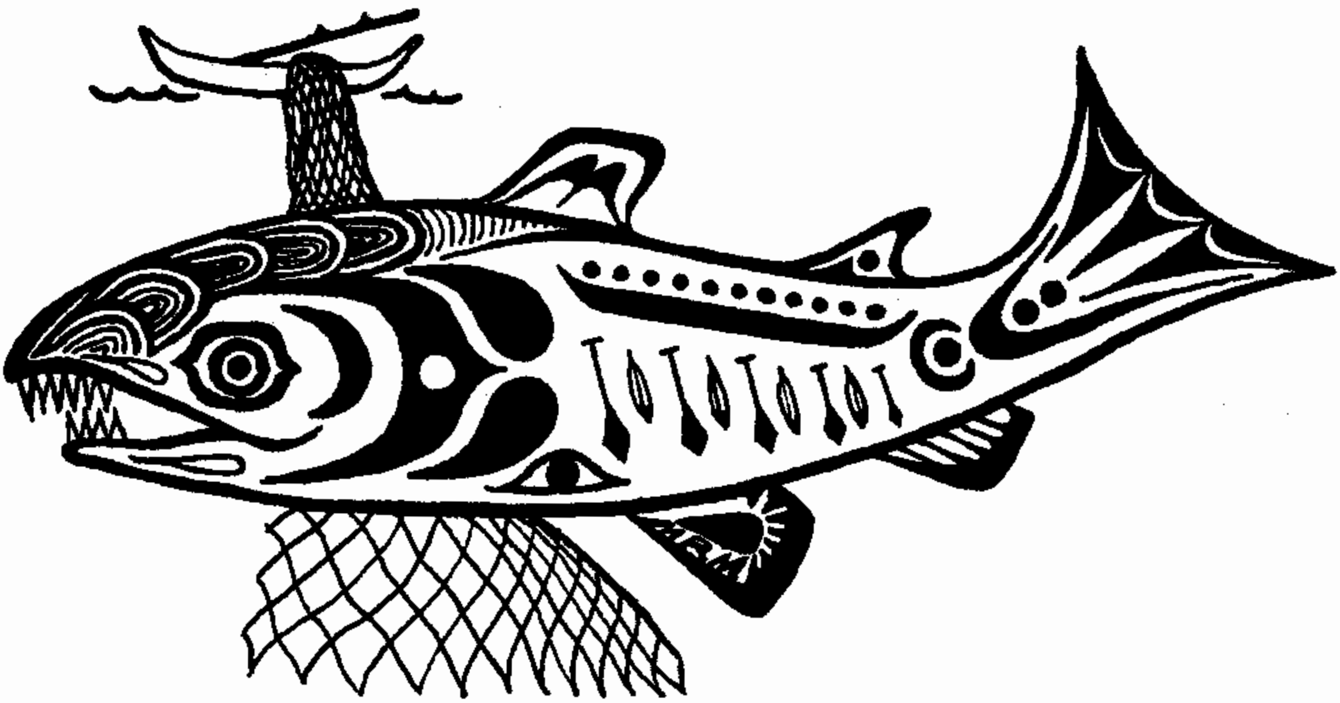
THE NISQUALLY CHUM SALMON RUN:

A STATUS REPORT



THE NISQUALLY CHUM SALMON RUN: A STATUS REPORT

by

Don L. Cole
Olympic National Park
Port Angeles, WA

Richard M. Comstock
U.S. Fish and Wildlife Service
Fisheries Assistance Office
Olympia, WA

Bill Harrington-Tweit
Nisqually Indian Tribe
Olympia, WA

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The long-term nature of this study resulted in the involvement of a large number of individuals, both from the Service and Tribe and also from other agencies. In the planning and initial implementation process, Fred Olney, Walt Ambrogetti, Bill Frank, Jr., Jim Heckman, and Steve Wilson were instrumental. In addition to many individuals on the Nisqually biological and FAO-Olympia staffs, Jim Stephenson of Fort Lewis, and Paul Svoboda of Nisqually provided assistance on numerous occasions. Lois Meyer typed this report.

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ABSTRACT

Mark-recapture studies to estimate total run size and escapement were conducted on the chum run in the Nisqually River, Washington, during the 1974-75 thru 1978-79 seasons. Run size and escapement were estimated for each season except 1977-78 when an illegal marine fishery precluded development of an escapement estimate. Run size estimates ranged from 12,600 to 60,800 and escapement estimates from 8,700 to 33,600.

In addition to post-season estimates, a method was developed for in-season projection of run size based on early season tag releases and recovery information in the river commercial fishery. Development of in-season run size projection was continued using this methodology through the 1981-82 season.

Biological information on length frequency, sex and age composition, and timing of the run was an important benefit of the studies. The population structure was heavily weighted towards three and four year old adults. Five year olds never constituted more than 2% of a run. Other maturation ages were rarely observed. The relative proportion of three and four year olds varied substantially between years, as did the sex ratio. The proportion of females in the run varied between 50 and 60%; the river gill net fishery, however, was selective for males. There was almost a 20 cm difference in mean fork length between three year olds and five year olds. The mean fork length of each age/sex cohort was quite consistent on an annual basis. Run timing in the river was influenced by the population structure; three year olds tended to enter earlier than fours and males earlier than females.

KEYWORDS

Chum salmon; Mark-recapture studies; Petersen population estimate; Salmon population age and sex composition; Adult salmon freshwater entry patterns.

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INTRODUCTION

In the winter of 1974-75, the Nisqually Indian Tribe and the U. S. Fish and Wildlife Service (USFWS), with the cooperation of the Washington Department of Fisheries (WDF), initiated a project to assess the status of the chum salmon (Oncorhynchus keta) resource of the Nisqually River. To that time the only available information on population characteristics of this run was from spawning ground surveys, which were sporadic and of limited extent, and catch data which probably had little relationship to historical run sizes. The 1974 Federal Court decision in U.S. vs. Washington, commonly referred to as the Boldt decision, necessitated that accurate information be available on the status of individual stocks. The 1974-75 study was the first attempt to gain this information on the Nisqually.

After the 1974-75 effort, a full-scale study was continued annually through the 1978-79 season. Although our original intent was to continue for only two or three years, the project was extended because in-season run size forecasting techniques were developed upon which the tribal commercial fishery was managed. Beginning in 1979-80, studies of limited duration were conducted to provide an early in-season run size projection. Tagging was discontinued as soon as a projection was made. The results of these limited duration studies are not presented in this report although subsets of the biological information collected since 1979 are included.

Progress reports were prepared on all of the full-scale studies (Nisqually Tribe and USFWS 1977, 1978 and 1979; Olney 1976). Although the results have not been revised greatly in this final review of the data, there are some changes and much new information.

STUDY AREA

The Nisqually River is a moderately large stream of glacial origin which enters the southern end of Puget Sound between Olympia and Tacoma (Figure 1). Substantial runs of chum and coho salmon and steelhead use the system along with smaller stocks of pink and chinook salmon and cutthroat trout. Access to the upper portion of the watershed is blocked by LaGrande and Alder dams at river miles 42.5 and 44.1, respectively. At river mile 26.2 is a laddered diversion dam where water is diverted and transported 14 miles downstream via a canal where it is returned to the river through a powerhouse. In its lower reaches the river is relatively undeveloped compared to most southern Puget Sound rivers due to the presence of Fort Lewis and the Nisqually Indian Reservation. Agriculture and logging are major activities on the upper watershed.

Major anadromous fish-producing tributaries of the Nisqually system include the Mashel River and Muck, Ohop, Tanwax, Clear, and Yelm creeks, as well as several mainstem sloughs and side channels. Two independent drainages, McAllister and Red Salmon creeks, enter Puget Sound near the mouth of the Nisqually. Chambers Creek, which enters Puget Sound several miles north of the mouth of the Nisqually, has a chum run of similar timing and is therefore of interest in this context.

The tribal commercial fishery for Nisqually chum is conducted in the lower eleven miles of the river. During the study period, no legal marine fishery targeted specifically on Nisqually late chums, although catches were made incidental to other fisheries. Interception was verified by observation of gill net scars on chum handled while tagging in the Nisqually Reach. The rate of interception was probably insignificant in most years, relative to the total run size. In 1977, an illegal non-treaty marine fishery took a significant segment of the run before it entered the river.

The Nisqually River Indian fishery can be characterized as primarily a set gill net fishery, several areas are also drift gill netted. Although chum are the most numerous species from December through February, steelhead are also taken commercially and complicate management during the winter season.

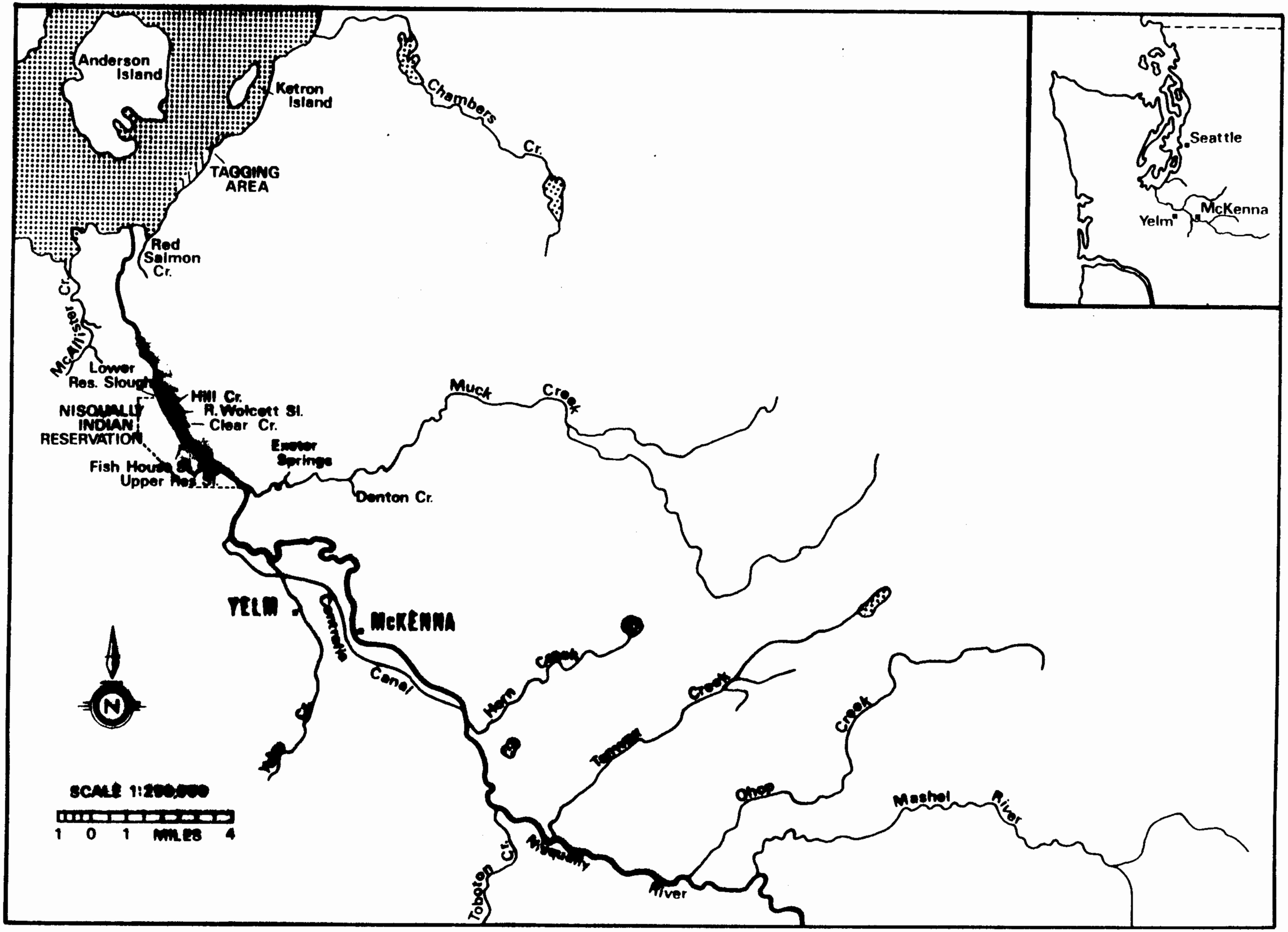

Figure 1. Nisqually River Drainage

OBJECTIVES

The original objective of this work was post-season evaluation of Nisqually chum run size and escapement. The escapement estimates could then be correlated with spawning ground counts to set up an indexing system whereby escapement could be monitored on a continuing basis. Although an indexing system was used by WDF prior to these population studies, the flaw in the system was the lack of an accurate base year escapement estimate. Very little information was available that related specifically to the status of the chum run in the Nisqually, even though this stock is one of the largest chum runs in Washington. The escapement estimates from the studies provided three base year escapement estimates that correlated well with spawning ground counts in Yelm Creek and carcass deposition on the Nisqually mainstem (Svoboda and Harrington-Tweit 1983). These variables, along with estimates of escapement into Muck Creek and Clear Creek, are now used to estimate Nisqually chum escapement annually.

Because the 1974-75 work had shown that the tagging data could be used to manage the river commercial fishery on an in-season basis, the scope of the project was expanded in 1975 to include development of in-season estimates of run size. After the 1975-76 season, development of in-season run size updates was a primary justification for continuation of the project.

In addition to the primary objectives, other information needs developed during the study. In 1976-77, the distribution of chum spawners within the watershed became a critical issue due to a proposed expansion of an artillery impact area on Fort Lewis which might have been detrimental to the fishery resources of Muck Creek. A weir was installed to monitor the escapement of both chum and steelhead in Muck Creek and to recover tags from the marking program. A separate report was prepared on the operation of the weir (Harrington-Tweit and Svoboda 1983). Also, valuable information was generated on length distribution, sex ratios, timing, and age composition of the stock.

TAGGING/RECOVERY METHODS

The initial study design of this project was predicated on the assumption that fish could be captured and tagged in the lower river or estuary and recovered by commercial fishery sampling and spawning ground surveys. In 1974-75, we experimented with beach seines, gill nets, and purse seines to capture fish for tagging. Purse seining was the most efficient method and was used exclusively in succeeding years.

In 1974-75, most of the chum were caught along the Dupont shoreline although substantial numbers were captured near the buoy at the mouth of the river. After 1974-75, nearly all sets were made along the Dupont shoreline between the Dupont dock and the southern end of Ketron Island. If fish were not present in this area, they generally could not be located elsewhere.

In 1974-75, tagging began on December 17 and continued sporadically through January 21, whereas in subsequent years it began either the 4th, 5th, or 6th of December and continued weekly until chum were no longer present, usually near the end of January. In 1974-75 and 1975-76, tagging was usually scheduled one day per week, whereas in 1976-77, 1977-78, and 1978-79 two days per week were scheduled. In 1974-75, a drum seiner, the Panther, was chartered to seine for the tagging operations, whereas from 1975-76 thru 1978-79 a power block seiner, the Adana R., was utilized. In 1976-77 and 1977-78, a bow drum purse seiner, the G. B. Heron, was used for the last couple of weeks of tagging. The drum seiners had two advantages in that they could make sets somewhat more rapidly and require a smaller crew, but the power block seiner may have been advantageous for handling fish because it was easy to remove fish which had tangled as the net was brought on board rather than having to drag the fish thru the fairleads before removal.

The actual seining process was similar to commercial seining techniques except that the bunt-end of the net was left in the water and the skiff operator held the net open to form a floating pen. From this pen the chum were dipnetted into a padded holding box from which they were transferred into tagging cradles. The fork length and sex were then recorded, the tag applied, and the adipose fin clipped to facilitate identification of fish which might shed their tags.

Several types of tags were used during the course of the study. In 1974-75, we used a spaghetti tag which had to be tied after insertion through the back of the fish just behind the dorsal fin. This tag proved unsatisfactory due to a very high rate of tag loss by the time the fish were recovered on the spawning grounds. In 1975-76, two types of tags were utilized: cinch-up spaghetti tags and metal butt-end (jaw) tags. The jaw tags proved to have a superior retention rate and were not selectively taken by gill nets. So, beginning in 1976-77, jaw tags were used exclusively.

The jaw tags were clamped on the right mandible of the fish. Several sizes were utilized based on size and sex of the fish. Males usually required larger tags than comparably sized females. With a little experience, taggers were able to choose the apropriate tag rapidly and accurately.

In 1975-76, we classified the condition of each fish on release as "1" if the fish swam away rapidly and "2" if it was sluggish or disoriented.

Beginning in 1976-77, the range of condition factors was expanded as follows:

1. Swam away rapidly
2. Swam away sluggishly
3. Disoriented

Tags were recovered from several sources, including the lower river commercial fishery and all known spawning areas. In 1977-78, broodstock capture activities provided a few recoveries, and in 1978-79 a significant number of recoveries came from the Muck Creek weir. At all recovery locations chum were examined for tags, missing adipose fins, and tag scars. On all spawning ground carcass recoveries the caudal fin was excised to prevent duplication of counting.

In addition to the Nisqually watershed, the nearby McAllister, Red Salmon, and Chambers creeks also have late-timed chum runs and were monitored for tag recoveries. Other southern Puget Sound streams were sampled but an insignificant number of recoveries were obtained.

The development of population estimates from mark-recapture data has become common practice in fisheries biology. Varying study conditions have necessitated that several models be developed. The simplest and most commonly used is the Petersen, or "Lincoln Index", model. Although simple, the Petersen estimate requires stringent assumptions. The Petersen model has been presented and discussed by several authors (Cormack 1968; Overton 1971; Ricker 1975; and Seber 1973) using the following basic assumptions:

1. The population is closed
2. All animals have the same probability of being caught in the first sample
3. The second sample is a simple random sample
4. Marking does not affect the catchability of an animal
5. Animals do not lose their marks between the two samples
6. Sampled animals are identified correctly as marked or unmarked

Actually, a number of assumptions can be substituted for assumption 1. However, under these alternative assumptions the population size is not constant so one must identify the point at which the estimate applies. The alternative assumptions are:

a. There is neither recruitment nor immigration and death, and emigration constitutes a simple random sample of the population
b. There is neither recruitment nor immigration and death, and emigration affects marked and unmarked equally
c. Knowledge is available from other sources such that adjustments can be made for migration, birth, and death prior to the analysis of the data

Chapman and Junge (1956) and Darroch (1961) have developed a stratified model that allows for relaxation of assumptions 2 and 3. Using this model, one can divide the marking and recovery samples into several strata, provided that:

a. Assumption 2 holds true within each marking stratum
b. Assumption 3 holds true within each recovery stratum

Seber (1973), whose notation is used in this paper, presents an excellent discussion of this model. Eames et al. (1981) apply both the simple and stratified models to population studies on adult salmon.

Theoretical variance estimation techniques have been developed for both the simple and stratified models. However, they are not always adequate in practical applications. In particular, both models fail to account for the variance introduced when estimating the number of marked fish that have strayed to watersheds other than the Nisqually. The stratified model also fails to account for the variance involved in the allocation of fish with lost tags to the various marking strata. In order to circumvent difficulties such as these a number of alternative methods based on random subsampling of the marked population have been developed. Hence, when sample size permitted, a technique of this type, the method of interpenetrating subsamples, was used to estimate variance. Eames et al. (1981) present a discussion and application of this method.

Assumption 1

For the purpose of run size estimation, the target population was defined as those chum salmon that entered the Nisqually River during a specific time period for the purpose of spawning. Once sexually mature and in a freshwater environment a chum salmon will not return to a state of immaturity and migrate back to a saltwater environment. Hence, there is no emigration from the population. Also, as adult salmon enter freshwater only as a consequence of sexual maturation, there is no recruitment into a population.

As all fish are destined to spawn and die during a season, mortality of fish is not a complication of the closure assumption. The assumptions of the simple model, however, require that the dead fish comprise a simple random sample of the entire population. The reasonableness of this assumption is addressed for each individual study year when considering population stratification.

In the Nisqually studies, technical difficulties in acquiring the first sample complicated fulfillment of the closure assumption. The first (marking) sample was composed of fish caught in a saltwater area close to the Nisqually River mouth rather than in the river itself. Salmon from other populations were in the sampling area during the taking of the first sample and, because they were not distinguishable, were sampled and marked. The fish, therefore, compose a sample from a population of fish migrating not only into the Nisqually River but also into other nearby streams. Although significant, the number of marked fish from populations other than the Nisqually was found to be reasonably small for each of the study years.

If estimates of the run size of all non-Nisqually populations are available, then an estimate of the run size of the Nisqually population can be obtained by estimating the size of the composite population represented by the marked fish and subtracting from this the size of all non-Nisqually populations. This technique was used to estimate the 1974-75 Nisqually run size. However, the unavailability of estimates of the size of the non-Nisqually marked population precluded the use of this technique after 1974-75.

After 1974-75, the number of marked fish belonging to non-Nisqually populations was estimated. This estimate was then subtracted from the number of marked fish. The resulting sample is an estimate of the number of originally marked salmon that were part of the Nisqually population.

A variety of methods were used to estimate the non-Nisqually marked fish. Most non-Nisqually populations were sampled. For each of these populations a subjective estimate of the sampling rate was made. An estimate of the number of marked fish in each of these populations was obtained by dividing the number of marked fish observed by the estimated sampling rate. The exceptions to this scheme were Chambers Creek and voluntary returns by marine sport fishermen. At Chambers Creek the Washington Departments of

Fisheries and Game maintain a trapping facility where an enumeration of the total number of marked fish was obtained. The few recoveries from marine sport fishermen could not be expanded because there was no information on the tag return rate of sport caught fish. These recoveries were, therefore, subtracted directly from the tagged population.

In some instances enumerations of segments of the Nisqually population were available. The number of salmon taken in the Nisqually Indian fishery was determined from Washington Department of Fisheries fish tickets. Also, during 1978-79 a weir was used to enumerate the number of salmon entering Muck Creek. As there is no need to estimate these known numbers of salmon, the number of marked salmon migrating past the Muck Creek weir and the estimated number of marked salmon taken in the fishery was subtracted from the marked sample. The resulting marked sample is therefore an estimate of the number of originally marked salmon that were part of non-enumerated segments of the Nisqually population. The exceptions to this rule occurred during the 1974-75 and 1975-76 studies. In 1974-75, a high rate of tag loss (83%) of tagged fish returning to spawning areas precluded use of the spawning ground information. In 1975-76, small sample sizes precluded the exclusion of the fishery sample from the second recovery sample.

Assumptions 2 and 3

In an attempt to satisfy assumptions 2 and 3, the marking and recapture schemes were designed to keep marking and recovery effort as consistent as possible over the ranges of values of the various attributes of the run. Both primary types of recovery gear are, however, thought to be selective over sex -- gill nets being selective toward males and spawning ground surveys being selective toward females. However, the purse seine marking gear was chosen because it was thought to be non-selective over size and sex class of salmon.

Although every effort was made to obtain random samples, certain problems were unavoidable. During peak densities fewer sets were made during a day because more of the day had to be spent processing fish, thereby reducing marking effort. Likewise, the periodic high flow conditions impeded spawning ground recovery efforts. Also, the Indian river fishery did not last throughout the duration of significant migration in all seasons, particularly not in 1975-76 when the fishery was severely restricted at the end of December. Even within a season fishing rates fluctuated due to changes in the number of days fished per week and river flow conditions. During the study years, fishing schemes were always designed to satisfy management goals rather than sampling goals. Therefore, the fishery did not sample randomly over time.

As marking occurred in a single location there can be no geographical stratification of marking effort. Spawning ground recovery did, however, occur in a number of locations. It is quite likely that spawning ground sampling was not random over recovery locations due to the distinct physical characteristics of the various spawning locations.

The data from each study year were tested for stratification using the techniques described by Darroch (1961). For the reasons stated above, time at marking and time or area at recovery were usually considered as the potential variables of stratification.

Assumption 4

Increases in the catchability of a fish in the spawning ground samples would occur only as a result of a mark making the fish more visible. The jaw tag, being a relatively small tag that has a dull color and fits flush with the mandible of a salmon, probably does not increase the visibility of its host. Likewise, an adipose fin clip should not increase the visibility of a fish. Marking, therefore, probably does not alter the catchability of fish that are available for recovery in spawning areas.

The adipose fin, being behind the part of the body that has maximum circumference, probably does not significantly influence catchability. Thus, the removal of the adipose fin should not affect catchability in the gill net fishery. Also, as a jaw tag is small and fits flush with the body in a location that is again away from the part of the body that is of maximum circumference, the application of a jaw tag should not affect the catchability of fish in the gill net fishery.

Assumption 4 also requires that there is no marking mortality. There are a number of biological considerations that support the notion that marking mortality was negligible. Typically, the chum were in an advanced state of maturity when they were marked. This, together with the low water temperatures that existed during the marking season, insured that the salmon were quite hardy. In addition, marking personnel were instructed to release all remaining salmon from the purse seine whenever the salmon showed signs of stress. Signs of stress included salmon showing lack of vigor or a few individuals starting to swim in a disoriented fashion.

Upon release from the marking station most fish swam away rapidly. However, some individuals appeared somewhat sluggish and still fewer appeared disoriented for a few moments. Marking personnel were instructed to observe the condition of fish upon release from marking and categorize the fish as condition 1, 2, or 3. Condition 1 fish swam away rapidly, condition 2 fish appeared sluggish, and condition 3 fish were disoriented.

If marking mortality was significant one would intuitively expect it to be correlated with stress at release. Using condition as a measure of stress, we performed a chi-square test of condition at release by recovery rate for all study years except 1974-75 (Table 1). During the 1974-75 season, condition at release was not recorded. The non-significance of these tests supports the assumption of negligible marking mortality.

Table 1. Number of Tagged Chum Recovered and Recovery Rate, by Condition at Release

Year	Condition 1	Condition 2	Condition 3	Chi-Square	P value
1975-76	293 (.26)	19 (.21)	--	1.36	.24
1976-77	945 (.34)	228 (.36)	10 (.38)	1.02	.60
1977-78	2,152 (.39)	195 (.37)	12 (.38)	.70	.70
1978-79	1,396 (.38)	285 (.40)	6 (.32)	1.59	.45

In addition to the above tests, construction of the weir on Muck Creek in 1978 allowed for the development of an estimate of run size which was independent of the marking and recovery processes and, therefore, not affected by handling or marking mortality. Because we were able to randomly sample the sex composition of the run prior to and after the gill net fishery and because the fishery was selective for males, we were able to use the "Change-in-Ratio" (CIR) or "Dichotomy" method described by Chapman (1955) and presented in Appendix 1.

The close agreement of the "Change-in-Ratio" and tagging estimates (52,234 for the CIR estimate versus 50,280 for the tagging estimate) has given us a great deal of confidence in the tagging study estimates. Marking or handling related mortality should have no impact on the CIR estimate so the close agreement between estimates strongly suggests that marking mortality was not a serious problem.

Assumption 5

In order that all marked fish could be recognized as such, they were marked with an adipose clip as well as a tag making it possible to enumerate all marked recoveries in any particular recovery sample. It was, however, not possible to ascertain all marking information about fish that had suffered tag loss.

The Petersen model, requiring only the total number of recoveries, is not necessarily affected by tag loss. For the stratified model, however, loss of tagging information makes it impossible to determine which stratum salmon were marked in. In order to use the stratified model the fish from a particular recovery stratum having adipose clips but no tags were apportioned to the various marking strata in ratios determined by the tagged fish from the same recovery stratum. For example, if 40% of the marked fish from a particular recovery stratum were marked in marking stratum 1, then 40% of the fish having lost tags from this stratum were also apportioned to marking stratum 1.

Assumption 6

Because trained samplers conducted all recovery sampling, we feel that it is very unlikely that they failed to recognize any marked fish.

POPULATION ESTIMATES

1974-75

Although a separate report was prepared on the 1974-75 study (Olney 1976), we have re-examined the data in this report for comparison purposes and because we became aware of other population models which are probably more apropriate for this type of data. The estimates have changed only slightly.

The experimental design of the 1974-75 study, because it was our initial attempt at this type of work, was somewhat dissimilar from the studies in the following years. The tagging operation did not begin until December 17, nearly two weeks later than the following years. We therefore missed the earliest segment of the run and this complicated the data analysis. We did tag 4,497 chum (Table 2) between December 17, 1974 and January 21, 1975.

A second difference was the type of tag used in 1974. A regular spaghetti tag was used rather than the cinch-up spaghetti or jaw tags used in later years. The retention rate of these tags to recovery on spawning grounds was so poor (17%) that we considered the spawning ground recovery data to be unuseable. The estimates were, therefore, based solely on fishery recoveries. The recovery information is summarized in Table 3.

Applying Darroch's tests for stratification to the 1974-75 tagging and recovery data indicates that the population is stratified by time at tagging and time at recovery (the test results are detailed in Appendix Tables B1 and B2). This is not surprising in that we started tagging later than in the following years and our schedule was sporadic, making it unlikely that we tagged a random sample of the run. Recovery effort, on the other hand, was dictated by an intermittent commercial fishery. This resulted in a non-random recovery sample of the population.

Grouping over marking and recovery strata was done to obtain necessary sample sizes. Sample sizes were considered adequate when the theoretical coefficient of variation was less than .25. Grouping of both tagging and recovery strata was based on temporal proximity. Table 4 presents the parameters and results of the stratified estimate. Availability constraints for the model were developed on the basis of the sex composition of the marking strata. This factor was chosen because males are selectively harvested in the gill net fishery while at the same time the sex composition of the population changes over the duration of the run. Also, the percentage of males generally declines as the run progresses (Table 5). Based on these considerations, availability was considered equal in the first two marking strata and in the second two strata.

Variance estimates were calculated using the method of interpenetrating subsamples. Eight subsamples were taken of the tagging and recovery data. The subsamples and results are shown in Appendix Table B3.

Table 2. 1974-75 Purse Seine Catches and Chum Tagged

Date	Number Captured	Number Tagged	Number Sets	Catch/set	Number Steelhead
12/17/74	780	751	4	195	0
12/18/74	604	604	2	302	0
12/23/74	768	768	4	192	0
12/30/74	1,148	1,007	3	383	0
1/6/75	1,004	979	3	335	0
1/15/75	311	294	5	62	3
1/21/75	97	94	4	24	1
Totals	4,712	4,497	25	188.5	4

Table 3. 1974-75 Tag Recovery Information

Recovery Area	Carcasses Sampled	Tags Recovered
Commercial Fishery	18,329	1,349
Yelm Creek	370	19
Muck Creek	864	44
Exeter Springs	592	46
Mainstem Nisqually	278	18
Tanwax Creek	2	0
Independent Drainages		
Red Salmon Creek	494	26
McAllister Creek	531	10
Chambers Creek	1,330	9

Table 4. Parameters and Results of the Stratified Population Estimate of the 1974-75 Run

Grouped Time of Tagging/Recovery Matrix

	Recovery Dates		
Tagging Dates	December 17-31	January 1-10	January 11-March 12
December 17, 18	268.22	135.72	44.98
December 23	114.76	63.80	39.76
December 30	24.02	128.48	164.26
January 6, 15, 21	0.00	109.00	253.00

Tagging vector (a_i): (1,355, 768, 1,007, 1,367)

Recovery vector (u_j): (5,859, 4,798, 6,326)

X Matrix:

$$\begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ .25 & .25 & .25 & .25 \end{bmatrix}$$

P-values: (.61, .51, .16)

N = 61,831 - 2,830 strays + 1,825 catch prior to initiation of tagging = 60,826

Coefficient of variation = .052

Table 5. Sex Ratio by Tagging Date for the 1974-75 Run

Date	% Male	% Female
12/17	49	51
12/18	51	49
12/23	49	51
12/30	46	54
1/6	45	55
1/15	43	57
1/21	40	60

Table 6. Mark-Recapture Information and Population Characteristics of the 1974-75 Run

Mark-Recapture Information	
Number Tagged	4,497
Number Sampled	
Fishery	18,329
Spawning Grounds	2,106
Number Tags Recovered	
Fishery	1,349
Spawning Grounds	127 1/
Population Characteristics	
Run Size	60,826 2/
Standard Deviation	7,695 3/
Catch	
Commercial	26,263
Ceremonial & Subsistence	883 4/
Sport	59
Total	27,205
Escapement	33,621
Escapement Goal	30,000
Exploitation Rate	.45

1/ The spawning ground information was not used in development of population estimates due to high rate of tag loss. This number includes lost tags.

2/ Includes 1,825 taken in commercial fishery before sampling was initiated

3/ Variance estimate derived by method of interpenetrating subsamples (Appendix B3)

4/ Nisqually Tribal estimate

1975-76

In the 1975-76 study, 1,210 chum were tagged in 11 days of tagging between December 4, 1975 and January 20, 1976 (Table 7). Tagging was conducted on a one or two day per week schedule.

Both jaw tags and cinch-up spaghetti tags were used in the 1975-76 study to evaluate the relative retention rates of the two types of tags. As was the case in the 1974-75 work, the spaghetti tags were shed at a very high rate (as high as 50% in some spawning ground recovery areas) whereas the jaw tags were shed at a much lower rate.

An environmental factor that impacted the 1975-76 study was extreme flood conditions in the month of December which made tagging and sampling difficult. Debris accumulations in the tagging area made seining very difficult during flooding and for a week after. The river fishery was unable to operate for several days during this time. Fortunately, the flood was prior to the initiation of spawning so that there was probably little direct impact on the reproductive success of the run.

Tag recovery information was gathered from spawning ground surveys and from the commercial fishery (Table 8). Because the 1975-76 run returned at levels far below the escapement goal, the fishery was terminated in late December with only an occasional one day opening after December 31. The early closure reduced fishery recoveries of the later tag groups.

Applying Darroch's tests for stratification to the 1975-76 tagging and recovery data yielded the results summarized in Table 9 and detailed in Appendix Tables B4 through B8. The tests indicate that the population is probably stratified by both time at tagging/area of recovery and by time at tagging/time of recovery. Due to the inclusion of the commercial catch data in the model it was necessary to stratify by time of tagging and area of recovery. Beginning with the 1976-77 run, we considered the commercial catch data to be an enumeration of the number removed from the population and we, therefore, subtracted tags taken in the fishery from the tagged population based on our sampling rate. Normally, only the spawning ground recoveries were used in the model. In the 1975-76 study, however, because so few recoveries were obtained on the spawning grounds and because of the high rate of tag loss, we included the fishery data in the model.

Table 10 presents the parameters and results of the stratified estimate. Grouping over marking and recovery strata was done to obtain necessary sample sizes. Sample sizes were considered adequate when the theoretical coefficient of variation was less than .25. Grouping of tagging strata was based primarily on temporal proximity with one important exception. Because the sex of tagged fish has been shown to be an important determinant in the probability of recovery, we grouped tagging days with similar sex composition. December 4, 15, and 18 were the only tagging days where males were more abundant than females (Table 11). In most other years there was a gradual transition with males more abundant early in the season and females later.

Recovery strata for the model were grouped on the basis of geographical proximity and similarity of stream type. The commercial fishery formed one strata while Muck Creek and its tributaries and Clear Creek was a second. The mainstem and Fish House Slough plus Kalama Creek all probably experienced a relatively low recovery rate of chum carcasses so this formed the third strata.

Availability constraints for the model were developed on the basis of the sex composition of the marking strata. This factor was chosen because males were selectively harvested by the gill net fishery. Because females were predominant in the last three strata, these were set equal (Table 11). Although other alternatives were explored, this alternative made sense biologically and yielded reasonable p-values.

A variance estimate for the 1975-76 estimate was calculated using the theoretical technique described by Darroch (1961). As mentioned previously, this approach does not account for variability introduced by our estimation procedures for strays and lost tags. However, it was the best that could be done. Interpenetrating subsamples could not be used because of the small sample sizes.

Table 12 summarizes the tagging study data and run size characteristics of the 1975-76 Nisqually chum run.

Table 7. 1975-76 Purse Seine Catches and Chum Tagged

Date	Number Captured	Number Tagged	Number Sets	Catch/ Set	Number Steelhead
12/4/75	147	147	3	49	1
12/9/75	26	26	4	7	1
12/12/75	175	173	4	44	3
12/15/75	99	99	5	20	1
12/18/75	224	222	4	56	7
12/23/75	304	299	4	76	1
12/30/75	130	125	4	33	7
1/6/76	107	106	4	27	2
1/12/76	5	5	4	1	3
1/13/76	5	5	3	2	0
1/20/76	4	3	4	1	4
Totals	1,226	1,210	43	28.5	30

Table 8. 1975-76 Tag Recovery Information

Recovery Area	Carcasses Sampled	Tags Recovered
Commercial Fishery	2,462	262
Yelm Creek	8	0
Muck Creek	99	10
Exeter Springs	137	12
Mainstem Nisqually	85	5
Fish House Slough	172	12
Kalama Creek	36	2
Clear (Hill) Creek	42	10
Independent Drainages		
Red Salmon Creek	298	37
McAllister Creek	328	35
Chambers Creek	323	4

Table 9. Summary of Stratification Tests for the 1975-76 Mark-Recapture Data

Test	Chi-Square	D.F.	P-Value
Recovery rate by time of tagging	41.43	5	0.00
Tag ratio by recovery location	14.58	6	.02
Tag ratio by time of recovery			
Fishery	18.20	5	0.00
Spawning grounds	5.28	3	.15
Time of tagging by recovery location	42.61	6	0.00

Table 10. Parameters and Results of the Stratified Population Estimate of the 1975-76 Run

Grouped Time of Tagging/Recovery Area Matrix

	Recovery Areas		
Tagging Dates	Commercial Fishery	Mainstem Kalama Creek Fish House Slough	Muck Creek Exeter Springs Clear Creek
December 4, 15, 18	132.64	4.33	7.0
December 9, 12	60.29	2.33	3.5
December 23	58.10	4.34	13.0
December 30, January 6, 12, 13, 20	10.79	8.00	8.5

Tagging vector (a_i): (416.63, 186.20, 266.32, 223.72)

Recovery vector (u_j): (2,237, 274, 254)

X Matrix:

$$\begin{bmatrix} 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & -1 \\ .25 & .25 & .25 & .25 \end{bmatrix}$$

P-values: (.48, .048, .21)

N = 12,568

Coefficient of variation = .172

S.D. = 1973

Table 11. Sex Ratio by Tagging Period for the 1975-76 Run

Tagging Period	% Male	% Female
12/4	59	41
12/9, 12/12	48	52
12/15, 12/18	53	47
12/23	44	56
12/30	45	55
1/6, 1/12, 1/13, 1/20	35	65

Table 12. Mark-Recapture Information and Population Characteristics of the 1975-76 Run

Mark-Recapture Information	
Number Tagged	1,210
Number Strays (estimated total)	117
Number Sampled	
Fishery	2,462
Spawning Grounds	579
Number Tags Recovered	
Fishery	262
Spawning Grounds	51
Population Characteristics	
Run Size	12,568
Standard Deviation	1,973 1/
Catch	
Commercial	3,550
Ceremonial and Subsistence	350 2/
Total	3,900
Escapement	8,668
Escapement Goal	30,000
Exploitation Rate	.31

1/ Theoretical variance estimate

2/ Nisqually Tribal estimate

In the 1976-77 study, 3,559 chum were tagged in 16 days of tagging between December 6, 1976 and January 26, 1977 (Table 13). Tagging was scheduled on a two day per week basis. The 1976-77 study was the first year that jaw tags were used exclusively.

The most unusual aspect of the 1976-77 study was the lack of precipitation during the fall and winter months. In terms of the chum study, this drought condition completely altered the distribution of spawners from what would be expected in a normal flow year. Muck Creek, the major chum-producing tributary of the watershed, was completely impassable above stream mile .5 resulting in much higher than normal escapements into the mainstem, and Yelm and Clear creeks. The tag recovery segment of the study was enhanced as a result of the low flows because low water levels and clear water made it relatively easy to see carcasses on the spawning grounds. Table 14 summarizes the tag recovery information for the study. Since adequate numbers of spawning ground recoveries were obtained, we subtracted the fishery recoveries from the tagged population by expanding the actual recoveries by the sampling rate for the river fishery.

Darroch's tests for stratification (Table 15 and Appendix Tables B9 through B13) indicate that both time at marking by time at recovery and time at marking by area of recovery are possible ways to stratify the data. In deciding which of these stratifications to use, we decided that sampling over recovery time intervals was probably not random because sampling from different recovery areas, which are sampled at different rates, usually occurred simultaneously. Although varying flow levels may also preclude the random sampling of recovery areas, it seems more reasonable to assume random sampling within recovery areas rather than within recovery weeks. Hence, to insure that assumption 3 is true within each recovery stratum, we decided to stratify the data by time at marking and area at recovery.

Table 16 presents the parameters and results of the stratified estimate. Grouping over marking and recovery strata was done to obtain necessary sample sizes. The grouping was done on the basis of temporal or geographical proximity. Sample sizes were considered adequate when the theoretical coefficient of variation was less than .25.

Because males were selectively harvested in the river gill net fishery, changes in the sex composition of the run will influence the availability of chum for recovery between marking strata. We, therefore, developed availability constraints based on sex composition of the marking strata. Sex composition of each stratum is presented in Table 17.

Because a 4 x 3 constraint matrix was developed, it was possible to configure different matrices using sex composition. The constraint matrix with the most reasonable p-values was chosen for the estimate.

Although other factors were considered in the development of the availability constraints, none were as biologically reasonable as sex composition nor did they yield as reasonable p-values.

Variance estimates were calculated using the method of interpenetrating subsamples. Four subsamples were taken of the tagging and recovery data. The subsamples and results are shown in Appendix Table B14.

Table 18 summarizes the tagging study data and run size characteristics of the 1976-77 Nisqually chum run.

Table 13. 1976-77 Purse Seine Catches and Chum Tagged

Date	Number Captured	Number Tagged	Number Sets	Catch/Set	Number Steelhead
12/6/76	240	240	3	80	3
12/7/76	241	240	4	80	33
12/15/76	293	291	4	73	37
12/16/76	203	203	5	41	29
12/20/76	656	550	2	328	5
12/21/76	889	485	2	445	2
12/28/76	424	318	4	108	13
12/29/76	150	150	4	38	3
1/3/77	694	377 1/	3	231	0
1/4/77	658	128 1/	3	219	12
1/6/77	643	0 1/	3	214	4
1/12/77	210	210 2/	4	53	0
1/13/77	303	303	3	101	0
1/18/77	17	17	5	3	0
1/19/77	25	25	4	8	0
1/25/77	2	2	4	1	11
1/26/77	20	20	5	4	3
Totals	5,668	3,559	62	91	155

1/ Concurrent broodstock collection

2/ G.B. Heron utilized beginning 1/12 until the conclusion of tagging

Table 14. 1976-77 Tag Recovery Information

Recovery Area	Carcasses Sampled	Tags Recovered
Commercial Fishery		
Frank's Landing	4,869	321
Doc Watson	3,388	304
Brown's Fish House	4,673	313
Yelm Creek	484	60
Muck Creek	591	33
Mainstem Nisqually	1,464	92
Clear Creek	471	38
Kalama Creek	34	7
Horn Creek	49	8
Fish House Slough	116	10
Independent Drainages		
Red Salmon Creek	329	30
McAllister Creek	496	14
Chambers Creek	1,623	28
Coulter Creek	344	1

Table 15. Summary of Stratification Tests for 1976-77 Mark-Recapture Data

Test	Chi-Square	D.F.	P-Value
Recovery rate by time of tagging	59.56	7	0.0
Tag ratio by recovery location	36.03	6	0.0
Tag ratio by time of recovery	47.15	7	0.0
Time of tagging by recovery location	50.85	5	0.0
Time of tagging by time of recovery	67.47	5	0.0

Table 16. Parameters and Results of the Stratified Population Estimate of the 1976-77 Run

Grouped Time of Tagging/Recovery Area Matrix

	Recovery Areas		
Tagging Dates	Mainstem, Fish House Slough	Kalama, Horn, Yelm Creeks	Clear, Muck Creeks
December 6, 7	4.39	12.18	4.71
December 15, 16, 20, 21	39.09	31.36	26.83
December 28, 29	40.28	20.24	16.10
January 3, 4, 12, 13, 18, 19, 25, 26	17.25	11.19	27.40

Tagging vector (a_i): (130.5, 614.8, 550.1, 400.3)

Recovery vector (u_j): (1,478.99, 492.03, 986.96)

X Matrix:

$$\begin{bmatrix} 1.09 & 0 & 0 & -1 \\ 1.10 & 0 & -1 & 0 \\ .25 & .25 & .25 & .25 \end{bmatrix}$$

P-values: (.108, .274, .138)

N = 24,292

Coefficient of variation = .118

Escapement = 24,292 - freshwater sport catch - C&S = 23,211

Table 17. Sex Ratio by Tagging Period for the 1976-77 Run

Tagging Period	% Male	% Female
12/6, 7	57	43
12/15, 16	37	63
12/20, 21	43	57
12/28, 29	36	54
1/3, 4	34	66
1/12, 26	39	61

Table 18. Mark-Recapture Information and Population Characteristics of the 1976-77 Run

<u>Mark-Recapture Information</u>	
Number Tagged	3,559
Number Strays (estimated total)	100
Number Sampled	
Fishery	12,930
Spawning Grounds	3,209
Number Tags Recovered	
Fishery	938
Spawning Grounds	248
<u>Population Characteristics</u>	
Run Size	50,103 1/
Standard Deviation	4,983 2/
Catch	
Commercial	24,664
Ceremonial and Subsistence	350 3/
Sport	731 4/
Broodstock	1,147
Total	26,892
Escapement	23,211
Escapement Goal	25,000
Exploitation Rate	.54

1/ Includes fish taken for broodstock in marine areas

2/ Variance estimate derived by method of interpenetrating subsamples (Appendix B14)

3/ Nisqually Tribal estimate

4/ From 1976 and 1977 WDF catch reports

1977-78

In 1977-78, 6,293 chum were tagged in 18 days of tagging between December 5, 1977 and February 2, 1978 (Table 19). Tagging was scheduled on a two day per week basis. Tags were recovered from the river net fishery and from spawning ground surveys (Table 20).

The 1977-78 study was unusual in that an illegal fishery occurred in the Nisqually Reach. Little is known about this fishery other than that it may have taken 10,000 to 20,000 late run chum. One sample of 749 chum was obtained, 71 of which were marked. Because this sample came from a single night's catch, it cannot be considered a random sample of the entire illegal fishery.

Due to the lack of an enumeration or a reasonable estimate of the number of fish taken in the fishery, it was not possible to estimate escapement. However, it was possible to develop a total run size estimate assuming that the illegal fishery took a random sample of tagged and untagged salmon.

The validity of the assumption of randomness of the fishery will be determined in part by the exact location of the fishery. If all or part of this fishery occurred farther away from the Nisqually estuary than did our marking operation, then the fishery would have exploited fish that had zero probability of being marked. In this case, the fishery would obviously not be random. We cannot precisely define the location of operation of the fishery although observations of boats fishing illegally were made only in the vicinity of the marking location.

The randomness of the illegal fishery also depends on the consistency of the marked to unmarked ratio in the Nisqually estuary over time. If, for example, the marked to unmarked ratio in the estuary changes dramatically between time periods, then the marked to unmarked ratio of the illegal fishery sample depends on the time periods in which the fishery occurred. From the biological section of this report, however, we see that fish typically average two weeks to migrate from the marking location to the Frank's Landing Indian fishery. As the Frank's Landing fishery occurs in the first three miles of the river, the delay in migration to the Indian fishery is likely the result of fish milling for extended periods in the estuary. Because fish do mill in the estuary, the marked to unmarked ratio in the estuary should remain relatively constant. There will, of course, be some change in the marked to unmarked ratio, the ratio being higher immediately after a marking day and gradually decreasing until the next marking day. We cannot be sure that this variation is insignificant. Finally, the marked to unmarked ratio of the single sample that was obtained from the illegal fishery is similar to the marked to unmarked ratio observed in the treaty fishery (Table 20).

As usual, the number of fish taken in the treaty fishery was determined from WDF fish tickets. So as not to estimate this known number of fish, the marked recoveries from the Indian fishery were subtracted from the marked population. The number of marked recoveries was estimated by dividing the actual recoveries by the sampling rate from the fishery.

The population was tested for stratification using tests described by Darroch (1961). The hypothesis that rate of recovery was homogenious over all marking periods is rejected (Table 21). We must assume that recovery was non-random.

However, the tests of homogeneity of the marked to unmarked ratio over both time and area are not significant. It appears, therefore, that marking was random. As the assumptions of the simple model are satisfied if either the marking or recovery sample is random, we assume that the simple model is appropriate in this case. Although we did not need to stratify the 1977-78 estimate, the sex ratio by tag day information (Table 22) is presented for comparison purposes.

Because there was an adequate number of recoveries, random subsampling was used to estimate the variance (Appendix Table B18).

Table 23 summarizes the tagging study and run size characteristics of the 1977-78 Nisqually chum run.

Table 19. 1977-78 Purse Seine Catches and Chum Tagged

Date	Number Captured	Number Tagged	Number Sets	Catch/Set	Number Steelhead
12/5/77	593	366	3	198	1
12/6/77	374	338	3	125	1
12/12/77	829	579	2	415	2
12/13/77	492	472	2	246	0
12/19/77	831	559	3	277	14
12/20/77	638	611	3	213	19
12/27/77	1,023	633	2	512	8
12/28/77	624	493	3	208	4
1/3/78	802	652	2	401	0
1/4/78	165	140	3	55	17
1/9/78	1,012	596	3	337	2
1/10/78	574	448	3	191	5
1/16/78	143	140	4	36	5
1/17/78	114	100	4	29	11
1/24/78	89	89 1/	7	13	19
1/25/78	49	49	8	6	3
1/31/78	23	23	6	4	8
2/2/78	5	5	4	1	0
Totals	8,380	6,293	65	129	119

1/ G.B. Heron utilized beginning 1/24 and continuing to the conclusion of the study.

Table 20. 1977-78 Tag Recovery Information

Recovery Area	Carcasses Sampled	Tags Recovered
Commercial Fishery	11,813	1,340
Muck Creek Drainage	5,982	716
Yelm Creek	315	41
Fish House Slough	161	13
Tanwax Creek	20	2
Mainstem Nisqually	333	38
Lower Reservation Slough	121	16
Upper Reservation Slough	62	10
Clear Creek	33	2
Walcott Slough	69	7
Hill Creek	31	5
Independent Drainages		
Red Salmon Creek	88	15
Chambers Creek	1,377	79
13B	237	2
McAllister Creek	745	53

Table 21. Summary of Stratification Tests for 1977-78 Mark-Recapture Data

Test	Chi-Square	D.F.	P-Value
Recovery rate by time of tagging	81.70	8	0.00
Tag ratio by recovery location	5.54	7	0.59
Tag ratio by time of recovery	4.90	7	0.67

Table 22. Sex Ratio by Tagging Period for the 1977-78 Run

Tagging Period	% Male	% Female
12/5, 6	55.6	44.4
12/12, 13	48.2	51.8
12/19, 20	46.6	53.4
12/27, 28	44.3	55.7
1/3, 4	40.2	59.8
1/9, 10	37.9	62.1
1/16, 17	33.0	67.0
1/24, 2/2	34.3	65.7

Table 23. Mark-Recapture Information and Population Characteristics of the 1977-78 Run

Mark-Recapture Information	
Number Tagged	6,293
Number Strays (estimated total)	189
Number Sampled	
Fishery	11,813
Spawning Grounds	7,127
Number Tags Recovered	
Fishery	1,340
Spawning Grounds	850
Population Characteristics	
Run Size	52,504
Standard Deviation	2,438 1/
Catch	
Commercial (freshwater)	22,420
Commercial (marine)	Unknown
Ceremonial and Subsistence	350 2/
Sport	82 3/
Broodstock	564
Escapement	Not estimated

1/ Variance estimate derived by method of interpenetrating subsamples (Appendix B18)

2/ Nisqually Tribal estimate

3/ From 1977 and 1978 WDF sport catch reports

The 1978-79 study, unlike the preceeding year, was not beset by any serious problems. The illegal fishery of 1977-78 did not re-occur in 1978-79. We made numerous nighttime observations of the Nisqually Reach area and only observed one boat which may or may not have been fishing illegally. The unusually cold weather which persisted for long periods in December and January, resulting in low flows in most parts of the watershed, was inconvenient but posed no serious impediments to accomplishment of study objectives.

In 1978-79, 4,434 chum were marked on 16 days between December 4 and January 23 (Table 24). In addition to the usual spawning ground and fishery recoveries (Table 25), we were also able to obtain a complete enumeration (Appendix C) of the number of chum that entered Muck Creek from a weir that was constructed near the confluence of the creek with the river. As this segment of the population was of known size, the marked fish in this segment were subtracted from the marked population.

As usual, an estimate of the fishery recoveries was subtracted from the marked population. This estimate was calculated for each marking stratum by dividing the number of marked fish observed by the sampling rate.

The population was tested for stratification using tests described by Darroch (1961). The rejection of the hypothesis that recovery rate is homogeneous over time period of marking and that the marked to unmarked ratio is homogeneous over recovery area implies that neither marking nor recovery is random (Table 26 and Appendix Tables B19 through B22). In addition, the rejection of the hypothesis that time of tagging is homogeneous over recovery area implies that there is incomplete mixing between marking and recovery.

Therefore, Darroch's stratified model was used for estimation. Table 27 presents the parameters and results of the stratified estimate. Grouping over marking and recovery strata was done to obtain necessary sample sizes. The grouping was done on the basis of temporal or geographical proximity. Sample sizes were considered adequate when the theoretical coefficient of variation was less than .25.

Since males were taken at a higher rate than females in the gill net fishery, the sex composition of marking stratum probably influenced the average recoverability of fish in that stratum. We therefore imposed availability constraints based on sex composition of the marking strata. Sex composition for each stratum, as estimated by the marking sample, is presented in Table 28.

As a 3 x 2 contraint matrix was used, it was possible to configure several matrices using sex composition as a basis for the constraint matrix. Estimates were calculated using all combinations of the constraint matrices. However, the constraint matrix presented in Table 27 yielded the most reasonable p-values. We also examined condition at tagging, color at tagging, and days to recovery for availability constraints. However, none

Table 25. 1978-79 Tag Recovery Informat

Recovery Area	C S
Commercial Fishery	
Muck Creek (past weir)	
Muck Creek (below weir)	
Clear Creek	
Yelm Creek	
Mainstem Nisqually	
Fish House Slough	
Upper Reservation Slough	
Lower Reservation Slough	
Tanwax Creek	
Independent Drainages	
McAllister Creek	
11-0328 (unnamed)	
Red Salmon Creek	
Chambers Creek	
Johns Creek	
Swift Creek	
Perry Creek	
Crescent Creek	
Lackey Creek	
Woodland Creek	
Woodard Creek	

Table 26. Summary of Stratification Tes
Data

Test	Ch
Recovery rate by time of tagging	
Tag ratio by recovery location	
Tag ratio by time of recovery	
Time of tagging by area at recovery	

Table 27. Parameters and Results of the Stratified Population Estimate of the 1978-79 Run

Grouped Time of Tagging/Recovery Area Matrix

	Recovery Areas	
Tagging Dates	All Areas Other Than Yelm Creek	Yelm Creek
December 4, 5, 11, 12	42.39	5.89
December 18, 19, 27, 28	78.64	55.39
January 3, 4, 9, 10, 15, 16, 22, 23	14.03	4.71

Tagging vector (a_i): (640.18, 994.76, 256.6)

Recovery vector (u_j): (1,097, 479)

X Matrix:

$$\begin{bmatrix} 1.028 & 0 & -1 \\ .333 & .333 & .333 \end{bmatrix}$$

P-values: (.108, .071)

N = 18,677 + 24,385 (catch) + 7,218 (Muck Creek return) = 50,280

Estimate standard deviation (using subsamples) = 3,062

Table 28. Sex Ratio by Tagging Period for the 1978-79 Run

Tagging Period	% Male	% Female
12/4, 5	54.5	45.5
12/11, 12	52.3	47.7
12/18, 19	50.4	49.6
12/27, 28	44.8	55.2
1/3, 4	40.2	59.8
1/9, 10	39.4	60.6
1/15, 23	40.9	59.1

Table 29. Mark-Recapture Information and Population Characteristics of the 1978-79 Run

Mark-Recapture Information	
Number Tagged	4,434
Number Strays (estimated out of system)	238
Number Sampled	
Fishery	11,272
Muck Creek (past weir)	7,219
Spawning Grounds	1,576
Number Tags Recovered	
Fishery	792
Muck Creek (past weir)	592
Spawning Grounds	201
Population Characteristics	
Run Size	50,280
Standard Deviation	3,062 1/
Catch	
Commercial	24,385
Ceremonial and Subsistence	500 2/
Sport	55 3/
Broodstock	650
Total	25,590
Escapement	24,690
Escapement Goal	27,000
Exploitation Rate	.51

1/ Variance estimate derived by method of interpenetrating subsamples (Appendix B23)

2/ Nisqually Tribal estimate

3/ From 1978 and 1979 WDF sport catch reports

During the 1974-75 run, it became apparent that the utility of the mark-recapture study could be increased significantly if the information could somehow be used as an in-season management tool. Although the studies were not designed originally with this purpose in mind, in-season management of the Nisqually run was difficult because no significant correlation could be detected between catch data and run size until after most of the run had passed through the fishery, far too late to be of value for management. Therefore, the following method was developed.

If we divide the duration of the run season into "n" discrete time intervals and let p_i be the expected proportion of the run that enters the terminal area during time interval i, then run timing can be described as the specification of the p_i's, i = 1 to n. If we have the estimates for both p_i and the number of fish that enter the terminal area during time interval i (N_i), then a total run size (NHAT) can be estimated by:

1) $NHAT = N_i / p_i$

OR, by utilizing a set of time strata

$NHAT = \Sigma N_i / \Sigma p_i$

This technique, applied to the first one or more time intervals, can be used to obtain in-season run size estimates that are needed for management of the river fishery. The adult tagging studies provide estimates of the number of fish that enter the terminal area during each time interval. In addition, these estimates can be obtained soon after the passing of the respective time interval.

The adult tagging studies can also be used to estimate the p as follows:

2) $p_i = N_i / NHAT$

From 2 it is apparent that the p are not available until NHAT is estimated, which is, of course, at the end of the run season. If, however, we assume that run timing, that is, the p_i's, remained consistant between years, then for a particular season we can use estimates of the p_i's obtained from tagging studies conducted during preceeding seasons.

The time period used as an index in making Nisqually in-season run size estimates begins at the start of the run and ends at a time that is determined by management needs. Rather than using past year's data to complete a pooled estimate of p_i for this interval, regression was used to determine the relationship between abundance during this interval and total run size.

Run size = a + b (Index); where
- a = constant
- b = slope
- (Index) = tags released to time i multiplied by the tag ratio to time j ($i < j$)

Regression analysis was conducted upon the tagging and recovery data generated from the 1974-75 thru 1978-79 studies (Appendix Tables D1 and D2) assuming the above relationship between run size and in-season tagging and recovery data. Example relationships are presented in Table 30. These values are slightly different than preliminary analysis indicated (Nisqually Tribe and FAO 1979) because the final run size estimates have changed slightly and some of the mark sampling data were excluded for various reasons.

Table 30. Examples of In-Season Run Size Projection Calculations

Tags Released Thru i	Time Lag	a	b	R
12/16	4	16,288	1.08	.75
12/23	3	4,204	1.42	.89
12/23	7	4,859	1.47	.91
12/30	5	3,819	1.45	.93
1/6	2	4,727	.94	.94
1/6	6	3,410	1.02	.96

The relationships presented are the most representative given the fishing and tagging patterns that occurred. However, they are not the only possibilities. We attempted to choose combinations of tagging and recovery data that were consistent between years with respect to tagging dates and time lags for the recovery data. However, there were so many gaps in the available information that this was not always possible. In 1974-75, tagging did not begin until December 17 so that early season tag information is not comparable to the following years. In 1975-76, tagging was conducted one day per week with little consistency within the weekly periods.

Further limitations are imposed by the tag recovery data from the commercial fishery. The river commercial fishery for chum was three or five days per week in the 1974-78 period. In order to have a consistent lag between tagging and recovery in the river fishery many combinations of the data were excluded. Also, in the 1975-76 season, the fishery was shifted from five days per week in December to one day per week for the remainder of the year. When there was a gap in the recovery data we chose the closest day for which there was recovery information.

Although the Nisqually run is not usually subjected to significant marine interceptions which would alter the timing to the terminal area, the timing assumption is still tenuous. The Nisqually run is composed primarily of three and four year fish which have distinct entry timing (see section on age composition). Therefore, changes in age composition may influence timing. Also, marine or freshwater environmental conditions could shift timing to some degree. Fortunately, as the season progresses the projections should become more accurate. By the end of the first week of January the estimates have generally been quite accurate.

The primary alternative to tagging is catch information which is also subject to timing fluctuations. The advantages of the tagging updates for in-season projections over other methods, such as catch data, is that the tagging estimates are independent of conditions which might affect the river fishery such as changes in efficiency due to flows, water clarity, and gear saturation. The major disadvantage is the expense in maintaining tagging crews and samplers virtually full-time until estimates have been developed. Another disadvantage is the situation which occurred in 1979-80 when the pre-season projection was below the escapement goal. Because the projection is dependent on catch data, no projection is possible when no fishery occurs. In 1979-80, an attempt was made to project run size based on the tagging data and Muck Creek weir returns. Because there was only one year of Muck Creek data for comparison and only a small amount of recovery data as of late December 1979, the early projections were not accurate.

Sex Ratios

Table 31 summarizes information on sex ratios collected in the 1974-79 studies. No information was included on sex ratios of carcasses examined during spawning ground surveys because spent females tend to beach themselves, while males tend to drift downstream, making it impossible to obtain random samples. Also, no information was collected from the fishery in 1977-78 and sampling of the fishery was not consistent in 1976-77.

Several points need clarifying with respect to the information in Table 31. The large disparity in sex ratio at tagging in 1977-78 was probably due to the illegal marine net fishery in the Nisqually Reach area. The low percentage of males is therefore not representative of the true population structure. There are no such explanations for the 1976-77 tagging data.

Duration of the fishery strongly affects the sex ratio of the fishery sample because males are more abundant early in the run and females later (see tagging data, Tables 5, 11, 17, 22 and 28). The fisheries in 1974-75 and 1978-79 showed that the river fishery was selective for males. These fisheries were unbiased since they lasted until late in the run. However, the fishery often exaggerates the true selectivity for males because it usually begins early in the run and ends when the catch quota is achieved. The fishery in 1979-80 probably exaggerated the selectivity considerably because the fishery was especially short.

Table 31. Nisqually Chum Sex Ratios

	Tagging		Fishery 1/		Muck Creek Weir	
Year	Male	Female	Male	Female	Male	Female
1974-75	46.7	53.3	53.1	46.9	--	--
1975-76	48.2	51.8	53.5	46.5	--	--
1976-77	41.0	59.0	49.7	50.3	--	--
1977-78	44.6	55.4	--	--	--	--
1978-79	49.2	50.8	54.6	45.4	44.3	55.7
1979-80	47.1	52.9	61.3	38.7	44.6	55.4

1/ Weekly sex ratio samples weighted by catch

Length Frequencies

Table 32 summarizes the length frequency information from the 1974-75 through 1979-80 Nisqually studies. No consistent relationship appears to exist between the average length at tagging, recovery in the river fishery, nor at the Muck Creek weir. We had suspected that the river fishery might be somewhat selective for larger fish but this does not appear to be the case. No length information was collected from spawned-out carcass recoveries.

The discrepancy in length between tagging and recovery at the weir in 1979-80 is probably due to non-random tagging. Although tagging was conducted through the run, the effort was concentrated early in the season when the age composition data indicated a preponderance of three year old fish.

Table 32. Average Length (in cm) of Nisqually Chum at Tagging in the Estuary, in the River Fishery, and at the Muck Creek Weir

Year	Tagging		Fishery 1/		Weir	
	Male	Female	Male	Female	Male	Female
1974-75	79.2	73.9	79.5	74.6	--	--
1975-76	75.5	71.5	75.5	71.6	--	--
1976-77	75.6	71.0	74.9	70.0	--	--
1977-78	79.1	74.4	79.9 2/	74.6 2/	--	--
1978-79	76.5	72.5	76.4	71.4	75.4	72.6
1979-80	75.5	70.9	--	--	79.7	74.0

1/ Length samples not weighted by catch

2/ Average lengths calculated from tag recoveries

Table 33 displays length frequency from the 1974-75 through 1981-82 combined marine and freshwater sampling by age and sex. Although overlap exists, the average sizes are substantially different. Each age/sex cohort shows some annual variation in average fork length. The average fork length of three year old fish is at least six cm smaller than the corresponding four year old fish. Five year old fish average larger than four year old fish, usually by two to four cm. There may be some elongation of the snout with maturation, but the difference in length between marine and freshwater recovery areas is probably slight because marine samples were taken when the fish were already quite mature.

Table 33. Average Fork Lengths (in cm) of each Nisqually Late Chum Age/Sex Cohort

Cohort	1974-75	1975-76	1976-77	1977-78	1978-79	1980-81	1981-82
3 Male	74.1	72.6	74.3	72.7	68.7	73.1	72.9
3 Female	69.3	69.3	69.1	69.7	66.1	68.7	68.2
4 Male	80.2	80.7	81.2	78.9	78.3	79.7	80.0
4 Female	75.4	75.0	75.5	73.8	74.1	74.4	73.5
5 Male	--	--	--	82.7	83.5	--	81.8
5 Female	--	--	--	77.3	--	--	78.6

Table 34 presents age composition data for the Nisqually run for the 1974-82 time period. No data are available for 1977-78. The data for 1974-75, 1975-76, 1976-77, 1978-79, and 1981-82 are from the freshwater commercial fishery, whereas the 1979-80 and 1980-81 data are a combination of freshwater commercial fishery data, marine samples from the tagging operation, from the 1980 marine fishery, and scales taken from carcasses in the spawning areas. The carcass recoveries were initiated in 1979-80 when we became aware that others had successfully been aging chum from carcass scales (Helle 1979). Age composition from 1978-79 on is estimated by weighting each sampling stratum by the proportion of the run it represents.

Table 34. Nisqually Late Chum Age Composition by Year

Year	% 3	% 4	% 5
1974-75 1/	16.8	81.8	1.4
1975-76 1/	60.5	39.2	0.3
1976-77 1/	67.4	32.6	0.0
1978-79	65.6	33.4	1.0
1979-80	30.1	68.2	1.7
1980-81	70.4	29.2	0.4
1981-82	17.3	81.0	1.7

1/ Inconsistent sampling data, sample data are unweighted by catch

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There is a lack of consistency in relative composition of three and four year old fish as indicated by these data. Three year old fish were more abundant in four of the years while four year olds were prevalent in the other three years. Five year olds were not a significant portion of the run.

Table 35 presents a breakdown of age composition by time for the 1974-75, 1975-76, 1978-79, 1979-80, 1980-81, and 1981-82 runs. No information was collected in 1977-78 and only two early season weeks of sampling were available for 1976-77. The trend in age composition within a season is indicated by these data. There are recurring differences in entry timing between three and four year old chum with threes returning early and exhibiting a declining trend in abundance while fours are increasing.

This trend is also shown by the data in Tables 36 and 37. In the 1979-80 sampling, there was a radical difference in composition between the marine samples on December 19 and January 7 to January 17. Threes were far more abundant in the early samples. In 1980-81, threes were a higher percentage of the sample of the freshwater catch than the marine catch. The freshwater fishery samples were taken between December 10 and January 15, whereas the marine sample was from January 9.

The inconsistency in the age structure and the difference in timing of three and four year old fish indicate the potential problems in any in-season run size estimation method which assumes consistent timing between years. The assumption of consistent timing is an obvious shortfall of the method presented in this report for in-season predictions.

An additional point of interest with respect to the age data in Tables 36 and 37 is the discrepancy between the Muck Creek samples and the rest of the watershed. The low abundance of three year old chum in Muck Creek in 1979-80 and the low abundance of four year olds in 1980-81 is explained by the fact that Muck Creek was inaccessible in 1976-77 due to the extreme low water. The only chum that were able to utilize the Muck Creek watershed spawned in its lower several hundred yards. The resulting distribution pattern supports the concept of discrete stocks within a watershed.

Table 35. Age Composition in the Nisqually River Chum Fishery by Time

1974-75	n	% 3	% 4	% 5
1-3 Jan 75	109	25	72	3
5-10 Jan 75	202	17	82	1
12-17 Jan 75	118	9	91	0
1975-76				
13-31 Dec 75	92	66	34	0
4-7 Jan 76	99	65	35	0
10-13 Jan 76	62	54	44	2
19-27 Jan 76	38	45	55	0
1978-79				
15-21 Jan 79	166	65	34	1
22-28 Jan 79	336	57	42	1
20 Jan - 4 Feb 79	136	52	44	3
5-11 Feb 79	220	50	46	4
1979-80				
1-6 Jan 80	134	57	42	1
7-13 Jan 80	97	38	60	2
14-20 Jan 80	78	28	71	1
1980-81				
8-14 Dec 80	80	83	17	0
15-21 Dec 80	230	84	16	0
22-28 Dec 80	119	79	21	0
29 Dec 80 - 4 Jan 81	179	81	19	0
5-18 Jan 81	80	71	29	0
1981-82				
29 Nov - 12 Dec 81	109	30	69	1
16-19 Dec 81	252	28	71	1
20-26 Dec 81	200	23	76	1
27 Dec 81 - 2 Jan 82	35	21	76	3
4-10 Jan 82	252	15	83	2
10-16 Jan 82	252	14	85	1
18-24 Jan 82	95	11	86	3

Table 36. 1979-80 Chum Age Composition by Time and Area

Recovery Dates	Location	Sample Size	% 3	% 4	% 5
19 Dec	Marine	100	52.0	47.0	1.0
7-17 Jan	Marine	100	19.0	80.0	1.0
Season	Nisqually Mainstem	26	30.8	69.2	0.0
Season	Clear Creek	23	43.5	56.5	0.0
Season	Fish House Slough	6	50.0	50.0	0.0
Season	Yelm Creek	56	30.4	66.1	3.5
Season	Muck Creek	272	10.7	87.9	1.4
9-16 Jan	Commercial Fishery	310	43.5	55.2	1.3

Table 37. 1980-81 Chum Age Composition by Time and Area

Recovery Dates	Location	Sample Size	% 3	% 4	% 5
9 Jan	Marine	117	55	45	0
Season	Nisqually Mainstem	59	44	54	2
Season	Clear Creek	76	68	32	0
Season	Yelm Creek	35	71	29	0
Season	Muck Creek	148	90	9	1
10 Dec-16 Jan	Freshwater Fishery	688	77	23	0

Figures 2 thru 9 (Appendix E) indicate timing of the Nisqually stock at various stages in their spawning cycle. To smooth fluctuations, the data were averaged by weekly periods.

Peak catches per purse seine set in most years were observed either between December 22-28 or December 29-January 4 (Figure 2). The peak in the 1976-77 study did not occur until January 5-11 but the winter of 1976-77 was extremely dry with reduced river flows so the chum probably remained in saltwater for longer than normal. Peak catches per landing for the river fishery generally were observed from January 5-11 but the 1976-77 peak was again later by one week (Figure 3).

Peak movement into the Muck Creek weir was the week of January 5-11 in 1978-79, January 12-18 in 1979-80, and December 29 to January 4 in 1980-81 (Figure 4, Appendix Table C1). Although the movement of fish through the weir is influenced at least on a short-term basis by changes in flows, the differences between the three runs probably indicate actual differences in timing of the Muck Creek runs. The two week difference in peaks between 1979-80 and 1980-81 runs is consistent with the age data presented in Table 34. The 1979-80 run was predominantly four year old fish which showed up later in our purse seine catches in 1979-80. However, the 1980-81 run was dominated by three year old fish which return earlier. The 1978-79 run was a more even mixture of three and four year olds.

Figures 5 thru 8 indicate timing in two Nisqually tributaries (Yelm and Clear creeks) and two independent drainages (McAllister and Red Salmon creeks) with late-timed chum stocks. The data are presented as weekly live counts per mile surveyed. Live counts are used because they are not biased by washouts and scavenging as carcass counts would be. The visibility is excellent in these streams so visibility problems should have very little influence on count accuracy.

An interesting aspect of the Yelm Creek information was the consistency of the peak counts. In all years, the peak counts were between January 20th and 24th, in spite of varying fishery regulations and wide variations in flow. More variation was apparent in the other systems: Clear Creek peak counts varied from January 10 to February 8, Red Salmon from January 14 to January 28, and McAllister from January 11 to 23.

The final timing graph (Figure 9) compares timing at tagging, capture in the fishery, at the Muck Creek weir, and on the spawning grounds. Because the data are summarized by weekly intervals, the differences will be multiples of seven days. The Muck Creek and fishery counts peak during the same week while tagging peaks two weeks earlier and spawning ground counts peak two weeks later.

Rate of movement through the system was determined by comparing time of estuary tagging with recovery at various freshwater locations (Table 38). For this analysis, we have excluded spawning ground recoveries because carcasses are often not recovered for one or more weeks after death of the fish. We also excluded data from the 1975-76 fishery because it closed very early and from the 1977-78 river fishery because the illegal marine fishery probably intercepted large portions of certain segments of the run. Only the 1978-79 weir recovery data were analyzed because tagging in 1979-80 and 1980-81 only covered the early segment of the run.

The 1974-75 data could not be broken down further than the general fishery because buying station was not specified in the original collection of the data. In 1976-77 and 1978-79 the buying stations were Frank's Landing, which handled fish from approximatey river mile 0 to 3.5, and Doc Watson's, which handled fish from river mile 3.5 to 11. Differences in prices between buyers might occasionally disrupt this pattern; however, this was not a problem in either 1976-77 or 1978-79.

Several points are interesting with respect to the data in Table 38. First, the difference in recovery time between the lower river fishery (Frank's Landing) and the upper river fishery (Doc Watson's) was about four days in 1976-77 and five days in 1978-79. Second, in comparing the 1978-79 samples from the upriver fishery and from Muck Creek from that year, there was virtually no difference in recovery time. Finally, even though our tagging locations are very near the mouth of the Nisqually, it took an average of two weeks for the fish to enter the lower river (Frank's Landing) freshwater fishery. Considering that the fishery operates near the mouth of the river and that the travel time estimates are probably conservative because a fish may be in the tagging area for a while before being caught, the fish apparently mill in the estuary for at least two weeks before entering the river.

Table 38. Nisqually Chum Transport Time from Tagging in the Estuary to Recovery in the River

	Days to Recovery					
Tagging Period	1974 Commercial Fishery	1976 Frank's L. Fishery	1976 Doc Watson Fishery	1978 Frank's L. Fishery	1978 Doc Watson Fishery	1978 Muck Cr. Weir
Dec 1-7	-	16.9	20.7	17.4	22.5	25.9
8-14	-	-	-	18.8	21.9	25.8
15-21	16.0	13.5	20.8	14.9	23.2	21.6
22-28	13.4	13.2	16.4	15.7	20.8	19.6
Jan 5-11	9.3	-	-	10.9	11.6	11.7
12-18	8.9	3.7	8.8	10.2	11.7	14.1
19-25	7.4	-	-	8.1	13.5	13.0
Seasonal Averages	13.3	13.6	17.4	14.3	19.2	20.1

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