A SYNTHESIS OF EXISTING DATA FOR RESIDENT FISHES IN THE SNOQUALMIE RIVER ABOVE SNOQUALMIE FALLS

PREPARED FOR PUGET SOUND ENERGY AS PARTIAL FULFILLMENT
OF THE SNOQUALMIE RIVER GAME FISH ENHANCEMENT PLAN
LICENSE ARTICLE 413

Prepared by
Nathanael C. Overman

Washington Department of Fish and Wildlife
Region 4, Mill Creek, Washington

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EXECUTIVE SUMMARY

This synthesis is a summary of the fisheries research conducted on trout and mountain whitefish *Prosopium williamsoni* in the Snoqualmie River, with emphasis on resident cutthroat trout *Oncorhynchus clarki*, rainbow trout *Oncorhynchus mykiss*, and eastern brook trout *Salvelinus fontinalis* above Snoqualmie Falls and sea-run cutthroat trout below the Falls. Specifically, it is intended to provide a comprehensive summary of the studies and data that will be useful in implementing the Snoqualmie River Game Fish Enhancement Plan (SRGFEP), and to identify data gaps for ten primary research topics identified in the Plan: relative trout abundance, trout distribution, trout movement, trout reproductive life history, age and growth studies, creel census, background environmental data monitoring, habitat surveys and mapping, habitat enhancement, and public education.

Fisheries and environmental data relevant to these topics have been collected periodically by various entities; however, rigorous field studies of the fish resources in the Snoqualmie River are limited. In 1985, a comprehensive management plan for wild trout was assembled for the Snoqualmie River above Snoqualmie Falls that summarized most of the relevant fisheries data from 1969-1984 (Pfeifer 1985). Since then, data have been collected both opportunistically and as part of larger studies, and this synthesis is intended to be as inclusive as possible.

Results of this review indicate that data gaps are present for almost all the research tasks identified in the Plan, although the extent to which research has already been conducted for each task varies from non-existent to comprehensive. Tasks with the fewest data gaps are the habitat surveys and mapping and background environmental data portions of the Plan. Most of this information has been collected or is currently being monitored, and allocating significant resources to these tasks is not warranted. Tasks with the most glaring data gaps include behavioral data such as instream movement and spawning behavior, and a rigorous age and growth analysis for each salmonid species including mountain whitefish. Trout densities have been estimated periodically for various reaches in all three forks, however species-specific abundance estimates for each fork are still needed. Existing creel survey data is outdated; updated creel information is needed to evaluate the state of the fishery, its potential, and regulations affecting angler harvest and effort. Finally, studies focused specifically on sea-run cutthroat trout in the Snoqualmie River below the falls are largely absent.

Relative Trout Abundance – Density and abundance estimates are outdated and surveys did not always differentiate among trout species. New species-specific density estimates should be obtained using more rigorous mark-recapture techniques.

Trout Distribution – Trout distribution and species composition needs to be reassessed in each fork and in the major tributaries to the forks using data collected with a variety of fisheries techniques.

Trout Movement – Radiotagging efforts are needed to assess whether trout exhibit extensive instream or among-fork movements including seasonal transitions to summer feeding stations, overwintering areas, and spawning sites.

Trout Reproductive Life History – Spawning surveys, radiotagging, and redd capping are needed to assess current spawning distribution, habitat preference, spawning duration, and egg/alevin incubation periods.

Age and Growth Studies – Rigorous age and growth analyses are needed for each salmonid species including mountain whitefish.

Creel Census – New creel surveys are needed to assess the current status of the fishery and to evaluate regulations affecting angler harvest and effort.

Background Environmental Data Monitoring – Measurements of stream temperature, turbidity, discharge, and other water quality parameters are currently recorded at monitoring stations operated by various agencies.

Habitat Surveys and Mapping – Extensive habitat surveys and mapping have already been conducted. The detail and extent of these surveys is beyond the scope of this project and allocating effort to this aspect of the Plan is largely unwarranted.

Habitat Enhancement – Very little habitat enhancement has been conducted on the Snoqualmie River. Enhancement recommendations should be provided to Puget Sound Energy and other government entities upon completion of the Plan.

Public Education – As the project nears completion, a pamphlet should be developed and posted on the WDFW website promoting the fishery resource in the Snoqualmie River. The potential for constructing kiosks or placing signs at strategic locations in the watershed should also be evaluated. The final report should be made available to the public and results presented at local angling clubs.

Trophic Interactions – Although the SRGFEP does not specifically outline plans to study trophic interactions, some of this data can be collected opportunistically while addressing other research questions. Diet data in particular is very sparse and should be collected during this study.

Sea-run Cutthroat Trout – Quantitative information for coastal cutthroat trout in the Snoqualmie River below the falls is minimal. Although the majority of the time and effort in this project will be directed above Snoqualmie Falls, some effort should be allocated to collection and analysis of sea-run cutthroat trout in the river below the falls. At a minimum, snorkeling should be conducted to characterize relative abundance and general distribution of sea-run cutthroat trout.

INTRODUCTION

In June 2004 the Federal Energy Regulatory Commission renewed the operating license for the Snoqualmie Falls Hydroelectric Project (FERC No. 2493) that is owned and operated by Puget Sound Energy. Terms of the renewal required Puget Sound Energy (PSE) to file a final Snoqualmie River Game Fish Enhancement Plan for the purpose of enhancing fish resources in the vicinity of the project. This Plan was developed through collaborative efforts with the Washington Department of Fish and Wildlife (WDFW), and a final report was submitted December 2005 (Puget Sound Energy 2005). The Plan provides for an intensive three-year study beginning with a literature review of the relevant studies already conducted in the basin. Puget Sound Energy contracted WDFW to implement the Plan, and the three-year study was initiated in January 2008.

The goal of the Plan is to enhance the game fish resources in the project vicinity, with emphasis on resident trout (cutthroat trout, rainbow trout, and eastern brook trout) above Snoqualmie Falls and sea-run cutthroat trout below the Falls. The Plan is consistent with WDFW's mission to provide maximum recreational fishing opportunities compatible with healthy and diverse fish populations, and is a necessary step for continued management of the Snoqualmie River as a wild trout resource. Investigations of trout abundance, distribution, life history, angling effort, and harvest data will be conducted using a variety of fisheries techniques. These will include electrofishing, snorkeling, radiotagging or other methods for investigating movement, creel surveys, spawner surveys, water quality monitoring, habitat assessment, and other methods described in the Plan. When appropriate, data from previous studies will be used to supplement data collected for this study and to help fulfill Plan objectives.

This synthesis of the relevant studies and data collected to date is provided to identify data gaps and to refine the scope of field work necessary to implement the SRGFEP. The intent, as outlined in the Plan, is to include all relevant fish inventories, limiting factors analyses, existing condition reports, physical habitat surveys and assessments, databases, and other reports published by the agencies, King and Snohomish Counties, tribes, consulting firms, and academia. This literature review focuses on the studies and data that will be most useful in implementing ten primary tasks that are outlined in the Plan as follows:

1. <u>Relative Trout Abundance</u> – Relative trout abundance will be estimated for various stream reaches in the basin.
2. <u>Trout Distribution</u> – This study will determine the presence or absence of native and non-native trout (juvenile and adult) in the basin as practical including some assessment of alpine lake trout stock influence on the distribution of native or non-native species.
3. <u>Trout Movement</u> – Trout movement will be studied to assess whether trout exhibit extensive instream movements including seasonal transitions to summer feeding stations, overwintering areas, and spawning sites.
4. <u>Trout Reproductive Life History</u> – Trout reproductive life history will be examined to determine spawning distribution, habitat preference, quality and type of spawning habitat, spawning duration, and egg/alevin incubation periods.
5. <u>Age and Growth Studies</u> – Age and growth studies will be conducted to refine knowledge of population age structure, growth, mortality, and age at maturity. This information is critical for establishment of size restrictions on harvestable trout.
6. <u>Creel Census</u> – Recreational and harvest effort for native and non-native trout will be quantified in the Snoqualmie River Basin as practical.
7. <u>Background Environmental Data Monitoring</u> – Water quality measurements including stream temperature, turbidity, and discharge are monitored by various agencies and will be used to assess potential impacts on trout ecology and life history.
8. <u>Habitat Surveys and Mapping</u> – Habitat surveys will be conducted in the three forks of the Snoqualmie River to describe the quality and quantity of game fish habitat.
9. <u>Habitat Enhancement</u> – Habitat enhancement needs may be identified during the literature review process and while completing the study.
10. <u>Public Education</u> – PSE will assist WDFW by providing resources to fund public education of the fishery resource in the Snoqualmie River.

Fisheries and environmental data relevant to these tasks have been collected periodically by various entities. Techniques used in these investigations include snorkel and electrofishing surveys, angling efforts, creel surveys, stream habitat surveys, and monitoring stream gauges. Rigorous field studies of the fish resources in the Snoqualmie River are limited, and tend to be focused on reaches where hydroelectric projects exist or have been proposed, such as the reach above the Black Canyon on the North Fork Snoqualmie River, and the Twin Falls region on the South Fork Snoqualmie River. In 1985, a comprehensive management plan for wild trout was assembled for the Snoqualmie River above Snoqualmie Falls (Pfeifer 1985). The intent of the report, which relied heavily on data from creel surveys and volunteer anglers, was to compile all the available biological data and relevant fisheries data for management purposes. Most of the relevant fisheries data from 1969-1984 were summarized in this report including intensive creel surveys on the North and Middle Fork Snoqualmie River in 1969 and on the North Fork in 1979, and a less intensive creel survey on all three forks in 1984.

U.S. Forest Service (USFS) stream habitat surveys have been conducted in all three forks of the Snoqualmie River (USFS, North Bend Ranger District Mount Baker-Snoqualmie National Forest). Stream surveys were conducted in the North Fork in 1993 and 2007, in the Middle Fork in 1990 and 1996 (Cascades Environmental Services 1997), and in the South Fork in 1990-1991 and in 1998. Several tributaries were also surveyed including Lennox Creek (North Fork tributary) in 1990, the Taylor River (Middle Fork tributary) in 1992, and the Pratt River (Middle Fork Tributary) in 1992 (Raleigh Consultants 1992), Carter Creek (South Fork tributary) in 1991, and Quartz Creek (Taylor River tributary) in 1991. With the exception of the 2007 survey in the North Fork, surveys included a species-specific count of juvenile and adult fish in the reaches surveyed.

Electrofishing and snorkel data have been collected on all three forks beginning in 1979 with mitigation studies on the North Fork (Kurko et al. 1980), and then periodically through the fall of 2000 when all three forks were snorkeled for presence of native char (Berge and Mavros 2001). Almost all of the USFS stream surveys included snorkel surveys and followed the USFS Stream Inventory Handbook Level I and II protocols (USFS 2006). The only long-term fisheries dataset is the mitigation work in the Twin Falls area of the South Fork where from 1984 to 2005 several study reaches were monitored for trout abundance with electrofishing and snorkel surveys (Twin Falls Hydro

Company 2006). In August 1992, snorkel survey index reaches were established in all three forks to determine baseline trout densities for future monitoring of fishing regulations and to evaluate the Basic Stream Management Strategy in effect for these streams (Jackson and Jackson 1993). Additional data from various reaches above Snoqualmie Falls have been collected both opportunistically and as part of larger studies, and are summarized in this review.

STUDY AREA

Snoqualmie River Basin

The Snoqualmie River drainage encompasses the southern 703 mi^2 of the Snohomish River Basin (**Fig. 1**)(Pentec Environmental and NW GIS, 1999). Tributaries extend high into the Cascade Mountains where flows are heavily influenced by snowmelt but are not glacially fed. The river runs through a relatively unconfined, alluvial floodplain that divides into two segments by bedrock protruding at Snoqualmie Falls (Pentec Environmental and NW GIS, 1999). Below the 268-ft falls, the river meanders through low gradient, moderately confined habitat until its confluence with the Skykomish River, at which point the two rivers form the Snohomish River. Above the falls (RM 40.4), the mainstem Snoqualmie River branches into three forks: the South Fork at RM 43.8, and both the Middle Fork and North Fork at RM 44.5. The mainstem Snoqualmie River continues as the Middle Fork at RM 44.5, whereas rivermiles reset to RM 0 at the mouths of the North and South Forks (Williams et al. 1975). Extensive analysis of the ecological structure and function, human dimension, and management of the basin is included in the Federal Watershed Analyses completed for the Middle Fork (USFS 1998a) and South Fork (USFS 1995) watersheds. Detailed descriptions of the three forks are provided in Williams et al. (1975) and again in Pfeifer (1985), and a brief summary from these documents is given below.

North Fork Snoqualmie River

The upper six miles of the North Fork Snoqualmie River (**Fig. 2**) runs through high-gradient, mountain habitat with a series of cascades, rapids, and small falls. For the next seven miles, habitat is relatively flat with moderately low gradient. Substrate switches from boulder, rubble and bedrock to primarily gravel, rubble, and silt in the slower areas. The channel width ranges from 6 to 12 yards in early Fall and exhibits considerable braiding. Pool habitat is abundant and there are many long, slow glides, with a few shallow riffles. The gradient becomes steeper from below this section down to the Black Canyon where a series of cascades fall through narrowly confined habitat. The remaining few miles until the confluence with the Middle Fork exhibit moderate gradient with quality pool-riffle habitat and boulder or rubble substrate (Williams et al. 1975; Pfeifer 1985).

Middle Fork Snoqualmie River

The upper ten miles of the Middle Fork Snoqualmie River (**Fig. 3**) flow through high-gradient habitat within a narrow valley and with mountain side-slopes rising to over 6000 feet in elevation. Below Burntboot Creek (RM 74.6), the gradient is moderate until just below Granite Creek (RM 56.3). Downstream of Granite Creek the gradient is relatively steep until the river flows east of North Bend where, for the final four miles, gradient is moderate to gentle. As in the upper reaches of the North Fork, substrate in the upper Middle Fork consists primarily of boulder, rubble, and bedrock. When the gradient levels out, substrate switches to gravel and rubble between stable earth or rock banks. Fall channel widths range from 6 to 30 yards in the stretch between Burntboot Creek and Granite Creek and the river exhibits relatively little braiding. Widths expand to between 15 and 40 yards in the eight miles below Granite Creek where fast riffles, a few rapids, and short cascades are separated by a number of large deep pools. Over the lower four miles of the Middle Fork, substrate is gravel or rubble and channel widths range from 10 to 25 yards with good pool-riffle balance (Williams et al. 1975; Pfeifer 1985).

South Fork Snoqualmie River

The upper six miles of the South Fork Snoqualmie River (**Fig. 4**) run through Fall channel widths of 3 to 7 yards in narrow ravine-like habitat with side-slopes rising to over 4000 feet. Below Rockdale Creek (RM 25.1), gradient is moderate and the channel is relatively confined with widths from 6 to 14 yards, and with occasional braided channel areas. Pool-riffle balance is good and long broad stretches of riffles are common. Substrate consists of gravel and rubble with only a few boulder areas, and the banks are primarily stable earth or rock. Below Change Creek (RM 12.9) gradient increases and widths range from 7 to 12 yards. This stretch is characterized by cascades and rapids and includes two relatively large falls, the largest being Twin Falls. Below Twin Falls (near RM 11), gradient is moderate, the channel is relatively confined with few braids, channel widths range from 8 to 20 yards, and substrate switches to gravel and rubble with a few scattered boulders. Most streambanks are naturally stable although considerable bank armoring exists near North Bend (Williams et al. 1975; Pfeifer 1985).

Mainstem Snoqualmie River above Snoqualmie Falls

The four-mile reach between the confluence of the North and Middle Forks and Snoqualmie Falls is broad and flat with moderate to low gradient. Quality pool-riffle habitat through gravel and rubble substrate turns to long riffle-free glides with a few sandy point bars, and finally to long deep glides and pools over sandy to muddy substrate as the river nears Snoqualmie Falls (Pfeifer 1985).

Mainstem Snoqualmie River below Snoqualmie Falls

The Snoqualmie River from below Snoqualmie Falls to its confluence with the Skykomish River (RM 20.5) drops about three feet per mile while meandering through a floodplain zoned primarily for low-density agriculture use (King County 2001). Channel widths vary from 67 to 133 yards with depths varying from 18 to 48 feet (U.S. Army Corps of Engineers 1968). Two large rivers drain into the Snoqualmie River below Snoqualmie Falls, the Raging River at RM 36.2 and the Tolt River at RM 24.9.

FISH RESOURCES

Above Snoqualmie Falls

Fish species known to inhabit the Snoqualmie River above Snoqualmie Falls include cutthroat trout, rainbow trout, eastern brook trout, mountain whitefish, largescale sucker *Catostomus macrocheilus*, longnose dace *Rhinichthys cataractae*, shorthead sculpin *Cottus confusus*, and mottled sculpin *Cottus bairdi* (Pfeifer 1985, Sweeney et al.

1981, Kurko et al. 1980). In addition to these species, substantial numbers of western brook lamprey *Lampetra richardsoni* were found in the mainstem below the South Fork confluence (Dames & Moore 1985), and threespine stickleback *Gasterosteus aculeatus* were found in Kimball Creek, a mainstem tributary approximately one-half mile above Snoqualmie Falls (U.S. Fish and Wildlife Service 1980, unpublished data). Hatchery propagated Chinook salmon *Oncorhynchus tshawytscha* and coho salmon juveniles *Oncorhynchus kisutch* were planted occasionally in the past to make use of rearing potential in the South Fork (Williams et al. 1975), but this no longer occurs (USFS 1995). In addition, the Washington Department of Fisheries made four plants of coho salmon fry in the North Fork between 1977 and 1979 (Kurko et al. 1980), and arctic grayling *Thymallus arcticus* eggs were planted in the Middle Fork in June 1947 (WDFW hatchery release database, Olympia Washington). There is no record of arctic grayling having survived. Dolly Varden *Salvelinus malma* or bull trout *Salvelinus confluentus* were listed in a popular fishing guide as present in the North Fork (Jones 1973, and newer editions of the Washington State Fishing Guide). However, no studies have reported observations of native char above Snoqualmie Falls, including during snorkel surveys designed to detect their presence (Berge and Mavros 2001). It is possible that these were misidentified brook trout introduced in prior years (Pfeifer 1985), or an undetermined species of char that once inhabited nearby Lake Calligan that drains into the North Fork (Rief 1906). The Smithsonian National Museum of Natural History has three other sculpin species in collection. Torrent sculpin *Cottus rhotheus* and Paiute sculpin *Cottus beldingii* were collected in the South Fork near North Bend in 1929, and in 2003, reticulate sculpin *Cottus perplexus* (and also torrent sculpin) were collected in the Pratt River (near RM 7), a tributary to the Middle Fork. Finally, a number of fishes have been planted in the alpine lakes within the Snoqualmie River drainage including: cutthroat trout, rainbow trout, golden trout *Oncorhynchus aguabonita*, eastern brook trout, arctic grayling, and lake trout *Salvelinus namaycush* (WDFW stocking records).

Cutthroat trout have always been known to be abundant and, along with mountain whitefish, are likely native to these reaches. Rainbow trout may be native above Snoqualmie Falls, but, as with eastern brook trout, have also been established through planting of hatchery fish (Pfeifer 1985). Hybrid characteristics between cutthroat trout and rainbow trout have been observed although genetic methods are required to determine the extent to which hybridization has occurred (Pfeifer 1985). There is a long history of stocking all three trout species, and detailed records beginning in 1933 are available in Pfeifer (1985) and in the WDFW hatchery release database. These records indicate that cutthroat trout were last planted in the North Fork in 1980, the Middle Fork (Quartz creek) in 1983, and the South Fork in 1990, that rainbow trout were last planted in the North Fork in 1982, the Middle Fork (Quartz creek) in 1983, and the South Fork in 1992, and that eastern brook trout were last planted in the North Fork in 1959, the Middle Fork in 1964, and the South Fork in 1965. Limited numbers of legal-sized trout were also stocked from 1956 through 2002 in either Coal Creek or Kimball Creek just above Snoqualmie Falls to supply fish for a juvenile fishing derby.

Quantitative fisheries data collected on the mainstem reach of the Snoqualmie River above the Falls are limited (Puget Sound Power & Light Company 1991, Dames & Moore 1985, City of Bellevue 1985). However, there is a long history of large, presumably wild cutthroat trout caught in this stretch of the river (Pfeifer 1985). Although some large rainbow trout from annual plants in Coal Creek and Kimball Creek have also been caught in the mainstem, survival of hatchery fish has probably been low (Pfeifer 1985).

Below Snoqualmie Falls

Snoqualmie Falls forms a natural barrier to fish passage. Below the falls, resident and anadromous salmonids use the river and many of the river's tributaries for spawning and rearing, however the high prevalence of sand and silt substrate renders portions of this stretch unsuitable for salmonid spawning (Lucchetti 2005). Anadromous salmonids known to use the Snoqualmie River include Chinook salmon, coho salmon, chum salmon *Oncorhynchus keta*, pink salmon *Oncorhynchus gorbuscha*, steelhead *Oncorhynchus mykiss*, and coastal cutthroat trout. Isolated observations of native char (bull trout or Dolly Varden) have been reported (Berge and Mavros 2001) but spawning has not been observed in the Snoqualmie Watershed (Snohomish Basin Salmon Recovery Forum 2005). A few sockeye salmon *Oncorhynchus nerka* have also been observed, but it is not known if these are strays or if a small spawning population exists (Lucchetti 2005).

Rainbow trout, cutthroat trout, and mountain whitefish are the common resident salmonids below the Falls, and a variety of warm-water fishes (primarily Centrarchid spp.) are also present (Pentec Environmental and NW GIS, 1999). Including those found in the tributaries and agricultural areas of the Snoqualmie River, at least thirty fish species have been observed in the Snoqualmie River drainage below the falls (H. Berge, personal communication). Cutthroat trout are ubiquitous throughout the Snohomish River Basin and exhibit anadromous, fluvial, adfluvial, and resident life history forms (Harring 2002). Limited information is available for sea-run coastal cutthroat trout in the Snoqualmie River, and their stock status in the Snohomish Basin is largely unknown (Haring 2002). Almost all tributaries in the Snoqualmie River below the falls contain sea-run cutthroat trout, with major producers including Cherry Creek, Stossel Creek, and the Raging River (Haring 2002).

Current Management

Currently, all three Snoqualmie River Forks are managed for wild trout. The Middle Fork is a year-round catch-and-release fishery, whereas from June through October, a two fish daily limit with a 10-inch minimum size is allowed in the other two forks and in the mainstem above the falls. From November through May all three forks are catch-and-release only. For mountain whitefish, the daily limit is fifteen. Selective gear rules apply for which only unscented artificial flies or lures with one single-point, barbless hook are allowed and fish must be landed with a knotless net. In the river below the falls, a two fish daily limit with a 14-inch minimum size is allowed for trout from June through February. Selective gear rules apply except that motors are allowed.

FISHERIES DATA AND STUDIES

Relative Trout Abundance

Electrofishing and snorkel surveys have been conducted in various reaches of all three forks by several different agencies and consulting firms. In 1979, seven river reaches were block netted and electrofished to estimate densities of fish in the North Fork (Kurko et al. 1980). The following year, the lower stretches of four tributaries and the upper North Fork (RM 21.2 - 22.0) were also electrofished (Sweeney et al. 1981). In nine miles of the river below RM 21.2, mainstem trout densities (all sizes combined) averaged 2,105 ± 358 trout/mile or 18,945 ± 3,222 trout **(Table 1)**. These densities were compared to density estimates from snorkel surveys (**Table 2**) conducted from late July to early October 1979 in twelve mainstem reaches (Kurko et al. 1980). The average snorkel survey covered a 1-mile stretch of river, and two or three observers with underwater wrist slates were used to record fish in 3-inch size categories. Species were recorded when possible, but cutthroat and rainbow trout were usually not differentiated. Three years later, electrofishing (RM 1.1 and 5.3) and snorkel (RM 0.0-6.7 and RM 6.0-11.5) surveys were resumed in the North Fork to supplement these studies (Dames & Moore 1985). Electrofishing produced only two trout at RM 1.1, whereas 1,497 rainbow trout/mile were estimated at RM 5.3 (**Table 3**). Snorkel surveys estimated an average of 109 trout/mile in two reaches above the Black Canyon and no trout were observed in the 0.8 mile reach near the confluence (**Table 4**). Cold autumn temperatures were suggested to have affected the comparability of trout densities with the 1979-80 surveys that had been conducted earlier in the year. Survey results from 1979-1984 for RM 5.3-13.3 are summarized in **Table 5**. It was concluded that several of the density estimates for trout were extreme (4,774, 139, 129, 30, 10 fish/mile) and not likely representative of actual long-term trout densities. Rather, the authors believed that 1,442 fish/mile (the average of six estimates presumed to be more reliable; standard deviation = 844, 95% confidence limit = +/- 1,688) provided a better estimate of trout density in the mainstem North Fork between RM 5.3 and 13.3. Nighttime snorkeling was conducted on October 28, 1983 in one reach below the South Fork confluence. Many more trout were seen attracted to the lights at night compared to surveys conducted in similar habitats after daybreak (Dames & Moore 1985). Trout often confine themselves in the substrate or in woody debris during the day when river temperatures drop below 9˚C (Thurow 1994), as would have been the case at the end of October.

Sections of Calligan Creek and Deep Creek, two North Fork tributaries, were also electrofished, and a mainstem Snoqualmie River site (RM 42.9) below the confluence of the South Fork was electrofished and snorkled (Dames & Moore 1985). Calligan Creek contained 1,388 rainbow trout/mile (only one cutthroat trout was captured) and Deep Creek contained 774 trout/mile (primarily rainbow trout and brook trout) in the lower reach and 1,044 trout/mile (primarily brook trout) in the upper reach (**Table 6**). Only three trout were observed while snorkeling the mainstem reach. However, electrofishing efforts estimated 1,599 cutthroat trout/mile in this area. No rainbow trout were caught, however a few mountain whitefish and a substantial number of sculpin and brook lamprey were encountered. Mountain whitefish in this reach were estimated at 270 fish/mile and largescale sucker were estimated at 245 fish/mile although these numbers were based on snorkel observations limited to about five percent of the stream cross section.

Two other electrofishing and snorkel surveys were conducted in the Black Canyon vicinity of the North Fork (RM 2.5 to 4.7), one by Ott Water Engineers in the Fall of 1984 and a similar survey in August 1985 by R.W. Beck and Associates (**Table 7**). Most fish were concentrated in small areas at the head of plunge pools immediately below cascades or riffles rather than distributed uniformly within study sites. Densities of fish were low in the large deep pools (Beck and Associates 1985).

The only consistent, long-term dataset monitoring trout abundance on the Snoqualmie River is for the South Fork (Twin Falls Hydro Company 2006). Snorkel and electrofishing surveys were conducted from 1984 through 1988 prior to construction of the hydroelectric facility, and again after construction from 1990 through 2005 (with the exception of 1992-1993) to monitor trout populations in the vicinity of the project (RM 10.4 to 16.5). Study sites included a bypass site approximately 1,000 ft upstream of the project's tailrace, two sites selected for habitat enhancement, and a control site. A fifth site at RM 11.3 was dropped from the study in 1996 because too little of the site included habitat affected by the project. Three snorkel surveys were conducted between mid-June and early September and these were followed by electrofishing surveys conducted in late September or early October. Trout densities varied substantially by site and across years, but were markedly higher below Twin Falls in the bypass reach in most years (**Table 8**). Prior to the long-term monitoring initiated in 1984, preliminary electrofishing and snorkel surveys were also conducted in the Twin Falls area by the Washington Department of Game, Hosey and Associates, and the University of Washington Fisheries Research Institute (Scott and Nakatani 1982a, 1982b).

In August 1992, the WDFW established snorkel survey index reaches in each fork of the Snoqualmie River and in the North Fork Tolt River to obtain baseline data for monitoring regulations (Jackson and Jackson 1993, Burley and Jackson 1993). Each reach was about 3 to 5 km long and was snorkeled by a three or four person crew. Trout densities were estimated by expanding snorkel lane counts for total stream width (**Table 9**). In the Snoqualmie River, trout density was highest in the middle reach of the South Fork (the lower South Fork was not surveyed), but was similar to that for the middle reach of the Middle Fork and the lower reach of the North Fork. Densities were relatively low in the upper reaches of the North and South forks, but comparatively high in the upper Middle Fork. Total trout densities in the North Fork had changed very little since surveys in 1979-80 (Sweeney et al. 1981), however densities of trout > 9 in had almost doubled in the middle and lower sections. Similarly, although the proportion of trout ≥ 12 inches had decreased in the Middle Fork, in all three forks, the proportion of trout ≥ 9 inches had increased substantially compared to angler-caught trout in the early 1980s (WDFW 1993).

The most recent data to include all three forks of the Snoqualmie River was collected in 2000 when each fork was snorkeled (October-December) for presence of native char (Berge and Mavros 2001) and electrofished (spring and summer of 1999 and 2000) in the upper reaches to determine the terminal limits of cutthroat trout distributed in the upper watersheds (Latterell 2001). Salmonid densities were 0.046 fish/m^2 in the upper mainstem of the North Fork, 0.026 fish/m^2 in the mainstem of the Middle Fork near RM 65, and 0.040 fish/m^2 in the mainstem of the South Fork upstream of Tinkham campground (Berge and Mavros 2001). No native char were observed.

Trout Distribution

Snorkel observations during USFS stream habitat surveys in the 1990s were used to estimate trout distribution in selected reaches of all three Snoqualmie River Forks including several tributaries to the forks (**Table 10 and 11**)(USFS 1998b, 1993, 1992a, 1992b, 1991a, 1991b, 1991c, 1990a, 1990b, 1990c, Cascades Environmental Services 1997). Cutthroat trout, rainbow trout, brook trout, and *Cottus* spp. were observed in all three forks. Mountain whitefish were observed in the Middle Fork, but not above the

Black Canyon in the North Fork (surveyed from RM 8.0 to 13.1) or above Twin Falls in the South Fork (surveyed from RM 17.3 to 30.6). Various cutthroat trout X rainbow trout hybrids were noted in the upper reaches of the Middle Fork (USFS 1990). Several unidentified salmonid fry were observed (August 22, 1996) in eddies, along channel margins, and in pools along the Middle Fork from RM 60.5 to 64.5, whereas all adult fish in this reach were found in pools (Cascades Environmental Services 1997). In the South Fork, adult and juvenile trout were observed in each reach, but fish diversity and numbers generally declined across reaches from RM 17.9 to 30.6 (USFS 1998b). In the lower two reaches (RM 17.9-23.3) fish were only present in lateral and mid-channel pools if there was wood, undercut banks, or overhanging cover. For all other reaches, fish were primarily found in pools with shade from overhanging cover or undercut bedrock banks (USFS 1998b). Surveys in Lennox Creek (tributary to the upper North Fork) indicated that cutthroat trout and juvenile brook trout were prevalent with a few rainbow trout in the lowermost reach (USFS 1990c). Brook trout were not observed in the Taylor and Pratt Rivers (tributaries to the Middle Fork); rainbow trout and cutthroat trout were the predominate species and a few whitefish were observed in the lowermost reach of the Taylor River (USFS 1992a, 1992b).

In the North Fork, species composition estimated from electrofishing and snorkel surveys heavily favored rainbow trout near the mouth, but gradually shifted to cutthroat trout towards the headwaters (**Table 1**)(Kurko et al. 1980). Cutthroat trout were not found in electrofished sections of the river below RM 11.5 or snorkeled sections below RM 13.3, and rainbow trout were not present in electrofished sections above RM 19 or snorkeled sections above RM 18.2. Brook trout were most abundant between RM 14.6 and 18.2 and never exceeded 15% of the catch in any section. Surveys in 1983 confirmed that salmonids were almost exclusively rainbow trout above the Black Canyon from RM 5 to 12, however cutthroat trout were the predominant trout below the canyon (Dames & Moore 1985). Species diversity was higher below the canyon and included mountain whitefish, largescale sucker, cottids, and brook lamprey.

Non-salmonid fishes were observed in significant numbers during these North Fork surveys. While spot electrofishing between RM 9.2 and 19.2 an average of 4.2 shorthead sculpin were caught for every trout (Kurko et al. 1980). A similar ratio of 3.6

sculpin for every trout was encountered at RM 5.3, and over 10,000 cottids/mile were estimated at Ernie's Grove near RM 1.1 (Dames & Moore 1985). In addition, two schools (N=3 and 80) of largescale sucker averaging 450 to 600 mm were observed in the reach between RM 0.3 and 1.8 (Sweeney et al. 1981) and 129 largescale sucker/mile were estimated in this area from snorkel surveys in 1983 (Dames & Moore 1985).

Creel surveys on the North Fork (1979) also indicated that rainbow trout were more heavily distributed across lower river reaches (Kurko et al. 1980). Of the 4,032 fish caught below RM 12, catch composition consisted almost exclusively of rainbow trout, and only one mountain whitefish was observed. Above RM 12, over 3,500 fish were caught. Species composition was not delineated but was suggested to reflect that for electrofishing results.

In the Middle and South Forks, small sample sizes of angler-caught trout prohibited estimating relative proportions of trout by species (Pfeifer 1985). However, catch data (1981-1984) from volunteer anglers who fished the Middle Fork in all river areas below Burntboot Creek (RM 74.6) indicated cutthroat trout catch rates were much higher than those for rainbow trout that constituted between 0 and 20% of the catch. Angler efforts in the South Fork indicated about 34.6% of Age II and Age III trout were rainbow trout, 17.3% were cutthroat trout, and 48.1% were hybrids. In the fall of 1990, catch results (N=332 trout) from 15 anglers who were used to fish the Middle Fork indicated that cutthroat trout comprised 95% of the catch (Pfeifer 1990). Rainbow trout comprised 22% of the catch in the lowermost section (RM 44.5-64.8) and 12% in the uppermost section (RM 77.5-84.0), but only between 1% and 7% in the middle three sections. One mountain whitefish was caught in the section between RM 70.2 and 77.5. Brook trout were also observed in the Middle Fork during snorkel surveys between approximately RM 60.5 and 81 (Cascades Environmental Services 1997), and were present in the South Fork during electrofishing and snorkel surveys in the vicinity of the Twin Falls Hydroelectric Project (Twin Falls Hydro Company data, 1984-2005).

The upstream limit of trout distribution was compared across 58 drainages in the Cascade Mountains including the three forks of the Snoqualmie River (Latterell 2003). Although upstream distribution was not reported separately for the mainstem headwaters of each fork, trout were consistently absent from streams when slopes were greater than

22% and where the mean width of the wetted channel was less than 0.3 m. Steep channel gradient, declines in pool abundance, and narrow or intermittent wetted channels (in logged drainages), were important predictors of the upstream limits of trout.

Snorkel and electrofishing surveys in the headwaters of the South Fork adjacent to the Alpental ski area (RM 29-30) found only cutthroat trout (Jones and Stokes 2001). Natural barriers, lack of spawning habitat, and naturally low productivity in the headwaters limit fish habitat, and all trout above Franklin Falls are likely descendants of fish plants rather than of wild origin. Coastal cutthroat trout have also been stocked in Source Lake, the upstream end to the South Fork.

In the mainstem Snoqualmie River from above Snoqualmie Falls to the lower reaches of all three forks, Puget Power biologists snorkeled twenty sites in July 1990 and recorded fish species, number, estimated size, and general locations (**Table 12**)(Puget Sound Power & Light Company 1991). The survey was repeated one and eight weeks later after temporary wooden flashboards were installed to study backwater effects resulting from raising the water level above the Project. In the upstream reaches of the mainstem, fish observations primarily consisted of cutthroat trout located in riffle areas and largescale sucker located in deep, slow channelized areas. In the downstream reaches, few cutthroat trout were observed, although numbers increased after water levels were raised. Mountain whitefish, found in faster-moving water or around structure such as logjams, and largescale sucker, again in deeper slower water, were the primary fish observed. In the North and Middle Forks, some cutthroat trout and mountain whitefish were found in the riffle areas, but most fish (which included cutthroat trout, rainbow trout, mountain whitefish, and suckers) were concentrated in the few deeper (2-3.5 ft) side pools. Fish observed in the South Fork tended to be distributed evenly across a variety of habitats such as riffle areas, turbulent and still pools, and around large organic debris. Cutthroat trout and mountain whitefish were the predominant species and were observed in much greater numbers than in the two other forks and in the mainstem. Some juvenile coho salmon, presumably escapees from a fish farm upstream of the Project, were also observed during licensing studies that included forebay and tailrace sampling (Puget Sound Power & Light Company 1991).

Trout Movement

In the summer of 1979, 150 North Fork rainbow and cutthroat trout larger than 130 mm were tagged behind the dorsal fin with a numbered, colored, Floy tag (Kurko et al. 1980). Several tagged fish were observed during snorkel surveys that summer, but observers were not able to get close enough to read the tags. After 10 months, anglers recovered two rainbow trout. One was recovered 1 mile downstream and had grown 64 mm, and the other was recovered 13 miles downstream and had grown 89 mm (Sweeney et al. 1981). It was noted that the number of larger trout observed during snorkel surveys generally increased downstream. It was further speculated that some downstream movement to better adult habitat might occur as trout grow. No other movement studies have been conducted in the Snoqualmie River above Snoqualmie Falls.

Trout Reproductive Life History

Reproductive life history data for fishes in the Snoqualmie River Forks is largely absent and has primarily been limited to a few ancillary observations during studies focused on other research questions. An early May to late July spawning period for wild trout was suggested by Pfeifer (1985) based on observed timing of fry emergence in Washington river systems (Scott and Nakatani 1982b) and Washington Department of Game surveys in the Yakima River in which a larger percent of rainbow trout were ripe or near-ripe in April compared to November (Johnston 1979, 1980). This differed from the late December to early February spawning period characteristic of Tokul Creek cutthroat trout and Mount Whitney rainbow trout that were often used for hatchery plants in the South Fork, and from anadromous coastal cutthroat trout in Washington, for which spawning usually peaks in February (Trotter 1989). Scale analysis for one Age IV (375 mm) rainbow trout from the North Fork indicated it had spawned at Age II. It was captured in October with eggs and was thought likely to have spawned again in the spring. Spawning every other year would be a pattern consistent with other higher elevation trout populations (Sweeney et al. 1981). In early November 1979, newly constructed brook trout redds were observed in the upper North Fork (Sweeney et al. 1981), which is consistent with a fall spawning period for char. Similarly, brook trout that were ripe with gametes and appeared to be spawning in nearby riffle habitat were observed in North Fork snorkel surveys conducted late October through November 2000 (Berge and Mavros 2001). Mountain whitefish are also late fall and winter spawners.

Instream flow studies for limited reaches of the North Fork (Beck and Associates 1985, Dames & Moore 1985, Sweeney et al. 1981), the South Fork (Steward and Stober 1983), and the mainstem above Snoqualmie Falls (Dames & Moore 1985) used the physical characteristics of the river (depth, velocity, and substrate) to quantify life-stage-specific habitat requirements and availability for trout and mountain whitefish. Below Snoqualmie Falls, habitat was modeled for selected life-stages of pink salmon, Chinook salmon, coho salmon, steelhead trout, sea-run cutthroat trout, and mountain whitefish (Dames & Moore 1985). For the North Fork, it was assumed that trout spawned in April and May, fry were present from July through December, and juveniles and adults were present year round (Beck and Associates 1985). For the South Fork, it was assumed that trout spawned from May through late July, and mountain whitefish spawned from October through December. Trout fry were assumed present from July through October, and mountain whitefish fry from April through mid-August, and juveniles and adults of all species were assumed present year round (Steward and Stober 1983). While useful for determining appropriate minimum flows for hydroelectric facilities, no actual observations of spawning behavior or reproductive life-history data were obtained.

Age and Growth Studies

Scale samples have been collected on several occasions from electrofishing and angling efforts but published age and growth data are minimal. Scales were analyzed for North Fork trout collected by electrofishing four high gradient tributaries and one mainstem reach near Lennox Creek (Sweeney et al. 1981). At this elevation, the mainstem is very similar in character to the tributaries. Growth rates were not compared to trout from lower mainstem reaches; however it was noted that numbers of larger trout observed while snorkeling generally increased on downstream surveys and the largest trout observed (estimated to be 20 inches) was in a large pool between RM 9.2 and 10.1 (Sweeney et al. 1981). Growth was also slower than for cutthroat trout collected in nearby beaver ponds. Although limited sample size necessitated combining both species for growth estimates, rainbow trout were not present in the electrofished mainstem sites above RM 19 and only 26.2% of trout sampled in the tributaries were rainbow trout. This suggests that trout used for aging were primarily cutthroat trout. Cutthroat trout and rainbow trout were not differentiated for growth estimates in the Middle and South Forks (Pfeifer 1985). Length frequencies of trout from all three forks are provided in **Figures 5, 6 and 7**.

Age and growth data from the North Fork study and from angler-caught trout collected on the Middle and South Forks from 1981 to 1984 were summarized in Pfeifer (1985)(**Fig. 8, Appendix**). In the tributaries and upper mainstem of the North Fork, length-at-age overlapped considerably for Age II and Age III trout but was discrete by Age IV. Fork lengths ranged from 80 to 174 mm (average 129 mm; N=53) for Age II trout, from 133 to 175 mm (average 158 mm; N=10) for Age III trout, and from 176 to 284 mm (average 224 mm; N=3) for Age IV trout. All trout from the mainstem site were Age II (range 89-164 mm; average 128 mm; N=24). These trout were similar in length to Age II trout from the tributaries (range 80-174 mm; average 130 mm; N=29). However, growth rates were much slower than for cutthroat trout captured in nearby beaver ponds that averaged 177 mm at Age I and 269 mm at Age II. In the Middle Fork, total lengths of angler-caught trout ranged from 108 to 222 mm (average 169 mm; N=52) for Age II trout, 171 to 246 mm (average 209 mm; N=44) for Age III trout, 155 to 318 mm (average 216 mm; N=9) for Age IV trout, 255 to 257 mm (average 256 mm; N=2) for Age V trout, and 259 to 346 mm (average 309 mm; N=3) for Age VI trout. In the South Fork, total lengths of angler-caught trout ranged from 100 to 185 mm (average 143 mm; N=23) for Age II trout, and from 145 to 253 mm (average 207 mm; N=25) for Age III trout. One mountain whitefish scale sample was aged from a fish caught below Ernie's Grove on the lower North Fork. It was 347 mm and six years old. Few mountain whitefish were observed that were larger than this individual (Sweeney et al. 1981).

Mean age at maturity for angler-caught female cutthroat trout in the Middle Fork was 3.9 years (Pfeifer 1990; N=50 trout caught from the Middle Fork mouth to Dingford Creek in 1981-1984 and September 1990). Whereas 100% (5 of 5) of Age V females were mature, 71% (5 of 7) of Age IV females were mature, 20% (3 of 15) of Age III females were mature, and 8.7% (2 of 23) Age II females were mature. Of first-time spawners collected in the Middle Fork in July of 1983 and 1984, nine females age 2-4 were mature (mean age 3.11) and five males age 2-3 were mature (mean age 3.20). On average, trout were first mature at about 211 mm (Pfeifer 1985). Raw data including river section, species, length, sex, maturity, and age for angler-caught trout in both the Middle Fork (N=142) and the South fork (N=52) are included in Pfeifer (1985), Tables 4.10 and 4.11.

Age composition of angler-caught trout in the Middle Fork caught on a single day in 1981 (N=60) and a single day in 1984 (N=61) included 61 Age II, 43 Age III, 11 Age IV, 3 Age V, and 3 Age VI trout. Total annual mortality was estimated to be 68.8% in 1981 and 50.0% in 1984 (Pfeifer 1985). Annual mortality in the South Fork was estimated to be 82.3% in 1986, 72.2% in 1987, and 69.1% in 1988 based on catch curves constructed from trout caught in electrofishing surveys in the Twin Falls region (Pfeifer 1990). Only Age II cutthroat trout were sampled on the upper mainstem of the North Fork (N=24), however 29 Age II, 10 Age III, and 3 Age IV trout were sampled in the upper North Fork tributaries (summarized in Pfeifer 1985).

Creel Census

Two comprehensive scientific creel surveys and several less-intensive surveys have been conducted on the forks of the Snoqualmie River (**Table 13**). Although limited, some creel data from the 1940s is also available for the South Fork and the mainstem Snoqualmie River (**Table 14**). Comprehensive surveys were conducted in 1969 (North Fork and Middle Fork) and 1979 (North Fork) as part of mitigation processes for proposed dam development (Engman 1970, Kurko et al. 1980). All three forks received a less-intensive creel survey in July, August, and September 1984 (Pfeifer 1985). These surveys were not conducted as rigorously as the 1969 or 1979 surveys, but it was felt that the data represented a reasonable estimate of the actual season-long averages. Miscellaneous creel checks were also made on the North and Middle Forks from 1977-1984 and are summarized with the primary results from the 1969 and 1979 surveys in Pfeifer (1985). In 1990, 44 anglers were interviewed along the South Fork (Pfeifer 1990). None had retained catch but 41 fish between 13 and 20 cm were released. Finally, limited creel data from spot checks in the 1940s suggests that fish caught at the end of May in the South Fork were generally 15-25 cm (6-10 inches)(**Table 14**). It should be noted that opportunistic creel checks can be biased when checks involve anglers who have not finished fishing or when surveys only interview anglers at common access points that may not represent more skilled or knowledgeable anglers willing to walk to more remote areas (Pfeifer 1985).

Below Snoqualmie Falls, creel checks from 1959-1979 were the only available data (as of 1980) for sea-run cutthroat trout in the Snoqualmie River. These included 593 creel checks surveying 12,202 anglers with 105 cutthroat trout caught (Pfeifer 1980). However, these checks were primarily of steelhead anglers who incidentally caught cutthroat trout, and catch per angler was low (0.01 trout/angler). Fishing pressure in the Snoqualmie River was thought to be light, but with a significant and consistent fishery in August and September.

Background Environmental Data Monitoring

Environmental data for the Snoqualmie River Basin have been collected during studies or monitored over longer periods by a number of entities including the United States Geological Survey (USGS), the Washington State Department of Ecology (Ecology), the Washington State Department of Natural Resources, the U.S. Army Corps of Engineers, and the King County Department of Natural Resources and Parks (KCDNRP), among others. Discharge and gauge levels for the Snoqualmie River have been recorded by the USGS since as early as 1898 and relevant statistics from streamflow stations are available for all three forks and the mainstem near both Carnation and Snoqualmie, Washington (http://water.usgs.gov/waterwatch/?m=real&r=wa). Ecology has long-term water quality monitoring stations at RM 2.7 near Monroe (station 07D050 installed 1992) and at RM 42.3 above the Falls at Snoqualmie (station 07D130 installed 1959) recording temperature, flow, turbidity, and other water quality parameters (http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#4), and has manual stage height flow stations operating at RM 2.7 near Monroe (station 07D050 installed 1997) and at RM 45.3 on the Middle Fork (station 07D150 installed 2000).

Ecology is currently conducting a TMDL (Total Maximum Daily Load) study for temperature in the Snoqualmie River watershed that includes the three forks up to the USFS boundary. Stream temperatures are being evaluated during critical dry weather months. Stream thermographs from 2006 indicate that temperatures in the Middle Fork are much higher on average than in the North and South Forks. Further research is needed to assess the effect of higher temperatures on trout in the Middle Fork (R. Svrjeck, Ecology, personal communication). King County also monitors temperature and flow in several tributaries below Snoqualmie Falls (http://dnrp.metrokc.gov/WLR/Waterres/hydrology/About.aspx).

Water quality was measured monthly (July 1979 to June 1980) during mitigation studies on the North Fork (U.S. Army Corps of Engineers 1980; summarized in Sweeney et al. 1981 and Kurko et al. 1980). Data included temperature, conductivity, pH, alkalinity, dissolved oxygen, turbidity, and phenolphthalein alkalinity measurements at two stations in the mainstem North Fork (approximately RM 12.1 and 20.4) and at single stations in both Sunday Creek and Lennox Creek (**Table 15**). Water quality was considered good in the North Fork Snoqualmie Basin to the extent that low alkalinity and nutrient values were possibly limiting aquatic production in the upper river (Sweeney et al. 1981). Stream temperatures and conductivity were highest at the downstream mainstem station. Low conductivity at the upper three stations made electrofishing more difficult during seasons other than late summer when conductivity was much higher.

Similar water quality measurements and analyses were summarized for various reaches of the South Fork in Appendix E of the South Fork Watershed Analysis (USFS 1995). The South Fork from its confluence to Twin Falls State Park is listed as a Class A ("excellent") waterway meeting or exceeding the requirements for all or substantially all uses, and a Class AA ("extraordinary") waterway markedly and uniformly exceeding the requirements of all or substantially all uses from Twin Falls State Park to the headwaters (USFS 1995). All streams and rivers in the Middle Fork watershed have been listed as Class AA by the State of Washington (USFS 1998a).

Habitat Surveys and Mapping

Habitat maps for the entire Snoqualmie River Basin in King County have been developed for Geographic Information System (GIS) analyses (King County Department of Natural Resources and Parks). However, finer-scale habitat mapping is limited. Habitat maps were developed for the North Fork using aerial photographs taken for all three forks in May 1979 (Kurko et al. 1980). These maps were refined with field surveys to demarcate pools, glides, riffles, boulders, and falls and to include the amount of streambank vegetation. Some beaver ponds, bogs, and oxbow sloughs were also plotted. To quantify suitable habitat for spawning and rearing, four North Fork tributaries (GF, Philippa, Sunday, and Lennox Creeks) and the mainstem above Forest Service Rd. 2527 were surveyed the following year (Sweeney et al. 1981). Using the same methodology, habitat was mapped again from RM 12.2 downstream to the confluence and then extended downstream on the mainstem to RM 42 at the State Highway 202 bridge in Snoqualmie (Dames & Moore 1985). In addition, habitat was surveyed for Calligan Creek (RM 8.5), Deep Creek (RM 11.2), and for two small ponds in the North Fork drainage. More recently, GIS data were used to locate suitable sites for snorkel surveys on all three forks (Berge and Mavros 2001). An initial query in ArcView™ was used to identify sites with acceptable stream gradient and channel width. Final site selection was made after evaluating access points and visually assessing potential sites. Habitat maps for the Snoqualmie River Basin include GIS layers for gradient, channel width, and land cover, among others (KCDNRP), and should provide a starting point for site selection when implementing the SRGFEP.

U.S. Forest Service stream habitat surveys were conducted in the upper North Fork in 2007 and throughout the 1990s in all three Snoqualmie River Forks including several tributaries to the forks (North Bend Ranger District Mount Baker-Snoqualmie National Forest). These surveys provided an extensive inventory of existing stream channel, riparian vegetation, and aquatic ecosystem conditions on a watershed scale. Surveys were conducted during low flow conditions and specific protocols were followed as outlined in the USFS Stream Inventory Handbook for Level I and II surveys (USFS 2006). Data were entered into the Aquatic Inventory and Aquatic Biota modules of the Natural Resource Inventory System database. A series of standard summary tables were produced from this database to provide the basic information necessary to describe stream condition, habitat, and function. Written documentation of survey results varied from unpublished general summaries to more detailed overviews and analyses describing pool quantity and quality, large woody debris quantity and complexity, spawning gravel quantity and quality, and relative fish abundance and distribution (e.g., Cascades Environmental Services 1997).

Instream flow studies have also taken detailed measurements of depth, velocity, and substrate along selected reaches of the North Fork (Dames & Moore 1985, Beck and Associates 1985, Sweeney et al. 1981) and the South Fork (Steward and Stober 1983). These habitat measurements were combined with published probability-of-use (habitat preference) curves for species-specific life stages (e.g., adult, spawning, juvenile, fry, and incubation) and used to estimate available habitat across a range of simulated flow levels. Fish habitat was reported in terms of Weighted Usable Area (WUA), an index used to quantify the square feet of useable fish habitat per linear length of stream. Spawning habitat WUA was relatively low for trout in the North Fork. However spawning habitat is rarely limiting for trout in western Washington streams and an abundance of juvenile trout observed in electrofishing surveys suggested that trout spawning habitat was adequate in the North Fork (Sweeney et al. 1981). In addition, substrate from RM 5 to 12, was described as generally course but with enough gravel in pockets to support in-reach spawning (Dames & Moore 1985). In the South Fork, available spawning habitat was determined to be minimal even at optimal flows, however the analysis was limited to one study area in the vicinity of the Twin Falls Hydroelectric Project, and the results were not extrapolated to other river sections (Steward and Stober 1983).

Habitat characteristics were measured in August 1992 at sites selected for snorkel surveys in all three forks (Jackson and Jackson 1993). With the exception of the lower reach of the South Fork, length and width of pools, riffles, runs, pocket water, and chutes and cascades were made for 3 to 5 km reaches of the upper, middle, and lower sections of each fork (**Table 16**). Average stream widths (upper, middle, lower) were 18.3 m, 22.8 m, and 22.5 m in the North Fork, 33.8 m, 38.9 m, and 33.2 m in the Middle Fork, and 16.3 m (upper) and 19.4 m (middle) in the South Fork.

General descriptions of the instream habitat from the mainstem above Snoqualmie Falls to the lower reaches of all three forks were provided in licensing studies for the Snoqualmie Falls Project (Puget Sound Power & Light Company 1991). In July 1990, twenty sites were snorkeled by Puget Power biologists and substrate, depth, riffle, and pool habitat were described. In the upstream reaches of the mainstem, depths were typically 10 to 12 feet with large cobble substrate and large amounts of impacted sand. Downstream reaches tended to be deeply channelized with depths about 15 feet. Substrate was primarily large cobble, fallen riprap material, and sunken logs buried in the sand.

Below Snoqualmie Falls to the confluence with the Skykomish River, riparian vegetation was quantitatively assessed to estimate vegetative cover and the potential to supply woody debris from near-channel processes (Pentec Environmental and NW GIS, 1999). Aerial photographs were used to describe the contents of the riparian corridor adjacent to the river and to quantify the channel conditions based on the proportion of diked or riprapped riverbank for each riparian category. It was concluded that flooding was the major force responsible for the formation and maintenance of riparian conditions and that in the absence of natural hydrologic disturbance regimes, any long-term benefit from off-channel or riparian enhancement efforts would require perpetual maintenance.

A Salmonid Habitat Limiting Factors Analysis is available for the Snohomish River Watershed that provides basic descriptions of substrate and riparian conditions and water quantity and quality for the Snoqualmie River (Haring 2002). In addition, Federal Watershed Analyses have been conducted for the Middle Fork (USFS 1998a) and South Fork (USFS 1995) Snoqualmie River. These analyses contain detailed reviews of habitat conditions and resource management in these watersheds.

Habitat Enhancement

Few habitat enhancement projects or investigations have occurred in the three forks of the Snoqualmie River and the mainstem in the Project vicinity. Known habitat enhancement has been limited to work conducted in the South Fork as part of the Twin Falls Aquatic Mitigation Plan (Twin Falls Hydro Company 2006). In 1984 through 1988, baseline snorkel and electrofishing surveys were conducted for the purpose of comparing trout densities before and after habitat enhancement measures were implemented and the hydroelectric facility was completed. Habitat enhancement measures began in 1988, with the placement of 97 boulders at two enhancement sites. These sites were highly impacted by channelization from adjacent highway construction. After two years, data indicated that trout numbers had not increased, and that the boulder placement was not successful.

Many boulders were heavily buried from a landside upstream of the enhancement sites and were not able to trap woody debris. These boulders have since resurfaced because the sediment that buried the boulders has moved through this reach (G. Gilmour, personal communication). Beginning in 1994, large woody debris (LWD) was placed in the enhancement sites each spring to maintain at least 40 logs and root wads during summer low flow conditions. Trout abundance monitoring in 1994-2005 indicated that these enhancement measures were successful in increasing trout numbers. However, increased abundance was only demonstrated from electrofishing data, presumably because trout using the LWD as cover were difficult to see during snorkel surveys.

Cascades Environmental Services conducted habitat surveys in the Middle Fork to identify stream channel, riparian vegetation, and aquatic habitat conditions (Cascades Environmental Services 1997). Enhancement recommendations were made following surveys of three reaches located between RM 60.5 below the Pratt River and RM 81 in the headwaters. For the two reaches between the Pratt River and Burntboot Creek, revegetation efforts were recommended to stabilize slide areas. These reaches were aggrading systems and successful bank stabilization was considered essential before any efforts to enhance fish habitat would be warranted. The removal of a logjam to divert flow away from the road and replacing riprap were also suggested to decrease erosion in the reach between Tributary #0731 and Burntboot Creek. Reach three in the headwaters was the most stable and enhancement was not deemed necessary.

The Western Federal Lands Highway Division of the U.S. Department of Transportation is currently designing improvements to the Middle Fork Snoqualmie River Road for the purpose of enhancing operational safety and consistency of the road to access National Forest Lands (DJ&A, P.C. 2008). Part of the project included an inventory of stream crossings, including descriptions and photographs of culverts and bridges. The report also provided descriptions of roadway that encroached into the river floodplain or floodway, or were inundated during the December 2006 50-year discharge event, or required bank stabilization. Thirteen reaches were listed as potential problem areas; one had been inundated during December 2006, and three required bank stabilization. The stream crossing assessment also provided an inventory of the active streams crossing the Middle Fork Snoqualmie River Road within the project limits; fish presence and habitat suitability were documented (Mason Bruce & Girard 2004). Fish were observed or assumed present in 14 of 26 streams and species observed included cutthroat trout, sculpin, and longnose dace. Four culverts were identified where fish passage should have been possible but the condition of the culvert for fish passage was poor and needed improvement. Culvert design recommendations included culvert type and size and suggested that culverts should be oversized to accommodate the bankfull width and that the invert of the culvert should be below the natural streambed elevation grade to accommodate natural stream bottom.

Public Education

Final implementation of the SRGFEP will include increasing public awareness of the fishery resource and the efforts that have been made to maximize resident and sea-run trout resources in the Snoqualmie River Basin. This may include developing pamphlets or constructing kiosks to promote game fish resources and to educate the public on game fish life history and recreational fishing opportunities in the Snoqualmie River. Local fisheries enhancement groups and volunteers may be beneficial in helping to lower costs and to maximize a sense of stewardship.

Trophic Interactions

Although the SRGFEP does not specifically outline plans to study trophic interactions, some of this data can be collected opportunistically while addressing other research questions. Diet data in particular is very sparse and should be collected during this study. Stomach contents were analyzed for 11 trout in the North Fork plus 3 trout from a nearby beaver pond (Kurko et al. 1980). Not surprisingly, diets primarily consisted of aquatic insects, but shorthead sculpin and a juvenile trout were eaten by several of the larger trout, and one cutthroat trout from the beaver pond had consumed a number of snails (**Table 17**). It was suspected that had more large trout been analyzed, small fish would have been observed more frequently in the diet (Kurko et al. 1980). More recently, of six cutthroat trout caught by angling in the North Fork above the confluence of Lennox Creek, one had consumed a sculpin (USFS 2007). Sculpin diets were not analyzed but some diet overlap with trout was likely. Given their high abundance in the North Fork, sculpin may have a significant effect on river ecology (Kurko et al. 1980). A measure of food availability was obtained from benthic samples collected in June (Kurko et al. 1980). Aquatic invertebrate densities ranged from 272 to 1600 insects/m^2 across seven sampling stations, with mayflies (*Ephemeroptera* spp.) comprising between 46.8 and 82.7 percent (**Table 18**).

CONCLUSIONS

Implementation of the SRGFEP will result in a large-scale inventory of the trout resources in the Snoqualmie River that will facilitate continued management of the resource as a healthy, wild trout fishery. Data gaps are present in almost all the research tasks listed in the Plan. Topics with the fewest data gaps are the habitat surveys and mapping and background environmental data portions of the Plan. Topics with the most glaring data gaps include behavioral data such as instream movement and spawning behavior, and a rigorous age and growth analysis for each salmonid species including mountain whitefish.

<u>Relative Trout Abundance</u> – Density and abundance estimates are outdated and surveys did not always differentiate among trout species. Whereas the Jackson and Jackson (1993) surveys and USFS surveys throughout the 1990s provided useful fish/mile counts based on snorkel observations, new species-specific density estimates should be obtained from more rigorous mark-recapture techniques.

<u>Trout Distribution</u> – Trout distribution was well documented in the North Fork in 1979-84, and was assessed in the other forks based on limited angling efforts in the early 1980s (Middle Fork) and in 1990 (Middle and South forks). The most recent species composition data has come from USFS snorkel surveys, however species identification (especially between rainbow and cutthroat trout) can be difficult without direct capture methods. Trout distribution and species composition needs to be reassessed in each fork and in the major tributaries to the forks using data collected with a variety of fisheries techniques.

<u>Trout Movement</u> – Trout movement data is virtually non-existent. Radiotagging efforts are needed to assess whether trout exhibit extensive instream or among-fork movements

including seasonal transitions to summer feeding stations, overwintering areas, and spawning sites. This data will be useful to evaluate the interconnectedness of the trout populations among the forks and the extent to which each fork should be managed as a separate fishery.

Trout Reproductive Life History – Trout reproductive life history data is largely absent and has primarily been limited to a few ancillary observations during studies focused on other research questions. Data gaps include current spawning distribution, habitat preference, spawning duration, and egg/alevin incubation periods. This data should be obtained from spawning surveys, radiotagging, and capping redds, and can be used by managers to maximize trout reproductive success by protecting trout during critical spawning periods.

Age and Growth Studies – Scale samples have been collected on several occasions from electrofishing and angling efforts but published age and growth data are minimal. Rigorous age and growth analyses are needed for each salmonid species including mountain whitefish. Current population age structure, mortality rates, and age at maturity are also critical for evaluating existing management of the resource including size restrictions on harvestable trout.

Creel Census – Creel surveys varying from opportunistic spot checks to extensive scientific creel surveys were conducted in 1969 (North Fork and Middle Fork), 1979 (North Fork), 1984 (all three forks), and 1990 (South Fork). New surveys are needed to assess the current status of the fishery and to evaluate regulations affecting angler harvest and effort.

Background Environmental Data Monitoring – The Washington State Department of Ecology is currently conducting a study monitoring temperatures in the Snoqualmie River watershed. Stream thermographs from 2006 indicate that further research is needed to assess the effect of higher temperatures on trout in the Middle Fork. Additional measurements of stream temperature, turbidity, discharge, and other water quality parameters are recorded at monitoring stations operated by various agencies.

Habitat Surveys and Mapping – Extensive habitat surveys and mapping were conducted in the North Fork and in the upper mainstem between 1979 and 1983, and USFS stream habitat surveys were conducted as recently as 2007 in the North Fork, 1996 on the

Middle Fork, and 1998 in the South Fork. The detail and extent of these surveys is beyond the scope of this project and allocating effort to this aspect of the Plan is largely unwarranted.

Habitat Enhancement – Very little habitat enhancement has been conducted on the Snoqualmie River. A log of sites where habitat disturbance could be negatively affecting fish (e.g., landslides or sites with excessive sedimentation from logging operations) should be kept while conducting research and enhancement recommendations should be provided to Puget Sound Energy and other government entities upon completion of the Plan.

Public Education – As the project nears completion, a pamphlet should be developed and posted on the WDFW website promoting the fishery resource in the Snoqualmie River. The potential for constructing kiosks or placing signs at strategic locations in the watershed should also be evaluated. The final report should be made available to the public and results presented at local angling clubs.

Trophic Interactions – Although the SRGFEP does not specifically outline plans to study trophic interactions, some of this data can be collected opportunistically while addressing other research questions. Diet data in particular is very sparse and should be collected during this study.

Sea-run Cutthroat Trout – Quantitative information for coastal cutthroat trout in the Snoqualmie River below the falls is minimal. Although the majority of the time and effort in this project will be directed above Snoqualmie Falls, some effort should be allocated to collection and analysis of sea-run cutthroat trout in the river below the falls. At a minimum, snorkeling should be conducted to characterize relative abundance and general distribution of sea-run cutthroat trout.

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Table 1.-Density, biomass, fork length, weight, and species composition of trout in the North Fork Snoqualmie River estimated in early September 1979 from electrofishing seven block netted stations (from Kurko et al. 1980). Rivermiles (RM) were approximated from Kurko et al. 1980, Figure 6.

Block net Station (Rivermile)	Fish/mile	Fish/m^2	g/m^2	Mean fork length (mm)	Length range (mm)	Mean weight (g)	Weight range (g)	Species Composition
1 (RM 21)	2050±100	0.20±0.010	2.17±0.11	88	41-207	11.0	<1-54	99% cutthroat trout 1% brook trout
2 (RM 18.8)	1811±325	0.09±0.016	0.40±0.07	66	37-129	4.5	<1-21	85% cutthroat trout 15% brook trout
3 (RM 16.3)	923±538	0.02±0.014	0.28±0.16	82	48-190	12.1	1-82	67% rainbow trout 22% cutthroat trout 11% brook trout
4 (RM 14.7)	567±6	0.01±0.000	0.20±0.00	93	46-173	16.0	1-68	65% rainbow trout 23% cutthroat trout 12% brook trout
5 (RM 13.4)	1900±100	0.05±0.003	1.29±0.07	116	40-244	25.7	<1-157	91% rainbow trout 9% cutthroat trout
6 (RM 11.5)	4774±1355	0.09±0.026	1.51±0.43	86	34-204	16.4	<1-89	99% rainbow trout 1% brook trout
7 (RM 6.7)	2708±84	0.05±0.002	0.84±0.04	83	39-271	15.9	<1-260	100% rainbow trout

Table 2.-Densities of trout and mountain whitefish (# fish/mile) estimated from snorkeling twelve reaches along the North Fork Snoqualmie River during July 24-October 4, 1979 (adapted from Sweeney et al. 1981).

	Number of fish/mile			
Rivermile	0-3" Trout	3-9" Trout	>9" Trout	Whitefish
0.3-1.8	31	261	89	407
3.3-4.5	33	244	81	0
9.2-10.1	23	74	42	0
12.2-13.3	54	637	25	0
13.3-13.7	8	147	8	0
13.7-14.6	17	165	4	0
14.6-15.6	13	161	9	0
15.6-16.4	15	132	2	0
16.4-17.3	6	65	6	0
17.3-18.2	30	187	13	0
18.2-19.1	79	206	13	0
19.1-20.0	160 trout/mile observed; sizes were not specified for this reach.			

Table 3.-Summary of electrofishing surveys in the North Fork and mainstem of the Snoqualmie River in 1983. Fork length (mm) was recorded for all fish except cottids. From Dames & Moore 1985, Table 2.

Station/	Date	Number		Length (mm)				Density[a]	
Species	Sampled	Captured	Measured	Mean	Min	Max	Fish/m^2	Fish/km	Fish/mile
A_1 North Fork	9/23/83								
Weyco Site (RM 5.3)									
Rainbow trout		19	17	104.2	54	181	0.044±0.02	932±463	1497±743
Cottids		68	68	52.6	28	102	(b)	(b)	(b)
A_3 North Fork	10/13/83								
Ernie's Grove (RM 1.1)									
Rainbow trout		1	1	62	--	--	(b)	(b)	(b)
Cutthroat trout		1	1	128	--	--	(b)	(b)	(b)
All trout		--	--	--	--	--	0.004±0.002	76±45	122±72
Large scale sucker		2	2	87.5	82	93	(b)	(b)	(b)
Cottids		156	156	79.6	31	166	0.32±0.05	6609±1107[c]	10614±1634[c]
Brook lamprey		5	5	124.0	65	142	(b)	(b)	(b)
B_1 Snoqualmie	10/7/83								
Mainstem									
Railroad Bridge to confluence of South Fork									
Cutthroat trout		10	10	115.6	58	150	0.016±0.01	995±620[c]	1599±996[c]
Mountain whitefish		3	3	88.3	85	90	(b)	(b)	(b)
Cottids		32	32	66.5	29	125	(b)	(b)	(b)
Brook lamprey		29	29	110.8	45	160	0.04±0.01	2755±764[c]	4425±1227[c]

(a) Plus or minus twice the standard error (Zippin 1958).
(b) Catch distribution precluded population estimates.
(c) Based on effective length of stream sampled (length of area sampled x percent of stream cross section represented).

Table 4.-Snorkel survey results in the North Fork Snoqualmie River. Surveys in 1983 were conducted using continuously moving divers covering long reaches of stream while 1984 surveys used very slow moving or stationary divers to thoroughly census short reaches of stream. It was concluded that trout densities were greatly underestimated in the 1983 survey, during which stream temperatures were reduced. From Dames & Moore 1985, Table 4.

	Stream Length Surveyed	Date	Total Trout Seen	Percent Coverage	Fish (Trout)/ Mile
1983					
Reach 1	0.6 mile	10/15/83	16	0.3	89
Wagner Bridge to Campground					
Reach 2	0.7 mile	10/14/83	18	0.2	129
(above A_1 RM 5.3)					
Reach 3	0.8 mile	10/06/83	0	0.2	0.0
Ernie's Grove to North Fork Bridge					
Reach 4	1.0 mile	10/06/83	3	0.05	60
Mainstem (South Fork confluence to Railroad Bridge)					
1984					
Reach 1a	100 yd	10/02/84	62	100	1091
Wagner Bridge	100 yd	10/03/84	48	100	845
Reach 1b	150 yd	10/02/84	2	100	24
USGS Gage	150 yd	10/03/84	3	100	35
Reach 1c	100 yd	10/02/84	36	100	634
Spur 10 Bridge	100 yd	10/03/84	33	100	581
Reach 2a	100 yd	10/02/84	106	100	1866
(Above A)	100 yd	10/03/84	139	100	2446

Table 5.-Summary of electrofishing and snorkel surveys in the North Fork Snoqualmie River, 1979-1984. From Dames & Moore 1985, Table 5. Surveys were conducted by Dames & Moore (D&M) or by the Washington Department of Game (WDG).

Station[(a)]	Survey Distance	Temp. (^{o}C)	Fish/mile	Fish/m^2	Mean Fork Length (mm) (Range)	Species Composition	Lifestage Composition (Percent)	Year[(b)]	Survey Organi-zation
RM 6.0 (snorkel)	100 yd	13	2156	NA	NA	Rainbow	Juv. 40% Adult 60%	1984	D&M
RM 6.0-5.3 (snorkel)	0.7 mile	8.3	129	NA	NA	Rainbow	Adult 100%	1983	D&M
RM 5.3-5.5 (snorkel)	0.2 mile	7.2	10	NA	NA	Rainbow	Adult 100%	1983	D&M
RM 5.5 (electrofishing)	--	NA	1497	0.044	NA (54-181)	Rainbow	NA	1983	D&M
RM 5.2 (electrofishing)	--	NA	2708	0.05	83 (39-271)	Rainbow	NA	1979	WDG
RM 7.0 (snorkel)	100 yd	12.5	608	NA	NA	Rainbow	Juv. 5% Adult 95%	1984	D&M
RM 9.4 (snorkel)	150 yd	12.1	30	NA	NA	Rainbow	Adult 100%	1984	D&M
RM 9.4-10.1 (snorkel)	0.9 mile	NA	139	NA	NA	Rainbow	Juv. 33% Adult 67%	1979	WDG
RM 11.5 (snorkel)	100 yd	13	968	NA	NA	Rainbow	Juv. 6% Adult 94%	1984	D&M
RM 12.0-13.1 (snorkel)	1.1 mile	NA	716	NA	NA	Rainbow Brook	Juv. 76% Adult 24%	1979	WDG
RM 11.5 (electrofishing)	--	NA	4774	0.09	86 (34-204)	Rainbow 99% Brook 1%	NA	1979	WDG

(a) River miles (RM) for WDG data adjusted to conform to system in use on North Fork Snoqualmie Project.
(b) Note that 1983 D&M surveys were conducted using continuously moving divers covering long reaches of stream while 1984 D&M surveys used very slow moving or stationary divers to thoroughly census short reaches of stream. 1984 D&M data reported are means of replicated surveys taken on consecutive days.

Table 6.-Summary electrofishing surveys in Calligan Creek and Deep Creek, two tributaries to the North Fork Snoqualmie River. Fork length (mm) was recorded for all fish except cottids. From Dames & Moore 1985, Table 1.

Station/	Date	Number		Length (mm)			Density[a]		
Species	Sampled	Captured	Measured	Mean	Min	Max	Fish/m^2	Fish/km	Fish/mile
Calligan Creek[c]	8/31/83								
Rainbow trout		31	31	144.4	41	225	0.13±0.06	864±423	1388±679
Cottids		106	0	--	--	--	0.49±0.11	3259±696	5234±1118
Deep Creek (below road)	8/31/83								
Rainbow trout		7	7	84.6	33	198	0.04±0.04	299±294	480±472
Cutthroat trout		1	1	216	--	--	(b)	(b)	(b)
Brook trout		4	4	137.5	78	218	0.02±0.01	138±55	222±88
All trout		12	12	--	--	--	0.07±0.04	482±279	774±448
Cottids		90	10	60.9	22	100	0.53±0.13	3643±859	5851±1380
Deep Creek (above road)	9/8/83								
Rainbow trout		1	1	138	--	--	(b)	(b)	(b)
Cutthroat trout		1	1	70	--	--	(b)	(b)	(b)
Brook trout		6	6	152.3	80	190	0.13±0.42	793±2636	1274±4234
All trout		8	8	--	--	--	0.10±0.06	650±348	1044±559
Cottids		12	7	69.1	32	93	0.17±0.10	1073±620	1720±995

(a) Plus or minus twice the standard error (Zippin 1958).
(b) Catch distribution precluded population estimates.
(c) Electrofishing took place in the vicinity of the lower bridge.

Table 7.-Species composition and length frequency distribution for fish collected by R.W. Beck and Associates (August 1985) and Ott Water Engineers (Fall 1984) in the Black Canyon reach of the North Fork Snoqualmie River. Adapted from R.W. Beck and Associates (1985).

	0-3 inch	3-7 inch	> 7 inch
R.W. Beck and Associates			
Rainbow trout	0	0	4
Cutthroat trout	0	0	10
Unidentified trout	2	54	16
Percent of all trout	2.3%	62.8%	34.9%
Ott Water Engineers			
Rainbow trout	19	52	13
Cutthroat trout	0	3	2
Unidentified trout	1	5	1
Percent of all trout	20.8%	62.5%	16.7%

Table 8.-Densities of trout (# fish/mile) estimated from snorkel surveys and electrofishing surveys at four sites in the vicinity of the Twin Falls hydroelectric project. Study sites included a bypass site approximately 1,000 ft upstream of the project's tailrace, two sites selected for habitat enhancement (upper boulder and lower boulder), and a control site (adapted from Twin Falls Hydro Company 2006). Surveys were not conducted in 1989, 1992, and 1993. The project began operation December 1989 with a minimum flow in the bypass reach of 75 cfs in Aug-Apr and 150 cfs in May-Jul. A year-round minimum flow of 75 cfs was established in 1996.

	Snorkel Survey Densities (#fish/mile)				Electrofishing Densities (#fish/mile)			
Year	Bypass	Upper boulder placement	Lower boulder placement	Control	Bypass	Upper boulder placement	Lower boulder placement	Control
1984	2103.8	184.8	880.0	1665.2		184.8	985.6	
1985	2508.0	34.3	176.0	812.3	3097.9	52.8	211.2	1056.0
1986	895.1	18.5	165.4	353.4	870.4	52.8	281.6	852.9
1987	1567.5	97.7	140.8	678.3	1365.4	211.2	281.6	1502.8
1988	1196.3	26.4	165.4	731.1	878.6	26.4	140.8	1787.1
1990	1435.5	113.5	186.6	1494.6	1464.4	211.2	281.6	3371.1
1991	1307.6	79.2	352.0	1462.2	878.6	211.2	352.0	1380.9
1994	2392.5	139.9	397.8	1165.7	3242.3	132.0	492.8	609.2
1995	2256.4	422.4	271.0	946.3	2223.4	686.4	704.0	731.1
1996	899.3	224.4	274.6	418.3	684.8	290.4	668.8	446.8
1997	1629.4	95.0	218.2	203.1	2198.6	369.6	387.2	406.2
1998	1637.6	237.6	362.6	243.7	2029.5	660.0	1091.2	1056.0
1999	1443.8	245.5	316.8	324.9	1765.5	554.4	1267.2	365.5
2000	961.1	124.1	130.2	597.0	1027.1	316.8	387.2	731.1
2001	1183.9	105.6	257.0	394.0	2107.9	316.8	528.0	487.4
2002	1608.8	176.9	397.8	702.6	1542.8	396.0	739.2	852.9
2003	1291.1	87.1	95.0	406.2	994.1	211.2	140.8	487.4
2004	1608.8	79.2	271.0	893.5	1196.3	211.2	211.2	568.6
2005	1773.8	211.2	257.0	662.0	2198.6	369.6	211.2	203.1

Table 9.-Densities of trout (# trout/km) by size group estimated in August 1992 from snorkel surveys in the three forks of the Snoqualmie River. Trout (all species combined) were estimated by expanding snorkel lane counts to total surveyed area; numbers in each pass are expanded estimates rather than actual counts (from Jackson and Jackson 1993).

Total length (cm)	1st pass	2nd pass	Mean	Mean trout/km	Mean % total
Upper North Fork (RM 16.3-18.4)					
<15	40	--	40	11.6	51.3
15-22	34	--	34	9.9	43.6
23-30	3	--	3	0.9	3.8
31-38	0	--	0	0.0	0.0
> 38	1	--	1	0.3	1.3
Total	78		78	22.7	
Middle North Fork (RM 6.85-9.44)					
<15	13	--	13	3.1	4.2
15-22	91	--	91	21.9	29.4
23-30	146	--	146	35.1	47.1
31-38	45	--	45	10.8	14.5
> 38	15	--	15	3.6	4.8
Total	310		310	74.5	
Lower North Fork (RM 0.25-2.42)					
<15	219	93	156.0	44.7	17.3
15-22	477	434	455.5	130.5	50.6
23-30	205	262	233.5	66.9	25.9
31-38	39	63	51.0	14.6	5.7
> 38	1	8	4.5	1.3	0.5
Total	941	860	900.5	258.0	
Upper Middle Fork (RM 63.05-64.95)					
<15	210	--	210	64.4	37.1
15-22	308	--	308	94.5	54.4
23-30	42	--	42	12.9	7.4
31-38	6	--	6	1.8	1.1
> 38	0	--	0	0.0	0.0
Total	566		566	173.6	

Table 9.-Concluded.

Total length (cm)	1st pass	2nd pass	Mean	Mean trout/km	Mean % total
Middle Middle Fork (RM 54.9-56.8)					
<15	173	183	178.0	57.4	20.5
15-22	504	508	506.0	163.2	58.3
23-30	144	197	170.5	55.0	19.6
31-38	8	16	2.0	3.9	1.4
> 38	0	4	2.0	0.7	0.2
Total	829	908	868.5	280.2	
Lower Middle Fork (RM 45-46.75)					
<15	13	13	13.0	4.6	5.4
15-22	104	121	112.5	40.0	46.4
23-30	66	104	85.0	30.3	35.0
31-38	23	28	25.5	9.1	10.5
> 38	5	8	6.5	2.3	2.7
Total	211	274	242.5	86.3	
Upper South Fork (RM 16.7-18.1)					
<15	30	--	30	14.4	42.8
15-22	16	--	16	7.7	22.9
23-30	18	--	18	8.6	25.7
31-38	6	--	6	2.9	8.6
> 38	0	--	0	0.0	0.0
Total	70		70	33.6	
Middle South Fork (RM 8.2-10.7)					
<15	459	--	459	114.2	35.6
15-22	516	--	516	128.4	40.1
23-30	226	--	226	56.2	17.6
31-38	84	--	84	20.9	6.5
> 38	3	--	3	0.8	0.2
Total	1288		1288	320.5	
Lower South Fork (RM 0.3-2.6) Not surveyed because of time constraints.					

Table 10.-Fish observed during snorkel surveys in the North Fork (1993), the Middle Fork (1996 and 1990) and the South Fork (1998, 1991, and 1990). Data are from USFS stream habitat surveys (USFS 1998b, 1993, 1991a, 1990a, 1990b and Cascades Environmental Services 1997). Reaches increase numerically moving upstream.

	Cutthroat trout		Rainbow trout		Brook trout		Unidentified		Whitefish	
Reach	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.
North Fork – 1993 (RM 8.0-13.1)										
1	No numbers reported									
2	--	--	50	50	--	--	--	1	--	--
3	--	--	23	34	--	--	--	3	--	--
4[(a)]	--	--	38	65	--	--	--	--	--	--
5	--	--	43	46	--	--	--	18	--	--
6	--	--	21	24	--	--	--	3	--	--
Middle Fork – 1996 (RM 60.5-81)										
1	15	32	5	40	--	--	--	--	11	2
2	Rainbow trout, cutthroat trout, brook trout, mountain whitefish, and sculpin spp.									
3	Cutthroat trout and brook trout.									
Middle Fork – 1990 (RM 45.9- 61.0)										
1[(b)]	--	--	7	--	4	1	--	--	156	50
2[(b)]	--	--	56	60	--	--	--	--	--	--
3[(b)]	--	--	--	--	10	1	--	--	--	--
South Fork – 1998 (RM 17.9-30.6)										
1	4	15	5	14	3	21	3	2	--	--
2	8	31	--	--	--	2	--	6	--	--
3	2	5	--	5	--	--	--	--	--	--
4	20	8	1	2	--	--	5	2	--	--
5[(c)]	4	2	--	1	--	--	4	1	--	--
6	2	--	--	--	--	--	1	1	--	--
7	Not snorkeled									
8	Not snorkeled									
9	2	--	--	--	--	--	--	1	--	--
10	3	--	1	--	--	--	--	1	--	--
11	--	--	--	--	--	--	--	1	--	--

(a) One unidentified adult sculpin observed.
(b) Sculpin (adult/juvenile): Reach 1 (148/49), Reach 2 (15/15), and Reach 3 (6/2).
(c) Two unidentified species of sculpin were observed at RM 25.74.

Table 10.-Concluded.

Reach	Cutthroat trout Adult	Cutthroat trout Juv.	Rainbow trout Adult	Rainbow trout Juv.	Brook trout Adult	Brook trout Juv.	Unidentified Adult	Unidentified Juv.	Whitefish Adult	Whitefish Juv.
South Fork – 1991 (RM 24.2-27.0)										
1	11	7	1	--	--	--	1	--	--	--
2	15	7	--	1	1	--	5	--	--	--
South Fork – 1990 (RM 17.3-24.2)										
1	--	--	33	53	17	1	1	6	--	--
2	1	--	81	105	4	2	--	1	--	--

Table 11.-Fish observed during snorkel or electrofishing surveys in Lennox Creek (North Fork tributary; 1990), the Taylor River (Middle Fork tributary; 1992), the Pratt River (Middle Fork tributary; 1992), Carter Creek (South Fork tributary; 1991), and Quartz Creek (Taylor River tributary; 1991). Data are from USFS stream habitat surveys (USFS 1992a, 1992b, 1991b, 1991c, and 1990c). Reaches increase numerically moving upstream.

	Cutthroat trout		Rainbow trout		Brook trout		Sculpin[a]		Whitefish	
Reach	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.
Lennox Creek – 1990 (RM 0.0-5.5) electrofishing survey.[b]										
1	25	17	2	2	--	40	40	64	--	--
2	13	39	--	--	--	2	40	63	--	--
3	This reach not surveyed.									
4[c]	13	44	--	--	--	2	0	4	--	--
5	6	15	--	--	2	4	28	16	--	--
Taylor River – 1992 (RM 0.0-6.7) snorkel survey.										
1	2	--	11	--	--	--	--	--	2	10
2	11	8	13	3	--	--	--	--	--	--
3	8	4	10	15	--	--	--	--	--	--
4	4	2	5	16	--	--	--	--	--	--
Pratt River – 1992 (RM 0.0-7.42) snorkel survey.										
1	9	--	7	14	--	--	--	--	--	--
2	4	--	16	19	--	--	--	--	--	--
3	14	--	32	59	--	--	--	--	--	--
4	7	--	11	53	--	--	--	--	--	--
Carter Creek – 1991 (RM 0.0- 0.6) electrofishing survey.										
1	3	3	--	1	--	--	--	--	--	--
Quartz Creek – 1991 (RM 0.0- 3.0) electrofishing survey.										
1[d]	--	--	0	1	--	--	4	10	--	--
2	--	--	--	--	--	--	3	3	--	--

(a) Recorded as "non-game" species in the Lennox Creek survey, and likely were sculpin.
(b) Data for the Lennox Creek survey was recounted from the raw data sheets and should be considered approximate.
(c) Counts from reach 4 were from snorkel observations.
(d) Three juvenile fish were recorded as Chinook salmon.

Table 12.-Snorkel observations made in July 1990 from the mainstem above Snoqualmie Falls to the lower reaches of the three forks [adapted from Puget Sound Power & Light Company (1991)]. With the exception of Kimball Creek, site numbers increased from upstream to downstream within each fork or mainstem area surveyed. Additional observations from one and eight weeks after backwater levels were raised are included in Puget Sound Power & Light Company (1991).

Site	Cutthroat <3 in	Cutthroat >3 in	Rainbow <3 in	Rainbow >3 in	Whitefish <3 in	Whitefish >3 in	Sucker	Other
Middle Fork								
1	--	--	--	--	--	1	--	--
2	4	--	--	--	--	--	2	--
North Fork								
3	22	--	--	3	--	3	18	--
4	--	--	--	--	4	--	--	--
Mainstem								
5	19	--	--	--	5	2	5	--
6	--	--	--	--	--	--	1	--
7	24	5	--	--	--	--	7	--
8	--	6	--	--	--	--	--	--
9	--	3	--	--	--	--	--	1
10	2	1	--	--	--	--	--	--
11	--	--	--	--	--	--	1	--
12	--	--	--	--	--	--	1	--
South Fork								
13	--	67	--	--	--	--	187	--
14	--	75	--	--	--	--	20	--
15	--	50	--	--	--	--	17	--
16	--	6	--	--	--	--	1	--
17	--	29	--	--	--	--	1	--
18	--	29	--	--	--	--	2	--
Kimball Creek								
19	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	1

Table 13.-Season-long effort and catch success from creel surveys conducted on the North, Middle, and South Forks of the Snoqualmie River (adapted from Pfeifer 1985).

	Anglers Checked	Hours/ Trip	Mean Catch/ Hour	Mean Fish/ Angler	% RB	% CT	% EB	Total Catch	Total Angler Days
North Fork									
1969	194	2.96	0.846	2.51	91.3	4.8	3.7	9860	3936
1979	2648[a]	4.23	0.676	2.86	--	--	--	--	--
1984[b]	34	1.59	0.833	1.23	77.8	15.6	6.7	5615	2823
Middle Fork									
1969	89	4.39	0.510	1.87	75.3	24.7	--	12443	7777
1984[b]	46	1.41	0.169	0.24	54.5	45.5	--	1153	3519
South Fork									
1984[b]	50	1.18	0.698	0.82	24.4	58.5	--	8083	3519
1990[c]	44	No fish were retained. 20% fishing with bait or illegal gear.							

(a) Number of anglers checked and number of fish caught were estimated totals from Kurko et al. 1980; raw, unexpanded data not available (Pfeifer 1985).
(b) Qualifications for estimated total catch and angler days are in Appendix V of Pfeifer (1985).
(c) Pfeifer 1990, unpublished report.

Table 14.-Snoqulmie River creel data from the 1940s. Data were copied opportunistically from a box of historical records. Additional data may be archived in Olympia (J. Mattila, personal communication). Cutthroat trout (CT); rainbow trout (RB).

Date Checked	No. of Anglers	No. of each species of fish taken	Average size (in or lbs)	Time of day checked
South Fork Snoqualmie River				
5/27/45	43	243 CT	6-8 in	AM
5/25/47	125	195 CT, 195 RB	6-10 in	AM
5/22/49	40	108 RB, 36 CT	7-10 in	PM
Snoqualmie River				
5/27/45	3	25 RB, 25 CT	8-14 in	PM
5/25/47	10	None	--	PM
6/1/47	7	8 RB	7-9 in	AM
6/15/47	10	None	--	PM
6/21/47	5	2 Steelhead	6-7 lbs	PM
6/22/47	7	1 Steelhead	4 lbs	PM
6/23/47	7	1 Steelhead	7 lbs	AM
6/26/47	4	None	--	PM
6/28/47	2	None	--	PM
7/2/47	6	None	--	PM
7/5/47	4	None	--	PM
6/5/48	4	None	--	PM
5/22/49	1	1 Steelhead	16”	AM

Table 15.-Water quality data from the U.S. Army Corps of Engineers North Fork Snoqualmie River sampling program (from Sweeney et al. 1981).

Date	Water Temp. Cent.	Conductivity at 25° C micromho	pH	DO MG/L	DO Satur. percent	Turbidity Trbidmtr Hatch FTU	Phenolphth-alien alk MG/L
North Fork Snoqualmie at upper NF Bridge (Station 4: 47 39 49.0 121 34 13.0 4)							
7/20/79	14.0	14	6.95	9.2	94.0	--	--
7/24/79	13.0	16	--	9.9	99.1	--	--
8/21/79	14.5	20	--	10.4	107.7	--	9
9/18/79	12.4	36	--	10.3	101.9	0.1	8
10/16/79	10.0	28	--	10.2	94.9	0.2	8
11/14/79	3.9	12	--	12.8	102.7	0.4	7
2/22/80	2.6	11	6.60	14.0	109.1	0.3	4
3/26/80	3.0	12	6.80	14.5	114.5	0.4	4
5/14/80	6.7	10	6.70	11.0	97.3	0.4	4
6/20/80	8.9	15	6.61	11.8	107.2	0.2	2
Lennox Cr. above mouth at County Road Bridge (Station 3: 47 39 34.0 121 48.0 4)							
7/20/79	15.4	11	6.91	9.5	100.0	--	--
7/24/79	13.4	12	--	10.2	102.9	--	--
8/21/79	14.6	17	--	10.9	113.1	--	7
9/18/79	12.2	30	--	10.8	106.4	0.1	7
10/16/79	9.3	20	--	11.0	100.3	0.1	6
11/14/79	2.6	14	--	13.8	107.1	0.1	6
2/22/80	2.0	8	6.60	14.6	111.9	0.3	4
3/26/80	1.8	11	6.80	15.2	116.4	0.3	4
5/14/80	5.6	--	6.60	--	--	0.5	1
6/20/80	9.0	10	6.45	11.9	108.7	0.4	1
Sunday Cr. above mouth at County Road Bridge (Station 2: 47 39 15.0 121 39 22.0 4)							
7/20/79	16.6	12	6.10	9.1	98.0	--	--
7/24/79	14.6	14	--	9.5	98.0	--	--
8/21/79	14.9	15	--	10.6	110.4	--	6
9/18/79	13.7	28	--	10.2	103.5	0.1	6
10/16/79	10.8	20	--	10.1	95.5	0.2	6
11/14/79	6.2	15	--	12.4	105.2	0.2	4
2/22/80	3.7	11	6.60	13.8	110.4	0.3	4
3/26/80	3.3	10	6.70	14.2	112.8	0.7	4
5/14/80	7.2	--	6.60	--	--	0.5	1
6/20/80	11.0	16	6.40	11.2	106.8	0.6	4

Table 15.-Concluded.

Date	Water Temp. Cent. Water	Conductivity at 25° C micromho Conductivity	pH	DO MG/L	DO Satur. percent DO	Turbidity Trbidmtr Hatch FTU Turbidity	Phenolphth- alien alk MG/L Phenolphth-
N. Fk Snoqualmie at Wagner Bridge (RM 12.1) (Station 1: 47 39 29.0 121 40 44.0 4)							
7/20/79	18.4	22	6.55	9.0	101.0	--	--
7/24/79	15.1	22	--	9.5	98.6	--	--
8/21/79	15.6	34	--	10.8	113.4	--	13
9/18/79	14.5	36	--	10.1	103.9	0.3	17
10/16/79	10.5	40	--	10.6	98.9	0.7	18
11/14/79	5.9	44	--	11.8	99.0	2.6	13
2/22/80	4.0	20	--	14.2	113.7	1.4	10
3/26/80	3.7	20	7.20	14.4	114.9	1.9	16
5/14/80	6.7	--	6.90	--	--	3.0	8
6/20/80	13.5	34	6.85	11.2	109.9	1.4	18
Beaver Pond							
7/20/79	16.0	54	--	8.1	--	--	--

Table 16.-Habitat measurements for snorkel survey sites selected in the upper, middle, and lower reaches of the three forks of the Snoqualmie River, August 1992 (from Jackson and Jackson 1993).

	No	Total length (m)	Average length (m)	% of total	No/km
Upper North Fork (RM 16.3-18.4)					
Pools	8	190.5	23.8	17.8	2.4
Riffles	18	300.5	16.7	40.0	5.4
Runs	19	2870.6	151.1	42.2	5.7
Middle North Fork (RM 6.85-9.44)					
Pools	16	74.5	4.7	20.5	4.8
Riffles	19	545.0	28.7	24.4	5.7
Runs	25	1550.5	62.0	32.1	7.5
Pocket water	12	1013.5	84.5	15.4	3.6
Chutes/Cascades	6	166.7	27.8	7.7	1.8
Lower North Fork (RM 0.25-2.42)					
Pools	7	578.5	82.6	17.9	2.0
Riffles	11	566.6	51.5	28.2	3.2
Runs	17	1798.0	105.8	43.6	4.9
Pocket water	4	541.3	135.3	10.3	1.1
Upper Middle Fork (RM 63.05-64.95)					
Pools	18	1241.2	69	31.6	5.5
Riffles	20	1080.8	54	35.1	6.1
Runs	17	858.6	50.5	29.8	5.2
Pocket water	2	78.3	39.2	3.5	0.6
Middle Middle Fork (RM 54.9-56.8)					
Pools	8	771.4	96.4	21.6	2.6
Riffles	12	1073.2	89.4	32.4	3.9
Runs	9	444.6	49.4	24.3	2.9
Pocket water	8	772.6	96.6	21.6	2.6
Lower Middle Fork (RM 45-46.75)					
Pools	9	767.9	85.3	29.0	3.2
Riffles	10	611.8	61.2	32.3	3.6
Runs	12	1427.2	118.9	38.7	4.3

Table 16.-Concluded

	No	Total length (m)	Average length (m)	% of total	No/km
Upper South Fork (RM 16.7-18.1)					
Pools	13	339.6	26.1	26	6.2
Riffles	12	256.6	21.4	24	5.7
Runs	21	1185.3	56.4	42	10
Pocket water	1	27.4	27.4	2	0.5
Chutes/Cascades	2	65.2	32.6	4	1.0
Enhanced Riffle	1	216.7	216.7	2	0.5
Middle South Fork (RM 8.2-10.7)					
Pools	23	870.6	37.9	22.3	5.7
Riffles	35	1471.5	42.0	34.0	8.7
Runs	33	1325.3	40.2	32.0	8.2
Pocket water	12	352.0	29.3	11.7	3.0
Lower South Fork (RM 0.3-2.6) Not surveyed because of time constraints.					

Table 17.-Stomach contents of trout caught in the North Fork Snoqualmie River and in beaver pond 6 (adapted from Kurko et al. 1980). Trout were caught between July 21 and August 26, 1979 by hook and line, with exception of the one rainbow trout and the 215 mm brook trout that were caught by electrofishing. Adult (Adt), Nymph (Nym), Pupae (Pup), Larvae (Lva).

Species	Location	Fork length (mm)	Fish	Pleco-ptera		Diptera			Tricho-ptera		Ephem-eroptera		Coleo-ptera		Ortho-ptera		Gastro-poda
				Adt	Nym	Adt	Pup	Lva	Adt	Lva	Adt	Nym	Adt	Lva	Adt	Lva	
Cutthroat	RM 19.1	≈ 190	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	1	1	--	--	1	--	2	--	1	1	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	--	1	--	--	--	--	--	--	--	3	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	--	3	--	--	5	--	1	--	3	--	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	--	--	--	1	--	--	1	--	--	--	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	--	1	1	--	--	--	3	--	--	--	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	1	--	3	--	3	--	--	--	2	--	--	--	--	--
Cutthroat	RM 19.1	≈ 190	--	--	--	--	--	--	--	4	--	--	1	--	--	--	--
Rainbow	RM 11.2	270	1[(a)]	--	--	--	--	--	--	8	--	--	--	--	--	--	--
Brook	RM 17.3	215	1[(b)]	--	--	--	--	--	--	24	--	--	--	--	--	--	--
Cutthroat	RM 16.4	186	1[(c)]	--	--	1	--	--	--	--	--	--	1	--	1	--	--
Cutthroat	Beaver Pd	266	--	--	--	--	--	--	--	--	--	--	--	--	--	--	20
Brook	Beaver Pd	225	--	--	--	--	--	--	--	6	--	--	1	--	--	--	--
Brook	Beaver Pd	197	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--

(a) juvenile trout (40mm).
(b) shorthead sculpin (30mm)
(c) shorthead sculpin (29mm), ALSO 2 Ants (Hymenoptera).

Table 18.-Densities of aquatic invertebrates (#/m^2) collected in North Fork Snoqualmie River, June, 1979 (from Kurko et al. 1980). Invertebrates were collected with a Mundie sampler at six sampling stations interspersed between approximately RM 6.6 and RM 20.2 plus one station in Lennox Creek (station 2).

	Sampling station						
	1	2	3	4	5	6	7
	#/m^2 (%)	#/m^2 (%)	#/m^2 (%)	#/m^2 (%)	#/m^2 (%)	#/m^2 (%)	#/m^2 (%)
Ephemeroptera	1272.5 (80.3)	483.4 (51.8)	161.1 (46.8)	966.7 (60.4)	188.9 (69.3)	533.4 (82.7)	527.8 (61.6)
Plecoptera	161.2 (10.2)	194.5 (20.8)	127.8 (37.1)	177.7 (11.1)	44.4 (16.3)	44.5 (6.9)	44.4 (5.2)
Trichoptera	28.0 (1.7)	5.6 (0.6)	5.6 (1.6)	38.9 (2.4)	5.6 (2.1)	--	16.8 (1.9)
Diptera	66.7 (4.2)	244.6 (26.2)	5.6 (1.6)	377.9 (23.7)	27.8 (10.2)	50.1 (7.8)	216.7 (25.3)
Coleoptera	5.6 (0.4)	--	--	38.9 (2.4)	5.6 (2.1)	5.6 (0.9)	16.7 (2.0)
Collembola	5.6 (0.4)	--	--	--	--	--	--
Oligocaeta	--	--	27.8 (8.1)	--	--	--	16.7 (2.0)
Unknown	44.4 (2.8)	5.6 (0.6)	16.7 (4.8)	--	--	11.1 (1.7)	16.7 (2.0)
TOTAL	1584.0 (100)	933.7 (100)	344.6 (100)	1600.1 (100)	272.3 (100)	644.7 (100)	855.8 (100)

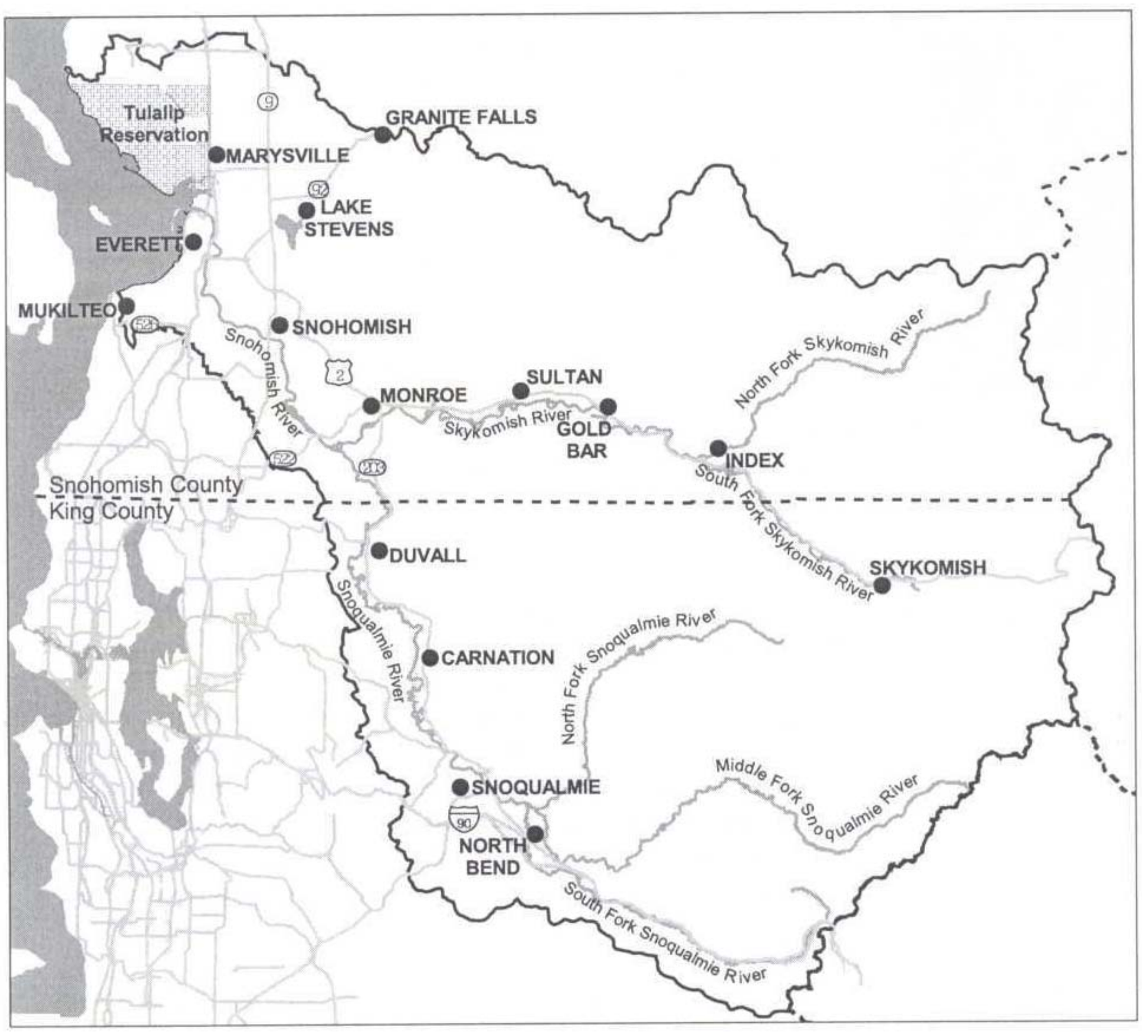

Figure 1.-Map of the Snohomish River Basin including the Snohomish, Skykomish, and Snoqualmie rivers and associated forks. From Snohomish Basin Salmon Recovery Forum (2005).

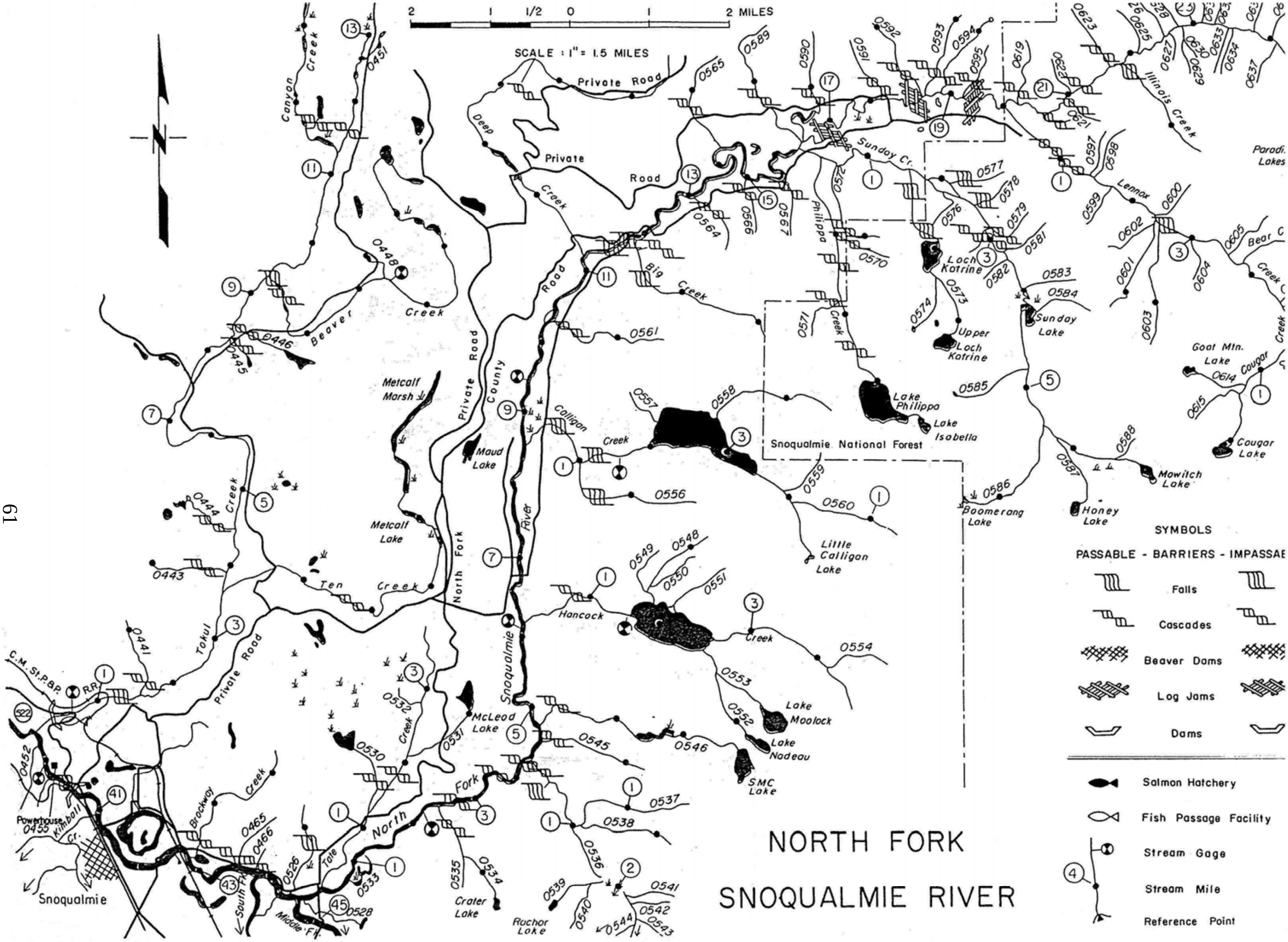

Figure 2.-Map of the North Fork Snoqualmie River including tributaries lakes, impassible migration barriers, and river miles (from Williams et al. 1975).

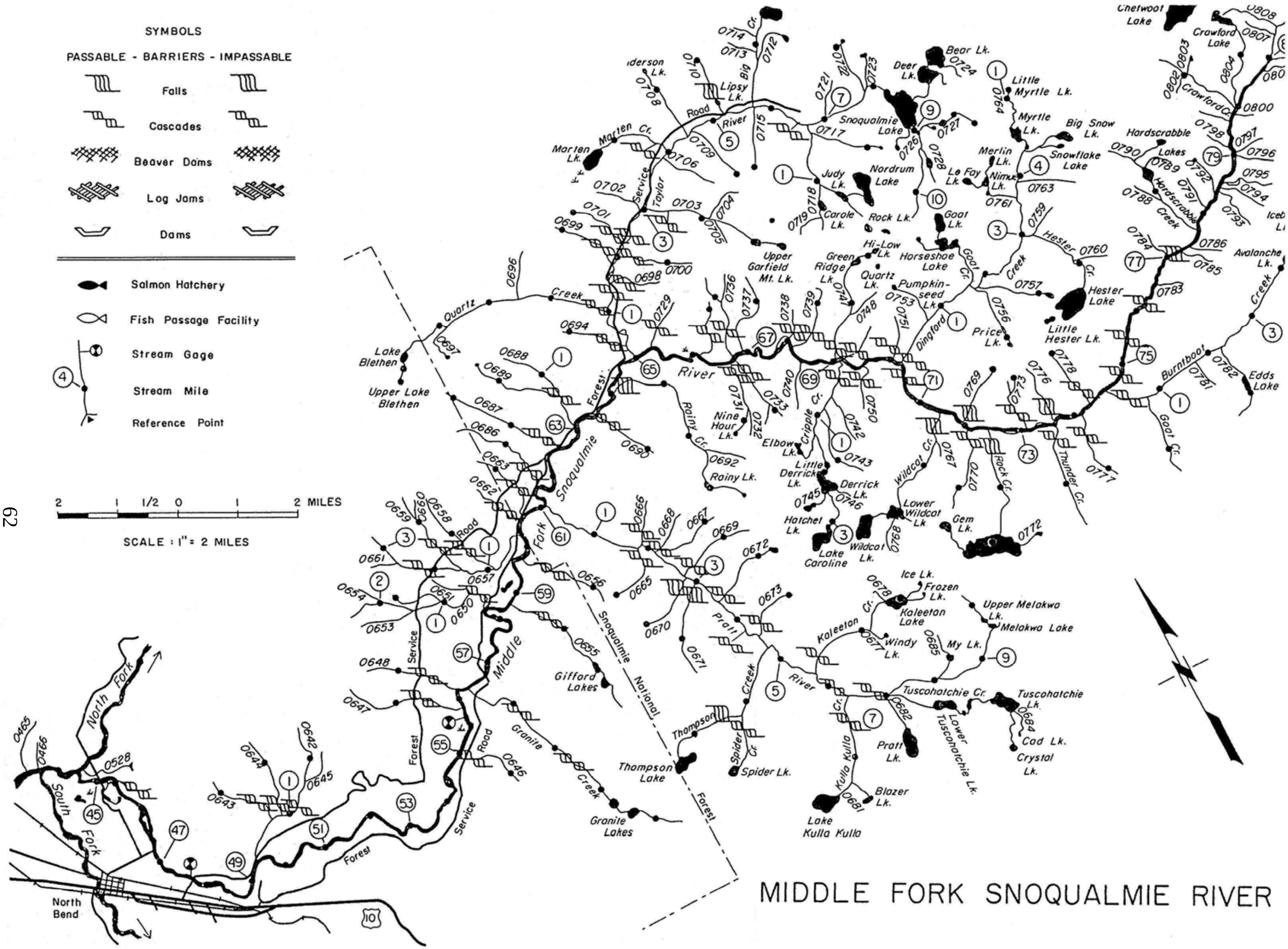

Figure 3.-Map of the Middle Fork Snoqualmie River including tributaries, lakes, impassible migration barriers, and river miles (from Williams et al. 1975). Middle Fork river miles start at RM 44.5.

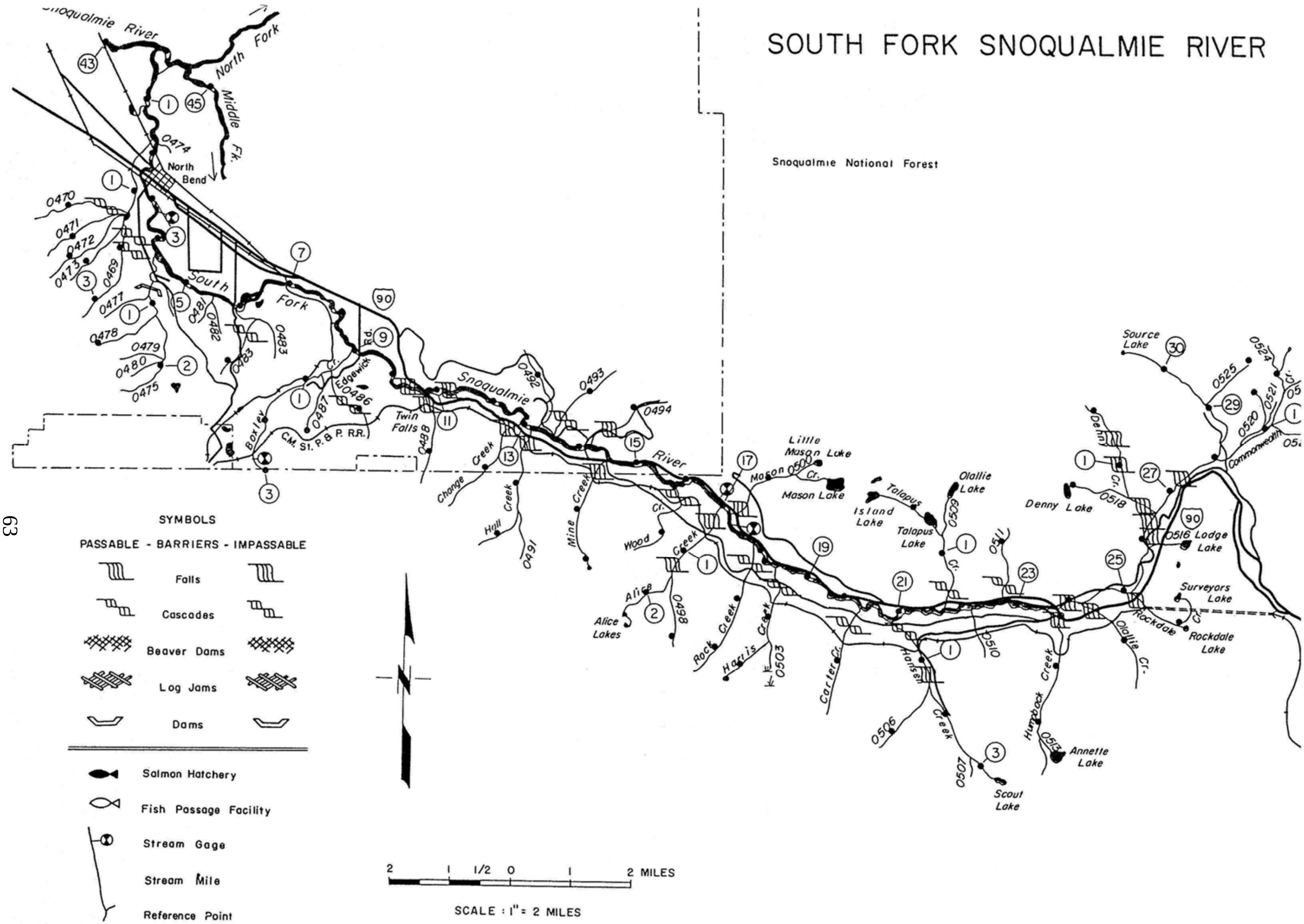

Figure 4.- Map of the South Fork Snoqulamie River including tributaries, lakes, impassible migration barriers, and river miles (from Williams et al. 1975).

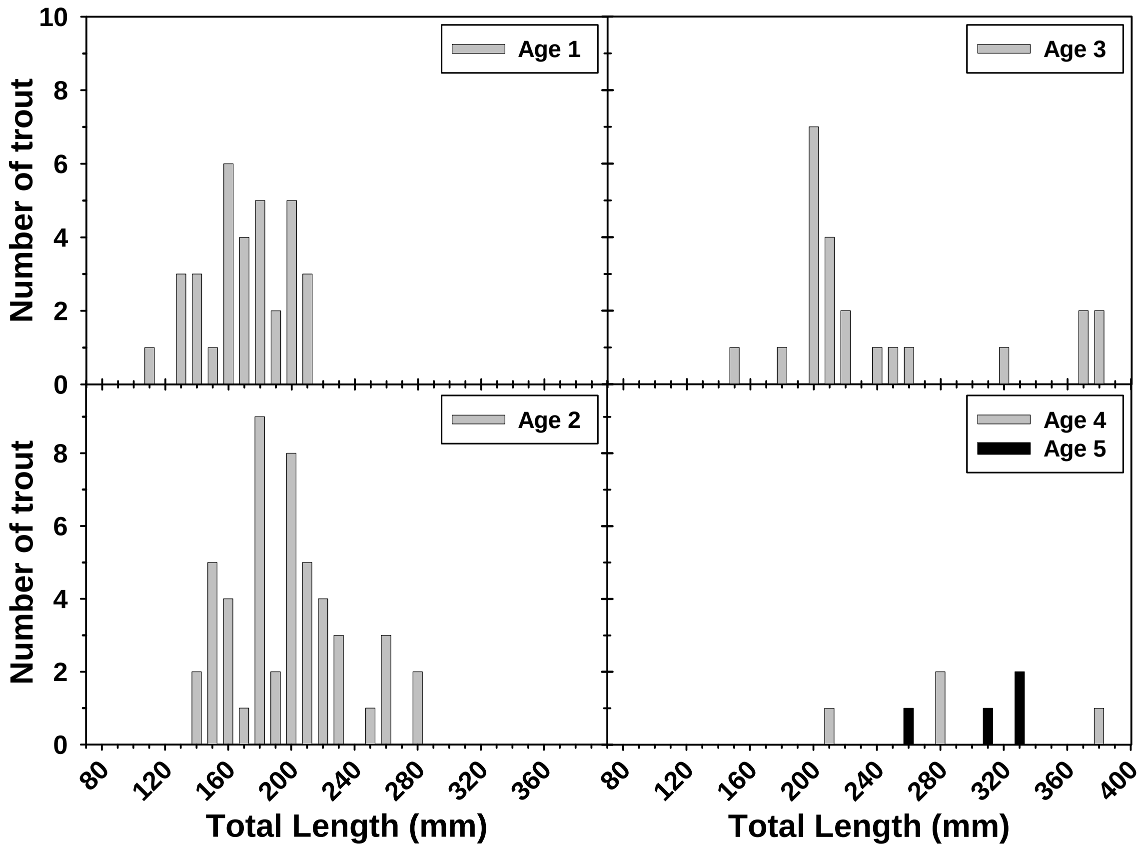

Figure 5.-Length frequencies (number of trout) by age for cutthroat trout collected by angling in the Middle Fork, 1981-1984 (adapted from Pfeifer 1990).

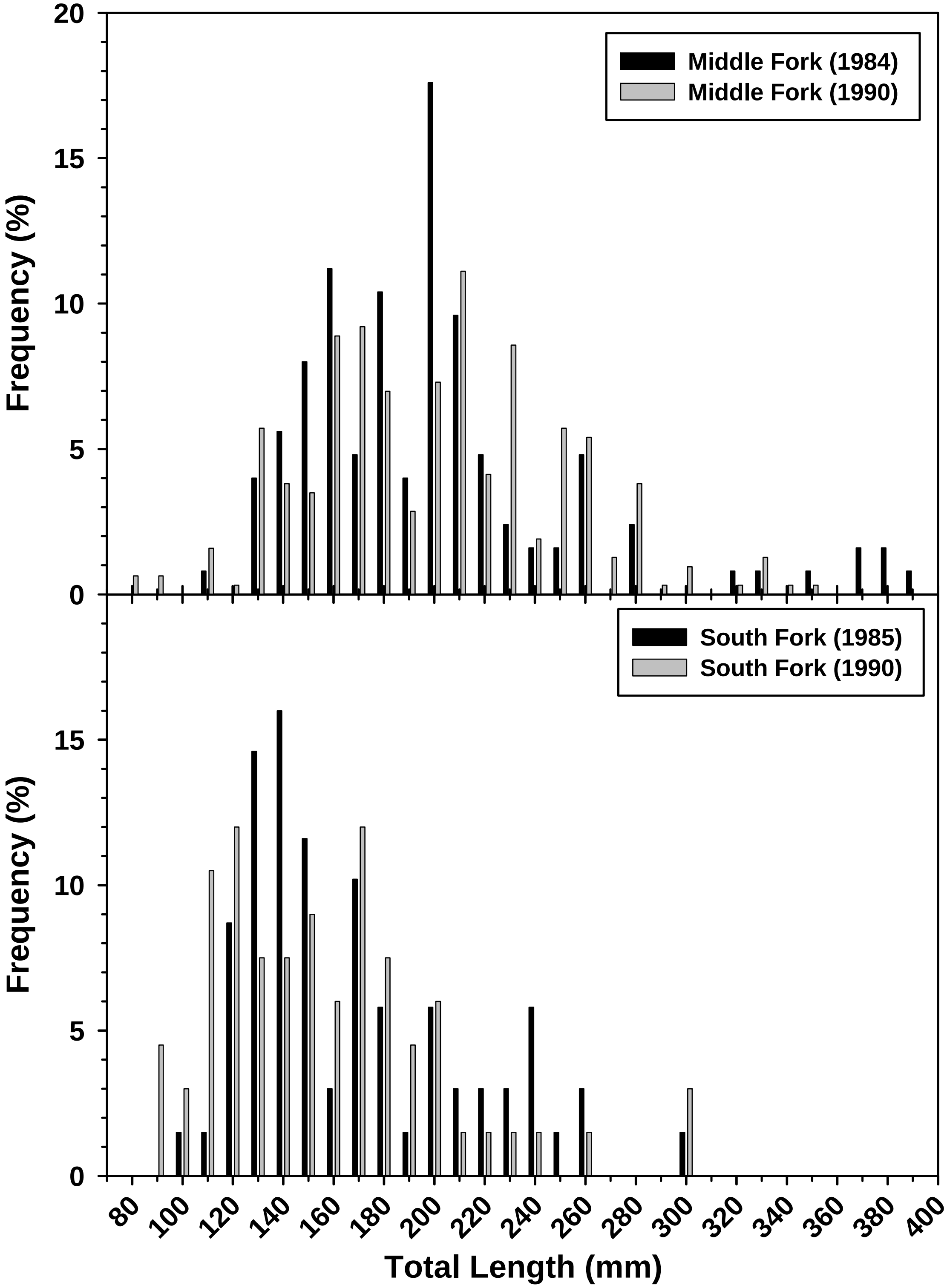

Figure 6.-Length frequencies (%) for cutthroat trout collected by angling in the Middle Fork and by electrofishing surveys in the South Fork (adapted from Pfeifer 1990).

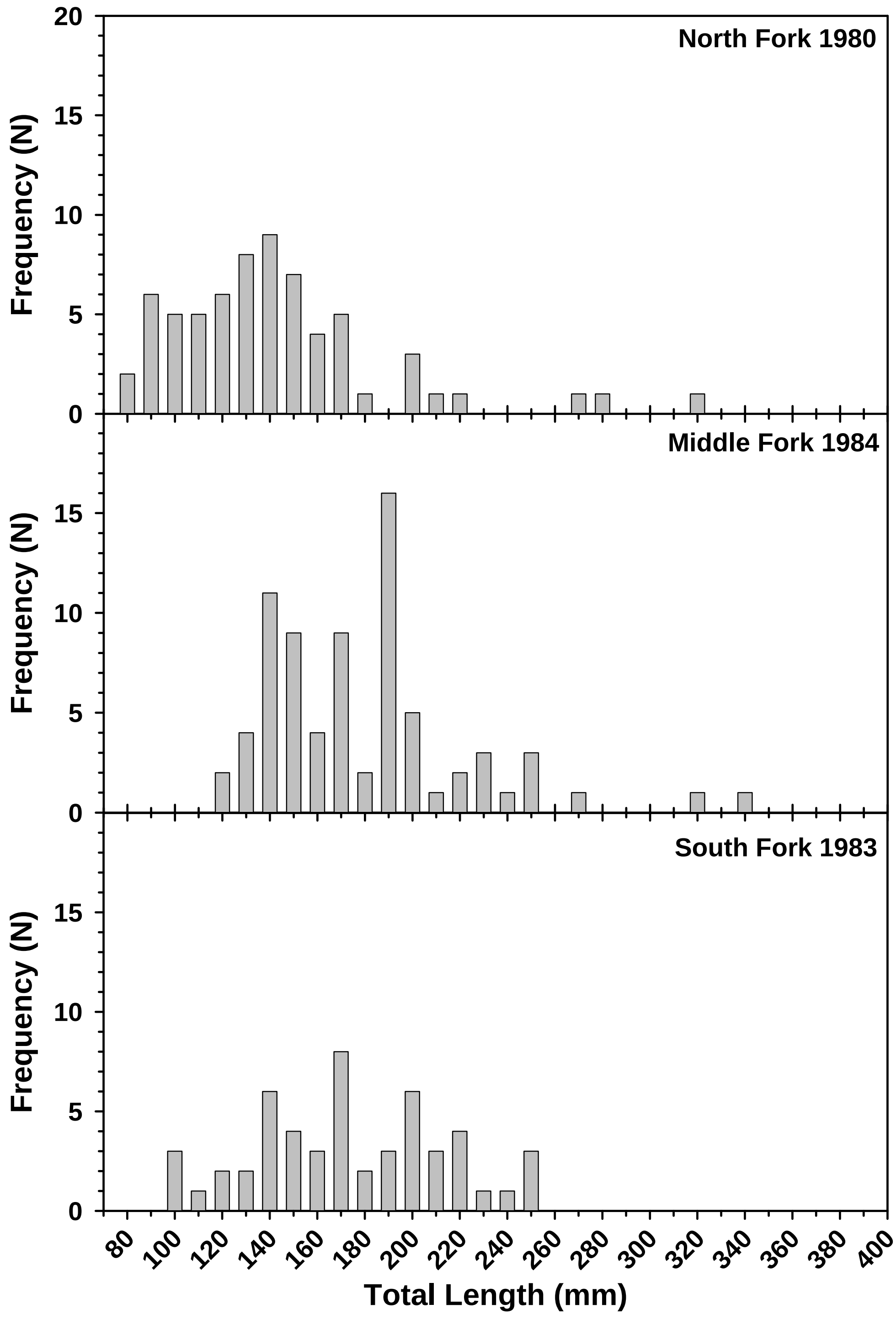

Figure 7.-Length frequencies (number of fish) for trout collected by electrofishing in the North Fork and by angling in the Middle Fork and South Fork (from Pfeifer 1985). It is possible that lengths of North Fork trout were not converted from fork length to total length for this figure (R. Pfeifer, personal communication).

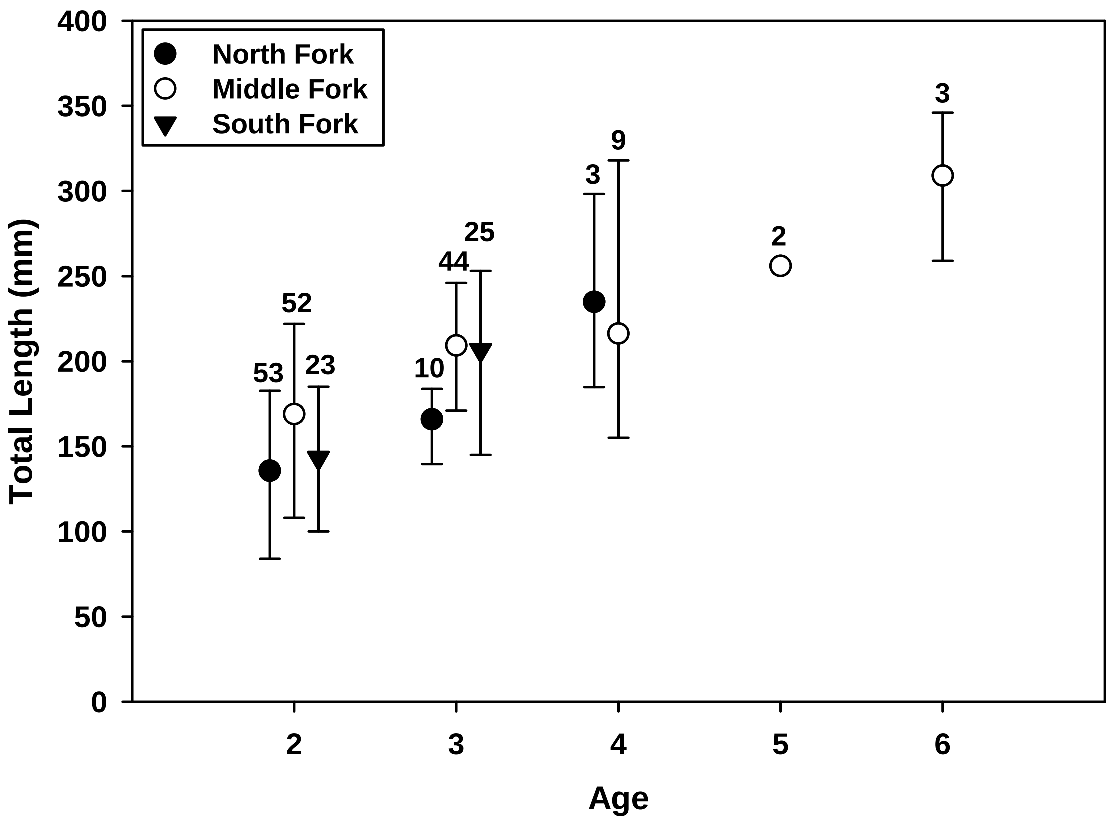

Figure 8.-Average total lengths (mm) at age for trout (cutthroat trout and rainbow trout combined) collected by electrofishing the North Fork and its tributaries and from angling in the Middle and South Forks. Adapted from Tables 4.2, 4.3, and 4.4 in Pfeifer (1985). Error bars represent min and max length observed and numbers represent sample size. Total lengths for North Fork trout were converted from fork lengths using a regression (TL = 1.050 FL) for cutthroat trout from the upper Yakima Basin (Trotter et al. 1999).

APPENDIX

Appendix Table 1.-Age and length data for cutthroat and rainbow trout collected by electrofishing in the North Fork Snoqualmie River and tributaries, 9/23/80–10/2/80. From Pfeifer (1985) Table 4.2. Scales were not taken from trout less than 80 mm (all Age I).

Water	Age	Ageable sample size (n)	Mean fork length (mm)	Range	Species	% RB	% CT
“GF” Creek	2	9	137.8	97 – 174	Ct	0.0	100.0
	3	3	175.0	-175-	Ct	0.0	100.0
Lennox Creek	2	9	129.3	80 – 171	Ct	0.0	100.0
Sunday Creek	2	4	115.0	106 – 125	Ct	0.0	100.0
	3	1	154.0	--	Ct	0.0	100.0
	4	1	176.0	--	Ct	0.0	100.0
Philippa Creek	2	7	131.3	121 – 147	Rb, Ct	28.6	71.4
	3	6	150.2	133 – 163	Rb	100.0	0.0
	4	2	247.5	211 – 284	Rb	100.0	0.0
North Fork above Lennox Creek	2	24	127.6	89 – 164	Ct	0.0	100.0
All Waters Combined[(a)]	2	53	129.2	80 – 174	Rb, Ct	3.8	96.2
	3	10	158.0	133 – 175	Rb, Ct	60.0	40.0
	4	3	223.7	176 – 284	Rb, Ct	66.7	33.3
All Tribs.	2	29	130.4	80 – 174	Rb, Ct	6.9	93.1
	3	10	158.0	133 – 175	Rb, Ct	60.0	40.0
	4	3	223.7	176 – 284	Rb, Ct	66.7	33.3

(a) t-tests showed no significant differences between river sections.

Appendix Table 2.-Age and length data for cutthroat and rainbow trout in the Middle Fork Snoqualmie River, 9/25/81 – 10/29/81. From Pfeifer (1985) Table 4.3.

River Section[(a)]	Age	Ageable sample size (n)	Mean fork length (mm)	Range	Species	% RB	% CT	% Ct/Rb
I	2	32	162.5	108 – 210	Rb, Ct	12.5	87.5	0.0
	3	24	218.6	171 – 279	Rb, Ct	4.2	95.8	0.0
	4	1	318.0	--	Ct	0.0	100.0	0.0
II	2	3	169.3	160 – 175	Ct/Rb, Ct	0.0	33.3	66.7
	3	2	203.5	197 – 210	Ct	0.0	100.0	0.0
Both Sections	2	35	163.1	108 – 210	Rb, Ct, Rb/Ct	11.4	82.9	5.7
Combined[(b)]	3	26	217.4	171 – 279	Rb, Ct	3.8	96.2	0.0
	4	1	318.0	--	Ct	0.0	100.0	0.0

(a) Section I = RM 0.0 to 20.3; Section II = RM 20.3 to 25.7.
(b) t-tests showed no significant differences between river sections.

Appendix Table 3.-Age and length data for cutthroat and rainbow trout in the Middle Fork Snoqualmie River, 7/29/84. From Pfeifer (1985) Table 4.3.

River Section[a]	Age	Ageable Sample Size (n)	Mean Fork Length (mm)	Range	Species	% RB	% CT
I	2	16	168.9	132 – 222	Ct, Rb	5.9	94.1
	3	16	196.5	135 – 246	Ct, Rb	11.1	88.9
	4	4	214.5	195 – 271	Ct, Rb	20.0	80.0
	5	1	257.0	--	Ct	0.0	100.0
	6	2	334.0	322 – 346	Ct	0.0	100.0
II	3	2	204.5	199 – 210	Ct	0.0	100.0
	4	1	231.0	--			
III	2	1	170.0	--	Ct	0.0	100.0
	4	2	192.0	190 – 194	Ct	0.0	100.0
IV	4	1	155.0	--	Ct[b]	0.0	100.0
	5	1	255.0	--	Ct[b]	0.0	100.0
	6	1	259.0	--	Ct[b]	0.0	100.0
All Sections Combined[c]	2	17	169.0	132 – 222	Ct, Rb	5.6	94.4
	3	18	197.4	135 – 246	Ct, Rb	10.0	90.0
	4	8	203.5	155 – 271	Ct, Rb	38.5	61.5
	5	2	256.0	255 – 257	Ct	33.3	66.6
	6	3	309.0	259 – 346	Ct	0.0	100.0

(a) Section I = RM 0.0 to 20.3; Section II = RM 20.3 to 25.7; Section III = RM 25.7 to 33.0; Section IV = RM 33.0 to 39.5.
(b) Text suggests these are Rb rather than Ct.
(c) t-tests showed no significant differences between river sections.

Appendix Table 4.-Age and length data for cutthroat and rainbow trout in the South Fork Snoqualmie River, 7/3/81– 8/14/81. All trout collected with hook and line. From Pfeifer (1985) Table 4.4.

River Section[a]	Age	Ageable Sample Size (n)	Mean Fork Length (mm)	Range	Species	% RB	% CT	% Rb/Ct
I	2	7	147.3	105 – 185	Rb, Ct, Rb/Ct	0.00	28.6	71.4
	3	5	217.0	145 – 240	Ct, Rb/Ct	0.00	60.0	40.0
II	2	9	119.4	100 – 165	Rb, Ct, Rb/Ct	33.3	33.3	33.4
	3	14	197.5	170 – 250	Rb, Rb/Ct	42.9	0.0	57.1
III	2	7	150.0	120 – 170	Rb, Ct, Rb/Ct	57.1	14.3	28.6
	3	6	218.8	195 – 253	Rb, Rb/Ct	16.7	0.0	83.3
All Sections	2	23	143.3	100 – 185	Rb, Ct, Rb/Ct	30.4	26.1	43.5
Combined[b]	3	25	206.5	145 – 253	Rb, Ct, Rb/Ct	28.0	12.0	60.0

(a) I: Mouth to Twin Falls (RM 10.8); II: Twin Falls to Exit 42 (RM 17.2); III: Exit 42 to Asahel Curtis Interchange (RM 23.4); IV: Asahel Curtis Interchange to source.
(b) t-tests showed no significant differences between river sections.

Appendix Table 5.-Summary of river spot electrofishing in the North Fork Snoqualmie River in 1979. From Kurko et al. 1980, Table 13. Either a Coeffelt model BP-1C (backpack) or a Coeffelt model VVP-2C (vvp) electroshocker was used.

Date	River mile	Shocking unit	Time (hr)	Fish Species	Number	Mean length (FL, mm)	Length range (FL, mm)	Mean weight (g)	Weight range (g)
7/3	9.2	backpack	--	rainbow fry	1	40	--	< 1	--
				shorthead sculpin	14	--	--	--	--
7/31	19.0	backpack	--	rainbow	1	117	--	81	--
				cutthroat	1	98	--	16	--
				shorthead sculpin	7	--	--	--	--
8/1	11.2	backpack	--	rainbow	8	143	74-270	58	5-272
				rainbow fry	10	40	--	< 1	--
				shorthead sculpin	39	79	72-90	5	3-8
8/1	11.6	backpack	1.0	rainbow	5	143	112-165	39	19-58
				rainbow fry	12	40	--	< 1	--
8/1	19.2	backpack	0.75	cutthroat	3	135	106-164	30	11-52
				cutthroat fry	5	66	64-68	2	--
				brook	1	130	--	21	--
8/2	17.5	backpack	1.5	cutthroat	5	137	86-238	43	11-138
				brook	1	215	--	115	--
				shorthead sculpin	45	--	--	--	--
8/9	11.6	vvp	1.2	rainbow	6	129	109-147	24	14-34
				rainbow fry	14	40	--	1	--
8/9	14.6	vvp	1.2	rainbow	6	113	103-125	17	13-19
				cutthroat	2	111	100-122	14	11-18
				shorthead sculpin	42	--	--	--	--
10/17	19.2	backpack	0.5	brook	14	81	59-170	10	2-62
				cutthroat	1	59	--	2	--