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Alaska Department of Fish and Game

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ABSTRACT

Southcentral Alaska contains the majority of the state's human population and receives the vast majority of the state's fishing pressure, both of which are increasing (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 Big Lake, Elmendorf, and Fort Richardson hatcheries were standardized for each of the stocking projects in 1993. This report presents the results of the 1993 marking program. In addition, results from the comparison of three different smolt enumeration techniques are examined and discussed. The size composition of each release group is also presented and discussed.

Over 390,000 coho and chinook salmon smolt for release at 10 locations in Cook Inlet were marked with an adipose finclip and a coded wire tag. Tag retention ranged from 92.3% to 98.8%.

Comparison of the three smolt enumeration techniques revealed three interesting trends. First, in most instances the mark-recapture estimate was the lowest of the three and the hatchery inventory estimate was the highest of the three. Second, the measured variability associated with the mark-recapture estimate was usually the smallest. Third, the difference between the mark-recapture estimate and the hatchery inventory estimate was similar for all groups.

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 *Oncorhynchus kisutch* smolt have been stocked in numerous locations throughout Southcentral Alaska to improve or create terminal sport fisheries.

The success of stocking hatchery smolt depends on numerous variables, many associated with the hatchery program. In the past each hatchery has been unique in how it produces, marks, releases, collects data, and reports information about the fish. Production, marking and release of fish were examined at three Alaskan hatcheries in 1992 and based on the findings of this examination it was recommended that some standardization and monitoring of hatchery practices be initiated (Peltz and Starkey 1993). 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. Seven coho salmon smolt stocking projects using fish produced at the Big Lake (BLH), 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 and chinook salmon in Willow Creek and the Ninilchik River.

Based on marking data examined in 1992 from the three hatcheries (Peltz and Starkey 1993), long-term retention of the CWT was a problem for some release groups. Half of the release groups had long-term (>30 days) tag loss of over 10% and one group experienced a tag loss of 24.1%. 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 differently tagged. This improves the quality of tag placement and improves overall tag retention. Consequently, the solution to the tag retention problem may be grading all fish to be marked by size and using different sizes of head molds to tag the appropriate sizes of fish.

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 the three hatcheries in 1992 indicated a variation of up to 32.9% between two different hatchery release estimation techniques (Peltz and Starkey 1993). 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 goal of this project was to improve hatchery practices by examining several hatchery procedures. 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 short-term (12-24 hours) tag retention rate of each group of marked fish;

4. to estimate the long-term (>30 days) tag retention rate of each group of marked fish;

5. to test the hypothesis that long-term tag retention rate is equal between smolt tagged using different head molds based on size and those groups where all fish were tagged using the same head mold; and

6. to determine if a relationship exists between tag application rate and long-term tag retention rate.

As part of this project, approximately 360,000 of the projected 1,360,000 coho and chinook smolt to be stocked in 1993 were to be marked 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 nine Cook Inlet release groups (Meyer et al. 1991).

Marking and collection of release data at the Big Lake, Elmendorf, and Fort Richardson hatcheries were standardized for each of the stocking projects in 1993. This report presents the results of the 1993 marking program. In addition, results from the comparison of 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. All fish raised at the Big Lake hatchery were from the Big Lake coho salmon brood stock. Coho salmon raised at the Elmendorf hatchery were from the Ship Creek brood stock. The Fort Richardson hatchery raised coho salmon from the Little Susitna River brood stock and chinook salmon from Willow Creek and Ninilchik River brood stocks. Eight of the ten release groups were marked with one tag code. Two of the release

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 1993.

Hatchery	Species	Release Location	Total Number Released	Total Number Tagged
Big Lake	Coho	Cottonwood Creek	75,000	40,000
		Fish Creek	75,000	40,000
		Wasilla Creek	75,000	40,000
Elmendorf	Coho	Ship Creek	65,000	40,000
Fort Richardson	Coho	Little Susitna River		
		Nancy Lake	150,000	20,000
		Houston	150,000	20,000
		Bird Creek	150,000	40,000
		Campbell Creek	150,000	40,000
Total	Coho		890,000	280,000
Fort Richardson	Chinook	Willow Creek	200,000	40,000
		Ninilchik River	270,000	40,000
Total	Chinook		470,000	80,000
Total	Smolt		1,360,000	360,000

groups, Nancy Lake and Houston, are in the Little Susitna River system and a single, separate tag code was used for both releases.

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. At the Big Lake and Elmendorf hatcheries, over 50% of each release group was 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 unlikely that a nonrandom sample was obtained if more than half the fish were marked. At the Fort Richardson hatchery less than 50% of each release group was to be marked. Fish in each rearing container were crowded causing mixing and 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. If fish for a particular release group were in more than one rearing container, then approximately the same proportion of fish in each container was marked (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. Due to poor tag retention rates in some of the 1992 release groups (Peltz and Starkey 1993) most of the release groups in 1993 were graded and tagged with the appropriate size head mold. All three release groups at the Big Lake hatchery and the one release group at the Elmendorf hatchery were graded and tagged. At the Fort Richardson hatchery, three two-sample proportion tests were to be conducted to determine if there were significant differences in long-term tag retention rates between groups of fish graded and tagged with different size head molds and groups of fish of which all sizes were tagged with one size head mold. However, problems encountered during tagging of the Willow Creek chinook salmon smolt resulted in abandoning one of the tests and both Willow Creek and Ninilchik River chinook salmon smolt were graded before tagging. The two tests compared the long-term tag retention rate between: (1) coho salmon for release at Houston and Nancy Lake in the Little Susitna River which were equally divided in adjacent raceways, and (2) coho salmon for stocking into Bird and Campbell creeks which were also in adjacent raceways. All four groups were approximately the same size. The Nancy Lake and Bird Creek raceways were graded and tagged with different size head molds and all fish in the Houston and Campbell Creek raceways were tagged with one head mold size.

The criteria for grading was determined for each species and stock of fish prior to tagging. The mean weight of each stock of fish to be tagged was estimated by hatchery personnel. The head mold corresponding to the mean fish size was selected for use as were the next smaller and larger head molds. A random sample of at least 510 fish (Thompson 1987) was obtained from each stock within 7 days of the initial tagging date to estimate the length distribution of each tag group and determine the proper size head mold. Fish were netted from throughout the rearing container, placed in a bucket, and the sample netted from the bucket. Each fish was measured for fork length to the nearest millimeter and fitted into a range of head molds to determine which mold size fit best. Fit was based on the amount of side to side and up and down head movement which occurred when the nose of the fish touched the back of the head mold. The head mold which allowed the least movement was judged the best fit. The fish length and appropriate head mold size were recorded on a spreadsheet. This produced a range of fish lengths corresponding to each head mold size. The range of fish lengths of different head mold sizes overlapped. Logical end points of head mold size to use in the length overlap range were based on the distribution of length data. Once the length distribution for each head mold size was determined, fish marking was initiated.

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 due to 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 approximately four times per day. Additional quality control checks were performed any time there was a change in head mold size. A minimum of five tagged fish during each period were dissected to determine tag placement (Moberly et al. 1977). If tag placement was determined to be outside the preferred area of placement (Figure 1), the head mold and/or needle was adjusted accordingly. The number of fish that were killed to determine tag placement was subtracted from the daily number of tagged fish and were not included as tagged fish.

After tagging, all fish were held in net pens overnight to determine short-term mortality and estimate short-term tag retention rate. All overnight mortalities were counted and recorded. 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 for 24 hours. Daily tag retention rate (D_i) of smolt that were finclipped, tagged, survived, and retained the tag was estimated as a binomial proportion as:

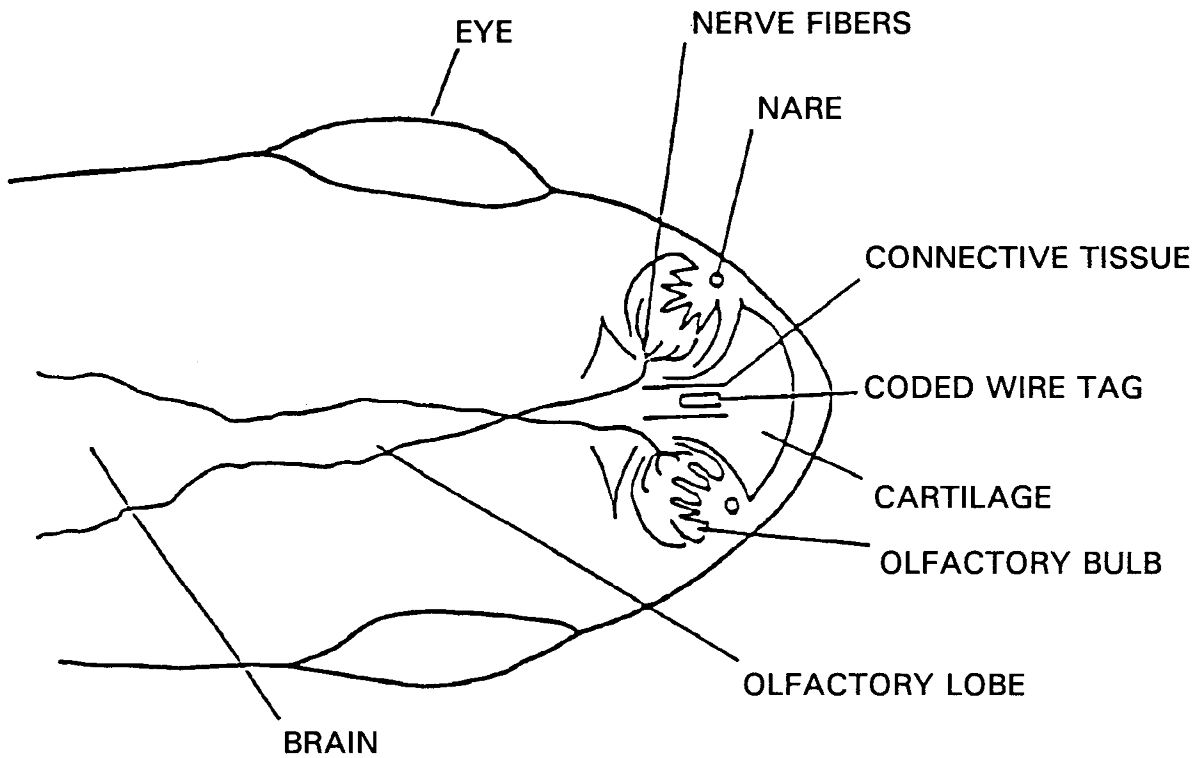
$$\hat{D}_i = \frac{n_i}{n_{ti}} \tag{1}$$

where:

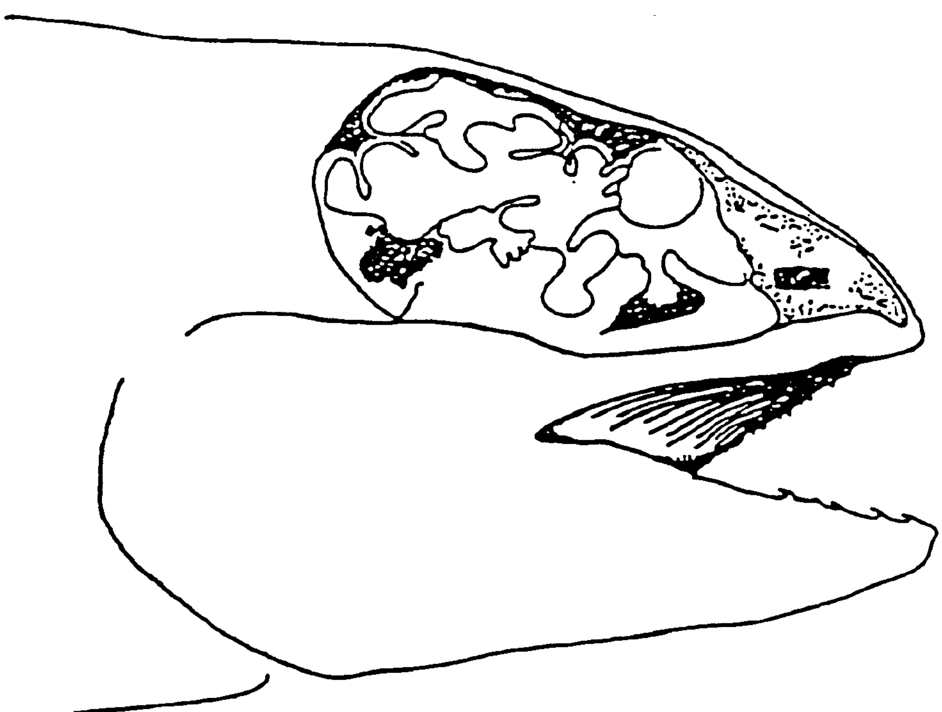
n_i = number of live smolt in the sample tagged on day i that retained the tag, and

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

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



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.

Once all tagging for a rearing container was completed, the tagged smolt were combined with untagged smolt and all fish received equal treatment 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, except for two release groups at the Big Lake hatchery, occurred more than 30 days after completion of tagging. After first crowding the fish in each rearing container, a minimum of 1,500 marked fish (adipose clipped) were randomly sampled from the population. Each of the 1,500 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). This level of sampling was also adequate to test the null hypothesis of no difference in long-term tag retention rate between groups tagged with different head molds based on fish length and those tagged with one head mold (Fleiss 1981). Long-term tag retention rate (D_j) of smolt that were finclipped, tagged, survived, and retained the tag, and its variance, were also estimated as a binomial proportion (formulas 1 and 2) for each group;

where:

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

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

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

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

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. Workers also doing hatchery work, who only worked on the tagging operation on a part-time basis, recorded only those hours worked on the tagging project. 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:

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

and

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

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 release group 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 or from estimates of body weight obtained at one or more stages of development. Water volume estimates were based on the amount of water displaced by fish in the transport tanks as they were loaded for stocking.

Mark-Recapture Estimates:

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. At least 1,500 marked fish were examined to estimate long-term tag retention rate. The number of unmarked fish examined to obtain 1,500 marked fish was recorded to use in the abundance estimate. This level of sampling exceeded that needed to estimate number of smolt with the desired precision and accuracy (Robson and Regier 1964).

The Bird Creek, Campbell Creek, Houston and Nancy Lake coho salmon release groups at FRH, the Willow Creek and Ninilchik chinook salmon groups at FRH, and the Cottonwood Creek and Wasilla Creek coho groups at BLH 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 (t-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.

One of the BLH release groups was split into six small raceways of 7,000 marked fish among 11,000 total fish per raceway. The estimate of the total abundance of the group and its variance was the sum of the independent estimates from the six raceways. At least 900 fish were examined from each raceway to calculate separate population estimates for each raceway. This level of sampling exceeded that needed to meet objective criteria.

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 marking was calculated as:

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

with variance:

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

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 or losses 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 t-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. However, analysis at EH was not necessary because the inventory was a complete census, nor at BLH because it was closed July 1, 1993.

The hatchery inventory estimate at EH for the Ship Creek coho salmon smolt release was established upon the completion of marking. A divider in the raceway separated all marked and unmarked fish. The number of marked fish was known. 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 estimate at FRH for the coho salmon smolt to be stocked at the Little Susitna River, Bird Creek and Campbell Creek 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):

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

where:

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

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

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

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

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

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

and then the ratio estimate was calculated as:

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

with variance:

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

where:

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

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

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

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

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:

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

The number of fish released from an outdoor raceway was the estimate (13) minus the number of mortalities from date of loading into the outdoor raceway to the date of release.

Water Volume Estimates:

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

Both the Big Lake and Fort Richardson hatcheries transported fish with a Fort Richardson hatchery vehicle and Elmendorf hatchery transported fish with an Elmendorf hatchery vehicle. Water volume displacement data for the Fort Richardson hatchery truck were collected. Fish displacement data for coho and chinook salmon smolt were collected from the Fort Richardson hatchery releases only.

Tank volume and the water volume displacement data for each tank on the FRH vehicles were collected after all fish were transported for release. Each tank was filled to the normal level for fish transport before loading and the water level on the tank sight gauge was recorded to the nearest millimeter. Water was then added in 25 gallon increments and the water level on the tank sight gauge was recorded to the nearest millimeter after each increment. This procedure continued until the tank was filled to the normal level for fish transport.

FRH has two vehicles for transporting fish: a boom truck and a flatbed trailer. Each vehicle has a tank divided into four compartments: the compartments on the truck are of two different sizes while the flatbed compartments are all the same size. Hereafter, compartments will be referred to as tanks. Fish displacement was estimated using Willow Creek chinook salmon smolt in one tank on the flatbed, Ninilchik River chinook salmon smolt in one tank on the boom truck, Houston coho salmon smolt in one tank on the flatbed and Nancy Lake, Bird Creek and Campbell Creek coho salmon smolt in three tanks on the boom truck.

For each tank, the ratio of the volume of water in the tank sight gauge displaced by the volume of water pumped into the tank was estimated as:

$$\hat{V} = \frac{\overline{s}_v}{\overline{t}} \qquad (15)$$

where:

S_v = the average water volume (number of millimeters) displaced in the tank sight gauge from the total of n_a water volume samples

$$= \frac{\sum_{k=1}^{n_a} s_{vk}}{n_a}$$

$\overline{t}$ = the average number of gallons of water put into the tank during each of the n_a water volume samples

$$= \frac{\sum_{k=1}^{n_a} t_k}{n_a}.$$

The jackknife procedure outlined in (10)-(12) was used to estimate the ratio of the water volume displaced in the tank sight gauge relative to water volume in the tank, and its variance. In these calculations n_d was replaced with n_a. No fpc was required because all of the samples filled the tank.

Twelve groups of coho salmon smolt from FRH, and six groups of chinook salmon smolt from FRH, were used. Each group was composed of 3,000-5,000 smolt netted from throughout their respective raceways, hand counted, and put into a holding pen in a raceway prior to stocking. Individual weight measurements were recorded from at least 80 smolt selected at random from each holding pen. 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. Three groups of fish were put into each of the tanks used to estimate fish displacement. The water level on the tank sight gauge was recorded after each group of fish was loaded into the tank. The mean weight of the fish in each group was estimated to allow estimating the weight of fish which displaced the water in the tank sight gauge.

The ratio of the number of fish put into a tank to the volume of water displaced in the tank sight gauge was estimated as:

$$\hat{F} = \frac{\overline{f}}{\overline{s}_F} \qquad (16)$$

where:

$\overline{f}$ = the average number of fish put into the tank in each sample from the total of n_b samples

$$= \frac{\sum_{l=1}^{n_b} f_l}{n_b}$$

$\bar{s}_F$ = the average water volume (number of millimeters) displaced in the tank sight gauge from the n_b samples

$$= \frac{\sum_{l=1}^{n_b} s_{Fl}}{n_b}.$$

The ratio of the weight of fish put into a tank to the volume of water displaced in the tank sight gauge is similarly estimated as:

$$\hat{G} = \frac{\bar{w}_F}{\bar{s}_F} \tag{17}$$

where:

$\bar{w}_F$ = the average weight of fish put into the tank from the total of n_b samples.

The jackknife procedure outlined in (10)-(12) was used to estimate the ratio of the number of fish put into the tank to the water volume displaced in the tank sight gauge, and its variance. In these calculations n_d was replaced with n_b. No fpc was required because the three samples of 3,000-4,000 fish each filled the tank. To estimate the variance of the weight of fish in the tank required incorporating the variance of mean fish weight within each of the n_b samples. Therefore, the variance of the ratio of weight of fish to volume of water in the tank site gauge was estimated as:

$$Var\left[\hat{G}_Q\right] = \frac{n_b - 1}{n_b} \sum_{l=1}^{n_b} \left(\hat{G}_{jl} - \bar{G}_j\right)^2. \tag{18}$$

Variation due to estimating weight was ignored because the sampling fraction of the first stage was small.

The amount of fish in a tank, either number or weight, was the product of total tank volume, the ratio of water volume displacement, and ratio of fish displacement, or:

$$\hat{N}_x = T\hat{V}\hat{X} \tag{19}$$

and the variance estimated as (Goodman 1960):

$$\hat{V}\left[\hat{N}_x\right] = T^2\left[\hat{V}^2 Var(X) + \hat{X}^2 Var\left(\hat{V}\right) - Var\left(\hat{X}\right) Var\left(\hat{V}\right)\right] \tag{20}$$

where:

T = total volume of water in the tank, and

$\hat{X}$ = $\hat{F}$ when estimating number of fish or $\hat{G}$ when estimating weight of fish.

Size Estimation

A random sample of at least 510 fish (Thompson 1987) was obtained from each release group of fish within 7 days of the stocking date to estimate weight and length composition of each group with the desired accuracy and precision. Fish were crowded to one end of the raceway and a sample was netted and put into a small holding pen. The BLH release group which was spread among six raceways had at least 85 fish measured from each raceway and the data were pooled to obtain a single estimate of length and weight composition. 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:

$$\hat{a}_{jk} = \frac{n_{jk}}{n_j} \tag{21}$$

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:

$$Var\left[\hat{a}_{jk}\right] = \frac{\hat{a}_{jk}\left(1 - \hat{a}_{jk}\right)}{n_j - 1}. \tag{22}$$

RESULTS

Smolt Marking

Over 390,000 coho and chinook salmon smolt for release at 10 locations in Cook Inlet were marked in 1993 (Table 2). This number exceeded the project goal by more than 8%. Tag retention ranged from 92.3% to 98.8% with an overall mean of 96.3%. An estimated 1.18 million coho and chinook salmon smolt were released which was 13.2% fewer fish than planned. The percentage of the total release which was marked ranged from 14.4% to 76.9% with an overall mean of 31.8%. Long-term tag retention was checked after the prescribed 30-day waiting period with all but two of the release groups. Both groups were from

Table 2. Summary of coded wire tag data at the Big Lake, Elmendorf, and Fort Richardson hatcheries for coho and chinook salmon smolt stocked in 10 locations in Cook Inlet in 1993.

	Coho Salmon								Chinook Salmon		
							Little Susitna River				
Parameter	Cottonwood Creek[a]	Fish Creek[a]	Wasilla Creek[a]	Ship Creek[b]	Bird Creek[c]	Campbell Creek[c]	Houston[c]	Nancy Lake[c]	Willow Creek[c]	Ninilchik River[c]	Total
Tag codes	31-21-41	31-21-40	31-21-42	31-21-36	31-21-39	31-21-38	31-21-37	31-21-37	31-21-60	31-21-59	ALL
Total marked and tagged[d]	43,253	44,102	43,139	42,633	43,584	43,554	21,794	21,151	43,005	44,696	390,911
Mortalities	136	52	138	521	143	114	390	150	223	209	2,076
Marked fish released	43,117	44,050	43,001	42,112	43,441	43,440	21,404	21,001	42,782	44,487	388,835
Tag retention sample size	1,679	2,009	1,647	1,555	1,546	1,544	1,620	1,751	1,633	1,618	16,602
Tag retention at release	94.8%	98.2%	97.0%	98.1%	97.5%	98.8%	96.5%	93.5%	92.3%	96.7%	96.3%
Tag retention Standard Error	0.005	0.003	0.004	0.003	0.004	0.003	0.005	0.006	0.007	0.004	
Tagged fish released	40,875	43,257	41,711	41,322	42,350	42,916	20,312	19,930	39,420	42,960	375,053
Tagged fish Standard Error	235	130	182	145	171	119	98	124	283	199	
Total fish released[e]	74,198	67,934	77,174	54,764	140,382	140,797	148,282	131,591	160,194	184,585	1,179,902
Percent tagged	58.1%	64.8%	55.7%	76.9%	30.9%	30.9%	14.4%	16.0%	26.7%	24.1%	31.8%
Tagging dates	4/21-5/3	5/10-17	5/3-10	2/16-3/2	3/22-31	3/16-22	3/8-10	3/11-16	3/31-4/10	4/12-19	
Date of tag retention check	6/7	6/3	6/7	5/25	5/26	5/27	5/21	5/20	6/1	6/2	
Date elapsed[f]		35	17	28	84	56		66	72	65	52

[a] Produced at the Big Lake hatchery

[b] Produced at the Elmendorf hatchery

[c] Produced at the Fort Richardson hatchery

[d] Marked fish refers to fish with an adipose finclip and tagged fish refers to fish with an adipose finclip and a coded wire tag.

[e] The release number is a total count for the Ship Creek release and the mark-recapture estimate for all other releases.

[f] Days elapsed between the last day of tagging and the day tag retention was checked.

the Big Lake hatchery. Tagging at the Big Lake hatchery was not completed until mid-May, consequently it was impossible to wait the prescribed 30 days before testing for tag retention.

Tag application rates varied dramatically among the release groups (Table 3). The Nancy Lake release group had a tag application rate of only 163.3 tags per worker hour, while the Wasilla Creek release group had a tag application rate of 256.0 tags per worker hour. Estimated long-term tag retention ranged from 92.3% for the Willow Creek smolt release to 98.8% for the Campbell Creek smolt release. A plot of tag application rates versus long-term tag retention rates is presented in Figure 2. The three lowest tag application rates corresponded to the three lowest long-term tag retention rates. 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.

Over 1,500 coho salmon from three different release groups were measured for length and fitted into a coded wire tag head mold. A definite area of overlap in the length frequency distributions existed between adjacent head mold sizes (Table 4). The break between head mold sizes 90 and 65 occurred at 90 mm to 94 mm, between sizes 65 and 45 occurred at 103 mm to 107 mm, and between sizes 45 and 30 occurred at 117 mm to 123 mm.

Over 1,000 chinook salmon from two different release groups were measured for length and fitted into a coded wire tag head mold. Once again, there was an area of overlap in the frequency distributions of adjacent head mold sizes (Table 5). The break between head mold sizes 90 and 65 occurred between 92 mm and 95 mm and the break between sizes 65 and 45 occurred between 106 mm and 110 mm.

The results of the comparisons of sorted and unsorted smolt for marking produced inconclusive results. In each of the comparisons, Houston (unsorted) versus Nancy Lake (sorted) and Campbell Creek (unsorted) versus Bird Creek (sorted), the unsorted smolt release had higher tag retention than the sorted group.

<u>Smolt Enumeration</u>

Mark-Recapture Estimates:

The mark-recapture estimates for the 10 release groups are presented in Table 6 and Figure 3. Only one estimate was calculated for the Ship Creek and Fish Creek groups. Z-tests were used to test for significant differences among the three abundance estimates from the same release group (overall α = 0.05). No significant differences were detected among the three estimates in six of the eight groups. The two remaining groups, Houston and Willow Creek, each had one estimate which was different from the other two estimates. The confidence intervals on the Cottonwood and Wasilla Creek estimates are narrow because such a high percentage (> 50%) of the population was marked. Conversely, the confidence intervals on the Houston estimates are wide because a low percentage (< 15%) of the population was marked.

Table 3. Numbers of fish coded wire tagged, tag application rates, tag codes, and tag retention rates at Big Lake, Elmendorf and Fort Richardson hatcheries in 1993.

	Coho Salmon								Chinook Salmon		
							Little Susitna River				
Parameter	Cottonwood Creek[a]	Fish Creek[a]	Wasilla Creek[a]	Ship Creek[b]	Bird Creek[c]	Campbell Creek[c]	Houston[c]	Nancy Lake[c]	Willow Creek[c]	Ninilchik River[c]	Total
Tag Codes	31-21-41	31-21-40	31-21-42	31-21-36	31-21-39	31-21-38	31-21-37	31-21-37	31-21-60	31-21-59	ALL
Total marked and tagged	43,253	44,102	43,139	42,633	43,584	43,554	21,794	21,151	43,005	44,696	390,911
Worker hours per tag code	226	219.5	168.5	212.5	195.5	191	108	129.5	253.5	193.5	1,897.5
Tags per worker hour	191.4	200.9	256.0	200.6	222.9	228.0	201.8	163.3	169.6	231.0	206.0
Tags/worker hr Standard Error	1.038	0.594	1.079	0.680	0.875	0.621	0.908	0.956	1.115	1.027	
Short-term tag retention	99.0%	98.8%	99.0%	99.6%	99.9%	99.7%	99.7%	99.7%	98.9%	99.3%	99.4%
Long-term tag retention	94.8%	98.2%	97.0%	98.1%	97.5%	98.8%	96.5%	93.5%	92.3%	96.7%	96.3%
Tag loss	4.2%	0.6%	2.0%	1.5%	2.4%	0.9%	3.2%	6.2%	6.6%	2.6%	3.0%
Days elapsed	35	17	28	84	56	66	72	65	52	44	

[a] Produced at the Big Lake hatchery

[b] Produced at the Elmendorf hatchery

[c] Produced at the Fort Richardson hatchery

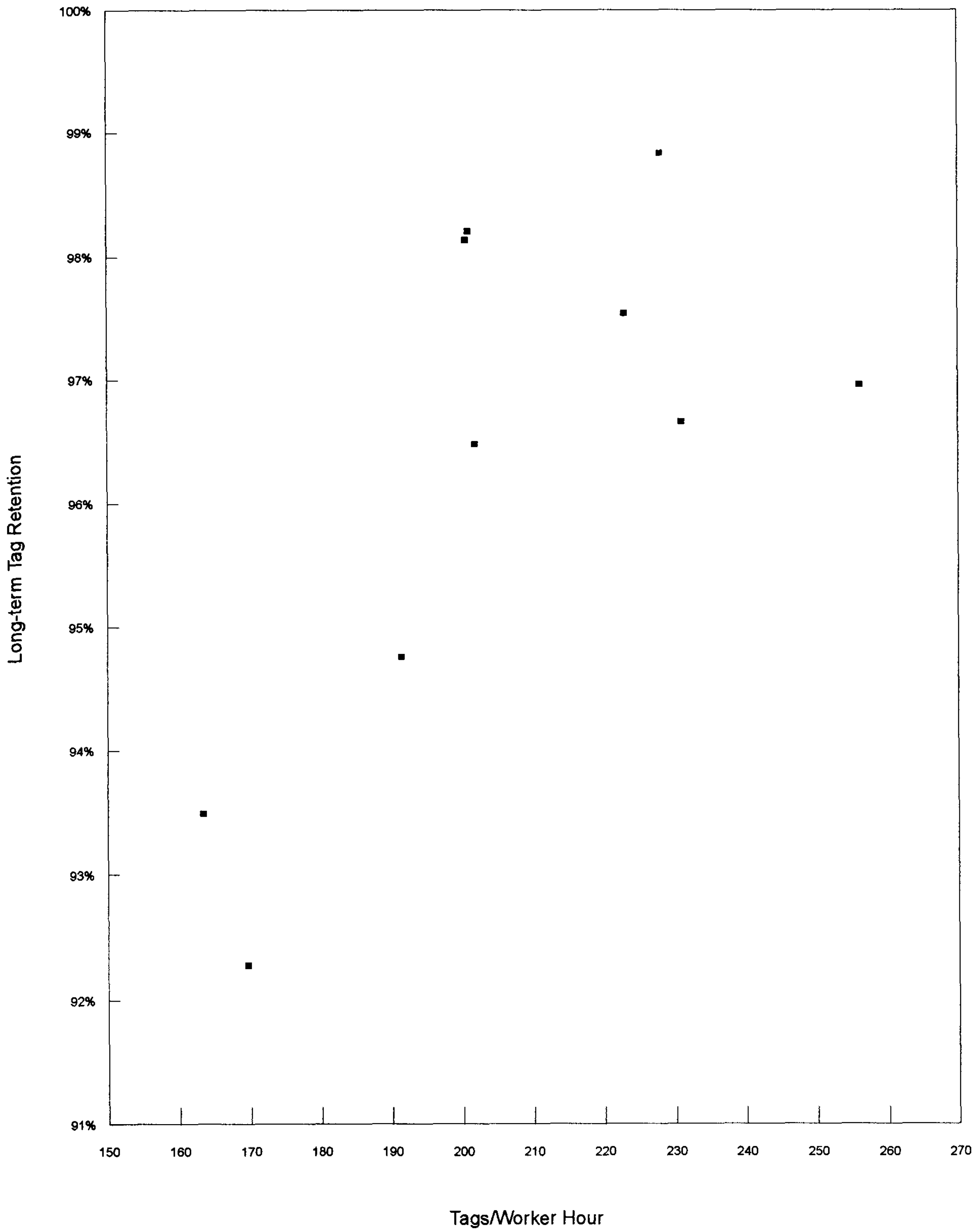


Figure 2. Comparison of tag application rates to long-term tag retention rate for 10 coho and chinook salmon release groups from the Big Lake, Elmendorf, and Fort Richardson hatcheries in 1993.

Table 4. Number and length of coho salmon from Big Lake and Little Susitna River brood stock which fit into a range of coded wire tagging head mold sizes.

	Head Mold Size				
Length	90	65	45	30	Total
52 - 70	16	2			18
71	6	1			7
72	2	1			3
73	2	2			4
74	3	1			4
75	5	3			8
76	6	2			8
77	5	4			9
78	10	4			14
79	7	1			8
80	10	3			13
81	7	1			8
82	17	3			20
83	11	0			11
84	6	0			6
85	11	1			12
86	11	5			16
87	17	1			18
88	19	5			24
89	12	4			16
90	16	5			21
91	17	7	1		25
92	11	10	0		21
93	7	17	0		24
94	5	22	0		27
95		19	0		19
96		19	0		19
97		33	1		34
98		28	1		29
99		23	1		24
100		27	5		32
101		27	1		28
102		23	5		28
103		25	12		37
104		21	7		28
105		25	15		40
106		10	22		32
107		18	44		62
108		7	58	1	66

-continued-

Table 4. (Page 2 of 2).

Length	90	65	45	30	Total
	Head Mold Size				
109		2	40	1	43
110		3	48	1	52
111		3	52	0	55
112		0	76	2	78
113		1	59	2	62
114			47	3	50
115			44	5	49
116			31	7	38
117			39	14	53
118			26	14	40
119			14	21	35
120			17	17	34
121			11	7	18
122			12	19	31
123			5	16	21
124			3	7	10
125			3	13	16
126			2	11	13
127			3	9	12
128			4	10	14
129			1	1	2
130			1	5	6
131 - 143			7	9	16
	239	419	718	195	1,571

Table 5. Number and length of chinook salmon from Willow Creek and Ninilchik River brood stock which fit into a range of coded wire tagging head mold sizes.

	Head Mold Size			
Length	90	65	45	Total
70 - 79	28	0	0	28
80	16	0	0	16
81	15	0	0	15
82	24	0	0	24
83	30	0	0	30
84	36	0	0	36
85	45	0	0	45
86	45	0	0	45
87	41	0	0	41
88	45	1	0	46
89	50	0	0	50
90	45	2	0	47
91	45	1	0	46
92	48	7	0	55
93	35	17	0	52
94	18	25	0	43
95	9	33	0	42
96	6	32	0	38
97	3	45	0	48
98	1	48	0	49
99	0	27	0	27
100	0	29	0	29
101	1	23	0	24
102	1	27	1	29
103	0	28	1	29
104	0	11	0	11
105	0	18	0	18
106	0	10	1	11
107	0	9	3	12
108	0	8	11	19
109	0	1	4	5
110	0	1	11	12
111	0	1	7	8
112	0	0	14	14
113	0	1	6	7
114	0	0	3	3
115	0	0	5	5
116	0	0	5	5
117	0	0	6	6
118	0	0	2	2
119	0	0	0	0
120 - 145	0	0	14	14
	587	405	94	1,086

Table 6. Mark-recapture population estimates of 10 Cook Inlet coho and chinook salmon smolt releases from Big Lake, Elmendorf, and Fort Richardson hatcheries in 1993.

	Coho Salmon								Chinook Salmon	
						Little Susitna River				
	Cottonwood Creek	Fish Creek	Wasilla Creek	Bird Creek	Campbell Creek	Houston	Nancy Lake	Ship Creek	Ninilchik River	Willow Creek
Mark-recapture Estimate #1	74,728	67,934	76,901	146,599	144,304	156,344	134,332	55,806	185,995	163,655
Standard Error	1,524	652	1,708	3,064	3,015	6,591	5,133	683	3,937	3,411
95% CI										
upper	77,715	69,211	80,249	152,605	150,214	169,262	144,392	57,145	193,712	170,341
lower	71,742	66,657	73,552	140,593	138,394	143,425	124,271	54,466	178,277	156,970
Mark-recapture Estimate #2	72,089		77,178	137,850	135,988	134,573	130,142		178,176	165,381
Standard Error	1,358		1,694	2,891	2,851	4,728	4,796		3,651	3,375
95% CI										
upper	74,751		80,499	143,516	141,577	143,840	139,543		185,332	171,996
lower	69,428		73,857	132,184	130,400	125,306	120,742		171,021	158,765
Mark-recapture Estimate #3	75,901		77,360	136,732	141,780	156,891	130,416		189,681	153,150
Standard Error	1,548		1,703	2,709	2,948	6,024	4,263		4,026	2,763
95% CI										
upper	78,935		80,697	142,042	147,558	168,697	138,772		197,571	158,565
lower	72,866		74,023	131,422	136,003	145,084	122,059		181,790	147,735
Mark-recapture Estimate Pooled	74,198		77,174	140,382	140,797	148,282	131,591		184,585	160,194
Standard Error	851		984	1,670	1,700	3,280	2,716		2,233	1,823
95% CI										
upper	75,866		79,102	143,655	144,128	154,711	136,914		188,963	163,767
lower	72,531		75,246	137,109	137,465	141,853	126,269		180,208	156,620

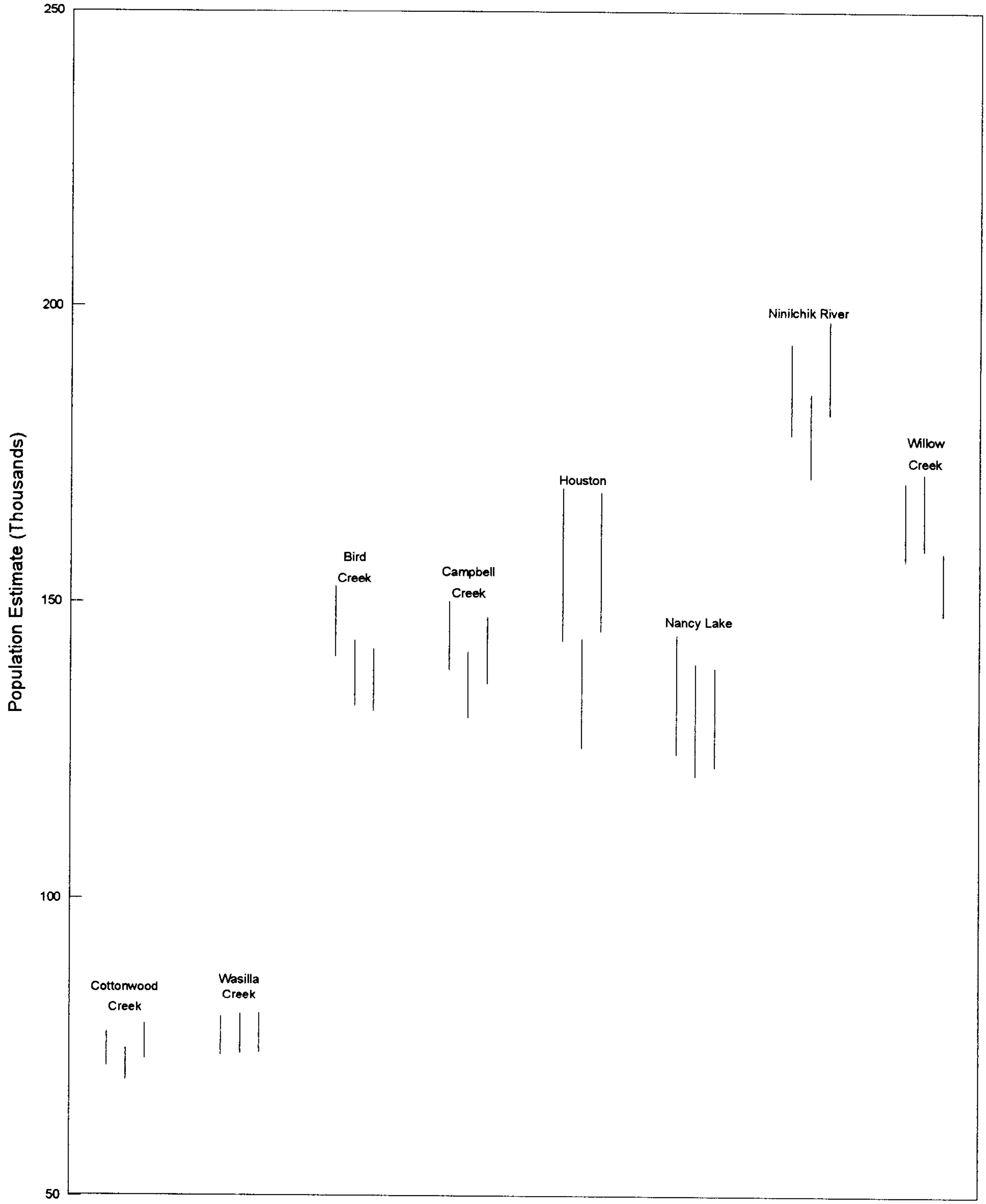


Figure 3. Comparison of 95% confidence intervals for mark-recapture population estimates for eight coho salmon and chinook salmon release groups from the Big Lake and Fort Richardson hatcheries in 1993.

Hatchery Inventory Estimates:

The mean weight per container of fish moved from indoor to outdoor raceways for the coho salmon smolt ranged from 7,120 g (Bird Creek) to 9,773 g (Campbell Creek) (Table 7). Both of the chinook salmon smolt groups had mean container weights over 9,000 g. The mean weight of the coho salmon subsamples ranged from 240 g (Campbell Creek) to 274 g (Houston), while the chinook salmon subsamples were 374 g (Ninilchik River) and 382 g (Willow Creek). 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 mean weight of a net load of coho salmon ranged from 2,373 g (Bird Creek) to 3,258 g (Campbell Creek). Likewise, the mean weight of a net load of chinook salmon was 3,252 g at Ninilchik River and 3,042 g at Willow Creek. The coho salmon subsamples were 7.4% to 10.2% of a full net load. The chinook salmon subsamples were 11.5% to 12.6% of a full net load. Although the mean weights of the subsamples varied, the mean number of fish in a subsample only varied from 71 to 75 fish among all groups.

The standard error of the Campbell Creek estimate was much higher than any of the other standard errors (Table 7). The smallest standard errors were associated with the two chinook salmon estimates because more subsamples were used to generate estimates from these two groups. Likewise, the standard error for the two chinook salmon estimates were small and the Campbell Creek standard error was large.

Water Volume Estimates:

Measurement of the transport tanks revealed that all the tanks on the boom truck had nearly identical ratios (2.335, 2.338, 2.329, and 2.320) of water volume displaced in the tank sight gauge to the volume of water placed in the tank (mm/gallon). The volume used to transport fish was the same for all the tanks on the boom truck. Similar measurements on the flatbed trailer (1.274, 1.284, and 1.286) indicated that those tanks were also nearly identical. The volume used to transport fish was the same for all tanks on the flatbed trailer.

None of the estimates of displacement values using the boom truck tanks were statistically different from one another (Z-tests, all P-values > 0.30, Table 8). Likewise, the two estimates of displacement value using the flatbed trailer tanks were not statistically different from each other (Z-test, P = 0.42).

All release groups except Ninilchik River had fish transported in both the boom truck tanks and the flatbed tanks. However, each group had a displacement value estimated for only one of the transport vehicles. Consequently, the Houston displacement value estimate for the flatbed tanks was used to estimate numbers of fish for all the coho salmon release groups. The Nancy Lake boom truck displacement value estimate was also used to estimate numbers of fish for the Houston release group. The Campbell Creek release group had the highest standard error and widest confidence interval and the Ninilchik River release group had the smallest standard error and narrowest confidence interval (Table 8).

Table 7. 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	
			Little Susitna River			
	Bird Creek	Campbell Creek	Houston	Nancy Lake	Willow	Ninilchik
Containers of fish moved	76	57	73	67	118	109
Total fish weight moved (g)	541,106	557,041	634,873	494,477	1,076,943	1,063,439
Mean weight/container (g)	7,120	9,773	8,697	7,380	9,127	9,756
Total number of subsamples	10	10	15	10	25	20
Total weight subsampled (g)	2,425	2,402	4,109	2,454	9,558	7,490
Percent of total weight moved which was subsampled	0.4%	0.4%	0.6%	0.5%	0.9%	0.7%
Mean weight/subsample (g)	242	240	274	245	382	374
Total number of fish counted	725	705	1,117	751	1,874	1,425
Number of fish/subsample	73	71	74	75	75	71
Total estimated number of fish[a]	158,563	160,374	169,565	149,130	200,580	187,736
Standard Error	3,916	7,001	2,633	3,545	2,266	1,754
95% Confidence Interval						
upper	166,239	174,096	174,725	156,078	205,022	191,173
lower	150,887	146,652	164,405	142,182	196,138	184,299

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

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

Release Site	Stocking Tank	Estimated Displacement Value[a]	Standard Error	MM of Fish Loaded Into Tank	Displacement Value Used in Estimate	Estimated Number of Fish	Standard Error	95% Confidence Interval Upper	95% Confidence Interval Lower
Bird Creek	Boom	1.766	0.077	1,002	1.766	84,393	1,618	87,564	81,222
	Pup			443	2.902	61,313	1,886	65,009	57,617
	Total					145,780	3,503	152,647	138,913
Campbell Creek	Boom	1.642	0.178	1,002	1.642	81,149	3,616	88,237	74,062
	Pup			458	2.902	65,555	1,885	69,250	61,860
	Total					146,757	5,501	157,539	135,974
Houston	Boom			998	1.674	92,286	1,753	95,721	88,851
	Pup	2.902	0.203	468	2.902	75,022	1,720	78,394	71,651
	Total					167,381	3,473	174,187	160,575
Nancy Lake	Boom	1.674	0.097	511	1.674	42,298	1,002	44,263	40,333
	Pup			621	2.902	89,111	2,550	94,108	84,114
	Total					131,519	3,552	138,481	124,557
Ninilchik	Boom	1.828	0.114	1,540	1.828	191,367	2,584	196,430	186,303
	Pup			0		0	0	0	0
	Total					191,462	2,584	196,525	186,398
Willow Creek	Boom			916	1.828	112,577	1,554	115,622	109,532
	Pup	3.225	0.289	396	3.225	85,862	1,702	89,199	82,525
	Total					198,487	3,256	204,869	192,105

[a] Displacement value is the number of kilograms of fish which displace 1 mm of water on the tank site gauge.

Size Estimation

The smallest coho salmon smolt in terms of length and weight were from the Fish Creek release, while the largest smolt were from the Ship Creek release for weight and the Bird Creek release for length (Table 9). The chinook salmon smolt from the Willow Creek and Ninilchik River releases were approximately the same size.

The vast majority of the coho salmon smolt released in Cottonwood, Fish and Wasilla creeks were less than 15.1 g (Table 10). Conversely, the majority of the coho salmon smolt released at Bird Creek, Campbell Creek, Houston, and Nancy Lake were between 15.1 g and 25.0 g. The Ship Creek coho salmon smolt release had substantial percentages of fish in each of the three size categories. The majority of the chinook salmon smolt released were between 5.1 g and 15.0 g. However, over 30% of the smolt in each group were over 15.0 g.

DISCUSSION

Smolt Marking

A major point of emphasis in the 1993 marking program was to improve long-term tag retention rates above 1992 levels. This was accomplished, since the combined 1993 long-term tag retention was 96.3% as compared to 89.4% in 1992. Based on our results from 1992 (Peltz and Starkey 1993) we hypothesized that grading fish by size and using different sizes of head molds would improve long-term tag retention. Consequently, we set up the comparisons between graded and ungraded fish to try to prove that grading improved long-term tag retention. However, the results indicated that the unsorted groups had higher tag retention than the sorted groups. We feel this anomaly can be satisfactorily explained. In one of the comparisons, we observed a higher incidence of rubbed noses in the sorted raceway than in the unsorted raceway. This is a common occurrence in this stock of fish and the degree of rubbing is variable. Some fish only have skin missing while others have the nose rubbed flat to a point just in front of the eyes. Placing coded wire tags in fish with a portion of the nose missing is difficult and reduced long-term tag retention would be expected. The incidence of rubbed noses in the two raceways wasn't quantified and we don't know why one raceway had a higher incidence than another, but we are confident the rubbed noses caused the lower long-term tag retention in the raceway of sorted fish. Another factor which may have negated our experimental design was the conscientiousness of the taggers. The taggers were aware of the importance of tag placement to achieve good long-term tag retention. Consequently, they adjusted for improper head mold size through meticulous positioning of the fish, rather than just putting the head of the fish in the head mold and tagging regardless of fit as was done in 1992.

Despite the lack of data and accompanying statistical support, we feel that grading fish and using different sizes of head molds for tagging is responsible for improving long-term tag retention rates in the release groups of coho and chinook salmon smolt. As previously stated, the combined long-term tag retention for all release groups in 1993 was 96.3%. It may be difficult to improve much beyond this level. The scatterplot in Figure 2 indicates that the highest tag retentions occur at tag application rates of approximately 200

Table 9. Mean lengths and weights of coho and chinook salmon smolt produced at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked at 10 locations in Cook Inlet in 1993.

	Coho Salmon								Chinook Salmon	
							Little Susitna River			
Parameter	Cottonwood Creek[a]	Fish Creek[a]	Wasilla Creek[a]	Ship Creek[b]	Bird Creek[c]	Campbell Creek[c]	Houston[c]	Nancy Lake[c]	Willow Creek[c]	Ninilchik River[c]
Sample Size	540	654	532	408	526	523	523	526	512	518
Sample Date	07-Jun	08-Jun	08-Jun	25-May	26-May	27-May	21-May	20-May	01-Jun	02 Jun
Release Dates	09-Jun	10-Jun	08-Jun	25-May	27-May	28-May	24-May	21-May	01-Jun	03-Jun
			09-Jun	26-May	28-May	01-Jun		24-May	02-Jun	07-Jun
Mean Length (mm)	100	95	97	125	126	125	121	125	108	107
Standard Error	12.3	11.1	12.4	15.4	8.5	8.5	8.0	8.4	11.2	11.3
Maximum	130	122	131	160	150	147	142	147	75	86
Minimum	55	62	56	61	83	84	82	72	157	165
Mean Weight (mm)	12.1	10.8	11.4	22.1	21.0	20.3	18.1	20.2	14.9	14.7
Standard Error	4.4	3.8	4.4	6.8	4.3	4.1	3.5	4.1	5.2	5.6
Maximum	27.5	24.0	27.4	46.5	36.9	35.0	28.4	32.5	3.2	6.7
Minimum	1.5	2.4	1.8	3.4	6.0	5.9	6.1	3.5	45.8	52.0

[a] Produced at the Big Lake hatchery.

[b] Produced at the Elmendorf hatchery.

[c] Produced at the Fort Richardson hatchery.

Table 10. Weight frequency distribution of hatchery coho and chinook salmon smolt produced at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked in 10 locations in Cook Inlet in 1993.

	Coho Salmon								Chinook Salmon	
							Little Susitna River			
Weight Distribution	Cottonwood Creek[a]	Fish Creek[a]	Wasilla Creek[a]	Ship Creek[b]	Bird Creek[c]	Campbell Creek[c]	Houston[c]	Nancy Lake[c]	Willow Creek[c]	Ninilchik River[c]
0-5	2.2%	4.1%	4.5%	0.5%				0.2%		
SE	0.0003	0.0003	0.0004	0.0002				0.0001		
5.1-10	36.1%	41.7%	38.7%	7.1%	0.2%	1.5%	1.5%	0.6%	12.7%	12.9%
SE	0.0009	0.0008	0.0009	0.0006	0.0001	0.0002	0.0002	0.0001	0.0007	0.0006
10.1-15	36.7%	39.8%	38.9%	8.3%	6.1%	5.9%	18.5%	7.4%	49.6%	52.7%
SE	0.0009	0.0007	0.0009	0.0007	0.0005	0.0005	0.0007	0.0005	0.0010	0.0010
15.1-20	20.9%	13.3%	13.2%	14.7%	36.9%	42.3%	50.5%	42.2%	23.6%	22.6%
SE	0.0008	0.0005	0.0006	0.0009	0.0009	0.0009	0.0010	0.0009	0.0008	0.0008
20.1-25	3.7%	1.1%	3.9%	35.8%	41.1%	40.2%	26.4%	36.7%	10.0%	6.8%
SE	0.0004	0.0002	0.0004	0.0012	0.0009	0.0009	0.0008	0.0009	0.0006	0.0005
25.1-30	0.4%		0.8%	25.2%	12.9%	8.6%	3.1%	11.8%	2.3%	3.3%
SE	0.0001		0.0002	0.0011	0.0006	0.0005	0.0003	0.0006	0.0003	0.0003
30.1-35				6.1%	2.7%	1.5%		1.1%	1.2%	0.4%
SE				0.0006	0.0003	0.0002		0.0002	0.0002	0.0001
35.1-40				1.5%	0.2%					0.4%
SE				0.0003	0.0001					0.0001
40.1-45				0.5%					0.4%	0.4%
SE				0.0002					0.0001	0.0001
45.1-50				0.2%					0.2%	0.4%
SE				0.0001					0.0001	0.0001
>50										0.2%
SE										0.0001
Coho Summary										
<15.1g	75.1%	85.8%	82.3%	16.0%	6.3%	7.5%	20.0%	8.2%		
15.1-25.0g	24.7%	14.4%	17.2%	50.6%	78.0%	82.5%	77.0%	79.0%		
>25.0g	0.4%	0.0%	0.8%	33.8%	15.9%	10.2%	3.1%	13.0%		
Chinook Summary										
<5.1g									0.0%	0.0%
5.1-150g									62.4%	65.7%
>15.0g									37.9%	34.6%

[a] Produced at the Big Lake hatchery.
[b] Produced at the Elmendorf hatchery.
[c] Produced at the Fort Richardson hatchery.

to 250 tags/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/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 tags/worker hour.

The head mold size range data (Tables 4 and 5) produced identifiable size ranges for use with different sizes of head molds. Differences in size range between coho and chinook salmon appears to be minimal. Consequently, it seems reasonable to establish a standard set of size ranges with discrete beginning and ending sizes for each head mold size. Besides the data, two other considerations were addressed in the selection of size ranges. First, cutoff points were multiples of 5 mm to simplify the measuring of fish. Second, in areas of overlap, the switch to a larger head mold was made at a smaller size than indicated by the data because it is easier to tag fish in a head mold which is a little to large than one which is slightly too small. Based on the data and the above considerations we propose establishing the standard size ranges as follows:

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

Smolt Enumeration

Comparison of the three smolt enumeration techniques revealed three interesting trends (Table 11 and Figure 4). First, in most instances the mark-recapture estimate was the lowest of the three, the hatchery inventory estimate was the highest of the three, and the water volume estimate was somewhere in between. Second, the measured variability associated with the mark-recapture estimate was usually smaller than either of the other two estimates. Third, the difference between the mark-recapture estimate and the hatchery inventory estimate was similar for all groups, especially for the four groups of coho salmon smolt.

Potential sources of error for each of the three smolt enumeration techniques have been discussed previously (Peltz and Starkey 1993). The most likely potential source of error for the mark-recapture technique is nonrandom distribution of marks in the population. Two of the eight 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) with a hand count. The mark-recapture estimate was 55,806 with a standard error of

Table 11. Comparison of three population estimation techniques for coho and chinook salmon smolt released from the Fort Richardson hatchery in 1993.

	Coho Salmon				Chinook Salmon	
			Little Susitna River			
	Bird Creek	Campbell Creek	Houston	Nancy Lake	Ninilchik River	Willow Creek
Mark-recapture Estimate Pooled	140,382	140,797	148,282	131,591	184,585	160,194
Standard Error	1,670	1,700	3,280	2,716	2,233	1,823
95% CI						
upper	143,655	144,128	154,711	136,914	188,963	163,767
lower	137,109	137,465	141,853	126,269	180,208	156,620
Water Volume Estimate	145,780	146,757	167,381	131,519	191,462	198,487
Standard Error	3,503	5,501	3,473	3,552	2,584	3,256
95% CI						
upper	152,647	157,539	174,114	138,481	196,525	204,869
lower	138,913	135,974	160,575	124,557	185,398	192,105
Hatchery Inventory Estimate	158,563	160,374	169,565	149,130	200,580	187,736
Standard Error	3,916	7,001	2,633	3,545	2,266	1,754
95% CI						
upper	166,239	174,096	174,725	156,078	205,022	191,173
lower	150,887	146,652	164,405	142,182	196,138	184,299
Difference Mark-recapture to Water Volume	3.8%	4.2%	12.9%	-0.1%	3.7%	23.9%
Difference Mark-recapture to Hatchery Inventory	13.0%	13.9%	14.4%	13.3%	8.7%	17.2%

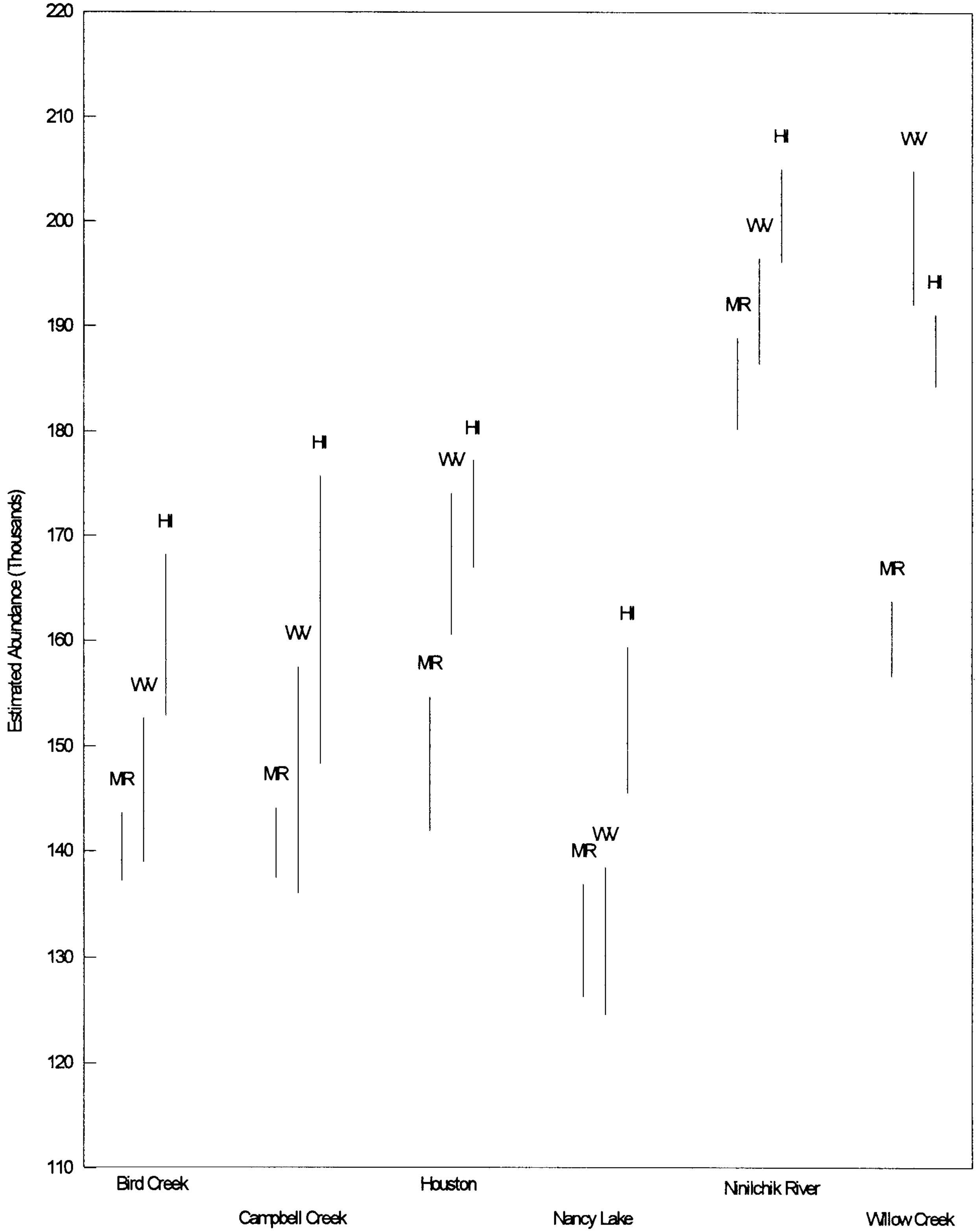


Figure 4. Comparison of the 95% confidence intervals of three smolt population techniques at the Fort Richardson hatchery in 1993. MR = mark-recaputre; WV = water volume; HI = hatchery inventory.

only 683 (Table 6). The hand count was 54,764 which differs from the mark-recapture estimate by only 1.9%. We feel the mark-recapture technique has sound methodology and is free from major sources of error.

The potential sources of error for the water volume estimate are tank calibration and the assumption that abundance estimates are independent of species, size, and stock of fish. Based on our measurements, all the tanks on the boom truck and all the tanks on the flatbed are the same size. Consequently, 1 mm of fish displaced in any of the boom truck tanks or any of the flatbed tanks should equal the same weight of fish. However, we did find a high degree of variability associated with the estimation of water displacement values. The variability existed within an individual estimate as well as among estimates from different release groups. This leads us to believe that abundance estimates are 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. With this technique small errors in measuring displacement are expanded to much larger errors in abundance estimates. We feel that the variability associated with the water volume technique increases the probability for errors and makes this technique unreliable.

The main potential source of error for the hatchery inventory estimate is improper enumeration of fry to initiate the inventory. At the Fort Richardson hatchery the bulk weighing method is used to estimate numbers of fry and initiate the inventory. We feel one major flaw exists with this methodology. The subsamples which were bulk weighed and then counted to estimate mean weight of an individual fish were only 7.4% to 12.6% of the net weight used to move fish. It is reasonable to assume that a full net with 8 to 12 times more fish in it than a subsample net will have a different mean weight than the subsample weight. More fish creates more interstitial spaces to hold water and increase the weight of a net. We feel that the subsampled net loads of fish were not representative of the net loads used to move the fish. The differences between the mark-recapture estimates and the hatchery inventory estimates were constant. Consequently, we feel that hatchery inventory estimates may be very precise, but due to the error associated with the subsampling the estimates may not be accurate.

We feel the mark-recapture estimates provide the easiest and most reliable estimates of smolt release numbers at the Fort Richardson hatchery. Whenever possible, this technique should be utilized. All the hatcheries examined in this report have come to rely on the water volume technique to produce easily obtained release numbers. Unfortunately, our data suggest that a high degree of variability associated with the estimation of water displacement values makes the reliability of this technique questionable. Continued reliance on the water volume technique would mean calibration of each release group, since the displacement values appear to be highly variable. 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 the Fort Richardson hatchery were not accurate but they were precise. We feel that refinement of the sampling methodology associated with this technique could make it both accurate and precise. A better method of calibrating subsampled net loads of fish needs to be developed. 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 the Fort Richardson hatchery enough to make it an acceptable technique for easily obtaining accurate estimates of release numbers.

Size Estimation

In a previous report, Peltz and Starkey (1993) suggested that a hatchery production goal for coho salmon smolt production is to make 80% of the smolt weigh between 15.1 g and 25.0 g. The coho salmon smolt produced at the Big Lake hatchery for release into Cottonwood, Fish and Wasilla creeks were substantially below this goal. The Big Lake hatchery smolt released in 1993 experienced the same health problems as the fish released in 1992. Consequently, the fish were much smaller than anticipated. Marine survival of these release groups will be well below anticipated levels unless a high percentage of fish remain in fresh water an additional year and return as adults a year later than anticipated. The coho salmon smolt produced at the 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 50%) 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 the Little Susitna River at Houston and Nancy Lake were all extremely close to achieving the size range production goal. The marine survival rates for these release groups should be at anticipated levels.

The 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 Willow Creek and the Ninilchik River did not achieve the production goal. Over 60% of each group were within the desired size range. However, the remaining fish were all 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).

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 most variable estimate of the three techniques measured. Some of the enumeration estimates produced using this technique appear to be accurate. Others do not. In addition, estimating the water volume displacement value for each release group is labor intensive and time consuming. Due to the variability of the water

volume displacement value among release groups, it is unlikely that a mean value can be determined and used in perpetuity for all release groups. This technique should only be used in situations where the other techniques can not be used or accuracy is not important.

3. The hatchery inventory estimates produced the least precise estimates of the three techniques measured. However, the difference between this technique and the mark-recapture estimates are remarkably similar for all release groups. 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. Hand counting full nets of fish is impractical and subsampling partial net loads does not appear to be accurate. 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. The precision and accuracy of hatchery inventory estimates at the Elmendorf hatchery have not been estimated because few fish were tagged prior to 1994. Seven release groups were tagged in 1994. Mark-recapture estimates should be performed on these releases and compared to the hatchery inventory estimates. If large discrepancies exist, then the Elmendorf hatchery methodology for estimating hatchery inventory will need investigation in 1995.

6. All fish for tagging should be graded and tagged using the appropriate head mold sizes.

7. The Big Lake hatchery coho salmon smolt planted at Cottonwood Creek, Wasilla Creek, and Fish Creek will probably produce below-average adult returns in 1994. The small size and poor health record lead us to believe that these fish will either have poor marine survival or hold over in fresh water for one more year and not return as adults until 1995.

8. The Elmendorf hatchery coho salmon smolt planted in Ship Creek had a high percentage (approximately 50%) 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.

9. The 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.

10. The Fort Richardson hatchery chinook salmon smolt planted in Ninilchik River and Willow Creek had a high percentage of fish (approximately 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.

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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, N.Y.

Fleiss, J. L. 1981. Statistical methods for rates and proportions, second edition. John Wiley and Sons, New York, N.Y.

Goodman, L. A. 1960. On the exact product of variances. J. American Statistical Association 66:708-713.

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. 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. 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. Fishery Data Series 93-51, Anchorage.

Peltz, L. and D. Sweet. 1993. Performance of the chinook salmon enhancement program in Willow Creek, Alaska, 1985-1992. 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.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41:42-46.

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