Fishery Data Series No. 13-42

# Smolt Abundance and Summary Statistics for Kenai River Coho Salmon, 2007

by

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

## Symbols and Abbreviations

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**Weights and measures (metric)**

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

**Weights and measures (English)**

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

**Time and temperature**

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

**Physics and chemistry**

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

**General**

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

**Mathematics, statistics**

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

*FISHERY DATA SERIES NO. 13-42*

# SMOLT ABUNDANCE AND SUMMARY STATISTICS FOR KENAI RIVER COHO SALMON, 2007

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# ABSTRACT

In spring 2007, 80,494 wild coho salmon (*Oncorhynchus kisutch*) smolt were captured within the Kenai River drainage, marked with an adipose finclip, injected with a coded wire tag (CWT), and released live at the Moose River by the Alaska Department of Fish and Game. Some of these fish were recovered as adults from the Kenai River sport fishery in 2008. Of the 3,018 adult coho salmon examined for adipose fins from Kenai River sport fish harvest samples in 2008, 197 did not have an adipose fin and carried a coded-wire tag. Based on these results, an estimated 1,227,344 (SE 83,999) coho salmon smolt emigrated from the Kenai River in 2007. Primary summary statistics from all Kenai River coho salmon research program elements since 1991 are provided.

Key words: coho salmon, *Oncorhynchus kisutch*, population assessment, weir, index, coded wire tag, Kenai River, smolt abundance, wild salmon, summary statistics

# INTRODUCTION

Wild coho salmon (*Oncorhynchus kisutch*) spawn and rear in freshwater drainages of Upper Cook Inlet, Alaska (UCI; Figure 1). As they return to spawn, adults are harvested annually in mixed-stock commercial and marine sport fisheries. Sport and personal use harvests also occur in fresh water. Cook Inlet ranks second among all regions of the state in the 1998–2007 average sport harvest of coho salmon, sixth in commercial harvest, and fourth in overall harvest (Figure 2). UCI coho salmon support the second largest sport harvest in the state (Mills 1979-1980, 1981a-b, 1982-1994; Howe et al. 1995-1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, 2006a-b, 2007, 2009a-b, 2010), contributing nearly 1 of every 3 coho salmon harvested by sport fishing from Alaskan waters.

A Kenai River coho salmon assessment program using coded-wire tags (CWT) was first initiated in 1992 to estimate the previously unknown commercial harvest of Kenai River coho salmon. An ancillary benefit of the CWT project was the generation of smolt abundance estimates. The program expanded to provide estimates of total annual run for a period of 6 years, followed by several years of adult abundance indexes. By 2006, commercial harvests were no longer estimated. The inriver sport harvest was estimated for many years prior to inception of the angler survey program. Below is a brief summary of the various Kenai River coho salmon research assessment products:

1) Commercial harvest estimates were generated annually from 1993 through 2005 utilizing a CWT release and recovery program (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2004a-b, 2007a-b; Massengill 2007a-b).

2) Mark–recapture estimates of smolt abundance were generated for the years 1992–2007 using the same CWT releases and an inriver adult sampling program (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2004a-b, 2007a-b; Massengill 2007a-c, 2008, 2013).

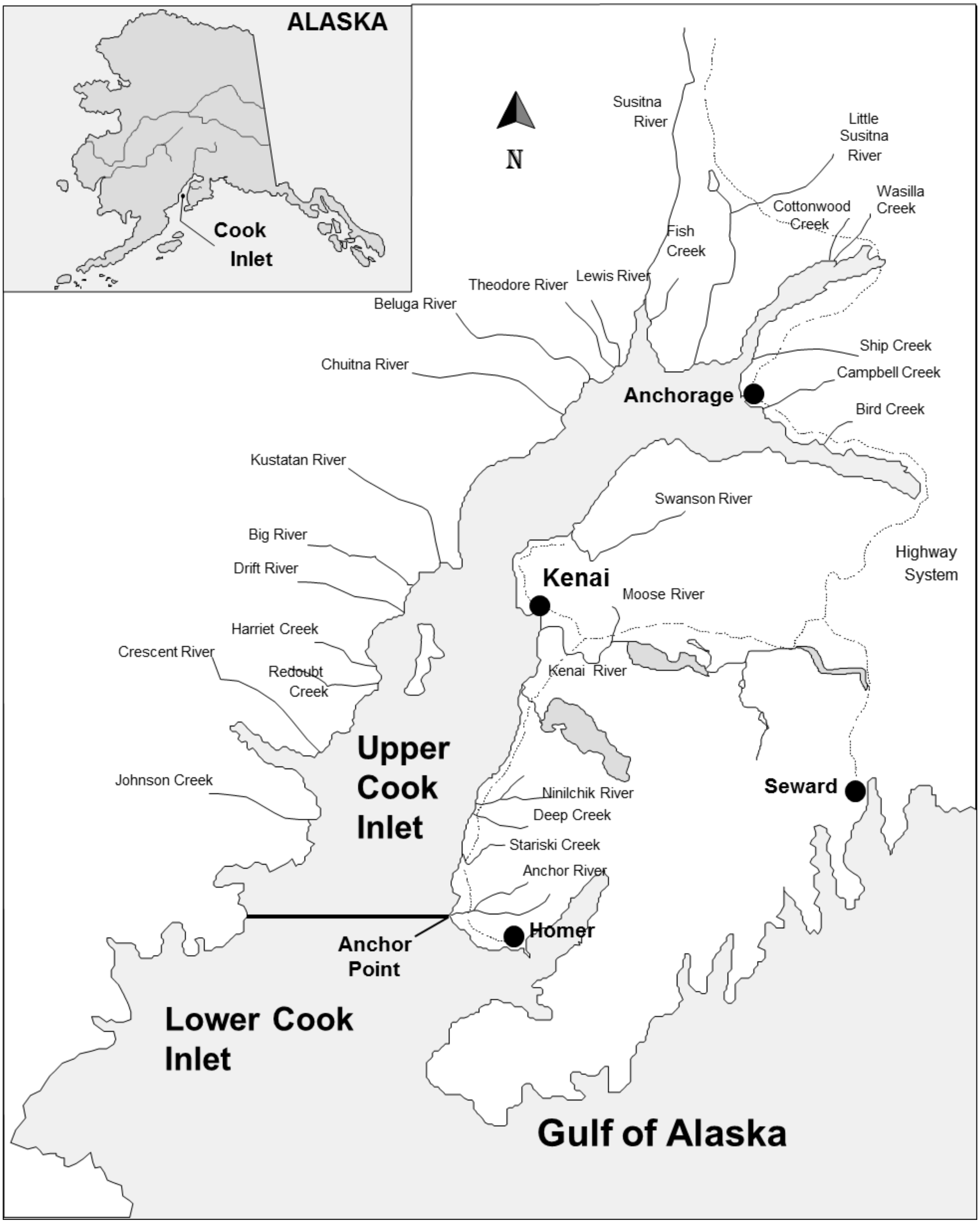


Figure 1.–The Cook Inlet Basin with major tributaries known to support coho salmon.

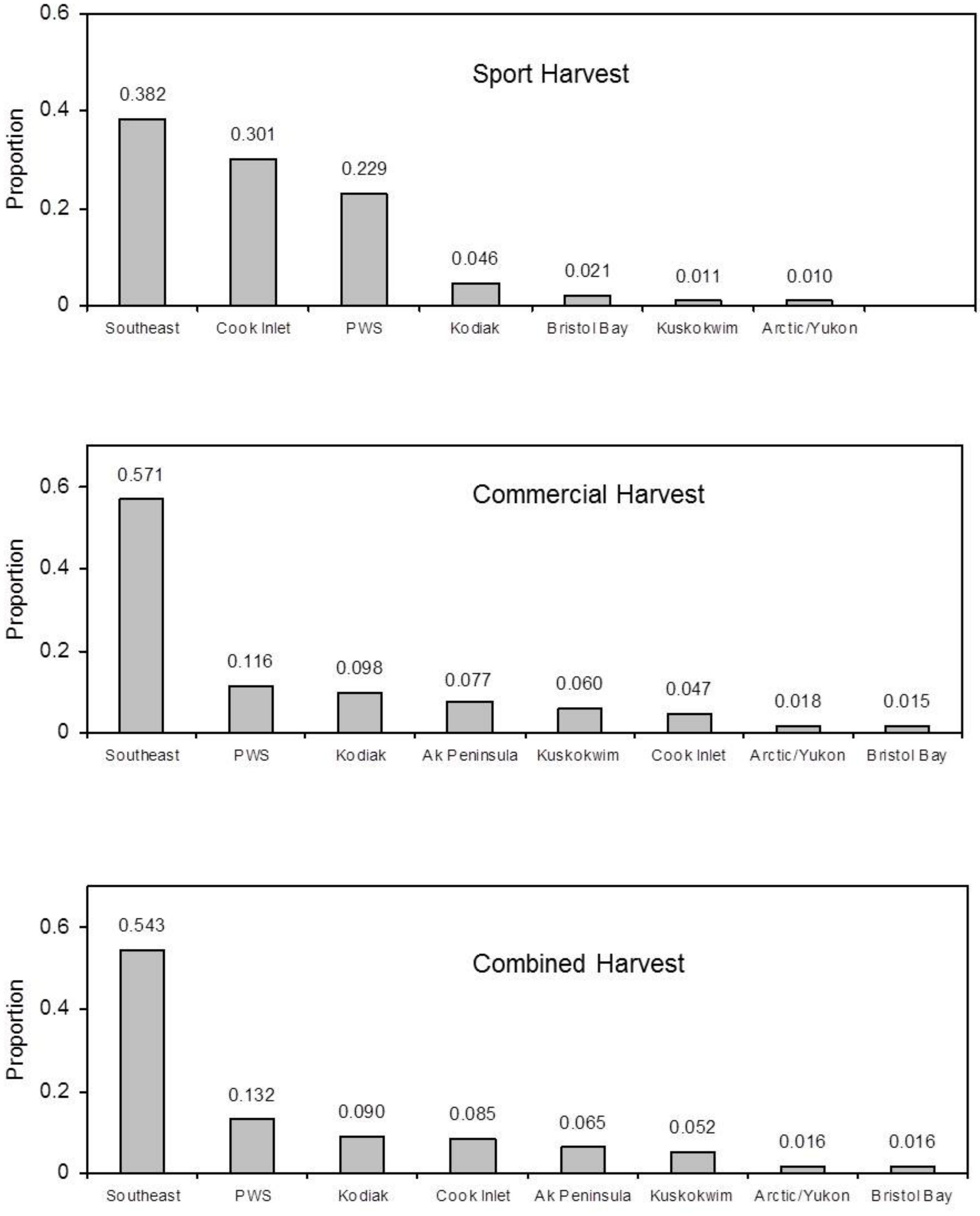


Figure 2.–Average proportions by region of the statewide sport (top), commercial (middle), and combined (bottom) harvests of coho salmon, 1998–2007.

3) Inriver harvests (sport and personal use) continue to be estimated annually, mostly through other programs. Sport harvests have been estimated by either creel or Statewide Harvest Survey (SWHS) or both since 1977 (Mills 1979-1980, 1981a-b, 1982-1994; Hammarstrom 1988-1992; Schwager-King 1993; Howe et al. 1995-1996, 2001 a-d; Walker et al. 2003; Jennings et al. 2004, 2006a-b, 2007, 2009a-b, 2010). Personal use harvests have been estimated since 1996 via mandatory permit reporting (Reimer and Sigurdsson 2004; Dunker and Lafferty 2007).

4) Inriver adult abundance was estimated using mark–recapture methodology from 1999 through 2004 (Carlon and Evans 2007; Massengill and Evans 2007). Attempts to estimate abundance using sonar were unsuccessful (Bendock and Vaught 1994).

5) Indexing of inriver adult abundance occurred during the years 2005–2007 utilizing cumulative catch per unit of fish wheel effort (CCPUE; Massengill 2007b, 2008, 2013).

The four earliest smolt emigration estimates (1992–1995) revealed a decline in smolt abundance.[1] Although the cause was unknown, the decline generated concern for the sustainability of historical harvests. A precautionary management plan was therefore developed and was in effect during the 1997 fishing season (Alaska Fish and Game Laws and Regulations Annotated, 1997–1998; 5AAC 21.357). A subsequent review of information in 2000[2] recommended additional precautions in response to a short-term decline in UCI commercial harvests of coho salmon and a more restrictive management plan was developed prior to the 2000 fishing season (Alaska Fish and Game Laws and Regulations Annotated, 2000–2001; 5AAC 21.357).

Annual Kenai River coho salmon assessments since 2000 indicate adult runs appear to have increased since the late 1990s when runs were perceived to be low. Overall exploitation appears to be sustainable and smolt production is stable. Recent Alaska Board of Fisheries (BOF) actions have increased fishing opportunity, most notably by extending the season for some UCI drift and eastside setnet commercial fisheries and the Kenai River coho salmon sport fishery. The Kenai River sport fishing daily bag limit for coho salmon was increased from 2 to 3 fish after 31 August. It is estimated that the combined increase in exploitation of Kenai River coho salmon resulting from the suite of 2008 BOF liberalizations is about 5% (unpublished BOF deliberation materials: Record Copy 83, ADF&G Commercial Fisheries Division, February 2008; Record Copy 36, ADF&G Sport Fish Division, February 2008). The current management plan is the Kenai River Coho Salmon Management Plan (Alaska Fish and Game Laws and Regulations Annotated, July 2008 Supplement, 5 AAC 57.170).

All Kenai River coho salmon assessment studies have now concluded following the 2007 smolt abundance estimate and the related inriver sport harvest sampling done in 2008. This is the final report of the results. This report also includes summary statistics from all historical Kenai River coho salmon program elements.

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[1] Carlon, J. A., and R. Clark. Unpublished. Stock status of Kenai River coho salmon: A report to the Alaska Board of Fisheries. Wasilla Alaska October Work Session, 1996. Available at Alaska Department of Fish and Game, Division of Sport Fish, Anchorage.

[2] Clark, B., R. Lafferty, G. Sandone, J. Fox, P. Cyr, J. Carlon, and J. Hasbrouck. Unpublished. Stock status of coho salmon in Upper Cook Inlet: A report to the Alaska Board of Fisheries, February 2000. Located at Alaska Department of Fish and Game, Division of Sport Fish, Anchorage.

## OBJECTIVES

The primary objectives of the 2007 smolt abundance study were as follows:

1. Estimate the number of coho salmon smolt that emigrated from the Kenai River drainage in 2007.

2. Census the coho salmon smolt emigration from the Moose River from 15 May through 30 June 2007.

## TASKS

1. Collect scales and lengths from the smolt emigration in 2007 and from the adult inriver return in 2008.
2. Collect tissue samples for genetic analysis from the 2008 Kenai River coho salmon run for the United States Fish and Wildlife Service (USFWS).

# METHODS

## SMOLT ABUNDANCE AND CENSUS, 2007

The 2007 smolt abundance experimental design was a 2-event mark–recapture study. A subsample of smolt were marked with an adipose finclip (AFC) and a CWT in the first event sample (2007). In the second event (2008), adults were recaptured and examined for a missing adipose fin and the presence of a CWT.

A weir was used from mid-May to late June to census the 2007 coho salmon smolt emigration from the Moose River (a tributary of the Kenai River) and to collect smolt for marking**.** The Moose River weir was the site of smolt capture and marking in 2007 and is located 7.5 RKM upstream of its confluence with the Kenai River (Figure 3). Before 1994, smolt were captured and tagged at a variety of locations (Carlon 1992; Carlon and Hasbrouck 1993). The Moose River was subsequently chosen as the marking site because 1) recovery of marked adults indicated that Moose River smolt were representative of the entire Kenai River population with respect to adult return timing (Carlon and Hasbrouck 1994) and 2) it was the only location where a sufficient number of smolt could be captured and tagged in order to meet objective precision criteria for abundance and harvest estimation.

A weir with a trap was installed in the mainstem of the Moose River on 17 May 2007 to capture smolt as they emigrated downstream from wintering habitats. The weir was a barrier to fish migration until 25 June 2007. From 20 May through 14 June, smolt were marked with both a CWT and an AFC.

Smolt were the primary lifestage captured and tagged at the Moose River. Smolt are characterized as being greater than 100 mm fork length (FL; length from tip of snout to fork of tail) and lacking parr marks. Although some coho salmon shorter than 100 mm FL were present, these were not considered smolt, both because of their size and because parr marks were highly visible and there was substantially less silver skin pigmentation; these were not marked. In addition, it was possible to identify smolt from scale samples. Most scale samples from fish shorter than 100 mm exhibit only 1 annulus. Most Kenai River coho salmon become smolt after 2 years in fresh water and exhibit 2 scale annuli (Hammarstrom 1988-1992). Furthermore, most (>99.9%) CWTs recovered from adults returning to spawn from 1993 through 2005 were implanted in fish emigrating from the Moose River the previous year (Carlon and Hasbrouck 1998; Carlon 2000, 2003; Massengill and Carlon 2004a-b), providing more evidence that smolt were correctly identified.

Most years we have observed temporal variation in the marked proportion of the inriver adult return (Massengill and Carlon 2004a-b, 2007a-b; Massengill 2007a-c, 2013). Although there is evidence that the return timing of marked adults is independent of the marking date, the marking strategy, adopted in 2003, provides for an even distribution of tags throughout the emigration and removes the tagging schedule as a factor influencing temporal changes in the marked fraction of adults. The 2007 tagging goal was approximately 3,500 tags per day for 3 weeks (75,000 total).

Fish captured in the weir throughout each day were partially immobilized by sedating with tricaine methanesulfonate (MS-222) to a level-2 anesthesia (Yoshikawa et al. 1988), hand-sorted into 2 length groups, and transferred to instream holding pens. An inriver tagging facility allowed fish to be netted directly into a holding tank for tagging. Fish were handled and marked following standard CWT procedures (Moberly et al. 1977). Fish were resedated to a level-3 anesthesia (Yoshikawa et al. 1988) and the adipose fin was excised with surgical scissors. All fish were then tagged with a Northwest Marine Technologies Mark IV tag injector[3] fitted with the optimal head mold. Head molds were chosen for proper and precise tag placement in fish of each length group (Northwest Marine Technologies Inc. 1990; Peltz and Hansen 1994). Fish less than or equal to 125 mm FL were tagged using a 30-per-pound head mold; those greater than 125 mm and less than or equal to 150 mm FL were tagged with a 20-per-pound head mold. Smolt greater than 150 mm were rarely captured and were released untagged because of the additional time required to sedate them. We encountered few fish of this size and it likely had no impact on the study. Marked fish were released to continue their downstream migration after recovering from anesthesia in an inriver holding pen.

Tag codes released in 2007 were verified visually with a binocular microscope on site and the number of smolt marked each day was recorded. Smolt were batch marked and a single tag code was applied to all individuals in a group.

Short-term survival and tag retention rates were estimated for smolt marked during each tagging shift by detaining about 200 marked fish in holding pens overnight. These rates were monitored as a quality control measure. Substantial decreases in survival or tag retention would identify a need to adjust the capture, handling, or marking procedures. Survival rates were used to estimate the total number of marked smolt that survived the marking procedure. Estimating the number of marked fish that survived marking and were released is a requirement of the model used to estimate smolt abundance.

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[3] Product names used in this publication are included for completeness but do not constitute product endorsement.

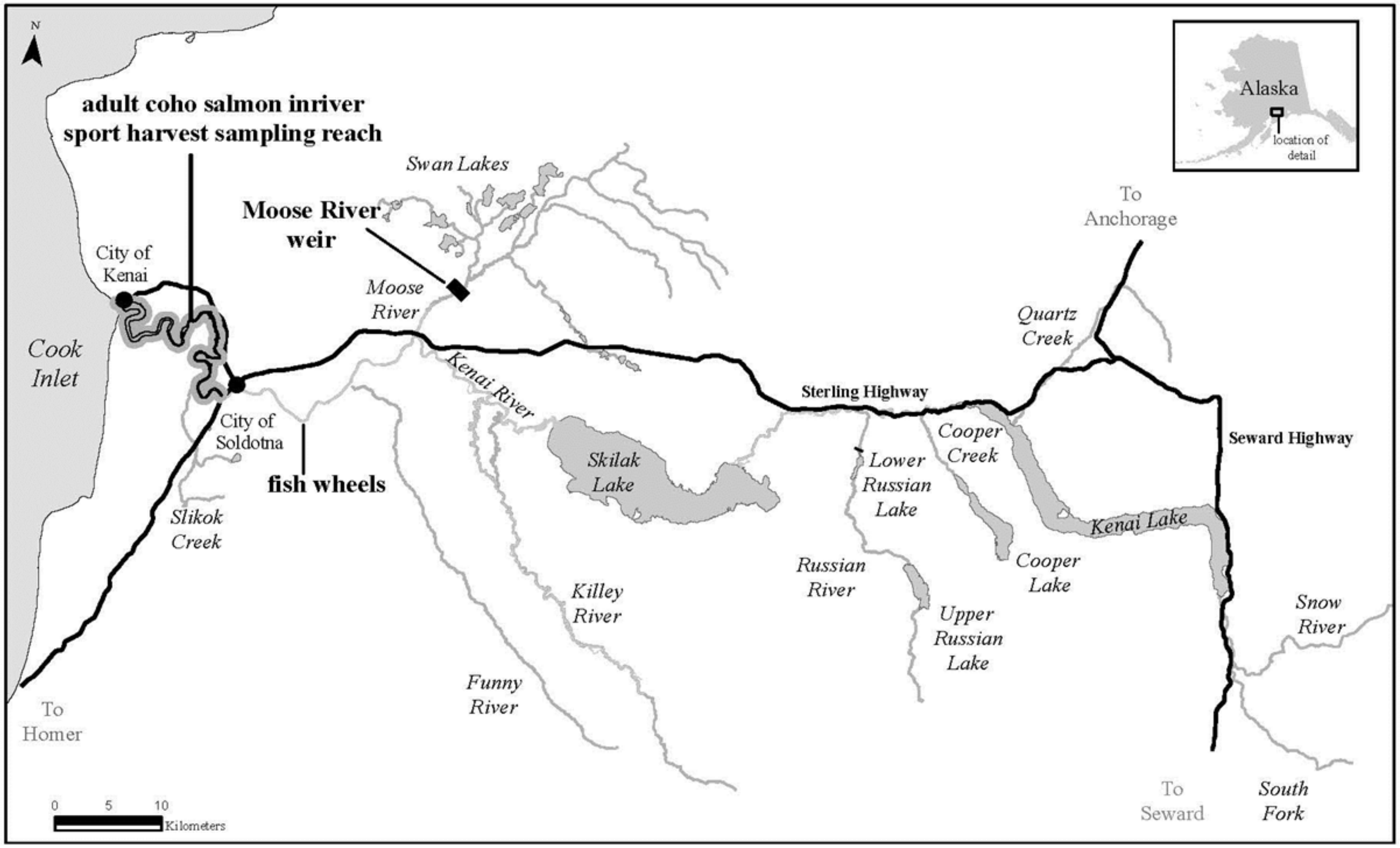


Figure 3.–The Kenai River drainage showing the Moose River weir site where marked coho salmon smolt were released in 2007, and the Kenai River adult sport harvest sampling reach in 2008.

### Smolt age and length sampling

Smolt scales were collected and archived in 2007. While current procedures used to determine ages from smolt scales are imperfect, radical changes in age class compositions are believed to be detectable. Although this approach is qualitative, it may provide important perspective when assessing population status. Collecting scales also provides an archive in the event that accurate scale reading techniques are developed.

As a result of the uncertainty regarding age estimates based on scale readings, placing strict objective criteria on the estimation of age class composition was not warranted, explaining the status of scale collection as a task. Sample size calculations (Thompson 1987) were, however, used to guide the number of scales collected. Assuming an illegibility rate of 15% and perfect identification of scale ages, 150 scales were needed such that, with 95% confidence, the estimates by age group were within 10 percentage points of their true values.

To minimize age and length bias during sampling, samples were collected systematically throughout the coho salmon smolt emigration by randomly sampling 50 smolt midway through each increment of 10,000 smolt passing the weir. This strategy provided a larger sample size than needed.

## RECOVERY OF MARKED ADULTS, 2008

The 2008 Kenai River coho salmon sport harvest below the Soldotna Bridge (RMK 34) was sampled for adults with missing adipose fins (Figure 3). Up to 3 technicians were scheduled daily to sample the sport harvest from 1 August through 30 September (Appendix A1). Harvest was sampled along the river by boat and at road-accessible points. Sampling was therefore distributed in time and space.

Sport-harvested coho salmon were examined for a missing adipose fin and every sampled fish received a caudal fin punch to avoid double sampling. Additionally, each technician sampled the first and every tenth coho salmon each day for age (scales) and FL. The first and every fourth coho salmon examined were sampled for genetic tissue as a courtesy for a USFWS study. All fish missing an adipose fin were checked for an embedded CWT using an electronic tag detection wand. If no tag was detected, the sampler would collect the head for further tag status confirmation by the project leader.

All tag recovery data were submitted electronically and archived by the Alaska Department of Fish and Game Tag Lab. The raw data are accessible via the World Wide Web at URL http://tagotoweb.adfg.state.ak.us.

## DATA ANALYSIS

### Smolt abundance in 2007

The following steps were used to estimate smolt abundance:

1) Estimate the number of smolt marked in 2007 that survived the marking process and retained a tag.
2) Record the number of adult coho salmon sampled in the inriver sport harvest during 2008.
3) Record how many of those adults were marked with both an adipose finclip and CWT.

It is noted that an unrelated study in the Kenai River released AFC coho salmon without CWTs in 2007. Only AFC adults that also possessed a CWT were therefore regarded as recaptures in the study reported herein.

To estimate the number of marked smolt released in 2007, short-term survival and tag retention rates were estimated from a representative sample of about 200 smolt from each daily shift that were detained in holding pens for 18 to 24 hours after marking. The short-term survival rate ($s_k$) for smolt marked and released during marking shift $k$ was estimated as the fraction of smolt that survived the detainment. The short-term tag retention rate ($b_k$) for smolt marked during a shift that survived was estimated as the fraction of surviving smolt that retained their tags. The number of smolt marked with a tag during each shift $(m'_k)$ was adjusted to account for short-term survival and tag retention to yield an estimate of the total number of tagged smolt that survived and retained a tag in shift $k$:

$$\hat{m}_k = m'_k \hat{s}_k \hat{b}_k. \tag{1}$$

The number of smolt that were marked, survived, and retained a tag at the Moose River in 2007 was estimated by summing $\hat{m}_k$ over all marking shifts.

The Chapman modified Lincoln-Petersen model (Seber 1982) was used to estimate abundance:

$$\hat{N} = \frac{(\hat{M}+1)(C+1)}{(R+1)} - 1, \tag{2}$$

where

$\hat{M}$ = the number of smolt marked in 2007 with an adipose finclip and CWT that survived to emigrate,

$C$ = the number of adult coho salmon examined for an adipose finclip in the 2008 return sample, and

$R$ = the number of adult coho salmon in the 2008 sample that had both an adipose finclip and CWT.

The variance of the smolt abundance estimate was estimated as follows:

$$\text{var}(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \tag{3}$$

$\hat{M}$ was used in place of $M$; the estimate is very precise, with a 95% relative precision of 0.4%.

This model produces unbiased estimates of abundance when all of the following assumptions are met:

1) A random sample of adult coho salmon were examined from the inriver run in 2008, or marked smolt were representative of the drainage-wide smolt emigration in 2007, or there was complete mixing of individuals between the mark and recapture events.

2) All juveniles marked at the Moose River in 2007 were smolt that returned to the Kenai River the following year (2008).

3) Survival and catchability were the same for marked and unmarked individuals.

4) Adipose fins were not regenerated between the mark and recovery events.

5) Within the examined population, there were no natural losses of adipose fins and no losses of CWTs at any time.

6) Fish were correctly categorized for the presence or absence of an adipose fin when examined in the sport fishery.

Independence between the timing of smolt tagging and adult return timing has been observed in both inriver and commercial recoveries (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000). The independence observed indicated that marked and unmarked fish mixed at least temporally after tagging. Recoveries of marked adults from all major Kenai River tributaries have occurred during genetic sampling efforts for the USFWS supporting the idea that emigrating smolt from the Moose River contain representatives from the entire Kenai River population. While independence between release and return timing and the presence of smolt from other Kenai drainages in the Moose River do not guarantee complete mixing of fish between tagging and recapture, or guarantee representative tagging of the entire Kenai River smolt population, they are consistent with the latter two conditions of assumption 1. The inriver sport harvest sampling is unlikely to produce a random adult sample because fish entering the river earlier in the season are exposed to far greater sport fishing effort than later in the season when angler participation drops considerably.

The other five assumptions are likely valid. Experience and observations indicate that most juveniles marked at the Moose River each year are smolt, and only 2 Moose River tags have been recovered in the same year they were released (assumption 2; Carlon and Hasbrouck 1998; Carlon 2000, 2003). Although long-term survival and catchability assumptions remain untested for this population, short-term survival of marked smolt has been nearly 100% during all smolt-marking events at the Moose River (assumption 3; Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2004a-b, 2007a-b; Massengill 2007a-c, 2008, 2013). Hatchery-produced coho salmon marked with adipose finclips and CWTs, and released in an eastern Kenai Peninsula drainage, experienced similar smolt-to-adult survival as unmarked coho salmon (assumption 3; Vincent-Lang 1993). Thompson and Blankenship (1997) found no regeneration of coho salmon adipose fins after excision if the fin was completely removed at the outset (assumption 4). There has been no quantitative study to estimate the occurrence of naturally missing adipose fins in salmon from the Kenai River drainage (assumption 5). However, over 1,500,000 Kenai River drainage coho salmon juveniles have been handled since 1991 and smolt with naturally missing adipose fins have been found only occasionally. Also, the short-term and long-term tag retention rates have been nearly identical (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2004a-b; Massengill and Carlon 2007a-b; Massengill 2007a-c, 2008, 2013). This observation supports the supposition that naturally missing adipose fins are rare in coho salmon of the Kenai River drainage. CWT shedding is likely to be small; 132 of 135 AFC fish examined in the 2007 return had CWTs (assumption 5).

# RESULTS

## SMOLT MARKING AND CENSUS IN 2007

Smolt were marked (and released) as they emigrated from the Moose River from 20 May through 14 June 2007; the last fish held for determining overnight tag retention rate were released on 15 June 2007. Seven different tag codes (batches) were released and the estimated number of surviving marked fish per batch ranged from 11,293 to 11,751.

Based on overnight retention samples, an estimated 99.9% of the 81,530 marked smolt survived the marking/tagging process (removal of the adipose fin and insertion of a CWT) yielding 81,482 smolt that were released alive. Of the smolt that were released alive (81,482), an estimated 99% (80,494) had retained their CWT. Although marking was discontinued after the sampling goal was achieved on 14 June 2007, the weir remained in place until 25 June to census the smolt emigration. A total of 222,774 coho salmon smolt arrived at the weir between 17 May and 25 June 2007. Of these smolt, 220,675 (>99%) passed through the weir alive. Scale and length samples from approximately 1,100 smolt were collected and archived.

## INRIVER RECOVERY OF MARKED ADULTS IN 2008

Adult coho salmon were sampled in the Kenai River sport harvest below the Soldotna Bridge (RKM 34) from 1 August through 30 September 2008. The mark of interest (missing adipose fin and coded wire tag) was found for 197 of 3,018 coho salmon examined from the sport harvest (Table 1). All coho salmon that were missing an adipose fin were also confirmed as carrying a CWT (Table 2). Scale and length samples from 358 coho salmon were collected and archived, meeting sampling goals.

## VARIATION IN THE MARKED PROPORTION

The assumptions required for an unbiased smolt abundance estimate are explained in the data analysis section. The sport fish sample is believed to have violated assumption 1 in particular because the fishery harvest was weighted towards the beginning of the season when angler participation was greatest and thus may not be a representative sample of the adult run. Furthermore, during the marking event, smolt were not subjected to equal probability of capture because smolt were only marked in the Moose River. Insignificant temporal variation in the marked proportion by week ($\chi^2 = 10.8$, df = 7, $P = 0.15$) does, however, indicate there was mixing of fish between marking and recovery. The observed variation in the weekly marked proportion ranged from a low of .048 to a high of .091 (Figure 4). An unbiased smolt abundance estimate using the pooled sample was therefore possible.

## 2007 SMOLT ABUNDANCE ESTIMATE

An estimated 1,227,344 (SE 83,999) coho salmon smolt emigrated from the Kenai River in 2007. This is the highest estimate on record dating back to 1992 and is 70% greater than the 1992–2006 average of 723,876 smolt (Table 3; Figure 5).

Table 1.–Daily summary of Kenai River coho salmon adults examined in the sport harvest downstream of the Soldotna Bridge between 1 August and 30 September 2008.

| | August | | | September | | | |
|---|---|---|---|---|---|---|---|
| Date | Number of fish examined with heads intact[a] | Number w/out adipose fin | Coded wire tag Detected | Date | Number of fish examined with heads intact[a] | Number w/out adipose fin | Coded wire tag detected |
| 1 Aug | 17 | | | 1 Sep | 60 | 5 | 5 |
| 2 Aug | 31 | 4 | 4 | 2 Sep | 39 | 4 | 4 |
| 3 Aug | 83 | 3 | 3 | 3 Sep | 31 | 3 | 3 |
| 4 Aug | 51 | 2 | 2 | 4 Sep | | | |
| 5 Aug | 151 | 9 | 9 | 5 Sep | 14 | 4 | 4 |
| 6 Aug | 99 | 7 | 7 | 6 Sep | 87 | 9 | 9 |
| 7 Aug | 57 | 4 | 4 | 7 Sep | 170 | 15 | 15 |
| 8 Aug | 39 | | | 8 Sep | 14 | 1 | 1 |
| 9 Aug | 104 | 7 | 7 | 9 Sep | 17 | 1 | 1 |
| 10 Aug | 172 | 11 | 11 | 10 Sep | 103 | 7 | 7 |
| 11 Aug | 74 | 1 | 1 | 11 Sep | 36 | 3 | 3 |
| 12 Aug | 220 | 6 | 6 | 12 Sep | 44 | 2 | 2 |
| 13 Aug | 135 | 10 | 10 | 13 Sep | 49 | 1 | 1 |
| 14 Aug | 64 | 4 | 4 | 14 Sep | 47 | 4 | 4 |
| 15 Aug | 121 | 7 | 7 | 15 Sep | 32 | 2 | 2 |
| 16 Aug | 38 | | | 16 Sep | 7 | | |
| 17 Aug | 55 | 4 | 4 | 17 Sep | 46 | 4 | 4 |
| 18 Aug | 24 | 3 | 3 | 18 Sep | | | |
| 19 Aug | 32 | 2 | 2 | 19 Sep | 9 | 1 | 1 |
| 20 Aug | 77 | 7 | 7 | 20 Sep | 39 | | |
| 21 Aug | 11 | 1 | 1 | 21 Sep | 32 | 2 | 2 |
| 22 Aug | 15 | | | 22 Sep | 9 | | |
| 23 Aug | 37 | 4 | 4 | 23 Sep | 20 | 1 | 1 |
| 24 Aug | 49 | 3 | 3 | 24 Sep | 41 | 3 | 3 |
| 25 Aug | 13 | 1 | 1 | 25 Sep | 10 | 1 | 1 |
| 26 Aug | 6 | | | 26 Sep | 4 | | |
| 27 Aug | 28 | 4 | 4 | 27 Sep | 10 | 1 | 1 |
| 28 Aug | 12 | 1 | 1 | 28 Sep | 3 | | |
| 29 Aug | 43 | 7 | 7 | 29 Sep | | | |
| 30 Aug | 124 | 7 | 7 | 30 Sep | 2 | | |
| 31 Aug | 61 | 4 | 4 | | | | |
| Aug total | 2,043 | 123 | 123 | Sep total | 975 | 74 | 74 |
| | | | | Grand Total | 3,018 | 197 | 197 |

[a] Restriction of sample to only those fish with intact heads enabled use of the tag-detection wand.

Table 2.–Kenai River coho salmon examined in the sport harvest from 1 August through 30 September 2008, with weekly marked proportion estimates.

| Weekly period | Number examined | Number bearing mark of interest[a] | Estimated proportion of marked fish |
|---|---|---|---|
| 1–7 Aug | 489 | 29 | 0.059 |
| 8–14 Aug | 808 | 39 | 0.048 |
| 15–21 Aug | 358 | 24 | 0.067 |
| 22–28 Aug | 160 | 13 | 0.081 |
| 29 Aug–4 Sep | 358 | 30 | 0.084 |
| 5–11 Sep | 441 | 40 | 0.091 |
| 12–18 Sep | 225 | 13 | 0.058 |
| 19–30 Sep | 179 | 8 | 0.050 |
| Total | 3018 | 196 | 0.065 |

*Note:* the sport harvest was sampled below RKM 34 (Soldotna Bridge).

[a] Adipose fin missing and CWT detected.

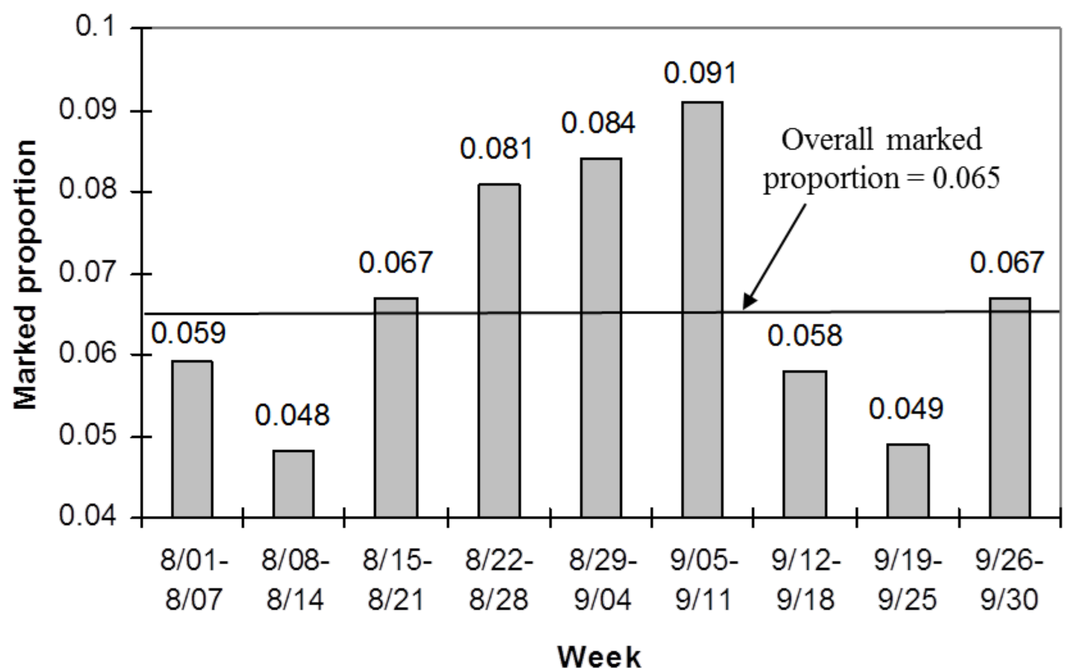


Figure 4.–Estimated weekly marked proportion of Kenai River coho salmon sampled in the inriver sport fishery, 1 August–30 September 2008.

## GENETIC SAMPLING

Tissue samples (axillary processes) were collected for genetic analysis from approximately every fourth coho salmon examined in the sport harvest. Tissue samples were preserved as instructed by the USFWS and forwarded to their Gene Conservation Lab in October 2008. A total of 826 samples were collected (Appendix A2).

Table 3.–Kenai River coho salmon smolt abundance estimates, 1992–2007.

| Smolt marking year | Number of marked fish released | Adult sampling year | Inriver adults sample | Marked adults observed[a] | Estimated smolt abundance | SE | 95% confidence limits Lower | 95% confidence limits Upper |
|---|---|---|---|---|---|---|---|---|
| 1992 | 73,580 | 1993 | 4,626 | 477 | 879,290 | 42,607 | 795,780 | 962,800 |
| 1993 | 99,525 | 1994 | 5,395 | 644 | 977,964 | 39,407 | 900,726 | 1,055,203 |
| 1994 | 170,058 | 1995 | 4,838 | 1,355 | 628,909 | 14,788 | 599,924 | 657,893 |
| 1995 | 94,535 | 1996 | 3,687 | 765 | 465,075 | 15,091 | 435,496 | 494,654 |
| 1996 | 98,032 | 1997 | 604 | 110 | 534,323 | 45,597 | 444,953 | 623,693 |
| 1997 | 96,486 | 1998 | 3,552 | 915 | 374,255 | 10,597 | 353,485 | 395,024 |
| 1998 | 101,133 | 1999 | 2,476 | 313 | 797,798 | 41,940 | 715,596 | 880,000 |
| 1999 | 114,885 | 2000 | 3,387 | 672 | 578,355 | 19,884 | 539,383 | 617,328 |
| 2000 | 103,319 | 2001 | 2,670 | 458 | 601,236 | 25,454 | 551,346 | 651,126 |
| 2001 | 147,931 | 2002 | 6,523 | 1,503 | 641,693 | 14,436 | 613,400 | 669,987 |
| 2002 | 108,520 | 2003 | 2,475 | 428 | 626,335 | 27,409 | 572,613 | 680,057 |
| 2003 | 120,305 | 2004 | 9,217 | 926 | 1,196,310 | 37,100 | 1,123,594 | 1,269,027 |
| 2004 | 83,674 | 2005 | 5,517 | 432 | 1,066,324 | 49,009 | 970,267 | 1,162,381 |
| 2005 | 79,932 | 2006 | 6,034 | 572 | 841,876 | 33,309 | 776,590 | 907,163 |
| 2006 | 81,953 | 2007 | 1,075 | 135 | 648,400 | 51,735 | 547,000 | 749,799 |
| 2007 | 80,494 | 2008 | 3,018 | 197 | 1,227,344 | 83,999 | 1,062,706 | 1,391,983 |
| | | | | Mean | 755,343 | 9,760 | | |

*Sources*: Carlon and Hasbrouck (1994, 1996-1998); Carlon (2000, 2003); Massengill (2007a-c, 2008); Massengill and Carlon (2004a-b, 2007a-b)

[a] The mark of interest beginning in 1997 has been a missing adipose fin. Prior to 1997, detection of a coded-wire tag that was implanted the prior year provided the mark of interest.

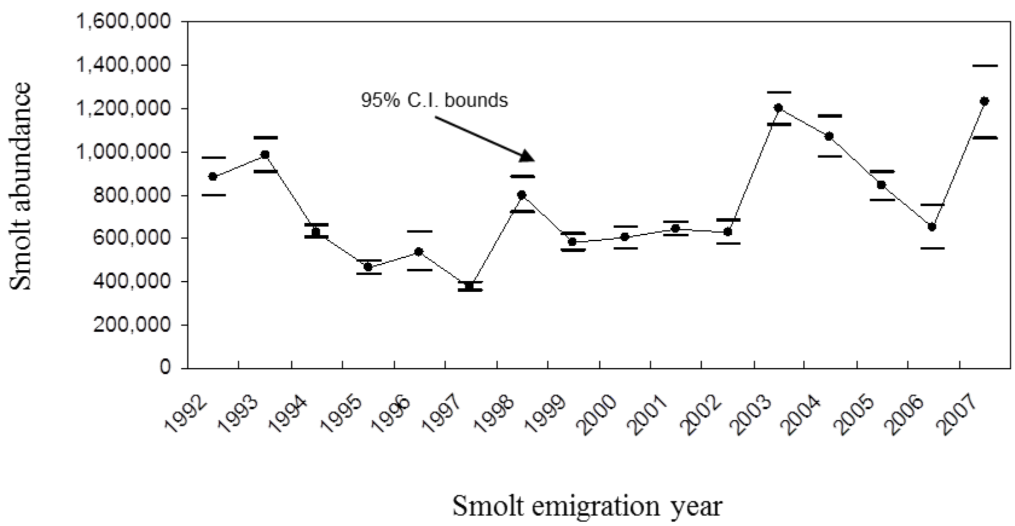


Figure 5.–Kenai River coho salmon smolt abundance estimates, 1992–2007.

## LENGTH AND SCALE SAMPLING

A total of 359 adult Kenai River coho salmon were sampled for FL and scale samples during 1 August through 30 September 2008. Scales were archived in the Soldotna ADF&G office. Total mean length in 2008 was 697 mm (SE 2.9) and varied weekly from a minimum of 655 mm to a maximum of 750 mm (Figure 6). Lengths for Kenai River coho salmon were recorded as mid eye to tail fork length measurements during the years 1991–1993 and 1998–2000, and as FL measurements from 2001 to 2008. FL measurements were deemed easier to collect, particularly from live fish sampled in mark–recapture studies. Mean lengths for all years are depicted in Figure 7.

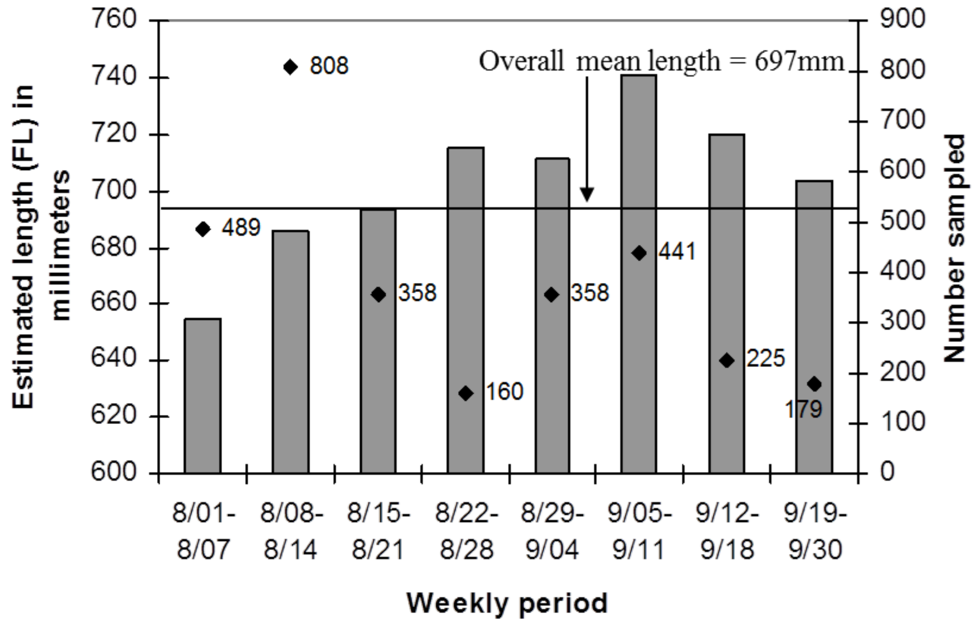


Figure 6.–Estimated weekly mean length (bars) and number sampled for marks (black points) of Kenai River coho salmon in the inriver sport fishery, 1 August–30 September 2008.

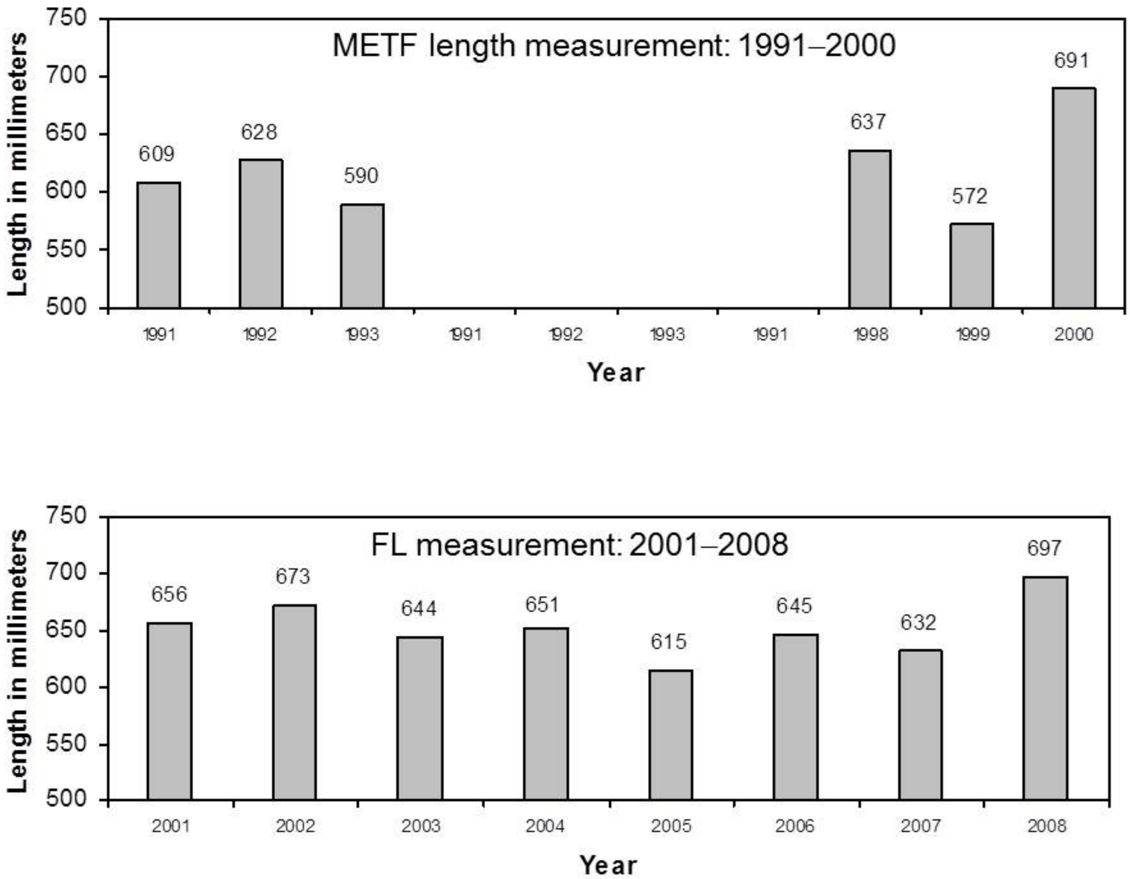


Figure 7.–Estimated annual mean mid eye to tail fork lengths (top) or fork lengths (bottom) of adult Kenai River coho salmon sampled 1 August–30 September, 1993–2008.

# DISCUSSION

## SMOLT ABUNDANCE OVERVIEW

The 2007 Kenai River coho salmon smolt abundance estimate is the 16th and final smolt estimate available. It also represents the sixth estimate of smolt production that can be associated with an estimated parent-year escapement for the Kenai River. Because most Kenai River coho salmon develop into age-2 smolt, the primary parent year for the 2007 smolt emigration is 2004. The escapement estimate for 2004 is 95,394 coho salmon (Massengill and Evans 2007) and is 23% higher than the 1999–2003 average. The 2004 escapement is associated with a 70% above average production of smolt in 2007 (Figure 8). A Bayesian measurement error analysis was used to model smolt abundance as a function of escapement using a power curve relationship. An informative prior on $\beta$ (in $Y = \alpha X^{\beta}$) was used to confine the relationship between 0 and 1; this constraint was considered reasonable because it ensured either an increasing straight line or saturation curve relationship between smolt abundance and escapement. The results are shown in Figure 9.

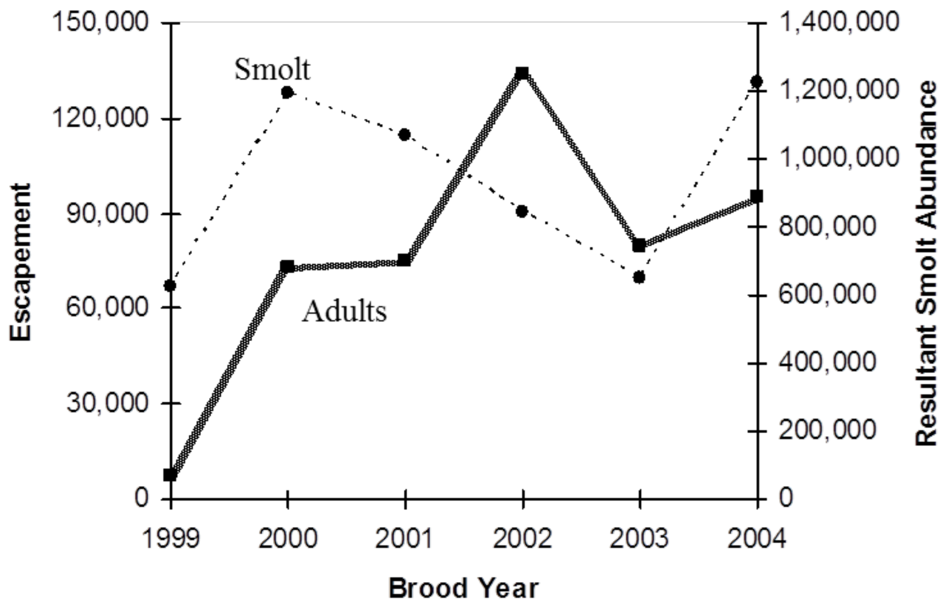


Figure 8.–Kenai River coho salmon brood year escapement and resulting smolt production during the years 1999–2004.

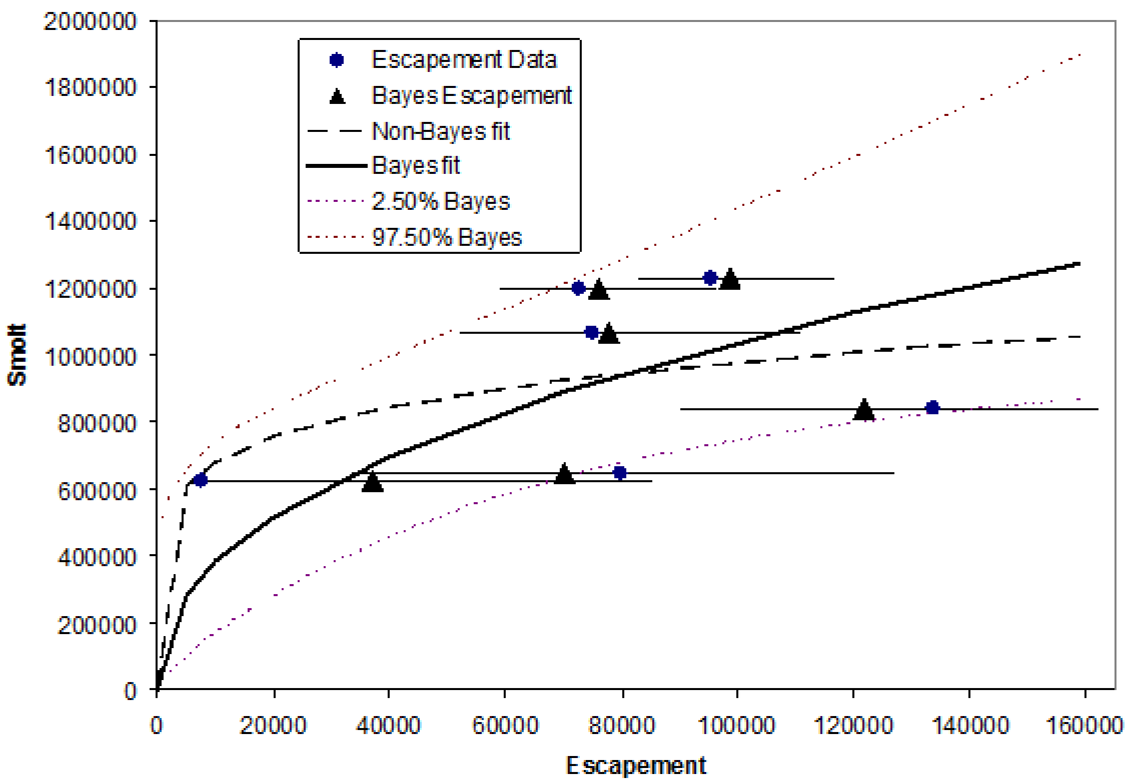


Figure 9.–Bayesian analysis for Kenai River coho salmon escapement and resulting smolt production, 1999–2004. Horizontal lines show Bayesian 2.5% and 97.5% credibility intervals for escapement means. A power curve ($Y = aX^b$) was assumed.

Initiated in the 1990s in the absence of total return data, the relationship between historical parent harvest (Table 4) and resultant smolt production was examined (Figure 10). The lowest smolt estimate on record (1997) is associated with the highest parent harvest (1994), although no discernable relationship was detected.

The record of smolt production in the Kenai River has been remarkably stable regardless of the variation in the estimated parent-year escapement. From 1992 to 2007, smolt abundance point estimates never varied more than 62% from the mean (755,343) although estimated parent-year escapement during the years 1999–2004 varied up to an order of magnitude from the mean (77,413).

In reviewing the roles different factors have on adult abundance of Pacific salmon, Emmett and Schiewe (1997) noted that in virtually all cases examined, there is strong evidence for density-dependent population regulation in coho salmon. The production of smolt appears strongly limited by the availability of suitable habitat (Chapman 1965; Bradford et al. 1997, as reported in Bradford et al. 2000). In studies from southeast Alaska, coho salmon returns were typically proportionate to spawner abundance up to a threshold escapement level, above which returns were stable at all escapement levels; juveniles were limited by territorial effects and unequal access to food, which tended to produce a relatively consistent number of smolt from highly variable levels of seeding (Shaul et al. 2003).

If the relationship between smolt and escapement observed by Shaul et al. (2003) exists for Southcentral Alaska, then the stable smolt production observed in the Kenai River drainage would suggest the threshold escapement has been met and that a density-dependent mechanism, perhaps through limiting rearing habitat, is limiting smolt production.

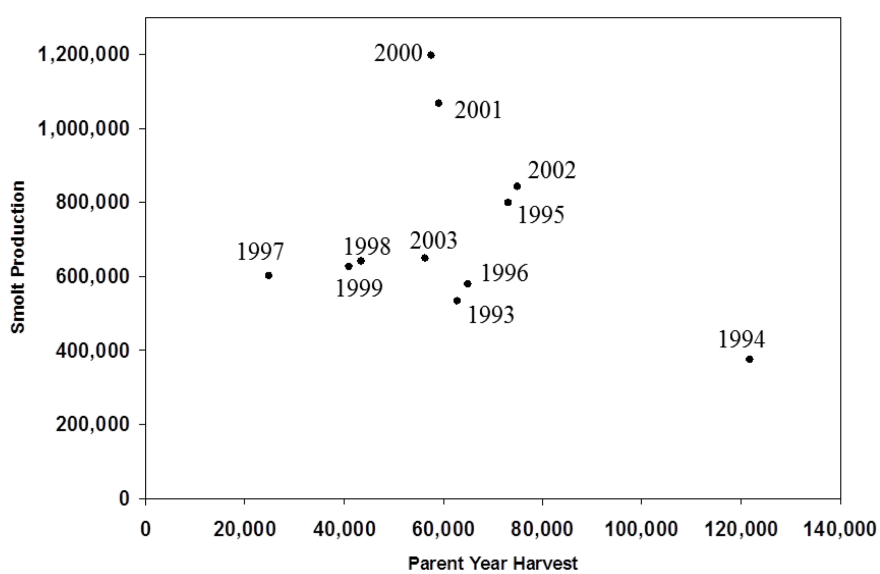


Figure 10.–Parent-year harvest and annual smolt production of Kenai River coho salmon.

Table 4.–Summary of harvest data for Kenai River coho salmon in Upper Cook Inlet, 1993–2007.

| | Kenai River | | | | | | | | | | | UCI Marine Commercial[d] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sport fish[a] | | | | | | | | | | | | | | |
| | Mainstem | | | | | | | | | | | | | | |
| Year | Unguided | Guided | Unk[b] | Hidden and Skilak lakes | Total | Russian River | Total | Personal use-subsistence | Inriver total | Ed.[c] | Eastside set gillnet | Drift gillnet | Northern District | Commercial total | Grand total |
| 1993 | 26,795 | 23,743 | | 27 | 50,565 | 2,290 | 52,855 | 1,597[e] | 54,452 | 427 | 6,806 | 930 | 148 | 7,884 | 62,763 |
| 1994 | 45,541 | 41,170 | | 127 | 86,838 | 4,607 | 91,445 | 2,535[f] | 93,980 | 829 | 14,673 | 11,732 | 477 | 26,882 | 121,691 |
| 1995 | 22,596 | 23,587 | | 67 | 46,250 | 4,077 | 50,327 | 1,261[g] | 51,588 | 868 | 13,152 | 6,956 | 582 | 20,690 | 73,146 |
| 1996 | 28,565 | 13,728 | | 899 | 43,192 | 4,599 | 47,791 | 1,932[h] | 49,723 | 592 | 11,856 | 2,671 | 29 | 14,556 | 64,871 |
| 1997 | 13,063 | 3,101 | | 0 | 16,164 | 4,586 | 20,750 | 559[h] | 21,309 | 191 | 2,093 | 1,236 | 36 | 3,365 | 24,865 |
| 1998 | 21,750 | 5,217 | | 0 | 26,967 | 4,612 | 31,579 | 1,011[h] | 32,590 | 638 | 8,096 | 1,974 | 175 | 10,245 | 43,473 |
| 1999 | 23,550 | 8,087 | | 7 | 31,644 | 3,910 | 35,554 | 1,009[h] | 36,563 | 530 | | 818 | 171 | 3,894 | 38,082 |
| 2000 | 39,170 | 9,349 | | 32 | 48,551 | 3,938 | 52,489 | 1,449[h] | 53,938 | 656 | 2,351 | 531 | 83 | 2,965 | 57,559 |
| 2001 | 36,264 | 13,518 | | 0 | 49,782 | 5,222 | 55,004 | 1,555[h] | 56,559 | 572 | 349 | 282 | 1,303 | 1,934 | 59,065 |
| 2002 | 45,206 | 14,444 | | 361 | 60,011 | 6,093 | 66,104 | 1,721[h] | 67,825 | 921 | 4,688 | 1,370 | 57 | 6,115 | 74,861 |
| 2003 | 34,658 | 11,964 | | 125 | 46,747 | 5,197 | 51,944 | 1,332[h] | 53,276 | 439 | 2,122 | 330 | 126 | 2,578 | 56,293 |
| 2004 | 51,070 | 14,845 | 37 | 39 | 65,991 | 6,574 | 72,565 | 2,661[i] | 75,226 | 765 | 5,921 | 4,251 | 977 | 11,149 | 87,140 |
| 2005 | 38,071 | 12,285 | | 44 | 50,400 | 3,868 | 54,268 | 2,512[i] | 56,780 | 489 | 3,310 | 1,533 | 176 | 5,019 | 62,288 |
| 2006 | 28,281 | 9,233 | | 136 | 37,650 | 5,431 | 43,081 | 2,235[i] | 45,316 | 689 | | | | | |
| 2007 | 27,705 | 10,312 | | 77 | 38,094 | 3,169 | 41,263 | 2,111[j] | 43,374 | | | | | | |
| Mean | 32,152 | 14,306 | | | 46,590 | 4,545 | 51,135 | 1,699 | 52,833 | 615 | 6,285 | 2,663 | 334 | 9,021 | 63,546 |

[a] Source is Statewide Harvest Survey (Mills 1994; Howe et al. 1995-1996, 2001a-d [1996-2000 are revised estimates]; Walker et al. 2003; Jennings et al. (2004); Jennings et al. 2004, 2006a-b, 2007, 2009a-b, 2010. Mainstem unguided includes Skilak Lake and Hidden Lake.

[b] Kenai River coho harvest from unknown guide or unguided status

[c] Kenai River harvest in the Kenaitze Tribal educational fishery (Larry Marsh -ADF&G, personal communication). Prior to 2002, these harvests included Kasilof and Swanson rivers harvests.

[d] Carlon and Hasbrouck (1994, 1996-1998); Carlon (2000, 2003); Massengill and Carlon (2004a-b, 2007a-b); Massengill (2007a-b).

[e] Kenai River personal use dipnet fishery harvest (Mills 1994).

[f] Kenai River subsistence dipnet fishery harvest (Brannian and Fox 1996).

[g] Kenai River personal use dipnet fishery harvest (Ruesch and Fox 1996).

[h] Reimer and Sigurdsson (2004).

[i] Dunker and Lafferty (2007).

[j] Dunker (2010).

## SUMMARY STATISTICS

Historical population parameter estimates for Kenai River coho salmon are available for smolt abundance, commercial harvest estimates, adult inriver abundance or total return estimates, and indexing of adult inriver abundance. A summary of these estimates can be found in Table 3, Table 4, Appendix B1, and Appendix B2, respectively.

Sport harvest estimates since 1977 were generated by another program (SWHS) and during some years also by creel survey. Estimates of all Kenai River coho salmon population parameters, including sport harvest estimates, have been reported in other reports, with the exception of the 1998 inriver creel survey sport harvest estimates. Therefore, the 1998 creel-based harvest estimates are reported for the first time in this report, including a description of the methods used (Appendix C1). The inriver sport fishing estimates for effort, catch, and harvest are provided for 1990–1993 and 1998 and are available only for selected sections of the river (Appendix B3); the interruption in annual creel harvest estimates resulted from the program being discontinued after 1993 and later reconstituted in 1997 and 1998. The 1997 creel program was aborted in early September due to poor fishing and low angler effort, therefore estimates were not feasible. In 1998, the creel program resumed and produced harvest estimates. Creel survey estimates were discontinued after 1998 due to budget constraints (Bethe et al. 2002). There is high correlation between lower river harvest estimates generated by the creel survey and SWHS estimates during the 1990s ($r$ = 0.97; Appendix B4). A Bayesian measurement error regression of the SWHS estimate on the creel estimate (Figure 11) reveals a slope of 0.88; the 2.5% and 97.5% credibility interval (0.73–1.05) includes 1.0. The non-measurement error model yielded a slope of 0.67 and was significantly different from 1, showing the importance of accounting for sampling errors in the creel estimates. The SWHS-based harvest estimates alone were cited in past management reports (Bethe et al. 2002; Pappas and Marsh 2004).

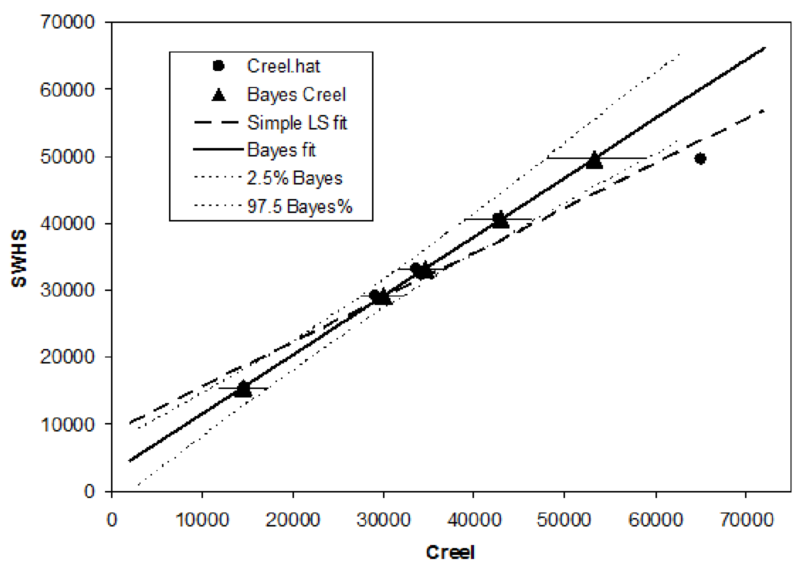


Figure 11.–Baysian Analysis for Kenai River coho salmon creel estimates and associated SWHS estimates (1990–1993 and 1998). Horizontal lines show Bayesian 2.5% and 97% credibility intervals for Creel means. A linear relationship (Y = a + bX) was assumed.

## ASSESSMENT OF EXPLOITATION RATES

Current harvest strategies should ensure sustainable harvests of Kenai River coho salmon at least into the near future. Average exploitation during the years 2000–2004 was about 42% and even with liberalizations since 2004, exploitation likely only increased by 5–6%, suggesting the harvest should be sustainable. Examples of sustainable exploitation rates for other Alaskan coho salmon populations can be found in Shaul et al. (2003): from 1982 through 2002 average coho salmon exploitation rates for 5 Southeast Alaska stocks ranged between 0.40 and 0.67, averaging 0.57, and all stocks were considered in excellent overall condition. Additionally, average annual exploitation rates measured in an aggregate of populations among 4 other intensively studied indicator streams in Southeast Alaska have ranged between 0.40 and 0.68, averaging 0.59 during the period 1982 through 2002 (Geiger and McPherson 2004). Geiger and McPherson (2004) also reviewed Southeast Alaska populations in general and reported an "excellent overall condition" with no populations of concern identified. Finally, the first 2 estimates of exploitation rates for a wild coho salmon population supporting long-term fisheries in northern Cook Inlet (Cottonwood Creek) were 0.47 and 0.29 for 1999 and 2000, respectively, averaging 0.38 (T. Namtvedt, Sport Fish Biologist, ADF&G Palmer, personal communication).

Sustainable exploitation rates observed in other Pacific Northwest areas indicate that the expected average exploitation rate for Kenai River coho salmon (approaching 50%) is sustainable. Based on stock-recruit data, the maximum sustainable exploitation rate on natural coho stocks in Oregon was estimated to be 73% (ODFW 1981) and for several coastal regions of British Columbia it was estimated at 71% (Wong 1982).

## ISSUES

During uncommonly weak Kenai River coho salmon runs such as that observed in 1999, exploitation can rise above what is believed sustainable. The 1999 exploitation rate was estimated to be nearly 84% (Carlon and Evans 2007). Although the 1999 escapement was the lowest ever estimated (<8,000 fish; Appendix B1), the 2002 smolt abundance estimate (believed to have been primarily produced by this escapement) was 626,335 smolt, which represents 83% of the1992–2007 average. Whether near-average smolt production can be expected indefinitely under consistently low escapements is unknown.

Determination of the parent to smolt relationship is complicated by difficulties in accurately discerning smolt ages with current aging techniques, which are conducted without the use of age validation information. Accurate aging of archived Kenai River coho salmon smolt scales could allow for brood table construction that might clarify the relationship between escapement and smolt production, particularly whether very low escapements produce small smolt broods. However, the author believes overall smolt production in the Kenai River drainage is currently adequate and that brood year table construction would probably not yield any management implications.

Currently, there is not a reliable method to detect Kenai River coho salmon abundance inseason to assist managers; a fish wheel–based adult abundance index had been tried with mixed results for the years 2005–2007 (Massengill 2013) and sonar proved unfeasible in 1994 (Bendock and Vaught 1994). Without a management tool to assess abundance inseason, further liberalizations to exploit Kenai River coho salmon should be avoided.

The record of Kenai River coho salmon smolt abundance estimates coupled with the Moose River smolt census data since 1992 demonstrate the importance of the Moose River to rearing juvenile coho salmon (Table 5). On average, 29% of the drainage-wide coho salmon smolt population rears in the Moose River drainage. Invasive northern pike, illegally introduced to the Soldotna Creek drainage decades ago, have expanded into 16 Kenai Peninsula lakes, and although unconfirmed and rare, there have been reports of northern pike caught by anglers in the Moose River. Because invasive northern pike have the potential to decimate salmonid populations, particularly those rearing in habitat preferred by northern pike (shallow, weedy, low flows such as that found in the Moose River drainage), the salmonid populations within the Moose River are considered highly vulnerable. This author encourages surveying the Moose River drainage for the presence of pike and supports all efforts to contain or eradicate invasive northern pike elsewhere on the Kenai Peninsula.

# ACKNOWLEDGMENTS

The following people comprised the team that marked smolt at the Moose River in 2007: Kurt Strausbaugh was the field project leader and participated in all phases of field investigation. Jake Glotfelty, Will Newberry, and Sandee Simons assisted with all phases of the field investigation including logistical support, weir operation and maintenance, and smolt tagging and enumeration. “Cotton” and Lorrayne Moore and Dr. Bill West graciously provided convenient access to the Moose River.

The team of people conducting the Kenai River coho salmon sport harvest sampling in 2007 consisted of Sean Boyer, Stacie Mallette, Julianne Petty, and Jerry Strait. Tim McKinley was the project supervisor and provided guidance for project planning, budgeting, and editorial reviews for the operational plan and this report. David Evans provided biometric oversight and editorial reviews of the operational plan and this report.

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# APPENDIX A: KENAI RIVER COHO SALMON SPORT HARVEST SAMPLING PROTOCOL, 2008

Appendix A1.–Kenai River coho salmon sport harvest technician sampling schedule, 2008.

| | | | Sampling hours | | | Sampling hours | |
|---|---|---|---|---|---|---|---|
| Month | Date | Day | Technician A[a] (FWT II) | Technician B[b,c] (FWT II) | Bank | Technician C[b] (FWT II) | Bank |
| August | 1 | Friday | 0800–1600 | 1330–2130 | N&S | Off | |
| | 2 | Saturday | 0630–1430 | 1030–1830 | N | 1330–2130 | S |
| | 3 | Sunday | 0630–1430 | 1330–2130 | S | 1330–2130 | N |
| | 4 | Monday | Off | 0630–1430 c | N&S | 1330–2130 | N&S |
| | 5 | Tuesday | Off | 0630–1430 c | N&S | 1330–2130 | N&S |
| | 6 | Wednesday | 0630–1430 | Off | | 1330–2130 | N&S |
| | 7 | Thursday | 0630–1430 | Off | | Off | |
| | 8 | Friday | 0630–1430 | 1330–2130 | N&S | Off | |
| | 9 | Saturday | 0630–1430 | 1030–1830 | N | 1330–2130 | S |
| | 10 | Sunday | 0630–1430 | 1030–1830 | S | 1330–2130 | N |
| | 11 | Monday | Off | 0630–1430 c | N&S | 1330–2130 | N&S |
| | 12 | Tuesday | Off | 0630–1430 c | N&S | 1330–2130 | N&S |
| | 13 | Wednesday | 0630–1430 | Off | | 1330-2130 | N&S |
| | 14 | Thursday | 0630–1430 | Off | | Off | |
| | 15 | Friday | 0630–1430 | 1330–2130 | N&S | Off | |
| | 16 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 17 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | 18 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 19 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 20 | Wednesday | 0630–1430 | | | 1330–2130 | N&S |
| | 21 | Thursday | 0630–1430 | | | Off | |
| | 22 | Friday | 0630–1430 | | N&S | Off | |
| | 23 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 24 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | 25 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 26 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 27 | Wednesday | 0630–1430 | | | 1330–2130 | N&S |
| | 28 | Thursday | 0630–1430 | | | Off | |
| | 29 | Friday | 0630–1430 | | N&S | Off | |
| | 30 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 31 | Sunday | 0630–1430 | | S | 1330–2130 | N |

-continued-

Appendix A1.–Part 2 of 2.

| | | | Sampling hours | | | Sampling hours | |
|---|---|---|---|---|---|---|---|
| | | | Technician A[a] | Technician B[b,c] | | Technician C[b] | |
| Month | Date | Day | (FWT II) | (FWT II) | Bank | (FWT II) | Bank |
| September | 1 | Monday | 0630–1430 | | N | 1330–2130 | S |
| | 2 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 3 | Wednesday | Off | | | 1330–2130 | N&S |
| | 4 | Thursday | 0630–1430 | | | Off | |
| | 5 | Friday | 0630–1430 | | N&S | Off | |
| | 6 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 7 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | | | | | | | |
| | 8 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 9 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 10 | Wednesday | 0630–1430 | | | 1330–2130 | N&S |
| | 11 | Thursday | 0630–1430 | | | Off | |
| | 12 | Friday | 0630–1430 | | N&S | Off | |
| | 13 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 14 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | | | | | | | |
| | 15 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 16 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 17 | Wednesday | 0630–1430 | | | 1330–2130 | N&S |
| | 18 | Thursday | 0630–1430 | | | Off | |
| | 19 | Friday | 0630–1430 | | N&S | Off | |
| | 20 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 21 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | | | | | | | |
| | 22 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 23 | Tuesday | Off | | N&S | 1330–2130 | N&S |
| | 24 | Wednesday | 0630–1430 | | | 1330–2130 | N&S |
| | 25 | Thursday | 0630–1430 | | | Off | |
| | 26 | Friday | 0630–1430 | | N&S | Off | |
| | 27 | Saturday | 0630–1430 | | N | 1330–2130 | S |
| | 28 | Sunday | 0630–1430 | | S | 1330–2130 | N |
| | | | | | | | |
| | 29 | Monday | Off | | N&S | 1330–2130 | N&S |
| | 30 | Tuesday | Off | | N&S | 1330–2130 | N&S |

[a] Technician A used a boat to sample coho salmon harvested below the Soldotna Bridge.

[b] Technicians B and C used a highway vehicle to sample coho salmon access locations.

[c] The technician B sampling schedule component was discontinued after 15 August to save money when it became evident that 2 samplers would likely satisfy the sample size goal for the project.

Appendix A2.–Kenai River coho salmon sport harvest genetic sampling summary, 2008.

| | August | | | September | |
|---|---|---|---|---|---|
| Date collected | Number of sport caught coho salmon examined[a,b] | Number of coho salmon tissue samples collected | Date collected | Number of sport caught coho salmon examined[b] | Number of coho salmon tissue samples collected |
| 1 Aug | 17 | 5 | 1 Sep | 60 | 16 |
| 2 Aug | 31 | 9 | 2 Sep | 39 | 10 |
| 3 Aug | 83 | 22 | 3 Sep | 31 | 8 |
| 4 Aug | 51 | 13 | 4 Sep | 0 | 0 |
| 5 Aug | 151 | 37 | 5 Sep | 14 | 4 |
| 6 Aug | 99 | 29 | 6 Sep | 87 | 23 |
| 7 Aug | 57 | 17 | 7 Sep | 170 | 43 |
| 8 Aug | 39 | 6 | 8 Sep | 14 | 4 |
| 9 Aug | 104 | 29 | 9 Sep | 17 | 5 |
| 10 Aug | 172 | 46 | 10 Sep | 103 | 27 |
| 11 Aug | 74 | 21 | 11 Sep | 36 | 12 |
| 12 Aug | 220 | 57 | 12 Sep | 44 | 13 |
| 13 Aug | 135 | 40 | 13 Sep | 49 | 13 |
| 14 Aug | 64 | 20 | 14 Sep | 47 | 13 |
| 15 Aug | 121 | 33 | 15 Sep | 33 | 9 |
| 16 Aug | 38 | 12 | 16 Sep | 7 | 3 |
| 17 Aug | 55 | 17 | 17 Sep | 46 | 13 |
| 18 Aug | 24 | 7 | 18 Sep | 0 | 0 |
| 19 Aug | 32 | 9 | 19 Sep | 9 | 3 |
| 20 Aug | 77 | 21 | 20 Sep | 39 | 11 |
| 21 Aug | 11 | 3 | 21 Sep | 32 | 9 |
| 22 Aug | 15 | 4 | 22 Sep | 9 | 3 |
| 23 Aug | 38 | 11 | 23 Sep | 20 | 5 |
| 24 Aug | 49 | 14 | 24 Sep | 41 | 11 |
| 25 Aug | 13 | 4 | 25 Sep | 10 | 3 |
| 26 Aug | 6 | 2 | 26 Sep | 4 | 2 |
| 27 Aug | 28 | 8 | 27 Sep | 10 | 3 |
| 28 Aug | 12 | 4 | 28 Sep | 3 | 1 |
| 29 Aug | 43 | 10 | 29 Sep | 0 | 0 |
| 30 Aug | 124 | 32 | 30 Sep | 2 | 1 |
| 31 Aug | 61 | 16 | | | |
| Aug total | 2,044 | 558 | Sep total | 976 | 268 |
| | | | Grand total | 3,020 | 826 |

[a] Samples were collected from the Kenai River sport harvest below the Soldotna Bridge (RKM 34) from 1 August through 30 September 2008.

[b] Total examined includes 2 fish without heads; these 2 fish were not included in the number examined in Table 1.

# APPENDIX B: HISTORICAL DATA FOR COHO SALMON FROM THE KENAI RIVER

Appendix B1.–Estimates of total return, exploitation, and marine survival for coho salmon from the Kenai River, 1999–2004.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Estimate | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| Abundance at fish wheels[a] | 23,001 | 89,918 | 93,524 | 156,960 | 99,309 | 120,489 |
| SE | 5,154 | 9,295 | 16,502 | 20,256 | 36,085 | 9,008 |
| Downstream sport harvest[b,c] | 20,442 | 35,868 | 37,142 | 43,724 | 32,759 | 49,576 |
| SE | 1,454 | 1,740 | 1,878 | 2,516 | 1,908 | 10,577 |
| Personal use harvest | 1,009 | 1,449 | 1,555 | 1,721 | 1,332 | 2,661 |
| SE | 108 | 62 | 105 | 96 | 68 | 66 |
| Commercial harvest[d] | 3,894 | 2,965 | 1,934 | 6,115 | 2,578 | 11,149 |
| SE | 326 | 255 | 176 | 499 | 263 | 1,232 |
| Total run | 48,346 | 130,200 | 134,155 | 208,520 | 135,978 | 183,875 |
| SE | 5,366 | 9,460 | 16,610 | 20,418 | 36,137 | 13,948 |
| Total harvest[e] | 40,457 | 56,903 | 58,493 | 73,940 | 55,854 | 86,375 |
| SE | 1,898 | 2,110 | 2,438 | 2,908 | 2,329 | 10,984 |
| Exploitation rate[f] | 0.837 | 0.437 | 0.436 | 0.355 | 0.411 | 0.470 |
| SE | 0.101 | 0.036 | 0.057 | 0.037 | 0.110 | 0.020 |
| Escapement estimate[a] | 7,696 | 72,742 | 75,122 | 133,612 | 79,915 | 95,394 |
| SE | 5,288 | 9,395 | 16,574 | 20,306 | 36,111 | 9,394 |
| Smolt abundance in prior year[d] | 799,687 | 578,355 | 601,236 | 641,693 | 626,335 | 1,196,310 |
| SE | 42,111 | 19,884 | 25,454 | 14,436 | 27,409 | 37,100 |
| Marine survival | 0.060 | 0.225 | 0.223 | 0.325 | 0.217 | 0.150 |
| SE | 0.007 | 0.018 | 0.029 | 0.033 | 0.058 | 0.010 |

[a] Data for 1999 through 2003 from Carlon and Evans (2007); data for 2004 from Massengill and Evans (2007).

[b] Source is the Statewide Harvest Survey (SWHS). Sport harvest occurred downstream from the locations to which the abundance estimates pertain. Data for 1999 were derived from the sum of SWHS estimates downstream of Soldotna Bridge; for the years 2000–2004, data were derived from half of the SWHS estimate for the river section between the Soldotna Bridge and the Moose River confluence plus all the estimated sport harvest downstream from Soldotna Bridge.

[c] For the years 2002–2004, an “unspecified river reach” category was added to the SWHS for the Kenai River. Prior to calculating the sport harvest downstream from river kilometer 45, the estimates for this category were apportioned among the four specified mainstem river reaches based on the proportion of the total mainstem harvest represented by the reach-specific harvest reported (standard errors were recalculated according to standard procedures).

[d] Data for 1999 from Massengill (2007c), data for 2000–2001 from Massengill and Carlon (2004a-b); data for 2002–2003 from Massengill and Carlon (2007a-b); data for 2004 from Massengill (2007a).

[e] Aggregate of all harvest estimates (sport, commercial, and personal-use, and subsistence); repeated for convenience.

[f] (Estimated Grand Total Harvest) / (Estimated Total Return).

Appendix B2.–Summary of the cumulative north and south bank fish wheel catch per unit of effort (CCPUE) and the natural log transformed CCPUE (lnCCPUE) of coho salmon during five temporal periods using adjusted data collected near RKM 45 Kenai River, Alaska, 1999–2007.

| | | Combined banks fish wheel | | | | | End-of-season |
|---|---|---|---|---|---|---|---|
| Year | | 1–14 Aug | 1–28 Aug | 1 Aug–11 Sep | 1 Aug–25 Sep | 1 Aug–30 Sep | classification[a] |
| 1999[b] | CCPUE | 4.46 | 25.86 | 30.34 | 36.19 | 37.63 | |
| | lnCCPUE | 1.50 | 3.25 | 3.41 | 3.59 | 3.63 | Low |
| 2000 | CCPUE | 14.79 | 34.86 | 79.87 | 135.90 | 143.40 | |
| | lnCCPUE | 2.69 | 3.55 | 4.38 | 4.91 | 4.97 | Medium |
| 2001 | CCPUE | 11.84 | 47.78 | 75.13 | 83.87 | 87.07 | |
| | lnCCPUE | 2.47 | 3.87 | 4.32 | 4.43 | 4.47 | Medium |
| 2002 | CCPUE | 13.52 | 133.71 | 287.93 | 399.00 | 411.33 | |
| | lnCCPUE | 2.60 | 4.90 | 5.66 | 5.99 | 6.02 | High |
| 2003 | CCPUE | 20.54 | 83.17 | 101.36 | 103.47 | 104.76 | |
| | lnCCPUE | 3.02 | 4.42 | 4.62 | 4.64 | 4.65 | Medium |
| 2004 | CCPUE | 58.17 | 305.68 | 459.94 | 550.89 | 574.55 | |
| | lnCCPUE | 4.06 | 5.72 | 6.13 | 6.31 | 6.35 | High |
| 2005 | CCPUE | 6.18 | 119.86 | 199.75 | 228.34 | 234.75 | |
| | lnCCPUE | 1.82 | 4.79 | 5.30 | 5.43 | 5.46 | Medium |
| 2006 | CCPUE | 15.63 | 113.54 | 200.82 | 303.99 | 324.02 | |
| | lnCCPUE | 2.75 | 4.73 | 5.30 | 5.72 | 5.78 | Medium |
| 2007 | CCPUE | 2.70 | 16.95 | 31.12 | 44.52 | 46.93 | |
| | lnCCPUE | 0.99 | 2.83 | 3.44 | 3.80 | 3.85 | Low |

*Note:* Summary of 1999–2004 CPUE includes only standardized daily fish wheel operation periods found in Appendix 1. The 1999–2004 summary does not include coho salmon recaptured, escaped, or considered unsuitable for marking (i.e., severely injured or dead).

*Source*: Massengill, R. In Prep. Assessment of coho salmon from the Kenai River, Alaska, 2007. Alaska Department of Fish and Game, Anchorage.

[a] End-of-season run classification indexes the Kenai River adult coho salmon abundance arriving to the fishwheel site into one of three levels as follows: Low <50,000, Medium >50,000 and <120,000, and High >120,000.

[b] Fish wheel locations in 1999 were RKM 31, and between RKM 43 and 45.

Appendix B3.–Summary of Kenai River coho salmon creel-based estimates of effort, harvest, and catch, 1990–1993 and 1998.

| | | | River section[a] | | | |
|---|---|---|---|---|---|---|
| Year | Month | Parameter | Downstream | Midstream | Upstream | Combined |
| 1990[b] | | | | | | |
| | August | | | | | |
| | | Effort | 216,074 | 23,735 | 28,512 | 268,321 |
| | | SE | 7,682 | 1,818 | 2,089 | 8,165 |
| | | Harvest | 26,789 | 2,119 | 2,793 | 31,701 |
| | | SE | 2,235 | 336 | 483 | 2,311 |
| | | Catch | 27,179 | 2,715 | 2,912 | 32,806 |
| | | SE | 2,259 | 338 | 486 | 2,335 |
| | September | | | | | |
| | | Effort | 97,639 | 14,938 | 18,528 | 131,105 |
| | | SE | 5,338 | 1,138 | 1,432 | 5,643 |
| | | Harvest | 15,849 | 2,201 | 5,991 | 24,041 |
| | | SE | 1,447 | 498 | 740 | 1,700 |
| | | Catch | 15,919 | 2,213 | 6,057 | 24,189 |
| | | SE | 1,450 | 498 | 740 | 1,702 |
| 1991[c] | | | | | | |
| | August | | | | | |
| | | Effort | 161,208 | | 44,829 | 206,037 |
| | | SE | 6,990 | | 8,632 | 11,107 |
| | | Harvest | 41,660 | | 7,030 | 48,690 |
| | | SE | 6,235 | | 3,255 | 7,033 |
| | | Catch | 42,034 | | 7,722 | 49,756 |
| | | SE | 6,272 | | 3,396 | 7,132 |
| | September | | | | | |
| | | Effort | 80,947 | | 23,920 | 104,867 |
| | | SE | 1,553 | | 2,267 | 2,748 |
| | | Harvest | 23,340 | | 3,372 | 26,712 |
| | | SE | 3,234 | | 900 | 3,357 |
| | | Catch | 23,339 | | 3,599 | 26,938 |
| | | SE | 3,234 | | 907 | 3,359 |
| 1992[d] | | | | | | |
| | August | | | | | |
| | | Effort | 176,554 | | | 176,554 |
| | | SE | 5,235 | | | |
| | | Harvest | 20,817 | | | 20,817 |
| | | SE | 2,254 | | | |
| | | Catch | 20,959 | | | 20,959 |
| | | SE | 2,277 | | | |
| | September | | | | | |
| | | Effort | 65,520 | | | 65,520 |
| | | SE | 3,249 | | | |
| | | Harvest | 12,794 | | | 12,794 |
| | | SE | 1,367 | | | |
| | | Catch | 12,806 | | | 12,806 |
| | | SE | 1,367 | | | |

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Appendix B3.–Part 2 of 2.

| | | | River section[a] | | | |
|---|---|---|---|---|---|---|
| Year | Month | Parameter | Downstream | Midstream | Upstream | Combined |
| 1993[e] | | | | | | |
| | August | | | | | |
| | | Effort | 101,176 | | | 101,176 |
| | | SE | 6,200 | | | |
| | | Harvest | 21,628 | | | 21,628 |
| | | SE | 2,429 | | | |
| | | Catch | 21,878 | | | 21,878 |
| | | SE | 2,437 | | | |
| | September | | | | | |
| | | Effort | 46,342 | | | 46,342 |
| | | SE | 2,643 | | | |
| | | Harvest | 7,444 | | | 7,444 |
| | | SE | 662 | | | |
| | | Catch | 7,454 | | | 7,454 |
| | | SE | 662 | | | |
| 1998[f] | | | | | | |
| | August | | | | | |
| | | Effort | 73,107 | | | 73,107 |
| | | SE | 6,145 | | | |
| | | Harvest | 10,386 | | | 10,386 |
| | | SE | 1,221 | | | |
| | | Catch | 10,819 | | | 10,819 |
| | | SE | 1,337 | | | |
| | 1998 | | | | | |
| | | Effort | 29,797 | | | 29,797 |
| | | SE | 2,218 | | | |
| | | Harvest | 4,281 | | | 4,281 |
| | | SE | 704 | | | |
| | | Catch | 4,303 | | | 4,303 |
| | | SE | 704 | | | |

*Note:* estimates are the combined estimates from guided, unguided and shore-based sport fishing. The creel survey coverage was reduced after 1990 and in 1991 did not include the middle river section; during 1992, 1993, and 1998, only the lower river section was surveyed.

[a] River section definitions: "downstream" = the entire river downstream of the Soldotna Bridge (RKM 34); "midstream" = between the Soldotna Bridge and Naptown Rapids (RKM 63.5); "upstream" = between Naptown Rapids and the outlet of Skilak Lake (RKM 80.4).

[b] Source of 1990 data: Hammarstrom 1991

[c] Source of 1991 data: Hammarstrom 1992

[d] Source of 1992 data: Schwager-King 1993

[e] Source of 1993 data: Schwager-King 1994

[f] Source of 1998 data: L. Marsh (Sport Fish Biologist, ADF&G, Soldotna, AK, unpublished data)

Appendix B4.–Comparison of lower Kenai River coho salmon inriver sport harvest estimates generated by the Statewide Harvest Survey (SWHS) and creel survey, 1990–1993 and 1998.

| | Survey Type | | |
|---|---|---|---|
| Year | Creel[a] | SWHS[b] | Percent SWHS estimate varies from creel estimate |
| 1990 | 42,638 | 40,567 | -4.9% |
| 1991 | 65,000 | 49,499 | -23.8% |
| 1992 | 33,611 | 33,175 | -1.3% |
| 1993 | 29,072 | 29,135 | 0.2% |
| 1998 | 14,667 | 15,461 | 5.4% |
| | | Average percent variation from creel estimate | 7.1% |

*Note:* The lower section of the Kenai River is defined as downstream of the Soldotnta Bridge (RKM 34) to the mouth. Comparison of creel and SWHS estimates is confined to the lower river section because that is the only section the creel survey was conducted all years during 1990–1993 and 1998.

[a] Creel survey data sources for 1990 and 1991: Hammarstrom 1991-1992; data sources for 1991 and 1992: Schwager-King 1993-1994; data source for 1998: L. Marsh (Sport Fish Biologist, ADF&G, Soldotna, AK, unpublished data).

[b] SWHS data sources for 1990–1993: Mills 1991-1994; data source for 1998: Howe et al. 2001c.

# APPENDIX C: DESCRIPTION OF THE STUDY DESIGN FOR THE 1998 CREEL SURVEY

## STUDY DESIGN

Effort, catch, and harvest rates were estimated for the coho salmon fishery occurring on the Kenai River from Cook Inlet to the Soldotna Bridge (RKM 34). A stratified 2-stage roving-access creel survey (Bernard et al. 1998) was used to estimate sport fishing effort (in angler-hours), and catch and harvest of coho salmon. Angler counts were considered instantaneous and reflect fishing effort at the time of the count. The harvest rate of coho salmon (number of fish harvested per hour fished) was estimated from completed-trip angler interviews. The number of coho salmon harvested by the fishery was estimated as the product of the effort and harvest rate estimates. The catch of coho salmon (total number of fish caught, including fish released) was estimated in a similar manner using the effort and catch rate estimates.

Stratification of the study design was based on both regulations and characteristics governing the coho salmon fishery. Unguided and guided boat anglers as well as unguided shore anglers participate in the Kenai River coho salmon fishery, with the majority of the effort from boats (Schwager-King 1993-1994). Guides are required to register and place a decal on their boat(s), making these two groups easily identifiable on the river. Harvest and catch rates can differ significantly ($P < 0.05$) between guided and unguided anglers in the Chinook salmon fishery (Schwager-King 1995; King 1996-1997); therefore, angler counts were also stratified by angler type. Effort, catch, harvest, and angler type were determined during completed-trip angler interviews (i.e., by design, interviews were not stratified by angler type), so estimates were post-stratified by angler type. Angler counts and harvest and catch rates have differed significantly ($P < 0.05$) among approximately biweekly time intervals and between weekdays and weekends or holidays in the Chinook salmon fishery (Schwager-King 1995, King 1996-1997). In addition, as part of the regulatory package that the Board of Fisheries adopted in 1997, anglers could no longer fish from a guided vessel on Mondays. Therefore, in order to evaluate the influence that these regulatory changes had on harvest, catch, and effort as well as to improve precision and minimize bias, the 1998 coho salmon creel survey was stratified by day type (weekdays and weekends or holidays). Monthly intervals (August and September) were used to provide managers a basis for historical comparison with prior years' information.

The first and second stages of the sampling design were angler-days (to be precise, periods 12–16 hours in length) and angler trips, respectively. The entire fishing day was sampled to prevent length-of-stay bias (Bernard et al. 1998). In August, the angler-day was 16 hours long for all angler types but in September the angler-day was only 12 hours in length with daylight hours declining towards winter.

Additional regulations on the fishery affected sampling. Guides were not allowed to fish while providing commercial services to anglers for coho salmon and therefore were not counted during angler counts. In addition, all anglers were required to discontinue fishing for all species on the Kenai River after retaining 3 coho salmon. This regulation was drafted to discourage "boat-limit" fishing and may have lowered the overall harvest in the fishery.

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Based on these factors, 16 strata were used for conducting angler counts and estimating creel statistics:

| Stratum | Run | Temporal | Day Type | Angler Type |
|---|---|---|---|---|
| 1 | Early | August | Weekday | Guided |
| 2 | | | | Unguided |
| 3 | | | | Shore |
| 4 | | | Weekend or holiday | Unguided |
| 5 | | | | Guided |
| 6 | | | | Shore |
| 7 | | | Monday | Unguided |
| 8 | | | | Shore |
| 9 | Late | September | Weekday | Guided |
| 10 | | | | Unguided |
| 11 | | | | Shore |
| 12 | | | Weekend or holiday | Unguided |
| 13 | | | | Guided |
| 14 | | | | Shore |
| 15 | | | Monday | Unguided |
| 16 | | | | Shore |

All weekend or holiday days and more than half of all possible weekday days were sampled. At least 2 randomly chosen weekday days were sampled during each week. Thus, the creel survey sampled 39 (64%) of the total possible 61 days of the fishery from 1 August to 30 September.

Two technicians conducted the angler counts from a boat (hereafter referred to as boat technicians). Four counts were made during each sampling day. Start time for the first count in August (0600, 0700, 0800, or 0900 hours) was chosen at random and all remaining counts in a day were done systematically, resulting in an angler count occurring every 4 hours. Start time for the first count in September (0700, 0800, or 0900 hours) was chosen at random and all remaining counts in a day were done systematically, resulting in an angler count occurring every 4 hours.

Completed-trip angler interviews were conducted by 2 creel technicians sampling at access areas (hereafter referred to as access technicians). Angler interviews were not stratified a priori by angler type. In general, access technicians conducted angler interviews between 0630 and 1330 hours for the first shift and between 1400 and 2130 hours for the second shift. The two technicians were assigned times to conduct interviews such that the entire fishing day was sampled.

Anglers were interviewed at the following seven popular campground or boat launch areas:

1) Centennial Campground
2) River Quest
3) Big Bend Campground
4) Stewart’s Landing
5) Eagle Rock Launch Area
6) Poacher’s Cove
7) Pillar’s Launch Area

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Sampled access areas were randomly selected and each area was sampled for approximately 2.5–3.0 hours each sampling day. Time-of-day for conducting interviews at an access location was chosen at random.

Effort, catch, and harvest were estimated for each sampled day and the means of the daily estimates were expanded over all days in each stratum to estimate stratum totals. Stratum estimates were then summed to obtain total estimates of each run.

## DATA COLLECTION

### Creel Survey

The coho salmon creel survey downstream of the Soldotna Bridge was conducted from 1 August through 30 September. It was conducted by 2 boat technicians and 2 access technicians using a 15-ft river boat and automobiles.

Angler counts and interviews were conducted on the Kenai River downstream of the Soldotna Bridge. As many completed angler interviews as possible were collected from all angler types during the coho salmon fishery (August through September) at the various access locations.

The direction (upstream or downstream) that the boat technician traveled to conduct the first angler count was chosen at random. All remaining counts on a sample day were conducted with the same direction of travel. The angler count was made as the boat was driven through the survey area (between the Soldotna and Warren Ames bridges), as quickly as safety permitted without causing undo interference to the fishery, to the opposite end of the survey area. This trip was usually accomplished in about 45 to 60 minutes. Every effort was made to ensure that the trip was completed in no more than 1 hour.

During the angler count, the boat technicians used multiple thumb counters to record the following: 1) total number of unguided power boats, 2) total number of unguided drift boats, 3) total number of guided power boats, 4) total number of guided drift boats, 5) total number of unguided anglers in power boats, 6) total number of unguided anglers in drift boats, 7) total number of guided anglers in power boats (excluding the guide), 8) total number of guided anglers in drift boats (excluding the guide), and 9) total number of shore anglers. Upon completion of the angler counts, the values were recorded on angler data forms. When the boat technicians were not conducting an angler count, they sampled harvested coho salmon for coded-wire tag data.

Access technicians conducting completed-trip angler interviews at access sites tried to interview all anglers leaving the fishery during the time surveyed. If more anglers were leaving the fishery than could be interviewed, the technicians randomly selected anglers to interview from those available. Care was taken to select anglers for interview without regard to who had harvested or caught a fish. During each completed-trip angler interview, technicians recorded the following information from each angler contacted: 1) boat or shore angler (if boat, powered or non-powered), 2) guided or unguided angler, 3) total hours fished, 4) total harvest (number retained) by species, and 5) total number released (not just broken off) by species. All data were entered into a Hewlett-Packard HP95LX data recorder. If the recording units failed, data were written on an angler data form.

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At the start of each survey shift, a boat technician took a secchi disk reading and recorded the results. This information was monitored inseason and analyzed postseason for possible influence on inriver CPUE.

Each technician returned their field data to the Soldotna Office daily. The Fisheries Biologist II project biologist (L. Marsh) ensured the data were returned each day. The data were edited and entered into the microcomputer daily.

## DATA ANALYSIS

All analyses were stratified by day-of-week (weekdays, weekend days, Mondays) and post-stratified by angler type (guided boat anglers, unguided boat anglers, and unguided shore anglers). Estimates were calculated post-stratum and calculated by stratum first, then summed to estimate seasonal totals.

### Angler Effort

For each angler type *g* and stratum *h*, total angler effort (in hours) during day *i* and its variance were estimated as follows:

$$\hat{E}_{ghi} = \bar{x}_{ghi} T_{hi} \text{ and} \quad \text{(D1)}$$

$$\hat{V}[\hat{E}_{ghi}] = \hat{V}[\bar{x}_{ghi}] T_{hi}^2 \quad \text{(D2)}$$

where $\bar{x}_{ghi}$ is the average number of anglers of type *g* counted fishing, $T_{hi}$ is the number of hours in each fishing day (16 in August, 12 in September), and $\hat{V}[\bar{x}_{ghi}]$ is obtained approximately by using the successive difference formula appropriate for systematic samples (Wolter 1985:251):

$$\hat{V}[\bar{x}_{ghi}] \approx \frac{\sum_{j=2}^{r_{hi}} (x_{ghij} - x_{ghi(j-1)})^2}{2 r_{hi} (r_{hi} - 1)}, \quad \text{(D3)}$$

where $x_{ghij}$ is number of type *g* anglers during angler count *j* and $r_{hi}$ is the number of angler counts per day (4).

Total effort by anglers of type *g* during stratum *h* was estimated by expanding over days:

$$\hat{E}_{gh} = D_h \bar{E}_{gh}, \quad \text{(D4)}$$

where

$$\bar{E}_{gh} = \frac{\sum_{i=1}^{d_h} \hat{E}_{ghi}}{d_h}, \quad \text{(D5)}$$

and $D_h$ and $d_h$ are the number of days and sampled days, respectively, of type *h* in the survey.

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The variance of angler effort by stratum was estimated as follows:

$$\hat{V}[\hat{E}_{gh}] = (1 - f_{1h}) \frac{D_h^2}{d_h} \frac{\sum_{i=1}^{d_h} (\hat{E}_{ghi} - \overline{E}_{gh})^2}{(d_h - 1)} + f_{1h} \frac{D_h^2}{d_h^2} \sum_{i=1}^{d_h} \hat{V}[\hat{E}_{ghi}], \tag{D6}$$

where $f_{1h}$ is the first-stage sampling fraction ($d_h/D_h$).

Total effort and its variance for angler-type $g$ (across all time strata $h$) were estimated as follows:

$$\hat{E}_g = \sum_{h=1}^{3} \hat{E}_{gh} \text{ and} \tag{D7}$$

$$\hat{V}[\hat{E}_g] = \sum_{h=1}^{3} \hat{V}[\hat{E}_{gh}]. \tag{D8}$$

Finally, total effort and its variance across all angler types were estimated as follows:

$$\hat{E} = \sum_{g=1}^{3} \hat{E}_g \text{ and} \tag{D9}$$

$$\hat{V}[\hat{E}] = \sum_{g=1}^{3} \hat{V}[\hat{E}_g]. \tag{D10}$$

## Angler Harvest and Catch

Harvest and catch, and their associated variances and standard errors were estimated using the following procedures.

Within day $i$ of stratum $h$, estimates of mean harvest per unit effort for anglers of type $g$ were calculated using a jackknife procedure (Efron 1982) to reduce bias. Only data from completed-trip interviews were used. First, the mean harvest of angler-trips was divided by the mean length of trip to estimate the sample ratio of HPUE:

$$\overline{HPUE}_{ghi} = \frac{\overline{H}_{ghi}}{\overline{e}_{ghi}} = \frac{\sum_{k=1}^{m_{ghi}} H_{ghik} \Big/ m_{ghi}}{\sum_{k=1}^{m_{ghi}} e_{ghik} \Big/ m_{ghi}} = \frac{\sum_{k=1}^{m_{ghi}} H_{ghik}}{\sum_{k=1}^{m_{ghi}} e_{ghik}}, \tag{D11}$$

where $H_{ghik}$ is the harvest, by species, during an angler trip $k$, $e_{ghik}$ is the effort expended (in hours) during angler-trip $k$, and $m_{ghi}$ is the number of completed-trip interviews from anglers of type $g$. Because the estimate of mean HPUE (Equation D11) has an inherent bias of order $1/m_{ghi}$ (Cochran 1977), the jackknifed estimate of mean HPUE was calculated as follows (Efron 1982):

$$\overline{HPUE}^*_{ghi} = \frac{\sum_{k=1}^{m_{ghi}} HPUE^*_{ghik}}{m_{ghi}}, \tag{D12}$$

-continued-

where

$$HPUE^{*}_{ghik} = \frac{\sum_{\substack{m=1\\m\neq k}}^{m_{ghi}} H_{ghim}}{\sum_{\substack{m=1\\m\neq k}}^{m_{ghi}} e_{ghim}}. \quad \text{(D13)}$$

The jackknifed estimate was used to reduce the inherent bias to order $1/m_{ghi}^2$ through the following adjustment:

$$\overline{HPUE}^{**}_{ghi} = m_{ghi}\left[\overline{HPUE}_{ghi} - \overline{HPUE}^{*}_{ghi}\right] + \overline{HPUE}^{*}_{ghi}. \quad \text{(D14)}$$

The variance of $\overline{HPUE}^{**}_{ghi}$ is the variance of $\overline{HPUE}^{*}_{ghi}$:

$$\hat{V}\left[\overline{HPUE}^{**}_{ghi}\right] = \hat{V}\left[\overline{HPUE}^{*}_{ghi}\right] = \frac{m_{ghi}-1}{m_{ghi}} \sum_{k=1}^{m_{ghi}} \left[\overline{HPUE}^{*}_{ghik} - \overline{HPUE}^{*}_{ghik}\right]^2. \quad \text{(D15)}$$

Mean catch per unit effort (CPUE) was estimated using equations D11–D15, after first substituting catch $C_{ghik}$ for harvest $H_{ghik}$.

Total harvest by anglers of type $g$ during day $i$ of stratum $h$ was estimated as the product of estimated effort and bias-corrected HPUE and its variance followed Goodman (1960):

$$\hat{H}_{ghi} = \hat{E}_{ghi}\overline{HPUE}^{**}_{ghi} \quad \text{(D16)}$$

and

$$\hat{V}\left[\hat{H}_{ghi}\right] = \hat{V}\left(\overline{HPUE}^{**}_{ghi}\right)\hat{E}^2_{ghi} + \hat{V}\left(\hat{E}_{ghi}\right)\overline{HPUE}^{**2}_{ghi} - \hat{V}\left(\overline{HPUE}^{**}_{ghi}\right)\hat{V}\left(\hat{E}_{ghi}\right). \quad \text{(D17)}$$

Occasionally, there were no guided boat anglers or unguided shore anglers interviewed on a given day, so $\overline{HPUE}^{**}_{ghi}$ was missing. When this occurred, an imputed value was substituted as follows:

$$\overline{HPUE}^{**}_{ghi} = a_{gg'h}\overline{HPUE}^{**}_{g'hi} \quad \text{(D18)}$$

$$\hat{V}\left[\overline{HPUE}^{**}_{ghi}\right] = a^2_{gg'h}\hat{V}\left[\overline{HPUE}^{**}_{g'hi}\right] \quad \text{(D19)}$$

where $\overline{HPUE}^{**}_{g'hi}$ is the bias-corrected mean harvest rate for unguided boat anglers for that day, and $a_{gg'h}$ is the weighted ratio of harvest rates between angler types $g$ (guided boat or unguided shore) and $g'$ (unguided boat):

$$a_{gg'h} = \frac{\sum_{i=1}^{d_h}\left(m_{ghi} + m_{g'hi}\right)\overline{HPUE}^{**}_{ghi}}{\sum_{i=1}^{d_h}\left(m_{ghi} + m_{g'hi}\right)\overline{HPUE}^{**}_{g'hi}} \quad \text{(D20)}$$

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where the summation is over all days in stratum *h* with at least 1 interview from angler type *g*, and the weights $\left(m_{ghi}+m_{g'hi}\right)$ are the total number of interviews of type *g* and *g*′.

Total harvest by anglers of type *g* during stratum *h* was estimated by expanding over days:

$$\hat{H}_{gh}=D_h\overline{H}_{gh}, \tag{D21}$$

where

$$\overline{H}_{gh}=\frac{\sum_{i=1}^{d_h}\hat{H}_{ghi}}{d_h}, \tag{D22}$$

and where $D_h$ and $d_h$ are the number of days and sampled days, respectively, of type *h* in the survey.

The variance of $\hat{H}_{gh}$ by stratum was estimated as follows:

$$\hat{V}\left[\hat{H}_{gh}\right]=\left(1-f_{1h}\right)\frac{D_h^2}{d_h}\frac{\sum_{i=1}^{d_h}\left(\hat{H}_{ghi}-\overline{H}_{gh}\right)^2}{\left(d_h-1\right)}+f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\hat{V}\left[\hat{H}_{ghi}\right]+ \\ 2f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}a_{gg'h}b_{ghi}\hat{V}\left[\overline{HPUE}_{ghi}^{**}\right]\hat{E}_{ghi}\hat{E}_{g'hi}, \tag{D23}$$

where $f_{1h}$ is the first-stage sampling fraction ($d_h/D_h$), the last term is the variance penalty for imputation (Bernard et al. 1998), and $b_{ghi}=1$ if day *i* has a substituted value for mean harvest rate or 0 if not.

Total harvest by anglers of type *g* (across all time strata *h*) and its variance were estimated as follows:

$$\hat{H}_g=\sum_{h=1}^{3}\hat{H}_{gh}\ \text{and} \tag{D24}$$

$$\hat{V}\left[\hat{H}_g\right]=\sum_{h=1}^{3}\hat{V}\left[\hat{H}_{gh}\right]. \tag{D25}$$

Finally, total harvest and its variance across all angler types was estimated as follows:

$$\hat{H}=\sum_{g=1}^{3}\hat{H}_g\ \text{and} \tag{D26}$$

$$\hat{V}\left[\hat{H}\right]=\sum_{g=1}^{3}\hat{V}\left[\hat{H}_g\right]. \tag{D27}$$

Catch statistics were estimated similarly, after substituting $\overline{CPUE}_{ghi}^{**}$ for $\overline{HPUE}_{ghi}^{**}$ in equations D16 and D17.