Fishery Data Series No. 96-15

Marking, Enumeration, and Size Estimation of Coho and Chinook Salmon Smolt Releases into Upper Cook Inlet, Alaska in 1995

by

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and

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July 1996

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

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by

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ABSTRACT

Southcentral Alaska contains the majority of the state's human population and receives the vast majority of the state's fishing pressure, both of which are increasing. To meet the growing demand on the sport fishery resource, hatchery-reared chinook salmon and coho salmon smolt have been stocked in numerous locations throughout Southcentral Alaska to improve or create terminal sport fisheries.

Over 495,000 coho *Oncorhynchus kisutch* and chinook salmon *Oncorhynchus tshawytscha* smolt released at 11 locations in Cook Inlet were marked with an adipose finclip and a coded wire tag. Tag retention ranged from 93.9% to 99.6%. About 70% of the coho salmon smolt produced at Ft. Richardson Hatchery for release into Ship Creek, Campbell Creek, and Nancy Lake were within the desired size range of 15.1 g to 25.0 g. Only 49.9% of the Bird Creek release group were in that size range and 48.4% were larger than 25 g. Late-run Homer Spit chinook salmon smolt produced at Elmendorf Hatchery achieved the production goal, with 90% of the smolt within the desired size range of 5.1 g to 15.0 g. None of the remaining chinook salmon release groups at Elmendorf Hatchery, nor the chinook salmon release groups at Ft. Richardson 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. The water volume estimate was the highest estimate in most instances at one hatchery, and the hatchery inventory estimate was the highest estimate in most instances at the other hatchery. The difference between mark-recapture and water volume estimates were not consistent for all groups. The difference between the mark-recapture estimate and the hatchery inventory estimate was consistent for most groups at each hatchery.

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

INTRODUCTION

Southcentral Alaska contains the majority of the state's human population and receives the vast majority of the state's fishing pressure, both of which are increasing (Howe et al. 1995). 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.

Until 1992, each hatchery was unique in how it produced, marked, released, collected data, and reported information about stocked fish. Since 1992, marking and release of fish has been monitored and standardized at each hatchery (Peltz and Starkey 1993; Peltz and Hansen 1994). 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. Four coho salmon smolt stocking projects using fish produced at the Fort Richardson hatchery (FRH) have been combined to form the Anchorage 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 coho salmon in the Little Susitna River (Nancy Lake release group), and 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, Kodiak and Seldovia. Chinook salmon smolt released at Willow Creek and Ninilchik River were tagged at FRH, and chinook salmon smolt released at Ship Creek, Kodiak, Crooked Creek, Homer Spit, Halibut Cove, and Seldovia were tagged at Elmendorf Hatchery (EH).

Blankenship (1990) found that tag loss ranged from 1.45% to 5.13% in four comparable groups of coho and chinook salmon tagged in Washington. 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. 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 1993 indicated a variation of up to 23.9% between two different hatchery release estimation techniques (Peltz and Hansen 1994). 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;
4. To determine if a relationship exists between tag application rate and long-term tag retention rate.

The goal of this project was to mark approximately 495,000 of the projected 1,900,000 coho and chinook salmon smolt to be stocked in 1995 with an adipose finclip and a coded wire tag. This entailed marking a representative sample of at least 40,000 coho or chinook salmon smolt from each of the 13 Cook Inlet release groups (Meyer et al. *Unpublished*).

Marking of smolt and collection of release data at the Elmendorf and Fort Richardson hatcheries were standardized for each of the stocking projects in 1995. This report presents the results of the 1995 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 Ship Creek, Homer/Crooked Creek, Ninilchik River, Willow 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 Cook Inlet in 13 release groups. 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 40,000 smolt to be tagged from each release group was dip netted and held separate from the remaining fish in the release group before tagging was initiated. All of the smolt in the Ninilchik River chinook salmon smolt release group were marked and tagged. A raceway with approximately 200,000 Ninilchik River chinook salmon smolt was crowded, and approximately 55,000 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 1 day of marking was dip netted and held separate from the rest of the release group in net pens. If fish for a particular release group were in more than one raceway, 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 mm) using a Northwest Marine Technology Mark IV tagging unit. All of the marked smolt from release groups in 1995 were graded and tagged with the appropriate size head mold. A minimum of 510 fish were obtained from each brood 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 back 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.

Following tag placement, fish were sent through a Quality Control Device (QCD). The QCD detects the magnetized tag and separates 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 five 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 killed to determine tag placement was subtracted from the daily number of tagged fish and was 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

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

Hatchery	Species	Stocking Site	Brood Stock	Number Stocked[a]	Number of Raceways	Number Marked per Raceway	Number to Examine per Raceway per Experiment	Number Mark-Recapture Experiments	Precision
Elmendorf	Chinook	Ship Creek	Ship Creek	124,430	2	21,423	7,250	1	±5
				122,169		19,999	7,500	1	±5
		Crooked Creek	Homer/Crooked Creek	102,788	2	21,910	5,500	3	±5
				108,367		19,317	6,750	1	±5
		Homer Spit Early	Homer/Crooked Creek	106,945	2	21,952	5,750	1	±5
				105,783		19,991	6,250	3	±5
		Seldovia	Homer/Crooked Creek	104,447	1	41,711	2,500	3	±5
		Halibut Cove	Ninilchik River	37,208	1	37,208		0	±0
		Kodiak	Willow Creek	88,739	1	41,810	1,750	1	±5
		Homer Spit Late	Homer/Kasilof River	119,068	1	41,169	3,000	1	±5
Fort Richardson	Coho	Nancy Lake	Little Susitna River	163,983	1	45,580	4,000	3	±5
		Bird Creek	Little Susitna River	162,585	1	45,771	4,000	1	±5
		Campbell Creek	Little Susitna River	163,955	1	45,743	4,000	1	±5
		Ship Creek	Little Susitna River	162,870	1	46,334	4,000	3	±5
	Chinook	Willow Creek	Willow Creek	210,000	1	47,091	5.250	3	±5
		Ninilchik River	Ninilchik River	55,105	1	55,105		0	±0
Totals				1,938,442		572,114			

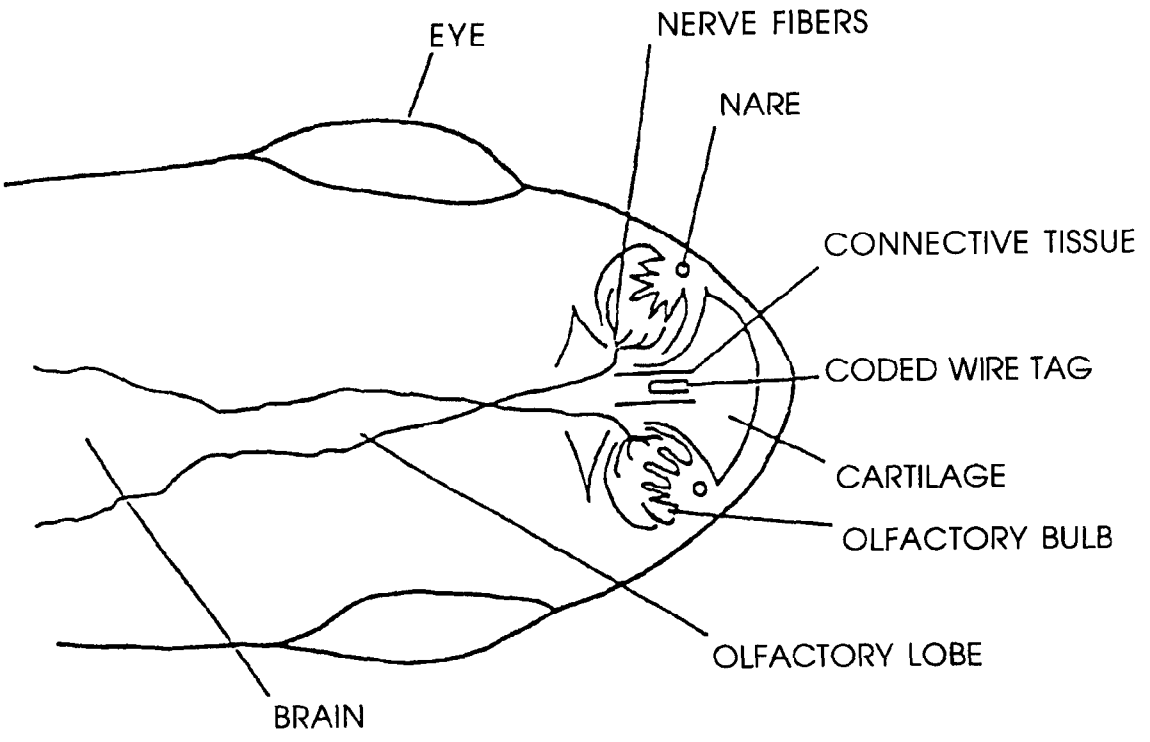
[a] Number stocked based on hatchery inventory

Table 2.-Summary of coded wire tagging data at Fort Richardson Hatchery for coho salmon smolt stocked at four locations in Cook Inlet in 1995.

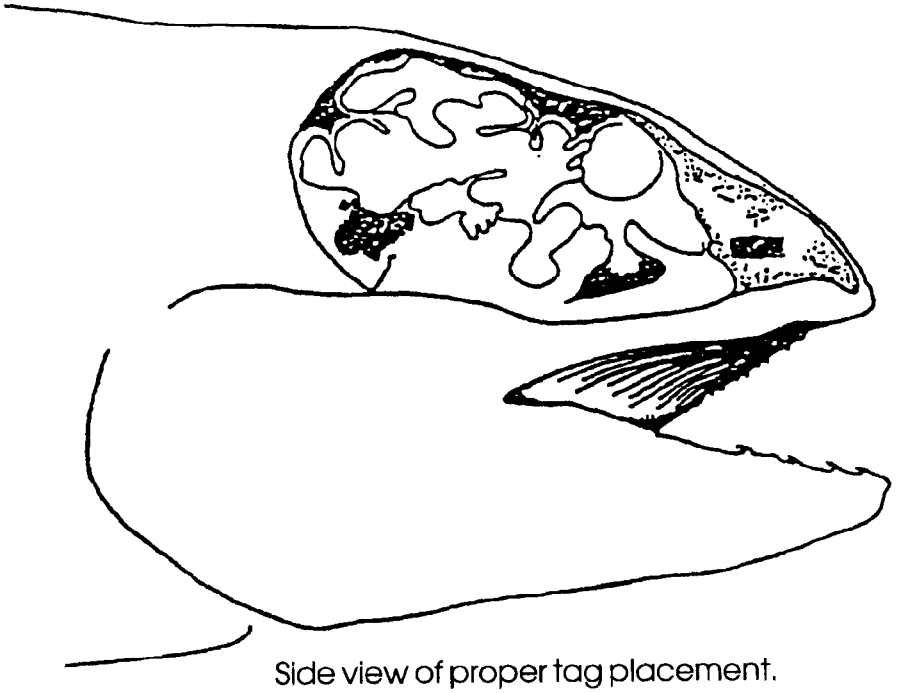
Parameter	Bird Creek E2	Campbell Creek E2	Nancy Lake E4	Ship Creek E3	Totals
Tag Codes	31-23-37	31-23-36	31-23-39	31-23-38	
Total marked and tagged	45,743	45,771	46,334	45,580	183,428
Mortalities	77	116	73	89	
Marked fish released	45,666	45,655	46,261	45,491	183,073
Tag retention sample size	777	761	774	761	
Tag retention at release	99.6%	98.6%	97.8%	98.2%	
Tag retention variance	4.956E-06	1.874E-05	0.00003	0.00002	
Tagged fish released	45,490	44,995	45,245	44,654	180,384
Tagged fish variance	10,336	39,070	59,472	49,172	
Total fish released for mark-recapture estimate	154,753	157,241	151,985	158,981	622,960
Percent tagged	29.5%	29.0%	30.4%	28.6%	29.0%
Tagging dates	11/10/94 11/17/94	10/19/94 10/26/94	10/26/94 11/02/94	11/03/94 11/09/94	
Date of tag retention check	5/19/95	5/19/95	5/17/95	5/18/95	
Days elapsed	183	205	196	190	

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 1995.

	Fort Richardson		Elmendorf										
Parameter	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14	TOTALS
Tag Codes	31-24-34	31-24-35	31-24-27	31-24-27	31-24-28	31-24-28	31-24-29	31-24-30	31-24-31	31-24-32	31-24-32	31-24-33	
Total marked and tagged	47,091	55,105	21,910	19,317	21,423	19,999	41,711	37,208	41,810	21,952	19,991	41,169	388,686
Mortalities	284	203	201	123	174	484	102	264	238	135	158	115	
Marked fish released	46,807	54,902	21,709	19,194	21,249	19,515	41,609	36,944	41,572	21,817	19,833	41,054	386,205
Tag retention sample size	764	769	776	778	777	776	760	758	758	771	784	768	
Tag retention at release	98.8%	99.0%	94.6%	93.2%	92.3%	97.2%	97.8%	99.3%	98.8%	97.0%	96.4%	98.6%	
Tag retention variance	0.00002	0.00002	0.00007	0.00008	0.00009	3.55E-05	0.00003	0.00001	1.55E-05	3.759E-05	4.4E-05	1.84E-05	
Tagged fish released	46,256	54,331	20,534	17,886	19,608	18,962	40,678	36,700	41,078	21,166	19,125	40,466	376,790
Tagged fish variance	33,427	45,989	31,131	30,100	41,461	13,536	49,882	11,815	26,785	17,890	17,301	31,023	
Total fish released for mark recapture estimate	184,740	54,902	90,473	93,576	118,201	100,286	116,165	37,577	84,349	110,764	105,262	123,048	1,219,343
Percent tagged	25.3%	100.0%	24.0%	20.5%	18.0%	19.5%	35.8%	98.3%	49.3%	19.7%	18.8%	33.4%	30.9%
Tagging dates	3/06/95 3/10/95	3/13/95 3/22/95	1/17/95 1/18/95	2/17/95 2/22/95	1/19/95 1/20/95	1/23/95 1/24/95	2/13/95 2/16/95	1/30/95 2/2/95	1/25/95 1/30/95	1/11/95 1/13/95	1/09/95 1/11/95	2/22/95 2/28/95	
Date of tag retention check	5/22/95	5/26/95	6/2/95	6/5/95	5/23/95	6/6/95	6/1/95	6/12/95	5/25/95	6/9/95	6/8/95	6/14/95	
Days elapsed	73	65	104	103	123	133	105	130	115	147	148	106	



Top view of proper placement of coded wire tag in fish's head.



Side view of proper tag placement.

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

recorded. Short-term tag 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:

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

where:

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

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

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

Once all tagging for a raceway 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 raceway, a minimum of 750 marked fish (adipose clipped) were randomly sampled from the population. Each of the 750 marked fish were passed through a QCD to estimate long-term tag retention. All fish having no tag were passed through the QCD again to verify the absence of a tag. 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 estimated as a binomial proportion (formulas 1 and 2) for each group,

where:

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

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

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

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

and its variance as:

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

where:

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

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

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

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, and work breaks 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 were calculated as:

$$TWH_j = \frac{\hat{T}_j}{W_j}; \quad (5)$$

and

$$Var\left(TWH_j\right) = \left[\frac{1}{W_j}\right]^2 Var\left(\hat{T}_j\right); \quad (6)$$

where:

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

A scatterplot was used to determine if TWH_j and long-term tag retention rates of release groups were related.

SMOLT ENUMERATION

The number of smolt in each group released from EH and 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. 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 release groups at FRH as well as three release groups 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 prior to release using a Chapman modified Petersen model (Seber 1982). The estimate of abundance at the time of release was calculated as:

$$\hat{N} = \frac{\left(n_1+1\right)\left(n_2+1\right)}{m_2+1} - 1; \quad (7)$$

with variance:

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

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 could not test the third assumption, the second sampling event just prior to release should have allowed 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 estimate at EH for the Halibut Cove chinook salmon smolt release group was established upon completion of marking. An attempt was made to tag 100% of the fish in the Halibut Cove release group. The number of fish tagged in this release group was recorded as the hatchery inventory estimate. Mortalities were monitored on a daily basis and subtracted from the inventory count to yield a final hatchery inventory estimate for the release group.

Hatchery inventory estimates at EH for the other chinook salmon releases were based on an electronic count of eggs. At the eyed-egg stage in mid-August all dead eggs were electronically removed and 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. 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 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. The inventory estimate on the day the fish were released was the reported number of fish released.

Fort Richardson Hatchery

The hatchery inventory estimate at FRH for chinook salmon smolt to be 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 the release group.

Hatchery inventory estimates at FRH for coho salmon smolt to be stocked at Ship Creek, Nancy Lake, Bird Creek and Campbell Creek, and for chinook salmon smolt to be stocked at Willow Creek were established when fry were moved from small indoor raceways to large outdoor raceways.

Each small raceway was crowded and a 4.7 x 4.7 x 4.7 cm 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. 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 10 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:

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

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:

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

The number of fish released from an outdoor raceway was the estimate (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, 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 estimated mean weight by obtaining subsamples from five nets of fish as they were loaded into the tanks. Each net of fish was split in half several times until the desired subsample size was achieved. The fish were poured into a preweighed bucket of water, weighed to the nearest gram, and counted out of the bucket. Mean weight was calculated for each of the five samples, and an overall mean weight was calculated by summing the five sample mean weights and dividing by the sum of the fish sampled.

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

RESULTS

SMOLT MARKING

About 183,000 coho salmon and 386,000 chinook salmon smolt for release at 11 locations in Cook Inlet were marked in 1995 (Tables 2 and 3). This number exceeded the project goal by more than 14%. The goal of marking and tagging a minimum of 40,000 smolt per release group was achieved for 12

of the 13 release groups. The small size of the Halibut Cove release group limited the number of marked fish to 37,208.

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 in each of the two raceways of Crooked Creek chinook salmon smolt was 24.0% and 20.5%, 18.0% and 19.5% for the two raceways of Ship Creek chinook salmon smolt, and 19.7% and 18.8% for the two raceways of Homer Spit early-run chinook salmon (Table 3).

Long-term tag retention was checked after the prescribed 30-day waiting period for all release groups. Waiting periods ranged from 65 days to 205 days, with 14 of the 16 raceways having waiting periods in excess of 100 days. Tag retention for the release groups ranged from 92.3% to 99.6% (Tables 2 and 3). An estimated 622,960 coho salmon and 1,219,343 chinook salmon smolt were released (Tables 2 and 3), which was 3.3% fewer fish than planned. The percentage of the total release which was marked ranged from 16.5% to 100%.

Tag application rates varied among raceways (Tables 4 and 5). Mean valid tag application rate was 230.35 TWH. Rates varied from 201.3 TWH for the Homer Spit RW 10 release group to 271.6 TWH for the Bird Creek release group. Long-term tag retention ranged from 92.3% for the Ship Creek RW 6 chinook salmon smolt release to 99.6% for the Bird Creek coho salmon smolt release. Tagging rates for coho salmon raceways were similar to tagging rates for most chinook salmon raceways. Three of the five slowest tag application rates for chinook salmon corresponded to three of the four lowest long-term tag retention rates for chinook salmon. Although data points are limited, tag application rates of 220 to 250 TWH appear to produce long-term tag retention rates of 97% or greater in coho and chinook salmon (Figure 2).

SMOLT ENUMERATION

Mark-Recapture Estimates

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

No significant differences were detected among the three mark-recapture estimates in five of the six release groups (Tables 6 and 7; Figure 3). Only the early-run Homer Spit release group 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 8,709 g (Bird Creek) to 9,670 g (Nancy Lake) (Table 8). Willow Creek chinook salmon smolt had a mean bucket weight of about 5,879 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

Table 4.-Numbers of fish coded wire tagged, tag application rates, tag codes, and tag retention rates for coho salmon release groups at Elmendorf and Fort Richardson hatcheries in 1995.

	Bird Creek	Campbell Creek	Nancy Lake	Ship Creek
Tag Codes	31-23-37	31-23-36	31-23-39	31-23-38
Total valid tags	45,490	44,995	45,245	44,654
Worker hours per tag code	167.5	200.0	203.0	177.0
Tags per worker hour	271.6	225.0	222.9	252.3
Tags/worker hour Standard Error	0.607	0.988	1.201	1.253
Short-term tag retention	100.0%	99.6%	99.5%	99.7%
Long-term tag retention	99.6%	98.6%	97.8%	98.2%
Tag loss	0.4%	1.0%	1.7%	1.5%
Days elapsed	183	205	196	190

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 1995.

	Fort Richardson		Elmendorf									
	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14
Tag Codes	31-24-34	31-24-35	31-24-27	31-24-27	31-24-28	31-24-28	31-24-29	31-24-30	31-24-31	31-24-32	31-24-32	31-24-33
Total valid tags	46,256	54,331	20,534	17,886	19,608	18,962	40,678	36,700	41,078	21,166	19,125	40,466
Worker hours per tag code	210.0	253.5	90.0	85.5	90.0	81.0	172.5	149.0	162.0	90.0	95.0	186.0
Tags per worker hour	220.3	214.3	228.2	209.2	217.9	234.1	235.8	246.3	253.6	235.2	201.3	217.6
Tags/worker hour Standard Error	0.871	0.846	1.960	2.029	2.262	1.436	1.295	0.729	2.459	1.486	1.385	0.947
Short-term tag retention	100.0%	99.8%	98.0%	98.9%	97.8%	99.5%	99.4%	100.0%	100.0%	100.0%	99.0%	99.5%
Long-term tag retention	98.8%	99.0%	94.6%	93.2%	92.3%	97.2%	97.8%	99.3%	98.8%	97.0%	96.4%	98.6%
Tag loss	1.2%	0.8%	3.4%	5.7%	5.5%	2.3%	1.6%	0.7%	1.2%	3.0%	2.6%	0.9%
Days elapsed	73	65	104	103	123	133	105	130	115	147	148	106

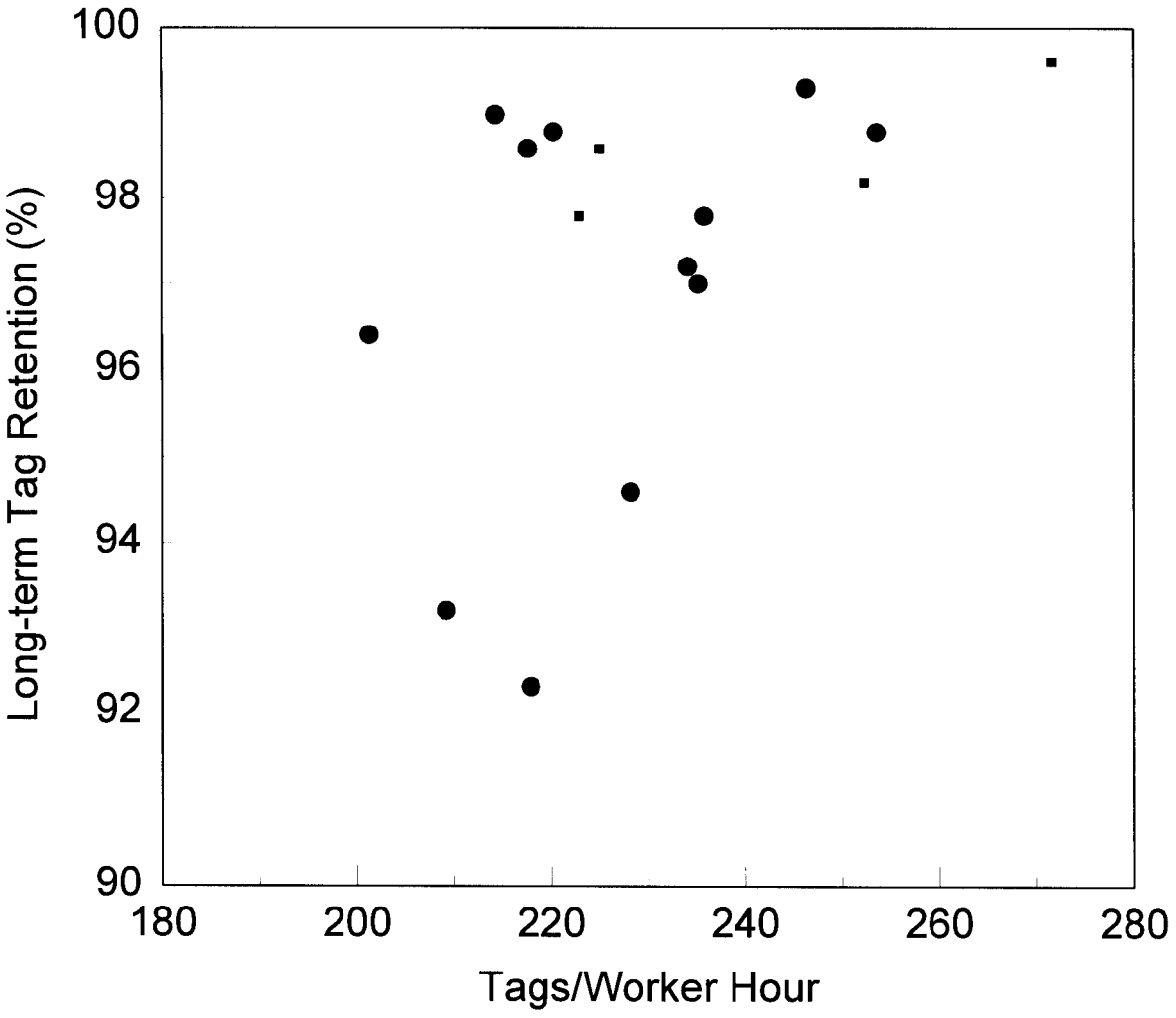


Figure 2.-Comparison of tag application rates to long-term tag retention rates for 16 coho (squares) and chinook salmon (circles) raceways from Elmendorf and Fort Richardson hatcheries in 1995.

Table 6.-Mark-recapture estimates for four Cook Inlet coho salmon smolt releases from Fort Richardson Hatchery in 1995.

	Bird Creek E2	Campbell Creek E1	Nancy Lake E4	Ship Creek E3
Mark/Recapture Estimate #1	154,753	157,241	150,219	167,052
Standard Error	3,714	3,819	3,508	4,252
Upper 95% CI	162,032	164,727	157,095	175,387
Lower 95% CI	147,474	149,755	143,343	158,718
Mark/Recapture Estimate #2			154,905	157,941
Standard Error			3,604	3,549
Upper 95% CI			161,970	164,898
Lower 95% CI			147,840	150,984
Mark/Recapture Estimate #3			150,781	153,309
Standard Error			3,272	3,445
Upper 95% CI			157,193	160,061
Lower 95% CI			144,368	146,557
Estimates Pooled	154,753	157,241	151,985	158,981
Standard Error	3,714	3,819	1,996	2,149
Upper 95% CI	162,032	164,727	155,898	163,193
Lower 95% CI	147,474	149,755	148,072	154,768

Table 7.-Mark-recapture estimates of nine Cook Inlet chinook salmon smolt releases from Elmendorf and Fort Richardson hatcheries in 1995.

	Fort Richardson		Elmendorf									
	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14
Mark/Recapture Est #1	181,752		93,646	93,576	118,201	100,286	118,254	37,577	84,349	110,764	100,306	123,048
Standard Error	4,172		2,226	2,159	2,870	2,250	3,162	175	1,944	2,853	2,472	3,045
Upper 95% CI	189,929		98,008	97,807	123,826	104,696	124,452	37,920	88,160	116,356	105,151	129,016
Lower 95% CI	173,575		89,284	89,345	112,576	95,876	112,056	37,234	80,538	105,173	95,462	117,079
Mark/Recapture Est #2	180,699		89,875				119,911				111,940	
Standard Error	3,986		1,942				3,182				2,800	
Upper 95% CI	188,511		93,683				126,147				117,428	
Lower 95% CI	172,887		86,068				113,674				106,451	
Mark/Recapture Est #3	191,375		88,642				110,940				103,814	
Standard Error	4,285		1,752				2,686				2,216	
Upper 95% CI	199,774		92,075				116,204				108,157	
Lower 95% CI	182,976		85,209				105,676				99,470	
Mark/Recapture Estimate Pooled	184,740		90,473	93,576	118,201	100,286	116,165	37,577	84,349	110,764	105,262	123,048
Standard Error	2,394		1,129	2,159	2,870	2,250	1,732	175	1,944	2,853	1,427	3,045
Upper 95% CI	189,433		92,685	97,807	123,826	104,696	119,559	37,920	88,160	116,356	108,059	129,016
Lower 95% CI	180,048		88,260	89,345	112,576	95,876	112,770	37,234	80,538	105,173	102,465	117,079

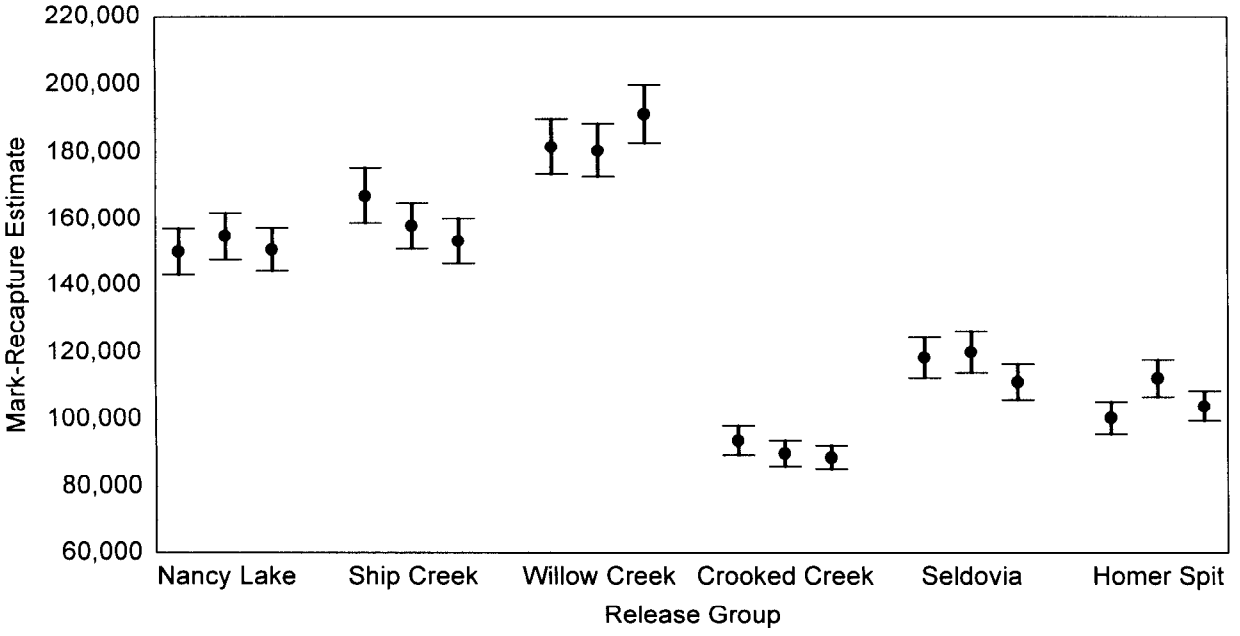


Figure 3.-Comparison of 95% confidence intervals for mark-recapture estimates conducted three times for six release groups of coho and chinook salmon in 1995.

Table 8.-Hatchery inventory data and hatchery inventory population estimates for five groups of coho and chinook salmon smolt released from the Fort Richardson Hatchery in 1995.

	Coho Salmon				Chinook Salmon
Parameter	Bird Creek	Campbell Creek	Nancy Lake	Ship Creek	Willow Creek
Containers of fish moved	63	61	57	56	174
Total fish weight moved (g)	548,648	547,543	551,192	515,562	1,023,018
Mean weight/container (g)	8,709	8,976	9,670	9,206	5,879
Total number of subsamples	10	9	15	10	18
Total weight subsampled (g)	3,942	3,702	5,581	3,074	108,028
Percent of total weight moved which was subsampled	0.71%	0.67%	1.00%	0.59%	9.55%
Percent of individual net which was subsampled	13.6%	13.8%	11.7%	9.4%	100%
Mean weight/subsample (g)	394	411	372	307	6,002
Total number of fish counted	1,192	1,116	2,854	924	23,185
Number of fish/subsample	119	124	190	92	1,288
Estimated number of fish enumerated by bulk weighing	165,229	165,228	165,681	165,874	220,931
Total number of fish placed in raceway at release[a]	163,848	162,464	162,773	163,859	220,374
Standard Error	1,723	2,032	1,254	1,483	1,525
Upper 95% CI	167,226	166,445	165,231	166,765	223,364
Lower 95% CI	160,470	158,482	160,315	160,953	217,385

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

load of coho salmon ranged from 2,903 g (Bird Creek) to 3,223 g (Nancy Lake). Likewise, the mean weight of a net load of chinook salmon was 1,560 g at Willow Creek. The coho salmon subsamples were 9.4% to 11.7% of a full net load. The mean weights of the coho salmon subsamples varied from 307 g to 411 g, and the mean number of fish in a subsample varied from 92 to 190 fish. Subsample size for the Willow Creek chinook salmon was increased to 100% of a full net load. The mean weight of the Willow Creek chinook salmon subsamples was 6,002 g, and the mean number of fish in a subsample was 1,288 fish.

The inventory estimates at EH for chinook salmon release groups were 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 were 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 47.0%. The percentage of fish enumerated into individual raceways via the bulk weighing method ranged from 0% to 82.8%. The percentage of fish enumerated from a raceway during the coded wire tagging process ranged from 0% to 16.7%. The percentage of fish enumerated from a raceway via the bulk weighing method ranged from 0% to 45.7%.

The inventory estimates for three of the raceways were determined entirely by subtracting the estimated number of fish removed from the inventory estimate established at the fry stage. All three of these raceways had fish removed from them by the coded wire tagging process and bulk weighing. None of these three raceways had fish enumerated into them via the coded wire tagging process or the bulk weighing process. The tagged fish in these three raceways were tagged into the same raceway they were taken from. The tagging process did not affect the hatchery inventory for these raceways.

Water Volume Estimates

The water volume estimate was higher than the mark-recapture estimate for four of the five release groups at FRH for which there was a mark-recapture estimate, and for seven of the 10 release groups at EH (Tables 10 and 11). At FRH the difference between the water volume estimate and the mark-recapture estimate was greater for the chinook salmon release group than for the coho salmon release groups.

No trend was evident at either FRH or EH in the differences between the mark-recapture estimates and the water volume estimates (Figure 4), but the difference between 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 five of the six release groups at FRH, and 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. The Homer Spit late-run release group and the Bird Creek release group are exceptions to this. All three types of estimates for the Homer Spit late-run release group were extremely close. The water volume estimate and hatchery inventory estimate were within 3.3% of the mark-recapture estimate. The Bird Creek release group water volume estimate and hatchery inventory estimate were within 5.9% of the mark-recapture 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 in 1995.

	RW 16 Crooked Creek	RW 17 Crooked Creek	RW 6 Ship Creek	RW 15 Ship Creek	RW 8 Seldovia	Halibut Cove[c]	Kodiak	RW 9 Homer Spit Early	RW 10 Homer Spit Early	Homer Spit Late
Inventory number prior to splitting	252,280	277,110		247,312						
MR est. at release[a]	90,473	93,576	118,201	100,286	116,165	37,577	84,349	110,764	105,262	123,048
HI after split[b]	102,972	108,663	124,673	122,555	104,454	37,208	89,002	107,153	105,985	119,153
Number of fish enumerated into rearing unit via CWT process			21,423		41,711		41,810	21,952	19,991	41,169
Number of fish enumerated into rearing unit via weighing			103,250		62,743		47,192	85,201	85,994	77,984
Number of fish removed from rearing unit via CWT process	42,021	41,796		21,507						
Number of fish removed from rearing unit via weighing	107,287	126,651		103,250						
Percentage of fish enumerated into rearing unit via CWT process			17.2%		39.9%		47.0%	20.5%	18.9%	34.6%
Percentage of fish enumerated into rearing unit via weighing			82.8%		60.1%		53.0%	79.5%	81.1%	65.4%
Percentage of fish enumerated at eyed egg stage	100%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percentage of fish removed from rearing unit via CWT process	16.7%	15.1%		8.7%						
Percentage of fish removed from rearing unit via weighing	42.5%	45.7%		41.7%						
Difference MR est. to HI est. at release	13%	16%	5%	22%	-10%	-2%	5%	-5%	2%	-3%

[a] MR = mark-recapture.

[b] Mortalities have not been subtracted from the hatchery inventory (HI) estimate.

[c] All fish found in Halibut Cove raceway were tagged. Hatchery inventory is based on this number.

Table 10.-A comparison of mark-recapture population estimates to water volume and hatchery inventory estimates for coho salmon smolt produced at Fort Richardson Hatchery and stocked in four locations in Cook Inlet in 1995.

	Bird Creek E2	Campbell Creek E1	Nancy Lake E4	Ship Creek E3
MR Estimate[a]				
#1	154,753	157,241	150,219	167,052
#2			154,905	157,941
#3			150,781	153,309
Pooled MR Estimate	154,753	157,241	151,985	158,981
WV[b]	149,353	176,173	168,065	164,329
HI Estimate[c]	163,848	162,464	162,773	163,859
Difference MR to WV	-3.5%	12.0%	10.6%	3.4%
Difference MR Pooled to HI	5.9%	3.3%	7.1%	3.1%
Difference HI to WV	9.7%	-7.8%	-3.1%	0.3%

[a] MR = Mark-recapture.

[b] WV = Water Volume. Water volume estimate was computed using water displacement values at Fort Richardson of 1.8 kg/m3 for the boom truck tanks, 3.1 kg/m3 for the trailer tanks and 0.91 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 for chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked in eight locations in Cook Inlet in 1995.

	Fort Richardson		Elmendorf									
	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak[a]	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14
MR Estimate[b]												
#1	181,752		93,646	93,576	118,201	100,286	118,254	37,577	84,349	110,764	100,306	123,048
#2	180,699		89,875				119,911				111,940	
#3	191,375		88,642				110,940				103,814	
Pooled Estimate	184,740		90,473	93,576	118,201	100,286	116,165	37,577	84,349	110,764	105,262	123,048
WV Estimate[c]	222,551	63,986	109,405	99,256	121,328	108,471	112,804	35,981	84,800	108,002	119,796	125,160
HI Estimate[d]	220,374	54,902	102,519	108,104	124,290	121,927	104,332	36,997	88,700	105,684	106,848	118,956
Difference MR to WV	20.5%	16.5%	20.9%	6.1%	2.6%	8.2%	-2.9%	-4.2%	0.5%	-2.5%	13.8%	1.7%
Difference MR to HI	19.3%		13.3%	15.5%	5.2%	21.6%	-10.2%	-1.5%	5.2%	-4.6%	1.5%	-3.3%
Difference HI to WV	-1.0%	-14.2%	-6.3%	8.9%	2.4%	12.4%	-7.5%	2.8%	4.6%	-2.1%	-10.8%	-5.0%

[a] The water volume (WV) estimate for the Kodiak release group does not include 2,400 fish that were excess production, and therefore not released with the rest of the Kodiak release group.

[b] MR = Mark-recapture.

[c] Water volume estimate (WV) was computed using water displacement values at Fort Richardson Hatchery 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.

[d] HI = Hatchery Inventory.

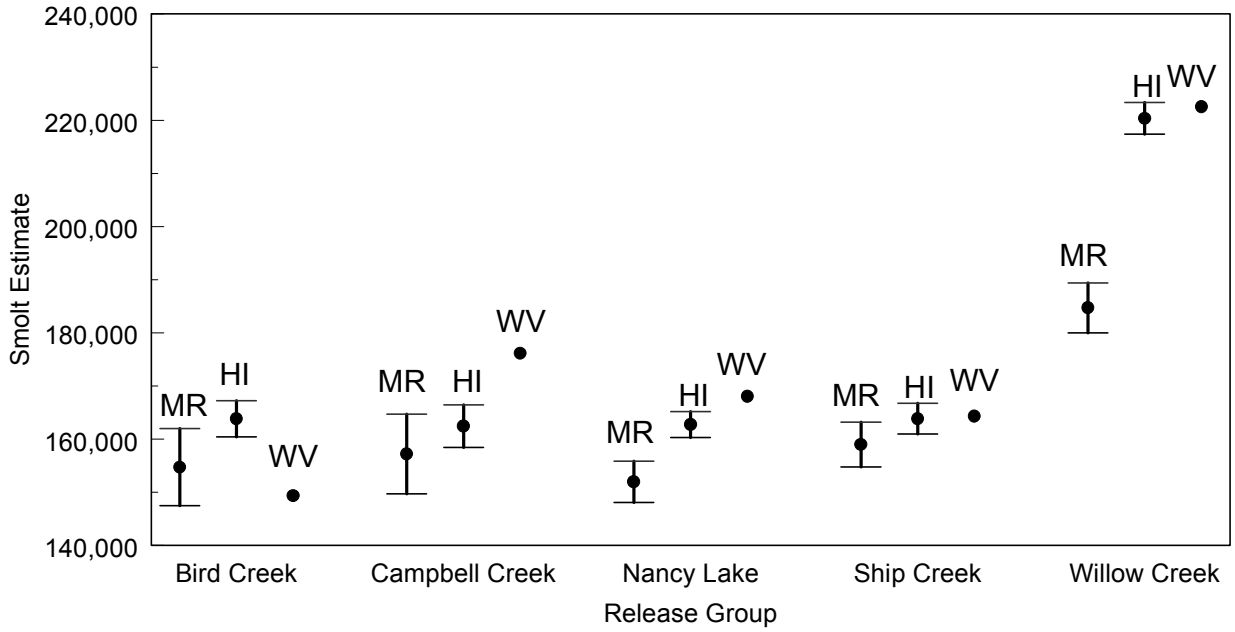


Figure 4.-Comparison of 95% confidence intervals for three techniques of estimating smolt populations at Fort Richardson Hatchery in 1995. Confidence intervals were not available for water volume estimates. MR = mark-recapture; HI = hatchery inventory; WV = water volume.

SIZE ESTIMATION

The smallest coho salmon smolt in terms of weight were from the Nancy Lake release, while the largest coho salmon smolt were from the Bird Creek release (Table 12). The smallest chinook salmon were from the Homer Spit late-run release, while the largest chinook salmon smolt were from the Halibut Cove release (Table 13).

The majority of the coho salmon smolt released at Ship Creek, Campbell Creek, and Nancy Lake were between 15.1 g and 25.0 g, whereas fish in that size range made up only 49.9% of the Bird Creek coho salmon smolt release (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 Homer Spit late were over 15.0 g. The majority of the chinook salmon smolt for the Homer Spit late release were between 5.1 g and 15.0 g.

DISCUSSION

SMOLT MARKING

A major point of emphasis in the 1995 marking program was to maintain if not improve long-term tag retention rates above 1994 levels. The combined 1995 long-term tag retention was 97.3% as compared to 97.8% in 1994. 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.

The highest tag retentions for coho and chinook salmon occurred at tag application rates of approximately 220 to 250 valid tags per worker hour (Figure 2). At some point,

Table 12.-Mean weights of coho salmon smolt produced at Fort Richardson hatchery and stocked at four locations in Cook Inlet in 1995.

Parameter	Bird Creek	Campbell Creek	Nancy Lake	Ship Creek
Sample Size	529	515	518	526
Sample Date	5/19/95	5/19/95	5/17/95	5/18/95
Release Dates	5/20/95	5/24-26/95	5/22/95	5/23/95
Sample Mean Weight (mm)	25.1	22.6	21.3	22.2
Standard Error	4.5	4.3	4.0	4.4
Maximum	40.6	34.4	36.0	37.1
Minimum	8.5	9.3	9.3	5.8

Table 13.-Mean weights of chinook salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked at eight locations in Cook Inlet in 1995.

	Fort Richardson		Elmendorf									
Parameter	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14
Sample Size	516	516	516	542	608	530	535	518	557	522	518	538
Sample Date	5/22/95	5/26/95	6/2/95	6/5/95	5/23/95	6/6/95	6/1/95	6/12/95	5/25/95	6/9/95	6/8/95	6/14/95
Release Dates	5/25/95	5/30/95	6/5/95	6/6/95	5/24/95	6/7/95	6/2/95	6/13/95	5/26/95	6/12/95	6/9/95	6/15/95
Mean Weight (mm)	14.6	14.1	19.1	18.5	16.6	20.9	17.9	23.6	16.7	19.1	18.8	11.9
Standard error	3.9	3.8	6.1	4.7	5.0	6.6	4.6	7.9	4.4	4.8	6.0	2.3
Maximum	31.1	36.7	61.4	44.4	45.7	70.1	44.1	69.2	65.3	49.1	54.4	22.7
Minimum	5.3	7.1	8.4	4.4	7.4	10.7	7.8	9.8	8.3	5.8	8.8	6.0

Table 14.-Weight frequency distribution of hatchery coho salmon smolt produced at Fort Richardson Hatchery and stocked in four locations in Cook Inlet in 1995.

Weight Distribution (g)	Bird Creek	Campbell Creek	Nancy Lake	Ship Creek
0 - 5				
SE				
5.1 - 10	0.4%	0.2%	0.2%	0.4%
SE	0.0001	0.0001	0.0001	0.0001
10.1 - 15	1.3%	3.5%	5.2%	5.3%
SE	0.0002	0.0004	0.0004	0.0004
15.1 - 20	11.5%	22.9%	35.1%	22.2%
SE	0.0006	0.0008	0.0009	0.0008
20.1 - 25	38.4%	46.4%	42.5%	49.8%
SE	0.0009	0.0010	0.0010	0.0010
25.1 - 30	33.5%	21.6%	14.3%	18.1%
SE	0.0009	0.0008	0.0007	0.0007
30.1 - 35	14.2%	5.4%	2.5%	4.0%
SE	0.0007	0.0004	0.0003	0.0004
35.1 - 40	0.6%		0.2%	0.2%
SE	0.0001		0.0001	0.0001
40.1 - 45	0.2%			
SE	0.0001			
45.1 - 50				
SE				
>50				
SE				
Summary				
< 15.1 g	1.7%	3.7%	5.4%	5.7%
15.1 - 25.0 g [a]	49.9%	69.3%	77.6%	72.1%
> 25.0 g	48.4%	27.0%	17.0%	22.2%

[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 1995.

	Fort Richardson		Elmendorf									
Weight Distribution	Willow Creek	Ninilchik River	Crooked Creek RW 16	Crooked Creek RW 17	Ship Creek RW 6	Ship Creek RW 15	Seldovia	Halibut Cove	Kodiak	Homer Spit RW 9	Homer Spit RW 10	Homer Spit Late RW 14
0 - 5				0.2%								
SE				0.0001								
5.1 - 10	10.7%	10.7%	0.6%	1.5%	1.8%		0.9%	0.4%	1.6%	0.8%	0.8%	20.1%
SE	0.0006	0.0006	0.0001	0.0002	0.0002		0.0002	0.0001	0.0002	0.0002	0.0002	0.0007
10.1 - 15	47.9%	54.7%	21.9%	19.0%	42.9%	6.4%	24.1%	6.2%	36.3%	14.0%	22.2%	69.9%
SE	0.0010	0.0010	0.0008	0.0007	0.0008	0.0005	0.0008	0.0005	0.0009	0.0007	0.0008	0.0009
15.1 - 20	32.2%	28.3%	45.2%	52.6%	39.1%	46.6%	52.0%	31.9%	45.6%	49.8%	47.9%	9.7%
SE	0.0009	0.0009	0.0010	0.0009	0.0008	0.0009	0.0009	0.0009	0.0009	0.0010	0.0010	0.0006
20.1 - 25	8.3%	5.2%	20.7%	18.8%	8.9%	34.5%	16.3%	30.1%	13.3%	27.2%	18.1%	0.4%
SE	0.0005	0.0004	0.0008	0.0007	0.0005	0.0009	0.0007	0.0009	0.0006	0.0009	0.0007	0.0001
25.1 - 30	0.8%	0.8%	7.0%	5.5%	4.8%	6.4%	4.5%	14.5%	2.0%	5.6%	6.6%	
SE	0.0002	0.0002	0.0005	0.0004	0.0004	0.0005	0.0004	0.0007	0.0003	0.0004	0.0005	
30.1 - 35	0.2%	0.2%	2.3%	1.3%	1.6%	1.7%	1.5%	7.9%	1.1%	1.1%	1.4%	
SE	0.0001	0.0001	0.0003	0.0002	0.0002	0.0002	0.0002	0.0005	0.0002	0.0002	0.0002	
35.1 - 40		0.2%	0.8%	0.7%	0.5%	1.7%	0.4%	3.9%		1.0%	1.0%	
SE		0.0001	0.0002	0.0002	0.0001	0.0002	0.0001	0.0004		0.0002	0.0002	
40.1 - 45			0.8%	0.4%	0.2%	1.3%	0.4%	3.5%		0.4%	1.5%	
SE			0.0002	0.0001	0.0001	0.0002	0.0001	0.0004		0.0001	0.0002	
45.1 - 50			0.4%		0.2%	0.2%		0.8%		0.2%	0.6%	
SE			0.0001		0.0001	0.0001		0.0002		0.0001	0.0001	
>50			0.4%			1.1%		1.0%	0.2%			
SE			0.0001			0.0002		0.0002	0.0001			
Summary												
< 5.1 g	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.1 - 15.0 g [a]	58.5%	65.3%	22.5%	20.5%	44.7%	6.4%	25.0%	6.6%	37.9%	14.8%	23.0%	90.0%
> 15.0 g	41.5%	34.7%	77.5%	79.3%	55.3%	93.6%	75.0%	93.4%	62.1%	85.2%	77.0%	10.0%

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

increased tagging speed will probably cause a corresponding decrease in quality control. Decreased quality control 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. Until several more years of data can be assimilated, we suggest that the tagging goal for each release group should be to achieve a 97% long-term tag retention rate at a tag application rate of 230 valid tags/worker hour for both chinook salmon and coho salmon.

Several factors contribute to tag application rates. Although we observed that coho salmon are much slower to react to the anesthetic during tagging and much slower to revive from the anesthetic than chinook salmon, tag application rates for coho salmon release groups were apparently not affected in 1995.

Tag application rate may be a function of size at tagging for coho salmon. The Bird Creek coho salmon release group had the largest mean length at tagging (95.12 mm), and the fastest tag rate (271.6 TWH). Because the other three coho salmon release groups were tagged within a 3-week period, only one length distribution was determined and each release group was assigned the same length at tagging. Of those three release groups, the Nancy Lake release group was tagged first and had the lowest tag application rate, and the Ship Creek release group was tagged last and had the highest tag application rate (Table 16).

Size at tagging does not appear to affect chinook salmon tagging rates. The Ninilchik River chinook salmon release group had the largest mean length at tagging (91.66 mm), but at a tag rate of only 214.3 TWH. The Homer Spit late release group had the smallest mean length at tagging (73.30 mm), and a tag rate of 217.6 TWH (Table 16).

Size distribution within a raceway may also contribute to tag application rates. In 1995, the size distributions at tagging for all coho and chinook salmon release groups at FRH and EH permitted tagging with two head molds. Mean tag application rate for 1995 raceways was 230.4 TWH. In 1994, all but one raceway of coho and chinook salmon smolt at FRH and EH required the use of three head molds, and the mean tag application rate was 214.5 TWH (Starkey et al. 1995). Release groups that were tagged at the beginning of the tagging project generally had slower tag rates than those tagged later in the project because crews got faster as time went by. The Bird Creek coho salmon release group (271.6 TWH) was the last group of coho salmon tagged at FRH, whereas the Homer Spit RW 10 chinook salmon release group (201.3 TWH) was the first group of salmon tagged at EH.

The rotation of personnel between tagging and marking duties may have affected some tag rates at the beginning of the project, but most crew members quickly became experienced at both tasks. Environmental factors such as darkness, extreme freezing temperatures, and deep snow can slow tagging operations and decrease tag application rates.

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:

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 1995.

	Coho Salmon				Chinook Salmon											
Parameter	Bird Creek [a]	Campbell Creek[a]	Nancy Lake [a]	Ship Creek [b]	Willow Creek [a]	Ninilchik River [a]	Crooked Creek [b] RW 16	Crooked Creek [b] RW 17	Ship Creek [b] RW 6	Ship Creek [b] RW 15	Seldovia[b]	Halibut Cove [b]	Kodiak[b]	Homer Spit [b] RW 9	Homer Spit [b] RW 10	Homer Spit Late [b] RW 14
Valid tags per worker hour	271.6	225.0	222.9	252.3	199.9	214.3	228.2	209.2	217.9	234.1	235.8	246.3	237.4	235.2	201.3	217.6
Mean size at tagging (mm)	95.12	91.57	91.57	91.57	89.94	91.66	76.42	83.34	79.64	79.64	83.34	87.33	81.77	76.42	76.42	73.30
# of different sizes of head molds used	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

[a] Fort Richardson Hatchery.

[b] Elmendorf Hatchery.

Head mold size	Fish Size Interval
200	≤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.

The size distribution for Halibut Cove chinook salmon smolt resulted in 82.5% of the fish fitting within two size ranges, but 17.3% of the remaining fish were smaller than the required head mold. There is less room for tag placement error in smaller fish than there is in larger fish. Instead of using a third head mold, tagging personnel tagged these smaller fish with their mouths closed, preventing a tag placement that was too deep. Tag placement checks demonstrated good tag placement, and long term retention for this release group was 99.3%. This method of tagging may work in situations where grading is needed, but the design of the tagging area makes grading difficult.

SMOLT ENUMERATION

Comparison of the three smolt enumeration techniques revealed interesting trends (Tables 10, 11, and 17, and Figure 4). First, at FRH the mark-recapture estimates were the lowest of the three methods, and the water volume estimates were the highest of the three for five of the six raceways. Second, the differences between the mark-recapture estimates and the water volume estimates, and the differences between the mark-recapture estimates and the hatchery inventory estimates were not consistent for all release groups.

At EH, the mark-recapture estimates were the lowest of the three methods for six of the 10 raceways. The hatchery inventory estimates were the highest for only four of the 10 raceways, the mark-recapture estimates were the highest for three of the 10 raceways, and the water volume estimates were the highest for three of the 10 raceways. Second, the differences between the mark-recapture estimates and the water volume estimates, and the differences between the mark-recapture estimates and the hatchery inventory estimates were not consistent for all raceways. Third, the discrepancy pattern between the mark-recapture estimate and the 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. One of the six groups did have one estimate which was different from the other two. 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

Table 17.-Comparison of three population estimation techniques for coho and chinook salmon smolt released from Fort Richardson Hatchery in 1995.

Estimate	Bird Creek	Campbell Creek	Nancy Lake	Ship Creek	Willow Creek	Ninilchik River
MR (Pooled)[a]	154,753	157,241	151,985	158,981	184,740	
Standard Error	3,714	3,819	1,996	2,149	2,394	
Upper 95% CI	162,032	164,727	155,898	163,193	189,433	
Lower 95% CI	147,474	149,755	148,072	154,768	180,048	
WV[b]	149,353	176,173	168,065	164,329	222,551	63,986
HI[c]	163,848	162,464	162,773	163,859	220,374	54,902
Standard Error	1,723	2,032	1,254	1,483	1,525	0
Upper 95% CI	167,226	166,445	165,231	166,765	223,364	54,902
Lower 95% CI	160,470	158,482	160,315	160,953	217,385	54,902
Difference MR to WV	-3.5%	12.0%	10.6%	3.4%	20.5%	16.5%
Difference MR to HI	5.9%	3.3%	7.1%	3.1%	19.3%	
Difference HI to WV	9.7	-7.8	-3.1	0.3	-1.0	-14.2

[a] MR = mark-recapture.

[b] WV = water volume.

[c] HI = hatchery inventory.

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 1995 release groups, therefore there is not a variance around the 1995 water volume estimates.

At EH, the difference between the water volume population estimates and mark-recapture population estimates for release groups ranged from -4.2% to 20.9%. One source of error in the water volume technique may be in the determination of mean weight of an individual fish. Mean weight was also 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, 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 1995 release groups of coho and chinook salmon, the number of subsamples from each coho salmon indoor raceway ranged from two to five subsamples. Fish from three to four different indoor raceways were transferred to outdoor raceways resulting in the total number of eight to 15 subsamples obtained per outdoor raceway. The number of samples from each chinook salmon indoor raceway ranged from five to eight samples. The size of the subsamples for the 1995 release groups of coho salmon smolt remained approximately the same as the size of the subsamples for the 1993 release groups (9.4% to 13.8% of a full net load in 1995 compared to 8% to 12% of a full net load in 1993). Increasing the number of subsamples did not appear to improve the accuracy of this technique for 1995 release groups at FRH. The size of the samples for the 1995 Willow Creek chinook salmon release group were increased to 100% of a net load. Increasing the size of the sample did not appear to improve the accuracy of this technique for this release group.

In 1995 hatchery inventory estimates at EH were based on a variety of techniques. For three 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. Data show that all seven of the raceways in which all of the fish were enumerated through the coded wire tagging process and/or bulk weighing method (Ship Creek RW6, Seldovia, Halibut Cove, Kodiak, and all Homer Spit raceways) had inventory estimates within 10% of the mark-recapture estimates (Table 9). For four of these seven raceways, the hatchery inventory estimate was less than the mark-recapture estimate. This indicates that the number of fish moved via the bulk weighing method was underestimated.

Three 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/or bulk weighing method, had inventory estimates that differed from the mark-recapture estimates by a range of 13.3% to 21.6%. All three of these raceways had inventory estimates that overestimated the populations when compared to the mark-recapture estimates. All raceways in which all fish were

enumerated through tagging or bulk weighing had mark-recapture and hatchery inventory estimates which were near agreement, and the three raceways in which the inventory estimate was based on the electronic count of eyed eggs had large discrepancies between their mark-recapture and hatchery inventory estimates. This indicates that consistent errors have been made in either the electronic eyed egg counts, or most probably in estimating the survival of eyed eggs to fry.

We feel that the 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. Both 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, and 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 feel that the hatcheries should not 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 higher than the hatchery inventory estimates for five of the six release groups, (0.3% to 16.5%) and higher than the mark-recapture estimates for five of the six release groups (-3.5% to 20.5%).

Accuracy and precision could possibly be improved by improving the 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 Ship Creek, Campbell Creek, and Nancy Lake were all close to achieving the size range production goal, with approximately 70% of the smolt in each release group within the desired size range. The marine survival rates for these release groups should be at anticipated levels. The Bird Creek release group had only 49.9% of its fish between 15.1 g and 25.0 g, and 48.4% were larger than 25 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 late-run Homer Spit chinook salmon smolt at EH achieved the production goal with 90% of the smolt within the desired size range. None of the remaining chinook salmon release groups at EH or the chinook salmon release groups at FRH 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 both release groups 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 precocial males or jacks (Peltz and Sweet 1993). Evidence also suggests that larger smolt reduces ocean residence, shifting the age composition of returns to younger, smaller fish (Sweet and Peltz 1994).

CONCLUSIONS AND RECOMMENDATIONS

1. We feel that 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 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.
3. 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 estimation of eyed eggs, or in the estimation of eyed egg to fry survival rates. Raceways in which all fish were enumerated via tagging and/or bulk weighing had fairly accurate hatchery inventory estimates.

   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.

4. 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.

5. All fish to be tagged 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.

6. Elmendorf Hatchery chinook salmon planted in Ship Creek, Crooked Creek, Kodiak, Homer Spit early, Halibut Cove, and Seldovia had a high percentage of fish (> 40%) 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 precocial males or jacks.

7. Fort Richardson Hatchery coho salmon smolt planted in Ship Creek, Campbell Creek, and Little Susitna River were all extremely close to the size range production goal. The marine survival rates for these release groups should be at anticipated levels. Coho salmon planted in Bird Creek had a high percentage of fish (> 40%) 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 precocial males or jacks.

8. Fort Richardson Hatchery chinook salmon smolt planted in the Ninilchik River and Willow Creek were close to the size range production goal. The marine survival rates for these release groups should be at anticipated levels.

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