

# FRED Reports

ENHANCEMENT OF CROOKED CREEK  
CHINOOK SALMON (*Oncorhynchus tshawytscha*)  
AND DEVELOPMENT OF A SPORT FISHERY  
ON THE KASILOF RIVER

by  
G. B. Kyle and D. S. Litchfield

Number 97



**Alaska Department of Fish & Game**  
Division of Fisheries Rehabilitation,  
Enhancement and Development

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## TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
ABSTRACT .....	1
INTRODUCTION .....	1
Study Site Description .....	2
METHODS .....	4
Egg Takes, Juvenile Rearing, and Smolt Tagging and Releases .....	4
Enumeration and Sampling of Chinook Salmon Returns to the Crooked Creek Weir .....	4
Kasilof River Sport Fishery Harvest and Angler Effort .....	5
Contribution of Hatchery-Produced Chinook Salmon to the Weir and the Kasilof River Sport Fishery .....	5
Estimation of the Economic Value of Crooked Creek Chinook Salmon Caught in the Kasilof River Sport Fishery .....	6
RESULTS .....	7
Egg Takes, Juvenile Rearing, and Smolt Tagging and Releases .....	7
Enumeration and Sampling of Chinook Salmon Returning to the Crooked Creek Weir .....	7
Kasilof River Sport Fishery Harvest and Angler Effort .....	12
Contribution of Hatchery-Produced Chinook Salmon to the Weir and the Kasilof River Sport Fishery .....	17
Economic Value of Sport-Caught Crooked Creek Chinook Salmon .....	17
DISCUSSION .....	20
ACKNOWLEDGMENTS .....	22
REFERENCES .....	23

## LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.	Summary of Crooked Creek chinook salmon egg takes, 1974-88 . . . . .	8
2.	Summary of chinook salmon smolt releases in Crooked Creek, 1975-88 . . . . .	9
3.	Adult returns and smolt-to-adult survivals for chinook salmon smolts released in Crooked Creek, 1975-88 . . . . .	10
4.	Ocean age-class composition of chinook salmon sampled at the Crooked Creek weir, 1978-88 . . . . .	14
5.	Mean lengths and weights of adult chinook salmon sampled at the Crooked Creek weir, 1978-88 . . . . .	15
6.	Estimated number and percent of hatchery-produced chinook salmon contributing to the Crooked Creek escapement, the Kasilof River sport fishery harvest, and the total return, 1978-88 . . . . .	18
7.	Estimated angler expenditures and economic impact for the Kasilof River chinook salmon sport fishery, 1986-88 . . . . .	19

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Map of Crooked Creek drainage in Southcentral Alaska showing location of the Kasilof River sport fishery and the Crooked Creek Hatchery . . . . .	3
2. Relationship between numbers (log transform) of chinook salmon smolts released into Crooked Creek and numbers (log transform) of adults produced for release years 1975-84. Inset shows the nontransformed relationship . . . . .	11
3. Scatter plots of the smolt-to-adult survival (A) and one-ocean jack age composition (B) compared to the size at release for chinook salmon smolts released in Crooked Creek, 1975-84 . . . . .	13
4. Summary of harvest (A) and angler effort (B) for the Kasilof River chinook salmon sport fishery, 1978-88 . . . . .	16

## ABSTRACT

Since 1975 a total of nearly 2.5 million chinook salmon smolts have been released in Crooked Creek. Ocean survival of age-0, accelerated-reared smolts released in Crooked Creek during the spring was significantly (ANOVA;  $p = .01$ ) less than that for age-1 smolts (age 0 averaged 2.5%,  $n = 8$ ; age 1 averaged 7.3%,  $n = 2$ ). Resulting adult returns have been used to develop a chinook salmon sport fishery on the Kasilof River and serve as broodstock for numerous other chinook salmon stocking programs throughout southcentral Alaska. The harvest of chinook salmon in the Kasilof River sport fishery during 1978-1988 averaged nearly 4,000 fish. In recent years, annual harvests of 7,000-11,000 in the Kasilof River fishery have rivaled harvests in the famed early-run Kenai River chinook salmon sport fishery. Over 66% of the chinook salmon returning to Crooked Creek during the last seven years resulted from the release of hatchery smolts. Finally, the estimated annual expenditure by anglers participating in the Kasilof River chinook salmon sport fishery for the last three years averaged \$1.7 million.

## INTRODUCTION

In 1973 the first chinook salmon (*Oncorhynchus tshawytscha*) enhancement project on the Kenai Peninsula was initiated by the Alaska Department of Fish and Game (ADF&G), Division of Fisheries Rehabilitation, Enhancement and Development (FRED) following completion of the Crooked Creek Hatchery. This project developed due to increasing demand for chinook salmon by sport anglers, as only three chinook salmon sport fisheries existed in the early 1970s, and the total harvest rarely exceeded 1,000 fish. The number of chinook salmon in Crooked Creek in the early 1970s numbered in the hundreds, but the accessibility of adult chinook salmon for hatchery broodstock and to anglers because of a roadside locality made this stock ideal for enhancement. Planners envisioned that someday a modest sport fishery on the Kasilof

River would result and that Crooked Creek chinook salmon would serve as a primary broodstock for juvenile chinook salmon released throughout southcentral Alaska.

In 1974 basic research was conducted on culturing chinook salmon of Crooked Creek as a small number of eggs were taken for test incubation and rearing. Since then, research expanded to include studies of juvenile life history and spawner distribution (Waite 1979), the number of adult chinook salmon caught in the Kasilof River sport fishery, and the evaluation of smolt-to-adult survivals (Waite 1983; unpublished Crooked Creek annual data reports, 1982-1988).

This report summarizes the development of hatchery chinook salmon returns from smolt releases in Crooked Creek from 1978 through 1988. In addition, annual harvest, angler effort, and economic value for the chinook salmon sport fishery on the Kasilof River is provided.

### Study Site Description

The Crooked Creek Hatchery is situated on Crooked Creek which is located 9 km south of Soldotna on the Kenai Peninsula (Figure 1). Crooked Creek originates in the Caribou Hills of the lower Kenai Peninsula and meanders 80 km through low grass and bog areas before flowing into the Kasilof River 6 km from Cook Inlet. Chinook salmon are the most abundant salmon species in Crooked Creek and, although it now receives large returns of enhanced chinook salmon, pre-enhanced escapements are largely unknown. However, based on sporadic spawner surveys, the wild chinook salmon escapement in Crooked Creek was generally considered to be less than 1,000 fish (Dave Nelson<sup>1</sup>, personal communication). The highest concentration of spawners is found ~7 km upstream of the hatchery. Juvenile chinook salmon rearing areas are widely distributed with preferred sites being deep pools with back eddies. Underyearling chinook salmon rear close to spawning areas in the creek and migrate over the summer to lower sections for overwintering before leaving as age-1 smolts (Waite 1979).

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<sup>1</sup> ADF&G, Sport Fish Division, 34828 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-3150.

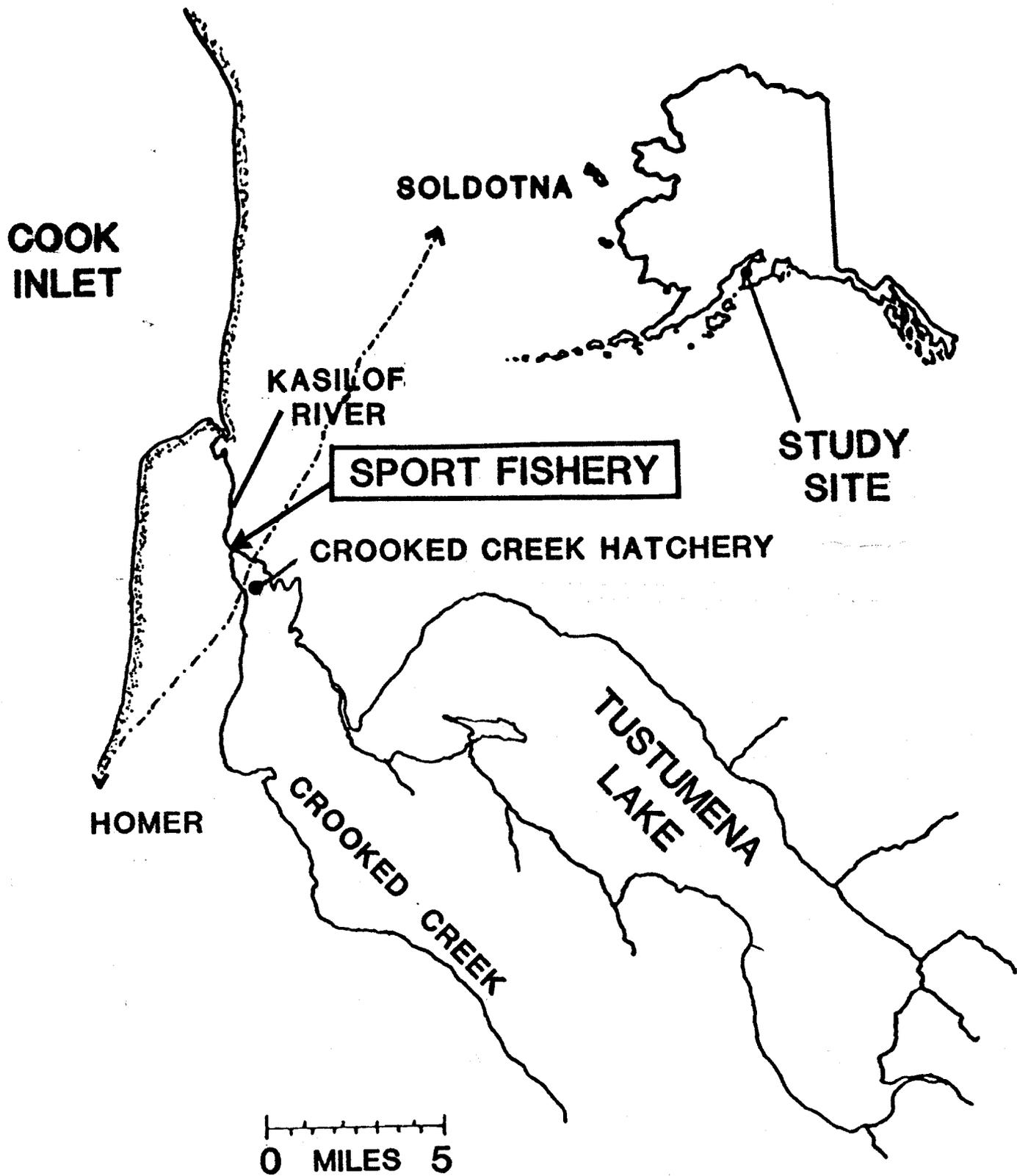


Figure 1. Map of Crooked Creek drainage in Southcentral Alaska showing location of the Kasilof River sport fishery and the Crooked Creek Hatchery.

## METHODS

### Egg Takes, Juvenile Rearing, and Smolt Tagging and Releases

Each year chinook salmon passing through a weir located at the Crooked Creek Hatchery were held approximately 2-3 weeks until ripe (mid- to late July). Eggs were stripped and immediately fertilized at the Crooked Creek egg-take site. After water-hardening, eggs were flown to Anchorage for incubation and rearing at either the Fort Richardson Hatchery (1974-1980) or at the Elmendorf Hatchery (1982-1988) until release as age-0 smolts in Crooked Creek. During 1982-1985 eggs were also incubated at the Crooked Creek Hatchery and juveniles were experimentally reared for release as age-1 smolts in Crooked Creek.

The Crooked Creek chinook salmon egg take, fecundity sampling, and rearing protocol followed the ADF&G Fish Culture Manual (FRED Staff 1983). The age-0 chinook salmon smolts produced at the Fort Richardson and Elmendorf Hatcheries were accelerated-reared on the warm water sources available at these facilities. Chinook salmon smolts produced at the Crooked Creek Hatchery were reared an additional year, as the water source at this facility is much cooler.

Approximately 15%-20% of the total number of chinook salmon smolts released each year into Crooked Creek were marked by an adipose fin clip and a coded-wire tag (CWT) following procedures described by Moberly et al. (1977). The smolts reared at the two Anchorage hatcheries were transported by hatchery tanker truck and released into Crooked Creek at the hatchery, ~10 km from Cook Inlet.

### Enumeration and Sampling of Chinook Salmon Returns to the Crooked Creek Weir

As returning Crooked Creek chinook salmon are exploited only by the sport fishery on the Kasilof River, evaluation of adult production from smolt releases was accomplished by creel census and weir returns. During the migration period (mid-May to mid-July),

all chinook salmon returning to the weir at the Crooked Creek Hatchery were enumerated and inspected for hatchery marks (missing adipose fins). Each year 20%-25% of the marked three- and four-ocean fish and all of the one- and two-ocean fish were sacrificed so that the CWTs embedded in the snouts could be recovered. Snouts were removed and sent to the ADF&G Tag Recovery Laboratory in Juneau for tag extraction and deciphering codes for the different release years and hatcheries. Each year between 170 and 1,300 adult chinook salmon were measured for size and sampled for age at the weir site throughout the migration. Adult chinook salmon were measured for fork-length (nearest 1.0 cm) and individual weight (nearest 0.1 kg). A scale smear was taken and pressed onto an acetate card for aging under magnification using a microfiche projector.

#### Kasilof River Sport Fishery Harvest and Angler Effort

The Kasilof River chinook salmon sport fishery occurs from late May through early July with most of the anglers fishing within 1.5 km of the confluence with Crooked Creek (See Figure 1). Angler effort was estimated by a modified, stratified-random sampling design using a roving creel survey (Neuhold and Lu 1957). The modification was a lattice design to ensure angler counts were never made in two consecutive periods during the same day, or in the same period on two consecutive days. This was necessary to minimize covariance between the angler counts. Angler counts were instantaneous and reflected the fishing effort at the time of the count. The catch rate (number of fish caught per hour) was estimated from completed angler interviews. The estimated number of chinook salmon harvested was the product of the effort and catch rate estimates.

#### Contribution of Hatchery-Produced Chinook Salmon to the Weir and the Kasilof River Sport Fishery

The contribution of hatchery-produced chinook salmon returning to the weir was estimated from expansion of the proportion marked from respective hatchery releases. All fish at the weir were examined for a hatchery mark and the age of all marked fish

was estimated based on length before it was passed through the weir. The ages of marked chinook salmon passed through the weir were later verified from CWT data. The percentages of each hatchery's fish for each age-class in the return were multiplied by the total adult return at the weir to determine unexpanded number of hatchery fish. As not all smolts stocked in Crooked Creek were marked, the number of each age-class of hatchery adults recovered was expanded by the marked-to-unmarked ratio for respective smolt release years and hatchery origin to obtain the total hatchery contribution.

The number of hatchery-produced chinook salmon caught in the Kasilof River sport fishery was determined from CWT information obtained from snouts voluntarily deposited in collection buckets by sport anglers and from the return of wild adults captured at the weir. Specifically, the number of sport-caught hatchery fish was sorted by age-class (mainly three- and four-ocean fish) and hatchery origin from CWT data. The number of hatchery-produced fish was then expanded by the mark-to-unmarked ratio (at time of release) and expressed in terms of a relative percentage. Finally, after subtracting out the wild component of fish caught in the sport fishery (using the percentage of wild fish observed at the weir), the relative percentage of hatchery-produced fish was multiplied by the total sport harvest to obtain the contribution of hatchery-produced fish in the sport fishery.

#### Estimation of the Economic Value of Crooked Creek Chinook Salmon Caught in the Kasilof River Sport Fishery

In 1986 a Fisheries Mini-Cabinet, under the direction of former Governor Bill Sheffield, began to evaluate costs and benefits associated with enhancement activities, including nonprofit hatcheries, regional aquaculture associations, and the State of Alaska. As a result, the FRED Division began coordinating fishery enhancement impact analysis in cooperation with the Alaska Department of Commerce and Economic Development, the Commercial Fisheries Entry Commission, and biometricians from the two other ADF&G fishery divisions. The results of this cooperative effort were used to estimate angler expenditure per angler day for the Kasilof River chinook salmon sport fishery, as

described by Hartman (1986). The economic impact analysis (estimation of personal income and number of jobs supported) followed a model established by the Institute of Social and Economic Research at the University of Alaska (Jeff Hartman<sup>2</sup>, personal communication).

## RESULTS

### Egg Takes, Juvenile Rearing, and Smolt Tagging and Releases

During the 1974-1988 brood years, over 13 million eggs have been taken from Crooked Creek chinook salmon (mean fecundity = 6,878) for enhancement projects at Crooked Creek and numerous other sites throughout southcentral Alaska (Table 1). Crooked Creek chinook salmon smolts have been released in creeks and ocean bays at 15 different sites throughout Cook Inlet and Prince William Sound, Alaska. In addition, there have been 35 landlocked lakes within southcentral Alaska that have been stocked with Crooked Creek chinook salmon fingerlings.

During 1975-1988, a total of 2,481,152 chinook salmon smolts have been stocked in Crooked Creek of which 19% were marked with an adipose fin clip and CWT (Table 2). Size of smolts released into Crooked Creek ranged from 10 g-28 g and averaged 17 g for the age-0 smolts and 20 g for the age-1 smolts (Table 2).

### Enumeration and Sampling of Chinook Salmon Returning to the Crooked Creek Weir

From a total of 1,379,654 age-0 chinook salmon smolts released during 1975-1984 into Crooked Creek, a total of 34,903 chinook salmon have returned (Table 3). The total production of returning adults was significantly ( $r_s = .86$ ,  $p < .01$ ; Spearman's rho) correlated to the number of smolts released (Figure 2). Smolt-to-adult survivals for age-0 smolts (1975-1984) ranged from 0.7%-6.3% and averaged 2.5%, whereas age-1

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<sup>2</sup> ADF&G, FRED Division, P.O. Box 3-2000, Juneau, AK 99802-2000.

Table 1. Summary of Crooked Creek chinook salmon egg takes, 1974-88.

Brood year	Number of fish used for egg-take			Total number eggs taken	Fecundity
	males	females	total		
1974	12	19	31	155,350	8,176
1975	32	40	72	300,000	7,500
1976	123	113	236	835,600	7,395
1977	232	223	455	1,474,000	6,610
1978	87	115	202	823,000	7,157
1979	76	105	181	671,792	6,398
1980	73	94	167	533,350	5,674
1981	25	24	49	172,783	7,199
1982	103	141	244	1,002,585	7,110
1983	216	280	496	1,773,937	6,335
1984	191	246	437	1,574,006	6,398
1985	121	170	291	1,224,000	7,200
1986	130	187	317	1,228,000	6,567
1987	136	188	324	1,294,000	6,882
1988	117	204	321	1,340,000	6,569
Total	1,674	2,149	3,823	13,062,403	Mean 6,878

Table 2. Summary of chinook salmon smolt releases in Crooked Creek, 1975-88.

Release year	Age-0 smolts					Age-1 smolts				
	Release date	Number released	Number marked	Percent marked	Release size (g)	Release date	Number released	Number marked	Percent marked	Release size (g)
Ft. Richardson Hatchery						Crooked Creek Hatchery				
1975	05 Aug	3,679	3,679	100.0	28.3		0			
1976	18-22 May	82,000	20,600	25.1	19.6		0			
1977	06-14 Jun	131,287	50,023	38.1	24.9		0			
1978	06-09 Jun	172,512	38,046	22.1	16.5		0			
1979	01-22 Jun	379,478	57,040	15.0	15.9		0			
1980	14 Apr	51,998	0	0	13.6		0			
1981	28-29 May	203,988	50,586	24.8	14.9		0			
1982		0					0			
Elmendorf Hatchery										
1983	24-27 May	211,179	14,648	6.9	10.2	07 Jun	53,741	10,942	20.4	18.2
1984	07-11 Jun	195,531	37,536	19.2	17.4	31 May	67,800	20,300	29.9	20.1
1985	24 May- 03 Jun	175,236	28,086	16.0	16.4	14 Jun	53,700	10,200	19.0	20.6
1986	11-12 Jun	184,456	30,861	16.7	13.1	10 Jun	69,164	10,564	15.3	21.6
1987	04-05 Jun	206,179	36,556	17.7	16.0		0			
1988	02-03 Jun	239,593	51,700	21.6	14.8		0			
	Total	2,237,116	419,361	Mean 18.8	17.0	Total	244,405	52,006	Mean 21.3	20.1

Table 3. Adult returns and smolt-to-adult survivals for chinook salmon smolts released in Crooked Creek, 1975-88.

Release year	Number released	Adult Returns					Smolt-to-adult survival (%)	
		1-ocean	2-ocean	3-ocean	4-ocean	Total		
Age-0 smolts								
1975	3,679	0	2	56	12	70	1.9	
1976	82,000	214	154	671	131	1,170	1.4	
1977	131,287	645	155	244	193	1,237	0.9	
1978	172,512	291	231	512	163	1,197	0.7	
1979	379,478	372	782	4,080	3669	8,903	2.4	
1980	51,998	Not evaluated						
1981	203,988	2,309	2,262	5,914	2,436	12,921	6.3	
1983	211,179	359	589	1,995	948	3,891	1.8	
1984	195,531	422	1,412	2,073	1,313	5,220	2.7	
Total	1,379,654 <sup>a</sup>					Total 34,609	Mean 2.5 <sup>b</sup>	
1985	175,236	968	938	3,977	N.A.	5,883	3.4 <sup>b</sup>	
1986	184,456	1,085	1,698	N.A.	N.A.	2,783	1.5 <sup>b</sup>	
1987	206,179	1,036	N.A.	N.A.	N.A.	1,036	0.5 <sup>b</sup>	
1988	239,593	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Age-1 smolts								
1983	53,741	329	1,140	3,485	403	5,357	10.0	
1984	67,800	104	604	2,070	748	3,526	5.2	
Total	121,541					Total 8,883	Mean 7.3 <sup>b</sup>	
1985	53,700	15	374	688	N.A.	1,077	2.0 <sup>b</sup>	
1986	69,164	180	1,015	N.A.	N.A.	1,195	1.7 <sup>b</sup>	

<sup>a</sup>Excludes 1980.

<sup>b</sup>Incomplete survival estimates as total adult returns are not available (N.A.) yet.

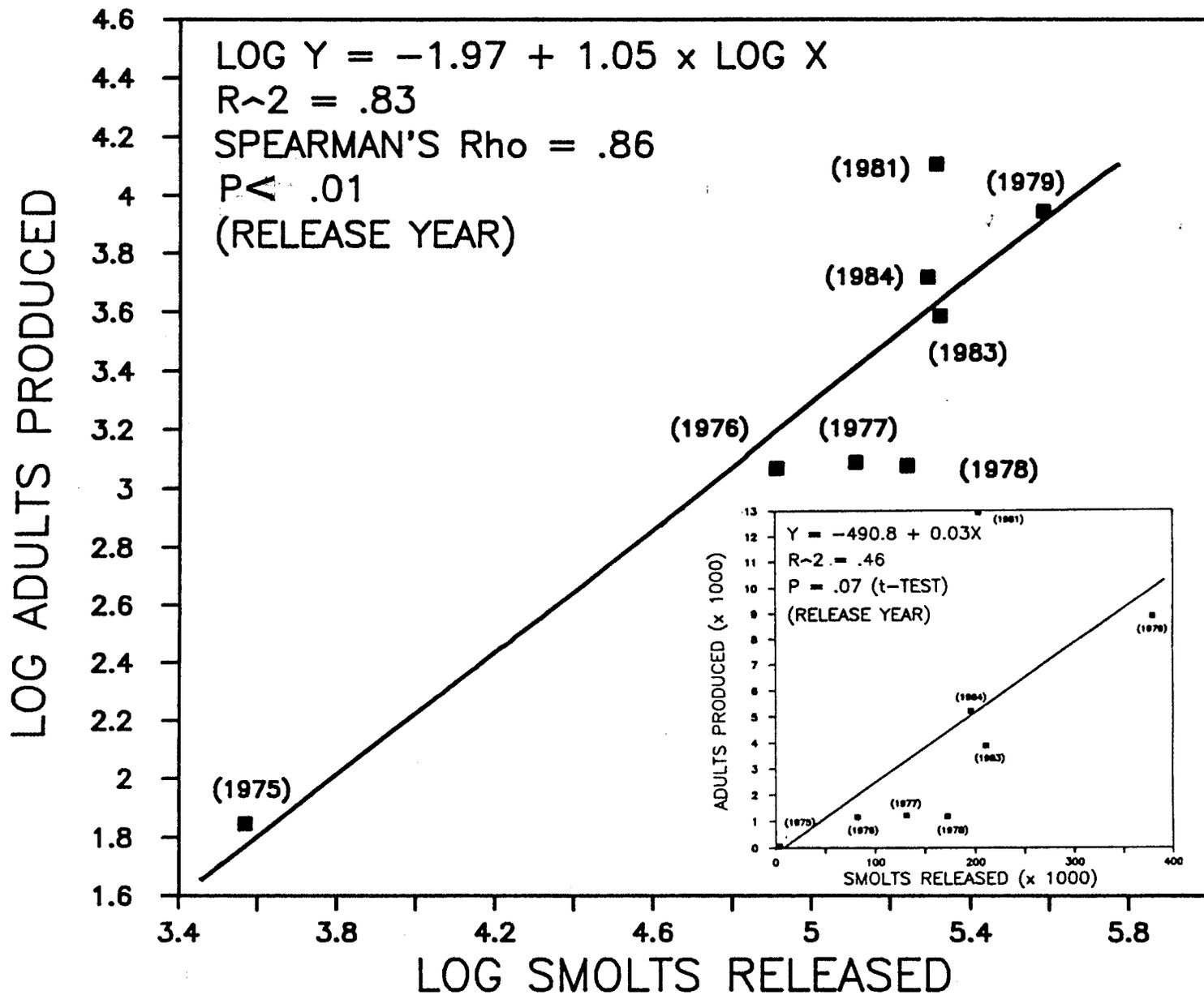


Figure 2. Relationship between numbers (log transform) of chinook salmon smolts released into Crooked Creek and numbers (log transform) of adults produced for release years 1975-84. Inset shows the nontransformed relationship.

smolts in 1983 and 1984 experienced significantly (ANOVA;  $p = .01$ ) higher smolt-to-adult survivals and averaged 7.3% (See Table 3).

As age-1 smolts released from the Crooked Creek Hatchery were larger in size than the age-0 smolts released from the Fort Richardson and Elmendorf Hatcheries (See Table 2), it could appear that release size could have influenced survival. However, no significant relationship or trend was found between numbers of adults produced from smolts ranging in weight from 10 g-28 g and released during 1975-1984 (Figure 3A). In addition, sizes of age-0 smolts released during 1975-1984 were not related to the return of one-ocean jacks (Figure 3B). Even with the exclusion of the one outlying point (smolt size of 28 g), there was no significant relationship (parametric or nonparametric test) between size of smolts released and return of one-ocean jacks.

The age-class composition of chinook salmon sampled at the Crooked Creek weir varied widely during 1978-1988 (Table 4). Overall, three-ocean fish dominated, ranging from 11%-65% and averaging 35% of the total weir return. Two- and four-ocean fish averaged 26% and 22% of the weir returns, respectively; however, the age composition of four-ocean fish ranged less dramatically than two-ocean fish. In addition, one-ocean jacks averaged 17% of the return to the weir and ranged from 0%-37%.

Finally, the mean size of all four age-classes of returning chinook salmon varied little during 1978-1988 (Table 5). One-ocean fish averaged 37 cm and 1.1 kg, two-ocean fish averaged 60 cm and 3.9 kg, three-ocean fish averaged 77 cm and 7.7 kg and, finally, four-ocean fish averaged 87 cm and 10.7 kg.

#### Kasilof River Sport Fishery Harvest and Angler Effort

The estimated annual harvest of Crooked Creek chinook salmon in the Kasilof River sport fishery ranged from <300 (developmental years 1978-1981) to over 11,000 (record high in 1988) (Figure 4A). The mean sport harvest of chinook salmon in this fishery during 1978-1988 was 3,995 fish; however, since 1983 (with the exception of the 1985

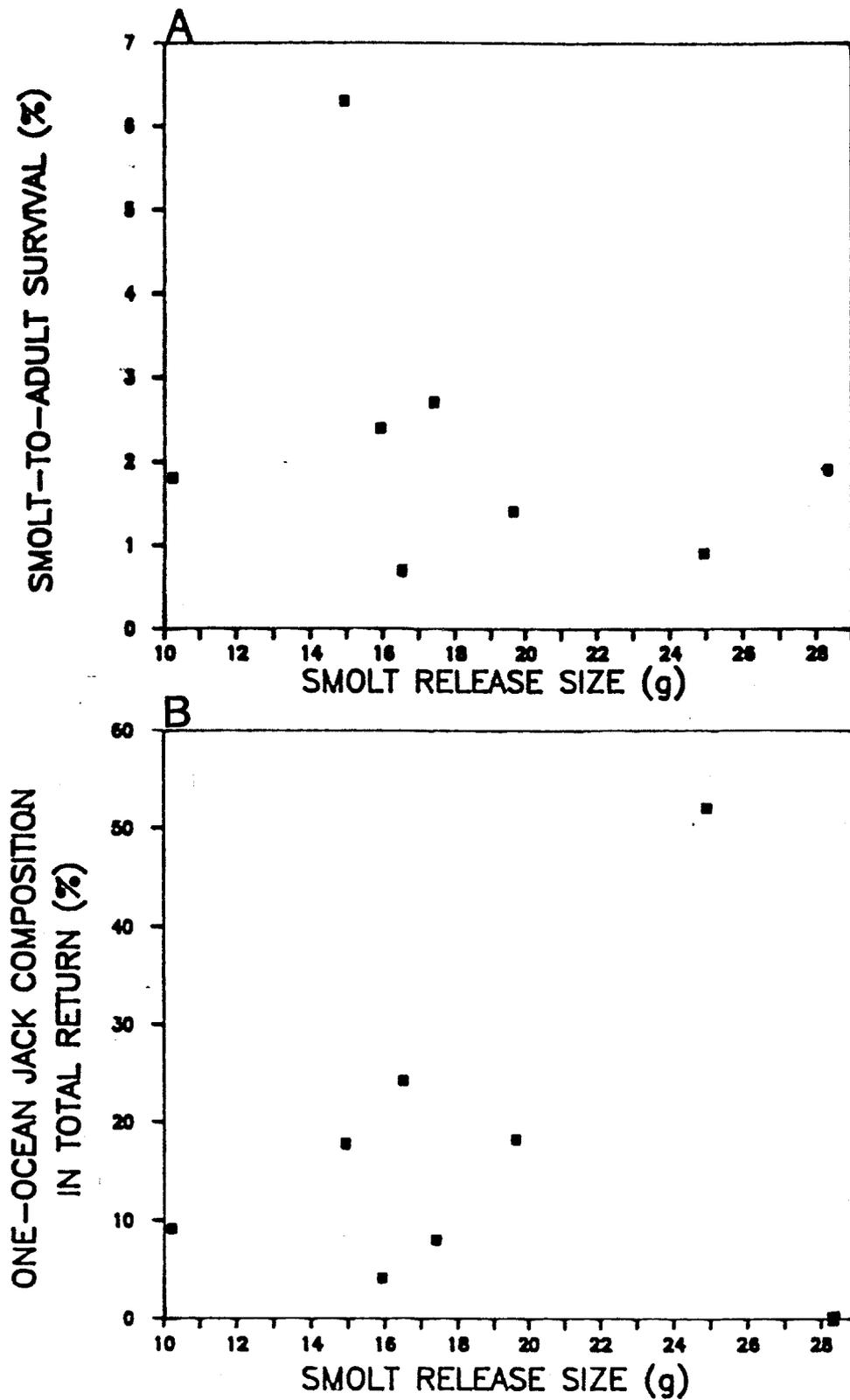


Figure 3. Scatter plots of the smolt-to-adult survival (A) and one-ocean jack age composition (B) compared to the size at release for chinook salmon smolts released in Crooked Creek, 1975-84.

Table 4. Ocean age-class composition of chinook salmon sampled at the Crooked Creek weir, 1978-88.

Return year	Sample size	Age-class composition (%)			
		1-ocean	2-ocean	3-ocean	4-ocean
1978	915	26.9	22.4	30.0	20.7
1979	841	8.0	10.0	54.0	28.0
1980	523	10.5	23.1	37.9	28.5
1981	598	3.0	26.3	41.8	28.9
1982	1,296	37.0	6.0	38.0	19.0
1983	579	0.0	57.3	10.7	32.0
1984	466	15.2	7.9	64.6	11.2
1985	600	24.0	39.7	10.7	25.6
1986	374	24.3	34.8	32.4	8.5
1987	207	13.5	30.0	36.7	19.8
1988	173	28.2	24.9	30.1	16.8
	Mean	17.3	25.7	35.2	21.7

Table 5. Mean lengths and weights of adult chinook salmon sampled at the Crooked Creek weir, 1978-88.

Ocean age-class	Return year	Sample Size	Average length (cm)	S.D.	Average weight (kg)	S.D.	
1-ocean	1978	260	38	5.1	1.0	0.2	
	1979	144	38	3.3	1.0	0.3	
	1980	31	40	4.9	1.7	0.8	
	1981	7	41	9.0	1.7	1.5	
	1982	260	39	3.5	1.2	0.3	
	1983	3	35	2.1	0.8	0.3	
	1984	71	36	3.1	1.0	0.2	
	1985	144	38	2.6	1.2	0.3	
	1986	91	37	3.2	1.1	0.1	
	1987	28	34	3.1	1.0	0.1	
	1988	49	36	2.9	0.7	0.2	
			Mean	37		1.1	
	2-ocean	1978	205	62	5.7	3.4	0.3
		1979	151	58	5.3	3.3	1.1
1980		101	60	7.8	4.3	1.4	
1981		190	60	5.8	3.9	1.1	
1982		45	60	7.3	3.9	1.1	
1983		349	61	5.7	4.1	0.8	
1984		37	58	5.4	3.7	0.8	
1985		238	61	5.1	4.2	0.9	
1986		130	61	4.5	4.5	0.8	
1987		62	57	5.8	3.7	0.9	
1988		43	62	5.0	3.7	1.0	
			Mean	60		3.9	
3-ocean		1978	274	77	6.7	7.4	1.6
		1979	352	78	5.0	7.8	1.5
	1980	211	75	6.1	7.5	1.7	
	1981	242	76	7.2	7.5	1.3	
	1982	743	79	5.1	8.2	1.4	
	1983	64	77	6.6	7.8	1.7	
	1984	301	77	5.5	7.7	1.3	
	1985	64	74	8.6	7.1	1.9	
	1986	121	78	5.7	8.0	1.5	
	1987	76	78	8.7	8.3	2.2	
	1988	52	77	5.5	7.3	1.4	
			Mean	77		7.7	
	4-ocean	1978	176	90	7.2	11.0	2.3
		1979	194	88	6.6	10.7	2.6
1980		180	87	5.0	11.6	2.5	
1981		159	85	6.2	10.0	2.0	
1982		248	89	5.0	11.5	1.9	
1983		201	88	6.0	10.8	2.1	
1984		52	87	7.4	11.0	2.2	
1985		154	85	5.9	10.1	1.8	
1986		32	87	7.0	10.6	1.9	
1987		41	89	8.6	10.9	2.1	
1988		29	89	6.2	10.2	1.4	
			Mean	87		10.7	

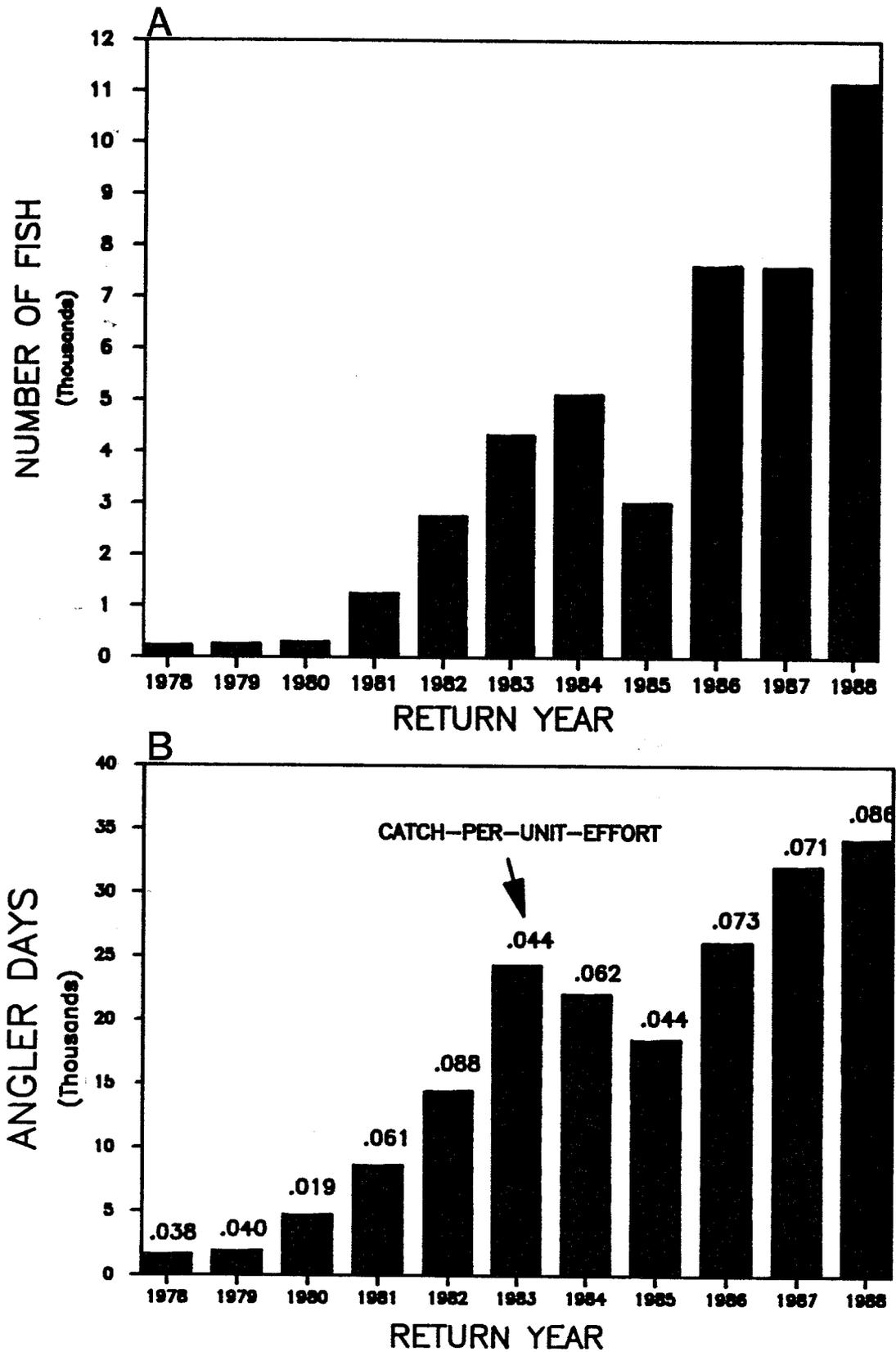


Figure 4. Summary of harvest (A) and angler effort (B) for the Kasilof River chinook salmon sport fishery, 1978-88.

return which excluded a large component of returning hatchery fish due to the lack of a hatchery plant in 1982) the chinook salmon harvest averaged 7,195.

Estimated effort (angler days) of sport angling during the Kasilof River chinook salmon sport fishery ranged from a low of <5,000 angler days per year (1978-1980) to over 34,000 angler days per year (1988) (See Figure 4B). Since 1983 a mean of 26,300 angler days of effort was expended each year. The catch-per-unit-effort (CPUE) ranged from a low of 0.19 in 1980 to a high of 0.88 in 1982 (See Figure 4B). Finally, since 1978 the CPUE averaged 0.057 or one fish every 17.5 hours, and for the last three years (1986-1988) averaged 0.077 or one fish every 13 hours.

#### Contribution of Hatchery-Produced Chinook Salmon to the Weir and the Kasilof River Sport Fishery

During 1978-1988 hatchery-produced chinook salmon represented 47% of the Crooked Creek escapement and averaged 1,679 adults (Table 6). During the same time period, an average of 2,611 hatchery-produced chinook salmon was harvested in the Kasilof River sport fishery, which represented 53% of the total harvest. Of the average annual chinook salmon return to Crooked Creek during 1978-1988 (7,514), a total of 4,285 or 50% were hatchery-produced. However, excluding the first four years (1978-1981) when the enhancement project was still developmental, the hatchery contribution to the total return of chinook salmon ranged from 59%-72% and averaged 66%. This hatchery contribution rate does not include the production from natural spawners in Crooked Creek which, for the most part, were adults produced from hatchery-released smolts.

#### Economic Value of Sport-Caught Crooked Creek Chinook Salmon

The economic value of the Kasilof River sport fishery is quite substantial, as the estimated angler expenditure for 1986-1988 averaged \$1.7 million (Table 7). In addition, the estimated personal annual income derived from this six-week fishery during 1986-1988 ranged from \$818,000 to \$1.2 million, an amount equivalent to 28 to 40 full-time

Table 6. Estimated number and percent of hatchery-produced chinook salmon contributing to the Crooked Creek escapement, the Kasilof River sport fishery harvest, and the total return, 1978-88.<sup>a</sup>

Return year	Escapement			Sport fishery harvest			Total return		
	Total	Hatchery-produced (no.)	(percent)	Total	Hatchery-produced (no.)	(percent)	Total	Hatchery-produced (no.)	(percent)
1978	4,715	180	4	251	10	4	4,966	190	4
1979	3,544	770	22	283	68	24	3,827	838	22
1980	2,282	518	23	320	88	27	2,602	606	23
1981	2,904	1,033	36	1,283	454	35	4,187	1,487	36
1982	3,503	2,054	59	2,787	2,189	79	6,290	4,243	68
1983	4,305	2,762	64	4,361	3,169	73	8,666	5,931	68
1984	3,650	2,278	62	5,138	3,686	72	8,788	5,964	68
1985	2,812	1,637	58	3,049	2,559	84	5,861	4,196	72
1986	3,478	2,335	67	7,657	5,161	67	11,135	7,496	67
1987	3,724	2,280	61	7,627	4,525	59	11,348	6,747	59
1988	3,796	2,622	59	11,192	6,817	61	14,988	9,439	63
Mean	3,519	1,679	47	3,995	2,611	53	7,514	4,285	50

<sup>a</sup>Excludes one-ocean jacks.

Table 7. Estimated angler expenditures and economic impact for the Kasilof River chinook salmon sport fishery, 1986-88.

RETURN YEAR	TOTAL NO. ANGLER DAYS	ESTIMATED EXPENDITURES	
		PER DAY	PER YEAR
1986	26,200	55	\$1,441,000
1987	32,200	55	1,771,000
1988	34,340	55	1,889,000
		AVERAGE	1,700,000

1986-1988

ESTIMATED PERSONAL INCOME: \$818,000-1,200,000

ESTIMATED NUMBER OF JOBS: 28-40

ESTIMATED EXPENDITURE PER FISH: \$170-225

ESTIMATED EXPENDITURE PER ANGLER DAY: \$47-63

jobs. Finally, angler expenditure per fish ranged from \$170 to \$225 and expenditures per angler day ranged between \$47 and \$63.

## DISCUSSION

Since 1975 a total of over two million age-0 chinook salmon smolts have been released into Crooked Creek. Adult survival has ranged from 0.7%-6.3% and averaged 2.5% for completed adult returns from age-0 smolts released through 1984. During 1983-1986, in conjunction with the age-0 smolts, over 240,000 age-1 smolts were released into Crooked Creek to compare smolt-to-adult survival and evaluate alternative production strategies. Although both releases were of Crooked Creek chinook salmon broodstock, the 1983 release of age-1 smolts from Crooked Creek Hatchery produced a survival rate of 10%; however, the 1983 release of age-0 smolts from the Elmendorf Hatchery resulted in a 1.8% survival rate. In 1984 the age-1 smolts survived at a rate of 5.2% compared to the 2.7% survival of the age-0 smolts. Although there were substantial differences in the size of the age-0 and age-1 smolts released in 1983 and 1984 (*See Table 2*), no significant relationship was found between smolt size at release and ocean survival (*See Figure 3A*). Conclusive reasons for the survival differences are unknown; however, it has been mentioned that the age-0 smolts released in 1983 from Elmendorf Hatchery were not as healthy as those released in 1984 (Darrell Keifer<sup>3</sup>, personal communication; Dudiak et al. 1987). Nonetheless, the increased ocean survival of stocked age-1 smolts in 1984 promotes the question of whether the benefit of a survival advantage sufficiently exceeds the added expense of an additional year of hatchery rearing to warrant a change in stocking strategy.

Much to the pleasure of early planners, and obviously to sport fishermen, the expected modest return of chinook salmon to Crooked Creek expanded into a substantial return. Due to the successful adult returns from hatchery-released smolts, a sport fishery of

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<sup>3</sup> ADF&G, FRED Division, Elmendorf Hatchery, 716 Steel Street, Anchorage, AK 99501.

hatchery-produced Crooked Creek chinook salmon was established on the Kasilof River in 1978. Since then a major sport fishery on the Kenai Peninsula has developed and, in recent years, the total harvest of chinook salmon in the Kasilof River sport fishery exceeded (1986) or was nearly identical (1988) to that of the renowned early-run Kenai River fishery. In addition, the average CPUE for the Kasilof River chinook salmon sport fishery of one fish for every 15 hours of fishing is half that of the Kenai River average of one chinook salmon every 30 hours (Hammarstrom 1988).

Furthermore, of the 43,000 chinook salmon harvested by sport anglers on the Kenai Peninsula in 1987, over 11,000 (25%) resulted from hatchery smolt releases of Crooked Creek broodstock (this includes adult returns from smolts released at sites other than Crooked Creek). Of the 11,000 hatchery-produced chinook salmon harvested, 7,627 or nearly 70% were harvested in the Kasilof River sport fishery, of which 4,525 (59%) were produced directly from smolt releases in Crooked Creek. Finally, not counting the chinook salmon harvest in the Kenai River (which are all naturally produced), 67% of the total 1987 non-Kenai River chinook salmon harvest was attributed to releases of Crooked Creek chinook salmon smolts on the Kenai Peninsula.

The success of enhancement projects utilizing the Crooked Creek chinook salmon broodstock on the Kenai Peninsula can be illustrated by comparing the current status of chinook salmon sport fisheries with those of the past. For example, during the 1970s there were only three chinook salmon fisheries on the Kenai Peninsula with a total harvest of 1,000 fish or less. The season limit was two fish and the fishing period was restricted to a few days. Today, there are nine chinook salmon sport fisheries, of which five depend on hatchery production using the Crooked Creek broodstock. The season limit is now five chinook salmon and the fishing period extends from mid-May through July.

Finally, over the years a combination of factors have contributed to the development of sensational chinook salmon sport fisheries, including management procedures, innovative fishing techniques, and environmental conditions. However, the economic and social

impact of chinook salmon enhancement programs on the Kenai Peninsula chinook salmon sport fisheries are substantial.

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