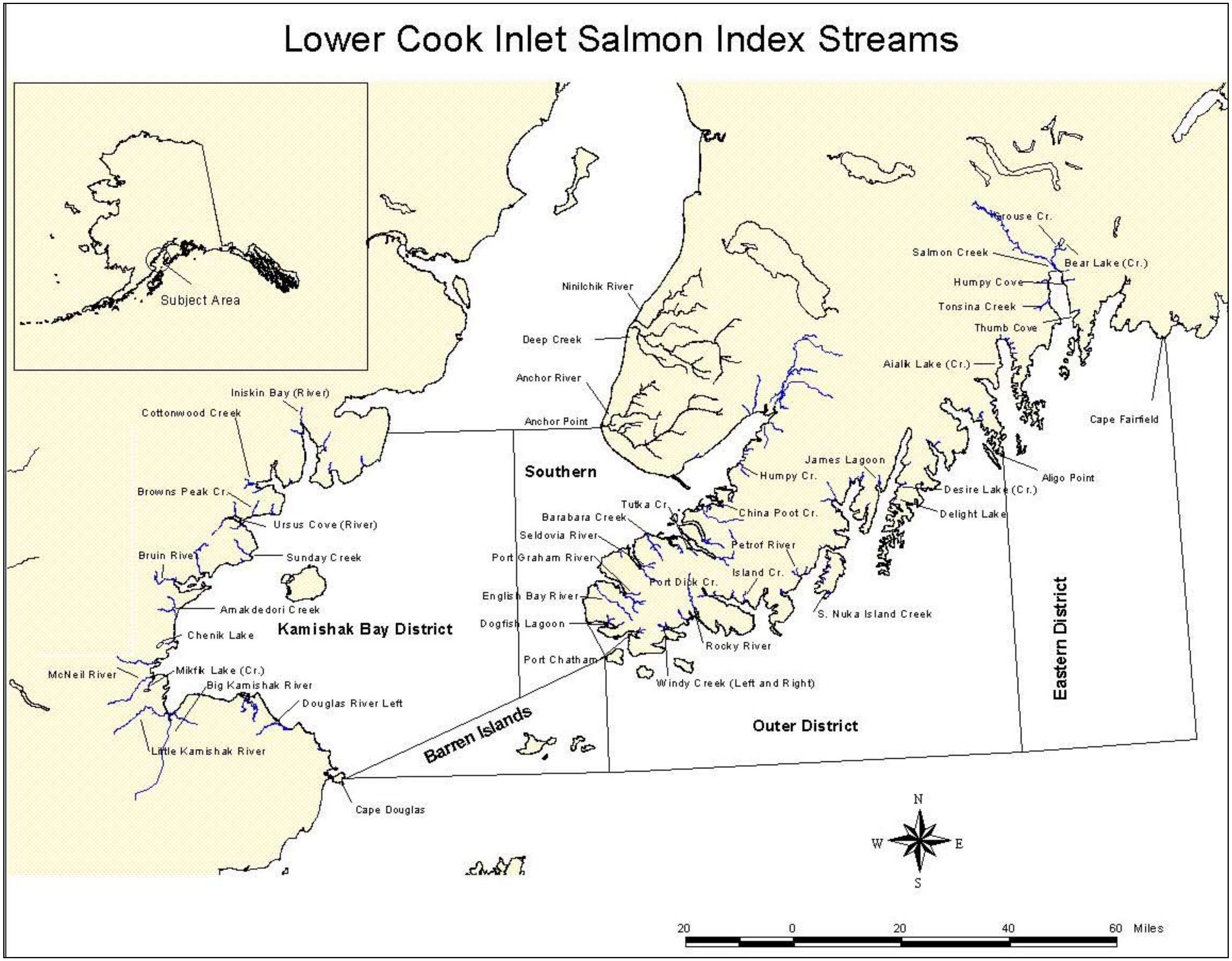

Figure 1.–Salmon producing streams with escapement goals, by district, in the Lower Cook Inlet management area.

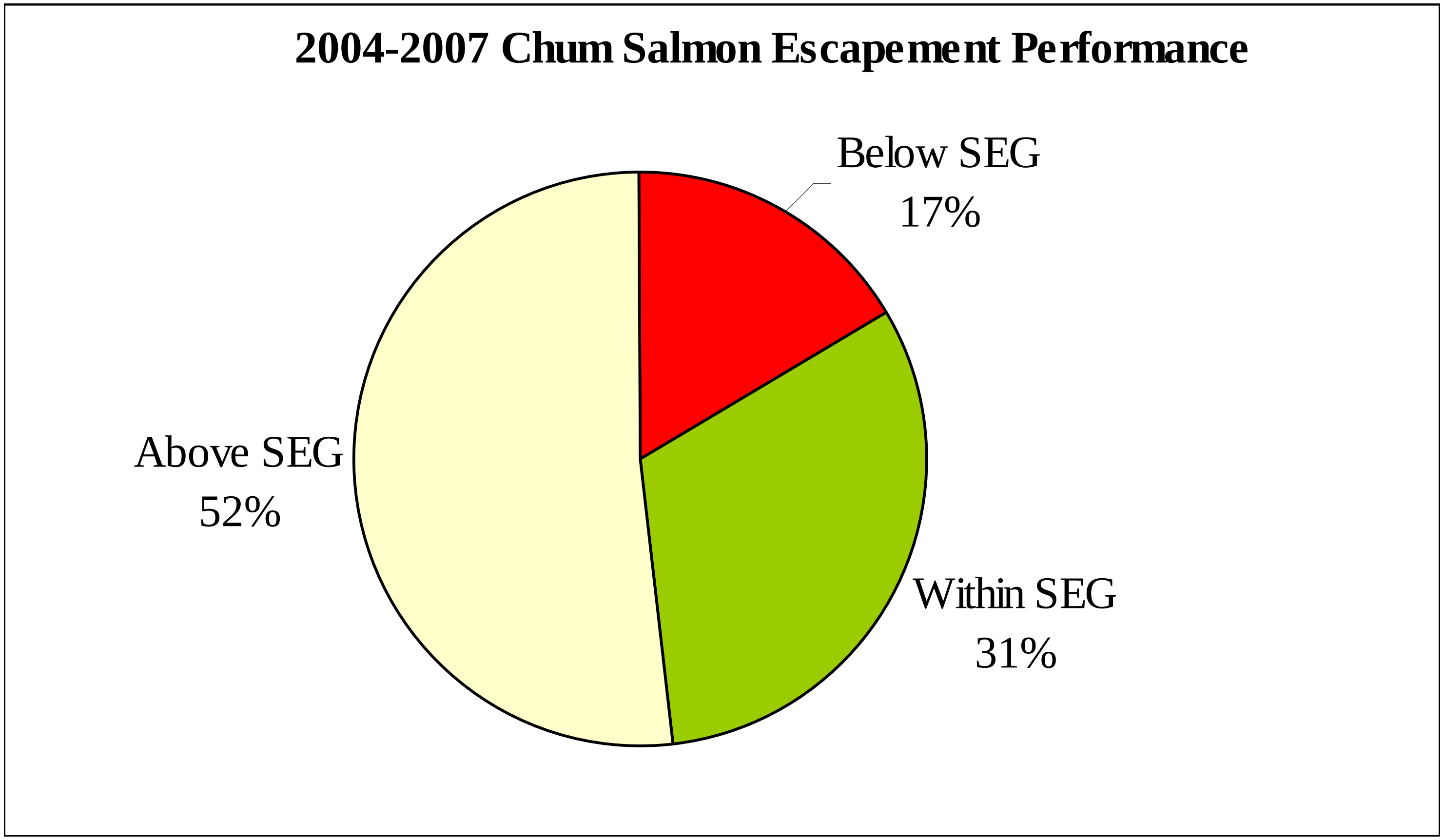

Figure 2.–2004–2007 Lower Cook Inlet chum salmon escapement performance for 12 stocks relative to their current sustainable escapement goal range.

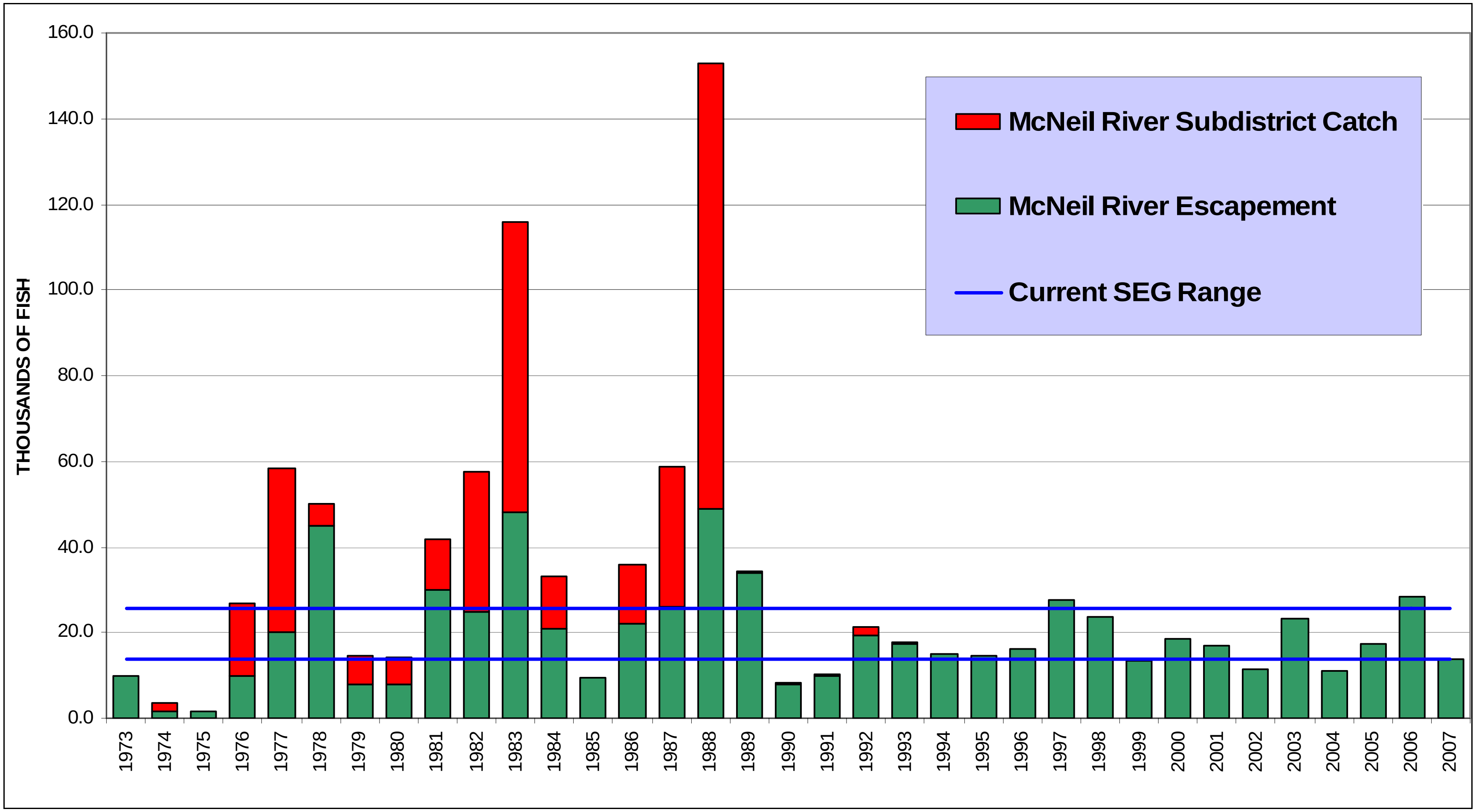

Figure 3.–McNeil River chum salmon historical catch and escapement abundance indices, 1973–2007, relative to the current escapement goal range.

Note: Escapement indices in this figure were estimated using the area-under-the-curve (AUC) method employing the historical stream life (SL) estimate of 17.5 d and an observer efficiency factor of 1.0.

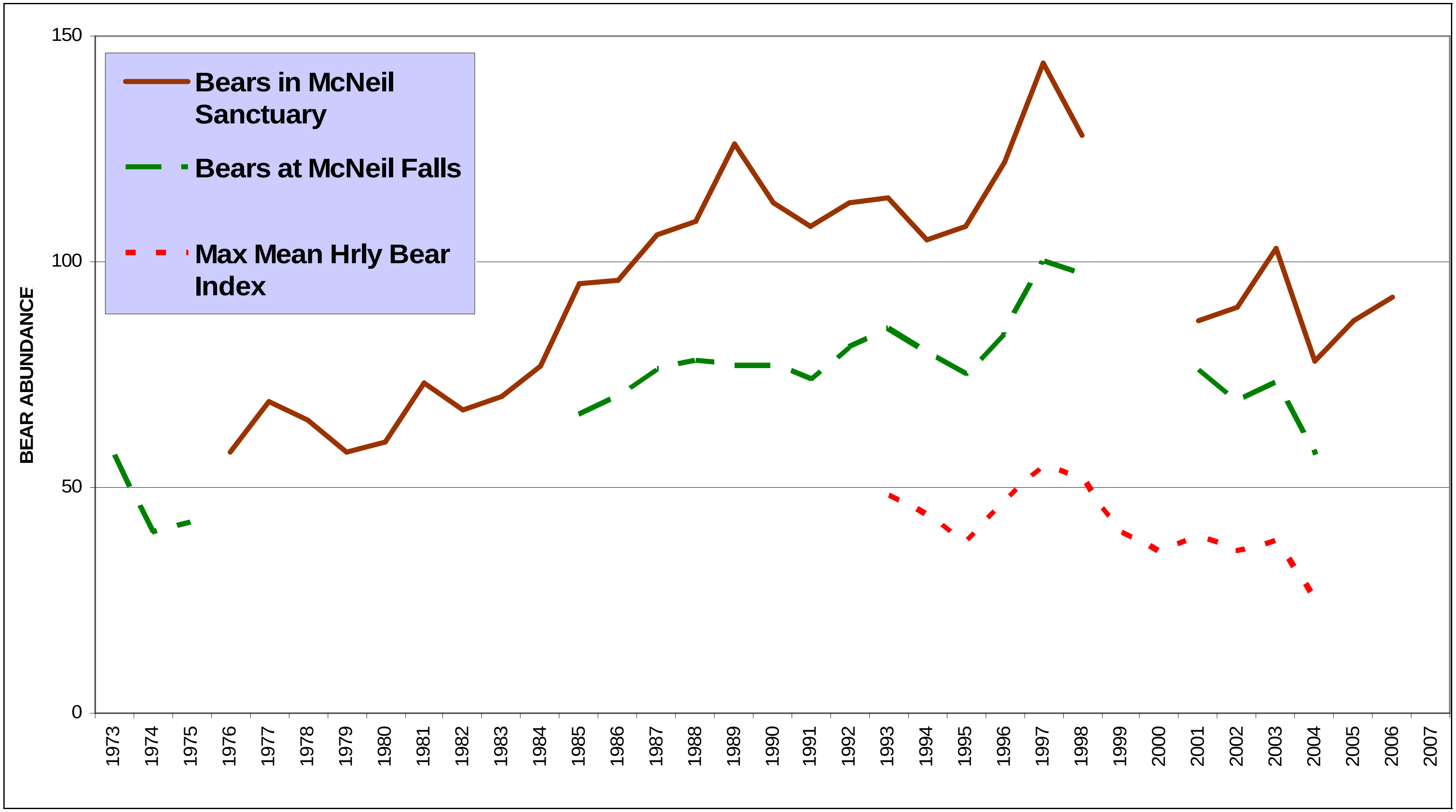

Figure 4.–Historical abundance of brown bears documented within the McNeil River State Game Sanctuary, and specifically at McNeil Falls, 1973–2006.

Source: McNeil River State Game Sanctuary staff, ADF&G Division of Wildlife Conservation, unpublished data.

Figure 5.–Aerial photo of McNeil Falls, located 2 km upstream from the ocean, illustrating physical impediments to chum salmon migration.

Note: for scale, the rock in mid-river is approximately 10 m across; photo by Ted Otis.

Figure 6.–Ground level photo of McNeil Falls, located 2 km upstream from the ocean, illustrating physical and biological impediments to chum salmon migration.

Note: photo by Mark Wipfli.

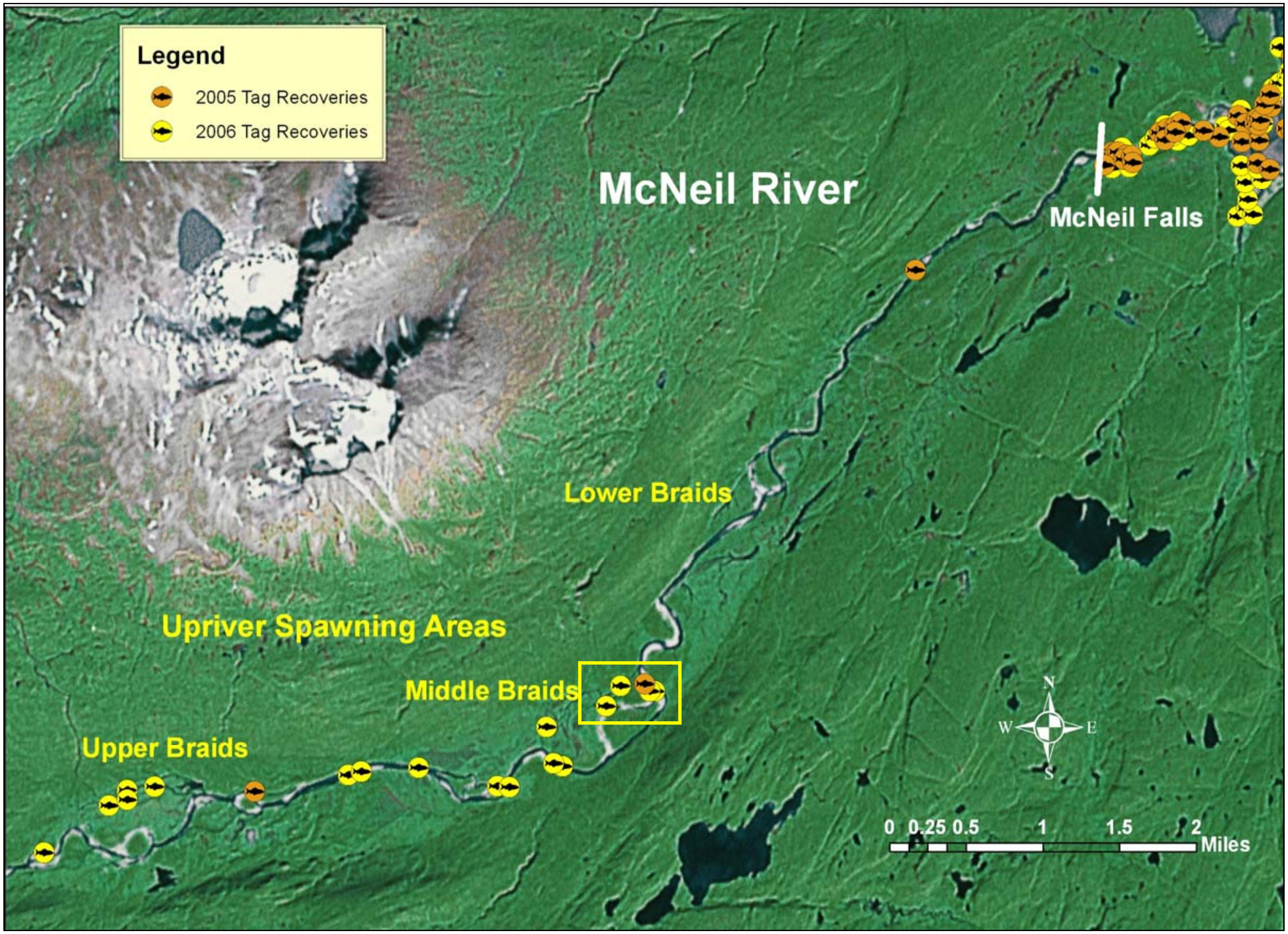

Figure 7.–Satellite image of McNeil River drainage illustrating the extensive spawning habitat available upstream of McNeil Falls.

Note: radiotagged fish that ascended McNeil Falls spawned at locations in the middle and upper braids in 2005–2006. Figure 8 magnifies the area inside the polygon.

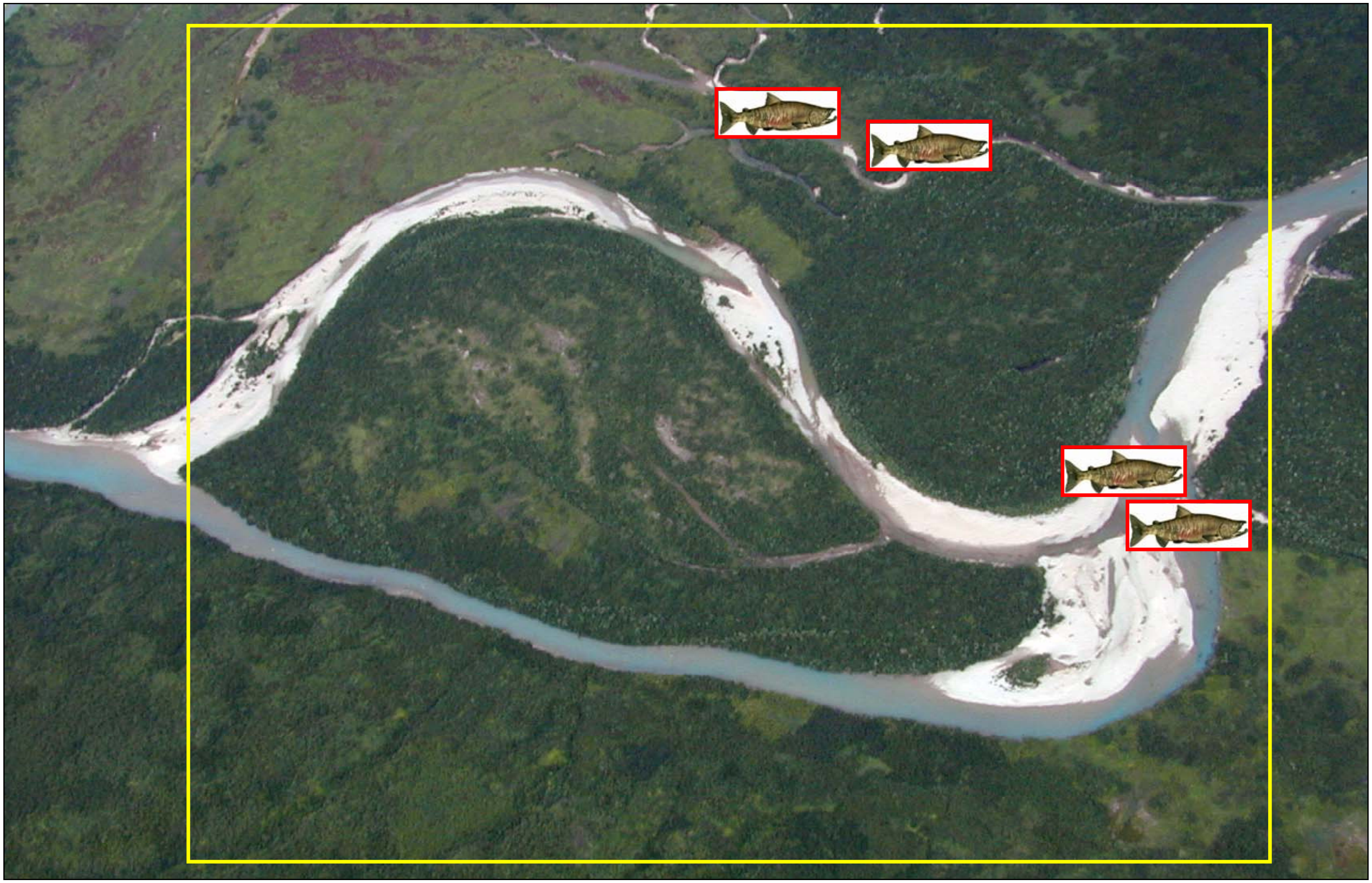

Figure 8.–Aerial close-up of one section of the middle braids where chum salmon selected main and side channels for spawning, sites likely to have groundwater and hyporheic upwelling.

Note: photo by Ted Otis.

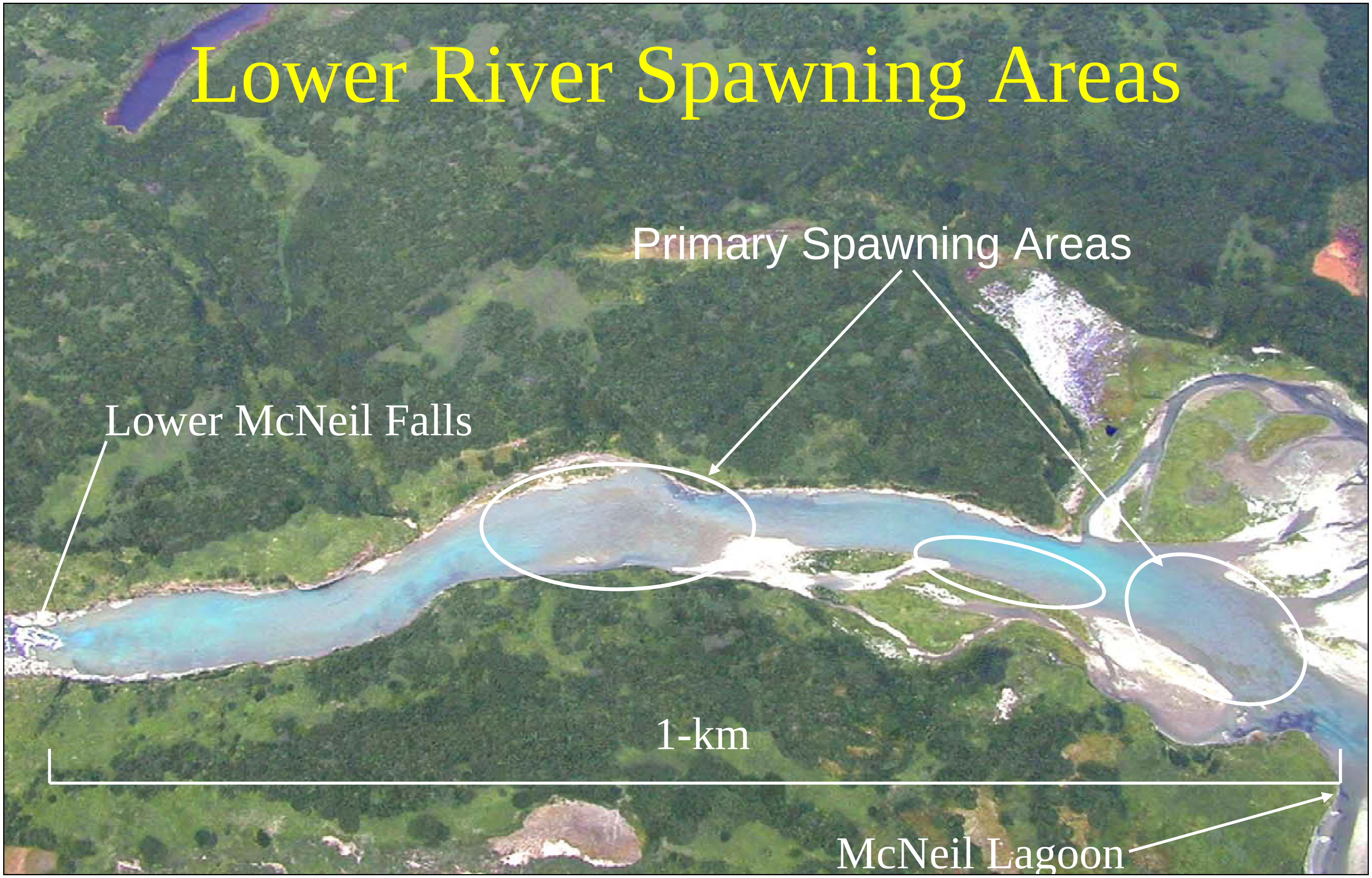

Figure 9.–Aerial photo of lower McNeil River illustrating the limited spawning area available below McNeil Falls.

Note: photo by Ted Otis.

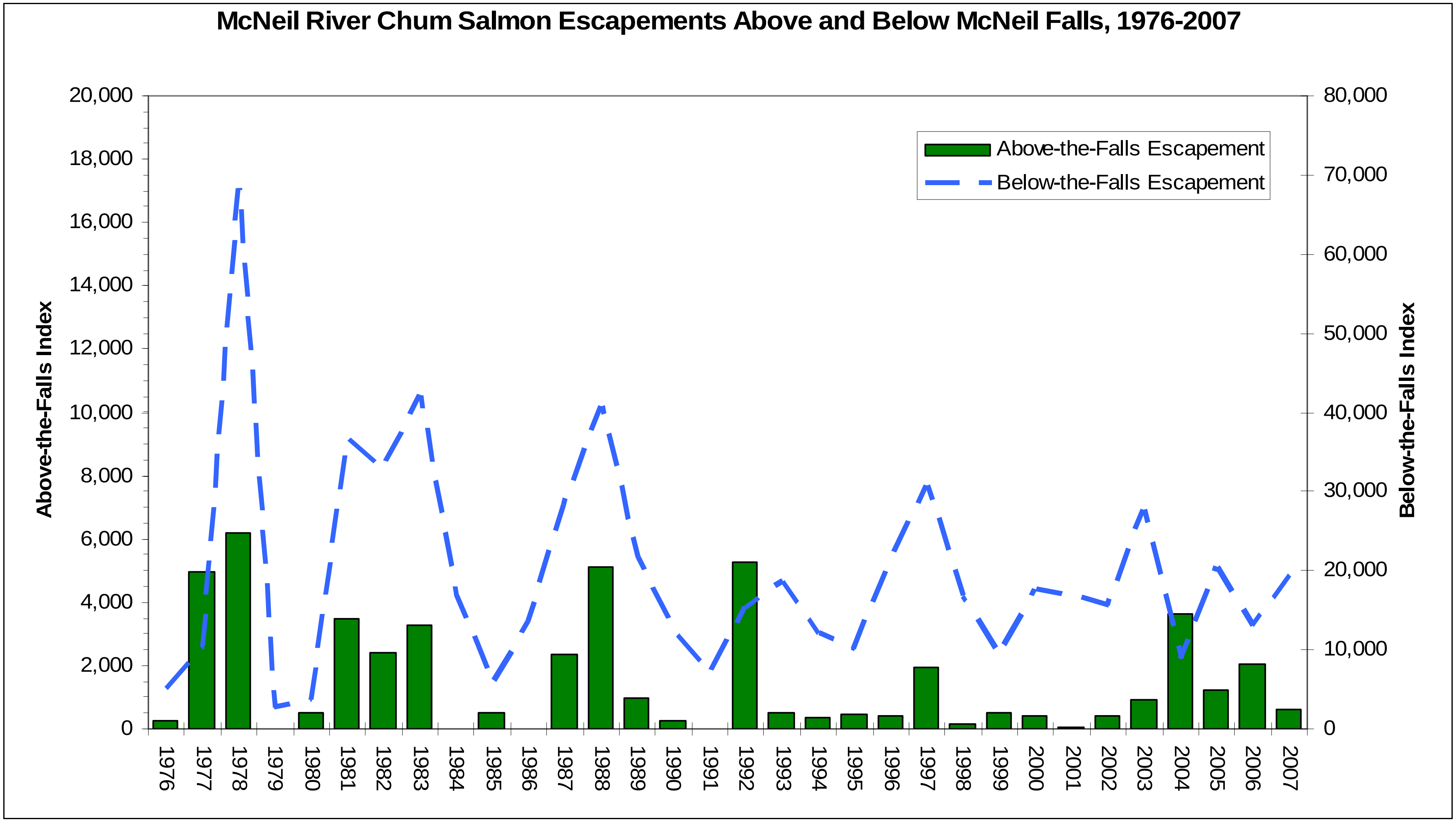

Figure 10.–Annual chum salmon escapement indices above (AF) and below (BF) McNeil Falls, 1976–2007, illustrating lower AF escapements during the past 19 years.

Note: The asterisks (*) denote years when AF escapement indices were not available. Escapement indices depicted in this figure were estimated using the area-under-the-curve (AUC) method employing reach-specific stream life (SL) estimates that were derived from a radio telemetry study (AF=21.9 d, BF=12.6 d). Observer efficiency was assumed to be 1.0.

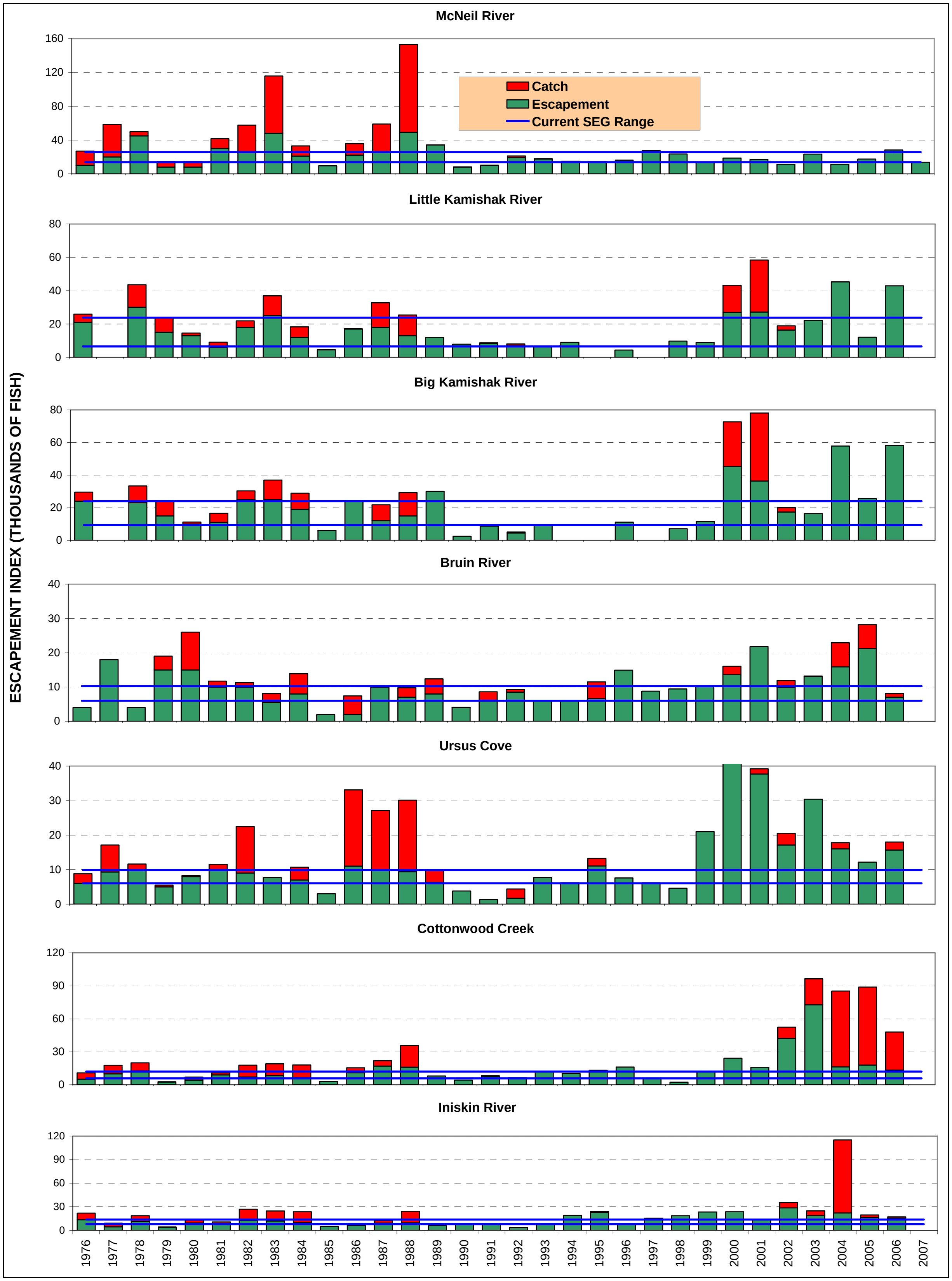

Figure 11.–Kamishak District chum salmon catch and escapement abundance indices, 1976–2007.

Note: Illustrates an area-wide decline in adult returns that began about 1989 and lasted until 1999, after which adult returns increased for all west side Cook Inlet stocks except McNeil River.

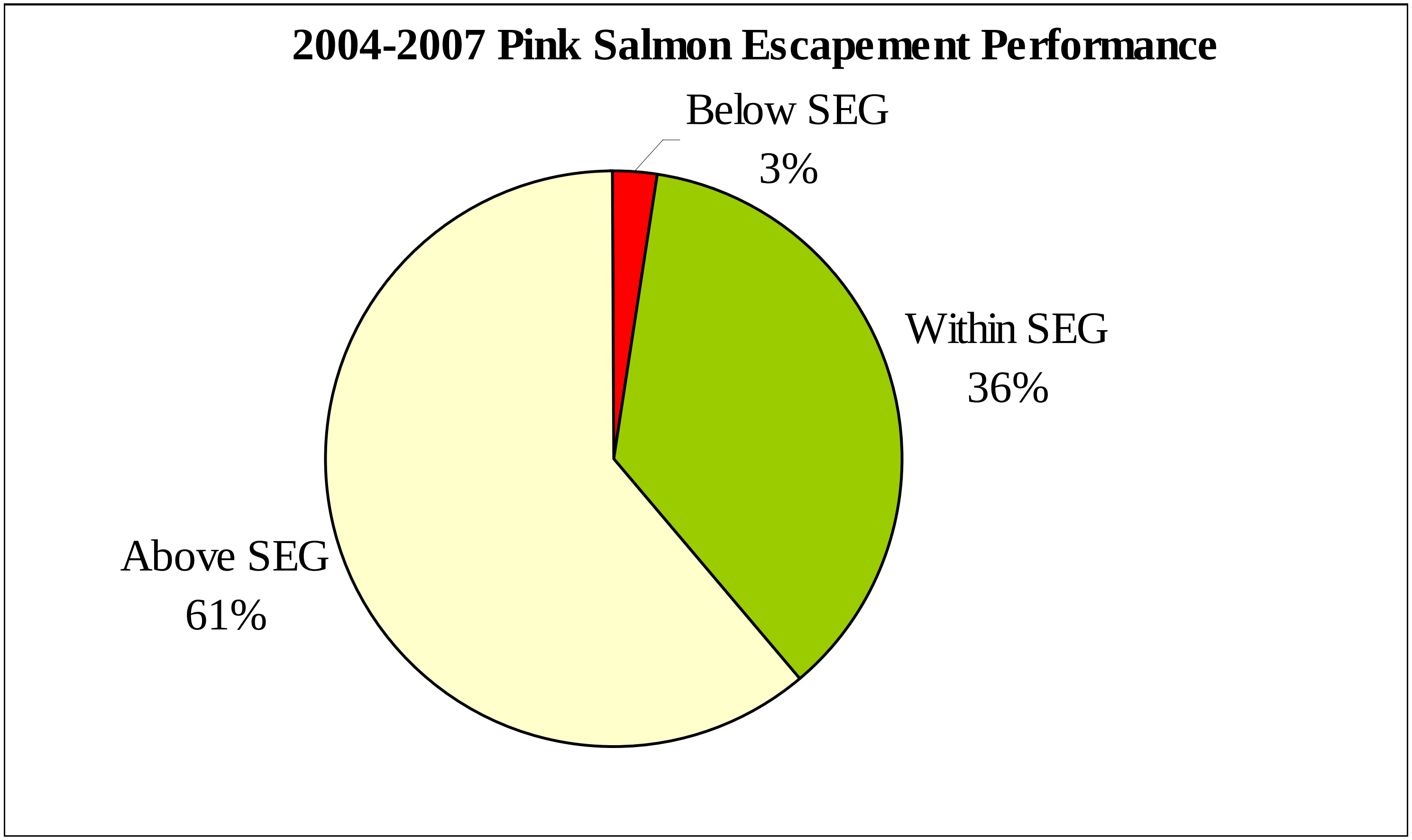

Figure 12.–2004–2007 Lower Cook Inlet pink salmon escapement performance for 21 stocks relative to their current sustainable escapement goal ranges.

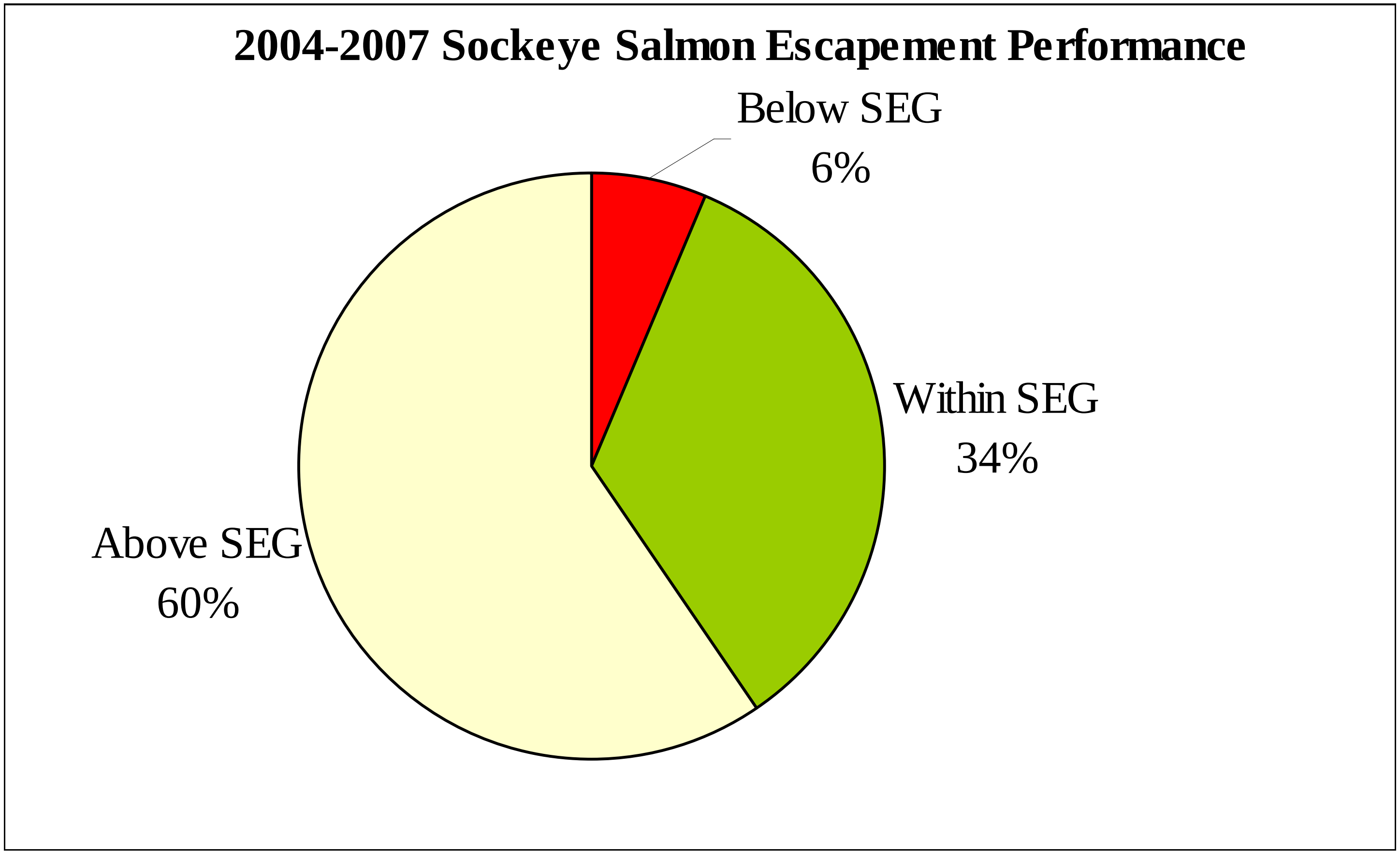

Figure 13.–2004–2007 Lower Cook Inlet sockeye salmon escapement performance for 8 stocks relative to their current sustainable escapement goal ranges.