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Creel Surveys on the Chinook Salmon Sport Fishery on the Lower Nushagak River and Mid-Mulchatna River, Alaska, 1991

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ABSTRACT

During the 1991 season, creel surveys were conducted on the chinook salmon *Oncorhynchus tshawytscha* sport fishery on the lower Nushagak River near the villages of Portage Creek and Ekwok, and at two sites on the middle section of the Mulchatna River. The surveys were conducted during the peak period of fishing activity for each day sampled and were limited to the peak of the fishing season as determined from previous studies. The survey objectives were to obtain data on anglers' relative success, the percentage of fish harvested by guided and unguided anglers, the percentage harvested by terminal tackle type, as well as to estimate the levels of effort, catch, and harvest during the survey period.

Survey results indicated that 28% to 40% of the anglers caught no fish and the majority of successful anglers caught one to five fish. Anglers in one site along the Mulchatna River were more successful with almost 95% reporting a catch of one or more fish. In all locations, most anglers voluntarily restricted their harvest of chinook salmon below the established bag limit. Anglers taking the full daily bag limit of three chinook salmon ranged from a low of zero to 20% (SE = 5.4). The first fish harvested by all interviewed anglers constituted 51% to 84% of the total harvest and the third fish in each angler's bag made up to 15% of the total harvest. Guided anglers harvested 64% to 100% of chinook salmon in all locations except at the mouth of the Stuyahok River where 93% of the harvest was taken by unguided anglers. Anglers used lures to harvest 46% to 100% of the chinook salmon while very few fish were taken on bait or flies.

Effort for the peak period of the fishery at all locations was estimated to be 11,880 angler-hours (SE = 582). Most of the effort occurred at the Portage Creek site and the mid-Mulchatna sites. During the peak of the chinook salmon sport fishery, an estimated 844 (SE = 93) fish were harvested from the mid-Mulchatna River sites, 585 (SE = 104) fish were harvested from the Portage Creek site, and 83 (SE = 20) fish were harvested from the Ekwok site. Harvests of incidentally caught species were estimated to be extremely low in all survey sites.

Biological data were collected from 350 sport harvested chinook salmon. Over 41% of the fish were age class 1.3 and 38% were age class 1.4. Females composed 34.5% (SE = 4.91) of the harvest and males made up the remaining 65.5% (SE = 4.91). The mean length for both sexes was 742 mm and the mean weight was 7.5 kg.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, sockeye salmon, *Oncorhynchus nerka*, chum salmon, *Oncorhynchus keta*, rainbow trout, *Oncorhynchus mykiss*, sport harvest, sport effort, creel survey, bag analysis, bag limit, guided anglers, unguided anglers, gear type, terminal tackle, age composition, Mulchatna River, Nushagak River, Portage Creek, Ekwok, Stuyahok River, Koktuli River, Bristol Bay.

INTRODUCTION

The Nushagak River drainage is located on the western side of Bristol Bay (Figure 1). It is the largest producer of all species of Pacific salmon *Oncorhynchus* except sockeye *O. nerka* in Bristol Bay. The drainage also supports sizable stocks of other species including rainbow trout *O. mykiss*, grayling *Thymallus arcticus*, and pike *Esox lucius*. The abundance and variety of fish attracts many sport anglers to the region each year.

Most anglers seeking chinook salmon *O. tshawytscha* use three areas within the Nushagak River drainage. Historically, the majority of the sport effort on the mainstem Nushagak River has taken place from Black Point upstream 20 km to the village of Portage Creek (Figure 1). Known as the Portage Creek site, this stretch of river is about 300 meters wide, moderately silty, and the current is influenced by tides. Further upstream, and above tidal influences, a sport fishery has developed near the village of Ekwok. The third major fishery is located along the middle portion of the Mulchatna River from approximately 3 miles below the mouth of the Stuyahok River upstream to the mouth of the Koktuli River.

The Nushagak River drainage chinook salmon stocks have been confronted with several developments in the last 15 years. Large returns were experienced during the late 1970s through mid-1980s and escapements were also high (Table 1). However, production from these escapements has been poor (Table 1) (ADF&G 1990a, 1990b). After experiencing peak harvest levels from 1976 through 1986, no directed commercial fishery on Nushagak River drainage chinook salmon was permitted from 1987 to 1990. During the years 1966 to 1976, the subsistence harvest averaged 5,740 fish per year. Since 1977, subsistence harvests have averaged 9,600 fish per year (ADF&G 1990a, 1990b). Much of the apparent increase in the subsistence take may be the result of improved and more intensive reporting procedures.

Sport angling for all species in the Nushagak River drainage has increased. For the years 1977 to 1981, sport effort was relatively consistent, averaging 3,208 angler-days per year, but since 1982, effort has increased to an average of 7,728 angler-days per year (Figure 2) (Mills 1979-1991). The sport harvest of chinook salmon has increased along with effort from an average 800 fish per year from 1977 to 1981, to an average of 2,870 fish per year since 1982 (Mills 1979-1991). The sport fishery has increased even though the bag limit on sport caught chinook salmon was reduced in 1987 and a 25 July spawning season closure was instituted in the spring of 1990 (ADF&G 1988, 1990c).

Poor production by Nushagak River chinook salmon stocks has prompted public demand for development of a management plan. Accurate characterization of the Nushagak River drainage chinook salmon sport fishery requires on-site assessment and includes the distribution of catch and harvest, harvest practices of the participants, and gear types used. This information augments effort and harvest data from the statewide harvest survey (Mills 1979-1990). Such information is particularly important in fisheries where a large fraction of the catch may be released.

Data concerning the sport fishery in the Nushagak River include the results of the ADF&G Statewide Harvest Survey (Mills 1979-1991) and three on-site creel

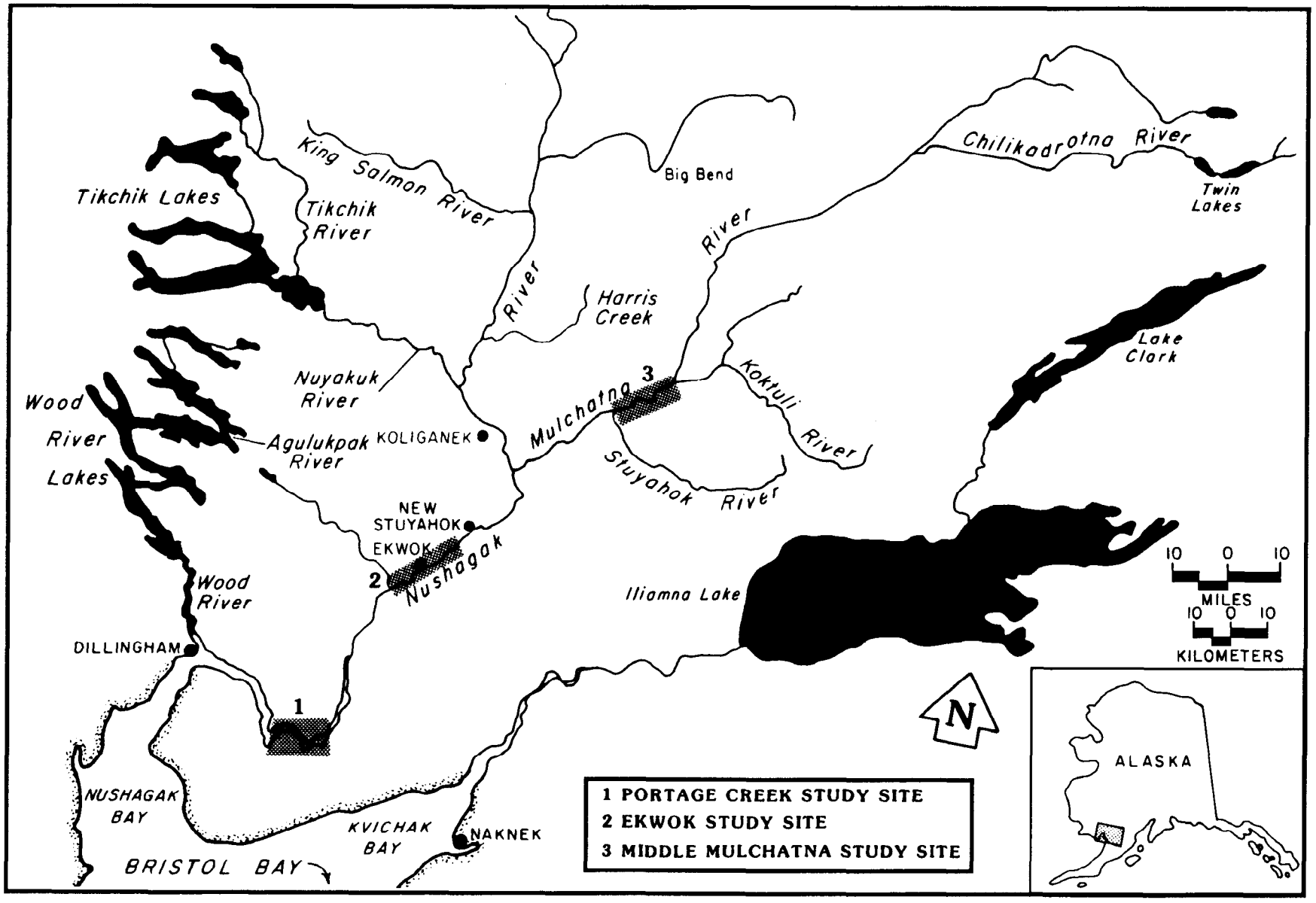

Figure 1. The Nushagak and Mulchatna rivers study area.

Table 1. Chinook salmon commercial, subsistence, and sport harvest plus escapement for the Nushagak drainage, 1966 to 1991.

	Harvest							
			Sport[b]					
Year	Commercial[a]	Subsistence	Nushagak River	Mulchatna River	Total	Total	Escapement[c]	Total Run[d]
1966	58,184	3,700				61,884	40,000	101,884
1967	96,240	3,700				99,940	65,000	164,940
1968	78,201	6,600				84,801	70,000	154,801
1969	80,803	7,100				87,903	35,000	122,903
1970	87,547	6,300				93,847	50,000	143,847
1971	82,769	4,400				87,169	40,000	127,169
1972	46,045	4,000				50,045	25,000	75,045
1973	30,470	6,600				37,070	35,000	72,070
1974	32,053	7,900				39,953	70,000	109,953
1975	21,454	7,100				28,554	70,000	98,554
1976	60,684	6,900				67,584	100,000	167,584
1977	85,074	5,200	402	521	923	91,197	65,000	156,197
1978	118,548	6,600	151	291	442	125,590	130,000	255,590
1979	157,321	8,900	312	342	654	166,875	95,000	261,875
1980	64,958	11,800	611	146	757	77,515	141,000	218,515
1981	193,461	11,500	929	291	1,220	206,181	150,000	356,181
1982	195,287	12,100	1,436	367	1,803	209,190	147,000	356,190
1983	137,123	11,800	1,615	388	2,003	150,926	161,730	312,656
1984	61,378	9,800	1,534	786	2,320	73,498	80,940	154,438
1985	67,783	7,900	1,517	292	1,809	77,492	115,720	193,212
1986	65,783	12,600	1,780	3,534	5,314	83,697	43,434	127,131
1987	45,983	12,200	1,371	1,860	3,231	61,414	84,309	145,723
1988[e]	16,648	10,079	2,383	403	2,786	29,513	56,905	86,418
1989[e]	17,637	8,097	2,807	754	3,561	29,295	78,302	107,597
1990[e]	14,092	11,932	1,594	1,409	3,003	29,027	63,955	92,982
All Years Average	76,621	8,192	1,317	813	2,130	86,944	80,532	167,476
1977-1990 Average	88,648	10,036	1,317	813	2,130	100,815	100,950	210,765
Percent	88%	10%			2%	100%		
1986 to 1990 5 Year Avg	32,029	10,982	1,987	1,592	3,579	46,589	65,381	111,970
Percent	69%	24%			8%	100%		
1991[e]	22,898	12,884[f]			NA[g]			

[a] Some commercial harvests were influenced by price disputes.
[b] Sport harvest estimates from Statewide Harvest Surveys.
[c] Escapement estimates: 1966 expanded from Nushagak River tower counts, 1967 is a combination of tower counts and aerial surveys, 1971 estimated from mean exploitation rates observed 1960-1970 and 1972-1976, 1972 - 1985 from aerial counts of index streams, 1986-1991 from sonar counts.
[d] Total run = sum of all harvests + escapement. Considered to be a minimum number.
[e] Commercial harvests from 1988 - 1991 are preliminary.
[f] 1991 preliminary estimates.
[g] Statewide harvest survey estimate not available for 1991.

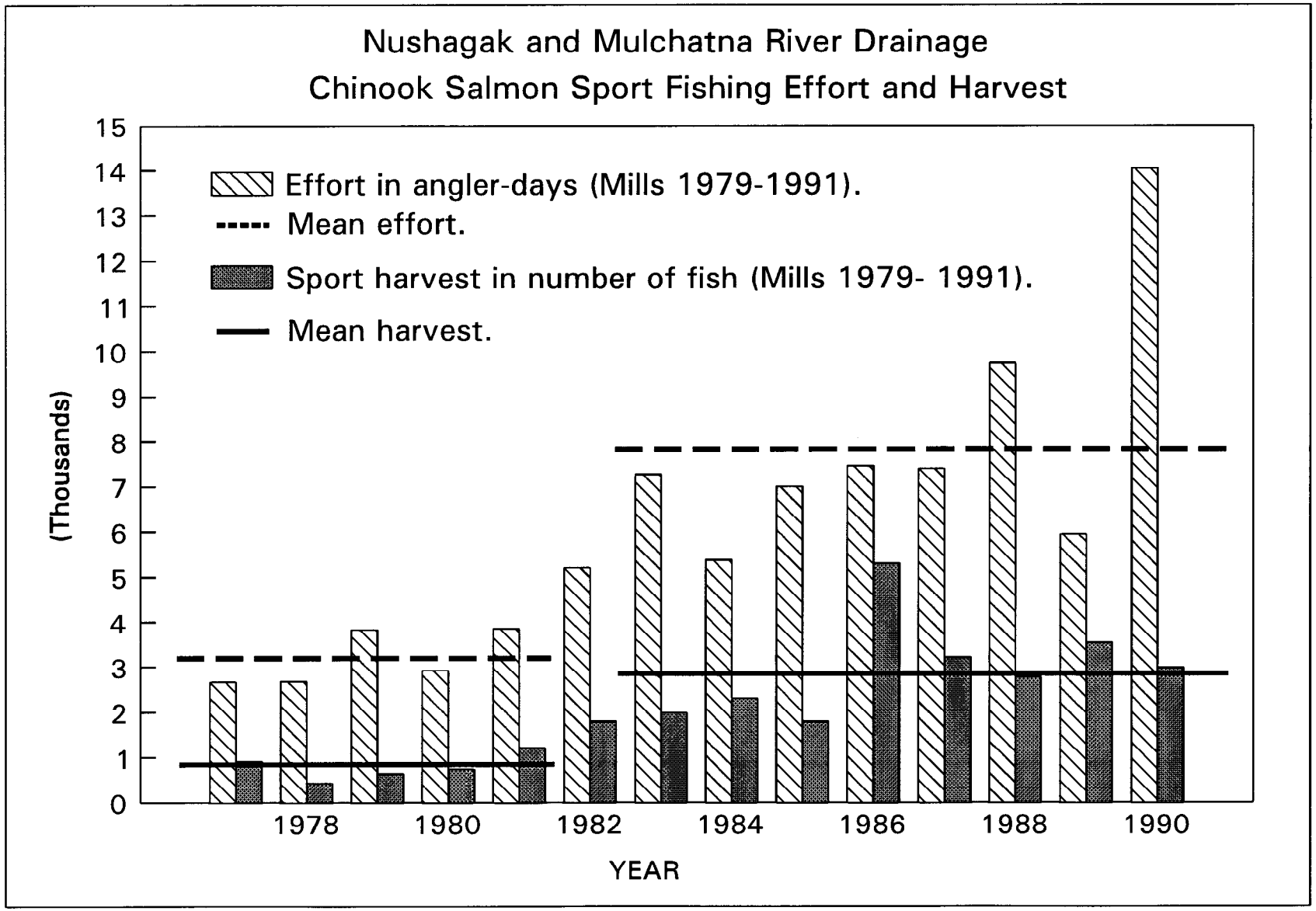

Figure 2. Estimates and means of effort (angler-days) and harvests of chinook salmon (1977 to 1990) by the sport fishery in the Nushagak and Mulchatna rivers.

surveys conducted in 1985, 1986, and 1987 (Minard and Morstad 1985, Minard 1987, Minard and Brookover 1988). Other than the output of the Statewide Harvest Survey (Mills 1979-1991), information on the Mulchatna River sport fishery is limited to the results of on-site creel surveys conducted in 1986 (Lipchak 1986) and 1990 (Dunaway et al. 1991). The 1986 creel survey was very brief, leaving the 1990 survey as the only full scale work available on the middle Mulchatna River sport fishery. Data on salmon escapements into the Nushagak River drainage are collected annually by the ADF&G Commercial Fisheries Division and published in the Annual Management Report series. Data on subsistence harvests in the area are collected by the ADF&G Subsistence Division. Summaries of subsistence harvests also appear in the Commercial Fisheries Division's Annual Management Report series.

Objectives for the 1991 creel surveys of chinook salmon sport fisheries occurring on the lower Nushagak River and middle portion of the Mulchatna River were:

1. To estimate the distribution of catch and harvest of chinook salmon by angler-day, during the peak of the fishing season.

2. To estimate the percent of harvest of chinook salmon for peak periods of the day during the peak of the fishing season by angler type, and terminal tackle type.

3. To estimate angling effort (in angler-hours), catch (fish kept plus released), and harvest (fish kept only), of chinook salmon caught in the recreational fisheries during the peak periods of each angling day during the peaks of the fishing seasons.

4. To estimate the age, sex, and length composition of chinook salmon harvested by the sport fisheries during the peak of the fishing season.

In addition, analysis of anglers' daily bags examined the harvest patterns that occurred at each site.

In 1991, anglers fishing the Nushagak and Mulchatna River drainages were allowed a daily bag and possession limit of three chinook salmon per day, only two of which could be over 71 cm (28 inches) (ADF&G 1991). The daily bag and possession limits of salmon other than chinook salmon (including sockeye, chum *O. keta*, pink *O. gorbuscha*, and coho *O. kisutch*) were five fish per day in any combination. The bag and possession limit on rainbow trout during the survey periods was two fish per day, only one of which could exceed 51 cm (20 inches) in length (ADF&G 1991).

METHODS

Creel Survey Study Design

Creel surveys were conducted on chinook salmon sport fisheries at two locations on the lower Nushagak River and two locations on the Mulchatna River. The first survey was conducted on the 20 km of the Nushagak River from Black Point upstream to the village of Portage Creek during the 17 days from

21 June to 7 July 1991. Further upstream, a second survey, known as the Ekwok site, was conducted on 30 km of the Nushagak River from the mouth of the Kokwok River upstream to the village of New Stuyahok during the 14 days from 8 July to 21 July 1991.

The two surveys on the middle portion of the Mulchatna River (mid-Mulchatna River) were conducted from 1 July to 15 July 1991. Sublocation 001 was the area within 200 m of the mouth of the Stuyahok River. Sublocation 002 included the mid-Mulchatna River from 3 miles below the mouth of the Stuyahok River upstream to the mouth of the Koktuli River (excluding the 200 meter area around the mouth of the Stuyahok River).

One technician worked at the Portage Creek site and then moved to the Ekwok study area. The technician was assisted by a volunteer high-school student for 1 week at each site. Two fulltime technicians staffed the remote Mulchatna River campsite.

The primary goal of the surveys was to obtain information on the portion of the chinook salmon fishery which likely harvested the majority of the fish. Therefore, the combinations of locations, time of season, and daily time periods were selected such that the creel surveys would be conducted during the peak of each fishery. The peak of the fishing season and peak period within the day for each location were determined from angler counts recorded at each site during earlier surveys (Minard and Brookover 1988, Dunaway et al. 1991). Timing for the previously unsurveyed Ekwok site was based on the Portage Creek recreational fishery and upon information provided by local guides.

Depending upon the location, one of two different random sampling designs was used for estimating the distribution of angler catches and harvests; the percentage of harvest by terminal tackle type and angler type; and the angling effort (in angler-hours).

Roving Surveys:

Roving creel surveys (Neuhold and Lu 1957) were conducted at the three creel survey sites of Portage Creek, Ekwok, and sublocation 002 of the mid-Mulchatna River. Previous survey data from these locations indicated that peak angler counts occurred from mid-morning through early evening (Minard and Brookover 1988, Dunaway et al. 1991). Therefore, the sampling day was defined as an 8-hour period from 1000 to 1800 hours. The sampling intensity in the roving surveys was set at the rate of 5 randomly selected sample days per 7-day week. The sample days were selected without replacement.

On each sampling day, the technician conducted three systematic angler counts. One of two counting schedules was randomly selected: schedule A count times were 1000, 1240, and 1520 hours; schedule B count times were 1120, 1500, and 1640 hours. The upper or lower end of the survey area was chosen as a starting point for the day's counts by the toss of a coin. The technician then counted anglers while running a boat through the survey area at a constant speed and without interruption. Angler counts were completed within 1 hour and were considered instantaneous. The mean of the three daily counts represented angler effort for the peak of the day in which the counts were conducted.

Angler interviews consisted of asking individual anglers the length of time fished, the number and species of fish caught and released, and the number and species of fish harvested. The type(s) of gear used, whether the services of a guide were used, and demographic data were recorded as well. The technician also collected biological data from all harvested fish that were encountered during the interviews.

The angler interviews were conducted as the technician passed through the fishery and between each of the three systematic angler counts. In the first interview session of a sample day, the technician attempted to interview every third boat load of anglers throughout the sample area. On subsequent interview sessions within each day the technician attempted to interview every third previously non-interviewed boat load of anglers until all anglers were interviewed once. While the practice of interviewing all anglers in a boat was not part of the original survey design and may have introduced some bias, the creel clerks found anglers to be much more cooperative if disturbance to their fishing was minimized. Many of the anglers at all three sites used boats and each boat typically carried two or three anglers. Shore anglers were interviewed according to the initial plan of contacting every third angler with each pass through the fishery until all were interviewed.

Incompleted-trip angler interviews and completed-trip interviews were collected by the clerks. An incompleted-trip interview consisted of an interview with an angler who had not concluded fishing for the day. All incompleted-trip anglers interviewed were handed a voluntary angling report card, and asked to provide their completed-trip information (Figure 3). Each report card had information identifying the card to the original incompleted-trip information recorded for the angler.

Data from the 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. Randomly selected sample days represented the first sampling stage. One of two systematic angler count combinations, randomly selected within sample days, represented the second sampling stage for angler effort estimation. Angler interviews represented the second sampling stage for catch and harvest rate estimation. In general, only completed-trip information, obtained from either the original interview or from the report cards, was used in obtaining estimates by the procedures outlined later in this report.

Information from angler interviews was also used to estimate the distribution of catches and harvests of chinook salmon by angler-day. The "distribution of catches and harvests by angler-day" was defined as the percentage of angler-days that resulted in catches or harvests of one or more chinook salmon, two or more chinook salmon, etc. We assumed that the distribution of catches and harvests did not vary within each angling day, so the estimates of catch and harvest distribution apply to the peak of the season. Angler counts were also used in estimating these percentages in order to obtain sample weights.

Direct Expansion Survey:

Sublocation 001 of the middle Mulchatna River was a confined area that afforded easy access to all anglers in the fishery. A random, single stage direct expansion survey (census) was used to estimate effort, catch, harvest,

ALASKA DEPARTMENT OF FISH AND GAME
VOLUNTARY CATCH REPORT CARD

Please fill out the information for the date written below.

Date _____ Litho code _____ Line # _____

Location _____

Time fishing started _____ am pm Ended _____ am pm

	Fish Released	Kept		Fish Released	Kept
King Salmon	_____	_____	Pink Salmon	_____	_____
Red Salmon	_____	_____	Chum Salmon	_____	_____
Rainbow Trout	_____	_____	Grayling	_____	_____
Coho Salmon	_____	_____	Dollies/Char	_____	_____

Other species caught, or comments, suggestions.

You may return card to nearby ADFG camp or by mail. Thank you for your help!

Figure 3. Voluntary angling report card used in the 1991 lower Nushagak and middle Mulchatna chinook salmon sport fishery creel surveys.

and harvest distribution. The sampling intensity was set at three, 24-hour (0001 to 2359 hours) sample days per 7-day week from the 15 day study period.

To obtain completed-trip interviews in sublocation 001, all anglers were interviewed as they exited the fishery during a sampling day. The completed-trip interviews provided total observed number of anglers, effort, catch, and harvest on sampled days. The mean daily effort, catch, and harvest was then expanded by the number of days in the study period to produce estimates of total effort, catch, and harvest.

As for the roving surveys, information from angler interviews was also used to estimate the distribution of catches and harvests of chinook salmon by angler-day on sublocation 001. Counts of the number of exiting anglers were also used in estimating these percentages in order to obtain sample weights.

The two technicians sharing work at sublocations 001 and 002 were able to adjust their interview and sampling activities to achieve a reasonable working day while thoroughly covering the 24-hour sampling day at sublocation 001. In the course of conducting interviews, the technicians sampled harvested fish encountered for biological data.

Creel Survey Data Analysis

Distributions of Angler Catches and Harvests:

Angler success was measured by the distribution of catches or harvests as defined as the fraction p_k of angler-days in which "k" or more fish were harvested, then "k" could be expressed as $k = 1$ to k_{max}. If $k_{max} = 5$, then one set of data was analyzed five times to obtain all possible fractions p_k in a set. Because there was a set of p_k's for both catch and harvest, there were two sets of p_k's. Additionally, we defined p_k for $k = 0$ to be the proportion of angler-days that resulted in the catch or harvest of zero fish.

The first step was to code the data prior to calculation. The coding was necessary because not all sampling periods (days) were the same "size": more anglers fished during some days than others. Ignoring these differences in "size" would have promoted bias in estimates of angler success when statistics were then averaged across days. The coding adjusted for this possible discrepancy (Sukhatme et al. 1984). After coding, standard two-stage estimation procedures (Cochran 1977) were used to estimate the various proportions, their variances, and standard errors.

Roving Surveys. Sample weight codes for the roving survey had to be estimated from the count and interview data since we did not have a direct measure of the number of angler-trips occurring during each sampled day. Specific estimation equations are presented in detail in Appendix A1.

Direct Expansion Survey. Sample weights were not estimated for the direct expansion survey, since the number of angler-days within each sampled day was known from the counts of exiting anglers. The estimation equations used to estimate the distribution of catches and harvests were otherwise similar to those used for the roving survey. Specific differences are detailed in Appendix A2.

Bag Limit Analysis. Interview data were used to calculate the percent of interviewed anglers taking daily bags of zero, one, two, or three fish at each site. The percent of harvest represented by the first, second, or third fish harvested among all completed-trip anglers was also calculated for each site. Both analyses used only the numbers of anglers and numbers of harvested chinook salmon recorded in the completed-trip interviews. No statistical methods were used to expand for all anglers participating in the fishery or for days during the survey period when no interviews were conducted.

Percent of Harvest by Angler and Terminal Tackle Types:

Estimates of the percentage of harvest of chinook salmon by angler type and terminal tackle type were obtained by the same procedures for both the roving and direct expansion creel surveys. The goal was to estimate the relative percentage of the harvest obtained by angler type (guided or unguided) and by anglers using various gear types (lures, flies, or bait). The estimates were obtained by identifying harvested fish observed in the creel survey as caught by the various categories involved, and then estimating the percentage by type. Specific calculating equations are presented in Appendix A3.

Angler Effort, Catch, and Harvest:

Two types of surveys, roving and direct expansion, were used to estimate selected fishery parameters during the peak of the day and peak of the fishing season. The procedures for estimating these parameters differ dependent upon the type of survey as described below.

Roving Surveys. A random estimator was used to estimate angler effort on a sampled peak-of-the-day basis. Catch and harvest estimates for each sampled day were obtained by a ratio estimator: by combining the estimated effort (for the peak-of-the-day) with estimates of catch per unit effort (CPUE) and harvest per unit effort (HPUE) obtained from the angler interviews. The CPUE and HPUE estimates were obtained by the jackknife estimation approach (Efron 1982). The jackknife approach for estimating CPUE and HPUE was appropriate since most other estimators are known to be biased (for use as ratio estimators, i.e., for expansion), and the jackknife estimate has been shown to be less biased and procedures exist for correcting some of this bias (see Cochran 1977, section 6.15, pages 174-177; and Smith 1980).

The individual sample estimates of peak-of-the-day effort, catch, and harvest were then used in a stratified two-stage estimation approach to obtain total estimates for the peak of the season for each fishery, as outlined in Appendix A4.

Direct Expansion Survey. The procedures used to estimate the angler effort, catch, and harvest parameters for the direct expansion creel survey are outlined in Appendix A5. These procedures involved the expansion of sample means by the sizes of the populations involved (i.e., means across anglers multiplied by the number of anglers counted exiting the fishery, then means across day multiplied by the number of days in the fishery).

Assumptions:

The following assumptions were necessary for unbiased point and variance estimates obtained in the procedures outlined above.

Roving Surveys. The assumptions for the roving surveys included:

1. interviewed anglers accurately reported their hours of fishing effort and the number of fish by species released;

2. interviewed anglers were representative of the total angler population;

3. the sampled harvest each day was representative of the distribution of harvest among "angler types" (for unbiased estimates of proportion of harvest by terminal tackle type and angler type);

4. the fisheries did not "behave" differently during hours of the day not surveyed (for unbiased catch and harvest distribution and proportional harvest estimates); and

5. catch and harvest rate and duration of fishing trip were independent (DiCostanzo 1956).

Direct Expansion Survey. The assumptions for the direct expansion survey included:

1. interviewed anglers accurately reported their hours of fishing effort and the number of fish released; and

2. all anglers participating in the defined fishery exited the fishery through the surveyed access site.

Sex, Age, Length, and Weight Sampling Study Design and Data Collection

Sport harvested chinook salmon encountered during the angler interview portion of the creel surveys were measured to the nearest millimeter for mid-eye to fork-of-tail length, weighed to the nearest 100 grams, and the sex was identified by external characteristics. In addition, three scales were removed from the preferred area[1] and mounted on an adhesive-coated card. The cards with the scales were pressed onto acetate cards in a heated hydraulic press. The resulting scale impressions were displayed on a microfiche projector for age determination[2].

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[1] The left side of the fish approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin as used on sockeye salmon by Clutter and Whitesel (1956).

[2] For salmon, the numeral preceding the decimal is the number of the 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.

Scale collection and age determination followed the same procedure used by Clutter and Whitesel (1956) for sockeye salmon.

Sex, Age, Length, and Weight Data Analysis

The data from sport harvested chinook salmon sampled in each location were combined to calculate the estimated mean length and weight (and associated standard errors) by sex and age group using the procedures outlined by Sokal and Rohlf (1981, Boxes 4.2 and 7.1, pages 56 and 139). The procedures were the same regardless of the type of survey and in the calculations we ignored the two-stage nature of the sampling program, and assumed that length or age composition did not change among days for the peak of each fishery.

Age composition (by sex and by both sexes combined), and associated standard errors, were first estimated for each survey site. Each percentage was calculated according to the standard procedures for estimating a binomial parameter (see Cochran 1977, equation 3.3, page 51). Variances of the estimated percentages were calculated from the standard equation for the variance of a binomial proportion (Cochran 1977, equation 3.8, page 52). In applying the procedures outlined in Cochran (1977) the estimated harvest (obtained by equation A3.7, Appendix A3, for the roving survey and equation A4.4, Appendix A4, for the direct expansion survey) was used in calculating the finite population correction (FPC) factor (i.e., the "N" term in Cochran's equation 3.8).

The estimated proportions and associated standard errors by sex and age class from each site were weighted by the site's proportion of the total estimated harvest. The adjusted proportions and standard errors for each sex and age class were summed across all sites to produce the overall estimated age composition of the sport harvested chinook salmon.

RESULTS

Catch and Harvest Distribution

There were no significant (α = 0.05) differences between the estimates of the distribution of catch and harvest of chinook salmon at Portage Creek, Ekwok, and the mouth of the Stuyahok River (Figures 4, 5, and 6, and Tables 2, 3, and 4). Anglers with catches of one or more fish ranged from 59.8% (SE = 5.0) at Portage Creek to 71.3% (SE = 9.9) at sublocation 001. Anglers harvesting one or more fish per trip ranged from a low of 36.3% (SE = 5.2) at Portage Creek to 58.5% (SE = 11.5) at Ekwok. No anglers reported trips with catches exceeding six fish or harvests exceeding two fish in the Ekwok area (Figure 5, Table 3).

The mid-Mulchatna River sublocation 002 had catch and harvest distributions that differed (α = 0.05) from the other three locations (Figure 7, Table 5). Angler success was extremely high with 94.9% (SE = 7.1) of the angler-trips catching at least one chinook salmon (Table 5). A large percentage of the angler-trips had multiple catches at the site with 16.5% (SE = 4.9) reporting 12 or more fish caught per daily trip (Figure 7, Table 5). Among the anglers who harvested fish, 78.2% (SE = 9.8) took one or more fish and 20% (SE = 5.4)

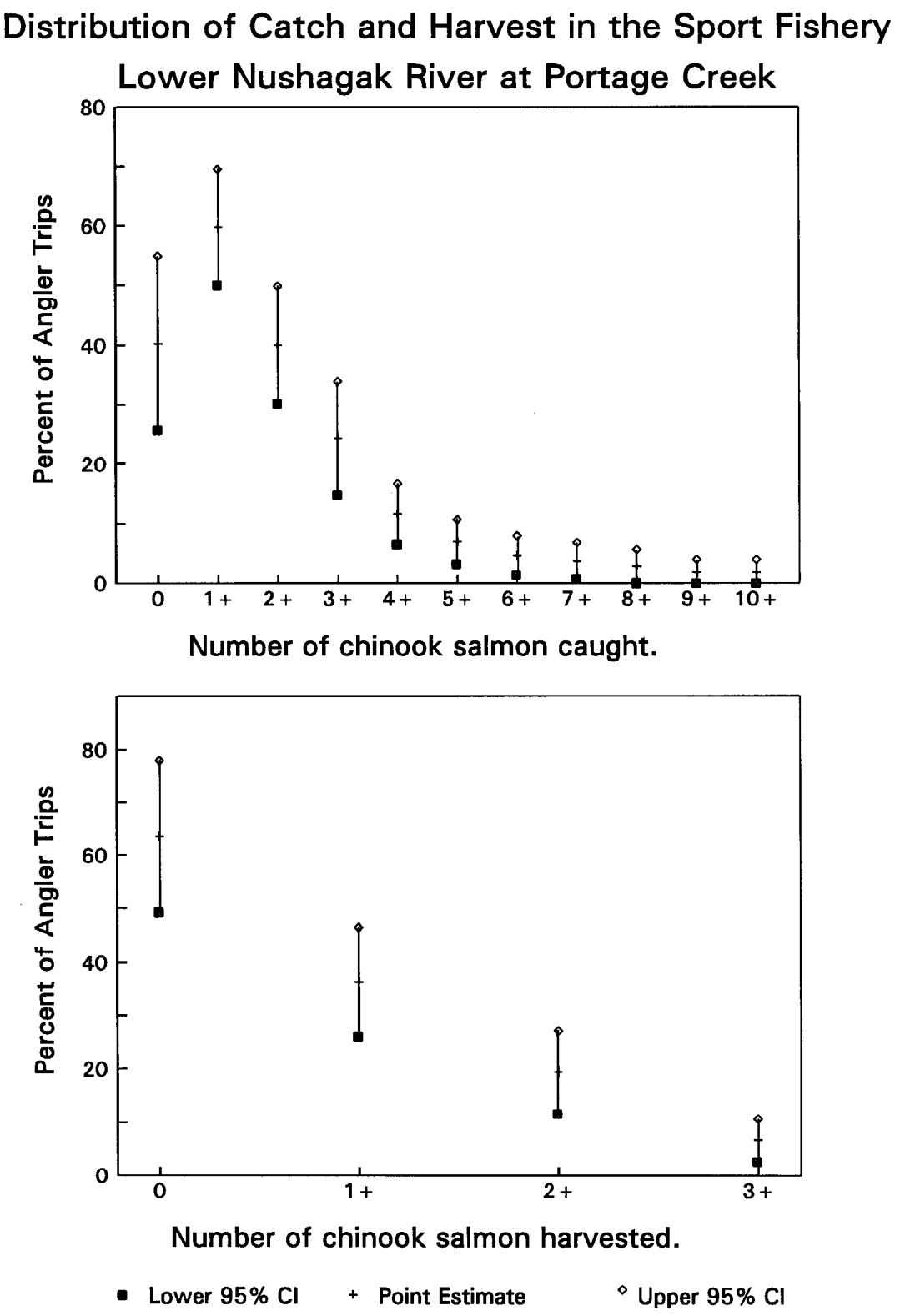


Figure 4. Distribution of catch and harvest in the sport fishery for chinook salmon on the lower Nushagak River at Portage Creek, 1991.

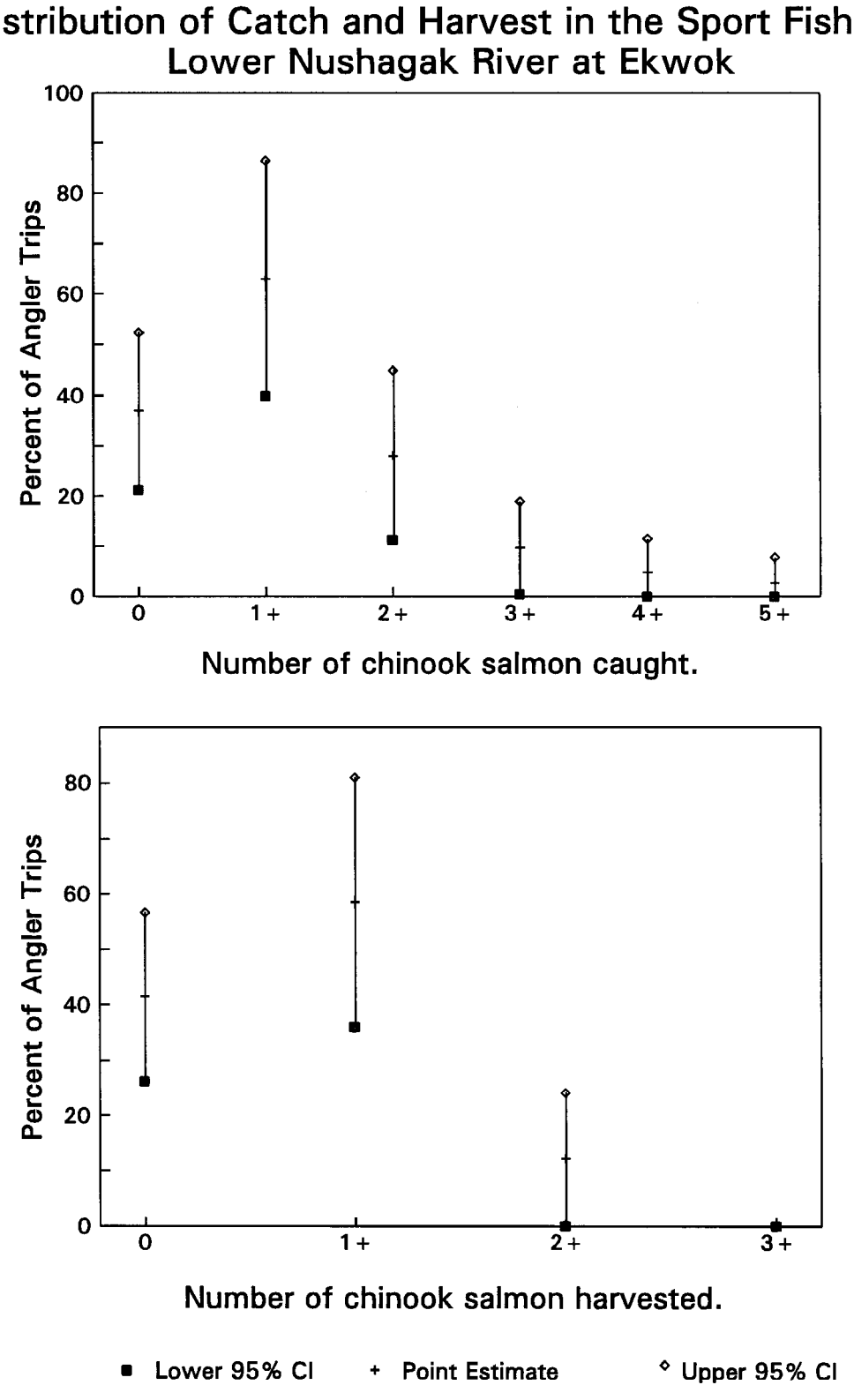


Figure 5. Distribution of catch and harvest in the sport fishery for chinook salmon on the lower Nushagak River at Ekwok, 1991.

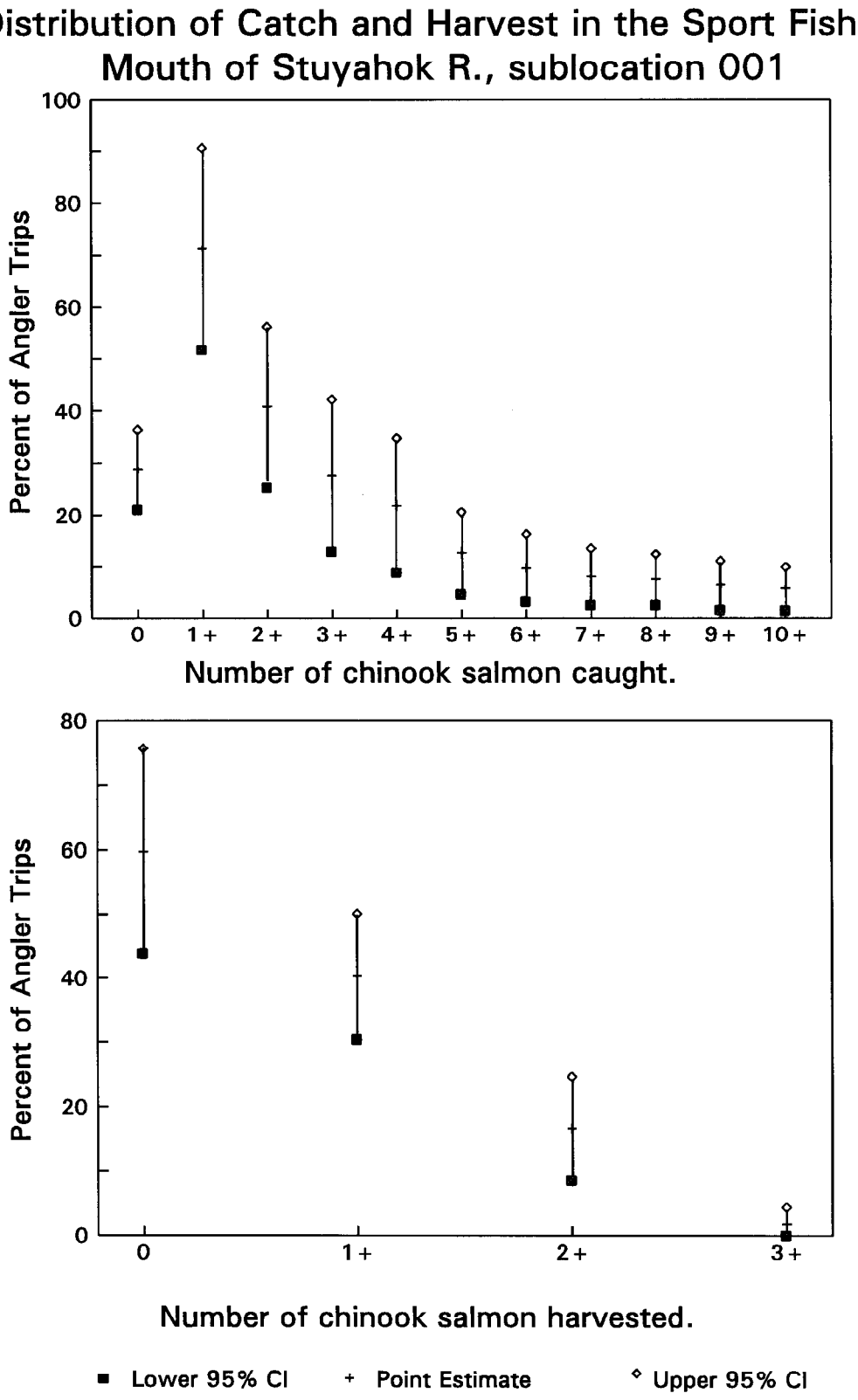


Figure 6. Distribution of catch and harvest in the sport fishery for chinook salmon on the mid-Mulchatna River at the mouth of the Stuyahok River (sublocation 001), 1991.

Table 2. Distribution of catch and harvest of chinook salmon by angler-trip in the sport fishery on the lower Nushagak River at Portage Creek, 1991.

	Catch				Harvest[a]			
Number of Fish	Percent of Trips	SE	95% Confidence Interval lower	upper	Percent of Trips	SE	95% Confidence Interval lower	upper
0	40.2	7.4	25.7 -	54.8	63.7	7.3	49.3 -	78.0
1+	59.8	5.0	50.0 -	69.5	36.3	5.2	26.1 -	46.6
2+	40.0	5.0	30.2 -	49.8	19.5	3.9	11.8 -	27.2
3+	24.3	4.9	14.8 -	33.9	6.7	2.0	2.8 -	10.7
4+	11.6	2.5	6.6 -	16.6				
5+	7.0	1.9	3.3 -	10.7				
6+	4.7	1.7	1.5 -	8.0				
7+	3.8	1.6	0.7 -	6.8				
8+	2.9	1.4	0.1 -	5.7				
9+	1.8	1.1	0.0 -	4.0				
10+	1.8	1.1	0.0 -	4.0				

[a] Harvest limit was three chinook salmon per day, only two of which may exceed 71 cm (28 inches) in length.

Table 3. Distribution of catch and harvest of chinook salmon by angler-trip in the sport fishery on the lower Nushagak River at Ekwok, 1991.

	Catch				Harvest[a]			
Number of Fish	Percent of Trips	SE	95% Confidence Interval lower	upper	Percent of Trips	SE	95% Confidence Interval lower	upper
0	36.8	8.0	21.2 -	52.4	41.5	7.8	26.3 -	56.7
1+	63.2	11.9	39.9 -	86.4	58.5	11.5	36.1 -	81.0
2+	28.0	8.6	11.2 -	44.9	12.1	6.1	0.1 -	24.2
3+	9.6	4.7	0.4 -	18.9	0.0	0.0	0.0 -	0.0
4+	4.8	3.4	0.0 -	11.4				
5+	2.6	2.6	0.0 -	7.7				

[a] Harvest limit was three chinook salmon per day, only two of which may exceed 71 cm (28 inches) in length.

Table 4. Distribution of catch and harvest of chinook salmon by angler-trip in the sport fishery at the mouth of the Stuyahok River (sublocation 001), 1991.

	Catch			Harvest[a]		
Number of Fish	Percent of Trips	SE	95% Confidence Interval lower - upper	Percent of Trips	SE	95% Confidence Interval lower - upper
0	28.7	3.9	21.1 - 36.3	59.8	8.1	43.9 - 75.7
1+	71.3	9.9	51.8 - 90.7	40.2	5.0	30.4 - 50.0
2+	40.8	7.9	25.4 - 56.2	16.7	4.1	8.6 - 24.7
3+	27.6	7.5	12.9 - 42.3	1.7	1.3	0.0 - 4.3
4+	21.8	6.6	8.9 - 34.8			
5+	12.6	4.1	4.7 - 20.6			
6+	9.8	3.3	3.2 - 16.3			
7+	8.0	2.8	2.5 - 13.6			
8+	7.5	2.5	2.5 - 12.4			
9+	6.3	2.4	1.6 - 11.1			
10+	5.7	2.1	1.5 - 9.9			

[a] Harvest limit was three chinook salmon per day, only two of which may exceed 71 cm (28 inches) in length.

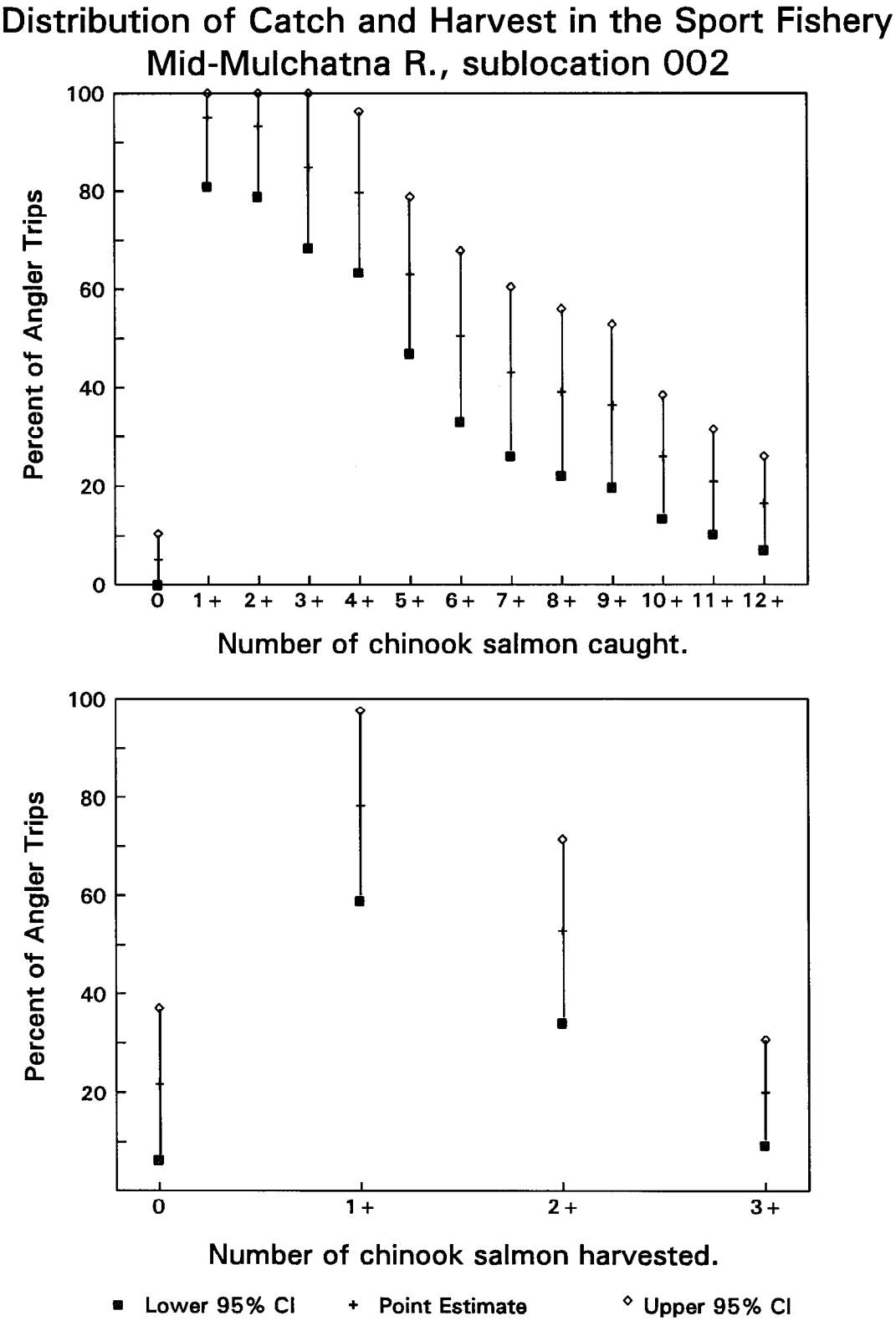


Figure 7. Distribution of catch and harvest in the sport fishery for chinook salmon on the mid-Mulchatna River at sublocation 002, 1991.

Table 5. Distribution of catch and harvest of chinook salmon by angler-trip in the sport fishery on the mid-Mulchatna River (sublocation 002), 1991.

	Catch				Harvest[a]			
	Percent		95% Confidence Interval		Percent		95% Confidence Interval	
Number of Fish	of Trips	SE	lower	upper	of Trips	SE	lower	upper
0	5.1	2.7	0.0 -	10.3	21.8	7.9	6.4 -	37.2
1+	94.9	7.1	81.0 -	100.0	78.2	9.8	59.0 -	97.5
2+	93.2	7.3	78.9 -	100.0	52.8	9.5	34.2 -	71.3
3+	84.7	8.3	68.5 -	100.0	20.0	5.4	9.4 -	30.6
4+	79.8	8.4	63.4 -	96.2				
5+	62.9	8.1	47.0 -	78.8				
6+	50.5	8.9	33.1 -	67.9				
7+	43.3	8.8	26.1 -	60.5				
8+	39.1	8.7	22.1 -	56.1				
9+	36.4	8.5	19.8 -	53.1				
10+	26.0	6.4	13.5 -	38.5				
11+	20.9	5.4	10.3 -	31.5				
12+	16.5	4.9	7.0 -	26.0				

[a] Harvest limit was three chinook salmon per day, only two of which may exceed 71 cm (28 inches) in length.

harvested the full daily bag limit of three chinook salmon (Figure 7, Table 5).

Bag Limit Analysis

As with the catch and harvest distributions, anglers at Portage Creek, Ekwok, and the mouth of the Stuyahok River showed similar harvest patterns. Most successful anglers interviewed at these locations harvested only one or two fish per day and 58% to 84% of the total reported harvest was a result of the first fish harvested by each angler (Figures 8, 9, and 10). On the other hand, anglers interviewed in sublocation 002 of the mid-Mulchatna River were much more consumptive with only 14% harvesting no fish and 26% taking the full three fish bag limit (Figure 11).

Estimates of Harvest by Angler and Gear Types

Guided anglers fishing during the peak time of day in the peak of the season harvested the majority of the chinook salmon throughout the fishery, with the exception of the anglers at the mouth of the Stuyahok River where unguided anglers accounted for 93% (SE = 3) of the harvest (Figures 12, 13, 14, and Table 6). Artificial lures were the preferred gear type for the fishery. Harvest levels by anglers using lures ranged from 46% (SE = 10) at Portage Creek to 100% (SE = trace) at both Ekwok and sublocation 002 of the mid-Mulchatna River (Figures 12, 13, 14, and Table 7). Unfortunately, the type of gear was not recorded for an estimated 48% of the harvests at Portage Creek (Figure 12, Table 7). It is doubtful that the harvests by unrecorded gear types departed substantially from those that were recorded.

Angler Effort, Catch, and Harvest

All estimates of effort, catch, and harvest apply only for the peak time of day during the peak of the chinook salmon fishery at each survey site. Estimates of effort ranged from a high of 5,470 angler-hours (SE = 372) at the Portage Creek site, to a low of 862 angler-hours (SE = 102) at the Ekwok site. (Table 8). The combined estimates of effort for all sites was 11,880 angler-hours (Table 8). Catch estimates ranged from 2,703 fish (SE = 337) at sublocation 002 of the mid-Mulchatna River to 126 fish (SE = 31) at Ekwok (Table 9). The combined estimated catch for both sites on the mid-Mulchatna River was 3,643 fish (SE = 401) and the catch for the lower Nushagak plus the mid-Mulchatna surveys was 5,234 fish (SE = 453) (Table 9). The harvest estimates were nearly identical at Portage Creek (585, SE = 104) and sublocation 002 (589, SE = 85) (Table 9). An estimated 255 chinook salmon (SE = 38) were harvested in sublocation 001 and only 83 fish (SE = 20) were harvested by the anglers around Ekwok (Table 9). The highest rate of harvest, expressed as a percentage of the fish caught, was 66% observed in the Ekwok fishery followed by 40% at Portage Creek (Table 9). The combined rate of harvest in the two mid-Mulchatna locations was 23% (Table 9).

In addition to chinook salmon, anglers reported catches of several other species. The incidental species most frequently caught included chum salmon, sockeye salmon, and rainbow trout. Anglers near Portage Creek caught an estimated 175 (SE = 73) chum salmon and 179 (SE = 90) sockeye salmon while harvests were estimated to be very limited (Table 10). Within the Ekwok survey, reported catches and harvests of other species were so infrequent that

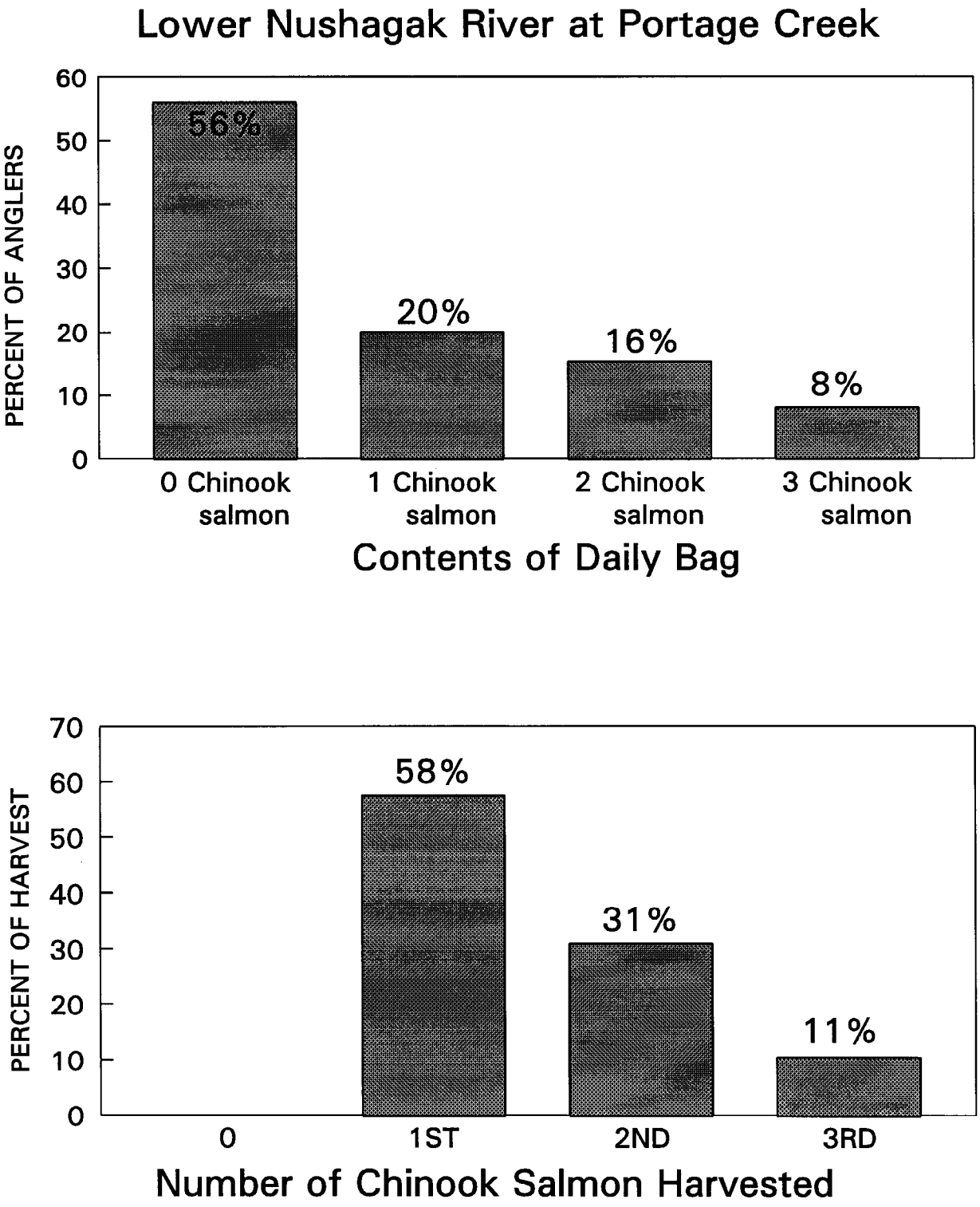


Figure 8. Contents of daily bags and contribution to the overall harvest of the first, second, and third chinook salmon harvested by all anglers who were interviewed upon completing a day of fishing on the lower Nushagak River at Portage Creek, 1991.

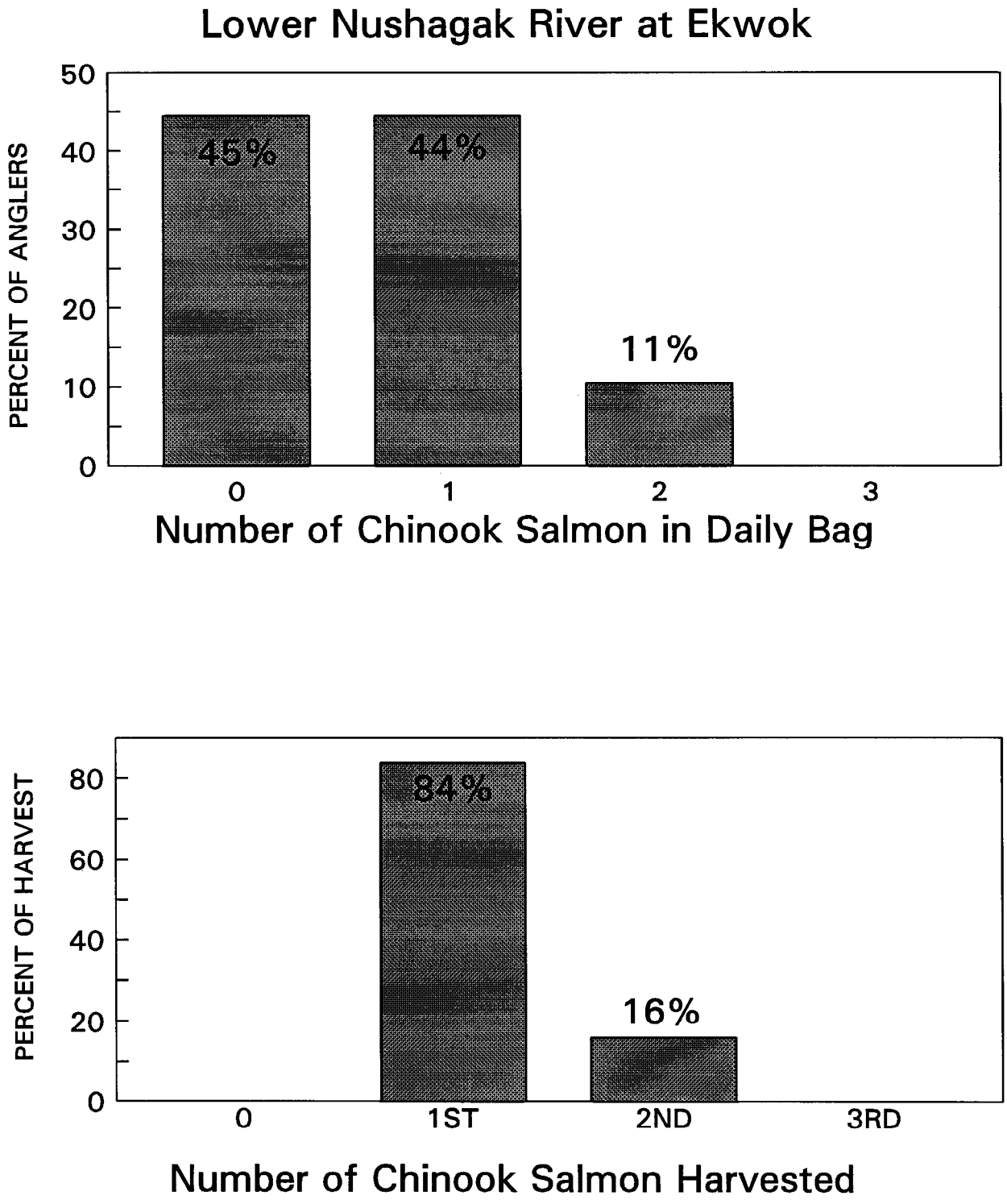
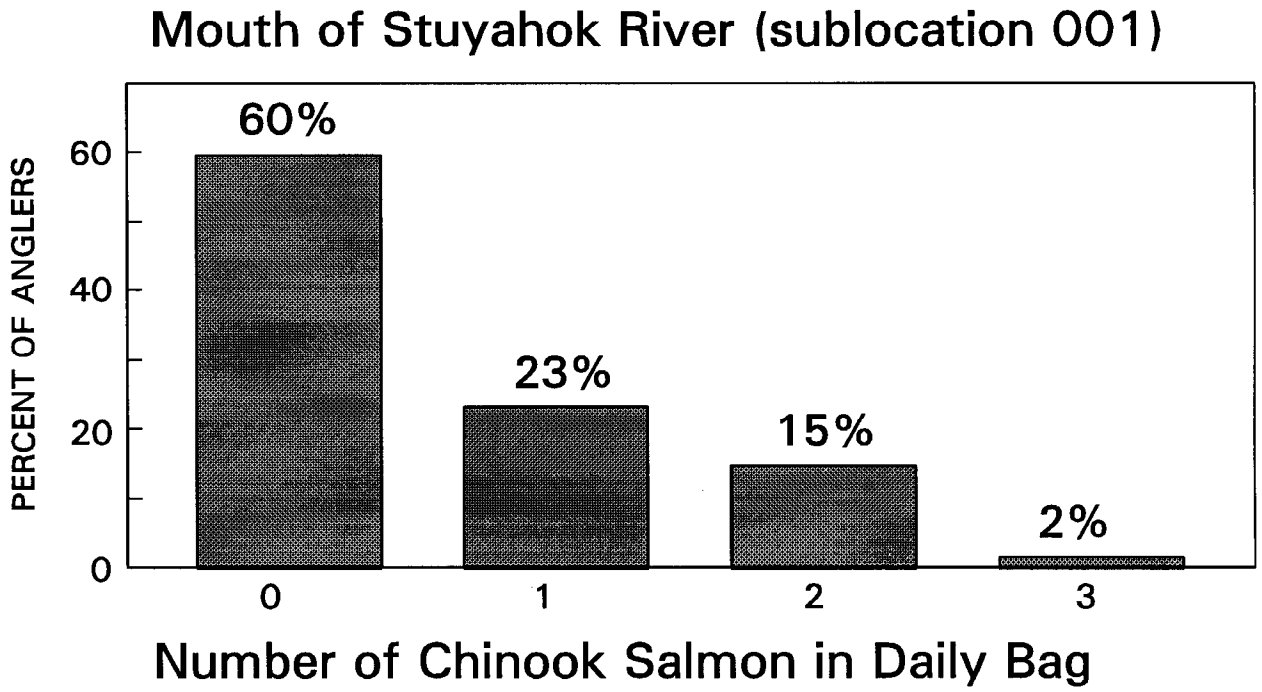


Figure 9. Contents of daily bags and contribution to the overall harvest of the first, second, and third chinook salmon harvested by all anglers who were interviewed upon completing a day of fishing on the lower Nushagak River at Ekwok, 1991.



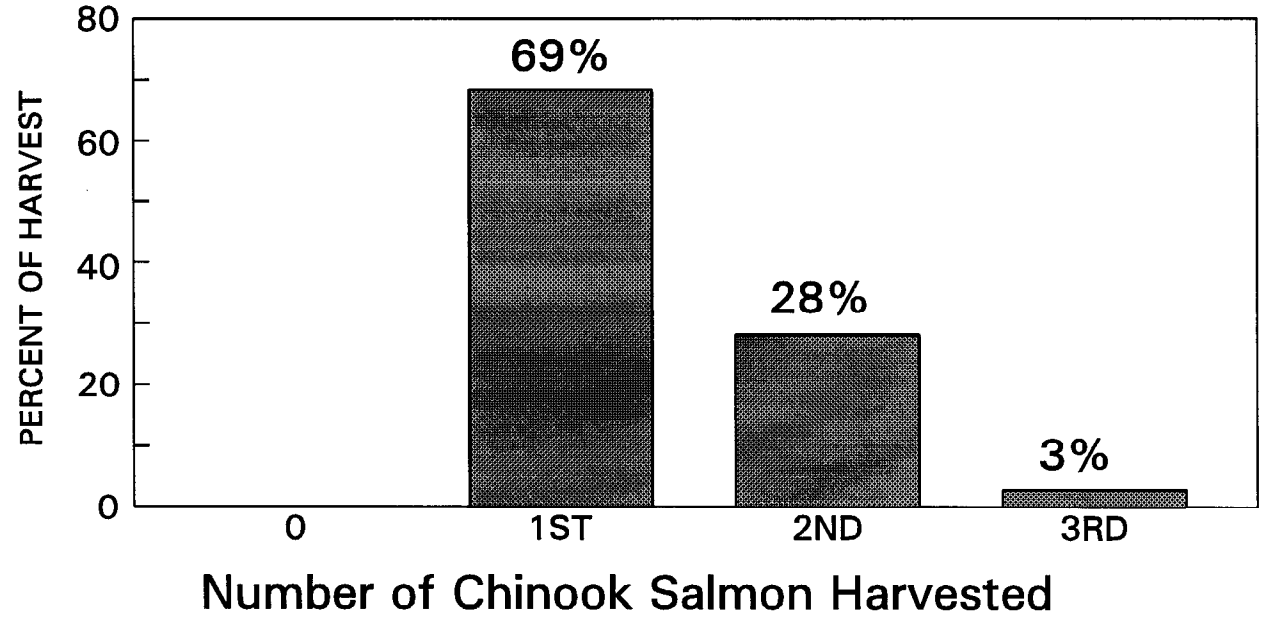


Figure 10. Contents of daily bags and contribution to the overall harvest of the first, second, and third chinook salmon harvested by all anglers who were interviewed upon completing a day of fishing on the mid-Mulchatna River at the mouth of the Stuyahok River (sublocation 001), 1991.

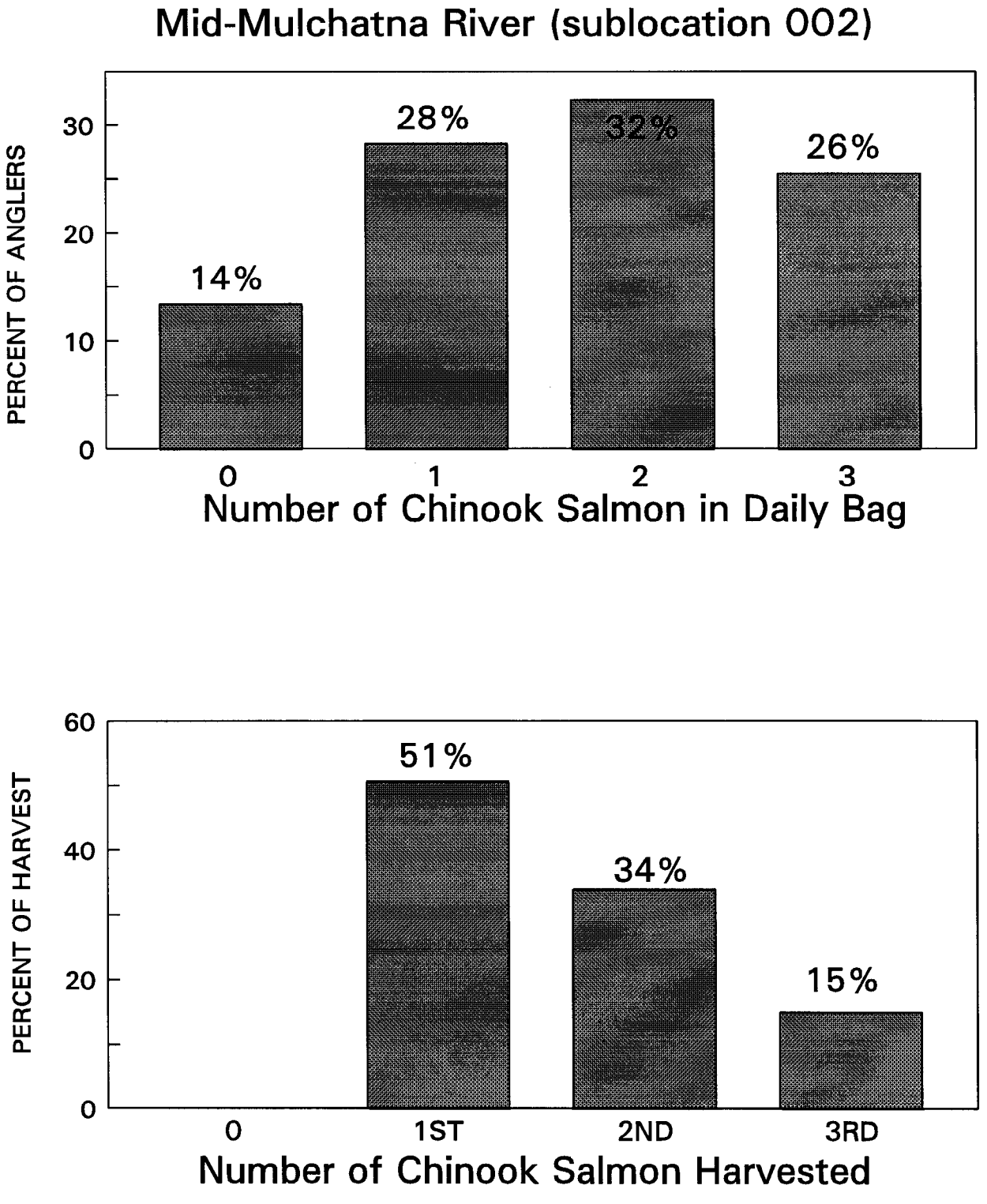


Figure 11. Contents of daily bags and contribution to the overall harvest of the first, second, and third chinook salmon harvested by all anglers who were interviewed upon completing a day of fishing on the mid-Mulchatna River at sublocation 002, 1991.

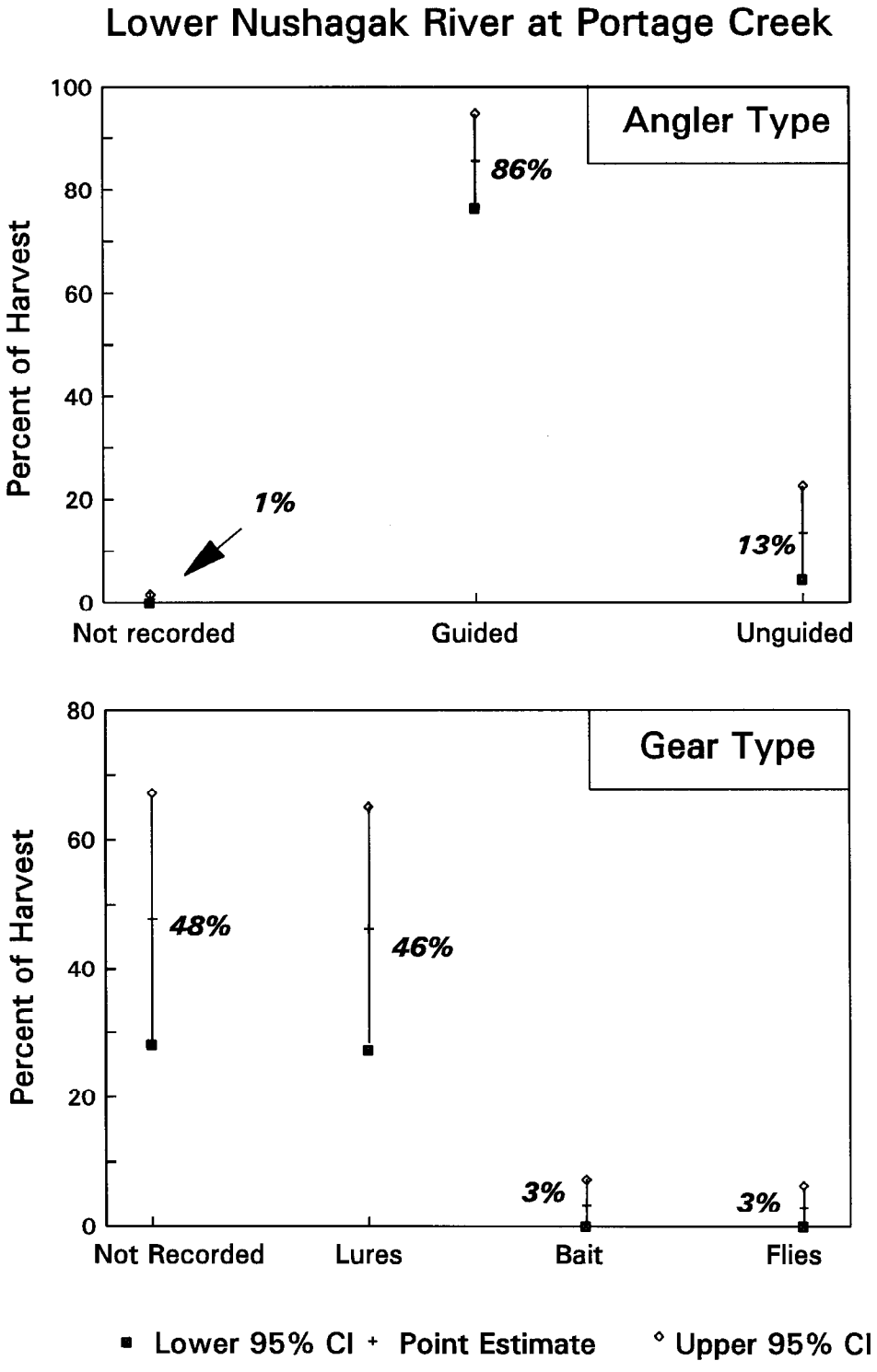


Figure 12. Percent of harvest by guided and unguided anglers and gear type in the chinook salmon sport fishery on the lower Nushagak River at Portage Creek, 1991.

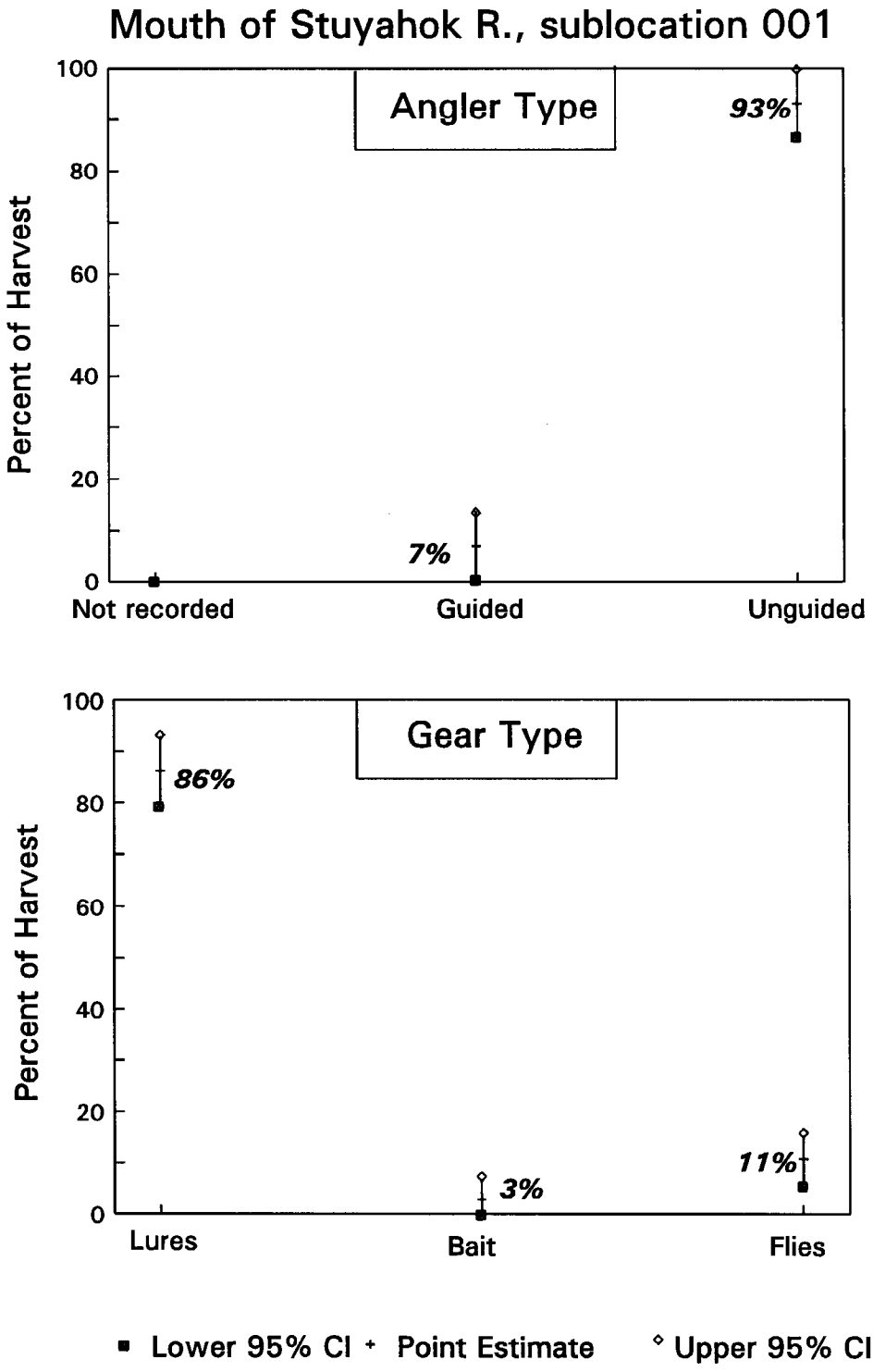


Figure 13. Percent of harvest by guided and unguided anglers and gear type in the chinook salmon sport fishery on the mid-Mulchatna River at the mouth of the Stuyahok River (sublocation 001), 1991.

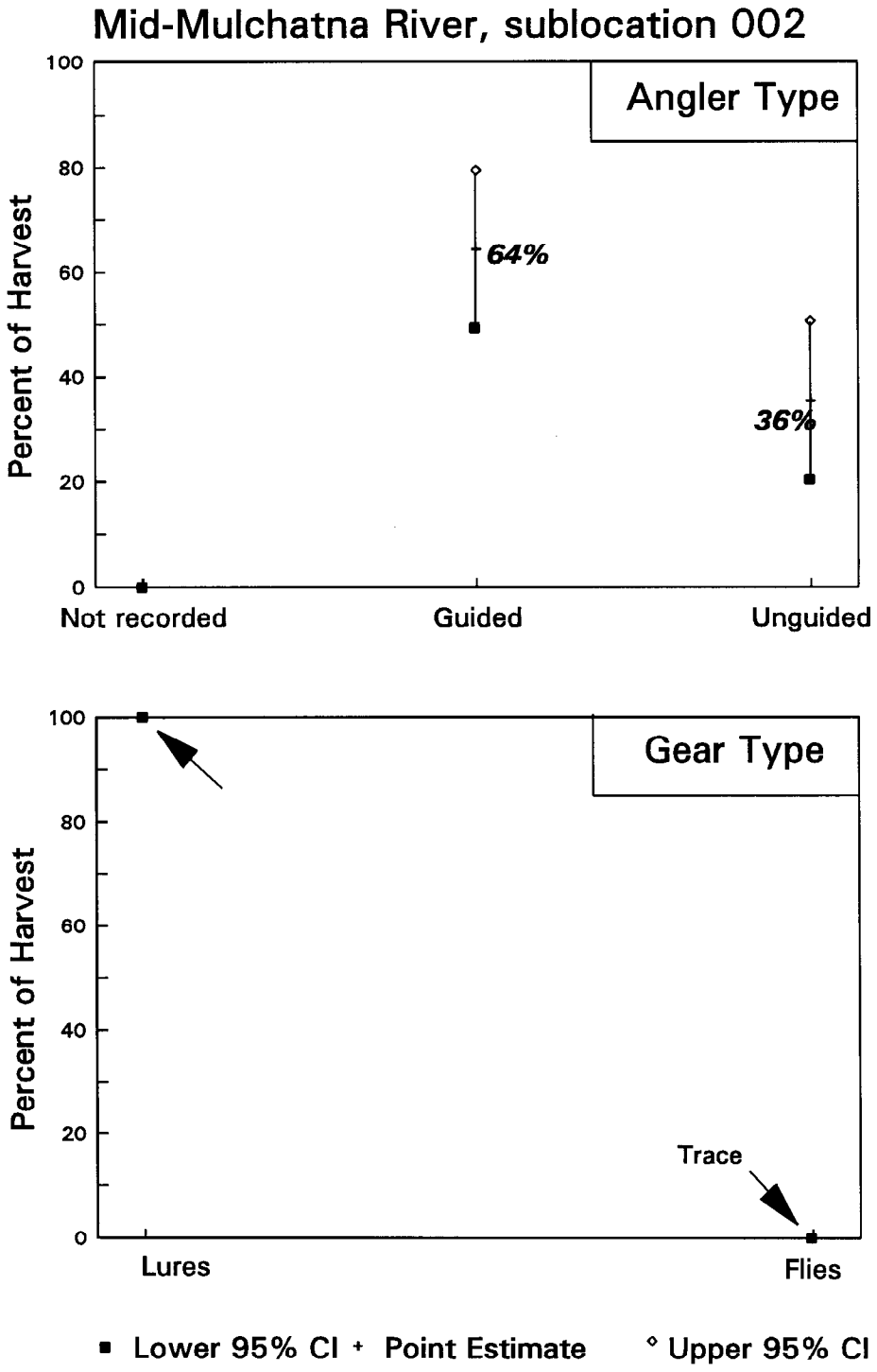


Figure 14. Percent of harvest by guided and unguided anglers and gear type in the chinook salmon sport fishery on the mid-Mulchatna River at the mouth of sublocation 002, 1991.

Table 6. Percent of chinook salmon harvested by angler type in the sport fisheries on the lower Nushagak River and mid-Mulchatna River, 1991.

Location	Angler Type	Percent Harvested	Standard Error (%)	95% Confidence Interval Lower	Upper
Lower Nushagak R. at Portage Creek					
	Not recorded	1	<1	0.0	1.5
	Guided	86	5	76.5	94.9
	Unguided	13	5	4.5	22.8
Lower Nushagak R. at Ekwok					
	Not recorded	trace	trace	---	---
	Guided	100	0	100.0	100.0
	Unguided	0	0	0.0	0.0
mid-Mulchatna River					
mouth of Stuyahok R. (sublocation 001)					
	Guided	7	3	0.3	13.5
	Unguided	93	3	86.5	99.7
mid-Mulchatna R. (sublocation 002)					
	Not recorded	trace	trace	---	---
	Guided	64	8	49.3	79.6
	Unguided	36	8	20.5	50.7

Table 7. Percent of chinook salmon harvested by gear type in the sport fisheries on the lower Nushagak River and mid-Mulchatna River, 1991.

Location	Gear Type	Percent Harvested	Standard Error	95% Confidence Interval Lower	Upper
Lower Nushagak R. at Portage Creek					
	Not recorded	48	10	28.1	- 67.2
	Lures	46	10	27.3	- 65.0
	Bait	3	2	0.0	- 7.2
	Flies	3	2	0.0	- 6.3
Lower Nushagak R. at Ekwok					
	Not recorded	trace	trace	---	---
	Lures	100	trace	100.0	- 100.0
	Bait	trace	trace	---	---
mid-Mulchatna River					
mouth of Stuyahok R. (sublocation 001)					
	Lures	86	3	79.4	- 93.1
	Bait	3	2	0.0	- 7.4
	Flies	11	3	5.7	- 15.9
mid-Mulchatna R. (sublocation 002)					
	Lures	100	trace	100.0	- 100.0
	Flies	trace	trace	---	---

Table 8. Estimates of effort (angler-hours) for the peak of the season, and peak time of day, in the sport fishery on the lower Nushagak and middle Mulchatna Rivers, 1991.

Location and Survey Dates	Days Sampled	Effort: Estimated Angler-Hours	SE	95% Confidence Interval: Lower	Upper	Relative Precision[a]
Lower Nushagak River at Portage Creek						
6/22-7/7	11	5,470	372	4,740	6,200	13%
Lower Nushagak River at Ekwok						
7/8-7/21	9	863	102	664	1,062	23%
Mid-Mulchatna River						
mouth of Stuyahok R. (sublocation 001)						
7/1-7/15	6	2,394	388	1,634	3,154	32%
mid-Mulchatna R.(sublocation 002)						
7/1-7/15	11	3,153	198	2,765	3,540	12%
Total All Sites	37	11,880	582	10,739	13,021	10%

[a] Relative precision = (1.96*SE/Point Estimate) * 100 where $\alpha = 0.05$.

Table 9. Estimates of catch and harvest of chinook salmon for the peak of the season, and peak time of day, in the sport fishery on the lower Nushagak and middle Mulchatna Rivers, 1991.

	Catch					Harvest					
Survey Dates	Number of fish	SE	95% Confidence Interval Lower	Upper	Relative Precision[a]	Number of fish	SE	95% Confidence Interval Lower	Upper	Relative Precision[a]	Percent of Catch Harvested
Lower Nushagak River at Portage Creek											
6/22-7/7	1,474	208	1,067	1,882	28%	585	104	381	789	35%	40%
Lower Nushagak River at Ekwok											
7/8-7/21	126	31	64	188	49%	83	20	44	122	47%	66%
Mid-Mulchatna River											
mouth of Stuyahok R. (sublocation 001)											
7/1-7/15	940	218	513	1,367	45%	255	38	181	329	29%	27%
mid-Mulchatna R. (sublocation 002)											
7/1-7/15	2,703	337	2,043	3,363	24%	589	85	422	756	28%	22%
Total All Sites	5,243	453	4,356	6,130	17%	1,512	141	1,235	1,789	18%	29%

[a] Relative precision = (1.96*SE/Point Estimate) * 100 where $\alpha = 0.05$.

Table 10. Estimates of catch and harvest of chum and sockeye salmon, and rainbow trout for the peak of the season, and peak time of day, in the sport fishery on the lower Nushagak and middle Mulchatna Rivers, 1991.

Location, Date, and Species	Catch					Harvest				
	Number of Fish	SE	95% Confidence Interval Lower	Upper	Relative Precision[a]	Number of Fish	SE	95% Confidence Interval Lower	Upper	Relative Precision[a]
Lower Nushagak River at Portage Creek										
6/22-7/7										
Chum Salmon	175	73	31	319	3	16	9	0	33	22%
Sockeye Salmon	179	90	3	355	2	26	21	0	66	10%
Lower Nushagak River at Ekwok										
7/8-7/21										
No significant numbers of other fish were caught or kept during the survey.										
Mid-Mulchatna River										
7/1-7/15										
Chum Salmon										
mouth of Stuyahok R. (sublocation 001)	213	62	92	334	3	13	8	0	28	26%
mid-Mulchatna R. (sublocation 002)	57	44	0	144	4	4	4	0	12	49%
Total	270	76	121	419	3	17	9	0	34	23%
Rainbow Trout										
mouth of Stuyahok R. (sublocation 001)	135	30	75	195	6	25	8	10	4	25%
mid-Mulchatna R. (sublocation 002)	101	26	49	153	7	5	4	0	13	49%
Total	236	40	157	315	5	30	9	13	47	22%

[a] Relative precision = (1.96*SE/Point Estimate) * 100 where $\alpha = 0.05$.

no estimates were generated. The two mid-Mulchatna locations produced a combined catch estimate of 270 (SE = 76) chum salmon and 236 (SE = 40) rainbow trout (Table 10). The great majority of chum salmon came from site 001. The estimated harvests of chum salmon and rainbow trout were very low in both mid-Mulchatna River fisheries (Table 10).

Sex, Age, Length, and Weight Composition.

Biological data were collected at all sites from a total of 350 sport harvested chinook salmon. Males made up 65.5% (SE = 4.91) of the fish harvested during the surveys (Table 11). Over 41% of the fish were age class 1.3 and 38% were age class 1.4. The mean length for both sexes was 742 mm (SE = 7.65) and the mean weight was 7.5 kg (SE = 0.21) (Table 11). The largest chinook salmon observed was taken in sublocation 002 of the mid-Mulchatna River and measured 860 mm (34 in) long and weighed 22.2 kg (48.8 lb).

Computerized data files used to generate these analyses are listed in Appendix B.

DISCUSSION

The 1991 surveys were the most extensive ever conducted on the Nushagak and Mulchatna River drainage chinook salmon sport fishery. Unlike previous surveys that focused on estimates of effort, catch, and harvest, the 1991 surveys were designed to obtain more information about anglers' relative success, the nature of the participants, the characteristics of anglers' harvests, and anglers' choice of gear during the peak time of day at the peak of the fishery.

The distributions of catches and harvests are one way to compare angler success among fishing sites. Anglers using sublocation 002 of the mid-Mulchatna clearly caught more fish per trip than the anglers at Ekwok (Figures 4 and 7, Tables 3 and 5). No anglers in the Ekwok area reported taking a daily bag limit though nearly 10% of the anglers had the opportunity to do so.

The analyses of anglers' bags provide information similar to the catch and harvest distribution, but it can help managers choose the most effective regulations for a fishery. For instance, reducing the drainage-wide bag limit from three to two chinook salmon per day would have affected 26% of the anglers using sublocation 002 of the mid-Mulchatna River while only reducing the harvest by 11% to 15% on parts of the system (Figures 8, 9, 10, and 11). It is important to realize that these analyses only apply to the observed harvests of anglers who were interviewed and cannot be used to predict how angler behavior might change with altered regulations.

The analysis of harvest by angler type increases our understanding of who harvested fish. Guided anglers might be the most influenced by changes to bag limits at Portage Creek, Ekwok, and sublocation 002, since they harvested the majority of the fish from these areas (Table 6).

Table 11. Age composition (percent), mean length (millimeters), and mean weight (kilograms) of chinook salmon, by sex and age group from samples collected from the sport fishery on the lower Nushagak and mid-Mulchatna Rivers, 21 June to 21 July 1991.

	Age Group					
	UNKNOWN	1.2	1.3	1.4	1.5	TOTAL[a]
FEMALES						
Percent[b]		3.9	11.4	17.4	1.8	34.5
SE[c]		1.95	3.17	3.81	0.89	4.91
Sample Size		8	29	56	7	100
Mean Length[d]	854	578	729	844	862	797
SE[d]	13.04	18.99	19.76	18.38	24.89	13.34
Sample Size	10	8	28	55	7	108
Mean Weight[d]	10.0	3.7	6.6	10.5	10.1	8.9
SE[d]	0.53	0.26	0.44	0.31	0.87	0.3
Sample Size	10	8	29	56	7	110
MALES						
Percent[b]		13.0	30.0	20.6	1.9	65.5
SE[c]		3.39	4.72	4.07	1.44	4.91
Sample Size		35	94	68	6	203
Mean Length[d]	703	593	681	829	813	717
SE[d]	21.00	14.75	11.60	13.31	65.63	8.90
Sample Size	37	35	93	68	6	239
Mean Weight[d]	6.7	3.8	5.5	9.9	10.9	6.8
SE[d]	0.62	0.47	0.26	0.5	2.7	0.26
Sample Size	37	35	94	68	6	240
ALL SAMPLES						
Percent[b]		16.9	41.4	38.0	3.7	100.0
SE[c]		3.78	5.09	4.87	1.84	
Sample Size		43	123	124	13	303
Mean Length[d]	735	590	692	836	839	742
SE[d]	19.02	12.46	10.15	11.01	32.33	7.65
Sample Size	47	43	121	123	13	347
Mean Weight[d]	7.4	3.7	5.8	10.2	10.5	7.5
SE[d]	0.53	0.38	0.23	0.30	1.27	0.21
Sample Size	47	43	123	124	13	350

[a] Total includes both aged and unaged samples.

[b] Percent age composition are weighted by harvest estimated for each sample location.

[c] SE of percent age compositions are weighted and are the square root of the variance with the finite population correction factor applied.

[d] Estimated mean lengths, weights, and associated SE's are not weighted (i.e., estimated as if they were obtained through a simple random sampling design).

Investigation of harvest by gear type not only shows anglers' preferences but may be used for regulatory decisions as well. The infrequent use of flies or bait reported in all the surveys indicate that the prohibition of such gear would affect few anglers and would not significantly change the sport harvest (Table 7). On the other hand, regulations dealing with the use of artificial lures might affect nearly all anglers as well as the total harvest.

As mentioned above, the estimates of effort, catch, and harvest were developed to describe the sport fisheries during the surveys. Since the surveys did not include the entire season and only the peak time of day (1000 to 1800 hours), these estimates are not directly comparable to previous survey estimates or to the results of the statewide harvest surveys (Mills 1979-1991). The estimates do show that the Ekwok fishery is quite minor when compared to the other locations (Tables 8 and 9). The two mid-Mulchatna River fisheries are as intensive as the Portage Creek fishery and together account for a substantially greater catch, but the total harvests are very similar (Tables 8 and 9).

Several days during the Portage Creek survey were very foggy until late in the morning and the estimates for this fishery may be considered minimal. The fog prevented or delayed an unknown number of anglers from flying in to participate in the fishery. A few late arriving anglers were observed fishing beyond the conclusion of the sampling day at 1800 hours (6:00 p.m.). Effort, catch, and harvest recorded by anglers returning the voluntary report cards were included in the estimates and may have included some of the late activity. However, so few completed cards were returned from the Portage Creek fishery that the data from them did not contribute much to the estimates.

Nearly one half of the returned cards from all locations were improperly marked and could not be used in the survey analysis. Simplified cards would have been easier for the technicians to issue and may have helped more anglers to complete them correctly.

In summary, the results of the 1991 creel surveys have added to the information on the participants in the chinook salmon sport fisheries in the Nushagak River drainage. The information should be helpful for evaluating proposed changes to the sport fishing regulations.

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APPENDIX A

Estimation Equations for Creel Survey Parameters

Appendix A1. Estimation equations for the distribution of catches and harvests for the roving type creel surveys conducted during 1991 on various chinook salmon fisheries in the Nushagak and mid-Mulchatna rivers.

The distribution of catches and harvest as described in the body of this report were estimated as described below for the roving creel surveys. We first coded the data to correct for possible biases due to changing amounts of angler effort (in terms of angler-days). From Sukhatme et al. (1984: equation 8.58; page 327), for the catch distribution the codes were:

$$y_{kio} = \begin{cases} \hat{M}_i / \bar{\hat{M}}^{*} & \text{if catch made by interviewed angler } o \text{ during day } i \text{ caught k or more fish of the species of interest (or zero fish if k = 0);} \\ 0 & \text{otherwise;} \end{cases} \quad \text{(A1.1)}$$

where:

$\hat{M}_i$ = estimated number of angler-trips for each day, obtained from the ratio of the estimated angler effort for the day divided by the mean angler effort from interviewed anglers for the day;

$$= \frac{\hat{E}_i}{\bar{e}_i}; \quad \text{(A1.2)}$$

$$\hat{E}_i = H_i \bar{x}_i; \quad \text{(A1.3)}$$

$$\bar{x}_i = \frac{\sum_{q=1}^{r_i} x_{iq}}{r_i}; \quad \text{(A1.4)}$$

H_i equaled number of hours in peak-of-the-day sampling period (equal to 8 hours as per design); x_{iq} was the number of anglers counted fishing during each count sample, within each day; r_i equaled the number of angler counts conducted on each sampled day (set to 3 counts as per schedule);

$$\bar{e}_i = \frac{\sum_{o=1}^{m_i} e_{io}}{m_i}; \quad \text{(A1.5)}$$

-continued-

m_i equaled the number of anglers interviewed within each sampled day; e_{io} equaled the angling effort in hours of each angler interviewed;

$\bar{\hat{M}}^*$ = the "restricted" mean of the estimated number of angler-trips for the fishery obtained as the mean of the daily estimated number of angler-trips (restricted to days in which one or more angler-trips are estimated):

$$= \frac{\sum_{i=1}^{d_1^*} \hat{M}_i^*}{d_1^*} ; \qquad \text{(A1.6)}$$

$\hat{M}_i^*$ equaled the estimated number of angler-trips for each day, restricted to those days with at least one angler-trip (obtained by equation A1.2, above); and

d_1^* equaled the number of days with at least one angler-trip estimated.

The angler met the criterion if his or her catch $c_{io} \geq k$ where $k = 1$ to k_{max} or $c_{io} = 0$ for $k = 0$; otherwise $y_{kio} = 0$. The data was re-coded for each iteration from 0 to k_{max}. After coding, the average fraction was found:

$$\bar{y}_k = \frac{\sum_{i=1}^{d_1^*} \bar{y}_{ki}}{d_1^*} ; \qquad \text{(A1.7)}$$

where:

$$\bar{y}_{ki} = \frac{\sum_{j=1}^{m_i} y_{kio}}{m_i} . \qquad \text{(A1.8)}$$

Estimates for harvest distribution were obtained similarly by substituting the appropriate harvest statistics in place of the catch statistics above.

-continued-

The variance of the estimated proportion for the distribution of catches and harvests for the roving surveys was obtained by the usual two-stage equation (Cochran 1977), omitting the second-stage finite population correction (FPC) factor:

$$\hat{V}[\bar{y}_k] = \left[(1 - f_1) \frac{s_{1k}^2}{d_1^*} \right] + \left[\frac{f_1}{d_2^{*2}} \sum_{i=1}^{d_2^*} \frac{s_{2ki}^2}{m_i} \right] ; \qquad \text{(A1.9)}$$

where:

$$s_{1k}^2 = \frac{\sum_{i=1}^{d_1^*} (\bar{y}_{ki} - \bar{\bar{y}}_k)^2}{d_1^* - 1} ; \qquad \text{(A1.10)}$$

$$s_{2ki}^2 = \frac{\sum_{o=1}^{m_i} (y_{kio} - \bar{y}_{ki})^2}{m_i - 1} ; \qquad \text{(A1.11)}$$

d_2^* equaled the number of days sampled with at least two anglers interviewed (i.e., second stage variance term is estimable), f_1 equaled the first stage sampling fraction (i.e., $f_1 = d / D$); d equaled the unrestricted number of days sampled; D equaled the number of days available for sampling in each creel survey; and all other terms were as defined above.

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

Appendix A2. Estimation equations for catches and harvests for the direct expansion creel survey conducted during 1991 on the chinook salmon fishery in the mid-Mulchatna River (sublocation 001).

Estimates of the distribution of angler catches and harvests for the direct expansion survey were obtained as outlined in the following procedures. Note, that although we interviewed all anglers exiting the fishery during each sampled day, the equations as presented below applied even if some anglers would not have been interviewed (but were counted). As with the roving surveys, first we weighted (to avoid possible biases due to differing numbers of angler-days for each sampled day, see Sukhatme et al. 1984):

$$y_{kio} = \begin{cases} M_i/\bar{M}^* & \text{if catch made by interviewed angler } o \text{ during day } i \text{ caught k or more fish of the species of interest (or zero fish if k = 0);} \\ 0 & \text{otherwise;} \end{cases} \qquad \text{(A2.1)}$$

where: M_i equaled the number of anglers counted exiting the fishery during each sampled day;

$\bar{M}^*$ equaled the "restricted" mean of the number of anglers for the fishery obtained as the mean of the daily number of anglers counted (restricted to days in which one or more anglers are counted), obtained as follows;

$$\bar{M}^* = \frac{\sum_{i=1}^{d_1^*} M_i^*}{d_1^*}; \qquad \text{(A2.2)}$$

M_i^* equaled the number of anglers counted exiting the fishery during each sampled day for days with at least one angler counted; M_i equals the unrestricted number of anglers counted exiting the fishery during each sampled day;

and d_1^* equaled the restricted number of days (with at least one angler counted)

Then $\bar{y}_k$ (the average proportion of anglers who catch or harvest k or more fish or 0 fish if $k = 0$) was obtained as outlined for the roving surveys (see equations A1.7 and A1.8, Appendix A1).

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The variance of the estimated proportion for the distribution of catches and harvests for the direct expansion survey was obtained by the usual two-stage equation, including the second-stage FPC factor (Cochran 1977):

$$\hat{\bar{V}}[y_k] = \left\{ (1 - f_1) \frac{s_{1k}^2}{d_1^*} \right\} + \left\{ \frac{f_1}{d_2^{*2}} \sum_{i=1}^{d_2^*} (1 - f_{2i}) \frac{s_{2ki}^2}{m_i} \right\} ; \quad (A2.3)$$

where: f_{2i} was the second-stage sampling fraction (i.e., $f_{2i} = m_i / M_i$); and all other terms were as defined in Appendix A1.

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

Appendix A3. Estimation equations for harvest and harvest proportions by angler type for the peak-of-the-day creel surveys conducted during 1991 on various chinook salmon fisheries in the Nushagak and mid-Mulchatna rivers.

Estimates of the proportion of harvest of chinook salmon by terminal tackle type and angler type were obtained by the same procedures for both the roving and direct expansion creel surveys, and are outlined below. The first step involved obtaining the mean harvest among anglers of the same type:

$$\bar{h}_{ui} = \frac{\sum_{i=1}^{m_{ui}} h_{uij}}{m_{ui}} . \qquad \text{(A3.1)}$$

where: m_{ui} equaled the number of anglers interviewed that were classified as being category u during day i; and h_{uij} equaled the number of harvested fish caught by each category u angler.

Next the estimated harvest of each category was estimated for each sampled day:

$$\hat{H}_{ui} = \hat{M}_{ui}\, \bar{h}_{ui} ; \qquad \text{(A3.2)}$$

where:

$$\hat{M}_{ui} = \hat{M}_i\, \hat{p}_{ui} \quad \text{for the roving surveys; or} \qquad \text{(A3.3a)}$$

$$\hat{M}_{ui} = M_i\, \hat{p}_{ui} \quad \text{for the direct expansion survey;} \qquad \text{(A3.3b)}$$

$\hat{p}_{ui}$ = proportion of anglers that are classified as category u during each sampled day;

$$= \frac{m'_{ui}}{m'_i} ; \qquad \text{(A3.4)}$$

m'_{ui} equaled the number of anglers interviewed (both completed-trip and incompleted-trip) that are classified as being category u during day i; m'_i equaled the total number of interviews (both completed-trip and incompleted-trip); and all other terms were as defined in Appendices A1, A2, and A5.

-continued-

The mean of the daily harvest estimate for each category over all days sampled (d) was then obtained:

$$\bar{\hat{H}}_u = \frac{\sum_{i=1}^{d} \hat{H}_{ui}}{d} . \qquad (A3.5)$$

Then the estimated harvest by category for the peak of the fishery was obtained by expanding by the number of days in the survey (D):

$$\hat{H}_u = D\,\bar{\hat{H}}_u . \qquad (A3.6)$$

Finally the proportion of harvest by category compared to the total harvest was obtained as follows:

$$\hat{p}_u = \frac{\hat{H}_u}{\hat{H}} ; \qquad (A3.7)$$

where: $\hat{H}$ equals the sum of the individual harvest estimates for all categories.

The variance of the estimated proportion of harvested fish by category was approximated using the delta method:

$$\hat{V}[\hat{p}_u] \approx \left[\frac{\hat{H}_u}{\hat{H}} \right]^2 \left[\frac{\hat{V}[\hat{H}_u]}{\hat{H}_u^2} + \frac{\hat{V}[\hat{H}]}{\hat{H}^2} - \frac{2\,\hat{V}[\hat{H}_u]}{\hat{H}_u \hat{H}} \right] . \qquad (A3.8)$$

where:

$$\hat{V}[\hat{H}_u] = \left[(1 - f_1) \frac{D^2}{d} S_{1u}^2 \right] + \left[f_1 \frac{D^2}{d_2^{*2}} \sum_{i=1}^{d_2^*} \hat{V}[\hat{H}_{ui}] \right] ; \qquad (A3.9)$$

$$S_{1u}^2 = \frac{\sum_{i=1}^{d} (\hat{H}_{ui} - \bar{\hat{H}}_u)^2}{d - 1} ; \qquad (A3.10)$$

-continued-

$$\hat{V}[\hat{H}_{ui}] = (1 - f_{2ui}) \frac{\hat{M}_{ui}^2}{m_{ui}} \frac{\sum_{j=1}^{m_{ui}} (h_{uij} - \bar{h}_{ui})^2}{m_{ui} - 1} ; \quad \text{(A3.11)}$$

the term $\hat{M}_{ui}$ above applied to the roving surveys; for the direct expansion survey this term was replaced by M_{ui} (since all anglers were interviewed then $M_{ui} = m_{ui}$);

$$f_{2ui} = \frac{m_{ui}}{\hat{M}_{ui}} \quad \text{for the roving surveys;} \quad \text{(A3.12a)}$$

$$f_{2ui} = \frac{m_{ui}}{M_{ui}} \quad \text{for the direct expansion survey; and} \quad \text{(A3.12b)}$$

all other terms were as defined above.

Appendix A4. Estimation equations for angler catch, effort, and harvest for the peak-of-the-day roving type creel surveys conducted during 1991 on various chinook salmon fisheries in the Nushagak and mid-Mulchatna rivers.

Estimates of angler effort (in angler-hours), catch, and harvest for the roving surveys were obtained by the following procedures. The first step involved obtaining the jackknife estimated sample mean of CPUE (or HPUE), by estimating the jackknifed CPUE for each interviewed angler within each sampled day:

$$CPUE^{*}_{ik} = \frac{\sum_{\substack{o=1 \\ o \neq k}}^{m_i} c_{io}}{\sum_{\substack{o=1 \\ o \neq k}}^{m_i} e_{io}} ; \qquad \text{(A4.1)}$$

where all terms were as defined in Appendix A1.

The jackknife mean CPUE for day i was then obtained from:

$$\overline{CPUE}^{*}_{i} = \frac{\sum_{k=1}^{m_i} CPUE^{*}_{ik}}{m_i} . \qquad \text{(A4.2)}$$

The bias correction (adapted from Efron 1982, equation 2.8, page 6) was then performed, unless the bias correction resulted in negative values (in which case the non-corrected version was used in all further calculations):

$$\overline{CPUE}^{*\dagger}_{i} = [m_i (\overline{CPUE}_i - \overline{CPUE}^{*}_{i})] + [\overline{CPUE}^{*}_{i}]; \qquad \text{(A4.3)}$$

where:

$$\overline{CPUE}_i = \frac{\sum_{o=1}^{m_i} c_{io}}{\sum_{o=1}^{m_i} e_{io}} . \qquad \text{(A4.4)}$$

The bias-corrected jackknife mean was then expanded by the estimated angler effort for the sampled day to obtain the estimated catch for each sampled peak-of-the-day:

$$\hat{C}_i = \hat{E}_i \, \overline{CPUE}^{*\dagger}_{i} ; \qquad \text{(A4.5)}$$

-continued-

where: $\hat{E}_i$ was as defined in equation A1.3 (Appendix A1).

The harvest for the sampled peak-of-the-day was estimated similarly by substituting the appropriate harvest statistics into equations A4.1 to A4.5, above.

Estimates of angler effort, catch, and harvest for the peak of the season (for the peak of each day) were obtained by first obtaining the mean values for the survey, as follows:

$\bar{\hat{Y}}$ = mean of the peak-of-the day estimates; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= \frac{\sum_{i=1}^{d} \hat{Y}_i}{d}; \qquad \text{(A4.6)}$$

where: d equaled the number of days sampled within each fishery during the peak of the season.

The estimated effort, catch, and harvest were then obtained by expanding by the number of days in each survey:

$$\hat{Y} = D\,\bar{\hat{Y}}; \qquad \text{(A4.7)}$$

where: D is the number of days within peak-of-the-season survey.

The variance of the estimated catch for the surveys was obtained by the two-stage variance equation, omitting the FPC factor for the second stage units (Cochran 1977):

$$\hat{V}[\hat{C}] = \left[(1 - f_1)\, D^2\, \frac{S_1^2}{d_1^*} \right] + \left[\frac{f_1}{d_2^{*2}}\, D^2 \sum_{i=1}^{d_2^*} \hat{V}[\hat{C}_i] \right]; \qquad \text{(A4.8)}$$

where:

$$S_1^2 = \frac{\sum_{i=1}^{d_1^*} (\hat{C}_i - \bar{\hat{C}})^2}{d_1^* - 1}; \qquad \text{(A4.9)}$$

-continued-

$\hat{V}[\hat{C}_i]$ = the within day variance for the estimated sample catch for each sampled day, obtained by using Goodman's (1960) formula for estimating the variance of a product of random variates;

$$= (\hat{E}_i)^2 \, s_{2i}^{*2} + (\overline{CPUE}_i^{*\dagger})^2 \, \hat{V}[\hat{E}_i] - s_{2i}^{*2} \, \hat{V}[\hat{E}_i] \; ; \qquad \text{(A4.10)}$$

s_{2i}^{*2} = jackknife estimate of the variance for the jackknifed sample mean CPUE (adapted from Efron 1982, equation 3.2, page 13);

$$= \frac{(m_i - 1)}{m_i} \sum_{k=1}^{m_i} (CPUE_{ik}^{*} - \overline{CPUE}_i^{*})^2 \; ; \text{ and} \qquad \text{(A4.11)}$$

$\hat{V}[\hat{E}_i]$ = estimated variance of the angler effort estimate for each sampled day adapted from the successive differences equation appropriate for systematic sampling as suggested by Wolter (1985):

$$= \frac{H_i^2}{r_i} \; \frac{\sum_{q=2}^{r_i} (x_{iq} - x_{i(q-1)})^2}{2 \, (r_i - 1)} \; ; \qquad \text{(A4.12)}$$

and all other terms were as defined in Appendix A1.

The variance estimate for the estimated harvest was obtained by replacing the appropriate harvest statistics (h's and H's) for the catch statistics (c's and C's) in equations A4.8 through A4.12.

The estimate of the variance of the angler effort was obtained in a similar manner to those for catch and harvest. The primary difference was in the second major term in equation A4.8:

$$\hat{V}[\hat{E}] = \left[(1 - f_1) \, D^2 \, \frac{S_1^2}{d_1^*} \right] + \left[\frac{f_1}{d_2^{*2}} \, D^2 \sum_{i=1}^{d_2^*} \hat{V}[\hat{E}_i] \right] \; ; \qquad \text{(A4.13)}$$

The values for the terms in equation A4.13 were obtained by replacing the catch statistics (C's) by the appropriate effort statistics (E's) in equation A4.9, and equation A4.12 was used in the final term in equation A4.13.

Appendix A5. Estimation equations for angler catch, effort, and harvest for the direct expansion creel survey conducted during 1991 on the chinook salmon fishery in the mid-Mulchatna River (sublocation 001).

The procedures for estimating the angler effort in angler-hours, catch, and harvest for the direct expansion survey are described below. The first step in obtaining the angler effort estimate involved the estimation of the mean angler effort for each sampled day over all anglers interviewed:

$$\bar{e}_i = \frac{\sum_{o=1}^{m_i} e_{io}}{m_i} ; \qquad \text{(A5.1)}$$

where: all terms were as defined in Appendix A2.

The angler effort estimate for the day was obtained by expanding by the number of anglers counted exiting the fishery (M_i):

$$\hat{E}_i = M_i \bar{e}_i . \qquad \text{(A5.2)}$$

The mean angler effort over all days sampled (d) during the peak of the fishery was then calculated:

$$\bar{\hat{E}} = \frac{\sum_{i=1}^{d} \hat{E}_i}{d} . \qquad \text{(A5.3)}$$

Then the estimated angler effort for the peak of the fishery was obtained by expanding by the number of days in the survey (D):

$$\hat{E} = D \bar{\hat{E}} . \qquad \text{(A5.4)}$$

The peak-of-the-season catch and harvest were obtained similarly, by substituting the appropriate catch or harvest statistics in place of the effort statistics in equations A5.1-A5.4.

The variance of the angler effort estimate for the direct expansion survey was obtained by the two-stage variance equation (Cochran 1977):

$$\hat{V}[\hat{E}] = \left[(1 - f_1) \frac{D^2}{d} S_1^2 \right] + \left[f_1 \frac{D^2}{d_2^{*2}} \sum_{i=1}^{d_2^*} \hat{V}[\hat{E}_i] \right] ; \qquad \text{(A5.5)}$$

-continued-

where:

$$S_1^2 = \frac{\sum_{i=1}^{d} (\hat{E}_i - \bar{\hat{E}})^2}{d - 1} ; \qquad \text{(A5.6)}$$

$$\hat{V}[\hat{E}_i] = (1 - f_{2i}) M_i^2 \frac{\sum_{o=1}^{m_i} (e_{io} - \bar{e}_i)^2}{m_i (m_i - 1)} ; \qquad \text{(A5.7)}$$

and all other terms were as defined in Appendix A2.

The variance estimates for the catch and harvest estimates were obtained similarly, by substituting the appropriate catch or harvest statistics in place of the effort statistics in equations A5.5-A5.7.

APPENDIX B

COMPUTER FILES USED TO PRODUCE THIS REPORT

Appendix B. Computer files used to produce this report.

Data Files

Lower Nushagak River at Portage Creek 21 June to 7 July 1991.

T003AIA1.DTA	Angler interviews including voluntary card data.
T003ACA1.DTA	Angler counts.
T003ABA1.DTA	Chinook salmon sport harvest biological data.

Lower Nushagak River at Ekwok 7 July to 21 July 1991.

T003BIA1.DTA	Original angler interviews.
EKWOK91.CRD	Voluntary report card data.
T003BIB1.DTA	T003BIA1.DTA adjusted with EKWOK91.CRD data.
T003BCA1.DTA	Angler counts.
T003BBA1.DTA	Chinook salmon sport harvest biological data.

Mouth of Stuyahok River (sublocation 001) 1 July to 15 July 1991.

T007AIA1.DTA	Angler interviews.
T007ABC1.DTA	Chinook salmon sport harvest biological data.

Mid-Mulchatna River (sublocation 002) 1 July to 15 July 1991.

T007BIA1.DTA	Original angler interviews.
MUL91B.CRD	Voluntary report card data.
T007BIB1.DTA	T007BIA1.DTA adjusted with MUL91B.CRD data.
T007BCA1.DTA	Angler counts.
T007BBB1.DTA	Chinook salmon sport harvest biological data.

Analysis Programs

UCSP91	Universal creel survey program: effort, catch, and harvest estimate program used in all three roving surveys in conjunction with location specific files listed below.
BBXPEXE	A series of programs that uses biological data files to produce tables of mean lengths and weights by sex and age group for a species.
CC91	A series of programs which sorts raw data from a file and produces frequency reports.

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Lower Nushagak River at Portage Creek 21 June to 7 July 1991.

BRA21POR.DB	UCSP91 table 1 data descriptive file.
BRA22POR.DB	UCSP91 table 2 data descriptive file.
T003AC01.DTD	UCSP91 count control data file.
T003AI01.DTD	UCSP91 interview data control file.
BRA21POR.RD	UCSP91 table 1 report descriptive file.
BRA22POR.RD	UCSP91 table 2 report descriptive file.
T003AC01.STB	UCSP91 count data header file.
T003AI01.STB	UCSP91 interview data header file.
POR91CHP.SAS	Program for estimation of proportion of harvest by angler type and gear type.
POR91CHD.SAS	Program for estimation of distribution of harvest by angler day.

Lower Nushagak River at Ekwok 7 July to 21 July 1991.

BRA21EKW.DB	UCSP91 table 1 data descriptive file.
BRA22EKW.DB	UCSP91 table 2 data descriptive file.
T003BC01.DTD	UCSP91 count control data file.
T003BI01.DTD	UCSP91 interview data control file.
BRA21EKW.RD	UCSP91 table 1 report descriptive file.
BRA22EKW.RD	UCSP91 table 2 report descriptive file.
T003BC01.STB	UCSP91 count data header file.
T003BI01.STB	UCSP91 interview data header file.
EKW91CHP.SAS	Program for estimation of proportion of harvest by angler type and gear type.
EKW91CHD.SAS	Program for estimation of distribution of harvest by angler day.

Mouth of Stuyahok River (sublocation 001) 1 July to 15 July 1991.

MMD91CHE.SAS	Direct expansion effort, catch, harvest estimation program.
MMD91CHP.SAS	Program for estimation of proportion of harvest by angler type and gear type.
MMD91CHD.SAS	Program for estimation of distribution of harvest by angler day.

Mid-Mulchatna River (sublocation 002) 1 July to 15 July 1991.

BRA21MUL.DB	UCSP91 table 1 data descriptive file.

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BRA22MUL.DB	UCSP91 table 2 data descriptive file.
T007BC01.DTD	UCSP91 count control data file.
T007BI01.DTD	UCSP91 interview data control file.
BRA21MUL.RD	UCSP91 table 1 report descriptive file.
BRA22MUL.RD	UCSP91 table 2 report descriptive file.
T007BC01.STB	UCSP91 count data header file.
T007BI01.STB	UCSP91 interview data header file.
MUL91CHP.SAS	Program for estimation of proportion of harvest by angler type and gear type.
MUL91CHD.SAS	Program for estimation of distribution of harvest by angler day.