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Assessment of Historical Runs and Escapement Goals for Kotzebue Area Chum Salmon

by

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and

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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 Department of Fish and Game	ADF&G
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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The Division of Sport Fish Fishery Manuscript series was established in 1987 for the publication of technically-oriented results of several years' work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods. Since 2004, the Division of Commercial Fisheries has also used the Fishery Manuscript series. Fishery Manuscripts are intended for fishery and other technical professionals. Fishery Manuscripts 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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ABSTRACT

Information concerning aerial survey indices of escapement, estimated commercial and subsistence harvests of wild and hatchery fish, returns of fish to the Sikusuilaq Springs Hatchery, results of limited tagging studies, results of limited sonar escapement counts in the Noatak River, and estimated age composition of chum salmon *Oncorhynchus keta* returning to the Kotzebue area of northwest Alaska during the years 1962–2004 was assembled. There were a number of occurrences where aerial survey counts were not conducted or conditions were unsuitable for accurate counts. These were estimated by interpolation or from estimated adjacent areas with correlated surveys. A run reconstruction model was fit to five data sets: (1) aerial survey index counts, (2) commercial fishery catch and effort, (3) terminal run estimates developed from tagging studies conducted during a few years in the time series, (4) Noatak River sonar counts conducted in a few years of the time series, and (5) Kobuk River test fishery indices. The run reconstruction model was used to estimate total runs from commercial catch and effort in years where no useable aerial survey index counts were available. The resultant estimated total runs by age from 1962–2004 were used to develop brood tables, consisting of estimated escapements and estimated resultant age-specific recruits from these escapements for the 1962–1998 brood years. Ricker-type stock recruit models were fit to the brood tables to develop aggregate escapement goals. Aggregate escapement goals were converted to aerial survey index units based on survey expansion factors estimated from the run reconstruction model and were allocated to individual river systems within the Kotzebue area based on historical distribution of aerial survey index counts among the rivers. Based upon the analysis herein, it is recommended that the following escapement goals for Kotzebue area chum salmon be formally adopted by the Alaska Department of Fish and Game:

(1) 9,700 to 21,000 index spawners per year in the upper Kobuk River;
(2) 3,300 to 7,200 index spawners per year in the Salmon River;
(3) 1,400 to 3,000 index spawners per year in the Tutuksuk River;
(4) 4,900 to 10,500 index spawners per year in the Squirrel River; and
(5) 42,000 to 91,000 index spawners per year in the Noatak River.

Key Words: chum salmon, *Oncorhynchus keta*, Kobuk River, Salmon River, Tutuksuk River, Squirrel River, Noatak River, Kotzebue area, brood table, escapement goal, maximum sustained yield, spawner-recruit relationship.

INTRODUCTION

The Kotzebue Sound Fishing District supports the northernmost commercial salmon fishery in Alaska. Although a few Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *Oncorhynchus nerka*, and pink salmon *Oncorhynchus gorbuscha* have been caught in the fishery, almost the entire salmon harvest has been comprised of chum salmon *Oncorhynchus keta* since the inception of the modern day fishery in 1962 (99.9% chum salmon since 1979). The commercial fishery became fully developed in the mid-1970s and the peak annual catch occurred in 1981 when over 677,000 chum salmon were commercially harvested. These chum salmon harvests are believed to be supported almost entirely by runs of chum salmon that return to the Kobuk and Noatak Rivers to spawn each year.

The Kobuk and Noatak chum salmon runs also support substantial subsistence fisheries. Documented subsistence harvests of chum salmon in the area have ranged from about 11,000 to 100,000 fish per year. A minor level of harvest by sport fishermen sometimes occurs; however these catches are so low that this fishery and its harvest effects are not considered further in this report [for example: the 1990 Northwest Area chum salmon sport harvest = 0 (Mills 1991) and the 1993 Northwest Area chum salmon sport harvest = 443 (Mills 1994)].

In 1981, a chum salmon hatchery was built at Sikusuilaq Springs, a tributary of the Noatak River. In 1995, the hatchery was closed. At peak production, the adult hatchery return was about 90,000 chum salmon and these fish contributed to commercial and subsistence fisheries in the Kotzebue area. Other than these hatchery produced chum salmon, the rest of the harvests are believed to be based upon wild spawning fish that return to freshwaters in the Kotzebue area.

The Noatak and Kobuk chum salmon stocks have been assessed since 1962 via aerial surveys of portions of the spawning grounds. A portion of the Noatak River and two tributaries have been surveyed to document escapement trends: (1) the Noatak River from the mouth to Kelly Bar, (2) the Eli River, and (3) the Kelly River and Lake (Table 1). Six sections of the upper Kobuk River have been surveyed: (1) the Kobuk River to Pah River, (2) from the Pah River to just below Selby River, (3) the Selby River mouth, slough, and Selby River, (4) from Selby River mouth to Beaver Creek, (5) Beaver Creek mouth and creek, and (6) Kobuk River above Beaver Creek (Table 2). Three tributaries located in the lower portion of the Kobuk River drainage have been surveyed: (1) the Salmon River, (2) the Tutuksuk River, and (3) the Squirrel River (Table 3).

Although staff from the Alaska Department of Fish and Game (ADF&G) have attempted to survey the Kobuk and Noatak spawning ground index areas several times each year, inclement weather and other problems have often prevented successful surveys. Fair et al. (1999) reviewed available chum salmon aerial survey data for the Kobuk and Noatak systems. They identified usable or successful surveys from the database as those that were conducted from August 1 to August 31 for the lower Kobuk River tributaries, from August 20 to September 20 for the upper Kobuk River, and from August 16 to September 16 for the Noatak River. Further, successful or useable surveys were those that were not limited by poor weather or turbid water that limited visibility. When more than one survey of a given area during a given year met the criteria identified above, the peak survey was selected as the index value. Such editing of the available data base concerning chum salmon aerial surveys for the three index areas during the 43 year period of 1962-2004 yielded for the Noatak River 78 (60%) useable and successful counts of chum salmon out of a possible 129 stream by year cells (Table 1), for the upper Kobuk River 126 (49%) useable and successful counts of chum salmon out of a possible 258 stream by year cells (Table 2), and for the lower Kobuk River tributaries 83 (64%) useable and successful counts of chum salmon out of a possible 129 stream by year cells (Table 3).

The ADF&G has managed the salmon fisheries in the Kotzebue Area over the past few decades with the dual goal of maintaining important fisheries while at the same time achieving desired escapement levels. Escapement objectives for the Kobuk and Noatak River chum salmon populations have been in effect over the past two to three decades. However, up until now, the technical basis for these escapement goals has been simple escapement averaging methodology.

Buklis (1993) provided the following information concerning the various escapement goals that ADF&G used for the Kobuk and Noatak River chum salmon stocks through the year 1992:

"*Kobuk River Chum Salmon*

Biological Escapement Goal and Units of Measure:

10,000 aerial survey count for Kobuk River from Kobuk Village to Beaver Cr.

11,500 aerial survey count for Squirrel River

7,000 aerial survey count for Salmon River

2,000 aerial survey count for Tutuksuk River

Method for Establishing This Biological Escapement Goal:

Peak annual aerial survey counts were averaged for years that produced average or better returns. Surveys that were incomplete or that were conducted under poor survey conditions were excluded.

Noatak River Chum Salmon

Biological Escapement Goal and Units of Measure:

80,000 aerial survey count for Noatak River from mouth to Kelly Bar.

Method for Establishing This Biological Escapement Goal:

Peak annual aerial survey counts were averaged for years that produced average or better returns. Surveys that were incomplete or that were conducted under poor survey conditions were excluded.

Historical Background Regarding Any Prior Escapement Goals for This Stock:

Escapement goal for the Noatak River had been 70,000 chum salmon from 1979 to 1981, but was changed to 80,000 effective beginning with the 1981 season."

Fair et al. (1999) using the updated database discussed above and aerial survey escapement averaging methodology made recommendations to alter chum salmon escapement goals for Kobuk and Noatak stocks as follows:

"*Upper Kobuk River: 10,000, Biological Escapement Goal Range = 8,000 to 16,000,*

Salmon River: 4,000, Biological Escapement Goal Range = 3,200 to 6,400,

Tutuksuk River: 1,500, Biological Escapement Goal Range = 1,200 to 2,400,

Squirrel River: 9,000, Biological Escapement Goal Range = 7,200 to 14,400, and

Noatak River: 80,000, Biological Escapement Goal Range = 64,000 to 128,000."

A purpose of this report is to develop estimates of annual total runs for Kotzebue area chum salmon stocks and to use these data to develop stock-recruit relationships for the Kobuk and Noatak chum salmon stocks. A further purpose of this report is to use these stock-recruit relationships to develop estimates of the escapement levels for the Kobuk and Noatak chum salmon stocks that will support maximum sustained yield fisheries and make recommendations to ADF&G as to appropriate escapement goals for these important stocks of chum salmon.

RUN RECONSTRUCTIONS

INDICES OF ESCAPEMENT

Counts of chum salmon during aerial surveys of Kotzebue Sound area streams were analyzed to develop indices of escapement for three areas. These include the Noatak River, which is the sum of indices for three sub-areas of the Noatak River that have been surveyed (Table 1); the upper Kobuk River, which includes the six portions of the upper Kobuk River that have been surveyed (Table 2); and the lower Kobuk River tributaries, which include the three tributaries that have been surveyed (Tutuksuk River, Squirrel River, and Tutuksuk River, Table 3). The aerial surveys for these areas as judged by Fair et al. (1999) to be successful and useable formed the basic building blocks of later escapement estimates. The discrete area by area indices were analyzed and manipulated to develop total escapement indices for the three major areas in the Kotzebue Sound watershed where spawning chum salmon have been historically counted.

During the 43-year period of 1962–2004, there were 18 years (42%) where useable surveys occurred for all three areas of the Noatak River spawning grounds (Table 1). The escapement index for the Noatak River was taken to be the sum of the three index areas in the Noatak River. There were nine additional years where useable surveys occurred for at least the largest area, the Noatak River below the Kelly River. For those years, the Noatak River escapement index was estimated by expanding the counts on the areas surveyed within the Noatak area by the average proportion observed in the years of complete surveys. The performance of this method based on its ability to hindcast the missing observations for years of complete surveys, was quite good (Table 4). Once those estimates were complete, they provided 27 out of 43 years (63%) where a total escapement index was available for the Noatak River. There remained six years where there were no useable surveys for the main spawning area in the Noatak River, however there were useable estimates of escapement indices for other Noatak River areas. For those six years and for two years when no surveys in the Noatak River occurred, the Noatak escapement index was estimated based on regressions of the escapement index of the Noatak River to escapement indices in the upper Kobuk River and/or the lower Kobuk tributaries (Table 5; Figure 1). These data manipulations provided 35 of 43 years (81%) of index escapement values for the Noatak River (Table 1; Figure 2).

During the 43-year period of 1962–2004, there were 13 years where useable surveys occurred for at least five of six areas of the upper Kobuk River spawning grounds, 3 years where surveys were not segregated by area, but were considered complete, and 2 years where four of the six areas were counted but the count was considered complete (Table 2). This provided reasonably complete index data for 18 of the 43 years (42%).

During the 43-year period of 1962–2004, there were 24 years (56%) where useable surveys occurred for all three tributaries in the lower

Kobuk River (Table 3). The escapement index for the lower Kobuk River was taken to be the sum of the counts in the three tributaries. There were seven years where useable surveys occurred for at least one of the tributaries; for those years, the lower Kobuk River tributary escapement index was estimated by expanding the counts on the tributary or tributaries surveyed by the average respective proportion observed in the years of complete surveys. The performance of this method, based on its ability to hind-cast the missing observations for years of complete surveys, was quite good (Table 4). This data manipulation resulted in 31 of 43 years (72%) where a total escapement index was available for the lower Kobuk River tributaries.

For the years and areas within the upper and lower Kobuk River with insufficient useable surveys within their respective areas for interpolation by expansion (Table 4), regression models (Table 5) were developed and used to estimate the missing escapement indices from other escapement index areas within the overall Kotzebue Area. Doing so resulted in an additional 17 annual estimates of escapement indices for the upper Kobuk River (Table 2; Figure 2); thus bringing the total number of annual estimates to 35 of the 43 years (81%). Doing so for the lower Kobuk River tributary data set (Table 3; Figure 2) resulted in an additional 4 annual estimates of escapement indices; thus bringing the total number of annual estimates to 35 of the 43 years (81%).

There were eight years (1977, 1979, 1989, 1994, 1997, 1998, 2000, and 2002) where there were an insufficient number of useable surveys conducted to estimate an escapement index for any of the three escapement index areas in the Kotzebue Area. For those years, the annual escapements were estimated based on a run reconstruction model fitted to several time series data sets.

COMMERCIAL HARVESTS

Chum salmon are harvested commercially in set gill net fisheries in sub-district 1 of the Kotzebue Sound District. Harvests in the commercial fishery are enumerated from fish tickets (sales receipts issued to fishermen from processors when their catches are sold). Commercial harvests are considered a census with no sampling error. During the 43 years from 1962 to 2004, commercial fishery harvests of chum salmon averaged 201,250 fish and ranged from a low of 8,390 chum salmon harvested in 2002 to a high of 677,239 chum salmon harvested in 1981 (Table 6). Some Kobuk and Noatak origin chum salmon are likely commercially harvested in other marine fisheries; however, little factual data exists to develop estimates of such harvests. Gaudet and Schaefer (1982) documented that a few chum salmon tagged in the Nome sub-district of Norton Sound were fish bound for the Kotzebue Area. The net effects of not taking these non-local harvests into account are likely a minor negative bias in estimates of total runs.

SUBSISTENCE HARVESTS

Chum salmon are harvested for subsistence use throughout the Kotzebue Area. Harvests in the subsistence fishery have been enumerated from either household surveys or from information provided when mail questionnaires are returned. Subsistence catch estimates are assumed to have only moderate precision. Kohler et al. (2005) provided a summary of subsistence catch estimates by village for the Kotzebue area. These data formed the building blocks of subsistence catch estimates used in this report (Table 7). These chum salmon subsistence catch estimates were expanded by interpolation to account for village-by-year cells wherein no direct catch estimates were made. Assumptions were made concerning the origin of chum salmon caught in various locales. Such methodology is more fully explained below. In addition, the surveys used to assess subsistence catches in the town of Kotzebue were very limited, prior to 1985 (Charles Lean, personal communication). This is apparent from inspection of the trend in reported catch for Kotzebue (Figure 4); with the ratio of average reported catch, 1985–2004 being 8.8-fold the average of reported catch, from 1962 to 1984. To correct for this underreporting, the reported subsistence catches for the town of Kotzebue for years before 1984 were expanded by a factor of 8.8.

It was assumed that all chum salmon caught in Kobuk River village subsistence fisheries (villages of Noorvik, Kiana, Ambler, Shungnak, and Kobuk) were Kobuk River origin chum salmon and that chum salmon catches in Noatak village were Noatak River origin. Annual subsistence catch data for these villages were plotted (Figures 3 and 4). Casual examination of subsistence catch trends supported the notion that the catches were trending or in other words, individual annual subsistence catches were not independent of catches just before or just after. Although many approaches could have been taken to capture these trends, we chose a simple approach. If only a single year of subsistence catch data was missing, we used the average of the year prior to and immediately after the missing year. For example, the Noorvik subsistence catch was not directly estimated in 1984, the average subsistence harvest in 1983 and 1985 was taken as the proxy estimate of the Noorvik subsistence harvest for the year 1984 (Tables 7 and 8). When larger blocks of catch estimates were missing, such as for the village of Kiana from 1986 to 1993, the approach was to use the average for the two-year block just before the missing values and the two -year block just after the missing values. So for the Kiana example, the subsistence catches for the years 1986–1993 were estimated as the average from the sampled years of 1982–1983 and 1994–1995. Table 7 provides the annual subsistence catch estimates used in this report; Table 8 provides a description of the basis for each of the interpolations.

Kohler et al. (2005) also provided chum salmon subsistence catch data for the communities of Kotzebue, Deering, Kivalina, Buckland, Candle, and Shishmaref. None of these communities are located in either the Kobuk or the Noatak drainages and hence origin of chum salmon catches in these subsistence fisheries is in question. Further, subsistence catch data has not been collected as regularly in these locations. We elected to only include the catches from the Kotzebue subsistence fishery as listed in Table 7 in this report because:

(1) Magnitude of catches in the other communities was low when they were directly sampled;
(2) Only a few years of data were available for these other communities; and
(3) It is uncertain as to whether or not they mostly fished on local stocks of chum salmon, rather than fish returning to the Kobuk and Noatak Rivers.

It is likely that some of the chum salmon taken in Deering, Kivalina, Buckland, Candle, and Shishmaref subsistence fisheries are of Kobuk and Noatak origin. The net effect of not taking these harvests into account is likely a minor negative bias in estimates of total runs of Kobuk and Noatak chum salmon.

SIKUSUILAQ SPRINGS HATCHERY RUNS

The Sikusuilaq Springs chum salmon hatchery on the Noatak River was established in 1981 and by 1986 was contributing a few fish to the Kotzebue Area fisheries. Steve McGee of ADF&G (personal communication) provided estimates of the hatchery contribution to the Noatak River subsistence fishery as well as returns to the hatchery for the years 1986 to 1995 (Table 9). The hatchery was closed in 1996. The last release of chum salmon fry occurred in 1995 and was from the 1994 brood (Table 10). Hatchery returns continued until 2000, however no direct estimates of the numbers of returning adults to the hatchery were made after 1995.

The 1986–1995 hatchery runs by age were reconstructed from the returns to the hatchery, subsistence catches, age composition of the commercial fishery catch, as well as estimated exploitation rate exerted by the commercial fishery. The exploitation rate exerted by the commercial fishery was estimated from the run reconstruction (see later section for details). The total hatchery return was estimated by expanding the inriver hatchery return by the commercial fishery exploitation rate. The Sikusuilaq Springs Hatchery inriver returns of chum salmon from the 1983 to 1989 broods were estimated as the sums of returns to the hatchery plus contributions to the Noatak subsistence fishery. The returns from the 1990 to 1994 hatchery broods were projected from the hatchery releases, average marine survivals as directly estimated for the 1983 to 1989 broods, and the average maturity schedule (i.e., the average age composition of the return).

TAGGING STUDIES

Independent estimates of the Kotzebue area terminal chum salmon runs are available for several years based on tagging studies. Tagging studies were conducted in the Kotzebue District in 1966–1968, (Geiger 1967; Yanagawa 1969) and in

1981–1982 (Dinnocenzo 1981; Bigler and Burwen 1983, 1984). In each of these five years, tags were deployed throughout the run from set gillnets deployed in near-shore areas throughout the Kotzebue District. During the 1966–1968 studies, tags were recovered from commercial fishermen and from the subsistence fisheries in the Noatak and Kobuk Rivers. An advertising campaign was conducted to recover tags. A $2 reward was offered for each tag returned to the ADF&G, and each returned tag was eligible for a lottery drawing for a $150 prize. The advertising campaign included radio announcement, the deployment of posters throughout the area, and repeated visits by ADF&G personnel to all villages in the Noatak and Kobuk drainages.

During the 1981–1982 studies, the ADF&G made extensive effort to recover tags from the commercial and subsistence fisheries. In addition, the ADF&G conducted extensive surveys of spawning areas in both the Noatak and Kobuk Rivers to recover tags. The tagging statistics for each of the above-mentioned tagging studies are shown in Table 11. Included are the tags deployed (M), documented removals from the tagged population due to commercial catch, the subsistence catch (C), and the recoveries (R) in the subsistence fishery. For all years, a Peterson-type estimate of Kotzebue District terminal run size was made (Table 12), assuming the marked population (M) is the tags deployed less the removals by the commercial fishery, the subsistence fishery is the second capture event with catch (C) and the reported tag recoveries (R) the relevant statistics.

$$N = {(M-1)(C-1)}\big/{(R-1)} \qquad (1)$$

For the 1981–1982 studies, when efforts were made to recover tags from the escapements in the Noatak and Kobuk Rivers, Peterson-type estimates were also made using the pooled subsistence and escapement samples. All of the estimates are shown in Table 12. For 1981 and 1982, the estimate based on the pooled subsistence fishery and escapement sample as the second capture event was used in fitting the run reconstruction models (see below).

NOATAK RIVER SONAR STUDIES

Sonar technology was used over a several year period to estimate chum salmon escapement in the Noatak River. Lack of funds prevented successful implementation of an on-going annual program. Bendix sonar was deployed on the Noatak River during the 1979–1980 seasons (Bird and Bigler 1982) and during the 1981 season (Bird 1981). The 1979 operation was a limited single bank approach that did not operate throughout the run. The site used in the 1980 study had problems with large numbers of fish passing outside the sonar beam. In 1980 and 1981 a full scale, two-bank operation occurred throughout the run. In addition, daily species apportionment sampling occurred throughout the run. The 1980 site was abandoned and a better site was selected for the 1981 assessment (Bird 1981). There was some passage outside the sonar beam at the site used in the 1981 assessment; however the estimated passage was 335,500 and considered to be considerably closer to the actual passage than the aerial survey counts (Bird 1981).

Enumeration studies of passing chum salmon in the Noatak River using Biosonics dual beam sonar gear were conducted from 1989 to 1994. The studies were considered as a feasibility effort during the first three years, and considered operational from 1992 to 1994 (Fleischman and Huttunen 1990; Fleischman et al. 1990; LaFlamme et al. 1992). A single bank operation with daily species apportionment sampling occurred in 1992–1993 (LaFlamme et al. 1993; LaFlamme 1995) and a two-bank operation with species apportionment sampling occurred in 1994 (LaFlamme et al. 1995). During the 1994 operation, only 7% of the chum salmon passage occurred on the bank not ensonified in the earlier years. The estimated passages in 1992 and 1993 were expanded by the respective bank passage proportions observed in 1994. The sonar site for the dual beam operations was located below the Noatak River subsistence fishery and the Sikusuilaq Springs chum salmon hatchery. Estimated subsistence catches and returns to the hatchery were subtracted from the sonar passages to estimate total wild escapement (Table 13). The 1981, and 1992 – 1994 sonar estimates (Table 13) were used in fitting the run reconstruction model.

RUN RECONSTRUCTIONS FOR WILD TERMINAL RUNS

Several data sources are available that provide estimates of the abundance of the Kotzebue Area chum salmon runs. There are a limited number of years of estimates of escapement. Estimates of the Kotzebue Area terminal chum salmon runs are available for five years (1966–1968, and 1981–1982). Estimates of Noatak River escapements based on sonar counts are available for four years (1981 and 1992–1994). In addition, trends in Kobuk River inriver runs are reflected in Kobuk River test fishery indices. There exist much more extensive data sets that provide indications of run strength, and include index escapement counts (35 years since 1962 where acceptable aerial surveys occurred). Further, commercial catches, and commercial fishery effort statistics are available for every year since 1962. These data enable the reconstruction of the Kotzebue Area terminal chum salmon runs using methods developed by Shotwell and Adkison (2004).

The components of the Kotzebue area terminal chum salmon runs include the commercial wild catch, hatchery commercial catch, subsistence catch in Noatak village and in Kobuk River villages, hatchery subsistence catch in Noatak village, hatchery escapements, and wild escapement to the Noatak and Kobuk Rivers.

A run reconstruction model was fit to several data sets:

(1) Commercial catch (C_i), subsistence catch (S_i) and combined Noatak River (L_i) and Kobuk River index escapement counts **(**K_i), for the years 1962–2004 except the years of unacceptable aerial surveys;
(2) Commercial fishing effort (F), for the years 1962–2004;
(3) Absolute estimates of terminal runs (T_i) for the years 1966–1968 and 1981–1982;
(4) Absolute estimates of Noatak River escapement (N_i) based on sonar counts for the years 1982 and 1992–1995; and
(5) Kobuk River test fishery index catch for the years 1993–2004.

Full Model Run Reconstruction

The following model was fit to predict terminal runs ($\hat{R}_i$) from the observed commercial catch (C_i), the observed Noatak River escapements based on sonar counts, observed subsistence catch (S_i), the observed Noatak River (L_i) and Kobuk River (K_i) index aerial survey counts.

$$\hat{R}_i = C_i + S_i + \hat{X}_N L_i + \hat{X}_K K_i \tag{2}$$

where the estimated parameter $\hat{X}_N$ is an expansion factor for the Noatak River index aerial survey counts, estimated parameter $\hat{X}_K$ is an expansion factor for the Kobuk River index aerial survey counts, and years (i), 1962–1965, 1969–1976, 1978, 1980, 1983–1988, 1990–1993, 1995–1996, 1999, 2001, 2003–2004.

The following model was used to predict the commercial catch ($\hat{C}_j$) from the estimated terminal run ($\hat{R}_j$) and observed commercial fishery effort (F_j).

$$\hat{C}_j = \hat{R}_j(1-\exp(-q_1 F_j))\text{ ; j = 1962–1992} \tag{3}$$

$$\hat{C}_j = \hat{R}_j(1-\exp(-q_2 F_j))\text{ ; j = 1993–2004} \tag{4}$$

where the parameter q_1 is the catchability coefficient for the years 1962 to 1992; and parameter q_2 is the catchability coefficient for the years 1993 to 2004. Note that the Kotzebue fisheries prior to and after 1993 were modeled separately. This is because short period openings were initiated in 1993 to reduce the time spent holding the catch, forcing fishermen to deliver to processors in a more timely manner and to improve product quality. This markedly increased the efficiency of the fishery and is reflective of differing catchability between the two time periods.

The following model was used to predict the terminal run ($\hat{T}_l$) estimated from mark-recapture experiments, from the observed commercial catch (C_l), observed subsistence catch (S_l), and the observed Noatak River (L_i) and Kobuk River (K_i) index aerial survey counts.

$$\hat{T}_l = C_l + S_l + \hat{X}_N L_l + \hat{X}_K K_l \tag{5}$$

where the estimated parameter $\hat{X}_N$ is an expansion factor for the Noatak River index aerial survey counts, estimated parameter $\hat{X}_K$ is an expansion factor for the Kobuk River index aerial survey counts, and years (l) = 1966–1968 and 1981–1982.

The following model was used to predict observed Noatak River escapements ($\hat{N}_m$) as estimated from sonar counts from the observed Noatak River aerial survey index counts (L_m).

$$\hat{N}_m = \hat{X}_N L_m \tag{6}$$

where, the estimated parameter $\hat{X}_N$ is an expansion factor for the Noatak River index aerial survey counts and years (m) =1981 and 1992–1994.

The following model was used to predict the estimated inriver runs to the Kobuk River based on the observed Kobuk River test fishery cumulative index (I_o).

$$\hat{X}_K K_o + S_o^K = \hat{E}_K I_o \tag{7}$$

where K_o is the Kobuk River index aerial survey count, S_o^K is the Kobuk River subsistence catch, the estimated parameter $\hat{E}_K$ is the escapement per test fish index, and years (o) where the test fishery operated and acceptable aerial surveys were implemented (1993, 1995–1996, 1999, 2001, and 2003–2004).

The run reconstruction model was fit to the five data sets using the principal of least squares. Here, the estimated parameters ($\hat{R}_i, \hat{X}_N, \hat{X}_K, \hat{q}_1, \hat{q}_2, \hat{E}_K$) of the model were selected as those values, which minimize the following

$$\begin{aligned} SS = {} & (I_1/35)\sum_i(\hat{R}_i - R_i)^2 + \\ & (I_2/35)\sum_j(\hat{C}_j - C_j)^2 + \\ & (I_3/5)\sum_k(\hat{T}_j - T_j)^2 + \\ & (I_4/4)\sum_m(\hat{N}_m - N_m)^2 + \\ & (I_5/7)\sum_o(\hat{X}_K K_o - \hat{E}_K I_0)^2 \end{aligned} \tag{8}$$

where I_1, I_2, I_3, I_4, I_5, are weighting factors for the index aerial survey count data, commercial fishery catch and effort data, absolute terminal run data, sonar count data, and Kobuk River test fishery index catch data.

Model 2 Run Reconstruction (Reduced Parameter Model)

A reduced parameter run reconstruction model (model 2) was fit to the data. Model 2 did not estimate terminal runs directly. Model 2 fit commercial catch data (equation 2 and 3), terminal run data (equation 4), sonar count data (equation 5), and the Kobuk River test fishery data (equation 6) as in the full model.

Model 2 was fit to the five data sets, using the principal of least squares. Here, the estimated parameters ($\hat{X}_N, \hat{X}_K, \hat{q}_1, \hat{q}_2, \hat{E}_K$) of the model were selected as those values, which minimize the following

$$\begin{aligned} SS = {} & (I_2/35)\sum_j(\hat{C}_j - C_j)^2 + \\ & (I_3/5)\sum_k(\hat{T}_j - T_j)^2 + \\ & (I_4/4)\sum_m(\hat{N}_m - N_m)^2 + \\ & (I_5/7)\sum_o(\hat{X}_K K_o - \hat{E}_K I_0)^2 \end{aligned} \tag{9}$$

where I_2, I_3, I_4, I_5 are weighting factors for the commercial fishery catch and effort data, absolute terminal run data, sonar count data, and Kobuk River test fishery index data.

In fitting the run reconstruction models, the weighing factors for the index aerial survey count data, commercial fishery catch and effort data, absolute terminal run data, the Noatak River sonar count data, and the Kobuk test fishery index data used were 5, 25, 10, 20, and 5, respectively. These factors were subjectively selected and generally reflect the relative quality of these data sets. The relatively high weighting for the terminal run and the sonar count data was to effectively scale run reconstructions so that trends in terminal runs determined mainly from the trends in index escapement and commercial fishery catch per effort were consistent with the absolute estimates of escapements and terminal runs when available. Because of the limited number of years where terminal runs and total escapements were directly estimated, the trends in terminal runs were influenced by trends in escapement indices and commercial catch per fishing effort. The estimated run reconstruction model parameters (Table 14) represent the result of model fits to the data. The expansion factors for Noatak and Kobuk aerial survey indices were 2.41 and 4.87 for the Full Model and 2.55 and 4.42 for Model 2, respectively (Table 15). The differences in the expansion factors for the Noatak and Kobuk river aerial surveys is consistent with the fact that fish are more difficult to survey in the Kobuk River due to the stained nature of the waters. The commercial fishery catchability coefficients for the early and late fisheries under the Full Model were 0.000193 and 0.00101, respectively; and for the reduced parameter model were 0.000182 and 0.00077, respectively. The estimated escapement per index for the Kobuk River test fishery was 210 for the Full Model and 191 for Model 2. For years where aerial survey index counts were not available the terminal runs were estimated from the observed commercial fishery catch and estimated catchability coefficient ($\hat{R} = C/(1-\exp(-\hat{q}F))$.

Although the terminal runs were estimated in the full model, the escapement based on the terminal run estimates were closely related to the expanded aerial index counts (Figure 5). Note also that the expanded aerial counts were consistent with absolute estimates of terminal runs based on mark–recapture experiments (Figure 5) and absolute escapement estimates based on sonar counts (Figure 6). In all the run reconstructions, the estimated commercial catch closely matched the observed commercial catch (Figure 7). There were very little differences in the estimated terminal runs between the two run reconstruction models (Figure 8). The relationship between the Kobuk River test fish index and estimated Kobuk inriver runs is shown in Figure 9.

In subsequent stock recruit analysis, both the full model and model 2 run reconstructions were used. Under the full model run reconstruction, the wild and hatchery runs for 1962–2004 are provided in Table 16. Runs for the years 1977, 1979, 1989, 1994, 1997–1998, 2000, and 2002 were estimated by expansion of observed commercial fishery catch and the exploitation rate estimated from the observed fishing effort for the respective year.

RECRUITS FROM 1962–1998 BROODS

Age composition of Kotzebue area chum salmon commercial catches have been routinely sampled since 1962 (Table 17). However, the 2002 catch was not sampled due to very low numbers. From 1962-2001 and 2002-2004, sample sizes of aged fish ranged from 69 fish aged in 1962 to 4,824 fish aged in 1997, averaging 1,865 aged fish per year. Because sample sizes are high, only a small loss of precision occurs when going from annual total runs to annual age-specific estimates of total runs. During the 43-year period of 1962 to 2004, age composition averaged 9.6 % age-3 chum salmon, 61.1% age-4 chum salmon, 27.1% age-5 chum salmon, 2.6% age-6 chum salmon, and 0.2% age-7 chum salmon (Table 17).

Age specific total return estimates were developed for wild Kotzebue Area chum salmon for the years 1962–2004. Annual age composition estimates as provided in Table 17 (note that the average age composition was used for 2002) were multiplied by the annual runs which were the sum of annual total escapement estimates, annual total commercial catch estimates, and annual total subsistence catch estimates.

The recruits, by age, from parent escapements for Kotzebue Area chum salmon, were estimated for the 1962–1998 brood years. The recruits from brood year *y* and age *a* are the sum of escapement, subsistence catch, and commercial catch for age *a* in calendar year *y* + *a*.

$$\hat{R}_{a,y} = \hat{E}_{a,y+a} + \hat{S}_{a,y+a} + \hat{C}_{a,y+a} \qquad (10)$$

Production for year classes 1962 through 1998 was estimated for each cohort as the sum of production at age over all ages of the cohort:

$$\hat{R}_y = \sum_{a=3}^{6} \hat{R}_{a,y} \qquad (11)$$

The estimated total runs for 1962–2004 for Kotzebue Area chum salmon are presented in Table 16 and estimates of recruits by age for the 1962–1998 brood years for Kotzebue Area chum salmon are presented in Tables 18. Plots of total runs and exploitation rates for the years 1974–1999 by stock are provided in Figure 10.

SPAWNER-RECRUIT RELATIONSHIPS

Spawner-recruit relationships were developed by fitting paired observations of recruits and escapement to the following model:

$$R_y = \alpha S_y e^{-\beta S_y} \exp(\varepsilon_y) \tag{12}$$

where: R_y = estimated total recruitment by brood y; S = spawning escapement that produced brood y; α = intrinsic rate of population increase in the absence of density-dependent limitations; β = density-dependent parameter; and ε_y = process error with mean 0 and variance σ^2_ε.

This model, commonly referred to as a Ricker recruitment curve (Ricker 1975), has two parameters, α and β, to estimate, given a series of spawner and resultant recruitment observations or estimates. We assumed the errors were log-normal (as is common for salmon returns), resulting in the log-transformed linear equation:

$$\ln(R_y / S_y) = \ln(\alpha) - \beta S_y + \varepsilon_y \tag{13}$$

Linear regression procedures provided estimates of the intercept (ln α) and the slope (β) in equation 13. Hilborn (1985) published the following empirical approximation of the estimated spawning size that produces maximum sustained yield or MSY (S_{MSY}) as a function of estimated parameters:

$$\hat{S}_{MSY} \cong \frac{\ln\hat{\alpha} + \frac{\hat{\sigma}^2_\varepsilon}{2}}{\hat{\beta}} \left[0.5 - 0.07 \left(\ln\hat{\alpha} + \frac{\hat{\sigma}^2_\varepsilon}{2} \right) \right] \tag{14}$$

where $\hat{\sigma}^2_\varepsilon$ = the mean square error from the regression.

The estimated variance $v(\hat{S}_{MSY})$ and 90% confidence intervals for $\hat{S}_{MSY}$ were calculated through non-parametric bootstrapping of residuals from the regression (see Efron and Tibshirani 1993:111–5). Residuals were calculated as differences between observed and predicted values:

$$\zeta_y = Y_y - \hat{\mathrm{E}}[Y_y] \tag{15}$$

where: ζ_y = the residual for brood y; Y_y = $\ln(R_y / S_y)$;

and $\hat{\mathrm{E}}[Y_y]$ = the predicted value. (16)

A new set of dependent variables were generated by sampling the residuals from the original regression:

$$\tilde{Y}_y = \zeta^*_y + \hat{E}[Y_y] \tag{17}$$

where, the ζ^*_y were drawn randomly with replacement from the original vector of the n original residuals $\{\zeta_y\}$ (n = the number of brood years in the analysis). In this fashion a new data set was created comprised of the original values for the independent variables (spawning abundance) and corresponding simulated values $\tilde{Y}_y$. The $\tilde{Y}_y$ were then regressed against the original values of the independent variables to produce a new, simulated set of parameter estimates for ln α, β, and σ^2_ε. These new parameter estimates were plugged into equation 14 to produce a simulated estimate $\tilde{S}_{MSY}$. This process was repeated 1,000 times to produce 1,000 simulated estimates of $\tilde{S}_{MSY}$. From Efron and Tibshirani (1993:47):

$$v(\hat{S}_{MSY}) = \frac{\sum_{b=1}^{1000} (\tilde{S}_{MSY(b)} - \bar{S}_{MSY})^2}{1{,}000 - 1} \tag{18}$$

where $\bar{S}_{MSY} = 1{,}000^{-1} \sum_{b=1}^{1{,}000} \tilde{S}_{MSY(b)}$. Ninety percent confidence intervals about $\hat{S}_{MSY}$ were estimated from the 1,000 simulations with the percentile method (Efron and Tibshirani 1993:124-126). The 1,000 values of $\tilde{S}_{MSY}$ for each scenario were sorted in ascending order making the 51st and the 950th values the lower and upper bounds of a 90% confidence interval.

The initial estimate of S_{MSY} was used as the point value for recommending a escapement goal and this escapement goal is expressed as a range. The range is estimated as the range of escapements that produce 90% or greater of maximum sustained yield.

Run reconstruction has been used to estimate the terminal runs of chum salmon to the Kotzebue Area during the period 1962–2004. Precision of estimates of escapements used in this analysis is considered poor to moderate. First, aerial surveys by their very nature provide variable results due to problems of weather, water visibility, and stream cover as well as timing of the survey relative to entry pattern of migrating fish. An additional problem is that in this data set many of the stream-by-year cells were not directly sampled, but were estimated based upon other counts. Because there were several years where estimates of Kotzebue area total runs and several years of estimates of total escapement in the Noatak River available, it was possible to estimate aerial survey expansion factors. For years when aerial survey index counts were not made, the run reconstruction model enabled the estimation of terminal runs based on commercial fishery catch and fishing effort.

Over the 43-year period of 1962–2004, the aggregate Kotzebue Area chum salmon escapement has been estimated to average 380 thousand fish, ranging from a low of about 139 thousand fish in 1963 to a high of about 1.44 million fish in 1996 (Table 16). Thus contrast in spawning abundance is about 10.4-fold, a high and meaningful level of variation in annual spawning abundance.

According to the CTC (1999), the following guidelines concerning contrast in spawning abundance can be used in statistical stock-recruit analyses:

> *"When estimates of spawning abundance are similar – the range is less than 4 times the smallest spawning abundance – statistical stock-recruit analysis is likely to produce a poor estimate of S_{MSY}.*
> *When range in spawning abundance is 4 to 8 times the smallest level, statistical stock-recruit analysis should produce better estimates of S_{MSY}, so long as measurement error is not extreme and some of the production-to-spawner ratios are below one at higher levels of spawning abundance.*
> *When range is more than 8, statistical analysis should produce the best estimates, so long as some of the production-to-spawner ratios are below one at higher levels of spawning abundance."*

With a contrast of spawning escapements of 10.4-fold, the Kotzebue area chum salmon analysis fits into the high contrast category identified by the CTC (1999) general methods, and thus production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Thirty-seven brood years of recruits are estimated and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, the criteria under the high contrast category is met, and there are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship was fit to full model and model 2 run reconstructions. However, there were little differences in the spawner recruit models estimated (Table 19). Therefore, in subsequent analysis, the full model run reconstructions were used. The fit of the Ricker-type spawner-recruit relationship (Figure 11) to the full model reconstructed aggregate Kotzebue Area chum salmon escapement and recruit data set was significant (p-value <0.001) with a corrected R-square of 0.39 indicating significant density dependence (Table 19) and statistical definition of a MSY escapement level. The residual plots for the Ricker-type spawner-recruit relationship (Figure 12) indicate no significant autocorrelation. The residual patterns in the estimated spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 12, respectively).

Analysis of the Ricker spawner-recruit relationship for the aggregate Kotzebue Area fall chum salmon stock resulted in an estimate of 300,000 spawners as the MSY escapement level (Table 19). The spawner–recruit relationship developed estimated that maximum surplus yield from the aggregate Kotzebue area stock of chum salmon is 368,000 fish, on average. If the aggregate Kotzebue area stock of fall chum salmon were managed at the indicated MSY escapement level of 300,000 spawners per year, the long-term average yield would be 368,000 fish. The exploitation rate in this case would be 55.1%.

The mean bootstrap estimate of MSY escapement for the aggregate Kotzebue area chum salmon is 311,000 spawners and the coefficient of variation for this mean statistic is 17.4% (Table 19). The 90% confidence interval for the estimated MSY escapement level for the aggregate Kotzebue fall chum salmon stock is estimated at 240,000 to 412,000 spawners (Table 19). The bootstrap mean estimate of the MSY escapement level (311,000) is slightly higher than that estimated (300,000) based on linear regression, indicating a slight positive bias of 3.6% (Table 19). The suggested escapement goal range for the aggregate Kotzebue Area chum salmon stock is 196,000 to 421,000 total spawners per year and is based on the range of escapements for which expected yield is greater than 90% of MSY.

The suggested escapement goal for the aggregate Kotzebue Area chum salmon stock is in reconstructed absolute escapement numbers. The long term monitoring of Kotzebue Area chum escapements is indexed by aerial surveys. The escapement goals for the Kotzebue Area should be expressed in units consistent with these long-term escapement indices. The stock assessments are in aerial survey index counts for the Noatak River, the upper Kobuk River, and for the three tributaries (Squirrel, Salmon, and Tutuksuk) of the lower Kobuk River. The recommended escapement goal in absolute escapement units was converted to aerial survey index units and apportioned to individual river systems based on the distribution of Noatak and Kobuk River escapements in absolute units based on the full model run reconstruction and upon the historical distribution of index aerial survey counts among areas within the Kotzebue Area (Table 20). The escapement goal in absolute escapement units was apportioned to Noatak (52%) and Kobuk Rivers (48%) based on average distribution of the escapement between the two rivers in the run reconstruction. The escapement goal for the Noatak and Kobuk Rivers was converted to aerial survey units based on the respective expansion factors estimated in run reconstruction. The Kobuk River escapement goals in aerial survey units were apportioned to individual rivers based on historical distribution of escapements which are 50.3%, 25.3%, 17.3%, and 7.1%, for the Upper Kobuk River, the Squirrel River, the Salmon River, and the Tutuksuk River, respectively. The recommended escapement goal in aerial survey index units for the Noatak River is a point count of 67,000 and a range of 42,000 to 91,000. The recommended escapement goal in aerial survey index units for the upper Kobuk River is a point count of 15,500 and a range of 9,700 to 21,000; for the Salmon River a point count of 5,300 and a range of 3,300 to 7,200, for the Tutuksuk River a point count of 2,200 and a range of 1,400 to 3,000, and for the Squirrel River a point count of 7,700 and a range of 4,900 to 10,500. These recommended escapement goals together with a comparison to historical escapement goals are provided in Table 21.

STOCK STATUS

Estimated escapements for the aggregate Kotzebue Area chum salmon stock based on the full model run reconstructions have generally been within or above the escapement goals herein recommended (Figure 13 upper left panel). The five-year moving average of estimated escapements has always been within or above the suggested range. This indicates the aggregate Kotzebue Area chum salmon stock is healthy.

Escapements for stocks of chum salmon by stream within the Kotzebue Area have generally been within or above our recommended escapement goal ranges (Table 22). For the upper Kobuk River stock, from 1962 to 2004, escapements in 7 of 35 years (20%) were below, 18 of 35 years (51%) were within, and 10 of 35 years (29%) were above the suggested escapement goal range (Table 22; Figure 13). For the Salmon River stock, from 1962 to 1999, escapements in 10 of 31 years (36%) were below, 10 of 31 years (36%) were within, and 8 of 31 years (28%) were above the suggested escapement goal range (Table 22; Figure 13). For the Tutuksuk River stock, from 1962 to 1999, escapements in 14 of 25 years (56%) were below, 4 of 25 years (16%) were within, and 7 of 25 years (28%) were above the suggested escapement goal range (Table 22; Figure 13). For the Squirrel River stock, from 1962 to 1999, escapements in 8 of 30 years (27%) were below, 14 of 30 years (46%) were within, and 8 of 30 years (27%) were above the suggested escapement goal range (Table 22; Figure 13). For the Noatak River stock, from 1962 to 2004, escapements in 7 of 35 years (20%) were below, 16 of 35 years (46%) were within, and 12 of 35 years (34%) were above the suggested escapement goal range (Table 22; Figure 13).

RECOMMENDATIONS

We recommend that the following escapement goals for chum salmon be formally adopted by the Alaska Department of Fish and Game:

(1) 9,700 to 21,000 index spawners per year in the upper Kobuk River;

(2) 3,300 to 7,200 index spawners per year in the Salmon River;

(3) 1,400 to 3,000 index spawners per year in the Tutuksuk River;

(4) 4,900 to 10,500 index spawners per year in the Squirrel River; and

(5) 42,000 to 91,000 index spawners per year in the Noatak River.

We also recommend that this escapement goal analysis be updated when and if a significant step of progress is made in the Kotzebue chum salmon stock assessment program. Refinement and further development of the relationships developed in this report based upon improved stock assessment information may lead to improved escapement goals that will better result in MSY fisheries.

We recommend the existing stock assessment program be continued, advanced, and improved upon. ADF&G should develop estimates of the overall escapements of chum salmon in the Noatak and Kobuk Rivers based upon an active sampling program. Sonar technology was tried for years but was not implemented on a continuing basis. There were problems with fish aggregating in schools and substantial numbers of Dolly Varden migrate together with chum salmon, making extensive species apportionment sampling necessary. With new developments in sonar technology, a feasible sonar enumeration program might be possible. Alternative stock assessment methods are available. We suggest large scale mark-recapture methods be used to estimate chum salmon in the Kobuk and Noatak rivers. Although such a program would be expensive and difficult to administer in such a remote part of Alaska, we believe such a stock assessment has the best chance of success. Such an approach has been used in remote parts of southeast and south-central Alaska to assess Chinook, sockeye, and coho salmon escapements. These stock assessment efforts should have as their objective to estimate the number and age composition of chum salmon spawning in the Kobuk and Noatak Rivers. Further, we recommend that a major radio tagging study be implemented to provide improved estimates of the distribution of spawning chum salmon in the Kobuk drainage. ADF&G should ensure that subsistence catch estimates by village in the Kotzebue area are obtained each and every year along with estimates of the precision of these subsistence catch estimates. Documenting these annual catches is a basic stock assessment activity and efforts are needed to ensure that situations such as have occurred in the past wherein such basic catch documentation did not occur do not again happen.

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TABLES

Table 1.–Observed peak aerial counts of chum salmon in areas of the Noatak River and predicted counts based on total Noatak escapement and average proportions. For some years estimated Noatak River index escapements are incomplete. See text, footnotes and Tables 4 and 5 for additional details. Index escapements not available for 1977, 1979, 1989, 1994, and 1997-2002 due to inadequate surveys.

	Noatak River below Kelly		Eli River		Kelly River & Lake		Noatak River	
Year	Observed	Predicted	Observed	Predicted	Observed	Predicted	System Total	Note
1962	168,000	162,323	9,080	12,657	1,818	3,918	178,898	
1963			35		600		34,910	a
1964	89,798						98,967	b
1965					3,155		87,201	c
1966	101,640	92,849	120	7,240	570	2,241	102,330	
1967					225		66,115	c
1968	39,394	41,077	5,502	3,203	375	991	45,271	
1969	33,945	30,998	68	2,417	150	748	34,163	
1970	138,145						152,251	b
1971	41,056						45,248	b
1972	64,315		3,286				69,115	d
1973	32,144				2,590		32,864	e
1974	129,640	139,069	22,249	10,844	1,381	3,357	153,270	
1975	96,509	92,321	1,302	7,199	3,937	2,228	101,748	
1976	44,574		1,205				46,804	d
1977								
1978	37,817		5,525				44,312	d
1979								
1980	164,474	165,289	10,277	12,888	7,416	3,990	182,167	
1981	116,352				13,770		118,957	e
1982	20,682	29,466	189	2,298	11,604	711	32,475	
1983	79,773	86,156	3,044	6,718	12,137	2,080	94,954	
1984	67,873	69,321	5,027	5,405	3,499	1,673	76,399	
1985	45,525	43,172	855	3,366	1,200	1,042	47,580	
1986	37,227	38,448	4,308	2,998	839	928	42,374	
1987			2,780		950		67,124	c
1988			8,639		1,460		81,430	c
1989								
1990			3,000				79,726	c
1991	82,750	78,344	2,940	6,109	654	1,891	86,344	
1992	34,335	32,449	701	2,530	726	783	35,762	
1993	25,415	27,419	4,795	2,138	9	662	30,219	
1994								
1995	147,260	148,355	7,860	11,568	8,384	3,581	163,504	
1996	306,900	307,017	30,040	23,939	1,427	7,410	338,367	
1997								
1998								
1999							103,500	a
2000								
2001							50,803	a
2002								
2003	34,575				1,566		38,893	e
2004	49,541	50,308	2,917	3,923	2,987	1,214	55,445	

[a] Estimate based on observed upper Kobuk escapement and regression of total Noatak escapement versus upper Kobuk escapements.
[b] Estimate based on expansion of observed escapement for Noatak River below Kelly and respective average proportion.
[c] Estimate based observed lower Kobuk escapement and on regression of total Noatak escapement versus lower Kobuk tributary escapement.
[d] Estimate based on expansion of observed escapement for Noatak River below Kelly and Eli River, and respective average proportions.
[e] Estimate based on expansion of observed escapement for Noatak River Below Kelly and Kelly River and Lake, and respective average proportion.

Table 2.–Observed peak aerial counts of chum salmon in areas of the upper Kobuk River. The escapement index for the upper Kobuk River is the sum of individual area indices for years when at least five of the six areas were surveyed. For some years the estimated total escapement index surveys were incomplete. See text, footnotes and Tables 4 and 5 for additional details. Index escapements not available for 1977, 1979, 1989, 1994, 1997–1998, 2000, and 2002 due to inadequate surveys.

Year	Kobuk to Pah River	Pah River to just below Selby River	Selby River mouth, Slough, and River	Selby R. mouth to Beaver C.	Beaver Creek mouth & Above	Above Beaver Creek	Upper Kobuk River Total
1962							9,224 [a]
1963	400	1,530	1,045	1,095		465	4,535
1964							20,992 [b]
1965	1,750	500	500				18,969 [b]
1966	266		630		460	118	13,964 [c]
1967			1,625	75	795		15,345 [b]
1968	530	50	70	170	1,550		2,370
1969							7,500 [a]
1970		1,753	20	4,820	2,385	4,930	13,908
1971	4,953	2,039	3,490	4,720	2,000		17,202
1972		1,865	7,400	3,170	3,000	2,720	18,155
1973				920	850	700	9,629 [b]
1974	2,255	4,710	7,380	13,775			30,325 [b]
1975	1,873	3,968		4,861			21,470 [b]
1976	485	2,037					12,026 [b]
1977							
1978	269	1,448	211	53			11,597 [b]
1979							
1980	1,694	2,069		6,925	784		35,292 [b]
1981	18	309	8,321				24,428 [b]
1982			2,454	7,268	1,711		9,563 [b]
1983	2,147	2,433	11,683	13,011	3,059	1,413	33,746
1984	402	257		5,910		4,052	17,113 [b]
1985	2,048	241	711	3,278			12,159 [b]
1986	531	511	673	3,282		1,018	6,015
1987		2,250	1,470	1,350		3,140	13,789 [c]
1988							17,309 [c]
1989							
1990	4,610	305	7,925		2,515		16,890 [c]
1991	9,840	2,780	2,500	5,250		4,155	24,525
1992	1,030	3,820	2,368	3,845		740	11,803
1993	3,896	1,535	2,624	929		3,174	12,158
1994							
1995	12,190	4,537	4,614	10,898		3,486	35,725
1996	20,700	4,600	19,050	15,480		14,940	74,770
1997							
1998							
1999							27,340 [c]
2000							
2001	2,790	1,380	1,780	7,470			13,420 [d]
2002							
2003	5,501	828	1,537	1,274		2,462	11,602
2004	7,493	1,885	7,606	6,215			23,199 [d]

[a] Surveys not recorded by index area.

[b] Estimate based on observed or estimated total Noatak River escapement and regression of upper Kobuk River escapements versus total Noatak River escapements.

[c] Estimate based on observed or estimated lower Kobuk tributary escapement and regression of upper Kobuk River escapements versus lower Kobuk tributary escapements.

[d] Estimate based on the sum of only four index area counts.

Table 3.–Observed peak aerial counts of chum salmon in tributaries of the lower Kobuk River. Predicted counts based on total lower Kobuk tributary escapement and average proportions. For some years, the estimated total lower Kobuk River tributary index escapements are incomplete. See text, footnotes and Tables 4 and 5 for additional details. Index escapements not available for 1977-1979, 1989, 1994, 1997–1998, and 2000-2004 due to inadequate surveys.

	Squirrel River		Salmon River		Tutuksuk River			
Year	Observed	Predicted	Observed	Predicted	Observed	Predicted	Total for Lower Kobuk Tributary Systems	Note
1962	5,834	11,403	12,936	12,200	10,841	6,008	29,611	
1963	2,200	1,696	1,535	1,815	670	894	4,405	
1964	8,009	7,720	9,353	8,259	2,685	4,068	20,047	
1965	7,230						18,775	a
1966	1,350	2,576	3,957	2,756	1,383	1,357	6,690	
1967	3,332	2,163	2,116	2,314	169	1,140	5,617	
1968	6,746		3,367				12,687	b
1969	6,714	3,633	2,561	3,887	159	1,914	9,434	
1970	4,418						11,472	a
1971	6,628	5,185	5,453	5,547	1,384	2,732	13,465	
1972	32,126						83,423	a
1973	12,345		6,891				24,133	b
1974	32,523	26,966	29,190	28,850	8,312	14,209	70,025	
1975	32,256		9,721				52,663	b
1976	7,229	3,523	1,161	3,769	758	1,856	9,148	
1977								
1978							15,715	d
1979								
1980	13,563	8,928	8,456	9,552	1,165	4,704	23,184	
1981	9,854	6,037	4,709	6,459	1,114	3,181	15,677	
1982	7,690	4,172	1,821	4,463	1,322	2,198	10,833	
1983	5,115	3,631	1,677	3,885	2,637	1,913	9,429	
1984	5,473	3,110	1,471	3,327	1,132	1,639	8,076	
1985	6,160	5,446	2,884	5,826	5,098	2,870	14,142	
1986	4,982	4,317	1,971	4,618	4,257	2,275	11,210	
1987	2,708	2,406	3,333	2,574	206	1,268	6,247	
1988			6,208		3,122		15,173	c
1989								
1990	5,500	5,434	6,335	5,813	2,275	2,863	14,110	
1991	4,606	4,311	5,845	4,612	744	2,272	11,195	
1992	2,765	2,030	1,345	2,172	1,162	1,070	5,272	
1993	4,463	7,524	13,880	8,050	1,196	3,965	19,539	
1994								
1995	10,605	10,973	13,988	11,739	3,901	5,782	28,494	
1996	10,740	21,694	23,790	23,210	21,805	11,431	56,335	
1997								
1998								
1999	13,513	8,244	4,989	8,820	2,906	4,344	21,408	
2000								
2001							18,297	e
2002								
2003							14,977	d
2004							16,983	d

[a] Estimate based on expansion of observed escapement for Squirrel River and respective average proportion.

[b] Estimate based on expansion of observed escapement for Squirrel River and Salmon River, and their respective average proportion.

[c] Estimate based on expansion of observed escapement for Salmon River and Tutuksuk Rivers, and their respective average proportion.

[d] Estimate based on observed or estimated total Noatak escapement and regression of lower Kobuk tributary escapements versus total Noatak escapements.

[e] Estimate based on observed upper Kobuk River escapement and regression of lower Kobuk tributary escapements versus upper Kobuk River escapements.

Table 4.–Performance of the method for estimating missing observations for areas within the Noatak River and within the lower Kobuk tributaries. Shown is the number of years when complete counts were made, correlations between expanded total counts and observed counts for years when surveys were complete, and proportion of total escapement within the areas that were expanded.

Survey Count Comparison	Number of Years With Successful Survey Counts	Correlation Coefficient	Significance Level of Correlation Coefficient	Proportion of Escapement in the Expanded Areas
Noatak River				
Expansion of Noatak River Below Kelly	16	0.998	<.001	0.91
Expansion of Noatak R. Below Kelly Plus Eli R.	16	0.998	<.001	0.97
Expansion of Noatak R. Below Kelly Plus Kelly R. and Lake	16	0.998	<.001	0.93
Lower Kobuk River Tributaries				
Expansion of Squirrel R.	24	0.834	<.001	0.38
Expansion of Squirrel R. and Salmon R.	24	0.970	<.001	0.80
Expansion of Salmon R. and Tutuksuk R.	24	0.951	<.001	0.62

Table 5.–Performance of the method for estimating missing observations for Noatak River, upper Kobuk River, and lower Kobuk Tributaries. Shown are the numbers of years where complete counts were made for both systems, regression R^2 and significance, and ratio of average chum salmon counts during paired surveys.

Aerial Survey Count Comparison	Number of Years When Successful Counts Were Made for Both Systems	Regression R^2	Significance Level of Regression	Ratio of Average Chum Salmon Counts During Paired Surveys
Noatak River				
Total Noatak R. versus Upper Kobuk R.	15	0.650	<.001	4.67
Total Noatak R. versus Lower Kobuk R. Tributaries	25	0.218	0.018	4.16
Lower Kobuk River Tributaries				
Lower Kobuk Tributaries versus Total Noatak R.	25	0.218	0.018	0.24
Lower Kobuk Tributaries versus Upper Kobuk R.	15	0.214	0.083	.80
Upper Kobuk River				
Upper Kobuk River Tributaries versus Total Noatak R.	15	0.651	<.001	0.21
Upper Kobuk River Tributaries versus Lower Kobuk R. Tributaries	14	0.214	0.082	0.91

Table 6.–Kotzebue District commercial catch statistics, 1962–2004.

Year	Total Catch	Total Days [a]	Boat Days [b]	Catch/Boat Day	Number Fishers [c]	Season Catch per Fisherman
1962	129,948	21.0	793	164	84	1,547
1963	54,445	20.0	693	79	61	893
1964	76,449	27.0	560	137	52	1,470
1965	40,025	32.0	410	98	45	889
1966	30,764	35.0	548	56	44	699
1967	29,400	33.0	556	53	30	980
1968	30,212	34.0	858	35	59	512
1969	59,335	40.0	798	74	52	1,141
1970	159,664	32.0	1,368	117	82	1,947
1971	154,956	29.0	1,468	106	91	1,703
1972	169,664	35.0	2,095	81	104	1,631
1973	375,432	25.0	2,217	169	148	2,537
1974 [d]	627,912	32.0	3,769	167	185	3,394
1975 [e]	563,345	39.0	4,301	131	267	2,110
1976	159,796	16.0	2,236	71	220	726
1977	195,895	21.0	2,353	83	224	875
1978	111,494	23.0	2,738	41	208	536
1979	141,623	21.0	2,462	58	181	782
1980	367,284	27.0	2,559	144	176	2,087
1981	677,239	27.0	3,336	203	187	3,622
1982	417,790	23.5	3,115	134	199	2,099
1983	175,762	12.5	1,557	113	189	930
1984	320,206	19.5	2,432	132	181	1,769
1985	521,406	25.5	3,376	154	189	2,759
1986	261,436	15.5	2,049	128	187	1,398
1987	109,467	11.5	1,160	94	160	684
1988	352,915	21.5	2,761	128	193	1,829
1989	254,617	22.2	1,961	130	165	1,543
1990	163,263	11.5	1,760	93	153	1,067
1991	239,923	22.5	1,795	134	142	1,690
1992	289,184	17.0	1,513	191	149	1,941
1993 [f]	73,071	7.0	431	170	114	641
1994 [g]	153,452	9.8	426	360	109	1,408

-continued-

Table 6.–Page 2 of 2.

Year	Total Catch	Total Days [a]	Boat Days [b]	Catch/Boat Day	Number Fishers [c]	Season Catch per Fisherman
1995	290,730	9.7	282	1031	92	3,160
1996 [h]	82,110	6.0	76	1080	55	1,493
1997	142,720	16.5	330	432	68	2,099
1998	55,907	13.0	187	300	45	1,242
1999	138,605	13.5	212	654	60	2,310
2000	159,802	14.0	283	565	64	2,497
2001 [I]	211,672	15.3	307	689	66	3,207
2002	8,390	14.0	19 [k]	442	3	2,797
2003 [j]	25,423	25.0	33 [k]	770	4	6,356
2004	51,038	27.0	139	367	43	1,187
Average	201,250					

[a] Day = 24 hours of open fishing time.

[b] Boat days standardized in 1983 for all prior years. Boat days = number of boats fishing times period length in hours divided by 24. total boat days = total season boat hours divided by 24.

[c] During 1962-1966 and 1968-1971 figures represent the number of vessels licensed to fish in the Kotzebue District, not the number of fishermen.

[d] Includes 6,567 chum salmon from the Deering experimental fishery.

[e] Includes 10,704 chum salmon from the Deering experimental fishery.

[f] Includes 2,000 chum salmon from the Sikusuilaq Springs Hatchery terminal fishery.

[g] Includes 4,000 chum salmon commercially caught but not sold on July 29.

[h] Includes 2,200 chum salmon commercially caught but not sold on July 29.

[i] Includes 10 chum salmon commercially caught but not sold on July 16.

[j] An additional 340 chum salmon from the commercial catch were kept for subsistence use.

[k] In 2002-2003 the season was open continuously and boat days are days fished.

[l] Although the season was open continuously from July 12 to August 31, boat days are calculated only from hours the buyer reported as have being fished.

Table 7.–Estimated subsistence catch of chum salmon by fishermen from various Kobuk River villages, from the Village of Noatak, and from the town of Kotzebue. Data source: Kohler et al. (2005). Estimates in normal text are from sampling; Town of Kotzebue subsistence catches before 1985 are expanded for assumed underreporting; shown in bold italics. Other estimates in bold italics are interpolated or estimated values; see Table 8 and text for basis of estimates.

Year	Kobuk River Village					Estimated Total Kobuk River Villages	Noatak Village	Town of Kotzebue
	Noorvik	Kiana	Ambler	Shungnak	Kobuk			
1962	15,934	3,139	***1,449***	***2,187***	2,321	25,030	48,890	***59,888***
1963	4,304	1,973	755	1,240	200	8,472	16,762	***51,435***
1964	2,167	783	2,142	3,134	1,020	9,246	12,763	***68,342***
1965	5,596	1,598	1,340	2,160	877	11,571	5,671	***71,030***
1966	3,141	433	912	899	625	6,010	19,700	***32,086***
1967	2,350	1,489	679	1,500	175	6,193	26,512	***35,542***
1968	2,424	2,488	457	1,600	1,030	7,999	5,490	***38,115***
1969	1,301	2,458	3,525	2,550	1,655	11,489	14,458	***15,585***
1970	6,077	3,457	2,899	3,450	600	16,483	4,210	***60,064***
1971	7,144	5,177	2,299	2,653	1,931	19,204	9,919	***15,311***
1972	1,744	1,435	1,469	2,665	2,119	9,432	741	***10,146***
1973	2,312	4,470	1,529	4,406	1,917	14,634	216	***10,331***
1974	6,809	2,726	1,651	6,243	2,251	19,680	4,320	***19,413***
1975	4,320	4,320	3,390	9,060	1,755	22,845	1,515	***19,413***
1976	1,555	1,579	2,000	4,213	562	9,909	4,448	***19,413***
1977	891	766	385	1,760	325	4,127	2,125	***19,413***
1978	2,034	1,493	2,224	4,766	852	11,369	1,495	***19,413***
1979	2,155	1,225	2,400	2,947	651	9,378	2,227	***19,413***
1980	22,229	2,551	660	2,704	350	28,494	2,135	***19,413***
1981	3,488	1,439	782	2,800	950	9,459	5,465	***21,041***
1982	7,433	4,918	2,506	4,191	600	19,648	5,479	***36,132***
1983	3,494	***4,206***	1,062	3,556	368	12,686	4,035	***24,813***
1984	***5,255***	***4,206***	2,990	4,241	***334***	17,026	6,049	***24,813***
1985	7,015	3,494	3,487	3,115	300	17,411	***3,648***	13,494
1986	8,418	***3,894***	***4,474***	4,483	***2,329***	23,598	1,246	36,311
1987	5,092	***3,894***	***4,474***	1,975	***2,329***	17,764	2,921	***37,772***
1988	7,500	***3,894***	***4,474***	6,223	***2,329***	24,420	***2,258***	***37,772***
1989	***5,927***	***3,894***	***4,474***	3,894	***2,329***	20,517	1,595	***37,772***
1990	4,353	***3,894***	***4,474***	***4,071***	***2,329***	19,121	3,915	***37,772***
1991	6,855	***3,894***	***4,474***	4,248	***2,329***	21,800	3,637	***37,772***
1992	8,370	***3,894***	***4,474***	3,890	***2,329***	22,957	2,043	***37,772***
1993	8,430	***3,894***	***4,474***	3,730	***2,329***	22,857	3,270	***37,772***
1994	8,157	1,891	2,860	7,982	5,722	26,612	6,126	***37,772***
1995	15,485	5,985	8,558	5,880	2,959	38,867	6,359	50,708
1996	13,611	5,935	9,062	8,649	1,819	39,076	10,091	50,573
1997	14,232	3,064	2,713	5,513	629	26,151	5,309	26,355
1998	9,845	3,414	2,432	4,676	1,031	21,398	2,614	24,968
1999	17,843	3,788	590	3,869	1,869	27,959	1,616	64,768
2000	10,391	2,876	4,009	2,944	318	20,538	7,293	37,144
2001	16,540	5,500	***2,864***	4,310	2,843	32,057	2,326	17,713
2002	13,943	***4,255***	***2,864***	***3,585***	***2,193***	26,840	2,937	***27,429***
2003	7,982	3,010	1,719	2,860	1,543	17,114	2,177	***27,429***
2004	***10,963***	***3,633***	***2,292***	***3,223***	***1,868***	***21,977***	***2,557***	***27,429***

Table 8.–Methodology associated with subsistence catch interpolated values.

Subsistence Fishery	Year of Fishery	Basis for Interpolated Value
Noorvik	1984	Average of 1983 and 1985
Noorvik	1989	Average of 1988 and 1990
Noorvik	2004	Average of 2002 and 2003
Kiana	1983–84	Average from 1981–1982 and 1985–1986
Kiana	1986–1993	Average from 1984–1985 & 1994–1995
Kiana	2002	Average of 2001 and 2003
Kiana	2004	Average of 2002 and 2003
Ambler	1962	Average of 1963–1964
Ambler	1986–1993	Average from 1983–1985 & 1994–1995
Ambler	2001–2002	Average of 2000 and 2003
Ambler	2004	Average of 2002 and 2003
Shungnak	1962	Average of 1963–1964
Shungnak	1990	Average from 1991, 1992, and 1993
Shungnak	2002	Average of 2001 and 2003
Shungnak	2004	Average of 2002 and 2003
Kobuk	1984	Average of 1983 and 1985
Kobuk	1986–1993	Average of 1983–1985 & 1994–1995
Kobuk	2002	Average of 2001 and 2003
Kobuk	2004	Average of 2002 and 2003
Noatak	1985	Average of 1984 and 1985
Noatak	1988	Average of 1987, and 1989
Noatak	2004	Average of 2002 and 2003
Kotzebue	1963–1973, 1981–1982	Reported catch expanded by 8.8 (see text for rationale)
Kotzebue	1974–1980	Average of 1972–1973 & 1981–1982
Kotzebue	1983–1984	Average of 1981–1983 & 1985–1986
Kotzebue	1987–1994	Average of 1985–1986 & 1995–1998
Kotzebue	2002–2004	Average of 2000–2001

Table 9.–Estimated total runs (commercial catch, subsistence catch, and hatchery escapement) by age from 1986–2002 for Sikusuilaq Springs Hatchery chum salmon. Runs from 1996–2000 estimated from projected returns for 1990–1994 brood years, see text and Table 10 for details.

			Hatchery Run								
Return Year	District Commercial Catch	Commercial Exploitation Rate[a]	Estimated Commercial Catch[b]	Estimated Subsistence Catch[c]	Reported Escapement–Brood Stock	Total Hatchery Run	No of Age-3	No of Age-4	No of Age-5	No of Age-6	No of Age-7
1986	261,436	0.434	843		1,100	1,943	6	361	1,533	43	
1987	109,467	0.239	2,979	1,969	1,246	4,225	634	1,817	1,310	465	
1988	352,915	0.434	2,782	609	2,228	5,010	326	3,747	847	85	5
1989	254,617	0.309	5,244	1,177	7,913	13,157	92	10,249	2,684	132	
1990	163,263	0.275	6,408	3,000	6,000	12,408	285	5,658	6,291	174	
1991	239,923	0.316	10,553	5,100	6,700	17,253	500	10,421	6,177	155	
1992	289,184	0.414	14,430	3,500	12,000	26,430	238	15,461	9,911	819	
1993	73,071	0.185	12,481	5,200	26,800	39,281	1,139	10,331	26,122	1,650	39
1994	153,452	0.269	26,760	3,500	60,000	86,760	2,863	54,659	26,722	2,516	
1995	290,730	0.244	14,306	3,500	30,000	44,306	1,019	26,495	15,950	842	
1996	82,110	0.047	2,778	3,500	52,348	58,626	1,236	26,435	27,776	3,178	
1997	142,720	0.255	14,663	3,500	39,474	57,637	1,118	27,869	26,121	2,531	
1998	55,907	0.147	8,094	3,500	43,516	55,110	0	25,193	27,537	2,380	
1999	138,605	0.182	4,976	3,500	18,926	27,402			24,893	2,509	
2000	159,802	0.248	562		1,706	2,268				2,268	
2001	211,672										
2002	8,390										

[a] Commercial fishery rate of exploitation as estimated from Kotzebue full model run reconstruction.
[b] Commercial catch, 1986–2000, estimated by applying annual fishery exploitation rate to annual estimated inriver hatchery run.
[c] Subsistence catch, 1986-1993 from Steve McGee, ADF&G (personal communication), 1994–2000, estimated as the 1992 value.

Table 10.–Estimated total return by brood year for Sikusuilaq Springs Hatchery chum salmon. Total returns for 1983–1989 brood years are based on observed total run (Table 9). Returns for 1990–1991 broods based on expansion of returns (1990 brood: observations through age-5; 1991 brood: observations through age-4) and assumed average maturity schedule. Returns for 1993–1994 broods based on projection of returns from average marine survival (0.68%) and assumed average maturity schedule.

Total Hatchery Returns				Return by Age						Percent by Age				
Brood Year	No. of Smolt Released	Hatchery Return	Estimated Marine Survival	3	4	5	6	7		3	4	5	6	7
1983	1,350,000	2,801	0.21%	6	1,817	847	132	0		0.2%	64.9%	30.2%	4.7%	0.0%
1984	1,690,000	7,239	0.43%	634	3,747	2,684	174	0		8.8%	51.8%	37.1%	2.4%	0.0%
1985	1,503,000	17,021	1.13%	326	10,249	6,291	155	0		1.9%	60.2%	37.0%	0.9%	0.0%
1986	1,440,000	12,785	0.89%	92	5,658	6,177	819	39		0.7%	44.3%	48.3%	6.4%	0.3%
1987	3,003,000	22,267	0.74%	285	10,421	9,911	1,650	0		1.3%	46.8%	44.5%	7.4%	0.0%
1988	6,052,000	44,600	0.74%	500	15,461	26,122	2,516	0		1.1%	34.7%	58.6%	5.6%	0.0%
1989	6,360,000	38,133	0.60%	238	10,331	26,722	842			0.6%	27.1%	70.1%	2.2%	0.0%
1990	7,365,000	74,959		1,139	54,659	15,950	3,178	33					*4.2%*	*0.0%*
1991	8,500,000	59,691		2,863	26,495	27,776	2,531	26				*46.5%*	*4.2%*	*0.0%*
1992	8,300,000	56,133	*0.68%*	1,019	26,435	26,121	2,380	25		*2.1%*	*47.1%*	*46.5%*	*4.2%*	*0.0%*
1993	8,750,000	59,176	*0.68%*	1,236	27,869	27,537	2,509	26		*2.1%*	*47.1%*	*46.5%*	*4.2%*	*0.0%*
1994	7,910,000	53,495	*0.68%*	1,118	25,193	24,893	2,268	23		*2.1%*	*47.1%*	*46.5%*	*4.2%*	*0.0%*
			Avg. = 0.68%						Avg.	2.1%	47.1%	46.5%	4.2%	0.0%

Table 11.–Raw statistics for the 1966–1968, and 1981–1982 Kotzebue chum salmon tagging studies.

Year	Marks Released	Kotzebue District Commercial Fishery		Noatak Subsistence Fishery		Kobuk Subsistence Fishery		Noatak Escapement		Kobuk Escapement	
		Catch	Recoveries	Catch	Recoveries	Catch	Recoveries	Sample Size	Recoveries	Sample Size	Recoveries
1966	727	34,404	83	19,700	69	6,010	18				
1967	1,457	33,432	237	26,512	106	6,193	33				
1968	1,444	34,536	199	5,490	23	7,999	97				
1981	3,305	679,626	671	5,465	26	9,459	69	49,173	55	22,276	38
1982	4,919	421,889	1,014	5,479	10	19,648	149	47,250	58	16,850	54

Table 12.–Estimates of Kotzebue chum salmon runs, based on mark–recapture estimates.

Year	Marked Population[a]	Subsistence Catch	Subsistence Recoveries	Escapement Sample	Escapement Recoveries	District Run Estimate: Based on Recoveries in Subsistence Catch	District Run Estimate: Based on Recoveries in Escapement and Subsistence Catch
1966	644	25,710	87			192,220	
1967	1,220	32,705	139			288,885	
1968	1,245	13,489	120			141,001	
1981	2,634	14,924	95	71,449	93	418,003	1,216,136
1982	3,905	25,127	159	64,100	112	620,835	1,290,142

[a] Tags deployed less documented recoveries from the commercial fishery.

Table 13.–Estimates of sonar passage and wild escapement for Noatak River chum salmon, 1981 and 1992–1993.

Year	Sonar Passage	Noatak Subsistence Catch	Hatchery Returns	Wild Escapement
1981	335,526	5,465		330,061
1992	75,687	2,043	12,000	61,644
1993	126,392	3,270	26,800	96,322
1994	163,663	6,126	60,000	97,537

Table 14.–Terminal runs estimated by full model and model 2 run reconstructions. Terminal runs in bold were estimated from commercial catch and estimated exploitation rates from fishery effort.

Year	Full Model	Model 2
1962	885,773	891,746
1963	269,741	259,691
1964	610,977	600,815
1965	522,141	517,730
1966	435,349	440,863
1967	358,860	359,004
1968	264,113	263,896
1969	277,640	262,944
1970	722,132	740,902
1971	492,874	450,546
1972	741,300	816,035
1973	792,443	633,911
1974	1,360,396	1,506,441
1975	1,088,744	1,194,792
1976	425,210	406,641
1977	**535,850**	**561,608**
1978	336,354	377,683
1979	**373,862**	**391,632**
1980	889,137	1,140,639
1981	1,194,846	1,194,035
1982	656,616	652,156
1983	660,649	650,544
1984	741,926	674,385
1985	941,996	793,721
1986	600,634	506,886
1987	445,475	427,755
1988	807,344	768,780
1989	**806,736**	**847,108**
1990	571,119	564,578
1991	725,710	681,415
1992	664,390	518,733
1993	326,931	354,379
1994	**471,945**	**553,222**
1995	1,133,348	1,087,841
1996	1,674,090	1,624,969
1997	**503,298**	**641,464**
1998	**325,477**	**421,701**
1999	735,798	712,660
2000	**642,492**	**823,222**
2001	599,733	533,732
2002	**441,187**	**583,244**
2003	297,504	288,995
2004	430,494	423,382

Table 15.–Parameter values estimated by two alternative run reconstruction models.

Parameter	Full Model	Model 2
Noatak River Aerial Survey Expansion	2.40	2.55
Kobuk River Aerial Survey Expansion	4.88	4.43
1962–1992 Commercial Fishery Catchability	0.000193	0.000182
1993–2004 Commercial Fishery Catchability	0.001011	0.000763
Kobuk River Escapement per Test Fish Index	190	173

Table 16.–Estimated Kotzebue District runs of wild and hatchery chum salmon, 1962–2004. Estimates based on full model run reconstruction, and run components include commercial catch, subsistence catch, and escapement. Years in bold italics are years without usable aerial survey counts (runs estimated by expansion of commercial catch based on estimated exploitation rate).

Year	Commercial Catch		Subsistence Catch		Escapement		Total Run		
	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Total	Hatchery	Wild
1962	129,948		59,888		622,018		811,854		811,854
1963	54,445		51,435		138,627		244,507		244,507
1964	76,449		68,342		444,177		588,968		588,968
1965	40,025		71,030		393,844		504,900		504,900
1966	30,764		32,086		346,789		409,639		409,639
1967	29,400		35,542		261,213		326,155		326,155
1968	30,212		38,115		182,296		250,624		250,624
1969	59,335		15,585		176,773		251,693		251,693
1970	159,664		60,064		481,710		701,438		701,438
1971	154,956		15,311		293,483		463,751		463,751
1972	169,664		10,146		551,317		731,127		731,127
1973	375,432		10,331		391,830		777,593		777,593
1974	627,912		19,413		689,072		1,336,397		1,336,397
1975	563,345		19,413		481,627		1,064,384		1,064,384
1976	159,796		19,413		231,645		***410,853***		***410,853***
1977	195,895		19,413		314,291		529,598		529,598
1978	111,494		19,413		192,584		323,490		323,490
1979	141,623		19,413		201,221		***362,257***		***362,257***
1980	367,284		19,413		471,811		858,508		858,508
1981	677,239		21,041		481,642		1,179,922		1,179,922
1982	417,790		36,132		177,567		631,489		631,489
1983	175,762		24,813		443,353		643,928		643,928
1984	320,206		24,813		373,832		718,851		718,851
1985	521,406		13,494		386,038		920,938		920,938
1986	260,593	843	36,311		276,944	1,100	575,791	1,943	573,848
1987	106,488	2,979	35,803	1,969	276,307	1,246	424,791	6,194	418,597
1988	350,133	2,782	37,163	609	387,752	2,228	780,666	5,619	775,048
1989	249,373	5,244	36,595	1,177	484,322	7,913	***784,624***	***14,334***	***770,290***
1990	156,855	6,408	34,772	3,000	341,049	6,000	548,084	15,408	532,676
1991	229,370	10,553	32,672	5,100	415,879	6,700	700,273	22,353	677,920
1992	274,754	14,430	34,272	3,500	300,435	12,000	639,391	29,930	609,461
1993	60,590	12,481	32,572	5,200	163,162	26,800	300,805	44,481	256,323
1994	126,692	26,760	34,272	3,500	187,984	60,000	***439,207***	***90,260***	***348,947***
1995	276,424	14,306	47,208	3,500	716,683	30,000	1,088,121	47,806	1,040,315
1996	79,332	2,778	47,073	3,500	1,439,892	52,348	1,624,923	58,626	1,566,297
1997	128,057	14,663	22,855	3,500	263,288	39,474	***471,838***	***57,637***	***414,200***
1998	47,813	8,094	21,468	3,500	177,074	43,516	***301,465***	***55,110***	***246,355***
1999	133,629	4,976	61,268	3,500	483,924	18,926	706,223	27,402	678,821
2000	159,240	562	37,144		416,010	1,706	***614,661***	***2,268***	***612,393***
2001	211,672		17,713		335,965		565,350		565,350
2002	8,390		27,429		375,591		***411,410***		***411,410***
2003	25,423		27,429		225,362		278,213		278,213
2004	51,038		27,429		327,493		405,960		405,960

Table 17.–Sample sizes and age composition (%) of chum salmon sampled from the Kotzebue fishery, 1962–2004.

Year	Sample Size	Age-0.2	Age-0.3	Age-0.4	Age-0.5	Age-0.6	Total
1962	69	7.3	63.3	28.0	1.4	-	100.0
1963	255	30.2	51.0	18.4	0.4	-	100.0
1964	463	52.9	45.0	1.7	0.4	-	100.0
1965	480	2.3	91.0	6.7	-	-	100.0
1966	430	10.0	67.2	22.8	-	-	100.0
1967	1,865	8.8	72.2	18.5	0.5	-	100.0
1968	1,989	21.2	58.1	19.8	0.9	-	100.0
1969	1,125	36.8	58.3	4.9	-	-	100.0
1970	267	3.7	91.1	5.2	-	-	100.0
1971	1,105	7.1	66.8	26.1	-	-	100.0
1972	980	15.8	59.5	24.1	0.6	-	100.0
1973	598	16.7	69.4	13.9	-	-	100.0
1974	350	28.6	63.4	7.7	0.3	-	100.0
1975	340	2.6	86.8	10.6	-	-	100.0
1976	566	11.1	51.4	37.3	0.2	-	100.0
1977	446	6.7	72.9	18.6	1.8	-	100.0
1978	579	10.5	57.5	31.8	0.2		100.0
1979	658	30.5	53.2	15.2	1.1	-	100.0
1980	710	15.1	78.2	6.6	0.1	-	100.0
1981	1,167	2.4	67.1	30.5	-	-	100.0
1982	983	5.9	48.3	40.3	5.5	-	100.0
1983	1,979	5.8	57.7	34.2	2.3	-	100.0
1984	2,933	14.6	64.4	19.7	1.3	-	100.0
1985	3,293	0.4	83.7	15.5	0.4	-	100.0
1986	3,095	0.3	18.6	78.9	2.2	-	100.0
1987	1,987	15.0	43.0	31.0	11.0	-	100.0
1988	3,324	6.5	74.8	16.9	1.7	0.1	100.0
1989	3,336	0.7	77.9	20.4	1.0	-	100.0
1990	2,497	2.3	45.6	50.7	1.4	-	100.0
1991	3,292	2.9	60.4	35.8	0.9	-	100.0
1992	3,706	0.9	58.5	37.5	3.1	-	100.0
1993	3,707	2.9	26.3	66.5	4.2	0.1	100.0
1994	3,744	3.3	63.0	30.8	2.9	-	100.0
1995	4,621	2.3	59.8	36.0	1.9	-	100.0
1996	2,386	0.9	36.9	52.3	9.5	0.4	100.0
1997	4,824	1.4	28.7	58.3	10.2	1.4	100.0
1998	3,043	5.4	51.9	29.2	12.8	0.7	100.0
1999	3,288	0.9	87.5	10.6	0.9	0.2	100.0
2000	3,179	2.1	61.6	35.2	1	0	100.0
2001	3,670	2.4	45.7	49.9	2	0.1	100.0
2002							
2003	969	0.7	65.6	27.2	6.5	0	100.0
2004	1,472	12.8	53.3	32.7	1	0.2	100.0
Average	1,865	9.6	61.1	27.1	2.6	0.2	100.0

Table 18.–Kotzebue area chum salmon estimated escapements and resultant recruits by age for 1962–1998 brood years based on full model run reconstruction.

		Recruits by Age					
Brood Year	Escapement	0.2	0.3	0.4	0.5	0.6	Total Recruits
1962	621,917	11,609	277,700	61,320	2,291	0	352,920
1963	138,600	41,324	239,315	50,397	0	0	331,037
1964	444,000	29,169	147,883	12,329	0	0	189,381
1965	393,677	53,961	146,692	36,472	0	0	237,125
1966	350,393	92,595	638,963	121,002	4,384	0	856,944
1967	266,520	25,951	309,691	176,090	0	0	511,732
1968	186,205	32,916	434,744	108,064	4,008	0	579,732
1969	176,697	115,445	539,541	102,875	0	0	757,860
1970	481,658	129,832	847,046	112,797	822	0	1,090,496
1971	293,342	382,106	923,658	153,216	9,531	0	1,468,510
1972	550,852	27,667	211,134	98,488	647	0	337,936
1973	391,673	45,595	386,009	102,835	3,984	0	538,424
1974	688,710	35,477	185,944	55,053	859	0	277,333
1975	481,364	33,955	192,686	56,664	0	0	283,306
1976	231,558	110,469	671,386	363,073	35,092	0	1,180,021
1977	314,197	129,641	798,761	257,132	14,806	0	1,200,340
1978	192,475	28,570	308,175	220,162	9,344	0	566,250
1979	201,157	37,645	371,442	141,594	3,683	0	554,364
1980	471,854	37,337	462,875	142,726	12,623	0	655,561
1981	492,124	104,938	770,719	452,708	46,038	775	1,375,177
1982	184,122	3,683	106,722	129,743	13,174	0	253,322
1983	443,173	1,721	179,966	130,960	7,701	0	320,349
1984	373,731	62,779	579,635	157,109	7,456	0	806,979
1985	385,911	50,369	599,941	270,003	6,100	0	926,413
1986	276,870	5,391	242,843	242,643	18,891	256	510,024
1987	276,236	12,249	409,375	228,520	10,759	0	660,903
1988	387,618	19,655	356,491	170,356	10,110	0	556,613
1989	484,176	5,484	67,374	107,379	19,760	6,263	206,260
1990	340,924	7,429	219,639	383,769	140,909	5,794	757,539
1991	415,733	11,505	612,574	765,605	42,213	1,723	1,433,620
1992	300,365	22,881	637,222	241,277	32,733	1,357	935,469
1993	163,002	14,091	118,776	72,110	6,107	0	211,085
1994	187,836	5,794	124,040	71,928	6,120	565	208,447
1995	716,396	15,259	593,747	215,409	11,304	940	836,658
1996	1,439,252	6,107	376,966	282,033	10,817	0	675,923
1997	262,959	12,851	258,295	111,514	18,075	811	401,546
1998	176,841	13,565	250,961	75,637	4,057		344,220
1999	483,675	39,462	182,418	132,680			
2000	415,574	1,947	216,264				
2001	335,811	51,936					
2002	375,248						
2003	225,224						
2004	327,282						

Table 19.–Stock-recruit relationship statistics for Kotzebue Sound chum salmon stocks based upon fit of Ricker stock recruit model to the 1962–1998 brood years of data derived from the full model and model 2 run reconstructions.

Stock-Recruitment Relationship Statistics	Full Model	Model 2
Ricker Alpha	1.3470	1.5313
Ricker Beta	-1.821E-03	-2.173E-03
Adjusted R Square	0.3919	0.4247
Significance of Relationship		
Lag 1 autocorrelation, Phi (p- value)	0.20 (p = 0.19)	0.18 (p = 0.22)
No. of Brood Years	37	37
MSY Escapement Estimate	300,000	277 ,000
Estimated Maximum Yield	368,000	425,000
Estimated MSY Exploitation Rate	55.1%	60.5%
Maximum Recruitment	777,000	783,000
Spawners at Maximum Recruitment	549,000	460,000
Equilibrium Stock Size	740,000	705,000
Lower Escapement that produces 90% of MSY	196,000	179,000
Upper Escapement that produces 90% of MSY	421,000	391,000
Bootstrapped Statistics		
Mean MSY Escapement	311,000	281,000
Standard Deviation	54,000	39,000
Coefficient of Variation	17.4%	13.7%
Lower 90% C.I.	240,000	229,000
Upper 90% C.I.	412,000	355,000
Indicated Bias	11,000	4,000
Indicated % Bias	3.6%	1.6%

Table 20.–Aerial survey index counts for various spawning populations of chum salmon in the Kotzebue area. The Kotzebue area escapement index for 1977, 1979, 1989, 1994, 1997–1998, 2000, and 2002 was estimated from the full model run reconstruction and is listed in bold face type.

Year	Noatak River Total	Upper Kobuk River Total	Lower Kobuk Tributary Systems				Kotzebue Area Escapement Index
			Squirrel River	Salmon River	Tutuksuk River	Total Lower Kobuk River Tributaries	
1962	178,898	9,224	5,834	12,936	10,841	29,611	217,733
1963	34,910	4,535	2,200	1,535	670	4,405	43,850
1964	98,967	20,992	8,009	9,353	2,685	20,047	140,006
1965	87,201	18,969	7,230			18,775	124,945
1966	102,330	13,964	1,350	3,957	1,383	6,690	122,984
1967	66,115	15,345	3,332	2,116	169	5,617	87,077
1968	45,271	2,370	6,746	3,367		12,687	60,328
1969	34,163	7,500	6,714	2,561	159	9,434	51,097
1970	152,251	13,908	4,418			11,472	177,632
1971	45,248	17,202	6,628	5,453	1,384	13,465	75,915
1972	69,115	18,155	32,126			83,423	170,693
1973	32,864	9,629	12,345	6,891		24,133	66,626
1974	153,270	30,325	32,523	29,190	8,312	70,025	253,620
1975	101,748	21,470	32,256	9,721		52,663	175,881
1976	46,804	12,026	7,229	1,161	758	9,148	67,978
1977							***98,234***
1978	44,312	11,597				15,715	71,624
1979							***63,095***
1980	182,167	35,292	13,563	8,456	1,165	23,184	240,643
1981	118,957	24,428	9,854	4,709	1,114	15,677	159,062
1982	32,475	9,563	7,690	1,821	1,322	10,833	52,871
1983	94,954	33,746	5,115	1,677	2,637	9,429	138,129
1984	76,399	17,113	5,473	1,471	1,132	8,076	101,588
1985	47,580	12,159	6,160	2,884	5,098	14,142	73,881
1986	42,374	6,015	4,982	1,971	4,257	11,210	59,599
1987	67,124	13,789	2,708	3,333	206	6,247	87,160
1988	81,430	17,309		6,208	3,122	15,173	113,912
1989							***137,626***
1990	79,726	16,890	5,500	6,335	2,275	14,110	110,726
1991	86,344	24,525	4,606	5,845	744	11,195	122,064
1992	35,762	11,803	2,765	1,345	1,162	5,272	52,837
1993	30,219	12,158	4,463	13,880	1,196	19,539	61,916
1994							***33,883***
1995	163,504	35,725	10,605	13,988	3,901	28,494	227,723
1996	338,367	74,770	10,740	23,790	21,805	56,335	469,472
1997							***74,940***
1998							***48,009***
1999	103,500	27,340	13,513	4,989	2,906	21,408	152,248
2000							***131,905***
2001	50,803	13,420				18,297	82,520
2002							***125,784***
2003	38,893	11,602				14,977	65,472
2004	55,445	23,199				16,983	95,627

Table 21.–Historic chum salmon escapement goals in the Kotzebue area contrasted against recommendations made in this report.

Escapement Goal Methodology, Time-frame, and Reference	Upper Kobuk River	Salmon River	Tutuksuk River	Squirrel River	Noatak River	Kotzebue Area
Escapement Averaging 1981 ADF&G 1981	5,000	None	None	10,000	70,000	
Escapement Averaging 1992 Buklis (1993)	10,000	7,000	2,000	11,500	80,000	
Escapement Averaging 1999	10,000	4,000	1,500	9,000	80,000	
Fair et al. (1999) BEG Range	8,000 to 16,000	3,200 to 6,400	1,200 to 2,400	7,200 to 14,400	64,000 to 128,000	
Stock-Recruit Analysis	15,500	5,300	2,200	7,700	67,000	98,000
Current Report Escapement Goal Range	9,700 to 21,000	3,300 to 7,200	1,400 to 3,000	4,900 to 10,500	42,000 to 91,000	62,000 to 132,000

Table 22.–Number of years when observed aerial survey index counts of chum salmon in the Kotzebue Area were below, within, or above the recommended escapement goals listed in this report.

Chum Salmon Spawning Area	Recommended Escapement Goal	No. Years When Escapement was Below Recommended Level	No. Years When Escapement was Within Recommended Level	No. Years When Escapement was Above Recommended Level
Upper Kobuk River Survey Area (total sample size = 35 years)	9,700 to 21,000	7 years 20 % of all years	18 years 51% of all years	10 years 29% of all years
Salmon River Survey Area (total sample size = 28 years)	3,300 to 7,200	10 years 36% of all years	10 years 36% of all years	8 years 28% of all years
Tutuksuk River Survey Area (total sample size = 25 years)	1,400 to 3,000	14 years 56% of all years	4 years 16% of all years	7 years 28% of all years
Squirrel River Survey Area (total sample size = 30 years)	4,900 to 10,500	8 years 27% of all years	14 years 46% of all years	8 years 27% of all years
Noatak River Survey Area (total sample size = 35 years)	42,000 to 91,000	7 years 20% of all years	16 years 46% of all years	12 years 34% of all years
Kotzebue Area Escapement Index (total sample size = 35 years)	62,000 to 132,000	5 years 14% of all years	18 years 52% of all years	12 years 34% of all years

Note: Annual aerial survey counts for the Salmon, Tutuksuk, and Squirrel Rivers summarized above consist of only those years when successful aerial surveys of chum salmon escapements occurred or when counts considered for the Noatak River, upper Kobuk River, and Kotzebue Area had sufficient useable counts for interpolation.

FIGURES

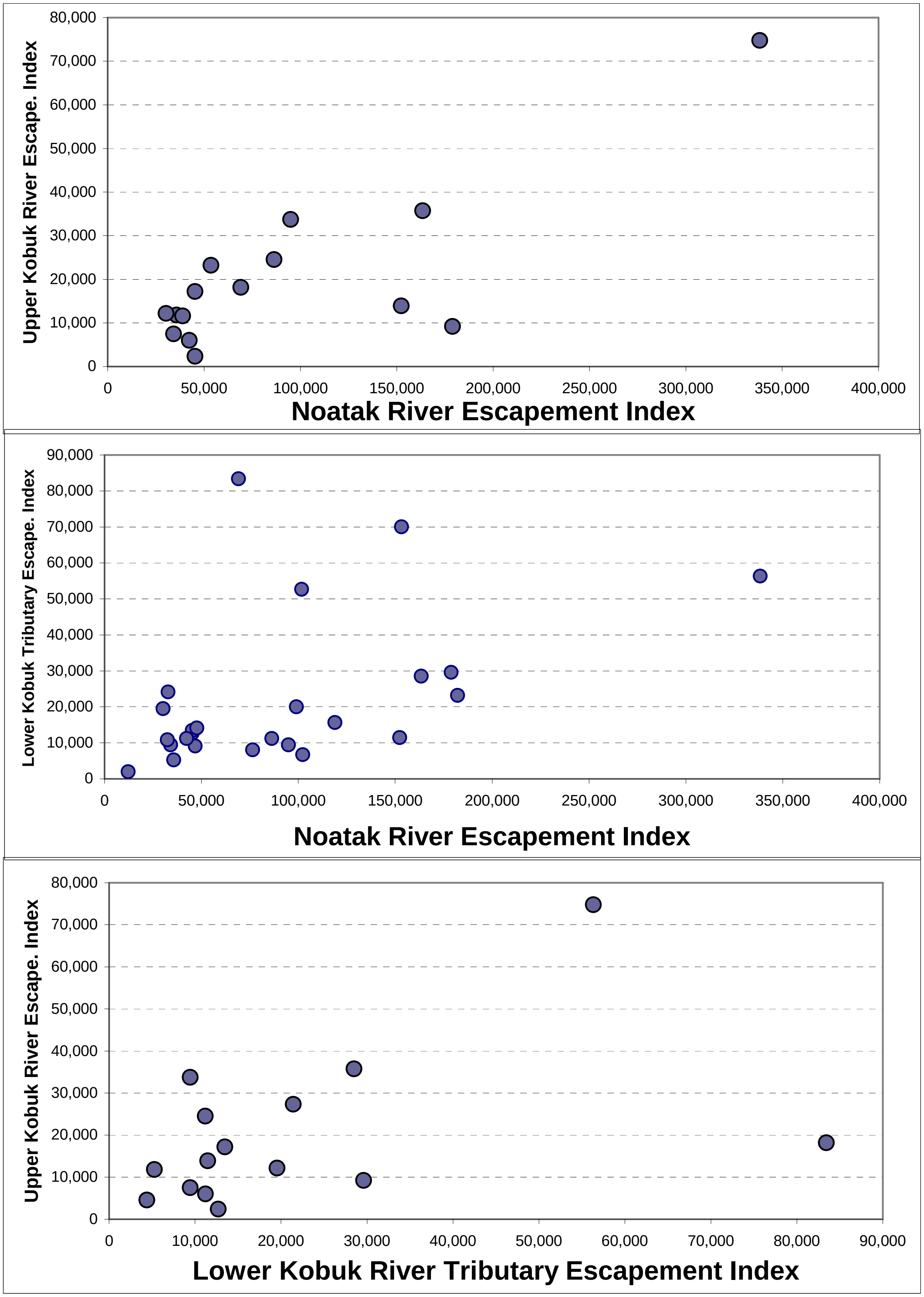

Figure 1.–Pair-wise plots of chum salmon aerial survey index counts among the Kotzebue area escapement index areas.

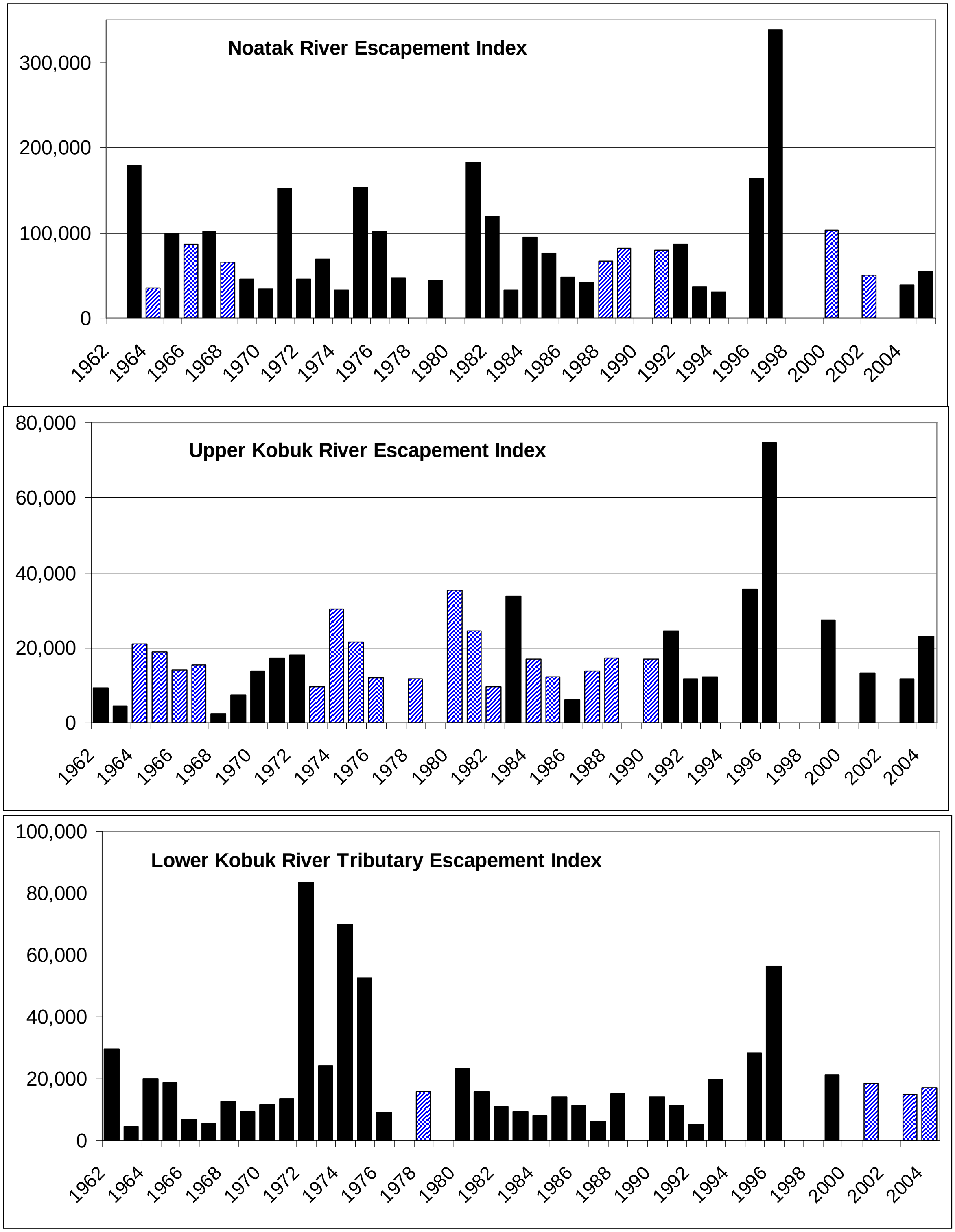

Figure 2.–Plots of chum salmon aerial survey indices of the Noatak River (upper plot), upper Kobuk River (center plot), and lower Kobuk River tributaries (lower plot). Note: the black bars correspond to direct observations and hatched bars correspond to estimated values based upon statistical relationships between different spawning areas among years in the data set.

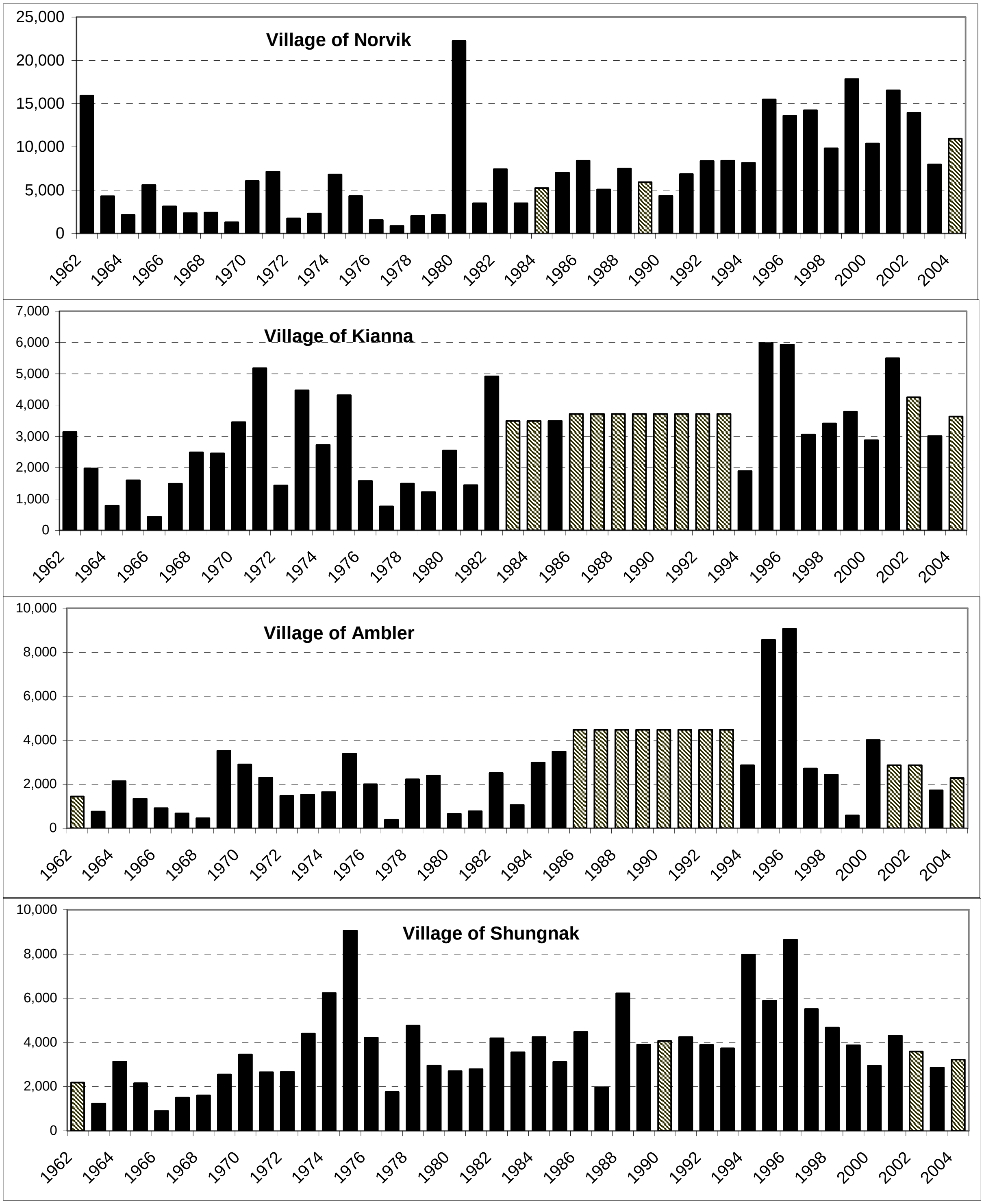

Figure 3.–Estimated subsistence catches of chum salmon by fishermen from the villages of Noorvik, Kiana, Ambler, and Shungnak, 1962–2004. Note: black bars are from Table 7 and data source is Kohler et al. (2005). Hatched bars are from interpolations, see Table 8 for methodology.

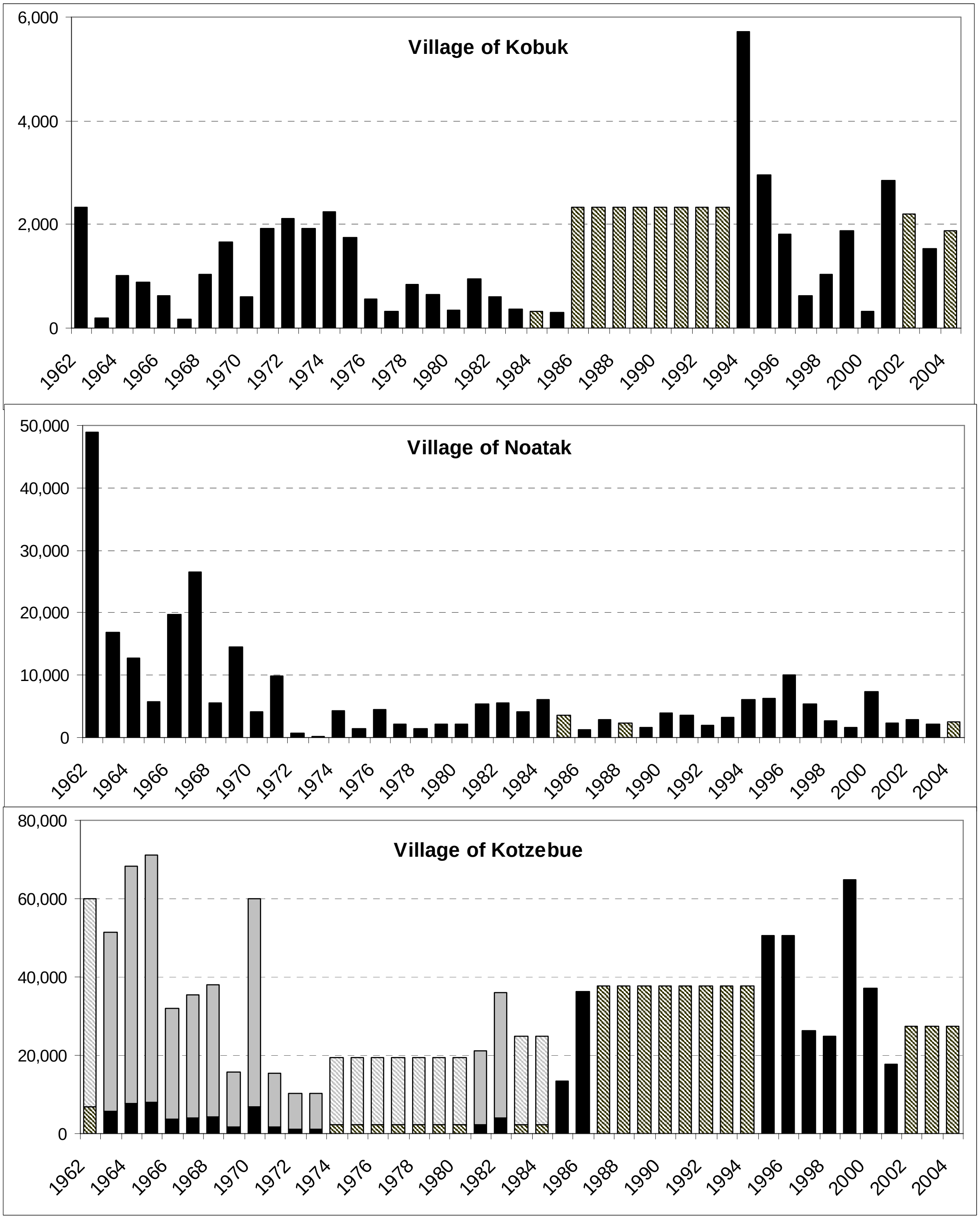

Figure 4.–Estimated subsistence catches of chum salmon by fishermen from Kobuk, Noatak, and Kotzebue, 1962–2004. Note black bars are from Table 7, data source is Kohler et al. (2005). Hatched bars are from interpolations, see Table 8 for methodology. The light solid and hatched bars before 1985 for Kotzebue are expanded for underreporting (see text).

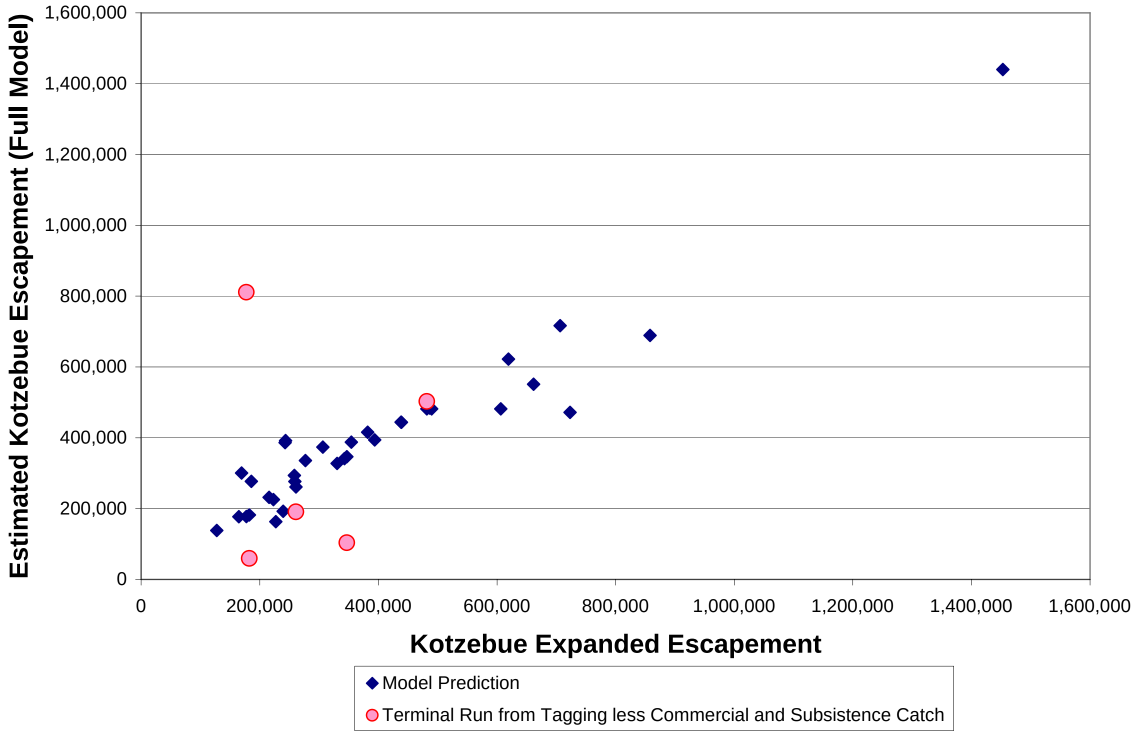

Figure 5.–Full model estimated escapements for Kotzebue chum salmon (diamonds) and independent escapements of escapement from tagging studies versus expanded Kotzebue chum salmon escapement estimates (i.e., 2.410 times the Noatak plus 4.787 times the Kobuk River escapement index) for Kotzebue area chum salmon.

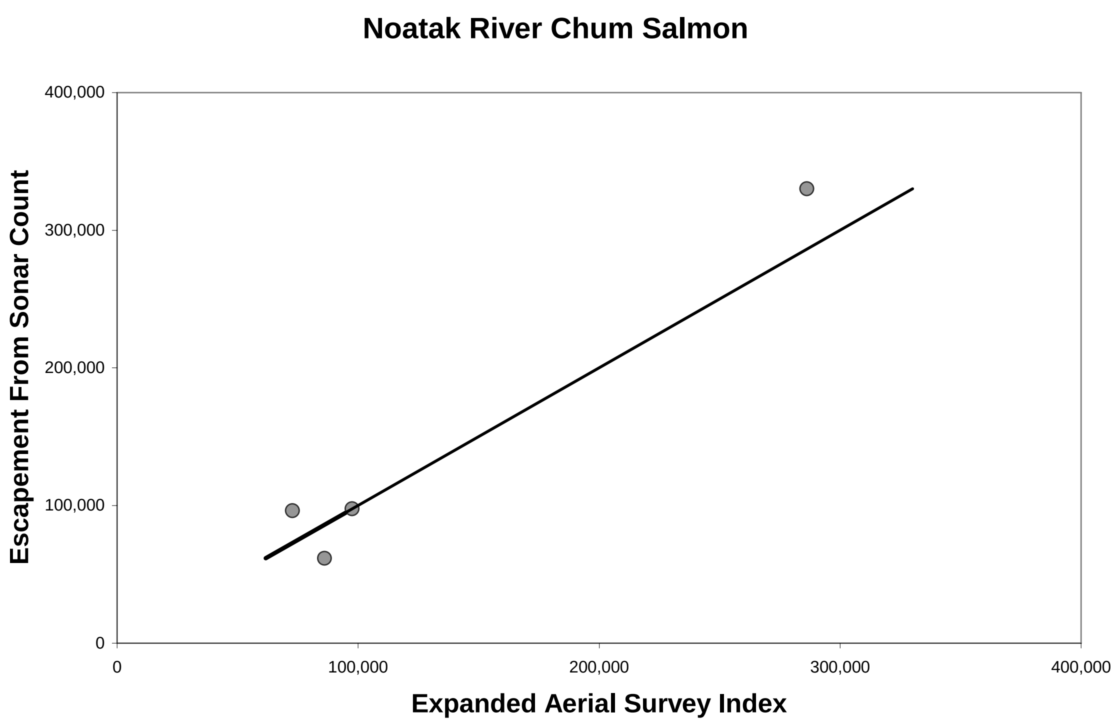

Figure 6.–Relationship between Noatak River escapement from sonar counts to expanded Noatak River aerial survey index counts (2.41 times the escapement index value).

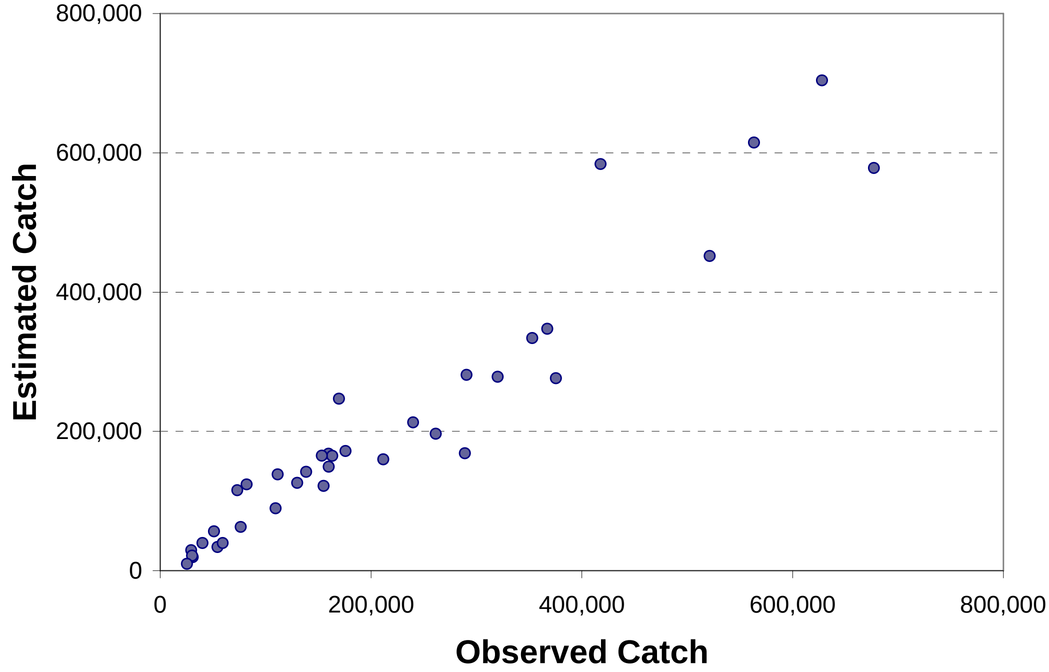

Figure 7.–Kotzebue District commercial catch estimated by full model run reconstruction versus observed catch.

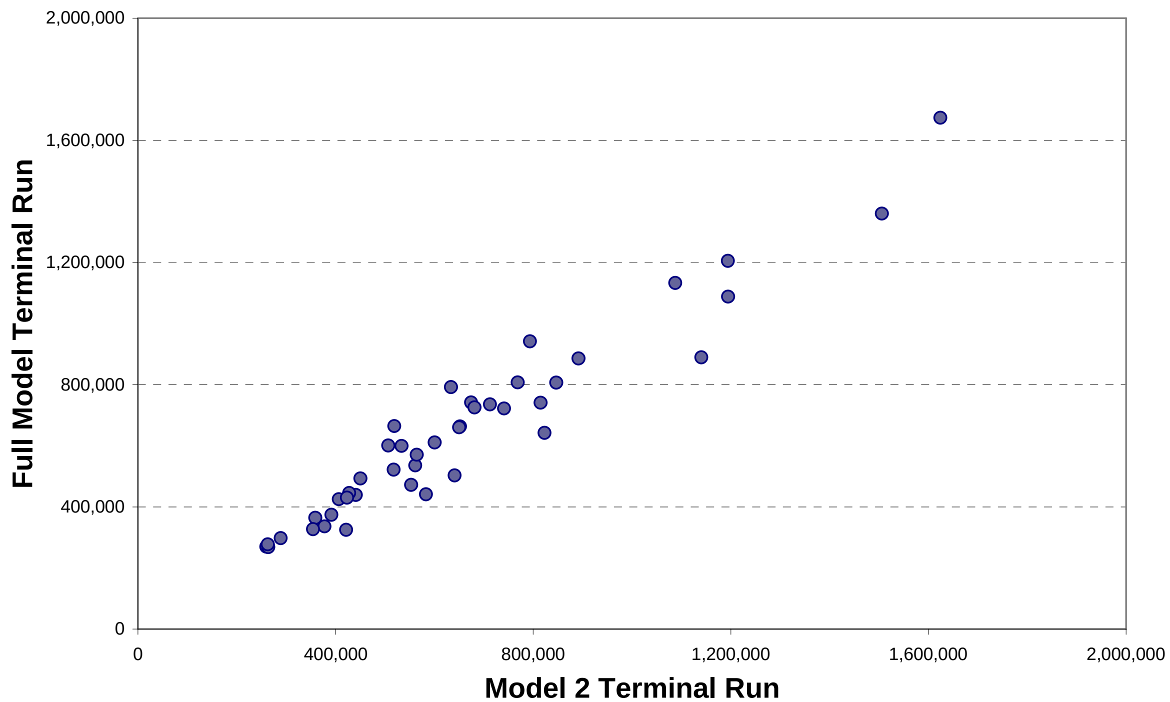

Figure 8.–Relationship of estimated Kotzebue District terminal runs estimated from the full model to that estimated from model 2 (the reduced parameter model).

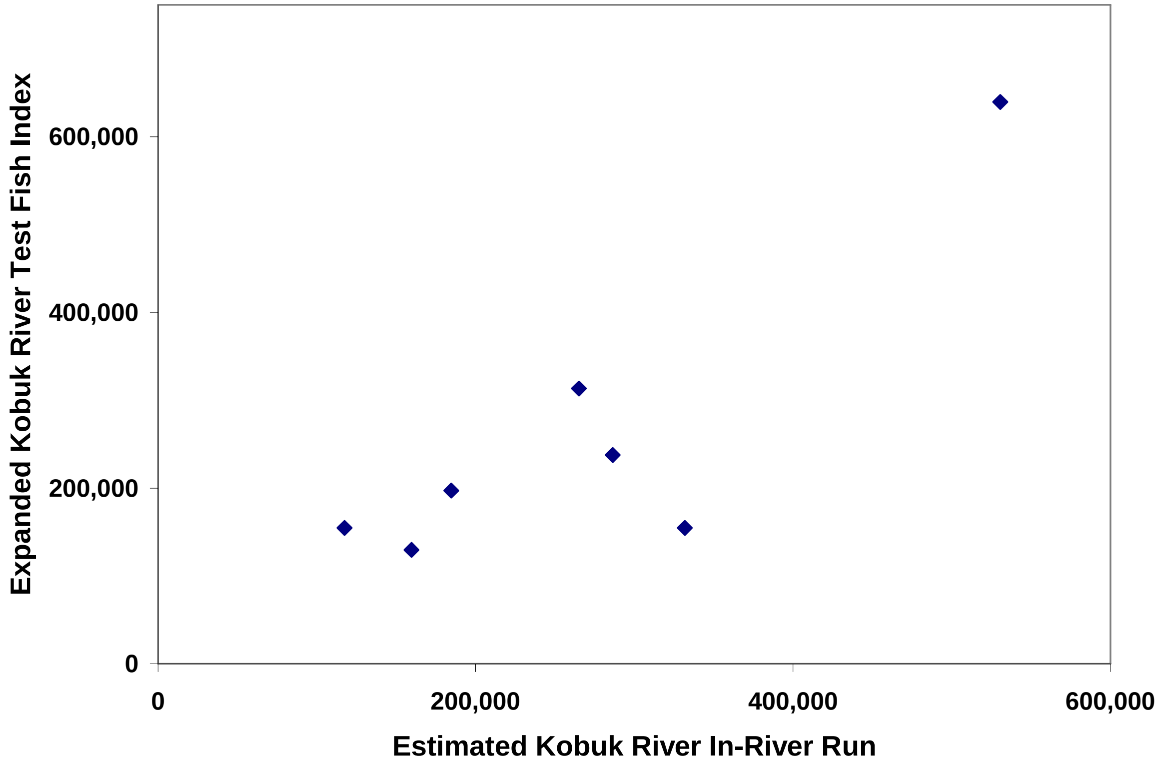

Figure 9.–Relationship between expanded Kobuk River test fish index (190 escapement per index) and estimated inriver run to the Kobuk River.

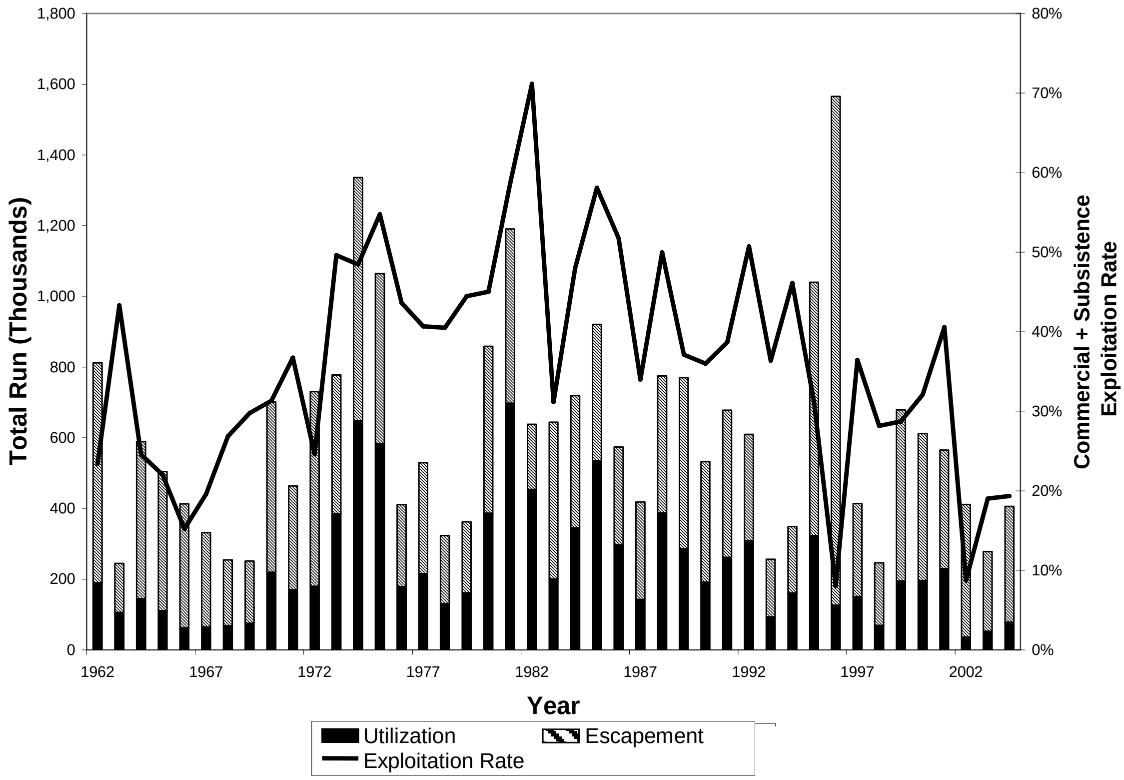

Figure 10.–Annual harvests (utilization), escapements, and total exploitation rates for Kotzebue area chum salmon, based on full model run reconstruction, 1962-2004.

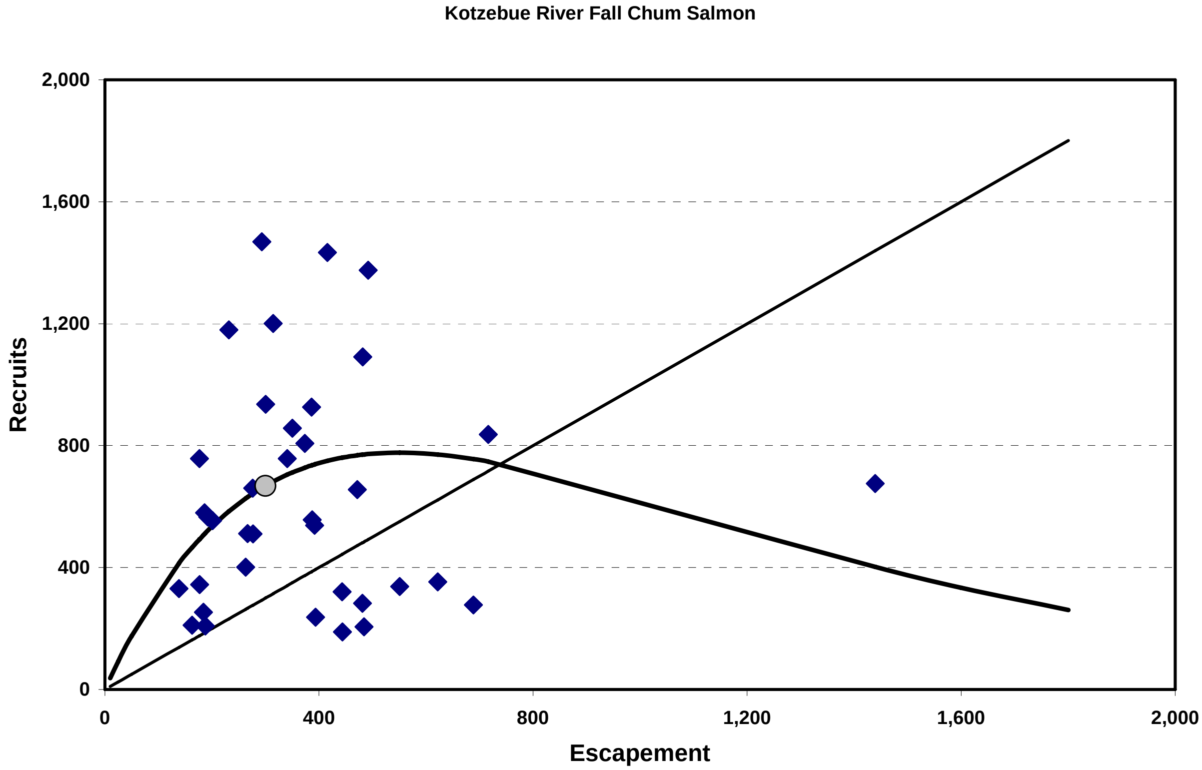

Figure 11.–Plot of the spawner-recruit relationship developed for Kotzebue area chum salmon (diamonds represent individual brood year escapements and resultant recruitments and the circle represents the estimated maximum sustained yield escapement value).

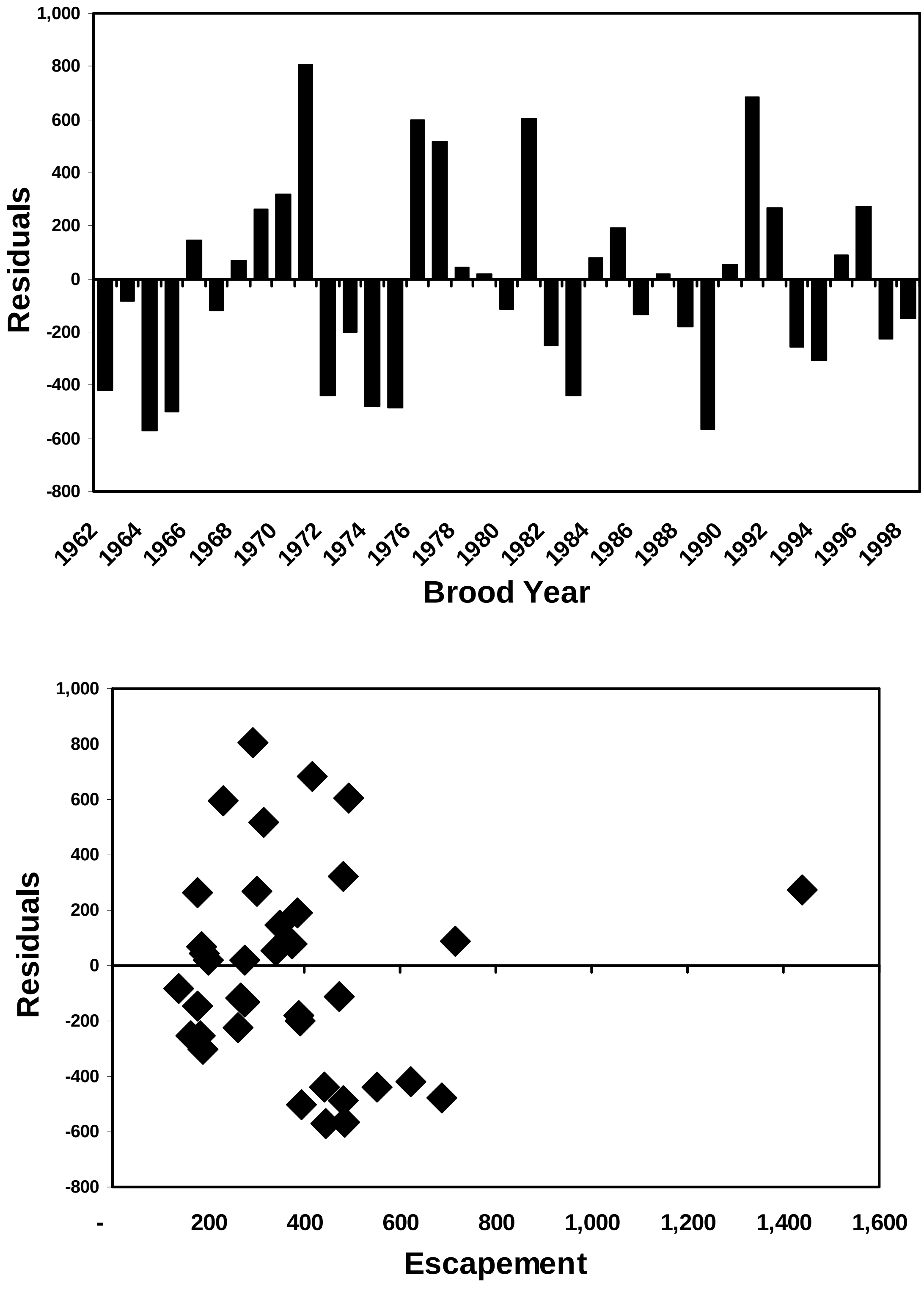

Figure 12.–Plots of residuals in the spawner-recruit relationship developed for Kotzebue area chum salmon (residuals versus time in the upper panel and residuals versus brood year escapements in the lower panel).

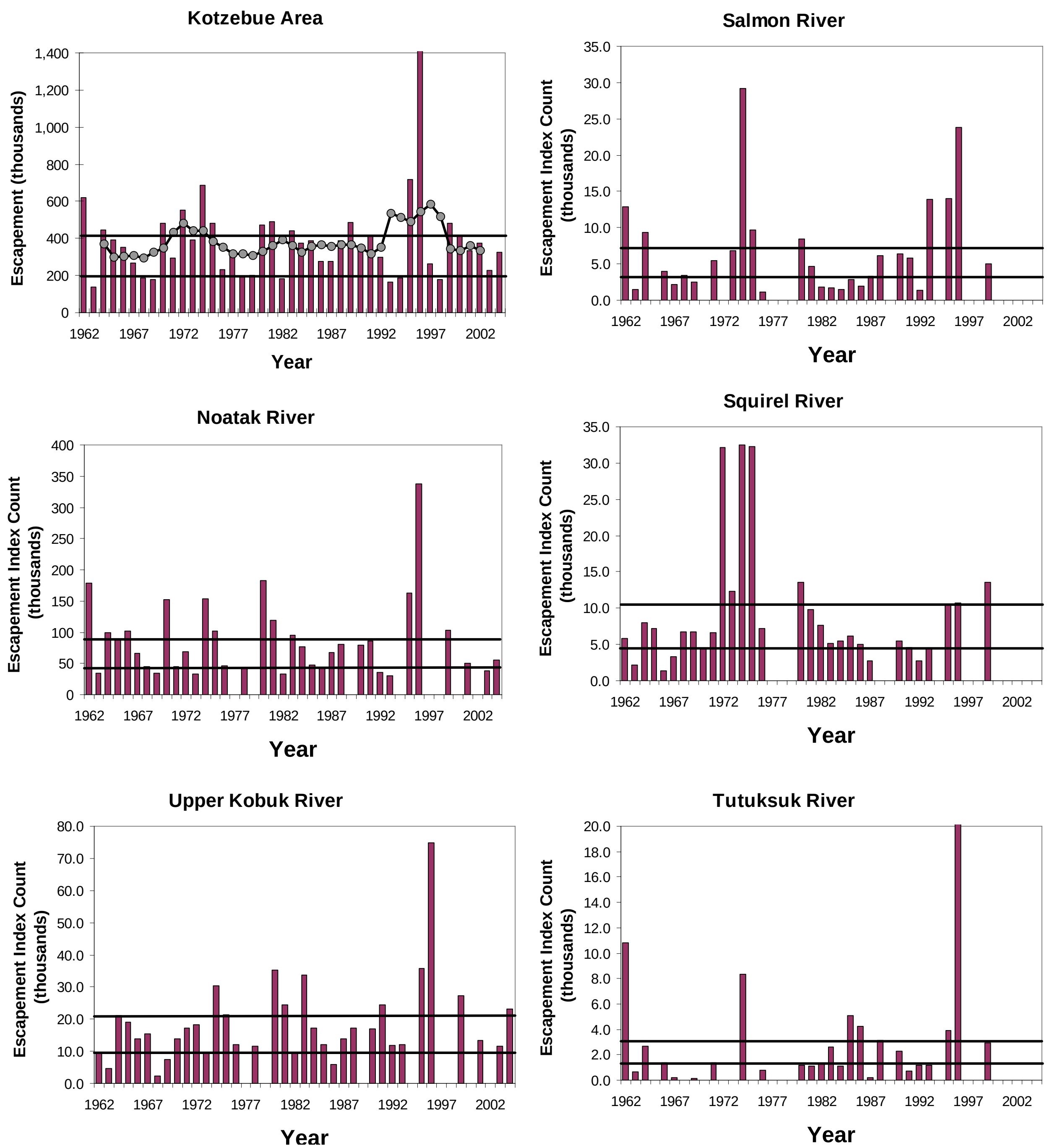

Figure 13.–Time series of escapements and the recommended escapement goal ranges from this report listed in aerial survey index units for the Noatak River (middle left panel), the upper Kobuk River (lower left panel), the Squirrel River (middle right panel), the Salmon River (upper right panel), and the Tutuksuk River (lower right panel). Upper left panel shows the time series of escapements, the recommended escapement goal range from this report, and the 5-year moving average of escapements for Kotzebue Area chum salmon (escapement estimates based on full model run reconstruction).