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Arlington, Washington, and
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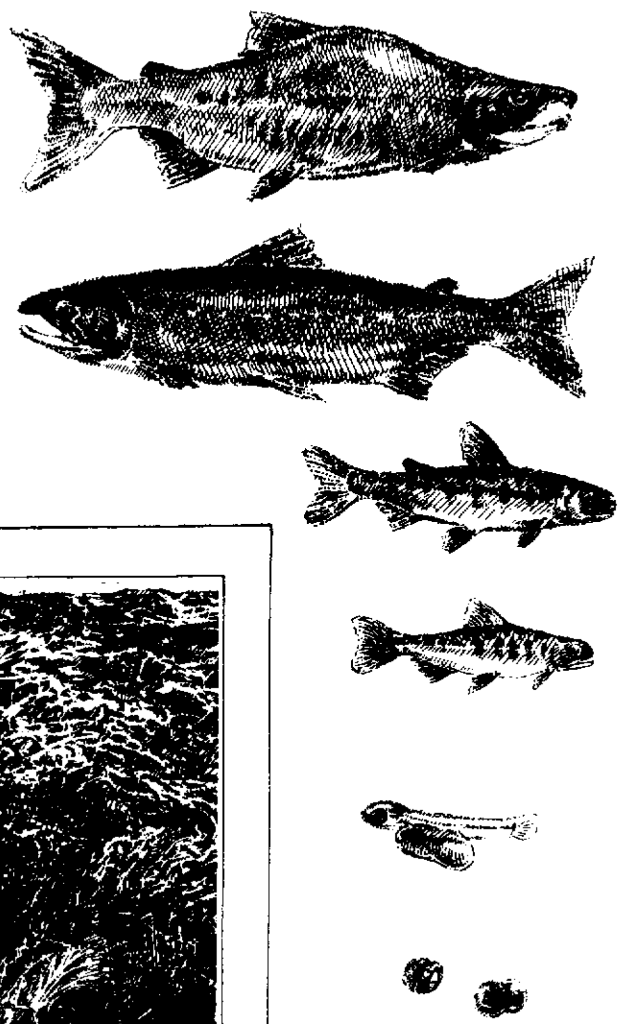

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INTRODUCTION

In 1980 the Stillaguamish Tribe of Indians and the Olympia Fisheries Assistance Office (FAO) of the U.S. Fish and Wildlife Service (FWS), with support from the National Marine Fisheries Service (NMFS), conducted a cooperative mark-and-recapture study to estimate escapement of chum salmon (*Oncorhynchus keta*) to the Stillaguamish River. A small-scale feasibility study had been conducted in 1979 to evaluate the potential for a mark-recapture study.

Stillaguamish stocks contribute to marine fisheries as well as to commercial and sport fisheries on the river. Two treaty Indian tribes, Tulalip and Stillaguamish, both conduct significant terminal area fisheries that harvest Stillaguamish chum. Between 1965 and 1978 the average terminal area treaty contribution of Stillaguamish stock has been 10,500 even year and 2,100 odd year chum with the Stillaguamish Tribe taking 5% in their river fishery and Tulalip taking the rest in their marine fishery in Ports Susan and Gardner which comprise Catch Area 8A (CH_2M Hill 1980).

With increasing demand for salmon, all river systems are being pressured for maximum production. As a result, it is imperative to obtain solid biological data on the status of the natural salmon stocks in such regions. Previously, the Washington State Department of Fisheries (WDF) has based chum salmon escapement estimates on index area live and dead counts, assuming that the current year's index count is the same proportion of the escapement as in the base year, 1968, when a mark-and-recapture study was done for all of Puget Sound (Mathews and Johnson 1969). However, the application of the 1968 study to specific watersheds was based on the questionable assumption that either all terminal runs were tagged at the same rate or else that fish were counted with equal efficiency in all watersheds. The problems of applying the 1968 results to specific watersheds and the probability of distribution patterns within the watershed changing over time made reevaluation of the baseline escapement estimate desirable.

In 1977 the WDF tagged chum in Port Gardner and recovered tags on the Stillaguamish and Snohomish Rivers, but the study is not used for a base year because an unusual proportion of fish entered the Snohomish instead of the Stillaguamish that year (Don Hendrick, WDF, personal communication). The present study avoids these difficulties by estimating only the Stillaguamish escapement.

The objectives of this project were:

1. to develop run size and escapement estimates,
2. to investigate methods for in-season monitoring of escapement, and
3. to obtain information on sex ratio, length frequency, age composition, timing, and distribution of the run.

The 1979 study demonstrated the feasibility of tagging in the lower river and of recovery on the spawning grounds. The 1980 study provided the escapement estimate reported here.

STUDY AREA

The Stillaguamish River basin (Figure 1) is situated between the Skagit and Snohomish basins on the eastern side of north Puget Sound. The river is composed of an 18-mile main stem and two 50-mile forks, which headwater in the Cascade Mountain range. Agriculture and forestry are the predominant land uses in the basin with small rural communities sporadically located along the river itself.

As in the neighboring Skagit and Snohomish rivers, the Stillaguamish salmon stocks are being managed by the tribes and WDF for natural production. Viable stocks of native chinook, coho, pink, and chum salmon exist in all reaches of the system, although the North Fork and its major tributaries supply the bulk of the production for all species.

The commercial fishery for Stillaguamish chum is conducted in the lower 15 miles of the river (Figure 2). Drift or set gill nets are commonly used, depending on the location.

METHODS

Returning adult chum salmon were tagged on the main channel of the Stillaguamish at River Mile (RM) 0.3, in the area known as Hat Slough (Figure 2). Tagging was done in daylight hours, usually five days a week, from October 21 through November 29. Two skiffs were used; one would set out a 50-fathom 6" mesh five-strand monofilament drift gill net. A second boat would follow along to pick up the fish as soon as they struck the net and bring them ashore to be tagged. Fish were cut out of the net with a knife and placed in a soft plastic water-filled pen onboard the boat. They were taken ashore, sexed, measured in a tagging cradle, and their ripeness was assessed as 1 = bright, 2 = intermediate, and 3 = dark. A numbered jaw tag was applied to the right mandible, the adipose fin was clipped, and the fish was released into a pen in the stream. We assessed the fish's condition after tagging as 1 = swam into pen quickly, 2 = swam into pen slowly, and 3 = disoriented. We generally held fish in the pen for several hours to assure their recovery before we released them upstream of tagging operations.

The selection of tag recovery areas was based on WDF spawning ground data reports (Egan 1978, 1979) and from field investigation during the past two years by the tribal biological staff. Because the North Fork contains the majority of the spawning, most of the tag recovery effort was focused in that area. Nonetheless, all known areas of chum spawning were surveyed, and all potential areas were surveyed at least once.

The tag recovery crews, composed of two surveyors each, sampled the area via foot surveys on small streams and combination float/foot surveys on the larger streams. Primary areas of chum spawning, that is, Browns, Squire, Furland, Ashton, Jim, Siberia, and Grants creeks and the North Fork from RM 30 to RM 22 (Figure 2) were surveyed twice weekly with secondary areas surveyed once a week. All areas were monitored between October 20 and December 31, though a general timing difference was observed between the South Fork areas and the North Fork, which allowed us to concentrate our early effort on the South Fork and the latter efforts on the North Fork.

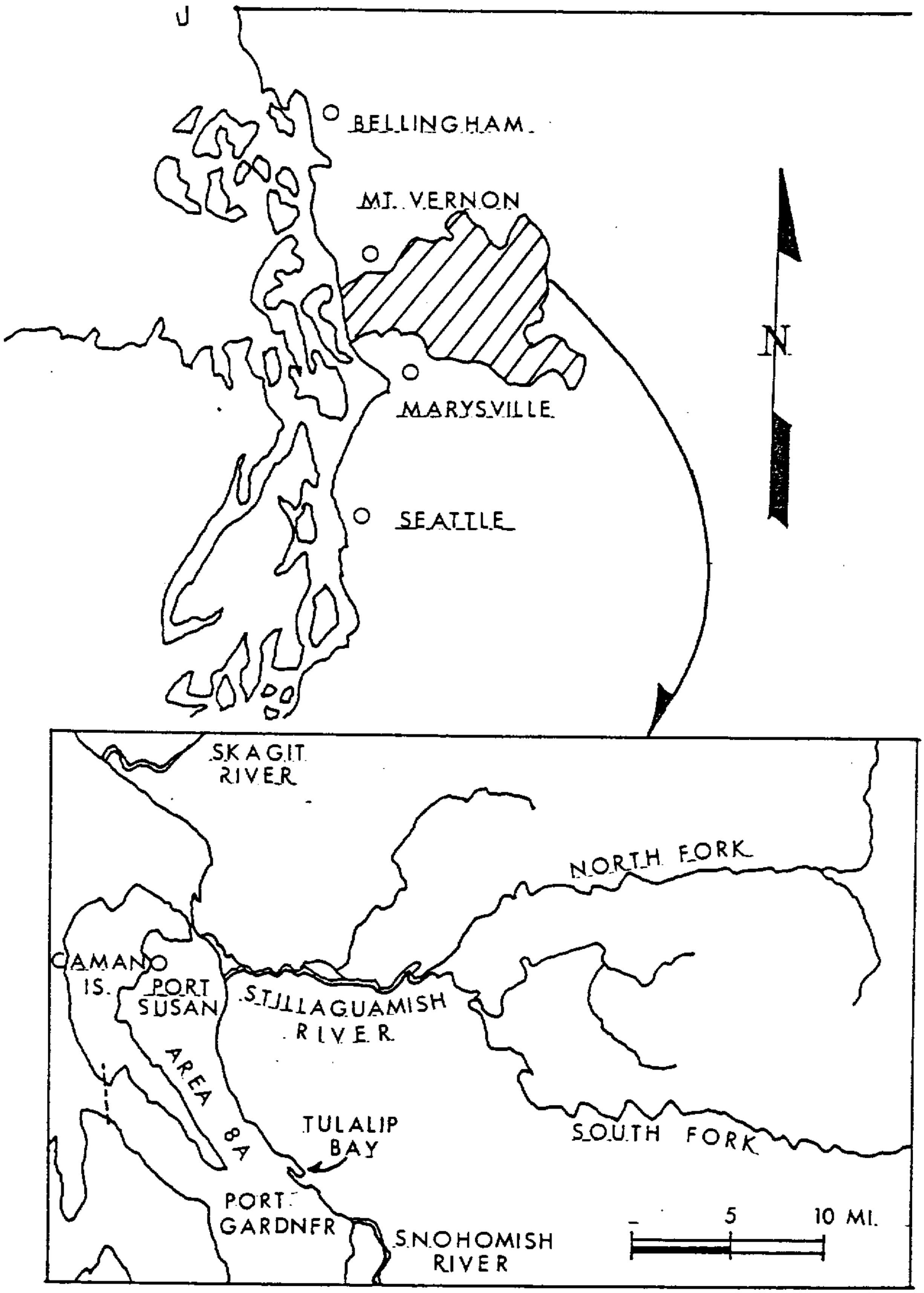

FIGURE 1. STILLAGUAMISH RIVER BASIN, SNOHOMISH COUNTY, WA

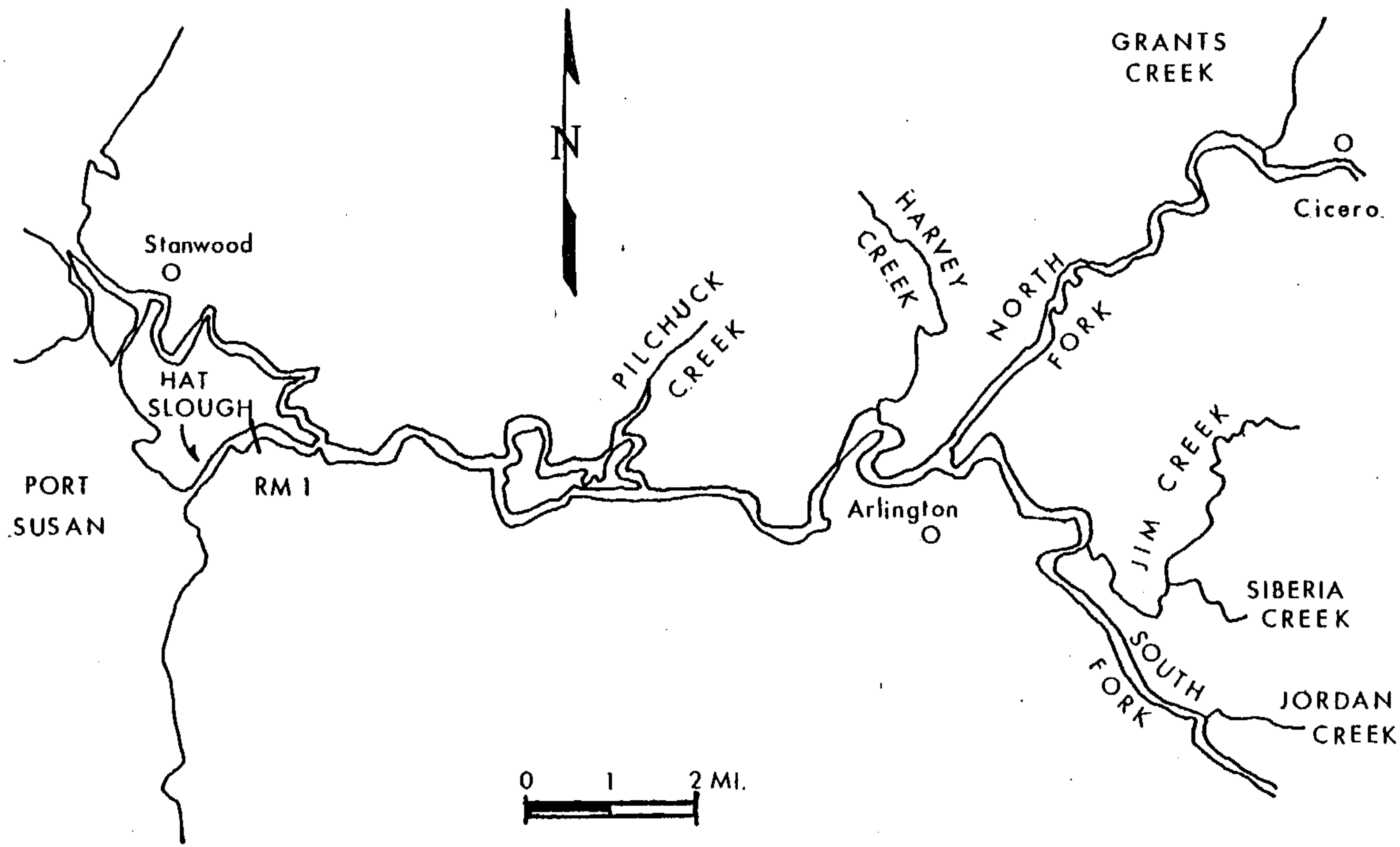

FIGURE 2. STILLAGUAMISH RIVER SHOWING CHUM STUDY SITES, 1980

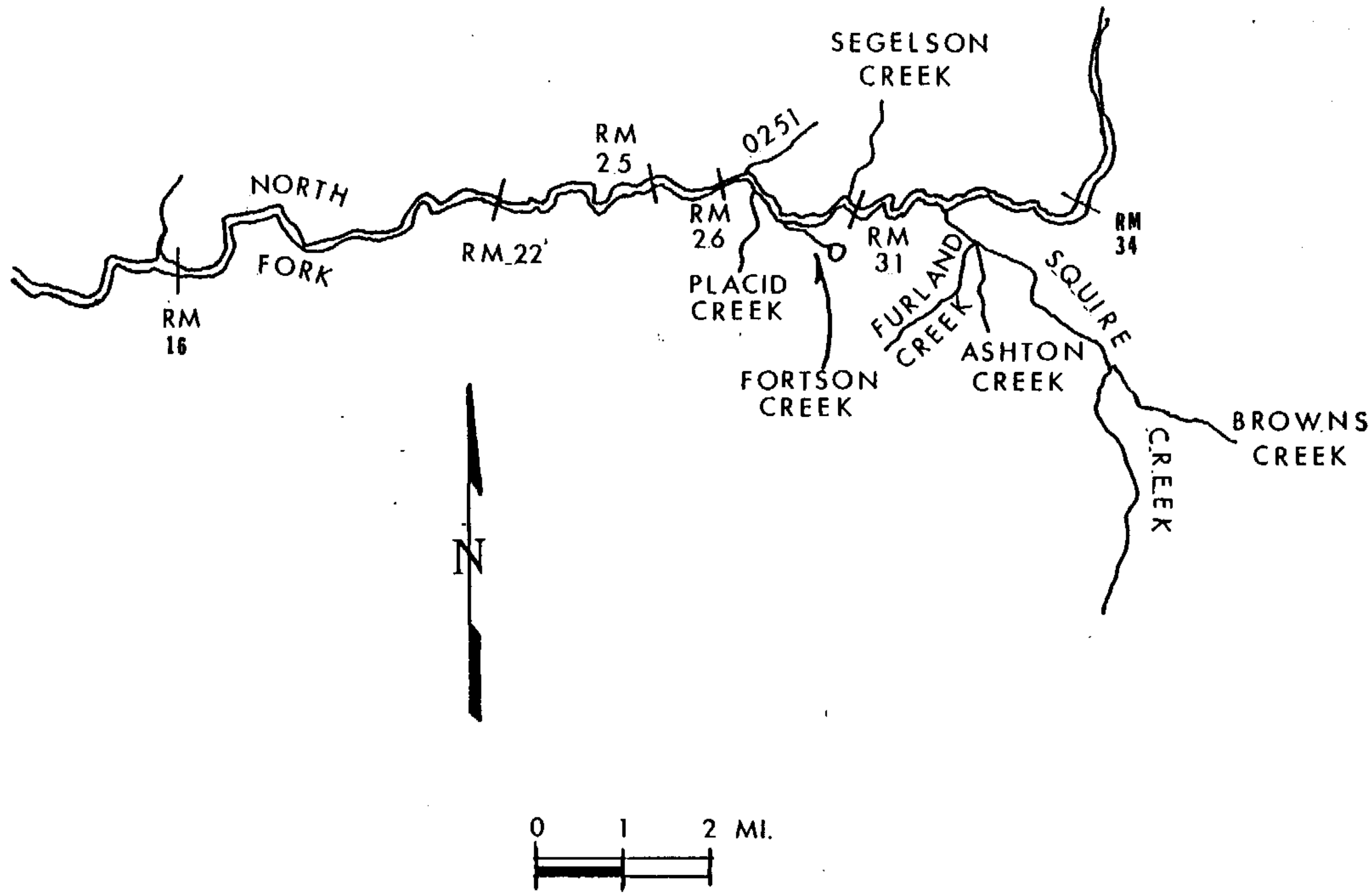

FIGURE 2 CONTINUED

The general procedure for recovery included: sex identification, mark inspection (adipose clip combined with either a jaw tag or a tag scar or net marks), measurement of fork length and weight, and scale sampling (10% of population). Length and weight frequencies were randomly gathered from surveyed carcasses from all significant spawning areas over the course of the entire run. In order to reduce sampling bias, length, weight and age sampling sites were selected at the beginning of each day and all fish within the site were measured, sexed and recorded.

The commercial catch was sampled to assure against interception of tags by the fishery, which was open only during the first week of tagging.

We calculated the population size by the formula

$$\hat{N} = \frac{n_1 \quad n_2}{m}$$

where n_1 = tags released and not later recovered by fishermen

n_2 = carcasses examined on spawner survey

m = adipose-clipped carcasses recovered on spawner survey

The variance was derived from Seber (1973:60) as

$$V = \hat{N} \sqrt{\frac{1}{m} + \frac{2}{m^2} + \frac{6}{m^3}}$$

The escapement consists of the estimated population minus the Stillaguamish River commercial catch, ceremonial and subsistence catch, and hatchery broodstock capture.

VALIDITY OF ASSUMPTIONS

The Petersen model requires several assumptions (Youngs and Robson 1978):

(1) the population is closed to recruitment and immigration--Seber (1973) requires closure to emigration as well;

(2) marked fish have the same mortality and behavior to gear as unmarked fish;

(3) marked fish do not lose their mark;

(4) all marked fish are reported on recapture; and

(5) either the marking or recapture sample is random, or there is random mixing of marked and unmarked fish.

If only Assumptions (1) through (4) are valid, the population can still be estimated, but the Darroch (1961) stratified model instead of the Petersen must be used. The Darroch model divides the marking and recovery samples into strata so that all fish have the same probability of being caught in each marking stratum, so that the sample is random in each recovery stratum.

Assumption 1

Closure implies that all fish must be available for recapture. This means they must not die before reaching a recovery location or stray from the Stillaguamish system to spawn elsewhere. Early mortality is probably insignificant because chum were tagged only a short time before spawning.

Straying was also probably insignificant. No tags were recovered on the Snohomish River incidental to WDF spawner survey there. The Snohomish is the only other major spawning stream entering the Port Susan area. However, two tagged fish were recovered outside the Stillaguamish system. One was recovered by a fisherman in Tulalip Bay, but it is impossible to say whether the fish was straying to another drainage or milling in Port Susan before reentering the Stillaguamish. Another tagged fish was recovered spawned out at Long Beach on Camano Island. The fish had probably spawned in the river and then been washed out. All other recoveries were within the system.

Assumption 2

Marking probably did not affect recoverability on spawning grounds because technicians were trained to examine all carcasses without bias. It is also unlikely that marking affected catchability in the gill net fishery because no marks were recovered in sampling the entire catch.

Further, it is not likely that marking caused mortality before fish reached recovery areas. If this were so, we would expect successively lower recovery rates in those classes of fish judged to be in successively poorer condition after marking. To test for this, a chi-square test of condition at release by recovery rate was performed (Table 1). The non-significance of the results supports the assumption of negligible marking mortality.

Assumption 3

No marks were lost before recovery, because clipped adipose fins were not regenerated in the short period before recovery.

Assumption 4

All marked fish were recognized as such, because technicians were trained to look primarily for the adipose clip.

Table 1. Recovery rate by condition at release from tagging.

Condition	Recovery Rate
1	0.149
2	0.209
3	0.214

Chi-square = 1.088 P > 0.5

Assumption 5

Marking and recapture were designed to take a random sample over time, area, sex, and length. However, we suspected that the first part of the run had entered before tagging began. To evaluate this and other possible discrepancies, the tagging and recapture populations were tested for stratification using Seber's (1973) techniques. The population was first tested by chi-square analysis to see if all fish had the same chance of being caught for marking. The tag ratio was tested against date, then location of recovery. The tag ratio is the number of marked fish recovered per number examined. Non-significance would establish randomness of the marking catch.

Next, the population was tested to see if recovery was random. The recovery rate was tested against date, length, and sex at tagging. Recovery rate is the number of marked fish recovered per number released. Non-significance would establish randomness of spawner survey.

Tests validated this assumption. Tagging was random with respect to time and location of recapture, and recovery was random with respect to time length, and sex at tagging (Table 2, Appendix Tables 1-5).

POPULATION ESTIMATE

We tagged 280 chum in 24 days of tagging between October 21 and November 29, 1980 (Table 3). We examined 4,108 carcasses in 44 days of spawner survey and brood stock capture between November 3 and December 30 and recovered 77 marked fish (Table 4). No marks were recovered in the commercial catch. An estimated 14,885 fish entered the river, and 14,429 escaped to spawn (Table 5).

BIOLOGICAL CHARACTERISTICS

Sex Ratio

There were slightly more females than males in the tagging catch, the male-female ratio being 1 to 1.07. The tagging catch is probably not a good indication of the sex ratio of the population, however, due to probable differences in gill net selectively for males and females. Males were more abundant early in the run and females later (Table 6).

Length Frequency

Males were larger on the average than females (Table 7). There was little difference between tagging and recovery length because the elongation of the snout which is customary in returning salmon had already occurred.

Age IV fish of both sexes were considerably larger than age III fish (Figure 3).

No definite difference in fish size between North and South Forks could be defined because only 27 fish were recovered from the South Fork system.

Age Composition

Age IV fish made up about 75% of the run, age III 24%, and age V, 1% (Table 8). Timing appeared related to age composition, with younger fish spawning later in the run. The opposite phenomenon was recently noted on the Nisqually River (Nisqually Tribe and USFWS, in preparation).

Age composition differed for the various parts of the system (Table 9). Most striking were the differences among Furland Creek, Ashton Creek, and the main stem North Fork.

Timing, Distribution, and Spawning Density

Tagging catch was highest on November 2 (Figure 4). The run could have either peaked then or between November 7 and 10, when high flows prevented fishing. Chum had already entered the river when tagging began on October 21. The run had cleared the lower river by December 1, since the last chum was caught November 29.

Live counts per mile surveyed indicate that most of the run was on the spawning grounds between November 11 and December 19 (Figure 5). Peak numbers occurred between November 11 and 27. However, chum were first seen on October 16 and were present on the last day of survey, December 30.

Average time elapsed between tagging and recovery for 45 fish was 31 days. This suggests that chum salmon enter the river system in early November and, assuming recovery shortly after death, spend a considerable time in the freshwater prior to death. Some individuals were observed to have spent in excess of six weeks between tagging and recovery. The least amount of time was two weeks, although it is not known when individual fish entered the spawning area, and therefore post-spawning life is unknown. One may suspect that the fish spend several days or weeks in holding areas within the North and South Forks.

Spawning was distributed, for the most part, in accordance with past records. Fish were observed in the South Fork between RM 18.2 and 23.0, and in its tributary Siberia Creek. Spawning was seen on the North Fork between RM 16.0 and 34.0 and on some of its tributaries from Grants Creek upstream to Squire Creek and its tributaries (Table 4, Figure 2). An exception was Harvey Creek, which had a small number of returns, although it does not have a run most years due to poor access. Another exception was Browns Creek, which showed no returns, although past runs have been substantial.

Spawning was observed on Placid Creek, a previously unsurveyed tributary. There were excellent numbers of spawners in a seemingly stable, suitable

Table 2. Results of chi-square analysis in examining assumptions of Peterson estimate

Test	X^2	df	P
Tag ratio by recovery period	7.969	6	>0.1
Tag ratio by recovery location	3.264	5	>0.5
Recovery rate by tagging period	5.450	5	>0.1
Recovery rate by sex	0.184	1	>0.5
Recovery rate by length	0.558	3	>0.9

Table 3. Gill net catch for tagging operations.

Date	Number of Sets	Chum	White Sturgeon	Coho	Steelhead
Oct. 21	9	3	4	1	0
22	7	8	0	22	0
23	6	0	5	0	0
24	3	3	3	0	0
27	9	19	1	2	0
28	3	2	0	0	0
29	6	3	0	3	0
Nov. 1	8	27	0	7	0
2	11	50	0	42	0
3	9	37	0	40	0
5	9	37	0	60	1
6	7	40	0	24	0
11	6	6	0	16	0
12	2	2	0	0	0
13	1	0	0	0	0
15	3	1	0	0	0
18	8	12	0	1	1
19	10	0	0	2	0
20	9	13	0	17	5
23	17	7	0	12	1
24	12	0	0	0	1
25	6	6	0	1	1
26	4	1	0	0	2
29	2	3	0	0	0
Dec. 1	2	0	0	0	5
2	2	0	0	0	1
3	2	0	0	0	1
4	2	0	0	0	2

Table 4. Recovery information by location.

Location	Method	Fish Examined	Tags Recovered[b]
South Fork near Jim Creek	Spawner Survey	10	0
Harvey Creek	Spawner Survey	13	0
North Fork RM 22.0-30.0[a]	Spawner Survey	1,771	25
North Fork RM 25.8	Broodstock Capture	279	9
Grants Creek	Spawner Survey	14	0
Placid Creek	Spawner Survey	390	9
Tributary 0251	Spawner Survey	7	0
Squire Creek	Spawner Survey	253	5
Furland Creek	Spawner Survey	229	3
Ashton Creek	Spawner Survey	797	15
Jim Creek	Spawner Survey	275	2
Jim Creek	Broodstock Capture	15	0
Siberia Creek	Spawner Survey	55	1

[a] Includes slough at RM 25.2-25.4 and Fortson Creek.

[b] Less 8 recoveries without location recorded.

Table 5. Mark-recapture information and population characteristics.

Mark-recapture Information	
Tagged	280
Out-of-system recoveries	1
Effective number tagged	279
Number sampled in spawner survey	4,108
Number of tags recovered in sample	77
Population Characteristics	
Run size	14,885
Standard deviation	1,719
Catch	
Freshwater commercial	160
Ceremonial and subsistence	2
Broodstock	294
Total	456
Escapement	14,429
Escapement goal	16,500
Exploitation rate, river only	0.031[a]

[a]Including broodstock capture.

Table 6. Sex ratio by tag date.

Dates	N	% M	% F
10/21 to 11/1	66	57.6	42.4
11/2 to 11/6	163	49.1	50.9
11/11 to 11/29	51	33.3	66.7
Combined	280	48.2	51.8

Table 7. Length at tagging and recovery (cm).

	Length (Sample size in parentheses)	
Location	M	F
Tagging Area	79.5 (135)	73.0 (145)
Spawning grounds	79.4 (189)	74.0 (186)

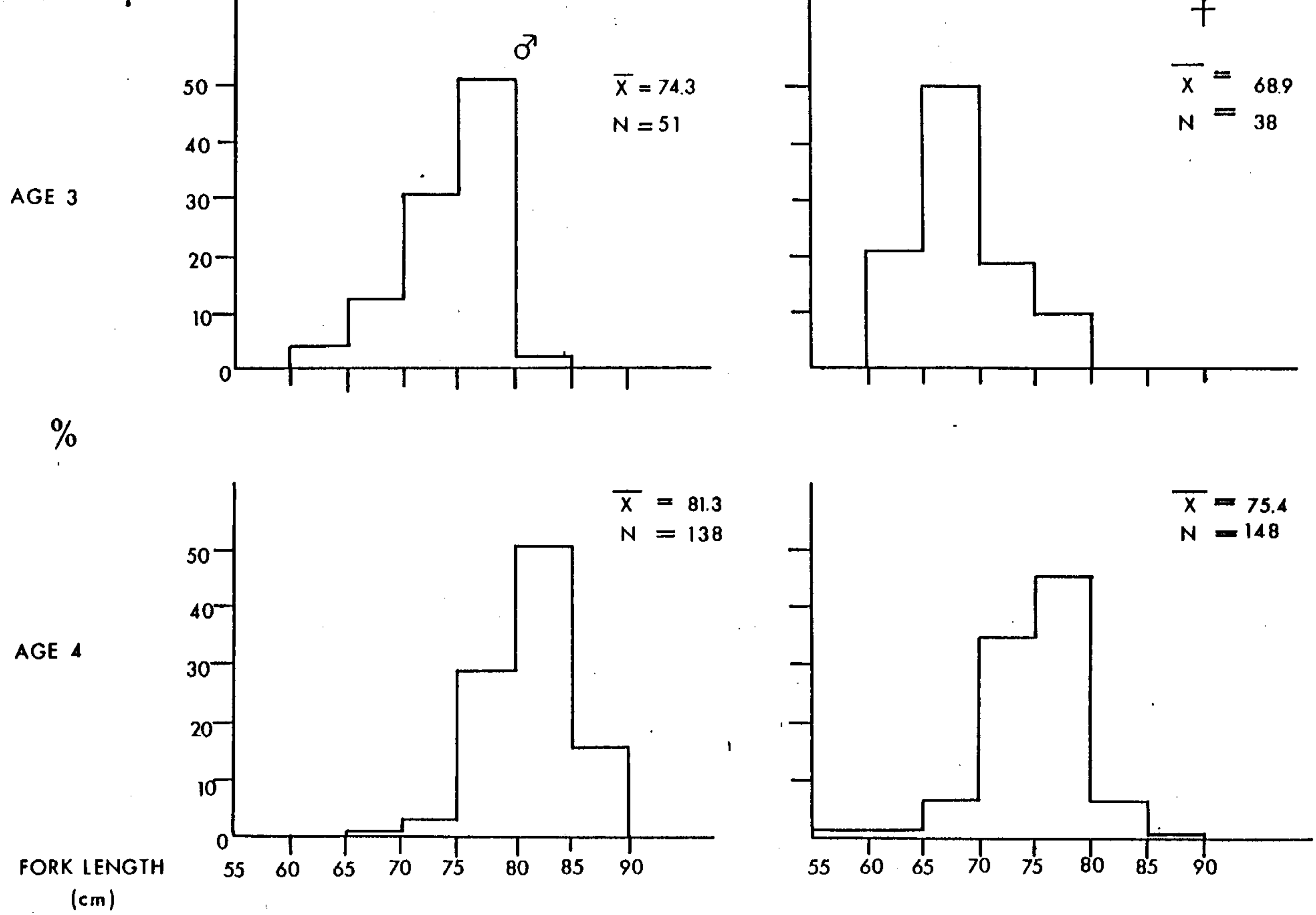

FIGURE 3. LENGTH FREQUENCY, SPAWNING GROUND CARCASS RECOVERIES.

Table 8. Age composition by date of carcass recovery.

Date	N	% III	% IV	% V
11/4 to 12/5	73	13.7	84.9	1.4
12/8 to 12/12	264	24.6	74.2	1.1
12/15	44	38.6	61.4	0.0
Combined	381	24.1	74.8	1.0

Table 9. Age composition by location.

Location	N	% III	% IV	% V
South Fork and Tributaries	27	11.1	85.2	3.7
Main Stem North Fork	141	9.9	88.7	1.4
Squire Creek	68	17.6	80.9	1.5
Furland Creek	51	35.3	64.7	0.0
Ashton Creek	57	63.2	36.8	0.0
Placid Creek	34	14.7	85.7	1.1
Combined	378	23.3	75,7	1.1

basin. No spawning was seen on four other previously unsurveyed tributaries, including Pilchuck Creek, Jordan Creek, North Fork Tributary 0166, and Segelson Creek. Different parts of the system had different peak spawning times as shown by live counts per mile (Figure 6). Chum spawning in the South Fork and its tributaries had peak spawning activity timing around the middle of November but few fish were observed. The North Fork and its tributaries had a peak at the end of the first week of December. This agrees with data gathered over the past four decades by WDF and the Stillaguamish Tribe.

Different parts of the North Fork also had different spawning times. Jim Creek and its tributary Siberia Creek were the earliest to show peak spawning, which occurred between November 11 and 14. The Squire Creek tributary system consisting in Squire, Furland, and Ashton creeks, followed with overall peak count between November 24-27. However, there appeared to be a succession in spawning times, first Squire Creek, then Furland, and finally Ashton Creek. Timing on Placid Creek, another North Fork tributary, was difficult to document because we did not discover the spawning population until after the counts had begun to decline. Most spawning was over after December 5. Grants Creek was the latest to receive spawners, with highest counts between December 8 and 12.

Differences in timing between different parts of the system did not necessarily coincide with differences in age composition. The main stem North Fork and the South Fork with its tributaries had about equal age composition, even though their timing differed. On the other hand, Furland and Ashton Creek returns had a higher proportion of age III fish than the main stem North Fork and Squire Creek, and also had a later peak return. Further, Ashton Creek had a higher proportion of age III fish than Furland and also had a later peak return. This suggests somewhat distinct runs into these tributaries.

Observed peak spawning density differed greatly among the tributaries, even though all had good visibility. The highest density was at Ashton Creek and the lowest, at Jim Creek (Figure 6).

The early spawning in the South Fork tributaries is consistent with historic spawning ground counts. Early entry of this segment of the run into the river was suggested by the comparatively low, although statistically not significant, tag ratio on the spawning grounds. Because recovery methods were uniform throughout the system, non-availability to tagging is plausible. This suggests that most of these fish entered and cleared the tagging area prior to tagging. If this happens each year, delaying the tribal fishery could reduce exploitation on the severely depressed South Fork segment and, coupled with the Tribe's enhancement efforts, aid in its restoration.

All areas of major chum spawning except Placid Creek fall within the index zones used by WDF in their escapement estimates. Therefore, future index counts by tribal and WDF staff should provide accurate estimates.

While a precise method for making in-season management decisions cannot be achieved with only one year's effort, some general patterns appear to exist that can be further evaluated in subsequent tribal fisheries. Chum catches in the tagging area in December indicate that the run substantially cleared the lower 0.5 miles of the river by the end of November. If this is a typical pattern, a tribal steelhead fishery could commence in early December without impacting the chum runs. This would be of major consequence as currently the chum management period by WDF extends through the end of December and, given the depressed status of the chum run, this usually results in conservation closures of the river until January. Because approximately 50% of the harvestable steelhead also clear the lower river during that time, the tribal steelhead fishery has never developed to its full potential. By allowing a December steelhead fishery in the lower river while affording chum stocks adequate protection, the tribal fishery will approach its potenial.

In conclusion, we feel that most of the objectives of this study were addressed by the data collection and analysis. Some interesting patterns were uncovered which could have a major impact on the ability of the management agencies to properly manage and enhance the native chum stocks of the Stillaguamish Basin.

A single year's data base is not sufficient to make general statements about the character of the Stillaguamish chum run, nor to make significant changes in management policies. Without a broader data base, particularly one which traces chum returns during a pink salmon brood year, many of our questions will go unanswered. Another year's study is, therefore, suggested.

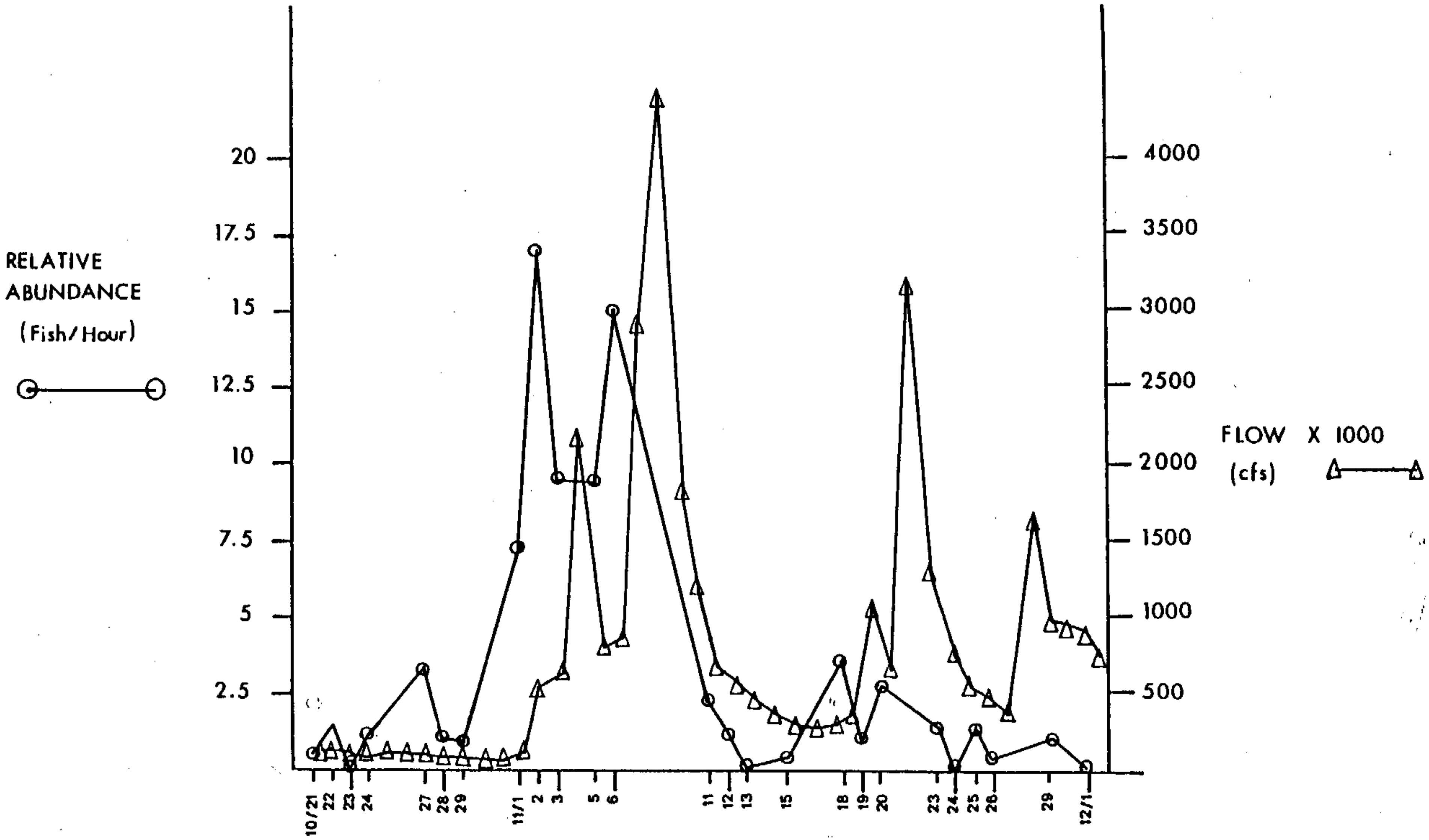

FIGURE 4. RELATIVE ABUNDANCE OF CHUM AT HAT SLOUGH AND MEAN DAILY DISCHARGE AT ARLINGTON

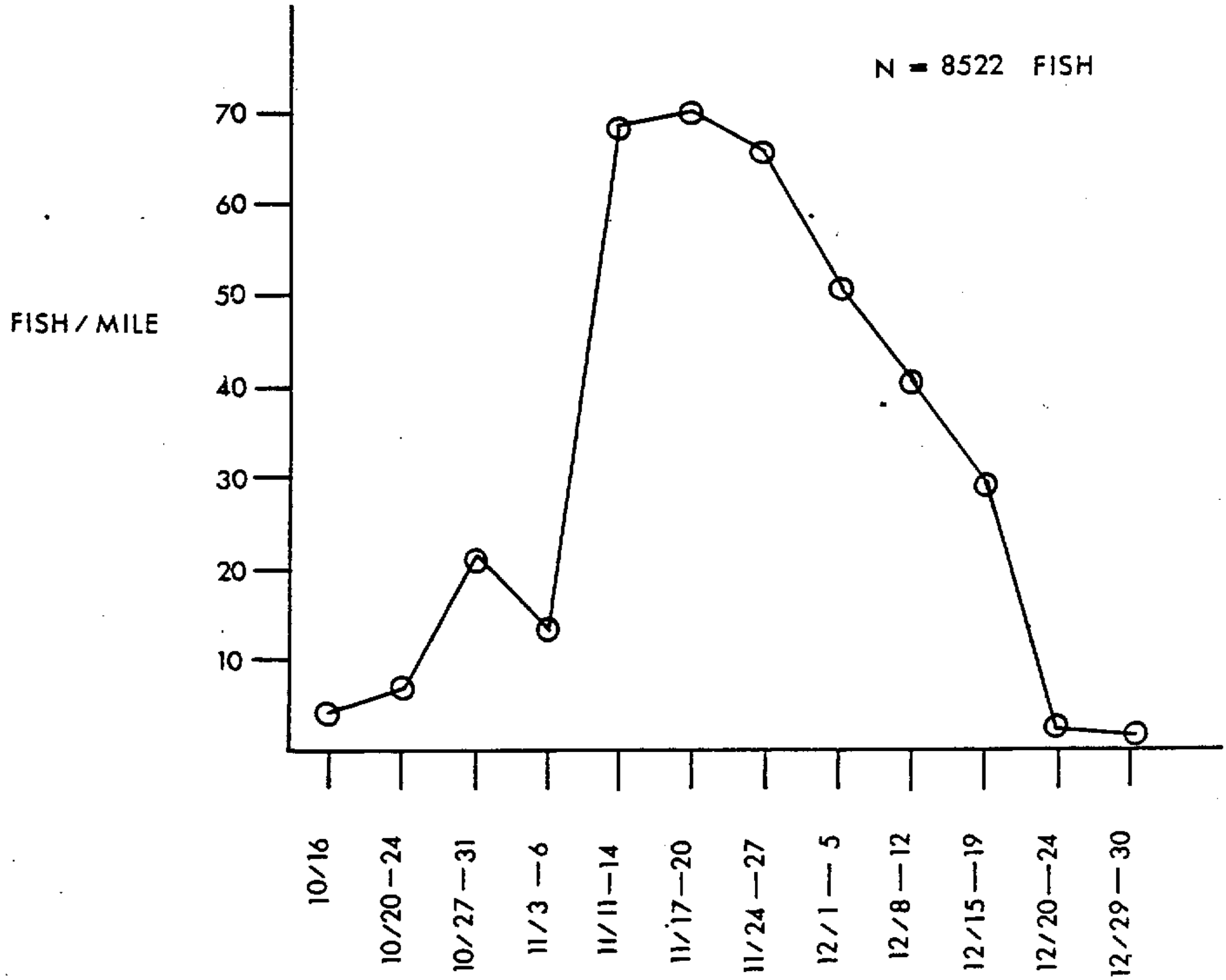

FIGURE 5. DENSITY OF LIVE FISH ON SPAWNING GROUNDS, ALL SITES COMBINED.

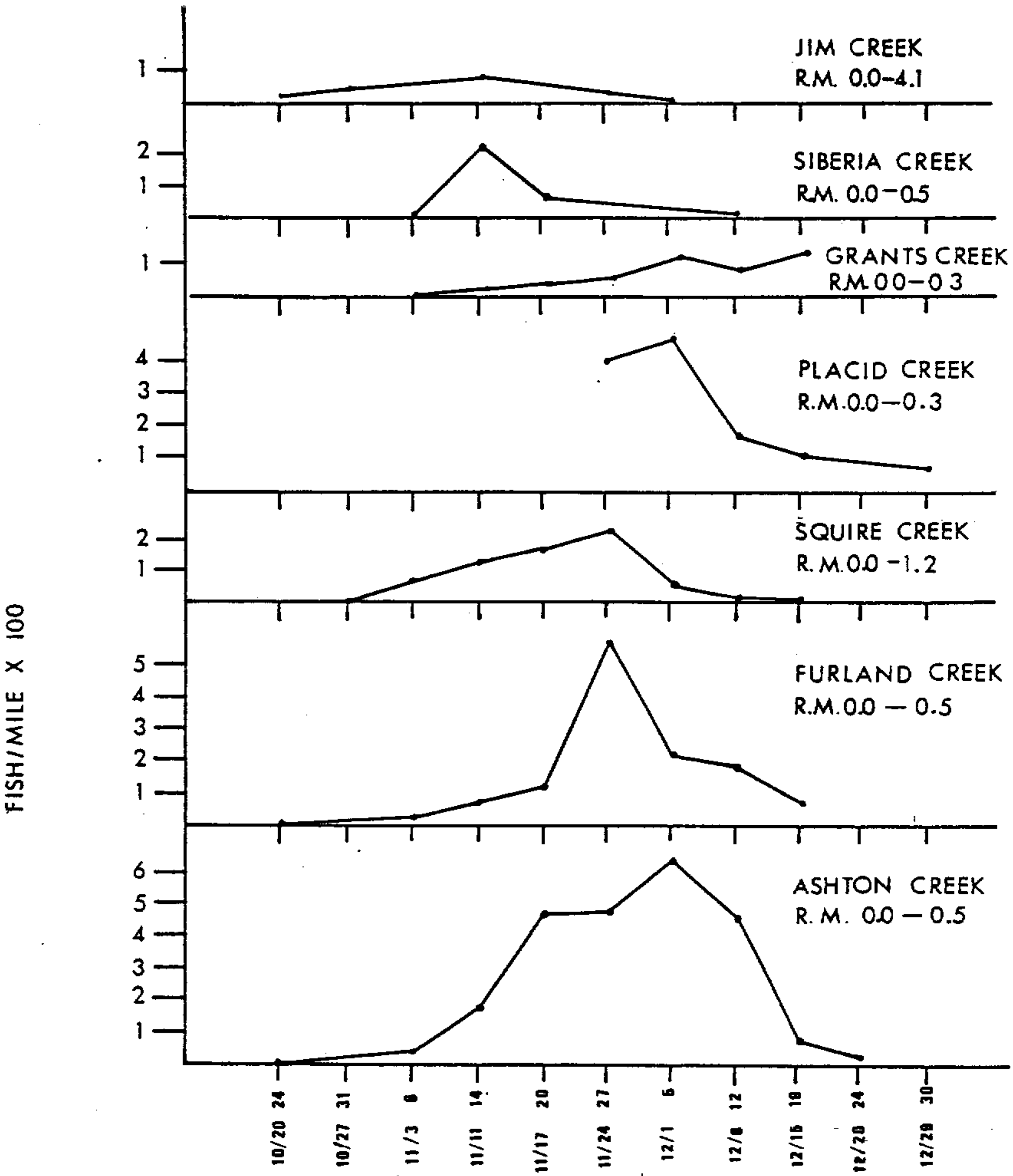

FIGURE 6

DENSITY OF LIVE FISH ON VARIOUS SPAWNING GROUNDS

ACKNOWLEDGEMENTS

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APPENDIX

Chi-square analysis of mark-
recapture data.

Table 1. Recovery rate by time of tagging

Tagging Date	Number Tagged[a]	Number Recovered[b]
10/19 - 10/23/80	14	2
10/26 - 11/02	50	10
11/03 - 11/08	159	31
11/09 - 11/15	9	0
11/16 - 11/22	25	2
11/23 - 11/29	17	3

Chi-squared = 5.450 $P > 0.5$

[a]Less 6 out-of-sample recoveries.

[b]Less 29 missing tags.

Table 2. Recovery rate by sex.

Sex	Number Tagged[a]	Number Recovered[b]
M	129	21
F	145	27

Chi-Squared = 0.184 $P > 0.5$

[a]Less 6 out-of-sample recoveries.

[b]Less 29 missing tags.

Table 3. Recovery rate by length

Length (cm)	Number tagged [a]	Number Recovered [b]
60-69	46	9
70-74	64	13
75-79	82	13
80-90	82	13

Chi-squared = 0.558   P >0.9

[a]Less 6 out-of-sample recoveries.

[b]Less 29 missing tags.

Table 4. Tag ratio by time of recovery.

Recovery Date	Number Examined	Marks Recovered[a]
10/19 - 11/15/80	311	4
11/16 - 11/22	566	13
11/23 - 11/29	547	15
11/30 - 12/06	842	15
12/07 - 12/13	1,024	11
12/14 - 12/20	635	8
12/21 - 12/30	183	3

Chi-squared = 7.969   P >0.1

[a]Less 8 recoveries with date not recorded.

Table 5. Tag ratio by location of recovery.

Recovery Location	Number Examined	Marks Recovered[a]
South Fork, Jim Creek, and Siberia Creek combined	355	3
North Fork, Harvey Creek, Grants Creek, and Tributary 0251 combined	2,084	34
Placid Creek	390	9
Squire Creek	253	5
Furland Creek	229	3
Ashton Creek	797	15

Chi-squared = 3.264   P > 0.5

[a]Less 8 recoveries with location not recorded