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**Summary Report:  
Hoko and Skokomish River Coho Salmon  
Spawning Escapement Evaluation Studies**

**1986-1990**



**PNPTC Technical Report TR 02-1**

**SUMMARY REPORT:  
HOKO AND SKOKOMISH RIVER COHO SALMON  
SPAWNING ESCAPEMENT EVALUATION STUDIES  
1986-1990**

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## ABSTRACT

In 1986 the Point No Point Treaty Council (PNPTC) initiated two studies to evaluate the redd enumeration methodology for assessing coho salmon escapements in the Hoko and Skokomish rivers. The studies were performed over a period of five spawning seasons. Their purpose was to investigate how the methodology should be applied to the two rivers and to attempt to quantify sampling variance and associated confidence limits. We summarize and synthesize the results of the studies in this report. We also present results of a new analysis that compares abundance estimates derived with the redd count methodology to those obtained using the live spawner count, area-under-the-curve (AUC) approach.

We found that the extent of some potential sources of error could not be sufficiently defined to compute total sampling variance. We summarize study findings related to four categories of potential error that affect results of the redd enumeration approach. These categories are sampling design, surveyor variability in counting, redd visibility, and expansion of redds to adult fish. The live spawner count, AUC methodology is subject to some of these same sources of error in addition to one other, stream residency time of adult fish. We discuss aspects of these sources of error as related to the AUC approach.

Our observations from this study suggest the AUC approach likely will estimate lower spawner abundance than the redd count method at relatively low to moderate spawner densities and, conversely, the AUC method likely will estimate higher spawner abundance at higher spawner densities. We therefore infer that the AUC approach will tend to underestimate the actual spawner abundance at low to moderate densities: coho spawners are generally more difficult to spot during surveys at these densities, whereas individual redds are more easily spotted and a more accurate accounting may be achieved with the redd count method. The situation appears reversed at much higher densities: the redd count method is more likely to underestimate actual spawner abundance because of the difficulty of distinguishing overlapping redds and the greater likelihood of redd superimposition. Thus, the AUC method may better represent actual spawner abundance at higher densities.

We conclude that the redd enumeration methodology would be more effective at monitoring escapements in western Washington at the current, generally low to moderate levels of spawner abundance. However, because the currently used fish count methods are often associated with long-term databases, it would be undesirable to lose continuity of such databases by switching to the redd count method. In such cases, it would be preferable to use the redd count method in conjunction with fish counts to give alternative measures of abundance and provide a means of checking accuracy.

On-going or future escapement assessment programs that use either estimation methodology should include efforts to understand the various sources of potential error well enough to manage and control it. We provide several recommendations for improving escapement assessment programs.



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## PREFACE

There was a limited distribution of this report in 1995. However, it was decided to ask several biologists (see below) to review and comment on the report. As a result of this review, the report was modified to improve clarity and correct minor errors, but its substance remained the same. Owing to the press of other business and to neglect, the modified report languished. Recent requests led to its resurrection and distribution at this time. This report would not have been possible without the contributions of the following people.

The project biologists who supervised field crews, participated in data collection, and compiled, summarized and made initial assessments of the data included: Dan Dougherty, Don Gruber, Greg Volkhardt and Tim Willson of the Hoko River studies; and Ted Arnold, Ken Keller, Gregg Martenson and Murray Schuh of the Skokomish River studies. Ken Newman assisted with project planning and early assessments of study results. Chuck Baranski and Tim Flint provided comments on project planning and coordinated the WDFW cooperation and data exchange. Chuck Baranski, Scott Chitwood and Bob Hayman provided comments on an early version of this report that substantially improved this final version. Gary Graves helped coordinate the report review. Katie Mobernd typed the report and organized the physical preparation and integration of the text, tables and figures.



## 1. INTRODUCTION

In 1986 the Point No Point Treaty Council (PNPTC) initiated two multi-year studies to evaluate a methodology for assessing natural spawning escapements of coho salmon (*Oncorhynchus kisutch*) in rivers within the Point No Point Treaty area in Washington State. The methodology is based on redd enumeration. The purpose of this report is to summarize and synthesize the results of those two studies.

The ability to effectively assess salmon escapements is important for a variety of salmon management needs. The management of fisheries depends on actions to limit harvest so that adequate numbers of adult salmon return to the spawning grounds. Escapement estimates provide the means of measuring the success of such management actions and are a critical component of salmon run reconstruction. Historical runs are reconstructed (including estimates of escapements and harvests) to serve as a basis for forecasting future runs; such forecasts, along with salmon escapement goals, help determine the management actions that limit salmon harvest. In addition, estimates of escapement provide measurements of the status of salmon runs in watersheds which may reflect on habitat conditions and the effects of land uses on the salmon resources.

Assessments of salmon spawning escapements in Pacific Northwest streams generally involve some type of survey of the spawning grounds to count spawners or their redds. The task is not trivial, if meaningful numbers are to be collected and then analyzed to yield assessments that have a valid application in management. The difficulty of doing good assessment work is largely the result of the diverse and dynamic environment in which salmon spawn, the expanse of geographic area involved, protracted spawning seasons, and the cryptic spawning behavior of certain species.

Over the past 25 years, two general methodologies have evolved for making such assessments. One involves making successive surveys over the period of spawning to count live spawners in index stream reaches. These data are then analyzed by a technique referred to as "area-under-the-curve" (AUC) to estimate the total number of spawners present during the season (Beidler and Nickelson 1980; Symons and Waldichuk 1984; Perrin and Irvine 1990). The second methodology consists of counting redds during successive surveys of index reaches, marking the redds in some fashion to avoid recounts on subsequent surveys, then summing them at the season end to obtain a total count (Newman 1984). Both approaches require some form of a sampling design within a river system to expand abundance estimates from indices to other stream reaches.

The AUC approach provides the basis for the escapement estimation method primarily used for coho salmon management planning in the Puget Sound Region (Flint 1984; SSC 1990). As a consequence of management needs and available data, this Puget Sound method includes distinct components not found in other applications of the AUC approach. For example, the application depends on the relationship within a base year of index survey data to an estimate of spawning escapement, a component of the method that has been criticized by the Scientific and Statistical

Committee of the Pacific Fisheries Management Council (SSC 1990). Also, this Puget Sound application estimates annual escapement by large river systems or entire sub-regions rather than by individual watersheds (the sub-regional application is used in the PNPTC areas of Hood Canal and Strait of Juan de Fuca).

The redd enumeration methodology has been mainly applied on the Washington coast, where it was developed as a result of being able to find redds more easily than live fish (Quinault Fisheries Division 1980; Chitwood and Parrack 1987; SSC 1990). Relatively low spawning densities compared to most Puget Sound streams, combined with more dynamic streamflows, create conditions whereby redds are less difficult to detect than live fish in coastal streams. The cryptic coloration and behavior of coho salmon spawners can make them particularly difficult to spot by surveyors (Irvine et al. 1992).

The PNPTC escapement studies were intended to evaluate a methodology that could be effectively applied to selected watersheds within the PNPTC management areas of Hood Canal and Strait of Juan de Fuca. We chose to focus on the redd enumeration methodology. Newman's (1984) description of a conceptual sampling design for estimating escapement based on redd counts appeared particularly promising and was the basis for the redd method used in the studies. Emphasis was placed on investigating how the redd methodology should be applied to the rivers of interest and on estimating sampling variance.

Two studies were performed, one on the Hoko River and the other on the Skokomish River. The studies were conducted over a period of five spawning seasons: 1986-87 through 1990-91.

This report presents the primary findings of both studies. Most of the information contained herein was previously reported in annual project reports prepared by the PNPTC. Annual reports for each of the five seasons on the Hoko River were prepared by (listed consecutively with respect to spawning season) Volkhardt (1988), Willson (1991b), Willson (1991a), Dougherty (1990), and Gruber (1993). Annual reports for four of the five seasons on the Skokomish River were prepared by Schuh and Newman (1989), Martenson (1991b), Martenson (1991a), and Keller (1992). A formal annual report was not prepared for the 1989-90 season on the Skokomish River. Information is also contained in informal reports prepared by Newman (Newman 1990a; Newman 1990b; Newman 1990c; Newman 1990d; Newman 1991a; Newman 1991b). In some cases, certain results presented herein may differ from the earlier reports due to inconsistencies that we encountered. We made corrections only where we believed it was needed for the sake of clarity and completeness.

We also present here the results of an analysis we did to estimate spawning escapements using an AUC type of approach. The studies were not designed to experimentally test the redd method against a spawner count or AUC approach; however, spawner count as well as redd count data were collected and, in this report, our analysis of these data provides some useful insights as to how they compare.

## 2. DESCRIPTION OF STUDY AREAS

The Hoko River, which drains approximately 51 square miles, enters the Strait of Juan de Fuca roughly three miles west of Sekiu on the Olympic Peninsula (Fig. 1). The drainage area is comprised principally of moderately sloped timberland with some development for agriculture and residence in the lower reaches. The largest tributary, the Little Hoko River, drains about 20% of the Hoko River basin, entering the main river at river mile (RM) 3.4. Coho salmon utilize at least 23 miles of the mainstem, 3.8 miles of the Little Hoko River, and various tributaries.

The Skokomish River, which heads on the eastern slopes of the Olympic Mountains, drains an area of 240 square miles. The river enters Hood Canal at the canal's furthest southern point (Fig. 2). In its upper reaches the river flows through steep and rugged terrain, and at lower elevation passes through a broad flood plain. Two hydroelectric projects are located in the canyon on the North Fork. The lower dam at RM 17.3 (distance from saltwater) prevents upstream migration past that point. Flows in the North Fork are heavily regulated and are relatively stable during the spawning season. Coho salmon utilization in the South Fork drainage occurs principally downstream of a steep canyon that begins at about RM 3 (distance from confluence with North Fork). The George Adams Salmon Hatchery, operated by the Washington Department of Fish and Wildlife (WDFW)<sup>1</sup>, is located on Purdy Creek, a tributary to the lower Skokomish River. Purdy Creek enters the mainstem at RM 4.1. Coho salmon produced from this hatchery comprised an average of 24 percent of the total Hood Canal coho salmon run between 1980 and 1989 (WDF 1990).

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<sup>1</sup>Formerly the Washington Department of Fisheries (WDF).

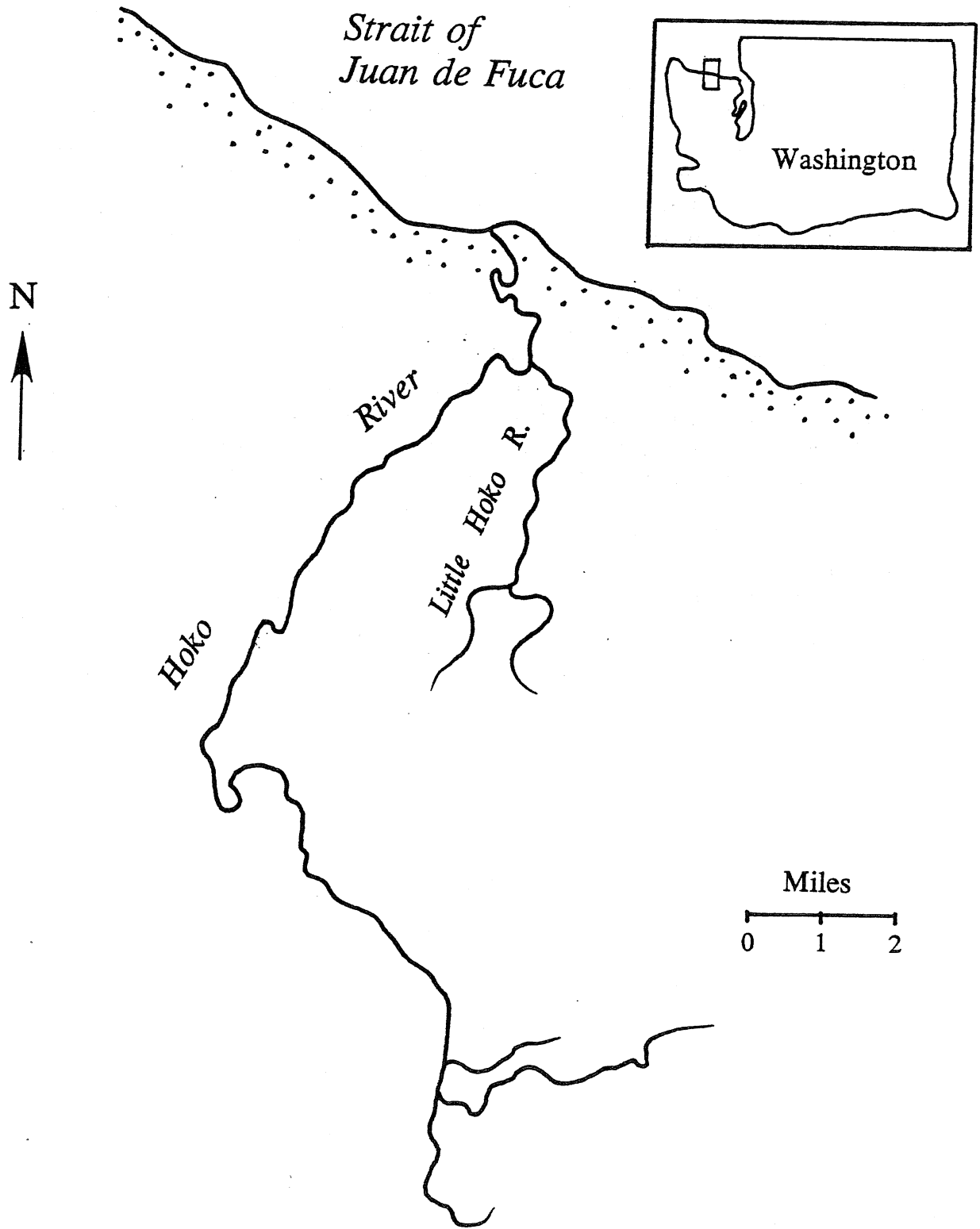


Figure 1. The Hoko River system.

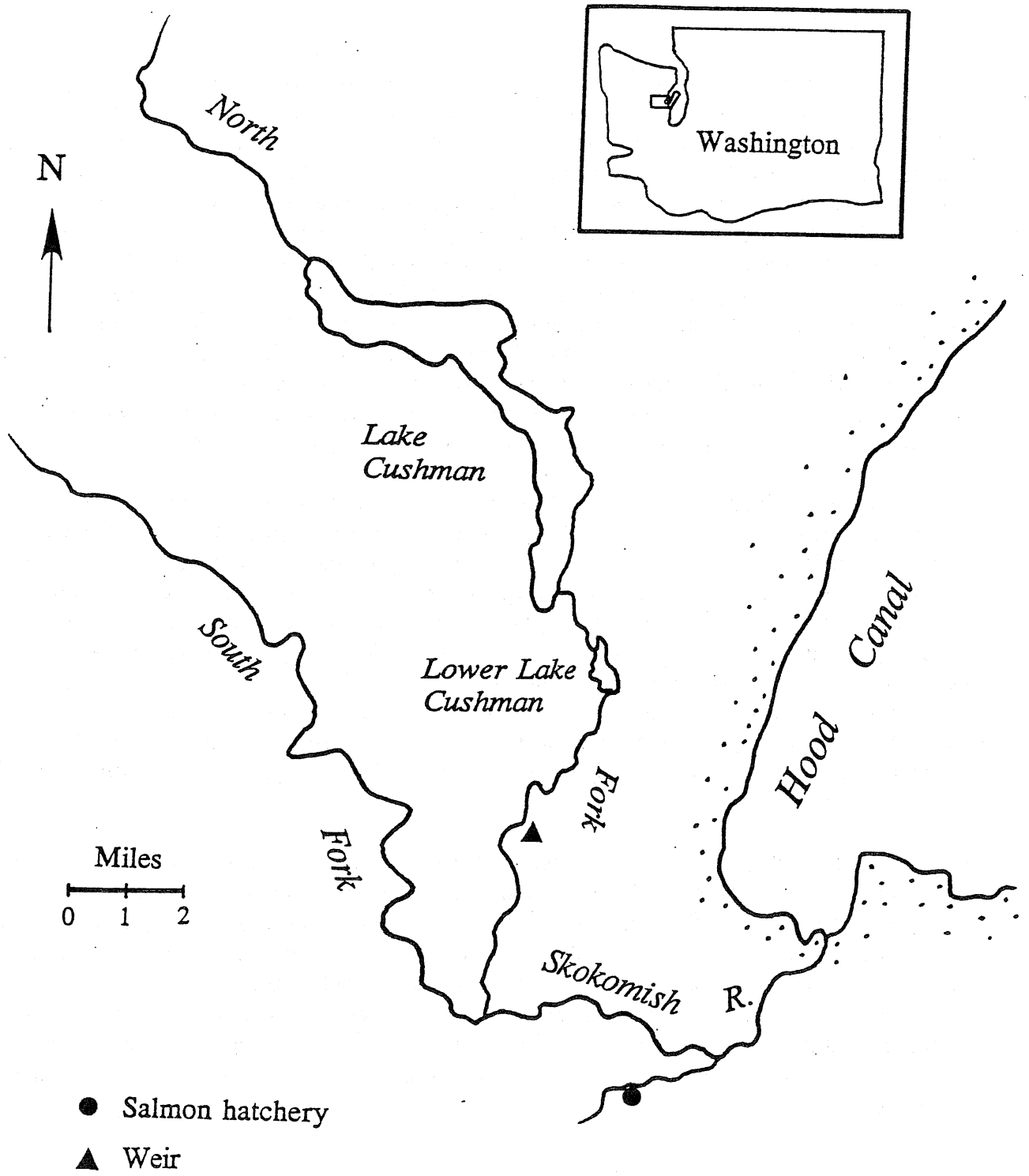


Figure 2. The Skokomish River.

### 3. METHODS

#### 3.1 APPROACH

The approach taken in these studies was to estimate natural coho salmon spawning escapements using an adaptation of the redd enumeration methodology developed on the Washington coast (Newman 1984), while simultaneously investigating sources and amount of error associated with the methodology. The geographic scale for the studies was established at the river basin level. Both the Hoko and Skokomish rivers, though components of larger management units, are separate river systems with importance to regional fishery management. The sizes of these river systems necessitated a sampling design that provided for different levels of sampling intensity between stream reaches. Their sizes were not so large, however, as to prohibit some level of sampling on all stream reaches in most years. An escapement evaluation study conducted by the Quinault Nation on the Washington coast (Chitwood and Parrack 1987; Chitwood 1988; Chitwood 1989) focused on much smaller streams than the Hoko and Skokomish rivers. The Quinault study aimed to more thoroughly investigate basic assumptions underlying the redd enumeration methodology. The findings of that study are complementary to the PNPTC studies.

The redd enumeration methodology can be generally described as the identification and counting of redds dug in index stream reaches over the duration of the spawning season, together with the counting of redds visible at or near the peak of spawning timing in other stream reaches sampled only once during the season. Surveys of index reaches are typically made weekly. The index reach data provide the basis for estimating the total numbers of redds dug during the season in the stream reaches sampled only once. The numbers of redds dug in any stream reaches not sampled during the season are then estimated by applying redd density estimates (redds per mile) from representative stream reaches to the unsampled reaches. The total of the redd estimates from all reaches constitutes the basin-wide estimate. An estimate of the number of adult spawners is then made by multiplying this number of redds by an estimate of the average number of adults per redd.

Escapement estimates derived with this approach are subject to several types of error. These generally fall into four categories: sampling design, surveyor variability in counting, visibility of redds, and the expansion of redd numbers to adult spawners. Originally, it was hoped that each source of error could be sufficiently defined to enable total variance estimates to be made, at least for redd abundance. A procedure to compile statistical confidence limits could then be formulated. However, due to the dynamics and complex nature of the possible errors involved, meaningful estimates of total variance could not be made. Our presentation focuses on providing study results to better describe the nature of the possible errors and how survey work should be structured to control it.

## 3.2 SAMPLING DESIGN FOR SPAWNING SURVEYS

Prior to initiating surveys in 1986, all mainstem and tributary reaches in the Hoko and Skokomish river systems either known or suspected to be used by coho salmon spawners were identified. Clear differences existed between many reaches with respect to channel size, hydrologic character, and extent of use by spawners. These differences suggested that dividing each river system into sampling strata for the purpose of minimizing sample variability would yield more precise estimates of redd abundance, consistent with Newman's (1984) observations.

### 3.2.1 Hoko River

Potential spawning reaches were divided into three sampling strata in the Hoko River system for the 1986-87 and 1987-88 spawning seasons. Stratum 1 was subdivided into Stratum 1A and 1B for the remaining three spawning seasons (through the 1990-91 season) because of differences in species composition and survey technique between the two areas. Stratum 1A was used heavily by chinook and chum spawners and needed to be surveyed by raft due to the size of the channel. Stratum 1B was used much less by these species and was surveyed on foot. In general, Stratum 1 included most of the mainstem spawning reaches and, in some years, Little Hoko River. Stratum 2 consisted of the larger tributaries and Stratum 3 the remainder of the spawning reaches. Approximately 48 miles of stream were assumed to be potentially used by coho salmon spawners in each year of the study.

Prior to beginning surveys in 1986, four stream reaches within each stratum were randomly selected to be used as index sections and to be sampled by PNPTC personnel. In addition, four other reaches in Stratum 2 were already a part of the survey work performed annually by the Washington Department of Fisheries (WDF)<sup>2</sup>. These reaches were also treated as index survey sections in estimating redd abundance. All reaches not identified as index sections were to be sampled at least once through supplemental surveys. The sampling design for each subsequent season remained unchanged except for some relatively minor adjustments. Details regarding the locations of the strata and of the reaches surveyed by year are contained in the Appendices.

### 3.2.2 Skokomish River

Potential spawning reaches were divided into four strata in the Skokomish River system for the 1986-87 and 1987-88 spawning seasons, then reduced to three strata for the remainder of the study. Stratification was based on general similarities between reaches in hydrologic character, redd life, and spawning timing. In general for the three strata grouping, Stratum 1 was characterized by November through late December spawning timing with relatively long average redd life, Stratum 2 by somewhat later spawning timing and shorter redd life, and Stratum 3 by

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<sup>2</sup> The Washington Department of Fisheries has since merged with the Washington Department of Wildlife to become the Washington Department of Fish and Wildlife. However, the reference in this report will be to the Washington Department of Fisheries or WDF.

the longest period of spawning with the longest redd life of all strata. Two of the strata for the original four strata grouping were found to be very similar and were combined to form the three strata used in the final three years of the study. See the Appendices for descriptions of the strata.

Between 20 and 24 miles of stream were assumed to be available for spawning in each year of the study. Differences in the mileage base were due to uncertainty about utilization in certain streams.

Stream sections within each stratum were selected to be surveyed as index reaches largely for logistical reasons. Certain reaches were much more easily accessed, making weekly surveys more feasible than on other reaches. In addition, two tributaries were already being surveyed as part of the WDF monitoring program. These reaches were treated as index sections. All remaining reaches not identified as index sections were to be sampled through supplemental surveys. Descriptions of the index and supplemental sections surveyed each year are contained in the Appendices.

### **3.3 SURVEY PROCEDURES**

Surveys of each index spawning reach within the two river systems were initiated in late October or early November each season. Index reaches were surveyed approximately weekly, stream flows and water visibility permitting, throughout the duration of spawning. Surveys usually ended in January or February. All reaches were surveyed by foot except for the largest ones, which were surveyed by boat when flows prohibited walking. Boat surveys were conducted on the mainstem Skokomish and South Fork Skokomish rivers and on the mainstem Hoko River downstream of RM 10.0.

During each survey of index reaches, all coho salmon redds newly dug since the previous survey were recorded as being "new." New redds were marked (flagged) by tying plastic survey ribbon on a nearby branch or other stationary object. Identification information was recorded on each flag and in the survey notes. As needed to maintain the unique identity of a redd, information on its location was recorded to enable the surveyor to distinguish it from other redds on future surveys. On each subsequent survey, previously marked redds were noted as being either still visible or not visible. Hence the total number of redds visible in the index reach for each survey date could be tabulated. The cumulative number of redds marked since the first survey in that reach could also be tabulated. The number of days between the survey when a redd was first marked and when it was no longer visible defined the period of "redd life" for that redd. The numbers of live and dead spawners by species were also counted and recorded for each survey date. Redds and fish of other species were also noted.

Supplemental surveys on other stream reaches besides index sections were normally conducted once during the spawning season. Numbers of visible redds and live and dead spawners were counted and recorded. Attempts were made to the extent feasible to have these surveys coincide approximately with the time of peak spawning for each stratum. In doing so, chances were