Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Final Report

Effects of Pink Salmon (*Oncorhynchus gorbuscha*) Escapement Level on Egg Retention, Preemergent Fry, and Adult Returns to the Kodiak and Chignik Management Areas Caused by the *Exxon Valdez* Oil Spill

Fish/Shellfish Study Numbers 7B and 8B
Final Report

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Study History: Fish/Shellfish Study Numbers 7B and 8B were initiated under a 1989 detailed study plan as Fish/Shellfish Studies 7 and 8 (Injury to Pink Salmon Spawning Areas and Pink Salmon eggs and Fry in Areas Outside of Prince William Sound). In October 1990 the study was stratified owing to disparate objectives and concerns into streams within Lower Cook Inlet (F/S Study Numbers 7A and 8A), and streams within the Kodiak-Chignik areas (F/S Study Numbers 7B and 8B). Injury assessment was continued with field studies terminating after the 1991 field season. a draft report was submitted by C.O. Swanton entitled Effects of Pink Salmon (*O. gorbuscha*) Escapement Level on Egg Retention, Preemergent Fry, and Adult Returns to the Kodiak and Chignik Management Areas Caused by the *Exxon Valdez* Oil Spill. No restoration efforts were required for pink salmon populations to either of the affected areas.

Abstract: Potential impacts of overescapement on several life history stages of pink salmon from streams located within the Kodiak and Chignik commercial salmon fishing areas were studied. The 1989 pink salmon escapement for Kodiak was 21.0 million (odd-year escapement goal 4.7 million) and for Chignik 1.4 million fish (odd-year escapement goal 0.7 million). Measurements of egg retention, fecundity, stream residence time (stream life), total available spawning habitat, and preemergent fry densities were obtained. Egg retention was found to be positively related to spawner density; observed 1990 preemergent fry densities were significantly below predicted values for 23 Kodiak and 7 Chignik streams indicating reduced spawner success for some streams. Return per spawner analyses for Kodiak showed a significant density dependent response, however no such result was found for the Chignik data. Overall no conclusive evidence of reduced production of pink salmon adults from the 1989 escapement event was found.

Key Words: Adult returns, Chignik, egg retention, *Exxon Valdez*, Kodiak, *Oncorhynchus gorbuscha*, overescapement, pink salmon, preemergent fry.

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EXECUTIVE SUMMARY

As a result of the 1989 *Exxon Valdez* oil spill, commercial salmon fishing in and around the Kodiak and Chignik areas was severely restricted throughout the 1989 season. Consequently, pink salmon escapements for these areas greatly exceeded targeted escapement objectives. Investigations were conducted within the Kodiak and Chignik Management Areas during 1989 and 1990 to determine if negative impacts on future odd-year brood line pink salmon production occurred as a result of overescapement in 1989.

The 1989 pink salmon escapements for the Kodiak and Chignik management areas were estimated to be 21.0 and 1.4 million fish, respectively; odd-year escapement objectives are 4.7 million (Kodiak) and 0.7 million (Chignik). Egg retention of spawners was found to be positively related to spawner density. Observed 1990 preemergent fry densities were significantly below those predicted from linear regression models in 23 Kodiak and 7 Chignik index streams; depressed fry production was found in 18 Kodiak and Chignik streams, collectively. Conversely, there were also Kodiak and Chignik preemergent fry index streams that had observed 1990 fry density values which were greater than average, suggesting no density dependent effect for these streams pink salmon populations. Return per spawner analyses for Kodiak resulted in a significant density dependent parameter estimate, while for Chignik no such result was found. A possible mechanism for the density dependence found within the return per spawner analysis is the effect of spawner density on egg retention with a subsequent reduction in preemergent fry yield for some Kodiak area streams.

For Kodiak, the 1991 pink salmon return was 22.0 million; predicted returns using midpoint and desired odd-year escapement goals of 4.7 and 7.0 million were 11.9 (range 3.6 to 24.4 million) and 15.7 (range 5.8 to 29.5 million) million, respectively. Had Kodiak area pink salmon escapement midpoint or desired goals been met the 1991 return could easily have been higher or lower than the actual return of 22.0 million. The Chignik area experienced a 1991 return of 1.9 million; the predicted return using the escapement goal (0.7 million) was 1.3 million.

Even though spawner density had an affect on egg retention and preemergent fry, we do not believe that a measurable impact occurred on either Kodiak or Chignik area pink salmon returns from the 1989 escapement event.

INTRODUCTION

During 1989, numerous salmon harvest opportunities within the Kodiak (KMA) and Chignik Management Areas (CMA) were foregone owing to the *Exxon Valdez* Oil Spill. Pink salmon (*Oncorhynchus gorbuscha*) runs occur in 454 Kodiak and 107 Chignik streams and comprise 78% and 31% (1978-1988), respectively, of the Kodiak and Chignik annual salmon harvests (Malloy and Prokopowich 1992; Thompson and Owen 1992). The ex-vessel value of this harvest has averaged (1978-1988), in millions of dollars, 14.2 and 1.5 for the Kodiak and Chignik areas. The KMA odd-year midpoint pink salmon escapement goal is 4.67 million, whereas the estimated total escapement for 1989 was about 21.0 million (Barrett et al. 1990). No annual escapement within the last three decades (1963-1991) has approached this level. The CMA desired pink salmon escapement goal is 0.70 million (Probasco et al. 1987); estimated total escapement during 1989 was 1.4 million (Barrett 1990).

In addition to monetary losses, the unrealized harvests of pink salmon could potentially have resulted in overescapement of spawners with consequent depression in returns from the 1989 brood year. Redd superimposition resulting from high spawner densities can be an important cause of mortality in Pacific salmon (Gilbert and Rich 1927; Smirnov 1947; Morgan and Henry 1959). McNeil (1964) demonstrated that pink salmon egg mortality during spawning was directly related to the density of females on spawning beds in two Southeastern Alaska streams. McNeil (1964) and Beverton and Holt (1957) both surmised that the production of fry within spawning beds is limited by maximum fry yields owing to density dependent mortality of eggs and alevins. Heard (1978) presented compelling evidence that this occurred in a Southeastern Alaska stream that experienced an extremely high pink salmon escapement in 1967.

The KMA encompasses the entire Kodiak archipelago and that portion of the Alaska Peninsula draining into Shelikof Strait from Cape Douglas to Kilokak Rocks bordering Imuya Bay (Figure 1). The archipelago and Alaska Peninsula portions of the management area are each about 241 km in length while Shelikof Strait which separates the two, averages approximately 48 km in width. The commercial salmon fishery occurs within seven districts which enclose about 454 pink salmon spawning streams. Fishery managers employ aerial and foot survey escapement counts into 51 index streams as part of the inseason fishery management program; 43 index streams have preemergent fry data collected for generating preseason run forecasts (Figure 2).

The CMA includes all coastal waters and inland drainages of the northwest Gulf of Alaska extending from Kilokak Rocks bordering Imuya Bay to Kupreanof Point (Figure 3). There are five commercial salmon fishing districts which contain 107 pink salmon spawning streams. Within the CMA are 31 aerial survey index streams, 18 of which have had preemergent fry sampling conducted (Figure 4).

We employed approaches spanning several life history stages for examining whether 1989 foregone harvests led to depression in spawning success, fry yields, and the subsequent returns of pink salmon. Egg retention, fecundity, stream residence time (stream life) and estimated total escapement, total available spawning habitat, and preemergent fry data were collected during 1989 and 1990. Goals of this study were:

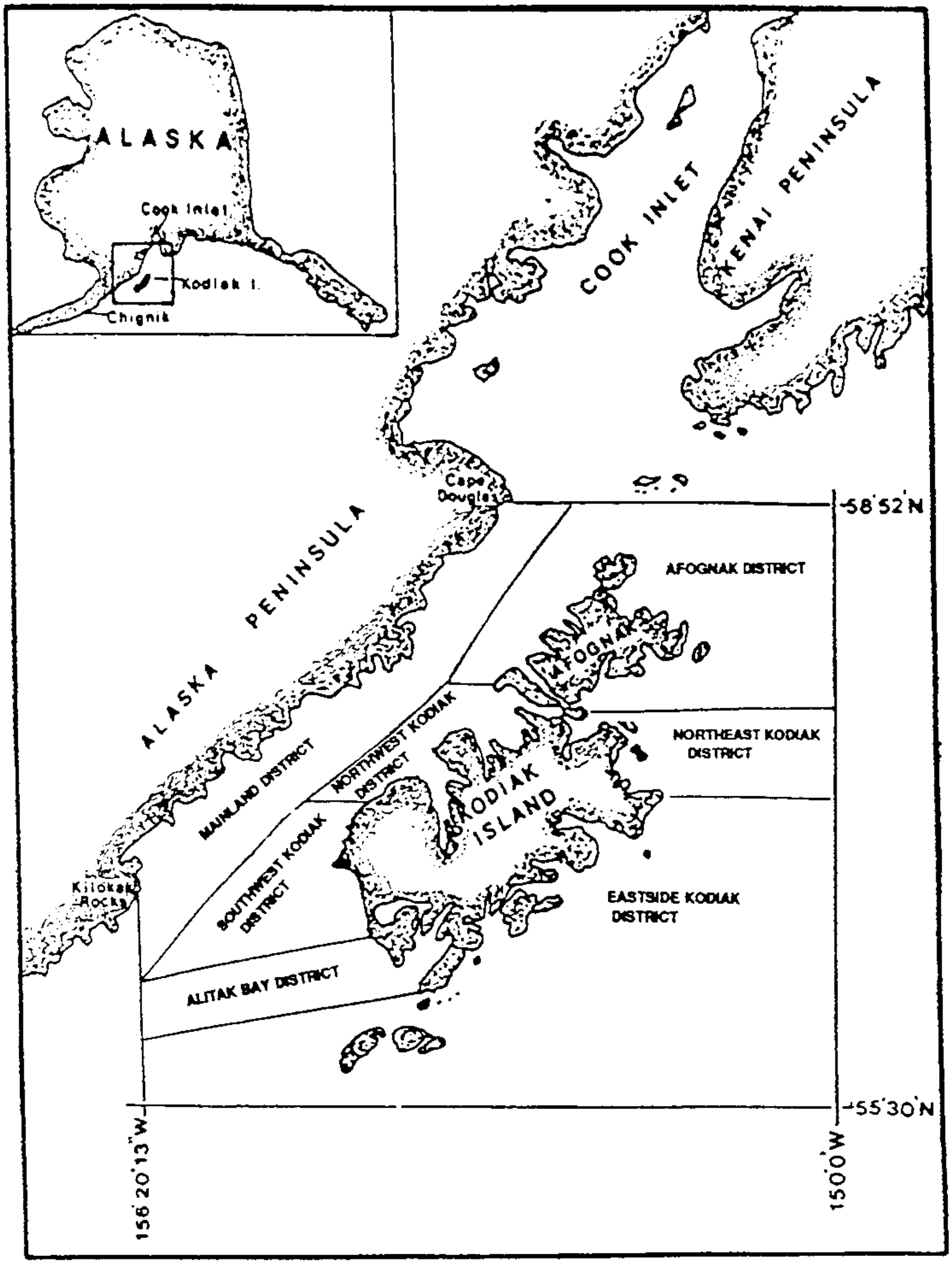

Figure 1. Map of the Kodiak Management Area and associated commercial salmon fishing districts.

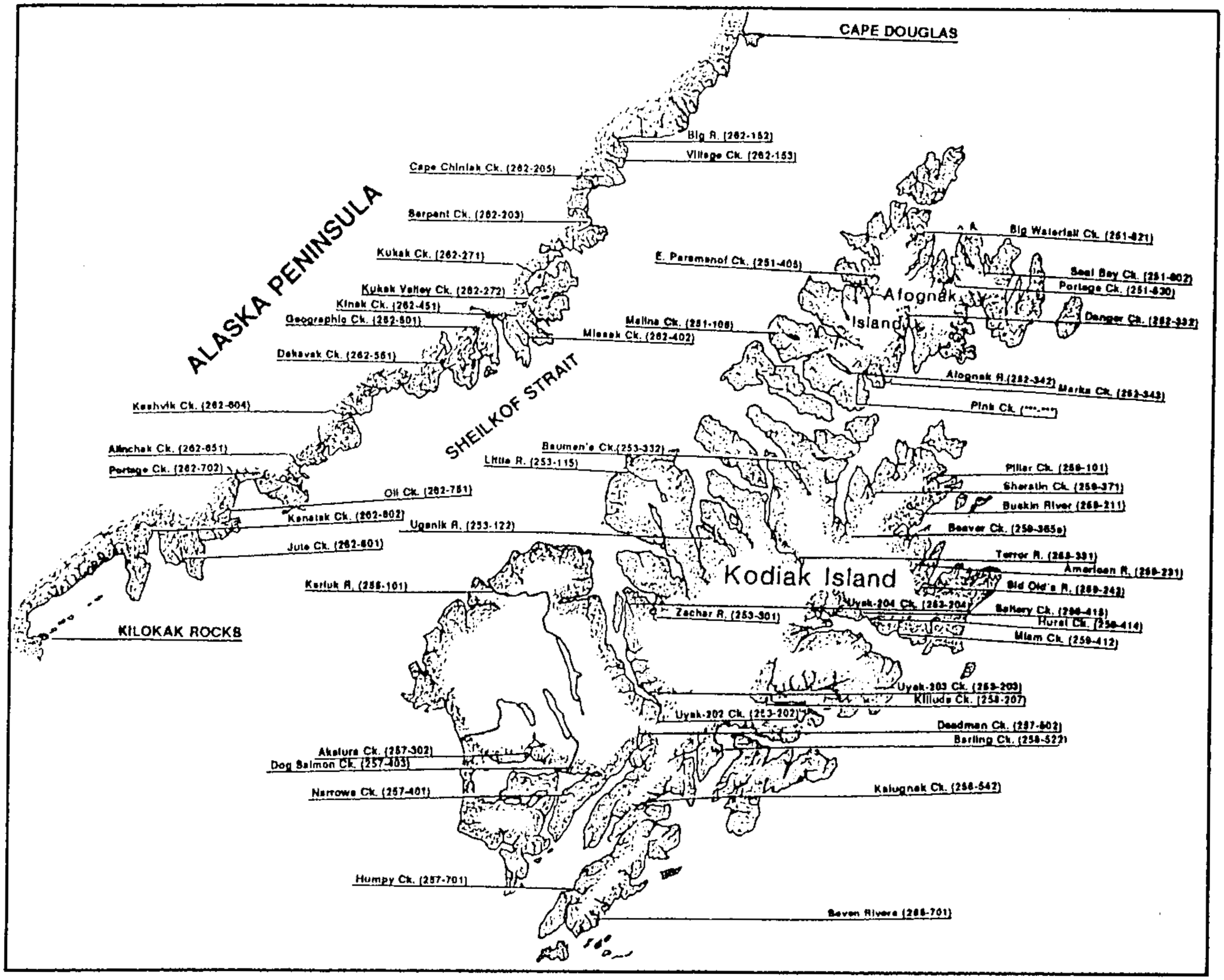

Figure 2. Approximate locations of Kodiak Management Area aerial escapement survey, preemergent fry, egg retention, stream life, and fecundity sampling streams.

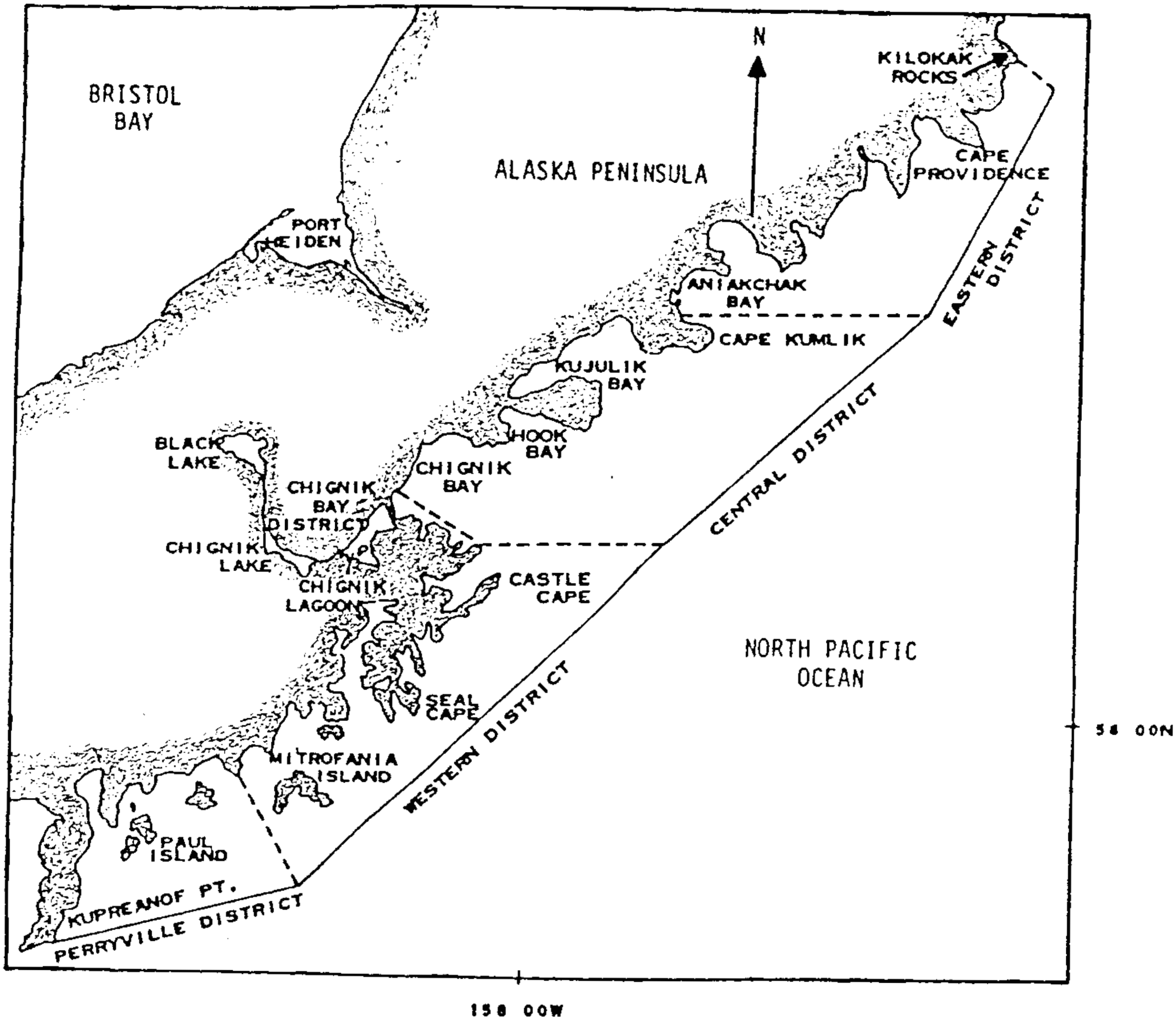

Figure 3. Map of the Chignik Management Area showing commercial salmon fishing districts.

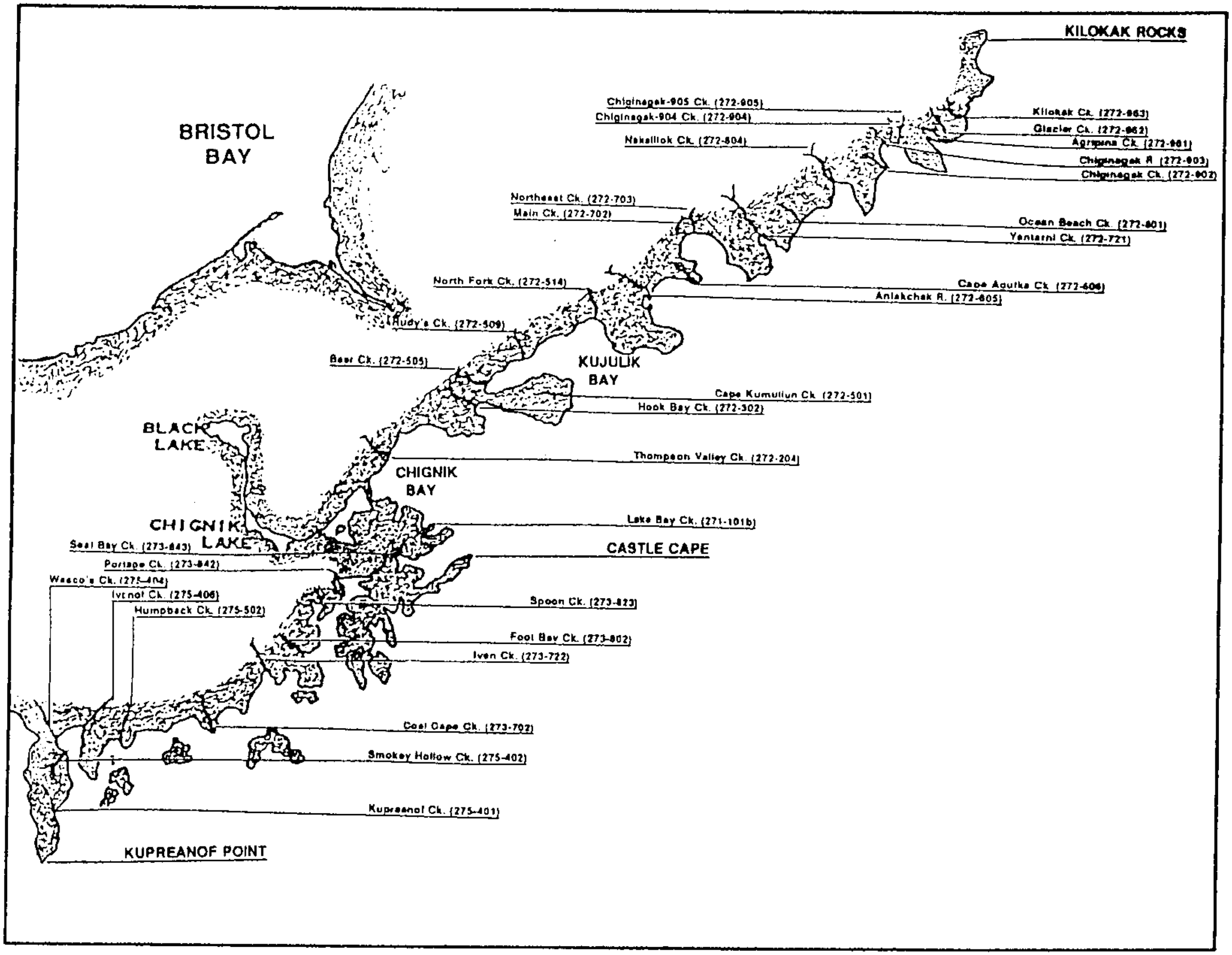

Figure 4. Chignik Management Area aerial escapement survey, preemergent fry, egg retention, and fecundity sampling index streams.

(1) estimate the numbers of spawning pink salmon by "index" stream for systems outside Prince William Sound where historical fry density data exist. These include 43+ streams in the Kodiak Island/Shelikof Strait mainland area and 18 streams in the Chignik area;

(2) produce a catalog of aerial photographs and detailed maps of pink salmon spawner distribution for index streams in the Kodiak and Chignik areas;

(3) determine abundance of pink salmon eggs and preemergent fry. Inclusive of deriving a fecundity-length relationship for selected odd-year Kodiak and Chignik populations; estimating egg retention for populations utilizing selected preemergent fry index streams; and determine total available spawning habitat for these streams;

(4) estimate or derive indicies of overwinter mortality (egg to preemergent fry) of pink salmon eggs;

(5) determine reductions, if any, in pink salmon returns from the 1989 escapement event;

(6) identify potential alternative methods and strategies for restoration of lost use, populations, or habitat where injury is identified.

OBJECTIVES

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METHODS

Stream Life

Stream life for this study is defined as the time span from when an individual pink salmon enters freshwater (counted through a weir or is tagged) until the individual dies (Bocking et al. 1988). It is represented as an average over all fish within a population. During 1989, fish counting weirs were installed on the Akalura, E. Paramanof, and Litnik systems to obtain daily and total escapement counts by species (Figure 2). On a minimum of two and maximum of three day rotational basis, stream foot surveys were conducted and live and dead pink salmon enumerated. Pillar Creek located about 12 km distant from the city of Kodiak, was foot surveyed only. Each survey performed had fish visibility conditions rated as affected by turbidity, water level, and cloud cover.

During 1990, weir stations were operated on the E. Paramanof, Litnik, Pink, Barling, Saltery, and Akalura streams. Daily, upstream migrating salmonids were identified and enumerated by species. Extending through about four weeks of each population's migration, color coded (unique color for each week) 30.5 cm long floy tags were affixed about 2.5 cm below the base of the dorsal fin to about 150 upstream migrants/population/week. Fish used for tagging were captured in a 2.7 m x 5.0 m trap constructed of aluminum weir panels attached to the upstream side of the weir. After tagging, fish were released upstream of the weir; tag color and number of tagged

fish released by date and location were recorded (Table 1). Foot surveys were conducted on a two to three day rotational basis beginning usually a day after tagging, with live and dead tagged (by color code) and untagged fish counted and recorded. Pillar Creek was foot surveyed only. For 1990, foot survey methods were modified so that after being counted, carcasses were removed from the stream bed and gravel bars to prevent double counting on subsequent surveys.

Total Escapement and Commercial Catch Estimation

Pink salmon escapements into Kodiak and Chignik management area streams have been assessed via aerial surveys using fixed wing aircraft and observers for over 30 years. Foot surveys and weir counts are also used for total escapement estimation. Modal "peak" pink salmon counts for a given stream-year are assumed to represent some unknown fraction of the total escapement for each species. Aerial and foot survey conditions were subjectively rated by the observer from poor to excellent depending upon fish visibility within a stream (David Prokopowich, Alaska Department of Fish and Game, Kodiak, personal communication). For this study the historical odd numbered year (odd-year brood line) survey databases for the years 1963-1991 from Kodiak and Chignik were employed to estimate total area wide pink salmon escapements (refer to Data Analysis). The 1989 pink salmon estimated total escapements and catch figures for the KMA were obtained from Barrett et al. (1990) and for the CMA from Barrett (1990).

Total KMA commercial catch numbers for 1963-1985 were extracted from Manthey et al. (1986) and for the years 1987-1991 from the ADF&G Division of Commercial Fisheries fish ticket summary reports. For annual KMA total commercial catch, Kitoi Bay hatchery produced pink salmon were not included. CMA catch numbers 1963-1989 were obtained from Thompson and Owen (1992); catch figures for 1991 were provided by David Owen (personal communication, Alaska Department of Fish and Game, Kodiak).

Total Available Spawning Habitat

Numerous aquatic habitat inventory sampling designs exist; however most are directed at estimating size of resident fish populations and impacts of land use practices (Platts et al. 1983; Frissel 1986; Murphy et al. 1987; Hankin and Reeves 1988). The use of visual classification of habitat units (Hankin and Reeves 1988) and substrate size (Shirazi and Seim 1979) are proven alternatives to designs relying upon direct measurements. According to habitat suitability index models developed by Raleigh and Nelson (1985), substrate size and water velocity have the largest control over spawning success of pink salmon, while substrate embeddedness is also thought to be influential (Platts et al. 1983). We employed visual classification of substrate size, flow velocity, and stream depth coupled with direct stream width measures for estimating total available pink salmon spawning habitat. The paucity of data for Kodiak and Chignik streams regarding habitat unit types (i.e. pools, riffles, and glide areas) precluded using a stratified systematic sampling design.

Table 1. Tagging dates and numbers of tagged fish released for estimating pink salmon stream life, 1990.

	System														
	Barling			Litnik			Akalura			Saltery			E. Paramanof		
Tagging Event	N	Date	Tag Color	N	Date	Tag Color	N	Date	Tag Color	N	Date	Tag Color	N	Date	Tag Color
1	150	8/6-7	Orange	150	8/7	Orange	134	8/27	Orange	150	8/7-8	Orange	150	7/28	Orange
2	150	8/15	Blue	150	8/18	Blue	140	9/3-5	Blue	151	8/14-15	Yellow	150	8/9-10	Yellow
3	150	8/22-23	Yellow							150	8/22-23	Blue	150	8/17-18	Blue
4										150	8/29-30	Pink	150	8/23-24	Pink

Streams utilized by pink salmon for spawning within the KMA and CMA are generally small (less than 10 km in length) second and third order streams with low base flows typically occurring in July-August. Spawning habitat data from 45 KMA and 14 CMA index streams were collected during 1989-1990. Utilizing enlargements of United States Geological Survey (USGS) 1:250,000 topographic maps, individual stream maps were constructed on which fishery managers demarcated observed reaches of historical pink salmon spawner distribution for each stream. Total stream length (km) was measured from maps with a calibrated map wheel. Braided channels, mainstem tributaries, and intertidal areas were included in length measures where applicable. A two stage systematic sampling design incorporating each stream's large scale linear trends in gravel size and flow regime was employed to select a maximum of 60 one-meter strip transects from each stream. Total stream length was divided into 300 m primary units and assigned a number (001 to N). Five primary units were randomly selected employing a random number table, and within each primary unit, a systematic sample of 12 one-meter subunits, spaced 25 m apart were chosen for measurement.

Location of selected primary units was accomplished using maps and helicopter instrumentation. Stream width was measured every 25 m providing 12 stream width measurements per selected primary unit. Measures of stream width were to the nearest 2.5 cm from bank to bank where water depth was greater than 15 cm using a hip chain; islands were excluded. Designation of percent spawning habitat (recorded to nearest 10%) was visually estimated as the overall area of a one meter strip transect with designations founded upon ranges of channel substrate size, stream depth, and velocity (Table 2). Gravel embeddedness was evaluated based upon whether extensive force was needed to loosen substrate materials. Suitable substrate size ranges of 0.6 to 13.7 cm; stream depth greater than 15 cm; and a water velocity range of 0.3 to 0.9 m/s were used in this study component. Habitat was deemed unsuitable for spawning if visual determinations were outside of these ranges (Andrew and Geen 1960; Chambers 1956; Dvinin 1952; Krueger 1981; Neave 1966; Raleigh and Nelson 1985; Wilson et al. 1981).

Fecundity and Egg Retention

Fecundity data (number of eggs per individual) were collected from three KMA streams (Akalura, E. Paramanof, and Litnik) and one CMA (Lake Bay) system in 1989. Sampling was conducted at fish counting weirs for Kodiak streams and with a beach seine measuring 50 m x 2.5 m with 110 mm stretch mesh for the Lake Bay system. Each fish was measured for length (mid-eye to fork-of-tail) to the nearest five mm, and egg skeins extracted. Afterward, each skein was immersed in boiling water and lightly teased to separate individual ovaries, and direct counts of eggs recorded. A total of 301 individuals, 200 from Kodiak, and 101 from Chignik were sampled.

Egg retention data from 34 spawning populations (23 KMA and 11 CMA) were collected during 1989 with a maximum of 150 postspawning females sampled from each population (run). Sampling was structured systematically by selecting every third carcass encountered where concentrations were visually estimated to be less than 1,000 and every fifth carcass for concentrations greater than 5,000. This approach was conceived because of the clumped distribution of carcasses within each stream. All samples were collected after the peak spawning

Table 2. Parameter values employed for estimating pink salmon total available spawning habitat, Kodiak and Chignik Management Area streams.

Spawning Habitat Parameter	Reported Range			Source
	Minimum		Maximum	
Water Velocity	0.4	to	0.8 m/s	Dvinin (1952)
	0.45	to	0.73 m/s	Hourston and Mackinnon (1957)
	0.19	to	0.66 m/s	Wilson et al. (1981)
	0.10	to	1.32 m/s	Graybill (1979)
	0.33	to	0.85 m/s	Andrew and Geen (1960)
Average	0.29	to	0.87 m/s	
Optimum	0.30	to	0.90 m/s	Raleigh and Nelson (1985)
Substrate Partical Size	0.04	to	25 cm (dia.)	Wilson et al. (1981)
	0.3	to	10 cm (dia.)	Andrew and Geen (1960)
	0.3	to	10 cm (dia.)	Chambers (1956)
	2.0	to	10 cm (dia.)	Lucas (1960)
Average	0.66	to	13.75 cm (dia.)	
Optimum	Unknown			
Water Depth	0.2 m			Dvinin (1952)
	0.2	to	7 m	Chambers (1956)
	0.28	to	0.78 m	Graybill (1979)
	0.37	to	0.63 m	Wilson et al. (1981)
Average	0.26	to	2.8 m	
	≥.15 m			Raleigh and Nelson (1985)

period from gravel bars and banks of each stream. The body cavity of each carcass was inspected and direct counts of retained eggs and length (mid-eye to fork-of-tail) recorded to the nearest 1 mm. Carcasses exhibiting signs of predation and those deemed unspawned were noted.

Preemergent Fry Sampling

Preemergent sac fry sampling of KMA index streams has been conducted on an annual or every-other year basis, although sampling did not actually occur in all scheduled years for most streams. The CMA preemergent fry sampling program was discontinued after 1983, however a database of at least eight odd-years were available for analysis. Sampling took place in late February through mid-April, after the period of hatching and early fry development but prior to any significant emergence and emigration having occurred. Numbers of sampling sites (spawning riffles) per stream varies from 2 to 15, and was directly proportional to escapement and stream size. Sampling site selection was based on spawner distribution and habitat usage recorded from aerial surveys; the same riffles were sampled each year. Normally, 10 samples (digs) were taken in an "X"-shaped configuration at a randomly selected site in each riffle. Digs were made with a cylindrical frame benthic sampler that captures material forced out of the substrate by a gas powered hydraulic pump and washed downstream into a five foot long net with attached codend. An aluminum mesh covered the front half of the frame to exclude material washed from upstream, outside of the dig area. The substrate area sampled was 0.18 m^2, and digs were made to a depth of approximately 15 to 47 cm for 1 to 3 minutes. Live and dead fry and eggs were counted separately, and stream temperature, predator presence, stage of fry development, number of egg fragments, and evidence of stream bed scouring and shifts were noted.

DATA ANALYSIS

Stream Life

Estimates of average pink salmon stream life during 1989 for the Litnik and E. Paramanof populations were derived from foot survey and cumulative weir count data, and an area-under-the spawner abundance curve (AUC) method (Johnson and Barrett 1988). Within the computer program employed for the AUC model, a stream life value was estimated iteratively until the resulting escapement estimate based on survey counts (converted to spawner days) converged on the total cumulative weir count, or "true" escapement. A spawner day represents each day that a fish is alive within the surveyed stream reach.

For foot survey data collected during 1990, several approaches were used to estimate average stream-life: (1) total number of spawner days derived from foot survey counts (live fish counts) divided by total escapement counted through the weir; (2) total spawner days obtained from foot surveys (live fish counts) divided by total carcass count; (3) iterated AUC (Johnson and Barrett 1988) method employing tagged fish data (live fish counts) where each tagged fish observed is treated as representing a spawner day; (4) iterated AUC method with tagging data adjusted for estimated proportion of tagged fish detectable; (5) iterated AUC method employing tagged carcass counts and total number of carcasses of a color code.

Adjustment of tagging data was founded upon the assumption that not all live tagged fish within the surveyed stream reach are visible to the observer (Perrin and Irvine 1990). We further assumed that: (1) the proportion of live tagged fish from the j^{th} release that were detectable was independent of survey date and release date; and (2) all fish from the initial release of a tag color remained alive for at least one day after their release. Let $N_{i,j,k}$ denote the number of tagged fish from the j^{th} release for the k^{th} stream that remain alive i days after release, noting that $N_{0,j,k}$ is the number of tagged fish released. Also, let $Ct_{i,j,k}$ equal the survey count of live fish from the j^{th} release in the k^{th} stream i days after release. From assumptions (1) and (2) above, the estimated proportion of live tagged fish from the j^{th} release detectable in stream k (P_{jk}) was estimated by:

$$\hat{P}_{jk} = \frac{Ct_{1,j,k}}{N_{0,j,k}} . \qquad (1)$$

Then, we estimated $N_{i,j,k}$ for i greater than one by:

$$\hat{N}_{i,j,k} = \frac{Ct_{i,j,k}}{\hat{P}_{j,k}} . \qquad (2)$$

Estimated Total Escapement

Historically within the KMA and CMA "peak" aerial and foot survey counts have been used to index pink salmon escapements. Owing to a number of factors peak counts represent only a fraction of the estimated total escapement (Cousens et al. 1982). Total pink salmon escapements for Kodiak and Chignik streams during 1989 were estimated using aerial and foot survey counts, an AUC model (Johnson and Barrett 1988) and a 15 d stream life value (Barrett et al. 1990; Barrett 1990). During 1989 for both areas more streams were surveyed and with greater frequency than any year on record. Performance of the AUC model improves (increased accuracy of escapement estimates) as survey frequency increases.

For the KMA odd-year 1963-1991 stream survey databases, both the frequency and number of streams surveyed were substantially less than in 1989, therefore the methods employed during 1989 were not used. However, 1989 estimated total escapements were employed for expanding odd-year (1963-1991) peak counts.

Estimating total escapements by year (ETE_j) incorporated the sum of peak aerial and foot survey counts for n streams in year j ($PC_{.j}$), index stream peak counts (PC_j^*), sum of all weir counts ($WC_{.j}$; assumed to be total escapement); and expansion factors $PCXF_{89}$ (expands PC_j's) and EDXF (which allows for estimating pink salmon escapements into streams not surveyed in year j) where;

$$PC_{.j}=\sum_{i=1}^{n_j} PC_{ij}, \tag{3}$$

$$PCXF_{89}=\frac{ETE_{89}}{PC_{89}}, \tag{4}$$

and

$$EDXF=\frac{\sum_{j=0}^{9} PC_{1969+2j}}{\sum_{j=0}^{9} PC^{*}_{1969+2j}}. \tag{5}$$

The KMA escapement distribution expansion factor (EDXF) used aerial and foot stream survey coverage data from odd-years 1969-1987. The total pink salmon escapement for a given year within an area was estimated by

$$ETE_j=PC_{.j}*PCXF_{89}*EDXF+WC_{.j}. \tag{6}$$

The KMA peak count (PC_j) to estimated total escapement (ETE_j) expansion factor ($PCXF_{89}$) was estimated to be 1.84 (Appendix A.1; Barrett et al. 1990); and the EDXF expansion factor was 1.06 (Appendix A.2).

The CMA $PCXF_{89}$ was estimated to be 1.20 (Appendix B.1; Barrett 1990); and the EDXF using data from 1969-1983 was 1.17 (Appendix B.2). Within the Chignik area for 1985-1991, estimated total escapements were derived using the AUC model (Johnson and Barrett 1988) and a 15 d stream life value (Barrett et al. 1990); adjustment for escapement distribution was also performed.

Total Available Spawning Habitat

Total available spawning habitat estimates for KMA and CMA pink salmon index streams employed the following equations from Cochran (1977) incorporating variance estimator modifications for systematic sampling by Wolter (1984), provided by B. Alan Johnson (Alaska Department of Fish and Game, Commercial Fisheries memorandum 9 February, 1990). Estimates for each stream's total available spawning habitat were derived by:

$$\hat{Y}=\frac{N}{n}\sum_{i=1}^{n} M_i\overline{Y}_i \;; \qquad (7)$$

where the sample mean for the i^{th} primary unit is equal to

$$\overline{Y}_i=\sum_{i=1}^{m_i} \frac{y_{ij}}{m_i}\;; \qquad (8)$$

and the overall sample mean per subunit is

$$\overline{y}=\sum_{i=1}^{n} \frac{\overline{Y}_i}{n}\,. \qquad (9)$$

For these equations n represents number of primary units sampled, N depicts total number of possible primary units, m_i number of subunits sampled within the i^{th} primary unit, M_i the total number of subunits within the i^{th} primary unit, and y_{ij} the measurement for the j^{th} subunit within the i^{th} primary unit. The variance estimator for total available spawning habitat is:

$$var\ \hat{y}=N^2\frac{(1-f_1)}{n}S_1^2+\frac{N}{n}\sum_{i=1}^{n}\frac{M_1^2(1-f_{2i})S_{2i}^2}{m_i}\,, \qquad (10)$$

which includes

$$s_1^2=M_i^2\sum_{i=2}^{n}\frac{(\overline{Y}_i-\overline{Y}_{i-1})^2}{2(n-1)} \qquad (11)$$

and

$$s_{2i}^2=\frac{1}{nm_i}\sum_{j=2}^{m_i}\frac{(y_{ij}-y_{i,j-1})^2}{2(m_{i-1})}\,, \qquad (12)$$

where f is the sampling fraction n/N for primary units, and f_{2i} equals m_i/M_i which is the sampling fraction of subunits within the i^{th} primary unit. Several Kodiak index streams (Russian River, Seal Bay, Geographic, and Alinchak Creeks) did not have complete surveys conducted, while two systems had all available subunits measured (Bauman's and Big Waterfall Creeks).

Total available spawning habitat estimates for each index stream were employed to derive spawner densities by dividing the 1989 estimated total escapement by the estimated spawning habitat for that stream, expressed as number of fish per m^2 of spawning habitat. Spawner density was used as an independent variable for analyses incorporating egg retention and preemergent fry data.

Fecundity and Length

We modeled the dependence of fecundity (F) on length (L) for the fecundity-length data collected from Litnik, E. Paramanof, Akalura, and Lake Bay as

$$F=\beta_o+\beta_1 L+\beta_2 Z_1+\beta_3 Z_2+\beta_4 Z_3+\beta_5 Z_1 L+\beta_6 Z_2 L+\beta_7 Z_3 L, \qquad (13)$$

where

$$Z_1=\begin{cases}1, & if\ Litnik\ sample\\ 0, & otherwise,\end{cases}$$

$$Z_2=\begin{cases}1, & if\ Paramanof\ sample\\ 0, & otherwise,\end{cases}$$

and,

$$Z_3=\begin{cases}1, & if\ Akalura\ sample\\ 0, & otherwise.\end{cases}$$

The model given by equation (13) allows the fecundity-length data from each of the four streams to be fit by a unique linear relationship. We therefore refer to equation (13) as the "full model" for fecundity on length. In contrast is the "reduced model", which allows for only one linear equation to describe the fecundity-length relationship for data from all populations as

$$F=\beta_0+\beta_1 L. \qquad (14)$$

Our interest was not with the exact values of the parameters β_2 through β_7 but whether these parameters differ significantly from zero. If β_2 through β_7 are zero, then the full model in equation (13) reduces to equation (14); i.e., zero values for these parameters indicate that a single linear equation is sufficient to describe the fecundity-length relationship within each of these four populations. However, if any of the β_2 through β_7 parameters differ from zero, then a single linear equation would erroneously describe the fecundity-length relationship within each of the four streams. We tested the adequacy of the reduced model relative to the full model by analysis of variance (Kleinbaum and Kupper 1978). The null hypothesis for the test was,

$$H_o: \beta_2=\beta_3=....=\beta_7=0,$$

versus the alternative hypothesis,

$$H_a: \beta_i \neq 0, \textit{ for at least one } i=2,3,...7.$$

The null hypothesis states that the fecundity-length relationship for each of the four samples falls on the same line. Deriving a single fecundity-length equation would allow for estimating pre-spawning fecundity for egg retention samples, potential egg deposition by index stream, and subsequently egg to preemergent fry survival.

Egg Retention

Conceptually for the egg retention data, we hypothesized that there should be a positive effect of spawner density (number of fish per m^2 of spawning habitat) on egg retention by individuals of a given population. To test this hypothesis we fit the data to a logistic model (Cox and Snell 1989),

$$P(ER_i=0)=\frac{\exp\beta_0+\beta_1\ln(D_i)}{1+\exp(\beta_0+\beta_1\ln(D_i))}, \tag{15}$$

where $P(ER_i=0)$ is the probability that a female from stream i retains no eggs after spawning, and D_i is the density of spawners in stream i. Negative values for the β_1 parameter in the above model indicate that the probability of a female retaining no eggs, decreases with increasing spawner density. Therefore, negative values for β_1 are consistent with a positive effect of spawner density on egg retention.

Spawner Success Of 1989 Brood Year

Linear regression analysis of preemergent fry sampling data prior to 1990 was performed for each stream to test dependence of fry density on several independent variables. Live fry density will be referred to as fry/m^2: live fry in all digs from a stream-year divided by total m^2 sampled. The independent variables were:

(1) total progeny density (TP/m^2): live and dead fry and eggs divided by m^2 sampled;
(2) egg to fry survival: live fry divided by total progeny;
(3) proportion of digs with progeny: number of digs with progeny divided by total number of digs;
(4) spawning activity index: total progeny multiplied by proportion of digs with progeny;
(5) spawning density index: total progeny divided by proportion of digs with progeny.

The fry/m^2 versus TP/m^2 relationship was consistently the most linear fit to the data, and for some streams linearity was further improved by logarithmic or square root transformations of one or both variables. Fry/m^2 on TP/m^2 models, with or without transformations, were used to test for depression in 1989 spawner success (i.e., low fry/m^2 relative to TP/m^2). Observed 1990 TP/m^2 values were entered into these models to generate corresponding predicted fry/m^2 values and $\alpha=0.10$ critical values of fry/m^2 for depression (one-tailed) to which observed 1990 fry/m^2 values were compared. Probabilities of fry/m^2 values less than or equal to those observed in 1990 were also calculated employing the TP/m^2 values and regression models. There were 47 streams (KMA and CMA combined) each with a database containing greater than 3 years of data for model construction. Employing data from all years, rather than only those associated with the odd-year brood line, improved model fit and allowed more streams to be analyzed. We hypothesized that survival of eggs to live fry after deposition is likely to depend on environmental factors and progeny density rather than on brood year.

The 1989 brood year spawner success was assessed by comparing 1990 fry/m^2 for the index streams to odd-year brood line historical fry/m^2 averages, standard deviations of the averages, and 90% confidence intervals of the averages (Appendix A.3).

Relationship Between Spawner and Live Fry Densities

The nonparametric Mann-Whitney "U" test compares rank sums for two groups of data that have been combined and rank ordered from lowest to highest (Zar 1984). This test was employed to make several comparisons of fry yield and spawner abundance using two indices of spawner abundance:

(1) spawner density: 1989 estimated total escapement for stream i (ETE_{i89}) divided by the estimated total available spawning habitat for stream i (ESH_i),

$$D_i = \frac{ETE_{i89}}{ESH_i}; \qquad (16)$$

(2) the difference or standardized residuals (E_{di}), in standard deviations of ETE_{i89} stream i

minus the odd-year average ($\bar{X}_{eod}$) divided by the standard deviation of average odd-year brood line escapement ($\#SD_{eod}$):

$$E_{di} = \frac{ETE_{i89} - \bar{X}_{eod}}{SD_{eod}} . \qquad (17)$$

This represents the 1989 escapement relative to the historical odd-year average escapement in terms of standard deviations of the historical odd-year average escapement. Our hypothesis regarding this study component is:

H_o: fry production increases as escapement increases for stream i versus the alternative hypothesis,
H_a: fry production decreases when escapement is above some level $\in'$.

Alternatively stated, fry production should tend to increase with increasing escapement level unless overescapement with associated density dependent mortality of eggs and fry occurs, resulting in reduction of fry produced. Therefore, index streams with very high escapements or spawner densities, might show either an increase or decrease in fry yield relative to streams with less extreme escapements.

To test whether streams that showed depressed spawner success (i.e. lower fry/m^2 relative to TP/m^2) by 1989 spawners had significantly higher spawner abundance than streams that did not show such depression, the ranks of the two indices were compared between the two stream groups in a one-tailed "U" test at $\alpha=0.10$.

Additionally, two relationships were tested for comparing fry yields between index streams with moderate spawner density and those with high spawner density: (1) D_i vs. fry/m^2; and (2) $\#SD_{esc}$ vs. $\#SD_{fry}/m^2$, which are the differences in standard deviations that 1989 escapements and 1990 fry/m^2 were from the historical odd-year brood line average escapement, and fry/m^2, respectively. To stratify streams into two groups for the first of these two-tailed "U" tests at $\alpha=0.10$, individual streams were ranked in order of increasing spawner density with cumulative spawner density calculated stepwise along this ascending order (Table 3). Moderate spawner density streams were those with cumulative spawner density less than the spawner density cut off point of 1.4 fish/m^2, derived from the midpoint escapement goal and spawning habitat estimates (Table 3; Appendix A.4). The moderate strata included Kodiak streams with individual spawner densities ranging from 0.09 to 4.35 fish/m^2. All other streams were designated as having high spawner density (range 5.68 to 60.9 fish/m^2). For the second of these tests, moderate escapement streams were those for which $\#SD_{esc}$ was less than 2 (range for Kodiak streams was -0.94 to 1.82), and high escapement streams were those for which 2 was less than $\#SD_{esc}$ (2.08 to 18.40 for Kodiak). All Mann-Whitney tests were conducted separately for Kodiak and Chignik streams because these areas experience considerably different abiotic conditions. Comparisons of fry yield between streams with moderate and high spawner abundances could not be made for Chignik, owing to a lack of streams with high spawner abundance.

Table 3. Moderate and high spawner density index streams of the preemergent fry sampling program, 1989 brood year.

Stream Name	Stream No.	Stream Specific Density: Spawner (fish/m²)	Stream Specific Density: Live Fry (fry/m²)	Cummulative: Spawning Habitat (m²)	Cummulative: Escapement (No. of fish)	Cummulative: Spawner Density (fish/m²)
Moderate Spawner Density Streams (Kodiak Management Area)						
Narrows	257-401	0.095	264.76	21,917	2,097	0.095
Karluk	255-101	0.132	0.08	853,844	111,977	0.131
Kukak	262-271	0.178	6.73	875,101	115,779	0.132
Marka	252-343	0.347	10.32	935,000	136,573	0.146
E. Paramanof	251-404	0.480	278.27	976,775	154,991	0.159
Zachar	254-301	0.889	12.06	1,094,540	258,974	0.237
Sheratin	259-371	1.714	39.85	1,164,507	378,917	0.325
Barling	258-522	1.900	51.70	1,242,067	526,340	0.424
Dakavak	262-551	1.902	0.36	1,276,702	592,250	0.464
Dog Salmon	257-403	2.290	179.86	1,414,457	907,809	0.642
Kashvik	262-604	2.348	0.81	1,534,814	1,190,409	0.776
Sid Old's	259-242	2.370	116.41	1,593,752	1,330,077	0.835
Kinak	262-451	2.415	161.66	1,616,239	1,384,404	0.857
Kiliuda	258-207	3.068	77.01	1,638,977	1,454,166	0.887
Little R.	253-115	3.097	5.62	1,701,348	1,647,333	0.968
Perenosa	251-830	3.274	72.29	1,730,571	1,743,033	1.007
Miam	259-412	3.655	118.56	1,784,208	1,939,120	1.087
American	259-231	3.910	255.97	1,877,741	2,304,503	1.227
Saltery	259-415	3.937	521.49	1,932,226	2,519,044	1.304
Jute	262-801	4.257	14.54	1,937,699	2,542,347	1.312
Hurst	259-414	4.351	102.65	1,970,451	2,684,882	1.363
High Spawner Density Streams (Kodiak Management Area)						
Buskin	259-211	5.689	89.75	2,018,396	2,957,667	1.465
Terror	253-331	6.625	0.75	2,080,416	3,368,580	1.619
Uyak-202	254-202	6.479	1,070.00	2,179,998	4,013,737	1.841
Missak	262-402	6.369	131.75	2,185,651	4,049,857	1.853
Kanatak	262-802	6.883	186.68	2,208,656	4,208,207	1.905
Bauman's	253-332	7.674	240.71	2,254,698	4,561,540	2.023
Deadman	257-502	9.679	546.94	2,367,674	5,655,083	2.388
Oil	262-751	10.300	225.90	2,378,890	5,770,695	2.426
Humpy	257-701	10.380	464.79	2,550,629	7,553,891	2.962
Kaiugnak	258-542	14.400	736.78	2,558,844	7,672,214	2.998
Uganik	253-122	16.530	9.42	2,606,981	8,468,113	3.248
Big Creek	262-851	26.460	131.75	2,685,530	10,546,546	3.927
Portage	262-702	29.640	2.33	2,690,215	10,685,426	3.972
Seal	251-901	38.730	869.79	2,690,370	10,691,426	3.974
Danger	252-332	46.690	292.54	2,691,210	10,730,633	3.987
Seven Rivers	258-701	60.880	383.53	2,711,190	11,923,316	4.398
L. Waterfall	251-822	63.530	70.00	2,712,864	12,029,663	4.434
Alinchak[a]	262-651	160.900	27.28	2,716,230	12,571,490	4.628
Moderate Spawner Density Streams (Chignik Management Area)						
Portage	272-842	0.062	64.22	19,107	1,200	0.063
Spoon	273-823	0.071	0.00	42,759	2,900	0.068
Ivan R.	273-722	0.169	13.68	231,759	34,900	0.151
North Fk.	272-702	0.197	0.00	360,596	60,397	0.167
Amber Ck.	272-703	0.264	0.00	560,637	113,397	0.202
Hook Bay	272-302	0.293	0.00	713,881	158,397	0.222
Humpback	275-502	0.462	65.59	824,175	209,397	0.254

-Continued-

Table 3. (page 2 of 2)

Stream		Stream Specific Density		Cummulative		
Name	No.	Spawner (fish/m^2)	Live Fry (fry/m^2)	Spawning Habitat (m^2)	Escapement (No. of fish)	Spawner Density (fish/m^2)
Foot Bay	273-802	0.575	227.79	842,955	220,197	0.261
Ivanof	275-406	0.655	200.65	1,099,678	388,600	0.353
Agripina	272-961	0.701	279.66	1,217,443	471,192	0.387
Chiginagak 905	272-905	1.639	180.85	1,271,727	560,192	0.440
Chiginagak 904	272-904	1.662	0.18	1,290,972	592,192	0.459
Kumliun	272-501	3.693	2.56	1,315,206	681,691	0.518

[a] Based upon incomplete spawning habitat survey.

Return Per Spawner Analyses

Spawner-recruit curves were fit to odd brood year (1963 to 1989) pink salmon escapement and return data from the Kodiak and Chignik management areas, separately. We used the models of Ricker (1954) and Beverton and Holt (1957) as two competing models for the spawner-recruit curve. For the Ricker model, number of returns (recruits) R_i, resulting from number of spawners, S_i, in year i is modelled as,

$$R_i=\beta_1 S_i \exp(-\beta_2 S_i) , \qquad (18)$$

while for the Beverton-Holt model the relationship is modelled as,

$$R_i=\frac{1}{\beta_1+\beta_2/S_i} . \qquad (19)$$

For both models the parameters β_1 and β_2 are constrained to be non-negative. Non-zero values of β_2 in both models define a negative effect of spawner numbers on subsequent returns per spawner. In both models, R_i will be 0 when S_i is 0, but the two models differ in the density dependent response in R_i to increasing values of S_i. For the Ricker model, R_i has a maximum value of $S_i=(\beta_2)^{-1}$ which is the carrying capacity of the environment for recruits, and decreases to 0 as S_i increases to ∞. The Ricker β_1 represents the estimated maximum return per spawner, commonly referred to as the productivity parameter. For the Beverton-Holt model R_i increases asymptotically to $(\beta_1)^{-1}$ as S_i increases to ∞.

We computed maximum likelihood estimates (MLE's) of the parameters for both models using the transform-both sides (TBS) methodology of Carrol and Ruppert (1988). Following Carrol and Ruppert, we used the modified power transformation of Box and Cox (1964) as the transforming function. MLE's were computed using the "pseudo-model" approach of Carrol and Ruppert and the nonlinear estimation routines (NONLIN) of SYSTAT (Wilkinson 1990).

RESULTS

Stream Life Estimates

Data collection from the Akalura system in 1989 suffered from poor survey conditions and high stream flow, therefore stream life was not estimated. Pink salmon stream life for East Paramanof Cr. (escapement of 20,561) and the Litnik R. (escapement of 7,477) populations averaged 8.5 and 8.3 days, respectively (Table 4).

Table 4. Stream life estimates derived using weir escapement, cumulative carcass, adjusted and not adjusted tagged fish counts from Kodiak Management Area pink salmon populations during 1989-1990.

Stream					Stream Life Estimate (Days)									
					Tagging Event									
					1		2		3		4		Avg.	
Name	Number	1989[a]	1990[a]	CC[b]	N_{adj}[c].	Adj.	N_{adj}.	Adj.	N_{adj}.	Adj.	N_{adj}.	Adj.	N_{adj}.	Adj.
Barling Cr.	258-522		7.9	15.4	10.4	15.4	7.3	15.1	7.7	14.8			8.5	15.1
Litnik R.	252-342	8.5	6.7		4.0	8.1	2.6	6.3					3.3	7.2
Pink Cr.			6.5	6.8										
Akalura Cr.	257-302	d	3.5	5.9	7.5	9.7	4.3	10.0						
Pillar Cr.	259-101			16.4										
Saltery Cr.	259-415		13.8	15.8	19.1	26.1	13.8	18.7	10.5	14.6	11.2	13.2	13.7	18.1
E.Paramanof	251-405	8.3	14.4	14.2	7.9	11.8	4.0		4.2	11.5	3.8	6.4	5.0	9.9
Average		8.4	8.8	12.4	9.8	14.2	6.4	12.5	7.5	13.6	7.5	9.8	7.6	12.6

[a] Area under the curve method employing foot survey and weir counts.
[b] Cumulative spawner days from foot survey counts divided by cumulative carcass counts.
[c] Stream life estimated using tagged fish survey data not adjusted for visibility.
[d] Data excluded due to high water conditions.

The 1990 stream life estimates derived from cumulative spawner days divided by total enumerated escapement were: 7.9 d Barling Cr., 6.7 d Afgonak R., 6.5 d Pink Cr., 3.5 d Akalura Cr., 13.8 d Saltery Cr., and 14.4 d East Paramanof Cr. (Table 4); the average over all populations was 8.8 days. Stream life estimated by cumulative spawner days divided by cumulative carcass counts were: 15.4, 6.8, 5.9, 16.4, 15.8, and 14.4 days for the Barling, Pink, Akalura, Pillar, Saltery, and East Paramanof systems; the average over all populations was 12.4 days.

Estimates using live tagged fish were completed for the East Paramanof and Saltery Creek's populations using all four tag colors with about 7-10 days separating each tagging event. Escapements into these systems were 21,749 and 4,556 fish, respectively (Appendix A.5). For the other three populations only two to three tag colors were used. Adjusting estimates for tagged fish visibility (tagged fish detectable P_{jk}) increased the unadjusted estimates by 2.6 to 10.0 days. A trend of decreasing stream life over time for the earliest to latest tagging events was observed for the East Paramanof, Saltery, and to a lesser extent Barling populations. Averages over all populations by tagging event, not adjusted were: 9.8 d, 6.4 d, 7.5 d, and 5.5 d. Adjusted estimates by event were: 14.2 d, 12.5 d, 13.6 d and 9.8 d (Table 4). A three day moving average of weir escapement counts for Barling, Saltery, and East Paramanof Creeks depicts tagging events by population, relative to escapement distribution (Figure 5).

Pink salmon stream life estimates generated from tagged fish carcass recovery data averaged over all tag colors for a population were: 17.9 d, 14.6 d, 15.6 d, and 11.4 d (Table 5). A decreasing trend in average stream life by date was observed.

Estimated Total Escapement and Commercial Catch

Kodiak Management Area odd-year brood line ETE_j's (1963-1991) averaged 4.9 million (range 1.21 to 21.0; Table 6). Commercial harvests excluding 1989, have ranged from 0.18 million to 15.25 million. The total return from the 1989 escapement was 21.63 million or about 1.02 returns per spawner; odd-year escapement goals range from 2.3 to 7.0 million with a midpoint of 4.67 (Appendix A.4; Barrett et al. 1990). The midpoint goal has been reached four times during 1963-1987. Escapement and run data (1969-1989) by fishing district depict the 1991 run was greater than average (1969-1987) for all districts except the Northeast District, which was slightly above average (Appendix A.6; Figure 6).

Within the CMA estimated escapements ranged from 0.21 million to 1.13 million. The 1989 escapement of 1.45 million was 2X both the escapement goal and 1963-1987 average escapement. Commercial harvests have averaged 0.7 million (range 25,000 to 1.87 million). The return from the 1989 escapement was 1.96 million (1.34 returns per spawner), whereas the odd-year average (1963-1987) is 1.41 million (Table 7). The escapement goal of 0.7 million has been exceeded five times during 1963-1987.

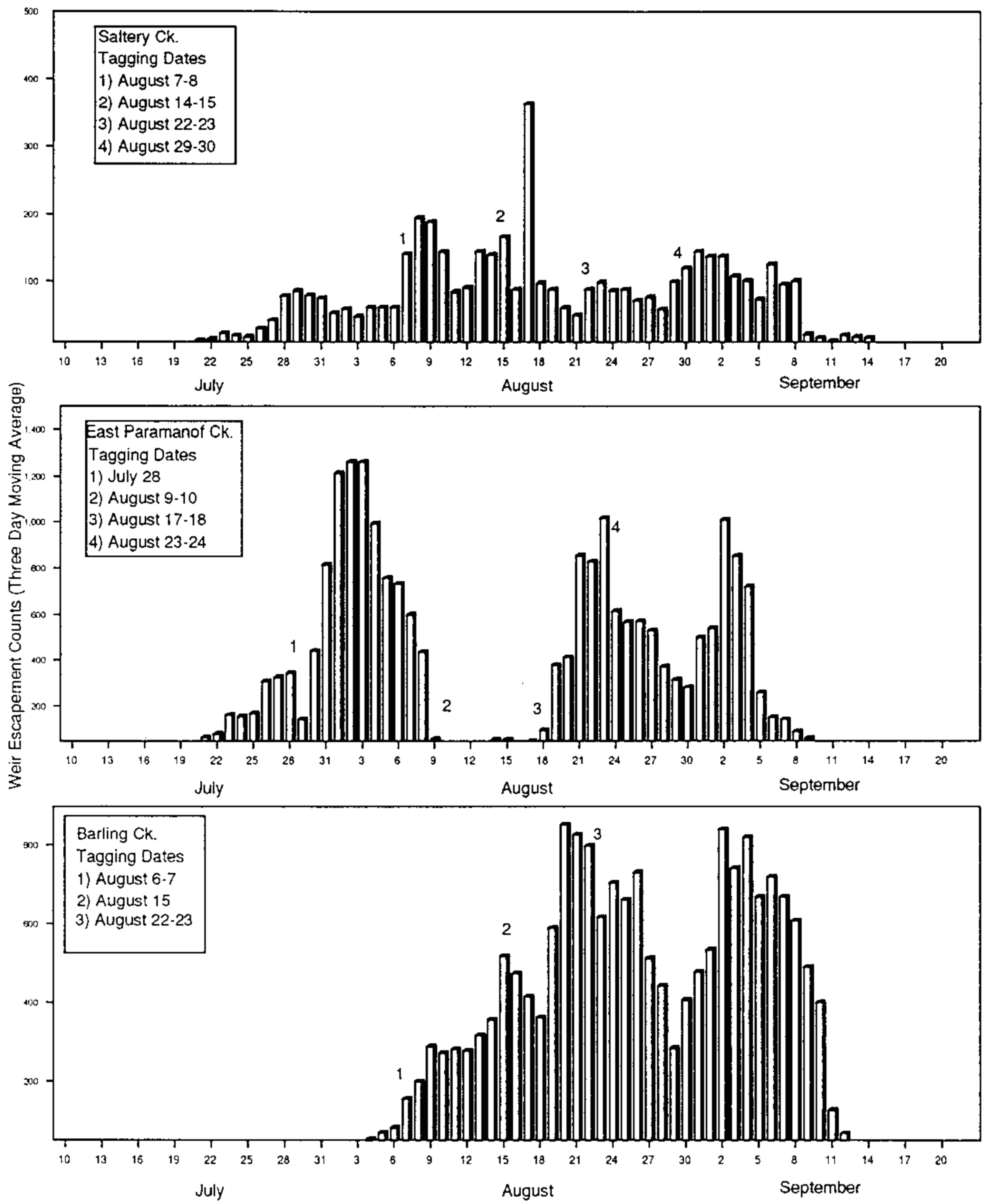

Figure 5. Three day moving average of daily escapement counts by system depicting tagging events in relation to escapement distribution.

Table 5. Stream life estimates derived for selected Kodiak pink salmon populations using color coded tagged fish carcass recoveries, 1990.

Stream		Stream Life Estimate by Tagging Event (Days)			
Name	Number	1	2	3	4
Barling Cr.	258-522	19.9	17.6	17.3	
Litnik R.	252-342	10.1	8.4		
Akalura Cr.	257-302	13.4	8.0		
Saltery Cr.	259-415	25.1	18.9	14.8	13.4
E.Paramanof Cr.	251-405	21.4	20.2	14.8	9.5
Average		17.9	14.6	15.6	11.4

Table 6. Kodiak Management Area odd-year pink salmon escapements, commercial catch, average weight, return, and return per spawner, 1963-1989.

Brood Year	Estimated Total Escapement	Commercial Catch Numbers	Commercial Catch Mean Weight (kg)	Return	Return/ Spawner[a]
1963	2,554,969	5,480,000	1.5	8,034,969	1.92
1965	2,026,981	2,886,831	1.7	4,913,812	1.19
1967	2,231,335	187,813	1.9	2,419,148	6.99
1969	3,110,525	12,492,576	1.8	15,603,101	2.13
1971	2,293,556	4,332,994	1.7	6,626,550	0.75
1973	1,213,496	511,708	1.8	1,725,204	4.30
1975	2,284,854	2,942,801	1.9	5,227,655	4.63
1977	4,334,716	6,250,667	1.9	10,585,383	3.88
1979	5,709,497	11,121,333	1.7	16,830,830	2.62
1981	5,802,258	9,183,467	1.7	14,985,725	1.44
1983	3,902,959	4,474,760	1.6	8,377,719	2.45
1985	5,710,970	3,886,501	1.6	9,597,471	1.55
1987	4,869,933	4,013,509	1.6	8,883,442	4.36
1989	21,084,539	183,235	1.3	21,267,774	1.02
1991	6,381,344	15,252,123	1.3	21,633,467	
Average	4,900,795	5,546,687	1.7[b]	10,447,483	2.94[c]

[a] Return is from brood year+2.
[b] Average weight excluding 1989 and 1991.
[c] Excluding 1989.

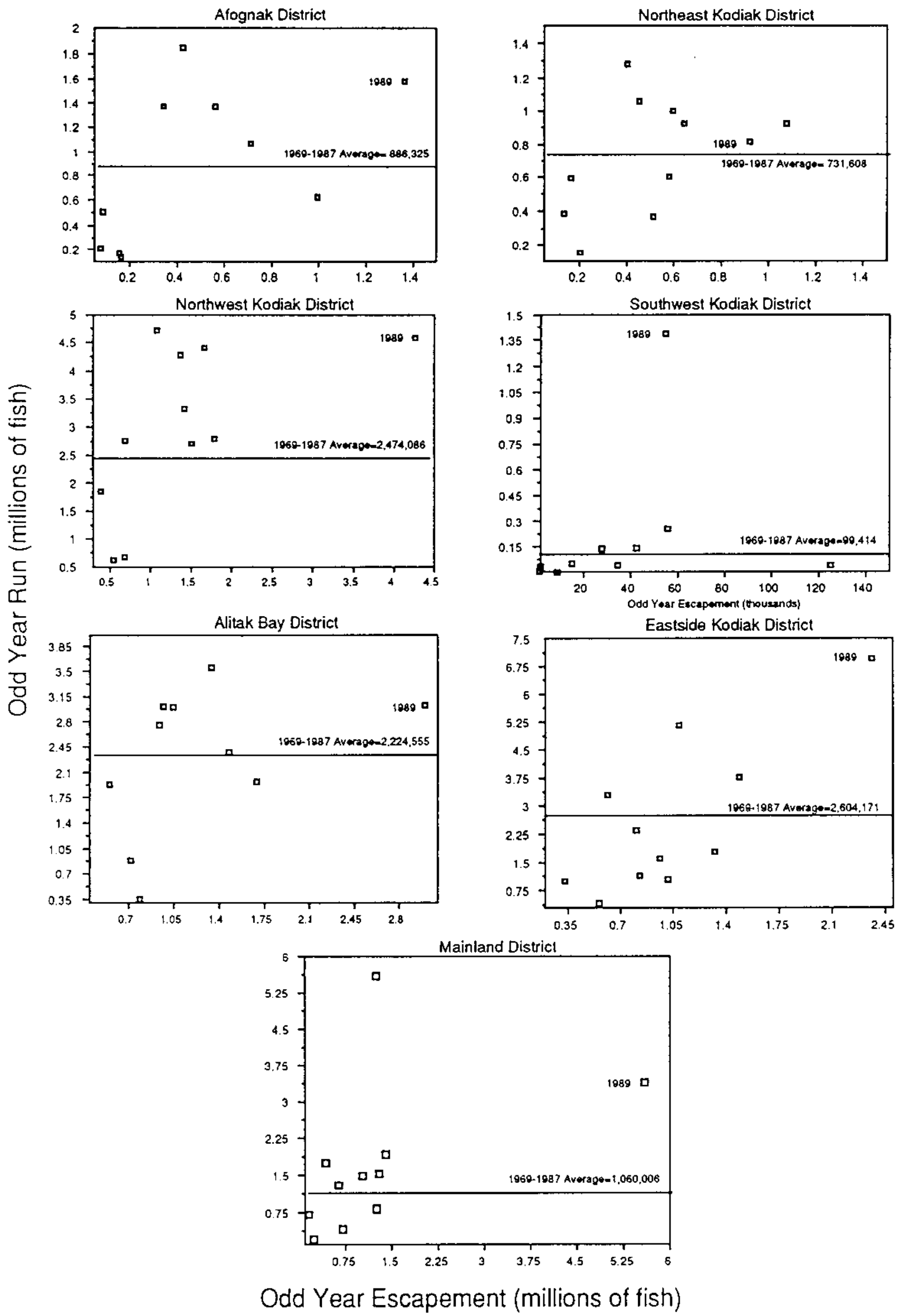

Figure 6. Kodiak Management Area odd year pink salmon estimated escapements, catch, and run numbers by fishing district, 1969-1991.

Table 7. Chignik Management Area odd-year pink salmon escapements, commercial catch, return, and return per spawner, 1963-1989.

Brood Year	Estimated Total Escapement	Commercial Catch	Return	Return/ Spawner[a]
1963	930,032	1,662,400	2,592,432	1.73
1965	494,437	1,117,100	1,611,537	1.12
1967	447,574	108,300	555,874	6.23
1969	1,010,858	1,779,800	2,790,658	1.14
1971	549,067	612,300	1,161,367	0.42
1973	209,438	25,500	234,938	1.81
1975	313,432	66,200	379,632	5.07
1977	987,032	604,700	1,591,732	3.04
1979	1,130,518	1,876,600	3,007,118	1.72
1981	787,072	1,162,600	1,949,672	0.67
1983	209,043	321,100	530,143	3.36
1985	528,989	175,000	703,989	1.20
1987	390,309	246,800	637,109	3.79
1989	1,453,450	27,712	1,481,162	1.34
1991	788,861	1,169,248	1,958,109	
Average	682,007	730,357	1,412,364	2.41[b]

[a] Return is from brood year+2.
[b] Excluding 1989.

Estimated Spawning Habitat and Spawner Densities

Within the KMA 46 of 51 aerial survey index streams had total available spawning habitat data collected. The Karluk and Ayakulik Rivers are the largest within the KMA and provide the greatest amount of spawning habitat 829,515 m^2 and 364,644 m^2, respectively (Table 8). However, both are even brood year dominant systems (Donnelly 1983). For odd-year dominant systems Humpy, Deadman, Kashvik, and Zachar Creeks along with the Dog Salmon River, all had greater than 100,000 m^2 of estimated spawning habitat. Spawner densities for these systems varied from 0.89 fish/m^2 (Zachar Cr.) to 10.38 fish/m^2 (Humpy Cr.). Spawner densities for all index streams ranged from 0.01 to 60.8 fish/m^2. Coefficients of variation (CV) for most streams were less than 10% (range 0.1% to 277.0%).

Within the CMA, 14 index streams had spawning habitat estimates generated, ranging from 17,885 m^2 to 256,723 m^2; coefficients of variation were all less than 10% (Table 9). Spawner densities between systems were variable with most substantially lower than estimates from the KMA. The Amber and Foot Bay systems both had spawning habitat estimated with incomplete surveys.

Fecundity

Of the four populations sampled for fecundity and length, East Paramanof Cr. pink salmon were the smallest in length ($\bar{X}_l$=465 mm) and least fecund ($\bar{X}_f$= 1,312 eggs/female). Alternatively, Akalura Cr. fish were the largest and most fecund (X_l=483 mm;X_f=1,627 eggs/female). The two northern populations (East Paramanof and Litnik) were the smallest as compared to the Akalura and Lake Bay populations located about 162 and 405 km respectively, to the south (Table 10).
Testing for differences between each population's linear relationship of fecundity on length provided an F statistic value of 9.38 with 6 and 293 df; we therefore rejected the null hypothesis (no significant difference of fecundity on length between populations) with P less than 10^{-8} (Table 11; Figure 7). We determined the fecundity-length relationship differs between pink salmon from the four populations sampled. Fecundity, according to our analysis does vary positively with body length within a given locality, however no single fecundity-length relationship was applicable to all localities. Therefore, no attempt was made to apply a single fecundity-length relationship to estimate fecundity for populations sampled for egg retention or preemergent fry.

Egg Retention

There were 4,743 carcasses examined from 34 spawning populations, 128 fish overall were designated unspawned. Egg retention from the Kodiak and Chignik pink salmon populations varied from zero to intact egg skeins. Mean egg retention for all populations ranged from 1.5 to 146.0 eggs/female with corresponding spawner densities of 0.2 to 60.8 fish/m^2 (Table 12).

Table 8. Estimates of total available spawning habitat and 1989 spawner densities for Kodiak Management Area aerial survey escapement index streams.

Stream			Spawning Habitat (m^2)				1989 Spawner Density
Name	Number	Length (km)	Est.	SD	CV	m_i[a]	(No. Fish/m^2)
Afognak District							
Malina Cr.	251-105	4.8	5,524	330.8	5.9	60	0.73
E. Paramanof Cr.	251-404	5.6	41,346	917.3	2.2	60	0.48
Big Waterfall Cr.	251-821	0.5	1,488	411.2	27.6	7	3.09
Portage Cr.	251-830	2.4	29,223	1,120.1	3.8	60	-[b,c]
Seal Bay Cr.	251-902	1.2	103	39.2	38.1	16	-[b,c]
Danger Cr.	252-332	6.4	839	138.9	16.6	60	46.73
Afognak R.	252-342	2.4	27,864	481.9	1.7	60	1.49
Marka Cr.	252-343	6.2	58,724	1,416.2	2.4	60	0.35
Northwest Kodiak District							
Sheratin Cr.	252-371	6.4	67,847	1,287.6	1.9	60	-[b,c]
Little R.	253-115	14.4	62,370	1,223.2	1.9	60	3.10
Uganik R.	253-122	7.6	46,903	3,536.9	7.5	60	8.76
Terror R.	253-331	14.8	61,192	2,032.5	3.3	60	6.64
Baumans Cr.	253-332	.6	44,646	1,733.1	3.9	48	7.91[c]
Browns Cr.	254-204	5.1	40,177	1,642.4	4.1	60	1.59
Uyak Cr.	254-202	5.6	97,818	1,112.2	1.1	60	6.59
Zacher Cr.	254-301	12.8	116,852	2,391.7	2.0	60	0.89
Southwest Kodiak District							
Karluk R.	255-101	34.4	829,515	5,437.2	<0.1	60	0.13
Ayakulik R.	256-201	38.4	364,644	3,460.6	<0.1	60	0.12
Sturgeon R.	256-401	22.4	178,278	1,668.2	<0.1	60	0.01
Alitak Bay District							
Narrows Cr.	257-401	5.6	21,532	803.8	3.7	60	0.10
Dog Salmon R.	257-403	6.8	137,754	2,059.0	1.5	60	2.29
Deadman Cr.	257-502	8.8	110,465	2,080.5	1.9	60	9.90
Humpy Cr.	257-701	14.4	171,739	2,041.9	1.1	60	10.38
Eastside Kodiak District							
Kiliuda Cr.	258-207	3.6	22,737	1,406.0	6.2	60	3.06
Barling R.	258-522	6.4	75,210	1,470.8	1.9	60	1.96
Kaiugnak Cr.	258-542	2.0	7,824	448.5	5.7	60	15.12
Seven R.	258-701	10.0	19,588	742.6	3.8	60	60.88
Miam Cr.	259-412	4.8	53,636	1,206.7	2.2	60	3.65
Hurst Cr.	259-414	11.6	32,471	914.6	2.8	60	4.39
Saltry Cr.	259-415	6.8	53,695	922.3	1.7	60	4.68
Northeast Kodiak District							
Pillar Cr.	259-102	1.6	2,541	196.2	7.7	60	16.90
Buskin R.	259-211	7.2	47,945	1,688.9	3.5	60	5.69
Sid Old's R.	259-231	8.2	93,533	1,869.1	1.9	60	3.90
Russian R.	259-242	3.8	58,938	1,406.3	2.4	48	-[b,c]
American R.	259-231	9.1	93,383	1,625.2	1.7	60	3.91

-Continued-

Table 8. (page 2 of 2)

Stream Name	Number	Length (km)	Spawning Habitat (m^2) Est.	SD	CV	m_i [a]	1989 Spawner Density (No. Fish/m^2)
Mainland District							
Kukak Cr.	262-271	2.4	21,257	654.1	3.1	60	0.17
Missak Cr.	262-402	2.8	5,292	713.7	13.5	53	6.82
Kinak Cr.	262-451	6.0	21,738	980.8	4.5	60	2.50
Geographic Cr.	262-501	1.2	63	174.7	277.2	12	- [b]
Dakavak Cr.	262-551	8.4	34,635	2,802.4	8.1	60	1.90
Kashvik Cr.	262-604	8.8	117,682	1,688.6	1.4	60	2.40
Alinchak Cr.	262-651	6.8	3,317	329.2	9.9	48	- [b]
Portage Cr.	262-702	3.6	4,543	618.8	13.6	60	30.57
Oil Cr.	262-751	4.4	10,966	673.7	6.1	60	10.54
Jute Cr.	262-801	3.6	5,473	468.7	8.5	60	4.25
Kanatak Cr.	262-802	2.4	23,005	1,083.7	4.7	60	6.88
Big Cr.	262-851	9.2	77,704	1,424.2	1.8	60	26.74

[a] Number of secondary units sampled.
[b] Streams that were not escapement surveyed in 1989.
[c] Entire stream reach available for spawning was measured.
[d] Incomplete spawning surveys, therefore estimates are approximate.

Table 9. Estimates of total available spawning habitat and 1989 spawner densities for Chignik Management Area aerial survey escapement index streams.

Stream			Spawning Habitat (m^2)				1989
Name	Number	Length (km)	Est.	SD	CV	m_i[a]	Spawner Density (No. Fish/m^2)
Eastern District							
Ocean Bch. Cr.	272-801	9.2	80,013	2,146.6	2.7	60	0.17
Chiginagak 904 Cr.	272-904	1.2	19,245	1,304.1	6.8	60	1.66
Chiginagak 905 Cr.	272-905	7.5	54,283	971.6	1.8	60	1.64
Agripina Cr.	272-961	11.2	115,699	1,863.3	1.6	60	2.33
Amber Cr.	272-702	21.6	200,041	2,399.3	1.2	48	0.26
Central District							
Hook Bay Cr.	272-302	18.3	153,244	3,022.7	1.9	60	0.30
Kumliun Cr.	272-501	9.9	24,234	551.8	2.3	60	3.69
North Fork Cr.	272-514	30.6	128,837	1,925.4	1.5	60	0.20
Perryville District							
Ivanof Cr.	275-406	28.2	256,723	1,971.7	<.1	60	0.66
Humpback Cr.	275-502	15.6	110,294	1,564.7	1.4	60	0.46
Western District							
Ivan Cr.	273-722	24.0	189,000	2,960.0	1.6	60	0.17
Foot Bay Cr.	273-802	2.0	17,885	891.5	5.0	57	0.60
Spoon Cr.	273-823	4.5	23,652	466.5	2.0	60	0.07
Portage Cr.	273-842	6.4	19,106	593.1	3.1	60	0.06

[a] Number of secondary units sampled.

Table 10. Pink salmon length and fecundity statistics from populations within the Kodiak and Chignik Management Areas, 1989.

Stream		Length (mm)					Fecundity (No. of eggs)					
					Range					Range		
Name	Area	Mean	Median	SD	Min.	Max.	Mean	Median	SD	Min.	Max.	N
Litnik R.	Kodiak	472	470	26.6	420	530	1,445	1,457	255.3	930	2,127	50
E.Paramanof Cr.	Kodiak	465	465	19.4	416	501	1,312	1,304	232.5	862	1,960	50
Akalura Cr.	Kodiak	483	485	26.5	426	564	1,627	1,625	324.2	892	2,448	100
Lake Bay Cr.	Chignik	478	485	38.2	376	581	1,587	1,631	301.5	708	2,279	101

Table 11. Analysis of variance for the full model regression of fecundity on length and partitioning of sums of squares (SS) for the full model into two components: (1) SS explained by the reduced model alone; and, (2) the additional SS explained by the full model ("Full|Reduced").

Source	df	SS	MS	F
Full Model				
Regression	7	$134,373 \times 10^2$	1,919,613.0	35.36
Residual	293	$159,028 \times 10^2$	54,275.61	
Reduced Model				
Regression	1	$103,802 \times 10^2$	$103,802 \times 10^2$	163.70
Residual	299	$189,599 \times 10^2$	63,410.946	
Full|Reduced				
Regression	6	$30,571 \times 10^2$	$5,095 \times 10^2$	9.38
Residual	293	$159,028 \times 10^2$	54,275.61	

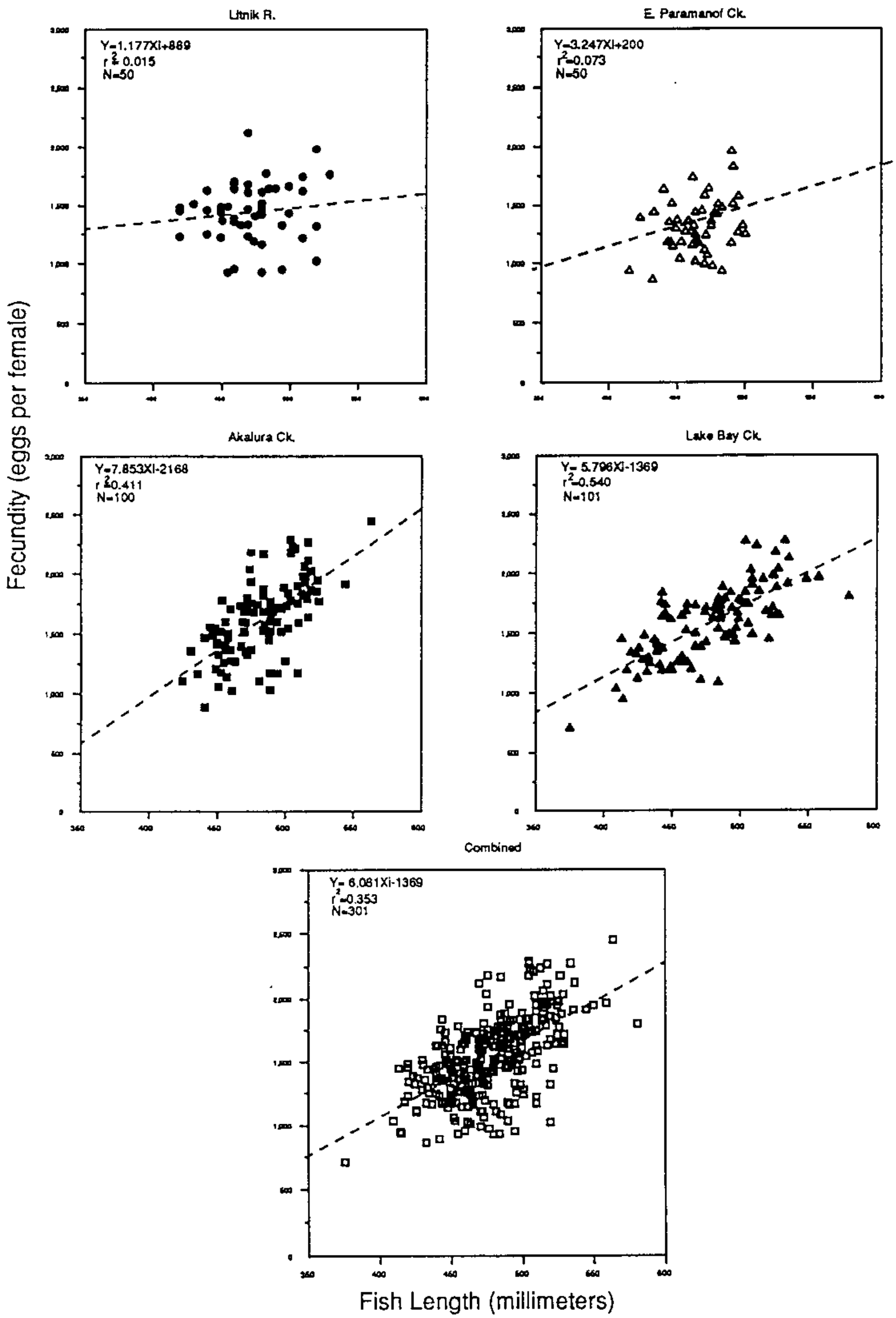

Figure 7. Pink salmon length-fecundity relationships from four populations studied, 1989.

Table 12. Egg retention statistics and spawner densities observed for Kodiak and Chignik area pink salmon populations, 1989.

Stream Name	Stream Number	1989 Spawner Density (No. of Fish/m^2)	Egg Retention Mean	Median	SD	Range Min.	Range Max.	Percent zero eggs	N
Kodiak Area Streams									
Narrows Cr.	257-401	0.10	15.7	0.0	44.1	0.0	267	57.0	86
Karluk R.	255-101	0.13	75.1	1.0	177.8	0.0	1,122	49.0	147
Marka Cr.	252-343	0.35	2.0	0.0	11.3	0.0	131	77.3	150
E. Paramanof Cr.	251-404	0.48	40.4	3.0	197.3	0.0	1,858	21.7	157
Browns Cr.	254-204	1.59	14.5	0.0	84.9	0.0	943	66.0	150
Barling Cr.	258-522	1.96	11.9	0.0	48.9	0.0	359	70.0	150
Dog Salmon R.	257-403	2.29	7.2	2.0	18.1	0.0	137	30.0	150
Portage Cr.	251-830	3.27	26.3	2.5	57.2	0.0	378	34.0	150
Miam Cr.	259-412	3.65	11.0	1.0	43.3	0.0	396	43.7	126
American R.	259-231	3.91	22.5	0.0	90.7	0.0	721	62.7	150
Hurst Cr.	259-414	4.35	71.3	2.0	211.5	0.0	1,249	28.0	150
Saltry Cr.	259-415	4.68	50.3	2.0	152.1	0.0	1,589	38.0	150
Buskin R.	259-211	5.69	24.0	0.0	94.6	0.0	765	58.9	146
Terror R.	253-331	6.64	32.4	1.0	117.9	0.0	1,097	45.4	152
Kanatak Cr.	262-802	6.88	18.3	0.0	59.2	0.0	402	65.3	150
Baumans Cr.	253-332	7.91	140.0	35.5	249.8	0.0	1,473	20.0	150
Uganik R.	253-122	8.76	19.3	0.0	54.8	0.0	385	59.3	150
Deadman R.	257-502	9.90	23.2	1.5	64.4	0.0	520	38.2	144
Humpy Cr.[a]	257-701	10.38	132.0	6.0	221.2	0.0	1,167	39.1	64[a]
Kaiugnak Cr.	258-542	15.12	19.5	0.0	63.2	0.0	429	54.1	148
Pillar Cr.	259-102	16.90	22.7	0.0	93.8	0.0	987	52.4	147
Danger Cr.	252-332	46.73	9.4	0.0	24.9	0.0	143	38.8	49
Seven R.	258-701	60.88	146.0	55.0	193.8	0.0	920	22.3	148
Chignik Area Streams									
Ocean Beach Cr.	272-801	0.17	1.9	0.0	7.4	0.0	59	72.2	108
Ivan R.	273-722	0.17	2.3	0.0	6.3	0.0	47	57.7	78
Amber Bay Cr.	272-702	0.26	6.7	0.0	54.1	0.0	655	57.3	150
Hook Bay Cr.	272-302	0.29	1.5	0.0	7.2	0.0	87	66.9	157
Humpback Cr.	275-502	0.46	23.4	1.0	146.4	0.0	1,432	43.6	156
Foot Bay Cr.	273-802	0.60	15.3	1.0	60.4	0.0	397	40.0	45
Ivanof Cr.	275-406	0.66	13.6	0.5	71.9	0.0	840	50.0	162
Chigniagak 905 Cr.	272-905	1.64	16.6	0.0	70.8	0.0	690	64.4	146
Chiginagak 904 Cr.	272-904	1.66	6.7	1.0	20.7	0.0	176	45.0	151
Agripina Cr.	272-961	2.33	60.0	2.0	159.9	0.0	872	32.2	146
Kumulin Cr.	272-501	3.69	8.3	0.0	39.6	0.0	343	58.6	152

[a] There were 84 individuals designated as being unspawned; these fish were excluded from analysis.

Kodiak populations had the largest range of egg retention and spawner densities. The Chignik egg retention data were more variable between populations.

Maximum likelihood parameter estimates (MLE) for the logistic model of spawner density on percent of sample with zero eggs was β_0 -0.042 (95% CI -0.023 to 0.107). The estimated β_1 value was -0.118 (95% CI of -0.155 to -0.082; Figure 8). These parameter estimates were consistent with the hypothesized positive effect of spawner density on egg retention (i.e., as spawner density increases the probability of a fish retaining zero eggs decreases).

Success Of 1989 Spawners and Brood Year

Observed 1990 preemergent fry/m^2 was significantly below that predicted by the fry/m^2 vs. TP/m^2 linear regression models for 23 Kodiak and 7 Chignik streams (Tables 13 and 14), indicating that spawner success was poor. Thirteen streams in Kodiak and two in Chignik did not show significant depression in fry/m^2 but eight of these had lower than predicted fry/m^2. An alternative method for both KMA & CMA index streams of employing escapement to predict preemergent fry/m^2 was discarded (Figure 9).

During 1990, preemergent fry/m^2 was greater than the odd-year brood line historical average in 23 streams in Kodiak (Table 13). For 13 of these, fry/m^2 was greater than the upper limit of the 90% confidence intervals of the average fry/m^2. In view of #SDfry/m^2 values (standardized residuals), which compare 1990 fry yield to past yield and variability in that yield, 1990 fry production was extremely high in the Paramanof, Uyak-202, and Saltery systems (Table 13; Figure 10). Fry yield was also very high in Seal Bay, Danger, and Narrows Creeks, even though the first of these three showed significantly depressed fry/m^2. Of the 13 other streams that had positive #SD_{fry}/m^2 values, 11 had significantly depressed fry/m^2 as compared to predicted values. The 1990 fry/m^2 was less than the odd-year brood line average in 13 Kodiak streams, and was significantly low in 11 of these. The most negative #SD_{fry}/m^2 value was only -1.42 for Little Waterfall Creek. The average 1990 fry/m^2 for index streams stratified by fishing district was greater than historical averages in all Kodiak districts except the Mainland, where the average of the historical averages was slightly higher. Average 1990 fry/m^2 values were substantially greater for the Northwest Kodiak, Alitak, and Eastside Kodiak Districts, but only slightly higher for the Afognak and Northeast Kodiak Districts.

For the CMA populations, 1990 fry/m^2 was greater than the odd-year average in only Ivanof River and Portage Creek. The Ivanof value was greater than the 90% CI of the average, but the fry/m^2 was significantly depressed as compared to the predicted value (Table 14). The 1990 fry/m^2 was less than average in the other seven streams, was significantly depressed in six of these, and was below the 90% CI of the average for the Ivan and Spoon Rivers. The deviations of 1990 fry/m^2 from average fry/m^2 were low for Chignik streams; the greatest #SD_{fry}/m^2 value being that of Spoon Creek -1.56 (Table 14; Figure 10). The average of the 1990 fry/m^2 values for Chignik streams were substantially lower than the average of the historical averages.

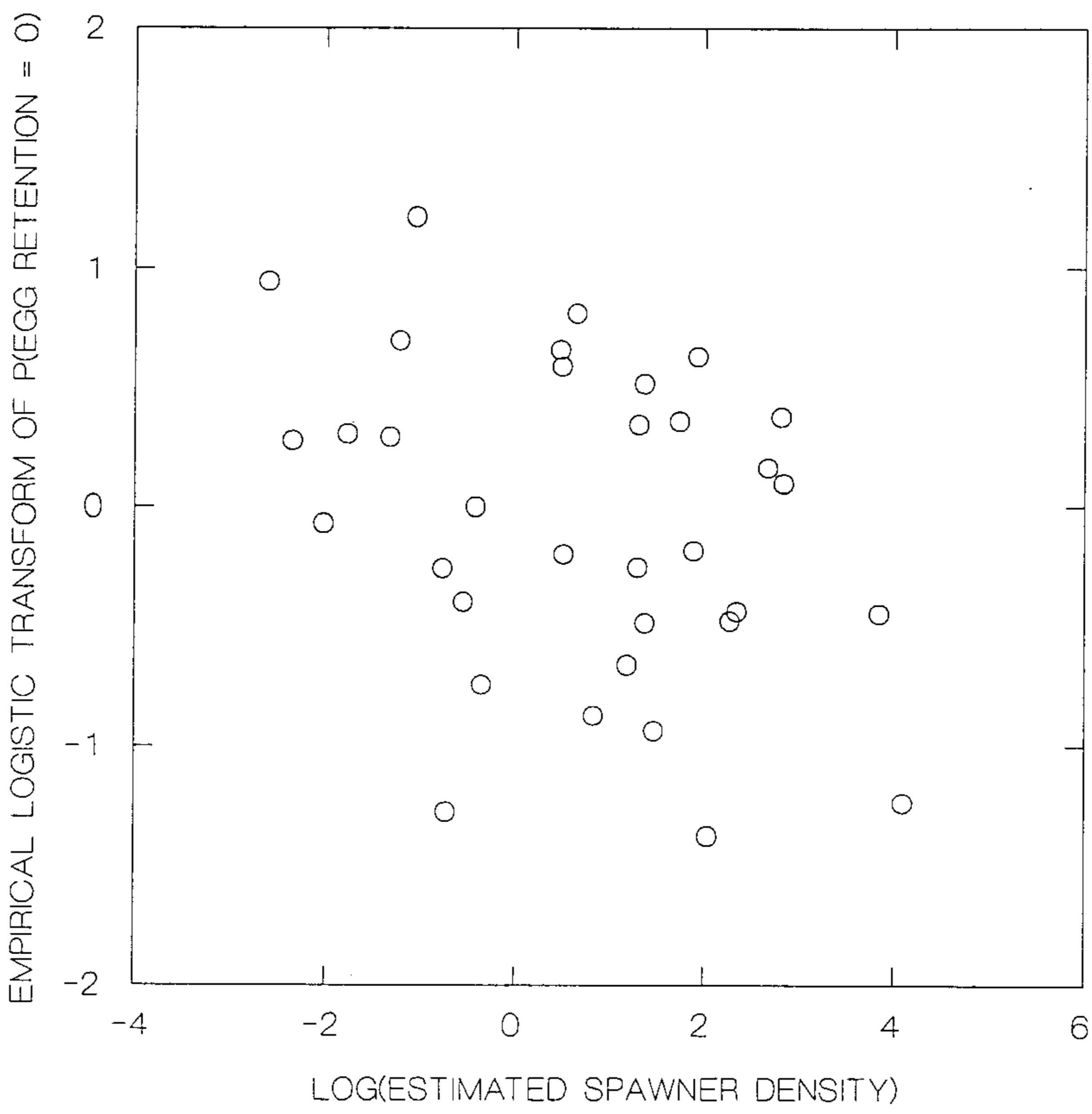

Figure 8. Pink salmon egg retention represented as percent of females sampled that retained no eggs as a function of spawner density.

Table 13. Results of linear regression analyses of 1990 preemergent fry sampling data (1989 brood year), and historical odd-year brood line live fry density data for the Kodiak Management Area.

Stream		Linear Regression Results						Historical Odd-year Brood Line Fry/m² Data				
			Number		1990 Fry/m²			Number	Fry/m²			
Name	Number	Model No[a].	Sampling Years	r^2	Predicted	Observed	P[b]. Pred.< Obser.	Years Averaged	Mean	SD	Standardized Residuals[c].	90% CI
Afognak District												
E. Paramanof	251-404	3	13	0.798	252.9	278.3	0.6046	11	21.16	25.2	10.20	7.39-34.92
L. Waterfall	251-822	2	8	0.682	532.2	70.0	0.0076	4	484.25	291.5	-1.42	141.24-827.26
Perenosa	251-830	4	14	0.765	289.7	72.3	0.0016	12	219.13	126.3	-1.16	153.64-284.61
Seal Bay	251-901	1	13	0.859	701.3	459.2	0.0054	6	315.04	236.7	2.34	120.29-509.79
Danger	252-332	1	21	0.849	259.9	292.5	0.7179	11	89.74	81.7	2.48	42.39-137.09
Marka	252-343	4	9	0.954	10.9	10.3	0.2896	0				
Average						234.5[d]			174.43[e]			
Northwest Kodiak District												
Sheratin	259-371	3	22	0.578	153.3	39.8	0.0529	11	40.63	33.3	-0.02	21.54-59.72
Uganik	253-122	1	22	0.720	132.4	9.4	0.0193	12	66.13	68.7	-0.83	30.51-101.74
Terror	253-331	3	22	0.387	56.5	0.7	0.0036	12	11.45	12.8	-0.83	4.78-18.11
Bauman's	253-332	1	23	0.915	843.6	240.7	0.0062	12	313.38	225.3	-0.32	196.55-430.20
Uyak-202	254-202	1	22	0.978	943.6	1,070.0	>0.9995	12	257.64	157.7	5.15	175.88-339.39
Uyuk-203	254-203	1	5	0.999	252.7	238.0	0.0024	6	207.59	271.9	0.11	0.00-431.29[f]
Zachar	254-301	1	22	0.746	92.0	12.1	0.0007	12	10.16	17.9	0.11	0.91-19.42
Average						230.1			124.64[e]			
Alitak Bay District												
Narrows	257-401	4	13	0.810	309.3	264.8	0.3671	12	91.77	69.1	2.50	55.92-127.62
Dog Salmon	257-403	4	22	0.982	159.5	179.9	0.7241	12	104.60	113.0	0.67	46.00-163.20
Deadman	257-502	4	22	0.985	664.4	546.9	0.0241	12	432.65	196.3	0.58	330.86-534.44
Humpy	257-701	1	23	0.876	742.6	464.8	0.0008	12	220.05	173.5	1.41	126.11-313.99
Average						364.1			212.27[e]			
Eastside Kodiak District												
Kiliuda	258-207	1	22	0.960	82.28	77.0	0.3925	10	34.62	40.4	1.05	11.47-57.76
Barling	258-522	1	20	0.782	132.25	51.7	0.0223	12	99.48	93.9	-0.51	48.22-150.74
Kaiugnak	258-542	1	22	0.899	814.35	736.8	0.2127	12	241.35	308.2	1.61	81.57-401.13
Seven Rivers	258-701	1	22	0.668	556.18	383.5	0.0534	12	284.73	158.1	0.62	202.76-366.70
Beaver	259-365a	1	9	0.995	573.48	549.9	0.2402	4	473.61	403.5	0.19	0.00-948.33[f]
Miam	259-412	1	12	0.667	118.26	118.6	0.5025	0				
Hurst	259-414	1	21	0.944	287.7	102.8	<0.0005	10	49.36	56.4	0.95	16.65-82.06
Saltery	259-415	1	22	0.644	371.9	521.5	0.9935	12	94.73	67.5	6.32	59.73-129.72
Average						317.73[g]			158.02[e]			

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Table 13. (page 2 of 2)

Stream Name	Stream Number	Linear Regression Results: Model No[a].	Number Sampling Years	r^2	1990 Fry/m^2: Predicted	Observed	P^b. Pred.< Obser.	Historical Odd-year Brood Line Fry/m^2 Data: Number Years Averaged	Fry/m^2: Mean	SD	Standardized Residuals[c].	90% CI
Northeast Kodiak District												
Monashka	259-101	4	9	0.576	75.4	2.7	0.0085	5	39.65	48.8	-0.76	22.87-56.43
Buskin	259-211	3	22	0.734	268.3	89.7	0.0326	12	143.01	122.1	-0.44	79.72-206.30
American	259-231	1	23	0.978	325.5	256.0	0.0021	12	142.93	124.4	0.91	78.43-207.42
Sid Old's	259-242	1	23	0.907	104.4	116.4	0.7024	12	93.02	70.2	0.33	56.63-129.41
Average						116.2			115.75[e]			
Mainland District												
Kukak	262-271	1	6	0.806	49.4	6.7	0.0320	3	52.09	47.6	-0.95	0.00-132.34[f]
Missak	262-271	1	12	0.939	226.1	131.7	0.0008	6	99.51	73.5	0.44	39.06-159.96
Kinak	262-451	1	12	0.886	238.0	161.7	0.0030	6	142.61	80.9	0.24	76.05-209.17
Dakavak	262-551	4	14	0.983	18.5	0.4	<0.0005	7	59.84	51.6	-1.07	21.94-97.74
Kashvik	262-604	2	14	0.844	7.1	0.8	0.1497	7	44.50	59.5	-0.73	0.79-88.21
Alinchak	262-651	1	10	0.843	137.5	27.3	0.0025	6	18.68	28.0	0.31	4.21-33.15
Portage	262-702	1	10	0.928	3.4	2.3	0.4890	4	19.52	35.9	-0.48	0.00-61.74[f]
Kanatak	262-802	1	9	0.964	176.9	186.7	0.6421	5	173.78	161.5	0.08	19.76-327.80
Big Creek	262-851	1	9	0.998	155.9	131.7	0.0013	5	115.03	166.2	0.10	0.00-273.51[f]
Average						72.1			81.09[e]			

[a] Linear regression model was live fry density (fry/m^2) vs. total progeny density (TP/m^2) with or without square root or logarithm transformation of either or both variables. The model numbers represent (dependent variable first): (1) fry/m^2 vs. TP/m^2; (2) square root fry/m^2 vs. TP/m^2; (3) square root fry/m^2 vs. square root TP/m^2; and (4) logarithm fry/m^2 vs. logarithm TP/m^2.

[b] The probability, according to 1990 TP/m^2 and the linear regression relationship, that fry/m^2 in 1990 would be ≤ the observed 1990 fry/m^2. Probabilities <0.10 indicate significantly low 1990 fry/m^2.

[c] Standarized Residuals=(1990 fry/m^2 - historical mean fry/m^2)/standard deviation of historical mean fry/m^2.

[d] Average calculated excluding Marka Creek.

[e] Weighted average.

[f] Zero was assigned to lower confidence limits that were negative numbers.

[g] Average calculated excluding Miam Creek.

Table 14. Results of linear regression analyses of 1990 preemergent fry sampling data (1989 brood year), and historical odd-year brood line live fry density data for the Chignik Management Area.

Stream Name	Number	Linear Regression Results: Model No.[a]	Number Sampling Years	r^2	1990 Fry/m²: Predicted	1990 Fry/m²: Observed	Prob[b]. Pred.< Obser.	Historical Odd-year Brood Line Fry/m² Data: Number Years Averaged	Fry/m²: Mean	SD	Standardized Residuals[c].	90% CI
Hook Bay	272-302	1	14	0.820	69.2	0.0	<0.0005	11	18.77	27.8	-0.67	0.00-44.71[a]
Kumliun	272-501	1	5	0.974	75.2	2.6	0.0009	4	45.93	40.3	-1.08	0.00-120.95[a]
Chiginagak 905	272-905	1	6	0.995	261.1	180.8	0.0007	2	209.22	83.2	-0.34	0.00-463.29[a]
Ivan	273-722	3	17	0.958	33.8	13.7	0.0498	9	111.61	113.4	-0.86	31.61-191.61
Foot Bay	273-802	1	11	0.977	304.3	227.8	0.0148	6	265.77	192.7	-0.20	102.58-428.95
Spoon	273-823	3	9	0.932	8.1	0.0	0.0206	5	99.09	63.6	-1.56	39.09-159.08
Portage	272-842	1	17	0.576	41.9	64.2	0.8035	6	40.34	40.0	0.60	14.49-66.19
Ivanof	275-406	3	17	0.983	267.2	200.6	<0.0005	9	99.66	94.3	1.07	39.44-159.88
Humpback	275-502	3	17	0.979	79.0	65.6	0.2900	9	185.38	249.7	-0.48	14.34-356.41
Average						68.7			119.52			

[a] Linear regression model was live fry density (fry/m²) as the dependent variable versus total progeny density (TP/m²) as the independent variable, with or without square root or logarithm transformation of either or both variables. The model numbers represent: (1) fry/m² vs. TP/m²; (2)square root fry/m² vs TP/m²; (3) square root fry/m² vs square root TP/m²; and (4) logarithm fry/m² vs logarithm TP/m².

[b] The probability, according to 1990 TP/m² and the linear regression relationship, that fry/m² in 1990 would be ≤ the observed 1990 fry/m². Probabilities <0.10 indicate significantly low 1990 fry/m².

[c] Zero assigned to lower confidence limits that were negative numbers.

[d] Weighted average.

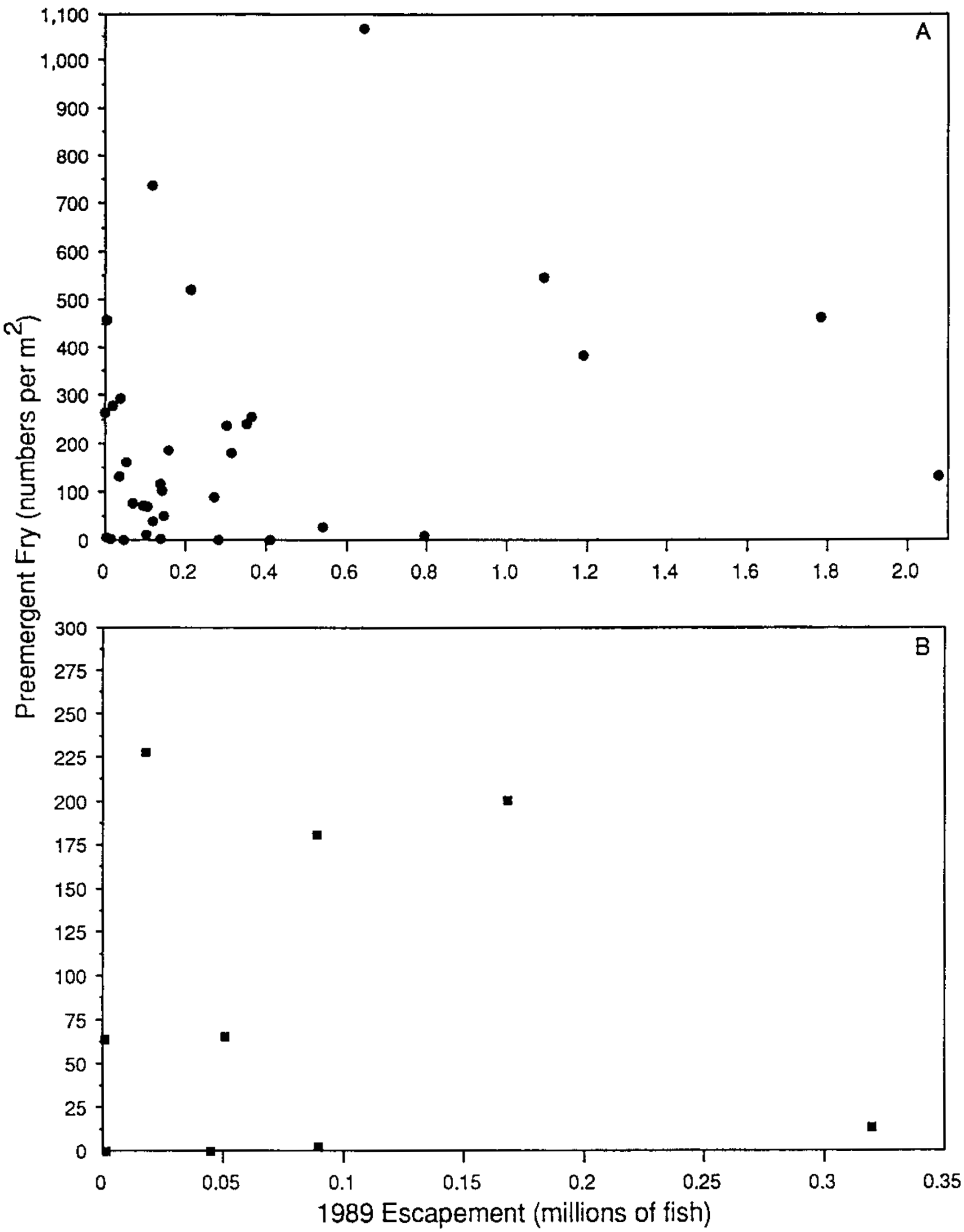

Figure 9. Pink salmon preemergent fry/m^2 as a function of escapement by index stream: (A) Kodiak; and (B) Chignik.

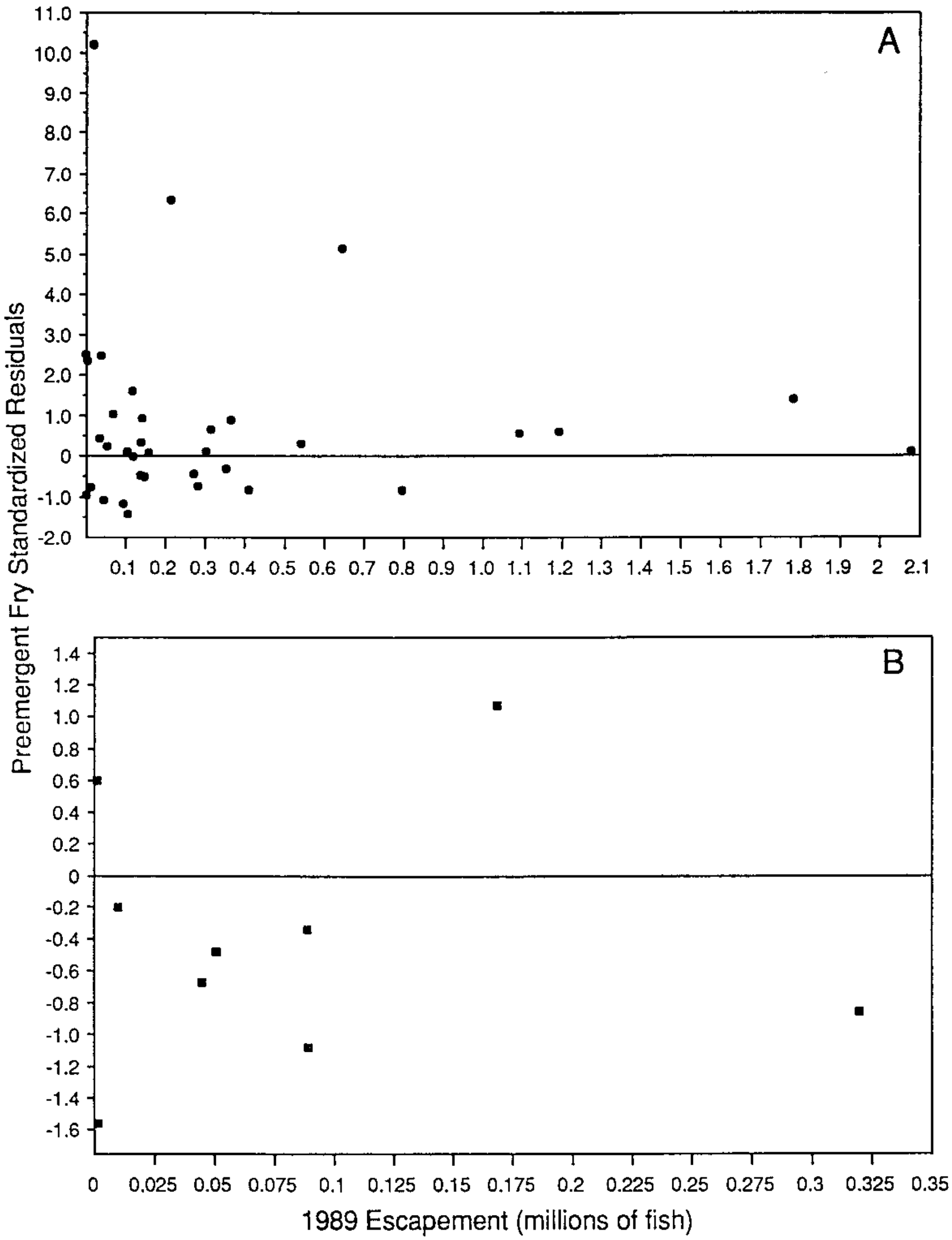

Figure 10. Preemergent fry standardized residuals as a function of 1989 escapements: (A) Kodiak; and (B) Chignik.

Relationship Between Spawner Abundance and Live Fry Density

There were a wide range of spawner densities experienced within the KMA index streams during 1989 with most escapements higher than the historical average; differences ranged from small fractions to large numbers of standard deviations (Table 15). Few streams had escapements that were lower than average, all by less than one SD. For CMA streams, escapements were below the 1963-1989 escapement average in six of nine preemergent index streams with Chiginagak-905 and Hook Bay Creeks receiving escapements greater than one SD above average (Table 16).

Of the Mann-Whitney comparisons of spawner abundance indices between streams that had depressed fry/m^2 (i.e. low fry/m^2 relative to TP/m^2) and streams that did not, only the comparison of spawner densities between these stream groups in Chignik yielded significant evidence (P=0.087) that depression was associated with increased spawner density (Table 17). However, the comparison of #SD_{esc} values between these Chignik groups provided a test statistic far below the critical value. Comparisons of these indices between stream groups for Kodiak produced test statistics close to but below the critical values. Moderate and high spawner density stream groups in Kodiak had significantly different 1989 fry/m^2 values (P=0.025). The average of the 1989 fry/m^2 values found in moderate spawner density streams (91.796) was much lower than the average value for high spawner density streams (291.41). Comparison of #SD_{esc} vs. #SD_{fry}/m^2 values between moderate and high escapement stream groups in Kodiak yielded a test statistic well below the critical value.

Spawner-Recruit

The Ricker and Beverton-Holt models fit to the Kodiak return per spawner data are essentially equivalent. What is important in the context of this study is that the Kodiak data indicates that for both models the β_2 or density dependent parameter is non-zero (Table 18; Figure 11). In contrast, parameter estimates for the Ricker and Beverton-Holt models based on Chignik data do not differ significantly from zero, suggesting that the dependence of return on number of spawners is weak over the range of observed data (Table 18; Figure 12). The predicted KMA 1991 pink salmon return from the odd-year midpoint escapement goal of 4.67 million (Ricker model) provided a return of 11.9 million fish or 2.5 returns per spawner (95% prediction interval of 3.6 to 24.4 million; 0.8 to 5.2 returns per spawner). The desired escapement goal of 7.0 million produced a predicted return of 15.7 million or 2.2 returns per spawner (95% prediction interval: 5.8 to 29.5 million; 0.8 to 4.2 returns per spawner). The maximum difference between replacement and the fitted curve occurs around 7.5 million (Figure 11). The CMA predicted return from the 0.7 million escapement goal was 1.3 million or 1.8 returns per spawner (95% prediction interval: 0.3 to 5.8 million; 0.4 to 8.3 returns per spawner).

Table 15. Preemergent fry sampling index streams classified as having moderate and high escapements within the Kodiak Management Area, 1989 brood year.

Stream Name	Stream Number	Odd-Year Escapements (Numbers of Fish) Mean	SD	1989	Escapement Years Averaged[a] (1963-1989)	SD Esc.[b]	SD Fry/m²[c]
Streams Classified as having Moderate Escapement in 1989							
Narrows Cr.	257-401	9,540	7,926	2,097	11	-0.939	2.50
Seal Bay Cr.	251-901	16,627	17,281	6,000	8	-0.615	2.34
Kinak Cr.	262-451	70,124	51,702	54,327	9	-0.306	0.24
L. Waterfall	251-822	125,736	161,451	106,347	4	-0.120	-1.42
Kukak Cr.	262-271	4,767	8,113	3,802	11	-0.119	-0.95
Dakavak Cr.	262-551	40,966	46,037	46,037	14	0.542	-1.07
E.Paramanof Cr.	251-404	12,029	14,287	20,056	12	0.562	10.20
Danger Cr.	252-332	20,047	21,711	39,207	14	0.883	2.48
Sid Olds R.	259-242	76,654	46,612	139,668	12	1.352	0.33
Perenosa Cr.	251-830	43,115	37,596	95,700	12	1.399	-1.16
Monashka Cr.	259-101	5,718	5,606	14,720	6	1.606	-0.76
Barling Cr.	258-522	73,541	43,206	147,423	14	1.710	-0.51
Saltry Cr.	259-415	106,916	58,975	214,541	14	1.825	6.32
Streams Classified as having High Escapement in 1989							
Kiliuda Cr.	258-207	19,501	24,151	69,762	12	2.081	1.05
Zachar Cr.	254-301	43,056	27,337	103,983	14	2.229	0.11
Buskin R.	259-211	82,622	79,360	272,785	14	2.396	-0.44
Dog Salmon R.	257-403	117,882	68,953	315,559	14	2.867	0.67
Missak Cr.	262-402	7,765	8,520	36,120	10	3.328	0.44
Sheratin R.	259-371	46,123	20,818	119,943	6	3.546	-0.02
American R.	259-231	83,179	75,003	365,383	14	3.763	0.91
Kanatak Cr.	262-802	32,785	28,689	158,350	11	4.377	0.08
Uyak 202 R.	254-202	170,582	97,247	645,157	14	4.880	5.15
Uyak 203 R.	254-203	59,559	48,415	303,600	12	5.041	0.11
Kaiugnak Cr.	258-542	25,997	16,997	118,323	14	5.432	1.61
Hurst Cr.	259-414	23,142	20,493	142,535	11	5.826	0.95
Kashvik Cr.	262-604	57,073	36,251	282,600	11	6.221	-0.73
Terror R.	253-331	95,579	45,623	410,913	14	6.912	-0.83
Portage Cr.	262-702	17,682	16,911	138,880	10	7.167	-0.48
Uganik R.	253-122	125,317	92,153	795,899	14	7.277	-0.83
Humpy Cr.	257-701	250,989	173,451	1,783,196	14	8.834	1.41
Deadman R.	257-502	187,443	101,643	1,093,543	14	8.915	0.58
Bauman's Cr.	253-332	21,903	22,980	353,333	13	14.423	-0.32
Seven River's	258-701	140,099	70,374	1,192,683	14	14.957	0.62
Alinchak R.	262-651	26,444	29,894	541,827	13	17.241	0.31
Big Creek	262-851	99,027	107,563	2,078,433	13	18.402	0.10

[a] Escapement years are odd-years only for which escapement counts were available.
[b] ((1989 escapement - mean escapement)/ standard deviation of mean escapement).
[c] ((1990 fry/m^2 - mean fry/m^2)/ standard deviation of mean fry/m^2).

Table 16. Preemergent fry sampling index streams classified as having moderate and high escapements within the Chignik Management Area, 1989 brood year.

Stream		Odd-Year Escapements (Numbers of Fish)			Escapement Years Averaged		SD
Name	Number	Mean	SD	1989	(1963-1989)[a]	Esc.[b]	Fry/m²[c]
Streams Classified as having Moderate Escapement in 1989							
Spoon Cr.	273-823	7,237	5,685	1,700	10	-0.974	-1.56
Ivan Cr.	273-722	211,287	185,450	320,000	10	-0.967	-0.86
Foot Bay Cr.	273-802	20,505	15,015	10,800	10	-0.646	-0.20
Portage Cr.	273-842	7,930	10,755	1,200	10	-0.626	0.60
Cape Kumliun Cr.	272-501	124,223	103,381	89,499	8	-0.336	-1.08
Humpback Cr.	275-502	59,432	43,164	51,000	10	-0.195	-0.48
Ivanof R.	275-406	128,598	89,116	168,403	10	0.447	1.07
Chiginagak 905 Cr.	272-905	33,157	38,645	89,000	10	1.445	-0.34
Streams Classified as having High Escapement in 1989							
Hook Bay Cr.	272-302	13,865	14,018	45,000	10	2.221	-0.67

[a] Escapement years are odd-years only for which escapement counts were available.
[b] ((1989 escapement - mean escapement)/ standard deviation of mean escapement).
[c] ((1990 fry/m^2 - mean fry/m^2)/ standard deviation of mean fry/m^2).

Table 17. Results of Mann-Whitney "U" test comparisons for preemergent fry sampling program index stream groups, Kodiak and Chignik Management Areas.

Stream Groups Compared			Management Area	Ranked[a] Test Variable	Test[b] Statistic	Critical Value (P=0.10)
Nondepressed fry/m^2 (n=14)	vs.	Depressed fry/m^2 (n=23)	Kodiak	$\#SD_{esc}$	193	203
Nondepressed fry/m^2 (n=2)	vs.	Depressed fry/m^2 (n=7)	Chignik	$\#SD_{esc}$	7	10
Nondepressed fry/m^2 (n=14)	vs.	Depressed fry/m^2 (n=21)	Kodiak	Spawner Density	183	186
Nondepressed fry/m^2 (n=14)	vs.	Depressed fry/m^2 (n=21)	Chignik	Spawner Density	11 (p=0.0875)	10
Moderate Spawner Density (n=18)	vs.	High Spawner Density (n=21)	Kodiak	fry/m^2	270 (p=0.0246)	248
Moderate Escapement (n=13)	vs.	High Escapement (n=22)	Kodiak	$\#SD_{fry}/m^2$	151	192

[a] $\#SD_{esc}$= (1989 escapement- historical average escapement)/ standard deviation of historical escapements; spawner density= 1989 escapement/ estimated total available spawning habitat; $\#SD_{fry}/m^2$ = (1989 fry/m^2-historical average fry/m^2)/standard deviation of historical fry/m^2 values.

[b] Test statistic value greater than the critical value indicates significant difference between the compared groups; significance level is stated in parenthesis.

Table 18. Ricker and Beverton-Holt model's parameter estimates for odd-year brood line (1963-1989) spawner-recruit data from the Kodiak and Chignik Management Areas.

Management Area	Model	Parameter Number	Parameter Estimate	SE	95% CI
Kodiak	Ricker	β_1	3.2500	0.7300	1.6500 to 4.8400
Kodiak	Ricker	β_2	0.0053	0.0022	0.0004 to 0.0102
Chignik	Ricker	β_1	2.8800	1.3500	-0.0900 to 2.8800
Chignik	Ricker	β_2	0.0610	0.0570	-0.0640 to 0.1850
Kodiak	Beverton-Holt	β_1	0.0031	0.0013	0.0002 to 0.0061
Kodiak	Beverton-Holt	β_2	0.2580	0.0940	0.0510 to 0.4650
Chignik	Beverton-Holt	β_1	0.0400	0.0340	-0.0350 to 0.1160
Chignik	Beverton-Holt	β_2	0.2640	0.2190	-0.2180 to 0.7460

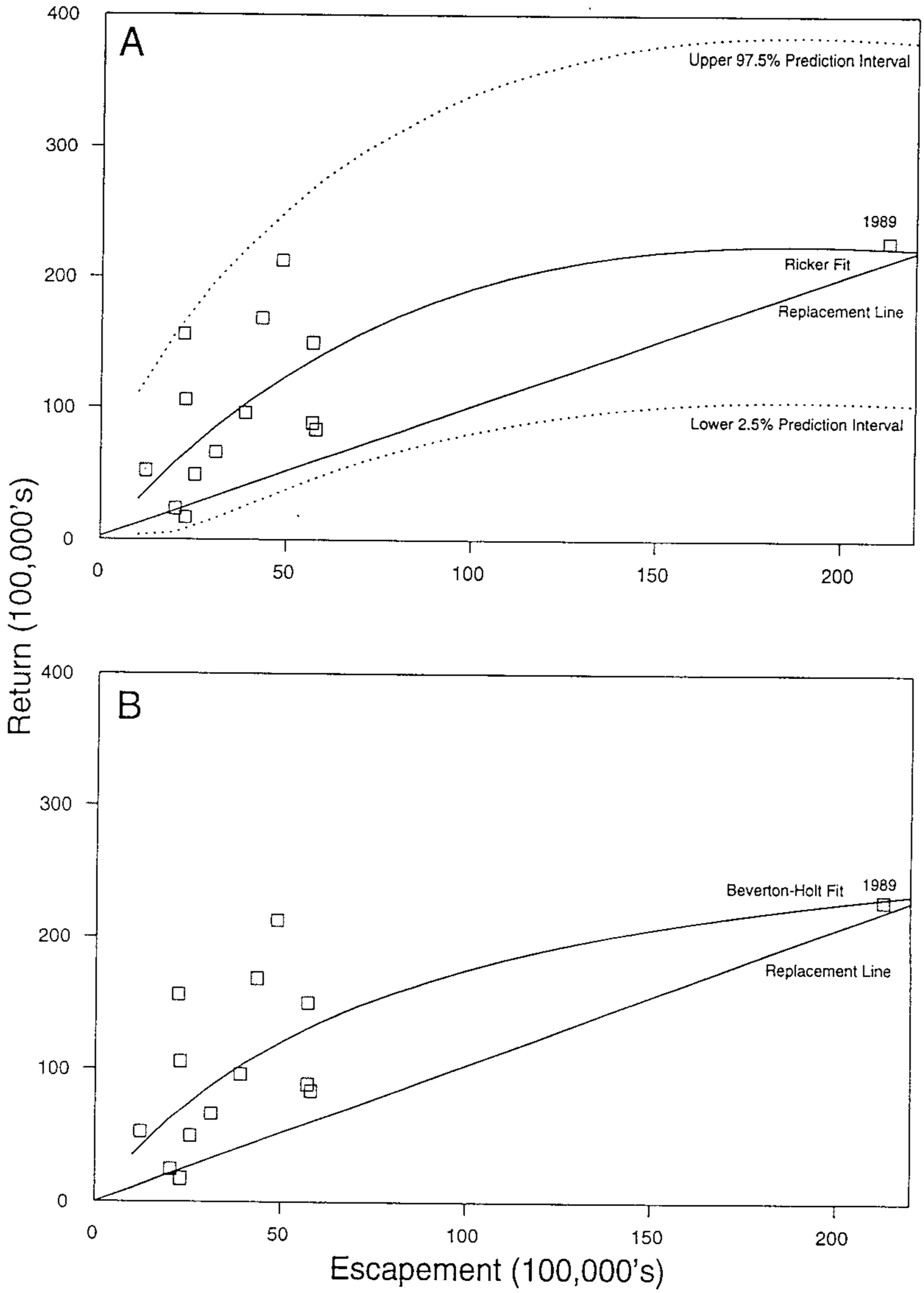

Figure 11. Spawner-recruit curves (A) Ricker model with 95% prediction intervals and (B) Beverton-Holt model for Kodiak Management Area odd-year broodline pink salmon, 1963-1989.

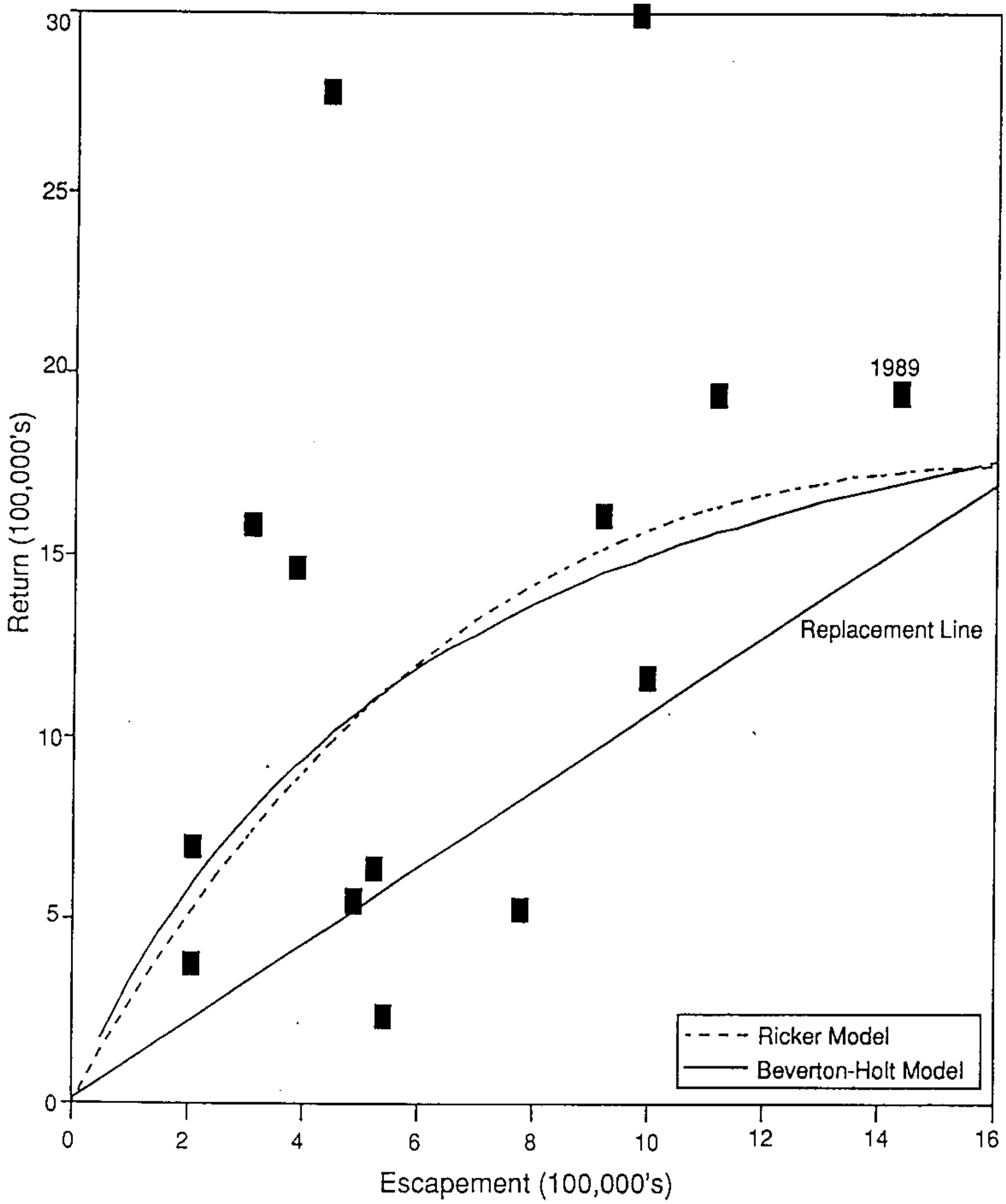

Figure 12. Spawner-recruit curves for Chignik Management Area odd-year broodline pink salmon, 1963-1989.

DISCUSSION

Stream life estimates generated from the various methods employed averaged 8.4 to 17.9 days and are similar to estimates generated from other studies (Perrin and Irvine 1990; Sharr and Sharp 1990). Pink salmon stream life appeared to decrease as the run progressed which is consistent with results from studies conducted in Southeast Alaska (Kingsbury 1977; Thomason and Jones 1984). Estimates generated using tagging data from Prince William Sound ranged from 7.2 to 21.9 days, whereas stream life reported by weekly strata had a grand mean of 13.9 days (range 9.9 d to 17.1 d); estimates decreased over time within a system (Sharr and Sharp 1990).

Stream life estimate variability between methods both within and among streams made selection of a single value difficult. Tagging data estimates adjusted for proportion of detectable tags had the least amount of perceived bias when compared to other methods. Given the wide range of estimated values and the influence stream life has on escapement estimation using the AUC approach and aerial survey data, we felt using a 15 d value was prudent. Had we incorporated more streams of various sizes within our study, a suite of values tailored to run timing and stream size similar to the approach used by Sharr and Sharp (1990) would have been instituted. Regardless, Perrin and Irvine (1990) suggest caution be exercised when using stream life estimates for escapement estimation which transcend areas, streams, or years.

Total available spawning habitat estimates for KMA index streams ranged from less than 1,000 m^2 (Danger Cr.) to 829,515 m^2 (Karluk R.). For some streams, estimates were considered approximate owing to incomplete spawning ground surveys. Streams having CV values greater than 10% were those where habitat surveys were incomplete. Spawning habitat estimates generated for CMA streams varied from 17,000 to 250,000 m^2; coefficients of variation were all less than 10%. Spawner density (D_i) estimates are precise as indicated by the spawning habitat CV values. However, our inability to accurately stratify populations which have bimodal run timing into early and late run components suggests that Di estimates for some spawning stocks might be overestimates. Alternatively, some spawning reaches had densities that were probably greater than those expressed in terms of the entire stream, as within stream direct measures for specific spawning areas were not estimated. In light of the escapement and total available spawning habitat estimates, the D_i's are not without error. We believe this error is relatively minor and imparts negligible influence on the egg retention and preemergent live fry analyses.

Fecundity estimates and the variability encountered between the four populations corresponds well with information on pink salmon presented by Heard (1991). Heard states that fecundity values deviate considerably between stocks, years, and regions. Therefore, our results are not atypical. Fecundity-length relationships for the four populations investigated were significantly different from one another. The lack of a single fecundity-length relationship severely limited our analysis of egg retention and preemergent fry survival.

For the egg retention data collected (Kodiak and Chignik populations combined), we found a highly variable relationship between mean egg retention and spawner density. A trend of increasing mean egg retention as a function of spawner density for most populations (Kodiak and

Chignik combined) was suggested by the data. However, the number of eggs retained was highly variable within samples and a known, but unspecifiable, relationship between fecundity and length further reduced clarity of this perceived trend. Interpretability and model fit was improved by transforming egg retention into a binary variable i.e., a value of zero when no eggs were retained and a value of one when eggs were retained. The index of egg retention for each population was expressed as the percent of each sample having zero eggs retained. Mean egg retention for the Kodiak pink salmon populations ranged from 1.5 to 146.0 eggs per female. Obtaining a statistically significant parameter estimate indicated the existence of a positive effect of spawner density on egg retention. Invariably, analyses were biased by omitting fish classified as "unspawned". However, ascertaining whether a fish had attempted to spawn prior to death or had died from kidney failure, oxygen depravation, or an epizootic proved unrealistic.

Few investigators have reported a relationship between spawner density (number of fish/m^2), egg retention, and subsequent fry survival with pink salmon. Hanavan and Skud (1954) showed that for *in-situ* pen enclosures with density controlled at 1.68 fish/m^2, mean egg retention was 409.4 eggs/female, while for densities of 3.7 fish/m^2 egg retention averaged 624.2 eggs/female. Corresponding egg to fry survival was reported as 10.1% and 7.7%, respectively. Hanavan and Scud (1954) cautioned against using this information for calculating optimum spawner densities, but felt that crowding was influential on subsequent fry survival. No causal mechanism other than mechanical disruption of previously deposited fertilized eggs was discussed. McNeil (1964), citing *in-situ* experiments conducted within two Southeast Alaska streams, reported that spawning success (measured as number of females spawning successfully within a given area) was greatest at 330 females per 100 m^2 of spawning habitat. Schroder (1973), relating density to spawning success with Chum salmon reported that spawning pairs were free from aggressive behavior only 8% of the time at spawner densities of 0.9 females/m^2, while mating activity decreased or ceased at densities above this level. For sockeye salmon data is limited, but Manzer and Miki (1986) have suggested that increased spawner density may cause increased egg retention.

Heard (1991) reports that pink salmon egg retention as a percentage of fecundity ranges from less than 1% to 40%. A value intermediate between these two would limit egg deposition and reproductive potential for a population. We found that mean egg retention for the streams with the highest spawner densities (140, 132, and 146 eggs/individual with spawner densities of 7.9, 10.3 and 60.9 fish/m^2, respectively) when evaluated using a fecundity value of 1,400 eggs/female, represent less than 11% of each populations total egg capacity. This would represent an insignificant impact on reproductive potential in light of superimposition and other avenues of egg loss. However, if populations with the highest levels of egg retention also had substantial losses of eggs due to superimposition, then combined they would represent a substantial loss to a populations potential egg deposition. Results from the preemergent fry study component discount that this occurred for KMA spawning populations during 1989.

The foregone salmon harvests of 1989 resulted in the largest escapement on record for the Kodiak Management Area (L. Malloy, ADF&G Kodiak, pers. comm); only five Kodiak index streams had less than average escapement. Brood year spawner success (predicted live fry/m^2 from TP/m^2, relative to observed 1990 live fry/m^2) by fishing district was apparently very good in the Northwest Kodiak, Alitak, and Eastside Kodiak Districts, and near average within the

Afognak, Northeast Kodiak, and Mainland Districts (Table 13). The 1989 brood year seems to have had poor success in Chignik but escapement for streams in this area were generally low (Mike Thompson, Alaska Department of Fish and Game Anchorage, personal communication). Brood year success was apparently good to exceptionally good in most Kodiak index streams (when evaluated independently) but was good in only two Chignik index streams. Some Kodiak streams and most Chignik streams showed only fair to low brood year success but none had particularly poor success. Significant depression in 1990 fry/m^2 relative to TP/m^2 indicated poor spawner success in most Kodiak and Chignik streams. Evidently, only the Uyak-202 River and Saltery Creek had exceptionally good spawner success.

Of the 23 Kodiak streams that had depressed spawner success, 12 had good brood year success (better than average fry/m^2) and 11 had poor brood year success (less than average fry/m^2), suggesting that overescapement with density dependent mortality occurred in some streams. High spawner density streams had significantly higher fry/m^2 than moderate spawner density streams because the moderate group contained streams with very low spawner densities and because the cumulative spawner density goal (1.4 fish/m^2) used to stratify the streams into the two groups may have been too low. Had the cut-off point been higher, perhaps 3.0, the two stream groups would have been much more similar in fry yields, suggesting that the Kodiak midpoint escapement goal is too low to obtain maximum fry yield. Moderate and high escapement stream groups were stratified at a level that was probably more extreme, and these groups did not differ significantly in their deviations from average fry/m^2. A well defined predictive relationship between parent year escapement and preemergent fry/m^2 produced would have undoubtedly simplified the analyses.

Although Kodiak pink salmon escapements were very large in 1989 and the spawner abundance indices tended to be somewhat higher for streams that showed significant depression than for streams that did not, there was no conclusive evidence that depression in fry/m^2 was directly caused by spawner density. Most Chignik index streams had low spawner abundance and depressed spawner success, although environmental conditions in this area are generally more extreme than in Kodiak and may have resulted in depressed 1989 spawner success. However, the spawner abundance indices quantify spawner abundance in entire streams and may not reflect spawner abundance in the sampled spawning riffles. Only 4 Kodiak streams had predicted 1990 fry/m^2 lower than the historical average fry/m^2, suggesting that egg deposition was greater than usual in most sampled spawning riffles.

Donnelly (1983) and Eggers et al. (1991) have reported significant density dependent relationships for Kodiak pink salmon populations. Both the egg retention and preemergent fry study components suggest that a density dependent response occurred between spawning and emergent fry for some Kodiak systems. This is partially substantiated with existence of a statistically significant density dependent parameter estimate for both the Ricker and Beverton-Holt models as applied to the Kodiak data.

The KMA and CMA catch data are assumed to be precise. Escapements estimated using a 15 d stream life value either directly (AUC approach) or indirectly (expansion factors) coupled with error associated with aerial survey data are of potential concern. Donnelly (1983) used an expansion factor of 2.5 to convert aerial survey peak counts to estimated total escapement; expansion factors used herein, when combined were similar to this value. Sharr and Sharp

(1990) reported from preliminary analysis that escapements not corrected for stream life and aerial survey bias were 38% below corrected estimates. Walters and Ludwig (1981) consider escapement measurement errors less than or equal to 30% to be "accurate". This level of error is probably realistic relative to evaluating the Kodiak and Chignik escapement data. Return per spawner analyses for both areas did not account for this error and probably led to the narrow confidence intervals for the parameter estimates. Significant parameter estimates from Kodiak, and non-significant estimates from Chignik could be explained by larger measurement error within the Chignik data than for Kodiak. Had we been able to quantify and correct the escapement estimate bias for both Kodiak and Chignik escapement data, a more concrete return per spawner relationship for both areas would have resulted.

Overall, no conclusive evidence of reduced production of pink salmon adults from the 1989 escapement was found in our study.

CONCLUSIONS

It is apparent that both egg retention and preemergent fry analyses demonstrated impact caused by spawner densities experienced within some streams during 1989. Evaluation of the overall 1989 brood year success using spawner-recruit analyses also demonstrated a density dependent response to the 1989 escapement. However, the variability in the Kodiak pink salmon return per spawner data made numerical estimation of the damage caused by this escapement event tenuous. The major question remaining unanswered is whether the 1989 odd-year escapement event has caused depressed production from the even-year brood line; since 1989, even-year brood line production has been well below forecast. This forecast is one of the most accurate for any salmon species in Alaska. We feel after evaluating even-year preemergent fry indices and escapement numbers that the causal mechanism for this depressed production is marine derived.

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APPENDIX

Appendix A.1. Pink salmon peak and estimated total escapement counts by fishing district for streams assessed using aerial and foot surveys within the Kodiak Management Area, 1989.

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
Afognak District			
251-101	0	0	
251-102	409	778	1.90
251-103	4,000	7,604	1.90
251-104	300	570	1.90
251-105	1,200	4,022	3.35
251-109	500	951	1.90
251-201	774	1,471	1.90
251-202	651	1,238	1.90
251-206	9	17	1.90
251-207	200	380	1.90
251-301	0	0	
251-403	200	1,351	6.76
251-405	75	143	1.90
251-406	27,500	27,500	1.00
251-407	8,425	8,425	1.00
251-502	225	225	1.00
251-503	0	0	
251-504	615	615	1.00
251-505	325	325	1.00
251-505A	424	424	1.00
251-506	274	274	1.00
251-507	287	287	1.00
251-510	2,000	2,000	1.00
251-811	41	41	1.00
251-812	2	2	1.00
251-813	2,150	2,150	1.00
251-821	0	0	
251-826	0	0	
251-829	0	0	
251-832	75	143	1.90
251-901	1,500	6,000	4.00
252-103	1,150	2,186	1.90
252-104	325	618	1.90
252-301	1,500	1,500	1.00
252-302	50,000	95,052	1.90
252-303	0	0	

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
252-305	3,000	3,000	1.00
252-306	150,000	285,157	1.90
252-307	60,000	114,063	1.90
252-308	3	6	1.90
252-309	60,000	114,063	1.90
252-317	1	8	8.00
252-318	150,000	285,157	1.90
252-319	0	0	
252-323	150,000	285,157	1.90
252-331	2,356	2,356	1.00
252-331A	1,429	2,717	1.90
252-331B	1,156	2,198	1.90
252-332	30,000	39,207	1.31
252-333	15,000	28,516	1.90
252-335	189	359	1.90
252-337	3	6	2.00
252-338	2	4	1.90
252-339	7	13	1.90
252-343	10,000	20,794	2.08
Subtotal	738,282	1,349,069	1.83
Northwest Kodiak District			
253-114	2,500	3,707	1.48
253-115	84,000	193,167	2.30
253-121	8,000	13,600	1.70
253-122	520,000	795,899	1.53
253-141	1,800	3,422	1.90
253-142	900	4,400	4.89
253-311	1,500	2,852	1.90
253-313	12,000	12,000	1.00
253-321	6,000	11,406	1.90
253-331	367,000	410,913	1.12
253-332	325,000	353,333	1.09
253-333	800	2,740	3.43
254-103	2,000	3,802	1.90
254-105	1,400	1,400	1.00
254-201	60,000	60,000	1.00
254-202	300,000	645,157	2.15
254-203	165,000	251,953	1.53
254-204	34,000	63,820	1.88
254-205	500	1,500	3.00
254-206	1,000	1,000	1.00
254-207	1,000	2,200	2.20
254-208	1,000	2,000	2.00
254-209	1,500	1,500	1.00
254-210	1,500	1,500	1.00
254-211	5,000	5,000	1.00
254-212	2,500	2,500	1.00

-Continued-

	Numbers of Fish		
Stream No.	Peak Count (PC)	Estimated Total Escapement (ETE)	ETE/PC[a]
254-301	95,000	103,983	1.09
254-302	3,000	3,000	1.00
254-401	48,000	91,250	1.90
254-402	2,500	4,753	1.90
254-403	100	190	1.90
254-404	1,500	4,833	3.22
254-405	400	1,920	4.80
259-363	0	0	
259-365	236,000	432,100	1.83
259-366	8,700	16,539	1.90
259-368	7,000	13,307	1.90
259-371	39,000	119,943	3.08
259-372	4,500	14,700	3.27
259-373	1,800	1,800	1.00
259-381	0	0	
259-382	54,000	126,000	2.33
259-383	0	0	
259-391	5,400	5,477	1.01
259-392	4,000	7,604	1.90
259-394	3,200	3,200	1.00
259-395	286	544	1.90
259-397	300	1,500	5.00
259-398A	36	68	1.90
259-398B	5	10	1.90
259-399	3	6	1.90
Subtotal	2,420,630	3,803,498	1.57
Southwest Kodiak District			
256-101	0	0	
256-102	0	0	
256-202	0	0	
256-301	1,500	2,852	1.90
256-302	0	0	
256-303	0	0	
256-303A	0	0	
256-401	1,250	1,692	1.35
256-402	3,000	5,800	1.93
Subtotal	5,750	10,344	1.80
Alitak Bay District			
257-101	0	0	
257-102	1,000	1,000	1.00
257-301	0	0	
257-303	600	1,400	2.33
257-401	550	2,097	3.81
257-402	300	570	1.90

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
257-405	6,000	6,000	1.00
257-502	410,000	1,093,543	2.67
257-503	87,000	139,417	1.60
257-504	32,000	67,133	2.10
257-601	12,000	24,800	2.07
257-602	35,000	72,333	2.07
257-603	55,000	62,962	1.14
257-604	123,000	212,733	1.73
257-605	7,000	14,260	2.04
257-701	690,000	1,783,196	2.58
257-702	94,000	103,400	1.10
257-702A	65,000	134,333	2.07
257-703	0	0	
Subtotal	1,618,450	3,719,177	2.30
Eastside Kodiak District			
258-101	2,600	12,880	4.95
258-201	4,700	28,420	6.05
258-202	200	271	1.36
258-203	150	150	1.00
258-204	200	227	1.14
258-205	300	340	1.13
258-206	4,100	7,653	1.87
258-207	60,500	69,762	1.15
258-208	900	1,647	1.83
258-209	1,600	1,600	1.00
258-210	0	0	
258-211	400	647	1.62
258-212	4,000	10,800	2.70
258-213	28,500	43,700	1.53
258-301	2,800	2,800	1.00
258-302	3,500	3,500	1.00
258-303	2	6	3.00
258-304	3,000	10,247	3.42
258-305	575	1,648	2.87
258-306	150	430	2.87
258-307	1,100	3,520	3.20
258-401	0	0	
258-511	0	0	
258-512	11,000	11,000	1.00
258-513	0	0	
258-514	10,800	35,800	3.31
258-521	15,000	42,437	2.83
258-522	53,300	147,423	2.77
258-531	0	0	
258-532	0	0	
258-533	0	0	
258-541	30,500	57,133	1.87

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
258-541A	0	0	
258-542	78,000	118,323	1.52
258-544	17,000	19,257	1.13
258-551	2,600	10,450	4.02
258-544	1,000	1,533	1.53
258-555	300	620	2.07
258-601	4,000	8,267	2.07
258-602	50,400	81,256	1.61
258-603	42,000	81,200	1.93
258-701	450,000	1,192,683	2.65
258-702	68,000	146,467	2.15
258-703	47,000	65,033	1.38
258-704	0	0	
258-705	19,000	25,367	1.34
258-706	0	0	
258-707	100	190	1.90
258-801	0	0	
258-803	0	0	
258-804	0	0	
258-805	0	0	
258-807	0	0	
258-808	100	200	2.00
258-809	0	0	
258-810	0	0	
258-851	0	0	
258-852	100	100	1.00
258-901	1,800	3,720	2.07
257-902	17,000	35,133	2.07
258-903	3,000	3,000	1.00
258-904	2,000	2,000	1.00
259-401	3,600	6,844	1.90
259-403	100	190	1.90
259-411	2,000	3,802	1.90
259-412	61,000	196,087	3.21
259-414	96,000	142,535	1.48
259-415[b]	81,000	251,741	3.11
259-416	6,500	12,357	1.90
259-417	500	1,300	2.60
259-417A	0	0	
259-418	0	0	
259-418A	900	1,711	1.90
259-418B	0	0	
259-419	0	0	
259-420	0	0	
259-421	0	0	
259-422	20,200	47,160	2.33
259-423	700	1,820	2.60
259-424	46,000	103,478	2.25
259-425	6,300	16,647	2.64
259-426	800	1,521	1.90
259-427	200	200	1.00
259-428	0	0	
Subtotal	1,369,077	3,076,233	2.25

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
Northeast Kodiak District			
259-101	8,000	11,519	1.44
259-102	42,100	42,950	1.02
259-105	4,000	7,298	1.82
259-221	22,000	41,823	1.90
259-222	36,500	108,498	2.97
259-223	113,000	329,627	2.92
259-231	152,000	365,383	2.40
259-233	500	951	1.90
259-235	3,700	5,427	1.47
259-242	46,000	139,668	3.04
259-243	47,700	90,680	1.90
259-244	12,600	12,600	1.00
259-245	10,200	19,391	1.90
259-246	300	300	1.00
259-251	39,400	74,901	1.90
Subtotal	538,000	1,251,015	2.33
Mainland District			
262-101	100	190	1.90
262-102	12,000	21,693	1.81
262-103	600	1,141	1.90
262-104	0	0	
262-105	0	0	
262-106	0	0	
262-107	0	0	
262-108	3,600	6,480	1.80
262-109	0	0	
262-110	0	0	
262-111	0	0	
262-113	3,800	7,224	1.90
262-151	0	0	
262-152	15,000	28,516	1.90
262-153	48,000	91,250	1.90
262-154	0	0	
262-155	800	1,521	1.90
262-201	3,000	12,000	4.00
262-202	0	0	
262-203	0	0	
262-204	0	0	
262-205	42,000	79,844	1.90
262-206	6,000	11,406	1.90
262-207	0	0	
262-254	100	190	1.90
262-271	2,000	3,802	1.90
262-272	0	0	
262-273	0	0	
262-301	0	0	
262-351	9,000	17,109	1.90
262-352	3,800	7,224	1.90

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
262-401	3,800	7,224	1.90
262-402	19,000	36,120	1.90
262-451	37,000	54,327	1.47
262-501	200,000	380,209	1.90
262-502	0	0	
262-503	1,000	1,901	1.90
262-504	10,000	10,000	1.00
262-505	10,000	10,000	1.00
262-551	38,000	65,910	1.73
262-552	0	0	
262-601	0	0	
262-602	0	0	
262-603	0	0	
262-604	80,000	282,600	3.53
262-605	10,000	22,667	2.27
262-606	20	38	1.90
262-651	445,000	541,827	1.22
262-652	162,000	201,400	1.24
262-653	230,000	230,000	1.00
262-654	0	0	
262-655	300	620	2.07
262-656	13,600	33,320	2.45
262-701	44,000	92,000	2.09
262-702	67,000	138,880	2.07
262-703	42,000	42,000	1.00
262-704	20,000	27,253	1.36
262-705	12,000	19,867	1.66
262-706	0	0	
262-751	73,000	115,612	1.58
262-752	10,000	11,560	1.16
262-753	3,500	6,654	1.90
262-801	22,000	23,303	1.06
262-802	76,000	158,350	2.08
262-803	500	500	1.00
262-804	200	200	1.00
262-850	5,000	5,000	1.00
262-851	1,320,000	2,078,433	1.57
262-852	91,000	110,580	1.22
262-853	66,000	124,200	1.88
262-854	10,000	12,000	1.20
262-856	100	190	1.90
262-858	1,900	2,489	1.31
262-859	0	0	
262-860	0	0	
262-861	9,000	18,600	2.07
262-862	200	200	1.00
262-863	0	0	
262-864	0	0	
262-865	50	95	1.90
262-866	800	1,521	1.90
262-868	100	190	1.90

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[a]
262-951	24,000	45,625	1.90
262-952	28,000	53,229	1.90
Subtotal	3,335,870	5,256,284	1.58
Total	10,026,059	18,465,619	1.84

[a] Estimated total escapements derived by the AUC method included fractions of whole numbers which the ETE/PC ratio reflects in several instances.
[b] Estimate includes estimates of fish spawning downstream of the counting weir.

Appendix A.2. Pink salmon aerial survey odd-year peak counts, Kodiak Management Area, 1969-1987.

	Peak Count											
Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
Afognak District													
251-101	0	3,200	200	0	0	5,000	450	600	1,200	7,500	1,815	0	
251-102	25	0		0	60	600		0			114	409	
251-103	0	50			30	675		170	0	0	132	4,000	
251-104		10			0			0		0	3	300	
251-105	1,000	100	3,800	900	10,000	19,000	16,500	13,500	3,500	25,000	9,330	1,200	*
251-106		0	0			0	0				0		
251-201	0	100		0	20	1,124	0	7,000	400		1,081	774	
251-201[a]	0	0			0	87	0	400		0	70		
251-202	0	100	0		600	450		3,300	20		639	651	
251-203					1,200	600	7,500				3,100		
251-204						68	0				34		
251-301	1,600	7,200			0	8,000	28,300	1,500	7,599	5,500	7,462	0	
251-302	25	300	700	0	0	15,000	11,000	0	0	0	2,703		
251-403	8,200	1,500	800	1,500	500	1,500	8,000	7,000	400	0	2,940	200	
251-404	2,900	1,300	3,000	200	1,300	13,000	26,000	13,000	9,900	6,500	7,710		*
251-405	0	0		0				0	10		2	75	
251-406		0		0	0	15					4	27,500	
251-407		0				3,499					1,750	8,425	
251-501					0				0		0		
251-502					0	5					3	225	
251-503				0	0	0					0	0	
251-504				0	0	0					0	615	
251-505				0	0	0					0	305	
251-601	0	0		0	0	0	0	0	0		0		
251-701	0	0			0		0	0	0		0		
251-702	0	0			0	0	100	0	87		27		
251-703					0	0	0	0	0		0		
251-706									3		3		
251-821	0			500	15		1,800	2,000	0	0	616	0	
251-822[c]							61,193	21,670	199,211	29,093	77,092	106,347	•
251-823					0		0	0	0	0	0		
251-824	0				0		0	0	0		0		
251-825						0	138	0			46		
251-826				0	10		73	0	0		17	0	
251-827					0	12	452	800	5,000	0	1,044		

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Stream No.	Peak Count 1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
251-828	100			0	0	0	581		375		176		
251-829						0	1,205	0	0		301	0	
251-830	25,000	25,000	11,000	21,000	21,600	71,000	56,000	18,000	33,145	12,094	29,384		*
251-831								533	26,904	202	9,213		*•
251-901	0	3,323		1,688	14,314	10,000	29,000	5,500	15,000		9,853	1,500	*•
251-901A						0					0		
251-902							500	0	3,000		1,167		
251-903A								0		0	0		
252-101		300		90		300	4,400	0	9,000		2,348		
252-102		50		0	0	700	8,500	0	11,000		2,893		
252-301									10,000		10,000	1,500	
252-302								100		0	50	50,000	
252-305								85		0	43	3,000	
252-306								2,550	15,000	0	5,850	150,000	
252-307								213	5,000	0	1,738	60,000	
252-308										0	0	3	
252-309							6,000			800	3,400	60,000	
252-311	0			25		0	500				131		
252-312	50			90	563	284	1,200				437		
252-314A					500						500		
252-315	25			200		90	1,200				379		
252-316	250	300		438	718	1,062					554		
252-317	0			0	1,409	1,012	100			0	420	1	
252-318				0	208	4	0		0		42	150,000	
252-319	0			0	25	0		0		0	4	0	
252-321	0			18		850	0				217		
252-323					0	300		0	10,000	0	2,060	150,000	
252-324		3,800		8,643	6,661	15,988	40,834	0	25,000	153,482	31,801		
252-331	600		200	0	158	3,200	18,500	1,096	200	1,200	2,795	2,356	
252-332	7,600	5,800	3,000	2,100	21,000	24,000	44,029	11,000	13,000	2,700	13,423	30,000	*
252-333	0			127		512	0	0		900	257	15,000	
252-335			100	0	0		0	0		0	17	189	
252-341	0			0	3	799	1,000	0			300		
252-342[b]	48,000	13,600	38,000	2,800	84,000	19,020	17,508	84,956	8,860	8,780	32,552	41,611	*
252-343	12,000	12,500	0	0	29,000	41,500	38,700	34,500	9,800	7,100	18,510	10,000	*•

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Stream No.	Peak Count 1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
Northwest Kodiak District													
253-114	100		0		0	4	250	50			67	2,500	
253-115	0		2,000		11,500	36,000	82,000	32,000	18,300	41,000	27,850	84,000	*
253-121	500	1,500	1,000	0	50	1,600	6,000	1,600		16,000	3,139	8,000	
253-122	50,000	37,000	53,000	77,500	44,000	99,000	75,000	128,000	114,000	190,000	86,750	520,000	*
253-123	0				0		0	0			0		
253-141								50			50	1,800	
253-201										0	0		
253-203										0	0		
253-311							100	350			225	1,500	
253-313			0		362	60	0	150	1,200	0	253	12,000	
253-321	1,500	2,500	3,000		325	4,800	11,700	1,400		2,600	3,478	6,000	
253-322				20	2	375	0	0			79		
253-323			0		362	60	0	0		0	70		
253-331	46,000	40,000	22,000	43,500	56,000	80,000	92,000	42,250	80,000	72,000	57,375	367,000	•
253-332	23,000	6,000	3,000	550	5,900	18,100	44,500	8,100	21,000	15,000	14,515	325,000	•
253-333					35	0	0	1,200	4,100	100	906	800	
253-351	0					0		0			0		
253-352	200					80		0			93		
254-103			0		300	1,800		190	80		474	2,000	
254-104					12,075		600				6,338		
254-105							3,000	700	30		1,243	1,400	
254-201	400		10	13,500	13,500	19,000	15,000	6,000	4,500	1,600	8,168	60,000	
254-202	103,000	65,000	50,000	72,000	111,000	147,000	136,000	180,000	175,500	96,500	113,600	300,000	•
254-203	13,000	30,000	4,000	24,000	24,130	58,000	58,000	62,500	80,000	30,000	38,363	165,000	*
254-204	2,600	400	800		4,500	5,200	32,000	4,500	7,100	11,000	7,567	34,000	•
254-205			0	1,200	1,950	400	0	0	0	0	444	500	
254-206				500	1,350	300	0	0	0	0	307	1,000	
254-207			0		8,500	1,500	0	0	40	300	1,477	1,000	
254-208					1,480	350	300	60	30	500	453	1,000	
254-209					640		0	0	0		160	1,500	
254-210					1,900		0	0	0		475	1,500	
254-211					560		0	0			187	5,000	
254-212					390		0	600	2,300		823	2,500	
254-213								220	1,500		860		
254-301	18,000	14,000	11,000	35,500	35,500	43,000	50,000	30,000	4,000	30,000	27,100	95,000	•

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Stream No.	Peak Count 1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
254-302	0		5,000	0	3,200	6,000	300	0		0	1,813	3,000	
254-401	2,000	20,000	0		45,000	18,000	0	30,000	0	0	12,778	48,000	
254-402						400	100	40			180	2,500	
254-403					400	150	50	20			155	100	
254-404							2,800	7,100	750	450	2,775	1,500	
254-405							2,300	100			1,200	400	
255-102			80		7,770	129		0			1,995		
259-362					125						125		
259-363	0		0	0	0	0	200	200	0	0	44	0	
259-364	1,400		50		400	12,000	4,500	400	2,500	2,100	2,919		
259-365	8,300	4,000	8,000	11,000	19,300	29,600	58,250	18,000	35,000	29,000	22,045	236,000	
259-366	1,500		300		150	16,500	4,300	600	1,600	4,700	3,706	8,700	
259-367					4		120			1,400	508		
259-368					73	2,700	20			50	711	7,000	
259-369					250		0			200	150		
259-371	11,200	6,400	4,000	12,000	18,000	38,000	20,500	18,000	40,900	15,000	18,400	39,000	*
259-372						60	0	200		2,000	565	4,500	
259-373							20				20	1,800	
259-381						0	6,000	0		0	1,500	0	
259-382	4,700	2,300	1,800	2,650	3,500	16,200	4,000	2,800	6,600	3,780	4,833	54,000	
259-383	1,700	200	500	0	500	3,800	0	2,900		800	1,156	0	
259-391	1,500		500	400	300	8,600	20,000	5,500	7,400	2,000	5,133	5,400	
259-392	2,500		200	900	2,500	1,300	6,500	0	3,000		2,113	4,000	
259-393	200		0	150	200	20	250	600	300	0	191		
259-394								700	5,400	1,900	2,667	3,200	
259-395								0		900	450	286	
259-397									4,500		4,500	300	
Southwest Kodiak District													
255-101[a]	0		57	210	52,319	82,973	51,248	38,902	41,232	24,222	32,351	109,880	•
256-201[a]	2,100	0	839	2,568	3,716	10,878	4,358	17,702	3,000	7,819	5,298		*
256-202			0	0	0	10		1,400			282	0	
256-301			0	0	3,500	3,000	13,000	3,000	2,600	3,440	3,568	1,500	
256-302			0	0	0	0	50	800		0	121	0	
256-303			0		0	0	0	1,100	10,500	0	1,657	0	
256-401	0	4,000	0	0	2,000	45,000	0	0	4,500	0	5,500	1,250	•
256-402		0		0	5,000	400		4,500	5,000		2,483	3,000	

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	Peak Count												
Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
Alitak Bay District													
257-101		0			0	0		0		0	0	0	
257-102	0	0			0	0	0	0	0	0	0	1,000	
257-301	0					1,500	0	0			375	0	
257-302	14,000		742	9,494	13,380	100	0	9,000	2,500	22,791	8,001	49,608	
257-303	0			0	2,500	0	0	600	0	0	388	600	
257-304	35,000	15,000	2,197	22,000	18,000	5,277	1,506	424	5,235	1,010	10,565		
257-305								10			10		
257-401	6,000	5,000	1,000	200	2,500	3,830	16,000	3,000	8,000		5,059	550	•
257-402	25	400	2,777	2,000	7,000	6,000	3,000	1,000	0	2,200	2,440	300	
257-403	60,000	63,000	22,000	38,000	98,000	85,178	157,000	72,000	141,000	55,993	79,303	315,559	*
257-404	19,000	19,000	8,000	3,500		17,000	50	5,000			10,221		
257-405	5,000			4,500	4,000	2,400	4,000	4,500			4,067	6,000	
257-406					300		3,500	700			1,500		
257-407					400		0	24			141		
257-409							0	0			0		
257-501			0	10	100			0	800		182		
257-502	140,000	100,000	40,000	76,700	141,000	97,500	180,000	148,000	166,500	130,700	122,040	410,000	*
257-503	15,000	4,000	500	340	8,000	7,000	13,000	8,200	9,000	6,100	7,114	87,000	
257-504			0	0		3,500		2,000	350		1,170	32,000	
257-505								0			0		
257-601	1,500	0	450	0	2,800	4,500	50	2,000	40,000	0	5,130	12,000	
257-602	1,700	4,000	400	900	3,000	6,000	3,800	8,700	35,000	25,000	8,850	35,000	
257-603	6,000	1,000	4,000	200	3,000	10,500	2,500	10,100	48,300	24,500	11,010	55,000	
257-604	2,000	400	1,000	2,400	4,500	6,000	800	15,500	58,000	0	9,060	123,000	
257-605	0	0	0	0	0		0	1,000	2,000		375	7,000	
257-701	44,000	122,000	45,000	71,300	92,000	306,000	240,000	142,000	273,000	208,500	154,380	690,000	•
257-702			500	4,200	10,500	900		1,600	8,000	0	3,671	94,000	
257-703	0			0	600	6,000		5,000	90	0	1,670	0	
Eastside Kodiak District													
258-101	1,100	200	0			6,300	9,000	200	1,100		2,557	2,600	
258-201	2,000		0	0		3,500	2,000	800	5,200	100	1,700	4,700	
258-202	15	100	250	0		1,000	0	20	70	400	206	200	
258-203	0	0		20		0	0	0	0	0	3	150	

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	Peak Count												
Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
258-204	0	200	0	100		0	1,000	200	0	0	167	200	
258-205		0	300	0		0	0	0	100	3,300	463	300	
258-206	2,500	3,000	700	200	1,350	4,400	9,000	6,000	13,400	6,080	4,663	4,100	
258-207	500	2,500	1,500	3,700	2,700	22,200	47,000	8,800	12,600	11,180	11,268	60,500	*
258-208			0	0	200	0	0	0	100	0	38	900	
258-209	1,000	50	500	0		1,200	3,100	2,500	1,200	100	1,072	1,600	
258-210	0	0	0	0		0	5,000	0		0	625	0	
258-211	0	1,000	10	0	400	0	0	0	50	0	146	400	
258-212	0		0	0	0	0	0	0	0	0	0	4,000	
258-213						150	0	0	0	0	30	28,500	
258-301	0				0	0	0	600	500		183	2,800	
258-302	0	200	10		2,600	0	0	300	400	0	390	3,500	
258-303	0		0	0	0	0	0	0	0		0	2	
258-304	1,100		20		13,000	11,000	6,300	4,200	2,800	200	4,828	3,000	
258-305	0		0	0	200	700	75	0	0		122	575	
258-306	0	0	0	0	0	0	0	0			0	150	
258-307						0	0	0	0	0	0	1,100	
258-401	500	0	1,000	0	500	0	0	0	400	0	240	0	
258-402					580	2,000		150	20		688		
258-403									800		800		
258-404									900	0	450		
258-511	2,200	5,400	300	0	600	3,500	8,600	3,000	3,600	0	2,720	0	
258-512	0		100		400	3,000	0	0	300	0	475	11,000	
258-513	0		50		2,760	0	0	100	700	0	451	0	
258-514							0	500	1,200	0	425	10,800	
258-515							8,000	0	0	0	2,000		
258-516									0	0	0		
258-521	1,900	1,900	5,000	13,500	28,000	6,000	22,000	22,000	15,000	3,400	11,870	15,000	
258-522	35,000	23,000	23,000	39,400	48,500	67,500	52,000	78,000	77,000	14,100	45,750	53,300	*
258-523	1,500	0	0	0	30	100	0	700	50		264		
258-531	0			0	60	0	5,000	400	1,100		937	0	
258-532	0			0	0	80	0	200	25		44	0	
258-533	0				0	0	0	25		0	4	0	
258-541	4,000	3,000	150	250	7,000	13,000	11,000	6,000	3,200	500	4,810	30,500	
258-542	25,000	1,500	1,100	1,600	13,000	17,000	22,000	23,100	21,000	11,000	13,630	78,000	*
258-543	0	0		0		0	4,000	0	10		573		
258-544						0	1,200	500	3,800	2,200	1,540	17,000	

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Stream No.	Peak Count 1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
258-551	7,000	0	3,000	0	400	500	34,000	2,000	1,800		5,411	2,600	
258-552	3,800		3,000		14,000	11,500	17,000	4,000	0	5,360	7,333		
258-553	8,000	0	200		15,000	9,500	16,000	6,000		850	6,944		
258-554	100		0	0	600	300	2,500	500			571	1,000	
258-555	25		0		50	0	0	200			46	300	
258-601	400			0	200	200	0	40	3,000		549	4,000	
258-602	22,000	10,000	1,500	2,500	9,000	33,000	2,500	30,800	10,000	8,800	13,010	50,400	
258-603	5,200	0	13,600	0	10,000	9,000	0	10,000	12,000	480	6,028	42,000	
258-701	39,000	54,000	24,000	86,000	53,000	100,700	128,000	86,000	60,000	164,400	79,570	450,000	*
258-702	8,000		0	0	9,000	8,000	10,600	4,000	5,200	8,580	5,931	68,000	
258-703					6,000	10,000	5,600	18,000	400		8,000	47,000	
258-704					0			800	0		267	0	
258-705							0		6		3	19,000	
258-706							10,000				10,000	0	
258-801	17,000		600	0	4,500	1,200	800	0			3,443	0	
258-801A				20		0	0				7		
258-801B							3,400				3,400		
258-802				0	20	0			200		55		
258-803				0	0	2		0	0		0	0	
258-803A		0		0	0	15					4	0	
258-804		0		0	90	0		0	0		15	0	
258-804A		0		0	0	0					0		
258-805		0		0	0	0		0	0		0	0	
258-806				0	0	0		0	0		0		
258-807									13		13	0	
258-808				0	100	100	0	450			130	100	
258-809				0		20		200			73	0	
258-810				0		700					350	0	
258-811				0							0		
258-851								1,500	500		1,000	0	
258-852									40		40	100	
258-853									0	0	0		
258-901								200	1,000		600	1,000	
258-902								6,000	8,000		7,000	17,000	
258-903								150	3,000	0	1,050	3,000	
258-904								0	0		0	2,000	
259-401	20,000	21,000	15,000	14,000	0	23,000	3,800	5,400	11,800	150	11,415	3,600	

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	Peak Count												
Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
259-402	10	0	0	0		0		120	0	0	16		
259-403	0	60	100	100		0		20	2,400	0	335	100	
259-404	0	130	0	50		200		0	10	0	49		
259-405	0		0			0		0	0	0	0		
259-410	2,100	7,000	2,900	12,000	100	14,000	4,100	3,800	6,600	12,000	6,460		
259-411	10,200	1,500	0	260	100	5,000	2,000	400	14,500	2,000	3,596	2,000	
259-412	4,000	3,000	1,100	12,000	11,900	71,000	15,380	17,500	40,000	22,500	19,838	61,000	*
259-413	0	0		300		0			10		62		
259-414	20,000	30,000	8,300	7,700	33,000	17,000	6,050	3,500	1,500	11,100	13,815	96,000	*
259-414A									50		50		
259-415[d]	85,000	57,000	25,000	46,000	144,000	68,000	57,000	39,000	28,400	39,687	58,909	81,000	*
259-416	10,000	3,000	1,000	6,600		8,600	3,000	7,500	7,700	0	5,267	6,500	
259-417			0	20		10	0	500	400	0	133	500	
259-418A	100	0	100	0	0	0	1,000	3,000	9,000	0	1,320	900	
259-418B	0	0	0	0	0	0	1,100	1,000	20	0	212	0	
259-419	0		0	0	0	0	0	0	80	200	31	0	
259-419A						445	0	0	250	0	139		
259-420				0			0				0	0	
259-421	0			0		2,400	0	10	30		349	0	
259-422	5,000	5,000	2,000	4,000		7,800	5,500	9,000	7,200	630	5,126	20,200	
259-423	2,100	2,000	0	6,000		3,000	500	4,000	2,000	1,700	2,367	700	
259-424	3,600	1,800	3,600	5,400	22,000	57,300	14,400	6,400	4,550	11,000	13,005	46,000	
259-424A					6,200						6,200		
259-425	600	0	0			800	0	300			283	6,300	
259-426	0	0	100	0		500	0	0		75	84	800	
259-427			0			100	200	0	0	0	50	200	
259-428	0	550	3,500		0	0	0	0	0		506	0	
Northeast Kodiak District													
259-101	3,500	0	50	600	3,800	3,300	1,300	1,250	8,700	295	2,280	8,000	
259-101A	300		500		200	400	2,500	650	2,800		1,050		
259-102	500	500	1,000	4,500	4,800	850	400	430	5,040	300	1,832	42,000	
259-103										0	0		
259-211	66,500	7,900	26,350	22,000	54,000	61,000	88,000	53,000	166,688	27,892	57,333		*
259-221	3,000	2,000	1,000		300	1,400	1,400	300	4,000	300	1,522	22,000	
259-222	16,340	3,100	2,250	6,000	12,000	24,200	5,600	2,000	10,400	18,200	10,009	36,500	

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Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
	Peak Count												
259-223	15,100	4,400	1,500	11,250	6,000	19,550	10,000	5,500	20,400	10,000	10,370	113,000	
259-224								0	3,000		1,500		
259-231	52,000	18,900	11,300	0	51,900	45,300	54,000	71,000	141,000	112,800	55,820	152,000	*
259-232				0				0			0		
259-233		1,000		20	200	0	0	0	0	1,000	278	500	
259-234							5,500				5,500		
259-235									300	200	250	3,700	
259-242	37,000	40,000	13,000	16,000	41,000	80,000	73,000	30,020	69,400	66,100	46,552	46,000	*
259-243	5,000	300		400		1,100	0	0		0	971	47,700	
259-244					0			0	0	0	0	12,600	
259-245								1,390	4,600	0	1,997	10,200	
259-246									0	0	0	300	
259-251	13,000	4,000	600	5,600	4,200	11,500	1,500	2,800	7,800	12,000	6,300	39,400	
259-252	300		50	0	500	500	0	260	60	14,000	1,841		
259-253				300			0	0	300	10	122		
259-254	4,000	1,500	200	1,300	2,700	4,000	650	3,000	10,500	9,950	3,780		
259-255	1,700	4,000	300	3,200	11,000	60	2,600		0	0	2,540		
Mainland District													
262-101		0				200	50	100	900		250	100	
262-102		0				600	0	300	0	0	150	12,000	
262-103		0				0	30	50	2,200	0	380	600	
263-104		0				0	0	0	0	0	0	0	
262-105		0				0	0	0	0	0	0	0	
262-106		0				4,000	0	500	0	0	750	0	
262-106A									1,500		1,500		
262-107		0				0	0	0	1,200	0	200	0	
262-108		50				300	0	0	600	0	158	3,600	
262-151	0	100	0	7,400	0	0	0	0	0	0	750	0	
262-151A			0								0		
262-152	70,000	15,000	15,000	11,000	40,000	25,000	40,000	11,000	25,000	22,000	27,400	15,000	*
262-152A			0	0	500						167		
262-153	99,000	20,000	500	27,000	70,000	19,050	42,000	33,000	15,000	9,000	33,455	48,000	*
262-153A			0	0	0						0		
262-153B					250						250		
262-154	0	0	0	40	300	0	0	0	0	0	34	0	

-Continued-

Stream No.	Peak Count 1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
262-155				0	50				0	100	38	800	
262-156				150	30						90		
262-157				0	0						0		
262-158				0	0						0		
262-159				0	200						100		
262-201	25	0	0	0	2,000	600	0	200	200	3,000	603	3,000	
262-202	0	0	6,000	0	0	0	0	0	0	200	620	0	
262-203	10,000	0	1,500	0	3,000	0	1,500	2,000	2,000	0	2,000	0	*
262-204	500	0	0	0	600	100	1,100	300	0	0	260	0	
262-205	2,000	1,000	500	2,500	3,500	6,000	11,000	450	7,700	3,400	3,805	42,000	*
262-253	0	0	0	0	0	0	50	0	1,700		194		
262-254	20	100		0		0	0	20	300	0	55	100	
262-255	1,500	0	50	0	100		0	220	75		243		
262-256	0	0	50	0	100		0	16	150		40		
262-271	0	0	0	15,000	5,000	3,000	2,000	500	2,000	1,000	2,850	2,000	*
262-272	0	0	0	0	6,000	300	500		900	0	856	0	*
262-301	0	0	0	0	3,600	0	0	0	0	0	360	0	
262-302							0				0		
262-351	0	0	0	0	5,000	3,000	6,000	2,600	2,500	600	1,970	9,000	
262-352						6,000	0	0			2,000	3,800	
262-401	0	0	0	0	1,500	1,200	9,300	500	2,700	100	1,530	3,800	
262-402	3,000	100	400	4,200	10,500	5,000	14,000	2,000	3,000	0	4,220	19,000	*
262-451	13,000		500	34,000	55,000	55,000	89,000	45,000	45,000	6,500	38,111	37,000	*
262-452		200	800		0	3,000	200	0	0		600		
262-453							0	1,100	0		367		
262-501	3,000	500	1,000	0	15,000	21,000	51,200	4,500	16,500	14,000	12,670	200,000	*
262-502					200	0	6,000	200		700	1,420	0	
262-551	18,000	1,000	3,000	29,000	76,000	77,000	31,000	8,000	17,000	18,000	27,800	38,000	*
262-552						0	0	0	0	0	0	0	
262-601	0	0			0	0	0	0	0		0	0	
262-602	2,000	5,000	2,000	0	3,000	0	0	0		2,000	1,556	0	
262-603	200	0	6,000	0	200	0	0	0	1,900	0	830	0	
262-604	14,000	18,000	9,500	16,000	60,000	38,700	37,000	33,000	45,000	63,000	33,420	80,000	*
262-605					4,300	1,200		0	1,200	700	1,480	10,000	
262-606							0			0	0	20	
262-651	7,000	6,000	6,000	5,200	28,000	17,000	11,000	12,000	42,000	51,000	18,520	445,000	*
262-652	1,300	800	500	20	0	300	1,500	2,000	15,000	28,000	4,942	162,000	

-Continued-

	Peak Count												
Stream No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean (1969-87)	1989	Index Stream
262-653	1,200	2,500	500	10		250	5,100	2,800	7,600	18,000	4,218	230,000	
262-654	3,300	5,000	2,500	2,000	9,000	0	0	0	2,000	1,100	2,490	0	
262-655		6,000				700	0			1,400	2,025	300	
262-656							0			600	300	13,600	
262-701	250	500	300	450	2,000	500	2,000	2,200	7,000	5,400	2,060	44,000	
262-702	4,300	2,000	3,000		7,000	12,000	14,000	6,800	16,000	31,000	10,678	67,000	*
262-702A	0	0	0	0	0	0	0	0	0	0	0		
262-703	0	0	0	120		0	0	0	0	0	13	42,000	
262-704	50	0	0	50	300	0	5,000	1,600	0	2,000	900	20,000	
262-705		0		0		300	250	1,200	2,000	4,200	1,136	12,000	
262-750		0		0		300	250				138		
262-751	4,000	2,500	5,000	2,200		5,700	15,000	3,100	31,000	13,000	9,056	73,000	*
262-752	1,500	0	0	3,500		400	0	200	0	4,700	1,144	10,000	
262-801	600	1,000	300	80	1,500	1,200	500	800	1,200	2,600	978	22,000	*
262-802	16,000	6,000	2,000	3,000	10,500	40,000	50,000	6,500	14,000	21,000	16,900	76,000	*
262-803	0	100		0	200	200	0	0	150	0	72	500	
262-804										0	0	200	
262-851	21,000	4,000	5,000	13,000	112,000	184,000	65,000	40,000	69,000	141,000	65,400	1,320,000	*
262-851A										0	0		
262-852	2,000	600	0	2,600	4,000	4,500	16,000	5,000	11,000	12,500	5,820	91,000	
262-853	3,800	0	0	200	600	500	2,500	6,000	4,200	8,200	2,600	66,000	
262-854	500	0	0	0	300	100	20	50	2,800	8,600	1,237	10,000	
262-854A					25						25		
262-855	0	0		4	0		0	15		0	3		
262-856	500	0	0	0		6,200	3,200	4,000	8,000	3,200	2,789	100	
262-856A						2,600		3,000	7,800	19,000	8,100		
262-856B						400		200	400	100	275		
262-857	0	0	0	10	0	0	0	0			1		
262-858	0	5,000	0	8,700	0	2,000	0	0	0	5,000	2,070	1,900	
262-859	0	6,000		0	300	200		500	0		1,000	0	
262-859A					75	0		0		4,500	1,144		
262-951					650						650	24,000	

[a] Total escapement counted through fish weirs.
[b] Afognak River fish weir was moved downstream in 1986. Counts preceeding were adjusted to account for fish spawning between the two weir sites.
[c] Little Waterfall (251-822) escapement counts pre-1981 were excluded owing to additional spawning habitat created by a fishpass.
[d] Saltery Creek (259-415) escapement counts reflect estimates of fish spawning downstream of the weir.

Appendix A.3. Odd-year pink salmon preemergent fry densities (live fry/m^2) by stream and brood year, Kodiak Management Area, 1965-1989.

STREAM	1965	1967	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Average 1965-1987	90% CI 1965-1987	1989
Alinchak					0.0		60.2	0.0	2.0	49.0	0.9		18.7	4.2-50.4	27.3
American	8.8	85.4	150.4	93.2	83.6	219.1	361.4	33.3	174.6	0.0	126.6	378.8	142.9	78.4-207.4	256.0
Barling		13.4	36.0	0.0	20.1	63.3	107.3	39.0	168.2	289.9	147.7	210.3	99.6	48.2-150.9	51.7
Bauman's	119.4	353.8	107.0	113.0	108.1	317.2	375.9	401.5	188.1	252.9	560.4	863.2	313.4	196.5-430.2	240.7
Beaver									1,037.0	493.9	171.4	192.1	473.6	0-948.3[a]	549.4
Big Creek					4.7		138.9	36.5		0.0		395.0	115.0	0-273.5[a]	131.8
Buskin	64.7	11.5	46.3	35.9	31.8	51.5	164.3	141.8	374.8	277.5	248.4	267.6	143.0	79.7-206.3	89.8
Dakavak					85.1	19.5	111.2	0.3	85.8	0.0		117.0	55.6	21.9-97.7	0.4
Danger		157.6	31.1	227.9	0.0		156.0	16.2	67.0	10.2	56.9	174.5	89.7	42.4-137.1	292.5
Deadman	283.8	403.5	351.1	725.4	218.7	532.2	691.5	238.3	755.2	242.4	349.6	400.3	432.7	330.9-534.4	546.9
Dog Salmon	73.8	254.7	46.7	88.2	0.0	83.0	67.2	21.2	49.6	120.4	50.1	400.3	104.6	46.0-163.2	179.9
Humpy	5.1	281.7	80.2	144.3	88.7	422.4	508.0	35.9	228.1	220.1	135.1	491.1	220.0	126.1-313.9	464.8
Hurst			96.3	172.7	22.7	12.7	69.5	34.6	0.0	0.0	0.1	84.9	49.4	16.7-82.1	102.9
Kaiugnak	60.4	908.8	68.4	0.9	21.6	213.6	768.2	9.8	295.2	55.5	421.4	72.2	241.3	81.6-401.1	736.8
Kanatak							48.2	124.9	452.9	159.2		83.6	173.8	19.8-327.8	186.7
Karluk															0.1
Kashvik					5.3	12.5	24.0	20.5	2.3	164.9		82.1	44.5	0.8-88.2	0.8
Kiliuda			81.6	14.1	3.6	19.3	0.8	11.8	90.1	5.0	104.5	15.5	34.6	11.5-57.8	77.0
Kinak						136.2	280.4	179.6	105.8	111.1		42.7	142.6	76.1-209.2	161.7
Kukak								106.8	29.3	20.2			52.1	0-132.3[a]	6.7
Little															5.6
Little Wtfl.									586.2	839.5	339.0	172.3	484.2	141.2-827.3	70.0
Marka															10.3
Miam															118.6
Missak						130.1	126.0	59.4	63.3	3.6		214.6	99.5	39.1-160.0	131.8

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Appendix A.3. (page 2 of 2)

STREAM	1965	1967	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Average 1965-1987	90% CI 1965-1987	1989
Monashka							3.6	21.0	50.6	119.8	3.3		39.6	22.9-56.4	2.7
Narrows	77.3	225.3	123.0	47.2	0.0	70.5	185.8	4.8	27.6	107.0	96.8	135.9	91.8	55.9-127.6	264.8
Paramanof		0.0	2.8	27.9	15.2	6.1	13.3	26.1	85.5	44.6	5.7	5.5	21.2	7.4-34.9	278.3
Perenosa	137.9	363.2	428.2	347.0	146.9	306.6	111.4	234.2	251.9	46.1	216.9	39.2	219.1	153.6-284.6	72.3
Portage							73.2	0.0	0.0	4.8			19.5	0-61.7[a]	2.3
Saltery	35.2	76.3	33.9	34.2	72.4	126.6	194.8	81.5	163.2	46.7	44.4	227.5	94.7	59.7-129.7	521.5
Seal Bay							616.0	99.0	331.5	89.8	582.2	171.7	315.0	120.3-509.8	869.8
7-Rivers	115.1	210.0	304.7	325.2	137.5	338.0	260.4	173.7	595.8	135.0	569.2	252.0	284.7	202.8-366.7	383.5
Sheratin	10.1	67.4	92.0		46.6	15.8	89.4	21.9	20.9	7.0	68.7	7.1	40.6	21.5-59.7	39.8
Sid Old's	1.4	100.2	163.6	134.2	43.7	91.1	31.8	50.1	44.5	183.8	44.4	227.5	93.0	56.6-129.4	116.4
Terror	1.2	4.1	7.1	11.9	7.4	47.0	11.7	7.0	21.6	2.0	0.2	16.2	11.4	4.8-18.1	0.8
Uganik	4.2	96.5	9.9	20.9	166.7	92.1	67.1	154.2	172.9	7.1	0.4	1.4	66.1	30.5-101.7	9.4
Uyak 202	59.5	175.2	313.8	187.7	70.9	377.8	258.5	199.1	605.5	233.4	162.5	447.7	257.6	175.9-339.4	1,070.0
Uyak 203							123.0	0.5	340.9	700.3	0.0	80.8	207.6	0-431.3[a]	238.0
Zachar	0.0	0.0	0.0	0.0	0.0	3.6	34.7	0.0	45.7	0.0	0.0	38.0	10.2	0.9-19.4	12.1
Total	1,057.9	3,788.5	2,573.9	2,751.8	1,401.4	3,707.8	6,133.8	2,584.6	7,513.5	5,042.8	4,506.6	6,308.5	5,303.2	175.9-339.4	8,321.7

[a]Zero was assigned to lower confidence intervals which were negative numbers.

Appendix A.4. Pink salmon escapement goals for odd and even year populations for Kodiak Management Area index streams employing peak counts and estimated total escapement.

Index Stream		Even Year Indexed Escapement goals		Odd-Year Escapement goals				
				Indexed[a]		Estimated Total		
Name	No.	Minimum	Desired	Minimum	Desired	Minimum	Desired	Mid Point
Afognak District								
Malina	251-105	20,000	60,000	5,000	15,000	9,200	27,600	18,400
Paramanof	251-404	10,000	30,000	5,000	15,000	9,200	27,600	18,400
L. Waterfall[b]	251-822	15,000	45,000	15,000	45,000	15,000	45,000	30,000
Discoverer	251-830	20,000	60,000	20,000	60,000	36,800	110,500	73,700
Pauls Bay[b]	251-831	3,000	9,000	3,000	9,000	3,000	9,000	6,000
Seal Bay	251-901	5,000	15,000	5,000	15,000	9,200	27,600	18,400
Big Danger	252-332	15,000	45,000	10,000	30,000	18,400	55,200	36,800
Marka	252-334	30,000	90,000	10,000	30,000	18,400	55,200	36,800
Litnik[b]	252-342	30,000	90,000	10,000	30,000	10,000	30,000	20,000
Subtotal		148,000	444,000	83,000	249,000	129,200	387,700	258,500
Northwest District								
Sheratin	253-371	15,000	45,000	10,000	30,000	18,400	55,200	36,800
Bauman's	253-333	5,000	15,000	5,000	15,000	9,200	27,600	18,400
Terror	253-331	40,000	120,000	30,000	90,000	55,200	165,800	110,500
Uganik	253-122	80,000	240,000	70,000	210,000	128,900	386,800	257,800
Little River	253-115	40,000	120,000	15,000	45,000	27,600	82,800	55,200
Zachar	254-301	40,000	120,000	20,000	60,000	36,800	110,500	73,700
Browns Lgn.	254-204	40,000	120,000	5,000	15,000	9,200	27,600	18,400
Uyak-202	254-202	50,000	150,000	50,000	150,000	92,100	276,300	184,200
Uyak-203	254-203	5,000	15,000	15,000	45,000	27,600	82,900	55,200
Subtotal		315,000	945,000	220,000	660,000	405,000	1,215,500	810,200

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Index Stream		Even Year Indexed Escapement goals		Odd-Year Escapement goals				
				Indexed[a]		Estimated Total		
Name	No.	Minimum	Desired	Minimum	Desired	Minimum	Desired	Mid Point
Southwest District								
Karluk[b]	255-101	800,000	1,600,000	20,000	60,000	20,000	60,000	40,000
Sturgeon	256-401	50,000	150,000	5,000	15,000	9,200	27,600	18,400
Ayakulik[b]	256-201	400,000	800,000	5,000	15,000	5,000	15,000	10,000
Subtotal		1,250,000	2,550,000	30,000	90,000	34,200	103,600	68,000
Alitak Bay District								
Narrows	257-401	2,000	6,000	2,000	6,000	3,700	11,000	7,400
Dog Salmon	257-403	50,000	150,000	60,000	180,000	60,000	180,000	120,000
Deadman	257-502	40,000	120,000	60,000	180,000	110,500	331,500	221,000
Humpy	257-701	70,000	210,000	90,000	270,000	165,800	497,300	331,500
Subtotal		162,000	486,000	212,000	636,000	340,000	1,019,500	679,900
Northeast District								
Sid Olds	259-242	30,000	90,000	30,000	90,000	55,200	165,800	110,500
American	259-231	30,000	90,000	30,000	90,000	55,200	165,800	110,500
Buskin[b]	259-211	60,000	180,000	50,000	150,000	50,000	150,000	100,000
Subtotal		120,000	360,000	110,000	330,000	160,400	481,600	321,000
Eastside District								
Seven Rivers	258-701	40,000	120,000	40,000	120,000	73,700	221,000	147,300
Kaiugnak	258-542	10,000	30,000	10,000	30,000	18,400	55,200	36,800
Barling	258-522	30,000	90,000	30,000	90,000	55,200	165,800	110,500
Kiliuda	258-207	20,000	60,000	10,000	30,000	18,400	55,200	36,800

-Continued-

Index Stream Name	No.	Even Year Indexed Escapement goals Minimum	Even Year Indexed Escapement goals Desired	Odd-Year Escapement goals Indexed[a] Minimum	Odd-Year Escapement goals Indexed[a] Desired	Odd-Year Escapement goals Estimated Total Minimum	Odd-Year Escapement goals Estimated Total Desired	Odd-Year Escapement goals Estimated Total Mid Point
Saltery[b]	259-415	20,000	60,000	30,000	90,000	30,000	90,000	60,000
Miam	259-412	20,000	60,000	10,000	30,000	18,400	55,200	36,800
Hurst	259-414	10,000	30,000	10,000	30,000	18,400	55,200	36,800
Subtotal		150,000	450,000	140,000	420,000	232,500	697,600	465,000
Mainland District								
Big River	262-152	10,000	30,000	10,000	30,000	18,400	55,200	36,800[c]
Village	262-153	15,000	45,000	15,000	45,000	27,600	82,900	55,200[c]
Cape Chiniak	262-205	5,000	15,000	3,000	9,000	5,500	16,600	11,000[c]
Big Hallo	262-203	2,000	6,000	2,000	6,000	3,700	11,000	7,400[c]
Kukak	262-271	3,000	9,000	2,000	6,000	3,700	11,000	7,400
Missak	262-402	5,000	15,000	3,000	9,000	5,500	16,600	11,000
Kinak	262-451	20,000	60,000	20,000	60,000	36,800	110,500	73,700
Geographic	262-501	4,000	12,000	4,000	12,000	7,400	22,100	14,700
Dakavak	262-551	25,000	75,000	20,000	60,000	36,800	110,000	73,700
Kashvik	262-604	25,000	75,000	25,000	75,000	46,000	138,100	92,100
Big Alinchak	262-651	30,000	90,000	20,000	60,000	36,800	110,500	73,700
Portage	262-702	15,000	45,000	10,000	30,000	18,400	55,200	36,800
Oil	262-751	15,000	45,000	10,000	30,000	18,400	55,200	36,800
Jute	262-801	2,000	6,000	1,000	3,000	1,800	5,500	3,700
Kanatak	262-802	10,000	30,000	10,000	30,000	18,400	55,200	36,800
Big Creek	262-851	70,000	210,000	60,000	180,000	110,500	331,500	221,000
Subtotal		256,000	768,000	215,000	645,000	395,700	1,187,100	791,800
Grand Total		2,401,000	6,003,000	1,010,000	3,030,000	1,697,000	5,092,600	3,394,400
Estimated total Escapement[d]						2,341,900	7,027,800	4,684,300[e]

-Continued-

[a] Non weir systems indexed escapements are peak count derived.
[b] Systems with escapements enumerated through weirs.
[c] Index streams for which total available spawning habitat was not estimated; these streams escapement goals were not included in deriving overall spawner density for all index streams.
[d] Production from these 51 index streams account for 72.70% of the total odd-year pink salmon production founded upon indexed escapements during 1969-1987. Estimated total escapements were generated by expanding the minimum, desired, and mid-point total estimated escapements for index streams by a factor of 1.38 (Barrett et al. 1990).
[e] The mid-point estimated total escapement figure minus the escapement figures for those streams that did not have total available spawning habitat estimated divided by the total habitat estimate for all Kodiak Management Area index streams (4,573,900/3,254,454) provides a spawning density of 1.4 fish/m^2 of spawning habitat based upon the mid-point escapement goal for odd-year brood line pink salmon.

Appendix A.5. Pink salmon daily weir escapement counts for systems selected for stream life estimation, 1990.

	Weired System Counts											
	Afognak		Pink		Barling		Akalura		E. Paramanof		Saltery	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
7/10	1	1										
7/11	0	1										
7/12	0	1										
7/13	0	1									3	3
7/14	2	3									0	3
7/15	0	3									0	3
7/16	0	3							2	2	0	3
7/17	0	3							10	12	2	5
7/18	2	5							23	35	0	5
7/19	0	5							13	48	10	15
7/20	1	6							10	58	0	15
7/21	0	6							0	58	4	19
7/22	16	22							190	248	31	50
7/23	5	27							54	302	6	56
7/24	0	27			10	10			243	545	30	86
7/25	0	27			3	13			171	716	21	107
7/26	1	28			2	15			89	805	0	107
7/27	63	91			8	23			654	1,459	68	175
7/28	370	461			16	39	2	2	223	1,682	59	234
7/29	88	549			19	58	0	2	142	1,824	110	344
7/30	13	562			18	76	0	2	66	1,890	90	434
7/31	93	655			2	78	0	2	1,116	3,006	41	475
8/1	689	1,344	3	3	0	78	0	2	1,263[a]	4,269	98	573
8/2	150	1,494	0	3	0	78	0	2	1,263[a]	5,532	20	593
8/3	323	1,817	0	3	51	129	0	2	1,263[a]	6,795	62[a]	655
8/4	313	2,130	14	17	24	153	0	2	1,263[a]	8,058	62[a]	717
8/5	125	2,255	28	45	84	237	0	2	498	8,556	62[a]	779
8/6	123	2,378	31	76	98	335	0	2	511	9,067	62[a]	841
8/7	1,124	3,502	94	170	64	399	0	2	1,188	10,255	117	958
8/8	1,995	5,497	283	453	302	701	1	3	95	10,350	239	1,197

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Appendix A.5. (page 2 of 3)

	Weired System Counts											
	Afognak		Pink		Barling		Akalura		E. Paramanof		Saltery	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
8/9	1,472	6,969	17	470	231	932	0	3	27	10,377	226	1,423
8/10	295	7,264	4	474	335	1,267	0	3	59	10,436	100	1,523
8/11	1,635	8,899	995[a]	1,465	250	1,517	6	9	0	10,436	100	1,623
8/12	654	9,553	156	1,621	260	1,777	6	15	0	10,436	55	1,678
8/13	770	10,323	113	1,734	323	2,100	0	15	0	10,436	117	1,795
8/14	935	11,258	30	1,764	370	2,470	6	21	117	10,553	258	2,053
8/15	1,181	12,439	172	1,936	379	2,849	3	24	51	10,604	39	2,092
8/16	3,287	15,726	192	2,128	804	3,653	0	24	4	10,608	199	2,291
8/17	2,966	18,692	26	2,154	237	3,890	7	31	71	10,679	27	2,318
8/18	304	18,966	54	2,208	200	4,090	28	59	79	10,683	137	2,455
8/19	1,447	20,443	163	2,371	653	4,743	40	99	143	10,826	126	2,581
8/20	1,216	21,659	131	2,502	913	5,656	7	106	908	11,734	1	2,582
8/21	500	22,159	29	2,531	988	6,644	13	119	185	11,919	55	2,637
8/22	246	22,405	61	2,592	575	7,219	4	123	1,470	13,389	95	2,732
8/23	255	22,660	27	2,619	829	8,048	4	127	830	14,219	115	2,847
8/24	317	22,977	4	2,623	447	8,495	60	187	643	14,862	85	2,932
8/25	182	23,159	90	2,713	839	9,334	112	299	369	15,231	62	2,994
8/26	60	23,219	266	2,979	703	10,037	368	667	690	15,921	118	3,112
8/27	102	23,321	44	3,023	652	10,689	463	1,130	653	16,574	37	3,149
8/28	68	23,389	40	3,063	181	10,870	51	1,181	244	16,818	76	3,225
8/29	10	23,399	1	3,064	492	11,362	183	1,364	212	17,030	64	3,289
8/30	14	23,413	3	3,067	186	11,548	38	1,402	478	17,508	154	3,443
8/31	92	23,505	10	3,077	539	12,087	176	1,578	147	17,655	135	3,578
9/1	155	23,660	1	3,078	705	12,792	18	1,596	868	18,523	141	3,719
9/2	99	23,759	114	3,192	359	13,151	186	1,782	605	19,128	132	3,851
9/3	671	24,430	997	4,189	1,453	14,604	198	1,980	1,549	20,677	91	3,942
9/4	267	24,697	13	4,202	417	15,021	23	2,003	400	21,077	96	4,038
9/5	141	24,838	2	4,204	584	15,605	126	2,129	212	21,289	117	4,155
9/6	96	24,934	13	4,217	1,005	16,610	38	2,167	159	21,448	8	4,163
9/7	374	25,308	27	4,244	570	17,180	38	2,205	85	21,533	247	4,410

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	Weired System Counts											
	Afognak		Pink		Barling		Akalura		E. Paramanof		Saltery	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
9/8	582	25,890	10	4,254	434	17,614	292	2,497	188	21,721	29	4,439
9/9	366	26,256	1	4,255	819	18,433	86	2,583	0	21,721	25	4,464
9/10	76	26,332	1	4,256	218	18,651	17	2,600	3	21,724	8	4,472
9/11	395	26,727	31	4,287	164	18,815	35	2,635	0	21,724	15	4,487
9/12	531	27,258	2	4,289	0	18,815	46	2,681	25	21,749	10	4,497
9/13	55	27,313	0	4,289	36	18,851	2	2,683	0	21,749	34	4,531
9/14	377	27,690	8	4,297			0	2,683			8	4,539
9/15	6	27,696	0	4,297			0	2,683			5	4,544
9/16	112	27,808	0	4,297			1	2,684			10	4,554
9/17							0	2,684			2	4,556
9/18							0	2,684				
9/19							1	2,685				
9/20							0	2,685				
9/21												
Total		27,808		4,297		18,851		2,685		21,749		4,556

[a] Counts represent estimates while weir was inoperable due to high water conditions.

Appendix A.6. Kodiak Management Area odd-year pink salmon escapement, catch, and run numbers by fishing district, 1969-1991.

District	Brood Year	Estimated Escapement	Commercial Catch	Run
Afognak				
	1969	186,747	32,819	219,566
	1971	165,335	3,389	168,724
	1973	91,279	57,911	149,190
	1975	90,474	119,150	209,624
	1977	340,793	161,474	502,267
	1979	580,287	782,546	1,362,833
	1981	984,370	1,440,345	2,424,715
	1983	422,129	192,784	614,913
	1985	975,721	1,132,382	2,108,103
	1987	597,819	505,497	1,103,316
	1989	1,991,845		1,991,845
	1991	472,029	1,112,192	1,584,221
Average (1969-1987)		443,495	442,830	886,325
Northwest Kodiak				
	1969	685,383	653,549	1,338,932
	1971	535,828	133,210	669,038
	1973	397,817	218,327	616,144
	1975	690,221	1,155,439	1,845,660
	1977	1,023,479	1,670,335	2,693,814
	1979	1,565,862	3,040,943	4,606,805
	1981	1,716,753	2,600,000	4,316,753
	1983	1,371,842	1,364,787	2,736,629
	1985	1,452,625	1,801,177	3,253,802
	1987	1,334,032	1,329,254	2,663,286
	1989	5,653,387		5,653,387
	1991	792,347	3,787,647	4,579,994
Average (1969-1987)		1,077,384	1,396,702	2,474,086
Southwest Kodiak				
	1969	2,100	6,669	8,769
	1971	9,347	294	9,641
	1973	896	4,261	5,157
	1975	2,778	11,923	14,701
	1977	80,571	8,188	88,759
	1979	206,975	15,234	222,209
	1981	86,081	8,090	94,171
	1983	81,841	753	82,594
	1985	97,832	88,270	186,102
	1987	40,079	241,954	282,033
	1989	168,972		168,972
	1991	188,005	1,375,838	1,563,843
Average (1969-1987)		60,850	38,564	99,414

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District	Brood Year	Estimated Escapement	Commercial Catch	Run
Alitak Bay				
	1969	816,069	3,775,182	4,591,251
	1971	780,024	100,896	880,920
	1973	309,780	49,932	359,712
	1975	550,886	235,711	786,592
	1977	961,780	961,673	1,923,453
	1979	1,330,071	1,664,410	2,994,481
	1981	1,460,981	2,073,629	3,534,610
	1983	1,029,028	1,428,526	2,457,554
	1985	1,864,240	1,057,940	2,922,180
	1987	877,906	916,883	1,794,789
	1989	4,483,424		4,483,424
	1991	662,294	2,373,521	3,035,815
Average (1969-1987)		998,076	1,226,478	2,224,555
Eastside Kodiak				
	1969	707,874	6,704,242	7,412,116
	1971	482,507	592,876	1,075,383
	1973	299,784	91,799	391,583
	1975	550,094	382,177	932,271
	1977	885,092	2,215,285	3,100,377
	1979	1,373,155	3,685,457	5,058,612
	1981	1,310,255	2,456,641	3,766,896
	1983	959,501	783,039	1,742,540
	1985	916,113	81,673	997,786
	1987	746,297	817,847	1,564,144
	1989	3,088,875		3,088,875
	1991	1,329,082	5,650,427	6,979,509
Average (1969-1987)		823,067	1,781,104	2,604,171
Northeast Kodiak				
	1969	421,086	1,262,800	1,683,886
	1971	194,143	163,216	357,359
	1973	100,543	16,211	116,754
	1975	136,900	218,793	355,693
	1977	377,880	135,921	513,801
	1979	510,039	458,116	968,155
	1981	458,266	416,920	875,186
	1983	330,144	193,880	524,024
	1985	840,387	203,409	1,043,796
	1987	600,770	276,657	877,427
	1989	1,520,402		1,520,402
	1991	524,455	296,438	820,893
Average (1969-1987)		397,016	334,592	731,608

-Continued-

District	Brood Year	Estimated Escapement	Commercial Catch	Run
Mainland				
	1969	709,324	65,562	774,886
	1971	254,828	153,319	408,147
	1973	168,016	24,356	192,372
	1975	437,996	270,804	708,800
	1977	1,267,433	343,295	1,610,728
	1979	1,284,305	623,117	1,907,422
	1981	1,222,730	271,758	1,492,488
	1983	569,060	183,735	752,795
	1985	1,022,058	261,059	1,283,117
	1987	1,239,439	228,238	1,467,677
	1989	7,614,276		7,614,276
	1991	2,231,218	1,166,188	3,397,406
Average (1969-1987)		817,519	242,524	1,060,006

Appendix B.1. Pink salmon peak counts and estimated total escapement for Chignik Management Area streams, 1989[a].

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[b]
Eastern District			
272-701	3,200	4,636	1.44
272-702	53,000	53,000	1.00
272-703	17,000	26,983	1.59
272-720	0	0	
272-721	10,900	14,000	1.28
272-722	0	0	
272-723	0	0	
272-801	10,900	14,080	1.29
272-802	9,000	16,018	1.78
272-802A	200	226	1.13
272-802B	750	848	1.13
272-803	36,000	36,000	1.00
272-804	10,600	10,600	1.00
272-805	19,000	19,000	1.00
272-821	0	0	
272-822	0	0	
272-823	0	0	
272-84	0	0	
272-843	0	0	
272-844	0	0	
272-845	0	0	
272-900	2,300	2,300	1.00
272-901	10,000	10,000	1.00
272-902	22,000	49,270	2.24
272-903	11,400	15,480	1.36
272-903A	18,400	21,200	1.15
272-903B	52,000	52,000	1.00
272-904	32,000	32,000	1.00
272-905	89,000	89,000	1.00
272-906	18,000	20,340	1.13
272-921	3,200	3,616	1.13
272-922	8,000	8,000	1.00
272-923	9,000	9,000	1.00
272-941	0	0	
272-961	53,000	82,592	1.56
272-961A	8,500	8,500	1.00
272-961B	135,000	202,667	1.50
272-961C	25,000	58,333	2.33
272-962	4	5	1.25
272-962A	350	817	2.33
272-962B	0	0	
272-963	10,500	10,500	1.00
Subtotal	678,204	871,011	1.28

-Continued-

Stream No.	Numbers of Fish: Peak Count (PC)	Numbers of Fish: Estimated Total Escapement (ETE)	ETE/PC[b]
Central District			
272-201	210	210	1.00
272-202	0	0	
272-202A	600	903	1.50
272-202B	200	200	1.00
272-204	16,600	24,460	1.47
272-205	5	5	1.00
272-206	230	230	1.00
272-302	45,500	45,500	1.00
272-501	63,000	89,499	1.42
272-502	0	0	
272-502A	0	0	
272-503	0	0	
272-504	0	0	
272-505	0	0	
272-506	300	300	1.00
272-507	0	0	
272-508	0	0	
272-509	7,300	7,300	1.00
272-510	1,350	1,350	1.00
272-511	0	0	
272-511A	500	500	1.00
272-511B	0	0	
272-512	0	0	
272-514	23,000	25,497	1.11
272-516	19,000	19,093	1.00
272-602	1,700	2,273	1.34
272-604	200	226	1.13
272-605	5,000	5,658	1.13
272-606	1,000	1,800	1.00
Subtotal	186,495	225,004	1.20
Chignik Bay District			
271-100	0	0	
271-101A	3,000	3,000	1.00
271-101B	4,000	4,000	1.00
271-102A	0	0	
271-102B	0	0	
271-102C	0	0	
271-103	250	250	1.00
271-104	4,800	4,800	1.00
271-105	400	400	1.00
271-106	1,020	1,020	1.00
Subtotal	13,470	13,470	1.00

-Continued-

Stream No.	Numbers of Fish Peak Count (PC)	 Estimated Total Escapement (ETE)	ETE/PC[b]
Western District			
273-702	2,900	2,900	1.00
273-720	0	0	
273-722	32,000	32,000	1.00
273-723	1,500	1,500	1.00
273-802	10,800	10,800	1.00
273-821	0	0	
273-822	2	2	1.00
273-823	1,700	1,700	1.00
273-842	1,200	1,200	1.00
273-843	1,700	1,700	1.00
273-844	0	0	
273-845	110	110	1.00
273-941	4,500	5,982	1.33
Subtotal	56,412	57,894	1.03
Perryville District			
275-401	4,200	4,760	1.13
275-402	9,400	9,400	1.00
275-403	0	0	
275-404	3,800	5,813	1.53
275-405	0	0	
275-406	161,000	168,403	1.04
275-408	200	207	1.03
275-502	51,000	51,000	1.00
275-503	40	45	1.12
275-504	3,700	3,700	1.00
275-505	19,000	19,000	1.00
275-506	2,380	2,618	1.10
275-600	100	103	1.03
275-601	1,600	2,370	1.48
Subtotal	256,420	267,419	1.04
Grand Total	1,191,001	1,434,798	1.20

[a] Table adapted from Barrett (1990).

[b] Estimated total escapements derived by the area-under-the-curve (AUC) method included fractions of whole numbers which the ETE/PC ratio reflects in several instances.

[c] Factor used to expand peak counts to Estimated total escapement for the years 1963-1983.

Appendix B.2. Pink salmon aerial survey odd-year peak counts, Chignik Management Area, 1969-1987.

Stream		Peak Count											
Name	No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean	1989
Eastern District													
Aniakchak	272-605	100	0	1,200	1,450	1,500	0	2,700	1,000	0	2,500	1,045	5,000
Cape Agutka	272-606	2,000	2,000	1,000	1,200	900	13,000	5,800	100	0	4,200	3,020	1,800
Main Creek	272-702	2,000	1,000	1,000	3,700	2,300	13,500	5,800	9,000	13,600	11,100	6,300	53,400
Northeast	272-703	4,500	2,000	1,100	350	5,000	7,000	3,300	2,600	9,000	5,500	4,035	19,000
Yantarni	272-721	1,000	0	300	100	1,700	14,000	13,500	3,600	12,000	13,000	5,920	11,000
Ocean Beach	272-801	4,000	0	450	400	1,000	1,000	10,500	2,600	4,500	9,350	3,380	11,400
Nakalilok	272-804	6,000	1,000	500	2,500	2,100	12,000	6,000	4,800	15,000	1,400	5,130	10,650
Chiginagak	272-902	1,000	2,500	300	400	2,100	11,000	5,000	400	2,500	3,200	2,840	22,550
Chiginagak R.	272-903	0	0	150	2,500	1,400	400	6,000	1,300	1,000	32,900	4,565	18,800
Chiginagak-904	272-904	5,500	1,000	500	650	3,100	7,000	6,950	1,700	5,000	11,000	4,240	32,100
Chiginagak-905	272-905	2,400	4,000	800	1,300	20,800	61,000	25,000	3,100	15,000	20,700	15,410	99,000
Agripina	272-961	2,500	6,000	4,200	2,050	3,200	23,500	13,400	5,000	30,000	1,000	9,085	135,000
Glacier	272-962	0	0	0	150	0	0	50	1,300		5,500	700	350
Kilokak	272-963	200		50	250	200	1,100	300	300		9,000	1,140	11,000
Central District													
Thompson Valley	272-204	19,000	6,500	2,300	8,700	24,500	35,000	6,500	1,520	0		11,558	16,600
Hook Bay	272-302	17,000	10,000	3,700	1,900	15,300	42,700	12,000	200	2,000	8,050	11,285	47,100
Cape Kumliun	272-501		51,000	23,300	10,000	113,000	153,000	35,000	0	118,100		55,933	63,245
Bear	272-505	0	0	0	0	500	0	100	2,000	0	12	261	0
Rudy's	272-509	200	0	0	0	5,800	12,000	700	0	0	0	2,062	7,300
North Fork	272-514	4,000	0	1,900	350	4,400	12,700	14,000	3,500	5,000	6,650	5,250	23,180
Western District													
Coal Cape	273-702	40,000	8,000	1,065	13,550	78,500	50,000	84,900	11,300	0	11,700	29,901	2,900
Ivan	273-722	255,000	130,000	35,000	73,100	236,000	85,000	80,000	12,200	20,000	12,800	93,910	38,700
Foot	273-802	14,000	30,000	7,000	8,700	13,000	9,600	10,000	1,200	5,000	5,340	10,384	12,920
Spoon	273-823	6,500	7,000	700	3,500	4,100	7,000	6,700	400	200	30	3,613	1,800
Portage	273-842	21,000	10,000	14,000	400	3,500	17,500	6,500	300	0	0	7,320	1,200
Seal Bay	273-843	7,500	5,000	1,500	5,000	3,000	200	9,000	1,000	5,000	500	3,770	1,700
Perryville District													
Kupreanof	275-401	6,500	3,500	200	650	3,000	28,000	14,000	3,500			7,419	4,200
Smokey Hollow	275-402	0	0	200	50	1,500	600	0	200	150	1,700	440	9,400
Wasco's	275-404	4,000	3,000	0	800	1,400	2,000	0	2,000	250	27,800	4,125	3,800

-Continued-

Appendix B.2. (page 2 of 2)

Stream		Peak Count											
Name	No.	1969	1971	1973	1975	1977	1979	1981	1983	1985	1987	Mean	1989
Ivanof	275-406	105,000	20,000	18,100	20,800	51,800	89,000	18,000	32,000	155,000	123,400	63,310	166,000
Humpback	275-502	59,000	8,000	5,000	8,100	48,200	59,000	39,000	11,000	25,000	19,800	28,510	51,000
Total Peak Count[a]	(TPC)	589,900	311,500	125,515	172,600	652,800	767,800	440,700	119,120	325,200	466,232	405,861	882,095
Total Escapement[b] Peak	(TE)	624,450	324,800	158,970	238,100	749,800	858,800	598,200	158,900				
TPC/TE[c]		94%	96%	79%	72%	87%	89%	74%	75%				

[a] Total peak counts for 31 Chigink Management Area index streams.
[b] Total escapement for all aerial surveyed streams obtained from Thompson and Owen (1991).
[c] Average of TPC/TE for 1969-1983 is 83.25%.