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ABSTRACT

Production of coho and chinook salmon *Oncorhynchus kisutch* and *O. tshawytscha* smolt, marking and release were monitored at three hatcheries in Cook Inlet, Alaska in 1992. An estimated 778,000 coho salmon smolt and 312,000 chinook salmon smolt were released at a total of 10 sites. A total of 301,184 coho salmon smolt and 87,737 chinook salmon smolt were marked with an adipose clip and injected with a coded wire tag prior to release. Long-term (53-101 days) tag retention varied from 75.9% to 95.8%. The groups of fish with the best tag retention were those which were graded and tagged using different head mold sizes. A smolt size quality index based on data from local wild fish populations and hatchery production in other areas of the Pacific Coast of North America was defined as the percentage of hatchery released coho salmon which were greater than 15 grams and less than or equal to 25 grams, and the percentage of hatchery released chinook salmon which were greater than or equal to 5 grams and less than or equal to 15 grams. Three different techniques for estimating smolt abundance were compared at all three hatcheries. For most release groups, the three techniques provided similar estimates of the number of fish released, but four of the release groups had estimates which differed from 14.1% to 32.9%. Based on our interpretation of the information, we feel that the mark/recapture estimate was the most accurate estimate of the number of fish released.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, coho salmon, *Oncorhynchus kisutch*, hatcheries, smolt, smolt size, release timing, blood sodium monitoring, smolt enumeration, mark/recapture, coded wire tagging, tag retention.

INTRODUCTION

Stocking of hatchery reared chinook and coho salmon smolt *Oncorhynchus tshawytscha* and *O. kisutch* to create terminal sport fisheries has been successful at select locations throughout Southcentral Alaska. Northern Cook Inlet (NCI) is the most urbanized area in Alaska. Sport fishing effort is increasing annually and future increases in effort are anticipated (Table 1).

A stocking program of coho salmon smolt was initiated in 1992 at eight sites in seven systems in the NCI urban area. Chinook salmon were also stocked in several NCI locations (Peltz and Sweet 1992; Boyle et al. 1993). The goals of this stocking program are to cost-effectively create or enhance a series of terminal sport fisheries in select NCI urban area streams, to attract additional recreational fishing participation, and to target the expanding fishing effort on hatchery stocks of fish (Whitmore and Roth 1991). Smolt for this program came from three hatcheries: Big Lake (BLH), Elmendorf (EH) and Fort Richardson (FRH) hatcheries (Figure 1). An evaluation program centered around coded wire tagging was initiated in 1992 to determine if the project goals were being achieved. In addition, all of the stocking sites have stocks of wild salmon, some of them significant, and the marking program is necessary to insure that wild stocks are properly managed and protected.

The success of smolt stocking programs is dependent on numerous variables. A great many of these variables are associated with the hatchery component of the program. Data which relate to the hatchery dependent variables can be classified into three categories: smolt production, smolt marking and smolt release.

Smolt production refers to fish culture activities which occur in the hatchery from the time eggs are incubated until the smolt are released. Parameters of importance include fish growth and health during hatchery residence. Additional parameters of interest which may yield some insight into the quality of the rearing environment are rearing temperatures and rearing densities. A final parameter of interest to smolt production is smolt readiness as measured by blood sodium content.

Smolt marking encompasses all aspects of the coded wire tagging of fish in the hatchery. Coded wire tagging methodology is extremely important. The basic tagging assumptions of random application of tags to the population and similar treatment of tagged and untagged fish must be validated (Vreeland 1990). Similarly, tag loss between the time of tagging and the time of release must be properly documented to avoid reduction in the accuracy of all statistics generated from coded wire tag recoveries (Blankenship 1990).

Smolt release refers to all parameters associated with the release of hatchery smolt into the wild. The total number of fish released and the methodology for determining that number are of critical importance (Vreeland 1990). Additional parameters of interest are the size of fish released and release dates. The release of fish at the wrong time or of the wrong size can reduce marine survival rates (Bilton et al. 1982).

In the past, each of the three hatcheries has been unique in the manner in which it raises fish, marks fish, collects data concerning the fish, and reports information about the fish. Due to the physical constraints of each

Table 1. Historical sport fishing effort in the Knik Arm drainage, Anchorage, East Susitna River drainage, West Cook Inlet-West Susitna River drainage, and Kenai Peninsula areas, 1981-1992.[a]

Year	Knik Arm Drainage	Anchorage	East Susitna River	West Cook Inlet-West Susitna	Kenai Peninsula
1981	105,052	67,618	59,854	40,658	519,662
1982	91,713	82,007	80,745	56,811	576,585
1983	138,389	74,972	67,471	74,652	592,846
1984	130,727	119,972	81,758	73,876	668,161
1985	122,626	96,760	67,764	95,887	743,455
1986	131,606	103,152	92,289	104,768	808,450
1987	140,167	115,145	77,817	103,350	829,267
1988	183,029	114,823	107,977	111,585	878,292
1989	146,912	107,613	96,864	115,054	799,409
1990	142,884	125,849	101,917	110,927	896,360
1991	146,605	117,780	113,178	121,505	869,715
1992[b]	142,538	141,571	149,484	116,360	884,296

[a] Mills 1982-1992, *In prep.*

[b] Mills *In prep.*

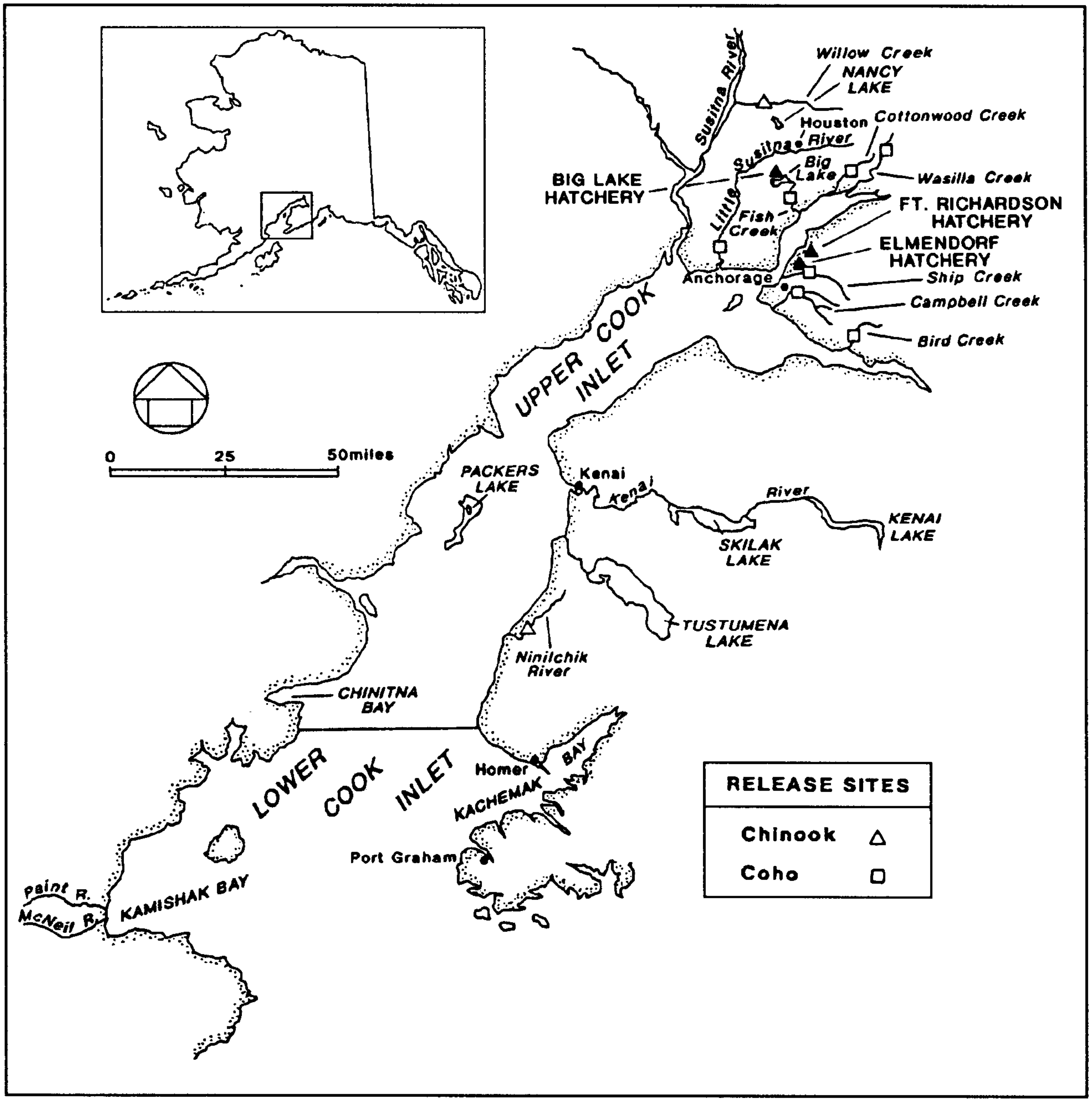

Figure 1. Map of Cook Inlet showing the locations of Big Lake, Elmendorf, and Fort Richardson hatcheries and stocking locations of chinook and coho salmon.

facility, it is impossible to standardize the manner in which fish are raised. However, it should be possible to standardize fish marking, data collection and data presentation. This report documents our attempt to standardize data collection and reporting for smolt production, smolt marking and smolt release at three NCI hatcheries. Other aspects of this evaluation program, such as sport fishing effort, harvest, and returns of stocked fish to terminal sport fisheries, will be reported separately.

METHODS

Smolt Production

FRH produced four release groups of coho salmon smolt of Little Susitna River origin (Figure 1). Two groups of approximately 150,000 fish per group were released into the Little Susitna River system: one at Nancy Lake and one into the Little Susitna River at Houston. The other two groups of approximately 100,000 fish per group were released into Campbell Creek and Bird Creek. FRH also produced two release groups of chinook salmon smolt: approximately 130,000 of Ninilchik River stock for release into the Ninilchik River and approximately 180,000 of Willow Creek stock for release into Deception Creek, a tributary of Willow Creek (Figure 1). EH produced one release group of approximately 65,000 coho salmon smolt of Ship Creek origin for release into Ship Creek (Figure 1). BLH produced three release groups of coho salmon smolt of Fish Creek origin: approximately 75,000 for release into Fish and Wasilla creeks and approximately 55,000 for release into Cottonwood Creek (Figure 1). Wild salmon inhabit all release sites. The Ninilchik River and Willow Creek both contain significant stocks of coho and chinook salmon.

Hatchery Rearing:

At all hatcheries, health records were kept for each rearing group of fish from the time the eggs were incubated to the time the smolt were released. Dates of disease outbreaks, treatments and mortality rates were recorded in the hatchery log book. Any changes which could cause stress or induce health problems, such as total dissolved gas (TDG) supersaturation, extreme temperature fluctuations, or low dissolved oxygen levels, were recorded.

Fort Richardson Hatchery. FRH coho salmon were incubated in Heath trays, and upon emergence in late January were moved into four indoor raceways where they were reared through spring. In June, the fingerlings were moved to outdoor raceways where they remained until release the following May. Chinook salmon eggs were also incubated in Heath trays and at emergence in late October they were moved into six indoor raceways. In December they were moved to four outdoor raceways where they remained until release in May.

While in the indoor raceways at FRH, salmon fry were sampled to estimate mean weight prior to changing feed size. To sample weights of salmon fry, a random group of fish was collected from among the raceways and three samples of approximately 80 to 180 fish from the group were subsampled. Each sampled fish was weighed to the nearest 25 g and the number of fish was counted to estimate the mean weight of one fish in each sample. An overall mean weight was calculated from the three subsample means. If any of the three sample means differed more than 5% from the overall mean, two more samples were taken and the overall mean recalculated.

While in the outdoor raceways, the fish were sampled four times to estimate mean weight. Fish were crowded to the end of the raceway, and five samples of approximately 50 to 100 fish were taken to estimate the mean weight of one fish. Individual length (tip of snout to fork of tail) was measured on 20 of the fish. Rearing temperatures were manually measured at the raceway and recorded daily in degrees Celsius. Density was estimated for each raceway of chinook salmon using estimated total weight of the population, volume of the raceway, and estimated mean length of one fish. Density was expressed as kilograms per cubic meter per centimeter of fish ($kg/m^3/cm$). Rearing densities were unavailable for coho salmon at FRH.

Elmendorf Hatchery. Coho salmon reared at EH were incubated in Heath trays. In late June, emergent fry were moved to one small outdoor trough that utilized well water. The fish were moved in late August to one larger outdoor raceway which utilized creek water.

The fish were sampled monthly for growth by drawing down the raceway to obtain a random mixture of fish and then taking three random samples of approximately 200 fish each at the fry stage or 100 to 150 fish at the smolt stage. Samples were bulk weighed and the fish were counted back into the raceway. The mean weight of one fish was calculated for each sample. Rearing density, expressed as kg/m^3, for the single Ship Creek raceway was calculated using the estimated weight of the entire raceway of fish for the amount of raceway volume available. The temperature of the raceway water was measured and recorded daily in degrees Celsius.

Big Lake Hatchery. Coho salmon eggs at BLH were incubated in Zenger incubators, and upon emergence in late April, the fry were put into a large outdoor raceway. The fish were initially sampled weekly for weight gain. A group of fish from throughout the raceway was randomly collected, and then three samples of at least 200 fry were weighed and counted from the group in order to determine the mean weight of one fish. If any of the three sample means differed from the overall mean by more than 5%, more samples were taken until the means of three samples were within 5% of the overall mean.

The fish were moved into eight small indoor raceways by mid-August. Sampling for fish growth indoors was performed monthly and an overall density, expressed as kg/m^3, was estimated based on estimated total weight of fish in all the raceways and the total amount of raceway volume used. Density was not determined for individual raceways. Rearing temperatures fluctuated during the day due to the mixing of water from different sources. Recorded rearing temperatures are an estimate of the mean for that day. By late spring the coho in the eight indoor raceways were split into 16 small indoor and outdoor raceways. The fish remained in the 16 raceways until release.

Test For Smoltification:

Clarke and Blackburn (1977) established that a plasma sodium concentration of less than 170 mmol/L after 24 hours in sea water is the threshold level for saltwater tolerance in coho and chinook salmon smolt. Subsequent work by Blackburn and Clarke (1987) showed a lower mean (165 mmol/L) blood sodium value for stocks of coho and chinook salmon smolt examined. However, variability does exist among fish stocks and laboratories doing the sampling. Blood sodium results can be expressed in at least three different ways (Blackburn and Clarke 1987): (1) the mean of the group after seawater challenge; (2) the group mean after seawater challenge minus the group mean for the freshwater controls; and (3) the percentage of fish over or under a threshold sodium value. None of the hatcheries involved in this project performed blood sodiums on freshwater controls, consequently the data cannot be expressed as a difference of means as in (2) above. Current hatchery practice is to express the data as a group mean. Rawson and Howe (1984) developed a relatively simple one-sample proportion test to determine if a group of smolt were ready for release. The one-sample proportion test indicates whether a large proportion (70% to 85%) of the fish to be released have attained the threshold smolt value (170 mmol/L). Sample sizes are dependent on the desired significance level (alpha) and power (beta). Although this approach was developed for use in Alaska, it is not currently being utilized by any of the hatcheries. In our examination of the blood sodium data, we presented the data as both a mean and a proportion. The proportion will yield a better indicator of smolt readiness if the data are not randomly distributed. This could occur if the fish size has a bimodal distribution or is skewed.

To determine if smolt were ready for release, 24-hour seawater challenge tests (Clarke and Blackburn 1977) were performed on a periodic basis beginning 6 to 8 weeks prior to release and continuing to release. Smolt were placed in 30 ppt sea water for 24 hours. Each smolt was weighed, measured for length and sacrificed to obtain a blood sample for analysis.

FRH randomly collected one group of 29 or 30 smolt from one of the four raceways of Little Susitna River stock coho salmon during the earlier tests and 14 to 27 chinook smolt from each of the Willow Creek and the Ninilchik River chinook salmon stocks. Prior to release, blood sodium tests were performed on fish from each individual raceway. If a fish did not provide enough blood for a sample, the blood of two fish of similar sizes were combined into one sample and both fish were assigned the same blood sodium value. Blood samples were analyzed using an Orion model 1020 Na/K analyzer.

EH randomly collected about 30 smolt from the head, middle and tail of the raceway. If a fish did not provide enough blood for a sample, the blood of two fish were combined and both fish were assigned the same blood sodium value. Blood samples were transported to FRH to be analyzed. EH sampled only the Bear Lake stock coho salmon for blood sodium levels under the assumption that both Bear Lake and Ship Creek stocks were at similar stages of smoltification.

BLH collected enough fish to provide between 14 and 39 blood sodium samples. Due to the small size of the BLH fish, it was often necessary to combine the blood of three to five fish in order to obtain enough blood for a sample. Attempts were made to combine the blood from fish of similar sizes but this was not always possible. Fish were collected from each raceway, but the results were combined to give one value for all raceways. Individual weights and lengths were obtained from each fish. Blood samples were transported to FRH and analyzed.

Smolt Marking

Eight groups of coho salmon smolt were coded wire tagged with full length tags at BLH, EH and FRH. Two groups of chinook salmon smolt were tagged at FRH. Smolt were randomly collected from the raceways. The weak, undersized and deformed smolt which appeared in the random sample were not culled, but were tagged along with the healthy smolt. In larger raceways, the fish were crowded prior to fish selection for tagging. In smaller raceways, the fish were collected throughout the entire length of the raceway.

Fish were tagged using a Northwest Marine Technology (NWMT) Mark IV injector. Tag implantation was checked by a Mark IV quality control device (QCD). Tag placement was checked four times daily: after initial start up (approximately 8:00 a.m.), following morning break (approximately 10:00 a.m.), after lunch (approximately 1:00 p.m.) and following afternoon break (approximately 2:30 p.m.). Two large, medium and small fish from each tagging machine in use were dissected to determine tag placement. Head mold and needle adjustments were made as necessary.

At EH and FRH, all fish within a raceway were tagged using one head mold size. Needle penetration was set at a depth that attempted to accommodate the size variations within each raceway. At BLH, the size distribution of small fish made it necessary to sort the randomly collected fish into two or three size groups and tag each group with different sized head molds. Tagged smolt were kept separate until overnight mortality and retention could be checked. Overnight retention was checked in 200 smolt per tagging technician. If the overnight retention was less than 90%, then the entire group of smolt the sample represented was sorted using the QCD and those that had lost their tag were tagged again and immediately released back into the raceway. The number of smolt tagged, overnight mortality, and overnight retention were recorded daily for each tagging technician. All data were computerized using Alaska Department of Fish and Game (ADF&G) CWT version 2.2 software.

Upon completion of a tag group, the tagged fish were combined with the untagged members of the raceway so that the rearing treatment for tagged and untagged members of the same release group was identical. Long-term retention was checked no longer than 10 days before release of the smolt into the wild. Smolt were randomly collected throughout the entire raceway for each release group. The fish were anesthetized using MS-222 and sorted into adipose clipped and nonadipose clipped groups. A minimum of 1,500 adipose clipped fish were passed through the Mark IV QCD. The Mark IV injector counted those fish that had retained their tag and the fish that had lost their tags were counted by hand.

<u>Smolt Release</u>

Size at Release:

At all three hatcheries, mean weights were estimated for each stocking group prior to release. At EH and BLH, fish were anesthetized using MS-222, weighed on an electronic scale to the nearest 0.1 g and measured with a metric ruler to the nearest millimeter. FRH utilized an electronic scale and electronic measuring board which were both interfaced to a computer. All data were automatically recorded and saved as the fish were sampled.

At FRH and EH, bulk samples of fish were weighed to the nearest 25 g and the number of individuals in each sample was counted to determine the mean weight of one fish. In addition, a subsample of at least 500 fish was individually weighed from each group. FRH took three random samples of approximately 50 to 100 fish, calculated the mean weight of one fish for the three samples and the overall mean. If the three individual means differed more than 5% from the overall mean, then two more samples were taken. BLH sampled until they had three randomly collected samples of approximately 50 to 100 fish whose mean weights were within 5% of the overall mean weight and any samples that did not fall within the accepted range were not included in the calculations.

EH obtained fish for their three samples while loading their transport truck. Approximately 100 to 150 fish were sampled as they were loaded into the first, second and fourth tanks of their four-tank truck. Individual smolt lengths and weights were obtained from a subsample of each group to be stocked in conjunction with the long-term tag retention sampling.

Number Released:

Three techniques of enumerating hatchery smolt were used to estimate the number of smolt released. Hatchery inventory estimates were either the result of an actual count or based on weight estimates obtained at one or more stages of development. BLH enumerated eyed eggs with an electronic counter. After emergence, the fry were enumerated again with an electronic counter as they were placed in a raceway. Mortality was recorded during rearing and the inventory number was adjusted accordingly. In July, an estimated 235,300 coho salmon fingerlings were removed for stocking interior lakes. All remaining coho salmon fingerlings were enumerated by means of bulk weighing as the fish were moved to the smaller indoor raceways. This inventory number was adjusted for daily mortality until the smolt were stocked. FRH coho and chinook salmon were first enumerated at the eyed egg stage. Three groups of 100 eggs each were weighed to obtain an overall average weight of one egg. Eyed eggs were then bulk weighed to obtain a total weight and the number of eggs was estimated. Coho and chinook salmon were estimated again as fingerlings by calculating mean individual weight and bulk weighing each group as they were moved into the outdoor raceways. This inventory number was adjusted for daily mortalities until the smolt were stocked. EH enumerated their eyed eggs by passing the eggs through an electronic counter. This inventory number was adjusted for daily mortalities until the smolt were stocked.

Water volume estimates were based on the amount of water displacement in the transport tanks. Each transport tank has a glass sight tube on the side of the tank which indicates the water level in the tank. A meter stick is permanently mounted behind the sight tube so that changes in water levels can be measured in millimeters. Each transport tank was partially filled with water and the water level in the sight tube recorded. Fish were added to the transport tank and upon completion of loading, the new water level in the sight tube was recorded. The total weight of fish in the tank was calculated using an estimated displacement value of kilograms of fish per millimeter of water displaced. FRH and BLH used the same transport tanks which have an estimated 1.8 kg of fish per millimeter of water displaced. EH tanks have an estimated 4.9 kg of fish per millimeter of water displaced. The total number of fish loaded was then calculated using the total weight divided by the mean weight of one fish. The mean weights determined through bulk weighing were used at EH and FRH while the individually measured mean weights were used at BLH.

The third method of estimating the number of fish released was a mark/recapture experiment. Each group to be stocked contained a known number of marked (adipose clipped) fish in the group. While the fish were being sorted from each group for estimation of long-term tag retention, a count was kept of all the clipped as well as the unclipped fish examined. The Chapman modification of the Petersen estimate (Seber 1982) was used to estimate the total number of fish in the group:

$$\hat{N} = \frac{(M + 1)(C + 1)}{(R + 1)} - 1 \qquad (1)$$

$$Var(\hat{N}) = \frac{(M + 1)(C + 1)(M - R)(C - R)}{(R + 1)^2(R + 2)} \qquad (2)$$

where:

$\hat{N}$ = estimated number of fish in the release group;
M = number of marked fish in the group just prior to sorting for the tag retention estimate;
C = number of fish examined for marks during sorting for the tag retention estimate; and,
R = number of marked fish found during sorting.

RESULTS

Smolt Production

Hatchery Rearing:

Mean rearing temperatures were warmest at FRH and coolest at BLH. Estimated rearing densities in May 1992 were about twice as high at BLH than at EH (Table 2). Both groups of chinook salmon at FRH were reared at identical temperatures and nearly identical densities (Table 3).

Coho salmon smolt reared at Big Lake Hatchery experienced a continuum of health problems during their rearing (Table 4). Gas bubble disease, the external parasite *Costia*, and the internal parasite *Hexamita* resulted in a continuous series of treatments utilizing formalin, Diquat, and Epsom salt (Wood 1974). The estimated mortality during rearing for this group of fish was 9.2%. The coho salmon smolt reared at Elmendorf Hatchery experienced an outbreak of gas bubble disease which caused low level mortality throughout rearing (5%). Low level incidence of cold water disease and coded wire tagging also caused minor mortalities. Neither the coho nor chinook salmon smolt at Fort Richardson Hatchery experienced health problems. However, it should be noted that an undetermined number of the coho salmon smolt had blunt noses from rubbing their heads on the screens at the ends of the raceways. Numerous fish looked deformed because of excessive nose erosion, but otherwise appeared healthy.

Test for Smoltification:

The coho salmon smolt measured at EH were the only group of coho salmon which had mean blood sodium levels below 170 mmol/L (Table 5). The FRH coho salmon smolt had lower estimated blood sodiums in April than in May. During May and June, the blood sodium levels of coho salmon smolt sampled at BLH were dropping but never approached the desired level of 170 mmol/L. The chinook

Table 2. Summary of rearing parameters for coho salmon smolt reared at Big Lake, Elmendorf, and Fort Richardson hatcheries and released into Cook Inlet in 1992.[a]

	Big Lake Hatchery			Elmendorf Hatchery			Fort Richardson Hatchery	
Month	Mean Rearing Temp. (°C)[b]	Weight(g)	Rearing Density (kg/m^3)	Mean Rearing Temp. (°C)	Weight(g)	Rearing Density (kg/m^3)	Mean Rearing Temp. (°C)	Weight(g)
April 1991							4.8	2.1
May 1991	10.0	0.4	6.5				4.9	2.5
June 1991	10.0	1.1	16.5		0.2		6.4	3.5
July 1991	6.0	1.8	14.0	4.3	0.4	3.7	8.6	
August 1991	3.0	2.5	23.0	3.5	0.6	5.9	10.5	5.8
September 1991	3.0	2.7	35.0	8.8	1.5	9.9	10.5	
October 1991	3.0	3.0	39.0	6.1	1.8	1.6	10.5	9.3
November 1991	3.0	3.3	41.0	6.7	2.3		6.2	
December 1991	3.0	3.6	30.0	6.9	2.9		5.3	
January 1992	3.0	4.4	36.0	6.9	3.9		4.2	
February 1992	3.0	4.8	39.0	6.9	5.8		3.8	14.3
March 1992	3.0	6.0	47.0	6.9	9.3		6.7	
April 1992	3.0	6.4	52.0	6.9	12.7		8.9	
May 1992	8.0	6.9	42.0	8.8	18.5	21.6	8.5	24.8
June 1992	10.0	7.7	57.0					

[a] Rearing densities were unavailable for FRH.

[b] During May, June, and July, the actual temperatures fluctuated widely depending on the water source. Temperatures listed are an estimated mean for the month.

Table 3. Summary of rearing parameters for chinook salmon smolt reared at Fort Richardson Hatchery and released into Cook Inlet in 1992.

	Willow Creek			Ninilchik River		
Month	Mean Rearing Temp. (°C)	Weight(g)	Rearing Density ($kg/m^3/cm$)	Mean Rearing Temp. (°C)	Weight(g)	Rearing Density ($kg/m^3/cm$)
November	12.0			12.0		
December	11.6	3.7		11.6	4.2	
January	13.2			13.2		
February	11.8	11.8		11.8	10.6	
March	11.0			11.0		
April	10.5	13.2		10.5	12.6	
May	9.7	13.5	5.5	9.7	12.5	4.8

Table 4. Health records of coho salmon smolt produced at Big Lake and Elmendorf hatcheries and released into Cook Inlet in 1992.

Date	Disease/Symptom	Treatment
Big Lake Hatchery		
24-May-91	Total dissolved gas spike of 109%	Water flows adjusted
06-Jun-91	Gas bubble disease apparent in coho salmon fry	Set up oxygen contactor
14-Jun-91	Gill problems detected in coho salmon fry	Fish taken off feed June 14 to 23 Diquat treatment (8.4 ppm) for gills
20-Jun-91	Coho salmon fry diagnosed as having COSTIA	Treated with formalin (1:6000) on June 20 Treated with formalin (1:6000) on June 22
25-Jun-91	Coho salmon fry not feeding well	Switched to well water only (3C) on June 26 Treated with Diquat (16.8 ppm) on June 26 Treated with Diquat (16.8 ppm) on June 27 Fish taken off feed June 26 to 30
22-Oct-91	Coho salmon fry diagnosed as having COSTIA	Treated with formalin (1:6000) on October 23 Treated with formalin (1:6000) on October 25 Treated with formalin (1:5000) on October 28 Treated with formalin (1:4000) on November 4 Treated with formalin (1:6000) on November 9
13-Nov-91	Coho salmon fry diagnosed with HEXAMITA and COSTIA, gills in poor condition	Treated with Epsom salt on November 18 Treated with Epsom salt on November 19 Treated with Epsom salt on November 20 Treated with formalin (1:6000) on November 21 Treated with formalin (1:6000) on November 22

-continued-

Table 4. (Page 2 of 3).

04-Dec-91	Coho salmon fry still have HEXAMITA	Treated with Epsom salt on December 4 Treated with Epsom salt on December 5 Treated with Epsom salt on December 6
13-Dec-91	Coho salmon fry have COSTIA in 2 of 12 raceways	Treated with formalin (1:6000) on December 13
10-Jan-92	Coho salmon fry have COSTIA in 4 of 12 raceways	Treated with formalin (1:6000) on January 10
13-Jan-92	Coho salmon fry have HEXAMITA in 4 of 12 raceways	Treated with Epsom salt in feed on January 13 Treated with Epsom salt in feed on January 14 Treated with Epsom salt in feed on January 15
16-Mar-92	Coho salmon fry have HEXAMITA in 2 of 12 raceways	Treated with Epsom salt in feed on March 16 Treated with Epsom salt in feed on March 17 Treated with Epsom salt in feed on March 18
23-Mar-92	Coho salmon fry have HEXAMITA in 2 of 12 raceways	Treated with Epsom salt in feed on March 23 Treated with Epsom salt in feed on March 24 Treated with Epsom salt in feed on March 25
09-Apr-92	Coho salmon fry have MYXOBACTERIA in 1 of 12 raceways	Treated with medicated feed (OTC) for 2 weeks

-continued-

Table 4. (Page 3 of 3).

Elmendorf Hatchery		
Aug 1991	Gas bubble disease in coho salmon fry	Fish transferred to raceways which use Ship Creek water, weak fish died (5.0%)
Dec 1991	Cold water disease in coho salmon fry	No treatment, weak fish died (less than 0.1%)
Feb 1992	Marking and tagging causes 1.3% mortality in coho salmon fry	No treatment

Table 5. Estimated blood sodium levels for coho salmon reared at Fort Richardson, Elmendorf, and Big Lake hatcheries prior to release in 1992.

	Fort Richardson Hatchery				Elmendorf Hatchery[a]				Big Lake Hatchery			
Week	Sample	Mean Weight(g)	Mean Sodium Level (mmol/L)	Percent Sampled <170 mmol/L	Sample	Mean Weight(g)	Mean Sodium Level (mmol/L)	Percent Sampled <170 mmol/L	Sample	Mean Weight(g)	Mean Sodium Level (mmol/L)	Percent Sampled <170 mmol/L
13-Apr	29	17.8	175.5	20.7%	26	13.3	174.2	69.2%				
20-Apr	29	17.9	188.1	3.4%								
27-Apr	30	20.4	172.2	43.3%								
04-May	29	19.3	185.9	0.0%								
11-May	30	23.1	187.6	0.0%	30	20.4	164.6	90.0%	14	8.3	243.2	0.0%
18-May	30	23.4	188.4	0.0%					25	7.8	212.5	0.0%
25-May	30	22.9	182.7	10.0%	30	21.7	164.8	90.0%	24	7.9	207.2	0.0%
01-Jun									39	10.2	214.1	0.0%
08-Jun									37	13.0	213.1	0.0%
15-Jun									32	11.7	198.1	0.0%

[a] The Bear Lake coho salmon smolt were sampled and were assumed to have the same blood sodium levels as the Ship Creek coho salmon smolt.

salmon blood sodium levels approached the desired level of 170 mmol/L in both groups of smolt sampled (Table 6). Both groups of smolt also exhibited a trend of decreasing mean blood sodium levels over time.

Smolt Marking:

A total of 403,546 coho and chinook salmon smolt were marked with an adipose finclip and coded wire tag in 1992 at Fort Richardson, Elmendorf and Big Lake hatcheries (Tables 7 and 8). Tag retention estimates of coho salmon smolt at the time of release were over 90% in the three groups of smolt reared at BLH. Only one of the other five groups of coho salmon smolt had estimated tag retentions over 90%. The percentage tagged varied from 12.1% in the Nancy Lake release to 61.1% in the Cottonwood Creek release. Tag retentions of chinook salmon smolt at Fort Richardson Hatchery were excellent in the Ninilchik River fish (94.7%) and poor (75.9%) in the Willow Creek fish (Table 8).

Smolt Release

Size at Release:

The coho salmon smolt sampled at FRH weighed over twice as much as those at BLH (Table 9). The mean weights estimated from bulk sampling were nearly identical to those estimated by individual sampling. Very few of the sampled BLH coho salmon smolt stocked in Cottonwood, Wasilla, and Fish creeks were larger than 15.0 g and over half of each group were less than 10.1 g (Table 10, Figure 2). Conversely, most (70.1%) of the EH smolt stocked in Ship Creek were over 15.0 g and almost all (95.0%) of the FRH coho salmon smolt which were stocked were over 15.0 g. The majority of the chinook salmon smolt stocked in Willow Creek (78.9%) and Ninilchik River (74.1%) were over 10.0 g in weight (Tables 11 and 12; Figure 3).

Number and Time of Release:

The mark/recapture estimate was lower than the water volume estimate for 9 of 10 stocking groups and lower than the hatchery inventory estimate for 7 of the 10 groups (Table 13). Only three of the water volume estimates and four of the hatchery inventory estimates were within the 95% confidence interval generated from the mark/recapture estimate. The water volume and hatchery inventory estimates which corresponded best with the mark recapture estimates were the three locations (Little Susitna River at Houston, Nancy Lake, and Willow Creek) which had the lowest percentage of marked fish.

Smolt were released over a 35-day period (Tables 9 and 11). The first smolt were released on May 20 at Nancy Lake and the last smolt release occurred at Fish Creek on June 23.

DISCUSSION

Quality of Smolt Production

The primary criteria for judging the quality of coho and chinook salmon smolt production at the three hatcheries has been fish size, but there is no

Table 6. Estimated blood sodium levels for chinook salmon reared at Fort Richardson Hatchery prior to release in 1992.

	Willow Creek				Ninilchik River			
Week Beginning	Sample Size	Mean Weight(g)	Sodium Level (mmol/L)	Percent Sampled <170 mmol/L	Sample Size	Mean Weight(g)	Sodium Level (mmol/L)	Percent Sampled <170 mmol/L
13-Apr					15	9.4	193.3	0.0%
20-Apr	24	12.3	202.4	0.0%	20	9.9	204.9	0.0%
27-Apr	15	11.7	189.5	0.0%	14	10.5	185.1	0.0%
04-May	20	11.9	192.4	10.0%	26	13.7	185.2	0.0%
11-May	27	13.0	176.0	22.2%	27	13.7	180.8	0.0%
18-May	25	14.9	177.9	20.0%	27	13.4	176.6	33.3%
25-May	26	13.9	173.3	38.5%	18	11.8	175.3	55.6%

Table 7. Summary of coded wire tagging data by release site for coho salmon reared at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked in Cook Inlet in 1992.

	Big Lake Hatchery			Elmendorf Hatchery	Fort Richardson Hatchery			
	Cottonwood Creek	Wasilla Creek	Fish Creek	Ship Creek	Houston	Nancy Lake	Bird Creek	Campbell Creek
Tag Codes	31-20-08 31-20-09	31-20-10 31-20-11	31-20-12 31-20-13	31-19-63 31-20-01	31-20-07	31-20-06	31-20-02 31-20-03	31-20-04 31-20-05
Total marked and tagged[a]	45,500	45,044	46,651	44,807	22,073	21,924	45,173	43,912
Mortalities[b]	10,159	896	1,113	721	189	326	270	231
Marked fish released	35,341	44,148	45,538	44,086	21,884	21,598	44,903	43,681
Tag retention sample size	1,890	1,786	1,798	1,723	842	934	1,684	1,717
Tag retention at release	93.2%	95.1%	95.8%	87.2%	89.4%	89.0%	83.8%	90.3%
Tagged fish released	32,938	41,985	43,625	38,443	19,564	19,222	37,629	39,444
Estimated total fish released[c]	53,900	76,315	74,953	67,178	154,466	158,459	95,377	97,076
Percent tagged	61.1%	55.0%	58.2%	57.2%	12.7%	12.1%	39.5%	40.6%
Tagging dates	3/4-20	4/3-15	3/20-4/3	1/29-2/7	2/27-3/9	2/25-27	3/9-13	3/16-19
Date of tag Retention check	6/18	6/18	6/18	5/18-19	5/19-20	5/19-20	5/19-20	5/19-20
Days elapsed[d]	90	64	76	101	71	82	67	61

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

[b] An estimated 7,368 tagged smolt destined for Cottonwood Creek were not released due to their small size.

[c] The release number is the mark/recapture estimate.

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

Table 8. Summary of coded wire tagging data by release site for chinook salmon reared at Fort Richardson Hatchery and stocked in Cook Inlet in 1992.

	Willow Creek	Ninilchik River
Tag Codes	31-21-03	31-21-04
Total marked and tagged[a]	44,344	44,118
Mortalities	255	470
Marked fish released	44,089	43,648
Tag retention sample size	2,056	1,605
Tag retention at release	75.9%	94.7%
Tagged fish released	33,464	41,335
Estimated total fish released[b]	179,724	132,387
Percent tagged	18.6%	31.2%
Tagging dates	3/20-27	3/27-4/3
Date of tag Retention check	5/19-20	5/26
Days elapsed[c]	53	53

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

[b] The release number is the mark/recapture estimate.

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

Table 9. Estimated mean lengths and weights, by release site, of coho salmon smolt produced at Big Lake, Elmendorf and Fort Richardson hatcheries and stocked in Cook Inlet in 1992.

	Big Lake Hatchery			Elmendorf Hatchery	Fort Richardson Hatchery			
Parameter	Cottonwood Creek	Wasilla Creek	Fish Creek	Ship Creek	Houston	Nancy Lake	Bird Creek	Campbell Creek
Sample Size	473	559	670	511	510	518	508	509
Sample Date	18-Jun	18-Jun	18-Jun	19-May	20-May	19-May	26-May	22-May
Release Date	22-Jun	22-Jun	23-Jun	21-May	21-May	20-May	26-May	22-May
Mean Length (mm)	98	98	97	120	134	132	133	132
Standard Error	12.4	11.7	12.9	14.7	11.0	10.1	9.0	10.0
Maximum	128	132	127	147	166	167	165	158
Minimum	49	57	55	56	77	82	108	85
Mean Weight (g)[a]	11.0	10.9	10.9	18.3	23.6	23.7	24.8	24.9
Standard Error	3.9	3.7	4.1	5.6	5.5	5.6	5.0	5.6
Maximum	24.0	23.1	23.1	33.0	45.4	44.9	45.1	47.8
Minimum	1.1	2.0	1.8	3.0	3.9	5.0	12.4	6.8
Mean Weight (g)[b]				18.5	24.1	23.9	25.1	27.1
Sample Date				21-May	21-May	20-May	26-May	22-May
Percent Difference				-1.1%	-2.1%	-0.8%	-1.2%	-8.1%

[a] Determined by weighing individual fish to the nearest 0.1 g.

[b] Determined by bulk weighing of fish.

Table 10. Weight frequency distribution, by release site, of coho salmon smolt sampled at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked in Cook Inlet in 1992.

	Big Lake Hatchery			Elmendorf Hatchery	Fort Richardson Hatchery			
Weight Distribution (g)	Cottonwood Creek	Wasilla Creek	Fish Creek	Ship Creek	Houston	Nancy Lake	Bird Creek	Campbell Creek
0.1 - 5.0	8.7%	9.7%	11.3%	2.5%	0.2%	0.4%		
5.1 - 10.0	43.8%	42.2%	41.8%	10.0%	1.4%	0.6%		0.6%
10.1 - 15.0	37.8%	38.8%	35.2%	17.4%	5.7%	6.0%	1.6%	3.5%
15.1 - 20.0	8.5%	8.8%	10.4%	38.0%	22.4%	25.3%	21.3%	19.8%
20.1 - 25.0	1.3%	0.5%	1.2%	24.1%	41.6%	38.2%	41.3%	38.3%
25.1 - 30.0				7.8%	21.6%	20.1%	26.6%	25.0%
30.1 - 35.0				0.2%	5.1%	6.8%	6.5%	9.4%
35.1 - 40.0					1.4%	1.9%	2.0%	2.4%
40.1 - 45.0					0.8%	0.8%	0.8%	0.8%
45.1 - 50.0								0.2%
>50.0								

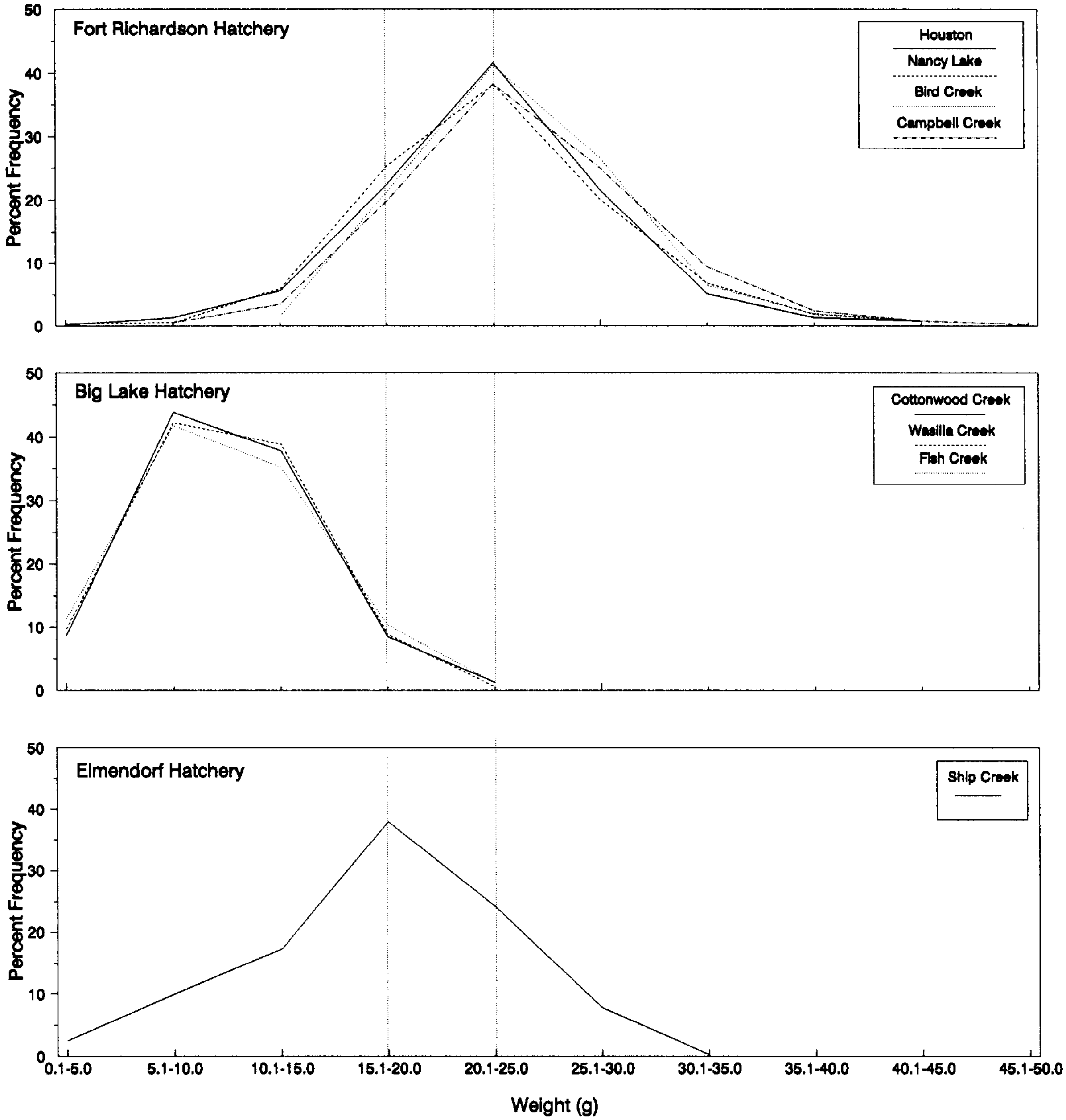

Figure 2. Weight frequency distribution, by stocking location, of coho salmon smolt reared at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked in Cook Inlet in 1992. Vertical dashed lines represent the recommended size quality index for coho salmon.

Table 11. Estimated mean lengths and weights of chinook salmon smolt, by release site, produced at Fort Richardson Hatchery and stocked in Cook Inlet in 1992.

Parameter	Willow Creek	Ninilchik River
Sample Size	506	526
Sample Date	28-May	27-May
Release Date	29-May	28-May
Mean Length (mm)	108	107
Standard Error	10.9	9.1
Maximum	159	147
Minimum	77	76
Mean Weight (g)[a]	13.6	12.5
Standard Error	5.0	3.8
Maximum	51.6	36.6
Minimum	4.1	3.7
Mean Weight (g)[b]	13.5	12.5
Sample Date	29-May	28-May
Percent Difference	0.7%	0.0%

[a] Determined by weighing individual fish to the nearest 0.1 g.

[b] Determined by bulk weighing fish.

Table 12. Weight frequency distribution of chinook salmon smolt sampled at Fort Richardson Hatchery and stocked in Cook Inlet in 1992.

Weight Distribution (g)	Willow Creek	Ninilchik River
0.1 - 5.0	0.2%	0.2%
5.1 - 10.0	20.9%	25.7%
10.1 - 15.0	53.0%	54.4%
15.1 - 20.0	18.8%	15.4%
20.1 - 25.0	4.5%	2.9%
25.1 - 30.0	1.2%	1.1%
30.1 - 35.0	0.8%	0.2%
35.1 - 40.0	0.0%	0.2%
40.1 - 45.0	0.4%	
45.1 - 50.0	0.2%	
>50.0	0.2%	

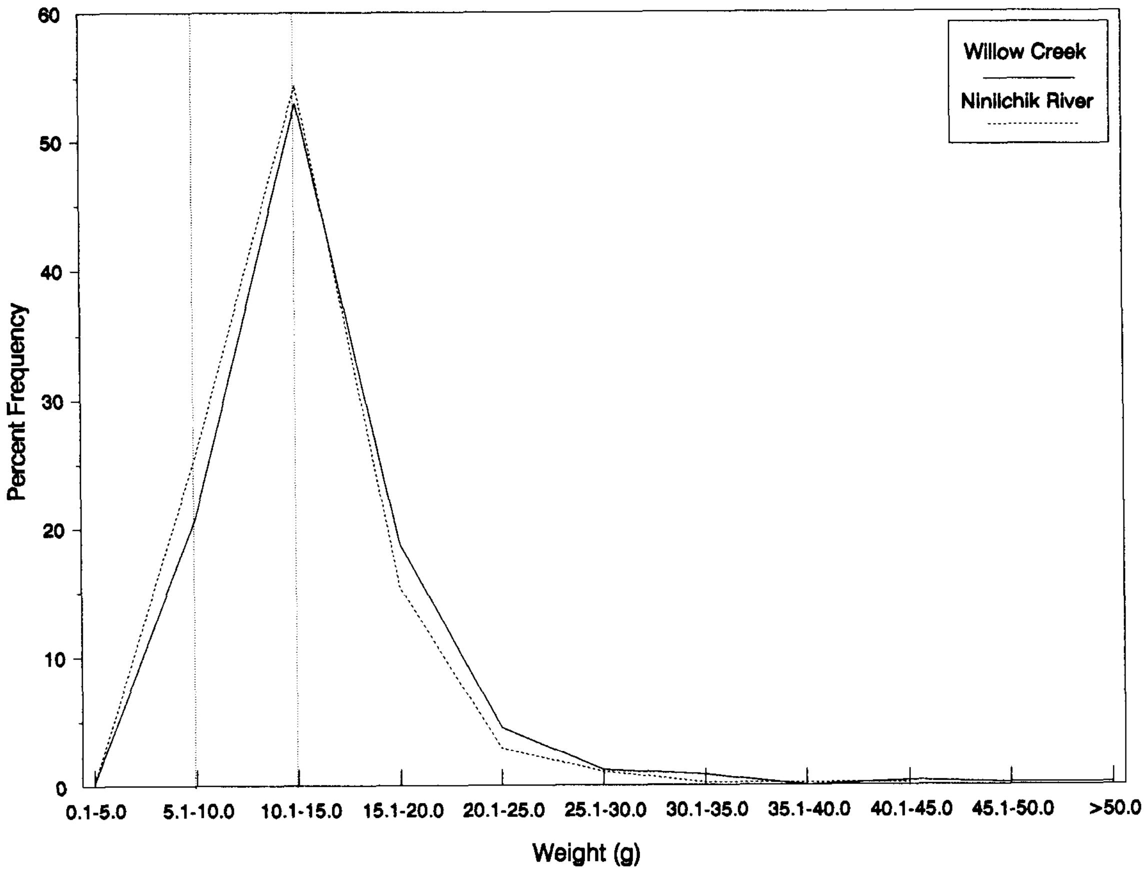

Figure 3. Weight frequency distribution, by stocking location, of chinook salmon smolt reared at Fort Richardson Hatchery and stocked in Cook Inlet in 1992. Vertical dashed lines represent the recommended size quality index for chinook salmon.

Table 13. Comparison of three techniques for estimating number of coho and chinook salmon smolt produced at Big Lake, Elmendorf, and Fort Richardson hatcheries and stocked in Cook Inlet in 1992.

	Coho								Chinook	
Parameter[a]	Cottonwood Creek[b]	Wasilla Creek[b]	Fish Creek[b]	Ship Creek[c]	Houston[d]	Nancy Lake[d]	Bird Creek[d]	Campbell Creek[d]	Willow Creek[d]	Ninilchik River[d]
Number of marked fish in raceway[e]	35,341	44,148	45,538	44,086	21,884	21,603	44,903	43,681	44,089	43,648
Number of fish examined	2,883	3,088	2,960	2,626	5,949	6,857	3,578	3,817	8,384	4,870
Number marked	1,890	1,786	1,798	1,723	842	934	1,684	1,717	2,056	1,605
Percent marked	65.6%	57.8%	60.7%	65.6%	14.2%	13.6%	47.1%	45.0%	24.5%	33.0%
Mark/recapture estimate[f]	53,900	76,315	74,953	67,178	154,466	158,459	95,377	97,076	179,724	132,387
Standard error	708	1,148	1,085	930	4,830	4,708	1,658	1,702	3,360	2,654
95% Confidence Interval - upper	55,287	78,564	77,079	69,000	163,933	167,687	98,626	100,412	186,311	137,588
- lower	52,513	74,065	72,827	65,356	144,999	149,231	92,127	93,740	173,138	127,186
Hatchery release estimates										
A. Water Volume[g]	62,537	82,087	82,662	71,249	157,046	154,974	115,869	110,758	185,051	175,897
B. Inventory[h]	57,480	85,111	80,881	66,752	149,926	149,520	114,621	114,684	181,017	146,788
Percent difference mark/recapture to:										
A. Water Volume	16.0%	7.6%	10.3%	6.1%	1.7%	-2.2%	21.5%	14.1%	3.0%	32.9%
B. Inventory	6.6%	11.5%	7.9%	-0.6%	-2.9%	-5.6%	20.2%	18.1%	0.7%	10.9%

[a] Marked refers to fish with a missing adipose fin.
[b] Produced at Big Lake Hatchery.
[c] Produced at Elmendorf Hatchery.
[d] Produced at Fort Richardson Hatchery.
[e] Number of marked fish put into the raceway minus the number of marked mortalities prior to release.
[f] Chapman modification of the Petersen estimate.
[g] Estimated number of fish determined by water volume displacement as the fish were loaded into transport tanks.
[h] Estimated number of fish which were enumerated into raceways early in their life minus the mortalities which occurred prior to release.

established optimum size for hatchery produced coho and chinook salmon in Alaska. Each hatchery has, through trial and error, developed a smolt rearing regime which produces smolt of a certain size. Mean weight of coho salmon smolt at release in Fisheries Rehabilitation, Enhancement, and Development (FRED) Division hatcheries ranged from 8.2 g to 35.2 g in 1991 (ADF&G 1992). Most research on determining optimal size of hatchery coho salmon smolt releases has associated size of release and time of release (Bilton et al. 1982; Mahnken et al. 1982; Bilton et al. 1984; and Morley et al. 1988).

Rather than measuring hatchery success by comparing mean smolt size at release to a theoretical optimum size, it may be more appropriate to judge hatchery production by size distribution of the smolt produced. Fish below a certain size (smolt threshold size) may not be smolt. These fish may not survive in the marine environment (Mahnken et al. 1982) and may stay in a freshwater environment if given the opportunity. Conversely, smolt above a certain size may have a higher incidence of precocial males which may reduce the survival rate to adult (Hager and Noble 1976). A better way to index smolt quality would be to determine the percentage of the total release which is greater than smolt threshold size and less than the size which causes an unacceptable increase in numbers of precocial males.

Based on results of several studies at Quinsam Hatchery in British Columbia, Morley et al. (1988) recommended the release of coho smolt in the 14 g to 30 g range. Although wild coho smolt size probably varies widely among stocks of fish and geographic areas, the mean weight of wild age-1 coho smolt should provide an indicator of the minimum size at which coho salmon smolt. Data from Big Lake for the period 1979-1991 show that the mean weight of age-1 coho salmon smolt was 14.7 g (Alaska Department of Fish and Game, FRED Division, Palmer, unpublished data). Likewise, data from Cottonwood Lake for the period 1980 to 1982 indicate a mean weight for age-1 smolt of 14.7 g (Alaska Department of Fish and Game, FRED Division, Palmer, unpublished data). Since both of these lakes are in the northern Cook Inlet, it seems reasonable to assume that 15 g approximates the size above which most hatchery coho salmon will smolt. The frequency of smolting probably declines at weights smaller than 15 g. Although several studies mention increased jacking rates among larger smolt (Hager and Noble 1976; Bilton et al. 1982) we found only one study (Morley et al. 1988) which suggested an upper limit to smolt size (30 g) to reduce jacking. Discussion with Alaskan hatchery managers indicates that a more realistic maximum size may be 25 g (Tim McDaniel, Alaska Department of Fish and Game, Anchorage, personal communication). As long as marine survival rates do not decline, hatcheries will substantially reduce rearing costs by making fish smaller. Consequently, until more definitive information is available, we will assume 25 g as the desired upper limit to smolt size. Therefore, we recommend that a size quality index for coho salmon smolt be defined as the percentage of hatchery released fish which are greater than 15 g and less than or equal to 25 g. The size quality index for coho salmon smolt in 1992 was 10.2% at BLH, 62.1% at EH and 62.1% at FRH.

A similar argument can be made for judging the quality of chinook salmon smolt releases. Chinook salmon smolt at Alaska hatcheries ranged from 12.1 g to 27.6 g in 1991 (ADF&G 1992). Bilton (1984) reported a five-fold increase in marine survival rates between release of 6 g smolt and 12 g smolt. Both Bilton (1984) and Martin and Wertheimer (1989) noted an increase in jacking as smolt size increased. The short rearing period (October-May) in the FRH makes rearing chinook salmon much larger than 15 g unrealistic. It may be appropriate to set 15 g as the upper limit of desired smolt size. Some information is known about the size of wild chinook salmon smolt in Cook Inlet. Roth and Stratton (1985) reported mean lengths of age-1+ chinook salmon fry of 78 mm and 90 mm in May and June, respectively, in the Susitna River. Corresponding weights were approximately 3 g to 5 g. Likewise, Kenai River chinook salmon smolt are approximately 3 g to 5 g (Terry Bendock, Alaska Department of Fish and Game, Soldotna, personal communication). It appears that hatchery smolt are substantially larger than their wild counterparts. However, hatchery released smolt in Cook Inlet are age 0 and wild smolt are predominantly age 1, so size comparisons in this instance may not be valid. Age-0 chinook salmon smolt have recently been documented in the Situk River in northern Southeast Alaska by Johnson et al. (1992). Situk River chinook salmon fry appear to move from fresh water to the ocean in mid to late summer when they reach a length of approximately 80 mm. A fish this size would weigh 3 to 5 g. Since chinook salmon populations of both age 0 and age 1+ are known to smolt at 3 g-5 g, it seems appropriate to set 5 g as the lower limit of desired smolt size. Based on the limited data available, we feel it is appropriate to establish 5 g as the lower boundary of the size quality index for chinook salmon smolt and 15 g as the upper boundary. The chinook salmon smolt quality index at FRH in 1992 was 73.9% for the Willow Creek smolt and 80.1% for the Ninilchik River smolt.

Production of coho salmon smolt at BLH was poor. Approximately 90% of the fish stocked at the three locations were small (< 15.0 g) and all three groups had an extensive history of health problems. Health problems were the major reason for the poor growth and quality of the BLH smolt. The gas supersaturation which initiated the sequence of problems has been addressed by installing oxygen contactors in the water system. The source of the protozoan parasites *Costia* and *Hexamita* is thought to have been water from Meadow Creek which was used for rearing. Water from Meadow Creek is used because it is up to 15°C warmer than the hatchery well supply. The warmer temperature is needed to obtain desired fish growth. Installation of a heat exchanger in the water system in 1992 allows the hatchery to use Meadow Creek water to warm well water without mixing the two water sources together. This eliminates the need for using water from Meadow Creek for rearing and hopefully reduces or eliminates the possibility of future disease outbreaks.

Coho salmon smolt production at EH was good. Production might have been better if the fish had not experienced gas bubble disease and cold water disease. Although mortalities from the diseases were minor, long-term impacts probably reduced the growth rate of surviving fish (Wood 1974).

Production of coho salmon smolt at FRH was excellent. A large proportion of fish destined for the four stocking locations was over 15 g and had experienced no major health problems during their hatchery residence. The nose erosion noted on the FRH coho salmon smolt is an annual occurrence with the Little Susitna River stock of fish. Each fall and again in the spring, the smolt actively attempt to move downstream and out of the raceways. No other stocks of fish at FRH, EH or BLH exhibit this phenomenon. We believe this is an adaptation to maximize survival in the Little Susitna River rearing environment and is triggered by photoperiod.

Chinook salmon smolt production at FRH was also excellent. Most fish released at the two stocking sites were over 5 g and had an excellent health record.

Goede and Barton (1990) have developed an autopsy-based condition assessment monitoring program as an indicator of health and condition of fish. This program provides a means of establishing a database for detecting trends in the health and condition of fish populations. The methodology involves a systematic autopsy for each individual in a population sample (usually 20 fish). Blood constituents, external condition indicators (extremities, eyes, gills, psuedobranch, and thymus), and internal condition indicators (mesenteric fat deposits, spleen, hind gut inflammation, kidney, liver, bile, and state of maturity) are all quantified. Application of this methodology to smolt production at BLH, EH, and FRH would undoubtedly improve our ability to judge the quality of fish produced and provide us with a database for comparing production between years or among different release groups of fish.

Utility of Blood Sodium Data

Blood sodium levels are another criteria for judging smolt quality. Blood sodium testing is performed to indicate to hatchery managers if a release group of fish is ready to adapt to ocean residence. The ability of smolt to osmoregulate in salt water is a key factor in successful early marine survival, but the degree of smolt readiness is less important in situations where smolt are stocked into a freshwater system and smolt migration into salt water is totally volitional. The distance of the freshwater stocking site from salt water and the size of the estuary are also important considerations. Stocking fish a short distance from salt water in a small freshwater stream with a limited estuary is probably not much different than stocking fish directly into salt water. Consequently, the importance of blood sodium data to the success of the 10 smolt stocking sites is site specific. The Houston, Nancy Lake, Campbell Creek, and Willow Creek smolt releases occur a great distance upstream and the blood sodium data are not of paramount importance. Conversely, the Ship Creek smolt are stocked directly into salt water and the blood sodium data are necessary to determine smolt readiness. The smolt stockings at Ninilchik River and Cottonwood, Wasilla, Fish and Bird creeks are at intermediate upstream sites where the smolt may or may not have an option as to whether or not they will go into salt water. The blood sodium data for these five systems may not be necessary, but it would be prudent to know whether or not the smolt can tolerate salt water if the environment makes it necessary.

Blood sodium testing at BLH, EH and FRH in 1992 had a limited amount of functional utility. The Ship Creek coho salmon reared at EH are released directly into salt water. The blood sodium values presented in Table 5 indicate that the fish were ready for a saltwater existence. However, these values are actually from the Bear Lake stock of coho salmon smolt which are raised in an adjacent raceway. In our opinion, it is not valid to assume that different stocks of fish raised adjacent to each other in a hatchery have similar blood sodium levels.

Another problem with the blood sodium data is the methodology employed to sample small fish. It is common practice with small fish to pool blood samples from two to three fish to get enough blood for one sample. Blackburn and Clarke (1987) have determined that pooled samples often show lysis. This is indicated by high potassium (>10 mmol/L) levels and requires that sodium values be adjusted. Potassium levels were not monitored during any of the 1992 testing. Consequently, any of the results obtained using pooled blood samples may have led to erroneous blood sodium determinations.

Sample selection may be a problem at hatcheries which obtain a random sample of one stock of fish from a common group of rearing containers. FRH randomly sampled coho salmon smolt from one of four large raceways on a rotational basis. This means that one raceway was sampled every 4 weeks. Even though the four raceways contained the same stock of fish, it is possible that the blood sodium levels of fish are different in each raceway.

The total numbers of fish used for sampling were statistically validated by Rawson and Howe (1984). However, the authors failed to define a population from which the sample should be obtained. To address this problem, we suggest that all rearing containers be considered discrete populations and that pooling of numerous large groups of fish be discontinued. If one group of fish is distributed among numerous rearing containers, we suggest that one container be selected to represent the population and that it be sampled on a continuous basis. However, we also suggest that the other rearing containers be sampled on a periodic basis to insure that blood sodium levels are comparable among containers.

Long-term Tag Retention

The marking and tagging of coho and chinook salmon smolt at the three hatcheries revealed a problem with long-term retention rates. Overnight tag retentions in all the groups were near 100%. However, only half of the release groups of coho and chinook salmon smolt had long-term tag retentions over 90%. A large number of fish in some release groups shed their coded wire tags. Although there are no established standards or goals for smolt coded wire tag retention rates, it should be possible to achieve a minimum of 90% tag retention in smolt-sized fish (Karen Crandall, Alaska Department of Fish and Game, Juneau, personal communication).

The elapsed time between the last day of tagging and measurement of tag retention was quite variable (53-101 days). Blankenship (1990) found that estimated tag loss in coho salmon did not change significantly after 29 days. Since the elapsed time in all groups was substantially greater than 29 days, it is unlikely that time differences in measurement had any impact on results. It is also possible that errors were made in the measurement of long-term tag retention. The QCD may not have been adjusted properly and all tags may not have been detected. However, at FRH the sensitivity of the QCD was adjusted to its highest level. Since FRH had the greatest tag retention problems, it is unlikely that the sensitivity of the QCD caused any major errors in measurement.

The primary cause of tag loss is poor tag placement. The three factors which commonly cause poor tag placement are: (1) needle depth adjustment, (2) positioning of the fish in the head mold during tagging, and (3) head mold size. Although tag placement is monitored throughout each tagging day, this quality control measure is qualitative rather than quantitative. Qualitative sampling is usually sufficient to detect major problems, especially if the needle depth is improperly adjusted or if a tagger is consistently positioning fish in the head mold improperly. Quantitative sampling for tag placement would be time consuming, cumbersome and subjective. In our opinion, a quantitative sampling program for tag placement would not improve the tagging operation.

Although the fish were tagged several months prior to release, the weight distributions in Tables 10 and 12 are probably indicative of the size diversity at the time of tagging. Each release group of fish contained a wide range of sizes. It is unlikely that one head mold size would properly fit the whole range of sizes for each release group. Sorting fish by size may improve tag placement and reduce tag loss (Vreeland 1990). BLH was the only hatchery to achieve over 90% long-term tag retention in all release groups, and BLH was the only hatchery which graded fish into three sizes and used three different head molds. To achieve long-term tag retention rates above 90% at FRH and EH, fish will probably have to be graded and several different sizes of head molds will have to be used.

An additional factor which could have impacted long-term tag retention in the coho salmon at FRH is nose erosion. Deformed fish most likely did not fit into the head mold properly and did not receive proper tag placement. It is impossible to determine the degree of impact this may have had on long-term tag retention since the nose erosion was not quantified.

Comparison of Smolt Enumeration Techniques

The number of fish released into the wild is the basis for predicting future returns to sport fisheries and making management decisions. Thus, accurate and precise estimates of the numbers of fish released are essential for stocking programs. The comparison of smolt enumeration techniques revealed a serious discrepancy among some of the individual estimates (Table 13). The differences in the techniques were not due to random error because all estimates obtained from the water volume technique and the inventory technique that differed significantly from the mark/recapture estimates were higher than the mark/recapture estimates. In a controlled environment such as a hatchery, the three techniques should produce very similar estimates and any error should be random. Therefore, the actual practices used for obtaining the three types of estimates should be examined carefully in the future to discover the sources of bias.

All three estimation techniques are subject to potential sources of error. Requirements for unbiased mark/recapture estimates are (Seber 1982): (1) marking does not affect the catchability of fish (there is no handling-induced "trap happiness" or "trap shyness", and there is no handling induced mortality; (2) fish do not lose their marks between events; (3) recruitment and death of fish do not occur between sampling events; (4) every fish has an equal probability of being marked and released alive during the first sampling event, or every fish has an equal probability of being captured during the second sampling event, or marked fish mix completely with unmarked fish between sampling events; and (5) all marked fish are recognized and reported during the mark and recapture events. In the controlled environment of the hatchery, it is unlikely that any of these are a large source of error in this study. One potential source of error is violation of the assumption that the marked fish are randomly distributed among the whole population (Ricker 1975). Seven of the 10 groups had at least 33% of the population marked. It is unlikely that such a large percentage of the population could be marked and not be randomly distributed in the population. Handling-induced mortality could also be a problem, but dead fish were removed from the raceways and examined for marks. Marked mortalities were subtracted from the total number of marked fish.

Sources of error in the water volume displacement technique are: addition of excess water to the transport tanks while the fish are being loaded; improper enumeration of the volume of water displaced by the fish; improper determination of the weight of fish which displace a unit of volume in the tank; and improper determination of the mean weight of an individual fish in the group. The fish are dewatered at all three hatcheries prior to loading. It is unlikely that much excess water gets into the transport tanks. It is possible for someone to err in determining the water volume displaced. However, an error of sizable proportions would be immediately evident and small errors are probably unbiased. FRH and BLH used the same transport truck and tanks to stock fish. FRH calibrated the transport tanks when they were new, counting fish into the tanks by hand and measuring the amount of water volume they displaced in the tank. They determined that a 1 mm change in water level equated to 1.8 kg of fish. EH uses their own transport tanks which were calibrated in a similar manner. They estimated that a 1 mm change in water level equaled 4.9 kg of fish. The mean weights of fish used to estimate number of fish corresponded with the mean weights determined by weighing individual fish. No error is apparent in mean weight determination. However, the tank calibrations have not been verified since the initial calibrations, and abundance estimates are assumed to be independent of species, size and stock of fish. Because the water volume estimates were consistently higher than the mark/recapture estimates, the tanks should be recalibrated, and the assumptions for estimating abundance of fish by the water volume method should be tested.

The two main sources of error in the hatchery inventory technique are improper enumeration of fry or eggs to initiate the inventory and poor enumeration of mortality once the inventory is initiated. Both BLH and FRH bulk weighed fingerlings into raceways to estimate fish numbers and initiate the inventory. Because of the manner in which the data were collected, statistics could not be generated around these estimates. Consequently, it is impossible to determine their degree of accuracy. EH electronically enumerates eyed eggs to initiate their inventory. The error associated with electronic enumeration is quite small (Joyce and Rawson 1988). The accuracy of mortality estimation can be quite variable. Accuracy rates are best when mortality rates are low. Typically, mortality rates are highest in younger fish. Therefore, mortality enumeration is usually quite accurate when the inventory is initiated in the later stages of fish production. Mortality estimation is probably the least accurate at EH since enumeration is initiated at the eyed egg stage and continues for over a year. Mortality estimation is probably quite accurate at FRH and BLH since enumeration is initiated at the fingerling stage after the highest levels of mortality have occurred. Consequently, the inventory estimate at EH is initially quite accurate but has the potential to lose a great degree of accuracy because of the long duration of estimating mortality. At FRH and BLH, the accuracy of the initial inventory estimate is unknown but the mortality estimation is probably quite accurate.

All three enumeration techniques, if properly executed, have the potential to produce accurate estimates of numbers of smolt released. The three techniques produced nearly identical estimates for the three largest release groups of smolt (Houston, Nancy Lake, and Willow Creek). These three groups contained the smallest percentage of marked fish for the mark/recapture estimate and they have the greatest potential for error using this technique. If the three potentially weakest mark/recapture estimates appear to be accurate, then all the mark/recapture estimates should be accurate. Consequently, we will use the mark/recapture estimates as the official release numbers for these stocking locations. We are unable to determine why several of the release estimates of the same group of fish are substantially different. However, we feel that undocumented errors in the execution of all the techniques could account for most of the differences.

Smolt Release Timing

As previously mentioned, numerous studies have attempted to document the relationship between smolt size and time of release to marine survival rates (Bilton et al. 1982; Bilton et al. 1984; Morley et al. 1988; and Mahnken et al. 1982). In an extensive review of the literature on emigration timing of wild coho salmon smolt, Sandercock (1991) noted a general trend of later smolt migrations as one moved northward. In addition, there are year to year variations in timing that are related to environmental factors. The timing of wild coho salmon smolt in Cook Inlet is fairly well documented. The mean period of peak coho salmon smolt migration from Fish Creek in upper Cook Inlet during the period 1978 to 1991 was between May 31 and June 4 (Alaska Department of Fish and Game, FRED Division, Palmer, unpublished data), with an estimated 78.5% of the migration occurring after May 30. Smolt sampling in the Kenai River in 1992 indicated that 95% of the coho smolt captured at River Mile 19 emigrated after May 30 with the peak also occurring between May 31 and June 4 (Terry Bendock, Alaska Department of Fish and Game, Soldotna, personal communication). Based on these observations, it appears that migration of wild coho salmon smolt to salt water in upper Cook Inlet begins in late May, peaks in early June, and continues into late June.

In this study, seven of the 10 sites were stocked prior to May 30. The three smolt stockings using fish from Big Lake Hatchery were stocked in late June. These fish could have been stocked sooner, but due to their small size they were held in the hatchery and fed for as long as possible. Four of the seven sites stocked in May are located a large distance upstream. These systems contain a lake or large stream where the stocked fish can hold for a length of time before migrating to salt water. Stocking dates on these systems are probably not critical. However, stocking dates on Ship Creek, Bird Creek and the Ninilchik River may be more important because these fish do not have an option to stay in fresh water if they are not ready for a saltwater existence. In 1992, the Ship Creek coho salmon were stocked into salt water on May 21. Data from 1992 indicate that few if any wild smolt from Fish Creek or the Kenai River were headed to salt water at that time. Wild smolt have evolved to enter salt water when food is abundant and conditions for survival are at optimum levels. Consequently, we conclude that the Ship Creek coho salmon smolt were stocked 10 to 14 days too early. We do not anticipate high survival rates for this release group. Bird Creek coho salmon smolt were stocked on May 26 in fresh water. However, there is little area in Bird Creek for these fish to hold and it is likely that they entered salt water shortly after stocking. We also conclude that the Bird Creek smolt were stocked too early and do not anticipate high survival rates for these fish. The Ninilchik River chinook salmon smolt were stocked in fresh water on May 28. There is little area in the Ninilchik River for these fish to hold and it is likely that they entered salt water shortly after stocking. We do not know enough about the timing of chinook salmon smolt migrations in Cook Inlet to comment on the time of stocking of this group of fish.

CONCLUSIONS AND RECOMMENDATIONS

1. The BLH coho salmon smolt stocked at Cottonwood Creek, Wasilla Creek, and Fish Creek will probably not produce many adult returns in 1993. 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 1994. The problems encountered at BLH are similar to those which have occurred at EH and FRH in the past. Both hatcheries addressed the problems and smolt production improved dramatically. Similarly, BLH has identified and addressed problems in the hatchery smolt production program. Future smolt releases from BLH should contain larger and healthier fish.

2. The EH coho salmon smolt stocked in Ship Creek were stocked 10 to 14 days too early. Marine survival rates may not reach anticipated levels.

3. All parameters associated with the FRH coho salmon smolt stocked in the Little Susitna River at Houston, Nancy Lake, and Campbell Creek indicate these releases should produce anticipated marine survival rates. The smolt stocked into Bird Creek may produce below anticipated marine survival rates because the fish were stocked early and had elevated blood sodium rates.

4. All parameters associated with the two FRH chinook salmon smolt releases indicate marine survival rates should reach anticipated levels.

5. The potential for using autopsy-based condition assessment as an indicator of the quality of smolt production should be investigated in at least one of the three hatcheries involved in this study.

6. The poor, long-term tag retention rates in some of the smolt release groups is probably due to using only one head mold size to tag all fish. In 1993, fish should be graded by size and tagged using either two or three different sizes of head molds.

7. Blood sodium sampling as presently conducted has limited utility. Pooling of samples should be avoided whenever possible. When blood from two fish must be combined, potassium levels should be monitored as described by Blackburn and Clarke (1987). Based on the distance of the release site from salt water, sampling should be mandatory for Ship Creek, Ninilchik River, Cottonwood Creek, Wasilla Creek, Fish Creek, and Bird Creek. Sampling is optional at the two Little Susitna River sites, Campbell Creek and Willow Creek.

8. Use of a smolt size quality index should continue. Rather than concentrating on producing fish of a target mean size, managers should try to achieve a smolt quality index of at least 80%. The index boundaries should be modified as new data on optimum smolt size are published or developed.

9. All three techniques for estimating the number of smolt released should be continued in 1993. Hatchery managers need to keep an inventory estimate so they can compute feeding rates and maintain proper rearing densities. The mark/recapture estimates are a byproduct of estimating

long-term tag retention and marked/unmarked release ratios. As a byproduct, the mark/recapture estimates cost nothing to obtain. The water volume displacement estimates are routinely generated as the fish are transported to release sites. A rigid set of operating plans should address the generation of each type of measurement so that the variability associated with each estimate can be measured. The three estimates will serve as a cross check of each other. Consequently, the quality control associated with each estimation technique will undoubtedly improve. Once the variability associated with each enumeration technique is established, a decision can be made as to which estimate will be used for future reporting purposes.

10. Monitoring of the smolt production for the 10 Cook Inlet stocking sites should continue. The format developed in this report should be used as a foundation for an annual reporting process. Separate operational plans should be written for collection of hatchery production, marking and release statistics. Hatchery managers and project leaders should work together to standardize data collection and reporting. As new information is developed or published, the goals and objectives of this program should be modified and adjusted.

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