Fishery Data Series No. 96-18

# Surveys of the Sockeye Salmon Sport Fishery in the Upper Kvichak River, Alaska, 1995

by

Dan O. Dunaway

and

Steve J. Fleischman

July 1996

Alaska Department of Fish and Game

Division of Sport Fish

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

**Weights and measures (metric)**

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

**Weights and measures (English)**

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

Spell out acre and ton.

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| hour (spell out for 24-hour clock) | h |
| minute | min |
| second | s |

Spell out year, month, and week.

**Physics and chemistry**

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

**General**

| | |
|---|---|
| All commonly accepted abbreviations. | e.g., Mr., Mrs., a.m., p.m., etc. |
| All commonly accepted professional titles. | e.g., Dr., Ph.D., R.N., etc. |
| and | & |
| at | @ |
| Compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| Copyright | © |
| Corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| et alii (and other people) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g., |
| 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 |
| number (before a number) | # (e.g., #10) |
| pounds (after a number) | # (e.g., 10#) |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S. state and District of Columbia abbreviations | use two-letter abbreviations (e.g., AK, DC) |

**Mathematics, statistics, fisheries**

| | |
|---|---|
| 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 | C.I. |
| correlation coefficient | R (multiple) |
| correlation coefficient | r (simple) |
| covariance | cov |
| degree (angular or temperature) | ° |
| degrees of freedom | df |
| divided by | ÷ or / (in equations) |
| equals | = |
| expected value | E |
| fork length | FL |
| 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. |
| mideye-to-fork | MEF |
| minute (angular) | ' |
| multiplied by | x |
| not significant | NS |
| null hypothesis | $H_0$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | $\alpha$ |
| probability of a type II error (acceptance of the null hypothesis when false) | $\beta$ |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| standard length | SL |
| total length | TL |
| variance | Var |

*FISHERY DATA SERIES NO. 96-18*

# SURVEYS OF THE SOCKEYE SALMON SPORT FISHERY IN THE UPPER KVICHAK RIVER, ALASKA, 1995

by

Dan O. Dunaway
*Division of Sport Fish, Dillingham*
and
Steve J. Fleischman
*Division of Sport Fish, Research and Technical Services, Anchorage*

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

July 1996

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-11, Job No. S-2-2.

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

*Dan O. Dunaway*
*Alaska Department of Fish and Game, Division of Sport Fish*
*P.O. Box 230, Dillingham, AK 99576-0230, USA*
*and*
*Steve J. Fleischman*
*Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services*
*333 Raspberry Road, Anchorage, AK 99518-1599, USA*

*This document should be cited as:*
*Dunaway, Dan O. and Steve J. Fleischman. 1996. Surveys of the sockeye salmon sport fishery in the Upper Kvichak River, Alaska, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-18, Anchorage.*

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES

# ABSTRACT

A roving creel survey was conducted on the sport fishery in the upper Kvichak River near Igiugig, Alaska from 26 June through 16 July 1995. Emphasis was on the sockeye salmon *Oncorhynchus nerka* sport fishery. Anglers were counted, and 460 anglers were interviewed to estimate 4,707 (SE = 434) angler-hours of effort. The catch and harvest of sockeye salmon were estimated to be 13,724 (SE = 1,596) and 3,186 (SE = 344) fish, respectively. The catch per hour (CPUE) for sockeye salmon ranged from 0.70 (SE = 0.06 ) to 5.80 (SE = 0.65). An estimated 97.5% (SE = 9.1%) of the daily angler trips resulted in a catch of one or more sockeye salmon and 89.4% (SE = 8.6%) of the trips harvested one or more sockeye salmon. The first sockeye salmon harvested among all daily harvests produced 24.0% (SE = 2.5%) of the total harvest during the survey. Most anglers (66%, SE = 2.2%) were guided, 81% (SE = 1.8%) were not Alaskan residents, and 97% ( SE = 0.8%) used fly tackle. Age 2.2 and 2.3 sockeye salmon comprised 79.4% (SE = 3.3%) and 18.7% (SE = 3.1%) of the sport harvest, respectively. An estimated 315 (SE = 83) rainbow trout *Oncorhynchus mykiss* were caught and 35 (SE = 19) were harvested during the study.



Key words: Sockeye salmon, *Oncorhynchus nerka,* red salmon, rainbow trout, *Oncorhynchus mykiss,* sport fishing, sport harvest, sport catch, creel survey, fishery survey, angler success, bag limit, guided anglers, unguided anglers, gear type, terminal tackle, Kvichak River, Iliamna Lake, Bristol Bay.


# INTRODUCTION

Recreational fisheries for sockeye (red) salmon *Oncorhynchus nerka* are becoming increasingly popular in Southwest Alaska. The Kvichak River drainage includes Alaska's largest lake, Iliamna, as well as Lake Clark, and many smaller tributaries (Figure 1). This large watershed hosts the world's largest sockeye salmon run and, since 1979, up to 42 million fish have ascended the Kvichak River in a single season (ADF&G 1995a). The river is easily accessed by air from the local transportation centers of Iliamna and King Salmon as well as directly from Anchorage or Kenai Peninsula communities. Float-equipped airplanes land on the river, the village airstrip provides wheel plane access, and the river is easily navigated by boat. Most of the fishery occurs in the upper 10 to 15 miles of the river with effort concentrated near the village of Igiugig during late June and early July. The daily bag and possession limit is five salmon of any combination of species except chinook salmon (ADF&G 1995b). Terminal tackle is restricted to unbaited single-hook artificial lures. As a result of the abundant salmon, liberal bag limits, and accessibility, the Kvichak River is becoming a popular destination for anglers targeting sockeye salmon.

Effort, catch and harvest in the Kvichak River sport fisheries have been estimated annually by mail surveys since 1977 (Mills 1979-1994, Howe et al. 1995). Sport fishing effort has more than doubled from 2,000 angler-days annually from 1977-1989 to an average 5,028 angler-days for 1990-1994 (Table 1). Although the Kvichak River supports a substantial rainbow trout *Oncorhynchus mykiss* fishery, much of the recent growth in effort probably occurred in the recreational sockeye salmon fishery. Commercial sockeye salmon fisheries in Bristol Bay have historically harvested about 50% of the annual return with the 1990 through 1994 harvests averaging over 12 million fish (Table 1). In addition, an average of 70,800 sockeye salmon were taken in the subsistence fishery from 1990 through 1994 (Table 1) (ADF&G 1995a). While sport anglers take sockeye salmon throughout the Kvichak River drainage, the annual harvest from the Kvichak River alone ranged from about 300 to 2,000 fish before 1989, then grew to average 2,625 fish from 1990 to 1994 (Table 1) (Mills 1990-1994; Howe et al. 1995). The peak sport harvest occurred in 1989 when 4,769 sockeye salmon were taken (Mills 1990).

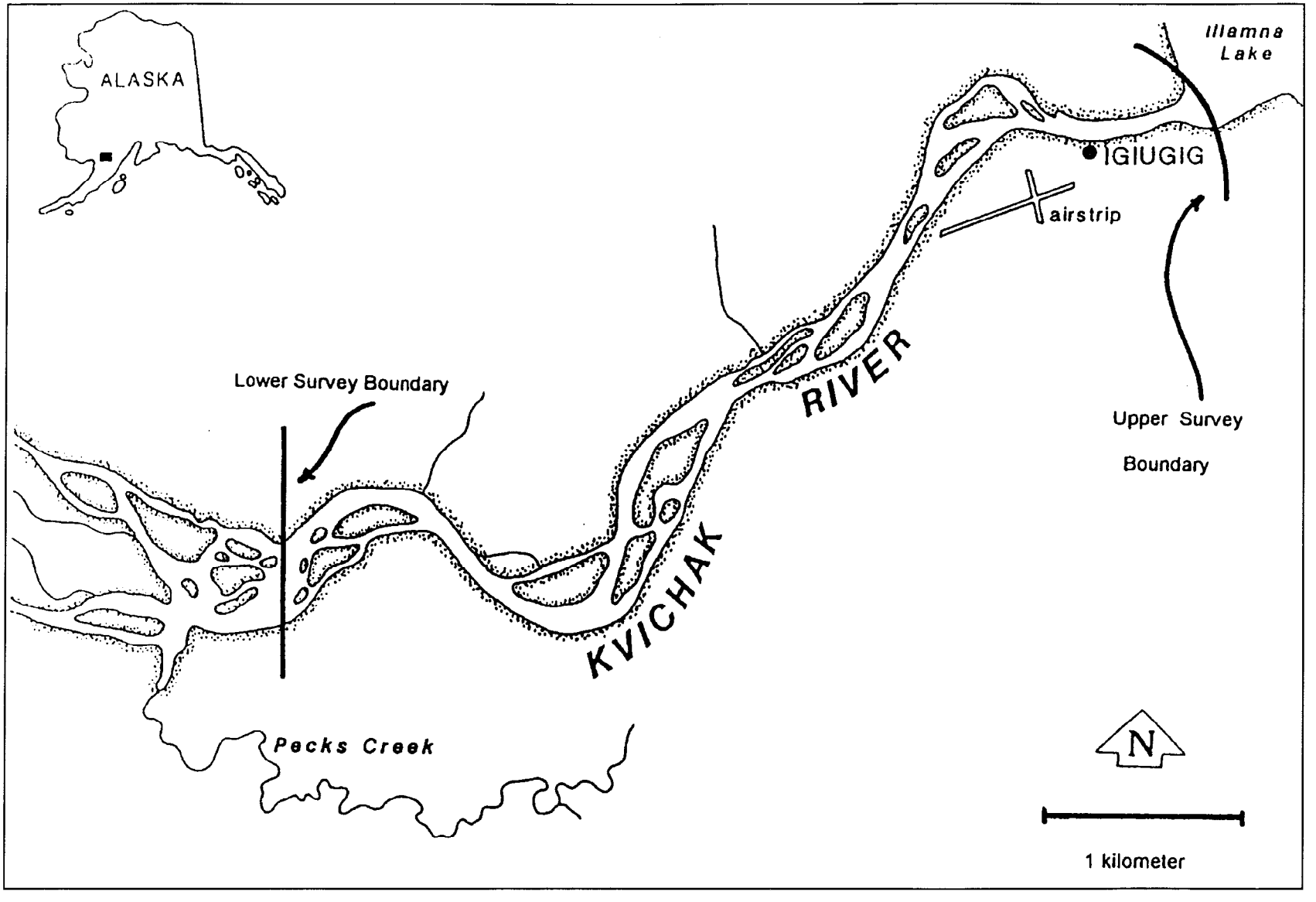



**Figure 1.-Upper Kvichak River study area.**

**Table 1.-Historic sockeye salmon harvests and escapements from the Kvichak River drainage, and sport effort and sockeye salmon harvest on the Kvichak River.**

| | Kvichak River Drainage | | | | | Kvichak River only Sport Fishery | |
|---|---|---|---|---|---|---|---|
| | Harvest | | | | | | |
| Year | Commercial | Subsistence [a] | Sport [b] | Total | Escapement [c] | Harvest [d] | Effort [d] |
| 1974 | 538,163 | 98,100 | | 636,263 | 4,433,844 | | |
| 1975 | 3,085,416 | 115,500 | | 3,200,916 | 13,140,450 | | |
| 1976 | 2,547,276 | 75,900 | | 2,623,176 | 1,965,282 | | |
| 1977 | 2,167,214 | 72,000 | 1,936 | 2,239,797 | 1,341,144 | 583 | 1,509 |
| 1978 | 5,123,668 | 83,900 | 2,803 | 5,207,948 | 4,149,288 | 380 | 948 |
| 1979 | 14,991,826 | 65,500 | 2,767 | 15,057,609 | 11,218,434 | 283 | 2,044 |
| 1980 | 15,120,457 | 72,600 | 1,646 | 15,193,811 | 22,505,268 | 754 | 2,056 |
| 1981 | 10,992,809 | 75,600 | 2,507 | 11,068,809 | 1,754,358 | 400 | 1,865 |
| 1982 | 5,005,802 | 61,300 | 3,683 | 5,067,741 | 1,134,840 | 639 | 1,877 |
| 1983 | 21,559,372 | 96,500 | 4,371 | 21,656,475 | 3,569,982 | 603 | 2,206 |
| 1984 | 14,546,710 | 100,500 | 4,738 | 14,648,108 | 10,490,670 | 898 | 2,576 |
| 1985 | 8,179,093 | 86,500 | 5,430 | 8,267,420 | 7,211,046 | 1,827 | 2,533 |
| 1986 | 2,892,171 | 59,900 | 612 | 2,952,173 | 1,179,322 | 102 | 2,379 |
| 1987 | 4,986,002 | 72,000 | 7,205 | 5,059,807 | 6,065,880 | 1,805 | 2,544 |
| 1988 | 3,480,836 | 77,100 | 4,427 | 3,558,462 | 4,065,216 | 526 | 1,346 |
| 1989 | 13,809,956 | 71,400 | 23,203 | 13,886,125 | 8,317,500 | 4,769 | 2,616 |
| 1990 | 17,272,224 | 76,600 | 10,214 | 17,351,812 | 6,970,020 | 2,988 | 6,107 |
| 1991 [e] | 10,475,206 | 66,786 | 12,793 | 10,543,241 | 4,222,788 | 1,249 | 3,047 |
| 1992 [e] | 9,395,948 | 72,148 | 11,204 | 9,479,300 | 4,725,864 | 1,964 | 4,716 |
| 1993 [e] | 8,907,876 | 74,123 | 16,330 | 8,998,329 | 4,025,166 | 2,923 | 5,475 |
| 1994 [e] | 16,262,625 | 64,343 | 15,813 | 16,342,781 | 8,337,840 | 4,001 | 5,796 |
| 1974-1994 average | 9,111,460 | 78,014 | 7,316 | 9,195,744 | 6,229,724 | 1,483 | 2,869 |
| 1990-1994 average | 12,462,776 | 70,800 | 13,271 | 12,546,847 | 5,656,336 | 2,625 | 5,028 |
| 1995 [f] | 20,415,430 | NA [g] | NA [g] | NA [g] | 10,038,720 | NA [g] | NA [g] |

[a] May not include some Kvichak River bound fish that may be taken in other communities (ADF&G 1995a). Significant proportions of the subsistence harvests were taken after passing the escapement counting tower; therefore the total run cannot be calculated by adding the total harvests and escapements from this table.

[b] All tributaries of the Kvichak River except the Alagnak River (Mills 1979-1994; Howe et al. 1995). Sport harvest estimates not available prior to 1977.

[c] Tower count (ADF&G 1995a).

[d] Mills 1979-1994, Howe et al. 1995. Kvichak River only. Effort in angler-days for ALL species; estimates of effort by species are not available. Estimates not available prior to 1977.

[e] Preliminary commercial and subsistence estimates (ADF&G 1995a).

[f] Preliminary estimates (commercial catch estimate from Jeff Regnart, ADF&G, Anchorage, personal communication).

[g] Data not currently available.

A public access project funded through the Department of Fish and Game, Sport Fish Division is under development in the village of Igiugig and is scheduled for completion in 1996 or 1997. The access project is expected to increase participation and harvest in the Kvichak River recreational fisheries in the next few years. It is not likely that the expanding fishery will create escapement problems, but conflicts between subsistence users and sport anglers may develop (Minard and Dunaway 1995). The management challenge of this fishery will be to provide increased recreational fishing opportunities while minimizing user conflicts. However, until 1995 no onsite surveys had been conducted and, other than the results of the statewide harvest survey (Mills 1979-1994; Howe et al. 1995), little was known about this fishery.

The objectives of the 1995 fishery survey on the Kvichak River were:

1. To estimate angling effort (in angler-hours) in the upper Kvichak River from 26 June to 16 July 1995;
2. To estimate the catch, harvest, and catch per unit effort (CPUE) of sockeye salmon caught in the upper Kvichak River sport fishery from 26 June to 16 July 1995;
3. To estimate the distribution of catch and harvest success by angler-trip among anglers in the upper Kvichak River sockeye salmon sport fishery;
4. To estimate the contributions to the harvests of each fish in anglers' daily bags during the upper Kvichak River sockeye salmon sport fishery;
5. To estimate the percentage of angler-trips by terminal tackle type and angler type (residency status, guided or unguided) in the upper Kvichak River sockeye salmon sport fishery; and
6. To estimate the age and sex composition of sockeye salmon harvested in the upper Kvichak River sport fishery.

# METHODS

From 26 June to 16 July 1995 we conducted a fishery survey on the upper Kvichak River from the outlet of Lake Iliamna downstream approximately 7 km (Figure 1). Adult sockeye salmon first return to the Kvichak River in mid to late June, peak during the first 10 days of July, then decline rapidly until late July. At the study site, the recreational sockeye salmon fishery is most active during the last days of June and first 2 weeks of July.

## STUDY DESIGN

We used a stratified three-stage sampling design to estimate effort (in angler-hours) and catch and harvest rates (fish per angler-hour) in the Kvichak River study area (Bernard et al. *In prep*). A roving creel survey (Neuhold and Lu 1957) design was used to count and interview anglers as well as to sample the sport harvest. Angler counts were used to estimate angler effort and angler interviews were used to estimate catch and harvest rates.

Estimates of catch and harvest were the product of the estimated effort and the estimated catch or harvest rates. Sampled days represent the first sampling stage; periods within days represent the

second sampling stage; angler counts within periods represent the third sampling stage for the angler effort estimation, and angler interviews represent the third sampling stage for catch and harvest rate estimation.

We used angler interview data to estimate the distribution of catches and harvests of sockeye salmon by angler-day, to estimate the contribution to the total harvest of each fish in anglers' daily bags, and to estimate the percentage of angler-trips by tackle type and angler type. The "distribution of catches and harvests by angler-trip" was defined as the proportion of angler-trips that result in catches and/or harvests of one or more sockeye salmon, two or more sockeye salmon, and up to 30 or more sockeye salmon for catches and up to five sockeye salmon for harvests.

We established the study site boundaries to include the major fishing areas used by anglers accessing the fishery from the Igiugig village air strip and nearby lodges (Figure 1). The upper boundary was located in Lake Iliamna about 300 meters upstream from the lake outlet and the lower boundary was established just upstream of the outlet of Peck's Creek; the study area was approximately 7 km in length.

The study period was determined from the sockeye salmon escapement records collected at Igiugig by the ADF&G Commercial Fisheries Management and Development Division (CFMD) (ADF&G 1995a) and from information provided by Igiugig residents. Local residents indicated that the sport fishery on the upper Kvichak River may be harvest driven (anglers seek full daily bag limits and quit fishing when it is achieved) and much of the angling occurs on weekends. From the fishery's relative proximity to Anchorage and communities on the Kenai Peninsula we expected that effort could vary substantially between weekdays and weekends. Therefore, the study period was stratified into weekdays and weekend days. All weekend days (Saturdays and Sundays) and 4 July were sampled. In addition, 2 weekdays (Monday through Friday) were sampled at random without replacement (WOR) each week. Sampling was conducted by a single technician throughout the study.

The 13.5 hour sampling day, from 0800 to 2130, was selected to include the hours in which most fishing activity was likely to occur. Again, personal communications with local residents, and lodge operators familiar with the study site helped us to establish the length of the sampling day.

To cover the sampling day and remain within the allowable work hours of the single creel technician, each day was divided into three 4.5-hour periods: A (0800 to 1229), B (1230 to 1659), and C (1700 to 2129). Two 4.5-hour periods were sampled at random (WOR) on each sample day. Within each sampled period there were six possible 45 minute count times; three counts were conducted systematically within a sampled period. The starting time for the first of the three counts in a period was selected at random from the two earliest available count times. The remaining two counts in a period started at 1.5 hour intervals after the starting time of the first count in a selected period. For instance, in period A counts would occur at 0800, 0930, and 1100, or 0845, 1015 and 1145. If counts were found to take less than 45 minutes to conduct (e.g., few anglers fishing so counts take less time), the survey technician timed the count so that it straddled the 45 minute time period. Sampling effort allocation is summarized in Appendix A1, the sampling schedule appears in Appendix A2.

Completed-trip angler interviews (anglers who had suspended fishing for the day) and incompleted-trip interviews were conducted during the sample periods when the survey technician was not occupied with angler counts. The survey technician traveled throughout the fishery to conduct interviews of all anglers participating in the fishery.

## DATA COLLECTION

### Effort, Catch and Harvest

Angler counts were conducted by first randomly selecting the upper or lower boundary as a starting point. Once at the starting point, the creel technician counted all anglers participating in the fishery while driving a boat at a constant rate of speed through the fishery to the far boundary of the study area.

Angler interviews consisted of obtaining effort (in total hours fished), catch and harvest by species, angler type, demographics, and terminal tackle selection. All interviewed anglers were also asked to report the amount of time spent fishing after the last harvested salmon was caught. This information was used to evaluate the validity of using interviews from both incompleted-trip and completed-trip anglers.

#### Voluntary Angler Report Cards

In addition to conducting the standard onsite interview described above, we gave anglers who had not completed fishing for the day at the time of the interview (incompleted-trip anglers) a voluntary angler report card (Appendix B1). On the voluntary report card the angler was asked to record his/her completed-trip data including the fishing start and stop times, the total time fished for the day, the number of fish released and number of fish kept by species during that day, and the time spent fishing after harvesting the last salmon. We numbered the cards to allow matching the onsite interview data and the data on the returned card. We recovered the cards by mail (many cards had postage included), by collecting them directly, by using strategically located collection boxes, and with the assistance of the fishing guides and lodge operators. Our survey technician explained the purpose of the cards and how to complete them to maximize the number of returns. The survey technician used every means to recover completed cards while respecting the voluntary nature of the program. Data from angler cards were used to augment the number of completed-trip interviews obtained onsite.

### Biological Sampling of Harvested Fish

While conducting angler interviews, the technician also collected weight and length information from the fish harvested by the anglers. She attempted to take measurements on every contacted angler's creel in order to sample a consistent proportion of the harvest. Following Thompson (1987) we calculated that 179 samples were needed to achieve Objective 6 given an expected harvest of 2,800 fish.

Salmon were measured to the nearest millimeter for mid-eye to fork-of-tail length; resident species were measured from the tip-of-the snout to the fork-of-tail. For each salmon or rainbow trout sampled, three or four scales were collected and placed on labeled and numbered adhesive coated cards (scale cards). The scales were removed from the left side of the fish from a point along a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin, and two rows of scales above the lateral line. When scales could not be obtained from the preferred area, three scales were taken from as close to the preferred area as possible.

However, scales were only taken from the area bounded dorsally by the fourth row of scales above the lateral line, ventrally by the lateral line, and between lines drawn vertically from the posterior insertion of the dorsal fin and the anterior insertion of the anal fin. When no scales were available in the preferred area on the left side of the fish, scales were collected from the preferred area on the right side of the fish.

The completed scale cards were pressed against acetate cards in a heated hydraulic press and the resulting scale impressions displayed on a microfiche projector for age determination. Age determination from the collected scales followed Clutter and Whitesel (1956), Jearld (1983) and Lux (1971). For salmon, the numeral preceding the decimal is the number of freshwater annuli, whereas the numeral following the decimal is the number of marine annuli (European method). Total age from brood year is the sum of the two numerals plus one.

## DATA ANALYSIS

### Assumptions

We started with the following assumptions about data from this survey, some testable and others not:

1. The angler count process is approximately instantaneous, i.e., the survey technician travels substantially faster than anglers move about or exit or enter the fishery;
2. Interviewed anglers accurately report their hours of effort and the number of fish released;
3. Anglers who return cards accurately report their hours of effort and the number of fish kept and released;
4. The survey technician accurately classifies anglers and the interviewed anglers accurately report their residency, trip type (guided versus unguided), and the terminal gear type used during their fishing trip;
5. The daily bag and possession limit of five salmon per day does not limit anglers' harvest or anglers who "limit out" quit fishing as soon as the fifth salmon is harvested (necessary for unbiased estimates of harvest using interviews of incompleted-trip anglers);
6. The effort and success of anglers who are not finished fishing at time of interview, are given a card, and return it, is the same as for anglers who are finished fishing at time of interview;
7. Anglers who return reporting cards are representative of all anglers who receive them;
8. Catch and harvest rate are independent of duration of fishing trip (DiCostanzo 1956).

We believe assumption 1 to be valid because counts took 45 minutes or less to complete. Assumptions 2, 3, and 4 cannot be tested, but anglers were expected to have fairly good recollection of their time spent fishing and the number of sockeye salmon kept and released, and to accurately report their fishing trip characteristics. When data from returned cards were inconsistent with data from the original onsite interviews (e.g. sockeye reported kept or released on the card less than that reported during the interview) the card data were not used. Only 5% of returned cards were rejected for this reason. Note that anglers interviewed onsite had their creel

inspected by the survey technician, so the accuracy of the number of fish harvested by them did not depend on their recollection.

Assumption 5 was tested and found to be invalid (Appendix C1); we therefore used data from completed-trip anglers only to estimate catch and harvest, as well as angler success. Completed-trip data were available from two sources: (1) anglers who had completed their fishing prior to being interviewed onsite; and (2) anglers who were issued voluntary report cards and returned them. We conducted several tests comparing the two data types and found that assumption 6 did not hold; i.e., angler effort and success differed between onsite completed-trip interviews and returned cards (Appendices C1, C2, and C3). Since >40% of voluntary report cards were not returned with sufficient data, information from anglers who had not finished fishing at time of interview was under-represented in the data. We attempted to adjust for this under-representation of card data when estimating angler effort, catch, harvest, and angler success (see below). Assumption 7 was necessary given our methods for making this adjustment (weighting card data to reflect the number of cards issued, not the number returned). Although assumption 7 was impossible to test directly, we did compare the success and effort at time of interview for anglers who would eventually return their card versus those who would not (Appendices C1 and C4).

Assumption 8 was necessary because, in a roving survey, the probability of interviewing an angler generally increases with the length of his/her fishing trip. If the catch or harvest rate also depend on trip length, then catch or harvest estimates will be biased. We tested this assumption and found it to be valid for catch but not harvest. Harvest rates generally decreased with length of trip (Appendices C1 and C5). Since the roving technique favors longer trips, catch and harvest estimates from this survey are probably biased somewhat low.

## Effort, Catch, and Harvest

Angler counts and completed-trip angler interviews were combined to provide estimates of effort in terms of angler-hours and angler-trips using the methods described in Appendix D1. The estimates of effort were subsequently combined with the catch and harvest data from completed-trip interviews to estimate the catch and harvest of sockeye salmon, using the procedures described in Appendix D2. Data from returned cards were weighted to reflect the number of cards issued (rather than the number of cards returned), before being combined with onsite interview data.

## Angler Success

In this survey several analyses were used to assess angler success. One indicator of success is catch per unit effort (CPUE), treated here as catch per hour fished. Appendix D3 describes the procedure used to estimate CPUE.

As a second method of characterizing angler success, we estimated the proportion of angler-trips catching 0 fish, 1 or more fish, 2 or more fish, and up to 30 or more fish. We also estimated the proportion of angler-trips harvesting 0 fish, 1 or more fish, 2 or more fish, up to 5 fish. Procedures detailed in Appendix D4 were used with data from completed-trips only to estimate these proportions.

For both measures of angler success above, data from returned cards were weighted to reflect the number of cards issued (rather than the number of cards returned) before being combined with onsite interview data.

Some anglers did not return voluntary report cards, and in general these anglers reported catching fewer fish at time of interview than anglers who were issued cards and later returned them. Therefore catch per angler estimates may be biased slightly high (Appendices C1 and C4).

### Harvest Analysis

In order to assess the possible effects of a changing bag limit on the fishery, it was useful to estimate the proportion of the total harvest contributed by the first fish in anglers' daily bags, the second fish in anglers' daily bags, up to the fifth fish. Procedures from Appendix D4 were used with data from completed trips only to estimate these proportions and their standard errors. Again, card and onsite interview data were weighted before the analysis.

### Angler Characteristics

Information on angler characteristics (guided vs. unguided, residency status, use of spin tackle vs. flies; Objective 5) was obtained from anglers personally during the interviews and anglers were never interviewed more than once in a day. Therefore data from all interviews could be used regardless of whether anglers had completed their fishing trip. The proportions of angler-trips[1] in the above categories were estimated as if the interview information was collected as a simple random sample of the fishery. That is, the estimated proportion of angler-trips with characteristic k and its variance (Cochran 1977:52) were calculated as:

$$\hat{p}_k = \frac{m_k}{m}, \tag{1}$$

$$\hat{V}(\hat{p}_k) = \frac{\hat{p}_k(1-\hat{p}_k)}{m-1}, \tag{2}$$

where $m_k$ equals the number of angler-trips having characteristic k, and m equals the total number of angler-trips.

Standard errors were obtained by taking the square root of the variance estimates.

### Biological Sampling of Harvested Fish

Estimates of sex and age composition were calculated for sockeye salmon harvested in the sport fishery on the upper Kvichak River (Objective 6).

The proportion of harvested sockeye salmon that were age u and its variance (Cochran 1977:52) were estimated as:

$$\hat{p}_u = \frac{n_u}{n}, \tag{3}$$

$$\hat{V}[\hat{p}_u] = \left(1 - \frac{n}{\hat{H}}\right)\frac{\hat{p}_u(1-\hat{p}_u)}{n-1}, \tag{4}$$

---

[1] Since each interview represented information collected from one angler during one trip to the surveyed fishery, the proportions estimated by equation (1) are for angler-trips, not anglers.

where $n_u$ is the number of the sampled sockeye salmon harvested that were age u, n is the total number of sockeye salmon sampled within each survey, and $\hat{H}$ is the estimated total harvest (Appendix D2).

Mean length-at-age of harvested sockeye salmon was estimated following standard procedures (Sokal and Rohlf 1981).

The computer programs and electronic data files used to complete this report are listed in Appendix E1.

# RESULTS

We conducted onsite interviews with 460 anglers, of which 62 had finished fishing for the day and 398 had not. Voluntary report cards were issued to those who had not finished fishing; of these, 257 (65%) cards were returned, but only 224 of the returned cards were sufficiently completed to permit inclusion in our analyses. A total of 286 completed-trip interviews provided the basis for most of our analyses. It should be noted that sockeye salmon arrived at the study area a few days later than normal and may have resulted in reduced angling effort.

## Effort, Catch, and Harvest

A total of 4,707 (SE = 434) angler-hours of effort was estimated to have occurred during the study (Table 2). The greatest effort was estimated during the third temporal component (3 July and 5-7 July) at 1,301 (SE = 288) angler-hours.

Anglers caught an estimated 13,724 (SE = 1,596) sockeye salmon during the survey and harvested 3,186 (SE = 344; Table 3). Most of the catch (8,827, SE = 1,305) occurred during temporal components 3 and 4 (3 July and 5-9 July), while the bulk of the harvest (2,161, SE = 224) occurred during temporal components 2 through 4 (1-9 July).

**Table 2.-Estimated effort (angler-hours), by temporal component, for the sockeye salmon sport fishery in the Kvichak River, 26 June through 16 July 1995.**

| Temporal Component | Days Sampled | Estimated Angler Hours | SE | 90% Confidence Interval | | RP[a] |
|---|---|---|---|---|---|---|
| | | | | Lower | Upper | |
| 1 (26-30 June) | 2 | 675 | 189 | 364 | 986 | 46.1% |
| 2 (1,2,4 July) | 3 | 965 | 100 | 801 | 1,130 | 17.0% |
| 3 (3,5-7 July) | 2 | 1,301 | 288 | 827 | 1,774 | 36.4% |
| 4 (8-9 July) | 2 | 853 | 100 | 689 | 1,017 | 19.2% |
| 5 (10-14 July) | 2 | 608 | 214 | 255 | 960 | 58.1% |
| 6 (15-16 July) | 2 | 306 | 63 | 202 | 410 | 33.9% |
| Season Total | 13 | 4,707 | 434 | 3,993 | 5,421 | 15.2% |

[a] Relative precision of the 90% confidence interval = 1.645·SE·100/estimate.

**Table 3.-Estimated catch and harvest of sockeye salmon by the sport fishery in the Kvichak River, 26 June through 16 July 1995.**

| Temporal Component and Date | Catch[a] | | | | | Harvest | | | | | Percent of Catch Harvested |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 90% Confidence Interval | | | | | 90% Confidence Interval | | | |
| | Estimate | SE | Lower | Upper | RP[b] | Estimate | SE | Lower | Upper | RP[b] | |
| 1 (26-30 June) | 1,626 | 771 | 359 | 2,894 | 77.9% | 537 | 209 | 193 | 880 | 64.1% | 33.0% |
| 2 (1,2,4 July) | 2,364 | 429 | 1,659 | 3,069 | 29.8% | 682 | 97 | 523 | 841 | 23.4% | 28.8% |
| 3 (3,5-7 July) | 4,717 | 1,066 | 2,963 | 6,472 | 37.2% | 832 | 185 | 527 | 1,137 | 36.6% | 17.6% |
| 4 (8-9 July) | 4,110 | 752 | 2,873 | 5,347 | 30.1% | 647 | 82 | 512 | 783 | 20.9% | 15.7% |
| 5 (10-14 July) | 422 | 194 | 102 | 742 | 75.8% | 288 | 145 | 50 | 526 | 82.6% | 68.3% |
| 6 (15-16 July) | 485 | 167 | 210 | 759 | 56.6% | 200 | 56 | 108 | 293 | 46.1% | 41.4% |
| Season Total | 13,724 | 1,596 | 11,099 | 16,349 | 19.1% | 3,186 | 344 | 2,621 | 3,752 | 17.8% | 23.2% |

[a] Catch = total fish kept + total fish released.

[b] Relative precision of the 90% confidence interval = 1.645·SE·100/estimate.

**Table 4.-Catch per unit effort as an indicator of angler success in the sockeye salmon sport fishery in the Kvichak River, 26 June through 16 July 1995.**

| Temporal Component | CPUE[a] | SE | 90% Confidence Interval | | RP[b] |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| 1 (26-30 June) | 2.29 | 0.38 | 1.67 | 2.91 | 27.2% |
| 2 (1,2,4 July) | 3.30 | 0.63 | 2.26 | 4.35 | 31.6% |
| 3 (3,5-7 July) | 4.08 | 0.89 | 2.62 | 5.54 | 35.9% |
| 4 (8-9 July) | 5.80 | 0.65 | 4.73 | 6.87 | 18.5% |
| 5 (10-14 July) | 0.70 | 0.06 | 0.60 | 0.80 | 13.7% |
| 6 (15-16 July) | 1.43 | 0.18 | 1.14 | 1.73 | 20.6% |

[a] Number of fish caught per angler-hour of effort. May include accidentally foul hooked (snagged) fish (released required by law) as well as intentionally caught fish that may have been kept or released.

[b] Relative precision of the 90% confidence interval = 1.645·SE·100/estimate.

## Angler Success

In general, anglers were quite successful during this fishery. Estimated CPUE ranged from 0.70 (SE = 0.06) sockeye salmon per hour in temporal component 5 (10-14 July) to 5.80 (SE = 0.65) in temporal component 4 (8-9 July; Table 4).

Almost every angler-trip (97.5%, SE = 9.1%) resulted in a catch of at least one sockeye salmon, and 77.7% (SE = 7.2%) resulted in a catch of five or more (Table 5, Figure 2). Furthermore, almost half of the angler-trips (46.4%, SE = 5.1%) resulted in 10 or more sockeye caught, and an estimated 16.5% (SE = 2.6%) resulted in 30 or more caught. Only 10.6% (SE = 8.6%) of the angler-trips resulted in no sockeye salmon harvested, 89.4% (SE = 8.6%) harvested one or more, and 56.4% (SE = 5.7%) harvested the full daily bag limit of five sockeye salmon (Table 6, Figure 2).

The high percentage of anglers taking their full daily bag limit is reflected in the relatively uniform percentages of the overall harvest represented by the first, second, third, fourth, and fifth sockeye salmon among all anglers' daily harvests (Table 7, Figure 3). The first fish kept among all anglers' daily harvests represented 24.0% (SE = 2.5%) of the sport harvest of sockeye salmon in the study area while the fifth fish represented 15.0% (SE = 1.5%; Table 7, Figure 3).

## Angler Characteristics and Tackle Selection

Of the 460 angler interviews conducted during the survey, 66% (SE = 2.2%) were guided, 81% (SE = 1.8%) were not Alaskan residents and 8% (SE = 1.3%) were residents of other countries (Table 8). The great majority of anglers were men (89%, SE = 1.5%). All anglers fished from the shore (100%), and most (97%, SE = 0.8%) used flies to catch their salmon (Table 8).

**Table 5.-Estimated percent of angler-trips catching zero, one or more, two or more, and up to 30 or more, sockeye salmon in the Kvichak River, 26 June through 16 July 1995.**

| Catch | Percent of Angler-Trips | Standard Error | 90% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower | Upper |
| 0 | 2.5 | 9.1 | 0.0 | 17.6 |
| 1+ | 97.5 | 9.1 | 82.4 | 100.0 |
| 2+ | 94.1 | 8.8 | 79.6 | 100.0 |
| 3+ | 89.3 | 8.3 | 75.6 | 100.0 |
| 4+ | 84.3 | 7.9 | 71.2 | 97.3 |
| 5+ | 77.7 | 7.2 | 65.8 | 89.6 |
| 6+ | 68.8 | 6.7 | 57.8 | 79.7 |
| 7+ | 64.1 | 6.3 | 53.7 | 74.4 |
| 8+ | 57.4 | 5.9 | 47.7 | 67.1 |
| 9+ | 52.0 | 5.5 | 43.0 | 61.0 |
| 10+ | 46.4 | 5.1 | 38.1 | 54.8 |
| 11+ | 42.8 | 4.6 | 35.2 | 50.4 |
| 12+ | 39.7 | 4.4 | 32.4 | 46.9 |
| 13+ | 36.9 | 4.3 | 29.9 | 43.9 |
| 14+ | 33.5 | 4.0 | 27.0 | 40.1 |
| 15+ | 31.3 | 3.8 | 25.1 | 37.5 |
| 16+ | 28.7 | 3.6 | 22.7 | 34.6 |
| 17+ | 27.9 | 3.6 | 22.0 | 33.7 |
| 18+ | 26.8 | 3.4 | 21.1 | 32.4 |
| 19+ | 26.2 | 3.4 | 20.6 | 31.8 |
| 20+ | 24.8 | 3.2 | 19.5 | 30.1 |
| 21+ | 22.9 | 3.1 | 17.8 | 28.1 |
| 22+ | 22.2 | 3.1 | 17.1 | 27.3 |
| 23+ | 21.0 | 3.0 | 16.2 | 25.9 |
| 24+ | 20.3 | 2.9 | 15.5 | 25.1 |
| 25+ | 20.0 | 2.9 | 15.3 | 24.8 |
| 26+ | 17.4 | 2.7 | 13.0 | 21.7 |
| 27+ | 17.0 | 2.6 | 12.7 | 21.3 |
| 28+ | 17.0 | 2.6 | 12.7 | 21.3 |
| 29+ | 17.0 | 2.6 | 12.7 | 21.3 |
| 30+ | 16.5 | 2.6 | 12.2 | 20.7 |

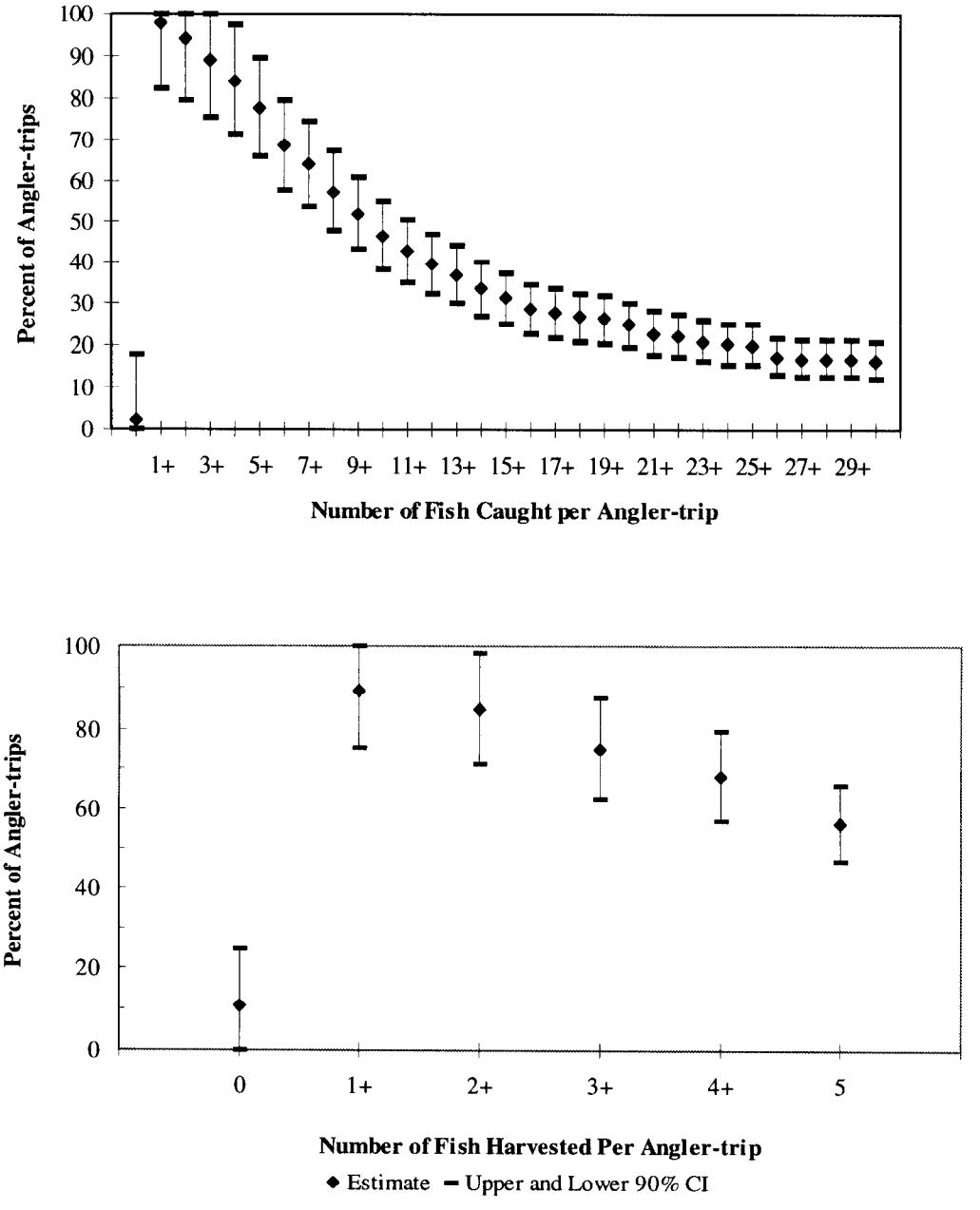



**Figure 2.-Distribution of catch and harvest success in the upper Kvichak River sockeye salmon sport fishery, 26 June through 16 July 1995.**

**Table 6.-Estimated percent of angler-trips harvesting zero, one or more, two or more, and up to five sockeye salmon in the Kvichak River, 26 June through 16 July 1995.**

| Harvest | Percent of Angler-Trips | Standard Error | 90% Confidence Interval Lower | Upper |
|---|---|---|---|---|
| 0 | 10.6 | 8.6 | 0.0 | 24.8 |
| 1+ | 89.4 | 8.6 | 75.2 | 100.0 |
| 2+ | 84.7 | 8.3 | 71.1 | 98.3 |
| 3+ | 75.0 | 7.6 | 62.5 | 87.5 |
| 4+ | 68.2 | 6.9 | 56.8 | 79.6 |
| 5 | 56.4 | 5.7 | 47.0 | 65.8 |

**Table 7.-Estimated percent of sockeye salmon harvest due to the first, second, third, fourth, and fifth fish among all anglers' daily harvests, Kvichak River, 26 June through 16 July 1995.**

| Fish | Percent of Harvest | Standard Error | 90% Confidence Interval Lower | Upper |
|---|---|---|---|---|
| #1 | 24.0 | 2.5 | 19.9 | 28.2 |
| #2 | 22.7 | 2.3 | 18.9 | 26.6 |
| #3 | 20.0 | 2.0 | 16.7 | 23.4 |
| #4 | 18.2 | 1.8 | 15.2 | 21.2 |
| #5 | 15.0 | 1.5 | 12.6 | 17.4 |

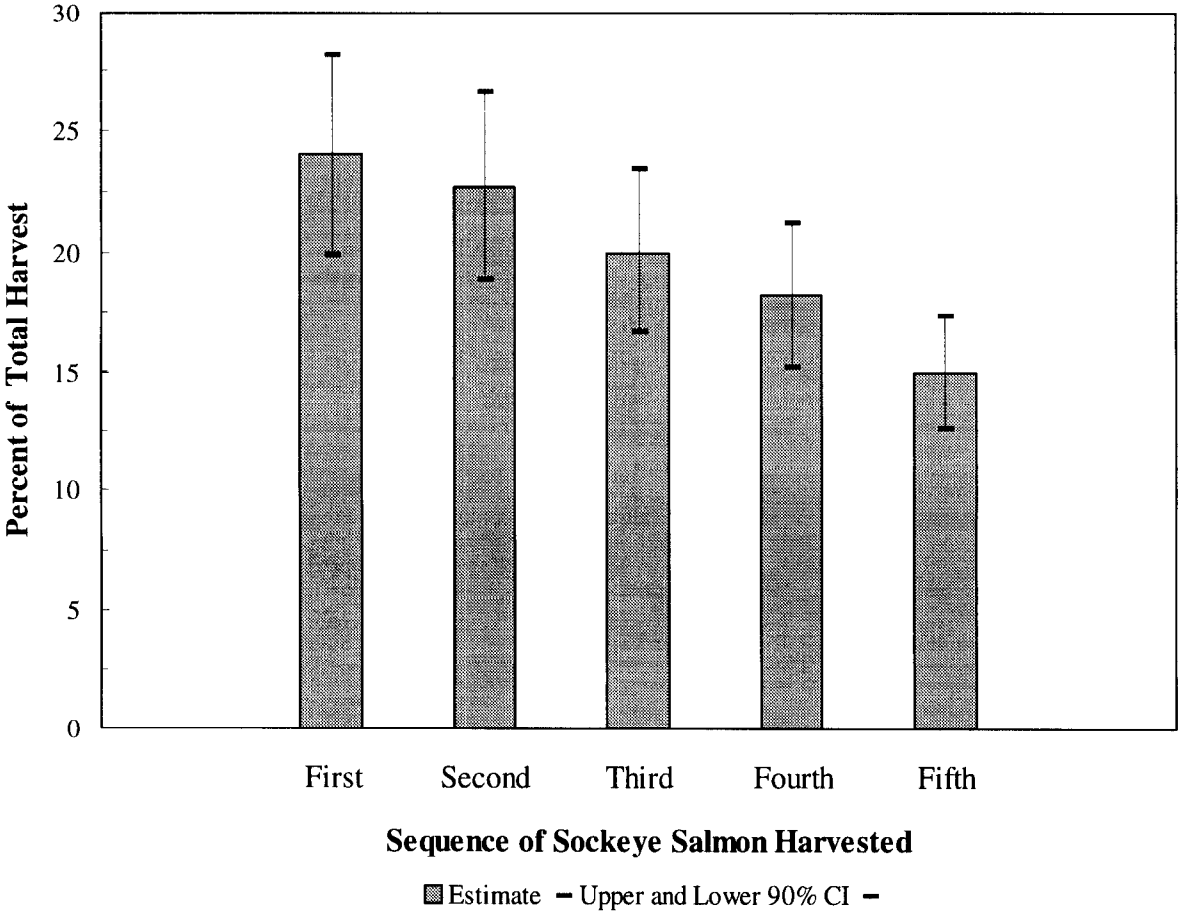



**Figure 3.-Percent of sockeye salmon harvest due to the first, second, third, fourth, and fifth fish in anglers' daily creels, upper Kvichak River, 26 June through 16 July 1995.**

**Table 8.-Number and percent of angler-trips by angler type and gear type during the upper Kvichak River sockeye salmon sport fishery, 26 June through 16 July 1995.**

| Characteristic | Angler-trips | Percent | SE (%) |
|---|---|---|---|
| ANGLER TYPE | | | |
| Guided | 305 | 66 | 2.2 |
| Unguided | 155 | 34 | 2.2 |
| Alaskan Residents | 89 | 19 | 1.8 |
| Local Alaskan Residents | 5 | 1 | 0.5 |
| Nonlocal Alaskan Residents | 84 | 18 | 1.8 |
| Non-Alaskan Residents | 371 | 81 | 1.8 |
| U.S. Residents | 336 | 73 | 2.1 |
| Non-U.S. Residents | 35 | 8 | 1.3 |
| Men | 411 | 89 | 1.5 |
| Women | 49 | 11 | 1.5 |
| Fished from boat | 0 | 0 | 0.0 |
| Fished from shore | 460 | 100 | 0.0 |
| TACKLE TYPE | | | |
| Lures | 2 | <1 | 0.3 |
| Fly | 448 | 97 | 0.8 |
| Lures and Fly | 4 | 1 | 0.4 |
| Unknown | 6 | 1 | 0.5 |
| TOTAL ANGLER-TRIPS | 460 | | |

## Age, Length at Age, and Sex Composition of the Sport Harvest

Biological data were collected from 176 sockeye salmon harvested during the survey. Females comprised 51.6% (SE = 4.0%) of the harvest while males made up the other 48.4 % (SE = 4.0%; Table 9). The predominant age group among all fish sampled was age 2.2 (79.4%, SE = 3.3%). Overall average length was 526 mm (SE = 3) and overall average weight was 2,414 g (SE = 42). The biggest fish sampled during the survey was an age 2.3 male that was 660 mm (26 in) long, weighed 4,550 g (10 lb), and was caught on 9 July.

**Table 9.-Mean lengths (mm) and weights (g) of sockeye salmon, by sex and age group, from samples collected from the upper Kvichak River, 26 June through 16 July 1995.**

| | Age Group | | | | |
|---|---|---|---|---|---|
| | Unknown | 1.2 | 2.2 | 2.3 | TOTAL |
| Females | | | | | |
| Percent | | | 42.6 | 9.0 | 51.6 |
| SE | | | 4.0 | 2.3 | 4.0 |
| Sample Size | | | 66 | 14 | 80 |
| Mean Length | 520 | | 506 | 571 | 518 |
| SE | 13 | | 3 | 8 | 4 |
| Sample Size | 12 | | 66 | 14 | 92 |
| Mean Weight | 2,283 | | 2,086 | 2,911 | 2,237 |
| SE | 146 | | 43 | 121 | 50 |
| Sample Size | 12 | | 66 | 14 | 92 |
| Males | | | | | |
| Percent | | 1.9 | 36.8 | 9.7 | 48.4 |
| SE | | 1.1 | 3.9 | 2.4 | 4.0 |
| Sample Size | | 3 | 123 | 29 | 155 |
| Mean Length | 532 | 554 | 528 | 560 | 535 |
| SE | 5 | 19 | 4 | 14 | 4 |
| Sample Size | 9 | 3 | 57 | 15 | 84 |
| Mean Weight | 2,478 | 2,963 | 2,517 | 2,959 | 2,608 |
| SE | 79 | 274 | 64 | 215 | 62 |
| Sample Size | 9 | 3 | 57 | 15 | 84 |
| All Samples | | | | | |
| Percent | | 1.9 | 79.4 | 18.7 | 100.0 |
| SE | | 1.1 | 3.3 | 3.1 | |
| Sample Size | | 3 | 123 | 29 | 155 |
| Mean Length | 525 | 554 | 516 | 565 | 526 |
| SE | 8 | 19 | 3 | 8 | 3 |
| Sample Size | 21 | 3 | 123 | 29 | 176 |
| Mean Weight | 2,367 | 2,963 | 2,286 | 2,936 | 2,414 |
| SE | 91 | 274 | 42 | 123 | 42 |
| Sample Size | 21 | 3 | 123 | 29 | 176 |

### Rainbow Trout

The Kvichak River is well known for rainbow trout as well as sockeye salmon. The main rainbow trout fishery for this water does not occur during the sockeye salmon run. In addition, anglers seeking rainbow trout usually switch to different and smaller tackle to participate in an essentially separate fishery. But we were curious about the magnitude of rainbow trout catch and harvest that may be associated with the sockeye salmon fishery. We estimated that 315 (SE = 83) rainbow trout were caught and 35 (SE = 19) were harvested during the survey (Appendix F1). These estimates must be recognized as indicators only since the survey was designed for the sockeye salmon fishery. Very few (if any) anglers encountered in the study area were there strictly to fish for rainbow trout. We were unable to collect any length, weight or scale samples from harvested rainbow trout.

## DISCUSSION

The 1990-1994 average effort of 5,028 angler-days and harvest of 2,625 sockeye salmon on the Kvichak River compares to an average 5,700 angler-days and 8,000 sockeye salmon harvested from the Newhalen River, also in the Kvichak River drainage (Howe et al. 1995). Among other sockeye salmon fisheries, the nearby Alagnak River averaged 9,672 angler-days and 1,115 sockeye salmon harvested from 1990 through 1994; during the same period the Naknek River sustained an average of 13,721 angler-days and harvests of about 800 fish per year (Howe et al. 1995). In 1994 the popular Russian River sockeye salmon fishery (on the Kenai Peninsula) received 65,996 angler-days of effort and 73,545 sockeye salmon were harvested. The Kenai River supported 340,904 angler-days and a harvest of 93,616 sockeye salmon in 1994 (Howe et al. 1995).

Overall, the 1995 Kvichak River sockeye salmon fishery was very successful, and harvest was found to be an important aspect for many of the anglers who participated. Considering the huge Kvichak River sockeye salmon stock, it is not likely that the sport harvest at Igiugig will significantly affect the spawning population any time soon. However if the number of anglers congregating along the village beach area continues to grow, subsistence fishers may be influenced and, in a few places, stream banks may begin to suffer. The access project currently planned for the area has been designed to address these two concerns.

It appears that the rainbow trout population was very lightly fished by anglers participating in the sockeye salmon fishery, and harvest of rainbow trout during this period does not appear to be significant. Given the different tackle used and often different waters fished, an accurate assessment of the rainbow trout fishery may require a separate survey or at least a design that would identify the rainbow trout effort separately.

While harvest was an important feature of the fishery, it wasn't the only attraction. Many anglers continued to fish after keeping their last salmon. In fact, there was no single description to typify most anglers participating in this fishery. For some anglers, the Igiugig fishery served as a morning rest stop for flights headed west from the upper Iliamna Lake to chinook salmon fisheries on the Nushagak and Alagnak rivers. Another group of anglers who seemed to be strictly harvest oriented fished a relatively short time, had a higher rate of harvest, and quit as soon as they had accumulated the fish they wanted (though this was not always the full daily bag limit). A third group of anglers who fished for extended periods of time tended to distribute their

harvest through the duration of their trip; this group tended to take more fish in a day than other anglers. This last group may have included less proficient anglers, very avid anglers, as well as highly selective anglers who were looking for unusually large fish. On at least two occasions our technician encountered individuals looking for "trophy class" sockeye salmon to harvest. When designing future studies of this fishery, these differences among the anglers may need to be addressed. Lengthening the angling day (earlier and later) and finding a way to interview more of the short-term anglers could improve the accuracy of a future study.

## ACKNOWLEDGMENTS

We thank the angling public, guides, and lodge operators for their patience and support during the survey. We would like to thank Cynde Wightman for her diligence and hard work collecting the data and doing all the other chores associated with the survey; and Allen Bingham for his guidance in survey design and data analysis. The CFMD counting tower crew at Igiugig deserves our thanks for their assistance in storing equipment at the end of the project. Finally, we thank Richard Russell and Jeff Regnart, Area Biologists for the Division of Commercial Fisheries Management and Development, for their assistance with equipment, supplies, and lodging facilities at Igiugig.

## LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1995a. Annual management report, 1994 Bristol Bay Area. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 2A95-11, Anchorage.

ADF&G (Alaska Department of Fish and Game). 1995b. 1995 Alaska sport fishing regulations summary. Alaska Department of Fish and Game, Juneau.

Bernard, D. R., A. E. Bingham, and M. Alexandersdottir. *In prep.* The mechanics of conducting onsite creel surveys in Alaska. Alaska Department of Fish and Game, Special Publication, Anchorage.

Clutter, R. I. and L. E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin IX of the International Pacific Salmon Fisheries Commission, New Westminster, British Columbia, Canada.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, New York.

DiCostanzo, C. J. 1956. Creel census techniques and harvest of fishes in Clear Lake, Iowa. Ph. D. dissertation, Iowa State College, Ames, Iowa.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society of Industrial and Applied Mathematics, Philadelphia.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Jearld, A. Jr. 1983. Age determination. Pages 301-324 in L. A. Nielsen, editor. Fisheries techniques. The American Fisheries Society, Bethesda, Maryland.

Lux, F. E. 1971. Age determination of fishes. National Marine Fisheries Service. Fishery Leaflet 637. Seattle, Washington.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-1), Juneau.

# LITERATURE CITED (Continued)


Mills, M. J. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-1), Juneau.

Mills, M. J. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

Mills, M. J. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-1), Juneau.

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-1), Juneau.

Mills, M. J. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984. Project F-9-16, 25 (SW-1-A), Juneau.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-1-A), Juneau.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2), Juneau.

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Minard, R. E. and D. O. Dunaway. 1995. 1994 Area management report for the recreational fisheries of the Southwest Alaska sport fish management area. Alaska Department of Fish and Game, Fishery Management Report No. 95-2, Anchorage.

Neuhold, J. M. and K. H. Lu. 1957. Creel census methods. Utah State Department of Fish and Game, Publication 8, Salt Lake City.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry, second edition. W. H. Freeman and Company, New York.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41:42-46.

# LITERATURE CITED (Continued)

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

# APPENDIX A. ANGLER COUNT AND INTERVIEW SAMPLING ALLOCATION AND SCHEDULE

**Appendix A1.-Allocation of sampling effort among strata for the Kvichak River sockeye salmon creel survey, 1995.**

| Stratum | Date(s) | Day Type | D[a] | d[b] | Time Available For Sampling | Hours Sampled |
|---|---|---|---|---|---|---|
| 1 | 6/26 - 6/30 | weekday | 5 | 2 | 27 | 18 |
| 2 | 7/1 - 7/2 & 7/4 | weekend | 3 | 3 | 40.5 | 27 |
| 3 | 7/3 & 7/5-7/7 | weekday | 4 | 2 | 27 | 18 |
| 4 | 7/8 - 7/9 | weekend | 2 | 2 | 27 | 18 |
| 5 | 7/10 - 7/14 | weekday | 5 | 2 | 27 | 18 |
| 6 | 7/15 - 7/16 | weekend | 2 | 2 | 27 | 18 |

[a] D = Days possible for sampling.

[b] d = Number of days selected during which three angler counts and interviews will occur within a sample period.

**Appendix A2.-Sampling schedule and number of anglers counted for the creel survey of the Kvichak River sockeye salmon fishery, 1995.**

| Date | Day of Week | Stratum | Period and Count Times A (0800-1229) | B (1230-1659) | C (1700-2129) |
|---|---|---|---|---|---|
| 26-Jun | Mon | 1 | | | |
| 27-Jun | Tues | 1 | | | |
| 28-Jun | Wed | 1 | | 1315 / 1445 / 1615 | 1700 / 1830 / 2000 |
| counts[a] | | | | 18 - 32 - 11 | 9 - 6 - 0 |
| 29-Jun | Thurs | 1 | 0800 / 0930 / 1100 | | 1700 / 1830 / 2000 |
| counts | | | 14 - 11 - 10 | | 6 - 3 - 0 |
| 30-Jun | Fri | 1 | | | |
| 1-Jul | Sat | 2 | | 1230 / 1400 / 1530 | 1700 / 1830 / 2000 |
| counts | | | | 23 - 32 - 13 | 14 -10 - 8 |
| 2-Jul | Sun | 2 | 0800 / 0930 / 1100 | | 1745 / 1915 / 2045 |
| counts | | | 28 - 32 - 28 | | 18 - 2 - 28 |
| 3-Jul | Mon | 3 | | 1230 / 1400 / 1530 | 1700 / 1830 / 2000 |
| counts | | | | 40 - 43 - 45 | 20 - 17 - 11 |
| 4-Jul | Tues | 2 | 0800 / 0930 / 1100 | 1315 / 1445 / 1615 | |
| counts | | | 15 - 36 - 47 | 28 - 33 - 34 | |
| 5-Jul | Wed | 3 | | | |
| 6-Jul | Thurs | 3 | | | |
| 7-Jul | Fri | 3 | | 1315 / 1445 / 1615 | 1745 / 1915 / 2045 |
| counts | | | | 9 - 47 - 28 | 18 - 3 - 8 |
| 8-Jul | Sat | 4 | 0800 / 0930 / 1100 | | 1745 / 1915 / 2045 |
| counts | | | 30 - 42 - 30 | | 25 - 9 - 16 |
| 9-Jul | Sun | 4 | 0800 / 0930 / 1100 | 1315 / 1445 / 1615 | |
| counts | | | 13 - 33 - 54 | 50 - 45 - 32 | |
| 10-Jul | Mon | 5 | | | |
| 11-Jul | Tues | 5 | | | |
| 12-Jul | Wed | 5 | 0845 / 1015 / 1145 | 1230 / 1400 / 1530 | |
| counts | | | 10 - 19 - 18 | 5 - 10 - 16 | |
| 13-Jul | Thurs | 5 | | | |
| 14-Jul | Fri | 5 | 0845 / 1015 / 1145 | | 1745 / 1915 / 2045 |
| counts | | | 6 - 3 - 7 | | 2 - 5 - 7 |
| 15-Jul | Sat | 6 | | 1230 / 1400 / 1530 | 1745 / 1915 / 2045 |
| counts | | | | 4 - 7 - 20 | 15 - 4 - 4 |
| 16-Jul | Sun | 6 | 0845 / 1015 / 1145 | 1230 / 1400 / 1530 | |
| counts | | | 19 - 22 - 21 | 10 - 4 - 6 | |

[a] Number of anglers counted.

# APPENDIX B. THE VOLUNTARY ANGLER REPORT CARD

**Appendix B1.-The voluntary angler report card.**

---

**ALASKA DEPARTMENT OF FISH & GAME**

**PLEASE WRITE THE NUMBER OF FISH YOU KEPT AND RELEASED WHILE FISHING TODAY (00:00 AM TO 23:59 PM).**

Time you began fishing _____ Time you quit _____

Total hours you fished today _____

**WRITE ZEROS (0) BELOW IF YOU DID NOT CATCH OR KEEP A FISH.**

| | Kept | Released |
|---|---|---|
| Red Salmon (Sockeye) | _____ | _____ |
| Rainbow Trout | _____ | _____ |

**Comments**

office use

Date _____

Page # _____

Line # _____

Initials _____

How long did you fish after keeping your last salmon?

hours _____ minutes ____

---

# APPENDIX C. TESTS OF ASSUMPTIONS

**Appendix C1.-Procedures used to test assumptions of Kvichak River sockeye salmon creel survey, 1995.**

We investigated the validity of the following testable assumptions.

**Assumption 5: Bag limit not effective or anglers quit fishing after fifth salmon harvested**
The five-fish bag limit clearly limited harvest: over half of completed-trip anglers harvested five sockeye salmon. However, the fishery apparently was not purely harvest-driven; in general anglers did not stop fishing after harvesting their fifth salmon. We concluded that using data from incompleted-trip anglers to estimate harvest rate would introduce a positive bias to the estimates, so only data from completed-trip anglers were used.

**Assumption 6: Angler effort and success did not differ by interview type**
Completed-trip data were available from two sources: (1) ONSITE: anglers who had completed their fishing prior to being interviewed onsite, and (2) CARD: anglers who had not completed their fishing prior to being interviewed, were issued voluntary report cards, correctly filled them out, and returned them. Since 44% of cards issued to anglers were either not returned or were incorrectly filled out (Appendix C3), completed-trip information from anglers who had not finished fishing at the time of interview was under-represented in the data. Assumption 6 was necessary if we wished to pool ONSITE and CARD data as is, without taking unreturned cards into account.

CARD anglers fished substantially longer ($\bar{x}$ = 6.2 h) than ONSITE anglers ($\bar{x}$ = 3.1 h, $t = 10.3$, $df = 170$, $P < 0.0001$). They also caught ($\chi^2 = 31.1$, $df = 3$, $P < 0.001$) and kept ($\chi^2 = 21.2$, $df = 5$, $P < 0.001$) more sockeye salmon (Appendix C2). Conversely, ONSITE anglers had higher harvest per unit effort ($\bar{x}$ = 2.2 sockeye/h) than CARD anglers ($\bar{x}$ = 0.9 sockeye/h; $t = 2.6$, $df = 63$, $P = 0.012$), although catch per unit effort did not differ between interview types ($t = 0.9$, $df = 73$, $P = 0.38$). Clearly, assumption 6 was not valid; CARD anglers fished longer, caught/kept more fish, but harvested fish at a slower rate than ONSITE anglers. Apparently, anglers who were done fishing at time of interview included many harvest-oriented anglers.

Because ONSITE and CARD anglers differed, and data from CARD anglers were under-represented due to unreturned cards, pooling the two data types as is would have biased estimates to some degree. Average trip length would be underestimated, as would catch and harvest per angler-trip. HPUE and total harvest would be overestimated. We attempted to avoid these potential biases by reweighting the card data to reflect the number of cards issued rather than the number returned (Appendix D).

**Assumption 7: Card-returning anglers were similar to card-retaining anglers**
Because some anglers did not return their cards or did not fill them out correctly (n = 174), estimates based only on those who did (n = 224) would be biased if angler effort or success differed between the two groups. Of course the completed-trip results of anglers not returning cards was unknown, so a direct test of this assumption is impossible. However the effort, catch, and harvest at time of interview was known for all anglers. In order to assess the above-noted potential for bias, we compared effort and success at time of interview between anglers who eventually returned cards versus those who did not.

At time of interview, anglers who returned cards did not differ from those who did not return them in number of sockeye harvested ($t = 1.963$, $df = 396$, $P = 0.0503$; see also Appendix C4), hours of effort ($t = 0.6$, $df = 396$, $P = 0.58$), or harvest per hour ($t = 1.66$, $df = 396$, $P = 0.10$). However anglers who returned cards reported catching more sockeye at time of interview, both per angler ($t = 2.76$, $df \approx 392$, $P = 0.006$; see also Appendix C4) and per hour ($t = 3.01$, $df \approx 341.2$, $P = 0.003$) than anglers who never returned their cards.

Perhaps the more successful anglers were more likely to go to the effort of returning their cards. If so, then the estimates of total catch, catch per angler, and catch per hour reported from this study may be biased somewhat high. We did not attempt to adjust for these potential biases.

**Assumption 8: Catch and harvest rate independent of fishing trip duration**

Catch rates did not appear to be strictly independent of trip duration, in that very high catch rates occurred only during very short trips (Appendix C5). However, catch rates of this magnitude (four trips with >20 fish/h) are unrealistically high and may have been due to reporting or recording error. Furthermore, even when these four trips are included, catch rate and trip duration were not significantly correlated (Spearman's rho = 0.07, $P = 0.12$). We concluded that there was no major departure from assumption 8 for catch rate.

Harvest rate, on the other hand, was negatively correlated with trip duration (Spearman's rho = -0.23, $P < 0.0001$) (Appendix C5). Anglers who fished longer generally had lower harvest rates, and assumption 8 failed for harvest rate. Harvest estimates from this survey may therefore be biased somewhat low. We know of no rigorous method for estimating or correcting for this bias at this time (e.g., see Pollock et al. 1994).

**Appendix C2.-Number of sockeye salmon caught and kept as recorded from card completed-trip interviews versus onsite completed-trip interviews on the Kvichak River, 1995.**

| | Number of Sockeye Salmon Caught | | | | |
|---|---|---|---|---|---|
| | 0-4 | 5-9 | 10-14 | 15+ | Total |
| Card | 36 | 60 | 36 | 92 | 224 |
| Onsite | 24 | 23 | 11 | 4 | 62 |
| Total | 60 | 83 | 57 | 86 | 286 |

$\chi^2$=31.1, df=3, P<0.001

| | Number of Sockeye Salmon Kept | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | Total |
| Card | 26 | 9 | 15 | 13 | 18 | 143 | 224 |
| Onsite | 2 | 8 | 6 | 5 | 13 | 28 | 62 |
| Total | 28 | 17 | 21 | 18 | 31 | 171 | 286 |

$\chi^2$=21.2, df=5, P<0.001

**Appendix C3.-Return rate of angler interview cards during the sockeye salmon sport fishery on the Kvichak River in 1995.**

| | Week | | | | |
|---|---|---|---|---|---|
| | 26 | 27 | 28 | 29 | Total |
| Cards returned | 20 | 111 | 69 | 24 | 224 |
| Cards not returned | 16 | 88 | 43 | 27 | 174 |
| Total | 36 | 199 | 112 | 51 | 398 |
| Proportion returned | 55.5 | 55.8 | 61.6 | 47.1 | 56.3 |
| $\chi^2 = 3.08$, df = 3, P = 0.379 | | | | | |

**Appendix C4.-Number of sockeye salmon caught and kept at time of interview as reported by anglers who were issued voluntary report cards and returned them versus anglers who were issued cards and did not return them, Kvichak River, 1995.**

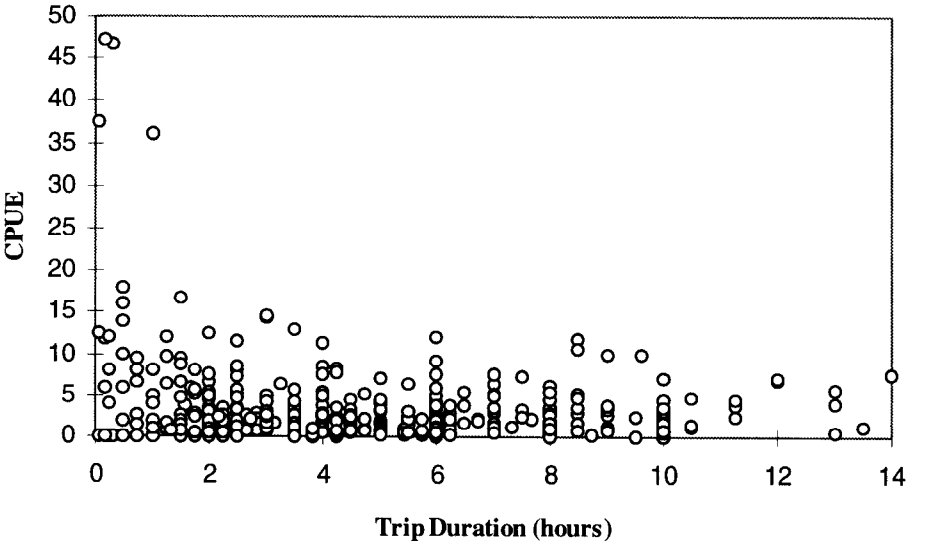
| | Number of Sockeye Salmon Caught at Time of Interview | | | | |
|---|---|---|---|---|---|
| | 0-4 | 5-9 | 10-14 | 15+ | Total |
| Card returned | 116 | 46 | 24 | 38 | 224 |
| Not returned | 118 | 25 | 17 | 14 | 174 |
| Total | 234 | 71 | 41 | 52 | 398 |

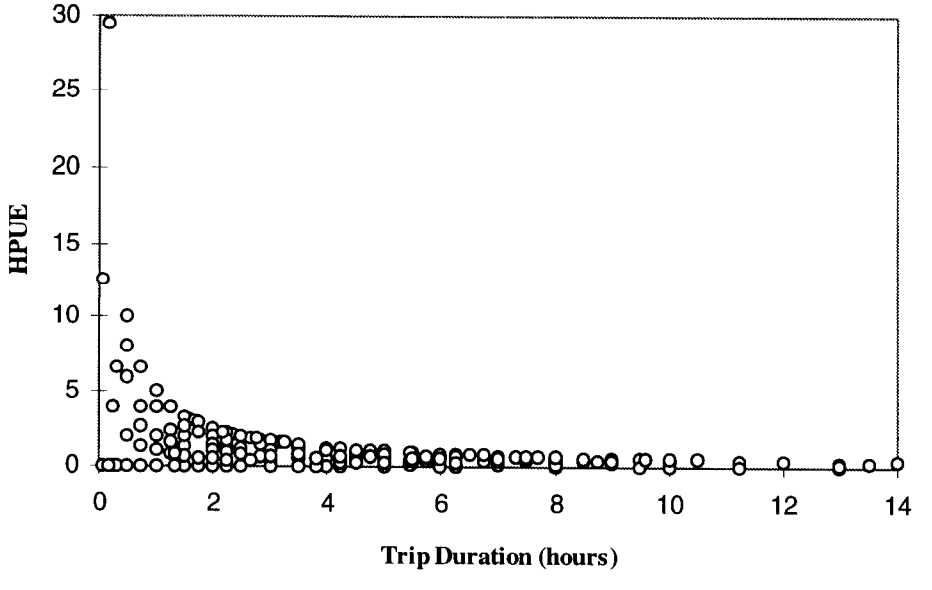
$\chi^2 = 12.4$, df = 3, P = 0.006

| | Number of Sockeye Salmon Kept at Time of Interview | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | Total |
| Card returned | 58 | 38 | 32 | 29 | 28 | 39 | 224 |
| Not returned | 57 | 33 | 22 | 21 | 22 | 19 | 174 |
| Total | 115 | 71 | 54 | 50 | 50 | 58 | 398 |

$\chi^2 = 4.9$, df = 5, P = 0.428

**Appendix C5.-Harvest per unit effort (HPUE) and catch per unit effort (CPUE) versus trip duration in hours observed during the Kvichak River sockeye salmon fishery, 26 June through 16 July 1995.**



# APPENDIX D. ESTIMATION PROCEDURES

**Appendix D1.-Procedures used to estimate angler effort (in hours and angler-trips) on the Kvichak River, 1995.**

Hours of angler effort, number of angler-trips, their associated variances, and standard errors were estimated using the following procedures.

## Hours of Angler Effort

Within each sampling period (second-stage sampling unit j) within each sampled day (first-stage sampling unit i) within each stratum (stratum h), total angler effort (in hours) and its variance were estimated as:

$$\hat{E}_{hij} = \bar{x}_{hij} T_{hij}, \tag{D1.1}$$

$$\hat{V}\left[\hat{E}_{hij}\right] = \hat{V}\left[\bar{x}_{hij}\right] T_{hij}^2, \tag{D1.2}$$

where $\bar{x}_{hij}$ is the average number of anglers counted fishing, $T_{hij}$ is the number of hours in each sampling period (4.5), and $\hat{V}\left[\bar{x}_{hij}\right]$ is the estimated variance of $\bar{x}_{hij}$, obtained approximately by using the successive difference formula appropriate for systematic samples (adapted from Wolter 1985, equation 7.2.4, page 251):

$$\hat{V}\left[\bar{x}_{hij}\right] \approx \frac{\sum_{k=2}^{r_{hij}} \left(x_{hijk} - x_{hij(k-1)}\right)^2}{2\, r_{hij}(r_{hij} - 1)}, \tag{D1.3}$$

where $x_{hijk}$ is number of anglers during angler count k and $r_{hij}$ is the number of angler counts per period.

Angler effort within each sampled day for each stratum was estimated by expanding over periods within each day:

$$\hat{E}_{hi} = Q_{hi} \bar{E}_{hi}, \tag{D1.4}$$

where:

$$\bar{E}_{hi} = \frac{\sum_{i=1}^{q_{hi}} \hat{E}_{hij}}{q_{hi}}, \tag{D1.5}$$

$Q_{hi}$ is the number of periods in each sampled day (three), and $q_{hi}$ is the number of periods sampled.

-continued-

Estimates of angler effort within each stratum were calculated by expanding over days:

$$\hat{E}_h = D_h \overline{E}_h \,, \tag{D1.6}$$

where:

$$\overline{E}_h = \frac{\sum_{i=1}^{d_h} \hat{E}_{hi}}{d_h} \,, \tag{D1.7}$$

$D_h$ is the number of days within each stratum (temporal component), and $d_h$ is the number of days sampled.

The variance of angler effort by stratum was estimated as:

$$\hat{V}\left[\hat{E}_h\right] = \left(1 - f_{1h}\right)\frac{D_h^2}{d_h}\frac{\sum_{i=1}^{d_h}\left(\hat{E}_{hi} - \overline{E}_h\right)^2}{d_h - 1} + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[\left(1 - f_{2hi}\right)\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}}\left(\hat{E}_{hij} - \overline{E}_{hi}\right)^2}{q_{hi} - 1}\right] + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[f_{2hi}\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}}\hat{V}\left[\hat{E}_{hij}\right]}{q'_{hi}}\right] \,, \tag{D1.8}$$

where $f_{1h}$ is the first-stage sampling fraction ($d_h/D_h$), $f_{2hi}$ is the second-stage sampling fraction for first-stage unit i ($q_{hi}/Q_{hi}$), and $q'_{hi}$ is the number of second-stage units in first-stage unit i in which the variance of the effort could be estimated (number of periods in which $r_{hij} > 1$).

The total angler effort (across all strata) and its variance were estimated as:

$$\hat{E} = \sum_{h=1}^{L} \hat{E}_h \,, \tag{D1.9}$$

$$\hat{V}\left[\hat{E}\right] = \sum_{h=1}^{L} \hat{V}\left[\hat{E}_h\right], \tag{D1.10}$$

where L is the number of strata.

-continued-

## Number of Angler-Trips

The number of angler-trips per stratum was estimated in order to provide a weighting factor for distributions of angler catch and harvest. The number of angler-trips during sampling period j of day i of stratum h was estimated as the ratio of the estimated angler effort in angler-hours divided by the average hours per completed angler-trip:

$$\hat{M}_{hij} \approx \frac{\hat{E}_{hij}}{\bar{e}_{hij}}, \tag{D1.11}$$

where $\bar{e}_{hij}$ is the mean of angler effort over all completed-trip anglers, with data from angler cards first reweighted to reflect the number of cards issued rather than the number of cards returned:

$$\bar{e}_{hij} = \frac{\sum_{l=1}^{m_{hij}} w_{hijl} e_{hijl}}{\sum_{l=1}^{m_{hij}} w_{hijl}}, \tag{D1.12}$$

where $e_{hijl}$ is the hours of effort expended by each completed-trip angler interviewed. The weights $w_{hijl}$ equaled one if the data from angler trip l originated from an onsite interview or $m_{Ihij}/m_{Rhij}$ if the data originated from a returned angler card, where $m_{Ihij}$ was the number of cards issued during sample period j and $m_{Rhij}$ was the number of cards issued during sample period j which were filled out correctly and returned.

Its variance was estimated as (Goodman 1960):

$$\hat{V}\left[\hat{M}_{hij}\right] = \hat{V}\left[1/\bar{e}_{hij}\right]\hat{E}_{hij}^2 + \hat{V}\left[\hat{E}_{hij}\right]\left(1/\bar{e}_{hij}\right)^2 - \hat{V}\left[\hat{E}_{hij}\right]\hat{V}\left[1/\bar{e}_{hij}\right], \tag{D1.13}$$

where:

$$\hat{V}\left[1/\bar{e}_{hij}\right] \approx \hat{V}\left[\bar{e}_{hij}\right]\left(1/\bar{e}_{hij}^4\right), \tag{D1.14}$$

where:

$$\hat{V}\left[\bar{e}_{hij}\right] = \frac{\sum_{l=1}^{m_{hij}} \left(e_{hijl} - \bar{e}_{hij}\right)^2}{m_{hij}\left(m_{hij} - 1\right)}. \tag{D1.15}$$

-continued-

Angler-trips per day was estimated by expanding over periods within each day:

$$\hat{M}_{hi} = Q_{hi}\overline{M}_{hi}, \tag{D1.16}$$

where:

$$\overline{M}_{hi} = \frac{\sum_{i=1}^{q_{hi}} \hat{M}_{hij}}{q_{hi}}. \tag{D1.17}$$

Estimates of angler effort within each stratum were calculated by expanding over days:

$$\hat{M}_h = D_h\overline{M}_h \quad , \tag{D1.18}$$

where:

$$\overline{M}_h = \frac{\sum_{i=1}^{d_h} \hat{M}_{hi}}{d_h}. \tag{D1.19}$$

Finally, the variance of the number of angler-trips during temporal component h was estimated as:

$$\hat{V}\left[\hat{M}_h\right] = \left(1-f_{1h}\right)\frac{D_h^2}{d_h}\frac{\sum_{i=1}^{d_h}\left(\hat{M}_{hi}-\hat{M}_h\right)^2}{d_h-1} + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[\left(1-f_{2hi}\right)\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}}\left(\hat{M}_{hij}-\overline{M}_{hi}\right)^2}{q_{hi}-1}\right] + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[f_{2hi}\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}}\hat{V}\left[\hat{M}_{hij}\right]}{q'_{hi}}\right]. \tag{D1.20}$$

**Appendix D2.-Procedures used to estimate harvest and catch, by species, on the Kvichak River, 1995.**

Harvest and catch, their associated variances, and standard errors were estimated using the following procedures. The following estimates of CPUE (and their variances) were not used to describe catch rates as indicators of success. Appendix D3 describes methods used to obtain such catch rates.

Within second-stage sampling unit j of first-stage unit i of stratum h, estimates of mean harvest per unit effort were calculated using a jackknife procedure (Efron 1982) to reduce bias. Data from completed-trip interviews only were used, with data from angler cards first reweighted to reflect the number of cards issued rather than the number of cards returned. First, the mean harvest of angler-trips was divided by the mean length of trip to estimate the sample ratio of HPUE:

$$\overline{HPUE}_{hij} = \frac{\bar{H}_{hij}}{\bar{e}_{hij}} = \frac{\sum_{l=1}^{m_{hij}} w_{hijl} H_{hijl} \Big/ \sum_{l=1}^{m_{hij}} w_{hijl}}{\sum_{l=1}^{m_{hij}} w_{hijl} e_{hijl} \Big/ \sum_{l=1}^{m_{hij}} w_{hijl}} = \frac{\sum_{l=1}^{m_{hij}} w_{hijl} H_{hijl}}{\sum_{l=1}^{m_{hij}} w_{hijl} e_{hijl}}, \quad \text{(D2.1)}$$

where $H_{hijl}$ was the harvest, by species, during an angler trip l, $e_{hijl}$ was the effort expended (in hours) during angler-trip l, and $m_{hij}$ was the number of completed-trip interviews. The weights $w_{hijl}$ equaled one if the data from angler trip l originated from an onsite interview or $m_{Ihij}/m_{Rhij}$ if the data originated from a returned angler card, where $m_{Ihij}$ was the number of cards issued during sample period j and $m_{Rhij}$ was the number of cards issued during sample period j which were filled out correctly and returned.

Since the above estimate of mean HPUE has an inherent bias of order $1/m_{hij}$ (Cochran 1977), the jackknifed estimate of mean HPUE was calculated (Efron 1982):

$$\overline{HPUE}^{*}_{hij} = \frac{\sum_{m=1}^{m_{hij}} HPUE^{*}_{hijm}}{m_{hij}}, \quad \text{(D2.2)}$$

-continued-

where:

$$HPUE^{*}_{hijm} = \frac{\sum_{\substack{l=1 \\ l\neq m}}^{m_{hij}} w_{hijl} H_{hijl}}{\sum_{\substack{l=1 \\ l\neq m}}^{m_{hij}} w_{hijl} e_{hijl}}. \qquad \text{(D2.3)}$$

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

$$\overline{HPUE}^{**}_{hij} = m_{hij}\left[\overline{HPUE}_{hij} - \overline{HPUE}^{*}_{hij}\right] + \overline{HPUE}^{*}_{hij}. \qquad \text{(D2.4)}$$

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

$$\hat{V}\left[\overline{HPUE}^{**}_{hij}\right] = \hat{V}\left[\overline{HPUE}^{*}_{hij}\right] = \frac{m_{hij}-1}{m_{hij}} \sum_{m=1}^{m_{hij}} \left[HPUE^{*}_{hijm} - \overline{HPUE}^{*}_{hij}\right]^2. \qquad \text{(D2.5)}$$

Mean catch per unit effort (CPUE) was estimated using equations (D2.1)-(D2.5), after first substituting catch $C_{hijl}$ for harvest $H_{hijl}$.

Total harvest, by species, during each sampling period of each sampled day of each stratum was estimated as the product of estimated effort and bias-corrected HPUE:

$$\hat{H}_{hij} = \hat{E}_{hij}\overline{HPUE}^{**}_{hij}, \qquad \text{(D2.6)}$$

and its variance followed Goodman (1960):

$$\hat{V}\left[\hat{H}_{hij}\right] = \hat{V}\left(\overline{HPUE}^{**}_{hij}\right)\hat{E}^2_{hij} + \hat{V}\left(\hat{E}_{hij}\right)\overline{HPUE}^{**2}_{hij} - \hat{V}\left(\overline{HPUE}^{**}_{hij}\right)\hat{V}\left(\hat{E}_{hij}\right). \qquad \text{(D2.7)}$$

Total number of fish harvested during day unit i of stratum h was estimated by expanding over sampling periods within each day:

$$\hat{H}_{hi} = Q_{hi}\overline{H}_{hi}, \qquad \text{(D2.8)}$$

where:

$$\overline{H}_{hi} = \frac{\sum_{j=1}^{q_{hi}} \hat{H}_{hij}}{q_{hi}}. \qquad \text{(D2.9)}$$

-continued-

Likewise, the total number of fish harvested during stratum h was estimated by expanding over days:

$$\hat{H}_h = D_h \overline{H}_h , \tag{D2.10}$$

where:

$$\overline{H}_h = \frac{\sum_{i=1}^{d_h} \hat{H}_{hi}}{d_h} . \tag{D2.11}$$

Its variance was estimated as:

$$V(\hat{H}_h) = (1-f_{1h})\frac{D_h^2}{d_h}\frac{\sum_{i=1}^{d_h}(\hat{H}_{hi}-\overline{H}_h)^2}{d_h-1} + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[(1-f_{2hi})\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}}(\hat{H}_{hij}-\overline{H}_{hi})^2}{q_{hi}-1}\right] + f_{1h}\frac{D_h^2}{d_h^2}\sum_{i=1}^{d_h}\left[f_{2hi}\frac{Q_{hi}^2}{q_{hi}}\frac{\sum_{j=1}^{q_{hi}} V[\hat{H}_{hij}]}{q''_{hi}}\right] , \tag{D2.12}$$

where $q''_{hi}$ is the number of periods sampled in day i in which the variance of the harvest could be estimated (number of periods in which $r_{hij} > 1$ and $m_{hij} > 1$).

Total harvest during the fishery, by species, and its variance were estimated by summing over strata:

$$\hat{H} = \sum_{h=1}^{L} \hat{H}_h , \tag{D2.13}$$

$$\hat{V}[\hat{H}] = \sum_{h=1}^{L} \hat{V}[\hat{H}_h] . \tag{D2.14}$$

Catch statistics were estimated similarly, after substituting $\overline{CPUE}^{**}_{hij}$ for $\overline{HPUE}^{**}_{hij}$ in equations (D2.6) through (D2.14).

**Appendix D3.-Procedure used to estimate catch per unit effort as an index of angler success on the Kvichak River, 1995.**

Catch per unit effort (CPUE) of anglers participating in the 1995 Kvichak River sockeye salmon fishery, an indicator of angler success, was estimated as follows. Data from completed-trip interviews only were used, with data from angler cards first reweighted to reflect the number of cards issued rather than the number of cards returned. First, CPUE was calculated for each completed-trip angler:

$$CPUE_{hijl} = \frac{C_{hijl}}{e_{hijl}}, \tag{D3.1}$$

where $C_{hijl}$ is the catch of angler l, during sampled period j of sampled day i of stratum h, and $e_{hijl}$ is defined in Appendix D1.

The weighted mean CPUE for each stratum was then calculated over all completed-trip anglers during each stratum:

$$\overline{CPUE}_h = \frac{\sum_{i=1}^{d_h}\sum_{j=1}^{q_{hi}}\sum_{l=1}^{m_{hij}} w_{hijl} CPUE_{hijl}}{\sum_{i=1}^{d_h}\sum_{j=1}^{q_{hi}}\sum_{l=1}^{m_{hij}} w_{hijl}}, \tag{D3.2}$$

where the weights $w_{hijl}$ equaled one if the data from angler trip l originated from an onsite interview or $m_{lhij}/m_{Rhij}$ if the data originated from a returned angler card, where $m_{lhij}$ was the number of cards issued during sample period j and $m_{Rhij}$ was the number of cards issued during sample period j which were filled out correctly and returned. The sum of the weights in the denominator of (2) is equal to the total number of anglers interviewed, whether finished fishing or not, during stratum h.

The variance of CPUE by stratum was estimated as:

$$\hat{V}\left[\overline{CPUE}_h\right] = \frac{\sum_{i=1}^{d_h}\sum_{j=1}^{q_{hi}}\sum_{l=1}^{m_{hij}} w_{hijl}\left(CPUE_{hijl} - \overline{CPUE}_h\right)^2}{m_h\left(\sum_{i=1}^{d_h}\sum_{j=1}^{q_{hi}}\sum_{l=1}^{m_{hij}} w_{hijl} - 1\right)}, \tag{D3.3}$$

where $m_h$ was the total number of completed trip anglers during stratum h.

**Appendix D4.-Procedures used to estimate, by species, the distributions of angler catch and harvest, and the contributions to harvest of each successive fish in the angler's creel, for the Kvichak River sockeye salmon sport fishery, 1995.**

## Distributions of Angler Catches and Harvests

The distribution of angler catches is defined as the proportions $p_g$ of angler-trips in which g or more fish were caught, from g = 1 to the maximum number of fish caught by any one angler ($g_{max}$). Additionally, $p_0$ is defined as the proportion of angler-trips with a catch of zero fish (by species). These proportions and their variances were calculated, by stratum, from completed-trip interviews only, after first reweighting so that the angler card data reflected the number of cards issued rather than the number of cards returned:

$$\hat{p}_{gh} = \frac{\sum_{i=1}^{d_h} \sum_{j=1}^{q_{hi}} \sum_{l=1}^{m_{hij}} w_{hijl} y_{ghijl}}{\sum_{i=1}^{d_h} \sum_{j=1}^{q_{hi}} \sum_{l=1}^{m_{hij}} w_{hijl}}, \tag{D4.1}$$

$$\hat{V}\left[\hat{p}_{gh}\right] = \frac{\hat{p}_{gh}\left(1-\hat{p}_{gh}\right)}{m_h - 1}, \tag{D4.2}$$

where $y_{ghijl}$ is an indicator variable equaling one if angler l, interviewed during day i period j of stratum h, caught g or more sockeye salmon, or zero otherwise. The weights $w_{hijl}$ equaled one if the data from angler trip l originated from an onsite interview or $m_{Ihij}/m_{Rhij}$ if the data originated from a returned angler card, where $m_{Ihij}$ was the number of cards issued during sample period j and $m_{Rhij}$ was the number of cards issued during sample period j which were filled out correctly and returned. The stratum sample size $m_h$ was the total number of completed-trip interviews within each stratum:

$$m_h = \sum_{i=1}^{d_h} \sum_{j=1}^{q_{hi}} m_{hij}, \tag{D4.3}$$

where $m_{hij}$ equals the number of completed-trip interviews within each sample.

The distributions of angler catches for the entire season (across all temporal components) were estimated by taking the weighted average of within-stratum estimates, with the weights being the estimated proportion of all angler-trips which occurred in each stratum. The proportions of angler-trips yielding a catch of *g* or more fish, and their variances, were estimated as:

$$\hat{p}_g = \sum_{h=1}^{L} \hat{W}_{Mh} \hat{p}_{gh}, \tag{D4.4}$$

-continued-

$$\hat{V}\left[\hat{p}_g\right] \approx \sum_{h=1}^{L}\left[\hat{W}_{Mh}^2 \hat{V}\left(\hat{p}_{gh}\right) + \hat{p}_{gh}^2 \hat{V}\left(\hat{W}_{Mh}\right) - \hat{V}\left(\hat{W}_{Mh}\right)\hat{V}\left(\hat{p}_{gh}\right)\right], \tag{D4.5}$$

where the stratum weights and their variances were estimated as:

$$\hat{W}_{Mh} = \frac{\hat{M}_h}{\sum_{h=1}^{L} \hat{M}_h}, \tag{D4.6}$$

$$\hat{V}\left[\hat{W}_{Mh}\right] \approx \hat{W}_{Mh}^2 \left[\frac{\hat{V}\left(\hat{M}_h\right)}{\hat{M}_h^2} + \frac{\hat{V}\left(\hat{M}\right)}{\hat{M}^2} - \frac{\hat{V}\left(\hat{M}_h\right)}{\hat{M}_h \hat{M}}\right], \tag{D4.7}$$

where $\hat{M}_h$ and $\hat{V}\left(\hat{M}_h\right)$ are the estimated number of angler-trips during stratum h and its variance, defined in Appendix D1, and where

$$\hat{M} = \sum_{h=1}^{L} \hat{M}_h \text{, and} \tag{D4.8}$$

$$\hat{V}\left[\hat{M}\right] = \sum_{h=1}^{L} \hat{V}\left[\hat{M}_h\right]. \tag{D4.9}$$

The distribution of angler harvests was calculated in the same manner as that of angler catches.

## Contributions to Total Harvest by Each Fish in Angler's Daily Bag

The contributions to total harvest by each fish in angler's daily bag were calculated by using the harvest distribution estimates. Harvest contribution estimates by stratum (proportion of the harvest that is due to the $g^{th}$ fish is each angler's daily bag during temporal component h) were calculated as follows:

$$\hat{s}_{gh} = \frac{\sum_{g'=g}^{g\max} \hat{q}_{g'h}}{\sum_{g'=1}^{g\max} g' \cdot q_{g'h}}, \tag{D4.10}$$

where:

$$\hat{q}_{gh} = \hat{p}_{gh} - \hat{p}_{(g+1)h} = \frac{\sum_{i=1}^{d_h} \sum_{j=1}^{q_{hi}} y_{ghij}}{m_h} \tag{D4.11}$$

-continued-

is the estimated proportion of anglers harvesting exactly g fish, $g_{max}$ is the largest observed number of fish in any angler's daily bag, and $y_{ghij}$ is the number of anglers harvesting exactly g fish during period j of day i of stratum h.

The variance of $\hat{s}_{gh}$ is calculated approximately (Delta method) by:

$$\begin{aligned}\hat{V}\left[\hat{s}_{gh}\right] \approx & \frac{1}{\overline{H}_h'^4}\sum_{g'=1}^{g-1}\left\{\left(g'\sum_{g''=g'}^{g\max}\hat{q}_{g''h}\right)^2 V\left[\hat{q}_{g'h}\right]\right\}+\frac{1}{\overline{H}'^4_h}\sum_{g'=g}^{g\max}\left\{\left(\overline{H}_h'-g'\sum_{g''=g'}^{g\max}\hat{q}_{g''h}\right)^2 V\left[\hat{q}_{g'h}\right]\right. \\ & +\frac{2}{\overline{H}_h'^4}\sum_{g'=1}^{g-1}\sum_{g''=g'+1}^{g\max}\left\{\left(g'\sum_{g'''=g'}^{g\max}\hat{q}_{g'''h}\right)\left(g''\sum_{g'''=g''}^{g\max}\hat{q}_{g'''h}\right)\operatorname{cov}\left[\hat{q}_{g'h}\hat{q}_{g''h}\right]\right\} \\ & \left.+\frac{2}{\overline{H}_h'^4}\sum_{g'=g}^{g\max}\sum_{g''=g'+1}^{g\max}\left\{\left(\overline{H}_h'-g'\sum_{g'''=g'}^{g\max}\hat{q}_{g'''h}\right)\left(\overline{H}_h'-g''\sum_{g'''=g''}^{g\max}\hat{q}_{g'''h}\right)\operatorname{cov}\left[\hat{q}_{g'h}\hat{q}_{g''h}\right]\right\}\right. ,\end{aligned} \tag{D4.12}$$

where:

$$\overline{H}_h' = \sum_{g=1}^{g\max} g\cdot\hat{q}_{gh}\,, \tag{D4.13}$$

$$\hat{V}\left[\hat{q}_{gh}\right] = \frac{\hat{q}_{gh}(1-\hat{q}_{gh})}{m_h}, \text{ and} \tag{D4.14}$$

$$\operatorname{cov}\left[\hat{q}_{g'h}\hat{q}_{g''h}\right] = \frac{-\hat{q}_{g'h}\hat{q}_{g''h}}{m_h-1}. \tag{D4.15}$$

-continued-

The contributions to harvest for the entire season (across all temporal components) were estimated by taking the weighted average of within-stratum estimates:

$$\hat{s}_g = \sum_{h=1}^{L} \hat{W}_{Hh}\hat{s}_{gh}\,, \tag{D4.16}$$

$$\hat{V}\left[\hat{s}_g\right] \approx \sum_{h=1}^{L}\left[\hat{W}_{Hh}^2\hat{V}\left(\hat{s}_{gh}\right) + \hat{s}_{gh}^2\hat{V}\left(\hat{W}_{Hh}\right) - \hat{V}\left(\hat{W}_{Hh}\right)\hat{V}\left(\hat{s}_{gh}\right)\right], \tag{D4.17}$$

where the weights were estimated proportions of total harvest by stratum:

$$\hat{W}_{Hh} = \frac{\hat{H}_h}{\sum_{h=1}^{L}\hat{H}_h}\,, \tag{D4.18}$$

$$\hat{V}\left[\hat{W}_{Hh}\right] \approx \hat{W}_{Hh}^2\left[\frac{\hat{V}\left(\hat{H}_h\right)}{\hat{H}_h^2} + \frac{\hat{V}\left(\hat{H}\right)}{\hat{H}^2} - \frac{\hat{V}\left(\hat{H}_h\right)}{\hat{H}_h\hat{H}}\right], \tag{D4.19}$$

where $\hat{H}_h$, $\hat{H}$, $\hat{V}\left(\hat{H}_h\right)$, and $\hat{V}\left(\hat{H}\right)$ are harvest statistics defined in Appendix D2.

# APPENDIX E. LIST OF DATA FILES AND PROGRAMS USED

**Appendix E1.-Data files and computer programs used to produce this report.**

| Data Files | |
|---|---|
| Angler count data: | |
| S003GCA5.DTA | Angler counts 6/28/95 to 7/4/95 |
| S003GCB5.DTA | Angler counts 7/7/95 to 7/17/95 |
| S003GCX5.DTA | Merged angler counts (above) used for analysis 6/28/95 to 7/17/95. |
| Angler interview data: | |
| S003GIA5.DTA | Angler Interviews - onsite 6/28/95 to 7/4/95 |
| S003GIB5.DTA | Angler Interviews - onsite 6/28/95 to 7/4/95 |
| S003GIX5.DTA | Merged angler interviews onsite (above) used for analysis and merging to card data 6/28/95 to 7/17/95. |
| S003GIX5.CRD | Voluntary report card data only. |
| S003GIX5.MRG | Merged onsite interview and card data. |
| Biological data: | |
| S003GB5.DTA | Upper Kvichak River sport harvested sockeye salmon biological data. |

| Analysis Programs | |
|---|---|
| CC91 | A series of programs which sort raw data files and produce frequency reports and assist data editing. The programs also summarize some of the raw data. |
| BBXPEXE | A series of programs that uses data files in standard Age, Weight, Length format to produce tables of mean lengths and weights by sex and age group. |
| DOINT90 | A set of Dbase® programs that reformats standard angler interview data files into a single row of data for each interview. |
| MERGE.PRG | A program using FoxPro® to merge the individual onsite angler interview data with the corresponding voluntary report card data. |

# APPENDIX F. RAINBOW TROUT CATCH AND HARVEST

**Appendix F1.-Estimated catch and harvest of rainbow trout by the sport fishery in the Kvichak River, 26 June through 16 July 1995.**

| Temporal Component and Date | Catch[a] | | | | | Harvest | | | | | Percent of Catch Harvested |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 90% Confidence Interval | | | | | 90% Confidence Interval | | | |
| | Estimate | SE | Lower | Upper | RP[b] | Estimate | SE | Lower | Upper | RP[b] | |
| 1 (26-30 June) | 3 | 3 | 0 | 8 | 164% | 2 | 2 | 0 | 4 | 164% | 50% |
| 2 (1,2,4 July) | 35 | 19 | 3 | 66 | 90% | 5 | 5 | 0 | 14 | 163% | 15% |
| 3 (3,5-7 July) | 66 | 46 | 0 | 142 | 115% | 0 | 0 | 0 | 0 | | 0% |
| 4 (8-9 July) | 81 | 47 | 3 | 159 | 96% | 17 | 17 | 0 | 45 | 169% | 21% |
| 5 (10-14 July) | 128 | 46 | 52 | 204 | 60% | 12 | 5 | 3 | 20 | 72% | 9% |
| 6 (15-16 July) | 2 | 2 | 0 | 5 | 141% | 0 | 0 | 0 | 0 | | 0% |
| Season Total | 315 | 83 | 178 | 452 | 43% | 35 | 19 | 4 | 66 | 88% | 11% |

[a] Catch = total fish kept + total fish released.

[b] Relative precision of the 90% confidence interval.