FEDERAL AID IN SPORT FISH RESTORATION
Kenai River Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, Studies
Summary Report 1983-1986

by
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Volume 1, Number 2

-- RESEARCH PROJECT SEGMENT

State: Alaska

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Study: 1 Study Title: Kenai River Juvenile Chinook Studies

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ABSTRACT

From the fall of 1983 through the spring of 1986, a juvenile chinook salmon, *Oncorhynchus tshawytscha*, study was conducted in the Kenai River.

In 1984, 1985, and 1986, 38,476, 71,025, and 4,939 juvenile chinook salmon were tagged, respectively. From recapture of these tagged juveniles, both upstream and downstream movement was observed; the predominate movement was downstream. Some juvenile chinook salmon tagged in the mainstem of the Kenai River moved upstream and were recaptured the following spring in the Killey River (a major tributary). Some age-1.0 chinook salmon smolts leaving the Killey River spent up to 1 month in the mainstem of the Kenai River before completing their migration to Cook Inlet.

During the 1983-1984 overwinter study, juvenile chinook salmon that had been marked in the fall were recovered the following spring in the same areas where they had been released. This suggests that the distribution of juvenile chinook salmon remains somewhat stable from the fall to spring.

Key Words: juvenile chinook salmon, *Oncorhynchus tshawytscha*, overwintering, instream movement, coded-wire tagging, minnow trapping.

INTRODUCTION

The Kenai River juvenile chinook salmon, *Oncorhynchus tshawytscha*, project included a tagging study and an over-wintering study; the major emphasis of the project was the tagging study.

The main glacial-water tributaries of the Kenai River are the Snow, Trail, and Skilak Rivers. Other important tributaries are the Russian, Moose, Killey, and Funny Rivers (Figure 1). Kenai and Skilak Lakes, two large lakes within the Kenai River system, are large impoundments that regulate the sediment load. The Kenai River watershed encompasses 5,700 square kilometers.

The Kenai River can be divided geographically into four reaches: the upper reach between Kenai and Skilak Lakes, a 14-mile reach between Skilak Lake and Moose River, an armored rapid reach from Moose River to the City of Soldotna, and the lower 20-mile reach that meanders between Soldotna and the mouth of the river at Kenai.

The discharge of the Kenai River in 1984 ranged from 42.5 m^3/s in January to 504.1 m^3/s in August. At the Soldotna gaging station, the highest discharge recorded was 954.4 m^3/s in September 1977. The mean annual discharge from 1965 to 1978 was 159.1 m^3/s (Scott 1981).

The Kenai River contains all five species of Pacific salmon; coho salmon, *O. kisutch*, pink salmon, *O. gorbuscha*, sockeye salmon, *O. nerka*, and chinook salmon are the primary species. Other anadromous and resident species are reported by the U.S. Army Corps of Engineers (1978).

The Kenai River chinook salmon population is comprised of an early run that are tributary spawners and a late run that are mainstem spawners. These chinook salmon generally spend 1 year rearing in fresh water and from 2 to 5 years in the ocean.

The Killey River, one of our study sites, is a major tributary that drains the large watershed west of the Kenai Mountains and the Killey Glacier. The Killey River becomes braided near its mouth and enters the Kenai at three locations: (1) River Mile (RM) 44.0 (its lowest and largest branch), (2) RM 44.4 (the middle and smallest branch), and (3) RM 45.9. Because of its large watershed and glacial nature, the Killey River water level fluctuates widely with the weather conditions. The Killey River is a major spawning area for early run chinook salmon (Burger et al. 1983).

Over the past decade the Kenai River has become the most heavily sport-fished river in Alaska. It is located within one of the fastest growing regions in the State of Alaska. The consequences of this growth in development and population are increasing pressure and conflict for natural resources. The fishing effort on the Kenai River has increased from a mean of 30,600 to 47,400 angler-days between 1976 and 1984 for early run chinook salmon and from 42,500 to 73,600 angler-days between 1974 and 1984 for late-run chinook salmon. This represents a 55% increase in fishing effort for the early run and a 73% increase for the late run during an 8- to 10-year span. The preliminary harvest estimates for the early and late runs of chinook salmon in 1985 were 7,971 and 8,055, respectively. The estimated 1985 escapements for early and late-run chinook salmon are approximately 8,000 and 22,000, respectively (Steve Hammarstrom pers. comm.).

In response to the increasing demands associated with the Kenai River and its fisheries resource, several studies of the river have been conducted. The U.S. Army Corps of Engineers (1978) completed a comprehensive report on the Kenai River. The U.S. Fish and Wildlife Service (USFWS) also conducted a fisheries and fish habitat study from 1979 to 1982 (Burger et al. 1983). The Alaska Department of Fish and Game has been continuously

collecting fisheries data on sport and commercially caught salmon since 1977 (Hammarstrom and Larson 1983; King and Tarbox 1983). Other fisheries studies have been conducted on Kenai River tributary spawning streams (Nelson 1984; Litchfield and Todd 1983; Elliott and Finn 1984).

OBJECTIVES

The juvenile tagging study was designed to identify the origin, relative magnitude, and contribution of juvenile chinook salmon within key rearing areas of the Kenai River system. Three major objectives to accomplish this work were (1) capture and mark a total of 50,000 wild juvenile chinook salmon from five key rearing areas in the Kenai River; (2) determine the relative importance of the major rearing areas by estimating relative abundance of juvenile chinook salmon, distribution, and rearing area overlap; and (3) describe the habitat characteristics of the rearing areas.

JUVENILE CHINOOK SALMON CAPTURE AND TAGGING

Introduction

The primary goals of the tagging project are to identify the place of origin, relative magnitude, and contribution of juvenile (i.e., presmolt) chinook salmon within reaches of the Kenai River system and to determine the relative importance of these nursery areas to adult production. This project will also provide fishery managers with information about the adult chinook salmon run timing, distribution, migration patterns, and interception.

Project objectives for 1984 and 1985 were to capture 50,000 and 70,000 juvenile chinook salmon, respectively, excise the adipose fins, and insert coded-wire tags (AD/CWT). In addition, 5,000 chinook salmon smolts were to be marked and tagged from the

Killey River in both 1985 and 1986. The original project design was for a 6-year project; 2 years were scheduled for juvenile chinook salmon tagging, and the remaining 4 years scheduled for recoveries of tagged adults.

In the process of capturing juveniles for the tagging study, other information such as their relative abundance in different river reaches, growth, and the movements of recaptured juvenile chinook salmon was also noted.

Materials and Methods

Capture and Tagging in the Kenai River:

All juvenile chinook salmon caught during the tagging study in the Kenai River were captured with Gee® minnow traps (44.5 x 22.9 x 0.6 cm). Minnow traps were baited with salmon eggs preserved with borax and disinfected with a 1:90 solution of Betadine®. The standard minnow-trap set used in 1984 was 20 traps fished for 100-110 minutes; in 1985, 25 traps were fished for 60 minutes. Captured juvenile salmon from each set were combined, sorted, and enumerated. Species other than chinook salmon were counted, recorded, and released. Traps were then reset above the previous release site to minimize retrapping of tagged fish. Captured juvenile chinook salmon were placed in an oxygenated 112- x 122- x 74-cm fish tote, transported by riverboat to a central tagging site (Figure 1), and transferred into a live-box. At the time of tagging, they were anesthetized with MS-222 (tricane methane sulfonate), their adipose fins were clipped, and a 1-mm-long coded-wire tag was injected into their snouts.

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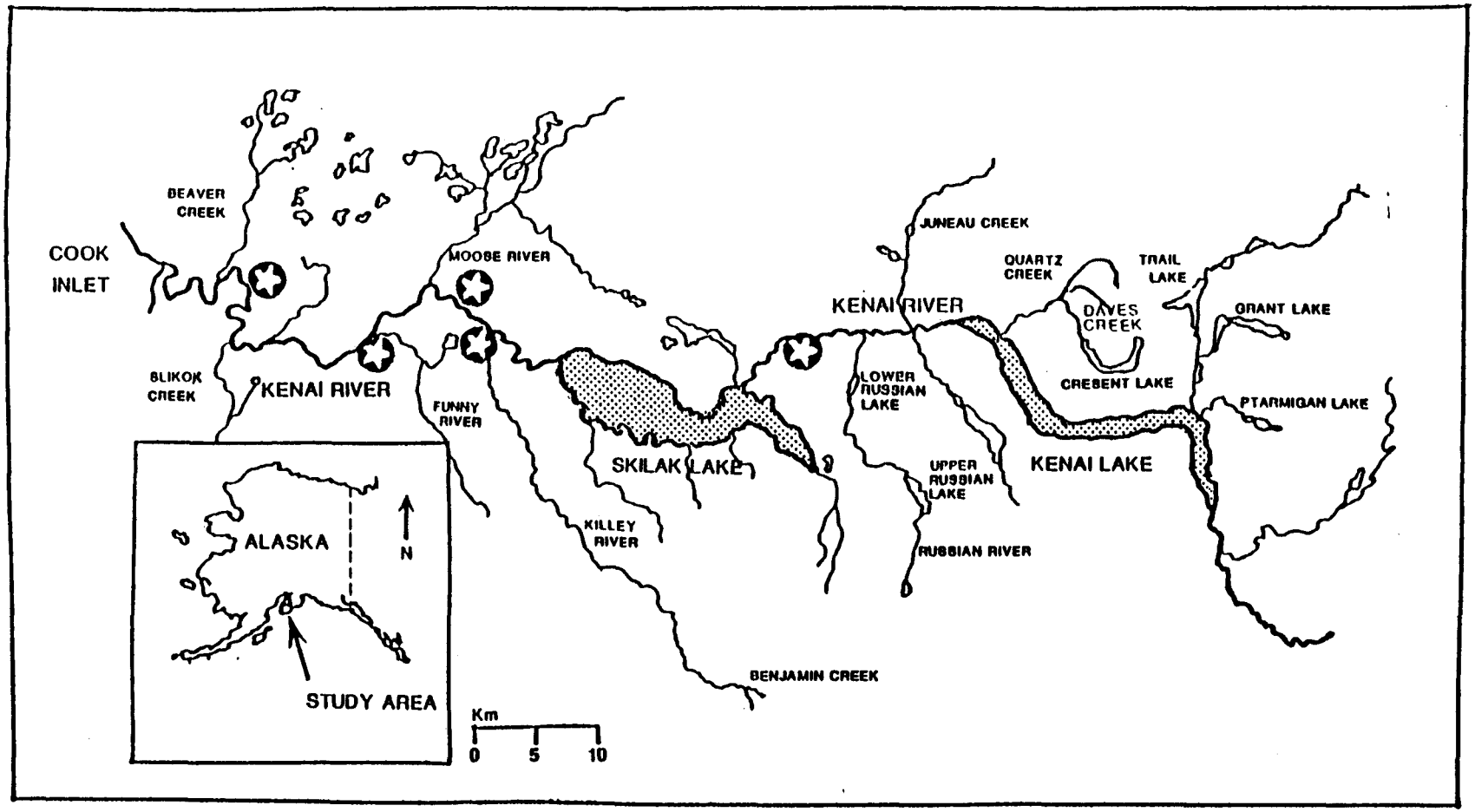


Figure 1. Location of juvenile chinook salmon tagging sites on the Kenai River, 1984-1986.

After tagging, fish were returned to the live-box and allowed to recover overnight. The following day, 200 fish were passed through a quality control device (QCD) to determine the rate of tag retention. All fish were then released at the approximate capture location. The numbers of dead fish and those that had rejected coded-wire tags were then subtracted from the number of fish tagged. Juvenile chinook salmon less than 50 mm in length were not marked or tagged. A detailed procedure used for coded-wire tagging is presented in Moberly et al. (1977).

In conjunction with tagging, 100 randomly selected salmon were weighed to the nearest 0.1 g (Model-1002 MP-9 Sartorius® Balance) and measured to the nearest mm (FL). Scale samples were also collected to determine the ages of the fish. Size data and scales were collected at three periods throughout the field season: (1) early May to compare growth from the previous fall period, (2) during the tagging operation, and (3) late September to document additional growth and to determine the ratio of tagged to untagged fish in the population.

Capture and Tagging in the Killey River:

In 1984 two inclined-plane traps and a fyke net were fished in the Killey River from 28 August to 11 September to determine if age-0.0 chinook salmon migrated from this important tributary to the mainstem of the Kenai River in the fall. To collect chinook salmon smolts for tagging, in 1985 three inclined-plane traps were fished intermittently from 20 May to 16 June, and in 1986 four inclined-plane traps were fished from 18 May to 10 June.

The inclined-plane traps had a 107- x 122-cm mouth and were 245 cm long. The dimensions of the attached live-box were 92 x 122 x 61 cm (Figure 2). The inclined-plane traps were initially fished on the bottom (without floats) with a tripod and pulley arrangement on the downstream end to raise or lower the cod end according to the water level. When the water depth became too

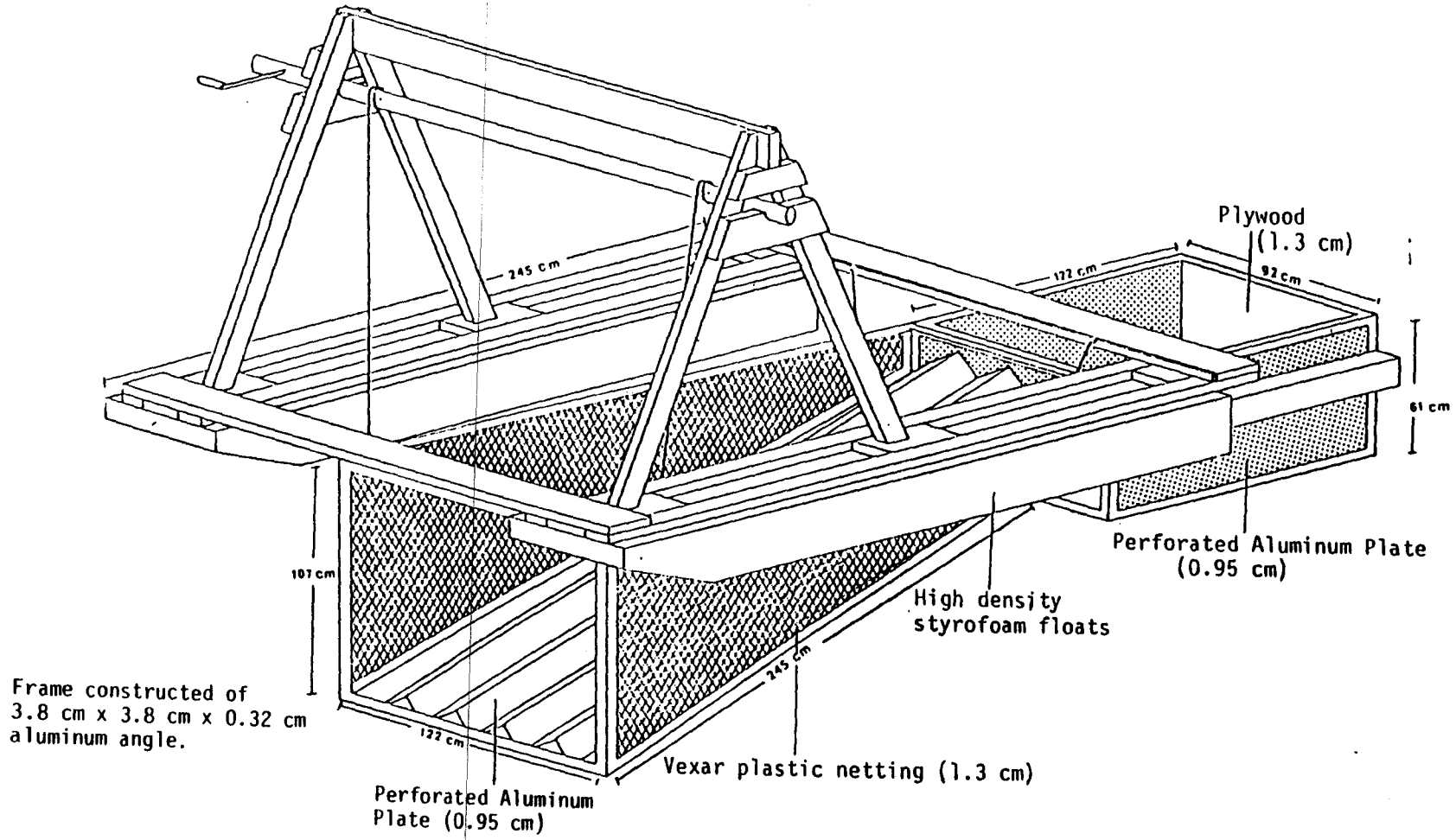


Figure 2. Diagram of inclined-plane trap used to capture chinook salmon in the Killey River, 1985-1986.

deep, the traps were fished from styrofoam floats. Traps were cleaned every 4-10 hours depending on debris load. Mostly, the traps were fished in the lowest branch of the river; however, in 1985 the upper branch of the Killey River was also fished. The tagging procedure was similar to that of the Kenai River except the tagged fish were released downstream of the traps.

Results

Kenai River:

A total of 38,476 juvenile chinook salmon was marked and tagged during the 1984 season. Of these, 22,353 were tagged and released in the Upper River (RM 39.5-48.0) and 16,123 were tagged and released in the Lower River. Four codes were used in the Upper River: 31/16/28, 31/16/29, 31/16/30, and 31/16/31. The two codes used in the Lower River were 4/21/8 and 31/16/32 (Table 1).

The total number of fish captured by species in 1984 was 47,248 age-0.0 chinook salmon, 9,803 age-0.0 coho salmon, 3,278 age-1.0 coho salmon, 11 age-2.0 coho salmon, 3,866 Dolly Varden, *Salvelinus malma*, 41 rainbow trout, *Salmo gairdneri*, and 1,120 sculpin, *Cottus* sp. (Table 2).

A total of 65,980 juvenile chinook salmon (age 0.0) was tagged in the mainstem Kenai River in 1985. These were from four sections of the Kenai River: 20,414 were tagged from RM 39.3 to 47.5; 15,178 were tagged from RM 68.0 to 70.6; 14,814 were tagged from RM 25.5 to 34.0; and 15,174 were tagged from RM 11.3 to 17.5 (Table 1).

The total number of fish captured by species in 1985 in the four mainstem Kenai River reaches were 76,831 age-0.0 chinook salmon, 461 age-1.0 chinook salmon, 14,998 age-0.0 coho salmon, 1,864

Table 1. Juvenile chinook salmon receiving adipose-fin clips and coded-wire tags in the Kenai River system, 1984-1986.

Location	River Mile	Dates tagged	Tag Code	Number of fish tagged	Total number of fish tagged
		1984			
Upper River	39.5-40.1	26 Jul-01 Aug	31 16/28	5509	
	40.1-41.2	01 Aug-03 Aug	31 16/29	5668	
	41.5-42.6	03 Aug-08 Aug	31 16/30	5508	
	45.0-47.6	10 Aug-15 Aug	31 16/31	5668	22,353
Lower River	9.2-21.0	18 Sep-02 Oct	04 21/08	10788	
	11.5-20.0	02 Oct-09 Oct	31 16/32	5335	16,123
		1985			
Killey River		24 May-17 Jun	31 16/63	5045	5,045
Upper River	39.3-40.1	20 Jul-24 Jul	31 16/34	5070	
	40.2-41.0	25 Jul-26 Jul	31 16/35	5233	
	42.0-42.5	27 Jul-31 Jul	31 16/36	5217	
	43.3-47.5	31 Jul-06 Aug	31 16/37	4894	20,414
Upper-Upper River	68.0-68.3	08 Aug-12 Aug	31 16/38	5066	
	69.2-69.7	13 Aug-15 Aug	31 16/39	4995	
	69.9-70.6	16 Aug-20 Aug	31 16/40	5117	15,178
Middle River	25.5-28.5	23 Aug-27 Aug	31 16/33	5110	
	30.0-34.0	28 Aug-06 Sep	04 03/52	9704	14,814
Lower River	11.3-17.5	11 Sep-21 Sep	31 16/55	15574	15,574
		1986			
Killey River		13 May-10 Jun	31 17/04	4939	4,939

Table 2. Juvenile fish captured by minnow trapping in the Kenai River, 1984 and 1985.

Year	Section	Date	River mile	Number of traps	Minutes fished	Tag code	Age-0.0 chinook	Age-1.0 chinook	Age-0.0 coho	Age-1.0 coho	Age2.0 coho	Dolly Varden	Rainbow Trout	Sculpin	Threespine stickleback	Sockeye
1984	Upper	26Jul-01Aug	39.5-40.1	162	25751	31 16/2	6810	0	1480	304	11	1260	22	845	---	---
	River	01Aug-03Aug	40.1-41.2	80	12503	31 16/2	6564	0	1232	61	0	204	6	12	---	---
		03Aug-08Aug	41.5-42.6	133	16845	31 16/3	6641	0	426	495	0	851	5	155	---	---
		10Aug-15Aug	45.0-47.6	162	32409	31 16/3	7811	0	1008	2147	0	1490	2	12	---	---
	Lower	18Sep-02Oct	9.2-21.0	430	13672	04 21/8	13672	0	2760	196	0	48	5	58	---	---
	River	02Oct-09Oct	11.5-20.0	211	5750	31 16/3	5750	0	1758	75	0	13	1	38	---	---
1985	Upper	18Jul-24Jul	39.3-40.1	193	13902	31 16/3	5966	157	68	95	0	283	6	158	3	2
	River	25Jul-26Jul	40.2-41.0	72	6496	31 16/3	6261	11	155	5	0	12	0	1	7	27
		27Jul-31Jul	42.0-42.5	95	7293	31 16/3	7650	80	261	53	0	38	0	4	89	2
		31Jul-06Aug	43.0-47.5	334	17310	31 16/3	5885	183	1680	1292	172	1427	20	49	310	44
	Upper-	08Aug-12Aug	68.0-68.3	100	8305	31 16/3	6068	23	21	96	0	139	4	13	0	6
	Upper	13Aug-15Aug	69.2-69.7	77	5025	31 16/3	6043	4	22	67	0	187	3	22	0	0
	River	16Aug-20Aug	69.9-70.6	75	3875	31 16/4	6094	1	12	26	0	171	33	22	1	0
	Middle	23Aug-27Aug	25.5-28.5	187	13155	31 16/3	5237	2	370	19	0	748	15	1602	13	0
	River	28Aug-06Sep	30.0-34.0	433	32052	04 3/52	10768	0	3085	128	0	1410	40	965	1157	16
	Lower River	11Sep-21Sep	11.3-17.5	765	53145	31 16/5	16859	0	9325	83	0	262	12	179	227	79

age-1.0 coho salmon, 172 age-2.0 coho salmon, 4,677 Dolly Varden, 133 rainbow trout, 3,015 sculpin, 1,897 threespine stickleback, *Gasterosteus aculeatus*, and 176 sockeye salmon (Table 2).

A detected mortality rate of 1.2% (446 of 38,476 fish) and 1.3% (866 of 66,866) resulted from Kenai River tagging operations in 1984 and 1985, respectively.

Killey River:

The catch of chinook salmon smolts from the Killey River during 1984 was too small to initiate the tagging operation, so none was marked. Totals of 6,249 age-1.0 chinook salmon, 2,981 age-1.0 coho salmon, 196 age-2.0 coho salmon, 159 sockeye salmon, 19 Dolly Varden, 3 rainbow trout, 396 stickleback, and 1,171 sculpin were captured from the Killey River in 1985 (Table 3).

In the spring of 1986, 5,971 age-1.0 chinook salmon, 2,063 age-1.0 coho salmon, 470 age-2.0 coho salmon, 301 sockeye salmon, 57 Dolly Varden, 98 threespine stickleback and 320 sculpin were captured with inclined-plane traps (Table 4). Several grayling, *Thymallus arcticus*, and a few lamprey, *Lampetra* sp., were caught.

Totals of 5,045 and 4,939 age-1.0 chinook salmon smolts leaving the Killey River were marked in 1985 and 1986, respectively.

Relative Abundance of Juvenile Chinook Salmon:

A measure of the relative abundance of juvenile salmon by river reach can be inferred from minnow-trap catch rates. The highest catch rate in 1984 was at RM 40.1-41.2, averaging 0.52 chinook salmon/trap minute. The second-highest catch rate, of 0.39 chinook salmon/trap minute occurred at RM 41.5-42.6.

Table 3. Juvenile fish caught by inclined-plane traps from the Killey River, 1985.

Date	Chinook salmon	Coho salmon		Sockeye salmon	Dolly Varden	Rainbow trout	Threespine stickleback	Sculpin
		Age 1	Age 2					
5/21	224	27		8				
5/22	138	8					5	17
5/23	356	115	7	13	3		70	254
5/24	300	226	14	6	7	1	128	598
5/25	392	507	10	10	22	1	30	181
5/26	451	598	4		11		4	12
5/27	501	359	5	14	15	1	19	23
5/28	724	309	1	14	1		63	16
5/29	302	64	1	1	7		3	5
5/30	611	74	6	6	7		5	11
5/31	340	107		9			9	2
6/01	267	58	3	5			3	4
6/02	83	11	1		1		11	1
6/03	691	139	55	26	16		27	34
6/04	25	2		Water Flooding Traps				
6/05				Traps Out - Not Fishing				
6/06				Traps Out - Not Fishing				
6/07	26	8	1		1			
6/08	106	23	1	2			2	
6/09	163	26	6	2			5	1
6/10	81	27	5	1				1
6/11	103	46	16	1			8	10
6/12	108	75	11	5	1		1	
6/13	83	69	9	7			2	
6/14	79	48	14	6			1	
6/15	89	50	16	23				1
6/16	6	5	10					
Totals	6,249	2,981	196	159	92	3	396	1,171

Table 4. Juvenile fish caught by inclined-plane traps from the Killey River, 1986.

Date	Chinook salmon	Coho salmon		Sockeye salmon	Dolly Varden	Threespine stickleback	Sculpin
		Age 1	Age 2				
5/13	498	29	11	22	--	4	18
5/14	220	38	18	34	--	11	19
5/15	446	65	43	25	2	8	19
5/16	212	38	15	4	1	4	27
5/17	234	24	6	17	--	5	29
5/18	198	31	5	9	--	3	23
5/19	241	38	24	11	3	4	20
5/20	331	76	30	6	7	--	42
5/21	319	91	16	3	2	1	21
5/22	463	222	12	8	9	7	16
5/23	527	210	23	5	6	4	22
5/24	475	114	17	5	--	5	10
5/25	521	140	12	9	4	8	10
5/26	255	102	17	10	1	2	3
5/27	181	30	10	9	--	2	2
5/28	304	209	46	29	3	8	16
5/29	154	165	58	11	6	8	10
5/30	164	195	23	14	9	4	5
5/31	48	49	9	4	--	--	--
6/01	56	30	3	--	--	3	--
6/02	38	33	1	6	--	1	1
6/03	9	9	1	5	--	--	2
6/04	3	8	--	1	--	1	--
6/05	6	9	1	7	--	--	--
6/06	20	24	17	8	--	--	--
6/07	9	15	15	19	1	4	2
6/08	25	57	31	10	2	1	2
6/09	14	12	6	10	1	--	1
Totals	5,971	2,063	470	301	57	98	320

In 1985 the highest catch rate of 1.06 chinook salmon/minute occurred at RM 68.0-70.6; this was followed by a catch rate of 0.58 juvenile chinook salmon/minute (Table 5) that occurred at RM 39.3-40.1. The lowest catch rate recorded occurred in the lower river during the fall of 1984 (0.23 chinook/min). The highest individual trap catch consisted of 238 chinook salmon from the upper river in 1985.

Juvenile Chinook Salmon Rearing Habitat:

The highest numbers of juvenile chinook salmon were caught in areas with moderate water velocities (i.e., 10-80 cm/s), especially along irregular shorelines or below islands. Most juvenile chinook salmon were caught near cover. The best cover types included flooded vegetation or sand bars and water-permeable log jams.

Growth of Juvenile Chinook Salmon:

The mean length of juvenile chinook salmon caught near RM 40.0 increased 6.2 mm (53.5-59.7 mm) from 30 July to 10 September 1984 (Table 6). Fish in samples collected from 14 August and 10 September at RM 45.0, however, showed no increase in size; possibly, smaller fry moved into this area.

From 9 June to 25 September 1985, the mean length of juvenile chinook salmon caught at RM 42.0-44.5 increased 24.8 mm (45.8-70.6 mm). The average sizes of both the coho and chinook salmon collected in the September sample were significantly larger in the lower river than in the upper river (Figure 3).

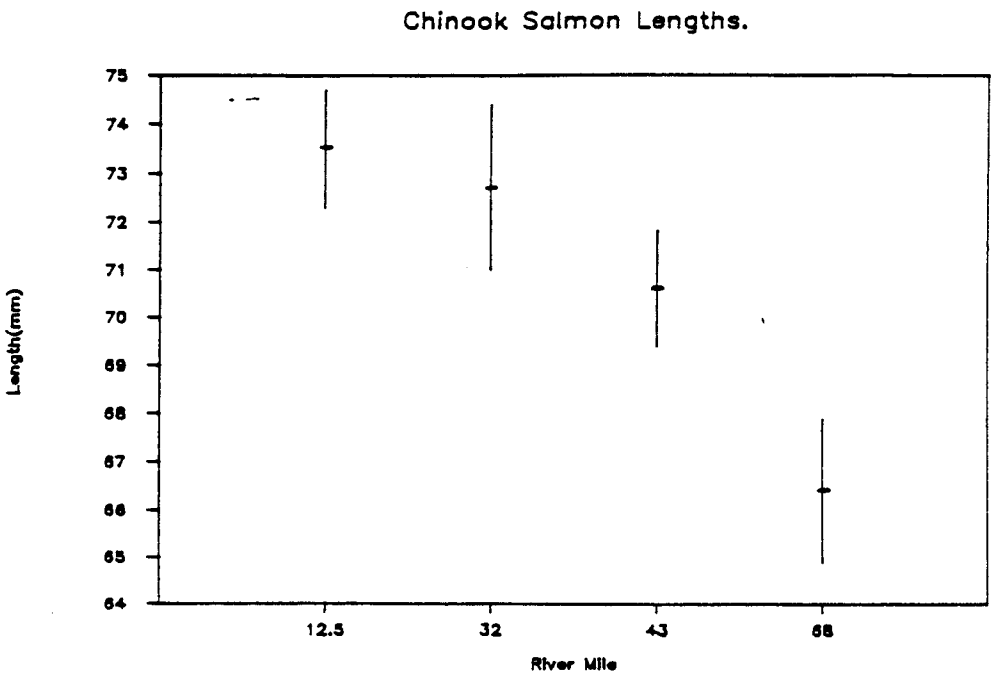
The mean length and weight of the 75 chinook salmon smolts sampled on 31 May from the Killey River were 65.5 mm (S.D. 7.7) and 2.4 g (S.D. 1.1), respectively.

Table 5. Juvenile chinook and coho salmon captured from the Kenai River, 1984 and 1985.

Year	Date	Section	River mile	Number of chinook salmon caught: Total	per trap	per trap/min	Number of coho salmon caught: Total	per trap	per trap/min
1984	26Jul-01Aug	Upper	39.5-40.1	6810	42.6	0.26	1795	11.2	0.07
	01Aug-03Aug		40.1-41.2	6564	82.1	0.52	1293	16.2	0.1
	03Aug-08Aug		41.5-42.6	6641	49.6	0.39	921	6.9	0.05
	10Aug-15Aug		45.0-47.6	7811	48.2	0.24	3155	19.5	0.1
	Total/average			27826	54.0	0.40	7164	13.4	0.08
	18Sep-09Oct	Lower	09.2-20.0	19422	30.3	0.23	4789	7.5	0.06
1985	20Jul-24Jul	Upper	39.3-40.1	6123	31.7	0.44	163	0.9	0.01
	25Jul-26Jul		40.2-41.0	6272	87.1	0.97	160	2.2	0.03
	27Jul-31Jul		42.0-42.5	7730	81.4	1.06	314	3.3	0.04
	31Jul-06Aug		43.3-47.5	6068	18.2	0.35	3144	9.4	0.18
	Total/average			26193	37.7	0.58	3781	5.4	0.08
	08Aug-12Aug	Upper-	68.0-68.3	6091	60.9	0.73	117	1.2	0.01
	13Aug-15Aug	Upper	69.2-69.7	6047	78.5	1.20	89	1.2	0.02
	16Aug-20Aug		69.9-70.6	6095	81.3	1.57	37	0.5	0.01
	Total/average			18233	72.4	1.06	243	1.0	0.01
	23Aug-27Aug	Middle	25.5-28.5	5239	28.0	0.40	389	2.1	0.03
	28Aug-06Sep		30.0-34.0	10768	24.9	0.34	3213	7.4	0.10
	Total/average			16007	25.8	0.35	3602	5.8	0.08
	11Sep-21Sep	Lower	11.3-17.5	16859	22.0	0.32	9408	12.3	0.18

Table 6. Mean length and weight of age-0.0 chinook and coho salmon sampled from the Kenai River system, 1984 and 1985.

Date	Location (RM)	Sample size	Mean length (SD)	Mean weight (SD)	Condition factor
			CHINOOK 1984		
30-July	39.5	50	53.5 (5.6)	2.1 (0.7)	1.4
14-Aug	45.0	50	65.9 (7.1)	2.6 (1.0)	0.9
07-Sep	Killey R	94	60.4 (7.6)	2.2 (1.0)	1.0
08-Sep	Killey R	21	78.3(10.7)	5.2 (2.2)	1.1
10-Sep	42.1	50	59.7 (4.8)	2.1 (0.7)	1.0
10-Sep	45.8	50	65.8 (6.2)	2.8 (1.0)	1.0
05-Oct	12.4	92	74.3 (5.2)	4.2 (1.0)	1.0
			CHINOOK 1985		
09-June	44.5	12	45.8 (2.5)	0.9 (0.1)	0.9
26-July	40.6	40	51.6 (4.4)	1.4 (0.4)	1.0
06-Aug	47.0	80	60.6 (5.7)	2.1 (0.7)	0.9
20-Aug	68.0	121	61.0 (7.8)	2.2 (0.9)	1.0
23-Aug	26.0	80	68.2 (7.2)	3.0 (1.0)	1.0
20-Sep	12.5	104	73.5 (6.0)	4.0 (1.1)	1.0
24-Sep	32.0	103	72.7 (8.3)	4.0 (1.3)	1.0
25-Sep	42.0	99	70.6 (6.2)	3.7 (1.0)	1.0
26-Sep	68.0	102	66.4 (7.7)	3.0 (1.2)	1.0
			COHO SALMON 1984		
30-July	39.5	43	41.9 (3.6)	1.0 (0.4)	1.4
14-Aug	45.0	16	55.4(15.1)	2.1 (0.9)	1.2
07-Sep	Killey R	100	52.8 (5.5)	1.3 (0.4)	0.9
10-Sep	42.1	50	48.0 (3.6)	1.0 (0.3)	0.9
10-Sep	45.8	50	53.5 (4.5)	1.5 (0.4)	1.0
05-Oct	12.4	75	58.0 (5.1)	2.0 (0.6)	1.0
			COHO SALMON 1985		
24-Sep	32.0	50	54.1 (5.1)	1.5 (0.4)	1.0
25-Sep	43.0	50	51.3 (5.5)	1.4 (0.4)	1.0
26-Sep	68.0	100	48.0 (3.1)	1.0 (0.3)	0.9



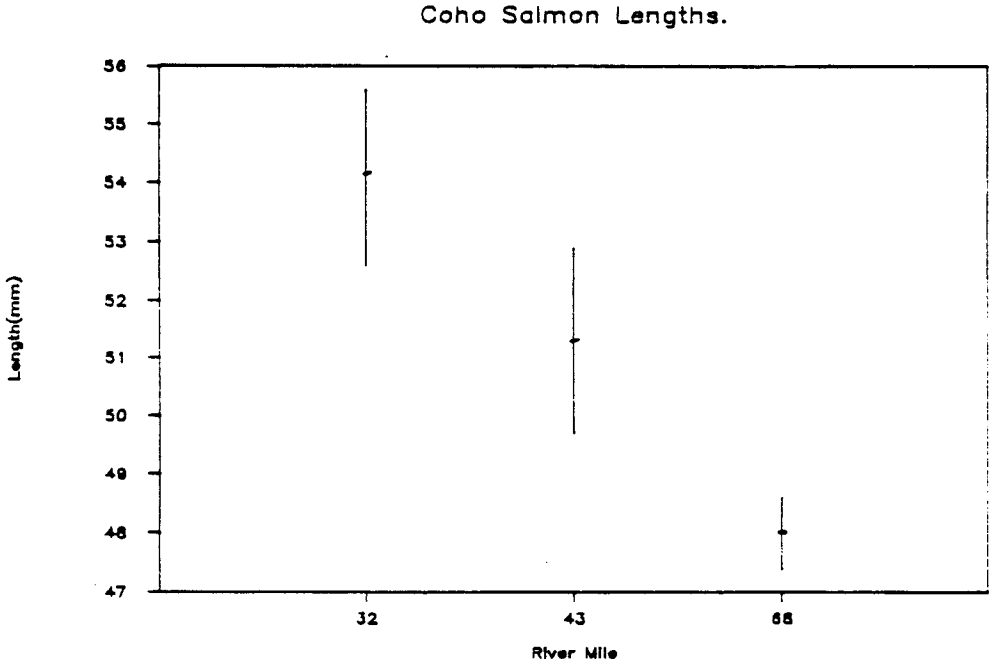


Figure 3. Lengths of juvenile chinook and coho salmon from different sampling locations (RM) in the Kenai River, 20-26 September 1985 (vertical lines represent 95% confidence levels).

Movements of Juvenile Chinook Salmon:

Downstream movement of tagged juvenile salmon was common (Figure 4); however, during the initial tagging in 1984, it was discovered that as the trapping locations proceeded upriver tagged juveniles that had been released downstream were being recaptured. The greatest movement noted in 1984 occurred when a juvenile chinook salmon moved upstream 2.5 miles from RM 42.5 to 45.0 (Figure 4); juveniles were also recaptured on the opposite river bank from their release site, showing lateral movements as well. The most dramatic upstream movement occurred in 1985 when five juveniles tagged the previous summer were retrapped as far as 4 miles upstream the following spring (Figure 5). In all, 41 juvenile chinook salmon from the upper river were captured in the lower river (Figure 4). Of the 223 tagged and recaptured juvenile chinook salmon collected in 1985, 14 (6%) had moved upriver, 53 (24%) had moved downriver, and 156 (70%) had been recaptured within their release area.

Seven tagged chinook salmon smolts trapped in the Killey River were later recaptured in the Kenai River. Some of these juveniles spent as long as 1 month rearing in the Kenai River. This suggests that at least some juvenile chinook salmon from tributaries spend some time rearing in the mainstem before leaving the system.

Discussion

The primary objective of this project was to capture and coded-wire tag sufficient numbers of juvenile chinook salmon so that adults could be recaptured in sufficient numbers in future years to provide estimates of interception, contribution, and survival. Unfortunately, because of subsequent budget constraints, it is unlikely that the adult recapture portion of this study will be accomplished. The Kenai River system was broken-down into four reaches and one major tributary for this

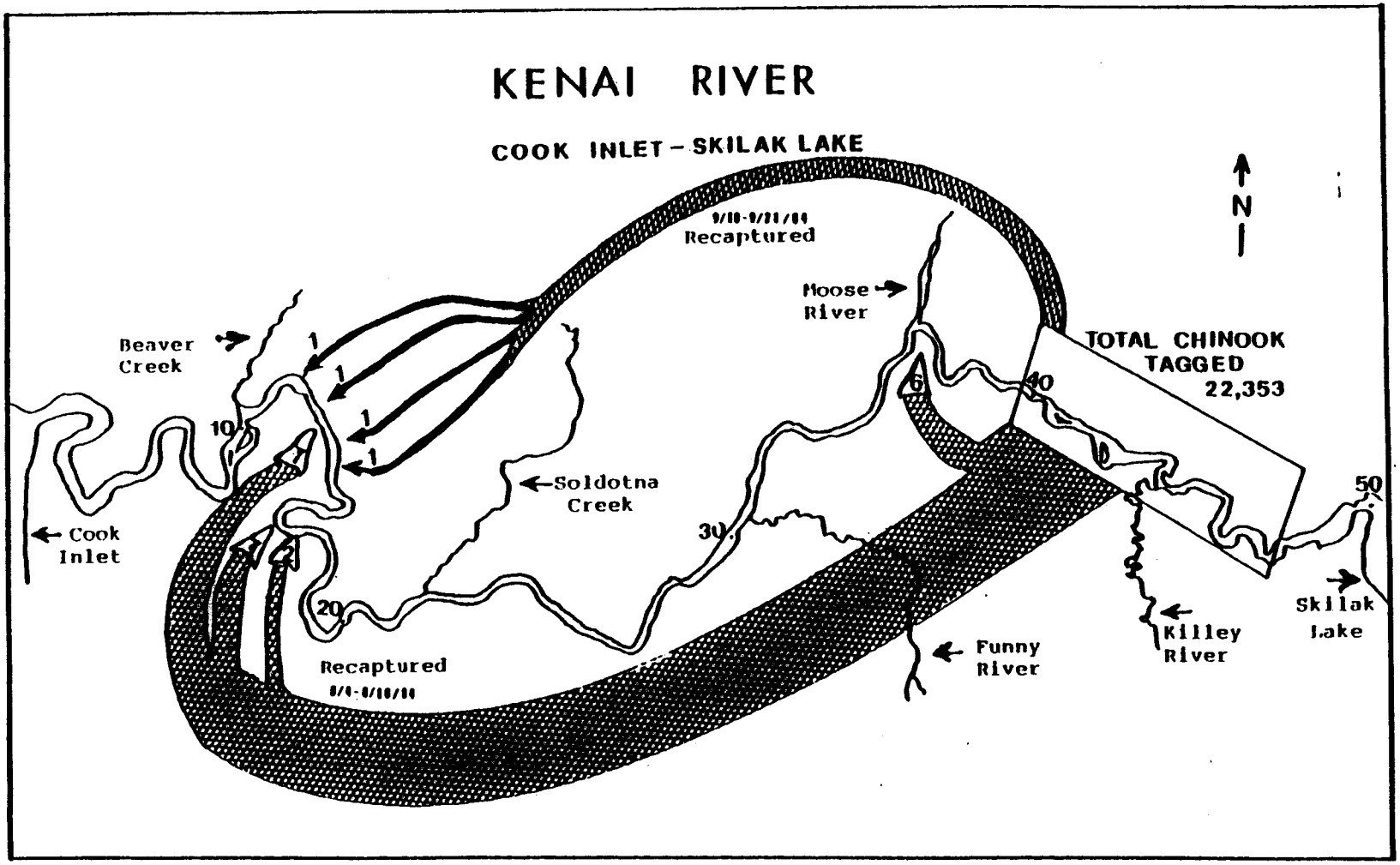


Figure 4. Recapture locations of tagged juvenile chinook salmon from upper Kenai River, 1984.

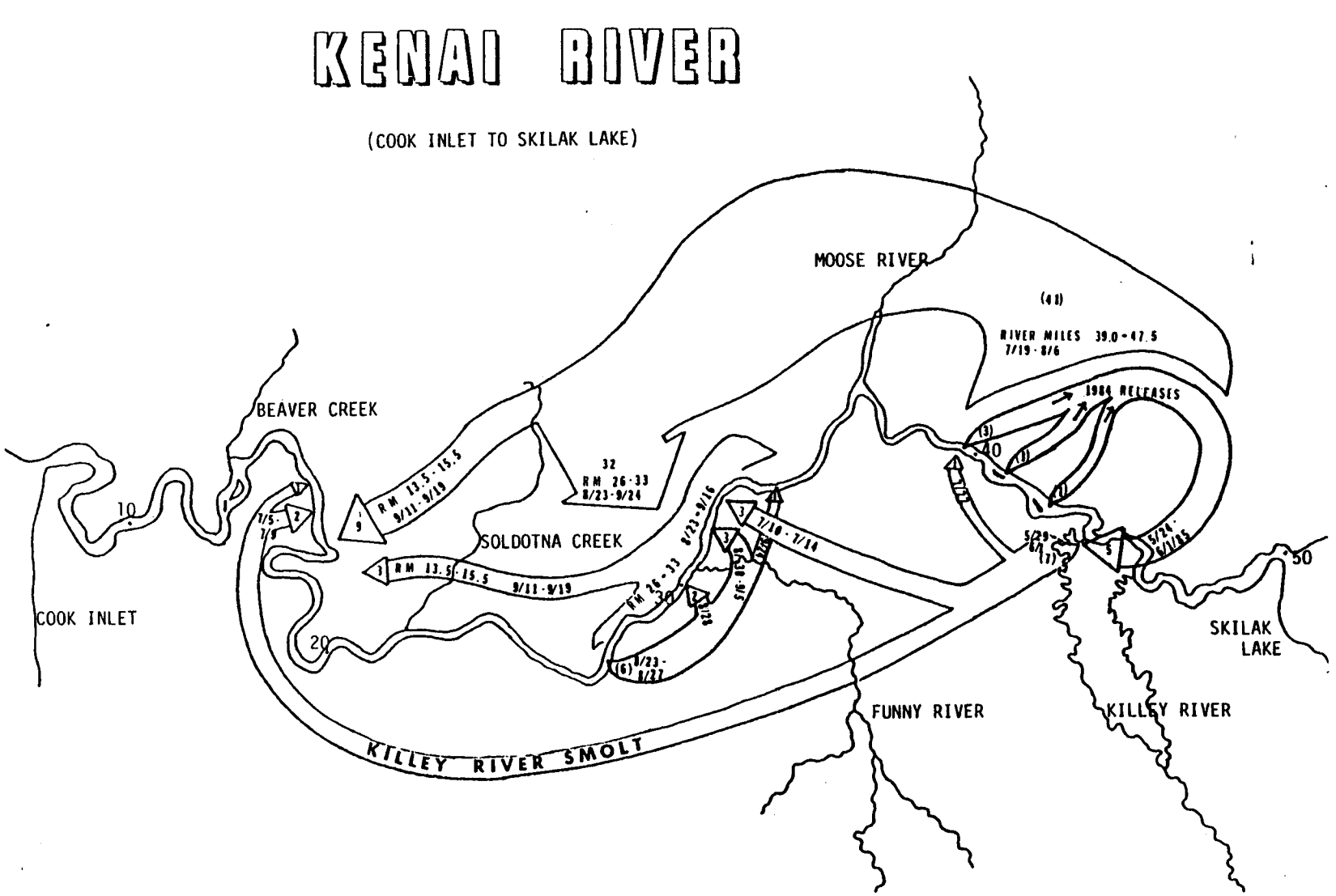


Figure 5. Recapture locations of tagged juvenile chinook salmon in the Kenai River system, 1985. (Numbers in point of arrows represent fish recaptures.)

study. In conjunction with the capture of juvenile chinook salmon, information on relative abundance, age and growth, and instream movement of juvenile salmon was collected. The relative abundance of rearing juvenile chinook salmon, however, was simply characterized by the average number caught per minute or per trap. We made no attempt to adjust catch rates for weather conditions, water conditions, or type of bait.

The increasing conflict of user groups competing for limited natural resources within the Kenai Peninsula Borough has forced decision makers to regulate uses of the river to reduce or control future impacts there. The fisheries resource is, indeed, an important use of the Kenai River because of its economic and recreational value to the community. The critical seasonal habitats and population densities of juvenile chinook salmon that may affect adult salmon production in the Kenai River system are not known; however, until more information is acquired, areas of high rearing densities should be noted so that protective measures can be implemented. The upper-upper Kenai River reach (RM 65.0-70.6) had the highest catches of juvenile chinook salmon; this was followed by the upper river reach, especially RM 40.1-41.2 and RM 41.5-42.6. Unfortunately, not all sampling sites were trapped at the same time, and some population loss and movement may have occurred.

Burger et al. (1983) found that the lower and upper Kenai River reaches had higher trap catch rates than the middle river during the fall and spring for age-0.0 chinook salmon. The catch rates were not significantly different between the upper and lower sections during the spring. These catch rates nearly halved during the fall. We also observed a reduction in catch rates from the upper and the lower river. More age-1.0 chinook salmon were found in the middle river during the spring, and this may be a winter staging area.

Juvenile chinook and coho salmon were captured throughout the river system, and chinook salmon was the most abundant species captured. Juvenile chinook and coho salmon increased in weight and length throughout the 1985 growing season. In 1984 at RM 45.0, however, no growth was apparent for either juvenile chinook or coho salmon between 14 August and 10 September (*see* Table 6). Also, a smaller mean size for juvenile chinook salmon was found in the upper sections in September (*see* Figure 3). Burger et al. (1983) also reported that the average size of juvenile chinook salmon was smaller in the upper river sections. The reason for this apparent lack of growth is most likely due to migration: larger fish moved out or smaller fish moved in.

The farthest movement upstream was observed when five juvenile chinook salmon that had been tagged and released from RM 39.3-42.5 the preceding summer were recaptured at the Killey River (RM 44.0) in the spring. These juveniles most likely overwintered in the Killey River and migrated as smolts in the spring. Upstream movements of juvenile salmonids is not uncommon. Several authors have documented upstream movement (Northcote 1962; McCart 1967; Brannon 1972; Raleigh and Chapman 1971); however, these species were sockeye salmon and rainbow and cutthroat trout, *Salmo clarki* Richardson. Elliott and Finn (1984) also found some upstream migration of juvenile chinook salmon into lower Kenai River tributaries from June to October.

Downstream movement of juvenile chinook salmon was also documented during this study. We had released 22,353 tagged juvenile chinook salmon from 26 July to 15 August 1984 in the upper river. During 4-16 August, the USFWS recaptured 22 salmon from this group in the middle and lower river. When the lower river tagging began in mid-September, four of the upper river fish were recaptured.

In 1985, of the 223 recaptured juvenile chinook salmon, 53 (24%) were found downstream from their release site. Some smolts that had been tagged and released in the Killey River were recaptured later in the Kenai River; several smolts migrated 30 miles in 37-41 days,while others remained in the Kenai River even longer (Figure 5).

Lister and Walker (1966) noted two periods of downstream migration for juvenile chinook salmon in the Big Qualicum River: (1) a large and variable migration and (2) a small and relatively constant late migration. Hoar (1953, 1958) suggested that these migrations are simply passive downward movements caused by the direction of the current. Nicholson (1954) speculated that the migrations are density regulated and the regulator may change seasonally with space and food in the spring, summer, and fall; while suitable space alone may govern density in winter. The aggressive behavior of rearing juvenile chinook salmon competing for space is well documented. During winter juveniles begin a period of dormancy that has been shown to reduce this territorial behavior (Hartman 1965; Mason 1966; Kallberg 1958). Densities of fish in certain areas of good winter habitat far exceeded maximal densities found in good summer habitat (Everest 1969). Genetics may also be involved in the migration process. Carl and Healey (1984) found three genetic stocks of chinook salmon in the Nanaimo River; the upper river juvenile stocks remained a full year in fresh water, the middle river stocks stayed 2 months in the river before migrating in the estuary, and the lower river stocks migrated immediately after emergence. We do not know whether the downstream movement we observed is passive, density dependent, or genetic; however, the high catch rates made in the river, the fact that juvenile chinook salmon were captured in all areas of the river, and the excellent condition of fish sampled suggest that a density-dependent mechanism may be influencing downstream movement.

JUVENILE CHINOOK SALMON OVERWINTER STUDY

Introduction

An overwintering study was initiated in November 1983 to determine winter habitat utilization and population stability of juvenile chinook salmon. The objectives of this follow:

1) develop winter sampling techniques to capture rearing salmonids in the mainstem of the Kenai River;
2) determine overwinter growth of juvenile chinook salmon; and
3) determine winter habitat used and population stability from fall to spring.

Two locations were selected in the lower Kenai River: RM 23.1 near Swiftwater Campground and RM 15.3 near Porter's Campground. The study location at RM 23.1 had higher velocity, larger-sized substrate, and a gradient of 1.1 m/km. The study area was near the shoreline and had substrate composed of small to large boulders. The study location at RM 15.3 had lower velocity, smaller-sized substrate, and a gradient of 0.43 m/km. This lower study area had submerged trees, lower flows, and a sand/silt substrate.

Materials and Methods

Juvenile Salmon Capture and Marking:

Three methods were employed to test the most effective means of capturing juvenile chinook salmon during this season: (1) minnow trapping, (2) seining, and (3) electro-fishing. Gee minnow traps were baited with borax-cured and disinfected salmon eggs and fished for one hour intervals. Seining was conducted with a 30.5-m x 0.6-cm mesh seine set at four locations; time and area fished per set was recorded. Electro-fishing was conducted with

a Coffelt electronics electro-shocker (Model BP-2) set at 75-100 volts and the fishing effort was defined in time and area fished (m^2).

Only those juvenile chinook salmon caught by minnow trapping were marked for the population stability study since these were less stressed. Juvenile fish captured in traps were enumerated by species, and all but chinook salmon were immediately released. The chinook salmon caught at RM 15.3 were marked by clipping the upper lobe of the caudal fin, and those caught at RM 23.1 had the lower lobe of the caudal fin clipped.

Size and Age Sampling:

In conjunction with capturing juvenile salmon for the marking study, 100 juvenile chinook and coho salmon from both study locations were randomly selected, weighed to the nearest 0.1 g with a Ohaus dial-a-gram balance (Model 2610), and measured to the nearest mm (fork length). Scale samples were taken for age determination.

Habitat Utilization:

Habitat parameters measured included water depth, water velocity, distance from cover, distance from shore, and substrate type. The data were collected at individual minnow trap sites. Depths and velocities were measured with a Marsh-McBirney meter (Model 201M); the distances from cover and shore and the substrate were visually estimated. Substrate was defined as follows: boulder, 300 mm; rubble, 76-300 mm; gravel, 2.5-76 mm; sand/silt, 2.5 mm; other matter (Herrington and Dunham 1967).

Results

Juvenile Capture and Marking:

A total of 75 minnow-trap sets was made during November, and 1,472 juvenile chinook salmon were captured; the catch rate was 0.20 chinook/min (Table 7). Twenty juvenile chinook salmon were caught in the four seine sets (0.50 chinook/min), and 79 juvenile chinook salmon were captured by electro-shocking for a catch rate of 0.43 chinook/min (Table 8).

A total of 1,272 age-0.0 juvenile chinook salmon was marked and released in November 1983 (Table 7). At RM 15.3, 704 fish were marked by removal of a portion of the upper caudal fin; at RM 23.1, 568 fish were marked by removal of a portion of the lower caudal fin. The percentage of marked fish recaptured during the last tagging survey in November was 27.7% at RM 15.3 and 21.7% at RM 23.1.

Size and Age Sampling:

The chinook salmon were larger in November at RM 23.1 (69.4 mm, 3.8 g) than at RM 15.3 (67.9 mm, 3.2 g) (Table 9). In May the respective mean lengths and weights of chinook salmon captured at RM 23.1 were 74.7 mm and 5.0 g, compared to 71.5 mm and 4.6 g at RM 15.3. This represents increases of 5.3 mm in length and 1.2 g in weight at RM 23.1 and 3.6 mm in length and 1.4 g in weight at RM 15.3.

Juvenile coho salmon increased 1.5 mm in length and 0.6 g in weight at RM 15.3; however, at RM 23.1 the mean length decreased 0.2 mm, while the mean weight increased 0.3 g. The small sample size taken at RM 23.1 could account for these differences.

Table 7. The numbers of traps and fish captured, marked, and released at RM 15.3 and RM 23.1, Kenai River, 1983.

Sampling location	Date	Number of traps	Chinook catch	Catch per trap/minute	Number of fins clipped	Number of recaptures
RM 23.1	11/04	6	53	0.10	53	0
	11/08	6	157	0.34	151	5
	11/08	6	139	0.24	134	5
	11/09	6	53	0.14	46	6
	11/09	6	35	0.10	29	3
	11/14	10	198	0.23	155	43
	Total[1/]	40	635	0.20	568	62
RM 15.3	11/02	6	54	0.18	50	0
	11/03	6	282	0.24	268	7
	11/07	10	278	0.28	224	51
	11/07	3	14	0.04	11	2
	11/10	10	209	0.23	151	58
	Total[2/]	35	837	0.20	704	118

1/ Also captured: 149 coho salmon (age 0.0), 6 coho salmon (age 1.0), 27 Dolly Varden, 7 rainbow trout, 4 sculpin, 5 sockeye salmon, 4 stickleback

2/ Also captured: 1,618 coho salmon, 1 Dolly Varden, 1 stickleback, 11 sockeye salmon, 12 rainbow trout

Table 8. Catches of juvenile chinook salmon from minnow traps, electro-fishing, and seining in the Kenai River, November 1983.

Sampling method	Location (RM)	Number of chinook	Minutes fished	Area fished	Catch per trap/minute
Trap	15.3	837	4,107	--	0.20
	23.1	635	3,136	--	0.20
Electro-fish	15.3	11	20	2 x 4 m	0.55
	15.3	15	20	2 x 4 m	0.75
	15.3	1	68	2 x 4 m	0.01
	Total	27	108		0.25
	23.1	10	20	4 x 4 m	0.50
	23.1	9	20	2 x 4 m	0.45
	23.1	12	20	2 x 4 m	0.60
	23.1	18	20	2 x 5 m	0.90
	23.1	2	20	3 x 4 m	0.10
	23.1	1	20	2 x 2 m	0.05
	Total	52	120		0.43
Seine	15.3	0	20	10 x 12 m	0.00
	23.1	1	20	15 x 15 m	0.05
	23.1	19	20	6 x 12 m	0.95
	Total	20	40		0.50

Table 9. Lengths and weights of juvenile chinook and coho salmon captured at lower Kenai River study sites, November 1983 and May 1984.

Species	Date	River mile	Sample size	Mean length (S.D.)	Sample size	Mean weight (S.D.)
Chinook	Nov 1983	15.3	120	67.9 (6.1)	86	3.2 (1.0)
	Nov 1983	23.1	131	69.4 (7.5)	69	3.8 (1.2)
	May 1984	15.3	75	71.5 (7.1)	75	4.6 (1.3)
	May 1984	23.1	95	74.7 (8.0)	95	5.0 (1.5)
Coho	Nov 1983	15.3	72	50.6 (4.4)	72	1.4 (0.4)
	Nov 1983	23.1	27	52.8 (3.2)	27	1.6 (0.3)
	May 1984	15.3	112	52.1 (4.7)	112	2.0 (0.5)
	May 1984	23.1	52	52.6 (4.3)	52	1.9 (0.5)

Juvenile Salmon Recapture and Habitat Utilization:

The two sites where marked juvenile chinook salmon had been released in November 1983 were again sampled from 19 March to 3 May 1984 to determine if marked salmon had overwintered within the same area and habitat type. No juvenile chinook salmon could be caught by seining; however, minnow-trapping and electro-shocking were effective. From a total catch of 75 chinook salmon at RM 15.3, two marked ones (2.7%) were recaptured, while from a total of 123 at RM 23.1, six marked chinook salmon (4.9%) were recaptured (Table 10). These data demonstrate that some portion of the juvenile chinook salmon population remains at the same location from fall until spring. The higher recapture rate at RM 23.1 could be due to a larger and more stable substrate; however, at RM 15.3 the trees along the shoreline that are normally submerged during the spring and summer were exposed during the fall sampling because of a reduction in river discharge, resulting in a subsequent reduction in fish habitat.

At both RM 15.3 and 23.1, most fish were caught along the shoreline at a depth of 1 m or less. At RM 15.3 and 23.1, 97% and 95%, respectively, of the fish were captured where the water velocities were 10 cm/s or less. Nearly all of the fish were caught within some cover; e.g., rocks or trees.

Discussion

An important aspect of juvenile chinook salmon life history is the overwintering behavior. A number of authors have reported that juvenile salmonids enter the substrate during winter. Hartman (1963) suggested that this behavior would protect the fish from predation, downstream displacement, and damage from ice scouring. Everest (1969) found that juvenile chinook salmon and steelhead trout began entering the substrate as stream temperatures drop below 7°C. He also observed that no fish were

Table 10. Number of fish captured by minnow traps and electro-fishing from March to May 1984, Kenai River.

Sampling Location	Sampling method	Date	Number of traps	Chinook captured	Number of marked fish recaptured
RM 23.1	Trap	03/29	20	0	0
		04/01	10	0	0
		04/13	10	28	1
		04/18	10	1	0
		04/18	10	5	0
		04/19	10	32	2
		04/30	3	8	0
		05/03	5	18	2
		Total[1/]	78	92	5
	Electro-fish	04/01	NA	7	0
		04/20	NA	24	1
		Total		31	1
RM 15.3	Trap	04/11	10	0	0
		04/18	10	0	0
		04/23	5	26	0
		05/03	3	30	2
		Total[2/]	28	56	2
	Electro-fish	04/20	NA	19	0

1/ Also captured:
- 52 coho salmon (age 1.0)
- 473 Dolly Varden
- 2 rainbow trout
- 5 stickleback
- 30 sculpin
- 1 sockeye salmon
- 1 lamprey

2/ Also captured:
- 112 coho salmon (age 1.0)
- 9 coho salmon (age 2.0)
- 40 chinook salmon (age 0.0)
- 2 stickleback
- 1 sockeye salmon
- 2 sculpin

found above substrate when stream temperatures fell below 5°C; he found them 15-30 cm deep in the substrate. Edmundson et al. (1968) had mixed results with branded chinook salmon and steelhead trout. Although there were numerous unbranded chinook salmon present, they did not find any branded chinook salmon in the study area during the winter; however, they found branded steelhead trout present in the areas where they had been released the previous summer.

Everest (1969) found all overwintering juvenile chinook salmon in substrate that was over 40 cm in size and had large enough spaces for fish and water passage. He mentioned that conditions and velocities above the substrate, although variable, had little impact on the fish.

Juvenile chinook salmon in the Kenai River also utilize the spaces in the substrate as overwintering cover. In the spring, we observed these young fish as they were drawn out of the substrate by the electro-shocking current. This may explain the difference in our winter recapture rates between RM 23.1 and RM 15.3: the substrate at RM 23.1 was larger than at RM 15.3 and may have offered a more suitable winter environment.

Burger et al. (1983) noted an increase in catches of juvenile salmon at or below RM 10.25 during October 1980 and 1981. They suggested that this increase was due to displacement of juveniles because of a drop in river discharge and a reduction of available rearing habitat.

The concept of a fall downstream movement of juvenile chinook salmon is further supported by the difference in recapture rates in the Lower River from 18 September to 9 October; only four of 4,564 (0.1%) juveniles were recaptured, compared to 22 of 2,041 (1.1%) fish recaptured from the middle and lower river from 4 to 16 August (*see* Figure 4). This decrease in the recapture rate of tagged fish suggests that either they migrated from the

river or a large number of unmarked fish migrated into this reach. Some, however, may have found suitable overwintering habitat elsewhere and, thus, had become less vulnerable to trapping. From all available evidence, however, we believe that some portion of the Kenai River juvenile chinook salmon annual production migrate prematurely into Cook Inlet. Furthermore, considering the apparent absence of any "age zero" adults (Hammarstrom, pers. comm.), survival of these early migrants is probably negligible.

Our data, together with the information from other reports, demonstrate the importance of good overwintering habitat as well as the importance for fish to occupy that habitat by late fall. Juvenile chinook salmon need the large noncompacted cobble substrate for overwintering protection,because after entering it they exhibited little movement between ice-up and break-up.

SUMMARY

1. A total of 114,440 juvenile chinook salmon was marked with an adipose finclip and a coded-wire tag in the Kenai River between July 1984 and June 1986. Of these, 38,476 and 65,980 were caught, marked, and released during 1984 and 1985, respectively, in four rearing areas in the mainstem of the Kenai River; and 9,984 were caught, marked, and released as they emigrated after rearing in a major tributary of the Kenai River.

2. The relative abundance (i.e., catch/trap-minute) of juvenile chinook salmon in the Kenai River suggests that the "Upper-Upper" reach (RM 65.0-70.6) may be one of the most important rearing areas for this species. The next most important rearing area for juvenile chinook salmon is the "Upper" reach (RM 39.3-47.6).

3. During the summer, most juvenile chinook salmon were caught in areas near cover; e.g., flooded vegetated sandbars with 10-80 cm/s water velocity. When the water temperature declines, however, the juvenile chinook salmon enter overwintering habitat where they apparently remain until spring. In the Kenai River, good overwintering habitat is found in reaches where the water covers large noncompacted cobble; the fish enter and utilize this substrate for protection throughout the winter.

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REFERENCES

Brannon, E. L. 1972. Mechanisms controlling migration of sockeye salmon fry. Int. Pac. Salm. Fish. Comm. Bull. 21. 86 pp.

Burger, C., D. Wangaard, R. Wilmont, and A. Palmisano. 1983. Salmon investigations in the Kenai River, Alaska 1979-1981. US Fish and Wildlife Service. National Fishery Research Center, Alaska Field Station, Anchorage, Alaska. 155 pp.

Carl, L. M. and M. C. Healey. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of chinook salmon, *Oncorhynchus tshawytscha*, in Nanaimo River, British Columbia. Can. J. Fish. Aquat. Sci. 41:1070-1077.

Edmundson, E., Everest, F. H., and D. W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Bd. Can. 25:1453-1464.

Elliott, G. V. and J. E. Finn. 1984. Fish use of several tributaries to the Kenai River. US Fish and Wildlife Service Special Studies. National Fishery Research Center, Alaska Field Station, Anchorage, Alaska. 225 pp.

Everest, F. H. 1969. Habitat selection and spatial interaction of juvenile chinook salmon and steelhead trout in two Idaho streams. Ph.D. Thesis, University of Idaho, Moscow. 77 pp.

Hammarstrom, S. L. and L. L. Larson. 1983. Evaluation of chinook salmon fisheries of the Kenai Peninsula. Alaska Department of Fish and Game, Sport Fish Division. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983. Project F-9-14, 24 (G-II-6) 36-67 pp.

Hartman, G. F. 1963. Observation on the behavior of juvenile brown trout in a stream aquarium during winter and spring. J. Fish Res. Bd. Can. 20:769-787.

Hartman, G.F. 1965. Role of behavior in the ecology and interaction of under yearling coho salmon, *Oncorhynchus kisutch*, and steelhead trout, *Salmo gairdneri*. J. Fish. Res. Bd. Can. 22:1035-1081.

Herrington, R. B. and D. K. Dunham. 1967. A technique for sampling general fish habitat characteristics of streams. US Forest Service Research Paper INT-41. 13 pp.

Hoar, W. S. 1953. Control and timing of fish migration. Biol. Rev. 28:437-452.

Hoar, W. S. 1958. The evolution of migratory behavior among juvenile salmon of the genus *Oncorhynchus*. J. Fish. Res. Bd. Can. 15:391-428.

Kallberg, H. 1958. Observation in a stream tank of territoriality and competition in juvenile salmon and trout. Rep. Inst. Freshwater Res. Drottningholm. 29:55-98.

King, B. E. and K. E. Tarbox. 1983. Upper Cook Inlet salmon, (*Oncorhynchus* sp.) escapement studies, 1982. Alaska Department of Fish and Game, Commercial Fish Division. Technical Report No. 93. 139 pp.

Litchfield, D. S. 1983. Trail Lakes Hatchery brood-stock development report, 1981. Alaska Department of Fish and Game, FRED Division. Technical Report. 66 pp.

Litchfield, D. S. and G. L. Todd. 1983. Trail Lakes brood-stock data report, 1982. Alaska Department of Fish and Game, FRED Division. Technical Report. 54 pp.

Lister, D. B. and C. E. Walker. 1966. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Can. Fish Cult. 37:3-25.

Mason, J. C. 1966. Behavioral ecology of juvenile coho salmon, *O. kisutch*, in stream aquaria with particular reference to competition and aggression. Ph.D. Thesis. Oregon State of University, Corvallis, Oregon. 195 pp.

McCart, P. 1967. Behavior and ecology of sockeye salmon fry in the Babine River. J. Fish. Res. Bd. Can. 24:375-428.

Moberly, S. A., Miller, R., Crandall, K., and S. Bates. 1977. Mark-Tag manual for salmon. Alaska Department of Fish and Game, FRED Division, Juneau, Alaska. 56 pp.

Nelson, D. C. 1984. Russian River sockeye salmon study. Alaska Department of Fish and Game, Sport Fish Division. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984. Project F-9-16, 25 (C-II-C):1-66.

Nicholson, A. J. 1954. An outline of the dynamics of animal populations. Aust. J. Zool. 2:9-65.

Northcote, 1962. Migratory behavior of juvenile rainbow trout, *Salmo gairdneri*, in outlet and inlet streams of Loon Lake, British Columbia. J. Fish. Res. Bd. Can. 19:201-270.

Raleigh, R. F. and D. W. Chapman. 1971. Genetic control in lakeward migrations of cutthroat trout fry. Trans. Am. Fish. Soc. 100:33-40.

Scott, K. M. 1981. Erosion and sedimentation in the Kenai River, Alaska. US Geological Survey Open File Report 81-219. 118 pp.

U.S. Army Corp of Engineers. 1978. Kenai River Review. US Army Engineer District, Anchorage, Alaska. 334 pp.