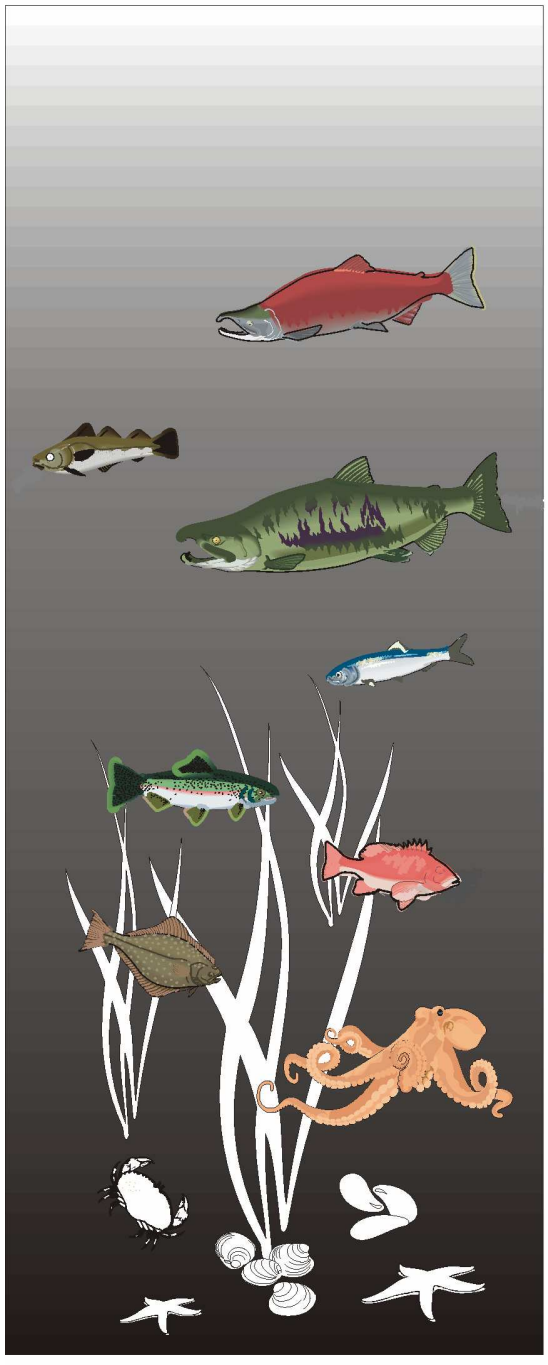
Northwest Fishery Resource Bulletin



Coho Salmon Escapement to the Skagit River Estimated Using a Mark-Recapture Method: 1989

By

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Project Report Series No. 9

Northwest Fishery Resource Bulletin

Project Report Series

The Northwest Fishery Resource Bulletin presents the results of investigations carried out by the Washington Dept. of Fish and Wildlife, Western Washington Treaty Tribes, and/or the Northwest Indian Fisheries Commission that are deemed of sufficient interest to be made available to the scientific community and the public.

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ABSTRACT

Since 1965, an index live-count method has been used to annually estimate the number of coho salmon in the escapement to the Skagit River. The accuracy and precision of the estimates from this method have never been critically examined. A five-year project to examine alternative methods of estimating the number of wild coho salmon in the escapement to the Skagit River was begun in 1986. In addition to the index live-count method, three other methods of estimating the coho salmon escapement to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count expansion method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement. **This report documents the results of the mark-recapture portion of the project for 1989.**

In 1989, coho salmon were captured with a beach seine at river mile 35 near the town of Lyman on the Skagit River from 6 September through 8 November. A total of 1,216 coho salmon were tagged with a jaw tag and marked with opercula punches. Tags were recovered during surveys designed to sample randomly the coho salmon escapement. Tag recovery samples were collected at 13 areas in the Skagit River drainage: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial or test fisheries. A total of 12,273 coho salmon were examined of which 11,969 fish were considered in-sample and 304 were not considered part of the population subject to tagging.

A total of 132 tagged or marked coho salmon were recovered during in-sample surveys. The tag recovery data indicate that approximately 1% of the coho salmon migrating through the lower Skagit River tagging area were caught and tagged. About 1.4% of the coho salmon returning to Marblemount Hatchery and 0.6% of the coho salmon returning to Baker River trap were tagged. About 2% of the fish were tagged in the samples from the Middle Skagit and Middle Sauk sub-basin spawning grounds above the tagging area. The percentage of tags found in the Baker River sample was significantly different from the other recovery areas with seven or more tag recoveries, therefore those data were not used for the abundance estimate. The tag recovery data indicate that some coho salmon from spawning areas substantially downstream of the tagging site were present in the tagging area. There were seven tags recovered in 1,941 coho salmon examined (0.4%) during commercial catch sampling of downstream areas.

The estimated abundance of coho salmon in 1989 was 78,667 fish with a 95% confidence interval of 65,997 to 99,805 fish. This estimate is for the number of coho salmon migrating through the tagging area after tagging began on 11 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was very precise (CV = 9.9%) because of the large number of fish examined for tags during in-sample surveys. To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 77,698 coho salmon. **The total return of coho salmon to Skagit Bay in 1989 is estimated to be 110,668 fish. There were an estimated 93,687 naturally-spawning coho salmon in the escapement to Skagit River spawning grounds**: 70,979 fish were estimated to have reached upstream spawning grounds and 22,708 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basins) spawning grounds (see summary table on the next page).

Table summarizing the total return of coho salmon to Skagit Bay in 1989 by its major components.

Component	Number of Fish
Total Terminal Run Size	110,668
Marblemount Hatchery	4,975
Baker River Hatchery	1,638
Commercial Fishery Catches	9,365
Test Fishery Catches	1,003
Subtotal	16,981
Wild Escapement	
Upstream Areas	70,979
Lower Areas	22,708
Subtotal	93,687
Sport Catch[a]	145

[a] An unknown portion of the sport catch should be subtracted from the wild escapement and the remainder added to the total terminal run size.

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INTRODUCTION

The Skagit River is the largest river system in the Puget Sound region. It has 162 miles of mainstem river and its headwaters are in Canada (Figure 1). This system is one of the largest producers of coho salmon (*Oncorhynchus kisutch*) in northern Puget Sound. Coho salmon from the Skagit River are caught in fisheries from Northern California to Southeast Alaska and are a major contributor to fisheries in the inside marine waters of Georgia Strait and Puget Sound (PFMC 1992). The Skagit River is managed for natural production of coho salmon (subsequently referred to as wild coho salmon). In years when the numbers of wild coho salmon projected to return to the Skagit River are small, fisheries from Cape Falcon, Oregon to the US/Canada border have been constrained to protect these fish (PFMC 1986, pg. III-9; and PFMC 1988, pg. III-11). Accurate annual assessments of stock status are required for coho salmon from the Skagit River because this stock can affect the management of fisheries over such a large geographic area. This ensures that fisheries are not unnecessarily restricted during years when there is not a conservation problem and prevents over-harvest of wild coho salmon from the Skagit River during years of small returns. An important component of the information needed to accurately assess the status of wild coho salmon from the Skagit River is an annual estimate of the number of coho salmon in the spawning escapement. Spawning escapement, as used in this report, refers to the number of adult coho salmon which are present in all natural spawning areas of the Skagit River and have the potential to spawn in these areas. It does not include coho salmon returning to Marblemount Hatchery or to the release site for hatchery-produced coho salmon at the Baker River dam.

Since 1965, the Washington Department of Fish and Wildlife (WDFW) has used an index live-count method to annually estimate the escapement of coho salmon to the Skagit River (Flint 1983). The accuracy and precision of the estimates from this method have not been critically examined. A five-year project to examine alternative methods of estimating the number of wild coho salmon in the spawning escapement to the Skagit River was begun in 1986. This project was conducted by the Skagit System Cooperative (SSC) in cooperation with personnel from WDFW and Puget Power and Light. Three methods of estimating the spawning escapement of coho salmon to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement.

This report is the fourth in a series of reports that will document the studies conducted from 1986 through 1990 which examined different methods for estimating the escapement of coho salmon to the Skagit River. The 1986, 1987, and 1988 studies are summarized, respectively, in Conrad et al. (1997, 1998a, 1998b). **This report summarizes the data and documents the results of the mark-recapture portion of the project for 1989.** Reports documenting the results for the other year that tagging was conducted (1990) and the other methods of estimation will follow. Some summary data from the other years of the study are used to support some of the assumptions required for the analysis of the tagging data from 1989. These data are documented in Conrad et al. (1997).

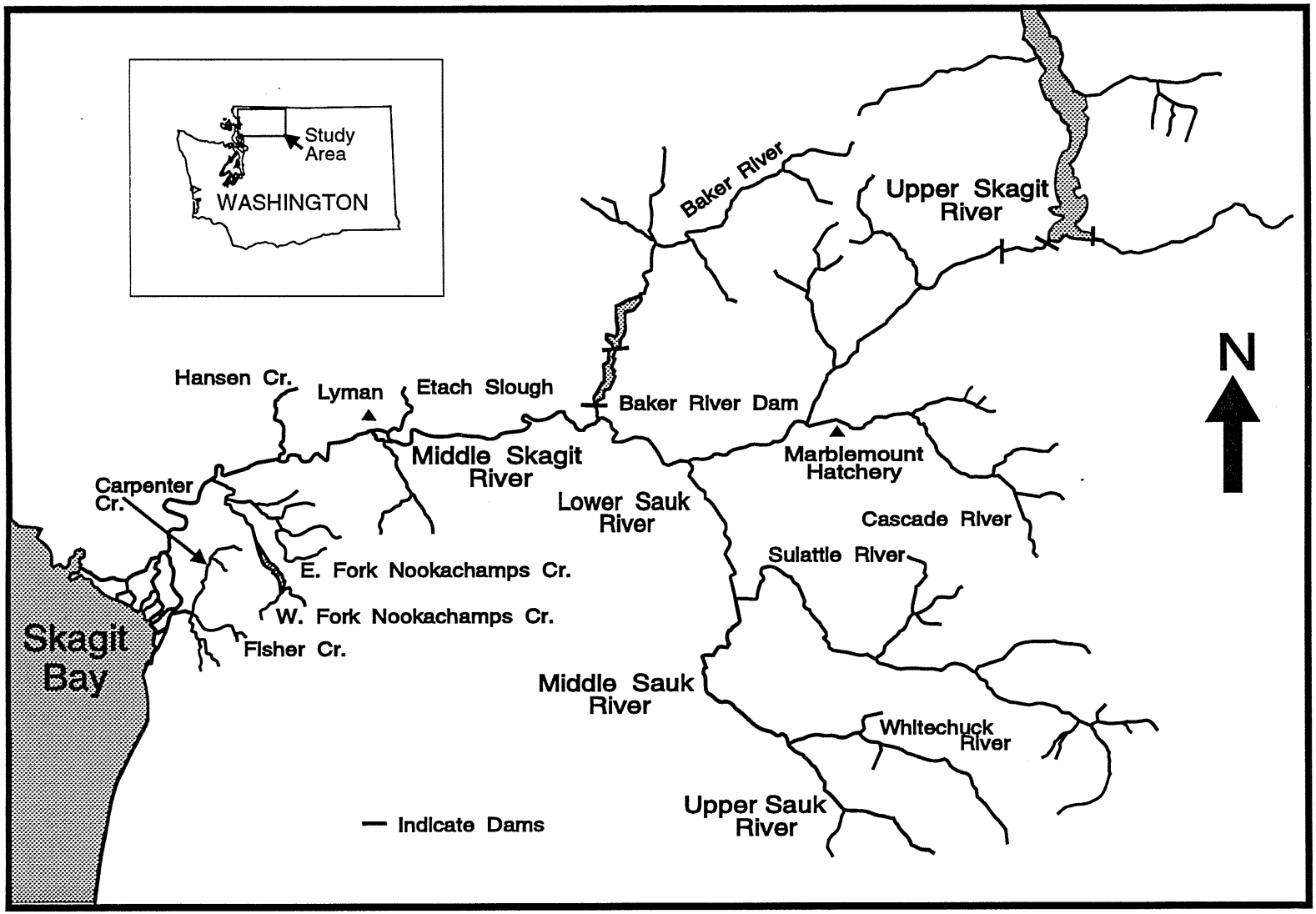

Figure 1. Map of the Skagit River system showing the location of the areas where tag recovery surveys were conducted.

METHODS

The description of methods is divided into four sections. The first section describes the methods used to capture coho salmon for tagging and the tagging procedure. The second section describes the surveys used to recover tags. This includes a description of the survey procedures for each of the tag recovery areas. Section three summarizes the statistical procedures used to estimate the abundance of coho salmon from the tag release-and-recovery data. The last section describes some miscellaneous analyses conducted to examine migration timing and the sex and length composition of the coho salmon that were sampled.

Tagging Methods

Beach Seining:

Coho salmon were captured for tagging using a beach seine operated by a five-man crew. Seining was conducted primarily at a single site at about RM 35 near the town of Lyman on the Skagit River (Figure 2). On October 9 and 10, beach seine sets were made at three drift sites near the Lyman location; 77 coho salmon were tagged at these sites in total. A beach seine that was 456′ long by 20′ deep was used to capture coho salmon. The seine had two wings: one was 90′ long and made of 3.5″ knotless nylon and the other was 330′ long and made of 2.75″ monofilament. The net had a 36′ bunt made of 2″ knotless seine material. Cork spacing was 8″ on the bunt and two feet on the rest of the net. The leadline was hung with 15 lb per 60′ of net. Modifications in net dimensions occurred whenever the seine was damaged. Due to heavy use, the leadline was rehung about every four fishing days and the monofilament was replaced after every eight to ten fishing days.

A boat was used to set the beach seine. One end of the seine was held by two crew members on a gravel bar while the boat backed away from the shore and the net was set off the bow of the boat. When the entire net was out, the boat-end of the net was towed downstream. The other end of the net was attached to a four-wheel drive truck and driven slowly downstream. Care was taken to prevent the shore-end of the net from getting ahead of the boat because fish tended to lead away from the shore and around the boat. During the drift, a seine plunger (a long pole with a cup on the end) was slammed into the water periodically to drive fish away from the river-end of the net and toward the shore. At a pre-designated point the boat returned to the gravel bar. Upon reaching the shore, the boat-end of the net was attached to the back of a second four-wheel drive truck. Both trucks then pulled the net up the gravel bar, perpendicular to the river, until only the bunt end of the net was in the water. The five-man crew then pulled the bunt in by hand until the leadline was on shore while the cork line and ends were cradled by the crew.

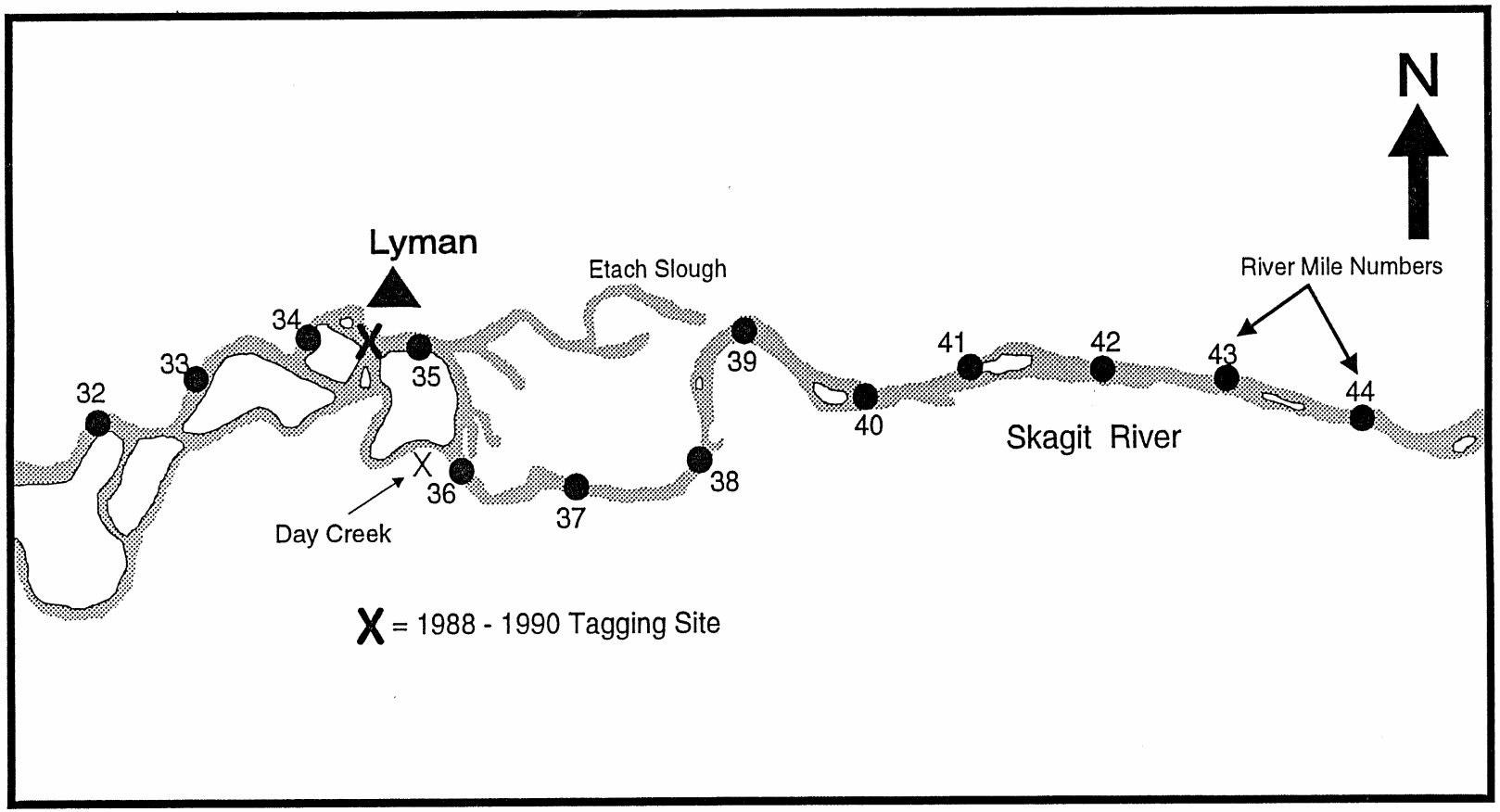

Figure 2. Map of the area of the Skagit River where coho salmon were captured and tagged, 1986-1990.

Tagging Procedures:

Coho salmon were removed from the bunt and placed into either of two net pens adjacent to the capture site. All other species were counted and returned to the river. The pens were 3′ by 5′ by 5′, constructed of PVC, and covered with 0.5″ knotless nylon mesh. Each coho salmon was taken from a net pen by a sampler wearing cotton gloves and placed on a V-shaped measuring board lined with high-density foam. A sequentially-numbered hog ring was clamped around the lower left mandible of each fish using a pair of hog-ring pliers and a 3/8″ hole was punched in the rear center of each gill operculum with a paper hole-puncher. The fork length (measured to the nearest cm), sex of the fish, any external marks, and a qualitative assessment of maturity (bright, blush, or dark) were recorded for each fish with the date and tag number. Each tagged salmon was held gently in the water until its equilibrium was regained before being released. If a tagged fish did not swim away or appeared to be injured it was given a condition rating of "X-". Fish that swam away normally were given a condition rating of "X". Fish with severe physical impairments (e.g., 50% scale loss, torn opercula, deep predator wounds) were released untagged. These included jack coho salmon (male salmon under 30 cm in length) which generally gilled in the net and were unfit for tagging.

Tag Recovery Surveys

Only tags recovered during surveys designed to randomly sample the coho salmon escapement were used for the abundance estimates. These are referred to as **in-sample recoveries**. Tag recovery surveys were conducted by sampling: (1) all fish spawned, surplused, or otherwise sacrificed at Marblemount Hatchery; (2) all fish caught at the fish trap at Baker River dam; (3) the catch by the in-river commercial fishery; (4) all test fishery catches; (5) every reachable and identifiable dead coho salmon found during spawning grounds surveys; and (6) every coho salmon caught in traps operated on: Carpenter Creek Slough (a tributary to Carpenter Creek) and Etach Slough (a tributary to the Middle Skagit sub-basin). During each survey or day of trap operation, the date, number of coho salmon inspected for tags, number of tagged or marked (with the opercula punches) fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Marblemount Hatchery:

Samples were collected by three different methods at WDFW's Marblemount Hatchery: spawned fish, surplused fish, and pond mortalities. After any processing, hatchery personnel sorted the fish from these groups into separate bins for tagged/marked and unmarked fish. SSC crews then re-checked these bins for coho salmon with tags or marks. The date of sampling, number of coho salmon inspected for tags, number of tagged or marked fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Coho salmon were spawned at Marblemount Hatchery to meet specific egg-take goals. Spawning was conducted when the portion of the run from which eggs were desired was present and there were large numbers of fish in the holding ponds. Hatchery personnel selected fish for spawning and sorted them into the bins after spawning for SSC crews to examine. Surplused fish were those in excess of the spawners needed for eggs. Surplus coho salmon were periodically sacrificed and sorted into the bins. The holding pond was periodically surveyed for mortalities and any dead coho salmon were removed and sorted into the bins. A schematic of the Marblemount Hatchery sampling procedure is shown in Figure 3.

Except for the pond mortalities, hatchery personnel selected the coho salmon for the other two groups, spawned and surplused, according to a visual assessment of the fish and the timing of the return to Marblemount Hatchery. Therefore, these fish were not strictly sampled at random and the percentage of tagged fish in these samples might have been influenced by the selection process. However, since all coho salmon returning to the hatchery were sampled, the Marblemount Hatchery sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at Marblemount Hatchery.

Baker River Trap:

A fish trap at Baker River dam caught all upstream migrating salmon. All coho salmon caught at the trap were examined. Fish caught in the trap were crowded into a brail and several removed at a time onto a sorting table. Each coho salmon was examined for a tag or mark. The sample date, condition, and tag number (when legible) were recorded for any jaw-tagged or opercula-punched coho salmon. After all live fish in the brail were removed, the racks and screen of the trap were searched for dead fish. Therefore, identically to the Marblemount Hatchery sample, the Baker River trap sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at the Baker River trap.

The Baker River stock is one of the earliest returning coho salmon stocks to the Skagit River. Coho salmon were counted at the Baker River trap before tagging began in the lower river during two years of the study. In the other years of the study, coho salmon were counted at the trap so soon after tagging was initiated that we assumed some fish had migrated past the tagging site before tagging had begun and, therefore, were not subject to capture. Since these early-arriving fish were not subject to tagging, we excluded them from the number of fish examined for tags that was used for the population estimates (i.e., they were not considered in-sample). We examined the number of days between release and recapture for all coho salmon recovered at the Baker River trap during the five years of tagging. The minimum travel time (number of days between being tagged and released in the lower river and recovered at Baker River trap) observed during the study years was four days (Conrad et al. 1997). Therefore, all fish counted at the Baker River trap prior to four days after tagging had begun were excluded from the in-sample survey.

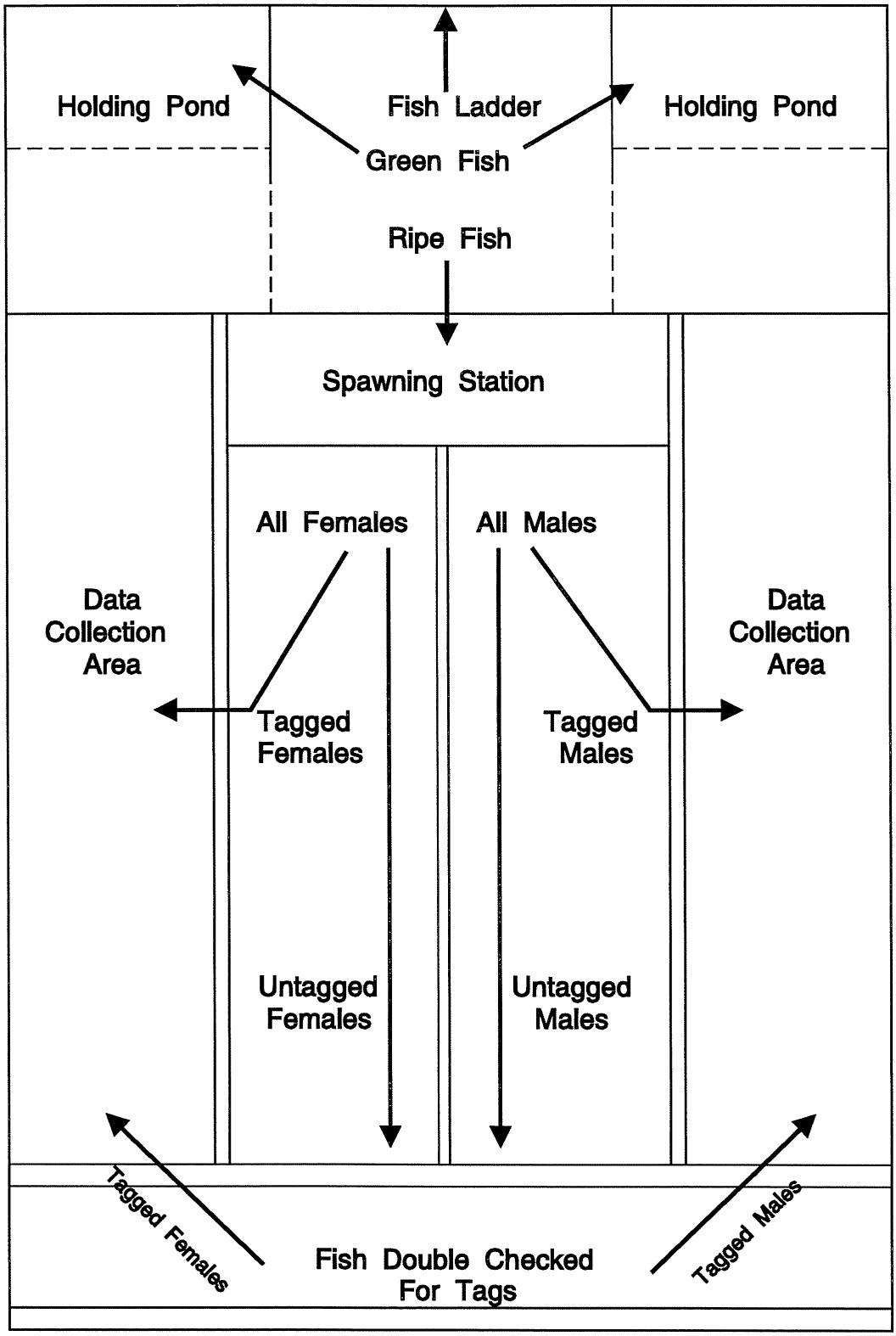

Figure 3. Schematic of the sampling procedure used to process coho salmon for tag examination at Marblemount Hatchery.

In-River Commercial and Test Fisheries:

Tag recovery samples from the commercial catch were collected in conjunction with routine commercial catch sampling activities. The Skagit River is divided into statistical areas for commercial catch regulation (Figure 4). To allow tag recovery samples from the catch to be analyzed by area of capture, all major salmon buyers were instructed to place catches from each statistical area into separate bins. This occurred during the fishery for chum salmon and the early part of the fishery for steelhead in the Upper Skagit River. In 1989, most samples were allocated to sub-areas (78D-2, 78D-3, etc.) within Area 78D. When the sub-area was not known (i.e., the sample was labeled "78D"), we assigned that sample to the upstream areas (78D-3 or 78D-4) for population analyses. Incidental catches of coho salmon during the later part of the steelhead fishery in the Upper Skagit River were not sorted by area. In addition, although all in-river catches were recorded on fish tickets, the sub-area of harvest within area 78D was not indicated on the ticket. In order to estimate the total number of coho salmon caught in Areas 78D-3 and 78D-4, we multiplied the total Upper Skagit River commercial catch of coho salmon by the proportion of their area-specific samples that came from Areas 78D-3 and 78D-4.

A test fishery was conducted each year by an SSC crew to provide an in-season assessment of the size of the coho salmon run. In 1989, test fisheries were conducted in: Area 2; Spudhouse; Blakes; and Jetty in Skagit Bay (Figure 4). Drift and set gill nets used at the test fish sites had mesh sizes ranging from 5″ to 6″. Hayman (1996) describes the test fishing procedures in detail. All coho salmon caught during the test fishery were inspected for tags or marks.

Both WDFW and tribal commercial catch and hatchery samplers in areas outside of the Skagit River were notified to look for jaw tags from the Skagit River study. These recoveries allowed us to assess the degree of out-of-system straying for coho salmon tagged in the mainstem of the Skagit River.

Spawning Grounds:

Tag recovery surveys of the spawning grounds were conducted in conjunction with surveys to estimate the coho salmon escapement using redd counts (Conrad et al. 1993). For the redd-count method, the Skagit River system was stratified into the nine sub-basins listed by Johnson (1986): Carpenter; Nookachamps; Middle Skagit; Upper Skagit; Lower Sauk; Middle Sauk; Upper Sauk; Suiattle; and Cascade (Figure 1). Stream sections in each sub-basin were surveyed from one to 12 times during the spawning period for coho salmon. In 1989, about 27% of the total length of potential spawning habitat in the Skagit River was surveyed (Conrad et al. 1993). During spawning ground surveys, any coho salmon carcasses observed were sampled for jaw tags and opercula marks. Gill opercula of untagged carcasses were carefully inspected for marks or healed marks. A healed (regenerated) mark was evident as a perfectly round discoloration on the gill cover that was lighter in color than the surrounding opercular tissue. Occasionally a carcass could not be sampled because of a missing head due to advanced decomposition or removal by predators. Unsampled carcasses were tallied during each survey. The date, survey location, number of coho salmon carcasses sampled, number of

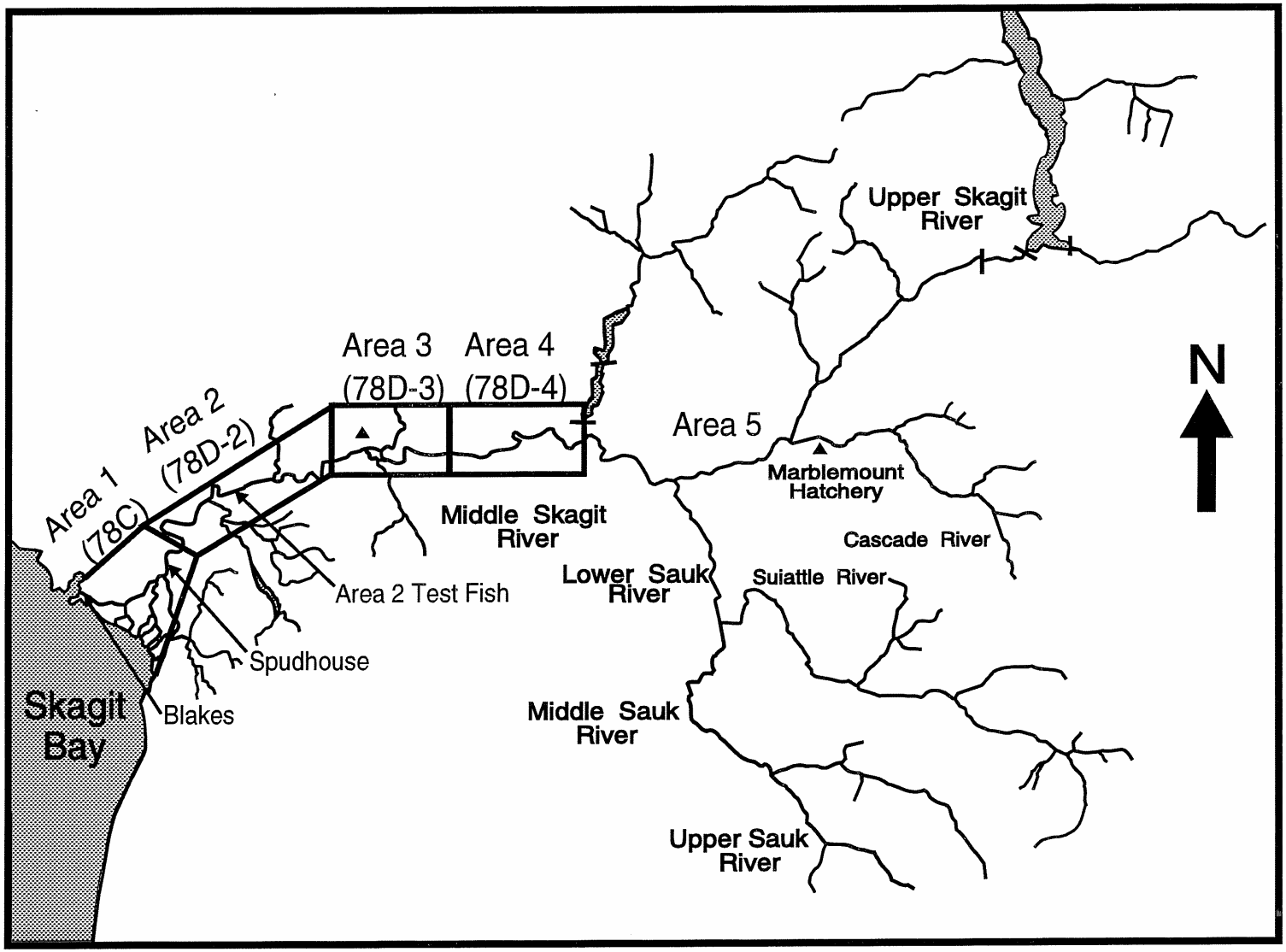

Figure 4. Commercial fishery areas of the Skagit River as designated by WDFW.

tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded during these surveys. The caudal fin of all sampled carcasses was removed to prevent the carcass from being sampled again during subsequent surveys.

Tributary Traps:

SSC operated traps on Carpenter Creek Slough (a tributary to the Carpenter sub-basin) and Etach (or Red Cabin) Slough (a tributary to the Middle Skagit sub-basin) in 1989. Both traps were wooden weirs that blocked the entire creek and funneled fish into a live box. The traps were located in areas that had easy accessibility, a section of relatively straight stream channel with a low gradient, and a stable substrate.

The traps were checked and cleaned at least twice daily. A knotless-nylon dip net was used to move the trapped coho salmon into a 30-gallon plastic container filled with water. All coho salmon caught were examined for tags or marks and then released upstream. A Petersen disk tag and a unique operculum punch (i.e., a punch pattern different from that used in the main-river tagging) were placed on all coho salmon released above the traps. The trap crews also recovered tags at the weirs from spawned-out carcasses which had washed downstream from the spawning areas (called rack recoveries). The caudal fin was cut off all rack recoveries. The date, number of coho salmon sampled, number of tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Abundance Estimates

Two different mark-recapture models were used to estimate the number of coho salmon passing through the tagging area in the lower Skagit River, the Petersen estimation model and Darroch's stratified estimation model. When tagging and recovery occur over an extended time period, such as occurred in this study, it is not uncommon to observe temporal changes in: (1) the probability of capture of fish in the target population; and/or (2) the probability of finding a tagged fish during tag recovery surveys. When such changes occur the Petersen model is often not the appropriate estimation model. Seber (1982) describes a series of χ^2 tests to determine whether the data are consistent with a Petersen estimate. Specifically, the tests determine whether the data are consistent with the following four conditions: (1) there was uniform recovery of tags across the tag recovery strata; (2) there was uniform tagging across the tag release strata; (3) there was complete mixing of the population between tagging and recovery; and (4) the expected number of tags recovered in each stratum was proportional to the number of unmarked individuals present.

Eames et al. (1981, 1983) describe the exact form of these tests for a study similar to ours in both the study design and estimation procedures. They captured chum and coho salmon in marine areas immediately in front of the mouths of major river systems in Puget Sound and tagged the fish with jaw tags. Tags were recovered during surveys of spawning grounds throughout these river systems. We followed procedures similar to those described by Eames et al. (1981, 1983) to determine the appropriate estimation model.

Petersen Estimation Model:

The simplest and most commonly used model for estimating abundance from mark-recapture data is the Petersen model. Conrad et al. (1997) discuss the necessary assumptions for the Petersen model as implemented for this study.

Robson and Regier (1964) recommend that a Petersen estimate include a minimum of seven tag recaptures to ensure that the bias of the estimate is negligible. Therefore, we estimated abundance from the tagging data only when there were at least seven recaptures of tagged or marked coho salmon from a recovery area. Chapman's unbiased form of the Petersen estimate (Seber 1982) was used to estimate abundance. Conrad et al. (1997) describe the model and the procedures used to estimate 95% confidence intervals. For any Petersen-type estimator (including Darroch's stratified estimator), the abundance estimate depends upon ρ, the proportion of the population tagged. The proportion of tags in the second (recovery) sample provides an estimate of ρ. Generally, as $\hat{\rho}$ becomes smaller the estimated abundance becomes larger for a given number of tags released.

Darroch's Stratified Estimation Model:

Darroch (1961) developed a stratified population model for open populations that is not predicated on constant probabilities of capture or recovery. The necessary assumptions for this model are discussed in Seber (1982) and summarized by Conrad et al. (1997). Conrad et al. (1997) also describe the model and its application to the tag release-and-recovery data collected for this study.

Definition of Strata:

Two different tag recovery percentages were examined to help define tag release and tag recovery strata. To determine if the probability of finding a tagged fish in recovery samples was different among recovery locations or among different time periods at the same location, the percentages of tags in recovery samples (ρ as defined previously) were compared. The percentages of tags recovered from releases during specific time strata, π, were compared to determine if there were differences in the probability of recovering fish tagged during different segments of the release period. For these tests it was necessary to define temporal strata for both the tag release data and the tag recovery data from each recovery area.

Tag release strata were established by dividing the release data into four to six strata with about an equal number of days of tagging in each stratum. The percentages of tagged fish recovered from each release stratum (π) were tested to determine if they were equal. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted to more precisely define the release strata by pooling adjacent strata which did not have significantly different π.

Three different criteria were used to establish tag recovery strata: (1) number of days of sampling; (2) number of tags recovered; and (3) number of fish examined for tags. Initially, two recovery strata were defined by dividing the data so there were approximately equal numbers of the criteria (days surveyed, number of tags, or number of fish examined) in each stratum. The percentages of tagged fish in each recovery stratum (ρ) were tested to determine if they were equal among recovery strata for each stratification criteria. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted within the initial strata to more precisely define the recovery strata.

Testing ρ and π:

Tests were conducted to determine if there were significant differences in tag recovery percentages (either ρ or π) between different samples or groups of fish (e.g., between surveys conducted by SSC and WDFW, or between samples collected during different time periods, or between samples collected at different locations, or between male and female coho salmon). When the expected number of tag recoveries for each group in a comparison was five or greater, a standard χ^2 test (Conover 1980) was used to test for differences in tag recovery percentages (ρ or π). If the number of tag recoveries was insufficient for a χ^2 test (one or more cells with expected frequencies less than five) and there were only two release strata or recovery locations to compare, Fisher's exact test (Conover 1980) was used. Otherwise, an approximate randomization test (ART) was conducted (Noreen 1989). An approximate randomization test is a computer-intensive method of testing whether the data in a contingency table are similar. It is similar to Fisher's exact test but uses a computer to repeatedly resample the data and approximately estimate the probability of observing the configuration of the data in the table (under the null hypothesis that the samples are from the same population).

Selection of Estimation Models:

If we assume that coho salmon bound for each recovery area are randomly sampled as they migrate through the lower river tagging area, the recovery data (number of tagged or marked fish found and number of fish examined) from each recovery area can be used to estimate ρ, the percentage of the population that was tagged. If the hypothesis of equal $\hat{\rho}$ among recovery areas was not rejected ($P > 0.10$), the tag recovery data from the different areas were pooled. The pooled data were then used in the tests to determine if the tag release-and-recovery data were consistent with the Petersen model. We feel that the variation in $\hat{\rho}$ among the recovery areas generally reflects sampling variation in the recovery areas. The number of carcasses examined for tags was relatively small for some recovery areas. In some cases, all samples were collected from a relatively discrete area within the general recovery area which could influence the proportion of tagged carcasses present. Generally, the areas with greatly different recovery percentages (more than a 0.5% difference from the major recovery areas) had less than seven tag recoveries each. The different population estimates that were generated using the data from different recovery areas (or pooled recovery areas) were usually not significantly different from each other. Therefore, we selected the estimate with the smallest coefficient of variation as the "best" estimate of abundance for each year.

The model used to estimate abundance, simple Petersen or Darroch's stratified, was determined by the results of the tests for the consistency of the data. The four χ^2 tests used to determine consistency are described by Seber (1982) and by Eames et al. (1981, 1983).

Allocating Marked-Only Fish to Release Strata:

From 12% to 24% of the in-sample recoveries each year had a tag with an illegible number or had no tag and were identified as tagged fish by the opercula punches. The release stratum for these fish was unknown and had to be estimated for the stratified estimator. Marked fish with missing or illegible tags were allocated to release strata within a recovery area based on the proportional distribution of legible tags from each release stratum (Conrad et al. 1997). This assumes that tag loss or tag illegibility is a random process and that coho salmon tagged during each release stratum have equal rates of tag loss, therefore, fish with missing or illegible tags are assumed to have a similar distribution for stratum of release as fish with legible tags. If tag loss (or a tag becoming illegible) is a time dependent process, then fish tagged during the earlier release strata might be expected to have higher rates of tag loss and this assumption would not be true. Eames et al. (1981, 1983) used procedures similar to ours to allocate fish recovered with missing tags to release strata in their study. Errors in the assignment of marked-only fish to release strata affect only the Darroch estimate.

Additional Analyses

Several additional analyses of the data collected during tagging and tag recovery surveys were conducted. These included analyses to determine the timing of the migration of different spawning groups through the tagging area and analyses of sex and length composition data. These analyses were not required for the abundance estimates but were conducted to describe the characteristics of the annual return of coho salmon to the Skagit River during the study years.

Migratory Timing to Major Recovery Areas:

The timing of coho salmon migrating through the lower river tagging area was estimated from an analysis of the release dates of the tags recovered in each major recovery area (excluding commercial and test fisheries). Only areas with ten or more legible tag recoveries were included in the analyses. Ten, 10-day time periods were defined for the migratory timing calculations: (1) 1 September to 10 September; (2) 11 September to 20 September; (3) 21 September to 30 September; (4) 1 October to 10 October; (5) 11 October to 20 October; (6) 21 October to 30 October; (7) 31 October to 9 November; (8) 10 November to 19 November; (9) 20 November to 29 November; and (10) 30 November to 9 December.

Catch-per-unit effort (CPUE) by the beach seine used to capture coho salmon for tagging was used to describe the timing of the run through the tagging area in the lower river. CPUE was calculated for each 10-day period as the total number of coho salmon caught divided by the total number of beach seine sets (catch per set). The number of tags recovered in each major recovery area from each of the release periods was used to estimate the CPUE of coho salmon

bound for these areas. The CPUE of coho salmon from recovery area *j* during release period *i* was estimated by:

$$\hat{\omega}_{ij} = \frac{r_{ij}}{f_i} \qquad [1]$$

where $\hat{\omega}_{ij}$ = the estimated CPUE of coho salmon from recovery area *j* during release period *i*,

r_{ij} = the number of tags recovered in area *j* that were released during period *i*, and

f_i = the number of beach seine sets made during period *i*.

For each area analyzed, the CPUE estimated for each 10-day period was summed across all ten time periods to estimate a season total CPUE of coho salmon bound for that recovery area. The estimated CPUE of coho salmon from recovery area *j* during time period *i* was converted to the percentage of this season total CPUE for recovery area *j* to describe migratory timing (Mundy 1982). These data were then graphed so that migratory timing for each major recovery area could be compared.

Analyses of Sex and Length Composition Data:

Significant differences in the probability of recovering coho salmon tagged during different release periods (π) were found at some recovery locations in 1989. Temporal trends in the probability of recovery could be due to changing environmental conditions at the tagging site which influenced the probability of capture. For example, high and low water conditions may have influenced the effectiveness of the beach seine used to capture fish in the tagging area. Under low water conditions a higher proportion of the coho salmon present might have been caught than under high water conditions. Another possible explanation is that physical characteristics of the fish themselves (for example, sex or length) may influence both rate of capture for tagging and rate of recovery in tag recovery samples. For example, the beach seine may capture larger coho salmon at a higher rate than smaller coho salmon so that a higher proportion of the larger fish were tagged. As long as there is random mixing of coho salmon tagged during different time periods in the recovery areas, and the recovery process does not have the same selectivity as the capture process, this presents no problems for the abundance estimates.

Significant differences in the probability of finding a tag during surveys conducted at different times in a recovery area (ρ) were often found. Temporal trends in the physical characteristics of the population, combined with temporal trends in capture efficiency at the tagging site, could cause the changes observed. During spawning ground surveys, male fish may be more likely to end up in locations that are sampled than female fish, or larger fish may have a higher probability of being seen and sampled during spawning ground surveys than smaller fish. The available data were examined to determine if these influences were present. The data used in these analyses were the length and sex composition data for all coho salmon tagged at the lower river tagging site and the tag recovery data used for the population estimates. Coho

salmon recovered with a missing or illegible tag but having an operculum punch could not be used since their length and sex were not recorded at time of recovery.

Seber recommends testing the release (tagging) and recovery (escapement) samples for randomness with respect to length. The recovery sample was tested by comparing the length distributions of individuals that were tagged but not recovered to those individuals that were tagged and recovered. Both a Mann-Whitney U test and a Kolmogorov-Smirnov (K-S) test (Conover 1980) were used to compare the length distributions of coho salmon from these two groups. These same tests were also used to compare the length distributions of male and female coho salmon that were tagged in the lower Skagit River.

If there was a significant difference between the length distributions of male and female coho salmon subsequent analyses were conducted for each sex separately. If there was a significant difference between the length distributions of coho salmon which were tagged but not recovered and those that were tagged and recovered, K-S tests were performed sequentially on the length distributions to determine length categories with no significant difference between the two groups. Testing began between 65 and 70 cm (above which both groups' length distributions were not significantly different) and length was sequentially decreased by one cm intervals until a significant difference ($P \leq 0.05$) between the groups was found. A K-S test was then performed on those fish that were at the length of the significant difference or smaller. If there was a significant difference between the fish which were tagged but not recovered and those that were tagged and recovered the process was repeated for the fish in this smaller length range.

RESULTS

The results of the tagging conducted in 1989 are summarized in the following five sections. The summary consists of: (1) tag releases by day; (2) tag recoveries by location; (3) abundance estimates produced using the tag release-and-recovery data; (4) additional analyses which include migratory timing information from the release-and-recovery data and sex-length composition data; and (5) a discussion of the "best" estimate of the number of coho salmon migrating through the lower Skagit River tagging area.

There are two different tag recovery percentages presented in the results; the percentage of tags recovered from the tag releases during a specific time stratum (π) and the percentage of tagged fish in samples collected during tag recovery surveys (ρ). The recovery data from each major area were tested to determine if there were significant temporal differences in both of these percentages. The results of these tests determined which data were pooled and which model was used to estimate the abundance of coho salmon using the recovery data for a specific area or group of areas pooled.

Tag Releases

The beach seining began on 6 September but only one coho salmon was caught that day and none were tagged. Tagging began on 11 September and continued through 8 November. A total of 1,216 coho salmon were tagged during 25 days of tagging (Table 1). About 11% of the tagged fish were eventually recovered during surveys conducted to estimate the percentage of tagged fish in the escapement.

The percentage of each day's release of tags that was recovered ranged from 0% to 44% (Figure 5). Generally, coho salmon tagged and released during September were recovered at a higher rate than those tagged and released in October and November. Four temporal release strata were defined to determine if there were significant differences in π among the release strata using the recoveries at each major area. The four release strata were:

1. 11 September to 26 September;
2. 2 October to 11 October;
3. 16 October to 24 October; and
4. 27 October to 8 November.

Significant differences in π among the release strata were found for the recoveries at Marblemount Hatchery, Baker River trap, and for all recovery data combined (Table 2). There were no significant temporal differences in π among release strata at the other major recovery areas (Middle Skagit sub-basin spawning grounds, the combined upriver spawning grounds, and the commercial fishery). These tests were conducted only for recovery areas with seven or more legible tag recoveries.

Table 1. Number of coho salmon tagged each day and number of in-sample tag recoveries from each day's release for the Skagit River, 1989.

	Number	Tag Recoveries by Area[a]											Recoveries	
Date	Tagged	MMH	BAK	MSK	USK	LSA	MSA	USA	SUI	OTH	CFS	TFS	Total	% (π)
06-Sep	0													
11-Sep	4	0	1	0	0	0	0	0	0	0	0	0	1	25.0%
12-Sep	4	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
15-Sep	24	1	0	0	0	0	0	0	0	0	0	0	1	4.2%
18-Sep	30	5	1	0	0	0	0	0	0	0	0	0	6	20.0%
19-Sep	18	1	0	0	0	0	0	0	0	0	0	0	1	5.6%
22-Sep	4	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
25-Sep	9	3	1	0	0	0	0	0	0	0	0	0	4	44.4%
26-Sep	6	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
02-Oct	8	0	1	0	0	0	0	0	0	0	0	0	1	12.5%
03-Oct	7	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
06-Oct	25	1	1	0	0	0	0	0	0	0	0	0	2	8.0%
09-Oct	69	5	0	0	0	0	0	0	0	0	2	0	7	10.1%
10-Oct	88	4	3	0	1	0	2	0	0	0	0	0	10	11.4%
11-Oct	119	12	2	0	0	0	0	0	0	0	2	0	16	13.4%
16-Oct	46	3	0	0	0	0	0	0	0	0	0	0	3	6.5%
17-Oct	41	1	0	0	1	1	0	0	0	0	0	0	3	7.3%
18-Oct	26	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
20-Oct	136	4	0	0	1	1	1	0	0	0	1	0	8	5.9%
23-Oct	267	12	5	1	0	0	0	0	0	0	4	0	22	8.2%
24-Oct	63	1	0	4	0	0	0	0	0	0	1	0	6	9.5%
27-Oct	68	5	0	0	0	0	0	0	0	0	0	0	5	7.4%
30-Oct	92	2	0	2	1	0	0	0	0	0	2	0	7	7.6%
31-Oct	15	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
02-Nov	32	0	0	0	0	1	0	0	0	0	0	0	1	3.1%
08-Nov	15	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
UNKNOWN[b]		8	2	6	1	1	7	0	0	0	3	0	28	
TOTALS	1,216	68	17	13	5	4	10	0	0	0	15	0	132	
% Recovered		5.6%	1.4%	1.1%	0.4%	0.3%	0.8%	0.0%	0.0%	0.0%	1.2%	0.0%	10.9%	

[a] Locations are: MMH - Marblemount Hatchery; BAK - Baker River trap; MSK - Middle Skagit sub-basin; USK - Upper Skagit sub-basin; LSA - Lower Sauk sub-basin; MSA - Middle Sauk sub-basin; USA - Upper Sauk sub-basin; SUI - Suiattle sub-basin; OTH - Cascade, Nookachamps, and Carpenter sub-basins; CFS - Commercial fishery; and TFS - Test fishery.

[b] Fish recovered with no tag but having the secondary mark (an operculum punch) or an illegible tag.

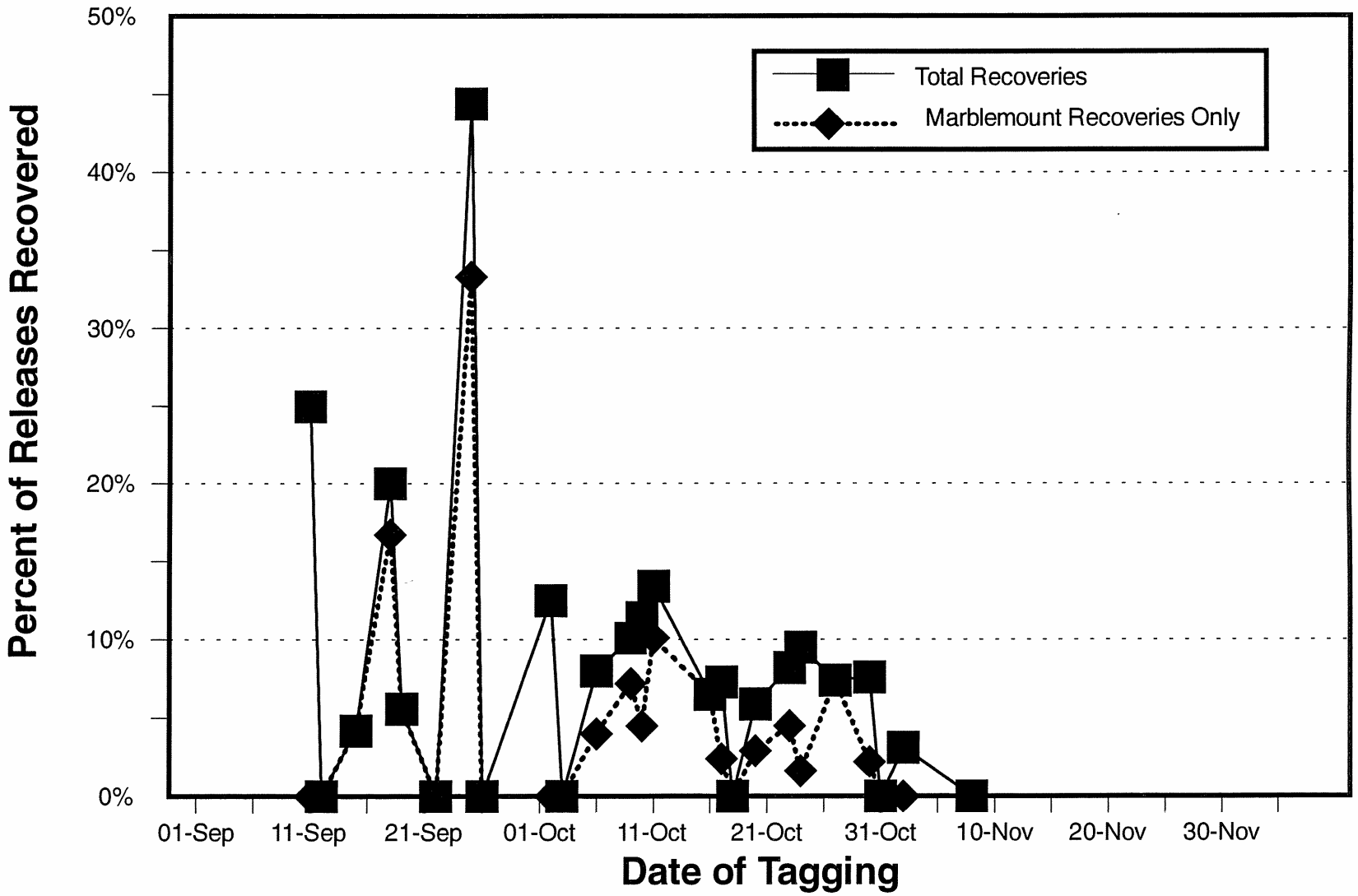

Figure 5. Percent of tags recovered during in-sample surveys from each day of release for coho salmon tagged in the Skagit River, 1989.

Table 2. Summary of the number of tag recoveries (#) from each release stratum in each major recovery area and the results of testing recovery percentages (π) for equality among release strata, 1989.

		RECOVERY AREA											
	Number	Marblemount		Baker R.		Mid. Skagit		Spawn. Gr.[a]		Comm. Fishery		Total	
Release Strata	Tagged	#	π	#	π	#	π	#	π	#	π	#	π
11-Sep thru 26-Sep	99	10	10.1%	3	3.0%	0	0.0%	0	0.0%	0	0.0%	13	13.1%
2-Oct thru 11-Oct	316	22	7.0%	7	2.2%	0	0.0%	3	0.9%	4	1.3%	36	11.4%
16-Oct thru 24-Oct	579	21	3.6%	5	0.9%	5	0.9%	10	1.7%	6	1.0%	42	7.3%
27-Oct thru 8-Nov	222	7	3.2%	0	0.0%	2	0.9%	4	1.8%	2	0.9%	13	5.9%
TOTALS	1,216	60	4.9%	15	1.2%	7	0.6%	17	1.4%	12	1.0%	104	8.6%
TEST RESULTS[b]													
Test Used:			χ^2		ART		ART		ART		ART		χ^2
Significance (P):			< 0.01		0.02		0.28		0.54		0.66		0.03
			***		**		NS		NS		NS		**

[a] Total for all spawning ground samples from the Middle Skagit sub-basin and above. The total does not include recoveries from Marblemount Hatchery, Baker River trap, or the Nookachamps and Carpenter sub-basins.

[b] Results of the tests to determine if the recovery percentages (π) were different among release strata. Test used: χ^2 = chi-square test, ART = approximate randomization test. NS = Not Significant, * = Significant, $0.05 < P \leq 0.10$, ** = Significant, $0.01 < P \leq 0.05$, *** = Significant, $P \leq 0.01$.

Tag Recoveries

Samples to estimate ρ were collected at 13 areas in the Skagit River drainage. A total of 12,273 coho salmon were examined of which 11,969 fish were considered in-sample and 304 were not considered part of the population subject to tagging. Sample surveys were conducted at: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial and test fisheries. Of the 132 in-sample recoveries, 28 fish (21%) had a tag with an illegible number or had a missing tag and were identified as tagged by the opercula punches. Most of the in-sample recoveries were at Marblemount Hatchery (68 recoveries or 52% of all in-sample recoveries). The areas with the next largest number of tag recoveries were Baker River (17 or 13%) and the commercial fishery (15 or 11%). Combined, these three areas account for 76% of all in-sample recoveries.

The percentage of tagged fish in the escapement samples (ρ) from the five recovery areas having seven or more tag recoveries ranged from 0.6% for the Baker River trap to 2.0% for Middle Sauk sub-basin spawning ground samples (Table 3). There was a significant difference (χ^2, $P < 0.01$) in ρ among these five areas.

The average number of days between release and recovery for in-sample tag recoveries was about 41 days (Table 4). Tagged coho salmon recovered at Baker River trap had the shortest average time between release and recovery, 25 days, and tag recoveries from the Middle Sauk sub-basin had the longest average time between release and recovery, 73 days. For the upstream recovery areas, tag recoveries at Baker River trap had the earliest average day of release (9 October) and recoveries in the Middle Skagit sub-basin had the latest average day of release (25 October).

Marblemount Hatchery:

Escapement samples were collected at Marblemount Hatchery from 15 September through 17 January. Recovery data collected on 15 September were excluded from the analysis since tagging did not begin until 11 September and it was assumed that tagged fish could not have reached Marblemount by this date. In addition, there was a distinct break between this sample and the next sample collected at Marblemount on 11 October (Appendix Table A-1). A total of 4,975 coho salmon were examined at Marblemount. Of these, 4,718 were examined after 15 September and 68 tagged fish (1.4%) were found. The Marblemount Hatchery sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ.

Baker River Trap:

Escapement samples were collected at Baker River trap from 13 September through 26 January. A total of 2,890 coho salmon were examined for tags. Based upon a four-day minimum travel time from the tagging area to Baker River dam determined from all five years of tagging data (Conrad et al. 1997), samples collected prior to 15 September were not considered in-sample

Table 3. Summary of the percentage of tagged or marked coho salmon found in each recovery area during in-sample surveys of the Skagit River, 1989.

Recovery Area	Time Period	Fish Examined	Tags Found[a]	% Tagged (ρ)
Marblemount Hatchery	X.[b] 15-Sep	257	0	0.0%
	1. 11-Oct - 17-Jan	4,718	68	1.4%
Baker River Trap	X. 13-Sep	47	0	0.0%
	1. 15-Sep - 26-Jan	2,843	17	0.6%
Commercial Fishery	1. 13-Nov - 15-Nov	172	5	2.9%
	2. 13-Dec - 17-Jan	449	3	0.7%
	Total	621	8	1.3%
Middle Skagit Sub-basin	1. 04-Nov - 07-Feb	731	13	1.8%
Middle Sauk Sub-basin	1. 16-Nov - 08-Feb	497	10	2.0%
Upper Skagit Sub-basin	1. 17-Nov - 07-Feb	272	5	1.8%
Lower Sauk Sub-basin	1. 16-Nov - 06-Feb	217	4	1.8%
Cascade Sub-basin	1. 11-Oct - 09-Jan	78	0	0.0%
Suiattle Sub-basin	1. 30-Nov - 26-Jan	43	0	0.0%
Upper Sauk Sub-basin	1. 21-Nov - 29-Jan	8	0	0.0%
IN-SAMPLE TOTAL FOR UPSTREAM AREAS		10,028	125	1.2%
Carpenter Sub-basin	1. 15-Oct - 04-Jan	42	0	0.0%
Nookachamps Sub-basin	1. 07-Nov - 31-Jan	269	0	0.2%
Commercial Fishery (downstream)	1. 13-Sep - 02-Jan	627	7	1.1%
Test Fishery (downstream)	1. 20-Sep - 13-Nov	1,003	0	0.0%
IN-SAMPLE TOTAL FOR DOWNSTREAM AREAS		1,941	7	0.4%
TOTAL CONSIDERED IN POPULATION BEFORE TAGGING		304	0	0.0%
IN-SAMPLE TOTAL FOR ALL AREAS		11,969	132	1.1%
GRAND TOTAL FOR ALL SAMPLES		12,273	132	1.1%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

[b] X indicates that these fish were considered to be in the population before tagging began and not subject to tagging (i.e., they were not considered in-sample fish for the abundance estimates).

Table 4. Average day of release (DOR) and average number of days between release and recovery (DBET) for coho salmon tagged and recovered in the Skagit River, 1989.

Recovery Area	Sample Size[a]	Average DOR	Stand. Error	Range	Average DBET	Stand. Error	Range
Marblemount Hatchery:							
Pond Mortalities	8	9-Oct	3.7	18-Sep - 23-Oct	47.5	6.5	29 - 78
Spawned	52	13-Oct	1.7	15-Sep - 30-Oct	43.0	2.0	19 - 85
Baker River Trap	15	9-Oct	3.4	11-Sep - 23-Oct	25.3	3.2	8 - 53
Commercial Fishery	12	19-Oct	2.2	9-Oct - 30-Oct	28.3	3.7	13 - 52
Middle Skagit Sub-basin	7	25-Oct	1.2	23-Oct - 30-Oct	43.3	6.4	14 - 64
Middle Sauk Sub-basin	3	13-Oct	3.3	10-Oct - 20-Oct	72.7	13.1	52 - 97
Upper Skagit Sub-basin	4	19-Oct	4.2	10-Oct - 30-Oct	49.3	4.1	39 - 59
Lower Sauk Sub-basin	3	23-Oct	4.9	17-Oct - 2-Nov	60.3	5.9	53 - 72
All Recoveries	104	14-Oct	1.2	11-Sep - 2-Nov	40.7	1.7	8 - 97

[a] Includes tag recoveries with legible numbers only.

since tagging did not begin until 11 September. From 15 September through 26 January, 2,843 coho salmon were examined for tags and 17 tagged fish (0.6%) were found (Appendix Table A-2). The Baker River trap sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ.

Commercial and Test Fishery Samples:

A commercial fishery was conducted in the river and in Skagit Bay on 38 days between 12 September and 17 January. Catches from areas above and below the tagging site were sampled. A total of 621 coho salmon were examined for tags and 8 tagged fish (1.3%) were found in catches from areas above the tagging site (Appendix Table A-3). All tags were recovered during the period from 13 November to 15 December. No tags were found in the samples collected during the period 20 December to 17 January even though about half (46%) of the total upstream sample was collected during this period. For the upstream samples, there was a significant difference (Fisher's exact test, $P < 0.041$) in ρ between the catches sampled before 16 November and those sampled after this date. Seven tagged coho salmon were found in 627 fish examined (1.1%) from catches in downstream areas (including Skagit Bay). Recovery data collected from the downstream areas were considered out-of-population and not used for the abundance estimates.

The total commercial catch in 1989 from the Skagit River terminal areas was 9,365 coho salmon of which 6,693 fish were taken in areas 8, 8E, and 78C, and 2,672 fish were caught in the Upper Skagit River fishery. For the jawtag samples that were identified by sub-area from those sampled from the Upper Skagit River fishery, 80.5% were from Areas 78D-3 and 78D-4 (401 out of 498 fish sampled). Therefore, we estimated that 80.5% of the Upper Skagit catch, or 2,152 coho salmon, came from areas 78D-3 and 78D-4. The total commercial catch from the downstream areas was estimated to be 7,213 coho salmon (6,693 fish from the lower river areas plus 520 fish estimated in the Upper River commercial catch).

Test fisheries were conducted on 12 days between 20 September and 13 November. A total of 1,003 coho salmon were examined for tags but no tagged fish (0.0%) were found (Appendix Table A-4).

Middle Skagit Sub-basin:

Tag recovery samples were collected during surveys of Middle Skagit sub-basin spawning grounds conducted from 15 November through 7 February and at a trap on Etach Slough operated from 4 November through 6 February. Surveys were conducted by SSC crews. There was not a significant difference in ρ between samples collected during surveys and at the trap (χ^2, $P = 0.77$) so the samples were combined. A total of 731 coho salmon were examined for tags and 13 tagged fish (1.8%) were found (Appendix Table A-5). The hypothesis of constant ρ for temporal strata in the recovery samples could not be rejected.

Upper Skagit Sub-basin:

Tag recovery samples were collected during surveys of Upper Skagit sub-basin spawning grounds conducted from 17 November through 7 February. Surveys were conducted by SSC crews. A total of 272 coho salmon were examined for tags and five tagged fish (1.8%) were found (Appendix Table A-6).

Lower Sauk Sub-basin:

Tag recovery samples were collected during surveys of Lower Sauk sub-basin spawning grounds conducted from 16 November through 6 February. Surveys were conducted by SSC crews. A total of 217 coho salmon were examined for tags and four tagged fish (1.8%) were found (Appendix Table A-7).

Middle Sauk Sub-basin:

Tag recovery samples were collected during surveys of Middle Sauk sub-basin spawning grounds conducted from 16 November through 8 February. Surveys were conducted by SSC crews. A total of 497 coho salmon were examined for tags and ten tagged fish (2.0%) were found (Appendix Table A-8). The hypothesis of constant ρ for temporal strata in the recovery samples could not be rejected.

Upper Sauk Sub-basin:

Tag recovery samples were collected during surveys of Upper Sauk sub-basin spawning grounds conducted from 21 November through 29 January. Surveys were conducted by SSC crews. Only eight coho salmon were examined for tags and no tagged fish (0.0%) were found (Appendix Table A-9).

Suiattle Sub-basin:

Tag recovery samples were collected during surveys of Suiattle sub-basin spawning grounds conducted from 30 November through 26 January. No surveys were conducted between 5 January and 24 January due to road closures. Surveys were conducted by SSC crews. Only 43 coho salmon were examined for tags and no tagged fish (0.0%) were found (Appendix Table A-10).

Other Spawning Ground Surveys:

Spawning ground surveys were conducted in three other areas: Nookachamps sub-basin, Carpenter sub-basin, and Cascade sub-basin. Tag recovery samples were collected during surveys of Nookachamps sub-basin spawning grounds by SSC crews. A total of 269 coho salmon were examined for tags but no tagged fish (0.0%) was found (Appendix Table A-11). Spawning ground surveys of the Carpenter sub-basin were conducted by SSC crews and a trap was operated by SSC on Carpenter Creek Slough. A total of 42 coho salmon were examined for tags but no tagged fish (0.0%) were found in these samples (Appendix Table A-12). SSC

crews surveyed Cascade sub-basin spawning grounds and examined 78 coho salmon (Appendix Table A-13) but no tagged fish (0.0%) were found.

Out-of-System Recoveries:

One jaw tag from the tagging conducted in the Skagit River during 1989 was recovered outside of the Skagit River system. This tag was recovered in the Tulalip Bay (Area 8D) commercial fishery.

Abundance Estimates

Estimates of coho salmon abundance from the tag recovery data for each major recovery area having seven or more tag recoveries are summarized in Table 5. The details of the abundance estimate for each location are in Appendix B. The Petersen estimate was not appropriate for the commercial fishery samples because there was a significant difference in ρ (Fisher's exact test, $P < 0.041$) between recovery samples collected in November and those collected in December and January. However, no feasible solution for Darroch's stratified estimator was found for the commercial fishery data. Even though there were seven tags recovered during commercial catch sampling in the area downstream of the tagging area, these data were not used to generate an abundance estimate. These tags were recovered from areas substantially below the tagging area and we do not feel that coho salmon caught and tagged at the Lyman tagging site randomly mixed in these areas.

The samples from Marblemount Hatchery and Baker River trap were both censuses so they were compared to determine if it was appropriate to pool them. The percentages of tags in the two samples were significantly different (χ^2, $P < 0.01$) so the data were not pooled. The samples from the two sub-basins above the tagging area with seven or more tag recoveries (Middle Skagit and Middle Sauk sub-basins) were compared and there was not a significant difference in ρ between the areas (χ^2, $P = 0.77$). Therefore, samples from these areas were pooled for an estimate. Finally, ρ for Marblemount Hatchery, Baker River trap, and the Middle Skagit and Middle Sauk sub-basins were compared. The differences among ρ were significant (χ^2, $P < 0.14$) when Baker River data were included. When Baker River data were not included in the tests, there was not a significant difference in ρ (χ^2, $P = 0.52$) among the three remaining areas (Marblemount Hatchery, Middle Skagit and Middle Sauk sub-basins). Therefore, samples from these three areas were pooled for an estimate.

Estimates of the number of coho salmon migrating through the lower Skagit River tagging area ranged from 55,096 coho salmon using Middle Sauk sub-basin recovery data to 192,285 coho salmon using Baker River trap recovery data. Pooled Marblemount-Middle Skagit-Middle Sauk data provided the most precise estimate (CV = 9.9%). The estimate with the largest CV was from Middle Sauk sub-basin recovery data (CV = 28.4%).

Table 5. Summary of estimates of the number of coho salmon in the Skagit River escapement using data from each major recovery area, 1989.

Recovery Area	Estimation Method	Estimated Abundance	Stand. Error	CV[a]	95% Confidence Interval
Marblemount	Petersen	83,231	9,591	11.5%	68,260 - 110,429
Baker River	Petersen	192,285	43,647	22.7%	116,227 - 326,695
Middle Skagit	Petersen	63,631	16,178	25.4%	35,556 - 118,223
Middle Sauk	Petersen	55,096	15,657	28.4%	28,284 - 113,618
M. Skagit - M. Sauk - pooled	Petersen	62,320	12,220	19.6%	40,557 - 97,509
Commercial Fishery	no feasible estimate				
Marblemount - Middle Skagit - Middle Sauk	Petersen	78,667	7,782	9.9%	65,997 - 99,805

[a] CV = coefficient of variation.

Additional Analyses

The release data were divided into ten, 10-day time periods for the migratory timing analysis and to describe temporal patterns in the length and sex composition of tagged coho salmon. Coho salmon were tagged and released during six of these periods.

Timing of Migrations to Major Recovery Areas:

The CPUE of coho salmon by the beach seine in the lower river tagging area is shown by day and for each 10-day period in Figure 6. CPUE peaked during the 21 October through 30 October time period. Two areas had ten or more recoveries of legible tags which could be used for the migratory timing calculations (Appendix Table A-14). The trends in CPUE of Marblemount Hatchery fish and fish bound for Baker River were very similar to the trend for total CPUE by 10-day period (Figure 7). CPUE of both groups peaked during the 21 October to 31 October period. There were no tags recovered from either of these groups from releases after this period.

Length and Sex Composition Analyses:

The sex and length data for the 1,216 coho salmon tagged and released in the lower Skagit River and the 104 in-sample recoveries with legible tags were analyzed. Both the K-S and M-W tests which compared the lengths of coho salmon tagged but not recovered to the lengths of those tagged and recovered were not significant ($P > 0.15$) indicating that the recovery samples were random with respect to length of fish. However, there was a significant difference between male and female length distributions (K-S test, $P < 0.01$), therefore, all subsequent analyses of length were conducted for each sex separately. It is evident from Figure 8 that male coho salmon had a higher proportion of smaller sizes (fish less than 50 cm) than female coho salmon. Coho salmon less than 50 cm in length composed about 29% of the males that were tagged but only 8% of the female coho salmon that were tagged.

Males Tagged male coho salmon averaged 54.1 cm in fork length (SE = 0.32). The mean length of male coho salmon that were tagged but not recovered was 54.0 cm (SE = 0.34) compared to a mean length of 55.2 cm (SE = 1.10) for male coho salmon that were tagged and recovered. The length distribution of male coho salmon that were tagged but not recovered was not significantly different (K-S test, $P = 0.81$) from the distribution of those that were tagged and recovered (Figure 9). Therefore, sequential K-S tests were not conducted (Appendix Table A-15).

Females Tagged female coho salmon averaged 57.3 cm in fork length (SE = 0.26). The mean length of female coho salmon that were tagged but not recovered was 57.3 cm (SE = 0.27) compared to a mean length of 58.0 cm (SE = 0.80) for female coho salmon that were tagged and recovered. The length distribution of female coho salmon that were tagged but not recovered was not significantly different (K-S test, $P = 0.55$) from the distribution of those that were tagged and recovered (Figure 9). Therefore, sequential K-S tests were not conducted (Appendix Table A-15).

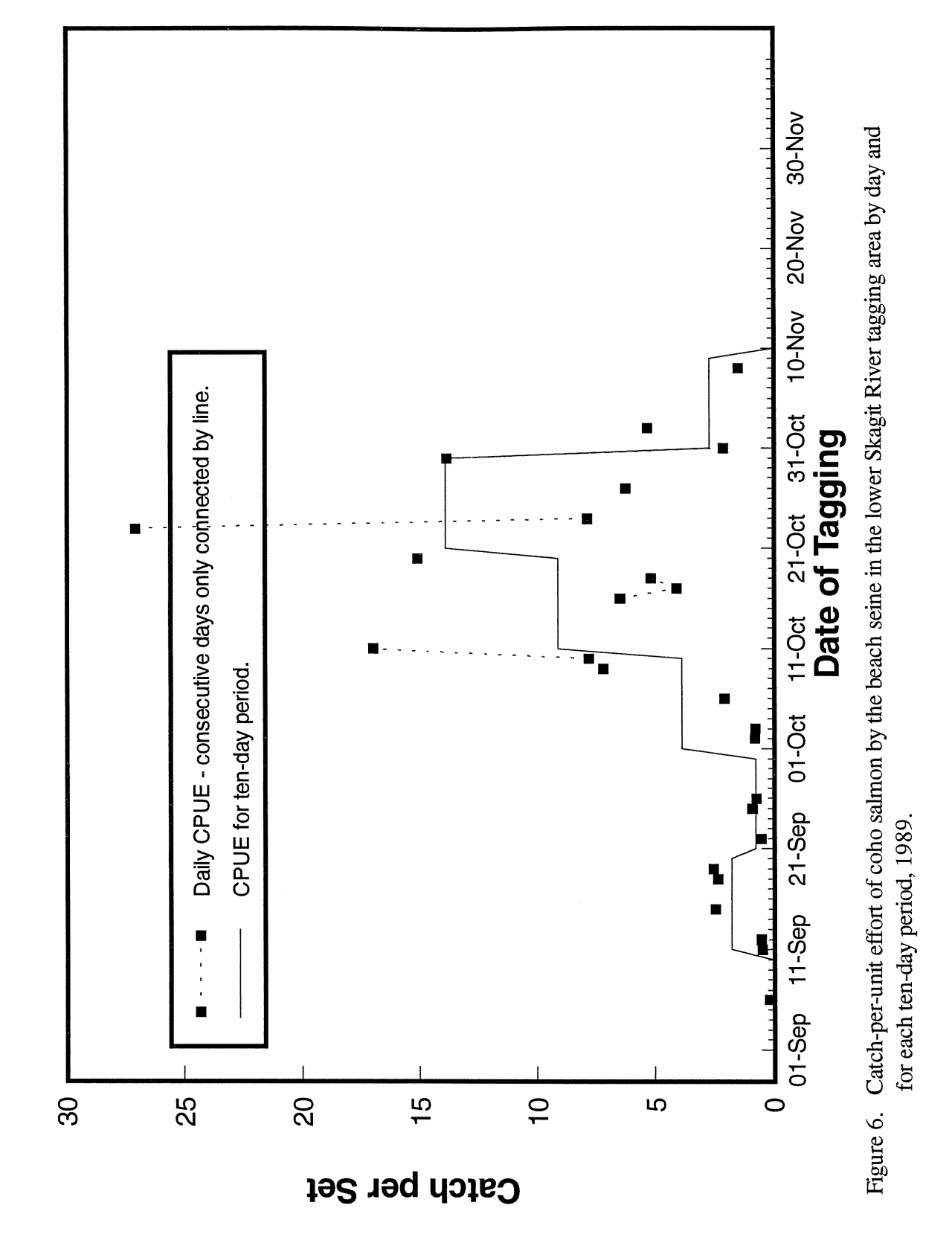

Figure 6. Catch-per-unit effort of coho salmon by the beach seine in the lower Skagit River tagging area by day and for each ten-day period, 1989.

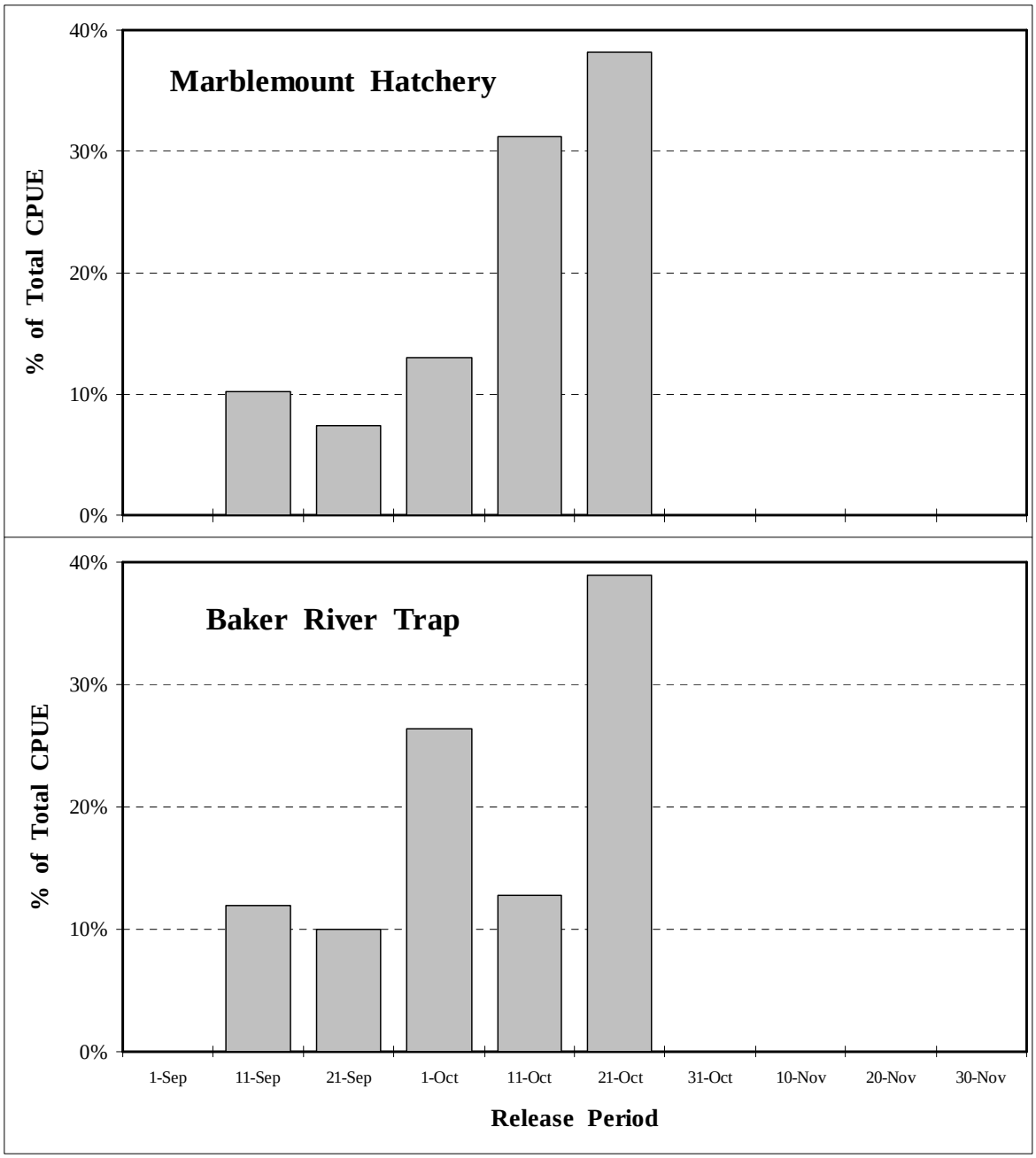

Figure 7. Beach seine catch-per-unit effort (CPUE) of coho salmon bound for major Skagit River tag recovery areas in 1989. CPUE is for ten-day periods (starting date of period shown) and is expressed as a percentage of the total CPUE for tagged fish recovered from the area.

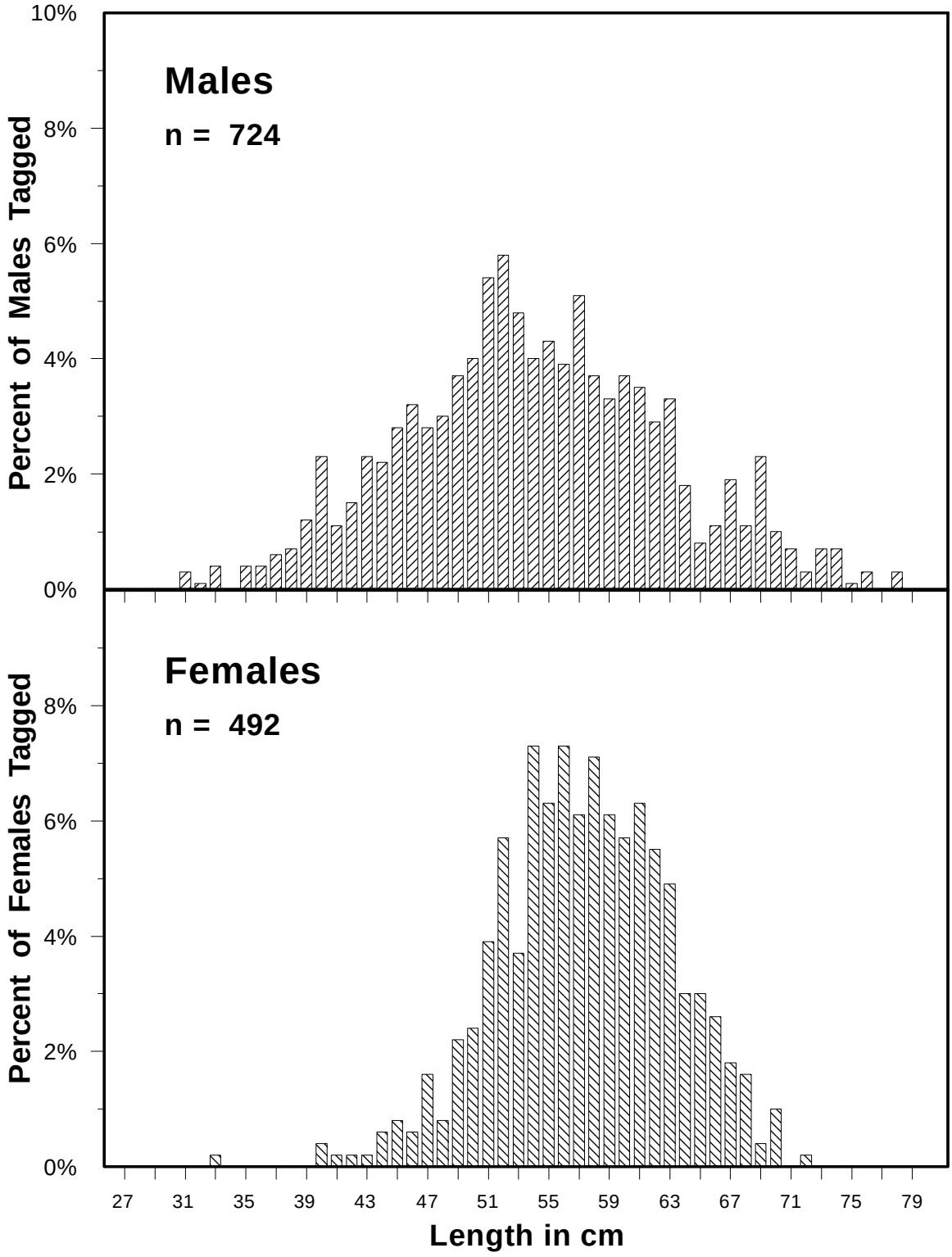

Figure 8. Comparison of length frequencies of male and female coho salmon tagged in the lower Skagit River, 1989.

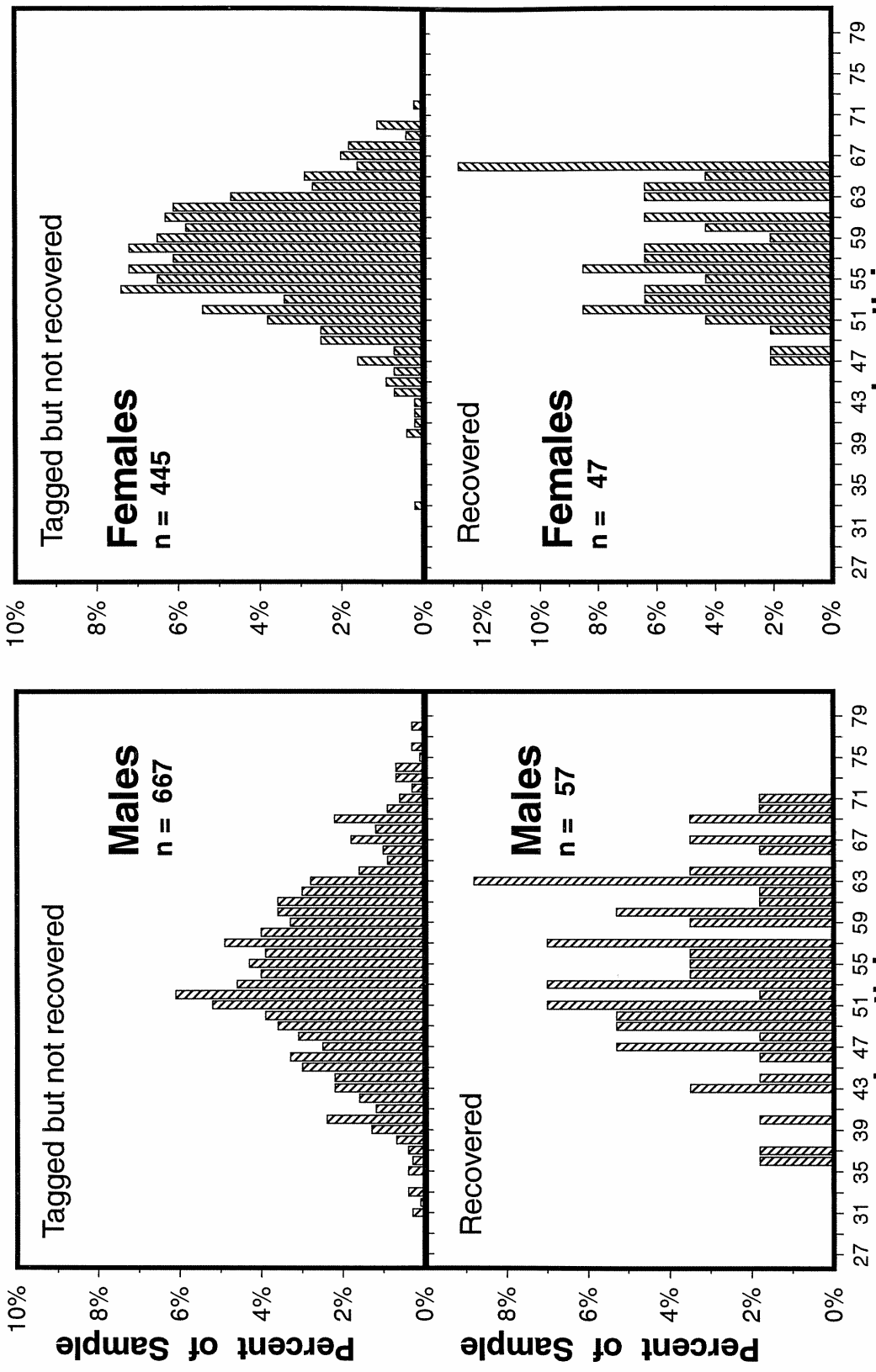

Figure 9. Comparison of length frequencies of coho salmon that were tagged but not recovered to those that were tagged and recovered, for males and females, 1989.

Tag Recovery Rates There was not a significant difference (χ^2, $P = 0.31$) in tag recovery rates between male and female coho salmon. Tag recovery rates were 7.9% and 9.6% for male and female coho salmon, respectively (Appendix Table A-16). There was not a significant difference in tag recovery rates among the release condition categories (χ^2, $P = 0.44$) or the maturity categories (χ^2, $P = 0.96$) either (Appendix Table A-16).

Sex-Length Composition There were temporal changes in both the sex composition and length composition for each sex during the tagging period (Figure 10). The percentage of males in the tagging samples gradually declined (from 74% to 52%) throughout the release period and the percentage of females gradually increased (from 26% to 48%). Both male and female coho salmon were classified into two length groups, small (≤ 49 cm) and large (≥ 50 cm). The percentage of small males decreased throughout the release period as the percentage of large males increased. The large length group composed 75% or more of the female coho salmon tagged throughout the period of tagging.

Conclusions

In 1989, the percentage of tags (ρ) in the samples from the major recovery areas (areas with seven or more tag recoveries) was much more variable than in the previous years of the study (1986, 1987, and 1988). The percentage of tagged or marked coho salmon ranged from 0.6% for the samples at Baker River trap to about 2% for the samples from the Middle Skagit sub-basin (1.8%) and Middle Sauk sub-basin (2.0%). The Marblemount Hatchery (1.4%) and commercial fishery samples (1.3%) were between these extremes. There were no tags recovered from spawning areas below the tagging site. However, there were seven tags recovered in 627 coho salmon examined (1.1%) from commercial catch samples in areas substantially downstream of the tagging site.

In 1989, there was a significant difference in ρ between the samples collected at Marblemount Hatchery and the Baker River trap samples. Both of these groups are censused. This is the first time that these two groups have had significantly different ρ during the four years of tagging. One possible explanation for the difference between the two samples in 1989 is that a greater portion of the group of fish bound for Baker River passed the tagging site before tagging began than we estimate. We assume a minimum travel time of four days between the tagging site and the Baker River trap. Therefore, in 1989 we assumed that all fish caught at the trap after 14 September had been exposed to capture by the beach seine used to catch fish for tagging. The first tagged fish was not observed at Baker River trap until 11 October, however, by which time 975 adult coho salmon (or 33% of the total number of fish counted at Baker River trap in 1989) had been sampled at the trap. The period between the date when we assumed the first group of fish subject to capture in the lower river were available at Baker River trap (assuming a minimum four-day travel time) and the first day a tagged fish was actually observed at the trap was 26 days in 1989. This was the longest time for this period during the four years of tagging (10 days in 1986, 18 days in 1987, and 7 days in 1988). Rather than make further adjustments to the number sampled at Baker River trap, we chose to be consistent throughout the study and use the four-day minimum travel time criteria. Therefore, we did not adjust the number sampled at Baker River trap and did not include the Baker River data in the data used for the "best" estimate.

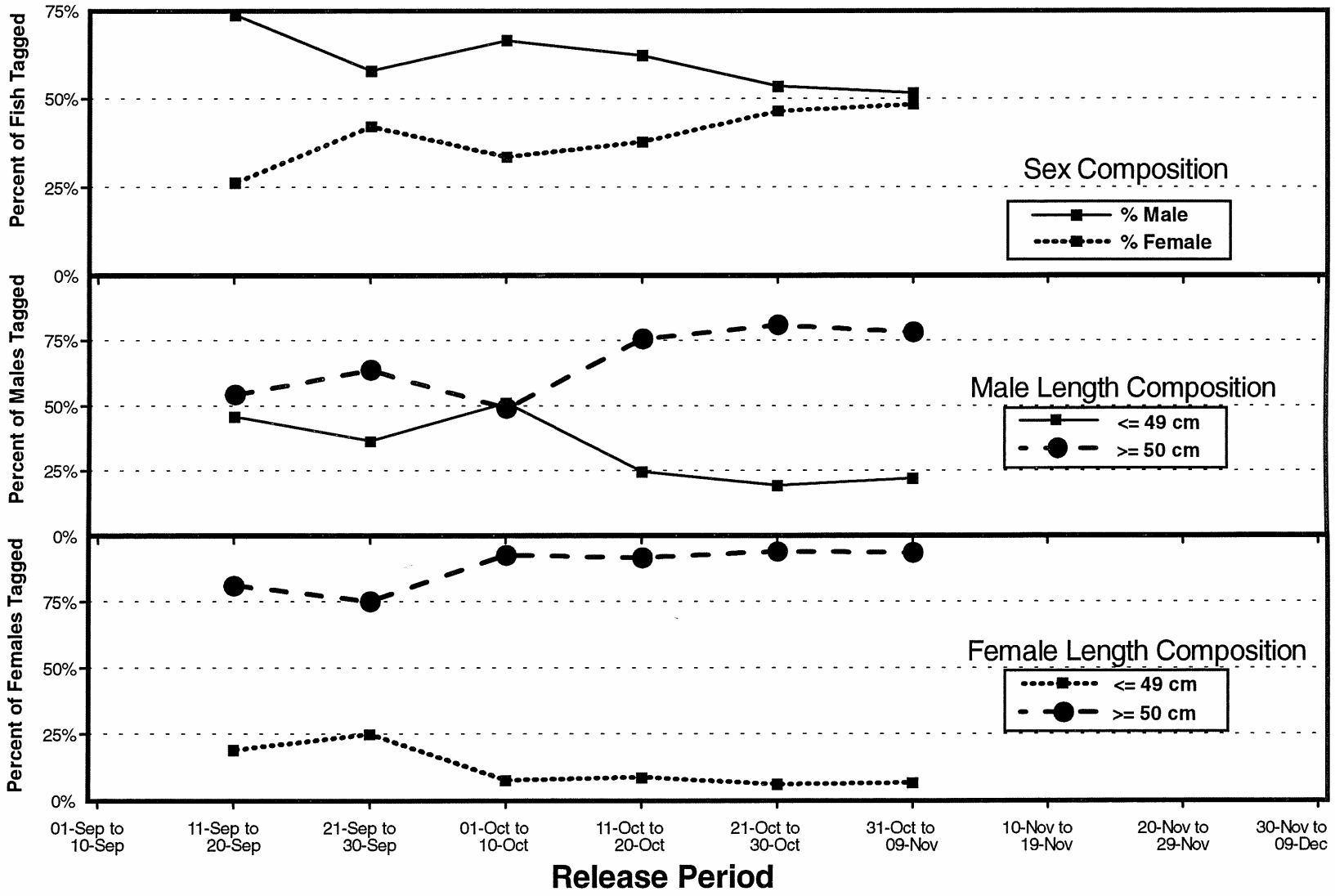

Figure 10. Sex and length composition, by release period, of coho salmon tagged in the lower Skagit River, 1989.

We recommend that the estimate using the pooled Marblemount-Middle Skagit-Middle Sauk data be considered the "best" estimate of coho salmon abundance for 1989. There was not a significant difference in ρ among these areas. The samples from Marblemount Hatchery are a census. There were no temporal differences in ρ for the samples from the two sub-basins. This estimate uses the largest number of tag recoveries (91) and therefore has the smallest CV.

The estimate, 78,667 coho salmon (95% confidence interval: 65,997 to 99,805), is for the number of fish present in the lower Skagit River tagging area during the period 11 September to 8 November. Unlike in 1986, 1987, and 1988, there is no evidence that coho salmon from spawning areas downstream of the tagging site were present in the tagging area. No tags (0) were recovered from 311 coho salmon examined in the escapement to the Nookachamps and Carpenter sub-basins. However, we feel that some coho salmon from these areas were present as in previous years but the level of sampling in 1989 was not sufficient to detect them. Also, the tagged fish recovered from the commercial fishery in areas downstream of the tagging site provide additional evidence that coho salmon from downstream spawning areas were present at the tagging site. Therefore, the estimate includes coho salmon bound for all spawning grounds above the tagging area and some portion of the escapement to areas downstream of the tagging site.

DISCUSSION

The number of coho salmon in the escapement to the Skagit River was estimated using the tag release-and-recovery data and the Petersen model. A discussion of how well the data meet the major assumptions of the Petersen model and a definition of the "population" which is being estimated follows.

Population was Closed

We assume that some coho salmon migrated through the tagging area before and after the period of tagging (11 September through 8 November). Although the Petersen model generally assumes a closed population, the population can be open but the exact point in time to which the estimate applies must be specified (Seber 1982). We feel the trend in CPUE for the beach seine used to capture coho salmon for tagging provides strong evidence that the tagging period encompassed the major portion of the coho salmon migration. The CPUE was low when tagging began and was followed by an increase in CPUE to a peak during the period 21 October through 30 October. This was followed by a decline in CPUE during early November (Figure 6).

Similarly to 1986, 1987, and 1988, adjustments were made to the total number of fish examined at Baker River trap and Marblemount Hatchery to account for early-arriving fish that were not subject to tagging. Therefore, the estimate includes only the portion of the population migrating through the tagging area after tagging began.

If we assume there is recruitment to the population (coho salmon migrating through the tagging area after tagging ends) but no mortality before the fish reach their spawning areas, and there is complete mixing of the fish on the spawning grounds, then the abundance estimate includes coho salmon migrating through the tagging area after the last day of tagging. Sampling at Marblemount Hatchery and at Baker River trap was conducted through 17 and 26 January, respectively. Tag recovery surveys were conducted in most sub-basin spawning grounds until late January or early February. We feel there was sufficient time for coho salmon migrating through the tagging area after tagging had ended to mix with the fish already present on the spawning grounds and at Marblemount Hatchery.

Area Encompassed by the Estimates:

The Petersen model estimates the number of coho salmon migrating though the tagging area in the lower river during the time period defined above. The estimate includes all coho salmon bound for spawning areas above the tagging area (including Marblemount Hatchery and Baker River) and all spawning areas in the Middle Skagit sub-basin above and including Hansen Creek (Figure 1). However, the percentage of tags in the combined samples from areas downstream of the tagging site, 0.04% (including downstream commercial and test fishery samples), was much smaller than in the upstream recovery areas. Although no tags were recovered from 311 coho salmon examined in the escapement to the Nookachamps and

Carpenter sub-basins, we feel that some coho salmon from these areas were present in the tagging area, as in previous years, but the level of sampling in 1989 was not sufficient to detect them. Therefore, we conclude that the abundance estimate includes only a portion of the coho salmon which spawned in the Carpenter and Nookachamps sub-basins. If the total number of tagged fish that migrated to these downstream areas could be estimated, this number could be removed from the total number of tags released and the abundance estimate would include only coho salmon bound for areas **upstream** of the tagging site and the Middle Skagit sub-basin. We estimated the number of tags "lost" to these downstream areas so that we could examine the effect of these tags on the abundance estimate for the upstream areas.

Estimate of the Number of Tagged Fish "Lost" to Areas Downstream of the Tagging Area:

Three groups of fish from areas downstream of the tagging area were examined for tags: (1) commercial fishery catches; (2) test fishery catches, and (3) fish spawning in the Carpenter and Nookachamps sub-basins. The commercial catch in area 78D was sampled by subareas (78D-2, 78D-3, and 78D-4; see Figure 4) in 1989 so we could estimate the percentage of tags in samples above and below the tagging area. The total commercial catch from area 78D is not recorded by these sub-areas, however. Therefore, we assumed that the proportional catch by sub-area for the commercial catch samples was the same as the entire commercial catch for area 78D. We pooled all catches and applied the percentage of tags found in downstream commercial and test fishery samples (Area 2, Spudhouse, Blakes, and Jetty; see Figure 4) to the pooled total. The number of tagged fish present on spawning grounds in the Carpenter and Nookachamps sub-basins was estimated by applying the percentage of tags found during in-sample surveys of these sub-basins combined (no tagged fish found in 311 fish examined for $\rho = 0.00\%$) to an independent estimate of the number of coho salmon spawning in these sub-basins. The spawning ground escapement to these sub-basins was estimated using a redd-count method (Conrad et al. 1993). There was one out-of-system tag recovery in 1989; this recovery was a voluntary recovery so it was not expanded. The numbers used for these calculations are summarized in Appendix Table A-17. We estimated that a total of 15 tags could have been "lost" to these downstream areas. If the number of tags released is adjusted to 1,201 (1,216 - 15), then (using the pooled Marblemount-Middle Skagit-Middle Sauk recovery data) the estimated abundance for areas upstream of the tagging area becomes 77,698 coho salmon. This is only 969 fish less than the "unadjusted" estimate which is about a one percent difference.

The presence of coho salmon bound for systems outside the Skagit River in the lower river tagging area would also affect the abundance estimate. In 1989, the single out-of-system recovery of a coho salmon tagged in the lower Skagit River was from Tulalip Bay. We do not feel that the contribution of coho salmon bound for systems outside the Skagit River was a major source of error in 1989.

All Coho Salmon Have an Equal Probability of Capture During Tagging or the Recovery Sample is a Simple Random Sample of the Population

These assumptions are often hard to satisfy as it is difficult or impossible to obtain simple random samples from highly dispersed and mobile populations. Fortunately, the estimates are still valid under certain alternative assumptions. Junge (1963) demonstrated that selectivity (non-randomness) may exist in both the tagging and recovery samples without introducing bias in the estimate if the sources of selectivity in the two samples are independent.

During the Skagit River study, there is evidence that the tagging sample may not have been random with respect to time. Certain portions of the population may have been tagged at higher rates than others. In 1989, there was no evidence that the recovery samples on the spawning grounds were selective with respect to the length of the fish but there was evidence that this occurred in previous years (Conrad et al. 1997, 1998a, 1998b). Eames et al. (1981, 1983) found that there was a correlation between time of entry and size of coho salmon for the returns to the Skagit River in 1976 and 1977. Smaller fish generally arrived earlier in the run than larger fish. This presents a problem if timing of passage through the tagging area is correlated with the size of fish and area of spawning (Junge 1963). If such selectivity had existed, the population estimates would have contained a negative bias. However, even if there had been such a bias, it would have been small, because the majority of the tag recovery data was collected from an area where there was no size selectivity (Marblemount Hatchery).

The use of different gears to obtain the tagging and recovery samples is a common technique for minimizing the bias due to selectivity (Ricker 1975; Seber 1982). In this study, coho salmon were captured for tagging using a beach seine. Recovery samples were either a census of all adults returning to an area (Marblemount Hatchery and Baker River trap) and thus non-selective, or were samples collected on the spawning grounds during foot surveys (and to a lesser extent by traps in some areas). We do not feel that selectivity (non-random sampling) was a significant source of bias for the estimates because: (1) the method used to capture coho salmon for tagging was different from the methods used to recover them; and (2) a majority of the tag recoveries used to estimate abundance were collected by a census.

Tagging Does Not Affect the Catchability of an Animal

This assumption is necessary because some of the coho salmon passing through the tagging area were subject to an in-river commercial fishery above the tagging area. If jaw-tagged coho salmon were removed at a different rate than untagged fish, the percentage of tags in any recovery samples collected after this removal would be different from the percentage of tags in the population immediately after tagging. There is no evidence of selective removal of tagged fish in the data. In 1989, the percentage of tagged fish in the commercial fishery samples from sub-areas of 78D upstream of the tagging area was essentially the same as that observed at Marblemount Hatchery and lower than that observed in the samples collected from spawning grounds in the Middle Skagit and Middle Sauk sub-basins. If tags were being removed selectively, we would expect the commercial fishery samples to have a higher percentage of tags than these samples.

Animals Do Not Lose Their Tags Between the First and Second Samples

In 1989, 21% of the tagged coho salmon recovered had missing or illegible tags. However, the use of opercula punches on all tagged fish allowed coho salmon with missing tags to be identified as previously tagged. Identified tag loss must be accounted for only in the Darroch estimate of abundance which requires that the release period of recovered individuals be known. When there was no tag but an operculum punch was present (or the tag was illegible), the release period was estimated as described in the Methods section. This was required only when the Darroch estimate was selected as the appropriate model. The Darroch estimate was not used for any of the abundance estimates produced in 1989. The Petersen estimate was selected as the appropriate model for all estimates. As long as all coho salmon with a missing tag are identified by an operculum punch, the Petersen estimate is not affected by the missing tags.

All Tagged Animals are Reported in the Second Sample

Because the majority of the tag recoveries used for the abundance estimates were from Marblemount Hatchery, and all coho salmon at Marblemount Hatchery were inspected twice for tags, we expect very few jaw-tagged (or marked) fish were missed. Live fish were individually inspected for tags and marks at Baker River dam. During surveys of spawning grounds, surveyors carefully inspected each carcass for an operculum punch if no tag was visible. Considering that some carcasses were in an advanced state of decay it is possible that some fish with a missing tag were not identified. In 1989, about 8% of the carcasses examined on the upriver spawning grounds (Middle Skagit sub-basin and above) could not be sampled because of their condition.

There are No Mortalities Due to Tagging

Tests to determine the extent of tagging mortality were conducted during four of the five study years. These tests and their results are documented in Conrad et al. (1997). Based on these tests we concluded that there was no evidence of tagging mortality. The tests provided strong evidence that there was no short-term (within 48 hours) tagging mortality. The tag recovery data from the commercial fishery samples provide additional evidence that there was no delayed tagging-induced mortality occurring from two weeks up to three months after tagging. The average time between tag release and recovery for the commercial fishery recoveries, about 28 days (Table 4), was the shortest of any of the upstream recovery areas except Baker River trap. Since the coho salmon caught in the commercial fishery are caught relatively soon after tagging, we would expect that if there is any delayed mortality caused by tagging it would cause the commercial fishery samples to have a higher percentage of tags than the samples that are taken much later, further upstream. In 1989, ρ for the commercial fishery samples from upstream areas (1.3%) was very similar to that for Marblemount Hatchery and less than that observed in the samples from spawning grounds above the tagging site which had tag recoveries.

CONCLUSIONS

The estimated abundance of coho salmon in 1989 was 78,667 fish with a 95% confidence interval of 65,997 to 99,805 fish. The mark-recapture estimate is for the number of coho salmon migrating through the tagging area after tagging began on 11 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was relatively precise (CV = 9.9%) because of the large number of fish examined for tags during in-sample surveys. To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 77,698 coho salmon. The variance of this estimate was not calculated because of the unknown precision for the estimated number of tags "lost" to downstream areas. The adjusted estimate falls within the 95% confidence interval of the original estimate.

To estimate the number of "wild" coho salmon which reached upstream spawning areas in the Skagit River in 1989, the number of hatchery fish plus any catches by the commercial and test fisheries above the tagging area need to be removed from the adjusted estimate and the number of fish which migrated through the tagging area prior to tagging needs to be added. However, fish which migrated through the tagging area before tagging began, and reached the spawning grounds, are already included in the spawning ground samples. In-population sport catches should also be subtracted from the adjusted population estimate. In-river catches of coho salmon by the sport fishery in the Skagit River were estimated to be only 145 fish in 1989 (WDF 1992) and were not included in the summary total as the specific dates and areas of harvest of these fish are unknown.

To estimate the total return to the upriver areas, prior-migrating fish returning to Baker River and Marblemount Hatchery, and fish caught in upper river fisheries before tagging started, need to be added. Since these returns were censused, we have a total count of the prior-migrating fish to these areas, 1,788 fish. A summary of the total terminal area run of coho salmon to the Skagit River in 1989 is presented in Table 6**. The total terminal area run of coho salmon to the Skagit River in 1989 is estimated to be 110,668 fish. An estimated 93,687 coho salmon were in the "wild" escapement to Skagit River spawning grounds**: 70,979 fish were estimated to have reached upstream spawning grounds and 22,708 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basin) spawning grounds. For comparison, the escapement of "wild" coho salmon to Skagit River spawning grounds estimated using index area surveys was 17,000 fish (Jeff Parkhurst, WDFW, personal communication). An alternative estimate, derived from CWT recoveries in the test fisheries and trap recoveries (Hayman 1996), was for a wild escapement of 30,000 to 34,000 fish (depending upon the hatchery stray rate assumed); this estimate was subsequently refined for a wild escapement estimate of 35,793 fish (Hayman 1997). Using a redd-count method, Conrad et al. (1993) estimated the wild escapement to be 52,700 to 79,100 fish (assuming two or three coho salmon per redd, respectively).

Table 6. Summary of the number of coho salmon returning to Skagit Bay in 1989.

Component	In-Population	Out of Population	Total
Upstream Estimated Total	77,698	2,046	79,744
Marblemount Hatchery	4,718	257	4,975
Baker River Hatchery[a]	1,522	116	1,638
Area 78D-3, 78D-4 Commercial Catch	737	1,415	2,152
Upstream Test Fishery Catch	0	0	0
Upstream Removals and Hatchery Fish	6,977	1,788	8,765
Estimated "Wild" Escapement to Upstream Spawning Areas	70,721	258	70,979
Nookachamps Sub-basin Estimated Escapement		21,747[b]	21,747
Carpenter Sub-basin Estimated Escapement		961	961
Areas 78D-1, 78D-2, 78C, 8E, 8 Commercial Catches		7,213	7,213
Downstream Test Fishery Catch		1,003	1,003
Downstream Total		30,924	30,924
"Wild" Escapement[c] to Spawning Grounds	70,721	22,966	93,687[d]
Total Terminal Run to Skagit Bay	77,698	32,970	110,668[d]

[a] Total number of hatchery coho salmon that returned to the Baker River trap. All coho salmon smolts from the Baker River Hatchery in the 1986 brood year (which primarily returned during 1989) were adipose fin clipped. The total return of coho salmon to the Baker River trap was 3,267 fish in 1989 (327 fish returned prior to 13 September when sampling began). Of these, 1,638 fish had adipose fin clips (i.e., were hatchery fish) and 1,629 were unmarked fish (assumed to be wild coho salmon). Of the unmarked fish, 258 returned prior to the first day of tagging and were considered out-of-population. The wild totals are included in the "wild" escapement numbers.

[b] The estimate of the number of wild coho spawning in the Nookachamps sub-basin in 1989 was unusually high compared to the other years of the study (see Appendix Table A-17C). This estimate (21,747 fish) was mainly due to the large number of redds (330) and timing of redd construction for one specific survey section in the Nookachamps sub-basin. This estimate should be viewed with caution because of the large influence of this single survey section. In comparison, the Nookachamps escapement in the other years was estimated to be 10,306 fish in 1986, 3,339 fish in 1987, and 1,405 fish in 1986.

[c] Includes estimated "wild" escapement to upstream spawning areas and estimated escapement to the Nookachamps and Carpenter sub-basins (from Conrad et. al 1993).

[d] The estimated catch by the in-river sport fishery was 145 coho salmon, but the specific dates and areas of harvest of these fish are unknown. The total wild escapement should be reduced by the number of coho salmon caught in the sport fishery in upstream areas after tagging began. The total terminal run should be increased by the number caught in downstream areas or before tagging started.

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APPENDIX A

Summary tables of sample data for 1989.

Appendix Table A-1. Summary of coho salmon escapement samples collected at Marblemount Hatchery in 1989.

Sample Date	Sample Method	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
15-Sep	Spawned	257	0	0.0%
11-Oct	Pond Mortality	1	0	0.0%
	Surplussed	91	0	0.0%
	Total	92	0	0.0%
17-Oct	Pond Mortality	1	1	100.0%
13-Nov	Pond Mortality	8	1	12.5%
15-Nov	Pond Mortality	2	1	50.0%
	Spawned	629	8	1.3%
	Total	631	9	1.4%
21-Nov	Pond Mortality	3	0	0.0%
	Spawned	897	29	3.2%
	Total	900	29	3.2%
22-Nov	Pond Mortality	48	1	2.1%
27-Nov	Pond Mortality	26	0	0.0%
29-Nov	Pond Mortality	152	1	0.7%
	Spawned	968	9	0.9%
	Total	1,120	10	0.9%
5-Dec	Pond Mortality	13	0	0.0%
6-Dec	Pond Mortality	26	1	3.8%
	Spawned	336	6	1.8%
	Total	362	7	1.9%
7-Dec	Pond Mortality	43	0	0.0%
11-Dec	Pond Mortality	27	1	3.7%
12-Dec	Pond Mortality	48	1	2.1%
	Spawned	297	3	1.0%
	Total	345	4	1.2%
13-Dec	Pond Mortality	78	0	0.0%
15-Dec	Pond Mortality	61	0	0.0%
18-Dec	Pond Mortality	70	0	0.0%
19-Dec	Pond Mortality	135	0	0.0%
	Spawned	257	1	0.4%
	Total	392	1	0.3%
20-Dec	Pond Mortality	60	0	0.0%
21-Dec	Pond Mortality	56	1	1.8%
22-Dec	Pond Mortality	34	0	0.0%
26-Dec	Pond Mortality	33	1	3.0%
27-Dec	Pond Mortality	25	0	0.0%

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Appendix Table A-1. Summary of coho salmon escapement samples collected at Marblemount Hatchery in 1989 (continued).

Sample Date	Sample Method	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
28-Dec	Pond Mortality	38	0	0.0%
2-Jan	Pond Mortality	38	0	0.0%
3-Jan	Pond Mortality	62	0	0.0%
	Spawned	46	2	4.3%
	Total	108	2	1.9%
4-Jan	Pond Mortality	34	0	0.0%
8-Jan	Pond Mortality	20	0	0.0%
11-Jan	Pond Mortality	4	0	0.0%
12-Jan	Pond Mortality	34	0	0.0%
17-Jan	Pond Mortality	4	0	0.0%
	Spawned	13	0	0.0%
	Total	17	0	0.0%
	Pond Mortality	1,184	10	0.8%
	Surplussed	91	0	0.0%
	Spawned	3,443	58	1.7%
	IN-SAMPLE TOTAL	4,718	68	1.4%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-2. Summary of coho salmon escapement samples collected at Baker River trap in 1989.

Sample Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
13-Sep	47	0	0.0%
15-Sep	38	0	0.0%
18-Sep	49	0	0.0%
20-Sep	28	0	0.0%
22-Sep	71	0	0.0%
25-Sep	92	0	0.0%
27-Sep	40	0	0.0%
29-Sep	86	0	0.0%
2-Oct	127	0	0.0%
4-Oct	288	0	0.0%
6-Oct	101	0	0.0%
9-Oct	55	0	0.0%
11-Oct	56	1	1.8%
13-Oct	122	0	0.0%
16-Oct	198	1	0.5%
17-Oct	25	0	0.0%
18-Oct	103	1	1.0%
19-Oct	76	1	1.3%
20-Oct	46	1	2.2%
23-Oct	113	0	0.0%
25-Oct	126	1	0.8%
26-Oct	114	0	0.0%
27-Oct	109	0	0.0%
30-Oct	121	0	0.0%
1-Nov	63	0	0.0%
3-Nov	90	3	3.3%
6-Nov	191	2	1.0%
13-Nov	96	3	3.1%
15-Nov	30	0	0.0%
17-Nov	10	0	0.0%
20-Nov	36	0	0.0%
22-Nov	30	1	3.3%
27-Nov	15	1	6.7%
29-Nov	21	1	4.8%
1-Dec	12	0	0.0%
8-Dec	25	0	0.0%
12-Dec	10	0	0.0%
15-Dec	3	0	0.0%
19-Dec	3	0	0.0%
22-Dec	6	0	0.0%
29-Dec	3	0	0.0%
5-Jan	6	0	0.0%
12-Jan	7	0	0.0%
19-Jan	1	0	0.0%
26-Jan	1	0	0.0%
IN-SAMPLE TOTAL	2,843	17	0.6%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-3. Summary of coho salmon catch samples collected from the commercial fishery in the Skagit River, 1989.

	UPSTREAM AREAS			DOWNSTREAM AREAS								
	Areas 78D, 78D-3, 78D-4			Areas 78D-1, 78C			Area 78D-2			Areas 8, 78C, 8E		
Sample Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
12-Sep	0	0	0.0%									
13-Sep										59	0	0.0%
20-Sep										7	0	0.0%
21-Sep										18	0	0.0%
22-Sep										22	0	0.0%
25-Sep										2	0	0.0%
4-Oct										16	0	0.0%
17-Oct										29	0	0.0%
18-Oct										29	0	0.0%
19-Oct										40	0	0.0%
20-Oct										10	0	0.0%
24-Oct										25	0	0.0%
25-Oct										9	0	0.0%
26-Oct										6	0	0.0%
27-Oct										9	1	11.1%
30-Oct										116	2	1.7%
31-Oct				7	0	0.0%				9	0	0.0%
1-Nov										5	0	0.0%
3-Nov										5	0	0.0%
6-Nov				24	0	0.0%				56	4	7.1%
8-Nov										1	0	0.0%
13-Nov	41	1	2.4%				28	0	0.0%			
14-Nov	15	0	0.0%				21	0	0.0%			
15-Nov	116	4	3.4%									
4-Dec				5	0	0.0%						
5-Dec				18	0	0.0%						
13-Dec	76	0	0.0%				37	0	0.0%			
14-Dec	64	2	3.1%				7	0	0.0%			
15-Dec	22	1	4.5%	1	0	0.0%						
19-Dec				2	0	0.0%						
20-Dec	156	0	0.0%				3	0	0.0%			
21-Dec	58	0	0.0%									
22-Dec	37	0	0.0%									
28-Dec	31	0	0.0%									
2-Jan				1	0	0.0%						
4-Jan	1	0	0.0%									
10-Jan	1	0	0.0%									
17-Jan	3	0	0.0%									
IN-SAMPLE TOTAL	621	8	1.3%	58	0	0.0%	96	0	0.0%	473	7	1.7%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-4. Summary of coho salmon catch samples collected during test fisheries in the Skagit River, 1989.

Sample Date	Area 2 Number Exam.	Area 2 Tags Found[a]	Area 2 % w/Tags (ρ)	Spudhouse Fish Exam.	Spudhouse Tags Found[a]	Spudhouse % w/Tags (ρ)	Blake's Fish Exam.	Blake's Tags Found[a]	Blake's % w/Tags (ρ)	Jetty Fish Exam.	Jetty Tags Found[a]	Jetty % w/Tags (ρ)
20-Sep				40	0	0.0%						
21-Sep							50	0	0.0%			
27-Sep	50	0	0.0%	32	0	0.0%	35	0	0.0%			
4-Oct	6	0	0.0%	70	0	0.0%	59	0	0.0%			
11-Oct	22	0	0.0%	130	0	0.0%	116	0	0.0%			
18-Oct	26	0	0.0%	96	0	0.0%	67	0	0.0%			
24-Oct	62	0	0.0%									
25-Oct				65	0	0.0%	32	0	0.0%			
1-Nov	26	0	0.0%									
2-Nov							3	0	0.0%			
3-Nov				14	0	0.0%						
13-Nov										2	0	0.0%
IN-SAMPLE TOTAL	192	0	0.0%	447	0	0.0%	362	0	0.0%	2	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-5. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative crews and at a trap on Etach Slough, 1989.

	SURVEYS			ETACH SLOUGH TRAP			SAMPLES COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
4-Nov				6	0	0.0%	6	0	0.0%
6-Nov				6	0	0.0%	6	0	0.0%
7-Nov				2	1	50.0%	2	1	50.0%
15-Nov	1	0	0.0%				1	0	0.0%
17-Nov	1	0	0.0%				1	0	0.0%
20-Nov	5	1	20.0%				5	1	20.0%
21-Nov				5	0	0.0%	5	0	0.0%
22-Nov	6	0	0.0%				6	0	0.0%
23-Nov				2	1	50.0%	2	1	50.0%
24-Nov				2	0	0.0%	2	0	0.0%
25-Nov	2	0	0.0%				2	0	0.0%
26-Nov				1	0	0.0%	1	0	0.0%
27-Nov				1	0	0.0%	1	0	0.0%
28-Nov	22	0	0.0%	3	0	0.0%	25	0	0.0%
29-Nov	5	0	0.0%	2	0	0.0%	7	0	0.0%
30-Nov	13	0	0.0%	2	0	0.0%	15	0	0.0%
1-Dec	9	0	0.0%				9	0	0.0%
3-Dec				36	0	0.0%	36	0	0.0%
4-Dec	5	0	0.0%				5	0	0.0%
7-Dec	18	0	0.0%	6	0	0.0%	24	0	0.0%
8-Dec	2	0	0.0%	3	0	0.0%	5	0	0.0%
9-Dec				3	0	0.0%	3	0	0.0%
10-Dec				4	0	0.0%	4	0	0.0%
11-Dec	21	1	4.8%	5	2	40.0%	26	3	11.5%
12-Dec				4	0	0.0%	4	0	0.0%
13-Dec				1	0	0.0%	1	0	0.0%
14-Dec				1	0	0.0%	1	0	0.0%
15-Dec	20	0	0.0%				20	0	0.0%
18-Dec	71	0	0.0%	2	0	0.0%	73	0	0.0%
20-Dec	15	0	0.0%	1	0	0.0%	16	0	0.0%
21-Dec				1	0	0.0%	1	0	0.0%
22-Dec	69	0	0.0%				69	0	0.0%
23-Dec				2	0	0.0%	2	0	0.0%
24-Dec				3	0	0.0%	3	0	0.0%
25-Dec				1	0	0.0%	1	0	0.0%
26-Dec	70	2	2.9%	2	0	0.0%	72	2	2.8%
28-Dec	25	0	0.0%				25	0	0.0%
29-Dec	85	5	5.9%	1	0	0.0%	86	5	5.8%
1-Jan				5	0	0.0%	5	0	0.0%
2-Jan	4	0	0.0%	1	0	0.0%	5	0	0.0%
4-Jan	3	0	0.0%	2	0	0.0%	5	0	0.0%
5-Jan	23	0	0.0%	2	0	0.0%	25	0	0.0%
6-Jan				5	0	0.0%	5	0	0.0%
7-Jan				7	0	0.0%	7	0	0.0%
8-Jan	1	0	0.0%	15	0	0.0%	16	0	0.0%
9-Jan				36	0	0.0%	36	0	0.0%
10-Jan				2	0	0.0%	2	0	0.0%
11-Jan	11	0	0.0%	3	0	0.0%	14	0	0.0%
12-Jan	1	0	0.0%				1	0	0.0%
13-Jan				1	0	0.0%	1	0	0.0%

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Appendix Table A-5. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative crews and at a trap on Etach Slough, 1989 (continued).

	SURVEYS			ETACH SLOUGH TRAP			SAMPLES COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
16-Jan				2	0	0.0%	2	0	0.0%
17-Jan	1	0	0.0%				1	0	0.0%
18-Jan	12	0	0.0%				12	0	0.0%
19-Jan	8	0	0.0%	1	0	0.0%	9	0	0.0%
20-Jan				1	0	0.0%	1	0	0.0%
21-Jan				1	0	0.0%	1	0	0.0%
22-Jan	1	0	0.0%	1	0	0.0%	2	0	0.0%
25-Jan				1	0	0.0%	1	0	0.0%
26-Jan	1	0	0.0%	1	0	0.0%	2	0	0.0%
27-Jan				1	0	0.0%	1	0	0.0%
28-Jan				1	0	0.0%	1	0	0.0%
29-Jan				1	0	0.0%	1	0	0.0%
31-Jan	0	0	0.0%				0	0	0.0%
2-Feb				0	0	0.0%	0	0	0.0%
6-Feb				1	0	0.0%	1	0	0.0%
7-Feb	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	532	9	1.7%	199	4	2.0%	731	13	1.8%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-6. Summary of coho salmon escapement samples from the Upper Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
17-Nov	1	0	0.0%
27-Nov	4	1	25.0%
28-Nov	2	1	50.0%
30-Nov	16	0	0.0%
5-Dec	0	0	0.0%
6-Dec	1	0	0.0%
7-Dec	12	1	8.3%
13-Dec	30	1	3.3%
14-Dec	21	0	0.0%
15-Dec	8	0	0.0%
19-Dec	2	0	0.0%
20-Dec	3	0	0.0%
21-Dec	54	0	0.0%
22-Dec	17	0	0.0%
27-Dec	6	0	0.0%
28-Dec	31	1	3.2%
29-Dec	19	0	0.0%
4-Jan	19	0	0.0%
5-Jan	2	0	0.0%
12-Jan	2	0	0.0%
16-Jan	5	0	0.0%
17-Jan	3	0	0.0%
18-Jan	4	0	0.0%
23-Jan	3	0	0.0%
24-Jan	4	0	0.0%
25-Jan	2	0	0.0%
7-Feb	1	0	0.0%
IN-SAMPLE TOTAL	272	5	1.8%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-7. Summary of coho salmon escapement samples from the Lower Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
16-Nov	1	0	0.0%
28-Nov	4	0	0.0%
30-Nov	1	0	0.0%
8-Dec	6	0	0.0%
11-Dec	1	0	0.0%
12-Dec	4	1	25.0%
18-Dec	12	0	0.0%
20-Dec	29	0	0.0%
28-Dec	59	2	3.4%
3-Jan	27	0	0.0%
5-Jan	9	0	0.0%
12-Jan	4	0	0.0%
23-Jan	59	1	1.7%
6-Feb	1	0	0.0%
IN-SAMPLE TOTAL	217	4	1.8%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-8. Summary of coho salmon escapement samples from the Middle Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
16-Nov	5	0	0.0%
21-Nov	4	0	0.0%
27-Nov	16	0	0.0%
1-Dec	4	1	25.0%
7-Dec	8	0	0.0%
8-Dec	1	0	0.0%
11-Dec	6	0	0.0%
12-Dec	8	1	12.5%
19-Dec	54	1	1.9%
20-Dec	66	2	3.0%
28-Dec	171	3	1.8%
3-Jan	20	0	0.0%
5-Jan	14	0	0.0%
12-Jan	6	1	16.7%
15-Jan	7	1	14.3%
16-Jan	3	0	0.0%
19-Jan	39	0	0.0%
23-Jan	34	0	0.0%
26-Jan	24	0	0.0%
31-Jan	1	0	0.0%
2-Feb	5	0	0.0%
8-Feb	1	0	0.0%
IN-SAMPLE TOTAL	497	10	2.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-9. Summary of coho salmon escapement samples from the Upper Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
21-Nov	1	0	0.0%
13-Dec	3	0	0.0%
29-Dec	1	0	0.0%
29-Jan	3	0	0.0%
IN-SAMPLE TOTAL	8	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-10. Summary of coho salmon escapement samples from the Suiattle sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
30-Nov	2	0	0.0%
1-Dec	3	0	0.0%
3-Dec	6	0	0.0%
7-Dec	1	0	0.0%
8-Dec	5	0	0.0%
13-Dec	3	0	0.0%
20-Dec	6	0	0.0%
21-Dec	3	0	0.0%
29-Dec	8	0	0.0%
4-Jan	3	0	0.0%
25-Jan	2	0	0.0%
26-Jan	1	0	0.0%
IN-SAMPLE TOTAL	43	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-11. Summary of coho salmon escapement samples from the Nookachamps sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
7-Nov	1	0	0.0%
21-Nov	4	0	0.0%
22-Nov	1	0	0.0%
27-Nov	3	0	0.0%
29-Nov	24	0	0.0%
1-Dec	10	0	0.0%
6-Dec	29	0	0.0%
8-Dec	9	0	0.0%
11-Dec	6	0	0.0%
12-Dec	1	0	0.0%
14-Dec	1	0	0.0%
15-Dec	3	0	0.0%
18-Dec	25	0	0.0%
21-Dec	12	0	0.0%
22-Dec	13	0	0.0%
26-Dec	77	0	0.0%
27-Dec	2	0	0.0%
28-Dec	1	0	0.0%
29-Dec	10	0	0.0%
5-Jan	14	0	0.0%
11-Jan	1	0	0.0%
12-Jan	14	0	0.0%
18-Jan	7	0	0.0%
31-Jan	1	0	0.0%
IN-SAMPLE TOTAL	269	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-12. Summary of coho salmon escapement samples from the Carpenter sub-basin collected during spawning ground surveys by Skagit System Cooperative crews and at a trap on Carpenter Creek Slough, 1989.

	SURVEYS			SLOUGH TRAP			SAMPLES COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
15-Oct	1	0	0.0%				1	0	0.0%
24-Oct	2	0	0.0%				2	0	0.0%
4-Nov	8	0	0.0%				8	0	0.0%
5-Nov	4	0	0.0%				4	0	0.0%
6-Nov	2	0	0.0%				2	0	0.0%
7-Nov	2	0	0.0%				2	0	0.0%
8-Nov	2	0	0.0%				2	0	0.0%
9-Nov	1	0	0.0%				1	0	0.0%
13-Nov	1	0	0.0%				1	0	0.0%
29-Nov				3	0	0.0%	3	0	0.0%
2-Dec				2	0	0.0%	2	0	0.0%
6-Dec				1	0	0.0%	1	0	0.0%
8-Dec				2	0	0.0%	2	0	0.0%
9-Dec	1	0	0.0%				1	0	0.0%
12-Dec	1	0	0.0%	1	0	0.0%	2	0	0.0%
14-Dec	1	0	0.0%				1	0	0.0%
18-Dec	2	0	0.0%				2	0	0.0%
26-Dec				2	0		2	0	0.0%
27-Dec				2	0		2	0	0.0%
4-Jan	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	29	0		13	0		42	0	

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-13. Summary of coho salmon escapement samples from the Cascade sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1989.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
11-Oct	2	0	0.0%
18-Oct	2	0	0.0%
22-Nov	3	0	0.0%
27-Nov	13	0	0.0%
28-Nov	6	0	0.0%
29-Nov	4	0	0.0%
13-Dec	8	0	0.0%
14-Dec	4	0	0.0%
19-Dec	1	0	0.0%
20-Dec	19	0	0.0%
22-Dec	1	0	0.0%
27-Dec	12	0	0.0%
8-Jan	1	0	0.0%
9-Jan	2	0	0.0%
IN-SAMPLE TOTAL	78	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-14. CPUE (catch per beach seine set) of coho salmon bound for major recovery areas in the Skagit River, 1989. CPUE for recovery areas estimated using in-sample tag recoveries.

Recoveries by release strata.

Tag Release Period	Number of Sets	Coho Catch	Catch/ Set	MM Hatchery	Baker R. Trap
1. 01-Sep to 10-Sep	5	1	0.2	0	0
2. 11-Sep to 20-Sep	47	83	1.8	7	2
3. 21-Sep to 30-Sep	28	21	0.8	3	1
4. 01-Oct to 10-Oct	53	206	3.9	10	5
5. 11-Oct to 20-Oct	44	400	9.1	20	2
6. 21-Oct to 30-Oct	36	500	13.9	20	5
7. 31-Oct to 09-Nov	23	62	2.7	0	0
8. 10-Nov to 19-Nov	0	0		0	0
9. 20-Nov to 29-Nov	0	0		0	0
10. 30-Nov to 09-Dec	0	0		0	0
Totals	236	1,273	5.4	60	15

CPUE of fish bound for indicated recovery areas.

Release Period	MM Hatchery	Baker R. Trap
1	0.00	0.00
2	0.15	0.04
3	0.11	0.04
4	0.19	0.09
5	0.45	0.05
6	0.56	0.14
7	0.00	0.00
8	0.00	0.00
9	0.00	0.00
10	0.00	0.00
Totals	1.45	0.36

CPUE standardized as a percentage of total for area.

Release Period	MM Hatchery	Baker R. Trap
1	0.0%	0.0%
2	10.2%	11.9%
3	7.4%	10.0%
4	13.0%	26.4%
5	31.2%	12.7%
6	38.2%	38.9%
7	0.0%	0.0%
8	0.0%	0.0%
9	0.0%	0.0%
10	0.0%	0.0%
Totals	100.0%	100.0%

Appendix Table A-15. Summary of the number of tag releases and number of in-sample tag recoveries by length for male and female coho salmon tagged in the lower Skagit River, 1989.

	MALES			FEMALES		
Length in cm	Number Released	Number Recovered	Percent Recovered	Number Released	Number Recovered	Percent Recovered
≤ 35	9	0	0.0%	0	0	0.0%
36	3	1	33.3%	0	0	0.0%
37	4	1	25.0%	0	0	0.0%
38	5	0	0.0%	0	0	0.0%
39	9	0	0.0%	0	0	0.0%
40	17	1	5.9%	2	0	0.0%
41	8	0	0.0%	1	0	0.0%
42	11	0	0.0%	1	0	0.0%
43	17	2	11.8%	1	0	0.0%
44	16	1	6.3%	3	0	0.0%
45	20	0	0.0%	4	0	0.0%
46	23	1	4.3%	3	0	0.0%
47	20	3	15.0%	8	1	12.5%
48	22	1	4.5%	4	1	25.0%
49	27	3	11.1%	11	0	0.0%
50	29	3	10.3%	12	1	8.3%
51	39	4	10.3%	19	2	10.5%
52	42	1	2.4%	28	4	14.3%
53	35	4	11.4%	18	3	16.7%
54	29	2	6.9%	36	3	8.3%
55	31	2	6.5%	31	2	6.5%
56	28	2	7.1%	36	4	11.1%
57	37	4	10.8%	30	3	10.0%
58	27	0	0.0%	35	3	8.6%
59	24	2	8.3%	30	1	3.3%
60	27	3	11.1%	28	2	7.1%
61	25	1	4.0%	31	3	9.7%
62	21	1	4.8%	27	0	0.0%
63	24	5	20.8%	24	3	12.5%
64	13	2	15.4%	15	3	20.0%
65	6	0	0.0%	15	2	13.3%
66	8	1	12.5%	13	6	46.2%
67	14	2	14.3%	9	0	0.0%
68	8	0	0.0%	8	0	0.0%
69	17	2	11.8%	2	0	0.0%
70	7	1	14.3%	5	0	0.0%
71	5	1	20.0%	0	0	0.0%
72	2	0	0.0%	1	0	0.0%
73	5	0	0.0%	0	0	0.0%
74	5	0	0.0%	0	0	0.0%
75	1	0	0.0%	0	0	0.0%
76	2	0	0.0%	0	0	0.0%
77	0	0	0.0%	0	0	0.0%
78	2	0	0.0%	0	0	0.0%
TOTAL	724	57	7.9%	492	47	9.6%

Appendix Table A-16. Daily summary of the numbers of coho salmon tagged in the lower Skagit River and recovered during in-sample surveys, by sex, release condition, and maturity classification, 1989.

	SEX				CONDITION				MATURITY					
	Male		Female		x-		x		Bright		Blush		Dark	
Date	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.
11-Sep	2	1	2	0	0	0	4	1	4	1	0	0	0	0
12-Sep	2	0	2	0	0	0	4	0	4	0	0	0	0	0
15-Sep	20	1	4	0	0	0	24	1	24	1	0	0	0	0
18-Sep	22	2	8	4	0	0	30	6	30	6	0	0	0	0
19-Sep	13	0	5	1	0	0	18	1	18	1	0	0	0	0
22-Sep	2	0	2	0	0	0	4	0	4	0	0	0	0	0
25-Sep	8	3	1	1	0	0	9	4	7	3	2	1	0	0
26-Sep	1	0	5	0	0	0	6	0	6	0	0	0	0	0
2-Oct	4	1	4	0	0	0	8	1	7	1	1	0	0	0
3-Oct	4	0	3	0	0	0	7	0	6	0	1	0	0	0
6-Oct	17	2	8	0	0	0	25	2	15	0	10	2	0	0
9-Oct	47	5	22	2	1	0	68	7	54	5	13	2	2	0
10-Oct	59	5	29	5	4	0	84	10	73	9	15	1	0	0
11-Oct	74	9	45	7	0	0	119	16	86	13	33	3	0	0
16-Oct	28	2	18	1	0	0	46	3	33	3	13	0	0	0
17-Oct	23	2	18	1	0	0	41	3	32	1	9	2	0	0
18-Oct	14	0	12	0	0	0	26	0	24	0	2	0	0	0
20-Oct	90	7	46	1	0	0	136	8	111	4	24	4	1	0
23-Oct	151	9	116	13	8	2	259	20	226	20	41	2	0	0
24-Oct	36	3	27	3	0	0	63	6	55	5	6	0	2	1
27-Oct	33	2	35	3	1	0	67	5	60	5	8	0	0	0
30-Oct	42	3	50	4	0	0	92	7	61	4	28	3	3	0
31-Oct	9	0	6	0	0	0	15	0	10	0	4	0	1	0
2-Nov	18	0	14	1	0	0	32	1	18	1	13	0	1	0
8-Nov	5	0	10	0	0	0	15	0	12	0	3	0	0	0
Total	724	57	492	47	14	2	1,202	102	980	83	226	20	10	1
% Recovered		7.9		9.6		14.3		8.5		8.5		8.8		10.0

Appendix Table A-17. Summary of the estimated number of tags from areas downstream of the tagging area in the lower Skagit River, 1989.

A. Downstream commercial fishery and test fishery catches.

Area	Catch[a] Before Tagging	Catch After Tagging	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
8E	0	1,397	239	1	
8/78C	4,826	470	232	6	
Test Fishery[b]	0	1,003	1,003	0	
78D-1, 78D-2	1,757	178[c]	97	0	
Total	6,583	3,048	1,571	7	13.6

[a] Catches prior to tagging not included in tag recovery expansions.

[b] Test fisheries at Area 2, Spudhouse, Blakes, and Jetty.

[c] Estimated catch below the tagging area by the commercial fishery after the onset of tagging.

B. Out-of-system recoveries.

Location	Number of Tags Found	Estimated Total Tags Present	Comments
Area 8D Tulalip Bay	1	1.0	Voluntary recovery.
Total	1	1.0	

C. Downstream spawning areas (redd data from Conrad et al. [1993]).

Area	Estimated Number of Redds	Estimated Number of Fish/Redd	Estimated Total Escapement	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
Carpenter	310	3.1	961	42	0	
Nookachamps	7,015	3.1	21,747	269	0	
Total	7,325		22,708	311	0	0

APPENDIX B

Details of abundance estimates generated for 1989.

APPENDIX B

RECOVERY LOCATION: Marblemount Hatchery

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 4,718
Number of Tagged or Marked Fish Recovered = 68

RECOVERY LOCATION: Baker River Trap

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 2,843
Number of Tagged or Marked Fish Recovered = 17

RECOVERY LOCATION: Middle Skagit Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 731
Number of Tagged or Marked Fish Recovered = 13

APPENDIX B

RECOVERY LOCATION: Middle Sauk Sub-Basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 497
Number of Tagged or Marked Fish Recovered = 10

RECOVERY LOCATION: Middle Sauk-Middle Skagit Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 1,228
Number of Tagged or Marked Fish Recovered = 23

RECOVERY LOCATION: Marblemount-Middle Skagit-Middle Sauk Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,216
Number of Fish Examined for Tags = 5,946
Number of Tagged or Marked Fish Recovered = 91
