Fishery Data Series No. 95-13

Marking, Enumeration, and Size Estimation for Coho and Chinook Salmon Smolt Releases into Upper Cook Inlet, Alaska in 1994

by

Diane Starkey,

Larry Peltz,

and

Patricia Hansen

August 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

FISHERY DATA SERIES NO. 95-13

MARKING, ENUMERATION, AND SIZE ESTIMATION FOR COHO AND CHINOOK SALMON SMOLT RELEASES INTO UPPER COOK INLET, ALASKA IN 1994

by

Diane Starkey,
Division of Sport Fish, Anchorage,
Larry Peltz,
Division of Sport Fish, Palmer,
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
August 1995

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-10, Job Number R-3-4(c).

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

Diane Starkey
Alaska Department of Fish and Game, Division of Sport Fish
333 Raspberry Road, Anchorage, Alaska 99518-1599 USA
Larry Peltz
Alaska Department of Fish and Game, Division of Sport Fish
1800 Glenn Highway, Suite 4
Palmer, Alaska 99645-6736 USA
Patricia Hansen
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska 99518-1599 USA

This document should be cited as:
Starkey, Diane, Larry Peltz, and Patricia Hansen. 1995. Marking, enumeration, and size estimation for coho and chinook salmon smolt releases into upper Cook Inlet, Alaska in 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-13, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

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 (Mills 1993). 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.

Marking and collection of release data at the Crooked Creek, Elmendorf, and Fort Richardson hatcheries were standardized for each of the stocking projects in 1994. This report presents the results of the 1994 marking program. In addition, three different smolt enumeration techniques are discussed, and the size composition of each release group is also presented and discussed.

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. Long-term (>30 d) tag retention ranged from 94.8% to 99.2%.

Comparison of the three smolt enumeration techniques revealed interesting trends. First, in most instances the mark-recapture estimate was the lowest of the three techniques and the hatchery inventory estimate was the highest. Second, the difference between the mark-recapture and the water volume estimates was not consistent for all groups. Third, the discrepancy pattern 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 (Mills 1993). 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 and relieve pressure on wild stocks.

Until 1992, each hatchery was unique in how it produced, marked, and released fish, and collected data and reported information. 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 Elmendorf (EH), and Fort Richardson hatcheries (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. 1991). 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, Ship Creek, and Eagle River; and to estimate the contribution to commercial and recreational marine fisheries of hatchery-reared chinook salmon released at the Ninilchik River, Crooked Creek, Homer Spit, Halibut Cove, and Seldovia. Chinook salmon smolt released at Willow Creek and Ninilchik River were tagged at FRH; chinook salmon smolt released at Ship Creek, Eagle River, Crooked Creek, Homer Spit, Halibut Cove, and Seldovia were tagged at EH; and Homer Spit late release groups of chinook salmon smolt were tagged at Crooked Creek Hatchery (CCH).

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. Grading all fish to be marked by size and using different sizes of head molds to tag the appropriate sizes of fish was performed at all three hatcheries, and on all the release groups.

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 two of the three 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).

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 length and 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 560,000 of the projected 1,945,000 coho and chinook smolt to be stocked in 1994 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 14 Cook Inlet release groups (Meyer et al. 1991).

Marking and collection of release data at the Elmendorf, Fort Richardson, and Crooked Creek hatcheries were standardized for each of the stocking projects in 1994. This report presents the results of the 1994 marking program. In addition, three different smolt enumeration techniques are examined and discussed. The size composition of each release group is also presented and discussed. Based on the data summarized in this report, recommendations are made for future marking and collection of release data.

METHODS

SMOLT MARKING

The planned number of fish to produce and mark at each hatchery in each release group is presented in Table 1. Elmendorf Hatchery raised coho salmon from the Ship Creek brood stock, and chinook salmon from the Ship Creek brood stock and the early-run

Table 1.-Planned Cook Inlet coho and chinook salmon smolt total release and number of fish to be marked with adipose clips and coded wire tags in 1994.

Hatchery	Species	Release Location	Total Number Released	Total Number Tagged
Fort Richardson	Coho	Nancy Lake	150,000	40,000
		Bird Creek	80,000	40,000
		Campbell Creek	100,000	40,000
Elmendorf	Coho	Ship Creek	65,000	40,000
Total	Coho		395,000	160,000
Fort Richardson	Chinook	Willow Creek	200,000	40,000
		Ninilchik River	200,000	40,000
Elmendorf	Chinook	Halibut Cove	105,000	40,000
		Seldovia	105,000	40,000
		Homer Spit Early	210,000	40,000
		Crooked Creek	210,000	40,000
		Eagle River	105,000	40,000
		Ship Creek	210,000	40,000
Crooked Creek	Chinook	Homer Spit Late	100,000	40,000
		Twin Falls	105,000	40,000
Total	Chinook		1,550,000	400,000
Grand Total	Smolt		1,945,000	560,000

Crooked Creek brood stock. Crooked Creek Hatchery raised chinook salmon from the Crooked Creek late-run chinook salmon brood stock. 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. Each of the 14 release groups were marked with a unique tag code.

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. To obtain random samples from the populations to be marked, one of two methods was followed. Over 50% of the smolt in the Bird Creek, Campbell Creek, and Ship Creek coho salmon smolt release groups and one of the Homer Spit late-run chinook salmon release groups were to be marked. These fish were dipnetted from throughout the rearing container(s) as needed. Hewitt and Burrows (1948) used the random dip net method to estimate fish populations in rearing containers. They determined that sampling bias occurred until at least 38% of the population was sampled. Consequently, it was likely that a random sample was obtained if more than 40% of the fish were marked.

Less than 40% of the Nancy Lake coho salmon smolt, and the Willow Creek and the Ninilchik River chinook salmon smolt at Fort Richardson Hatchery, as well as all release groups of chinook salmon smolt at Elmendorf Hatchery, and one rearing container of Homer Spit late-run chinook salmon at Crooked Creek Hatchery were marked and tagged. Fish in each of these rearing containers were crowded to cause mixing, thereby increasing the likelihood that a random sample was obtained. Once the rearing container was crowded, fish were dipnetted and held separate from the rest of the population until they were marked. At Fort Richardson, the entire group of 40,000 smolt to be tagged from each release group was dipnetted and held separate from the remaining fish in the release group before tagging was initiated. At Elmendorf Hatchery, the rearing container was crowded once a day and enough fish for one day of marking were dipnetted and held separate in net pens. At Crooked Creek Hatchery, fish were dipnetted from a crowded rearing container as needed. If fish for a particular release group were in more than one rearing container, then an attempt was made to mark approximately the same proportion of fish in each container (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 1994 were graded and tagged with the appropriate size head mold. A minimum of 510 fish was obtained from each stock within 7 days of the initial date of tagging. Each fish was measured for fork length to the nearest millimeter, and a length frequency distribution was calculated. Earlier studies produced a range of lengths corresponding to each head mold size (Peltz and Hansen 1994). 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. Several release groups contained a large proportion (>33%) of fish which were <81 mm, and did not fit within the 1993 criteria for grading. Fish in this size class were measured and fitted into various head molds to determine the length distributions for the smaller size head molds (Peltz and Hansen 1994).

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. However, the tagging supervisor checked finclips several times a day to ensure that all finclips were good.

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 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 that were killed to determine tag placement was subtracted from the daily number of 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. A random sample of 200 fish was passed through the QCD to estimate short-term tag retention. 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). Tag retention rate was estimated daily from a sample of tagged smolt placed in a holding net pen and held overnight. Daily tag retention rate (D_i) of smolt that were finclipped, tagged, survived, and retained the tag was estimated as a binomial proportion as:

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

where:

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

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

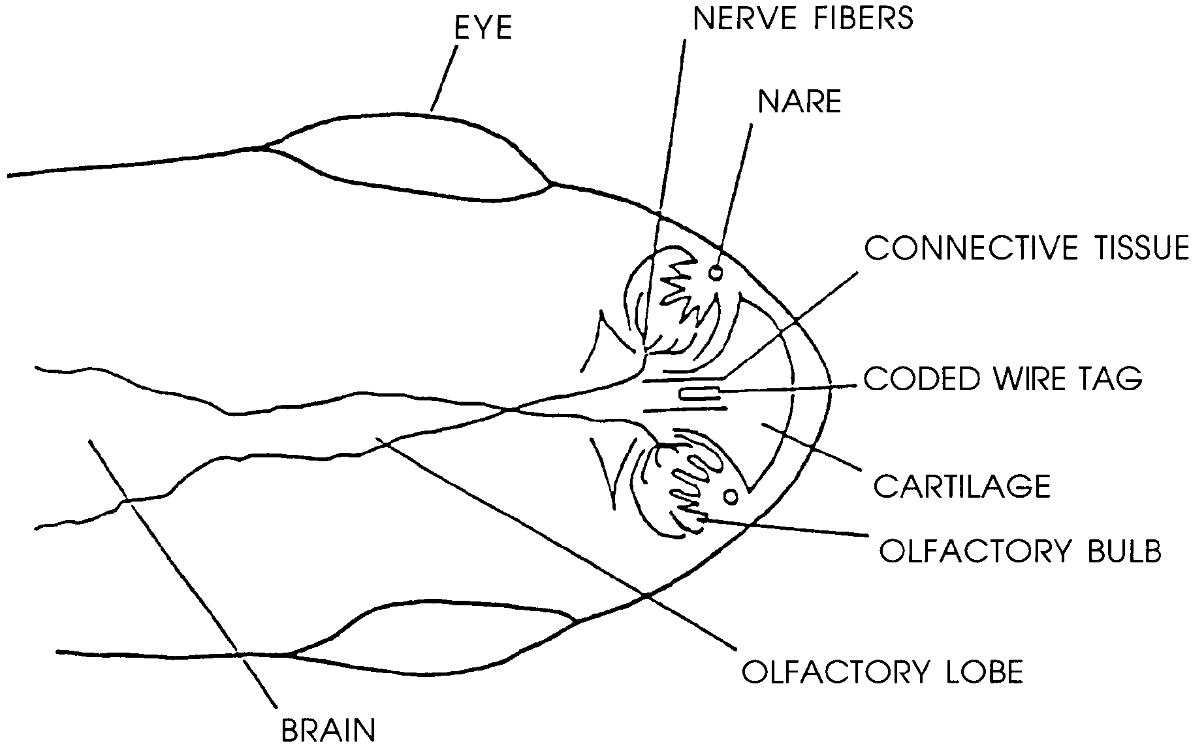
$$\mathrm{Var}\left(\hat{D}_i\right) = \frac{\hat{D}_i\left(1-\hat{D}_i\right)}{n_{ti}-1}. \qquad (2)$$

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

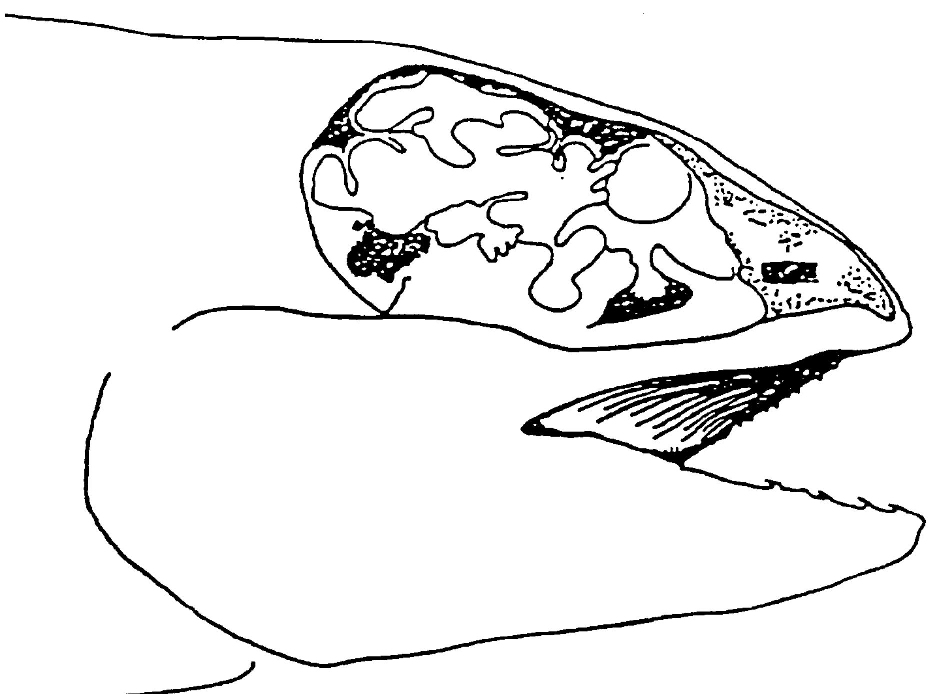
Long-term tag retention was estimated for each release group prior to release. Blankenship (1990) found that tag loss rates were stable after 29 days. Consequently, all long-term tag retention measurements occurred more than 30 days after completion of tagging. After first crowding the fish in each rearing container, a minimum of 750 marked fish (adipose clipped) were randomly sampled from the population. Each of the 750 marked fish were passed through a QCD to estimate the long-term tag retention. All fish having no tag were passed through the QCD again to assure 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 also estimated as a binomial proportion (formulas 1 and 2) for each group;

where:

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



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.

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:

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

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, 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 was calculated as:

$$TWH_j = \frac{\hat{T}_j}{W_j} \tag{5}$$

and

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

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 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. At Crooked Creek Hatchery, the number of smolt released for each release group was estimated with a mark-recapture estimate, and a hatchery inventory estimate.

Mark-Recapture Estimates

A random sample of smolt from each raceway was marked with an adipose finclip and a coded wire tag and returned to the raceway. Thus, each release group of salmon smolt contained a known number of marked fish. 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. The 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).

All release groups at FRH as well as the Eagle River chinook salmon 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:

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

with variance:

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

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.

The hatchery inventory estimate at EH for the Ship Creek coho salmon smolt release was established upon the completion of marking. The marked fish were counted during the tagging process. The remaining unmarked fish were hand counted and mixed with the marked fish. This hatchery inventory estimate was an exact count. Mortalities were monitored on a daily basis and subtracted from the inventory count to yield a final hatchery inventory estimate.

The hatchery inventory estimates at EH for the 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 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 pre-weighed bucket of water and weighed to the nearest 5 grams. All fish that were moved from one raceway to another without being tagged, were weighed. The weight was recorded and the total weight of all fish removed from the raceway was obtained by adding the individual net weights. During the course of this operation three randomly selected net loads of fish from the beginning, middle, and end of the weighing process were sampled to obtain an estimate of individual fish weight. One net full of fish was too large to enumerate (approximately 1,300 fish). Consequently, the net was manually halved numerous times until approximately 150 fish were still in the net. These fish were weighed in the same manner as the other net loads and hand counted out of the bucket. Mean weight was then divided into the total weight of fish moved out of each raceway to establish the hatchery inventory number in the new raceway. The estimated number of fish transferred to the new raceway was subtracted from the estimated number of fish in the original raceway to determine the number of fish still in the original raceway. Following the fish transfers, daily mortalities in each raceway were enumerated and subtracted from the individual raceway inventory estimates. The inventory estimate on the day the fish were released was the number of fish released.

The hatchery inventory estimate at FRH for the coho salmon smolt to be stocked at Nancy Lake, Bird Creek and Campbell Creek, and for the chinook salmon smolt to be stocked at Willow Creek and the Ninilchik River, was established when the fry were moved from the small indoor raceways to the 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. The fish were poured into a pre-weighed bucket of water and weighed to the nearest gram. The weight was recorded and the total weight of all fish in the raceway was obtained by adding individual dip net bulk weights. During the course of this operation 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. The dip net samples were used to estimate the ratio of the number of fish to total fish weight by (Cochran 1977):

$$\hat{R} = \frac{\bar{n}}{\bar{w}} \quad (9)$$

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:

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

and then the ratio estimate was calculated as:

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

with variance:

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

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:

$$\hat{N}_r = W_r \hat{R}_Q \quad (13)$$

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.

The hatchery inventory estimate at Crooked Creek Hatchery for chinook salmon smolt to be stocked at Homer Spit was established by determining the total biomass in each rearing unit at the fingerling stage. Each rearing unit was crowded, and full dip nets of fish (approximately 7 kg) were removed from the rearing unit, weighed, and placed back into the rearing unit on the other side of the crowder. All fish in the rearing unit were weighed. Two samples were taken during the weighing process to determine the mean weight of an individual fish. Each sample consisted of one half of a full dip net (approximately 3.5 kg or 700 to 800 fish). The sample was weighed, and the fish were hand counted into the rearing unit. The mean weight was then divided into the total weight of fish in the rearing unit to establish the hatchery inventory. Daily mortalities in each rearing unit were enumerated and subtracted from the individual rearing unit inventory estimates. The inventory estimate on the day the fish were released was the number of fish released.

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 two vehicles for transporting fish, a boom truck and a flatbed trailer. Each vehicle has a tank divided into four compartments. EH has a flatbed trailer which has a tank divided into four compartments. Hereafter, compartments will be referred to as tanks. Crooked Creek Hatchery does not use water volume estimates, and will not be discussed here.

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. The 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 the 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, and the large transport tanks have an estimated 3.1 kg of fish per mm of water displaced; while EH transport tanks have an estimated 4.9 kg of fish per mm of water displaced (Peltz and Starkey 1993). The total number of fish was then calculated by dividing the total weight by the estimated mean weight of a fish. FRH estimated the mean weight from weights of a random sample of 510 fish. EH estimated mean weight by removing a small dip net sample of fish from 3 of the 4 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 three. 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 length and weight from the Halibut Cove, Seldovia, Eagle River, and Ship Creek (coho salmon) release groups at EH; the Campbell Creek, Bird Creek, Willow Creek, and Ninilchik River release groups at FRH; and one of the two late Homer Spit chinook salmon smolt release groups at CCH. A minimum of 510 fish from each of the two raceways of the Homer Spit, Crooked Creek, and Ship Creek (chinook salmon) release groups at EH; the Nancy Lake release group at FRH, and one of the two late Homer Spit chinook salmon release groups at CCH were individually measured for length and weight. Fish were crowded to one end of the raceway and a sample was netted and put into a small holding pen. Length of each fish was measured from the tip of the snout to fork of the tail (FL) and recorded to the nearest millimeter. Each fish was weighed to the nearest 0.1 gram on an electronic scale. Mean length and weight and the associated variances of fish in each release group and in each holding pen group were estimated using standard normal procedures.

The proportion of fish in a length class in each release group ($\hat{a}_{jk}$) was estimated as a binomial proportion as:

$$\hat{a}_{jk} = \frac{n_{jk}}{n_j} \qquad (15)$$

where:

n_{jk} = number of fish of length class k in release group j, and

n_j = total number of fish sampled from release group j.

The variance of each proportion was estimated as:

$$\text{Var}\left[\hat{a}_{jk}\right] = \frac{\hat{a}_{jk}\left(1-\hat{a}_{jk}\right)}{n_j - 1}. \qquad (16)$$

RESULTS

SMOLT MARKING

Over 600,000 coho and chinook salmon smolt for release at 11 locations in Cook Inlet were marked in 1994 (Tables 2 and 3). This number exceeded the project goal by more than 5%. The goal of marking and tagging a minimum of 40,000 smolt per release group was achieved for 12 of the 14 release groups. Due to time constraints, the goal of 40,000 marked smolt from the Halibut Cove (21,382 marked smolt) and Homer Spit (26,612 marked smolt) release groups at EH was not achieved.

Three of the five release groups in which fish were reared in two different rearing containers had different proportions of marked fish in each container. The Ship Creek chinook salmon smolt release group was divided unevenly (64,656 smolt in one rearing container and 135,174 smolt in the other) when the rearing containers were split. Approximately the same number of marked smolt were placed into each rearing container, resulting in 34.5% of the smolt in one rearing container being marked, and only 16.2% of the smolt in the second rearing container being marked. Time constraints restricted the marking and tagging operations for the Homer Spit early-run chinook salmon release group. Although the smolt populations were approximately the same for each rearing container, the number of marked smolt in

Table 2.-Summary of coded wire tagging data at Elmendorf and Fort Richardson hatcheries for hatchery produced coho salmon smolt stocked at four locations in Cook Inlet in 1994.

Parameter	E3 Nancy Lake[a]	E4 Nancy Lake[a]	Bird Creek[a]	Campbell Creek[a]	Ship Creek[b]
Tag Codes	31-23-01	31-23-01	31-23-02	31-23-03	31-23-04
Total marked and tagged	22,465	22,220	45,750	44,276	44,169
Mortalities	124	72	530	132	138
Marked fish released	22,341	22,148	45,220	44,144	44,031
Tag retention sample size	797	793	762	785	839
Tag retention at release	98.2%	98.7%	98.8%	97.3%	94.8%
Tag retention variance	0.00002	0.000016	0.00002	0.00003	0.00006
Tagged fish released	21,949	21,869	44,686	42,963	41,722
Tagged fish variance	10,821	7,712	31,362	64,714	114,966
Total fish released	61,912	64,782	84,643	87,686	75,779
Percent tagged	36.1%	34.2%	53.4%	50.3%	58.1%
Tagging dates	10/28/93 11/02/93	11/02/93 11/05/93	11/08/93 11/15/93	10/19/93 10/28/93	01/10/94 01/19/94
Date of tag retention check	05/20/94	05/19/94	05/25/94	05/26/94	05/24/94
Days elapsed	199	195	191	210	125

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

Table 3.-Summary of coded wire tagging data at Elmendorf, Fort Richardson, and Crooked Creek hatcheries for hatchery produced chinook salmon stocked at 10 locations in Cook Inlet in 1994.

Parameter	Willow Creek[b]	Ninilchik River[b]	RW19[a] Ship Creek[c]	RW20 Ship Creek[c]	RW9 Crooked Creek[c]	RW10 Crooked Creek[c]	Eagle River[c]	RW15 Homer Spit Early[c]	RW16 Homer Spit Early[c]	Halibut Cove[c]	Seldovia[c]	RW5 Homer Spit Late[d,e]	RW6 Homer Spit Late[d]	RW8 Homer Spit Late[d]	TOTALS
Tag Codes	31-23-17	31-23-18	31-23-12	31-23-12	31-23-14	31-23-14	31-23-13	31-23-16	31-23-16	31-23-15	31-23-11	31-23-20	31-23-19	31-23-19	
Total marked and tagged	47,155	46,978	22,415	22,302	21,023	23,274	44,643	17,348	9,209	21,382	47,476	47,177	24,222	22,752	596,236
Mortalities	866	785	131	448	235	453	1,031	336	218	177	722	587	207	140	
Marked fish released	46,289	46,193	22,284	21,854	20,788	22,821	43,612	17,012	8,991	21,205	46,754	46,590	24,015	22,612	588,904
Tag retention sample size	754	772	786	773	798	821	808	752	784	762	782	787	774	791	
Tag retention at release	99.2%	98.6%	96.3%	97.9%	99.4%	98.1%	95.5%	99.3%	96.9%	99.2%	97.2%	97.7%	99.1%	99.0%	97.8%
Tag retention variance	0.00001	0.00001	0.00005	0.00003	0.00001	0.000023	0.00005	0.00001	0.000023	0.0000103	0.000035	0.000028	0.000012	0.000013	
Tagged fish released	45,921	45,535	21,462	21,402	20,658	22,376	41,669	16,899	8,716	21,038	45,439	45,524	23,798	22,383	576,007
Tagged fish variance	22,463	22,370	22,478	12,540	3,376	12,136	100,331	2,545	1,884	4,616	76,526	61,718	6,686	6,480	
Total fish released	177,913	201,513	64,656	135,174	111,873	112,911	98,872	81,278	82,685	98,872	107,246	60,302	39,651	56,920	1,804,667
Percent tagged	26.0%	22.9%	34.5%	16.2%	18.6%	20.2%	44.1%	20.9%	10.9%	21.4%	43.6%	77.3%	60.6%	39.7%	31.9%
Tagging dates	03/21/94 03/29/94	03/30/94 04/05/94	02/11/94 02/15/94	02/01/94 02/03/94	02/15/94 02/17/94	02/18/94 02/23/94	02/03/94 02/10/94	02/28/94 03/01/94	03/02/94 03/03/94	02/23/94 02/25/94	01/21/94 01/31/94	04/19/94 04/27/94	04/11/94 04/14/94	04/14/94 04/19/94	
Date of tag retention check	05/23/94	05/27/94	05/31/94	06/06/94	06/07/94	06/01/94	06/02/94	06/06/94	06/13/94	06/09/94	06/10/94	07/18/94	07/18/94	07/18/94	
Days elapsed	55	52	105	123	110	98	112	97	102	104	130	82	95	90	

[a] RW = raceway.

[b] Produced at Fort Richardson Hatchery.

[c] Produced at Elmendorf Hatchery.

[d] Produced at Crooked Creek Hatchery.

[e] Homer Spit (RW 5) is considered a separate release site.

each rearing container differed. This resulted in one rearing container having 20.2% of its population marked, and the other rearing container with 10.9% of its population marked.

Fish in the release group of late-run Homer Spit chinook salmon at CCH which were reared in two rearing containers were not distributed evenly between the two rearing containers. Approximately the same number of marked fish were placed in each rearing container. The difference in fish populations resulted in one rearing container having 60.6% of its population marked, and the other rearing container having 39.7% of its population marked. The stocking of chinook salmon smolt at Twin Falls was eliminated, resulting in additional chinook salmon smolt being stocked at Homer Spit.

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 52 days to 210 days, with 12 of the 20 rearing units having waiting periods in excess of 100 days. Tag retention ranged from 94.8% to 99.2% with an overall mean of 97.8%. An estimated 1.80 million coho and chinook salmon smolt were released which was 7.5% fewer fish than planned. The percentage of the total release which was marked ranged from 15.9% to 77.3% with an overall mean of 31.9%.

Tag application rates varied dramatically among the release groups (Tables 4 and 5). The mean valid tag application rate was 210.7 valid tags per worker-hour (t/wh). The Ship Creek coho salmon release group had a tag application rate of only 164.6 valid tags per worker-hour, while the Ninilchik River release group had a tag application rate of 264.0 valid tags per worker-hour. Estimated long-term tag retention ranged from 94.8% for the Ship Creek coho salmon smolt release to

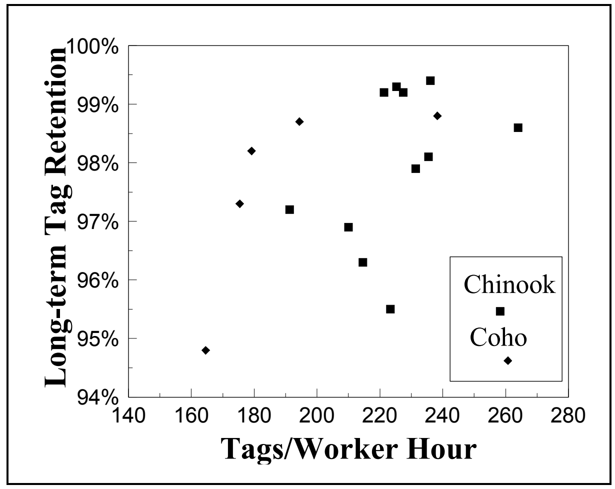


Figure 2.-Comparison of tag application rate to tag retention for chinook and coho salmon release groups at Elmendorf and Fort Richardson hatcheries, 1994.

99.2% for the Willow Creek and Halibut Cove chinook salmon smolt releases. A plot of tag application rates versus long-term tag retention rates for coho and chinook salmon release groups at EH and FRH is presented in Figure 2. The tagging rate for most of the coho salmon release groups was slower than the tagging rate for the chinook salmon release groups. Four of the five coho salmon rearing units had the four slowest tags per worker-hour rates. Three of the four 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 200 to 250 tags per worker-hour appear to produce long-term tag retention rates of 97% or greater in chinook salmon.

SMOLT ENUMERATION

Mark-Recapture Estimates

Only one mark-recapture estimate was calculated for the Ship Creek coho salmon, and Ship Creek, Crooked Creek, Homer Spit, Halibut Cove, and Seldovia chinook salmon releases from EH. The two Homer Spit

Table 4.-Numbers of coho salmon coded wire tagged, tag application rates, tag codes, and tag retention rates at Elmendorf and Fort Richardson hatcheries in 1994.

	Nancy Lake[a]	Nancy Lake [a]	Bird Creek [a]	Campbell Creek[a]	Ship Creek [b]
Tag Codes	31-23-01	31-23-01	31-23-02	31-23-03	31-23-04
Total valid tags	21,949	21,869	44,686	42,963	41,722
Worker hours per tag code	122.5	112.5	187.5	245.0	253.5
Tags per worker hour	179.2	194.4	238.3	175.4	164.6
Tags/worker hr (SE)	0.849	0.781	0.944	1.038	1.338
Short-term tag retention	99.8%	99.6%	99.9%	99.5%	99.6%
Long-term tag retention	98.2%	98.7%	98.8%	97.3%	94.8%
Tag loss	1.6%	0.9%	1.1%	2.2%	4.8%
Days elapsed	199	195	191	210	125

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

Table 5.-Numbers of chinook salmon coded wire tagged, tag application rates, tag codes, and tag retention rates at Elmendorf, Fort Richardson, and Crooked Creek hatcheries in 1994.

	Willow Creek[a]	Ninilchik River [a]	Ship Creek [b] RW 19 [c]	Ship Creek [b] RW 20	Crooked Creek [b] RW 9	Crooked Creek [b] RW 10	Eagle River [b]	Homer Spit Early [b]	Homer Spit Early [b]	Halibut Cove [b]	Seldovia[b]	Homer Spit Late [d] RW 5	Homer Spit Late [d] RW 6	Homer Spit Late [d] RW 8
Tag Codes	31-23-17	31-23-18	31-23-12	31-23-12	31-23-14	31-23-14	31-23-13	31-23-16	31-23-16	31-23-15	31-23-11	31-23-20	31-23-19	31-23-19
Total valid tags	45,921	45,535	21,462	21,402	20,658	22,376	41,669	16,899	8,716	21,038	45,439	45,524	23,798	22,383
Worker hours per tag code	207.5	172.5	100.0	92.5	87.5	95.0	186.5	75.0	41.5	92.5	237.5	228.0	142.5	110.0
Tags per worker hour	221.3	264.0	214.6	231.4	236.1	235.5	223.4	225.3	210.0	227.4	191.3	199.7	167.0	203.5
Tags/worker hr Standard Error	0.722	0.867	1.499	1.211	0.664	1.160	1.698	0.673	1.046	0.734	1.165	1.090	0.574	0.732
Short-term tag retention	99.8%	99.9%	99.9%	99.9%	100.0%	99.8%	99.6%	100.0%	99.8%	100.0%	99.5%	99.7%	99.7%	99.5%
Long-term tag retention	99.2%	98.6%	96.3%	97.9%	99.4%	98.1%	95.5%	99.3%	96.9%	99.2%	97.2%	97.7%	99.1%	99.0%
Tag loss	0.6%	1.3%	3.6%	2.0%	0.6%	1.7%	4.1%	0.7%	2.9%	0.8%	2.3%	2.0%	0.6%	0.5%
Days elapsed	55	52	105	123	110	98	112	97	102	104	130	82	95	90

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

[c] RW = raceway.

[d] Produced at Crooked Creek Hatchery.

chinook salmon release groups at CCH also had one estimate. Three estimates were calculated for the Bird Creek, Campbell Creek, and both raceways of Nancy Lake coho salmon release groups at FRH. Three estimates were also calculated for the Willow Creek and Ninilchik River chinook salmon release groups at FRH, and the Eagle River chinook salmon release group at EH. No significant differences were detected among the three estimates in six of the seven groups (Tables 6 and 7 and Figure 3). The remaining group, one Nancy Lake raceway, had one estimate which was different from the other two estimates. The confidence intervals on the Nancy Lake, Bird Creek, and Campbell Creek estimates are narrow because such a high percentage (>34%-53%) of the populations were marked. Conversely, the confidence intervals on the Ninilchik River estimates are wide because a low percentage (< 23%) of the population was marked.

Hatchery Inventory Estimates

The mean weight per container of fish at FRH moved from indoor to outdoor raceways for coho salmon smolt ranged from 7,511 g (Campbell Creek) to 8,787 g (Nancy Lake E3) (Table 8). Both of the chinook salmon smolt groups had mean container weights over 10,000 g. Most of the containers 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 container, then the

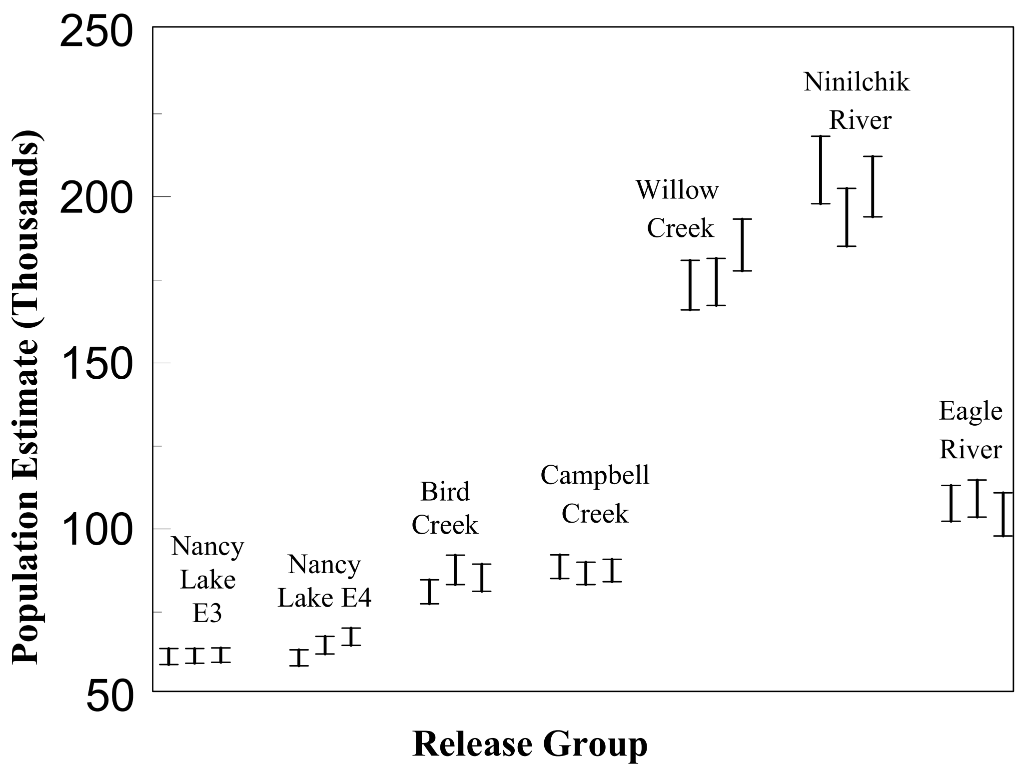


Figure 3.-Comparison of 95% confidence intervals of 1994 mark-recapture population estimates.

Table 6.-Mark-recapture estimates of coho salmon smolt released from Elmendorf and Fort Richardson hatcheries conducted within 7 days of stocking at four Cook Inlet release sites.

	E3 Nancy Lake [a]	E4 Nancy Lake [a]	Bird Creek[a]	Campbell Creek[a]	Ship Creek[b]
Estimate #1					
	61,677	61,263	81,183	88,740	75,779
Standard Error	1,237	1,220	1,840	1,811	2,159
Upper 95% CI	64,102	63,654	84,790	92,289	80,011
Lower 95% CI	59,252	58,872	77,576	85,191	71,547
Estimate #2					
Number of Smolt	61,865	65,056	87,772	86,660	
Standard Error	1,144	1,346	2,264	1,736	
Upper 95% CI	64,108	67,694	92,208	90,062	
Lower 95% CI	59,622	62,419	83,335	83,257	
Estimate #3					
Number of Smolt	62,097	67,625	85,417	87,600	
Standard Error	1,109	1,319	2,083	1,707	
Upper 95% CI	64,269	70,210	89,501	90,945	
Lower 95% CI	59,924	65,040	81,334	84,255	
Pooled Estimate					
Number of Smolt	61,912	64,782	84,643	87,686	75,779
Standard Error	670	745	1,184	1,012	2,159
Upper 95% CI	63,225	66,243	86,963	89,669	80,011
Lower 95% CI	60,599	63,321	82,324	85,702	71,547

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

Table 7.-Mark-recapture estimates of chinook salmon smolt released from Elmendorf, Fort Richardson, and Crooked Creek hatcheries conducted within 7 days of stocking at 10 Cook Inlet release sites.

	Willow Creek[a]	Ninilchik River[a]	RW 19 [b] Ship Creek[c]	RW20 Ship Creek[c]	RW10 Crooked Creek[c]	RW9 Crooked Creek[c]	Eagle River[c]	RW 15 Homer Spit Early[c]	RW 16 Homer Spit Early[c]	Halibut Cove[c]	Seldovia[c]	RW 5 Homer Spit Late [d]	RW 6 Homer Spit Late [d]	RW 8 Homer Spit Late [d]
Estimate #1														
Number of Smolt	173,476	208,136	64,656	135,174	112,911	111,873	107,743	81,278	82,685	98,872	107,246	60,302	39,651	56,920
Standard Error	3,816	5,171	1,534	4,355	2,721	2,794	2,745	2,689	2,636	2,896	2,558	987	874	1,459
Upper 95% CI	180,956	218,271	67,663	143,709	118,244	117,350	113,124	86,548	87,852	104,547	112,260	62,236	41,364	59,781
Lower 95% CI	165,996	198,000	61,648	126,639	107,578	106,396	102,362	76,007	77,518	93,196	102,233	58,368	37,937	54,060
Estimate #2														
Number of Smolt	174,421	193,904					109,239							
Standard Error	3,590	4,443					2,855							
Upper 95% CI	181,457	202,613					114,835							
Lower 95% CI	167,386	185,195					103,643							
Estimate #3														
Number of Smolt	185,523	203,069					104,424							
Standard Error	3,985	4,631					3,309							
Upper 95% CI	193,333	212,145					110,910							
Lower 95% CI	177,713	193,992					97,939							
Pooled Estimate														
Number of Smolt	177,913	201,513	64,656	135,174	112,911	111,873	107,547	81,278	82,685	98,872	107,246	60,302	39,651	56,920
Standard Error	2,189	2,734	1,534	4,355	2,721	2,794	1,703	2,689	2,636	2,896	2,558	987	874	1,459
Upper 95% CI	182,203	206,871	67,663	143,709	118,244	117,350	110,885	86,548	87,852	104,547	112,260	62,236	41,364	59,781
Lower 95% CI	173,624	196,154	61,648	126,639	107,578	106,396	104,208	76,007	77,518	93,196	102,233	58,368	37,937	54,060

[a] Produced at Fort Richardson Hatchery.

[b] RW = raceway.

[c] Produced at Elmendorf Hatchery.

[d] Produced at Crooked Creek Hatchery.

Table 8.-Hatchery inventory data and hatchery inventory population estimates for six groups of coho and chinook salmon smolt released from the Fort Richardson Hatchery in 1993.

	Coho Salmon				Chinook Salmon	
Parameter	E3 Nancy Lake[a]	E4 Nancy Lake [a]	Bird Creek [a]	Campbell Creek[a]	Willow Creek[a]	Ninilchik River[a]
Containers of fish moved	40	45	55	63	95	99
Total fish weight moved (g)	354,031	376,376	436,383	475,572	1,047,572	1,074,062
Mean weight/container (g)	8,787	8,300	7,889	7,511	11,027	10,849
Total number of subsamples	10	10	9	10	20	15
Total weight subsampled (g)	2,535	2,897	2,471	2,350	8,530	5,712
Percent of total weight moved which was subsampled	0.71%	0.76%	0.56%	0.49%	0.81%	0.53%
Percent of individual net which was subsampled	8.7%	10.5%	10.4%	10.0%	11.6%	10.5%
Mean weight/subsample (g)	254	290	275	250	427	379
Total number of fish counted	544	592	486	506	1,740	1,181
Number of fish/subsample	54	59	54	51	87	79
Estimated number of fish enumerated by bulk weighing	75,876	76,893	85,877	100,957	212,332	223,596
Additional fish added later by tagging or weighing (samples not available)					15,450	
Number of fish placed in raceway as fry						
Total number of fish placed in raceway[a]	75,022	76,212	84,507	99,941	227,782	215,940
Standard Error	1,647	1,626	2,532	953		2,572
Upper 95% Confidence Interval	78,250	79,399	89,469	101,810		220,981
Lower 95% Confidence Interval	71,794	73,025	79,545	98,073		210,900

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

mean weight of a net load of coho salmon ranged from 2,504 g (Campbell Creek) to 2,929 g (Nancy Lake). Likewise, the mean weight of a net load of chinook salmon was 3,616 g at Ninilchik River and 3,676 g at Willow Creek. The coho salmon subsamples were 8.7% to 10.5% of a full net load. The mean weights of the coho salmon subsamples varied from 250 g to 290 g, and the mean number of fish in a subsample varied from 51 to 59 fish. The chinook salmon subsamples were 10.5% to 11.6% of a full net load. The mean weights of the chinook salmon subsamples varied from 379 to 427 g, and the mean number of fish in a subsample varied from 79 to 100 fish. Sample weights and dip net weights were not available for 15,450 chinook salmon smolt which were transferred into the Willow Creek release group at a later date than the other smolt in that release group.

The inventory estimate at EH for Ship Creek coho salmon is an exact count of the population. During the coded wire tagging process 58.1% of the population was enumerated, and the remaining fish in the population were hand counted at the completion of tagging. 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 rearing unit after an estimated number of fish have been removed. Each rearing unit 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 rearing units via the coded wire tagging process ranged from 0% to 45.9%. The percentage of fish enumerated into individual rearing units via the bulk weighing method ranged from 0% to 79.7%. The percentage of fish enumerated from a rearing unit during the coded wire tagging process ranged from 0% to 27.4%. The percentage of fish enumerated from a rearing unit via the bulk weighing method ranged from 0% to 43.6%. The inventory estimates for four of the rearing units were determined entirely by subtracting the estimated number of fish removed from the inventory estimate established at the fry stage. Two of these rearing units had fish removed from them by the coded wire tagging process and bulk weighing, and two of the rearing units had fish removed from them using only the bulk weighing method. Three of the rearing units had fish neither enumerated into them nor enumerated out of them via the coded wire tagging process. The tagged fish in these three rearing units were tagged into the same rearing unit they were taken from. The tagging process did not affect the hatchery inventory for these rearing units. The mean weight per container of fish moved from one rearing unit to another via the bulk weight method ranged from 6,593 g (Crooked Creek raceway 10) to 9,910 g (Ship Creek raceway 20). The mean weight of subsamples ranged from 858 g (Seldovia) to 1,217 g (Crooked Creek raceway 9). Subsamples ranged from 10.6% to 16.9% of a full net load.

The inventory estimate at CCH was calculated after determining the total biomass in each of the three rearing units. The fish in each crowded rearing unit were dipnetted, weighed, and returned to the rearing unit. Each rearing unit contained approximately 50 to 60 individual dip nets of fish, and each full dip net weighed approximately 7 kg. Two samples consisting of approximately 50% of a full dip net were obtained for each rearing unit. The samples were weighed, and the fish were hand counted into the rearing unit. Each sample consisted of approximately 700 to 800 fish. The mean weight of an individual fish,

Table 9.-A comparison of hatchery inventory and mark-recapture population estimates for chinook salmon release groups at Elmendorf Hatchery in relation to enumeration method(s) used.

	RW 19[a] Ship Creek	RW20 Ship Creek	RW10 Crooked Creek	RW9 Crooked Creek	Eagle River	RW 15 Homer Spit Early	RW 16 Homer Spit Early	Halibut Cove	Seldovia
Inventory number prior to splitting	244,015	75,372				181,325	180,875	184,095	
Mark/Recap est. at release	64,656	135,174	112,911	111,873	107,547	81,278	82,685	98,872	107,246
Hatchery inventory after split[b]	105,570	107,174	104,662	103,323	106,621	104,025	102,012	104,928	103,458
Number of fish enumerated into rearing unit via CWT process[c]		22,302	23,274	21,023	44,621			14,309	47,458
Number of fish enumerated into rearing unit via weighing[c]		9,500	86,388	82,300	62,000			10,000	56,000
Number of fish removed from rearing unit via CWT process	66,945							47,476	
Number of fish removed from rearing unit via weighing	71,500		5,000			77,300	78,863	56,000	
Percentage of fish enumerated into rearing unit via CWT process		20.8%	21.2%	20.3%	41.9%			13.6%	45.9%
Percentage of fish enumerated into rearing unit via weighing		8.9%	78.8%	79.7%	58.1%			9.5%	54.1%
Percentage of fish enumerated at eyed egg stage	100%	70.3%	0%	0%	0%	100%	100%	76.8%	0%
Percentage of fish removed from rearing unit via CWT process	27.4%							25.8%	
Percentage of fish removed from rearing unit via weighing	29.3%					42.6%	43.6%	30.4%	
Difference Mark-Recap est. to book est. at release	62.6%	-21.6%	-7.9%	-8.1%	-2.0%	26.3%	21.7%	4.3%	-4.7%

[a] RW = raceway.

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

[c] RW 15, 16, and 19 did not have any fish transferred into them via tagging or bulk weighing.

and the fish population were determined for each rearing unit.

Water Volume Estimates

A comparison of mark-recapture population estimates to water volume population estimates reveals that the water volume estimate was higher than the mark-recapture estimate for five of the six release groups at FRH, and for five of the seven release groups at EH (Tables 10 and 11). 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 all release groups at FRH, and for six of the nine rearing units at EH (Tables 10 and 11). For each of these rearing containers, 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 Eagle River release group is an exception to this, but all three types of estimates for this release group were extremely close (water volume estimate and hatchery inventory estimate were within 2% of the mark-recapture estimate). The Ship Creek chinook rearing units were also exceptions to this trend.

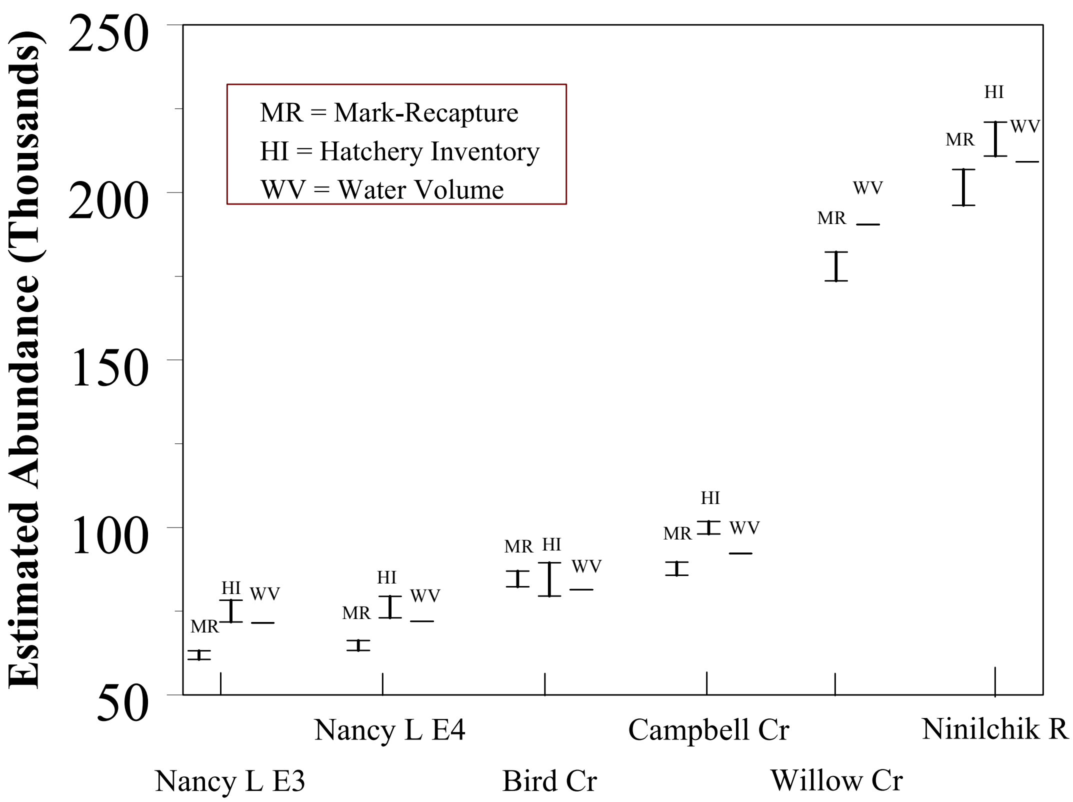


Figure 4.-Comparison of mark-recapture, hatchery inventory and water volume estimates at Fort Richardson Hatchery, 1994.

Table 10.-A comparison of mark-recapture population estimates to water volume and hatchery inventory estimates for coho salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked in four locations in Cook Inlet in 1994.

	E3 Nancy Lake[a] FRH	E4 Nancy Lake[a] FRH	Bird Creek[a] FRH	Campbell Creek[a] FRH	Ship Creek[b] EH
Mark-Recapture					
Estimate #1	61,677	61,263	81,183	88,740	75,779
Estimate #2	61,865	65,056	87,772	86,660	
Estimate #3	62,097	67,625	85,417	87,600	
Pooled Estimate	61,912	66,827	84,643	87,686	75,779
Water Volume (WV)	71,543	71,964	81,417	92,248	78,007
Hatchery Inventory Estimate (HI)	75,022	76,212	84,504	99,941	75,907[c]
Difference Mark-Recap Mean to WV	15.6%	7.7%	-3.8%	5.2%	2.9%
Difference Mark-Recap Mean to HI	21.2%	14.0%	-0.2%	14.0%	0.2%
Difference WV to HI	4.9%	5.9%	3.8%	8.3%	-2.7%

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

[b] Water volume estimate was computed using water displacement values at Elmendorf Hatchery of 4.9 kg/m^3 for the trailer tanks.

[c] Hand count.

Table 11.-A comparison of mark-recapture population estimates to water volume and hatchery inventory estimates for chinook salmon smolt produced at Elmendorf, Fort Richardson, and Crooked Creek hatcheries and stocked in 10 locations in Cook Inlet in 1994.

	Willow Creek[b] FRH	Ninilchik River[b] FRH	RW 19[a] Ship Creek[c] EH	RW20 Ship Creek[c] EH	RW10 Crooked Creek[c] EH	RW9 Crooked Creek[c,d] EH	Eagle River[c] EH	RW 15 Homer Spit Early[c] EH	RW 16 Homer Spit Early[c] EH	Halibut Cove[c] EH	Seldovia[c] EH	RW 5 Homer Spit Late [e] CCH	RW 6 Homer Spit Late [e] CCH	RW 8 Homer Spit Late [e] CCH
Mark-Recapture														
Estimate #1	173,476	208,136	64,656	135,174	112,911	111,873	107,743	81,278	82,685	98,872	107,246	60,302	39,651	56,920
Estimate #2	174,421	193,904					109,239							
Estimate #3	185,523	203,069					104,424							
Pooled Estimate	177,913	201,513	64,656	135,174	112,911	111,873	107,547	81,278	82,685	98,872	107,246	60,302	39,651	56,920
Water Volume Estimate (WV)	190,443	209,154	64,300	151,865	106,418	109,175	109,165	92,986	98,842	107,390	106,318	N/A	N/A	N/A
Hatchery Inventory Estimate (HI)	215,579	215,940	105,153	105,991	104,027	102,814	105,399	102,646	100,588	103,162	102,232	63,468	40,111	54,154
Difference Mark-Recap Mean to WV	7.0%	3.8%	-0.6%	12.3%	-5.8%	-2.4%	1.5%	14.4%	19.5%	8.6%	-0.9%			
Difference Mark-Recap Mean to HI	21.2%	7.2%	62.6%	-21.6%	-7.9%	-8.1%	-2.0%	26.3%	21.7%	4.3%	-4.7%	5.3%	1.2%	-4.9%
Difference WV est to HI	13.2%	3.2%	63.5%	-30.2%	-2.2%	-5.8%	-3.4%	10.4%	1.8%	-3.9%	-3.8%			

[a] RW = raceway.

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

[c] Water volume estimate was computed using water displacement values at Elmendorf Hatchery of 4.9 kg/m^3 for the trailer tanks.

[d] Crooked Creek water volume estimate for raceway 9 includes an estimated 9,032 fish left over from RW8 Kodiak release group.

[e] Crooked Creek Hatchery does not determine water volume estimates.

Size Estimation

The smallest coho salmon smolt in terms of length and weight were from the Nancy Lake release, while the largest smolt were from the Ship Creek release (Table 12). The smallest chinook salmon were from the Ninilchik River release, while the largest chinook salmon smolt were from the Seldovia release (Table 13). The majority of the coho salmon smolt released at Bird Creek, Campbell Creek, and Nancy Lake were between 15.1 g and 25.0 g, whereas the Ship Creek coho salmon smolt release had substantial percentages of fish in the 25.1 g to 30.0 g category (Table 14). At FRH the majority of the chinook salmon smolt released were between 5.1 g and 15.0 g. At EH and CCH the majority of the chinook salmon smolt released were over 15.0 g (Table 15).

DISCUSSION

Smolt Marking

A major point of emphasis in the 1994 marking program was to maintain, if not improve, long-term tag retention rates above 1993 levels. This was accomplished, since the combined 1994 long-term tag retention was 97.8% as compared to 96.3% in 1993. We feel that grading fish and using different sizes of head molds for tagging is responsible for improving and maintaining acceptable long-term tag retention rates in the release groups of coho and chinook salmon smolt. The scatterplot in Figure 2 indicates that the highest tag retentions for chinook salmon occur at tag application rates of approximately 220 to 250 valid tags per worker-hour, and that the highest tag retentions for coho salmon occur at tag application rates of approximately 170 to 240 valid tags per worker-hour. At some point, increased tagging speed will 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 chinook salmon and 190 valid tags/worker-hour for coho salmon.

There are a number of factors that contribute to tag application rates. The difference in tag application rates between coho salmon and chinook salmon may be species related. It was observed during tagging that coho salmon are much slower to react to the anesthetic, and much slower to revive from the anesthetic than the chinook salmon. Consequently more time is lost with coho salmon waiting for the fish to be anesthetized enough to handle. In addition, 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 (99.54 mm), and the fastest tag rate (238.3 t/wh). The Ship Creek coho salmon release group had the smallest mean length at tagging (81.52 mm), and the slowest tag rate (164.6 t/wh) (Table 16). Size at tagging does not appear to affect chinook salmon tagging rates. The mean lengths at tagging were within 3 mm of each other for all release groups of chinook salmon at EH, yet tag rates varied from 191.3 t/wh to 236.1 t/wh. At FRH, the mean lengths at tagging for the Willow Creek and the Ninilchik River chinook salmon were within 1.06 mm of each other, yet their tag rates varied by 42.7 t/wh (Table 17). Fish size distribution may also be a factor. The release group with the slowest tags per worker-hour rate was the Ship Creek coho salmon group which was tagged with four sizes of head molds due to the wide size distribution. The

Table 12.-Mean lengths and weights of coho salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked at four locations in Cook Inlet in 1994.

Parameter	Nancy Lake[a] E3	Nancy Lake[a] E4	Bird Creek[a]	Campbell Creek[a]	Ship Creek[b]
Sample Size	523	512	509	532	525
Sample Date	5/20/94	5/19/94	5/25/94	5/26/94	5/24/94
Release Dates	5/23/94	5/20/94	5/26/94	5/27/94	5/25/94
Mean Length (mm)	122	120	123	122	130
Standard Error	8.5	8.6	8.1	8.9	16.4
Maximum	150	147	144	144	161
Minimum	86	71	79	75	77
Hatchery Mean Weight					23.4
Sample Mean Weight (gm)	19.7	19.6	21.6	20.1	22.0
Standard Error	4.3	4.3	4.2	4.3	6.9
Maximum	39.1	35.2	33.9	34.7	38.7
Minimum	6.9	3.8	5.8	4.4	4.4

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

Table 13.-Mean lengths and weights of chinook salmon smolt produced at Elmendorf, Fort Richardson and Crooked Creek hatcheries and stocked at 10 locations in Cook Inlet in 1994.

Parameter	Willow Creek[a]	Ninilchik River[a]	Ship Creek[b] RW19[c]	Ship Creek[b] RW20	Crooked Creek[b] RW9	Crooked Creek[b] RW10	Eagle River[b]	Homer Spit[b] RW15	Homer Spit[b] RW16	Halibut Cove[b]	Seldovia[b]	Homer Spit Late[d] RW5	Homer Spit Late[d] RW6	Homer Spit Late[d] RW8
Sample Size	514	516	527	533	518	549	523	513	525	523	515	517	524	528
Sample Date	5/23/94	5/27/94	5/31/94	6/3/94	6/7/94	6/1/94	6/2/94	6/6/94	6/13/94	6/9/94	6/10/94	7/18/94	7/18/94	7/18/94
Release Dates	5/24/94 5/25/94	5/31/94	6/1/94	6/6/94	6/8/94	6/2/94	6/6/94	6/7/94	6/14/94	6/10/94	6/13/94	7/18/94	7/18/94	7/18/94
Mean Length (mm)	104	100	112	110	112	109	112	115	117	116	117	113	118	113
Standard error	10.1	9.3	8.2	8.1	8.2	8.6	7.6	7.7	8.0	8.1	8.7	6.4	7.1	6.0
Maximum	144	133	150	139	142	139	145	139	166	150	149	130	140	130
Minimum	79	77	56	88	74	68	93	95	98	89	75	89	91	94
Hatchery Mean Weight			16.0	14.1	15.8	14.1	15.3	16.8	17.5	17.4	18.3			
Sample Mean Weight (gm)	13.3	12.0	16.0	14.9	15.5	14.2	16.2	16.6	18.5	17.5	19.0	16.1	18.5	15.7
Standard error	4.3	3.6	4.0	4.3	4.1	3.7	4.1	3.9	5.7	4.7	5.7	2.8	3.5	2.6
Maximum	35.7	29.9	40.7	36.0	35.1	34.0	43.9	35.5	76.2	46	52.2	24.5	30.8	23.1
Minimum	5.8	5.4	3.3	4.2	3.7	3.5	8.3	8.7	10.0	7.6	6.1	7.4	8.6	9.8

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

[c] RW = raceway.

[d] Produced at Crooked Creek Hatchery.

Table 14.-Weight frequency distribution of coho salmon smolt produced at Elmendorf and Fort Richardson hatcheries and stocked in four locations in Cook Inlet in 1994.

Weight Distribution	Nancy Lake[a] E3	Nancy Lake[a] E4	Bird Creek[a]	Campbell Creek[a]	Ship Creek[b]
0 - 5 g		0.2%		0.4%	0.4%
SE		0.0001		0.0001	0.0001
5.1 - 10 g	0.8%	0.8%	0.8%	0.9%	7.2%
SE	0.0002	0.0002	0.0002	0.0002	0.0005
10.1 - 15 g	10.5%	11.3%	4.9%	8.3%	11.0%
SE	0.0006	0.0006	0.0004	0.0005	0.0006
15.1 - 20 g	43.2%	45.7%	29.3%	38.5%	13.0%
SE	0.0009	0.0010	0.0009	0.0009	0.0006
20.1 - 25 g	35.6%	29.7%	45.0%	40.6%	32.6%
SE	0.0009	0.0009	0.0010	0.0009	0.0009
25.1 - 30 g	8.2%	10.7%	18.3%	9.8%	25.9%
SE	0.0005	0.0006	0.0008	0.0006	0.0008
30.1 - 35 g	1.5%	1.4%	1.8%	1.5%	8.0%
SE	0.0002	0.0002	0.0003	0.0002	0.0005
35.1 - 40 g	0.2%	0.2%			1.9%
SE	0.0001	0.0001			0.0003
Coho Summary					
< 15.1 g	11.3%	12.3%	5.7%	9.6%	18.7%
15.1 - 25.0 g	78.8%	75.4%	74.3%	79.1%	45.5%
> 25.0 g	9.9%	12.3%	20.0%	11.3%	35.8%

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

Table 15.-Weight frequency distribution of chinook salmon smolt produced at Elmendorf, Fort Richardson, and Crooked Creek hatcheries, and stocked in 10 locations in Cook Inlet in 1994.

Weight Distribution	Willow Creek [a]	Ninilchik River [a]	Ship Creek [b] RW19[c]	Ship Creek [b] RW20	Crooked Creek [b] RW9	Crooked Creek [b] RW10	Eagle River [b]	Homer Spit [b] RW15	Homer Spit [b] RW16	Halibut Cove [b]	Seldovia [b]	Homer Spit Late [d] RW5	Homer Spit Late [d] RW6	Homer Spit Late [d] RW8
0 - 5 g			0.2%	0.2%	0.2%	0.5%								
SE			0.0001	0.0001	0.0001	0.0001								
5.1 - 10 g	22.8%	32.9%	2.1%	6.2%	4.8%	8.4%	1.5%	1.4%	0.2%	1.3%	1.0%	1.0%	0.2%	0.2%
SE	0.0008	0.0009	0.0003	0.0005	0.0004	0.0005	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
10.1 - 15 g	48.1%	50.0%	39.3%	53.8%	47.3%	58.3%	43.2%	38.0%	22.3%	28.3%	21.0%	35.6%	16.6%	44.1%
SE	0.0010	0.0010	0.0009	0.0009	0.0010	0.0009	0.0009	0.0009	0.0008	0.0009	0.0008	0.0009	0.0007	0.0009
15.1 - 20 g	20.6%	14.1%	46.1%	31.3%	37.3%	27.7%	42.6%	45.4%	52.4%	50.1%	44.1%	53.8%	50.4%	49.8%
SE	0.0008	0.0007	0.0009	0.0009	0.0009	0.0008	0.0009	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0009
20.1 - 25 g	7.2%	2.5%	10.8%	4.7%	7.3%	3.1%	9.9%	11.9%	16.8%	14.7%	25.2%	9.7%	28.8%	5.9%
SE	0.0005	0.0003	0.0006	0.0004	0.0005	0.0003	0.0006	0.0006	0.0007	0.0007	0.0008	0.0006	0.0009	0.0004
25.1 - 30 g	0.8%	0.4%	0.8%	2.3%	2.1%	1.6%	1.3%	2.5%	5.0%	3.4%	4.9%		3.8%	
SE	0.0002	0.0001	0.0002	0.0003	0.0003	0.0002	0.0002	0.0003	0.0004	0.0003	0.0004		0.0004	
30.1 - 35 g	0.4%	0.0%	0.2%	0.9%	0.8%	0.4%	0.8%	0.6%	1.5%	1.0%	1.7%		0.2%	
SE	0.0001	0.0000	0.0001	0.0002	0.0002	0.0001	0.0002	0.0001	0.0002	0.0002	0.0003		0.0001	
35.1 - 40 g	0.2%		0.4%	0.6%	0.2%		0.0%	0.2%	0.8%	0.6%	0.6%			
SE	0.0001		0.0001	0.0001	0.0001		0.0000	0.0001	0.0002	0.0001	0.0001			
40.1 - 45 g			0.2%				0.6%		0.8%	0.4%	0.8%			
SE			0.0001				0.0001		0.0002	0.0001	0.0002			
45.1 - 50 g									0.2%	0.2%	0.4%			
SE									0.0001	0.0001	0.0001			
>50 g									0.2%		0.4%			
SE									0.0001		0.0001			
Chinook Summary														
< 5.1 g	0.0%	0.0%	0.2%	0.2%	0.2%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.1 - 15.0 g	70.8%	82.9%	41.4%	60.0%	52.1%	66.7%	44.7%	39.4%	22.5%	29.6%	21.9%	36.6%	16.8%	44.3%
> 15.0 g	29.2%	17.1%	58.4%	39.8%	47.7%	32.8%	55.3%	60.6%	77.5%	70.4%	78.1%	63.4%	83.2%	55.7%

[a] Produced at Fort Richardson Hatchery.

[b] Produced at Elmendorf Hatchery.

[c] RW = raceway.

[d] Produced at Crooked Creek Hatchery.

Table 16.-Tag application rates in relation to mean size at tagging and fish size distribution at tagging for coho salmon smolt at Elmendorf, Fort Richardson, and Crooked Creek hatcheries and released into four locations in Cook Inlet in 1994.

Parameter	Nancy Lake[a]	Nancy Lake[a]	Bird Creek[a]	Campbell Creek[a]	Ship Creek[b]
Valid tags per worker hour	179.2	194.4	238.3	175.4	164.6
Mean size at tagging (mm)	92.47	92.47	99.54	92.47	81.52
# of different sizes of head molds used	3	3	3	3	4

[a] Fort Richardson Hatchery.

[b] Elmendorf Hatchery.

Table 17.-Tag application rates in relation to mean size at tagging and fish size distribution at tagging for chinook salmon smolt at Elmendorf, Fort Richardson, and Crooked Creek hatcheries and released into 10 locations in Cook Inlet in 1994.

Parameter	Willow Creek[a]	Ninilchik River[a]	Ship Creek[b] RW 19[c]	Ship Creek[b] RW 20	Crooked Creek[b] RW 9	Crooked Creek[b] RW 10	Eagle River [b]	Homer Spit Early[b]	Homer Spit Early[b]	Halibut Cove[b]	Seldovia[b]	Homer Spit Late[d] RW 5	Homer Spit Late[d] RW 6	Homer Spit Late[d] RW 8
Valid tags per worker hour	221.3	264.0	214.6	231.4	236.1	235.5	223.4	225.3	210.0	227.4	191.3	199.7	167.0	203.5
Mean size at tagging (mm)	90.35	89.29	74.45	74.45	77.32	77.32	75.57	77.32	77.32	77.32	77.32	81.68	81.68	81.68
# of different sizes of head molds used	3	2	3	3	3	3	3	3	3	3	3	2	2	2

[a] Fort Richardson Hatchery.

[b] Elmendorf Hatchery.

[c] RW = raceway.

[d] Crooked Creek Hatchery.

release group with the fastest tags per worker-hour rate was the Ninilchik River chinook salmon group which was tagged with two sizes of head molds and had a narrow size distribution. All other release groups at EH and FRH were tagged with three different size head molds. Using different head mold sizes requires extra time to set up machines and sort fish. Consequently, sorting and tagging with different head molds does decrease tag application rates somewhat. The tag application rates at CCH were low even though only two head mold sizes were used. An inexperienced tagging crew performed marking and tagging duties at CCH.

There are a number of other factors that contribute to tag rates. Release groups that were tagged at the beginning of the tagging project generally have slower tag rates than those tagged later in the project. Crews get faster as time goes on. The Bird Creek coho salmon release group (238.3 t/wh) was the last group of coho salmon tagged at FRH, whereas the Ship Creek coho salmon release group (164.6 t/wh) was the first group of salmon tagged at EH. The rotation of personnel between tagging and marking duties may affect some tag rates at the beginning of the project, but all 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). Some release groups in 1994 contained a large proportion of fish that were <81 mm in length, necessitating the establishment of a new size interval for the 120/lb size head mold. Fish in this size range were measured, tagged, and dissected to check for proper tag placement in order to determine the new minimum fish size to be tagged with the 120/lb size head mold. Fish smaller than this size were then tagged with the 200/lb size head mold. The standard size ranges tagged for each size head mold are as follows:

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 90/lb head mold was used in tagging each of the four coho salmon release groups, and in tagging the two chinook salmon release groups at CCH. 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 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. Tagging records from 1993 indicate that the 45/lb head mold was the primary head mold used when tagging the Little Susitna River coho salmon release groups. In 1994 it was observed during tagging that the fish in the 1994 release groups of Little Susitna River coho salmon had narrow heads, and the wide width of the 45/lb size head mold made it difficult to obtain good tag placement on a routine basis. These fish that would have normally been tagged using the 45/lb size head mold were tagged with the narrower 30/lb size head mold set at a shallower setting than normally used when tagging with the 30/lb size head mold.

SMOLT ENUMERATION

Comparison of the three smolt enumeration techniques revealed interesting trends (Tables 10, 11, and 18; Figure 4). First, at FRH the mark-recapture estimates were the lowest of the three, and the hatchery inventory estimates were the highest of the three for five of the six rearing units. At EH, the mark-recapture estimates were the lowest of the three, and the hatchery inventory estimates were the highest of the three for only four of the 10 rearing units. At CCH, the mark-recapture estimates were lower then the hatchery inventory estimates for two of the three rearing units. 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 groups at each hatchery. Third, the discrepancy pattern between the mark-recapture estimate and the hatchery inventory estimate was consistent with the hatchery inventory method used for most groups at each hatchery.

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 seven 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. We were able to verify one mark-recapture estimate (Ship Creek coho salmon) with a hand count. The mark-recapture estimate was 75,799 with a standard error of 2,159 (Table 6). The hand count was 75,907, which differs from the mark-recapture estimate by only 0.2%. We feel the mark-recapture technique has sound methodology and is free from major sources of error.

Comparisons of the three population estimation techniques were performed previously at Fort Richardson Hatchery 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 1994 release groups, therefore there is not a variance around the 1994 water volume estimates.

The difference between the water volume population estimates and mark-recapture population estimates for release groups at EH ranged from - 0.9% to 19.5% (Tables 10 and 11). One source of error in the water volume technique may be in the determination of mean weight of an individual fish. Prior to release, two separate mean weights were determined by two different methods for each rearing unit at EH. Mean weight was determined from the individual weights of a random sample of 510 fish, and mean weight was also determined from three small dip net samples of fish removed from the transport tanks on the transport vehicle. The differences between the two means ranged from 0.0 g to 1.4 g. EH used the mean

Table 18.-Comparison of three population estimation techniques for coho and chinook salmon smolt released from the Fort Richardson Hatchery in 1994.

	Coho Salmon				Chinook Salmon	
	Nancy Lake E3	Nancy Lake E4	Bird Creek	Campbell Creek	Willow Creek	Ninilchik River
Mark-Recapture (M-R)						
Pooled Estimate	61,912	64,782	84,643	87,686	177,913	201,513
Standard Error	670	745	1,184	1,012	2,189	2,734
Upper 95% CI	63,225	66,243	86,963	89,669	182,203	206,871
Lower 95% CI	60,599	63,321	82,324	85,702	173,624	196,154
Water Volume (WV)						
Estimate	71,543	71,964	81,417	92,248	190,443	209,154
Hatchery Inventory (HI)						
Estimate	75,022	76,212	84,507	99,941	215,579	215,940
Standard Error	1,647	1,626	2,532	953		2572
Upper 95% CI	78,250	79,399	89,469	101,810		220,981
Lower 95% CI	71,794	73,025	79,545	98,073		210,900
Difference M-R to WV	15.6%	11.1%	-3.8%	5.2%		3.8%
Difference M-R to HI	21.2%	17.6%	-0.2%	14.0%		7.2%

weights determined from the dip net samples when calculating water volume population estimates. The differences in the mean weights however does not account for the entire discrepancy between the water volume and mark-recapture estimates. 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 rearing unit of coho salmon, and five to 10 subsamples were obtained from each indoor rearing unit of chinook salmon during the transferring of fish from indoor rearing units to outdoor rearing units. For 1994 release groups of coho and chinook salmon, the number of subsamples from each coho salmon indoor rearing unit increased to 10 subsamples, and the number of subsamples from each chinook indoor rearing unit ranged from 5 to 8. The size of the subsamples for the 1994 release groups remained approximately the same as the size of the subsamples for the 1993 release groups (8.7% to 11.6% of a full net load in 1994 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 1994 release groups at FRH.

In 1994, hatchery inventory estimates at EH were based on a variety of techniques. For five rearing units, 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 rearing unit were split into two rearing units, the inventory estimate became the estimated number of fish that were moved into a different rearing unit, or the estimated number of fish that remained in the rearing unit after an estimated number of fish were removed. Fish were enumerated and moved to different rearing units by two different methods. Fish that were moved from one rearing unit 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 rearing units in which all of the fish were enumerated through the coded wire tagging process and/or bulk weighing method had inventory estimates within 10% of the mark-recapture estimates (Table 9). For each of these rearing units, 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. Although the two types of population estimates were close for each of these rearing units, data indicate that the higher the proportion of fish that were enumerated via the bulk weighing method, the greater the difference between the hatchery inventory estimate and the mark-recapture estimate.

Four of the five rearing units at EH in which the inventory number was the estimated fry inventory number plus or minus the estimated number of fish that were either added to or removed from the rearing unit 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 -21.6% to 62.6%. Three of these four rearing units had inventory estimates that overestimated the populations when compared to the mark-recapture estimates. The fourth rearing unit (Ship Creek chinook salmon, raceway 20) had an inventory estimate that underestimated the population when compared to the mark-recapture estimate. This exception to the trend is easily explained when the mark-recapture and inventory estimates are examined for both rearing units of Ship Creek chinook salmon. Data indicate that a large error was made either during the initial inventory of the eyed eggs, or during the ponding of fry. It appears that during the initial ponding, rearing unit 20 received more fish than the hatchery inventory records indicate, and rearing unit 19 received fewer fish than the hatchery inventory records indicate. All rearing units in which all fish were enumerated through tagging or bulk weighing had mark-recapture and hatchery inventory estimates which were near agreement, and four out of five rearing units 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.

At CCH the mark-recapture and hatchery inventory population estimates were within 6% of each other for each of the three rearing units. CCH measured total biomass in each rearing unit prior to release and estimated mean weight by using a large subsample of a full net. We feel that the determination of total biomass for each rearing unit in combination with a sample size that is approximately 50% of a full dip net may be the key to determining accurate hatchery inventory estimates when bulk weighing is used.

We feel 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 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 hatchery inventory estimates at Fort Richardson Hatchery were always higher than the water volume estimates (3.2% to 13.2%) and higher than the mark-recapture estimates for five of the six release groups (-0.2% to 21.2%). Accuracy and precision could possibly be improved by improving bulk weighing techniques. The hatchery inventory estimates at Elmendorf Hatchery 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 Elmendorf Hatchery for stocking into Ship Creek did not achieve the stated size goal. This release group of smolt had the highest mean weight of all the groups, however, a high percentage of fish (approximately 55%) were either smaller or larger than desired. It is questionable whether this release group will survive at anticipated levels. The coho salmon smolt produced at the Fort Richardson Hatchery for release into Bird Creek, Campbell Creek, and Nancy Lake were all extremely close to achieving the size range production goal, with approximately 75% 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 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 at the Fort Richardson Hatchery for release into the Ninilchik River achieved the production goal with 83% of the smolt within the desired size range. Over 70% of the Willow Creek release group was within the desired size range. However, the remaining fish were all larger than 15.0 g. None of the chinook salmon release groups at EH or CCH achieved the production goal. The majority of the fish in four of the six chinook salmon release groups at EH were larger than 15.0 g, and the majority of fish in both chinook salmon release groups at CCH were larger than 15.0 g. The marine survival rates for these release groups may be at anticipated levels, but due to the large size of the smolt a large percentage of the returns may be as precocial males or jacks (Peltz and Sweet 1993). Evidence also exists 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 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 (Peltz and Hansen 1994), 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 Elmendorf Hatchery 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. Rearing units in which all fish were enumerated via tagging and/or bulk weighing had fairly accurate hatchery inventory estimates. We suggest that bulk weighing entire rearing units 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 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.

6. Elmendorf Hatchery coho salmon smolt planted in Ship Creek had a high percentage (approximately 55%) of the release which were either smaller (< 15.0 g) or larger (> 25.0 g) than desired. It is questionable whether this group of fish will survive near anticipated levels.

7. Elmendorf Hatchery chinook salmon planted in Ship Creek, Crooked Creek, Eagle River, Homer Spit, 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 as precocial males or jacks.

8. Fort Richardson Hatchery coho salmon smolt planted in Bird Creek, Campbell Creek, and Little Susitna River 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 achieved the size range production goal, and the chinook salmon smolt planted in Willow Creek were close to achieving the size range

production goal. The marine survival rates for these release groups should be at anticipated levels.

10. Crooked Creek Hatchery chinook salmon smolt planted at Homer Spit had a high percentage of fish (approximately 65%) 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.

ACKNOWLEDGMENTS

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

LITERATURE CITED

Blankenship, H. L. 1990. Effects of time and fish size on coded wire tag loss from chinook and coho salmon. American Fisheries Society Symposium 7:237-243.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, New York, NY

Hewitt, G. S. and R. E. Burrows. 1948. Enumerating hatchery fish population. Progressive Fish Culturist 10:23-27.

Meyer, S., D. Vincent-Lang, and D. McBride. 1991. Goal statement and study plan for the development of a stock assessment program for Upper Cook Inlet coho salmon stocks. Alaska Department of Fish and Game, Division of Sport Fish, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Moberly, S. A., R. Miller, K. Crandall, and S. Bates. 1977. Mark tag manual for salmon. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development, Juneau.

Peltz, L. R. and P. A. Hansen. 1994. Marking, enumeration, and size estimation for coho and chinook salmon smolt releases into Upper Cook Inlet, Alaska in 1993. Alaska Department of Fish and Game, Fishery Data Series 94 -21, Anchorage.

Peltz, L. R. and J. Miller. 1990. Performance of half-length coded wire tags in a pink salmon hatchery marking program. American Fisheries Society Symposium 7:244-252.

Peltz, L. R. and D. Starkey. 1993. Summary and synthesis of production, marking and release data for coho and chinook salmon smolt released into Upper Cook Inlet, Alaska in 1992. Alaska Department of Fish and Game, Fishery Data Series 93-51, Anchorage.

Peltz, L. R. and D. E. Sweet. 1993. Performance of the chinook salmon enhancement program in Willow Creek, Alaska, 1985-1992. Alaska Department of Fish and Game, Fishery Data Series 93-22, Anchorage.

Robson, D. S. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:216-226.

Seber, G. A. F. 1982. The estimation of animal abundance, second edition. Griffin and Company, Ltd., London.

Schurman, G. C. and D. A. Thompson. 1990. Washington Department of Fisheries' mobile tagging units: construction and operation. American Fisheries Society Symposium 7:232-236.

Sweet, D. E. and L. R. Peltz. 1994. Performance of the chinook salmon enhancement program in Willow Creek, Alaska, 1985-1993. Alaska Department of Fish and Game, Fishery Manuscript No. 94-3, Anchorage.

Vreeland, R. R. 1990. Random-sampling design to estimate hatchery contributions to fisheries. American Fisheries Society Symposium 7:691-707.