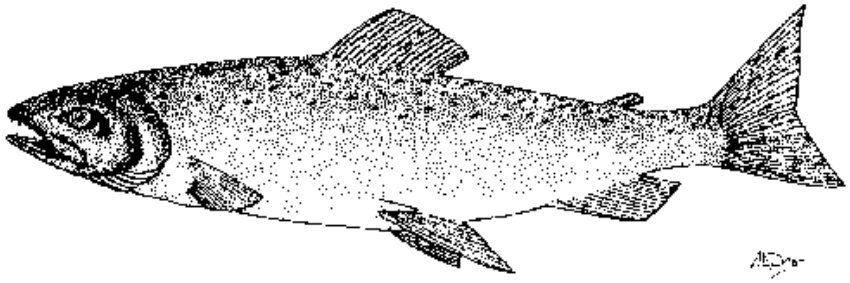
# Skagit River Chum Escapement Strategy

Project # SF-2006-I-14

# Final Report

July 2007



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## Introduction

The Skagit River is home to the largest chum salmon run in Puget Sound. Skagit River wild chum are estimated to make up an average of 17%, and in some years more than 30%, of the Puget Sound total. The escapement estimates, however, are highly suspect. Escapements are estimated by comparing live counts in just 4 index areas to the counts recorded in those sections in 1976 and 1977, when mark-recapture studies were conducted (Hendrick 2003). However, these estimates are highly imprecise, because chum distributions in the index sections were very different between these two years, and because changes in river morphology, habitat restoration actions, and improvements in managed flow regimes, which started in 1984, have significantly changed the distribution of chum spawning on the Skagit River, (Connor and Pflug 2004) thereby violating the basic assumption that the indexes still represent the same proportion of system escapement as in the base years.

In response to these problems, the Skagit River System Cooperative (SRSC), and the Washington Department of Fish and Wildlife (WDFW) proposed a multi-year study to improve the methods used in estimating the escapement of Skagit chum. Funding for the first year of the study was approved by the Pacific Salmon Commission Southern Fund, as well as the Non-Flow Coordinating Committee (a group representing the interveners in the Seattle City Light Flow Agreement). Since Skagit chum abundance follows a four-year cycle, 2006 (a "high-high" year) and 2007 (a "low-low" year) present an opportunity to conduct the study at both endpoints of the abundance cycle. This report details the results of the study in 2006, its first year.

The specific objectives of this study were to:

1. Tag and sample sufficient Skagit chum to estimate total system spawning escapement to within a C.V. $\leq$ 10%.

2. Establish new chum index sections in the mainstem Skagit from Newhalem to Shovel Spur and from Alma Creek to Marblemount, in three sections of the mainstem Sauk, in the lower Cascade, and in selected Lower Skagit tributaries.

3. Use 2006 and 2007 as base years, and the new index sections, to calculate Skagit chum escapements in future years, and recalculate Skagit chum escapements back to 1984 (which is when the current flow regime went into effect).

In order to achieve these objectives, we planned to estimate chum spawning escapement in the Skagit System by capturing, tagging, and releasing live chum salmon in the lower part of the Skagit River, and recovering them on the spawning grounds and in in-river fisheries. Simultaneously, spawning survey crews would conduct the normal live and

dead counts in existing index areas, as well as in potential future index areas. These data would then be used to estimate chum spawning escapement in the study years, and to recalibrate the index areas for past and future escapement estimates.

Field work for the study proceeded according to plan until a flood in early November 2006. The flood peaked on November 7, with a peak flow at Concrete of 143,000 CFS. This flood disrupted nearly every component of the study. Our tagging site was inaccessible until flood waters had receded and we were able to clear deposited sediment and debris from the access road. For the rest of the season, visibility in the river was essentially zero, which prevented us from counting chum on the spawning grounds.

In 2006, we expected to need to tag 1,000 chum and sample 10,000 on the spawning grounds and in commercial fisheries in order to estimate the total escapement within a CV of $\leq$ 10%. These numerical goals were exceeded, as we tagged 1,393 chum and checked nearly 43,000 for tags. Ultimately, however, the effects of the flood prevented us from accurately estimating the escapement. Tagging was suspended for more than two weeks during and immediately after the flood, which occurred at the peak of the chum spawning migration. After the flood, continuing turbidity prevented effective surveys and counts of chum in potential index areas for the remainder of the spawning season. Finally, the flood appears to have caused the loss of an unknown number of tagged fish from the population. Tagged chum were found as far away as Everett, and many appear to have been captured in fisheries near the mouth of the Skagit, 25 miles downstream from the tagging site. Relatively few tags were recovered on the spawning grounds, especially from those chum tagged before the flood, also suggesting that the flood removed tagged chum from the population.

Together, these problems led to the violation of several requirements of the study. First, not all chum were equally susceptible to being tagged, as many undoubtedly migrated past the tagging site during the hiatus from tagging operations. The loss of an unknown number of tagged chum from the population violates the assumption of a closed population, biasing the resulting estimate high. Together, these two factors prevented making a statistically sound escapement estimate. While we did generate a population estimate of about 2.4 million chum, this estimate is obviously unrealistically high. Even if a valid escapement estimate had been possible, the lack of survey counts would have prevented us from establishing new index sections. For these reasons, we were not able to achieve our study objectives in 2006.

Another component of the study appears to have been more successful. In conjunction with the mark-recapture study, Seattle City Light funded the purchase of 100 internal acoustic tags to be placed in chum captured during tagging operations. These uniquely-coded tags can be detected by receivers placed throughout the Skagit River and Puget Sound, as well as other river basins. Ninety-two chum were acoustically tagged; 50 before the flood and 42 after the flood. Of these, 78 were later detected by receivers. Data from the acoustic tagging studies is being compiled and will hopefully aid in determining the effects that the 2006 flood had on chum in the Skagit River.

## Methods

### Capture and tagging

Tagging operations took place on a gravel bar at river mile 25.8, about two miles upstream from the town of Sedro-Woolley (Figure 1). Chum were captured using a 3.875" mesh beach seine that was 260 feet long and seventeen feet deep, tapered along 60 feet of one end to six feet deep. To set the seine, the shallow end was fastened to a pickup truck stationed at the waterline, and a jet boat was used to deploy the net across the river and downstream to form a "hook." The truck and the boat then towed each end of the net slowly downstream and down the gravel bar. The boat then returned to the shore, where the net was attached to another truck, and both ends were towed up the beach until most of the seine had been pulled out of the water. As the net was hauled up the beach, the crew would adjust the cork and lead lines, and then pull the bunt in by hand. At that point, any chum salmon caught were placed in floating PVC-frame net pens. Other species, such as coho, were counted and released. After each set, the seine was restacked in the boat for the next set.

After being held in the floating net pen, each chum was then removed from the water and placed in a foam-lined V-shaped trough. While one crew member immobilized the fish, another applied a jaw tag and punched a hole in its operculum as a secondary mark. The jaw tags were metal hog-rings fitted with a sequentially numbered, bright yellow plastic sheath. The sex and length of each fish was recorded, as well as a condition code of '+' or '-'. Healthy fish were assigned a '+', while fish with predator scars, fungus, or other impairments were assigned a '-'. Any fish that appeared unlikely to survive was released without tagging. After being tagged, each fish was held in the water for a few seconds to regain equilibrium and released once it could swim away vigorously.

As part of another project investigating the migration timing and patterns of Skagit chum, some chum were implanted with acoustic tags. These acoustic tags emitted uniquely-coded "pings" designed to be received by a network of hydrophones throughout the Skagit basin. Chum that were implanted with an acoustic tag were tagged with a red jaw tag and two holes were punched in their opercula to differentiate them from conventionally tagged chum. The acoustic tag was implanted orally into the gut, after which the fish were placed in vinyl holding bags for up to several hours to recuperate. After this holding period, the bag was checked for a regurgitated tag, and the fish was released.

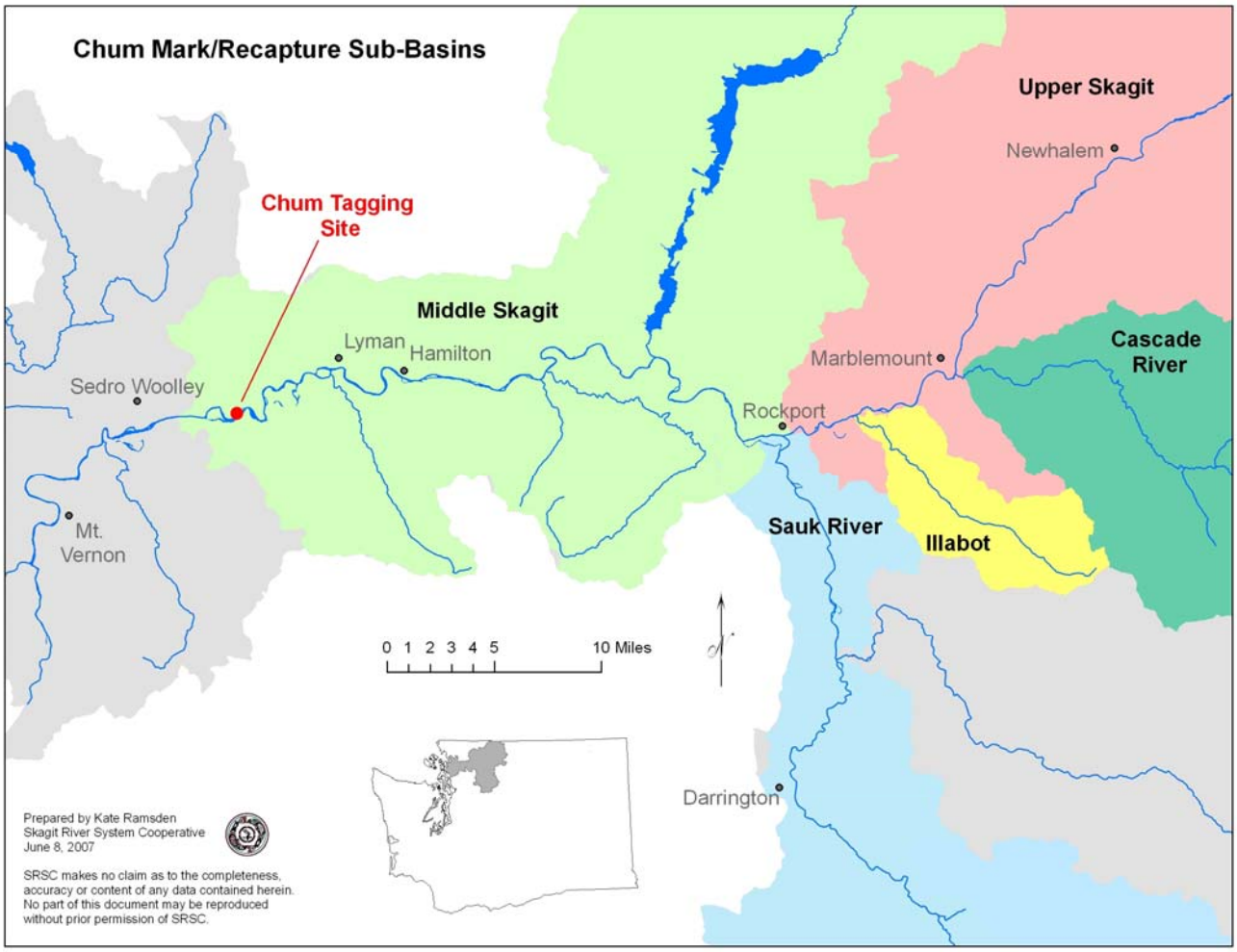


Figure 1. Location map of Skagit River sub-basins.

### Spawning grounds sampling

Tag recovery surveys were conducted in chum spawning grounds throughout the Skagit basin. During these surveys, chum carcasses were checked for the presence of jaw tags and punched opercula. The number of carcasses checked in each location and date was tallied, as well as the tag numbers of any tags found. If the tag numbers were not legible, the tag color and any legible digits were recorded. After being sampled, the tail was cut off of each carcass to prevent it from being resampled on subsequent surveys.

Counts of live and dead chum in potential index areas had been planned as part of this study. However, due to poor visibility, these surveys could not be performed as planned.

**Commercial catch sampling**

During the study, tribal commercial fisheries targeting salmon were conducted in the Skagit River both upstream and downstream of the tagging site. Two tribes, the Upper Skagit and Swinomish, were responsible for most of the fishing effort, while effort from a third tribe, the Sauk-Suiattle, was limited to a single fisher.

The Skagit River is divided into statistical catch areas for purposes of managing these fisheries (Figure 2.) The fishing grounds of the Upper Skagit Tribe include the Skagit River upstream of the confluence of the North and South Fork distributaries near Mount Vernon. This includes areas 78D-4, 78D-3, 78D-2 and a portion of 78C. The Swinomish Tribe fishes Skagit Bay (Area 8) and the Skagit River upstream to Mount Vernon (Area 78C). The tagging site is located near the boundary of Areas 78D-2 and 78D-3.

Since the tagging site was located within the fishing grounds of the Upper Skagit tribe, several Upper Skagit fishers were asked to inspect any chum salmon they caught for jaw tags and opercular punches. Fishers are required to report their catch to tribal and state fishery managers using "fish tickets." The fishers checking their catch for tags and marks recorded sampling data on these tickets, including the number of fish checked, and number of recovered jaw tags. Recovered tags were then given to tribal fisheries staff so that the tag number could be confirmed.

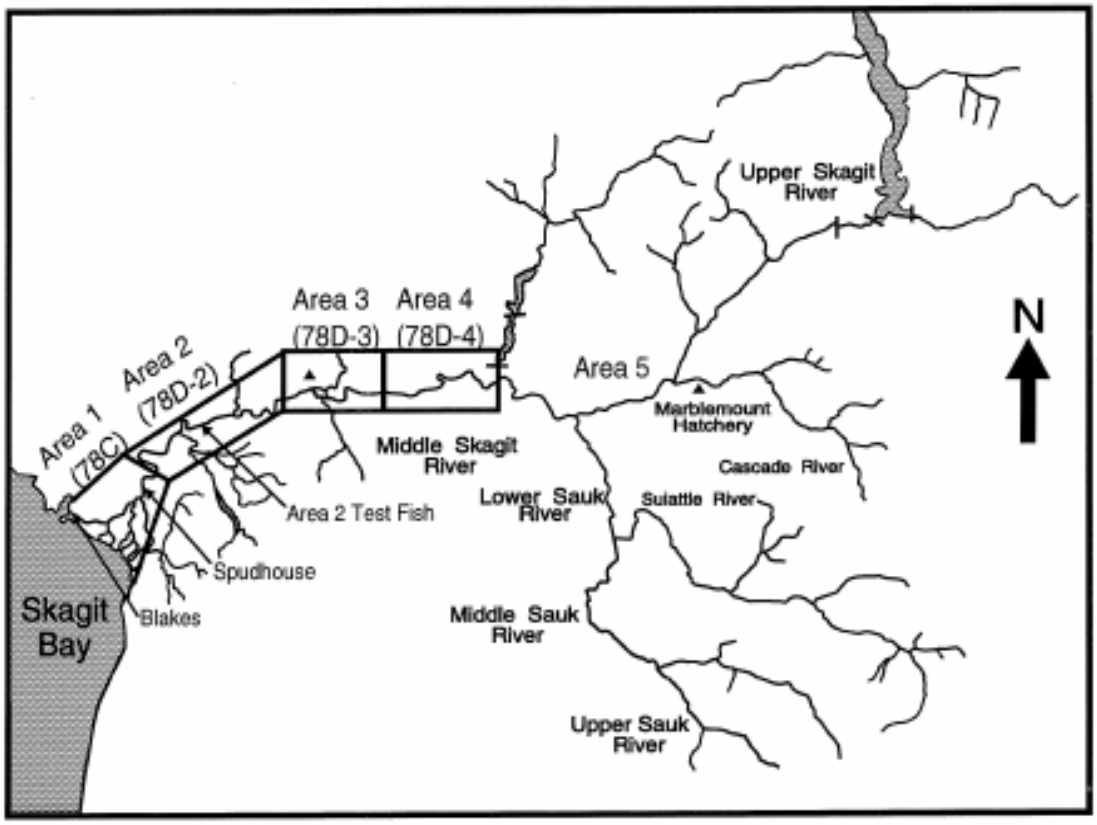


Figure 2. Commercial fishery areas of the Skagit River as designated by WDFW.

A number of tags were recovered in other fisheries and reported to SRSC or WDFW biologists. However, these volunteer tag recoveries were not part of any systematic sampling and were considered "out of sample." Chum caught in commercial fisheries conducted by the Swinomish tribe or non-treaty fisheries were not systematically sampled, as these fisheries take place downstream of the tagging site.

Chum caught in weekly test fisheries conducted by the Upper Skagit Tribe and SRSC were also checked for tags. These fisheries take place at Blakes and Spudhouse drifts in catch area 78C, and at the Highway 9 bridge in area 78D-2. The catch from the Jetty and Skagit Bay test fisheries was also checked. All of these fisheries occur downstream of the tagging site. The Upper Skagit tribe also collects chum broodstock from the Skagit River in areas 78D-3 and 78D-4 (upstream of the tagging site), for use in their hatchery. These fish were checked for tags and marks as well.

## Results and Analysis

The tagging release-recovery data for Skagit River chum salmon were examined to see if a statistically appropriate estimate of escapement could be produced using the data.

There were several challenges presented by the data. Despite a relatively large number of tags released (1,393 fish tagged) and a huge recovery effort (42,869 fish examined for tags during tag recovery surveys of the commercial catch and on the spawning grounds), there were only 21 tag recoveries (a 1.51% tag recovery rate): 12 tags during spawning ground surveys and 9 tags during commercial catch sampling. An additional 18 tag recoveries were reported, but not used in analyses as they were not part of a systematic sampling effort (Table 1).

| Recovery type | Tag date | Recovery date | Recovery location (Catch Area) | Upstream / downstream |
|---|---|---|---|---|
| **Commercial** | 10/17/06 | 10/27/06 | Blakes (78C) | Down |
| | 10/19/06 | 10/30/06 | Blakes (78C) | Down |
| | 10/24/06 | 10/27/06 | Blakes (78C) | Down |
| | 10/24/06 | 11/5/06 | Jetty (8) | Down |
| | 10/27/06 | 11/11/06 | 78C | Down |
| | 10/30/06 | 11/9/06 | Jetty (8) | Down |
| | 10/30/06 | 11/13/06 | Tulalip Bay (8D) | Down |
| | 10/30/06 | 11/11/06 | 78C | Down |
| | 11/2/06 | 11/15/06 | Tulalip Bay (8D) | Down |
| | 11/2/06 | 11/11/06 | 78C | Down |
| | 11/2/06 | 11/16/06 | 78C | Down |
| | 11/2/06 | 11/14/06 | Everett (8A) | Down |
| | 11/2/06 | 11/14/06 | 78D-2 | Down |
| | 11/20/06 | 12/2/06 | 78D-2 | Down |
| **Sport** | 10/27/06 | 10/29/06 | Gilligan Cr. | Up |
| | 10/27/06 | 10/28/06 | Sedro-Woolley | Down |
| | 10/30/06 | 11/1/06 | Jackman Cr. | Up |

Table 1. Out-of-sample recoveries of tagged chum in commercial and sport fisheries in 2006.

Another challenge was presented by a prolonged interruption in the tag releases due to river conditions. During the period 3 October through 2 November tagging was conducted on 12 separate days with an average of 97 fish tagged each day. There was no tagging conducted between 3 November and 19 November (inclusive) because of river conditions. A total of 5 days of tagging then occurred between 20 November and 5 December with an average of only 46 fish tagged each day. Based on daily catches for tagging, the period of peak chum salmon abundance was beginning when tagging was interrupted (Figure 3).

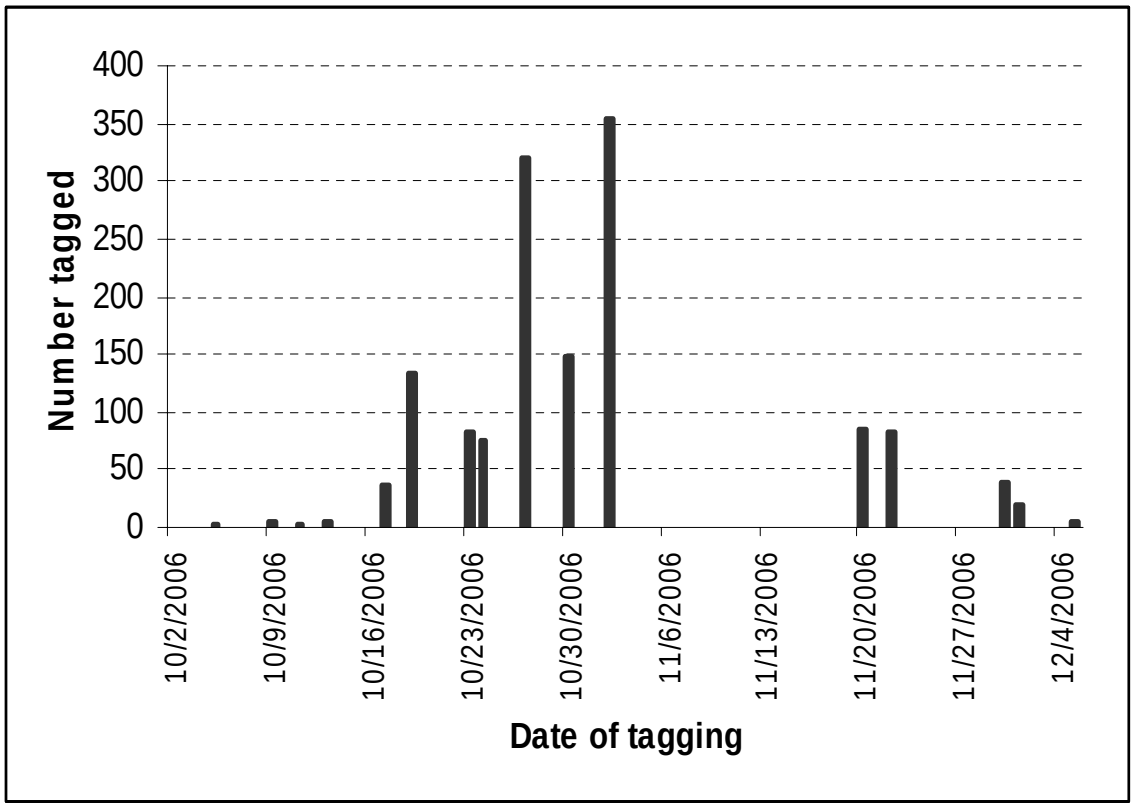


**Figure 3.**

Of all the assumptions needed for a Petersen-type estimator to be appropriate for the tagging data, the ones we are concerned with most for these data are:

(1) All animals in the population have an equal probability of capture during the first (tagging) sample, and
(2) The second (recovery) sample is a simple random sample of the population.

If a stratified (Darroch) type estimator is used, these two assumptions then become:

(1) All animals in the $i^{th}$ release stratum have an equal probability of capture during the first (tagging) sample, and
(2) All animals in the $j^{th}$ recovery stratum, whether tagged or not, have an equal probability of being sampled by the recover process.

**TAG RELEASE DATA**

**Table 2.**

| Tagging Date | Number Tagged and Not Recovered | Number Tagged and Recovered | Total Tagged | Percent Recovered |
|---|---|---|---|---|
| 10/5/2006 | 2 | 0 | 2 | 0.0% |
| 10/9/2006 | 5 | 0 | 5 | 0.0% |
| 10/11/2006 | 2 | 0 | 2 | 0.0% |
| 10/13/2006 | 5 | 0 | 5 | 0.0% |
| 10/17/2006 | 36 | 0 | 36 | 0.0% |
| 10/19/2006 | 130 | 4 | 134 | 3.0% |
| 10/23/2006 | 83 | 0 | 83 | 0.0% |
| 10/24/2006 | 74 | 0 | 74 | 0.0% |
| 10/27/2006 | 318 | 1 | 319 | 0.3% |
| 10/30/2006 | 148 | 1 | 149 | 0.7% |
| 11/2/2006 | 353 | 0 | 353 | 0.0% |
| 11/20/2006 | 80 | 6 | 86 | 7.0% |
| 11/22/2006 | 79 | 3 | 82 | 3.7% |
| 11/30/2006 | 38 | 1 | 39 | 2.6% |
| 12/1/2006 | 19 | 1 | 20 | 5.0% |
| 12/5/2006 | 4 | 0 | 4 | 0.0% |
| **Total** | 1,376 | 17 | 1,393 | 1.2% |

Does not include four tag recoveries with no tag number legible | recorded.

Table 2 shows that chum tagged during the first period (5 October through 2 November) had a recovery rate of only 0.516% while those tagged form 20 November though 5 December had a recovery rate of 4.762%. These two recovery rates are significantly different ($P < 0.001$ for Fisher's exact test). In summary, chum salmon tagged after the high water period had a much higher probability of being recovered during tag recovery surveys than those tagged before the period of high water.

## TAG RECOVERY DATA

There were two types of tag recovery surveys conducted (a recovery survey randomly samples the population in search of tags, i.e., both tagged and untagged animals have an equal probability of being examined): carcass surveys of spawning grounds and commercial catch sample surveys. Table 3 summarizes the results of the carcass surveys for the five major sub-basin surveyed (Nookachamps sub-basin omitted). The percentage of tagged fish in the sub-basin recovery samples ranged from 0.000% to 0.05%. The percentages of tagged fish in the sub-basin recovery samples were not significantly different ($P$ = 1.00 for Fisher's exact test) indicating that the sub-basin samples could be pooled.

**Table 3.**

| Sub-basin | Start Date | End Date | Number Examined | Number Tags Recovered | Percentage Tagged |
|---|---|---|---|---|---|
| Middle Skagit | 10/25/06 | 12/28/06 | 3,130 | 1 | 0.032% |
| Sauk River | 10/30/06 | 12/18/06 | 1,547 | 0 | 0.000% |
| Illabot | 11/2/06 | 12/22/06 | 8,503 | 4 | 0.047% |
| Cascade | 11/20/06 | 12/4/06 | 158 | 0 | 0.0% |
| Upper Skagit | 11/1/06 | 1/3/06 | 14,029 | 7 | 0.050% |
| **Total** | | | 27,367 | 12 | 0.044% |

Table 4 summarizes tag survey data for commercial fishery samples, brood stock samples, and test fishery samples (CF/BS/TF). Several $\chi^2$ tests were conducted to determine if there were differences among the percentage of tagged fish in the commercial fishery samples. The first test compared percentages for the four commercial catch strata defined in the Table 4. The percentages of tagged fish in the commercial catch strata samples were not significantly different ($P$ = 0.254 for Fisher's exact test) indicating that the samples could be pooled. Before pooling, the percentage of tagged fish in the upstream stratum was compared to the percentage in the pooled downstream strata (for the commercial catch data only). The percentages of tagged fish in the upstream vs downstream stratum were not significantly different ($P$ = 0.672 for Fisher's exact test) indicating that the samples could be pooled. Finally, the percentages of tagged fish in all upstream samples combined were compared to the percentage in all downstream samples combined (second and third to last lines in Table 4). The percentages of tagged fish in these two pooled samples were not significantly different ($P$ = 0.503 for Fisher's exact test) indicating that the upstream|downstream samples could be pooled.

**Table 4.**

| Type/Area | Upstream or Downstream | Start Date | End Date | Number Examined | Number Tags Recovered | Percentage Tagged |
|---|---|---|---|---|---|---|
| **Commercial Catch** | | | | | | |
| Area 8 | Down | 10/31/06 | | 190 | 1 | 0.526% |
| 78C | Down | 10/31/06 | 11/27/06 | 1,827 | 1 | 0.055% |
| 78D-2 | Down | 11/22/06 | 12/6/06 | 134 | 0 | 0.0% |
| 78D-3 | Up | 10/3/06 | 12/28/06 | 9,648 | 7 | 0.073% |
| **Total** | | | | 11,799 | 9 | 0.076% |
| **Broodstock** | | | | | | |
| 78D-3 | Up | 12/12/06 | 12/21/06 | 207 | 0 | 0.0% |
| 78D-4 | Up | 12/13/06 | 12/15/06 | 40 | 0 | 0.0% |
| **Total** | | | | 247 | 0 | 0.0% |
| **Test Fishery** | | | | | | |
| Skagit Bay (8) | Down | 10/30/06 | 11/5/06 | 1,045 | 0 | 0.0% |
| Jetty (8) | Down | 11/2/06 | | 193 | 0 | 0.0% |
| Blakes (78C) | Down | 10/5/06 | 11/1/06 | 1,343 | 0 | 0.0% |
| Spudhouse (78C) | Down | 10/7/06 | 11/3/06 | 564 | 0 | 0.0% |
| Area 2 (78D-2) | Down | 10/4/06 | 10/30/06 | 311 | 0 | 0.0% |
| **Total** | | | | 3,456 | 0 | 0.0% |
| **Total Upstream** | | | | 9,895 | 7 | 0.071% |
| **Total Downstream** | | | | 5,607 | 2 | 0.036% |
| **Grand Total** | | | | 15,502 | 9 | 0.058% |

Finally, the percentage of tags present in the combined spawning ground survey samples was compared to the percentage of tags present in the combined commercial catch, brood stock, and test fishery samples (Table 5). The percentages of tagged fish in these two samples was not significantly different ($P = 0.506$ for Fisher's exact test) indicating that the samples could be pooled (see Table 5).

**Table 5.**

| Recovery Survey | Start Date | End Date | Number Examined | Number Tags Recovered | Percentage Tagged |
|---|---|---|---|---|---|
| CF/BS/TF | 10/3/06 | 12/28/06 | 15,502 | 9 | 0.058% |
| Spawning Ground | 10/25/06 | 1/3/06 | 27,367 | 12 | 0.044% |
| **Total** | | | 42,869 | 21 | 0.049% |

Next the recovery data were examined for temporal differences in the percentage of tags present in the recovery samples. Figure 4 below shows, by date, the number of fish examined for tags during spawning ground surveys, the number examined in CF/BS/TF samples, and the percentage of tags present in the combined samples. The percentages of tags in these four strata were not significantly different ($P = 0.310$ for Fisher's exact test) indicating that the samples could be pooled (see Table 6).

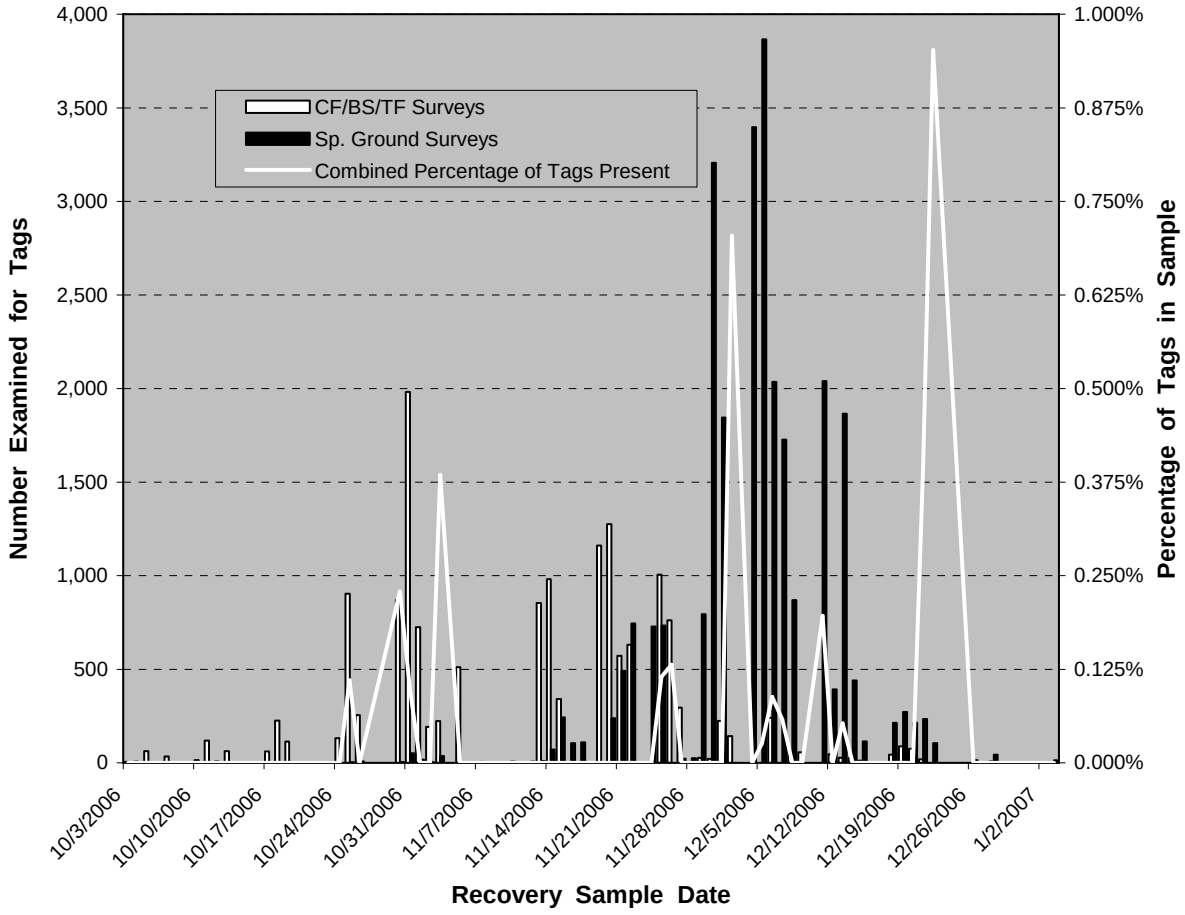


**Figure 4.**

**Table 6.**

| Recovery Survey | Recovery Dates | Number Examined | Number Tags Recovered | Percentage Tagged |
|---|---|---|---|---|
| CF/BS/TF | Oct 3 – Nov 19 | 9,840 | 5 | 0.051% |
| Spawning Ground | Oct 3 – Nov 19 | 677 | 1 | 0.148% |
| CF/BS/TF | Nov 20 – Jan 3 | 5,662 | 4 | 0.071% |
| Spawning Ground | Nov 20 – Jan 3 | 26,690 | 11 | 0.041% |
| **Total** | | 42,869 | 21 | 0.049% |

In summary, there is no indication that the percent of tags present in tag recovery samples was different:

- between spawning ground surveys conducted in different sub-basins,
- between commercial catch samples from different areas of the Skagit River,
- between upstream and downstream CF/BS/TF samples,
- between spawning ground survey samples and CF/BS/TF samples, and
- between spawning ground survey samples and CF/BS/TF samples separated into two separate time periods.

Therefore, the tag recovery data were pooled and could be treated as a single sample.

Table 7 summarizes the tag release-and-recovery data by the two tag release periods defined and the four recovery strata defined in Table 6. There were two tag recoveries with unknown tag numbers in the spawning ground samples (hence unknown release dates[1]) which could not be included in the table.

**Table 7.**

| Tag Release Period | Number Tagged | Recovery Strata | | | | Total |
|---|---|---|---|---|---|---|
| | | CF/BS/TF 1 | SG 1 | CF/BS/TF 2 | SG 2 | |
| Oct 5 – Nov 2 | 1,162 | 6 | 1 | 0 | 1 | 8 |
| Nov 20 – Dec 5 | 231 | 0 | 0 | 3 | 8 | 11 |
| **Total** | **1,393** | **6** | **1** | **3** | **9** | **19** |
| **Number Examined for Tags** | | **9,840** | **677** | **5,662** | **26,690** | **42,869** |

[1] There were two tags recovered during spawning ground surveys where the first three numbers on the tag were legible but the last number was not. Although the complete tag number was unknown, based on the first three numbers on the tag a release period could be assigned.

**POPULATION ESTIMATE:**

The data in Table 7 were collapsed into two release period strata and two recovery period strata for final analysis (see below). This matrix of data was then submitted to the SPAS (Stratified Population Analysis System) (Arnason et. al. 1996) program for analysis. This program analyses data from two-sample, mark-recapture experiments in stratified populations and produces estimates of population abundance. A number of different estimators are available in the program: (1) the maximum likelihood method of Darroch; (2) Darroch's moment estimator; (3) Schaefer estimate, (4) a least squares estimate; and (5) a pooled Petersen estimate.

| Tag Release Period | Number Tagged | Recovery Strata | | Total |
|---|---|---|---|---|
| | | Oct 3 – Nov 19 | Nov 20 - Jan 3 | |
| Oct 5 – Nov 2 | 1,162 | 7 | 1 | 8 |
| Nov 20 – Dec 5 | 231 | 0 | 11 | 11 |
| **Total** | **1,393** | **7** | **12** | **19** |
| **Number Examined for Tags** | | **10,517** | **32,352** | **42,869** |

A stratified estimator is appropriate for these data because of the significantly different probability of recovery for tags released during the two time periods (before high water and after high water). Because the data were presented as a square matrix (2 release strata x 2 recovery strata), the first three estimators produce identical abundance estimates. The estimates are:

Release Stratum 1: 1,745,822 fish
Release Stratum 2: 647,841 fish
Total: 2,393,663 fish with a 95% confidence interval: 1,072,680 to 3,714,646.

For comparison, if a simple Petersen estimate was applied to the data the abundance would be estimated as: 2,716,398 fish with a 95% confidence interval from: 1,732,376 to 4,353,334.

The Schaefer and pooled Petersen estimators are not appropriate for these data and result in even larger estimates of abundance.

**Tag loss from system:** Some chum salmon tagged in the Skagit River were recovered outside the Skagit system, or downstream of the tagging site in 2006. This represents the loss of tags from the system. In any Petersen-type estimate, this would result in an over-estimate of the population abundance since there are actually fewer tags in the population available to recover than the number of tags released.

Data from the acoustic tagging experiment was used to estimate how many tagged chum were lost from the population during the mark-recapture study. A number of acoustically-tagged chum were never detected by receivers in the Skagit after being released; these were considered "lost." For each management week, the percentage of acoustically-tagged chum that were lost was multiplied by the number of conventionally-tagged (i.e. jaw tag only) chum to estimate the number of "effective tags," or tagged chum that were not lost from the system (table 8). The highest rate of "lost" tags was in the week before the flood, when only one of ten acoustically-tagged chum was later detected by a receiver. Using this estimation method, nearly half of the jaw-tagged chum may have been removed from the population, either through mortality or by being displaced downstream and not returning upstream to the spawning grounds.

| Week number | Number tagged | Number of acoustic tags | Percent detected | Effective number tagged |
|---|---|---|---|---|
| 40 | 2 | 2 | 100% | 2 |
| 41 | 12 | 12 | 100% | 12 |
| 42 | 170 | 11 | 64% | 108 |
| 43 | 476 | 15 | 73% | 349 |
| 44 | 502 | 10 | 10% | 50 |
| (Tagging suspended weeks 45-46) | | | | |
| 47 | 168 | 20 | 95% | 160 |
| 48 | 59 | 20 | 80% | 47 |
| 49 | 4 | 2 | 100% | 4 |
| **Total** | **1393** | **92** | | **732** |

Table 8.

The actual number of tagged chum lost to the flood may have been much higher. Some acoustically-tagged chum were detected upstream several days before the flood, but were not detected after the flood, and may have been lost during the event. No detections occurred during the flood due to noisy river conditions, so it is impossible to determine their movement during the flood. Many chum likely moved into off-channel habitat to spawn during the flood and continuing high-water conditions, where they would not have been detectable by receivers, but would have been available to samplers. None of the chum tagged before the flood were detected after the flood, so it may be that few fish already past the tagging site at the onset of the flood continued with substantial upstream migration when the flood had subsided. Some chum were reportedly detected in other river basins (Nooksack and Snohomish Rivers), but specific information on those is not yet available.

The chum salmon escapement estimate for 2006 was 105,000 (Brett Barkdull, WDFW, pers. comm.). This estimate was made using carcass counts in the index sections from the 1976-77 mark-recapture study. Usually, live counts are used, but poor survey conditions prevented the use of live counts to derive an escapement estimate in 2006. Using this escapement estimate and the sampling data from the mark-recapture study, we can roughly estimate the number of tagged chum that were available to samplers on the spawning grounds. Of the 105,000 that were in the escapement, we checked 27,370 for tags, and found only twelve tagged fish. This suggests that there may only have been about 46 (105,000/27,370 *12) tagged chum available to find on the spawning grounds.

While there appears to have been substantial loss of tagged chum from the population, we are unable to explain the disappearance of over 95% of them, as appears to have happened. It is unlikely that tagged chum simply lost their tags, as the jaw tags used were extremely firmly attached. In fact, it was difficult to remove them without cutting off the entire lower jaw. It is also unlikely that that significant numbers of tagged chum suffered delayed mortality from the stress of being handled. The chum implanted with acoustic tags experienced much more extensive handling than conventionally tagged fish, and appeared to survive well (independently of the flood effects).

Most likely, the "missing" tagged chum were lost through a variety of mechanisms. Some probably suffered direct mortality from the flood, while others were displaced downstream where they were subjected to harvest in unsampled fisheries. Others may have spawned in other basins after being moved down to marine waters. Any tagged carcasses present at the time of the flood would probably have been buried or otherwise lost. Whatever the exact cause, it is obvious that the flood disrupted the study to the point that the statistical assumptions of the 2006 population estimate were clearly violated. It is hoped that the planned second year of the study will not suffer the same fate.

**References**

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