Calibration of Methods to Survey for Fall Chinook Salmon in North Fork Nehalem and South Fork Coos Rivers

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INTRODUCTION

The Oregon Department of Fish and Wildlife (ODFW) has completed the first year of a multi-year study designed to develop methods that provide reliable estimates of fall chinook spawner escapements for Oregon coastal streams. Funding for this study was obtained through the US Letter of Agreement (LOA) and is administered by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission. The CTC is responsible for evaluating the rebuilding process of naturally spawning chinook stocks covered by the Pacific Salmon Treaty and is comprised of scientists from all member states and countries. Three stock aggregates have been identified to originate from Oregon coastal basins. These aggregates are thought to represent populations within distinct genetic and behavioral characteristics and are managed separately. The North Oregon Coast (NOC) and Mid Oregon Coast (MOC) are the two stock aggregates that are north migrating, and are subjected to the CTC's abundance-based management program (USCTC 1997).

Current monitoring programs for Oregon coastal fall chinook (*Oncorhynchus tshawytscha*) do not supply the CTC with information that is adequate for the management and rebuilding of an abundance-based fishery. ODFW has conducted standard surveys for more than 40 years to monitor the status of chinook stocks along coastal Oregon (Jacobs and Cooney 1997). A total of 56 standard index spawner surveys (45.8 miles) are monitored on an annual basis throughout 1,500 stream miles of spawning habitat to estimate peak escapement levels and track trends of north-migrating stocks. Although counts in these standard surveys may be sufficient to index long-term trends of spawner abundance, they are considered inadequate for deriving dependable annual estimates of spawner escapement. To provide estimates of escapements, index counts must be calibrated to known population levels. Without calibration, counts provide only trend information that may or may not follow actual population fluctuations.

There are many weakness associated with using standard surveys as a means to estimate fall chinook escapement. These surveys were not selected randomly, and cannot be considered to be representative of coast-wide spawning habitat. Also, fall chinook are known to spawn extensively in mainstem reaches and large tributaries which are not conducive to the foot surveys currently conducted in most standard surveys. Obtaining accurate estimates of fall chinook spawner density in these mainstem reaches are extremely difficult. Typically, these areas exhibit high variations in stream flow and turbidity which create difficult and sometimes dangerous survey conditions resulting in unreliable visual counts. Alternative methods should be employed and a more reliable estimate may be possible by way of calibrated carcass counts. This procedure essentially uses counts of post-spawned carcasses, which are adjusted for bias in observation efficiency to estimate spawner density. Observation bias can be estimated using carcass mark-recovery techniques similar to those described in Boydstun (1994).

The goal of this project is to develop a survey design that can be used to estimate spawner abundance for the NOC and MOC stock aggregates. The North Fork Nehalem River (NOC) and the South Fork Coos River (MOC) are the two river systems selected as initial calibration sites to test potential survey designs. A mark-recapture program is necessary to obtain a precise estimate of fall chinook populations in each river system and provide a standard to use for evaluating survey designs. Various survey designs are then used to independently estimate spawner abundance in each system. These designs include foot and boat surveys to obtain live fish counts and carcass counts. Live counts are used to estimate escapement in smaller tributaries using Area Under the Curve (AUC) methodology (Jacobs and Nickelson 1998). Carcass counts are used to provide an index of escapement into mainstem

spawning reaches. The carcass counts are calibrated to adjust for site-specific recovery rates using a carcass mark-recapture experiment.

The purpose of this report is to describe the initial results obtained during the first year of the study (1998). Specific objectives are as follows:

1. Define the sampling methods.

2. Present adult chinook salmon population estimates and associated 95% confidence intervals derived from a Petersen mark-recapture experiment.

3. Present escapement estimates based on the survey design.

4. Discuss the adequacy of the methods and suggest refinements or changes in the survey design that will improve the accuracy and precision of the estimates.

STUDY AREA

The North Fork of the Nehalem and the South Fork of the Coos Rivers were the two systems selected as calibration sites to assess the degree of feasibility of surveys designed to obtain a reliable escapement estimate (Figure 1). These two sites were chosen because they provided trap sites located downstream from fairly extensive expanses of spawning habitat. Trapping was necessary to establish an independent escapement estimate using a mark-recapture experiment in each of the river systems.

North Fork Nehalem River

The Nehalem River basin drains 667 square miles, with an average discharge of 2,669 ft^3/s. The North Fork is a major tributary of the basin consisting of about 31 miles of fall chinook spawning habitat out of 107 total stream miles. Trapping was conducted at a fish ladder that was designed to aid with fish passage around a falls, located approximately 14 miles upriver from the mouth, and about eight miles above head of tide. Of the 31 miles of spawning habitat, 23 miles of suitable habitat for chinook spawning are located above the trap. Approximately five of these miles are considered to consist of mainstem reaches. There is minimal angling effort for fall chinook above the falls.

The falls are not a complete passage barrier and modifications to the ladder were necessary to assure adequate trapping efficiency. Blasting of rock at the base of the ladder was done to straighten the entrance and allow for greater attractant flow. Within the ladder, a rotating, self-cleaning weir was fitted to the trap to clear the weir of leaves and debris to prevent backup, and allow for continuous water flow through the ladder.

South Fork Coos River

Fall chinook were collected at a permanent weir located at Dellwood, approximately 11 miles up river at the head of tide. The weir is constructed of large boulders and wire gabions
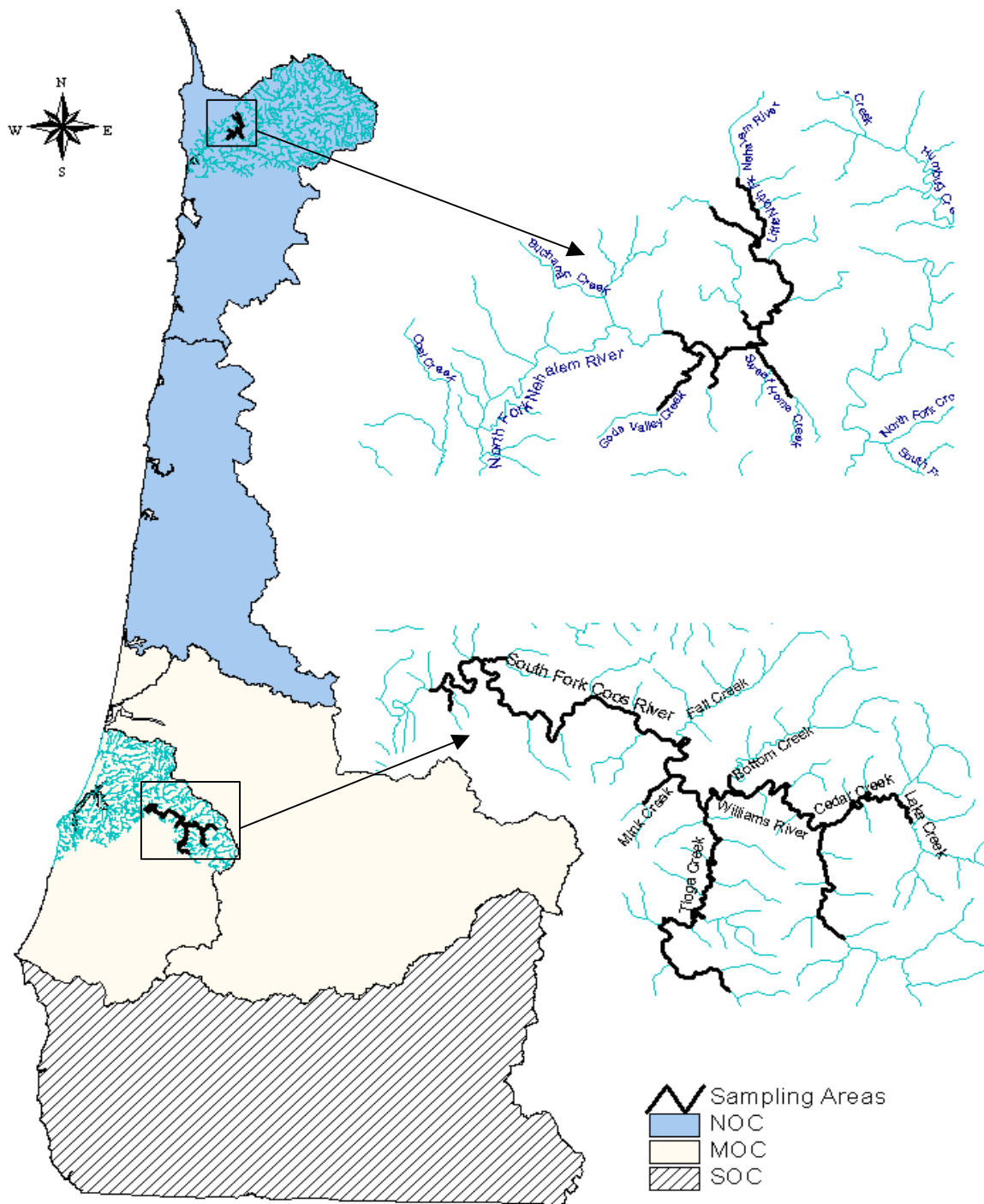
Figure 1. Map of Oregon coast depicting fall chinook stock aggregates and study area, with enlargements of the study sites.

encased in concrete and asphalt. The weir stands approximately four feet high and spans the width of the channel, terminating at a fishway. The fishway is constructed of two concrete slabs approximately five feet high and four feet apart. The fishway was fitted with a wooden holding pen that measures 12 by 8 feet. There is about 55 miles of habitat upstream from the weir available for chinook spawning. Approximately 32 of these miles are considered to be within mainstem habitat. A small in-river recreational fishery exists; however, few chinook are harvested above the trap site.

METHODS

A mark-recapture experiment was used to provide quantitative estimates of chinook spawner escapement. Two capture events were used, the initial tagging event at each tagging location and a subsequent recapture event of carcasses upstream of the trap. In conjunction with the mark-recapture experiment, random spawner and carcass surveys were conducted to estimate index values. Live counts were recorded from the spawner surveys, and lengths, sex, tag presence and tag identification number were recorded from recovered carcasses.

The occurrence of spawning in small tributaries can be estimated by visual counts recorded during foot surveys. Part of the survey design to index abundance of fall chinook salmon was to conduct regular surveys in tributaries and record live counts on the spawning grounds (Riggers 1998). For the purpose of this study, tributary strata were defined as those stream areas that support habitat that is conducive to fall chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) spawning as documented in the ODFW database of salmon spawning distribution (Jacobs and Nickelson 1998). To maximize personnel efficiency, the random chinook survey design in tributary reaches incorporated all coho surveys that overlapped with chinook spawning habitat. These surveys were selected through the EMAP selection process as part of the monitoring associated with the Oregon Plan for Salmonids and Watersheds (Firman, in preparation). Additional surveys were randomly selected to increase the sampling rate to explore effects of sample size on precision.

Mainstem spawning reaches are generally not conducive to survey methods that use live counts as an index of spawner abundance due to high flows and subsequent turbidity. Calibrated carcass counts were used to estimate abundance in these reaches. Mainstem strata for the two calibration sites were designated as those areas that were downstream of coho spawner distribution and include mainstems and large tributaries upstream of tidewater. Surveys were conducted on foot in mainstem strata when flows permitted safe navigation. Surveyors floated these mainstem surveys in inflatable kayaks during periods of higher flows.

The survey design consisted of a combination of mainstem and tributary strata, and incorporated the random selection of coho surveys within chinook habitat that were selected for the existing coho monitoring project. Surveyors collected basic biological and physical data including live counts, carcass counts, length, gender and occurrence of fin marks. The tails of sampled carcass were severed to prevent re-sampling, unless chosen to be carcass tagged. Spawner abundance was estimated using AUC techniques based on live counts and by a combination of live counts in tributary reaches and calibrated carcass counts in mainstem reaches.

Mark-Recapture

Chinook salmon were tagged and released from October 5, 1998 through November 20, 1998 at the North Fork Nehalem River trap, and from September 19, 1998 through November 20, 1998 at the South Fork Coos River trap. High water severely impacted the ability to trap fish after November 20th. The trap on the Coos River was dismantled on the 20th of November to prevent damage to the holding pen and possible damage to downstream structures. Tagging occurred on a daily basis to limit the amount of time that upstream migration was delayed. Trapped salmon were placed into a hooded cradle for tagging and inspection. Anchor tags were place on each side of the dorsal using a Dennison Mark II® tagging gun. A double tagging procedure was preformed to assess tag retention. Tags displayed a unique number and were of a neutral color, so as not to bias recovery of tagged fish. Fork length, sex, tag number and presence of fin clips were recorded before release.

Spawning ground surveys were conducted to recover carcasses and record live counts. Carcasses were sampled for length, sex, and number of tags and tag identification number. Surveys designated as part of the random survey design were conducted on 7 to 10 day intervals according to survey protocol. Areas consistent with holding carcasses, such as inside of river bends, debris jams and low energy spots, were surveyed as weather and time permitted to optimize the effort for the recovery of carcasses.

Tributary and Mainstem Surveys

Four surveys totaling 4.3 miles and equating to approximately 25% of the available tributary habitat were conducted above the trap on the North Fork Nehalem River (Table 1). Seven surveys were conducted above the trap on the South Fork Coos River, totaling 6.7 miles and 31% of the available tributary chinook spawning habitat (Table 1). All of these surveys were performed according to ODFW spawner survey protocol (ODFW 1998). Surveys were walked in an upstream direction and at a pace adapted to weather and viewing conditions. Surveys were not conducted if the bottom of rifles could not be seen. Surveyors worked in pairs and each wore polarized glasses to aid in location and identification of live fish.

Mainstem surveys were conducted on a regular basis as flows and visibility conditions allowed. Kayaks were used in order to access and search both riverbanks. Two mainstem surveys totaling 2.2 miles and equating to approximately 45% of the available mainstem habitat were conducted above the trap on the North Fork Nehalem River. There were 6 surveys conducted above the trap on the South Fork Coos River, combining for approximately 16 miles and 39% of the available mainstem chinook spawning habitat (Table 1). Surveyors searched all areas of the banks, pools, and other low energy areas where carcasses are likely to be deposited.

Carcass Recovery Efficiency

Carcass recovery efficiency of fall chinook was determined through the mark and recapture of carcasses similar to the method described in Boydstun (1994). All chinook carcasses recovered with intact skeleton and at least one clear eye qualified for the

Table 1. List of fall chinook surveys conducted in the North Fork Nehalem and South Fork Coos Rivers. Start and endpoints designates reach breaks and are not necessarily surveys boundaries. Lengths are in miles.

Location	Reach	Start	End	Segment	Length
Nehalem River					1.2
Mainstem:	Nehalem R, N Fk	Sweet Home Cr	Fall Cr	-	
	Nehalem R, N Fk	Gods Valley Cr	Lost Cr	-	1.0
Tributary:	Fall Cr	Mouth	Headwaters	1	0.9
	Nehalem R, N Fk	Fall Cr	Trib. R	1	1.3
	Little N Fk	Mouth	Headwaters	2	1.0
	Nehalem R, N Fk	Little N Fk	Trib A	1	1.2
Coos River					
Mainstem:	Coos R, S Fk	Salmon Cr	West Cr	-	3.5
	Coos R, S Fk	Cox Cr	Elk Cr	-	4.3
	Coos R, S Fk	Mink Cr	Tioga Cr	-	2.5
	Williams R	Bottom Cr	Fall Cr	-	2.6
	Williams R	Skip Cr	Trib A	-	1.5
	Williams R	Cabin Cr	Fall Cr	-	1.5
			Hatcher Cr		
Tributary:	Tioga Cr	Mouth		1	0.5
	Tioga Cr	Hatcher Cr	Shotgun Cr	1	1.1
	Tioga Cr	Shotgun Cr	Susan Cr	1	1.4
	Tioga Cr	Shotgun Cr	Susan Cr	2	1.0
	Tioga Cr	Susan Cr	Hog Ranch Cr	1	0.7
	Tioga Cr	Hog Ranch Cr	Burnt Cr	1	0.5
	Tioga Cr	Burnt Cr	Buck Cr	1	0.9

mark/recapture experiment. A Floy-flag tag was placed through the base of the tail with a Dennison Mark II® tagging gun. Tag color designated whether it was placed in a tributary or mainstem reach. Marked carcasses were returned to the nearest moving water and assumed to behave in the same manner as a non-sampled carcass drifting naturally through the selected location.

Tag loss of carcass tags was assumed to be negligible due to tag placement and the criteria established for qualifying of a recovery. The primary factors contributing to tag loss, such as decomposition and scavenging, would prevent the carcass as being counted as a qualifying recovery, thus eliminating it from the experiment. Tags placed during the final week of surveys were not used in the calculations. Upon recovery the tails were severed to prevent re-sampling.

Population Estimates

Mark-Recapture

The Chapman version of the Petersen mark/recapture formula (Ricker 1975) was used to estimate fall chinook escapement above trap sites:

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

where

$\hat{N}_i$ = the estimated population of fall chinook above the trap for calibration site i.
M = the number of fall chinook tagged at the trap site.
C = the number of fall chinook recovered on the spawning grounds.
R = the number of recovered tagged fall chinook.

Adjustments were made to the population of tagged fish based on the probability of losing one or both tags (Caughely 1977). This effectively reduced the population of tagged salmon available for recapture as a carcass. Assuming tag loss is independent of one another, the probability factor for losing a single tag was calculated using the following equation.

$$p = F_1/2F_2 + F_1$$

where

p = the probability of a single tagged salmon losing that tag.
F_1 = the number of carcass recoveries that retain one of the two original tags.
F_2 = the number of carcasses recovered with both tags.

The Petersen formula was modified to account for tag loss as follows:

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

where

p^2 = the probability of a double tagged salmon losing both tags.

A bootstrap technique was used to estimate variance, bias and confidence intervals of the population estimate (Buckland and Garthwaite 1991, Mooney and Duval 1993). The fate of chinook that pass by each trapping facility were divided into several capture histories to form an empirical probability distribution as follows:

1. marked and harvested in fishery ($= H_i$), for 1998 this was assumed zero for both rivers.
2. marked and were captured out of the experiment area ($= F_i$).
3. marked and recaptured on the spawning grounds ($= R_i$).

4. marked and never seen again $(= \hat{M}_i - R_i)$.

5. unmarked and inspected on the spawning grounds, and $(= C_i - R_i)$.

6. unmarked and never seen $(= \hat{N}_i - \hat{M}_i - C_i + R_i)$.

where, $\hat{M}_i = M_i - H_i - F_i$, M_i = the number of fish tagged at a trap site, and $\hat{N}_i$ is the population estimate.

A random sample of size $\hat{N}_i^* (= \hat{N}_i + F_i + H_i)$ was drawn with replacement from the empirical probability distribution. Values for the statistics $\hat{M}_i^*, R_i^*, C_i^*, F_i^*, H_i^*$ were calculated and a new population size $\hat{N}_i^*$ estimated. We repeated this process 1,000 times to obtain samples for estimates of variance, bias and bounds of 95% confidence intervals.

Variance was estimated by:

$$v(\hat{N}_i^*) = \frac{\sum_{b=1}^{B} \left(\hat{N}_{i(b)}^* - \overline{\hat{N}_i^*} \right)^2}{B-1}$$

where B equals 1,000 (the number of bootstrap samples).

To estimate the statistical bias, the average or expected bootstrap population estimate was subtracted from the point estimate (Mooney and Duvall 1993:31).

$$Bias(\hat{N}_i) = \hat{N}_i - \overline{\hat{N}_i^*}, \text{ where } \overline{\hat{N}_i^*} = \frac{\sum_{b=1}^{B} \hat{N}_{i(b)}^*}{B}$$

The percentile method was used to calculate the 95% confidence intervals from the 1,000 bootstrap samples (Mooney and Duvall 1993). The interval lies between the 25th lowest value and 25th highest value of bootstrap population estimates, $\hat{N}_{i(b)}^*$.

Estimates Based on Carcass Counts

Carcass counts were used to estimate spawner abundance as follows. A count per unit length calculation was used to estimate abundance of chinook carcasses (E_h) for each river system using the following equation:

$$E_h = \left[\left(\frac{(M_h+1)(C_h+1)}{(R_h+1)} \right) \Big/ \sum L_h \right] S_h$$

where

M_h = total number of carcasses tagged in stratum h.
R_h = total number of tagged carcass recoveries in stratum h.
C_h = count of carcasses in surveys in stratum h.
L_h = length of surveys conducted above trap site (miles) in stratum h.
S_h = miles of spawning habitat in stratum h.

Estimates Based on Live Counts

Counts of live spawners in survey sites were used to estimate abundance in a given stratum using the procedure described in Jacobs and Nickelson (1998). Basically, this procedure involved calculating AUC estimates of spawner density for each survey site and aggregating these to estimate spawner abundance. In making these estimates we assumed a life span of 12.1 days (Perrin and Irvine 1990) and also assumed that surveyors saw an average of 76% of the live spawners (Solazzi 1984).

RESULTS

Mark-Recapture Escapement Estimate

A total of 167 fall chinook were tagged and released above the trap at the North Fork Nehalem River site. The tagged population was comprised of 77 males and 90 females. The probability of losing a tag was estimated to be 15%. The tagged population adjusted for tag loss and tag recoveries downstream of the trap was 72 males and 86 females, for a total of 158 fall chinook above the North Fork Nehalem River trap site (Table 2). Chinook were tagged from October 5th to November 20th; this time period is believed to have encompassed the entire spawning run. The peak of the run occurred during a three-day period from November 4th through November 6th when 46, 21 and 30 chinook were tagged, respectively. Carcasses were recovered on the spawning grounds from November 4th through December 17th. A total of 68 carcasses were sampled, of which 36 were males and 32 were females. Tags were recovered from 16 of these carcasses, 5 males and 11 females. Escapement above the trap was estimated at 689 fall chinook (95% C. I. = 415 – 1230,Table 2). Relative bias of the estimate was 0.185 (Bias/SE[(bootstrap)]). A relative bias less than 0.25 can usually be ignored (Efron and Tibshirani 1993). Because of the low numbers of recaptures, this estimate was not stratified by size or sex. Analysis of the length data showed similar sizes of marked and recaptured fish (Kolomogorov-Smirnov (K-S) two-sample test, Figure 2).

Table 2. Estimate of fall chinook escapement derived from the mark-recapture experiment conducted at both site locations.

Location	Tagged[a]	Sampled	Tags Recovered	Estimate	95% Confidence Limits
North Fork, Nehalem River	158	68	16	645	415 – 1,230
South Fork, Coos River	479	87	13	3,014	1,864 – 6,047

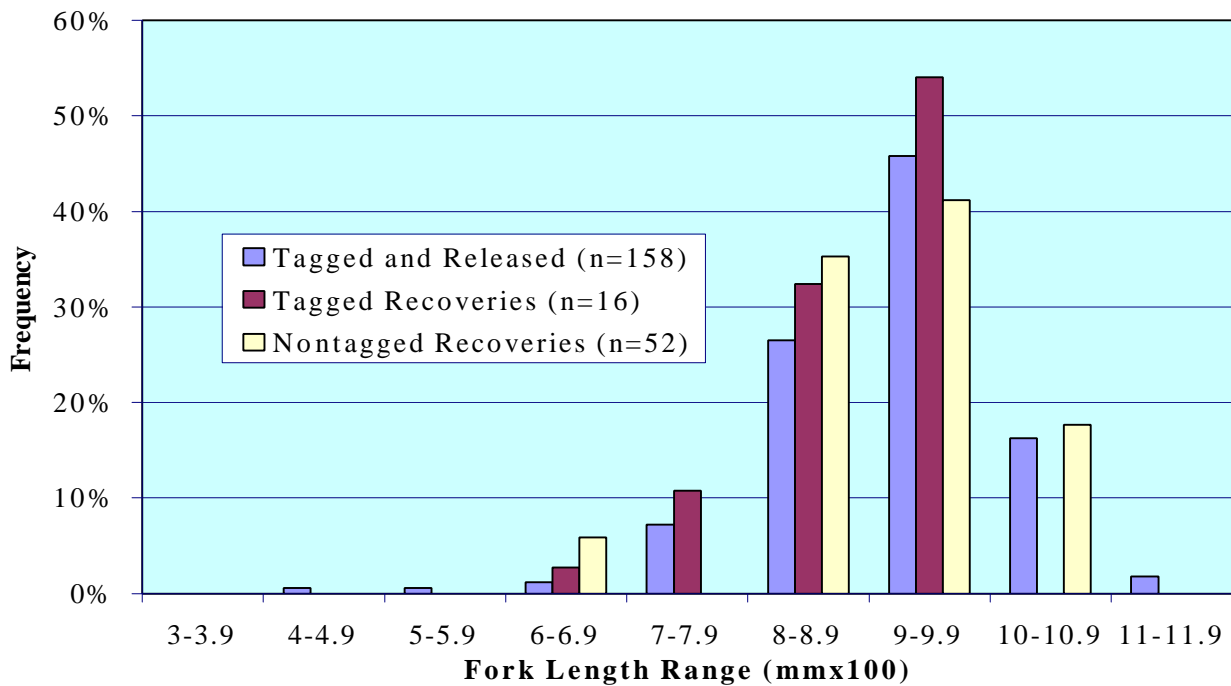a *Tagged population has been adjusted to account for tag loss.*

Figure 2. Length frequency comparison between tagged and released chinook, recovered chinook, and non-tagged recovered chinook in the North Fork Nehalem River, 1998. Lengths of recovered carcass were converted from Mid Eye Posterior Scale (MEPS) lengths to fork lengths, using a MEPS to fork ratio of 1.21:1 (Boechler and Jacobs 1987).

A total of 516 fall chinook were tagged at the South Fork Coos River trap site. The tagging population was comprised of 281 males and 235 females. The probability of losing a tag was calculated to be 27%. The adjusted-tagged population based on the probability of a losing a tag totaled 479 chinook, of which an estimated 261 were males and 218 were females (Table 2). The peak of the run occurred on November 15th when 162 chinook were tagged and released above the trap. Carcasses recovered on the spawning grounds were comprised of 42 males and 45 females, of which 13 of were tagged (6 males and 7 females). Carcasses were recovered on the spawning grounds from November 15th to December 27th. Carcass recovery was highly variable depending on flow conditions. A peak of 9 recoveries was recorded on December 16th. Figure 3 illustrates length frequency distribution of first event captures and second event tagged and non-tagged captures. There does appear to be a bias towards the recovery of large tagged fish (Figure 3). This could be attributed to low sample size of recoveries as well as sampling techniques. K-S tests of length frequencies show significant size differences for males between both capture events (Figure 4). As with the North Fork Nehalem, low numbers of second event captures did not allow stratification by size or sex. Fall chinook escapement above the trap was estimated at 3,015 (95% C.I.= 1864 – 6047; bias = 0.27) (Table 2).
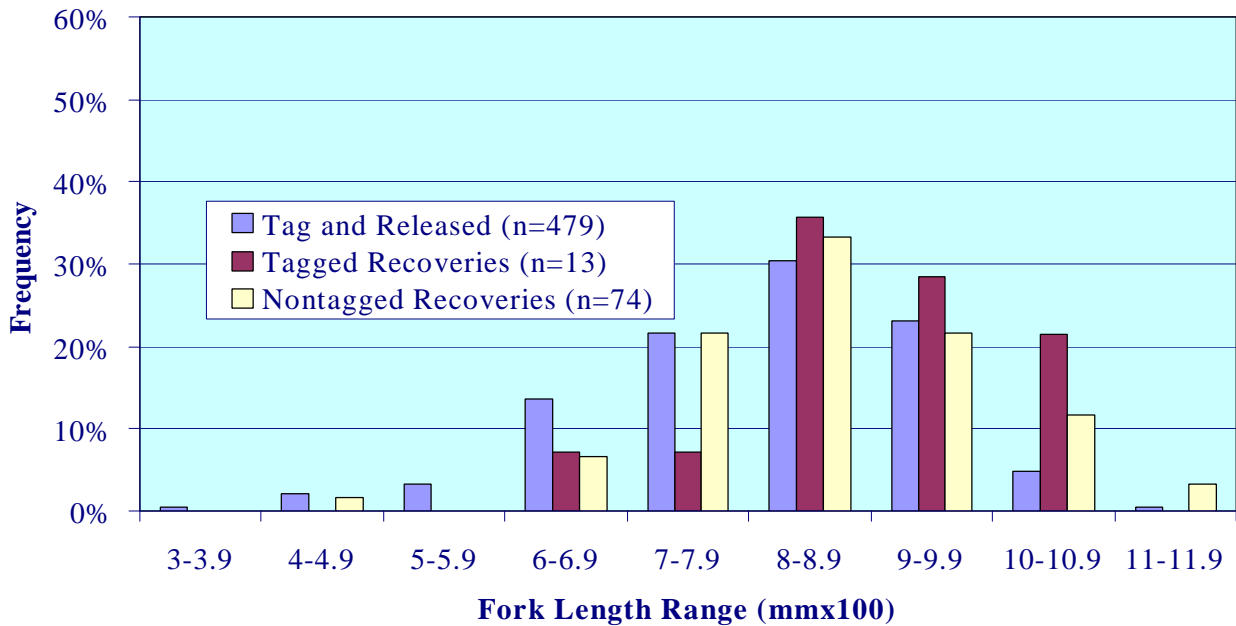
Figure 3. Length frequency comparison between tagged and released chinook, recovered chinook, and non-tagged recovered chinook in the South Fork Coos River, 1998. Lengths of recovered carcass were converted from Mid Eye Posterior Scale (MEPS) lengths to fork lengths, using a MEPS to fork ratio 1.21:1 (Boechler and Jacobs 1987).
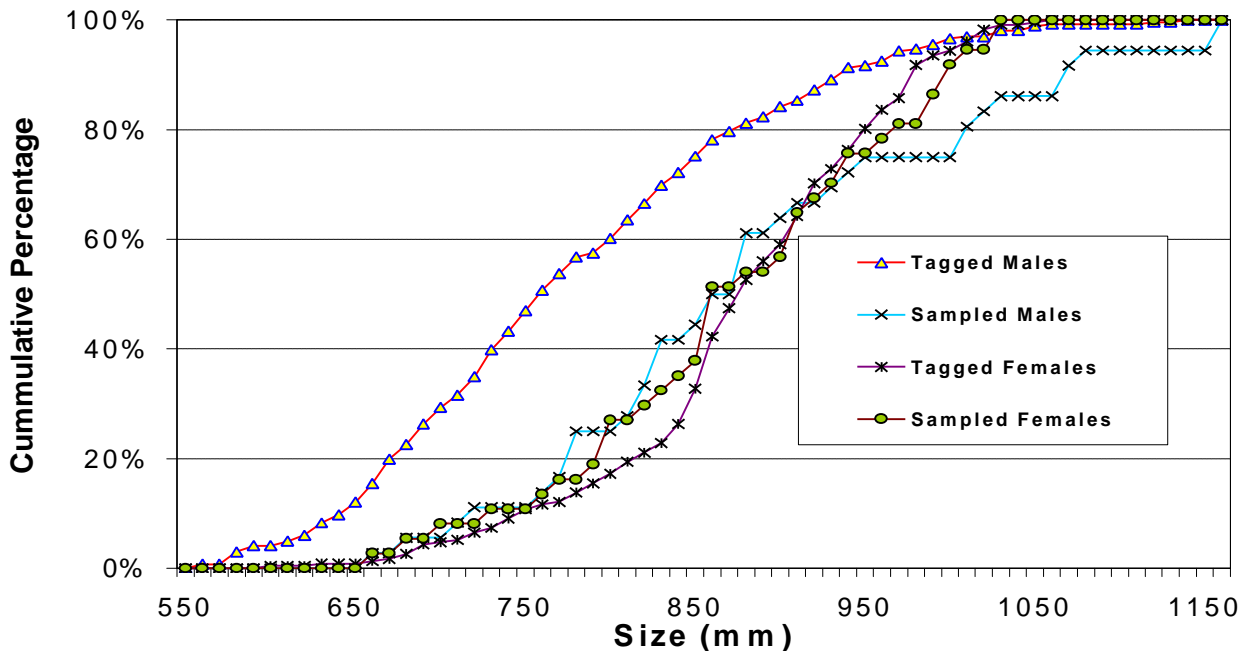

Figure 4. South Fork Coos River length distribution by sex and capture event.

Escapement Estimates-Tributary Stratum

Chinook were observed in 2 of the 4 random tributary surveys conducted above the trap on the North Fork Nehalem River (**Appendix A**). The highest spawner densities were observed in Fall Creek, where a peak count of 44 fall chinook was recorded on November 15th. We estimated a total of 266 adult and 0 jack fall chinook using AUC techniques. Applying our estimate of observation bias resulted in a total escapement estimate of 351 fall chinook in tributary habitat above the trap.

All but 1 of the 13 surveys conducted in South Fork Coos River tributary reaches recorded live counts of chinook salmon **(Appendix B)**. A peak count of 24 chinook per mile occurred on November 12th in segment 1 of Tioga creek, between the confluence of Shotgun and Susan creeks. Abundance estimates of 441 adults and 17 jacks were generated using AUC methodology. Factoring in the observation bias resulted in a total escapement estimate in South Fork Coos River tributary habitat of 602 fall chinook salmon.

Carcass Recovery Efficiency

A total of 13 qualifying carcasses were tagged from carcasses recovered on North Fork Nehalem surveys. Only one of these tagged carcasses was recovered during subsequent surveys, resulting in an estimated recovery efficiency of 8%. Surveyors on the South Fork Coos River placed 23 carcass tags of which 3 were recovered. Surveyors only recovered an estimated 13% of the available carcasses on any particular survey on the South Fork Coos River. These are not statistically robust estimates due to low sample size.

Escapement Estimates-Mainstem Stratum

Surveyors in the North Fork Nehalem River recovered 19 carcasses on 2 mainstem survey reaches above the trap. The gender composition was 7 males and 12 females. A total mainstem escapement of 312 fish was estimated when adjusted for carcass recovery efficiency (Table 3). Surveys in mainstem reaches were conducted frequently enough to also qualify for AUC estimates and an escapement of 258 fall chinook was calculated using AUC techniques (Table 3).

A total of 46 carcasses were recovered while conducting random surveys on mainstem reaches on the South Fork Coos River. Of these, 21 were males, 23 were females and two were of undetermined gender. Factoring in the carcass recovery efficiency resulted in a total estimated escapement of 729 fall chinook in mainstem reaches of the South Fork Coos River (Table 3). Combining tributary estimates of 602 based on AUC methodology results in a population estimate of 1,331 fall chinook in the South Fork Coos River. Chinook escapement was estimated to be 138 in mainstem stratum using AUC techniques. This was done for comparison only, as these surveys did not meet the criteria for survey intervals not to exceed 20 days.

Table 3. Summary of escapement estimates above the trap sites at the South Fork Coos River and North Fork Nehalem River as calculated from the sampling design. The AUC tributary estimate was added to the calibrated carcass estimate for the combined escapement estimate.

Location	Mark-Recapture Estimate	Survey-Based Estimate				
		AUC Methodology[b]			Calibrated Carcass Counts	Combined
		Mainstem	Tributary	Total		
North Fork Nehalem R.	415–1,230	258	351	609	312	663
South Fork Coos River	1,864–6,047	DNQ	602	-	729	1,331

b- *Adjusted for observation bias.*
DNQ- *did not qualify.*

DISCUSSION

Reliability of Petersen Mark-Recapture Estimates

Experiment Assumptions

The following is a list of the assumptions that pertain to the use of the Petersen formula in making unbiased population estimates. These assumptions are discussed as they pertain to this study:

1. *The marked fish become randomly mixed with the unmarked fish in the population between events.*

The temporal distribution of carcass recovery was similar among tagged and non-tagged fish in both the North Fork Nehalem and South Fork Coos basins (Figure 5). Chi-square analysis showed no significant difference in the timing of recoveries of tagged and non-tagged fish in either the North Fork Nehalem (P = 0.47) or South Fork Coos (P= 0.97) Basins. Also, there did not appear to be a significant difference in spatial distribution between tagged and non-tagged carcass recoveries for either system (Figure 6). Chi-square analysis revealed no significant differences in the spatial distribution of tagged and non-tagged recoveries in either system. These analyses suggest random mixing of marked and unmarked fall chinook did occur, but the low numbers of tag recoveries that reduced the power of detecting differences must temper this conclusion.

2. *There is no amount of recruitment to the catchable population between events.*

This assumption does not apply to this study. Adult fish are captured, tagged and recovered within a few months. Spawning salmon do not have recruitment during the spawning season; thus there is no recruitment into this population.

3. *The marked fish suffer the same natural mortality as the unmarked fish.*

Although this is difficult to assess, it is assumed that there was no difference in the mortality rate between marked and unmarked fish. This assumption is a least substantiated by the fact that
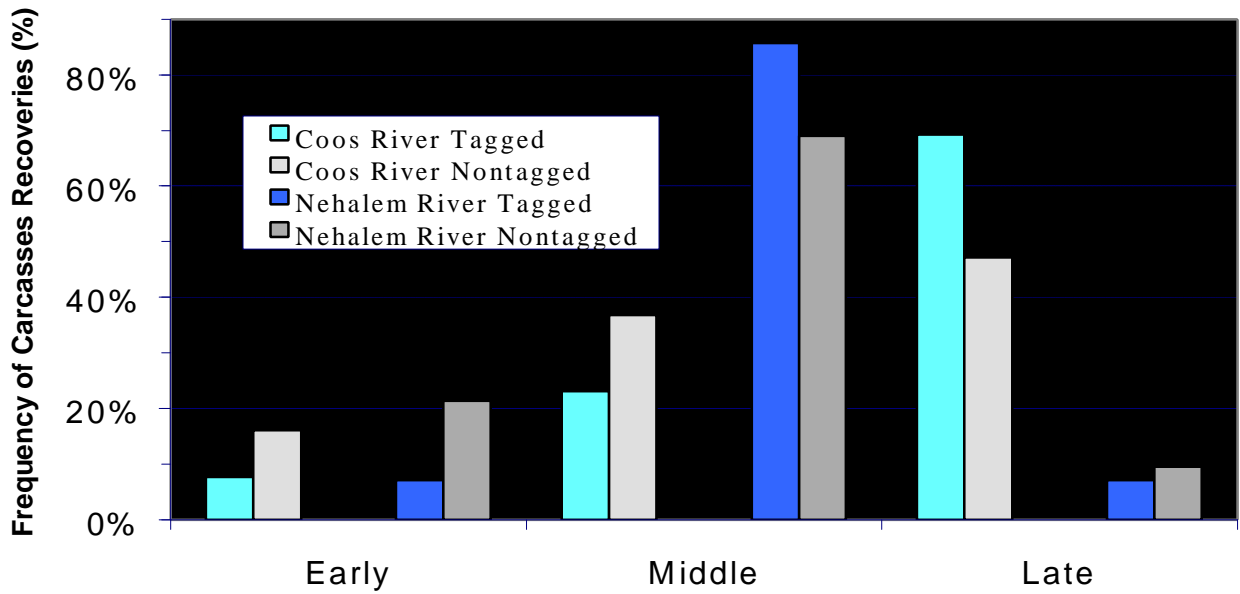
Figure 5. Temporal distribution of tagged and non-tagged carcasses recovered on the North Fork Nehalem and South Fork Coos Rivers. Early: 11/15-11/28, Middle: 11/29-12/12 and Late: 12/13-12/26.
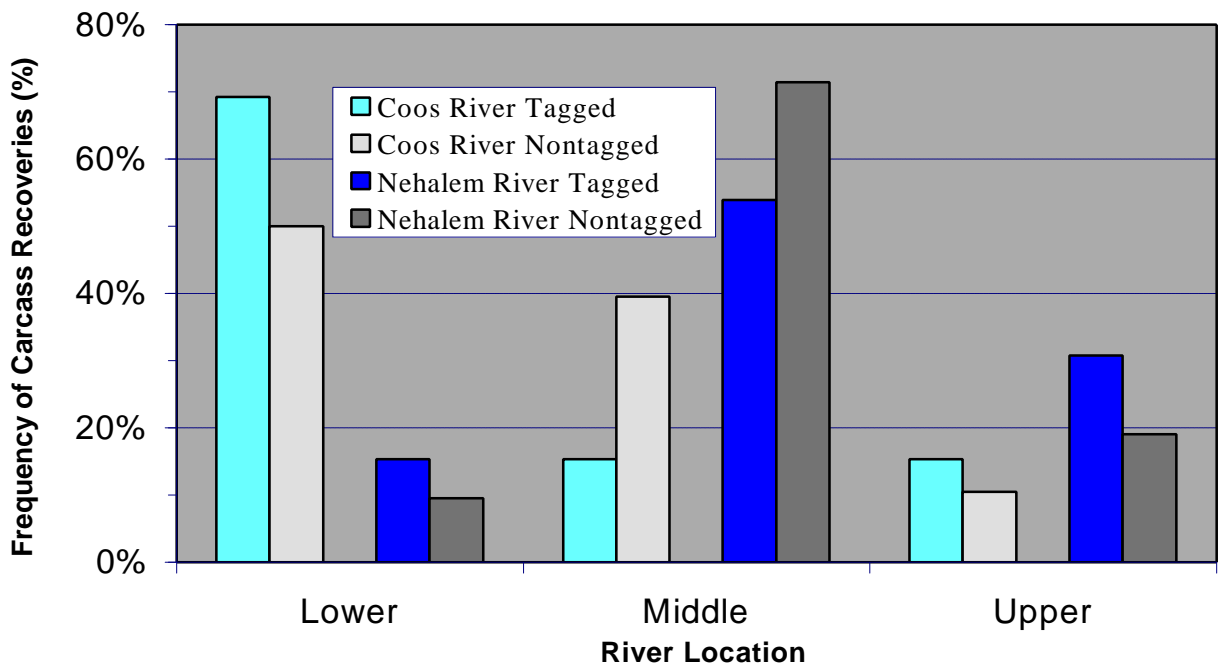

Figure 6. Spatial distribution of tagged and non-tagged carcasses recovered on the North Fork Nehalem and South Fork Coos Rivers.

there was no apparent mortality at the trap site, and all of the tagged fall chinook recovered as carcasses appeared to have spawned prior to death.

4. *The marked fish do not lose their mark and all marks are recognized and reported on recovery.*

Tag loss was assessed by a double tagging procedure and a calculation of the probability of losing one or both tags as described in Caughley (1977). Tag loss was calculated at 15% and 27% for North Fork Nehalem and South Fork Coos Rivers respectively. Adjustments were made to the population of tagged salmon thus reducing the number of carcasses available for sampling. Tag size, color and placement were specifically chosen to minimize the bias associated with the recoveries of marked carcasses. Small, neutrally-colored tags were placed in both sides of the fish at the base of the dorsal fin. Personnel were trained on the procedures for locating carcasses, identifying marks and recording the necessary data.

5. *The marked fish are as vulnerable to the fishing being carried on (method of recovery in the second capture event), as are the unmarked ones.*

From the information gathered, we are unable to detect any behavioral difference between marked and unmarked fish pertaining to recovery on the spawning grounds. The tags that were used were relatively small and neutrally colored and thus should not have influenced recoverability of the marked fish.

Precision

The primary objective of this study and the ultimate goal of the project depend on obtaining a precise escapement estimate of fall chinook above trap sites of each targeted river systems. The precision of the estimate, which we hoped to achieve, is one that was within 30% of the true value 95% of the time. This target was not attained at either calibration site. The major reason for not attaining the target level of precision was the low recovery rate of carcasses on spawning surveys. Factors that contributed to low recovery rates were unusually high stream flows and the scheduling of spawning surveys. Stream flow gauges located on the North Fork Nehalem and South Fork Coquille Rivers documented flows that were much higher and more prolonged than average (Figures 7 and 8). The Coquille River was selected as representative flows for south coast basins because it is the nearest drainage to the Coos River that is monitored with a flow gauge. Prolonged periods of rain and subsequent high flows created unfavorable and unfortunate surveying scenarios. These high flows during the peak of the spawning run widely distributed carcasses and accelerated their decomposition process. Many carcasses were shredded by the torrent and parts were scattered throughout the river, high in trees and lodged within woody debris. Flood conditions and related sediment load prevented surveyors from conducting their duties and hindered their ability to locate fish due to poor visibility.

In order to improve the precision of the population estimate, a larger proportion of the available carcasses must be recovered. More time must be spent searching those areas where carcasses are likely to be deposited and survey sites need to be visited more frequently before carcasses are scavenged or allowed to drift out of the survey area. The survey design should be changed to focus in and around areas where spawning occurs. This would result in a more efficient survey effort, as surveyors will spend less time searching non-productive locations allowing for frequent visits to areas of known spawning.

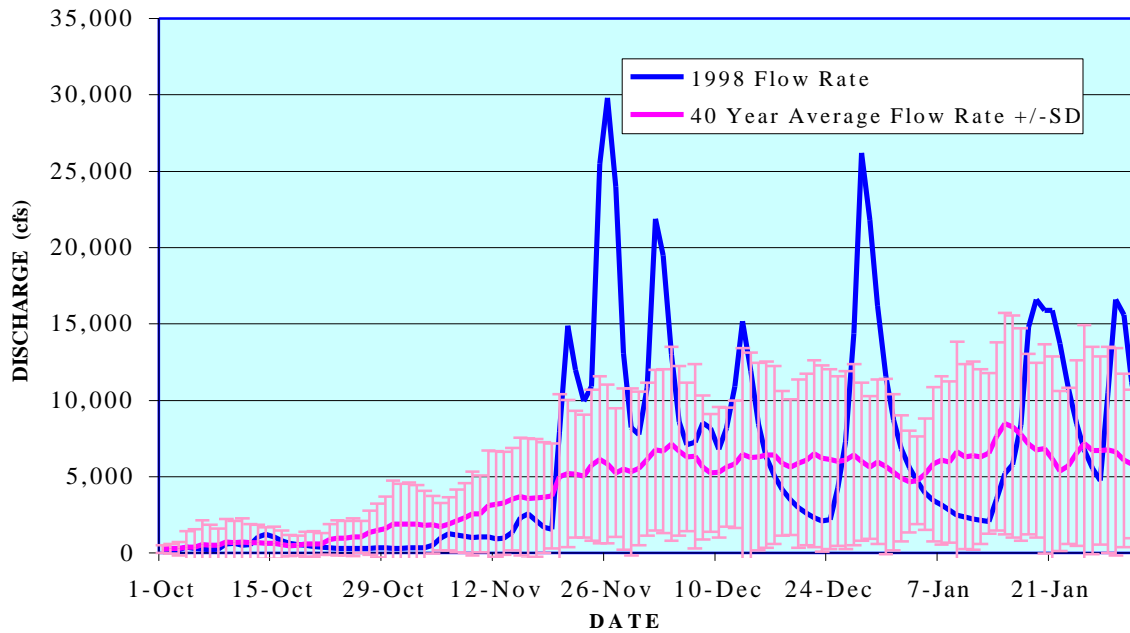Figure 7. Comparison of the 1998 discharge rates and the 40-year average discharge rates for the Nehalem River at Foss. Vertical bars represent one standard deviation of the 40-year average.
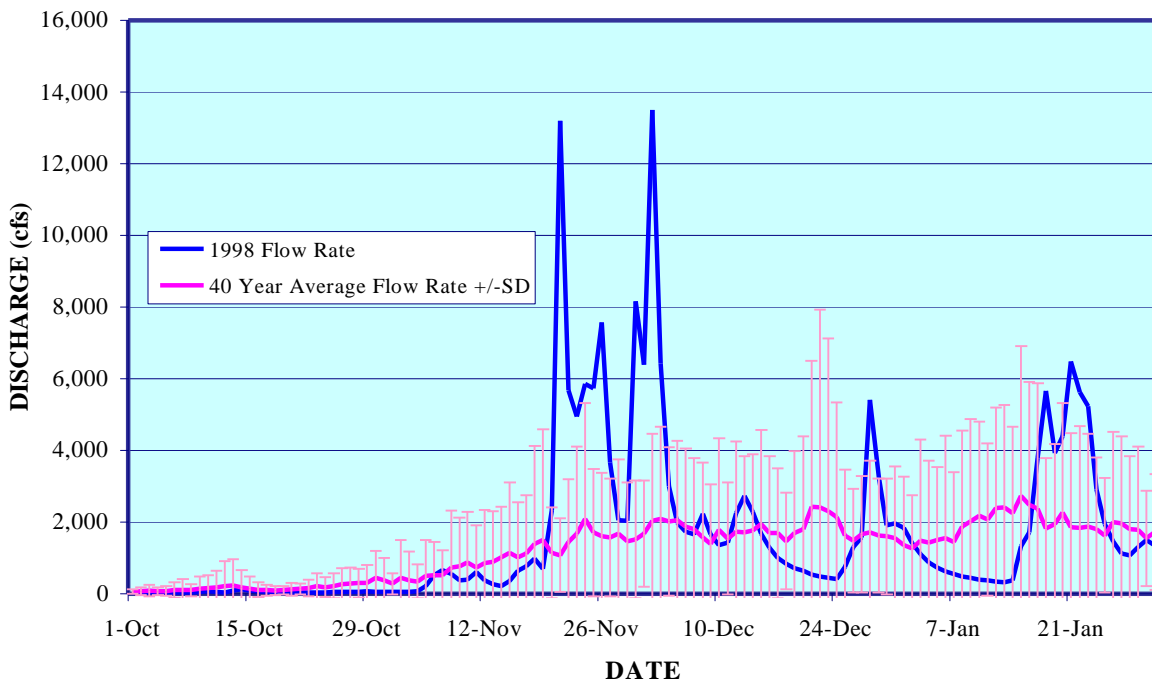

Figure 8. Comparison of the 1998 average daily discharge and the 40 year average discharge rate in the South Fork Coquille River at Powers. Vertical bars represent one standard deviation of the 40-year average.

We will begin a project to identify the extent of fall chinook spawning habitat beginning in the summer of 1999. This will be a modified version of the criteria and procedures developed by a previous ODFW study (Hodgson and Jacobs 1997) that was successful in documenting mainstem habitat where spawners are likely to be present. The North Fork Nehalem River was completed during this study, and these findings will be used to guide locations of surveys to recover carcasses. The South Fork Coos River will be inventoried during the summer of 1999. Completion of this inventory will allow us to modify the habitat database and selection process to where a substantial portion of the habitat can be surveyed at greater frequencies and adapted on a coast-wide basis. Fish can then be enumerated by unit area as opposed to stream length, which should be more representative of the basin.

Observation Efficiency

Observation efficiency is the term used to quantify the human error element inherent in all survey schemes. Solozzi (1984) reported that 76% of adult chinook and 64% of the jacks were observed during foot spawner surveys. Solozzi's study was conducted in small tributary reaches where stream channel widths were between 4.7 and 8.2 meters. This may not be valid in mainstem habitat. Solozzi also reported that 76% of the chinook carcasses were observed during surveys on the spawning grounds. We factored in the Solozzi value as part of the AUC estimates for the tributary habitat being assessed in this study. When adjusted in this manner, the sum of AUC estimates for the two strata correlated closely with the North Fork Nehalem mark-recapture estimate. It is difficult to assess the accuracy of the tributary escapement estimate in the South Fork Coos due to the inability to obtain a precise mark-recapture estimate. There is a need to repeat this survey methodology to gather more data points in order to correlate this observation efficiency under various flow and survey conditions.

Determining observation efficiency of live counts is much more difficult in mainstem habitat due to the extreme variability in flow and visibility. The Solozzi (1984) study does not apply to larger stream widths and in a separate study (Shardlow et al 1987) reports a 28% observation efficiency of chinook salmon when walking streams. This study was conducted in the Big Qualicum River on Vancouver Island, where stream flows averaged 72 to 422 ft^3/sec and a channel width of approximately 20 meters. The study also reports that species, habitat type, and observer experience affects the ability to identify and count fish. In some years it may be possible to use live counts as an abundance index in mainstems, but observation efficiency is likely to be highly variable on a year-to-year bases, so it is not really practical. The variables that affect the ability to observe live fish become more severe as stream width increases. Few marked carcasses were recovered; thus the observation efficiency of carcass recovery during this study year is highly questionable. Modifications to the methods of calibrated carcass counts must be explored. Increasing the frequency of surveys and narrowing the sampling universe to known fall chinook spawning habitat will greatly improve the ability to recover carcasses.

Accuracy of Survey-Based Population Estimates

Estimates based on live counts are generally thought not to be a good indicator of densities in mainstem reaches due to difficulties adhering to survey protocol. The Nehalem surveys may be an exception to this because of the limited habitat sampled that is representative of mainstem spawning. These surveys only encompassed the upper four miles of mainstem reaches, which were not subjected to prolonged high flows and turbidity problems that plague lower reaches of mainstem and large tributaries. Surveyors generally experienced

the same visibility and hazards in these reaches as in the tributary reaches. Visibility increased and flows dropped to surveying standards in North Fork Nehalem mainstem surveys within a day or two of tributary surveys. In this particular instance, it was feasible to treat mainstem North Fork Nehalem surveys in the same manner as tributary surveys and use estimates derived through AUC techniques for both mainstem and tributary habitat as an index of spawner density. The combined mainstem and tributary escapement estimate of 609 based on AUC methodology compares favorably with the mark-recapture estimate ranging from 415 to 1,230. The combination of a mainstem escapement derived through carcass counts and a tributary escapement derived through AUC methodology resulted in a total estimate of 663 fall chinook above the trap in the North Fork Nehalem River (Table 3). These initial results suggest that survey based sampling may provide reliable spawner escapement estimates at this calibration site. However, given the poor precision of the Petersen estimate, this conclusion is premature without sampling additional run years.

There are some questions as to the accuracy of the Coos River tributary estimates. All the survey methodologies severely underestimated the escapement of fall chinook in the South Fork Coos River as compared to the mark-recapture estimate, which ranged from 1,864 to 6,047. An escapement estimate of 602 fall chinook was calculated using AUC techniques in tributary habitat of the South Fork Coos River. A total escapement estimate of 1,331 fall chinook was calculated by combining the tributary estimate with a mainstem estimate of 706 fall chinook (Table 3), which was derived through calibrated carcass counts. We were unable to calculate an escapement estimate in the mainstem reaches based on AUC methodology due to weather and flow conditions that prevented surveys from being conducted according to protocol. A return to more typical weather conditions should also improve tributary estimates.

The survey design was not compatible with the unusual weather and flow conditions that washed carcasses out of the survey area between survey intervals. Retention studies on coho salmon conducted on spawning streams in Washington's Olympic Peninsula indicate that the majority of carcasses were generally retained within 600 meters of the point of release (Cederholm et al 1989). A study to assess the drift of chum salmon carcasses in the much larger Skagit River of Washington state revealed that, although carcasses may drift as far as 39 km, most of the carcasses were retained within the general spawning areas. Only 20% of the carcasses drifted more than 1.5 km during the first five days of monitoring (Glock et al 1980). This latter study is probably more representative of mainstem habitat in Oregon coastal streams in regards to channel widths, morphology and the susceptibility to rapid changes in flow levels. This data combined with observations reported from surveyors suggests that a higher proportion of carcasses should be available for recovery if survey intervals were three to five days as opposed to the current protocol of seven to ten day intervals. Narrowing the sampling universe by identifying the specific areas of spawning habitat in mainstem reaches would also allow for a more intensive survey design and more frequent visits.

Carcass retention is directly related to flow, and inversely related to the presence of organic debris and scavenging. Scavenging appeared to be a key contributing factor for the low numbers of recoveries. Most carcasses encountered had been consumed in some degree by scavengers, primarily raccoons, otters and eagles. Many were stripped of all flesh leaving only the head, tail and a pile of bones. This certainly contributed to tag loss and the inability to mark carcasses. Cederholm (1989) substantiates these observations with reports of total biomass of coho carcass consumption up to 80% in some streams.

To partially counteract the impact of scavenging on carcass recoveries surveys should be conducted more frequently, with optimum intervals of three days and not to exceed five days.

In addition to this, a secondary tag or a different tag type should be considered. Tags placed near the dorsal are extremely vulnerable to displacement during scavenging as the flesh is often separated from the skeleton. A cinch tag placed around the caudal peduncle has the advantage of being located in an area that is seldom consumed and cannot be pulled out, it may even become protected at times if the skin has been peeled down to the tail. A jaw tag or an operculum punch should also be considered as secondary tags that are less likely to be lost.

RECOMMENDATIONS

1. Narrow the sampling universe by identifying habitat most likely to support spawners.

2. Survey procedures should be changed to utilize a stratified sampling method, so that those areas conducive to spawning activity are sampled at a higher rate than areas of low spawning activity.

3. Surveys should be conducted more frequently, with optimum intervals of three days and not to exceed five days.

4. A secondary mutilation tag should be used to assess tag loss.

5. A less invasive tag should be tested, such as a cinch tag placed around the caudal peduncle.

ACKNOWLEDGMENTS

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Results of spawning surveys conducted in the North Fork Nehalem River, 1998.

	REACH	SEG-MENT	NUMBER SURVEYS	MILES	VISITS	PEAK COUNTS (LIVE AND DEAD) ADULTS PEAK	PER MILE	DATE	JACKS PEAK	PER MILE	DATE	ESTIMATED RUN SIZE (AUC) ADULTS AUC	PER MILE	JACKS AUC	PER MILE
NORTH COAST			**15**	**13.3**	**115**	**15**				**0**			**22**		**0**
NEHALEM RIVER			**15**	**13.3**	**115**	**15**				**0**			**22**		**0**
NORTH FORK			**15**	**13.3**	**115**	**15**				**0**			**22**		**0**
SALLY CR	25871.30	1		0.4	7	0	0		0	0		0	0	0	0
NEHALEM R, N FK	25871.70	1		1.0	4	4	4	12/15/98	0	0		0	0		
GODS VALLEY CR	25872.00	1		1.0	8	14	14	11/18/98	0	0		18	18	0	0
GODS VALLEY CR	25872.00	6		0.5	11	0	0		0	0		0	0	0	0
NEHALEM R, N FK	25873.00	1		1.0	8	30	31	11/19/98	0	0		40	41	0	0
LOST CR	25874.00	1		1.0	8	0	0		0	0		0	0	0	0
NEHALEM R, N FK	25875.00	1		0.6	7	15	24	11/19/98	0	0		11	17	0	0
NEHALEM R, N FK	25875.00	2		0.6	7	42	70	11/10/98	1	2	11/4/98	69	115	1	2
SWEET HOME CR	25876.00	1		1.0	4	1	1	11/18/98	0	0		0	0		
NEHALEM R, N FK	25877.00	1		1.2	8	25	21	11/17/98	1	1	11/8/98	55	46	1	1
FALL CR	25878.00	1		0.9	13	44	51	11/15/98	1	1	11/9/98	42	48	1	1
NEHALEM R, N FK	25879.00	1		1.3	8	10	8	11/5/98	0	0		21	17	0	0
NEHALEM R, N FK	25879.00	2		0.6	5	8	14	11/11/98	0	0		14	24	0	0
NEHALEM R, LITTLE N	25880.00	2		1.0	8	0	0		0	0		0	0	0	0
NEHALEM R, N FK	25881.00	1		1.2	9	0	0		0	0		0	0	0	0

Appendix B. Results of spawning surveys conducted in the South Fork Coos River, 1998.

| | | | | | PEAK COUNTS (LIVE AND DEAD) | | | | | | | ESTIMATED RUN SIZE (AUC) | | | |
| | | | | | ADULTS | | | JACKS | | | ADULTS | | JACKS | |
	REACH	SEG-MENT	NUMBER SURVEYS	MILES	VISITS	PEAK	PER MILE	DATE	PEAK	PER MILE	DATE	AUC	PER MILE	AUC	PER MILE
COOS-COQUILLE			**17**	**26.7**	**103**		**7**			**0**			**14**		**1**
COOS RIVER			**17**	**26.7**	**103**		**7**			**0**			**14**		**1**
SOUTH FORK			**17**	**26.7**	**103**		**7**			**0**			**14**		**1**
COOS R, S FK	22169.00	1		3.5	4	4	1	11/5/98	0	0		0	0		
COOS R, S FK	22175.00	1		4.3	2	24	6	11/13/98	0	0		0	0		
MINK CR	22182.00	2		1.1	4	2	2	12/9/98	0	0		0	0		
COOS R, S FK	22183.00	1		2.5	4	6	2	11/10/98	0	0		0	0		
TIOGA CR	22184.00	1		0.5	8	7	14	12/11/98	0	0		8	16	0	0
TIOGA CR	22186.00	1		1.1	9	18	16	11/17/98	2	2	11/17/98	28	25	2	2
TIOGA CR	22188.00	1		1.4	9	24	17	11/12/98	2	1	12/11/98	38	27	2	1
TIOGA CR	22188.00	2		1.0	7	18	19	11/17/98	1	1	11/12/98	30	31	1	1
TIOGA CR	22190.00	1		0.7	9	17	24	11/12/98	2	3	12/7/98	34	47	2	3
TIOGA CR	22192.00	1		1.0	9	7	7	11/18/98	1	1	12/7/98	5	5	0	0
TIOGA CR	22194.00	1		0.9	9	17	18	11/19/98	0	0		30	32	0	0
TIOGA CR	22194.00	1		0.9	9	17	18	11/19/98	0	0		30	32	0	0
TIOGA CR	22196.00	1		1.1	3	12	11	12/12/98	2	2	12/12/98	0	0		
WILLIAMS R	22201.00	1		2.6	4	3	1	11/28/98	0	0		0	0		
WILLIAMS R	22201.50	1		1.5	4	0	0		0	0		0	0		
WILLIAMS R	22215.00	1		1.0	5	13	13	11/19/98	0	0		25	25	0	0
WILLIAMS R	22215.70	1		1.5	4	7	5	12/10/98	0	0		0	0		