Fishery Data Series No. 95-17

Marking Juvenile Chinook Salmon in the Kenai River and Deep Creek, Alaska, 1993-1994

by

Terry Bendock

September 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 95-17

MARKING JUVENILE CHINOOK SALMON IN THE KENAI RIVER AND DEEP CREEK, ALASKA, 1993-1994

by

Terry Bendock
Division of Sport Fish, Soldotna

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

September 1995

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-10, Job No. S-2-6.

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

Terry Bendock
Alaska Department of Fish and Game, Division of Sport Fish,
34828 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8367, USA

This document should be cited as:
Bendock, Terry. 1995. Marking juvenile chinook salmon in the Kenai River and Deep Creek, Alaska, 1993-1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-17, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The contribution of selected wild stocks of chinook salmon *Oncorhynchus tshawytscha* to an expanding mixed-stock marine recreational harvest in Cook Inlet will be assessed using a coded wire tag marking and recovery program. Chinook salmon stocks in the Kenai River and Deep Creek have been selected for assessment. An estimated 252,092 fingerling chinook salmon of Kenai River origin were marked and released during 1993 through 1994. An estimated 13,255 chinook salmon smolt of Deep Creek origin were marked and released during 1994. The number of fish marked in both rivers fell short of our anticipated goals. The contribution of these tagged cohorts will be estimated beginning in 1997. Chinook salmon smolt were present in lower Deep Creek throughout the summer with peak numbers emigrating between mid-June and mid-July. Two ages-classes of smolt were present in Deep Creek catches. Yearling smolt were the predominant age class and averaged 88 mm in fork length. Fingerling chinook salmon appeared to emigrate beginning in late July after attaining a length of approximately 70 mm. Mean lengths of fingerling chinook salmon increased 0.64 mm/d during July.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, smolt, fingerling, juvenile, coded wire tag, Kenai River, Deep Creek, Cook Inlet, mixed-stock, recreational fishery.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* stocks returning annually to Cook Inlet are thought to be fully utilized in existing fisheries. Biological escapement goals have been identified for managing major stocks of Cook Inlet chinook salmon and attainment of these goals is assessed annually using aerial survey techniques, weirs, or sonar. Many gillnet and hook-and-line fisheries harvest mixed stocks of chinook salmon as they return to spawn in Cook Inlet drainages. Since the harvest of this resource is fully allocated, growth in one fishery may occur at the peril of another, complicating sustained yield management and causing economic disruption.

The Cook Inlet marine recreational fishery (Figure 1) harvests mixed stocks of chinook salmon along eastside Cook Inlet beaches from Ninilchik south to Anchor Point (McKinley *In press*). Most effort in this fishery takes place within one-half mile from shore during May through July. Harvests are thought to be composed of mature fish returning primarily to Kenai Peninsula drainages and hatchery release sites. This fishery began in the early 1970s and remained fairly stable through the late 1980s. However, increased marketing by sport fish guiding and tourism industries, improved boat launching facilities, and restrictions in other Cook Inlet inriver fisheries have resulted in recent growth in the marine fishery. Harvests of chinook salmon in the marine fishery increased by approximately 57% (2,700 fish) between 1987 and 1994 (Mills 1994). This growth appears to be only modest at this time, yet stock specific contributions to the marine harvest remain unknown, and more conservative management has been necessary to meet several Cook Inlet escapement objectives. The lack of quantifiable harvest composition data precludes development of meaningful management objectives for the marine fishery and compromises our ability to reconstruct stock-specific adult returns of chinook salmon.

To address these concerns, a long-term study has been initiated to assess growth and characteristics of the marine fishery, evaluate ongoing efforts to supplement harvests using hatchery fish, and estimate the contributions of specific wild stocks to the marine harvest. As part of this long-term effort, the contributions of wild Kenai River and Deep Creek chinook salmon as well as all hatchery smolt released in Cook Inlet will be estimated using a coded wire tag (CWT) marking and recovery program. Marking wild chinook

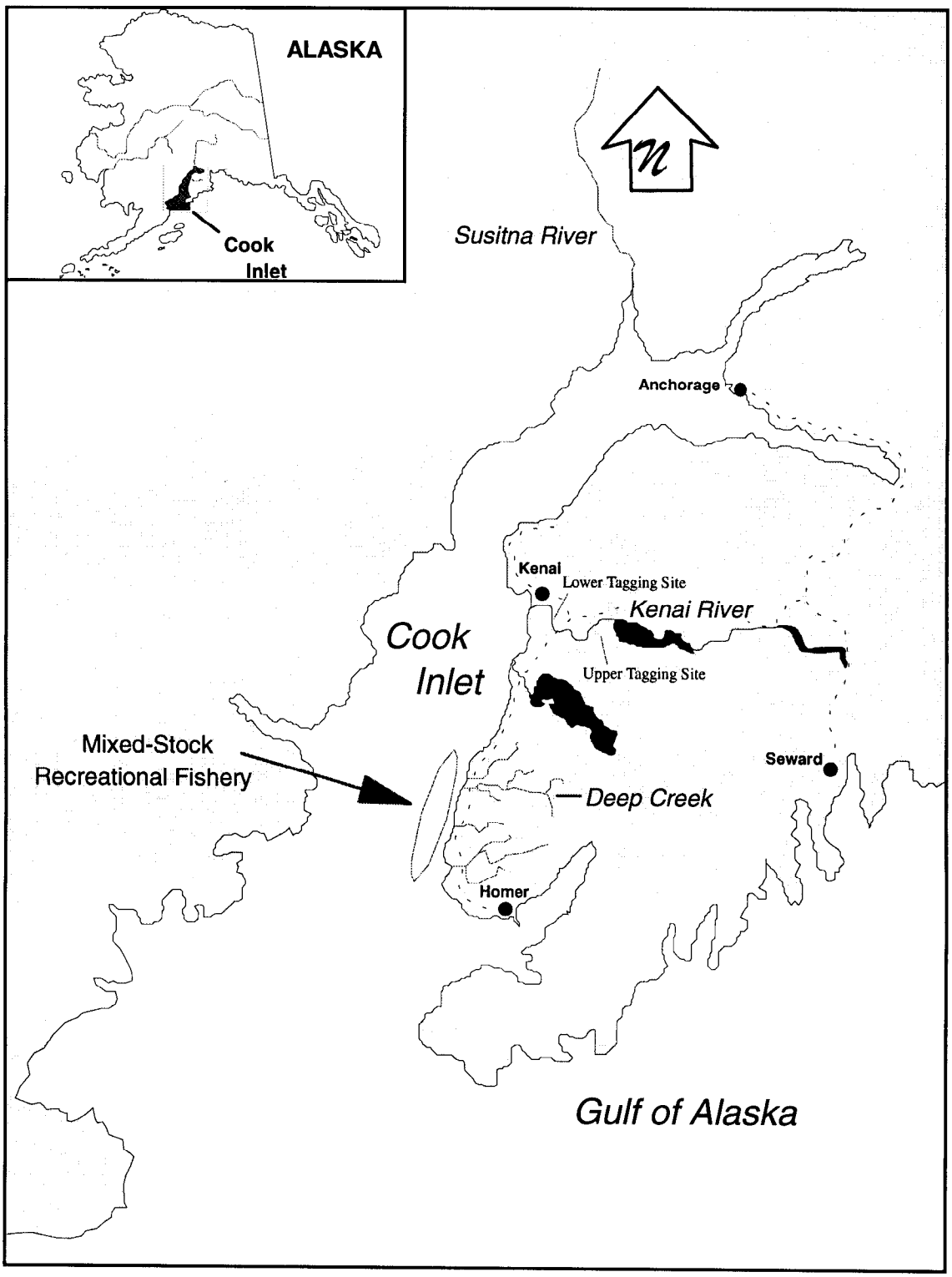

Figure 1.-Map of Cook Inlet showing the locations of the Kenai River, Deep Creek, and the marine recreational fishery.

salmon of known origin is an essential step in this process and is the subject of this report.

The Kenai River and Deep Creek were selected as candidate streams for tagging wild salmon for different reasons. The Kenai River is the largest freshwater chinook salmon fishery in Alaska (Mills 1994). Exploitation of early and late-run chinook salmon bound for the Kenai River is governed by management plans adopted by the Alaska Board of Fisheries. These plans stipulate specific escapement goals for each run and the manner in which these fisheries are to be managed in the event of a conservation shortfall. The Kenai River is also the primary Cook Inlet drainage having late-run chinook salmon. Hence, all chinook salmon harvested in Cook Inlet after 1 July are considered of Kenai River origin. All other chinook salmon stocks entering Cook Inlet exhibit early run timing and are harvested in unknown proportions in the marine fisheries. Estimating the contribution of early-run Kenai River chinook salmon to the marine fishery will provide a final piece of harvest data necessary for total run reconstruction, and will provide important information for making allocative decisions concerning the harvest of this stock.

Deep Creek was selected as a tagging site because of its proximity to the growing marine fishery. Deep Creek supports a small run of chinook salmon that is harvested on weekends only from Memorial Day through the third week of June. The marine fishery takes place beyond a 1-mile radius of the mouth of Deep Creek. Additional exploitation of Deep Creek fish in marine waters may result in the overharvest of this conservatively managed stock. Estimating the contribution of Deep Creek chinook salmon to the marine fishery will therefore provide important information for making conservation and allocative decisions concerning the harvest of this stock.

This report documents the methods and numbers of wild juvenile chinook salmon that were marked and released in Deep Creek during 1994, and the Kenai River during 1993 and 1994. Additional information on chinook salmon size at age and smolt timing is presented for Deep Creek. The contribution of these tagged cohorts to the marine fishery will be estimated beginning in 1997.

METHODS

STUDY DESIGN

To achieve our goal of estimating the contribution of Kenai River and Deep Creek chinook salmon to the Cook Inlet marine recreational fishery, a sample of chinook salmon from each drainage was captured, marked using coded wire tags and an adipose finclip, and released. Marking juvenile salmon in freshwater rearing habitats permits a positive identification of the natal drainage (stock) in which the fish were produced. Juveniles marked with uniquely coded micro-wire tags can then be identified when harvested as adults in mixed-stock fisheries.

To estimate the contribution of a cohort to a mixed-stock fishery, an estimate of its marked proportion is required. Since this proportion is unknown at the completion of marking, it will be estimated for a return year by examining a sample of the inriver sport harvest of adults. An examination of the inriver harvest will establish whether or not the marked proportion of the return remains constant, or varies over the duration of the return. A constant proportion of marked adults will indicate that a representative sample of juveniles was marked. This proportion will then represent the marked proportion available to the mixed-stock fishery and can be used to estimate the contribution for the cohort of known origin.

A variable proportion of marked adults in the inriver return will indicate bias in the marked sample of released juveniles. Variation in the inriver marked proportion is indicative of temporal changes in the marked proportion passing through the mixed-stock harvest area. At present, it is not possible to accurately apply changing marked proportions to the marine fishery because the lag times of adult chinook salmon migrating through the fishery are unknown.

Estimating Sample Size Requirements

We used procedures outlined in Meyer et al. (*Unpublished*) and Clark and Bernard (1987) to estimate sample size requirements for marking juveniles in the Kenai River and Deep Creek. The first step in determining sample size requirements was to estimate average smolt/fingerling abundance. We accomplished this by dividing the average estimated total return by an approximate smolt-to-adult survival rate. The resulting quotient was then divided by an approximate fingerling-to-smolt survival rate to estimate the number of fingerlings in the population. Hence, the number of Kenai River fingerling chinook salmon was estimated by:

$$\frac{60{,}000 \text{ (Total Return)}}{0.05 \text{ (Smolt Survival)}} = 1{,}200{,}000 \text{ (Smolt)} \quad (1)$$

$$\frac{1{,}200{,}000 \text{ (Smolt)}}{0.5 \text{ (Fingerling Survival)}} = 2{,}400{,}000 \text{ (Fingerlings)}. \quad (2)$$

Similarly, the number of Deep Creek chinook salmon smolt was estimated by:

$$\frac{1{,}550 \text{ (Total Return)}}{0.05 \text{ (Smolt Survival)}} = 31{,}000 \text{ (Smolt)}. \quad (3)$$

The next step was to estimate the number of fingerling/smolt (t) to be marked (Clark and Bernard 1987):

$$t = \frac{\left(z^2 N_s / \phi\right)}{nd^2 + z^2} \quad (4)$$

where:

- z = the acceptable probability of a type I error,
- N_s = smolt/fingerling abundance at the time of tagging,
- ϕ = the fraction of the harvest examined for tags,
- n = an a priori estimate of contribution, and
- d = the desired relative precision of the estimate.

Assuming $z = 1.645$ ($\alpha = 0.10$), N_s = 2,400,000, $\phi = 0.5$, $n = 1{,}500$, and $d = 0.20$, then the number of Kenai River fingerling to be tagged was 207,140. Whereas, assuming $z = 1.645$ ($\alpha = 0.10$), $N_s = 31{,}000$, $\phi = 0.5$, $n = 100$, and $d = 0.20$, then the number of Deep Creek chinook salmon smolt to be tagged was 25,018.

Coded Wire Tag Deployment

Methods of capturing fish in the Kenai River and Deep Creek were dissimilar due to the physical characteristics of both rivers and different ages of fish used for marking in each system.

Kenai River

Efforts to capture large numbers of age-1 chinook salmon smolt have not been successful in the Kenai River, but baited minnow traps were demonstrated in previous studies to be an effective gear for catching fingerlings (Burger et al. 1983, Bendock 1989). Minnow traps measuring 48 cm X 20 cm X 0.6 cm and baited with brine-cured salmon roe were used to capture fingerling (age-0) chinook salmon at two mainstem locations in the Kenai River during 1993. A lower river reach from river miles (rm) 12 to 18 was trapped during the period 21 July through 15 September; while an upper river reach from rm 41 to 46 was trapped during 28 July through 13 September. Only the lower river reach was trapped during 1994 in an effort to more efficiently use our personnel and equipment. However, procedures for capturing and handling fish were similar in both years.

Twelve baited minnow traps were typically deployed along 200 ft of shoreline for approximately 20 min each. The resulting catch was placed into 5 gallon plastic buckets and transported by river boat to centrally located (rm 15 and 44) tagging facilities. Fish were then transferred to screened holding pens that were secured in the water column. Chinook salmon fingerlings $\geq$55 mm fork length were anesthetized with tricaine methanesulfonate (MS-222), marked by removing the adipose fin, and injected with a full length (1.0 mm) coded wire tag using a Northwest Marine Technologies Inc. (NMT) Mark IV tag injector. Fish < 55 mm were not tagged because tag loss increases when fish this small are tagged with full length tags. Tagged fish were passed head-first through a NMT quality control device that magnetized and confirmed the presence of each tag. Fish were then allowed to recover in a holding tank for approximately 1 hour and released at their point of capture. Short-term handling mortality and tag retention rates were estimated using observed frequencies in a daily random sample of approximately 200 tagged fish that was held overnight (18 to 24 h), inspected for dead fish, and passed again through the quality control device. We trapped fish along both shorelines beginning at the downstream end of each tagging reach and systematically advanced upstream after marked fish were returned to a site. Species other than chinook salmon were released.

Deep Creek

A rotary smolt trap, constructed by E. G. Solutions of Corvallis, Oregon, was fished in Deep Creek approximately one-half mile above its confluence with Cook Inlet. The trap had an 8-foot diameter upstream opening and was positioned in the thalweg adjacent to a steep riprap bank where emigrating smolt were presumed to be present. The trap was fished continuously from 11 May through 3 August 1994. Technicians left the trap unattended at night but inspected it every 2-3 hours between 0800 hours and 2300 hours. Fine debris which collected on the trap cone was removed using a high pressure water hose. Captured fish were removed from the live box each morning. Chinook salmon smolt were placed in a holding pen, while other species were identified, counted, and released. Catch composition, water and air temperature, water level (using a staff gauge), and trap revolutions per minute were recorded daily. Chinook salmon smolt were tagged using procedures identical to those described above for the Kenai River. All tagged smolt were released into Deep Creek approximately 100 ft downstream from the trap.

Two age classes of chinook salmon were simultaneously represented in Deep Creek catches. Age-0 (1993 brood year) and age-1 (1992 brood year) fish were initially distinguished by their distinctly different sizes early in the season. However, as age-0

chinook salmon increased in length, it became increasingly difficult to distinguish the two groups. Fork lengths (nearest millimeter) and scales were obtained from random samples of approximately 100 "large" and 100 "small" chinook salmon during weekly intervals. Scale smears were mounted on 25 mm by 75 mm glass slides and viewed using a microfiche projector. Throughout the season, age-0 chinook salmon ≥55 mm were marked and tagged using a different tag code to distinguish them from age-1 emigrants. To test for growth over time, the SAS (1982) analysis of variance procedure was used to test for differences in fork lengths for each age group among sample periods.

A salinity tolerance bioassay was conducted on 20 July to test the osmocompetence of age-0 chinook salmon captured in Deep Creek. This test was used as an indication of the ability of age-0 fish to emigrate. A sample of 218 fingerlings was placed in a 5 gal plastic container holding 32 ppt sea water which was prepared using a commercially available aquarium mix. The container was aerated and held at ambient water temperature. Survival was calculated after 24 h using observed frequencies of dead and live fish.

RESULTS

CHINOOK SALMON TAGGING

Tagging results are presented covering 2 years of releases in the Kenai River and a single season of tagging in Deep Creek.

Kenai River

An estimated 152,397 chinook salmon fingerlings ≥ 55 mm fork length were marked using coded wire tags and released in the Kenai River during 1993. Of this total, 52,702 were captured and released in the upper reach during 28 July through 13 September and the remaining 99,695 were captured and released in the lower reach during 21 July through 15 September (Table 1). Overall short-term mortality rates associated with fish handling and tagging were 1.3% and 0.3% for the upper and lower sites, respectively. Overnight tag retention rates were 98.7% for the upper river site and 99.0% for the lower site.

Chinook salmon were only captured in the lower-river reach during 1994. An estimated 88,109 fingerlings ≥ 55 mm fork length were marked and released during 18 July through 14 September 1994 (Table 2). Overall short-term mortality and tag retention rates for 1994 were 0.2% and 99.3%, respectively.

Deep Creek Marking During 1994

An estimated 13,255 chinook salmon smolt were marked and released in Deep Creek during 1994. Of this total, 9,611 were age-1 emigrants from the 1992 brood year, while the remaining 3,644 were age-0 emigrants from the 1993 brood year (Table 3). Overall tag retention for Deep Creek smolt was 99.6% and there was no short-term mortality.

DEEP CREEK CATCH COMPOSITION AND SMOLT TIMING

The rotary trap sampled approximately 16% of the available water column (Figure 2). Stream discharge decreased and water temperature increased throughout the sampling period at Deep Creek (Figure 3). Water depth, measured using a staff gauge at the trap site, ranged from a high of 31 in on 14 May to a low of 11 in on 3 August. Water level declined steadily through mid-June, and then remained low for the rest of the season except during brief freshets. Water temperature ranged from 2.0° C to 16.0° C. Water temperature increased rapidly until mid-June and then remained relatively high through July.

Eleven species of freshwater and anadromous fish were captured in Deep Creek using the rotary smolt trap (Figure 4). Daily catches

Table 1.-Dates, codes, and numbers of chinook salmon fingerlings marked with coded wire tags and released in the Kenai River during 1993.

Dates	Tag Code	Brood Year	Age	Number
[Rivermile 44]				
7/28 - 8/04	31-22-23	1992	0	4,373
8/05 - 8/12	31-22-60	1992	0	11,411
8/16 - 8/24	31-22-61	1992	0	12,830
8/25 - 8/31	31-22-62	1992	0	10,521
9/01 - 9/13	31-22-63	1992	0	13,567
		Up-River Subtotal		52,702
[Rivermile 15]				
7/21 - 7/28	31-22-30	1992	0	5,845
7/28 - 8/03	31-22-31	1992	0	5,788
8/03 - 8/09	31-22-44	1992	0	12,087
8/09 - 8/17	31-22-45	1992	0	11,888
8/17 - 8/24	31-22-46	1992	0	11,639
8/24 - 8/30	31-22-47	1992	0	11,721
8/31 - 9/07	31-22-56	1992	0	11,843
9/07 - 9/10	31-22-57	1992	0	11,611
9/10 - 9/14	31-22-58	1992	0	12,048
9/14 - 9/15	31-22-59	1992	0	5,225
		Down-River Subtotal		99,695
Kenai River Total for 1993				152,397

Table 2.-Dates, codes, and numbers of chinook salmon fingerlings marked with coded wire tags and released in the Kenai River during 1994.

Dates	Tag Code	Brood Year	Age	Number
7/18 - 7/27	31-22-18	1993	0	5,885
7/27 - 8/01	31-22-36	1993	0	5,980
8/01 - 8/04	31-22-38	1993	0	6,158
8/04 - 8/08	31-22-39	1993	0	6,222
8/08 - 8/09	31-22-37	1993	0	6,258
8/09 - 8/12	31-22-50	1993	0	11,581
8/12 - 8/18	31-22-49	1993	0	11,512
8/18 - 8/24	31-22-48	1993	0	11,695
8/24 - 9/02	31-22-51	1993	0	11,373
9/02 - 9/14	31-24-09	1993	0	11,445
Kenai River Total for 1994				88,109

Table 3.-Dates, codes, and numbers of chinook salmon smolt marked with coded wire tags and released in Deep Creek during 1994.

Dates	Tag Code	Brood Year	Age	Number
5/20 - 6/28	31-22-16	1992	1	2,430
6/28 - 7/04	31-23-60	1992	1	2,684
7/04 - 7/10	31-23-61	1992	1	2,678
7/10 - 8/03	31-23-62	1992	1	1,819
7/21 - 7/29	31-23-63	1993	0	2,837
7/29 - 8/03	31-24-01	1993	0	807
Deep Creek Total for 1994				13,255

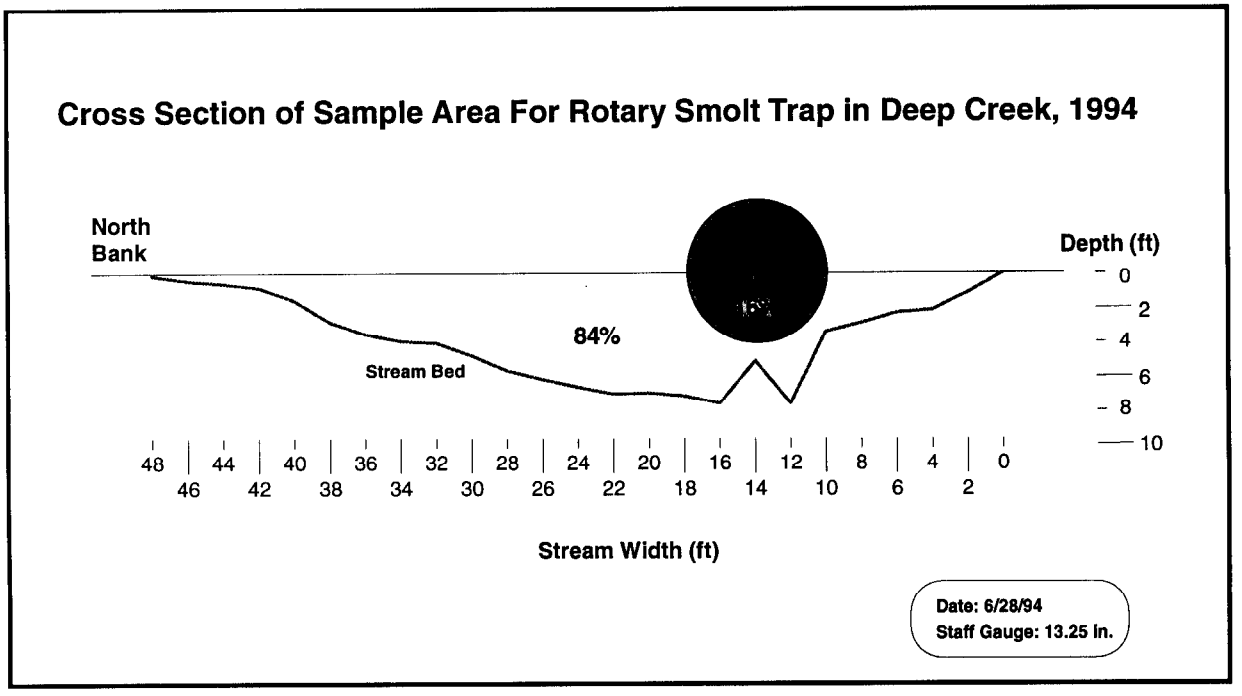

Figure 2.-Schematic cross section of Deep Creek showing the sampling area of the rotary smolt trap.

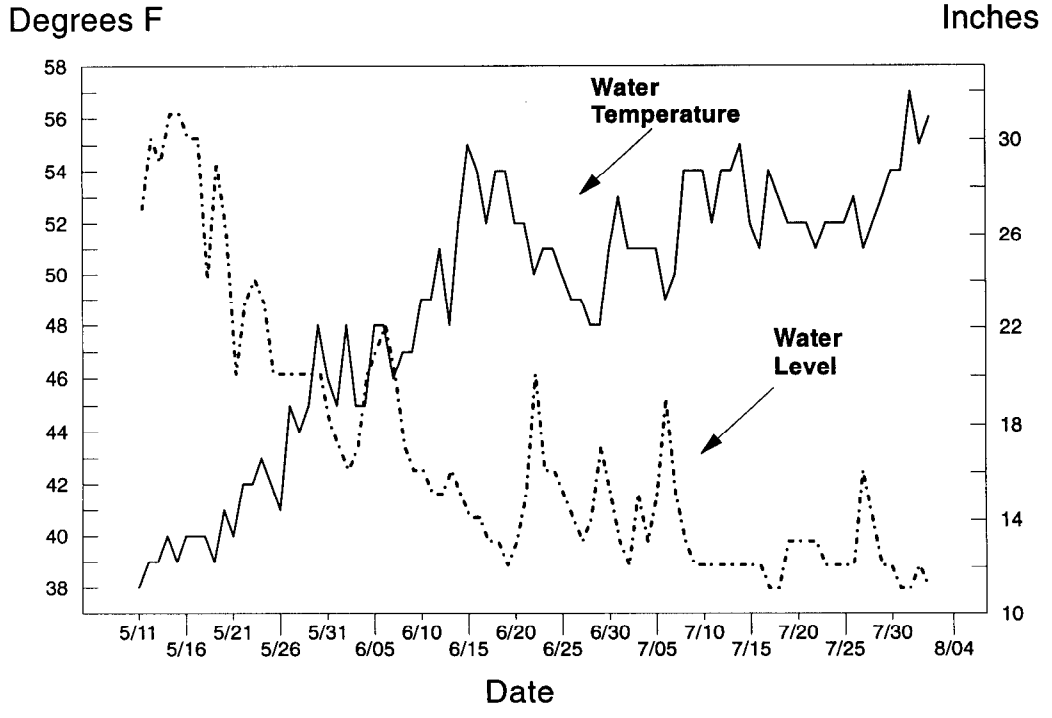

Figure 3.-Water temperature and water level in Deep Creek during 11 May through 3 August 1994.

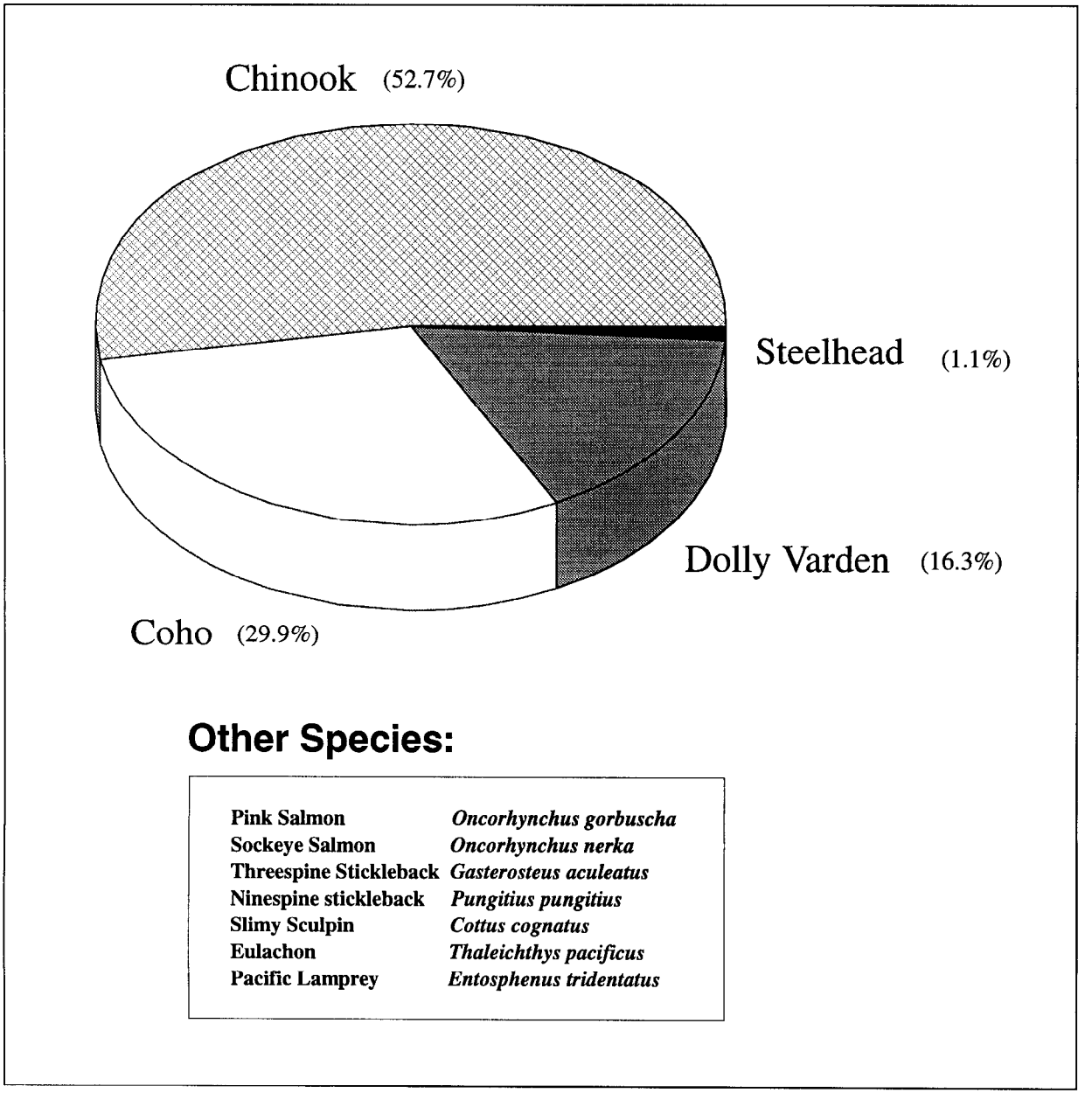

Figure 4.-Rotary smolt trap catch composition for Deep Creek during 1994.

were tallied for smolt, which included four emigrant species: Dolly Varden *Salvelinus malma,* coho salmon *Oncorhynchus kisutch,* steelhead *Oncorhynchus mykiss,* and age-1 chinook salmon (Appendix A1). A total of 21,020 smolts was captured in Deep Creek from 11 May through 3 August 1994. Age-1 chinook salmon accounted for the majority of the catch (53%), followed by coho salmon (30%), Dolly Varden (16%), and steelhead (1%).

Emigration timing for each of these species was unique, resulting in the presence of smolt in Deep Creek throughout most of the open water season (Figure 5). Dolly Varden smolt emigrated during mid-May through the first week of June with a peak catch on 23 May. Coho salmon smolt emigrated during the last week of May through the first week of July with a peak catch on 13 June. Chinook salmon smolt were present throughout the entire sampling period; however, most chinook salmon emigrated during mid-June through mid-July. The peak catch of chinook salmon smolt occurred on 6 July. Steelhead catches peaked on 7 July but our small total catch of steelhead (n=226) precluded detailed analysis.

Deep Creek Chinook Salmon Size and Age

Two age classes of juvenile chinook salmon were captured in Deep Creek concurrently. During May and June, age-1 chinook salmon smolt were easily separated from post emergent fingerling chinook salmon by their larger size. Age-1 chinook salmon smolt ranged from 72 mm to 108 mm in fork length (Figure 6). Mean and median fork lengths for age-1 smolt were 88.7 mm and 89 mm, respectively. A one-way analysis of variance indicated a significant change in mean lengths of age-1 smolt over time ($F = 22.72$; $df = 6, 811$; $P < 0.0001$). Mean lengths increased from 85.5 mm in mid-June to 92.7 mm in mid-July.

Large numbers of post emergent chinook salmon fry were captured in our smolt trap from the onset of trapping. These fry were typically less than 40 mm in fork length. Age-0 chinook salmon were usually mixed with large numbers of emigrant pink salmon (*Oncorhynchus gorbuscha*) fry which often impinged upon the cleaning screen and were passed out of the live box. Thus, we did not attempt to enumerate catches of chinook salmon fry. Chinook salmon fry also increased significantly in mean length over time ($F = 204.75$; $df = 4, 559$; $P < 0.0001$). The mean growth rate for age-0 chinook salmon in Deep Creek was 0.64 mm per day during the period 25 June to 26 July (Figure 7).

By late July, fingerling chinook salmon began to resemble age-1 smolt in size and appearance and were the prominent age class in daily trap catches. Fingerling (71 mm mean FL) survival on 20 July in 32 ppt sea water was 96%. A marked (caudal clip) sample of fingerlings was transported and released 1.0 mi upstream from our trap on 26 July, and 17% of these fish were recovered in the trap during the subsequent 36 h. These indications that age-0 chinook salmon were moving downstream and might also be emigrating from Deep Creek resulted in our tagging of fingerlings during 21 July through 3 August. After releasing 3,644 tagged fingerlings in Deep Creek approximately 100 ft below our trap site, only two of these fish were recaptured, providing further evidence that age-0 fingerlings were emigrating to sea.

DISCUSSION

Chinook Salmon Tagging

Numerous factors affect the number of fish that are marked for a contribution estimate.

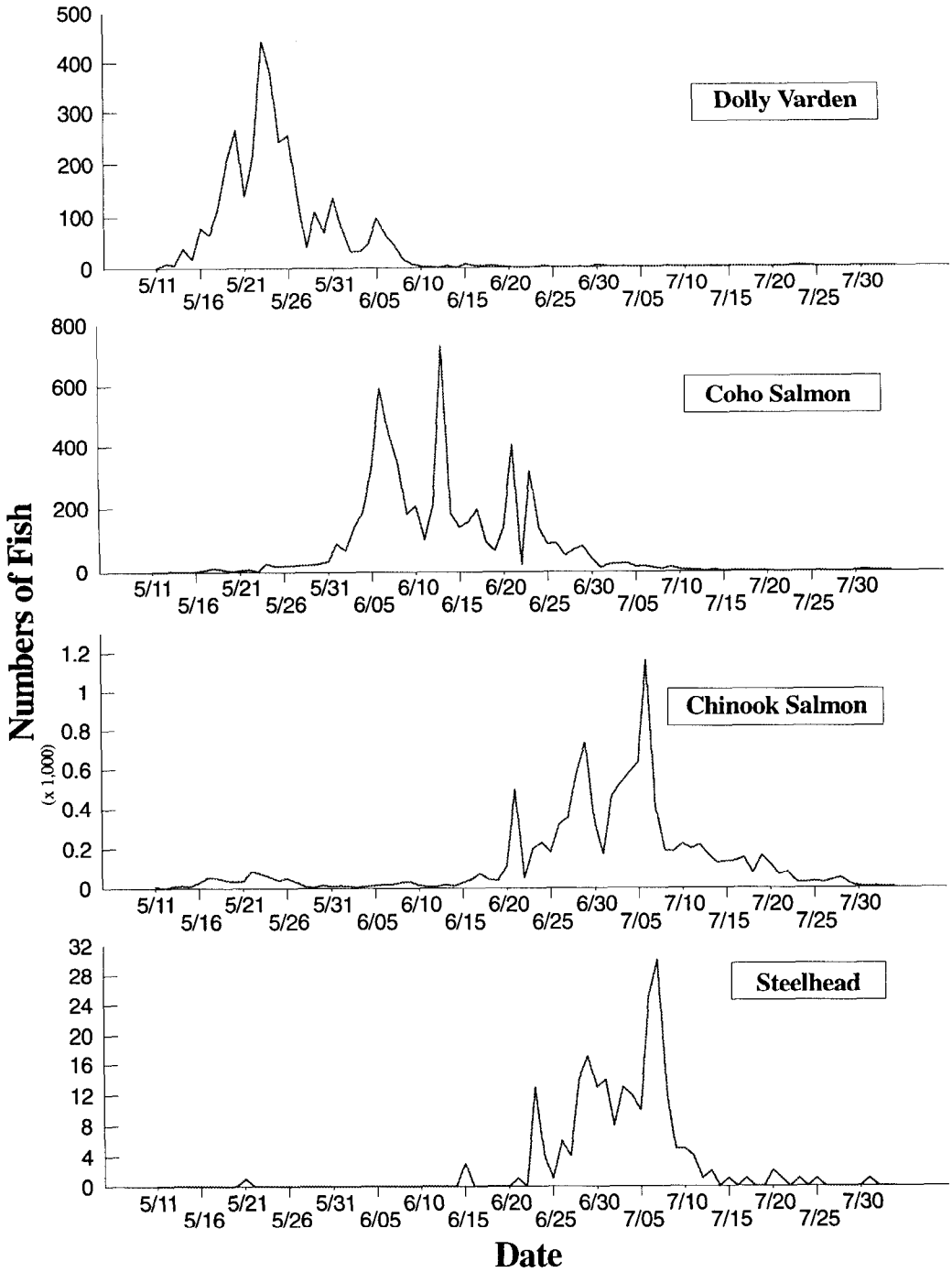

Figure 5.-Daily catches for age-1 chinook salmon, coho salmon, Dolly Varden, and steelhead smolt in Deep Creek, 1994.

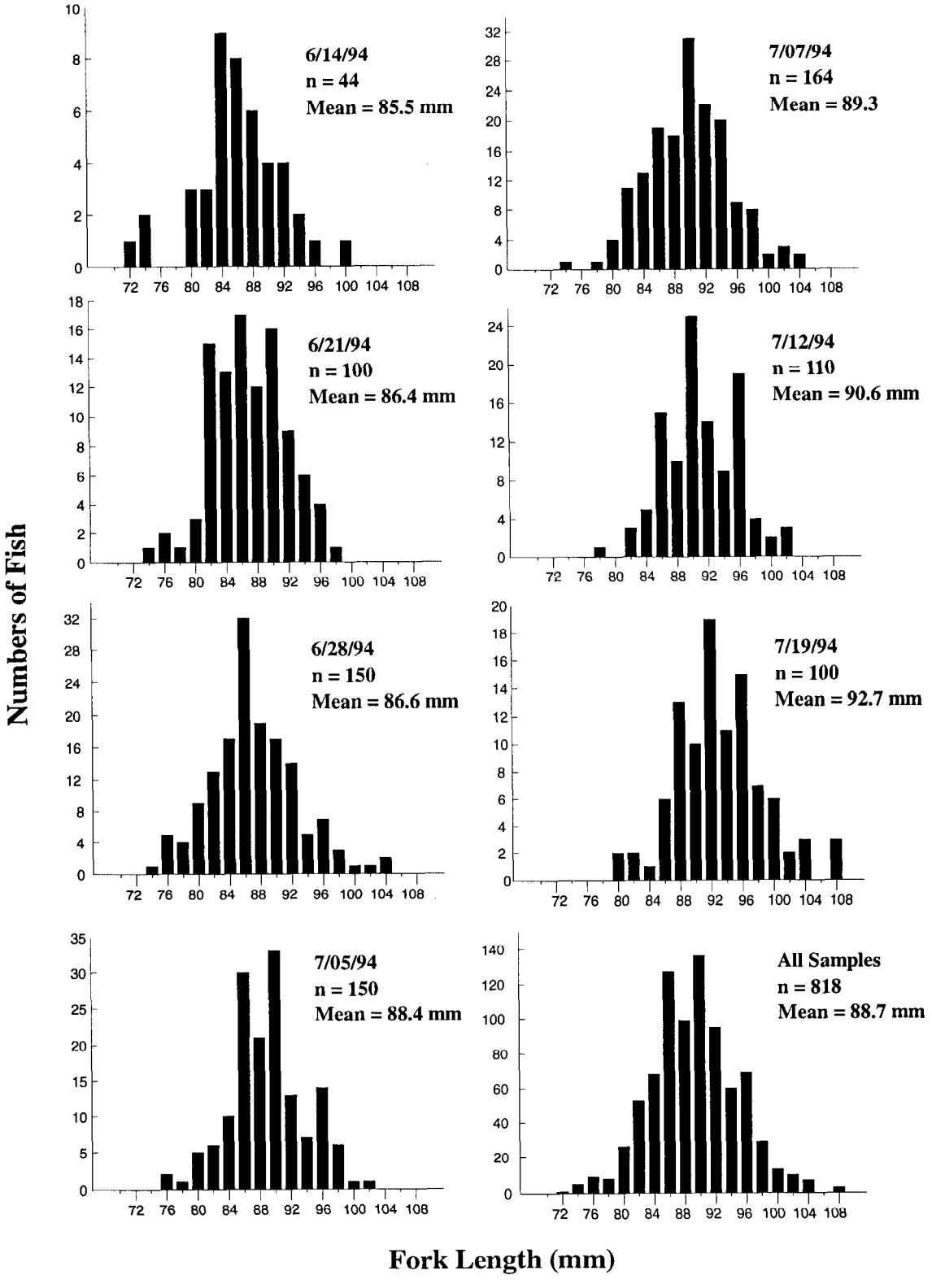

Figure 6.-Length frequency distributions for age-1 chinook salmon smolt captured in Deep Creek, 1994.

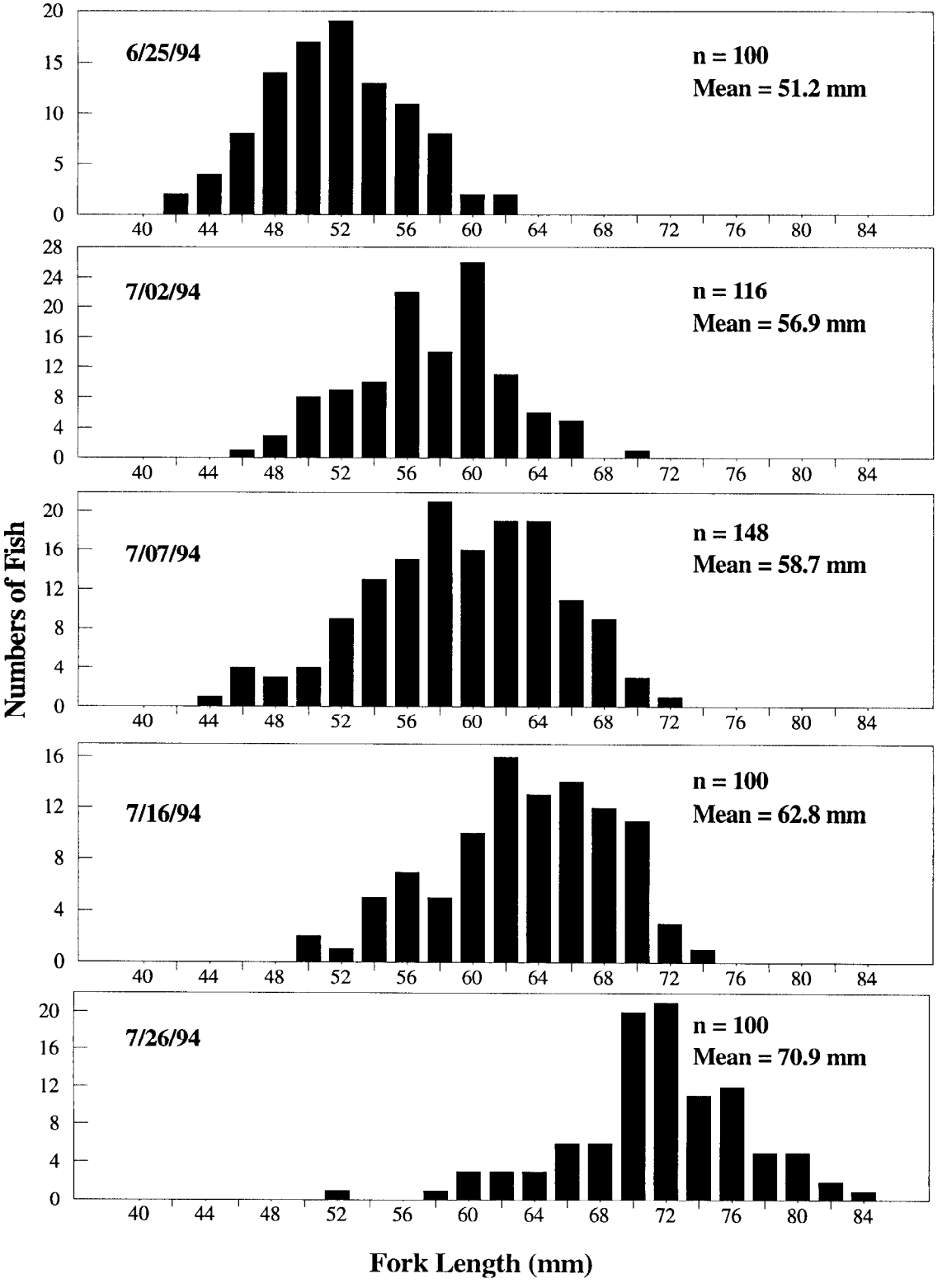

Figure 7.-Length frequency distributions for fingerling chinook salmon captured in Deep Creek, 1994.

These include the number of fish available, desired levels of relative precision and accuracy, the fraction of the harvest inspected for marks, an a priori estimate of contribution, catchability, and costs. We were unable to achieve our marking goals in both the Kenai River and Deep Creek. During 1993, we marked 73% of our goal for the Kenai River but that fraction dropped to only 43% in 1994. We tagged 53% of our goal for Deep Creek in 1994. It is not possible, at this time, to verify the assumptions that were used to generate the marking goals since we can not estimate smolt abundance until marked adults return. If subsequent adult returns verify our assumed estimates of smolt abundance, we will need to increase our tagging rates or increase the fraction of the harvest inspected in order to meet our desired levels of precision and accuracy.

The number of juvenile chinook salmon captured and tagged in Deep Creek can be increased by relocating the trap to a site that is narrower, faster, and deeper than the present site. A better site is available along the north bank of Deep Creek approximately 200 ft downstream from our present site. Preliminary measurements suggest that the sampling volume of the trap at the new site will be more than double that of the old site. The trap will be fished at the new site in 1995.

Increasing tagging rates in the Kenai River can be best accomplished by tagging age-1 smolt instead of age-0 fingerlings. By tagging smolt, we will avoid overwinter losses of marked fingerlings and thereby reduce our overall marking goal for the Kenai River. We propose operating an 8 ft diameter rotary smolt trap in the lower Kenai River during mid-June through July in future years to capture and tag age-1 emigrant smolt.

SMOLT TIMING, AGE, AND SIZE

Our results from Deep Creek suggest that chinook salmon smolt emigrate throughout much of the open water season with peak movements in early summer during mid-June through mid-July. Smolt timing coincided with peak water temperatures and seasonal low flows but movements appeared to have been stimulated by freshets which occurred on 21 and 28 June and 5 July. While coho salmon and Dolly Varden were usually absent in catches prior to and following their emigration from Deep Creek, chinook salmon smolt were present throughout the entire trapping period. Similar chinook salmon peak emigration times are reported for other Cook Inlet drainages including the Anchor River (Allin 1957), Kasilof River (Waite 1979) and the Kenai River (King et al. 1993). Emigration times for Cook Inlet chinook salmon stocks are later than those reported for stocks in more southern latitudes (Healey 1991).

Juvenile chinook salmon in Alaska typically rear in fresh water for at least 1 year before migrating to sea as "stream-type" smolt. Large downstream movements of fry immediately following emergence are typical of most chinook populations, but ocean-type (age-0) smolt are only reported from the Situk River in Alaska (Johnson et al. 1992). Stream and ocean-type salmon, occupying the same tributary, are only reported in large systems such as the Columbia and often are spatially separated and associated with distinct seasonal adult spawning times and ocean migration patterns (Taylor 1990). Return timing and other characteristics of adults in Deep Creek reflect the presence of a single chinook salmon race. Hence, the existence of both races of juveniles in Deep Creek is inconsistent with the current hypothesis that different early life history types reflect different adult behaviors and are, at least in part, genetically controlled (Taylor 1990, Healey 1991). Our evidence suggests that age-1 smolt leave Deep Creek during June and July, and age-0 smolt leave beginning in

late July, upon reaching approximately 70 mm in fork length. More work needs to be done to confirm the presence of age-0 smolt in Deep Creek. Since this age class was marked with unique tag codes, we can ascertain the importance of this strategy as adults return in subsequent years.

Age-0 chinook salmon increased from approximately 40 to 71 mm between early-May and late-July. Growth appeared slow until mid-June, but increased rapidly during July. Fingerlings increased in length an average of 0.64 mm/d during July. This rate of growth is comparable to that recorded for fingerling chinook salmon smolt in several Pacific Northwest drainages (Healey 1991). The mean length of age-0 smolt in Deep Creek during late-July (71 mm) is also consistent with observed lengths of age-0 smolt from the Pacific Northwest (52.7-77.3 mm).

Age-1 smolt in Deep Creek also increased in length throughout the summer but at a much slower rate than fingerlings. Age-1 smolt averaged 88.7 mm in length but only increased 0.21 mm/d between 14 June and 19 July. Yearling chinook salmon smolt vary greatly in size but are typically from 70 to 150 mm in fork length (Healey 1991).

ACKNOWLEDGMENTS

The author would like to thank Jay Carlon who supervised all of the tagging conducted in the Kenai River during 1993. Jeffery Breakfield acted as crew leader on both Deep Creek and the Kenai River during 1994. Earl Chauvin, Greg Corner, Wendy Langston, Tim McKinley, Shane Nicholson, Jan Rumble, Jerry Strait, and Curt Strausbaugh were responsible for capturing and tagging the fish used in this study. Jim Hasbrouck acted as project biometrician for this study and participated in the planning, design, and analysis of data.

LITERATURE CITED

Allin, R. W. 1957. Environmental studies of the steelhead of Alaska as related to their spawning habits, age, growth, fecundity, migrations, and movements. U.S. Fish and Wildlife Service. Federal Aid in Fish Restoration, Job Completion Report 7(4). Juneau.

Bendock, Terry N. 1989. Lakeward movements of juvenile chinook salmon and recommendations for habitat management in the Kenai River, Alaska, 1986-1988. Alaska Department of Fish and Game, Fishery Manuscript No. 7, Juneau.

Burger, C. V., D. B. Wangaard,. R. L. Wilmot, and A. N. Palmiso. 1983. Salmon investigations in the Kenai River, Alaska, 1979-1981. U.S. Fish and Wildlife Service, National Fisheries Research Center, Alaska Field Station, Anchorage.

Clark, J. E. and D. R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing coded microwire tag recovery from commercial salmon catches in Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 261, Juneau.

Healey, M. C. 1991. Life history of chinook salmon. Pages 311-393 in C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Johnson, S. W., J. F. Thedinga, and K. V. Koski. 1992. Life history of juvenile ocean-type chinook salmon (*Oncorhynchus tshawytscha*) in the Situk River, Alaska. Can. J. Fish. Aquat. Sci. 49:2621-2629.

King, B. E., L. K. Brannian, and K. E. Tarbox. 1993. Kenai River sockeye salmon smolt studies, 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A94-41, Anchorage.

McKinley, T. *In press.* Angler effort and harvest of chinook salmon and Pacific halibut in the marine recreational fishery of central Cook Inlet, 1994. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Meyer, S., D. Vincent-Lang, and D. McBride. *Unpublished.* Goal statement and study plan for the development of a stock assessment program for upper Cook Inlet coho salmon stocks (1991). Located at: Alaska Department of Fish and Game, Division of Sport Fish, 333 Raspberry Road, Anchorage, Alaska, 99518.

LITERATURE CITED (Continued)

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

SAS. 1982. SAS user's guide: statistics. SAS Institute, Cary, North Carolina.

Taylor, E. B. 1990. Environmental correlates of life-history variation in juvenile chinook salmon *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 37:1-17.

Waite, D. C. 1979. Chinook enhancement on the Kenai Peninsula. No. AFS 46-1, completion report. Alaska Department of Fish and Game, Fisheries Rehabilitation and Enhancement Division, Juneau.

APPENDIX A

Appendix A1.-Daily and cumulative catches of age-1 chinook salmon, coho salmon, Dolly Varden, and steelhead using a rotary smolt trap in Deep Creek, 1994.

Date	Chinook Salmon		Coho Salmon		Dolly Varden		Steelhead	
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
05/11	9	9		0	1	1	0	0
05/12	1	10	0	0	8	9	0	0
05/13	9	19	1	1	5	14	0	0
05/14	13	32	0	1	38	52	0	0
05/15	10	42	0	1	17	69	0	0
05/16	28	70	2	3	78	147	0	0
05/17	53	123	6	9	65	212	0	0
05/18	52	175	12	21	115	327	0	0
05/19	40	215	8	29	203	530	0	0
05/20	33	248	1	30	266	796	0	0
05/21	36	284	4	34	139	935	1	1
05/22	84	368	8	42	214	1,149	0	1
05/23	73	441	2	44	443	1,592	0	1
05/24	58	499	25	69	381	1,973	0	1
05/25	39	538	17	86	243	2,216	0	1
05/26	50	588	19	105	256	2,472	0	1
05/27	32	620	20	125	140	2,612	0	1
05/28	10	630	21	146	41	2,653	0	1
05/29	5	635	22	168	110	2,763	0	1
05/30	16	651	25	193	70	2,833	0	1
05/31	11	662	32	225	135	2,968	0	1
06/01	14	676	88	313	79	3,047	0	1
06/02	12	688	67	380	31	3,078	0	1
06/03	7	695	138	518	31	3,109	0	1
06/04	11	706	186	704	47	3,156	0	1
06/05	15	721	322	1,026	98	3,254	0	1
06/06	19	740	593	1,619	64	3,318	0	1
06/07	19	759	441	2,060	42	3,360	0	1
06/08	30	789	344	2,404	15	3,375	0	1
06/09	32	821	182	2,586	7	3,382	0	1
06/10	15	836	207	2,793	2	3,384	0	1
06/11	7	843	100	2,893	2	3,386	0	1
06/12	9	852	212	3,105	0	3,386	0	1
06/13	18	870	729	3,834	4	3,390	0	1
06/14	12	882	182	4,016	0	3,390	0	1
06/15	29	911	138	4,154	7	3,397	3	4
06/16	44	955	155	4,309	4	3,401	0	4
06/17	73	1,028	197	4,506	2	3,403	0	4
06/18	42	1,070	92	4,598	4	3,407	0	4
06/19	39	1,109	65	4,663	2	3,409	0	4
06/20	109	1,218	138	4,801	1	3,410	0	4
06/21	493	1,711	403	5,204	0	3,410	1	5
06/22	51	1,762	23	5,227	0	3,410	0	5
06/23	199	1,961	316	5,543	1	3,411	13	18

-continued-

Appendix A1.-Page 2 of 2.

Date	Chinook Salmon Daily	Chinook Salmon Cum.	Coho Salmon Daily	Coho Salmon Cum.	Dolly Varden Daily	Dolly Varden Cum.	Steelhead Daily	Steelhead Cum.
06/24	229	2,190	136	5,679	2	3,413	4	22
06/25	179	2,369	87	5,766	0	3,413	1	23
06/26	319	2,688	89	5,855	0	3,413	6	29
06/27	352	3,040	50	5,905	0	3,413	4	33
06/28	572	3,612	69	5,974	1	3,414	14	47
06/29	737	4,349	80	6,054	0	3,414	17	64
06/30	328	4,677	39	6,093	4	3,418	13	77
07/01	172	4,849	13	6,106	1	3,419	14	91
07/02	457	5,306	22	6,128	0	3,419	8	99
07/03	525	5,831	24	6,152	1	3,420	13	112
07/04	578	6,409	25	6,177	0	3,420	12	124
07/05	633	7,042	15	6,192	0	3,420	10	134
07/06	1,156	8,198	16	6,208	0	3,420	25	159
07/07	405	8,603	11	6,219	0	3,420	30	189
07/08	190	8,793	8	6,227	1	3,421	12	201
07/09	183	8,976	14	6,241	0	3,421	5	206
07/10	222	9,198	7	6,248	0	3,421	5	211
07/11	198	9,396	5	6,253	0	3,421	4	215
07/12	218	9,614	4	6,257	0	3,421	1	216
07/13	165	9,779	2	6,259	1	3,422	2	218
07/14	129	9,908	5	6,264	1	3,423	0	218
07/15	133	10,041	2	6,266	0	3,423	1	219
07/16	136	10,177	1	6,267	0	3,423	0	219
07/17	152	10,329	1	6,268	0	3,423	1	220
07/18	77	10,406	2	6,270	0	3,423	0	220
07/19	162	10,568	2	6,272	0	3,423	0	220
07/20	122	10,690	1	6,273	0	3,423	2	222
07/21	66	10,756	0	6,273	0	3,423	1	223
07/22	82	10,838	0	6,273	1	3,424	0	223
07/23	27	10,865	0	6,273	2	3,426	1	224
07/24	27	10,892	0	6,273	1	3,427	0	224
07/25	33	10,925	0	6,273	0	3,427	1	225
07/26	26	10,951	1	6,274	0	3,427	0	225
07/27	39	10,990	0	6,274	0	3,427	0	225
07/28	50	11,040	0	6,274	0	3,427	0	225
07/29	21	11,061	0	6,274	0	3,427	0	225
07/30	5	11,066	1	6,275	0	3,427	0	225
07/31	4	11,070	4	6,279	0	3,427	1	226
08/01	6	11,076	1	6,280	0	3,427	0	226
08/02	3	11,079	1	6,281	0	3,427	0	226
08/03	5	11,084	2	6,283	0	3,427	0	226