Fishery Data Series No. 97-13

Marking, Enumeration, and Size Estimation for Coho and Chinook Salmon Smolt Releases into Upper Cook Inlet, Alaska in 1996

by

Diane Starkey,

Carmen Olito,

and

Patricia Hansen

July 1997

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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by
Diane Starkey
and
Carmen Olito,
Division of Sport Fish, Anchorage
and
Patricia Hansen,
Division of Sport Fish, Research and Technical Services, Anchorage

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

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

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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 560,000 coho and chinook salmon smolt released at 11 locations in Cook Inlet were marked with an adipose finclip and a coded wire tag in 1996. Tag retention for individual raceways ranged from 93.8% to 99.7%. Our production goal was to make 80% of the coho salmon smolt within the size range of 15.1 g to 25.0 g. Coho salmon produced at Ft. Richardson Hatchery and released into Bird Creek, Wasilla Creek, and Campbell and Ship creeks (both Anchorage urban streams) met 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 chinook salmon smolt produced at Ft. Richardson Hatchery were close to achieving the production goal with 79.1% of the smolt within the desired range. None of the remaining chinook salmon release groups at Ft. Richardson Hatchery, nor the chinook salmon release groups at Elmendorf Hatchery, achieved the production goal.

Three smolt enumeration techniques were compared. In most instances the mark-recapture estimate was the lowest of the three techniques at both hatcheries. While no trend was evident when comparing the hatchery inventory estimates with the water volume estimates at Fort Richardson Hatchery, 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. Therefore, we used the mark-recapture method for estimating numbers of smolt released.

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 have been monitored and standardized at each hatchery (Starkey et al. 1996). 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. 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 Willow 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, Halibut Cove, Buskin River, and Seldovia. Chinook salmon smolt released at Willow Creek and Ninilchik River were tagged at FRH; and chinook salmon smolt released at Ship Creek, Buskin River, Crooked Creek, Homer Spit, 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. (1996) found that tag loss ranged from 0.4% to 5.7% 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 1995 indicated a variation of up to 14.2% between two different hatchery release estimation techniques (Starkey et al. 1996). 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; and
4. To determine if a relationship exists between tag application rate and long-term retention rate.

The goal of this project was to mark approximately 530,000 of the projected 1,900,000 coho and chinook smolt to be stocked in 1996 with an adipose finclip and a coded wire tag. This entailed marking a representative sample of at least 40,000 smolt from each of the 12 Cook Inlet release groups (Meyer et al. *Unpublished*).

Marking and collection of release data at the Elmendorf and Fort Richardson hatcheries were standardized for each of the stocking projects in 1996. This report presents the results of the 1996 marking program. In addition, three different smolt enumeration techniques are compared. The size composition of each release group is also presented. 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 the Ship Creek, Ninilchik River, Willow 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 the Willow Creek and Ninilchik River brood stocks (Table 1). Fish were released at 11 different sites in 12 release groups. Although Campbell Creek and Ship Creek are discrete release sites, the coho salmon smolt released at both sites have the same tag code and are considered one release group, Anchorage Urban Coho. 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 20,000 to 40,000 smolt to be tagged in each raceway was dipnetted and held separate from the remaining fish in the raceway before tagging was initiated. All of the smolt in the Ninilchik River chinook salmon smolt release group were marked and tagged. A rearing container with approximately 200,000 Ninilchik River chinook salmon smolt was crowded, and approximately 52,000 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 1996 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 carelessness. A finclip grading program to reduce the estimated number of valid marks by the proportion of poor finclips was not necessary.

table 1

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

Hatchery	Species	Stocking Site	Stock	Number Stocked[a]	Number of Raceways	Number Marked per Raceway	Number to Examine per Raceway per Experiment	Number M-R[c] Experiments	Precision
Elmendorf	Chinook	Ship Creek	Ship Creek	112,892	2	21,169	6,500	1	±5
				113,851		20,572	6,750	3	±5
		Crooked Creek	Homer (Crooked Cr)	105,922	2	20,746	6,000	1	±5
				108,396		20,813	6,250	1	±5
		Homer Spit Early	Homer (Crooked Cr)	98,586	2	22,372	5,000	3	±5
				108,096		19,379	6,750	1	±5
		Seldovia	Ninilchik River	106,251		41,257	2,500	3	±5
		Halibut Cove	Ninilchik River	105,975	1	41,179	2,500	1	±5
		Buskin River	Willow Creek	100,359	1	41,376	2,250	1	±5
		Homer Spit Late	Homer (Kasilof River)	120,209	1	41,407	3,000	1	±5
					1				
Fort Richardson	Coho	Bird Creek	Little Susitna River	159,002		46,762	3,750	3	±5
		Wasilla Creek	Little Susitna River	157,827	1	47,306	3,750	3	±5
		Anchorage Urban E2 [b]	Little Susitna River	156,959	1	46,886	3,750	1	±5
		Anchorage Urban E3 [b]	Little Susitna River	157,903		47,668	3,500	1	±5
					1				
	Chinook	Willow Creek	Willow Creek	107,093	2	24,807	5,000	3	±5
				107,135		23,186	5,500	1	±5
		Ninilchik River	Ninilchik River	52,246	1	52,246	0	0	±5
TOTALS				**1,978,675**		**579,234**			

[a] Hatchery inventory estimates as of 4/1/96.

[b] 77,346 coho salmon smolt from Anchorage Urban raceway E2 were stocked at Campbell Creek. 79,757 coho salmon smolt from Anchorage Urban raceway E2 plus all coho salmon smolt from Anchorage Urban raceway E3 were stocked at Ship Creek.

[c] Mark-Recapture

Table 2.-Summary of coded wire tagging data at Fort Richardson Hatchery for coho salmon smolt stocked at four locations in Cook Inlet in 1996.

Parameter	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3	Totals
Tag Codes	31-25-04	31-25-06	31-25-05	31-25-06	
Total marked and tagged	46,762	46,886	47,306	47,668	188,622
Mortalities	234	221	326	358	
Marked fish released	46,528	46,665	46,980	47,310	187,483
Tag retention sample size	762	753	752	755	
Tag retention at release	97.6%	98.7%	99.7%	98.3%	
Tag retention variance	3.078E-05	1.706E-05	3.98E-06	0.00002	
Tagged fish released	45,411	46,058	46,839	46,506	184,814
Tagged fish variance	66,635	37,156	8,790	49,606	
Total fish released from mark-recapture estimate	147,618	156,050	145,923	146,807	596,398
Percent marked	31.5%	29.9%	32%	32.2%	31.4%
Percent tagged	30.8%	29.5%	32.1%	31.7%	31.0%
Tagging dates	10/16/95 10/24/96	11/08/95 11/15/95	10/25/95 10/31/95	11/01/95 11/08/95	
Date of tag retention check	5/24/96	5/29/96	5/16/96	5/20/96	
Days elapsed	212	196	211	194	

Table 3.-Summary of coded wire tagging data at Elmendorf and Fort Richardson hatcheries for chinook salmon stocked at eight locations in Cook Inlet in 1996.

	Fort Richardson			Elmendorf										
Parameter	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Early Run RW9	Homer Early Run RW16	Homer Spit Late run RW14	Totals
Tag Codes	31-25-14	31-25-14	31-25-15	31-25-12	31-25-12	31-25-08	31-25-08	31-25-10	31-25-11	31-25-09	31-25-07	31-25-07	31-25-13	
Total marked and tagged	23,186	24,807	52,246	20,746	20,813	21,169	20,572	41,257	41,179	41,376	22,372	19,379	41,407	390,509
Mortalities	116	177	560	219	513	168	352	590	491	117	476	407	792	
Marked fish released	23,070	24,630	51,686	20,527	20,300	21,001	20,220	40,667	40,688	41,259	21,896	18,972	40,615	385,531
Tag retention sample size	760	771	803	758	803	763	762	813	756	769	770	763	760	
Tag retention at release	99.3%	98.4%	98.6%	99.3%	97.6%	97.4%	97.2%	97.4%	96.7%	98.6%	93.8%	97.4%	95.5%	
Tag retention variance	0.00001	0.00002	0.00002	0.00001	0.00003	0.00003	3.6E-05	0.00003	0.00004	1.8E-05	7.6E-05	3.3E-05	5.7E-05	
Tagged fish released	22,909	24,236	50,962	20,383	19,813	20,455	19,654	39,610	39,345	40,681	20,538	18,479	38,787	375,853
Tagged fish variance	4,874	12,404	45,981	3,869	12,036	14,657	14,622	51,578	69,972	30,597	36,257	11,962	93,400	
Total fish released from mark-recapture estimate	93,981	92,937	51,686	100,215	92,965	123,763	107,681	118,274	97,729	113,220	106,107	97,978	108,204	1,304,741
Percent marked	24.5%	26.5%	100.0%	20.5%	21.8%	17.0%	18.8%	34.4%	41.6%	36.4%	20.6%	19.4%	37.5%	30.2%
Percent tagged	24.4%	26.1%	98.6%	20.3%	21.3%	16.5%	18.3%	33.5%	40.3%	35.9%	19.4%	18.9%	35.8%	29.5%
Tagging dates	3/11/96 3/13/96	3/4/96 3/7/96	3/18/96 3/26/96	2/12/96 2/14/96	2/14/96 2/20/96	1/12/96 1/18/96	1/29/96 1/31/96	1/31/96 2/06/96	2/06/96 2/12/96	1/18/96 1/24/96	1/09/96 1/11/96	1/24/96 1/29/96	2/20/96 2/26/96	
Date of tag retention check	6/14/96	6/12/96	6/11/96	6/07/96	6/05/96	6/06/96	5/28/96	6/10/96	6/03/96	5/22/96	6/4/96	5/30/96	6/13/96	
Days elapsed	99	91	77	114	106	140	118	125	112	96	145	122	108	

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 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 needle 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 actual retention rate was at least 85%, this level of sampling would have provided an estimate 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:

$$\hat{D}_i = \frac{n_i}{n_{ti}}, \tag{1}$$

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

$$\mathrm{Var}\left(\hat{D}_i\right) = \frac{\hat{D}_i\left(1-\hat{D}_i\right)}{n_{ti}-1}. \tag{2}$$

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 was passed through a QCD to estimate 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 actual 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,

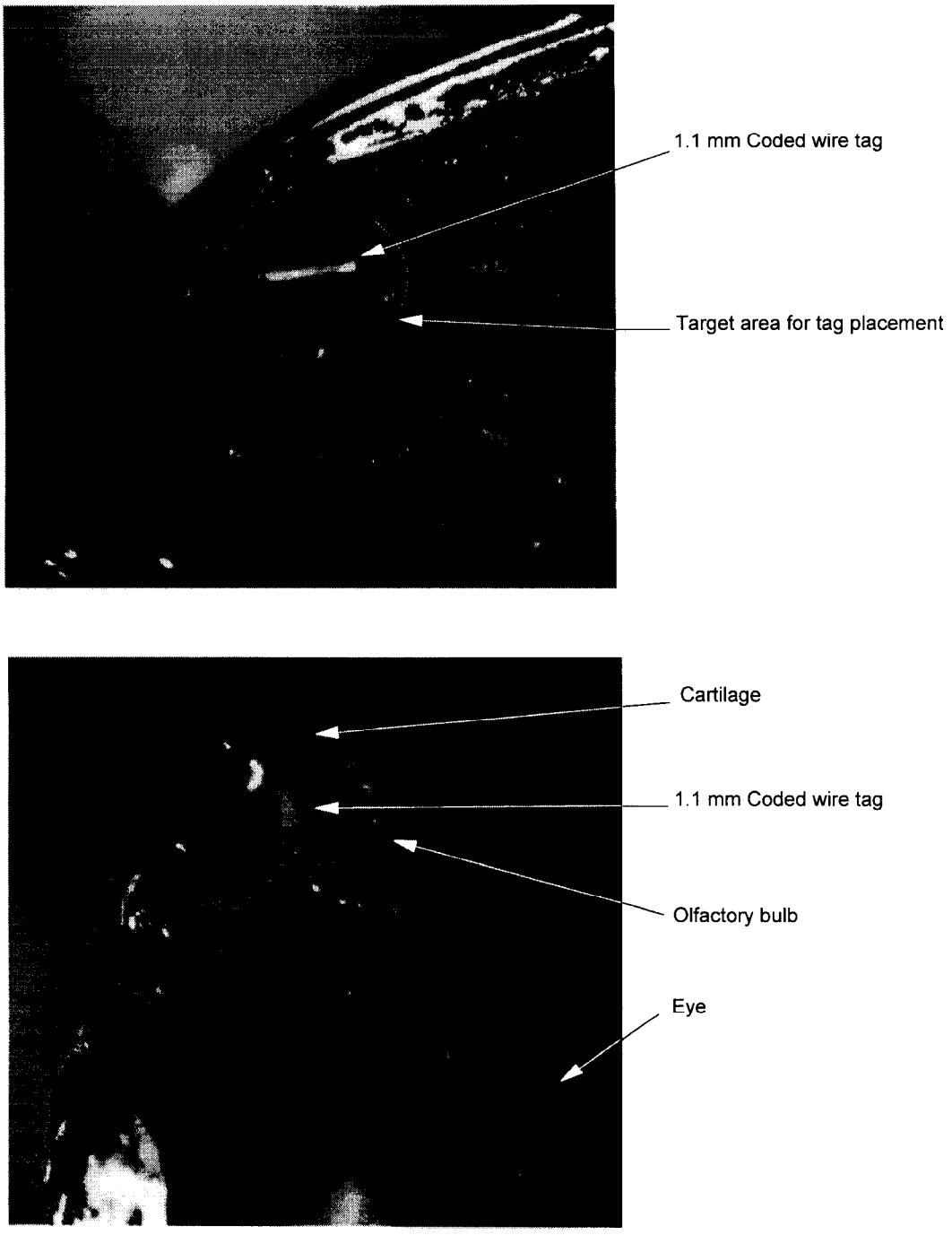

Figure 1.-Proper placement of a coded wire tag in a small fish.

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:

$$\hat{T}_j = \left(N_j - M_j\right)\hat{D}_j \,, \tag{3}$$

and its variance as:

$$\mathrm{Var}\left[\hat{T}_j\right] = \left(N_j - M_j\right)^2 \mathrm{Var}\left[\hat{D}_j\right], \tag{4}$$

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.

The number of worker hours expended on tagging was recorded on a daily basis. Worker hours included taggers, finclippers, and any quality control personnel. Recorded work times were the number of hours recorded on timesheets and not the actual time spent exclusively tagging. For example, during a 7.5 hour work day, a worker may have spent 5.5 hours tagging or clipping, but quality control work, machine maintenance, work breaks, and the process of finishing one raceway of fish and moving to another raceway of fish accounted for the other 2 hours. All times were recorded to the nearest quarter hour. The number of valid tags of a release group applied per worker hour (TWH_j) and its variance was calculated as:

$$\mathrm{TWH}_j = \frac{\hat{T}_j}{W_j}, \tag{5}$$

and

$$\mathrm{Var}\left(\mathrm{TWH}_j\right) = \left[\frac{1}{W_j}\right]^2 \mathrm{Var}\left(\hat{T}_j\right), \tag{6}$$

where:

W_j = total number of worker hours spent tagging release group j.

A scatterplot was used to determine if a relationship exists between TWH_j and the long-term tag retention rates of the release groups.

SMOLT ENUMERATION

The number of smolt in each group released from EH and FRH, with the exception of the Ninilchik River release group from FRH, was estimated using three different techniques. 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 an actual count,

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.

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).

Three raceways at FRH as well as three raceways at EH were sampled three times to generate three independent estimates of abundance. Sample sizes outlined in Table 1 were used when making these additional estimates. 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 within 7 days of release using a Chapman modified Petersen model (Seber 1982). The estimate of abundance at the time of release was calculated as:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{m_2+1} - 1, \tag{7}$$

with variance:

$$\mathrm{Var}\left[\hat{N}\right] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}, \tag{8}$$

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 7 and 8 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. This minimized 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 and the relative precision of the estimates with those from the mark-recapture and water volume methods. 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 four of the raceways of chinook salmon were based on an electronic count of eggs. At the eyed-egg stage in mid-August 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.

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 fish 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 out of the net. The fish were poured into a preweighed 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 hatchery inventory estimate at FRH for the chinook salmon smolt stocked at the Ninilchik River was established upon completion of tagging. Fish were removed from one raceway, tagged, and placed into a different raceway. Fish were counted during the tagging process, and all fish in the Ninilchik River release group were tagged. Mortalities were monitored on a daily basis and subtracted from the inventory count to yield a final hatchery inventory estimate for each release group.

The hatchery inventory estimates at FRH for the coho salmon smolt stocked at Wasilla Creek, Bird Creek, and both Anchorage urban streams (Ship Creek and Campbell Creek), and for the chinook salmon smolt stocked at Willow 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 out of the net. The fish were poured into a preweighed 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 eight 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 by (Cochran 1977):

$$\hat{R} = \frac{\bar{n}}{\bar{w}}, \tag{9}$$

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,

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

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

$$= \frac{\sum_{i=1}^{n_d} w_i}{n_d}.$$

The jackknife procedure was used to estimate a ratio with a smaller bias (Cochran 1977; pp. 175-180). First we calculated a series of jackknife ratio estimates:

$$\hat{R}_j = \frac{\sum_{\substack{i=1 \\ i \neq j}}^{n_d} n_i}{\sum_{\substack{i=1 \\ i \neq j}}^{n_d} w_i}, \tag{10}$$

and then the ratio estimate was calculated as:

$$\hat{R}_Q = n_d \hat{R} - (n_d - 1)\bar{R}_j ; \tag{11}$$

with variance:

$$\mathrm{Var}\left[\hat{R}_Q\right] = \frac{n_d - 1}{n_d} \sum_{i=1}^{n_d} \left(\hat{R}_{ji} - \bar{R}_j\right)^2 ; \tag{12}$$

where:

$\hat{R}_j$ = the average of the R_j of fish moved to the outdoor raceway.

The finite population correction (FPC) was ignored because the number of dip nets sampled was extremely small relative to the total number of dip net loads which could be sampled (i.e. $f = n_d/N_d \approx 0$).

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

$$\hat{N}_r = W_r \hat{R}_Q, \tag{13}$$

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:

$$\mathrm{Var}\left[\hat{N}_r\right] = W_r^2 \mathrm{Var}\left[\hat{R}_Q\right]. \quad (14)$$

The number of fish released from an outdoor raceway was the estimate (equation 13) 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 three vehicles for transporting fish: a boom truck, a flatbed trailer, and a pickup truck. The first two vehicles have a tank divided into four compartments. The pickup truck has 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 small transport tanks have an estimated 1.8 kg of fish per mm of water displaced, the large transport tanks have an estimated 3.1 kg of fish per mm of water displaced, and the pickup truck tanks have an estimated 0.91 kg of fish per mm water displaced; EH transport tanks have an estimated 4.9 kg of fish per mm 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.

SIZE ESTIMATION

A minimum of 510 fish were individually measured for weight from the Halibut Cove, Seldovia, Buskin River, and Homer Spit late run release groups at EH; and the Wasilla Creek, Bird Creek, and Ninilchik River 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 release groups at EH; and from each of the two raceways of the Willow Creek and Anchorage Urban Streams 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 187,000 coho salmon and 385,000 chinook salmon smolt for release at 11 locations in Cook Inlet were marked in 1996 (Tables 2 and 3). This number exceeded the project goal by more than 8%. The goal of marking and tagging a minimum of 80,000 smolt for the Anchorage Urban Streams, 50,000 smolt for Ninilchik River, and 40,000 smolt for the remaining release groups was achieved.

Three of the Elmendorf Hatchery release groups of chinook salmon were reared in two different raceways (Table 1). The percentage of tagged fish at release was 20.5% and 21.8% in each of the two Crooked Creek chinook salmon smolt raceways, 17.0% and 18.8% for the two raceways of Ship Creek chinook salmon smolt, and 20.6% and 19.4% for the two raceways of Homer early-run chinook salmon (Table 3). 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 Anchorage Urban Streams raceways was 29.9% and 32.2% (Table 2). The percentage of tagged chinook salmon smolt at release in each of the two Willow Creek raceways was 24.5% and 26.5% (Table 3).

Long-term tag retention was checked after the prescribed 30-day waiting period with all of the release groups. The length of waiting periods ranged from 77 days to 212 days, with 13 of the 17 raceways having waiting periods in excess of 100 days. Tag retention for the release groups ranged from 95.5% to 99.7% with an overall mean of 97.7%. Homer Spit early-run RW 9 had the lowest long-term retention rate of 93.8% for an individual raceway, but the combination of both Homer Spit early-run raceways yields an overall release group retention rate of 95.5%. An estimated 596,400 coho salmon and 1,304,700 chinook salmon smolt were released, achieving the total release goal of 1,900,000 (Tables 2 and 3). Except for the Ninilchik River release group for which 100% of the smolt were marked, the percentage of the total release which was marked per raceway ranged from 17.0% to 41.6%.

Tag application rates varied from 171.2 to 271.3 valid tags per worker hour among the raceways with a mean valid tag application rate of 223.18 valid tags per worker hour (Tables 4 and 5). The tagging rates for the coho salmon raceways were similar to the tagging rates for most of the chinook salmon raceways. Estimated long-term tag retention ranged from 93.8% for one

raceway of the Homer Spit early-run chinook salmon smolt release to 99.7% for the Wasilla Creek coho salmon smolt release. A plot of tag application rates versus long-term tag retention rates for coho and chinook salmon raceways at EH and FRH showed no relationship between tagging rate and long-term tag-retention (Figure 2).

SMOLT ENUMERATION

Mark-Recapture Estimates

Three mark-recapture estimates were made for each of six raceways. One mark-recapture estimate was made for the remaining raceways, except for the Ninilchik River release group because 100% of the fish in that release group were marked.

Table 4.-Numbers of fish coded wire tagged, tag application rates, tag codes, and tag retention rates for coho salmon release groups at Fort Richardson Hatchery in 1996.

	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3
Tag Codes	31-25-04	31-25-06	31-25-05	31-25-06
Total valid tags	45,411	46,058	46,839	46,506
Worker hours per tag code	230.0	75.0	194.0	215.0
Tags per worker hour	197.4	263.2	241.4	216.3
Tags/worker hr Variance	1.260	1.213	0.234	1.073
Short-term tag retention	98.9%	99.6%	99.7%	99.6%
Long-term tag retention	97.6%	98.7%	99.7%	98.3%
Tag loss	1.3%	0.9%	0.0%	1.3%
Days elapsed	212	196	211	194

table 5

Table 5.-Numbers of fish coded wire tagged, tag application rates, tag codes, and tag retention rates for chinook salmon release groups at Elmendorf and Fort Richardson hatcheries in 1996.

	Fort Richardson			Elmendorf									
	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
Tag Codes	31-25-14	31-25-14	31-25-15	31-25-12	31-25-12	31-25-08	31-25-08	31-25-10	31-25-11	31-25-09	31-25-07	31-25-07	31-25-13
Total valid tags	22,909	24,236	50,962	20,383	19,813	20,455	19,654	39,610	39,345	40,681	20,538	18,479	38,787
Worker hours per tag code	122.5	97.5	228.0	77.0	92.0	117.0	92.0	153.0	145.0	204.5	120.0	96.0	152.0
Tags per worker hour	187.0	248.6	223.5	264.7	215.4	174.8	213.6	258.9	271.3	198.9	171.2	192.5	255.2
Tags/worker hr Variance	0.325	1.305	0.885	0.653	1.422	1.071	1.728	2.203	3.328	0.732	2.518	1.298	4.043
Short-term tag retention	99.9%	100.0%	99.6%	99.8%	100.0%	99.8%	100.0%	99.5%	99.7%	99.2%	97.9%	99.7%	99.5%
Long-term tag retention	99.3%	98.4%	98.6%	99.3%	97.6%	97.4%	97.2%	97.4%	96.7%	98.6%	93.8%	97.4%	95.5%
Tag loss	0.6%	1.6%	1.0%	0.5%	2.4%	2.4%	2.8%	2.1%	3.0%	0.6%	4.1%	2.3%	4.0%
Days elapsed	99	91	77	114	106	140	118	125	112	96	145	122	108

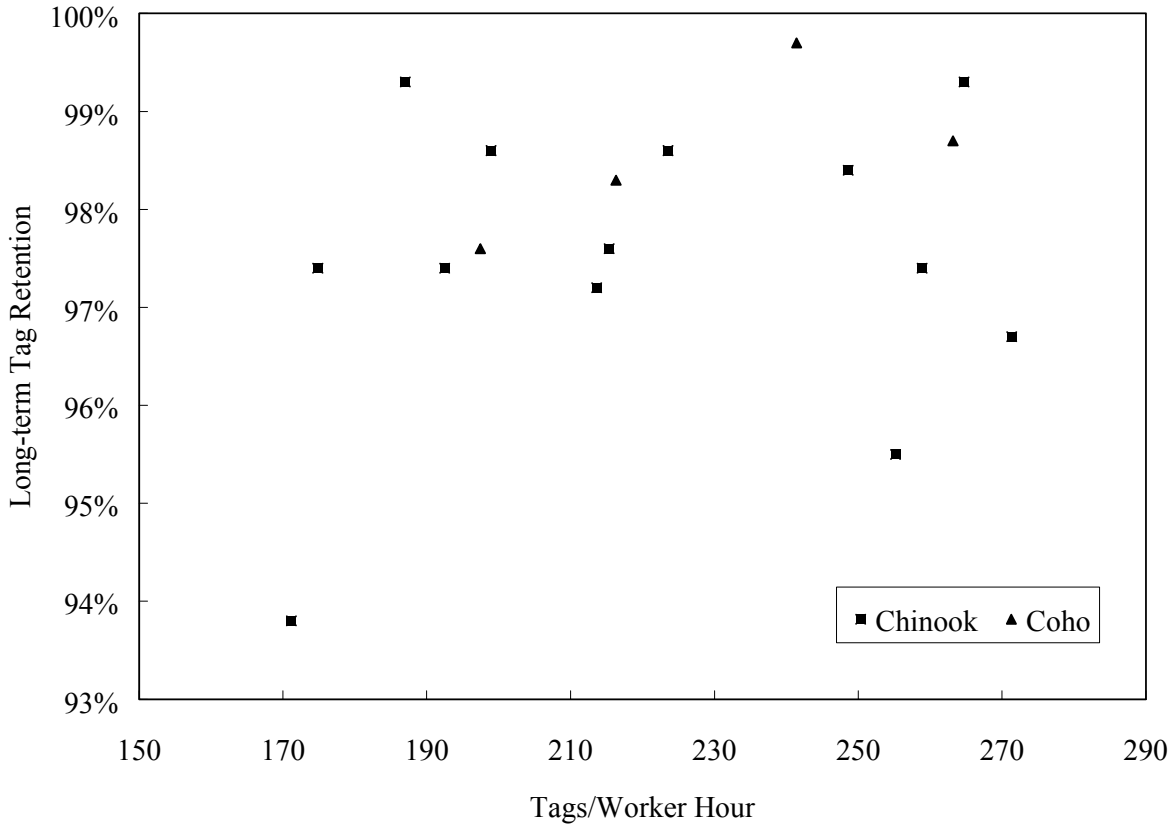

Figure 2.-Comparison of tag application rates to long-term tag retention rates for 17 coho and chinook salmon rearing containers at Fort Richardson and Elmendorf hatcheries, 1996.

No significant differences were detected among the three estimates in four of the six groups (Tables 6 and 7; Figure 3). Bird Creek and Seldovia release groups each had one estimate which was significantly different from the other two estimates.

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 7,996 g (Bird Creek) to 8,692 g (Anchorage Urban Streams E3) (Table 8). The two raceways of Willow Creek chinook salmon smolt had mean bucket weights of 8,615 g and 8,943 g (Table 8).

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 2,665 g (Bird Creek) to 2,897 g (Anchorage Urban Streams E3). Likewise, the mean weight of a net load of chinook salmon for Willow Creek ranged from 2,872 g to 2,981 g. The coho salmon subsamples were 9.7% to 10.8% of a full net load. The mean weights of the coho salmon subsamples varied from 276 g to 295 g, and the mean number of fish in a subsample varied from 74 to 78 fish. The chinook salmon subsamples were 8.0% to 8.7% of a

Table 6.-Mark-recapture estimates for four Cook Inlet coho salmon smolt releases from Fort Richardson Hatchery in 1996.

	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3
Mark/Recapture Estimate #1	140,655	156,050	147,567	146,807
Standard Error	3,193	3,846	3,421	2,959
Upper 95% CI	146,914	163,589	154,272	152,606
Lower 95% CI	134,396	148,511	140,861	141,008
Mark/Recapture Estimate #2	146,976		144,803	
Standard Error	3,398		3,258	
Upper 95% CI	153,637		151,188	
Lower 95% CI	140,316		138,418	
Mark/Recapture Estimate #3	154,834		145,377	
Standard Error	3,558		3,127	
Upper 95% CI	161,807		151,507	
Lower 95% CI	147,861		139,248	
Estimates Pooled	147,618	156,050	145,923	146,807
Standard Error	1,953	3,846	1,886	2,959
Upper 95% CI	151,445	163,589	149,620	152,606
Lower 95% CI	143,791	148,511	142,226	141,008

full net load. The mean weights of the chinook salmon subsamples were 231 g and 260 g, and the mean number of fish in a subsample ranged from 57 to 61 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 9). The percentage of fish enumerated into individual raceways via the coded wire tagging process ranged from 0% to 41.2%. The percentage of fish enumerated into individual raceways via the bulk weighing method ranged from 0% to 81.3%. The percentage of fish enumerated from a raceway during the coded wire tagging process ranged from 0% to 14.4%. The percentage of fish enumerated from a raceway via the bulk weighing method ranged from 0% to 40.5%.

The inventory estimates for four of the raceways were determined entirely by subtracting the estimated number of fish removed from the inventory estimate established at the fry stage. All four of these 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.

Table 7.-Mark-recapture estimates of nine Cook Inlet chinook salmon smolt releases from Elmendorf and Fort Richardson hatcheries in 1996.

	Fort Richardson			Elmendorf									
	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
Mark/Recapture Estimate #1	93,981	90,860		100,215	92,965	123,763	103,343	118,655	97,729	113,220	109,819	97,978	108,204
Standard Error	2,219	1,909		2,419	2,146	3,276	2,397	3,171	2,251	2,795	2,963	2,345	2,463
Upper 95% CI	98,331	94,602		104,956	97,171	130,183	108,041	124,870	102,141	118,699	115,627	102,573	113,031
Lower 95% CI	89,631	87,117		95,475	88,759	117,342	98,644	112,440	93,316	107,741	104,011	93,383	103,377
Mark/Recapture Estimate #2		90,614					107,475	110,893			106,540		
Standard Error		1,781					2,454	2,716			2,735		
Upper 95% CI		94,104					112,283	116,215			111,901		
Lower 95% CI		87,124					102,666	105,570			101,178		
Mark/Recapture Estimate #3		96,704					111,452	126,172			102,724		
Standard Error		1,871					2,429	3,446			2,408		
Upper 95% CI		100,371					116,213	132,926			107,445		
Lower 95% CI		93,036					106,691	119,417			98,004		
Mark/Recapture Estimate Pooled	93,981	92,937		100,215	92,965	123,763	107,681	118,274	97,729	113,220	106,107	97,978	108,204
Standard Error	2,219	1,068		2,419	2,146	3,276	1,399	1,783	2,251	2,795	1,552	2,345	2,463
Upper 95% CI	98,331	95,030		104,956	97,171	130,183	110,423	121,770	102,141	118,699	109,149	102,573	113,031
Lower 95% CI	89,631	90,843		95,475	88,759	117,342	104,939	114,779	93,316	107,741	103,065	93,383	103,377

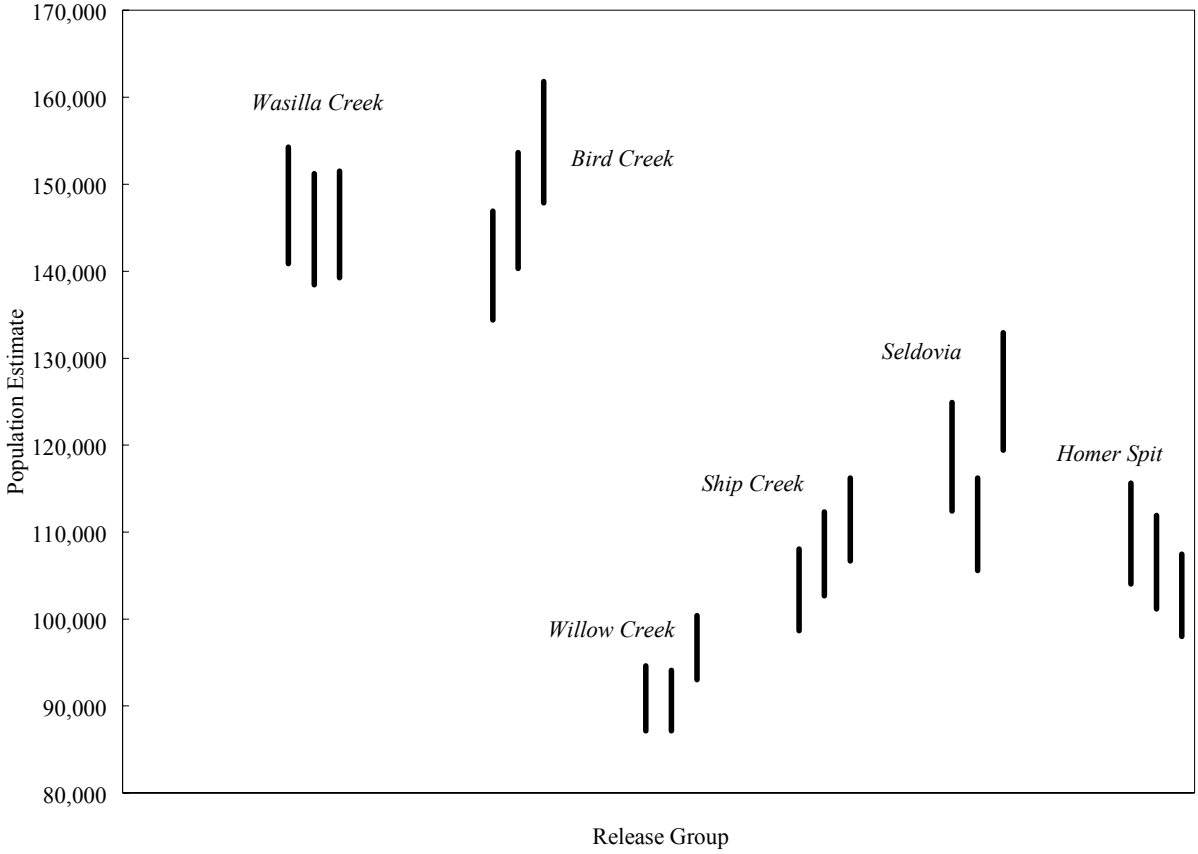

Figure 3.-Comparison of 95% confidence interval for mark-recapture population estimates for six coho salmon and chinook salmon raceways at Elmendorf and Fort Richardson hatcheries in 1996.

Water Volume Estimates

The water volume estimate was higher than the mark-recapture estimate for all six raceways at FRH on which mark-recapture estimates were made, and for seven of the 10 raceways at EH. There is not a mark-recapture estimate for the Ninilchik River release group at FRH since all fish in that group were tagged At FRH the water volume estimates are within 5% of the hatchery inventory estimates for six of the seven raceways, and within 10% for all seven raceways. The hatchery inventory estimates were higher than the water volume estimates for four of the seven raceways. At EH the water volume estimates and the hatchery inventory estimates were within 5% 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 followed a similar trend for nine of the 10 raceways at EH (Tables 10 and 11). For each of these raceways, the water volume and hatchery inventory estimates were either both higher than the mark-recapture estimate, or both lower than the mark-recapture estimate. One raceway of the Homer Spit early release group is an exception.

Table 8.-Hatchery inventory data and hatchery inventory population estimates for six raceways of coho and chinook salmon smolt released from the Fort Richardson Hatchery in 1996.

	Coho Salmon				Chinook Salmon	
Parameter	Bird Creek [a] RW E1	Anchorage Urban Stream[a] RW E2	Wasilla Creek [a] RW E4	Anchorage Urban Stream[a] RW E3	Willow Creek[a] D2	Willow Creek[a] D3
Containers of fish moved	75	71	74	69	51	51
Total fish weight moved (g)	599,682	605,804	606,136	599,756	456,071	439,353
Mean weight/container (g)	7,996	8,532	8,191	8,692	8,943	8,615
Total number of subsamples	30	28	32	29	9	9
Total weight subsampled (g)	8,419	7,739	9,444	8,382	2,340	2,076
Percent of total weight moved which was subsampled	1.40%	1.28%	1.56%	1.40%	0.51%	0.47%
Percent of individual net which was subsampled	10.5%	9.7%	10.8%	10.0%	8.7%	8.0%
Mean weight/subsample (g)	281	276	295	289	260	231
Total number of fish counted	2,262	2,067	2,498	2,232	551	509
Number of fish/subsample	75	74	78	77	61	57
Estimated number of fish enumerated by bulk weighing	159,992	161,228	161,347	159,932	107,237	107,752
Total number of fish placed in raceway at release[a]	158,649	157,281	157,538	157,702	106,607	107,350
Standard Error	2,709	3,306	2,369	3,292	1,630	1,308
95% Confidence Interval						
upper	163,959	163,761	162,182	164,154	109,801	109,914
lower	153,340	150,801	152,894	151,250	103,413	104,786

[a] The number of mortalities from the time the fish were moved until the fish were released has been subtracted from the estimate.

Table 9.-A comparison of hatchery inventory estimates in relation to the inventory estimation method used for chinook salmon smolt release groups from Elmendorf Hatchery, 1996.

	Crooked Creek RW 8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit Early RW9	Homer Spit Early RW16	Homer Spit Late RW14
Inventory number prior to splitting		214,786		227,120		286,950			207,185	
Hatchery inventory after split[a]	106,012	108,752	113,133	113,882	106,426	110,263	100,453	98,761	108,337	120,407
Number of fish enumerated into rearing unit via CWT process	20,746		21,169		41,257		41,376	22,372		41,407
Number of fish enumerated into rearing unit via weighing	85,266		91,964		65,169		59,077	76,389		79,000
Number of fish removed from rearing unit via CWT process		20,768		21,274		41,358			22,459	
Number of fish removed from rearing unit via weighing		85,266		91,964		65,169			76,389	
Percentage of fish enumerated into rearing unit via CWT process	19.6%		18.7%		38.8%		41.2%	22.7%		34.4%
Percentage of fish enumerated into rearing unit via weighing	80.4%		81.3%		61.2%		58.8%	77.3%		65.6%
Percentage of fish removed from rearing unit via CWT process		9.7%		9.4%		14.4%			10.8%	
Percentage of fish removed from rearing unit via weighing		39.7%		40.5%		22.7%			36.9%	
Percentage of fish enumerated at eyed egg stage	100%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
MR est. at release[b]	100,215	92,965	123,763	107,681	118,274	97,729	113,220	106,107	97,978	108,204
HI[c] relative to MR	105.2%	114.8%	90.8%	105.4%	88.8%	107.5%	88.5%	91.8%	110.1%	109.3%

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

[b] MR = mark-recapture

[c] HI = hatchery inventory

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 coho salmon smolt produced at Fort Richardson Hatchery and stocked in four locations in Cook Inlet in 1996.

	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3
MR Estimate[a]				
#1	140,655	156,050	147,567	146,807
#2	146,976	49,302	144,803	50,698
#3	154,834	49,302	145,377	50,698
Pooled MR Estimate	147,618	156,050	145,923	146,807
WV Estimate[b]	165,800	157,103	156,074	157,510
HI Estimate[c]	158,649	157,281	157,538	157,702
WV relative to MR	112.3%	100.7%	107.0%	107.3%
HI relative to MR	107.5%	100.8%	108.0%	107.4%
WV relative to HI	104.5%	99.9%	99.1%	99.9%

[a] MR = Mark-recapture.

[b] WV = Water Volume. Water volume estimate was computed using water displacement values at Fort Richardson of 1.8 kg/m^3 for the boom truck tanks, 3.1 kg/m^3 for the trailer tanks and 0.91 kg/m^3 for the pickup truck tanks.

[c] HI = Hatchery Inventory.

Table 11.-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 eight locations in Cook Inlet in 1996.

	Fort Richardson			Elmendorf									
	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
MR Estimate[a]													
#1	93,981	90,860		100,215	92,965	123,763	103,343	118,655	97,729	113,220	109,819	97,978	108,204
#2		90,614					107,475	110,893			106,540		
#3		96,704					111,452	126,172			102,724		
Pooled Estimate	93,981	92,937		100,215	92,965	123,763	107,681	118,274	97,729	113,220	106,107	97,978	108,204
WV Estimate[b]	102,516	114,831	51,767	110,128	102,800	115,522	113,591	109,004	102,649	103,803	110,128	108,916	121,405
HI Estimate[c]	106,607	107,350	51,686	105,413	106,724	112,427	113,447	105,057	105,023	100,188	97,369	107,842	118,274
WV relative to MR	109.1%	123.6%		109.9%	110.6%	93.3%	105.5%	92.2%	105.0%	91.7%	103.8%	111.2%	112.2%
HI relative to MR	113.4%	115.5%		105.2%	114.8%	90.8%	105.4%	88.8%	107.5%	88.5%	91.8%	110.1%	109.3%
WV relative to HI	96.2%	107.0%	100.2%	104.5%	96.3%	102.8%	100.1%	103.8%	97.7%	103.6%	113.1%	101.0%	102.6%

[a] MR = Mark-recapture.

[b] WV = Water Volume. Water volume estimate was computed using water displacement values at Fort Richardson of 1.8 kg/m^3 for the boom truck tanks, 3.1 kg/m^3 for the trailer 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

SIZE ESTIMATION

The smallest coho salmon smolt in terms of weight were from the Bird Creek release, while the largest coho salmon smolt were from the Wasilla Creek release (Table 12). The smallest chinook salmon were from the Ninilchik River release, while the largest chinook salmon smolt were from the Homer (Crooked Creek) release (Table 13).

The majority of the coho salmon smolt released at Bird Creek, Wasilla Creek, and both Anchorage urban streams, Campbell Creek and Ship Creek, were between 15.1 g and 25.0 g (Table 14). At FRH the majority of the chinook salmon smolt released were between 5.1 g and 15.0 g (Table 15). At EH the majority of the chinook salmon smolt for all release groups except the Buskin River release group were over 15.0 g. The majority of the chinook salmon smolt for the Buskin River release group were between 5.1 g and 15.0 g.

Table 12.-Mean weights of coho salmon smolt produced at Fort Richardson Hatchery and stocked at four locations in Cook Inlet in 1996.

Parameter	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3
Sample Size	555	514	526	513
Sample Date	5/24/96	1/29/96	5/16/96	5/20/96
Release Dates	5/29-29/96	5/30-31/96	5/21-22/96	5/23/96
Sample Mean Weight (g)	20.0	20.8	20.9	20.7
Standard error	4.4	3.8	4.1	4.2
Maximum	38.7	38.4	35.2	33.4
Minimum	5.4	7.6	5	6.1

Table 13.-Mean weights of chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked at eight locations in Cook Inlet in 1996.

	Fort Richardson			Elmendorf									
Parameter	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
Sample Size	528	513	541	512	512	511	530	524	519	583	533	531	514
Sample Date	6/14/96	6/12/96	6/11/96	6/7/96	6/5/96	6/6/96	5/28/96	6/10/96	6/3/96	5/22/96	6/4/96	5/30/96	6/13/96
Release Dates	6/17-18/96	6/14/96	6/13/96	6/10/96	6/6/96	6/7/96	5/29/96	6/12/96	6/4/96	5/23/96	6/5/96	5/31/96	6/14/96
Mean Weight (mm)	15.1	13.7	12.9	19.2	20.2	16.9	19.4	18.2	18.5	14.4	19.1	20.9	15.5
Standard error	3.8	3.1	3.0	3.7	3.9	3.3	4.1	3.7	4.3	3.1	4.9	4.8	3.6
Maximum	39.8	26.5	27.1	40.5	33.6	38.4	45.1	44.4	59.3	36.5	51.5	56.4	30.7
Minimum	5.6	3.9	6.4	8.8	7.7	8.3	9.5	7.2	2.7	3.7	7.1	12.3	6.7

Table 14.-Weight frequency distribution of hatchery coho salmon smolt produced at Fort Richardson Hatchery and stocked in four locations in Cook Inlet in 1996.

Weight Distribution	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3
0 - 5			0.2%	
SE			0.0001	
5.1 - 10	1.3%	0.8%	0.6%	1.2%
SE	0.0002	0.0002	0.0001	0.0002
10.1 - 15	9.7%	4.1%	5.7%	6.6%
SE	0.0005	0.0004	0.0004	0.0005
15.1 - 20	41.8%	38.5%	37.1%	37.6%
SE	0.0009	0.0009	0.0009	0.0009
20.1 - 25	36.0%	45.1%	41.3%	41.3%
SE	0.0009	0.0010	0.0009	0.0010
25.1 - 30	9.4%	9.9%	13.1%	10.9%
SE	0.0005	0.0006	0.0006	0.0006
30.1 - 35	1.3%	1.4%	1.9%	2.3%
SE	0.0002	0.0002	0.0003	0.0003
35.1 - 40	0.5%	0.2%	0.2%	0.0%
SE	0.0001	0.0001	0.0001	0.0000
40.1 - 45				
SE				
45.1 - 50				
SE				
>50				
SE				
Summary				
< 15.1 g	10.99%	4.86%	6.5%	7.8%
15.1 - 25.0 g [a]	77.84%	83.66%	78.3%	78.9%
> 25.0 g	11.17%	11.48%	15.2%	13.3%

[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 eight locations in Cook Inlet in 1996.

	Fort Richardson			Elmendorf									
Weight Distribution	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia D10	Halibut Cove D20	Buskin River D7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
0 - 5		0.4%							0.2%	0.2%			
SE		0.0001							0.0001	0.0001			
5.1 - 10	4.0%	7.4%	16.5%	0.2%	0.4%	0.2%	0.2%	0.2%	0.6%	4.1%	0.6%		4.9%
SE	0.0004	0.0005	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001		0.0004
10.1 - 15	53.2%	62.4%	62.7%	9.6%	9.2%	29.0%	11.7%	16.8%	17.7%	60.2%	13.3%	6.2%	43.8%
SE	0.0009	0.0009	0.0009	0.0006	0.0006	0.0009	0.0006	0.0007	0.0007	0.0008	0.0006	0.0005	0.0010
15.1 - 20	33.7%	26.7%	18.7%	57.0%	40.0%	56.0%	49.1%	56.7%	51.8%	31.2%	56.3%	41.2%	42.0%
SE	0.0009	0.0009	0.0007	0.0010	0.0010	0.0010	0.0009	0.0009	0.0010	0.0008	0.0009	0.0009	0.0010
20.1 - 25	6.4%	2.3%	2.0%	26.6%	39.1%	13.3%	31.1%	22.7%	23.1%	3.8%	22.0%	37.1%	7.8%
SE	0.0005	0.0003	0.0003	0.0009	0.0010	0.0007	0.0009	0.0008	0.0008	0.0003	0.0008	0.0009	0.0005
25.1 - 30	1.9%	0.8%	0.2%	5.1%	10.9%	1.2%	6.2%	2.7%	5.8%	0.3%	3.4%	12.1%	1.4%
SE	0.0003	0.0002	0.0001	0.0004	0.0006	0.0002	0.0005	0.0003	0.0005	0.0001	0.0003	0.0006	0.0002
30.1 - 35	0.6%			1.2%	0.4%		1.1%	0.6%	0.6%	0.0%	2.6%	1.7%	0.2%
SE	0.0001			0.0002	0.0001		0.0002	0.0001	0.0001	0.0000	0.0003	0.0002	0.0001
35.1 - 40	0.2%			0.2%		0.4%	0.2%	0.2%		0.2%	1.1%	0.9%	
SE	0.0001			0.0001		0.0001	0.0001	0.0001		0.0001	0.0002	0.0002	
40.1 - 45				0.2%			0.2%	0.2%			0.4%	0.4%	
SE				0.0001			0.0001	0.0001			0.0001	0.0001	
45.1 - 50							0.2%				0.2%		
SE							0.0001				0.0001		
>50									0.2%		0.2%	0.4%	
SE									0.0001		0.0001	0.0001	
Summary													
< 5.1 g	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%
5.1 - 15.0 g	57.2%	69.8%	79.1%	9.8%	9.6%	29.2%	11.9%	17.0%	18.3%	64.3%	13.9%	6.2%	48.6%
> 15.0 g	42.8%	29.8%	20.9%	90.2%	90.4%	70.8%	88.1%	83.0%	81.5%	35.5%	86.1%	93.8%	51.4%

[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 in the 1996 marking program was to maintain if not improve long-term tag retention rates above 1995 levels. The combined 1996 long-term tag retention was 97.7% as compared to 97.3% in 1995. 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. To help reduce the possibility of injury due to repetitive motion, crew members rotated between clipping and tagging every 2 to 4 hours. All tagging personnel participated in tagging each raceway. During the 1995 tagging year crew members rotated duties on a weekly basis. Any one raceway had only two or three different taggers responsible for tagging the fish. Although the mean long-term retention rates for 1995 and 1996 are similar, the long-term retentions for individual raceways appear to be more consistent among the 1996 raceways (Tables 2 and 3, Figures 4 and 5) (Starkey et al. 1996).

Several factors may contribute to the rate of tag application and long-term retention rate, including experience of taggers. Although there are exceptions, in general, raceways that were tagged toward the beginning of the project tend to have lower rates of tag application and long-term retention rates than raceways that were tagged later in the project. Bird Creek coho salmon smolt release group had the lowest long-term retention rate (97.6%) and lowest tag application rate (197.4 TWH) of all of the coho salmon release groups, and was the first coho salmon group to be tagged. Likewise, Homer Spit early-run RW 9 chinook salmon smolt raceway had the lowest long-term retention (93.8%) and lowest tag application rate (171.15 TWH) of all of the chinook salmon raceways and was the first chinook salmon raceway to be tagged. Other factors which contribute to rate of tag application are size distribution, changing stocks of fish, changing raceways, eagerness to complete a project, and environmental factors such as deep snow, ice, and darkness.

Factors which can contribute to lower long-term retention rates are size distribution, improper placement of the fish into the head mold, and improper set up of the injector. 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. 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. A short-term retention rate of less than 99% indicates a problem which is likely to result in low long-term retention rates. Homer Spit RW 9 had a 97.9% short-term retention and a 93.8% long-term retention rate. Bird Creek release group had a short-term retention rate of 98.9% and a long-term retention rate of 97.6%. 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). Short-term retention rates between 99% and 100%, however, do not guarantee excellent long-term retention rates.

Size at tagging does not appear to affect rate of tagging. For raceways with a mean size at tagging <80 mm, the tag application rate ranged from 174.2 TWH to 271.3 TWH. For raceways with a mean size at tagging >80 mm, the tag application rate ranged from 197.4 TWH to 264.7 TWH (Table 16).

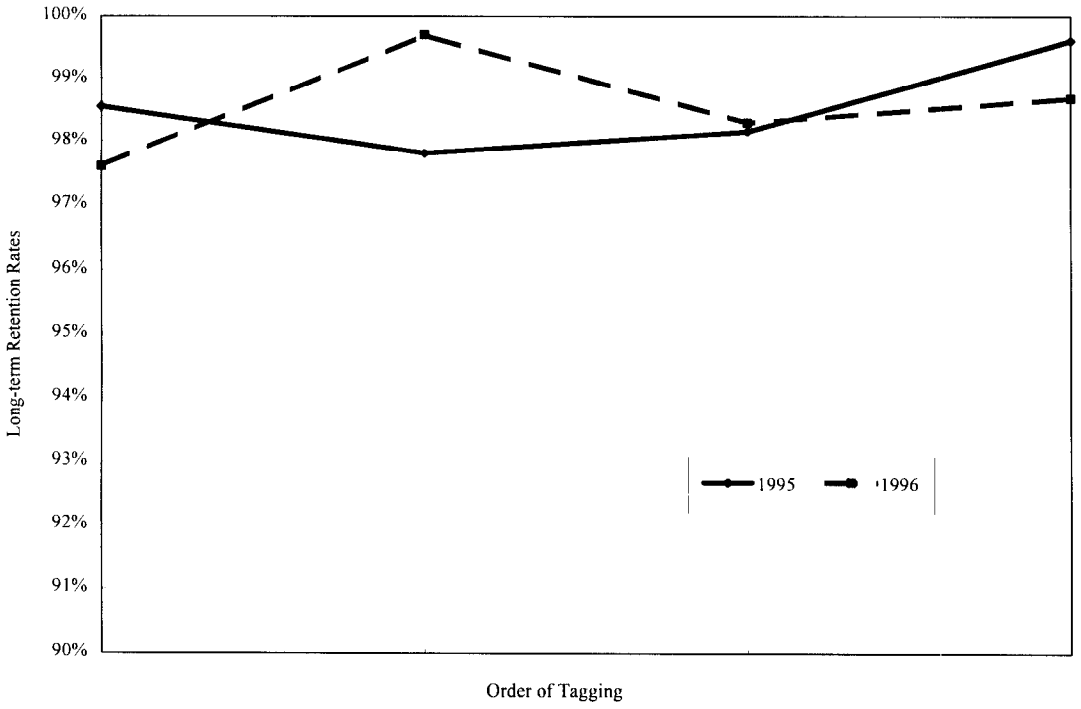

Figure 4.-Comparison of long-term tag retention rates for rearing units of coho salmon at Fort Richardson Hatchery in 1995 and 1996.

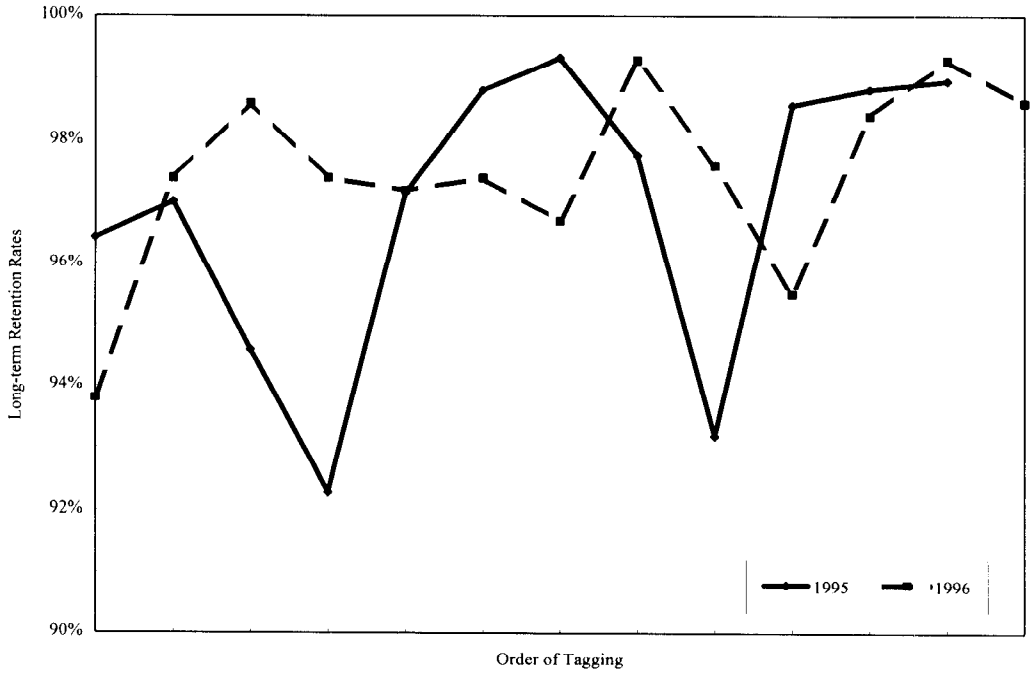

Figure 5.-Comparison of long-term tag retention rates for rearing units of chinook salmon at Elmendorf and Fort Richardson hatcheries in 1995 and 1996.

Table 16.-Tag application rates as they relate to mean size at tagging and fish size distribution of coho and chinook salmon smolt stocked in 11 locations in Cook Inlet in 1996.

	Coho Salmon				Chinook Salmon												
	Fort Richardson				Fort Richardson			Elmendorf									
Parameter	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3	Willow Creek D2	Willow Creek D3	Ninilchik River D4	Crooked Creek RW8	Crooked Creek RW17	Ship Creek RW6	Ship Creek RW15	Seldovia RW 10	Halibut Cove RW 20	Buskin River RW 7	Homer Spit RW9	Homer Spit RW16	Homer Spit Late RW14
Valid tags per worker hour	197.4	263.2	241.4	216.3	187.0	248.6	223.5	264.7	215.4	174.8	213.6	258.9	271.3	198.9	171.2	192.5	255.2
Mean size at tagging in mm	88.92	96.98	88.92	88.92	73.47	73.47	80.94	82.45	82.45	73.73	73.73	77.30	77.30	75.86	75.04	75.04	76.40
# of different sizes of head molds used	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2

Rate of tag application and long-term retention do not appear to have a consistent relationship (Figure 2). Factors such as changing raceways or machine malfunctions affect the tag application rate but do not affect the long-term tag retention rate. Five raceways have tag application rates >250 TWH and have long-term retention rates ranging from 95.5 TWH to 99.3 TWH. Twelve raceways have tag application rates <250 TWH and have long-term retention rates ranging from 93.8 TWH to 99.7 TWH (Tables 4 and 5). At some point, increased tagging speed will cause a corresponding decrease in quality. Decreased quality will in turn produce a decrease in long-term tag retention rates. We suspect that if we had numerous data points beyond 250 tags per worker hour, long-term tag retentions would begin to decrease.

A standard set of size ranges with discrete beginning and ending sizes for most head mold sizes was established in 1993 for coho and chinook salmon smolt (Peltz and Hansen 1994). Size ranges were established in 1994 for coho and chinook salmon smolt that were <81 mm in length (Starkey et al. 1995). The standard size ranges tagged for each size head mold are as follows:

Head mold size	Fish Size Interval
20	≤71 mm
120	72 mm to 80 mm
90	81 mm to 90 mm
65	91 mm to 105 mm
45	106 mm to 120 mm
30	>120 mm

These 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. 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.

SMOLT ENUMERATION

We feel mark-recapture estimates provide the easiest to obtain and most reliable estimates of smolt release numbers at Fort Richardson and Elmendorf hatcheries. Whenever possible, this technique should be utilized.

Comparison of the three smolt enumeration techniques revealed interesting trends (Tables 10, 11, and 17 and Figures 6 and 7). At FRH the mark-recapture estimates were the lowest of the three estimation techniques for all six raceways which had mark-recapture estimates performed on them, and the hatchery inventory estimates were the highest of the three techniques for four of the six raceways.

At EH, the mark-recapture estimates were the lowest of the three for six of the 10 raceways. The hatchery inventory estimates were the highest of the three for only two of the 10 raceways, the mark-recapture estimates were the highest of the three for three of the 10 raceways, and the water volume estimates were the highest of the three for five of the 10 raceways. Second, the water volume estimate relative to the hatchery inventory estimate was within 5% for 9 of the 10 raceways. Third, the discrepancy pattern between the mark-recapture estimate and the

Table 17.-Comparison of three population estimation techniques for coho and chinook salmon smolt released from Fort Richardson Hatchery in 1996.

Estimate	Bird Creek E1	Anchorage Urban Streams E2	Wasilla Creek E4	Anchorage Urban Streams E3	Willow Creek D2	Willow Creek D3	Ninilchik River D4
MR (Pooled)[a]	147,618	156,050	145,923	146,807	93,981	92,937	
Standard Error	1,953	3,846	1,886	2,959	2,219	1,871	
Upper 95% CI	151,445	163,589	149,620	152,606	98,331	96,604	
Lower 95% CI	143,791	148,511	142,226	141,008	89,631	89,269	
WV[b]	165,800	157,103	156,074	157,510	102,516	114,831	51,767
HI[c]	158,649	157,281	157,538	157,702	106,607	107,350	51,686
Standard Error	2,709	3,306	2,369	3,292	1,630	1,308	
Upper 95% CI	163,959	163,761	162,182	164,154	109,801	109,914	
Lower 95% CI	153,340	150,801	152,894	151,250	103,413	104,786	
WV relative to MR	112.3%	100.7%	107.0%	107.3%	109.1%	123.6%	
HI relative to MR	107.5%	100.8%	108.0%	107.4%	113.4%	115.5%	
WV relative to HI	104.5%	99.9%	99.1%	99.9%	96.2%	107.0%	100.2%

[a] MR = Mark-recapture

[b] WV = Water Volume

[c] HI = Hatchery Inventory

hatchery inventory estimate was consistent with the hatchery inventory method used for most of the raceways.

Potential sources of error for each of the three smolt enumeration techniques have been discussed previously (Peltz and Starkey 1993). The most likely potential source of error for the mark-recapture technique is nonrandom distribution of marks in the population. Two of the six groups did have one estimate which was different from the other two. Fish in the raceways were crowded, and dip nets of fish were collected throughout the crowded group of fish and placed into netpens 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; a disproportionate number of small fish would be captured for both the marking and recapture events. If small fish were tagged at a higher rate and small fish were overrepresented in the recapture event, the Petersen estimator would underestimate the abundance. This may explain why the mark-recapture estimate was the lowest estimator 75% of the time.

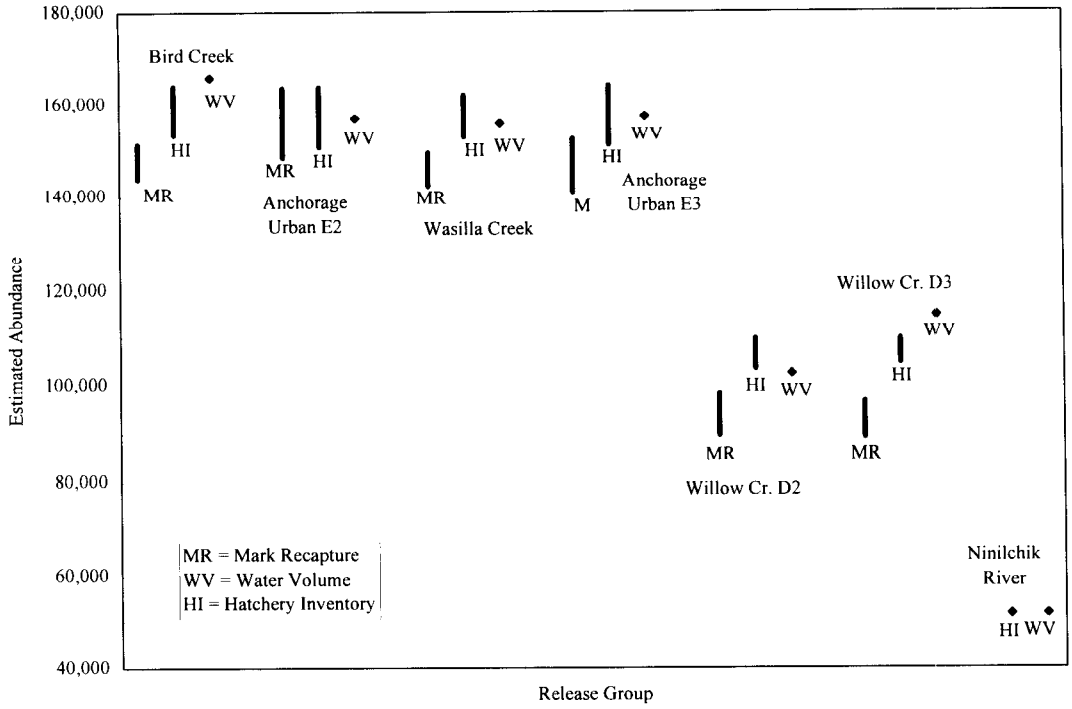

Figure 6.-Comparison of the 95% confidence intervals of three smolt population techniques at Fort Richardson Hatchery in 1996.

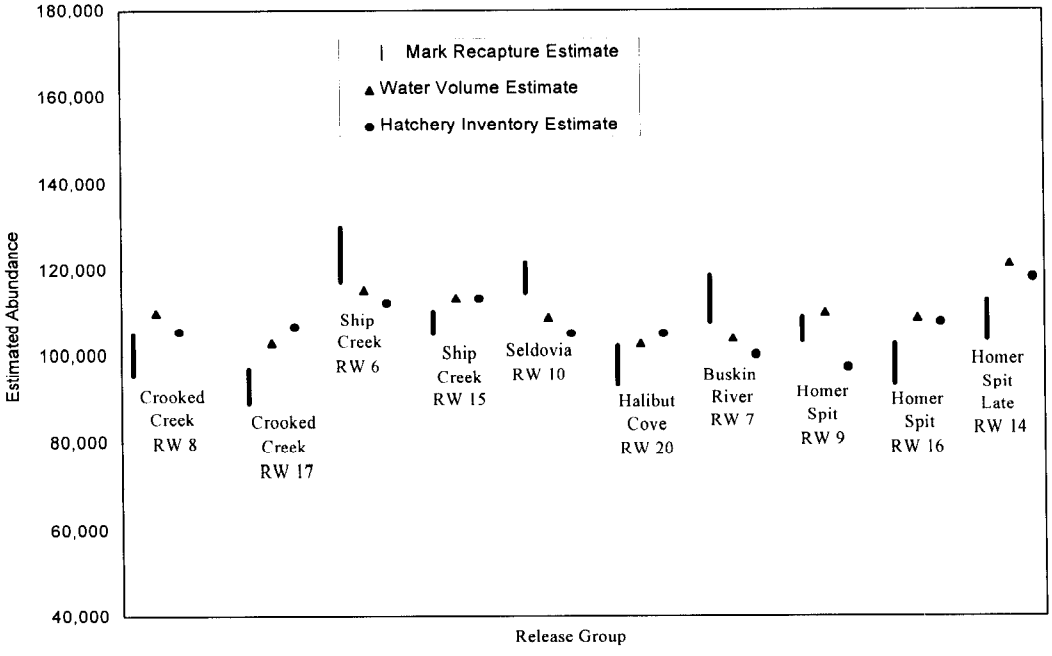

Figure 7.-Comparison of the 95% confidence intervals of three smolt population techniques at Elmendorf Hatchery in 1996.

Three of the four times when the mark-recapture estimate was not the lowest, the population of smolt had been moved. Again, if the fish were not properly crowded, the smolt that were moved to the new raceway could have had a higher proportion of small fish. If there was selectivity for small fish during marking and the new raceway contained mostly small fish, then it is possible that the marked fish were representative of the fish in the new raceway and the mark-recapture estimate would not be biased low. The mark-recapture abundance estimate of smolt in the original raceway would be biased low. All four of the original raceways had mark-recapture estimates lower than the other two estimators.

Although we consider the mark-recapture method to be the most reliable and recommend this method over others, size selectivity from nonrandom sampling biased our results in 1996. 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. If care is taken so all fish have a chance to mix, nonrandom distribution of marks should not be a major problem.

Comparisons of the three population estimation techniques were performed previously at FRH for 1993 coho and chinook salmon release groups (Peltz and Hansen 1994). Water volume displacement tests indicated that abundance estimates 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. Water volume displacement tests were not conducted for 1996 release groups; therefore, there is not a variance around the 1996 water volume estimates.

At EH, the water volume population estimates relative to mark-recapture population estimates for individual raceways ranged from 91.7% to 112.2%. 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.

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.

In determining the hatchery inventory estimates for 1993 release groups of coho and chinook salmon, five subsamples were obtained from each indoor raceway of coho salmon, and five to 10 subsamples were obtained from each indoor raceway of chinook salmon during the transferring of fish from indoor raceways to outdoor raceways. For 1996 release groups of coho salmon, the number of subsamples from each coho salmon indoor raceway ranged from three to eight

subsamples from each coho salmon indoor raceway. Fish from five to six different indoor raceways were transferred to each of the four outdoor raceways resulting in the total number of 28 to 32 subsamples obtained per outdoor raceway. The size of the subsamples for the 1996 release groups of coho salmon smolt remained approximately the same as the size of the subsamples for the 1993 release groups (9.7% to 10.8% of a full net load in 1996 compared to 8% to 12% of a full net load in 1993).

The two indoor raceways of 1996 Willow Creek release group chinook salmon were each sampled nine 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 1996 release group of Willow Creek chinook salmon ranged from 8.0% to 8.7% of a full net load. This is a decrease in sample size from the 1995 Willow Creek chinook salmon release group where the size of the samples were increased to 100% of a net load in an unsuccessful attempt to improve the accuracy of this technique (Starkey et al. 1996).

In 1996 hatchery inventory estimates at EH were based on a variety of techniques. For four 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.

Crooked Creek RW 17 was split into a second Crooked Creek raceway, Homer Spit RW 16 was split into a second Homer Spit early-run raceway, and Ship Creek RW 15 was split into a second Ship Creek raceway. Ninilchik River stock RW 20 was split into a raceway for Seldovia, a raceway for another stocking project, and the remaining fish were designated for Halibut Cove. A comparison of the combined hatchery inventory estimates relative to the combined mark-recapture estimates at release is located on Table 18. The two estimates are within 5% for three of the four groups and within 10% for the remaining group. This indicates that the electronic eyed egg count and the estimated survival to fry from the eyed egg stage were fairly accurate.

The six raceways in which all fish were enumerated through tagging or bulk weighing had hatchery inventory estimates relative to mark-recapture estimates ranging from 88.5% to 109.3%. This indicates inconsistent errors have been made in estimating the number of fish moved via bulk weighing. Data show that four of the six raceways in which all of the fish were enumerated through the coded wire tagging process and bulk weighing method had hatchery inventory estimates which were less than the mark-recapture estimate (Table 9). This indicates that for these four raceways the number of fish moved via the bulk weighing method was underestimated. Overestimating the average weight of one fish or other errors in bulk weighing could result in underestimating the number of fish moved.

Table 18.-A comparison of hatchery inventory and mark-recapture population estimates for four groups of raceways that were split into two or more raceways during rearing.

	Crooked Creek RW's 8 and 17	Ship Creek RW's 6 and 15	Halibut Cove and Seldovia	Homer Spit RW's 9 and 16
HI[a] at release	212,137	225,874	210,080	205,211
MR[b] at release	193,180	231,444	216,003	204,085
HI relative to MR	109.8%	97.6%	97.3%	100.6%

[a] HI = Hatchery Inventory

[b] MR = Mark-recapture

All four raceways at EH in which the inventory number was the estimated fry inventory number minus the estimated number of fish that were removed from the raceway through the coded wire tagging process and bulk weighing method had inventory estimates relative to mark-recapture estimates ranging from 105.4% to 114.8%. The overestimated inventory estimate when compared to the mark-recapture estimates indicates fewer fish remained in the raceway following the split than the inventory records indicated. This is consistent with the idea that more fish are removed during the splitting process than realized, leaving behind fewer fish. If the original raceway and the one that was split into are part of the same release group, then the number of fish released are the same regardless of the split (Crooked Creek, Ship Creek, and Homer Spit Early). If the original raceway and the one that was split into are two different release groups, then one release group may contain more fish and the other release group contain fewer fish than what the inventory records indicate (RW 20 was split into Seldovia and Halibut Cove release groups).

The water volume estimate was higher than the hatchery inventory estimate for eight of the 10 raceways at EH. Both estimates were within 5% of each other for nine of 10 raceways. For these nine raceways, the water volume estimate and the inventory estimate were either both higher than the mark-recapture estimate or both lower than the mark-recapture estimate. RW 9 Homer Spit early-run chinook salmon smolt was the exception to this.

Two raceways of coho salmon smolt at FRH that were tagged with the same tag code were stocked as the Anchorage Urban Streams release group. Ship Creek and Campbell Creek are the two release sites for the Anchorage Urban Streams release group. All fish from one raceway plus a portion of fish from a second raceway were released at Ship Creek. The remaining fish in the second raceway were released at Campbell Creek. A mark-recapture estimate was performed on each raceway prior to the release. Water volume estimates were performed separately for the Ship Creek portion and the Campbell Creek portion of the second raceway, and the two individual water volume estimates were added together to obtain a total water volume estimate for the raceway (Table 19). Using the water volume estimates, the percentage of the second

Table 19.-Water volume and mark-recapture estimates for coho salmon smolt reared in RW E2 and released at Campbell Creek and Ship Creek.

	Anchorage Urban RW E2	Campbell Creek	Ship Creek
Water Volume Estimate	157,103	77,346	79,757
Percent of total population	100%	49.2%	50.8%
Mark-Recapture Population Estimate	156,050	76,828	79,222
Number of marked fish in population	46,665	22,974	23,691

raceway stocked at each location was determined. That percentage was applied to the mark-recapture estimate for the raceway in order to determine the estimated number of fish stocked in each location as well as the estimated number of marked fish stocked in each location.

FRH and EH have come to rely on the water volume technique to produce easily obtained release numbers. Unfortunately, a comparison of this method to the mark-recapture method shows that the differences in the population estimates are inconsistent, that sometimes the water volume estimates are higher than the mark-recapture population estimates, and sometimes they are lower. 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.

The water volume estimates at FRH were close to the hatchery inventory estimates for all seven of the raceways (WV relative to HI 96.2% to 107.0%) and higher than the mark-recapture estimates for all seven of the raceways (WV relative to MR 100.7% to 123.6%). Accuracy and precision could possibly be improved by improving on their bulk weighing techniques. 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. Increasing the subsample size to 50% of a full net load to determine the mean weight of one fish may provide more accurate hatchery inventory estimates.

Technology associated with mechanical enumeration of fish is constantly evolving. Using a mechanical counter to count the number of fish in a subsample could improve the accuracy of the hatchery inventory technique at Fort Richardson and Elmendorf hatcheries enough to make it an acceptable technique for easily obtaining accurate estimates of release numbers.

SIZE ESTIMATION

In a previous report, 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 Bird Creek and Wasilla Creek and the coho salmon smolt in one of the two Anchorage urban streams raceways were all close to achieving the size range production goal with approximately 78% of the smolt in each release group or raceway within the desired size range. The marine survival rates for these release groups should be at anticipated levels. One raceway of the Anchorage urban streams release group achieved the goal with 83.66% of its fish between 15.1 g and 25.0 g.

The suggested hatchery 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 at FRH nearly achieved the production goal with 79.1% of the smolt within the desired size range The Willow Creek chinook salmon release group at FRH nor any of the chinook salmon release groups at EH achieved the production goal. The majority of the fish in six of the seven chinook salmon release groups at EH were larger than 15.0 g. The majority of fish in both chinook salmon release groups at FRH were between 5.1 g and 15.0 g, but the Willow Creek release group contained significant numbers of fish greater 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 feel the mark-recapture estimates produce the most accurate and precise enumeration estimate of the three techniques measured. However, not all release groups from the hatchery contain marked fish. Consequently, this technique is not applicable to many hatchery releases. The mark-recapture technique should be used to estimate releases of all groups containing fish which are coded wire tagged.
2. The methods used for obtaining unbiased samples for tagging and for mark-recapture population estimates need to be improved. Small fish are more readily caught than large fish. Biased samples will result in erroneous mark-recapture estimates. To avoid this bias, a systematic method of sampling should be developed based on the percentage of fish to be tagged in each raceway.
3. 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.
4. The hatchery inventory estimates produced the least precise estimates of the three techniques measured. At EH the major 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. We suggest that bulk weighing entire raceways instead of relying on fry estimates would increase the accuracy of hatchery inventory estimates at EH. At FRH, the major problem associated with the hatchery inventory estimates appears to be the calibration of nets to determine the mean weight of a fish in a loaded net. Subsampling partial net loads does not appear to be accurate. Increasing the sample size to 50% of a full net load may result in more accurate hatchery inventory estimates at FRH and EH. If a better method of calibrating net loads of fish can be developed, this technique may be a better method for estimating hatchery release numbers than water volume displacement.

5. Mechanical enumeration should be explored. New technology for mechanically enumerating fish is constantly evolving. There may be a product on the market which can be used to enumerate hatchery fish prior to release or can be used to calibrate hatchery inventory estimates.
6. 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.
7. Elmendorf Hatchery chinook salmon planted in Ship Creek, Crooked Creek, Homer Spit late, Homer Spit early, Halibut Cove, and Seldovia had a high percentage of fish (> 50%) which were larger than the desired size range. 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.
8. Fort Richardson Hatchery coho salmon smolt planted in both Anchorage urban streams, Bird Creek, and Wasilla 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.
9. Fort Richardson Hatchery chinook salmon smolt planted in the Ninilchik River were close to achieving the size range production goal (79.1%). Chinook salmon smolt planted in Willow Creek had a high percentage of fish (> 36%) which were larger than the desired size range. The marine survival rates for these release groups should 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.

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APPENDIX A. HISTORICAL RELEASES OF ADIPOSE FINCLIPPED AND CODED WIRE TAGGED HATCHERY CHINOOK AND COHO SALMON SINCE 1992

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

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	29.5%

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

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	39.5%
1991	Little Susitna	Ft. Richardson	1993	31-21-39	140,382	43,441	42,350	30.2%
1992	Little Susitna	Ft. Richardson	1994	31-23-02	84,643	45,220	44,686	52.8%
1993	Little Susitna	Ft. Richardson	1995	31-23-37	154,753	45,666	45,490	29.4%
1994	Little Susitna	Ft. Richardson	1996	31-25-04	147,618	46,528	45,411	30.8%

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

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

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	40.6%
1991	Little Susitna	Ft. Richardson	1993	31-21-38	140,797	43,440	42,916	30.5%
1992	Little Susitna	Ft. Richardson	1994	31-23-03	87,686	44,144	42,963	49.0%
1993	Little Susitna	Ft. Richardson	1995	31-23-36	157,241	45,655	44,995	28.6%

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

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

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

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	61.1%
1991	Fish Creek	Big Lake	1993	31-21-41	74,198	43,117	40,875	55.1%

[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.

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	58.2%
1991	Fish Creek	Big Lake	1993	31-21-40	67,934	44,050	43,257	63.7%

[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.

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	12.7%
1991	Little Susitna	Ft. Richardson	1993	31-21-37	148,282	21,404	20,312	13.7%

[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.

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	12.1%
1991	Little Susitna	Ft. Richardson	1993	31-21-37	131,591	21,001	19,930	15.2%
1992	Little Susitna	Ft. Richardson	1994	31-23-01	126,694	44,489	43,818	34.6%
1993	Little Susitna	Ft. Richardson	1995	31-23-39	151,985	46,261	45,245	29.8%

[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.

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	57.2%
1991	Ship Creek	Elmendorf	1993	31-21-36	54,764	42,112	41,322	75.5%
1992	Ship Creek	Elmendorf	1994	31-23-04	75,779	44,031	41,722	55.1%
1993	Little Susitna	Ft. Richardson	1995	31-23-38	158,981	45,491	44,654	28.1%

Note: In 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 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.

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	55.0%
1991	Fish Creek	Big Lake	1992	31-21-42	77,174	43,001	41,711	54.1%
1994	Little Susitna	Ft. Richardson	1996	31-25-05	145,923	46,980	46,839	32.1%

[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.

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	48.7%
1995	Willow Creek	Elmendorf	1996	31-25-09	113,220	41,259	40,681	35.9%

[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.

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	19.1%
1994	Homer (Crooked Cr)	Elmendorf	1995	31-24-27	184,049	40,903	38,420	20.9%
1995	Homer (Crooked Cr)	Elmendorf	1996	31-25-12	193,180	40,827	40,196	20.8%

[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.

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	42.1%

[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.

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	21.3%
1994	Ninilchik River	Elmendorf	1995	31-24-30	37,577	36,944	36,700	97.7%
1995	Ninilchik River	Elmendorf	1996	31-25-11	97,729	40,688	39,345	40.3%

[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.

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	15.6%
1994	Homer (Crooked Cr)	Elmendorf	1995	31-24-32	216,026	41,650	40,291	18.7%
1995	Homer (Crooked Cr)	Elmendorf	1996	31-25-07	204,085	40,868	39,017	19.1%

[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.

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%

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

Appendix A16.-Historical releases into Ninilchik River of chinook salmon marked with adipose finclips and tagged with coded wire.

Brood Year	Brood Stock	Hatchery	Release Year	CWT Code	Total Released[ab]	Marked Fish Released[b]	Tagged Fish Released[b]	Percent Tagged
1991	Ninilchik River	Ft. Richardson	1992	31-21-04	132,387	43,648	41,335	31.2%
1992	Ninilchik River	Ft. Richardson	1993	31-21-59	184,585	44,487	42,960	23.3%
1993	Ninilchik River	Ft. Richardson	1994	31-23-18	201,513	46,193	45,535	22.6%
1994	Ninilchik River	Ft. Richardson	1995	31-24-35	54,662	54,662	54,115	99.0%
1995	Ninilchik River	Ft. Richardson	1996	31-25-15	51,688	51,588	50,866	98.6%

[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 A17.-Historical releases into Seldovia of chinook salmon marked with adipose finclips and tagged with coded wire.

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	42.4%
1994	Homer (Crooked Cr)	Elmendorf	1995	31-24-29	116,165	41,609	40,678	35.0%
1995	Ninilchik River	Elmendorf	1996	31-25-10	118,274	40,667	39,610	33.5%

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

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

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	21.5%
1994	Ship Creek	Elmendorf	1995	31-24-28	218,487	40,764	38,570	17.7%
1995	Ship Creek	Elmendorf	1996	31-25-08	231,444	41,221	40,109	17.3%

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

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

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	18.6%
1992	Willow Creek	Ft. Richardson	1993	31-21-60	160,194	42,782	39,420	24.6%
1993	Willow Creek	Ft. Richardson	1994	31-23-17	177,913	46,289	45,921	25.8%
1994	Willow Creek	Ft. Richardson	1995	31-24-34	184,740	46,807	46,256	25.0%
1995	Willow Creek	Ft. Richardson	1996	31-25-14	186,918	47,700	47,145	25.2%

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