Fishery Data Series No. 99-1

Marking, Enumeration, and Size Estimation for Coho and Chinook Salmon Smolt Releases into Upper Cook Inlet and Resurrection Bay, Alaska in 1997

by

Diane Starkey,

Carmen Olito,

and

Patricia Hansen

April 1999

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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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

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Diane Starkey,
Carmen Olito,
and
Patricia Hansen

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

April 1999

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-13, Job No. S-2-12.

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Diane Starkey and Carmen Olito,
Alaska Department of Fish and Game, Division of Sport Fish,
and Patricia Hansen,
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services,
333 Raspberry Road, Anchorage, AK 99518-1599, USA

This document should be cited as:
Starkey, D., C. Olito, and P. Hansen. 1998. Marking, enumeration, and size estimation for coho and chinook salmon smolt releases into upper Cook Inlet and Resurrection Bay, Alaska in 1997. Alaska Department of Fish and Game, Fishery Data Series No. 99-1, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

ABSTRACT

Over half of Alaskans live in Southcentral Alaska, which receives the vast majority of the state's sport fishing effort. The population of Southcentral and sport fishing effort are increasing. To meet the growing demand on the sport fishery resource, hatchery-reared chinook salmon *Oncorhynchus tshawytscha* and coho salmon *O. kisutch* smolt have been stocked in numerous locations throughout Southcentral Alaska to improve or create terminal sport fisheries.

Over 730,000 coho and chinook salmon smolt released at 10 locations in Cook Inlet and Resurrection Bay were marked with an adipose finclip and a coded wire tag in 1997. Tag retention for individual raceways ranged from 93.6% to 99.6%. Our production goal for coho salmon was to make 80% of the smolt within the size range of 15.1 g to 25.0 g. Coho salmon produced at Ft. Richardson Hatchery and released into Campbell Creek and Ship Creek were extremely close to meeting the goal. Our production goal for chinook salmon smolt was to make 80% of the smolt within the range of 5.1 g to 15.0 g. Ninilchik River and Deception Creek chinook salmon smolt produced at Ft. Richardson Hatchery, as well as the Lowell Creek and Homer Spit late-run chinook salmon release groups at Elmendorf met this goal. None of the remaining chinook salmon release groups at Elmendorf Hatchery, nor the Bird Creek coho salmon release group at Fort Richardson Hatchery achieved the production goal.

Three smolt enumeration estimation techniques were compared. At Fort Richardson Hatchery, the hatchery inventory estimate appeared to be the most accurate of the three estimation techniques when compared to physical counts, and in a comparison of mark-recapture estimates to physical counts it appears that the mark-recapture technique tends to underestimate the population within a rearing unit. Therefore, at Fort Richardson Hatchery we used the physical count where possible, and the hatchery inventory estimate elsewhere for estimating numbers of smolt released. At Elmendorf Hatchery, the mark-recapture estimate is the highest of the three enumeration estimation techniques for half of the rearing units. The water volume estimate was higher than the hatchery inventory estimate in most instances at Elmendorf Hatchery. In most instances, the differences between hatchery inventory estimates and mark-recapture estimates at Elmendorf Hatchery depended upon the method used to obtain the hatchery inventory estimate. The mark-recapture method was used for obtaining numbers of smolt released from Elmendorf Hatchery.

Key words: hatchery, marking, coded wire tags, chinook salmon, *Oncorhynchus tshawytscha*, coho salmon, *Oncorhynchus kisutch*, mark-recapture, hatchery inventory, water volume, tag retention, size composition.

INTRODUCTION

Over half of Alaskans live in Southcentral Alaska, which receives the vast majority of the state's sport fishing effort. The population of Southcentral and sport fishing effort are increasing. To meet the growing demand on the sport fishery resource, hatchery-reared chinook salmon *Oncorhynchus tshawytscha* and coho salmon *Oncorhynchus kisutch* smolt have been stocked in numerous locations throughout Southcentral Alaska to improve or create terminal sport fisheries and relieve pressure on wild stocks (Appendix A).

Until 1992, each hatchery was unique in how it produced, marked, released, collected data, and reported information about the fish. Since 1992, marking and release of fish has been monitored and standardized at each hatchery (Starkey et al. 1997). The standardization of practices is necessary to make meaningful comparisons among hatchery releases. These comparisons may in turn allow project managers to better understand factors critical to the success of smolt stocking projects and to improve existing programs.

The use of coded wire tags (CWT) to mark smolt is a critical element of most coho and chinook salmon hatchery smolt stocking projects in Cook Inlet and Resurrection Bay. Three coho salmon smolt stocking projects using fish produced at Fort Richardson Hatchery (FRH) have been combined to form the Northern Cook Inlet Urban Coho Program. One of the goals of the Urban Coho Program is to estimate the contribution from the individual stockings to the Upper Cook

Inlet commercial fishery (Meyer et al. *Unpublished*). This goal is evaluated using a CWT program. In addition, CWTs are used to estimate sport fishery harvests of hatchery-reared chinook salmon in Deception Creek and Ship Creek; and to estimate the contribution to commercial and recreational marine fisheries of hatchery-reared chinook salmon released at Ninilchik River, Crooked Creek, Homer Spit, Lowell Creek, Halibut Cove, and Seldovia. Chinook salmon smolt released at Deception Creek and Ninilchik River were tagged at FRH, and chinook salmon smolt released at Ship Creek, Crooked Creek, Homer Spit, Lowell Creek, Halibut Cove, and Seldovia were tagged at Elmendorf Hatchery (EH).

According to Schurman and Thompson (1990) all fish tagged in the State of Washington fish hatcheries are sorted by size and differentially tagged. This improves the quality of tag placement and improves overall tag retention. Starkey et al. (1997) found that tag loss ranged from 0.3% to 6.2% in 16 comparable groups of coho and chinook salmon. All fish to be marked were graded by size and different head mold sizes were used to tag the appropriate sized fish at both hatcheries, and on all the release groups. A range of lengths corresponding to each head mold size for fish ≥81 mm was developed by Peltz and Hansen (1994) and for fish <81 mm by Starkey et al. (1995).

The accuracy of contribution estimates from mark recoveries is highly dependent upon the accuracy of the estimated number of unmarked fish in the release population. The smolt release data from both hatcheries in 1996 indicated a variation of up to 13.1% between two different hatchery release estimation techniques (Starkey et al. 1997). This level of discrepancy between estimates is unacceptable and means that either one or both of the estimates are highly inaccurate. The greater the probability of error in release estimates, the less useful the contribution estimates (Vreeland 1990).

Another important element of hatchery smolt stocking programs is the size of the fish. Mean size and size distribution at release are indicators of the quality of hatchery smolt production (Peltz and Starkey 1993). Releasing larger smolt reduces ocean residence, thus shifting the age composition of returns to younger, smaller fish (Sweet and Peltz 1994).

The specific objectives for this project were:

1. To estimate the number of coho and chinook salmon smolt released at each stocking site using mark-recapture techniques;
2. To estimate the weight composition of each release group;
3. To estimate the long-term (>30 days) tag retention rate of each group of marked fish.

The goal of this project was to mark approximately 690,000 of the projected 2,005,000 coho and chinook smolt to be stocked in 1997 with an adipose clip and a coded wire tag. This entailed marking a representative sample of at least 40,000 coho or chinook salmon smolt from each of the 12 Cook Inlet and Resurrection Bay release groups (Meyer et al. *Unpublished*).

Marking and collection of release data at Elmendorf and Fort Richardson hatcheries were standardized for each of the stocking projects in 1997. This report presents the results of the 1997 marking program. Three different smolt enumeration estimation techniques are compared to each other and in some cases compared to a physical count. The size composition of each release group is also presented. In addition, an overview of the tagging program from 1994 through the

present is presented and discussed. Based on the data summarized in this report, recommendations are made for future marking and collection of release data.

METHODS

SMOLT MARKING

Elmendorf Hatchery raised chinook salmon from Ship Creek, Ninilchik River, Deception Creek, Homer (Crooked Creek), and Homer (Kasilof River) brood stocks. Fort Richardson Hatchery raised coho salmon from the Little Susitna River brood stock and chinook salmon from Deception Creek and Ninilchik River brood stocks (Table 1). Fish from 12 release groups were released at 10 different sites in Cook Inlet and Resurrection Bay. Each release group was marked with a unique tag code (Tables 2 and 3).

Because marked fish were considered representative of the entire release group and catches of marked fish were expanded to estimate the fishery contribution of that release group, obtaining a random sample of smolt for marking was important.

At FRH the fish in each raceway (RW) were crowded to cause mixing, thereby increasing the likelihood that a random sample was obtained. The entire group of approximately 40,000 smolt to be tagged in each raceway of coho salmon was dipnetted and held separate from the remaining fish in the raceway before tagging was initiated. All of the smolt in the Ninilchik River and Deception Creek chinook salmon smolt release groups were marked and tagged. The fish in a rearing unit containing approximately 200,000 Ninilchik River chinook salmon smolt were crowded, and approximately 51,000 chinook salmon smolt were removed as they were tagged, and held in a separate raceway until release. The remaining Ninilchik River chinook salmon were used in other stocking programs.

At EH the fish in the raceway were crowded once a day, and enough fish for one day of marking were dipnetted and held separate from the rest of the release group in net pens. Attempts were made to mark and tag all of the fish in the net pen prior to the addition of more fish. If fish for a particular release group were in more than one raceway, then an attempt was made to mark approximately the same proportion of fish in each raceway (Peltz and Miller 1990).

All fish were tagged with a full-length coded wire tag (1.1 mm) using a Northwest Marine Technology Mark IV tagging unit. All of the marked smolt from release groups in 1997 were graded and tagged with the appropriate size head mold. A minimum of 510 fish were obtained from each stock up to 7 days before the start of tagging. Each fish was measured for fork length to the nearest millimeter, and a length frequency distribution was calculated. The two or three head mold sizes that cumulatively fit at least 80% of the fish length distribution were selected for tagging, and the fish were graded accordingly.

Fish that were to be marked were anesthetized with MS-222. The adipose fin was excised at the base of the fin using surgical scissors. Coho and chinook salmon have highly visible adipose fins and the only reason for poor finclips was due to carelessness. A finclip grading program to reduce the estimated number of valid marks by the proportion of poor finclips was not necessary.

Following tag placement the fish were sent through a Quality Control Device (QCD). The QCD detects the magnetized tag and separates the fish with tags from those without tags. All fish without tags were tagged again. Quality control checks for tag placement were conducted following initial daily startup, and following a change in head mold size or a change in tagging personnel. A minimum of two tagged fish during each

Table 1.-Total release, number of fish marked with adipose clips and coded wire tags stocked into various systems in Cook Inlet and Resurrection Bay, and the number of fish examined to achieve the desired level of precision.

Hatchery	Species	Stocking Site	Brood Stock	Number of fish in Raceway	Enumeration Method Used	Number of Raceways	Number Marked per Raceway	Average Examined per Raceway per Experiment	Number M-R[a] Experiments	Precision
Elmendorf	Chinook	Crooked Creek	Homer (Crooked Creek)	114,903	Mark Recapture	2	20,693	6,431	3	±2.7
				108,298	Mark Recapture		20,356	6,367	1	±4.9
		Ship Creek	Ship Creek	115,091	Mark Recapture	3	20,360	6,539	3	±5.1
				101,358	Mark Recapture		20,162	8,007	1	±4.2
				109,922	Hatchery Inventory		0	0	0	
		Seldovia	Ninilchik River	103,757	Mark Recapture	1	41,279	1,579	3	±3.4
		Halibut Cove	Ninilchik River	78,133	Mark Recapture	1	40,919	1,538	1	±4.7
		Lowell Creek	Deception Creek	102,147	Mark Recapture	1	40,906	2,566	1	±4.7
		Homer Spit Early	Homer (Crooked Creek)	120,317	Mark Recapture	2	20,663	6,136	1	±5.3
				97,416	Mark Recapture		20,449	6,847	3	±2.4
		Homer Spit Late	Homer (Kasilof River)	100,933	Mark Recapture	1	41,028	2,587	1	±4.6
Fort Richardson	Chinook	Deception Creek	Willow Creek	105,782	Physical Count	2	105,782	0	NA	±0
				103,862	Physical Count		103,862	0	NA	±0
		Ninilchik River	Ninilchik River	50698	Physical Count	1	50,698	0	NA	±0
	Total Chinook			**1,412,618**			**547,157**			
	Coho	Bird Creek	Little Susitna River	146,612	Hatchery Inventory	2	45,901	3,521	1	±4.4
				147,953	Hatchery Inventory		45,836	3,618	3	±2.6
		Ship Creek	Little Susitna River	232,066 [b]	Hatchery Inventory/ Physical Count	1	45,925	0	NA	±0
		Campbell Creek	Little Susitna River	71,519 [c]	Physical Count	1	45,840	0	NA	±0
	Total Coho			**598,150**			**183,502**			
Totals				**2,010,768**			**730,659**			

[a] Mark-recapture.

[b] Ship Creek coho salmon release group contained one entire rearing unit (E2) plus a portion of another rearing unit (E1).

[c] Campbell Creek coho salmon release group contained a portion of the fish reared in rearing unit E1.

Table 2.-Summary of coded wire tagging data and mark-recapture estimates at Fort Richardson Hatchery for coho salmon smolt stocked at three locations in Cook Inlet in 1997.

Parameter	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4	Totals
Tag Codes	31-25-62	31-25-63	31-26-01	31-26-02	
Total marked and tagged	46,183	46,168	46,078	46,077	184,506
Mortalities	343	243	177	241	
Marked fish released	45,840	45,925	45,901	45,836	183,502
Tag retention sample size	774	779	784	777	
Tag retention at release	98.8%	99.6%	99.1%	99.2%	99.2%
Tag retention variance	1.53E-05	5.12E-06	1.14E-05	1.02E-05	
Tagged fish released	45,290	45,741	45,488	45,469	181,988
Tagged fish variance	32,229	10,800	23,999	21,486	
Total fish released from mark-recapture estimate	139,838	153,013	130,692	141,633	565,177
Percent tagged	32.8%	30.0%	35%	32.4%	32.5%
Tagging dates	10/28/96 11/01/96	11/18/96 11/22/96	11/12/96 11/15/96	11/4/96 11/8/96	
Date of tag retention check	5/21/97	5/20/97	5/20/97	5/19/97	
Days elapsed	201	179	186	192	

quality control check were dissected to determine tag placement (Moberly et al. 1977). If tag placement was determined to be outside the preferred area of placement (Figure 1), the head mold and/or wire was adjusted accordingly. The number of fish that were killed to determine tag placement was subtracted from the daily number of tagged fish and were not included as tagged fish.

After tagging, all fish were held in net pens overnight to determine short-term mortality and estimate short-term tag retention rate. All overnight mortalities were counted and recorded. Short-term retention rates were estimated daily by passing a random sample of 200 fish through the QCD. If the physical retention rate was at least 85%, this level of sampling would have provided an estimate

Table 3.-Summary of coded wire tagging data and mark-recapture estimates at Elmendorf and Fort Richardson hatcheries for chinook salmon stocked at seven locations in Cook Inlet and one location in Resurrection Bay in 1997.

	Fort Richardson			Elmendorf										
Parameter	Deception Creek D2	Deception Creek D3	Ninilchik River D4	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Early Run RW10	Homer Early Run RW17	Homer Spit Late run RW14	Totals
Tag Codes	31-26-03 31-26-05 31-26-06	31-26-04 31-26-06 31-26-07	31-26-08	31-25-55	31-25-55	31-25-56	31-25-56	31-25-57	31-25-58	31-25-59	31-25-60	31-25-60	31-25-61	
Total marked and tagged	105,834	103,892	51,132	20,746	20,402	20,532	20,232	41,616	41,002	41,125	20,756	20,562	41,425	549,256
Mortalities	52	30	434	53	46	172	70	337	83	219	93	113	397	
Marked fish released	105,782	103,862	50,698	20,693	20,356	20,360	20,162	41,279	40,919	40,906	20,663	20,449	41,028	547,157
Tag retention sample size	783	751	769	767	761	765	800	801	789	838	759	776	782	
Tag retention at release	99.5%	98.9%	99.2%	96.5%	93.6%	99.5%	99.5%	96.5%	96.5%	99.0%	94.5%	94.3%	95.7%	97.9%
Tag retention variance	6.36E-06	1.45E-05	1.03E-05	4.41E-05	7.88E-05	6.51E-06	6.23E-06	4.22E-05	4.29E-05	1.18E-05	6.86E-05	6.94E-05	5.27E-05	
Tagged fish released	105,253	102,720	50,292	19,969	19,053	20,258	20,061	39,834	39,487	40,497	19,527	19,283	39,264	535,498
Tagged fish variance	71,189	156,474	26,560	18,881	32,661	2,699	2,581	71,939	71,766	19,792	29,276	29,002	88,693	
Total fish released from mark-recapture estimate				114,903	108,298	115,091	101,358	103,757	78,133	102,147	120,317	97,416	100,933	1,042,354
Percent marked	100.0%	100.0%	100.0%	18.0%	18.8%	17.7%	19.9%	39.8%	52.4%	40.0%	17.2%	21.0%	40.6%	52.5%
Tagging dates	2/25/97 3/19/97	2/28/97 4/2/97	4/3/97 4/11/97	1/13/97 1/15/97	1/15/97 1/17/97	02/06/97 02/10/97	02/11/97 02/12/97	1/28/97 1/31/97	1/21/97 1/27/97	2/3/97 2/6/97	1/06/97 1/09/97	1/09/97 1/13/97	2/13/97 2/20/97	
Date of tag retention check	6/10/97	6/10/97	6/10/97	5/29/97	5/29/97	6/9/97	5/27/97	6/5/97	6/6/97	6/2/97	5/30/97	6/4/97	6/11/97	
Days elapsed	83	69	60	134	132	119	104	125	130	116	141	142	111	

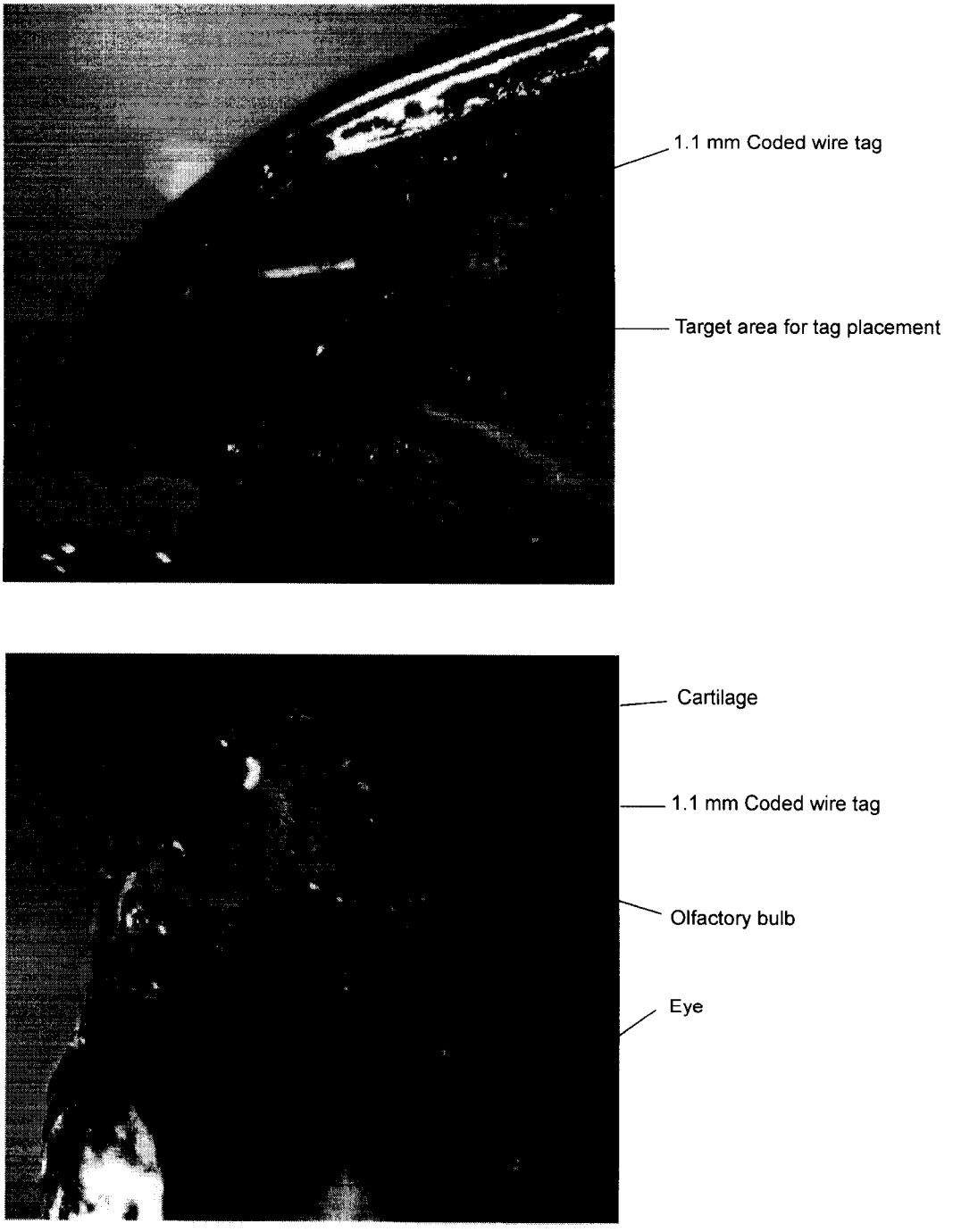

Figure 1.-Proper placement of a coded wire tag in a small fish.

that was within 5 percentage points of the true retention rate 95% of the time (Cochran 1977). Daily tag retention rate (D_i) of smolt that were finclipped, tagged, survived, and retained the tag was estimated as a binomial proportion as:

$$\hat{D}_i = \frac{n_i}{n_{ti}}, \quad (1)$$

where:

n_i = number of live smolt in the sample tagged on day i that retained the tag, and

n_{ti} = total number of live smolt in the sample tagged on day i, and

$$Var(\hat{D}_i) = \frac{\hat{D}_i(1-\hat{D}_i)}{n_{ti}-1}. \quad (2)$$

Once all tagging for a rearing container was completed, tagged smolt were combined with untagged smolt and all fish were treated the same until release. Fish mortality in each raceway was monitored daily and all mortalities of tagged and untagged fish were recorded.

Long-term tag retention was estimated for each release group prior to release. Blankenship (1990) found that tag loss rates were stable after 29 days. Consequently, all long-term tag retention measurements occurred more than 30 days after completion of tagging. After first crowding the fish in each rearing container, a minimum of 750 marked fish (adipose-clipped) were randomly sampled from the population. Each of the 750 marked fish were passed through a QCD to estimate the long-term tag retention. The QCD counted the number of fish possessing a coded wire tag. The QCD has the ability to identify fish lacking a tag, but lacks the ability to count such fish. Fish that were lacking a tag but possessed an adipose-clip were considered to have lost their tag, and were manually counted. If the physical retention rate was at least 75%, this level of sampling would have provided an estimate that is within 2.5 percentage points of the true retention rate 97.5% of the time (Cochran 1977).

Long-term tag retention rate (D_j) of smolt that were finclipped, tagged, survived, and retained the tag, and its variance, were also estimated as a binomial proportion (formulas 1 and 2) for each group,

where:

n_i = number of tagged smolt in the sample that retained the tag; and

n_{ti} = total number of tagged smolt in the sample.

The number of fish released with valid coded wire tags was estimated as:

$$\hat{T}_j = (N_j - M_j)\hat{D}_j; \quad (3)$$

and its variance as:

$$Var[\hat{T}_j] = (N_j - M_j)^2 Var[\hat{D}_j]; \quad (4)$$

where:

N_j = number of fish injected with a tag in group j,

$\hat{D}_j$ = long-term tag retention of release group j, and

M_j = total number of mortalities of tagged fish in group j.

SMOLT ENUMERATION

The number of smolt in each group released from EH and in each rearing unit of coho salmon at FRH was estimated using three different techniques. The number of smolt in the three rearing units of chinook salmon at FRH were estimated using two different techniques, and a physical count was obtained as well for those rearing units. The number of smolt in one rearing unit of coho salmon released from FRH was also determined by a

physical count. Mark-recapture estimates were based on a known number of marked (adipose-clipped and coded wire tagged) fish put into each raceway. Hatchery inventory estimates resulted from a count obtained from an electronic counting device used by hatchery personnel, from estimates of body weight obtained at one or more stages of development, or a combination of both. Water volume estimates were based on the amount of water displaced by fish in the transport tanks as they were loaded for stocking. Physical counts are not an estimate but rather a physical count determined by tagging personnel during the tagging season on rearing units in which all fish were to be tagged, or a physical count conducted just prior to release of all fish in a rearing unit.

Mark-Recapture Estimates

Each release group contained a known number of fish marked with an adipose clip and a coded wire tag. These marked fish were used in mark-recapture experiments to estimate the number of fish in each release group. A second random sample of fish from each raceway was examined for marks prior to release and the number of marked and unmarked fish was recorded.

Fish were crowded in the raceway and dip net samples of fish were taken from several locations and placed into net pens. Given the number of marked fish per raceway, the number of fish per raceway that needed to be examined for marks in order to obtain the desired level of precision was calculated using formulas from Robson and Regier (1964).

Two raceways at FRH as well as three raceways at EH were sampled three times to generate three independent estimates of abundance just prior to release. Sample sizes outlined in Table 1 were used when making these additional estimates. A mark-recapture estimate was also performed on one rearing unit of Deception Creek chinook salmon at the time of tagging. Approximately 20,000 fish were marked and tagged, and then returned to the general population to mix for several days. The raceway was then sampled three times to generate three independent estimates of abundance. Multiple estimates of abundance on the same population provided insights into our ability to collect random samples of marked and unmarked fish from raceways and alerted us to potential violation of the assumption that marked fish mix with unmarked fish. If the estimates of abundance were not significantly different (Z-tests), we would conclude that this method is fairly reliable and the estimates are not biased and could be combined. If the estimates were significantly different, then this approach may produce biased estimates and methods used to collect samples of fish will need to be changed in the future.

The number of fish in each raceway was estimated using a Chapman modified Petersen model (Seber 1982). The estimate of abundance at the time of release was calculated as:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{m_2+1} - 1; \qquad (5)$$

with variance:

$$\mathrm{Var}\left[\hat{N}\right] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}, \qquad (6)$$

where:

n_1 = the number of fish marked with an adipose finclip and coded wire tag in each raceway,

n_2 = the number of fish examined for marks in each raceway during the second sampling event, and

m_2 = the number of marked fish observed in each raceway during the second sampling event.

A pooled estimate using formulas 5 and 6 above was generated for the release groups with three mark-recapture estimates. The numbers of marked and unmarked fish used to generate the three estimates were added together to generate the pooled estimate.

This two-sample mark-recapture model assumes:

1. The population is closed, with no additions, and losses are known between sampling events;
2. All fish have an equal probability of capture during the marking event or during the second sampling event, or marked fish mix completely with unmarked fish prior to the second sampling event;
3. Marking does not affect the probability of capture during the second sampling event;
4. Marks are not lost between sampling events; and
5. Marked fish observed during the second sampling event are correctly identified and recorded.

There were no additions to any raceway and all mortalities between events were known. Personnel took fish from all areas of the raceway during both the marking and second sampling events, thus attempting to minimize violating the second assumption. In addition, getting three estimates of abundance from some release groups allows evaluating how well marked and unmarked fish mixed. If the Z-tests indicated the estimates were significantly different, one reason for this result could have been that the marked fish did not mix completely with unmarked fish. Although we cannot test the third assumption, the second sampling event just prior to release should allow fish to recover from handling and marking. The crew(s) were careful when handling and marking fish, examining fish for marks, and recording data to minimize violating model assumptions.

Hatchery Inventory Estimates

The goal of analyzing hatchery inventory data was to compare the estimates with the mark-recapture and water volume estimates, and when possible to a physical count. If necessary, hatchery inventory procedures may then be modified to improve the accuracy and/or precision of the estimates.

Elmendorf Hatchery

The hatchery inventory estimates at EH for five of the raceways of chinook salmon were based on an electronic count of eggs. At the eyed-egg stage all dead eggs were electronically removed and the live eggs were counted with a Northwest Marine Technology FCI fry counter. Known numbers of live eyed eggs were put back into each incubator.

Beginning in October, emergent fry from a known number of incubators were placed in a single raceway. The dead eggs and fry remaining in each of the incubators were counted (if mortalities were light and individual eggs were discernible) or estimated (if mortalities were heavy and dead eggs were concentrated in fungus clumps). The mortality count from all the incubators used to populate one raceway was subtracted from the number of live eyed eggs put in those incubators to establish a count of live fish put into each raceway. Mortalities in each raceway were enumerated daily and subtracted from the inventory number.

In January and February each raceway was split into two or more raceways. Some of the fish were transferred during the coded wire tagging process. Fish were removed from one raceway, tagged, and placed into a different raceway.

When fish other than those to be marked were moved, the raceway was crowded and a dip

net was used to remove fish. Each net of fish was held out of the water for several seconds to allow water to drain from the net. The fish were poured into a pre-weighed bucket of water and weighed to the nearest 5 grams. All fish that were moved from one raceway to another without being tagged, were weighed. The weight was recorded and the total weight of all fish removed from the raceway was obtained by adding the individual net weights.

During the course of this operation three randomly selected net loads of fish from the beginning, middle, and end of the weighing process were sampled to obtain an estimate of individual fish weight. One net full of fish was too large to enumerate (approximately 1,300 fish). Consequently, the net was manually halved numerous times until approximately 150 fish were still in the net. These fish were weighed in the same manner as the other net loads and hand counted out of the bucket.

Mean weight was then divided into the total weight of fish moved out of each raceway to establish the hatchery inventory number in the new raceway. The estimated number of fish transferred to the new raceway was subtracted from the estimated number of fish in the original raceway to determine the number of fish still in the original raceway. Following the fish transfers, daily mortalities in each raceway were enumerated and subtracted from the individual raceway inventory estimates.

Fort Richardson Hatchery

The initial hatchery inventory estimates at FRH for the four rearing units of coho salmon smolt stocked at Bird Creek, Ship Creek, and Campbell Creek; and for the chinook salmon smolt stocked at Deception Creek, were established when the fry were moved from the small indoor raceways to the large outdoor raceways.

Each small raceway was crowded and a dip net was used to remove fish. Each net of fish was held out of the water for several seconds to allow water to drain from the net. The fish were poured into a pre-weighed bucket of water and weighed to the nearest gram. The weight was recorded and the total weight of all fish in the raceway was obtained by adding individual dip net bulk weights.

During the course of this operation, approximately 8 randomly selected net loads of fish from throughout the weighing process were sampled to obtain an estimate of individual fish weight. One net full of fish was too large to enumerate (approximately 600-800 fish). Consequently, the net was manually halved numerous times until 50 to 100 fish were still in the net. These fish were weighed in the same manner as the other net loads and hand counted out of the bucket.

Dip net samples were used to estimate the ratio of the number of fish to total fish weight. The average weight of one fish was determined to be the sum of the weights of the sample dip nets divided by the sum of the number of fish in the sample dip nets. This average weight was then divided into the total weight of fish moved in order to determine the number of fish moved.

Dip net samples were used to estimate the ratio of the number of fish to total fish weight by (Cochran 1977):

$$\hat{R} = \frac{\bar{n}}{\bar{w}}, \tag{7}$$

where:

$\bar{n}$ = the average number of fish in a dip net sample from the total of n_d dip net samples moved to an outdoor raceway,

$$= \frac{\sum_{i=1}^{n_d} n_i}{n_d}, \tag{8}$$

$\bar{w}$ = the average weight of a dip net sample from the n_d samples moved to an outdoor raceway,

$$= \frac{\sum_{i=1}^{n_d} w_i}{n_d}. \quad (9)$$

The number of fish moved to an outdoor raceway was estimated as:

$$\hat{N}_r = W_r \hat{R}_Q, \quad (10)$$

where:

W_r = total weight of all fish moved to the outdoor raceway.

The variance of the number of fish moved to an outdoor raceway was estimated as:

$$Var[\hat{N}_r] = W_r^2 Var[\hat{R}_Q]. \quad (11)$$

The number of fish released from an outdoor raceway was the estimate (10) minus any fish stocked or transferred, and minus the number of mortalities from date of loading into the outdoor raceway to the date of release.

Water Volume Estimates

The abundance of fish in a release group was also estimated by determining the amount of fish (number or weight) in each tank when transporting fish to the release site. This estimate is a function of the tank volume (gallons), the estimated ratio of the volume of water displaced in the tank sight gauge to the volume of water placed in the tank (mm/gallon), and the estimated ratio of the number (or weight) of fish which displace a volume of water in the tank sight gauge (fish/mm or kg/mm).

FRH has four vehicles for transporting fish: a boom truck, a large tanker truck, and two pickup trucks. The first two vehicles have a tank divided into four compartments. The pickup trucks have a tank divided into two compartments. EH has a flatbed trailer which has a tank divided into four compartments. Hereafter, compartments will be referred to as tanks.

At the time of transport, each tank was filled with water to the normal level for fish transport and the water level on the tank sight gauge recorded to the nearest millimeter. Fish were then pumped from the raceway into each of the transport tanks. The water level on the tank sight gauge was recorded again after fish were loaded into each of the tanks. The millimeters of water displacement for each tank sight gauge was determined, and using a known displacement value of kilograms of fish per millimeter of water displaced in the tank sight gauge, the total weight of fish in the tank was calculated.

FRH aluminum transport tanks on the tanker truck have an estimated 2.23 kg of fish per mm of water displaced. The transport tanks on the boom truck and trailer have an estimated 1.7 kg and 3.1 kg of fish per mm of water displaced, and the pickup truck tanks have an estimated 0.91 kg of fish per millimeter water displaced. EH transport tanks have an estimated 4.9 kg of fish per millimeter of water displaced (Peltz and Starkey 1993).

Total number of fish was then calculated by dividing the total weight by the estimated mean weight of a fish. FRH used the estimated mean weight that was determined from obtaining a minimum of 510 individual weights from each release group.

EH estimated mean weight by removing a small dip net sample of fish from three of the four transport tanks on the transport vehicle. Each net of fish was held out of the water for several seconds to allow for most of the water to drain out of the net. The fish were poured into a pre-weighed bucket of water, weighed to the nearest gram, and counted out of the bucket. Mean weight was calculated for each of the three samples, and an overall mean weight was calculated by summing the three

sample mean weights and dividing by 3. Because only one displacement reading was taken, the variance around the water volume estimates could not be calculated.

Physical Counts

The physical counts at FRH for the chinook salmon smolt stocked at Ninilchik River and Deception Creek were established upon completion of tagging. For the Ninilchik River release group, fish were removed from one raceway, tagged, and placed into a different raceway. For the Deception Creek chinook salmon release group, two crowders were placed in each raceway. An empty space was left between the crowders so that fish passage around either crowder could be detected. Fish were removed from one side of the crowders, tagged, and returned to the raceway on the other side of the crowders. Fish were counted during the tagging process, and attempts were made to tag all fish in the Ninilchik River and Deception Creek release groups. Mortalities were monitored on a daily basis and subtracted from the original count to yield a final physical count for each release group. A physical count was obtained prior to release on the rearing unit of coho salmon smolt at FRH that was designated for release at Campbell and Ship creeks. Two crowders were placed in the raceway thus dividing the raceway into three sections. To prevent one tag code from being released at two release sites, the tagged fish were separated from the untagged fish during the process of obtaining the physical count. The tagged fish along with approximately 25,000 untagged fish were counted and placed into one section of the raceway designated for release into Campbell Creek. The remaining untagged fish were counted and placed into another section designated for release into Ship Creek. These fish were considered to be part of the Ship Creek release group that were in a different raceway and contained fish tagged with a different tag code than those released into Campbell Creek. A physical count was obtained for the entire raceway, for the component of fish released into Campbell Creek, and for the component of fish released into Ship Creek. A physical count of the tagged fish released into Campbell Creek was also obtained.

Size Estimation

A minimum of 510 fish were individually measured for weight from one rearing unit of Halibut Cove, Seldovia, Lowell Creek, and Homer Spit late-run release groups at EH; and the Campbell Creek and Ship Creek coho salmon and Ninilchik River chinook salmon release groups at FRH. A minimum of 510 fish from each of the two raceways of the Homer Spit early run, Crooked Creek, and Ship Creek chinook salmon release groups at EH; and from each of the two raceways of the Deception Creek chinook salmon and Bird Creek coho salmon release groups at FRH were individually measured for weight. Fish were crowded to one end of the raceway and a sample was netted and put into a small holding pen. Each fish was weighed to the nearest 0.1 gram on an electronic scale. Mean weight and the associated variances of fish in each release group and in each holding pen group were estimated using standard normal procedures.

RESULTS

SMOLT MARKING

About 183,000 coho salmon and 547,000 chinook salmon smolt for release at 10 locations in Cook Inlet and Resurrection Bay were marked in 1997 (Table 1). This number exceeded the project goal by more than 5%. The goal of marking and tagging a minimum of 200,000 smolt for the Deception Creek release group, 50,000 smolt for Ninilchik River, and 40,000 smolt for the remaining release groups was achieved.

Two of the Elmendorf Hatchery release groups of chinook salmon were reared in two different raceways, and one release group of chinook salmon was reared in three different raceways (Table 1). The percentage of tagged fish at release was 18.0% and 18.8% in each of the two Crooked Creek chinook salmon smolt raceways, 17.2% and 21.0% for the two raceways of Homer Spit early-run chinook salmon, and 17.7% and 19.9% for two of the three raceways of Ship Creek chinook salmon smolt (Table 3). The third rearing unit of Ship Creek chinook salmon did not contain tagged fish, and was added to the Ship Creek release group after the tagging season was completed. Two of the Fort Richardson Hatchery release groups were reared in two different raceways. The percentage of tagged coho salmon smolt at release in each of the two Bird Creek raceways was 32.4% and 35.0% (Table 2). One hundred percent of the chinook salmon smolt in each of the two Deception Creek raceways were tagged (Table 3).

Long-term tag retention was checked after the prescribed 30-day waiting period for all of the release groups. The length of waiting periods ranged from 60 days to 201 days, with 14 of the 17 raceways having waiting periods in excess of 100 days. Tag retention for the release groups ranged from 94.4% to 99.6% with an overall mean of 98.2% (Tables 2 and 3). Crooked Creek RW 18 had the lowest long-term retention rate of 93.6% for an individual raceway, but the combination of both Crooked Creek raceways yields an overall release group retention rate of 95.1%. An estimated 598,000 coho salmon and 1,412,600 chinook salmon smolt were released, thus exceeding the total release goal of 2,005,000 (Table 1). The percentage of the total release which was marked per release group ranged from 18.4% to 100% (Tables 2 and 3).

SMOLT ENUMERATION

Mark-Recapture Estimates

Three mark-recapture estimates were made for each of six raceways, with the estimate for one of the Deception Creek raceways taking place at the time of tagging. One mark-recapture estimate was made for the remaining raceways, except for the Ninilchik River release group and the remaining Deception Creek raceway because 100% of the fish in those rearing units were marked.

No significant differences were detected among the three estimates in four of the five release groups that were sampled at the time of release (Tables 4 and 5; Figure 2). The Seldovia release group had one estimate which was significantly different from the other two estimates. The mark-recapture estimates that were performed at the time of tagging on one rearing unit of Deception Creek chinook salmon smolt also resulted in one estimate which was significantly different from the other two estimates (Table 6).

Hatchery Inventory Estimates

The mean weight per bucket of fish at FRH moved from indoor to outdoor raceways for the coho salmon smolt ranged from 7,768 g (Campbell/Ship Creeks) to 8,425 g (Bird Creek E4) (Table 7). The two raceways of Deception Creek chinook salmon smolt group had mean bucket weights of 8,233 g and 8,411 g (Table 7).

Most buckets of fish which were moved contained two to three net loads of fish. If we assume that three net loads of fish were in each bucket, then the mean weight of a net load of coho salmon ranged from 2,589 g (Campbell/Ship Creeks) to 2,808 g (Bird Creek E4). Likewise, the mean weight of a net load of chinook salmon for Deception Creek ranged from 2,744 g to 2,804 g. The coho salmon subsamples were 15.2% to 17.2% of a full net load. The mean weights of

Table 4.-Mark-recapture estimates for four rearing units of Cook Inlet coho salmon smolt released from Fort Richardson Hatchery in 1997.

	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4
Mark-recapture Estimate #1	141,683	153,013	130,692	140,727
Standard Error	2,559	3,888	2,951	3,275
Upper 95% CI	146,699	160,634	136,476	147,147
Lower 95% CI	136,667	145,393	124,907	134,308
Mark-recapture Estimate #2	135,980			142,376
Standard Error	2,333			3,310
Upper 95% CI	140,553			148,864
Lower 95% CI	131,407			135,888
Mark-recapture Estimate #3	142,016			141,630
Standard Error	2,544			3,218
Upper 95% CI	147,002			147,938
Lower 95% CI	137,030			135,322
Estimates Pooled	139,838	153,013	130,692	141,633
Standard Error	1,430	3,888	2,951	1,888
Upper 95% CI	142,640	160,634	136,476	145,334
Lower 95% CI	137,037	145,393	124,907	137,932

the coho salmon subsamples varied from 394 g to 472 g, and the mean number of fish in a subsample varied from 92 to 116 fish. The chinook salmon subsamples were 9.3% to 10.4% of a full net load. The mean weights of the chinook salmon subsamples were 255 g and 293 g, and the mean number of fish in a subsample ranged from 57 to 66 fish.

The inventory estimates at EH for chinook salmon release groups are based on the number of fish enumerated during the coded wire tagging process, the number of fish estimated using a bulk weighing method, and the estimated number of fish remaining in a raceway after an estimated number of fish have been removed. Each raceway differed in the percentages of fish enumerated by the coded wire tagging process, bulk weighing, or by subtraction of those removed (Table 8). The percentage of fish enumerated into individual raceways via the coded wire tagging process ranged from 0% to 52.8%. The percentage of fish enumerated into individual raceways via the bulk weighing method ranged from 0% to 81.1%. The percentage of fish enumerated from a raceway during the coded wire tagging process ranged from 0% to 26.1%. The percentage of fish enumerated from a raceway via the bulk weighing method ranged from 0% to 32.6%.

The inventory estimates for five of the raceways were determined entirely by subtracting the estimated number of fish removed from the inventory estimate established at the fry stage. One raceway did not contain any tagged fish although it is

Table 5.-Mark-recapture estimates of nine rearing units of Cook Inlet chinook salmon smolt and one rearing unit of Resurrection Bay chinook salmon smolt released from Elmendorf Hatchery in 1997.

	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit RW10	Homer Spit RW17	Homer Spit Late RW14
Mark-Recapture Est #1	120,057	108,298	115,091	101,358	111,158	78,133	102,147	120,317	94,182	100,933
Standard Error	3,159	2,735	2,980	2,181	3,533	1,879	2,434	3,284	2,080	2,365
Upper 95% CI	126,249	113,659	120,931	105,632	118,083	81,816	106,919	126,754	98,258	105,570
Lower 95% CI	113,865	102,936	109,250	97,084	104,233	74,449	97,376	113,880	90,106	96,297
Mark-Recapture Est #2	114,830				97,352				95,424	
Standard Error	2,796				2,783				2,047	
Upper 95% CI	120,311				102,806				99,437	
Lower 95% CI	109,349				91,898				91,411	
Mark-Recapture Est #3	111,018				103,387				101,329	
Standard Error	2,474				3,124				1,973	
Upper 95% CI	115,867				109,511				105,197	
Lower 95% CI	106,169				97,263				97,462	
Mark-Recapture Estimate Pooled	114,903	108,298	115,091	101,358	103,757	78,133	102,147	120,317	97,416	100,933
Standard Error	1,610	2,735	2,980	2,181	1,811	1,879	2,434	3,284	1,171	2,365
Upper 95% CI	118,058	113,659	120,931	105,632	107,307	81,816	106,919	126,754	99,712	105,570
Lower 95% CI	111,748	102,937	109,250	97,084	100,208	74,449	97,376	113,880	95,121	96,297

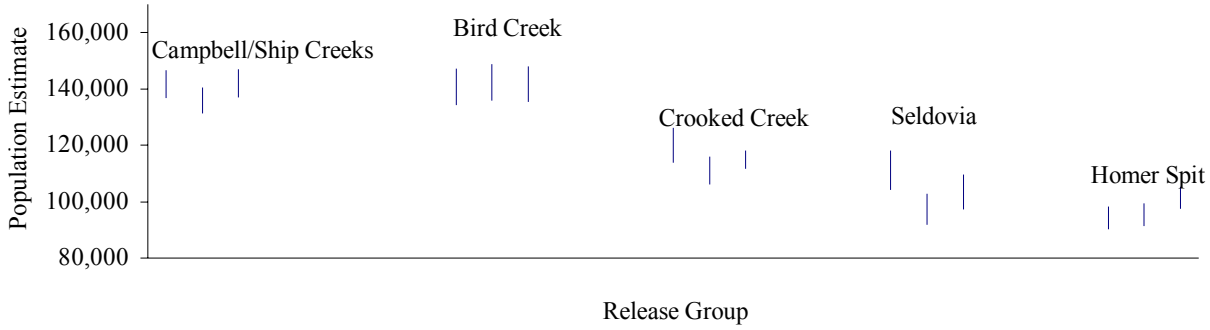

Figure 2.-Comparison of 95% confidence intervals for mark-recapture population estimates for five rearing units of coho salmon and chinook salmon released from Elmendorf and Fort Richardson hatcheries in 1997.

Table 6.-Mark-recapture estimate performed during the tagging process on one rearing unit (D2) of Deception Creek chinook salmon released from Fort Richardson Hatchery in 1997.

Mark-Recapture Estimate #1		91,303
	Standard Error	2,109
	95% CI	
	upper	95,436
	lower	87,169
Mark-Recapture Estimate #2		96,516
	Standard Error	2,137
	95% CI	
	upper	100,703
	lower	92,328
Mark-Recapture Estimate #3		101,604
	Standard Error	2,193
	95% CI	
	upper	105,903
	lower	97,304
Mark-Recapture Estimate Pooled [a]		96,832
	Standard Error	1,238
	95% CI	
	upper	99,259
	lower	94,406
Hatchery Inventory Estimate at release		105,258
Water Volume Estimate at release		102,785
Physical Count at release		103,862

[a] Thirty mortalities were removed after the mark-recapture estimate was performed. These mortalities are reflected in the hatchery inventory, water volume and physical count numbers. Total mortality is reflected in the hatchery inventory, water volume, and physical count values.

Table 7.-Hatchery inventory data and hatchery inventory population estimates for six raceways of coho and chinook salmon smolt released from the Fort Richardson hatchery in 1997.

	Coho Salmon				Chinook Salmon	
Parameter	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4	Willow Creek D2	Willow Creek D3
Containers of fish moved	98	94	69	71	57	55
Total fish weight moved (g)	761,231	732,680	536,661	598,155	469,278	462,617
Mean weight/container (g)	7,768	7,794	7,778	8,425	8,233	8,411
Total number of subsamples	14	13	10	11	8	8
Total weight subsampled (g)	5,549	5,804	3,940	5,195	2,043	2,342
Percent of total weight moved which was subsampled	0.73%	0.79%	0.73%	0.87%	0.44%	0.51%
Percent of individual net which was subsampled	15.3%	17.2%	15.2%	16.8%	9.3%	10.4%
Mean weight/subsample (g)	396	446	394	472	255	293
Total number of fish counted	1,427	1,506	918	1,204	459	526
Number of fish/subsample	102	116	92	109	57	66
Weight per net load	2,589	2,598	2,593	2,808	2,744	2,804
Estimated number of fish enumerated by bulk weighing [a]	195,730	189,358	123,886	138,593	103,904	105,366
Total number of fish placed in raceway at release [b]	150,370	150,918	146,612	147,953	103,794	105,258

[a] This number includes fish which were later stocked or transferred. Sample information for these stockings and transfers was not available.

[b] The number of mortalities as well as the number of fish stocked or transferred since the time of the original hatchery inventory estimate until the fish were released have been subtracted from or added to the estimate.

considered to be part of the Ship Creek release group. All four of the remaining raceways had fish removed from them by the coded wire tagging process and bulk weighing. None of these four raceways had fish enumerated into them via the coded wire tagging process or the bulk weighing process. The tagged fish in these four raceways were tagged into the same raceway they were taken from. The tagging process did not affect the hatchery inventory for these raceways.

Water Volume Estimates

The water volume estimate was higher than the mark-recapture estimate for three of the four raceways at FRH on which mark-recapture estimates were made, and for five of the 10 raceways at EH. At FRH the water volume estimates are within 5% of the hatchery inventory estimates for five of the six raceways which have a hatchery inventory estimate (Tables 9 and 10). The hatchery inventory estimates were higher than the water volume estimates for three of the six

Table 8.-A comparison of hatchery inventory estimates in relation to the inventory estimation method used for chinook salmon smolt release groups released from Elmendorf Hatchery in 1997.

	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Ship Creek RW16	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit Early RW10	Homer Spit Early RW17	Homer Spit Late RW14
Inventory number prior to splitting		177,643		165,972	163,271	157,327				178,448	
Hatchery inventory after split [a]	106,724	106,907	108,679	110,480	110,084	79,639	77,688	105,119	106,631	106,867	102,493
Number of fish enumerated into rearing unit via CWT process	20,746		20,532				41,002	41,125	20,756		41,425
Number of fish enumerated into rearing unit via weighing	85,978		88,147				36,686	63,994	85,875		61,068
Number of fish removed from rearing unit via CWT process		20,746		20,532		41,002				20,756	
Number of fish removed from rearing unit via weighing		49,990		34,960	53,187	36,686				50,825	
Percentage of fish enumerated into rearing unit via CWT process	19.4%	0%	18.9%	0%	0%	0%	52.8%	39.1%	19.5%	0%	40.4%
Percentage of fish enumerated into rearing unit via weighing	80.6%	0%	81.1%	0%	0%	0%	47.2%	60.9%	80.5%	0%	59.6%
Percentage of fish removed from rearing unit via CWT process	0%	11.7%	0%	12.4%	0%	26.1%	0%	0%	0%	11.6%	0%
Percentage of fish removed from rearing unit via weighing	0%	28.1%	0%	21.1%	32.6%	23.3%	0%	0%	0%	28.5%	0%
Percentage of fish enumerated at eyed egg stage	0%	100.0%	0.0%	100.0%	0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
HI estimate at release [b]	106,550	106,728	108,426	110,239	109,922	78,951	77,539	104,847	106,439	106,315	101,522
MR est. at release [c]	114,903	108,298	115,091	101,358		103,757	78,133	102,147	120,317	97,416	100,933
HI relative to MR	92.7%	98.6%	94.2%	108.8%		76.1%	99.2%	102.6%	88.5%	109.1%	100.6%

[a] Mortalities have not been subtracted from the hatchery inventory estimate.

[b] HI = hatchery inventory.

[c] MR = mark-recapture.

Table 9.-A comparison of mark-recapture population estimates to water volume and hatchery inventory estimates, and a comparison of water volume estimates to hatchery inventory estimates for coho salmon smolt produced at Fort Richardson Hatchery and stocked in three locations in Cook Inlet in 1997.

	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4
MR Estimate [a]				
#1	141,683	153,013	130,692	140,727
#2	135,980	48,392	48,186	142,376
#3	142,016	48,392	48,186	141,630
Pooled MR Estimate	139,838	153,013	130,692	141,633
WV Estimate[b]	157,594	135,592	152,309	146,308
HI Estimate[c]	150,370	150,918	146,612	147,953
WV relative to MR	112.7%	88.6%	116.5%	103.3%
HI relative to MR	107.5%	98.6%	112.2%	104.5%
HI relative to WV	95.4%	111.3%	96.3%	101.1%

[a] MR = Mark-recapture.

[b] WV = Water Volume. Water volume estimate was computed using water displacement values at Fort Richardson of 1.6955 kg/m^3 for the boom truck tanks, 2.35 kg/m^3 for the silver slug and 0.91 kg/m^3 for the pickup truck tanks.

[c] HI = Hatchery Inventory.

raceways. The water volume estimate was within 3% of the physical count for all four rearing units on which physical counts were obtained. The water volume estimate was higher than the physical count for three of the four rearing units. At EH the water volume estimates and the hatchery inventory estimates were within 5% of each other for seven of the 10 raceways and within 6% of each other for nine of the 10 raceways. The difference between the mark-recapture estimates and water volume estimates, and the difference between the mark-recapture estimates and the hatchery inventory estimates, follow a similar trend for nine of the 10 raceways at EH (Table 10). For each of these raceways, the water volume and hatchery inventory estimates were either both higher than the mark-recapture

Table 10.-A comparison of mark-recapture population estimates to water volume and hatchery inventory estimates, and a comparison of water volume estimates to hatchery inventory estimates for chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked in seven locations in Cook Inlet and one location in Resurrection Bay in 1997.

	Fort Richardson			Elmendorf									
	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit RW10	Homer Spit RW17	Homer Spit Late RW14
MR Estimate[a]													
#1				120,057	108,298	115,091	101,358	111,158	78,133	102,147	120,317	94,182	100,933
#2				114,830				97,352				95,424	
#3				111,018				103,387				101,329	
Pooled Estimate				114,903	108,298	115,091	101,358	103,757	78,133	102,147	120,317	97,416	100,933
WV Estimate[b]	104,990	102,785	51,100	112,559	106,560	114,905	110,244	92,339	78,347	105,880	111,904	104,099	105,043
HI Estimate[c]	103,794	105,258		106,550	106,728	108,426	110,239	78,951	77,539	104,847	106,439	106,315	101,522
WV relative to MR				98.0%	98.4%	99.8%	108.8%	89.0%	100.3%	103.7%	93.0%	106.9%	104.1%
HI relative to MR				92.7%	98.6%	94.2%	108.8%	76.1%	99.2%	102.6%	88.5%	109.1%	100.6%
HI relative to WV	99.0%	102.5%		94.7%	100.2%	94.4%	100.0%	85.5%	99.0%	99.0%	95.1%	102.1%	96.6%

[a] MR = Mark-recapture.

[b] WV = Water Volume. Water volume estimate was computed using water displacement values at Fort Richardson of 1.6955 kg/m^3 for the boom truck tanks, 2.35 kg/m^3 for the silver slug tanks and 0.91 kg/m^3 for the pickup truck tanks and at Elmendorf Hatchery using a displacement value of 4.9 kg/m^3.

[c] HI = Hatchery Inventory.

estimate, or both lower than the mark-recapture estimate. The raceway containing the Halibut Cove release group is the exception to this. For this release group, all three estimates are within 2% of each other.

Physical Counts

Physical counts were obtained on all three rearing units of chinook salmon and one rearing unit of coho salmon at FRH. A mark-recapture estimate was performed on one rearing unit of Deception Creek chinook salmon at the time of tagging in order to compare that estimate and the hatchery inventory estimate to the physical count. A physical count was also obtained on the rearing unit of coho salmon at the time of release in order to compare it to the mark-recapture estimate and the hatchery inventory estimate (Table 11). When compared to the physical count, the mark-recapture estimate underestimated the population of the Deception Creek fish by 6.8%, and underestimated the population in the coho salmon raceway by 8.4%. The hatchery inventory estimate and the physical count for each of the three rearing units were very close. The physical counts differ by less than 2% from the hatchery inventory estimates for all three rearing units. For two of the rearing units the physical count was greater than the

Table 11.-A comparison of physical count results to mark-recapture population estimates, water volume estimates, and hatchery inventory estimates, for four rearing units of coho salmon and chinook salmon reared at Fort Richardson Hatchery and stocked in three locations in Cook Inlet in 1997.

Parameter	Campbell/ Ship Creeks E1 [a]	Willow Creek D2[b]	Willow Creek D3[b,c]	Ninilchik River D4 [b]
Mark Recapture estimate	139,838	NA	96,832	
Hatchery Inventory estimate	150,370	103,794	105,258	
Water Volume Estimate	157,594	104,990	102,785	51,100
Physical Count	152,667	105,782	103,862	50,698
MR relative to PC	-8.4%		-6.8%	
HI relative to PC	-1.5%	-1.8%	+1.4%	
WV relative to PC	+3.2%	-0.7%	-1.0%	+0.8%

[a] Estimate and physical count obtained at release.

[b] Physical count obtained at the time of tagging. The number reported is minus any mortalities that occurred since the time of tagging.

[c] Mark-recapture estimate performed at the time of tagging. Other estimates are at time of release.

hatchery inventory estimate. A physical count of the number of tagged fish in the Campbell Creek coho salmon release group (45,840) was also obtained and compared to the number of marked fish at tagging minus any mortality that occurred after that the time of tagging (45,937).

SIZE ESTIMATION

The smallest coho salmon smolt in terms of weight were from the Ship Creek release, while the largest coho salmon smolt were from the Bird Creek release (Table 12). The smallest chinook salmon smolt were from the Ninilchik River release, while the largest chinook salmon smolt were from the Homer Spit early-run release (Table 13). A size estimate at release was not obtained on the rearing unit of Ship Creek chinook salmon smolt at EH which did not contain any marked fish.

The majority of the coho salmon smolt released at Bird Creek, Campbell Creek, and Ship Creek were between 15.1 g and 25.0 g (Table 14). At FRH and EH the majority of the chinook salmon smolt released were between 5.1 g and 15.0 g (Table 15).

Table 12.-Mean weights of coho salmon smolt produced at Fort Richardson Hatchery and stocked at three locations in Cook Inlet in 1997.

Parameter	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4
Sample Size	588	514	538	518
Sample Date	5/29/97	5/27/97	5/20/97	5/19/97
Release Dates	5/30/97	5/28/97	5/20/97	5/20/97
Mean Weight (millimeters)	20.7	19.4	23.1	22.7
Standard error	4.1	4.3	4.7	4.6
Maximum	34.3	31.8	39.1	39.0
Minimum	5.5	5.0	4.7	5.0

Table 13.-Mean weights of chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked at seven locations in Cook Inlet and one location in Resurrection Bay in 1997.

	Fort Richardson			Elmendorf									
Parameter	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit RW10	Homer Spit RW17	Homer Spit Late RW14
Sample Size	513	510	512	515	520	524	511	510	527	567	521	526	529
Sample Date	6/10/97	6/10/97	6/11/97	5/29/97	5/28/97	6/9/97	5/27/97	6/5/97	6/6/97	6/2/97	5/30/97	6/4/97	6/11/97
Release Dates	6/11/97	6/11/97	6/17/97	5/30/97	5/29/97	6/10/97	5/28/97	6/6/97	6/9/97	6/3/97	6/2/97	6/5/97	6/12/97
Mean Weight (mm)	12.3	12.1	12.0	12.6	14.2	14.0	14.0	13.6	13.4	13.2	12.6	18.0	12.6
Standard error	2.7	2.3	3.4	2.4	3.2	2.6	3.3	2.8	2.5	3.4	2.8	4.6	2.9
Maximum	24.1	19.8	40.0	22.1	31.6	29.9	36.9	32.2	28.0	32.5	27.7	44.4	28.5
Minimum	6.8	5.8	5.4	6.9	3.7	6.5	7.2	5.3	7.2	6.3	6.3	7.7	4.7

Table 14.-Weight frequency distribution of hatchery coho salmon smolt produced at Fort Richardson Hatchery and stocked in three locations in Cook Inlet in 1997.

Weight Distribution (grams)	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4
0 - 5		0.2%	0.2%	0.2%
SE		0.0001	0.0001	0.0001
5.1 - 10	0.5%	2.5%	0.4%	0.8%
SE	0.0001	0.0003	0.0001	0.0002
10.1 - 15	7.3%	10.1%	3.0%	2.5%
SE	0.0004	0.0006	0.0003	0.0003
15.1 - 20	36.1%	44.6%	22.9%	25.3%
SE	0.0008	0.0010	0.0008	0.0008
20.1 - 25	42.5%	34.2%	40.7%	43.8%
SE	0.0008	0.0009	0.0009	0.0010
25.1 - 30	11.9%	7.8%	26.4%	22.0%
SE	0.0006	0.0005	0.0008	0.0008
30.1 - 35	1.7%	0.6%	4.8%	5.0%
SE	0.0002	0.0001	0.0004	0.0004
35.1 - 40			1.7%	0.4%
SE			0.0002	0.0001
40.1 - 45				
SE				
45.1 - 50				
SE				
>50				
SE				
Summary				
< 15.1 g	7.82%	12.84%	3.5%	3.5%
15.1 - 25.0 g [a]	78.57%	78.79%	63.6%	69.1%
> 25.0 g	13.61%	8.37%	32.9%	27.4%

[a] Production goal for coho salmon is to make 80% of the smolt weigh between 15.1 g and 25.0 g.

Table 15.-Weight frequency distribution of hatchery chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries, and stocked in seven locations in Cook Inlet and one location in Resurrection Bay in 1997.

	Fort Richardson			Elmendorf									
Weight Distribution (grams)	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW9	Crooked Creek RW18	Ship Creek RW6	Ship Creek RW15	Seldovia RW 20	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit RW10	Homer Spit RW17	Homer Spit Late RW14
0 - 5					0.2%								0.2%
SE					0.0001								0.0001
5.1 - 10	16.6%	20.6%	30.3%	12.4%	6.3%	4.0%	6.8%	7.1%	6.8%	11.8%	15.9%	1.0%	17.6%
SE	0.0007	0.0008	0.0009	0.0006	0.0005	0.0004	0.0005	0.0005	0.0005	0.0006	0.0007	0.0002	0.0007
10.1 - 15	70.0%	67.6%	53.7%	73.6%	58.5%	65.6%	64.0%	66.3%	69.8%	68.6%	68.1%	26.2%	65.0%
SE	0.0009	0.0009	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0009	0.0008	0.0009
15.1 - 20	11.9%	11.8%	13.9%	13.4%	31.5%	28.2%	24.9%	24.9%	21.6%	14.5%	14.6%	47.0%	15.5%
SE	0.0006	0.0006	0.0007	0.0007	0.0009	0.0009	0.0008	0.0008	0.0008	0.0006	0.0007	0.0010	0.0007
20.1 - 25	1.6%		2.0%	0.6%	2.7%	1.7%	3.1%	1.4%	1.5%	3.9%	1.2%	19.8%	1.5%
SE	0.0002		0.0003	0.0001	0.0003	0.0002	0.0003	0.0002	0.0002	0.0003	0.0002	0.0008	0.0002
25.1 - 30					0.4%	0.4%	0.8%	0.2%	0.2%	0.9%	0.2%	4.0%	0.2%
SE					0.0001	0.0001	0.0002	0.0001	0.0001	0.0002	0.0001	0.0004	0.0001
30.1 - 35					0.4%		0.2%	0.2%	0.0%	0.4%		1.5%	
SE					0.0001		0.0001	0.0001	0.0000	0.0001		0.0002	
35.1 - 40			0.2%				0.2%					0.4%	
SE			0.0001				0.0001					0.0001	
40.1 - 45												0.2%	
SE												0.0001	
45.1 - 50													
SE													
>50													
SE													
Summary													
< 5.1 g	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
5.1 - 15.0 g	86.5%	88.2%	84.0%	86.0%	64.8%	69.7%	70.8%	73.3%	76.7%	80.4%	84.1%	27.2%	82.6%
> 15.0 g	13.5%	11.8%	16.0%	14.0%	35.0%	30.3%	29.2%	26.7%	23.3%	19.6%	15.9%	72.8%	17.2%

[a] Production goal for chinook salmon is to make 80% of the smolt weigh between 5.1 g and 15.0 g.

DISCUSSION

SMOLT MARKING

A major point of emphasis for the marking program has been to achieve, maintain, and improve if possible, long-term tag retention rates above the preceding year's levels. This goal has usually been obtained, as overall retention levels have remained fairly steady over the past four tagging seasons. The combined 1997 long-term tag retention was 98.2% as compared to 97.8% in 1996. Excellent tag retention (approximately 99.2%) for the Deception Creek chinook salmon release group contributed to the increase in the overall average because that release group contained approximately 209,000 of the approximately 730,000 tagged fish released (Tables 2 and 3). We feel that grading fish and using different sizes of head molds for tagging is responsible for maintaining acceptable long-term tag retention rates in the release groups of coho and chinook salmon smolt. A second goal of achieving a minimum long-term retention rate of 97% for each individual rearing unit has yet to be achieved for any given tagging season.

In 1992, the coho and chinook salmon at EH and FRH were not sorted by size. The fish were tagged with the one head mold size that accommodated a majority of the fish in the rearing unit. Long term tag retentions ranged from 83.8% to 90.3% for the five rearing groups of coho salmon, and were 75.9% and 94.7% for the two rearing groups of chinook salmon (Peltz and Starkey 1993). At Big Lake Hatchery (BLH), the fish were small, and it was decided that sorting them into different size groups, and tagging them with different sizes of head molds would result in better tag placement and retention. Long-term tag retention rates at BLH in 1992 ranged from 93.2% to 95.8%. In 1993 fish length ranges for each head mold size were established, and long-term tag retention comparisons were performed on similar rearing units that were either sorted by size and tagged, or not sorted prior to tagging (Peltz and Hansen 1994). Between tagging fish which were sorted by size, and an increase in the conscientiousness of the tagging personnel, the combined long-term tag retention was 96.3% as compared to 89.4% in 1992 (Peltz and Hansen 1994). Since 1993, all rearing units of chinook and coho salmon have been measured and sorted by size prior to tagging.

A standard set of size ranges provided tagging crews with a basic idea of which head molds to use, but not all head molds worked well for all stocks of fish or for all species (Peltz and Hansen 1994). The shape of the 90/lb head mold size made it difficult to obtain good tag placement on a routine basis for chinook salmon release groups at EH and for coho and chinook salmon release groups at FRH. The fish in these release groups that would have normally been tagged using the 90/lb size head mold were tagged with the 120/lb size head mold that was set at a deeper setting than normally used when tagging with the 120/lb size head mold. Fish that were too small to be tagged using the 200/lb head mold with their mouth open, were tagged with their mouth closed to prevent a tag placement that was too deep. Tag placement checks demonstrated good tag placement when using this method for tagging undersized fish.

Factors which can contribute to lower long-term tag retention rates are size of the individual fish, size distribution, improper placement of the fish into the head mold, improper set up of the injector, and experience of the taggers. Although it is difficult to assess, tagger attitude and conscientiousness may also have significant effects on long-term tag retention rates. A comparison of short-term to long-term tag retention rates since 1994 indicates that low

Table 16.-A comparison of short-term and long-term tag retentions in relation to size of fish at tagging based on the percentage of smolt tagged using various sizes of head molds for rearing units of coho salmon released from Fort Richardson and Elmendorf hatcheries from 1994 through 1997.

1997	Coho Salmon			
Parameter	Campbell/ Ship Creeks E1	Bird Creek E4	Bird Creek E3	Ship Creek E2
Short-term retention	99.7%	99.6%	99.4%	99.9%
Long-term retention	98.8%	99.2%	99.1%	99.6%
% tagged with 65/lb head mold	73.9%	87.1%	86.9%	74.8%
% tagged with 120L/lb head mold [a]	26.1%	12.9%	13.1%	25.2%

1996	Coho Salmon			
Parameter	Bird Creek E1	Anchorage Urban Streams E4	Wasilla Creek E3	Anchorage Urban Streams E2
Short-term retention	99.2%	99.7%	99.6%	99.6%
Long-term retention	97.6%	99.7%	98.3%	98.7%
% tagged with 65/lb head mold	64.6%	74.6%	79.8%	84.1%
% tagged with 120L/lb head mold[a]	35.4%	25.4%	20.2%	15.9%

1995	Coho Salmon			
Parameter	Campbell Creek E1	Nancy Lake E4	Ship Creek E3	Bird Creek E2
Short-term retention	99.6%	99.5%	99.7%	100.0%
Long-term retention	99.6%	98.2%	97.8%	98.6%
% tagged with 65/lb head mold	69.4%	66.1%	75.4%	81.5%
% tagged with 90/lb head mold	30.6%	33.9%	24.6%	18.5%

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short-term retention rates <99% usually results in long-term retention rates <97% (Tables 16, 17, and 18). In 1995 three raceways of chinook salmon at EH had short-term retentions less than 99%, and all three raceways had long-term retention rates less than 95% (Starkey et al. 1996). In 1997, four rearing units of chinook salmon at EH had short-term tag retentions ≤99.2% and all four of these rearing units had long-term tag retention rates ≤96.5%. Short-term retention rates between 99% and 100% however, do not

Table 16.-Page 2 of 2.

1994	Coho Salmon				
Parameter	Campbell Creek E1	Bird Creek E2	Nancy Lake E3	Nancy Lake E4	EH Ship Creek [c]
Short-term retention	99.5%	99.9%	99.8%	99.6%	99.6%
Long-term retention	97.3%	98.8%	98.2%	98.7%	94.8%
% tagged with 30/lb head mold		14.2%	11.5%	7.0%	
% tagged with 65/lb head mold	80.4%	74.9%	76.9%	79.3%	24.8%
% tagged with 90/lb head mold	19.6%	10.9%	11.6%	13.7%	33.6%
% tagged with 120L/lb head mold[a]					27.8%
% tagged with 120S/lb head mold[b]					13.7%

[a] 120L/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 81 to 90 mm in length.

[b] 120S/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 73 to 80 mm in length.

[c] Released from Elmendorf Hatchery

guarantee excellent long-term retention rates. One rearing unit of chinook salmon at EH in 1997 had a short-term tag retention of 100%, but a long-term tag retention of only 96.5%.

Smaller fish require more patience when tagging as there is less room for error. If the fish is not properly placed into the head mold, the tag might be placed to the right or left of center which can result in the tag being placed into the olfactory bulb region (Figure 1). Some of these will fall out before the short-term retention rate has been determined, many will fall out after that time resulting in low long-term tag retention rates. Tables 16, 17, and 18 compare long-term retentions from 1994 through 1997 in relation to the size of fish at tagging. Information from 1992 and 1993 will not be compared to 1994 through 1997 information, as the program was evolving during those years, and crew composition was different. The size of fish at tagging is based on the size of the head molds which were used at the time of tagging. For 1994 through 1997, six head mold sizes or settings have been used to tag the chinook salmon and coho salmon smolt. The 200/lb, the 120/lb (shallow), the 120/lb (deep), and the 65/lb head molds are generally used, and the 90/lb and the 30/lb have been used on occasion. The 120/lb head mold is used at two different settings in order to accommodate two size groups of fish.

For the 1997 tagging season it appears that size at tagging may have been one factor contributing to the long-term tag retention rate. All rearing units which contained fish of such a size that required the use of only the two smallest head mold sizes and settings had long-term retentions <97%. These are rearing units where at least 80% of the fish were smaller than 81 mm (approximately 5.8 g). All other rearing units contained slightly

Table 17.-A comparison of short-term and long-term tag retentions in relation to size of fish at tagging based on the percentage of smolt tagged using various sizes of head molds for rearing units of chinook salmon released from Elmendorf Hatchery from 1994 through 1997.

1997	Elmendorf									
Parameter	Homer Early Run RW10	Homer Early Run RW17	Crooked Creek RW9	Crooked Creek RW18	Halibut Cove RW 8	Seldovia RW 20	Lowell Creek RW 7	Ship Creek RW6	Ship Creek RW15	Homer Spit Late run RW14
Short-term retention	98.5%	99.2%	100.0%	99.2%	99.6%	99.1%	99.9%	100.0%	99.7%	98.8%
Long-term retention	94.5%	94.3%	96.5%	93.6%	96.5%	96.5%	99.0%	99.5%	99.5%	95.7%
% tagged with 120L/lb head mold [a]							65.9%	46.5%		
% tagged with 120S/lb head mold [b]	64.8%	67.2%	72.9%	73.0%	73.0%	80.6%	34.1%	53.5%		76.8%
% tagged with 200/lb head mold	35.2%	32.8%	27.1%	27.0%	27.0%	19.4%				23.2%

1996	Elmendorf									
Parameter	Homer Spit RW9	Ship Creek RW6	Kodiak	Homer Spit RW16	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Crooked Creek RW8	Crooked Creek RW17	Homer Spit Late run RW14
Short-term retention	97.9%	99.8%	99.2%	99.7%	100.0%	99.5%	99.7%	100.0%	100.0%	99.5%
Long-term retention	93.8%	97.4%	98.6%	97.4%	97.2%	97.4%	96.7%	99.3	97.6%	95.5%
% tagged with 120L/lb head mold [a]				34.0%	32.3%	35.7%	36.9%	71.3%	74.0%	29.6%
% tagged with 120S/lb head mold [b]	85.5%	71.6%	80.0%	58.0%	67.7%	64.3%	63.1%	28.7%	26.0%	70.4%
% tagged with 200/lb head mold	14.5%	28.4%	20.0%	8.0%						

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larger fish which required the use of the 120/lb head mold set at both the shallow and deep settings, the 200/lb and the 120/lb used at both settings, or the 120/lb head mold set at a deeper setting as well as a 65/lb head mold. These rearing units had long-term tag retentions >98%. In previous years, size did not appear to have a great affect on the long-term retention rate. In 1996, four of the five rearing units tagged with the smallest two head mold sizes and settings had long-term retentions >97%, and 3 of those were above 98%. In 1995, two of the four rearing units tagged with the smallest two head mold sizes and settings had long-term retentions ≥97%, while two rearing units containing larger fish which were tagged with the 120/lb set at a deep setting and the 120/lb set at a shallow setting had long-term tag retentions <94%. These are the same sized head molds for the same size of fish that were used for the rearing units of chinook salmon at EH in 1997 which had excellent (≥98.9%) long-term retention.

Table 17.-Page 2 of 2.

1995	Elmendorf									
Parameter	Homer Spit RW10	Homer Spit RW9	Crooked Creek RW16	Ship Creek RW6	Ship Creek RW15	Kodiak RW 7	Halibut Cove RW20	Seldovia RW	Crooked Creek RW17	Homer Spit Late run RW14
Short-term retention	98.9%	100.0%	98.0%	97.7%	98.6%	100.0%	100.0%	99.4%	98.2%	99.5%
Long-term retention	96.4%	97.0%	94.6%	92.3%	97.2	98.8%	99.3%	97.8%	93.2%	98.6%
% tagged with 65/lb headmold							31.2%			
% tagged with 120L/lb headmold [a]				41.2%	52.3%	60.4%	68.8%	66.8%	74.0%	
% tagged with 120S/lb headmold [b]	81.7%	85.7%	86.7%	58.8%	47.7%	39.6%		33.2%	26.0%	65.5%
% tagged with 200/lb headmold	18.3%	14.3%	13.3%							34.5%

1994	Elmendorf								
Parameter	Seldovia RW 13	Ship Creek RW20	Eagle River RW 7	Ship Creek RW19	Crooked Creek RW9	Crooked Creek RW10	Halibut Cove RW 18	Homer Early Run RW15	Homer Early Run RW16
Short-term retention	99.5%	99.9%	99.6%	99.9%	100.0%	99.8%	100.0%	100.0%	99.8%
Long-term retention	97.2%	97.9%	95.5%	96.3%	99.4%	98.1%	99.2%	99.3%	96.9%
% tagged with 65/lb headmold							14.8%	11.4%	10.8%
% tagged with 120L/lb headmold [a]	27.0%	18.9%	28.3%	31.9%	44.6%	44.8%	64.3%	61.8%	62.6%
% tagged with 120S/lb headmold [b]	64.3%	67.8%	58.6%	55.7%	43.0%	45.0%	20.9%	26.8%	26.6%
% tagged with 200/lb headmold	8.7%	13.3%	13.1%	12.5%	12.4%	10.2%			

[a] 120L/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 81 to 90 mm in length.

[b] 120S/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 73 to 80 mm in length.

Long-term retentions tend to be better at FRH than they are at EH (Table 19). In 1997, the overall long-term tag retentions for both coho salmon and chinook salmon at FRH were 99.2 %, while the overall long-term tag retention at EH was 96.7%. From 1994 through 1997, overall long-term tag retentions at FRH range from 98.5% to 99.2%, while overall long-term tag retentions at EH range from 96.7% to 97.1% for those same years. With a few exceptions, the same tagging crew is used at both hatcheries within a tagging season, the composition of the crew has changed very little for the last 4 years, and all rearing units were sorted by size prior to tagging. The overall long-term tag retentions for coho salmon at FRH are good (ranging from 98.2 in 1994 to 99.2 in 1997). The coho salmon smolt are the largest fish at the time of tagging. These fish are typically tagged using

Table 18.-A comparison of short-term and long-term tag retentions in relation to size of fish at tagging based on the percentage of smolt tagged using various sizes of headmolds for rearing units of chinook salmon released from Fort Richardson and Crooked Creek hatcheries from 1994 through 1997.

1997	Fort Richardson		
Parameter	Deception Creek D2	Deception Creek D3	Ninilchik River
Short-term retention	99.6%	99.9%	99.9%
Long-term retention	99.5%	98.9%	99.2%
% tagged with 65/lb headmold			41.5%
% tagged with 120L/lb headmold [a]	28.3%	39.7%	58.5%
% tagged with 120S/lb headmold [b]	48.7%	55.4%	
% tagged with 200/lb headmold	23.0%	5.0%	

1996	Fort Richardson		
Parameter	Deception Creek D3	Deception Creek D2	Ninilchik River
Short-term retention	100.0%	99.9%	99.6%
Long-term retention	98.4%	99.3%	98.6%
% tagged with 65/lb headmold			
% tagged with 120L/lb headmold [a]			65.8%
% tagged with 120S/lb headmold [b]	85.6%	65.5%	34.2%
% tagged with 200/lb headmold	14.4%	34.5%	

1995	Fort Richardson	
Parameter	Deception Creek D2	Ninilchik River
Short-term retention	100.0%	99.8%
Long-term retention	98.8%	99.0%
% tagged with 65/lb headmold	57.8%	50.5%
% tagged with 120L/lb headmold [a]	42.2%	49.5%

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Table 18.-Page 2 of 2.

1994	Fort Richardson		Crooked Creek Hatchery		
	Deception Creek	Ninilchik	Homer Spit Late run	Homer Spit Late run	Homer Spit Late run
Parameter	D2	River	RW5	RW6	RW8
Short-term retention	99.8%	99.9%	99.7%	99.7%	99.5%
Long-term retention	99.2%	98.6%	97.7%	99.1%	99.0%
% tagged with 65/lb headmold	47.6%	46.2%			
% tagged with 90/lb headmold			60.5%	70.6%	54.4%
% tagged with 120L/lb headmold [a]	29.8%	53.8%	39.5%	29.4%	45.6%
% tagged with 120S/lb headmold [b]	22.6%				
% tagged with 200/lb headmold					

[a] 120L/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 81 to 90 mm in length.

[b] 120S/lb headmold is a 120/lb headmold that is placed in such a manner to achieve proper placement of a coded wire tag into fish ranging 73 to 80 mm in length.

a 120/lb head mold set at a deeper setting for larger fish, and a 65/lb head mold. The larger size of the coho smolt at the time of tagging may explain why their long-term tag retentions are high. Size of fish at tagging is most likely not the reason why the chinook salmon long-term tag retentions are better at FRH than they are at EH. Both good (≥ 98%) and poor (< 97%) long-term tag retentions have occurred in all sizes of chinook salmon smolt, and large and small chinook salmon smolt have been tagged at both EH and FRH (Tables 17 and 18). Overall long-term tag retentions from 1994 to 1997 for chinook salmon ranged from 98.7% to 99.2% at FRH, and 96.7% to 97.5% at EH.

Attitude of taggers and working conditions may affect quality of tagging, and thus, tag retention rates. Tagging is performed in January and February at EH. These are the coldest and darkest months of the tagging season. Support chores such as retrieving fish and storing them in outdoor net pens are difficult to perform in the dark and freezing temperatures as rearing units are located below the level of the walkways, making access difficult. The chinook salmon at FRH are tagged in March and April. The weather is typically much warmer, and the number of daylight hours is increasing. The rearing units are physically easier to work in because many are above ground level rather than below ground level.

The long-term tag retention distributions for coho and chinook salmon at FRH have changed very little over the past 4 years as 23 of the 26 long-term retentions have been ≥98%, and all 26 long-term retentions have been greater than 97% (Tables 16 and 18, Figures 3 and 4). Long-term tag retentions from 1994 to 1997 at EH are more variable, ranging from 92.3% to 99.5% (Table 17, Figure 4). Only twelve of the 40 long-term retentions at EH have been ≥98%, and 11 of

Table 19.-A comparison of long-term tag retention by species and by hatchery for 1994 through 1997.

	FRH[a] Coho	FRH Chinook	FRH Total	EH[b] Coho	EH Chinook	CCH[c] Chinook	EH Total	Total Coho	Total Chinook	Grand Total
1994										
#marked	133,853	92,482	226,335	44,031	225,321	93,217	269,352	177,884	411,020	588,904
#tagged	131,466	91,455	222,922	41,722	219,658	91,706	261,380	173,188	402,819	576,007
Long-term retention	98.2%	98.9%	98.5%	94.8%	97.5%	98.4%	97.0%	97.4%	98.0%	97.8%
1995										
#marked	183,073	101,709	284,782		284,496		284,496	183,073	386,205	569,278
#tagged	180,384	100,586	280,970		276,204		276,204	180,384	376,791	557,174
Long-term retention	98.5%	98.9%	98.7%		97.1%		97.1%	98.5%	97.6%	97.9%
1996										
#marked	187,483	99,386	286,869		286,145		286,145	187,483	385,531	573,014
#tagged	184,814	98,107	282,921		277,746		277,746	184,814	375,853	560,667
Long-term retention	98.6%	98.7%	98.6%		97.1%		97.1%	98.6%	97.5%	97.8%
1997										
#marked	183,502	260,342	443,844		286,815		286,815	183,502	547,157	730,659
#tagged	181,988	258,265	440,253		277,233		277,233	181,988	535,498	717,487
Long-term retention	99.2%	99.2%	99.2%		96.7%		96.7%	99.2%	97.9%	98.2%

[a] FRH = Fort Richardson Hatchery

[b] EH = Elmendorf Hatchery

[c] CCH = Crooked Creek Hatchery

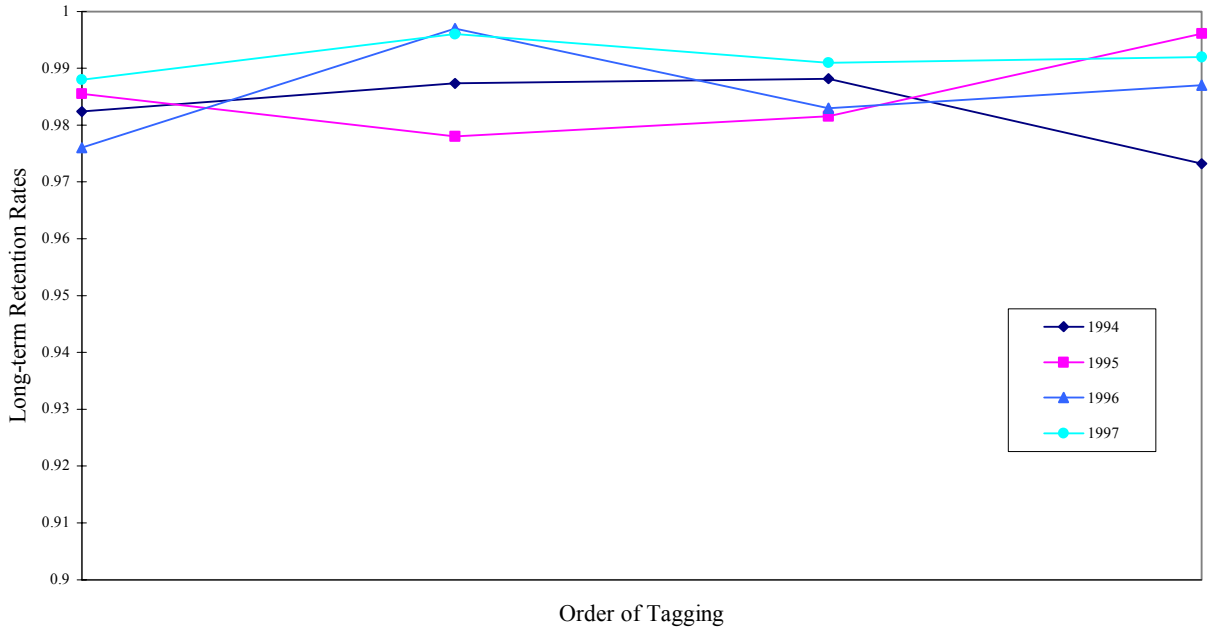

Figure 3.-Comparison of long-term retention rates for rearing units of coho salmon at Fort Richardson Hatchery in 1994–1997.

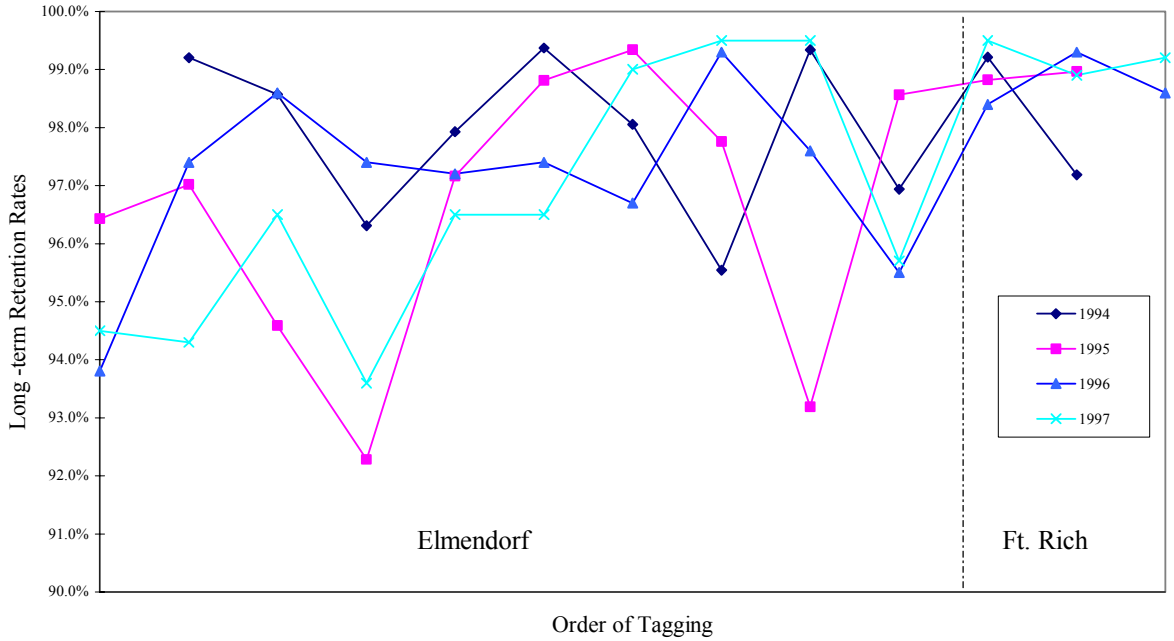

Figure 4.-Comparison of long-term retention rates for rearing units of chinook salmon at Elmendorf and Fort Richardson hatcheries in 1994-1997.

the 40 long-term retentions have been ≤96%. In 1994 and 1995, crew members switched tasks between tagging and clipping weekly. For those two tagging seasons, the tag retentions may be related to which tagging personnel happened to be tagging that week. In 1996, crews began rotating duties every 2 to 4 hours. With every person tagging every day, we saw a decrease in the number of rearing units with high retentions or low retentions, and an increase in middle range retentions. The 1997 distribution shows an almost even distribution of long term tag retentions amongst the low, middle, and high long-term retention ranges.

SMOLT ENUMERATION

In 1992, hatchery book estimates, water volume estimates, and mark-recapture estimates for release groups of coho and chinook salmon at Elmendorf, Fort Richardson, and Big Lake hatcheries were examined and compared (Peltz and Starkey 1993). The two hatchery generated estimates, hatchery inventory and water volume estimates, did not always agree within a raceway, and the differences appeared to be inconsistent among raceways. Sometimes the book estimate was higher than the water volume estimate, and other times the water volume estimate was higher than the book estimate. It was decided at that time that the mark-recapture estimate would be a more accurate and consistent estimate.

Water volume displacement tests were performed previously at FRH for 1993 coho and chinook salmon release groups (Peltz and Hansen 1994). The tests indicated that abundance estimates based on displacement were not independent of species, size, and stock of fish. In addition, other variables such as water temperature, length of time since the fish were fed, method of loading fish into the tank, and fish size distribution may affect water volume abundance estimates and be potential sources of error. Due to the high degree of variability associated with the estimation of water displacement values, they felt that this technique was unreliable.

Peltz and Hansen (1994) reported that the major source of error associated with the hatchery inventory technique at FRH appears to be the calibration of nets to determine the mean weight of a fish in a loaded net. They suggested that if a better method of calibrating net loads of fish could be developed, then this technique could produce more reliable estimates. A comparison of the 1997 hatchery inventory (HI) estimates for the two rearing units of Deception Creek chinook salmon, and the one rearing unit of Campbell Creek and Ship Creek coho salmon, to the physical counts for these rearing units indicates that the technique for determining HI estimates is reliable at FRH (Table 20). Improved sampling methods such as obtaining samples throughout the transferring process instead of only at the beginning of the transferring process may be responsible for the increase in reliability of this type of estimate at FRH.

Accurate mark-recapture (MR) estimates are dependent on obtaining a random sample during both sampling periods. Random samples are difficult to obtain as small fish tend to be caught first within any container of fish. Unless care is taken to collect fish as randomly as possible within a container, or all the fish in the container are utilized, bias will be introduced.

Over the years, trends have developed in relation to the three types of estimates at both FRH and EH. At FRH there have been 34 mark-recapture estimates, 35 hatchery inventory estimates, 38 water volume estimates, and six physical counts performed over the last 6 tagging seasons (Table 21). The relationship of the HI estimates to the water volume (WV) estimates is the most inconsistent. For the 35 rearing units which

Table 20.-Comparison of three population estimation techniques and physical counts for coho and chinook salmon smolt released from Fort Richardson Hatchery in 1997.

Estimate	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4	Willow Creek D2	Willow Creek D3	Ninilchik River D4
MR (Pooled)[a]	139,838	153,013	130,692	141,633			
Standard Error	1,430	3,888	2,951	1,888			
Upper 95% CI	142,640	160,634	136,476	145,334			
Lower 95% CI	137,037	145,393	124,907	137,932			
WV[b]	157,594	135,592	152,309	146,308	104,990	102,785	51,100
HI[c]	150,370	150,918	146,612	147,953	103,794	105,258	
PC[d]	152,667				105,782	103,862	50,698
WV relative to MR	112.7%	88.6%	116.5%	103.3%			
HI relative to MR	107.5%	98.6%	112.2%	104.5%			
PC relative to MR	109.2%						
WV relative to HI	104.8%	89.8%	103.9%	98.9%	101.2%	97.7%	
PC relative to HI	101.5%				101.9%	98.7%	
PC relative to WV	96.9%				100.8%	101.0%	99.2%

[a] MR = Mark-recapture.

[b] WV = Water volume.

[c] HI = Hatchery inventory.

[d] PC = Physical count.

Table 21.-The results of three smolt population estimation techniques, and a comparison of the hatchery inventory estimate to the water volume estimate for rearing units of coho salmon and chinook salmon released from Fort Richardson Hatchery from 1992 through 1997.

1992	Houston	Nancy Lake	Bird Creek	Campbell Creek	Willow Creek	Ninilchik River
Water Volume estimate	157,046	154,974	115,869	110,758	185,051	175,897
Hatchery Inventory estimate	149,926	149,520	114,621	114,684	181,017	146,788
Mark-recapture estimate	154,166	158,459	95,377	97,076	179,724	132,387
HI relative to WV	95.5%	96.5%	98.9%	103.5%	97.8%	83.5%

1993	Bird Creek	Campbell Creek	Houston	Nancy Lake	Ninilchik River	Deception Creek
Water Volume estimate	145,780	146,757	167,381	131,519	191,462	198,487
Hatchery Inventory estimate	158,563	160,374	169,565	149,130	200,580	187,736
Mark-recapture estimate	140,382	140,797	148,282	131,591	184,585	160,194
HI relative to WV	108.8%	109.3%	101.3%	113.4%	104.8%	94.6%

1994	E3 Nancy Lake FRH	E4 Nancy Lake FRH	Bird Creek FRH	Campbell Creek FRH	Willow Creek FRH	Ninilchik River FRH
Water Volume estimate	71,543	71,964	81,417	92,248	190,443	209,154
Hatchery Inventory estimate	75,022	76,212	84,504	99,941	215,579	215,940
Mark-recapture estimate	61,912	66,827	84,643	87,686	177,913	201,513
HI relative to WV	104.9%	105.9%	103.8%	108.3%	113.2%	103.2%

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had both HI and WV estimates, the HI estimate was higher than the WV estimate 20 times. The differences between the two types of estimates ranges from 0.1% to 16.6%. When comparing the WV estimates to the physical count (PC), sometimes the WV estimate appears to be accurate, and other times it does not. In 1995, 1996, and 1997, the WV estimates for the Ninilchik River release groups were compared to physical counts conducted at the time of tagging, minus any mortality that occurred from the

Table 21.-Page 2 of 2.

1995	Bird Creek E2	Campbell Creek E1	Nancy Lake E4	Ship Creek E3	Willow Creek [a]	Ninilchik River [a]
Water Volume estimate	149,353	176,173	168,065	164,329	222,551	63,986
Hatchery Inventory estimate	163,848	162,464	162,773	163,859	220,374	
Mark-recapture estimate	154,753	157,241	151,985	158,981	184,740	
Physical Count						54,902
HI relative to WV	109.7%	92.2%	96.9%	99.7%	99.0%	85.8%

1996	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3	Willow Creek D2	Willow Creek D3	Ninilchik River
Water Volume estimate	165,800	157,103	156,074	157,510	102,516	114,831	51,767
Hatchery Inventory estimate	158,649	157,281	157,538	157,702	106,607	107,350	
Mark-recapture estimate	147,618	156,050	145,923	146,807	93,981	92,937	
Physical Count							51,686
HI relative to WV	95.7%	100.1%	100.9%	100.1%	104.0%	93.5%	

1997	Campbell/ Ship Creeks E1	Ship Creek E2	Bird Creek E3	Bird Creek E4	Willow Creek D2	Willow Creek D3	Ninilchik River
Water Volume estimate	157,594	135,592	152,309	146,308	104,990	102,785	51,100
Hatchery Inventory estimate	150,370	150,918	146,612	147,953	103,794	105,258	
Mark-recapture estimate	139,838	153,013	130,692	141,633		96,832	
Physical Count	152,667				105,782	103,862	50,698
HI relative to WV	95.4%	111.3%	96.3%	101.1%	98.9%	102.5%	

time tagging was completed to the time of release. In 1995 the WV estimate relative to the physical count was 116.5 %. In 1996 the WV estimate relative to the physical count was 100.2%, and in 1997, the WV estimate relative to the physical count was 100.8%. The inconsistent relationship between the WV estimate and the physical counts indicates that the WV estimate is not very reliable. In 1997, one rearing unit of coho salmon also had a

physical count as well as the two rearing units of Deception Creek chinook salmon. The WV estimate relative to the physical count for the rearing unit of coho salmon and for the two rearing units of Deception Creek chinook salmon were 103.2%, 99.3% and 99.0%, respectively (Table 11). In 1997 FRH received and used some different transport tanks than what had been used in the past. The rearing units with physical counts were used to help determine volumetric displacement values for the new tanks. Large samples of entire rearing units (approximately 50,000 to 150,000 physically counted fish) were used. This resulted in accurate WV estimates for most of the rearing units released from FRH in 1997. The water volume estimates at FRH were close to the hatchery inventory estimates for five of the six raceways (HI relative to WV 95.4% to 111.3%), and higher than the mark-recapture estimates for three of the four raceways (WV relative to MR 88.6% to 116.5%).

Initial HI estimates for 1997 release groups of coho and chinook salmon at FRH were calculated when the fish were transferred from indoor to outdoor rearing units. The number of subsamples during the indoor to outdoor transfer of coho salmon ranged from six to 10 subsamples from each coho salmon indoor raceway. Fish from three different indoor raceways were transferred to each of the four outdoor raceways resulting in the total number of 11 to 14 subsamples per outdoor raceway. The size of the subsamples for the 1997 release groups of coho salmon ranged from 15.2% to 17.2% of a full net load. This is an increase from any previous year.

In 1995 the sample sizes for chinook salmon at FRH were increased to 100% of a net load in an unsuccessful attempt to improve the accuracy of this technique (Starkey et al. 1996). Since then samples have been reduced to a smaller subsample of a full net load. The two indoor raceways of the 1997 Deception Creek chinook salmon release group were each sampled eight times during the transfer of fish to the two outdoor raceways. Each of the two outdoor raceways received fish from one of the two indoor raceways. The size of the subsamples for the 1997 release group of Deception Creek chinook salmon ranged from 9.3% to 10.4% of a full net load.

The relationship between HI and MR estimates appears to be more consistent than the relationship between HI and WV estimates at FRH over the last six tagging seasons. Of the 33 times that MR estimates have been performed at FRH, the HI estimate has been higher than the MR estimate 29 times. This most likely indicates that either the HI estimate consistently over estimates the population, the MR estimate consistently under estimates the population, or both. In 1997, the MR estimate was the lowest of all the estimates for four of the five rearing units which had MR estimates performed on them (Table 21, Figure 5). In 1997 there were two rearing units in which the MR estimate and the HI estimate could be compared to a physical count of the fish in those rearing units (Table 11). The MR estimate relative to the PC for the rearing unit of coho salmon was 91.6%. One rearing unit of chinook salmon had a mark-recapture estimate performed on it during the tagging process. A physical count was obtained for that rearing unit approximately 2 weeks later upon completion of tagging that rearing unit. The MR estimate relative to the PC for that rearing unit was 93.2% (Table 11). HI estimates were also compared to the physical counts for those two rearing units as well as for a second rearing unit of chinook salmon. The HI estimates relative to the physical counts for the one rearing unit of coho salmon and the two rearing units of chinook salmon were 98.5%, 98.1%, and 101.4%, respectively (Table 11). These comparisons indicate that

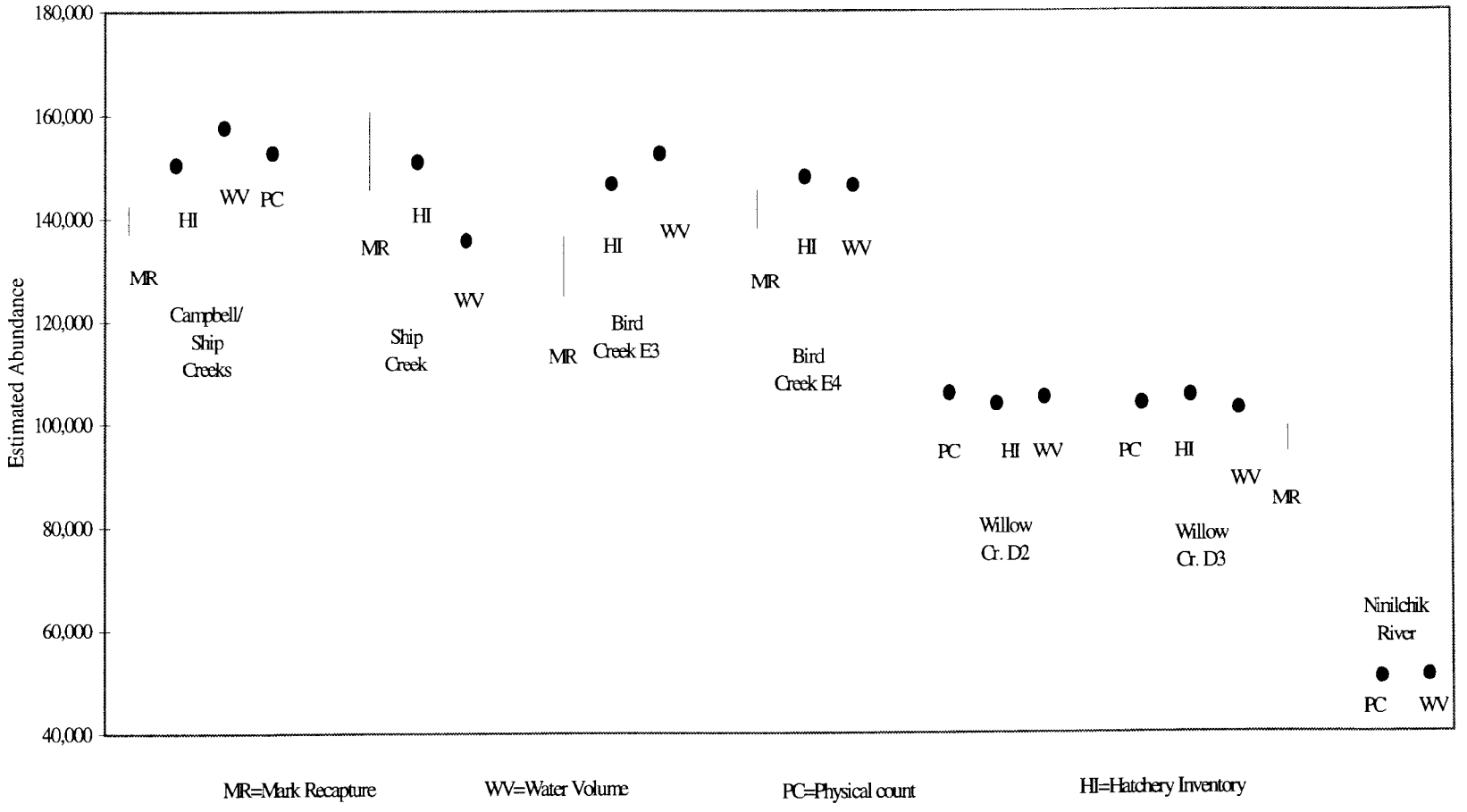

Figure 5.-Comparison of the 95% confidence intervals of the mark-recapture population estimate, to hatchery inventory estimate and water volume estimate for rearing units and the physical count for rearing units at Fort Richardson Hatchery in 1997.

the HI estimates at FRH are more accurate than the MR estimates, and that at FRH it appears that the MR estimates tend to underestimate the population in the rearing units.

The relationship between the three types of estimates at EH varies with the method used to obtain the HI estimate. In 1992 and 1993, only one rearing unit of coho salmon was tagged each year as part of the tagging program at EH. The population estimates for those two rearing units will not be discussed as a majority of fish in each of those rearing units were marked, and the HI estimate was a physical count obtained at the time of tagging. From 1994 to 1997, 39 rearing units of chinook salmon and one rearing unit of coho salmon contained fish which were tagged for this program, and MR, HI, and WV estimates were performed on each of those rearing units (Table 22). For ease of comparison, the 40 rearing units of salmon have been divided into three categories. One category contains 15 rearing units from which fish were removed via tagging and/or weighing, a second category contains 21 rearing units in which fish were moved into them via tagging and weighing, and a third category contains four rearing units which are exceptions to the above mentioned categories. These exceptions include two rearing units in which physical counts were used for the HI, a rearing unit in which the HI was an estimated survival to fry based on an eyed egg count plus the number of fish counted into it via tagging plus an estimated number of fish weighed into it, and a rearing unit in which the HI was an estimated survival to fry based on an eyed egg count minus the number of fish removed from it via tagging and weighing, plus the number of fish added to it via tagging and weighing.

For 15 of the 21 rearing units in which the HI estimate is based on the number of fish moved into it via tagging plus an estimated number of fish moved into it via weighing, the MR estimate is greater than the HI estimate. If the MR estimate is considered to be accurate, this appears to indicate that more fish are being moved at the time of splitting than what hatchery records indicate. For 13 of the 15 rearing units in which the HI estimate is based on the estimated survival of fry from the eyed egg, the HI estimate is greater than the MR estimate. Once again, if the MR estimate is considered to be accurate, then fewer fish are remaining in the rearing units than the hatchery records indicate. This is consistent with the theory that more fish are being removed from these rearing units than what the hatchery records indicate. Another possible explanation as to why the HI estimate tends to be greater than the MR estimate for these rearing units may be that the survival from eyed egg to fry was perhaps not as good as it was estimated to be, and the original number of fish in the rearing unit is fewer than what the HI records indicate. In 1996 the combined MR estimates and the combined HI estimates for each of the split raceways were compared (Starkey et al. 1997). Three of the four combined MR estimates are within 5% of the combined HI estimates. This indicates that the MR and the HI estimates are consistent for the total number of fish, and that the inconsistency lies with the estimation of the number of fish in the rearing units after the original number of fish in the rearing unit is split. The combined estimates for the 1997 release groups of Halibut Cove and Seldovia rearing units can be compared. These combined estimates are not close (HI estimate relative to MR estimate 86.0%). The Halibut Cove HI estimate is significantly different from the MR estimate. The 1994, 1995, and the remaining 1997 HI and MR estimates for split rearing units can not be combined because in those years rearing units were sometimes split into two or three other rearing units, or they received fish from two or three

Table 22.-The results of three smolt population estimation techniques, and a comparison of the hatchery inventory estimate to the water volume estimate for rearing units of coho salmon and chinook salmon released from Elmendorf Hatchery from 1994 through 1997.

1994	**RW19 Ship Creek**[a]	RW20 Ship Creek[a]	RW10 Crooked Creek	RW9 Crooked Creek	Eagle River	**RW15 Homer Spit Early**	**RW16 Homer Spit Early**	**Halibut Cove**	Seldovia	Ship Creek Coho [b]
Water Volume estimate	**64,300**	151,865	106,418	109,175	109,165	**92,986**	**98,842**	**107,390**	106,318	* 78,007
Hatchery Inventory estimate	**105,153**	105,991	104,027	111,846	105,399	**102,646**	**100,588**	**103,162**	102,232	75,907
Mark-recapture estimate	**64,656**	135,174	112,911	111,873	107,547	**81,278**	**82,685**	**98,872**	107,246	75,779
HI relative to WV	163.5%	69.8%	97.8%	102.4%	96.6%	110.4%	101.8%	96.1%	96.2%	97.3%

1995	**Crooked Creek RW16**	**Crooked Creek RW17**	Ship Creek RW6	**Ship Creek RW15**	Seldovia	Halibut Cove [b]	Kodiak	Homer Spit RW9	Homer Spit RW10	Homer Spit Late RW14
Water Volume estimate	**109,405**	**99,256**	* 121,328	**108,471**	112,804	35,981	* 84,800	108,002	* 119,796	125,160
Hatchery Inventory estimate	**102,519**	**108,104**	124,290	**121,927**	104,332	36,997	88,700	105,684	106,848	118,956
Mark-recapture estimate	**90,473**	**93,576**	118,201	**100,286**	116,165	37,577	84,349	110,764	105,262	123,048
HI relative to WV	93.7%	108.9%	102.4%	112.4%	92.5%	102.8%	104.6%	97.9%	89.2%	95.0%

1996	Crooked Creek RW8	**Crooked Creek RW17**	Ship Creek RW6	**Ship Creek RW15**	Seldovia	**Halibut Cove**	Kodiak	Homer Spit RW9	**Homer Spit RW16**	Homer Spit Late RW14
Water Volume estimate	* 110,128	**102,800**	115,522	**113,591**	109,004	**102,649**	103,803	110,128	**108,916**	* 121,405
Hatchery Inventory estimate	105,413	**106,724**	112,427	**113,447**	105,057	**105,023**	100,188	97,369	**107,842**	118,274
Mark-recapture estimate	100,215	**92,965**	123,763	**107,681**	118,274	**97,729**	113,220	106,107	**97,978**	108,204
HI relative to WV	95.7%	103.8%	97.3%	99.9%	96.4%	102.3%	96.5%	88.4%	99.0%	97.4%

1997	Crooked Creek RW9	**Crooked Creek RW18**	Ship Creek RW6	**Ship Creek RW15**	**Seldovia RW 20**	Halibut Cove RW 8	Lowell Creek RW 7	Homer Spit RW10	**Homer Spit RW17**	Homer Spit Late RW14
Water Volume estimate	112,559	* **106,560**	114,905	**110,244**	* **92,339**	78,347	* 105,880	111,904	**104,099**	* 105,043
Hatchery Inventory estimate	106,550	**106,728**	108,426	**110,239**	**78,951**	77,539	104,847	106,439	**106,315**	101,522
Mark-recapture estimate	114,903	**108,298**	115,091	**101,358**	**103,757**	78,133	102,147	120,317	**97,416**	100,933
HI relative to WV	94.7%	100.2%	94.4%	100.0%	85.5%	99.0%	99.0%	95.1%	102.1%	96.6%

Bold face type indicates rearing units which were split into two or more rearing units

* Indicates exceptions to the splitting trend of rearing units which when split tend to have an HI greater than the MR estimate, and rearing units resulting from a split which tend to have an MR greater than the HI estimate.

[a] Rearing units in which a large error was made in either the initial number of fingerling placed in the rearing unit, or in the splitting process.

[b] Rearing units in which the HI estimate is based on an actual count.

different rearing units. Some of the rearing units involved with the splits and transfers were not part of the tagging program. This makes comparisons of combined MR estimates and HI estimates difficult if not impossible.

One other trend at EH is that over the last four tagging seasons, the HI and WV estimates for a given rearing unit either tend to be both greater than the MR estimate or both less than the MR estimate for that same rearing unit. Of the 40 sets of estimates over the last four tagging seasons, there are only six exceptions to this trend. The MR estimate is higher than the HI and WV estimates for 14 of the 34 sets of estimates that follow the trend.

As in previous years, the 1997 hatchery inventory estimates at EH were based on two different techniques. For five raceways, the hatchery inventory estimate was based on the estimate of fry survival from the eyed egg stage. An electronic count of eggs was obtained at the eyed egg stage. When the fish in a raceway were split into two raceways, the inventory estimate became the estimated number of fish that were moved into a different raceway, or the estimated number of fish that remained in the raceway after an estimated number of fish were removed. Fish were enumerated and moved to different raceways by two different methods. Fish that were moved from one raceway to another during the marking and coded wire tagging process were counted by the tagging injector as they were tagged. The remaining fish that were transferred were enumerated through a bulk weighing method. For 1997, the trend that the MR estimate is greater than the HI estimate for the rearing units in which fish were split into, and the trend that the MR is less than the HI estimate for the original rearing units holds true for only six of the 10 rearing units (Table 22). The trend that both the HI and WV estimates are both either higher than or both lower than the MR estimate does hold true for nine of the 10 rearing units (Table 22, Figure 6). The hatchery inventory estimates at EH were not accurate, but trends were evident for each of the hatchery inventory methods. We feel that refinement of the sampling methodology associated with obtaining a hatchery inventory estimate could make it both accurate and precise. A better method of calibrating subsampled net loads of fish needs to be developed. Accuracy and precision could possibly be improved by improving on their bulk weighing techniques and/or their sampling techniques.

For 1992, 1993, and 1994, a physical count at the time of tagging minus any mortality that occurred from the time tagging was completed to the time of release was compared to the MR estimate at release for Ship Creek coho salmon release groups at EH (Peltz and Starkey 1993; Peltz and Hansen 1994; and Starkey et al. 1995). The MR estimates were very close to the physical counts, but the percentage of fish tagged in these release groups was high (at least 57.2 %) when compared to the percentage of fish tagged in other release groups at EH on which MR estimates were performed (no greater than 44.1%) during the last six tagging seasons.

One explanation for inaccurate MR estimates at EH could be the inability to obtain a truly random sample of the population either at the time of tagging, the time the estimate is performed, or both. For the rearing units in which the fish are transferred into, approximately 20,000 to 40,000 fish are collected and removed from the original rearing unit during the tagging process, and then the remaining fish to be transferred are weighed and transferred. The fish that are weighed in come from one or two different rearing units. If the tagged fish come from one rearing unit, and the fish that are weighed

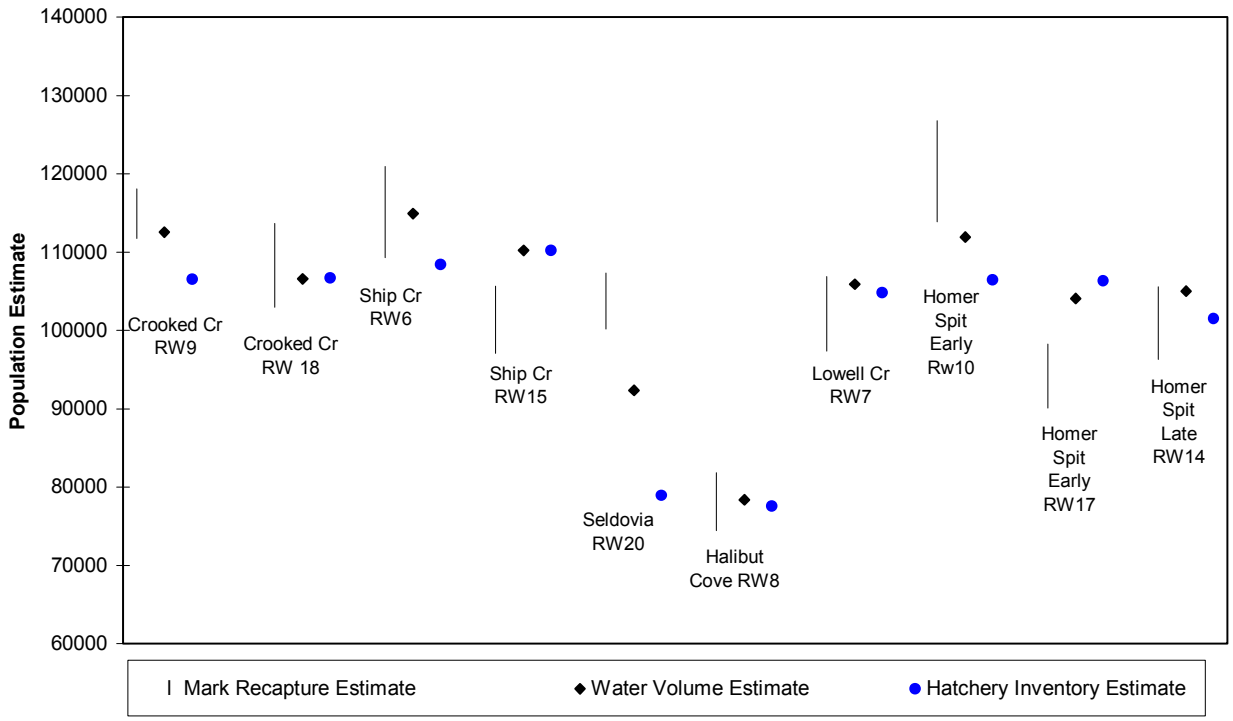

Figure 6.-Comparison of 95% confidence intervals for mark-recapture population estimates to hatchery inventory estimates and water volume estimates for 10 rearing units of chinook salmon released from Elmendorf Hatchery in 1997.

come from two rearing units, then the tagged fish are not a representative sample of the fish in that second rearing unit. This could result in an MR estimate that is biased. Approximately 20,000 to 40,000 fish are then collected from the original rearing unit, tagged, and returned to the original rearing unit. These tagged fish are representative of only those fish in that rearing unit. These rearing units are similar to the rearing units at FRH in that the fish that are tagged are collected from and returned to the same population, and like FRH the HI estimates for these rearing units are usually higher than the MR estimates. These rearing units at EH do differ from the FRH rearing units in the method used to obtain the original HI estimate. The HI estimate for these rearing units is the estimated survival to fry from an eyed egg count, minus the number of fish removed through tagging, minus the estimated number of fish removed via weighing.

Another potential source of error for the mark-recapture technique is nonrandom distribution of marks in the population. Homer Spit and Deception Creek mark-recapture estimates had one estimate that was different from the other two (Table 6, Figure 2). Fish in the raceways were crowded and dip nets of fish were collected throughout the crowded group of fish and placed into net pens or between two crowders. If the fish in the raceway are not crowded enough to get a good mix, then the likelihood of obtaining a biased sample can increase. Crowding fish enough to obtain a good mix can cause low dissolved oxygen levels resulting in stressed fish. It is difficult to obtain an unbiased sample from any container as smaller fish tend to be caught first, and larger fish tend to

be caught last. Attempts were made to minimize this problem by dipping fast and to the bottom of the pen, and crowding the fish in the pen to get a good mix as the population of fish in the pen decreased.

Developing a method to systematically collect fish to be tagged, and again to collect fish for the second sampling (MR estimates), should increase the likelihood of obtaining random samples, and reduce the error in the MR estimates.

At EH, the water volume population estimates relative to mark-recapture population estimates for individual raceways ranged from 89.0% to 108.8% for 1997 (Table 10). One source of error in the water volume technique may be in the determination of mean weight of an individual fish. Mean weight was determined from three small dip net samples of fish removed from the transport tanks on the transport vehicle. Another source of error may be the inconsistency in fish densities. The same problems of variability associated with the estimation of water displacement values that are present for release groups at FRH are probably also present for release groups at EH. We feel that the variability associated with the water volume technique increases the probability for errors and makes this technique unreliable.

At FRH it appears that the hatchery inventory estimates are the most reliable estimates of smolt release numbers as long as adequate sampling is performed at the time the original estimate is obtained. Because the hatchery inventory estimates at EH appear to vary with the method used to obtain the estimate, it appears that the mark-recapture estimate provides the most reliable estimate of smolt release numbers at EH.

Both FRH and EH have come to rely on the water volume technique to produce easily obtained release numbers. Continued reliance on the water volume technique would mean calibration of each release group, since the displacement values appear to be highly variable (Peltz and Hansen 1994). This calibration would create a large amount of extra work and extra handling of fish, neither of which are desirable just prior to release. We do not feel the hatcheries should rely on the water volume technique to produce estimates of release numbers unless no other option exists or accuracy within 30% of the true value is acceptable.

Beginning with the 1998 release groups of coho and chinook salmon, a mechanical counter will be used to count the number of fish in each rearing unit at FRH prior to release. Using the mechanical counter will eliminate the need to perform mark-recapture estimates on any of the groups of fish released from FRH.

SIZE ESTIMATION

Peltz and Starkey (1993) suggested that a hatchery production goal for coho salmon smolt production is to make 80% of the smolt weigh between 15.1 g and 25.0 g. The coho salmon smolt produced at the FRH for release into Campbell Creek and Ship Creek were close to achieving the size range production goal with approximately 78% of the smolt in each release group within the desired size range. The marine survival rates for these release groups should be at anticipated levels. The two rearing units of coho salmon released at Bird Creek did not meet the production goal. A majority of the smolt were between 15.1 g and 25.0 g, but the release group contained a significant number of fish greater than 25.0 g.

The production goal for chinook salmon smolt is to make 80% of the smolt weigh between 5.1 g and 15.0 g. The chinook salmon smolt produced as Ninilchik River chinook salmon smolt and Deception Creek chinook salmon smolt at FRH, and the chinook salmon smolt produced as Lowell Creek chinook salmon

smolt and Homer Spit Late Run chinook salmon smolt achieved the production goal. The majority of the fish in the remaining five chinook salmon release groups at EH were between 5.1 g and 15.0 g. At least 70% of the smolt in the Crooked Creek, Ship Creek, Seldovia, and Halibut Cove release groups and only 58.6% of the smolt in the Homer Spit early-run release group were between 5.1 g and 15.0 g, with the majority of the remaining fish being larger than 15.0 g. The marine survival rates for these release groups may be at anticipated levels, but due to the large size of the smolt a large percentage of the returns may be as precocial males or jacks (Peltz and Sweet 1993). Evidence exists that larger smolt reduces ocean residence. This shifts the age composition of returns to younger, smaller fish (Sweet and Peltz 1994).

CONCLUSIONS AND RECOMMENDATIONS

1. We believe the hatchery inventory estimates at Fort Richardson Hatchery produce the most accurate and precise enumeration estimate of the three estimate techniques measured. Reliable hatchery inventory estimates are most likely a result of improved sampling techniques.
2. We do not know which of the three enumeration techniques used at Elmendorf Hatchery produces the most accurate and precise estimate. All techniques are inconsistent relative to each other and we have not yet had the opportunity to do a physical count. We should continue using all three techniques as well as do a physical count of at least one rearing unit prior to release.
3. The methods used for obtaining nonbiased samples for tagging and for mark-recapture population estimates need to be improved upon. Small fish are more readily caught than large fish. Biased samples will result in erroneous mark-recapture estimates. A method for systematically obtaining fish to be tagged needs to be used, as well as a method for obtaining fish at the time mark-recapture estimates are performed. At EH rearing units need to be split prior to tagging so that the tagged portion of that rearing unit is representative of all the fish in that rearing unit.
4. The water volume estimates produce the least consistent estimate of the three techniques measured. Some of the enumeration estimates produced using this technique appear to be accurate. Others do not. In addition, estimating the water volume displacement value for each release group is labor intensive and time consuming. Due to the variability of the water volume displacement value among release groups, it is unlikely that a mean value can be determined and used in perpetuity for all release groups. This technique should only be used in situations where the other techniques can not be used or accuracy is not important.
5. The hatchery inventory estimates produced the least precise estimates of the three techniques measured at EH. One problem associated with the hatchery inventory estimates appears to be either in the determination of the mean weight of a fish during sampling, or in the weighing buckets of fish procedures for the rearing unit into which fish were transferred. Increasing the sample size, or increasing the number of samples and obtaining samples throughout the transfer process may result in more accurate hatchery inventory estimates at EH. If a better method of sampling or weighing buckets of fish can be developed, this technique may be a better method for estimating hatchery release numbers than water

volume displacement. Another problem associated with the hatchery inventory estimates at EH may be in the estimation of survival from eyed egg to fry for some of the rearing units in which the HI estimate is based on that number. We suggest that bulk weighing entire raceways instead of relying on fry estimates would increase the accuracy of hatchery inventory estimates.

6. If a mechanical fish counter is ordered as expected, a mechanical count of fish should be obtained for all release groups at FRH and EH beginning with those released in 1998.
7. All fish for tagging should be graded and tagged using the appropriate head mold sizes. Head mold sizes that cannot consistently provide proper tag placement for specific stocks or species of fish should not be used for that group. The head mold that is closest to the appropriate size for these fish should be adjusted for use with these fish.
8. Elmendorf Hatchery chinook salmon planted in Ship Creek, Crooked Creek, Lowell Creek, Halibut Cove, and Seldovia were all close in achieving the size range production goal with more than 70% of the fish within the desired size range; and the Homer Spit late release group achieved the size range production goal with more than 80% of the fish within the desired size range. The marine survival rates for these release groups should be at anticipated levels. The Homer Spit early-run release group contained a large number of fish (>40%) which were larger than the desired size range. The marine survival rates for this release group may be at anticipated levels, but due to the large size of the smolt a large percentage of the returns may be a precocial males or jacks.
9. Fort Richardson Hatchery coho salmon smolt planted in both Campbell Creek and Ship Creek were all extremely close to achieving the size range production goal. The marine survival rates for these release groups should be at anticipated levels. The Bird Creek coho salmon release group contained a significant number of fish (>33%) larger than the recommended size range. The marine survival rates for this release group may be at anticipated levels, but due to the large size of the smolt a large percentage of the returns may be as precocial males or jacks.
10. Fort Richardson Hatchery chinook salmon smolt planted in Deception Creek and Ninilchik River achieved the size range production goal. The marine survival rates for these release groups should be at anticipated levels.

ACKNOWLEDGMENTS

We would like to thank Gary Wall and Darrell Keifer for their help and cooperation during coded wire tagging operations at Fort Richardson and Elmendorf Hatcheries. We would also like to thank the members of the tagging crews for performing an excellent job at each of the hatcheries.

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APPENDIX A

Appendix A1.-Historical releases into Anchorage Urban Streams of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1994	Little Susitna	Ft. Richardson	1996	31-25-06	156,050	46,665	46,058	29.50%

Note: Ship Creek and Campbell Creek are considered one release site designated Anchorage Urban Streams in 1996.

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A2.-Historical releases into Bird Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Little Susitna	Ft. Richardson	1992	31-20-02, 31-20-03	95,377	44,903	37,629	39.50%
1991	Little Susitna	Ft. Richardson	1993	31-21-39	140,382	43,441	42,350	30.20%
1992	Little Susitna	Ft. Richardson	1994	31-23-02	84,643	45,220	44,686	52.80%
1993	Little Susitna	Ft. Richardson	1995	31-23-37	154,753	45,666	45,490	29.40%
1994	Little Susitna	Ft. Richardson	1996	31-25-04	147,618	46,528	45,411	30.80%
1995	Little Susitna	Ft. Richardson	1997	31-26-01	146,612	45,901	45,488	31.03%
1995	Little Susitna	Ft. Richardson	1997	31-26-02	147,953	45,836	45,469	30.73%

[a] Total released number is a mark-recapture estimate for 1992 through 1996 releases. 1997 releases are a hatchery inventory estimate.

Appendix A3.-Historical releases into Campbell Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Little Susitna	Ft. Richardson	1992	31-20-04, 31-20-05	97,076	43,681	39,444	40.60%
1991	Little Susitna	Ft. Richardson	1993	31-21-38	140,797	43,440	42,916	30.50%
1992	Little Susitna	Ft. Richardson	1994	31-23-03	87,686	44,144	42,963	49.00%
1993	Little Susitna	Ft. Richardson	1995	31-23-36	157,241	45,655	44,995	28.60%
1995	Little Susitna	Ft. Richardson	1997	31-25-62	71,519	45,840	45,290	63.33%

Note: In 1996 Campbell Creek releases were combined with Ship Creek releases and designated Anchorage Urban Streams.

[a] Total released number is an actual count for 1997. Total released in a mark-recapture estimate for all other releases.

Appendix A4.-Historical releases into Cottonwood Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Fish Creek	Big Lake	1992	31-20-08, 31-21-09	53,900	35,341	32,938	61.10%
1991	Fish Creek	Big Lake	1993	31-21-41	74,198	43,117	40,875	55.10%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A5.-Historical releases into Fish Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Fish Creek	Big Lake	1992	31-20-12, 31-20-13	74,953	45,538	43,625	58.20%
1991	Fish Creek	Big Lake	1993	31-21-40	67,934	44,050	43,257	63.70%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A6.-Historical releases into Little Susitna at Houston of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Little Susitna	Ft. Richardson	1992	31-20-07	154,466	21,884	19,564	12.70%
1991	Little Susitna	Ft. Richardson	1993	31-21-37	148,282	21,404	20,312	13.70%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A7.-Historical releases into Nancy Lake of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Little Susitna	Ft. Richardson	1992	31-20-06	158,459	21,598	19,222	12.10%
1991	Little Susitna	Ft. Richardson	1993	31-21-37	131,591	21,001	19,930	15.20%
1992	Little Susitna	Ft. Richardson	1994	31-23-01	126,694	44,489	43,818	34.60%
1993	Little Susitna	Ft. Richardson	1995	31-23-39	151,985	46,261	45,245	29.80%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A8.-Historical releases into Ship Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Ship Creek	Elmendorf	1992	31-19-63, 31-20-01	67,178	44,086	38,443	57.20%
1991	Ship Creek	Elmendorf	1993	31-21-36	54,764	42,112	41,322	75.50%
1992	Ship Creek	Elmendorf	1994	31-23-04	75,779	44,031	41,722	55.10%
1993	Little Susitna	Ft. Richardson	1995	31-23-38	158,981	45,491	44,654	28.10%
1995	Little Susitna	Ft. Richardson	1997	31-25-63	232,066	45,925	45,741	19.71%

Note: 1996 Ship Creek releases were combined with Campbell Creek releases and designated Anchorage Urban Streams.

[a] Total released number is an actual count in 1993, a combination of a hand count plus a hatchery inventory estimate in 1997, and mark-recapture estimate for all other releases.

Appendix A9.-Historical releases into Wasilla Creek of coho salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1990	Fish Creek	Big Lake	1992	31-20-10, 31-20-11	76,315	44,148	41,985	55.00%
1991	Fish Creek	Big Lake	1992	31-21-42	77,174	43,001	41,711	54.10%
1994	Little Susitna	Ft. Richardson	1996	31-25-05	145,923	46,980	46,839	32.10%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A10.-Historical releases into Buskin River of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1994	Willow Creek	Elmendorf	1995	31-24-31	84,349	41,572	41,078	48.70%
1995	Willow Creek	Elmendorf	1996	31-25-09	113,220	41,259	40,681	35.90%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A11.-Historical releases into Crooked Creek of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Crooked Creek	Elmendorf	1994	31-23-14	224,784	43,609	43,034	19.10%
1994	Homer(Crooked Ck)	Elmendorf	1995	31-24-27	184,049	40,903	38,420	20.90%
1995	Homer(Crooked Ck)	Elmendorf	1996	31-25-12	193,180	40,827	40,196	20.80%
1996	Homer(Crooked Ck)	Elmendorf	1997	31-25-55	223,201	41,049	39,022	95.06%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A12.-Historical releases into Eagle River of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Ship Creek	Elmendorf	1994	31-23-13	98,872	43,612	41,669	42.10%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A13.-Historical releases into Halibut Cove of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Crooked Creek	Elmendorf	1994	31-23-15	98,872	21,205	21,038	21.30%
1994	Ninilchik River	Elmendorf	1995	31-24-30	37,577	36,944	36,700	97.70%
1995	Ninilchik River	Elmendorf	1996	31-25-11	97,729	40,688	39,345	40.30%
1996	Ninilchik River	Elmendorf	1997	31-25-58	78,133	40,919	39,487	96.50%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A14.-Historical releases into Homer Spit (early run) of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Crooked Creek	Elmendorf	1994	31-23-16	163,963	26,003	25,615	15.60%
1994	Homer (Crooked Ck)	Elmendorf	1995	31-24-32	216,026	41,650	40,291	18.70%
1995	Homer (Crooked Ck)	Elmendorf	1996	31-25-07	204,085	40,868	39,017	19.10%
1996	Homer (Crooked Ck)	Elmendorf	1997	31-25-60	217,733	41,112	38,810	94.40%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A15.-Historical releases into Homer Spit (late run) of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood stock	Hatchery	Release Year	CWT Code	Total Released [a]	Marked Fish Released	Tagged Fish Released	Percent tagged
1992	Kasilof River	Crooked Creek	1994	31-23-19	156,893	93,217	91,705	58.45%
1994	Homer (Kasilof R)	Elmendorf	1995	31-24-33	123,048	41,054	40,466	32.90%
1995	Homer (Kasilof R)	Elmendorf	1996	31-25-13	108,204	40,615	38,787	35.80%
1996	Homer (Kasilof R)	Elmendorf	1997	31-25-61	100,933	41,028	39,264	38.90%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A16.-Historical releases into Lowell Creek of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1996	Willow Creek	Elmendorf	1997	31-25-59	102,147	40,906	40,497	99.00%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A17.-Historical releases into Ninilchik River of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1991	Ninilchik River	Ft. Richardson	1992	31-21-04	132,387	43,648	41,335	31.20%
1992	Ninilchik River	Ft. Richardson	1993	31-21-59	184,585	44,487	42,960	23.30%
1993	Ninilchik River	Ft. Richardson	1994	31-23-18	201,513	46,193	45,535	22.60%
1994	Ninilchik River	Ft. Richardson	1995	31-24-35	54,662	54,662	54,115	99.00%
1995[b]	Ninilchik River	Ft. Richardson	1996	31-25-15	51,688	51,588	50,866	98.60%
1996[b]	Ninilchik River	Ft. Richardson	1997	31-26-08	50,698	50,698	50,292	99.20%

[a] Total released number is a mark-recapture estimate for releases in 1992-1994 and an actual count thereafter.

[b] 1995 and 1996 numbers have been adjusted for holding mortality before release.

Appendix A18.-Historical releases into Seldovia of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Crooked Creek	Elmendorf	1994	31-23-11	107,246	46,754	45,439	42.40%
1994	Homer (Crooked Ck)	Elmendorf	1995	31-24-29	116,165	41,609	40,678	35.00%
1995	Ninilchik River	Elmendorf	1996	31-25-10	118,274	40,667	39,610	33.50%
1996	Ninilchik River	Elmendorf	1997	31-25-57	103,757	41,279	39,834	96.50%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A19.-Historical releases into Ship Creek of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1993	Ship Creek	Elmendorf	1994	31-23-12	199,830	44,138	42,864	21.50%
1994	Ship Creek	Elmendorf	1995	31-24-28	218,487	40,764	38,570	17.70%
1995	Ship Creek	Elmendorf	1996	31-25-08	231,444	41,221	40,109	17.30%
1996	Ship Creek	Elmendorf	1997	31-25-56	326,371	40,522	40,319	12.35%

[a] Total released number is a mark-recapture estimate for all releases.

Appendix A20.-Historical releases into Willow Creek of chinook salmon marked with adipose finclips and tagged with coded wire tags.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[a]	Marked Fish Released	Tagged Fish Released	Percent Tagged
1991	Willow Creek	Ft. Richardson	1992	31-21-03	179,724	44,089	33,464	18.60%
1992	Willow Creek	Ft. Richardson	1993	31-21-60	160,194	42,782	39,420	24.60%
1993	Willow Creek	Ft. Richardson	1994	31-23-17	177,913	46,289	45,921	25.80%
1994	Willow Creek	Ft. Richardson	1995	31-24-34	184,740	46,807	46,256	25.00%
1995	Willow Creek	Ft. Richardson	1996	31-25-14	186,918	47,700	47,145	25.20%
1996	Willow Creek	Ft. Richardson	1997	31-26-03, 04, 05, 06, 07	209,644	209,644	207,973	99.20%

[a] Total released number is a mark-recapture estimate for all releases prior to the 1997 release. The 1997 release was a physical count.