AN ABSTRACT OF THE THESIS OF

Samuel J. Brenkman for the degree of Master of Science in Fisheries Science presented on February 26, 1998. Title: Factors Influencing Spawning Migration of Bull Trout (*Salvelinus confluentus*) in the North Fork Skokomish River, Olympic National Park, Washington.

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Gary L. Larson

Distribution and life history characteristics of lacustrine-adfluvial bull trout (*Salvelinus confluentus*) were described in the North Fork Skokomish River Basin (including Lake Cushman, a reservoir) from 1994 to 1996. Day snorkeling was conducted in the river to determine initiation of the bull trout spawning migration, abundance of spawners, and duration of spawning. Declining photoperiod, increased river discharge, and decreased water temperature appeared to influence timing of migration and spawning. Lacustrine-adfluvial bull trout typically entered the North Fork Skokomish River in October although some fish entered as early as May. Mean lengths of spawners consistently increased from June to December 1996, and early migrating bull trout were shorter than those fish that entered after river discharge increased in October. The presence of two phases of the spawning migration may be indicative of two populations spawning in the river. Bull trout spawned between mid-September and December in the river and tributaries after water temperatures declined. All spawning occurred at temperatures less than 7.5°C.

Comparisons with studies of other lacustrine-adfluvial bull trout populations that inhabit river and reservoir complexes suggested that bull trout exhibit specific migratory strategies related to local environmental conditions. In the North Fork Skokomish River, changes in abundance of bull trout, mountain whitefish (*Prosopium williamsoni)*, cutthroat trout (*Oncorhynchus clarki)*, and rainbow trout (*Oncorhynchus mykiss*) revealed distinct temporal segregation among these species. Olympic National Park, a designated Biosphere Reserve, contains one of the largest remaining areas of relatively pristine habitat in the range of bull trout. Knowledge of responses of bull trout to changes in river discharge and temperature from relatively undisturbed systems, such as the North Fork Skokomish River, may be useful in understanding patterns observed in degraded environments.

Factors Influencing Spawning Migration of Bull Trout (*Salvelinus confluentus*) in the North Fork Skokomish River, Olympic National Park, Washington

by

Samuel J. Brenkman

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Samuel J. Brenkman, Author

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INTRODUCTION

Bull trout (*Salvelinus confluentus*) is a recently described species of char indigenous to western North America that belongs to a genus with circumpolar distribution. In 1978, bull trout were taxonomically separated from the closely related Dolly Varden (*Salvelinus malma*) (Cavendar 1978). Less than two decades after its description, bull trout now are believed to be at risk of local and regional extirpations. Based on widespread declines in distribution and abundance, bull trout in the Klamath and Columbia River Basins are proposed for listing under the federal Endangered Species Act. Significant declines in distribution and abundance of this species are attributed to habitat degradation (Fraley and Shepard 1989; Rieman and McIntyre 1993), overexploitation by angling (Carl et al. 1989; Ratliff and Howell 1992), mortality associated with dams and diversions (Rode 1990), and displacement by introduced fish species (Donald and Alger 1992; Markle 1992; Leary et al. 1993).

In Washington State, 43% of native char populations surveyed were categorized as being at moderate to high risk of extinction (Mongillo 1992). However, distinct population segments of bull trout that inhabit drainages of the Olympic Peninsula and Puget Sound were not warranted for listing under the Endangered Species Act. Olympic National Park (OLYM), a designated Biosphere Reserve located on the Olympic Peninsula, contains one of the largest contiguous areas of relatively pristine habitat in the range of bull trout. This study was conducted in the North Fork Skokomish River Basin, OLYM, which drains into Lake Cushman (a reservoir) (Fig. 1). Mongillo (1992) suggested that the North Fork Skokomish River was the only bull trout population increasing in abundance in Washington.

Distributions of Bull Trout:

Bull trout inhabit lakes, streams, and rivers along the Rocky Mountain and Cascade ranges of North America (Goetz 1989). Western distributions of bull trout include drainages of coastal British Columbia, Alaska, and Puget Sound and Olympic Peninsula, Washington (Cavendar 1978; Haas and McPhail 1991). At the time of this study, bull trout distributions were poorly defined in Washington State. Historic records from the Washington Department of Fish and Wildlife (WDFW) and federal agencies referred to all native char as Dolly Varden, and only recently had researchers attempted to delineate the distributions of bull trout (Mongillo 1992; Brown 1994; WDFW 1997). No studies have defined basin-scale distributions of populations in Olympic National Park. As a result of the lack of distributional information in the North Fork Skokomish River (NFSR), Mongillo (1992) recommended a study of the status of bull trout in the river.

Spawning Migrations of Bull Trout:

Four diverse life history strategies of bull trout have been defined that include lacustrine-adfluvial, stream resident, fluvial-adfluvial, and perhaps, anadromous forms (Goetz 1989). For the purposes of this research, lacustrine-adfluvial bull trout are defined

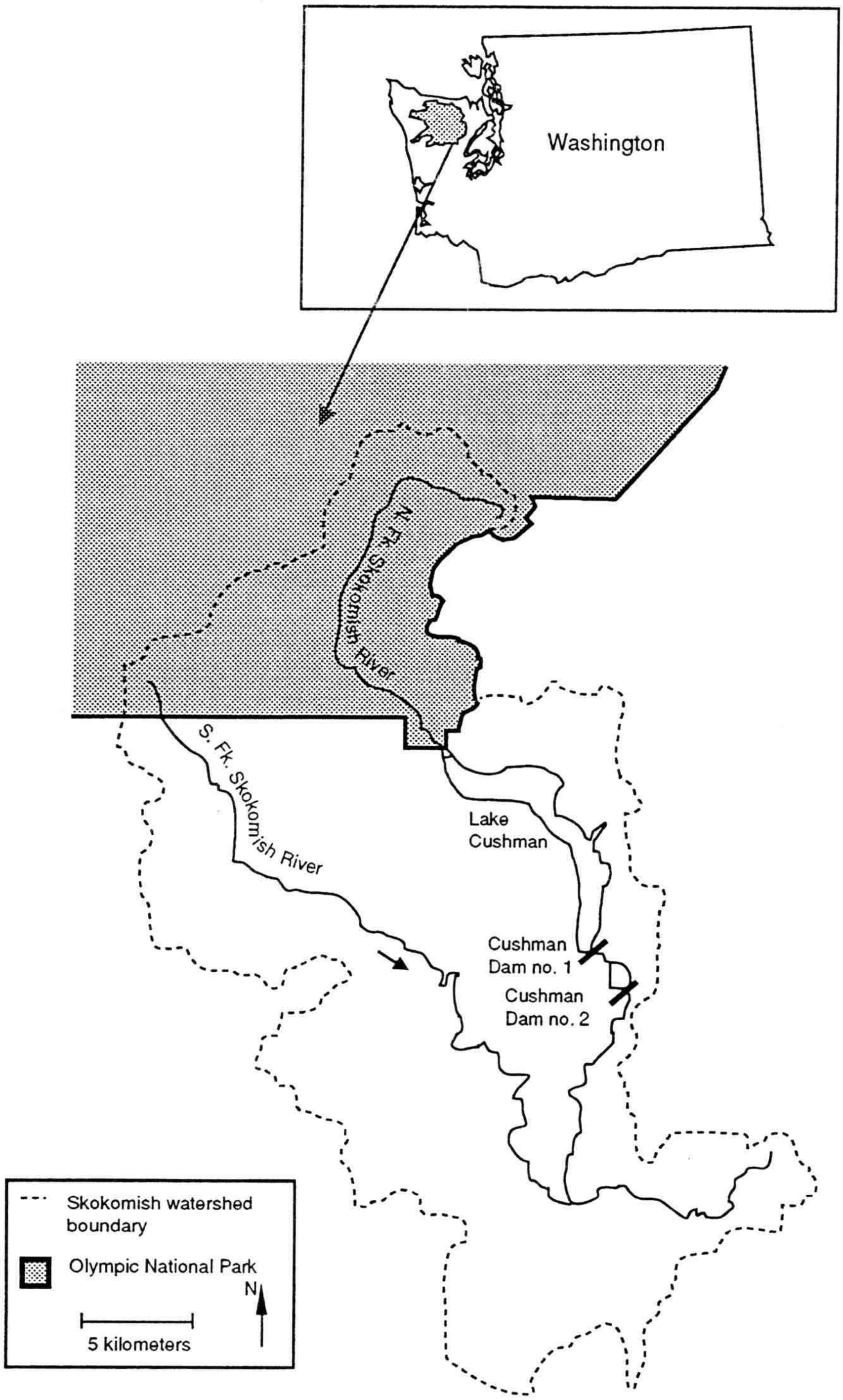

Figure 1. Map of study area in North Fork Skokomish River Basin, Olympic National Park, Washington.

as fish that reside in a lake and migrate into river or stream tributaries to spawn (Varley and Gresswell 1988). Lacustrine-adfluvial bull trout mature in lakes and reservoirs, spawn every year or alternate years in rivers or tributary streams, and attain the largest body size of the four life history forms (Fraley and Shepard 1989; Ratliff 1992). There have been few comparative studies of spawning migrations (Pratt 1992), and it is likely that timing of river entry, duration of spawning, and environmental factors that influence migration and spawning are variable among lacustrine-adfluvial populations.

Timing of bull trout spawning migrations and initiation of spawning likely are related to photoperiod, streamflow, and water temperature (Fraley and Shepard 1989; Rode 1990). These environmental factors are known to trigger and regulate the intensity of migrations of other fish species (Northcote 1984; Jonsson 1991). Spawning migrations of bull trout on the Olympic Peninsula have not been explored, and few studies have focused specifically on mechanisms that influence upstream movements of bull trout.

Temporal Shifts in Abundance of Bull Trout and Other Salmonids:

The interaction between bull trout and other native fish species has not been widely addressed (Rieman and McIntyre 1993), particularly in Washington and Oregon (Goetz 1989). Past studies on bull trout interactions with other fish species have necessarily focused on foraging behavior, feeding habitats, resource utilization, and habitat use and selection (Pratt 1984; Boag 1987; Nakano et al. 1992; Bonneau 1994). These studies have provided much insight into the biology of bull trout, but results are often limited to comparison of bull trout to only one other fish species (Pratt 1984; Boag 1987; Bonneau

1994). Temporal shifts in abundance of native salmonids in relation to bull trout have not been reported, particularly at spatial scales of several river kilometers (rkm).

Research on bull trout typically has focused on degraded rivers and streams. The NFSR is different from other study areas because National Park Service management policies have reduced anthropogenic influences in the basin. As a result of these policies, the river offers a unique location for defining distributions and describing life history characteristics of bull trout. Specifically, quantitative descriptions of changes in streamflow and water temperature in relation to migration and spawning of bull trout may be essential in characterizing the range of conditions tolerated by lacustrine-adfluvial populations (Rieman and McIntyre 1993). It is believed that understanding responses of bull trout to changes in streamflow and temperature in degraded habitats will necessarily require detailed information from relatively undisturbed habitats such as rivers at OLYM.

Research Objectives:

The primary objectives of this research were to: (1) determine distributions of lacustrine-adfluvial bull trout in the NFSR Basin; (2) describe life history characteristics of bull trout relative to the initiation of the spawning migration, abundance of spawners, duration of spawning, and location of juvenile rearing areas; (3) provide a quantitative description of the influences of photoperiod, river discharge, and water temperature on migration and spawning; and (4) assess temporal shifts in abundances of bull trout, whitefish (*Prosopium williamsoni)*, cutthroat trout (*Oncorhynchus clarki)*, and rainbow trout (*Oncorhynchus mykiss*) in the NFSR upstream from Lake Cushman.

The secondary objectives of this research were to: (1) evaluate if Staircase Rapids in the river was impassable to migratory bull trout; (2) assess the possibility that a non-migratory population of bull trout existed within the NFSR Basin; and (3) provide officials at OLYM and WDFW with specific data required to develop management strategies to ensure the long-term persistence of bull trout in the river and reservoir system.

STUDY AREA

This study was conducted from June 1994 to December 1996 in the NFSR Basin, which includes Lake Cushman (a reservoir) and the river system upstream from the reservoir (Fig. 1). The NFSR (latitude 47° 30' N, longitude 123° 22' W) flows in a southeasterly direction from its headwaters in the Olympic Mountains to its confluence with Lake Cushman. Lake Cushman, located in Olympic National Forest, is a 1,620 ha impoundment at the downstream end of the study area. Before the completion of two dams in 1926 and 1930, Lake Cushman was a natural oligotrophic lake with a mean depth of 61 m, and the lake was smaller in size than the current reservoir. The reservoir is 13.7 km in length, 82 m deep at full stage, and has a storage capacity of 5.5×10^8 m^3 (Wolcott 1965). The eastern and western shorelines of the reservoir have been developed for residential and recreational purposes.

The river basin within the park upstream of Lake Cushman drains 126 km^2 (Katherine Beirne, personal communication, OLYM). Upstream of Lake Cushman the river and most of the 14 named tributaries are located within the boundary of OLYM. The river flows through forests of old-growth Douglas-fir (*Pseudotsuga menziesii)* and western redcedar (*Thuja plicata)* and descends in elevation from 1,622 m in the headwaters to 225 m at its confluence with Lake Cushman outside of the park. Steep montane topography in basaltic geologic material results in high gradient tributaries in the upper basin (Fig. 2). A road provides access to the section of river directly upstream of Lake Cushman; beyond this point a trail parallels the river. In the study site, a series of cascades (termed Staircase Rapids) prevents upstream passage of some fish species (Fig. 3).

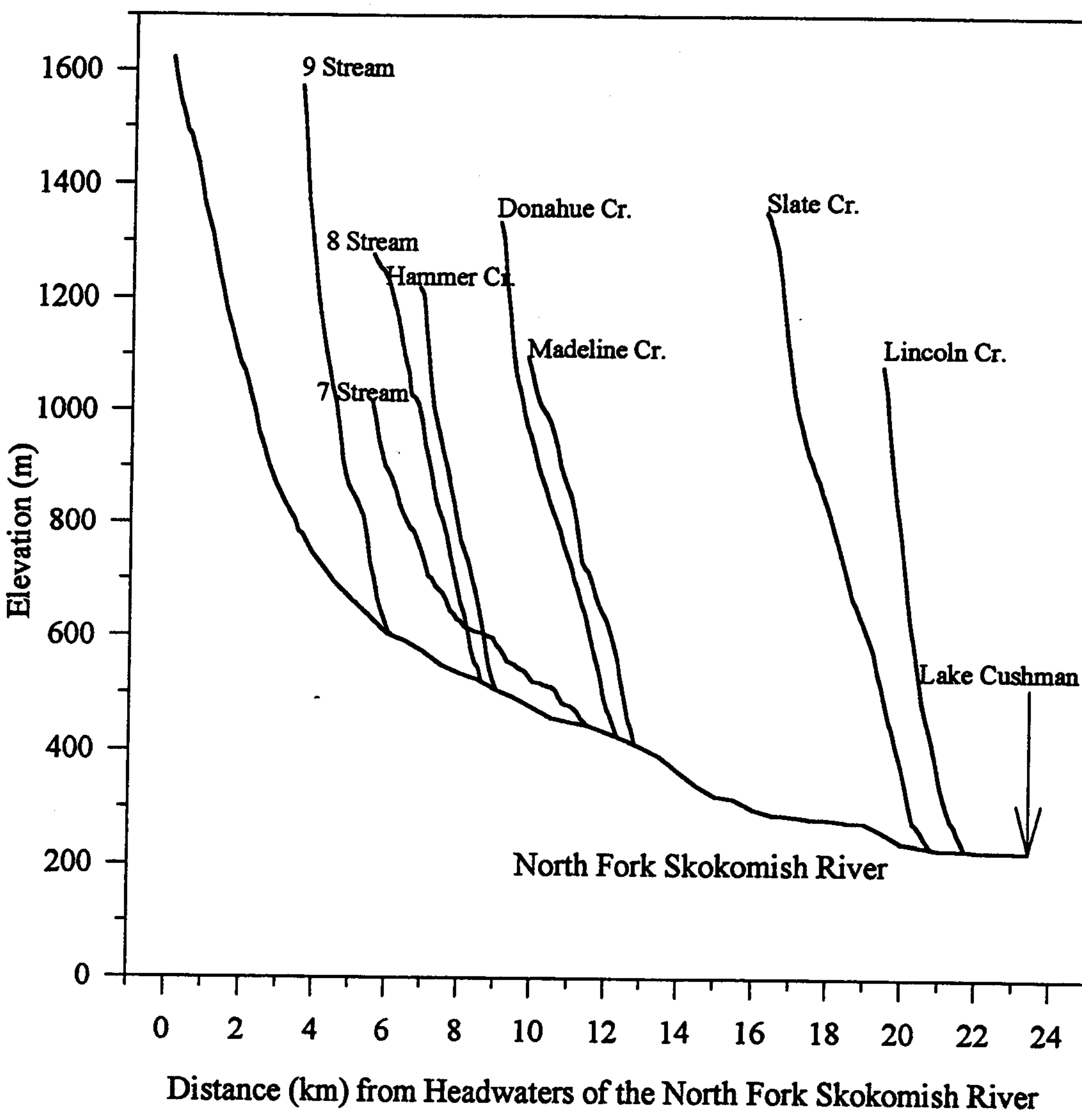

Figure 2. Elevational profile of North Fork Skokomish River and tributaries.

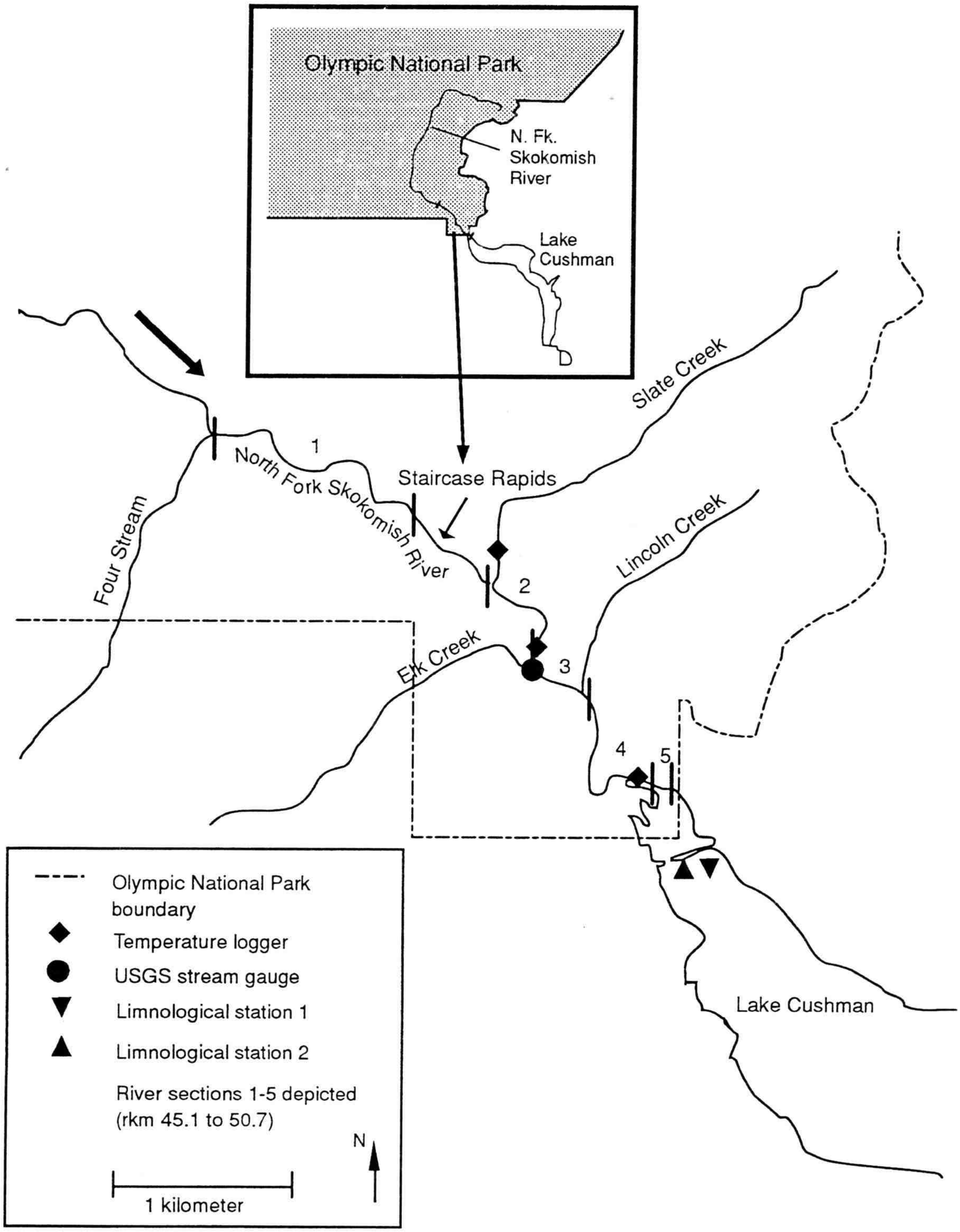

Figure 3. Location of river sampling sections (1-5), Staircase Rapids, USGS stream gauge, temperature loggers, and limnological stations one and two in the North Fork Skokomish River Basin.

River discharge is strongly influenced by rainfall in winter while spring runoff is predominantly influenced by snowmelt. Mean annual precipitation from 1984 to 1996 at Cushman dam #1 was 231 cm, most of which occurred as rain from November to January. In 1996, there was 290 cm of precipitation at Cushman Dam #1 (unpublished data, Tacoma Public Utilities). From April to December 1996, air temperature averaged 10.3°C at an elevation of 232 m.

Historic accounts indicate that native char were present in the original Lake Cushman prior to its impoundment. In 1890, the O'Neil expedition described catches of "speckled beauties" or "charpies" from the lake (Wood 1976). Overland (1974) also mentioned that "Dolly Varden" were caught from the lake in 1893. More recently, bull trout provided a popular fishery in both the NFSR and Lake Cushman until the early 1980's when apparent overharvest of spawning adults severely depleted the population. Harvest of bull trout was eliminated from the NFSR in 1982 and from Lake Cushman in 1986 (WDFW 1997). From 1992 to present, National Park Service biologists implemented catch-and-release fishing regulations for all species in the river to improve the quality of the fishery and to protect vulnerable fish species. Currently, WDFW regulates angling on Lake Cushman and requires catch-and-release of bull trout.

At the time of this study, there was not a list of fish species present in the NFSR. Twelve fish species were identified during this study. In addition to bull trout, native fishes observed during this study in the river downstream of Staircase Rapids included whitefish (*Prosopium williamsoni)* (see McPhail 1987), shorthead sculpin (*Cottus confusus*), speckled dace (*Rhinichthys osculus*), and longnose/salish sucker (*Catostomus*

catostomus). Longnose/salish suckers were documented in the drainage in 1937, and this species is believed to be endangered throughout British Columbia, Canada (Schultz 1947; McPhail 1987). Kokanee salmon (*Oncorhynchus nerka*), rainbow trout (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*) also were observed during this study. It is believed that these species are native to the drainage although extensive hatchery plantings of salmonids into Lake Cushman since 1935 confused the issue as to whether these species were native (Appendix A). Land-locked chinook salmon (*Oncorhynchus tshawytscha*) inhabited the river during this study and may be part of a remnant anadromous fall chinook population which historically occupied the Skokomish River (WDFW 1957). Non-native largemouth bass (*Micropterus salmoides*) were observed downstream of the park boundary, and one brook trout (*Salvelinus fontinalis*) was found in Donahue Creek, a tributary in the upper river. Prickly sculpin (*Cottus asper*) have been recorded by WDFW (unpublished files, WDFW 1996). Crayfish (*Pacifastacus leniusculus trowbridgii*) were found in the lower section of the river, and were reported to be present in Lake Cushman (Miller 1960). One whitefish (specimen identification OS 16591) and three longnose/salish suckers (OS specimen identifications OS 16515, OS 16516, and OS 16517) collected from the river were catalogued at the Ichthyological Museum at Oregon State University.

The two-dam complex at Lake Cushman (Fig. 1), operated by Tacoma City Light, prevents upstream and downstream passage of migratory fish between the Hood Canal and NFSR. As part of the operation of this complex from 1930 to 1988, the entire flow of the NFSR downstream of Cushman dam #2 was diverted to a power station near Potlatch, Washington. Since 1988, 0.85 cubic meters per second (cms) of water has been released to the North Fork, an amount equal to 4% of the rivers average natural flow (American Rivers 1996). According to Hosey and Associates (1990), full-pool retention time for the reservoir is 307 days each year and water is withdrawn at a maximum rate of 71 cms for power generation. Currently, the reservoir inundates 17.2 km of river including areas of the original Lake Cushman (Hosey and Associates 1990). Management of the reservoir results in annual water level fluctuations of up to 21 m, with peak levels occurring during summer and low levels in fall and winter. The high magnitude of fluctuations in water level results in periodic inundation of 12 ha of the NFSR in Olympic National Park.

At the time of this study, the City of Tacoma and OLYM were negotiating to exchange land and relocate the park boundary along the NFSR. The negotiations were conducted to resolve a boundary trespass by the Cushman Hydroelectric Project (National Park Service 1994). On March 3, 1997, the park boundary was moved upstream and resulted in the removal of 12 ha of riparian and riverine habitat in the lower section of the park and study area (Office of the Federal Register 1997). Any reference to the park boundary in this study refers to the original boundary. The exact location of the past boundary can be found on the 7.5 minute topographic map of Mount Skokomish, Washington Provisional Edition 1990.

METHODS

Genetic Analysis:

To confirm the presence of bull trout in the NFSR, genetic analysis was conducted on four female fish captured by hook-and-line on October 19 and 20, 1996. Each fish was captured in river section four (Fig. 3), and total lengths were recorded. Adipose fins were removed from adult bull trout and placed in glass vials containing 95% ethanol. Fish were safely released at their point of capture. Samples of adipose fins were shipped to the Wild Trout and Salmon Genetics Lab at the University of Montana, Missoula, Montana to determine species identification. The identity of the fish was determined by using SINE-mediated PCR, a technique that examines multiple nuclear DNA loci simultaneously (Paul Spruell, personal communication, University of Montana).

Distribution of Salmonids in the North Fork Skokomish River Basin:

In June 1996, daytime snorkel surveys were conducted to determine distributions of salmonids in Nine Stream, Seven Stream, Hammer Creek, Donahue Creek, and Madeline Creek. Day snorkel surveys also were employed to identify fish species present in the river from the confluence of Nine Stream to the confluence of Madeline Creek. Additionally, divers assessed fish distributions in the river immediately downstream from the confluence of Five Stream to Lake Cushman. All day snorkel surveys proceeded upstream in tributaries and terminated once a fish barrier was encountered. In the river, divers proceeded downstream identifying and counting salmonids.

Electrofishing also was conducted to determine relative distributions of salmonids in six tributaries and the NFSR from June 17 to August 26, 1996. Single-pass electrofishing without block nets was employed during summer low-flow conditions in Elk, Slate, Four Stream, Bear Gulch, Dry, and Donahue Creeks. A two person crew, equipped with a Smith-Root Model 12A backpack electroshocker and dip-nets proceeded upstream in tributaries capturing and identifying fish. Fish were released at their point of capture, and surveys terminated once a fish barrier was encountered. A Thommen altimeter was used to measure the elevation corresponding to the upper distribution of each fish species.

Day *and Night* Snorkel *Surveys:*

Daytime snorkeling was the chosen means of counting fish in the NFSR because it was logistically feasible in roadless areas, had less impact on sensitive or protected fish species, and was known to produce reliable and duplicable counts in larger river systems (Northcote and Wilkie 1963; Schill and Griffith 1984; Thurow 1994). The high water clarity coupled with the presence of deep pools made the NFSR more conducive to snorkeling than other methods such as electrofishing.

To describe the spawning migration of lacustrine-adfluvial bull trout, weekly snorkel counts were conducted in the river from April 13 to December 7, 1996 between the confluence of Four Stream and Lake Cushman (rkm 50.7 to rkm 45.1) (Fig. 3). For sampling purposes, this section of river was divided into five sequentially numbered sections beginning at the confluence of Four Stream and proceeding downstream to the OLYM boundary (Fig. 3). Changes in abundances of bull trout, whitefish, cutthroat trout, and rainbow trout resulting from fish movements between the river and Lake Cushman were documented in 1994, 1995, and 1996. River sections one to five were sampled during most surveys conducted between June 20, 1994 and December 7, 1996 (Table 1). Weekly snorkel counts in 1996 were compared to monthly snorkel surveys conducted over this same section of river from June to November 1994 and June to October 1995.

Two experienced snorkelers, each equipped with a drysuit, mask, snorkel, and a data recording sleeve proceeded downstream identifying fish species, estimating fish lengths (TL), and counting numbers of bull trout, whitefish, cutthroat trout, and rainbow trout within each river section. Because of the difficulty in distinguishing between cutthroat trout and rainbow trout underwater, counts of these two species were combined as cutthroat/rainbow trout. Divers positioned themselves near the midline of the wetted channel width and floated through habitat units parallel to one another while remaining as motionless as possible (Fig. 4). Each diver counted fish in their respective lane as they passed the fish, and hand signals were used to coordinate counts. The diver to the right of the midline only counted those fish on the right side; the other diver counted fish on the left side of the midline. Snorkelers made recording stops approximately every 200 m, and observations were discussed to minimize duplication of counts (Slaney and Martin 1987). When fish were observed in large aggregations during spawning migrations, divers commonly made two passes in their respective lanes' and averaged the counts. All daytime surveys were conducted between 1000 and 1700 hours during optimal light conditions and the duration of the survey was recorded.

Table 1. North Fork Skokomish River sections sampled (X) from 1994 to 1996. Section locations shown on Figure 4. (*) Walking and snorkel survey conducted by WDFW employees.

Date	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
6/20/94	X	X	X	X		
7/12/94	X	X	X	X		
8/16/94	X	X	X	X	X	
9/15/94	X	X	X	X	X	
10/27/94*		X	X	X	X	X
6/29/95	X	X	X	X	X	
7/27/95	X	X	X	X	X	
8/23/95	X	X	X	X	X	
9/13/95	X	X	X	X	X	
10/19/95	X	X	X	X	X	X
4/13/96	X	X	X	X	X	
5/15/96	X	X	X	X	X	
6/5/96	X	X	X	X	X	
6/18/96	X	X	X	X	X	
7/1/96	X	X	X	X	X	
7/17/96	X	X	X	X	X	
7/25/96	X	X	X	X	X	
7/31/96	X	X	X	X	X	
8/8/96	X	X	X	X	X	
8/14/96	X	X	X	X	X	
8/21/96	X	X	X	X	X	
8/28/96	X	X	X	X	X	
9/6/96	X	X	X	X	X	
9/12/96	X	X	X	X	X	
9/19/96	X	X	X	X	X	
9/26/96	X	X	X	X	X	
10/9/96	X	X	X	X	X	X
10/12/96	X	X	X	X	X	X
10/19/96	X	X	X	X	X	X
10/26/96	X	X	X	X	X	X
11/9/96	X	X	X	X	X	X
11/16/96		X	X	X	X	X
11/23/96		X	X	X	X	X
12/7/96		X	X	X	X	X

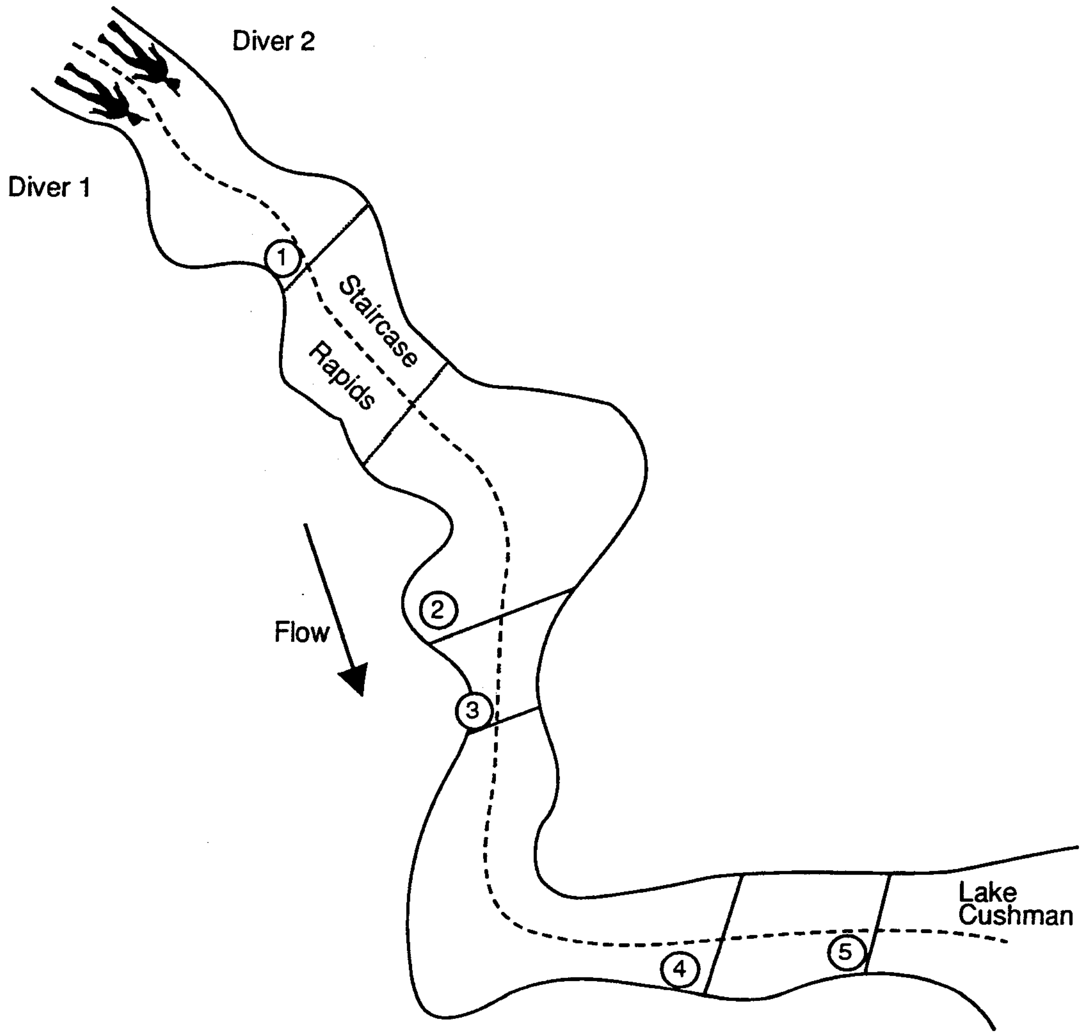

Figure 4. Schematic diagram of divers counting fish in a downstream direction in their respective lanes. River sections one to five and Staircase Rapids depicted.

Because objects tend to appear larger when observed underwater, care was taken to calibrate underwater estimates of fish lengths. At the beginning of each survey, mean visibility of the river was determined by measuring the distance at which a 20 cm piece of white PVC pipe (held underwater) disappeared and reappeared as a snorkeler moved away from and toward the pipe (Thurow 1994). Each snorkeler calibrated for length estimates by viewing wooden fish replicas of known lengths (15, 30, 38, 46, 51, and 58 cm) prior to each survey. Fish replicas were held underwater at distances up to 25 m downstream from the observer, and lengths were estimated. Occasionally, a viewing station was set up where one person held the fish replicas while the other drifted downstream and estimated their lengths. This was repeated until each diver was able to record accurate estimates.

During snorkel counts conducted in 1996, bull trout lengths (TL) were estimated to the to 2.54 cm, and lengths of whitefish, cutthroat trout, and rainbow trout were estimated using two size classes (less than and greater than 30 cm). Attempts were made to estimate lengths of adult bull trout in large aggregations, but usually only counts were feasible. A two sample Kolmogorov-Smirnov test was used to detect significant differences (at 95% confidence level) in length-frequency distributions of early (prior to September 26) and late migrating bull trout. The date of September 26 was chosen as a reference point because it enabled comparison of length distributions of migrating bull trout prior to and after increased river flows. There was no attempt to enumerate young-of-the-year of any species. Snorkel counts were made for kokanee salmon (1994 to 1995) and land-locked chinook salmon (1994 to 1996) but were not included in the data analysis. To evaluate the percent composition of bull trout, whitefish, and cutthroat/rainbow trout on each sample date, section one was analyzed separately from sections two to five because section one was located upstream of Staircase Rapids, a barrier to migratory whitefish.

Night snorkel surveys were conducted to locate juvenile bull trout in the river between the hours of 2100 and 2300. In an attempt to detect differences between day and night snorkel counts of fish, comparisons of day versus night counts also were made in section four on September 10 and section one on September 17, 1996. Methods of night snorkeling were similar to methods used during the day, except underwater halogen dive lights were used at night, and divers overturned stream bed substrate in an attempt to locate juvenile bull trout.

Bull Trout Spawner Surveys:

The onset, duration, and distribution of spawning was determined by weekly walking surveys conducted in Elk Creek, Slate Creek, Four Stream, and occasionally in the river from October 3 to December 6, 1996. A walking survey also was conducted in the river in January 1998. Two surveyors each positioned on opposite stream banks walked upstream looking for adult bull trout and redds. Walking surveys also provided information on the prevalence of tributary spawners in the population.

Replicate Snorkel Counts:

To determine the reliability and consistency of snorkel counts of bull trout, whitefish, and cutthroat/rainbow trout, two replicate passes were made in a 1.6 km section downstream of Staircase Rapids on July 11 and 23, August 13 and 27, and September 18, 1996. A total of 15 habitat units within the 1.6 km river segment were numbered and flagged and fish counts were made within each unit. Habitat units were defined as homogenous lengths of stream characterized by bed form, streamflow, and water surface slope (e.g. pools, riffles, cascades, glides, and rapids) (Moore et al. 1995). Fish counts by habitat unit were attained using methods similar to those described above. The first pass consisted of one diver positioned to the right of the midline of the wetted channel and the other diver located to the left of the midline. Divers counted fish in each habitat unit within their respective lane and recording stops were made at the downstream end of each habitat unit. The number of fish counted in each habitat unit was privately recorded to avoid potential biases on the second pass. Divers one and two switched positions on the replicate count which was conducted within 90 minutes of the first pass. It was assumed that fish did not leave the sample area in-between replicate counts.

Physical Data:

To describe physical habitat variables and estimate fish densities by river section, a habitat survey was conducted between August 5-7, 1996. Habitat inventory protocol as described in Moore et al. (1995) was used for surveys with the exception that lengths and widths of each habitat unit were measured and not visually estimated.

Day lengths were determined using the declination of the sun at 48°N latitude (Sunrise Sunset Software Version 1.1 and Smithsonian Meteorological Tables 1931). Daily mean, monthly mean, and monthly minimum and maximum values of discharge from the NFSR were obtained from USGS stream gauge number 12056500 located downstream of Staircase Rapids at an elevation of 232 m (Fig. 3) (unpublished data, USGS). Stream discharge values were missing for water year 1989. Discharge was measured at Slate Creek and Elk Creek on November 25, 1996 using a digital Marsh-McBirney Model 2000 flow meter.

Daily fluctuations of water temperature (°C) were recorded by Stow-Away (Onset Computer Corporation) temperature loggers placed in river and Slate Creek (Fig. 3). Water temperature (°C) of the reservoir was recorded at two stations on the northern end of Lake Cushman on six dates from July 12 to October 16, 1996 (Fig. 3). Temperature values were recorded at intervals of one meter from the surface of the reservoir to a depth of 31 m using a Hydrolab (®) multi-parameter monitoring device. For thermal profiles of the water columns, temperature values at the two stations were averaged by date and depth.

RESULTS

Snorkel surveys were judged sufficient to determine relative distributions and changes in abundance of bull trout, whitefish, and cutthroat/rainbow trout in the NFSR. In this study, underwater visibility was deemed the most important criteria for snorkeling methodologies. Generally, measurements of underwater visibility were high in the NFSR (up to 25 m), and the deepest pools were visible to points of maximum depth. Snorkel surveys were not attempted when horizontal water visibility was less than 5 m. The high visibility of the river and the large size of the adult lacustrine-adfluvial bull trout made it unlikely that an observer would miss counting individual fish during daylight hours. Furthermore, adult bull trout generally swam upstream past observers and did not exhibit a downstream avoidance response. Overall, it was believed that snorkel counts for adult bull trout were consistent between replicate passes and abundances of adult whitefish and cutthroat/rainbow trout were reasonably reliable (Appendix B). Because of low visibility (less than 3 m) in the river on November 9, 1996, the low count of adult bull trout was eliminated from analysis. On that date, river discharge was 15.4 cms which was the highest value for any sample date between 1994 and 1996.

Distribution of Salmonids in North Fork Skokomish River Basin:

Lacustrine-adfluvial bull trout were distributed in the river upstream from Lake Cushman to the confluence of Four Stream, and were found in the lower sections of Elk Creek and Slate Creek (Fig. 5). Bull trout were not found in any other tributaries (Fig. 5).

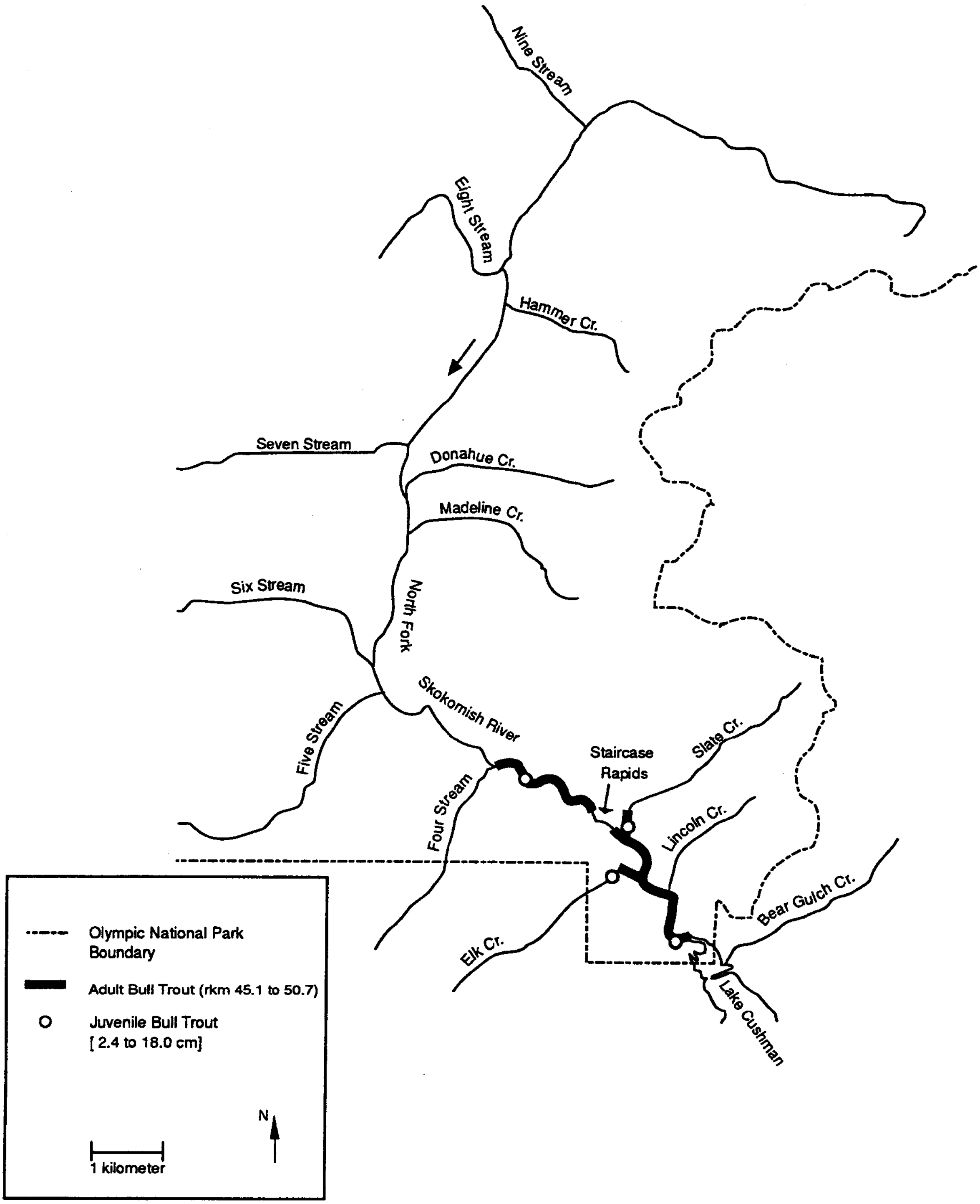

Figure 5. Distribution of adult (▬) and juvenile (o) bull trout in the North Fork Skokomish River Basin, Olympic National Park in 1996.

Whitefish were distributed in the river from Lake Cushman to a point immediately downstream of Staircase Rapids (Fig. 6). Chinook salmon were found in the river upstream from Lake Cushman, but were not observed upstream of Staircase Rapids. Cutthroat/rainbow trout were ubiquitous throughout tributaries of the NFSR, and extended in the river from Lake Cushman upstream to the confluence of Nine Stream (Fig. 6). Rainbow trout and cutthroat trout collected by electrofishing were more readily identifiable than those fish observed during snorkel surveys. Cutthroat trout were present in Bear Gulch, Elk Creek, Slate Creek, and rainbow trout inhabited Donahue Creek. One brook trout was found in the lower section of Donahue Creek and likely originated from Flapjack Lakes, the origin of the creek.

Migration and Spawning of Bull Trout:

Genetic analysis of four native char revealed that these fish were bull trout (mean length 59.1 cm; range 53.3 to 65.5 cm), and therefore, all native char in the NFSR were assumed to be bull trout. Bull trout spawners entered the NFSR as early as May (1996), but the primary spawning migration began in October from 1994 to 1996 (Fig. 7). In 1988, 1991, and 1992 most adult bull trout entered the river in September (Appendix C) (unpublished files, WDFW). Adult bull trout were first observed upstream of Staircase Rapids in July of 1994, 1995, and 1996. High numbers of bull trout first entered the river on October 3, 1996 after a period of precipitation and subsequent increased river discharge. On that date, 37 adults were counted in the river near the northernmost end of Lake Cushman during a walking survey.

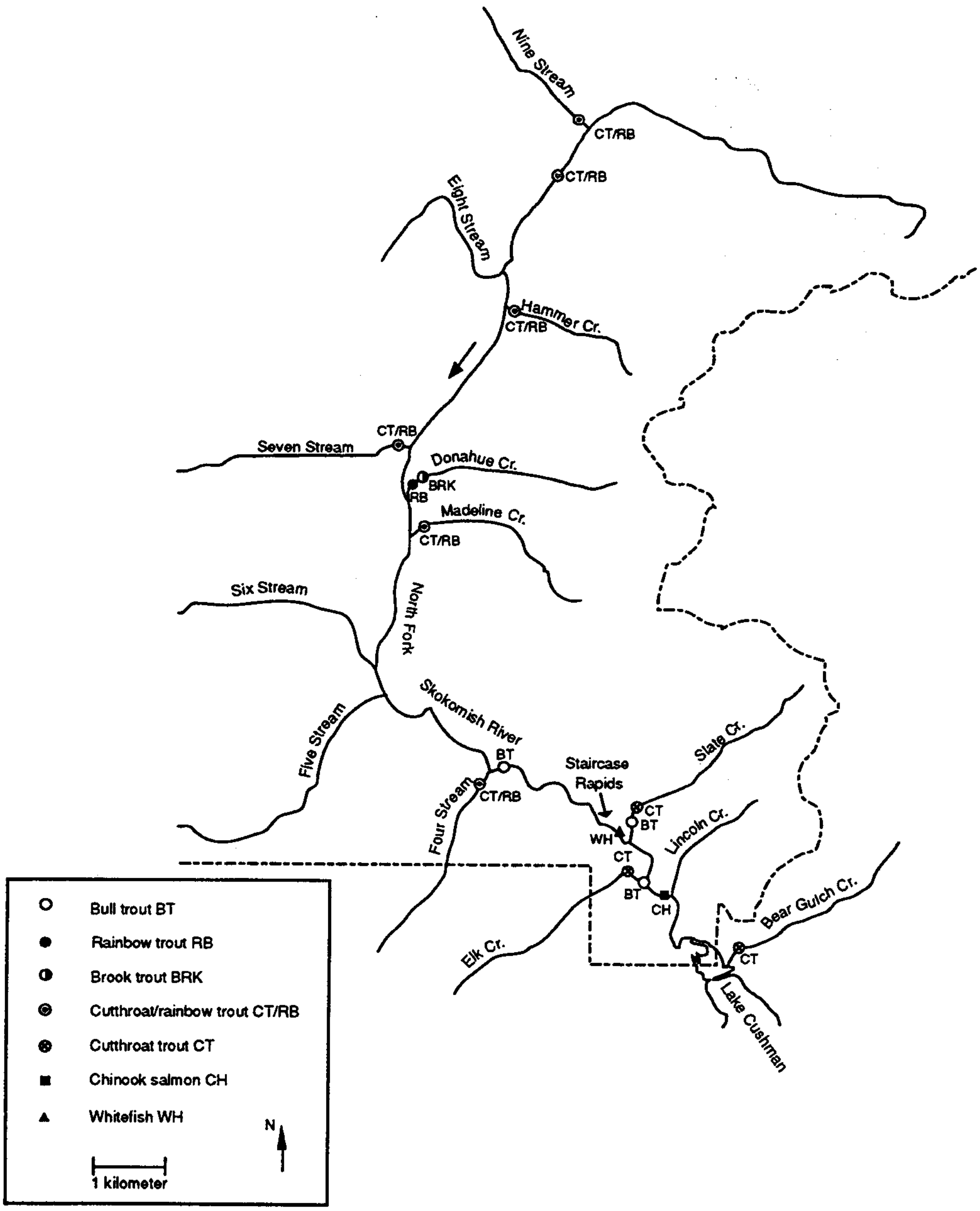

Figure 6. Uppermost distributions of salmonids in North Fork Skokomish River Basin as determined by day snorkel surveys and electrofishing.

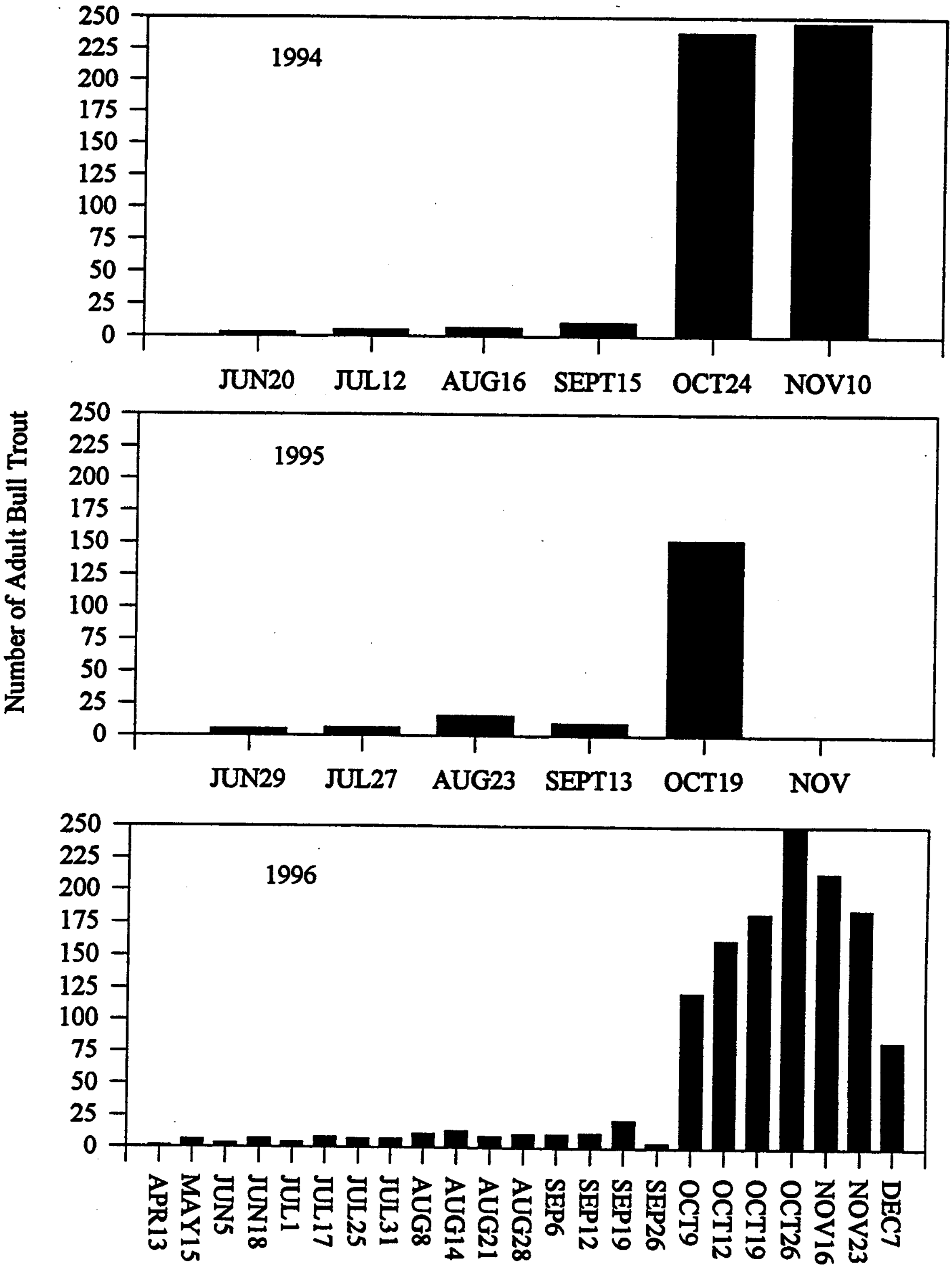

Figure 7. Abundances of adult bull trout in the N. Fk. Skokomish River sections 1 to 5 from June to November 1994, June to October 1995, and April to December 1996 (6/20 & 7/12/94 sections 1-4; 10/24/94 WDFW sections 2-6; 11/16-12/7/96 sections 2-5).

A snorkel survey on October 9, 1996 revealed 122 adults in the river (Fig. 7). The peak count of 250 adults occurred on October 26 in river sections one to five (292 adults from Four Stream to Lake Cushman). In relation to the peak count (250), 73% of all adults had entered the river by October 19. Bull trout staging in the river (near section five) tended to be found in schools, the largest of which was 77 adults (October 26, 1996). The number of adults in the river declined throughout November, and 83 adults inhabited the river during the final survey on December 7 (Fig. 7).

Densities of adult bull trout were low in the river upstream of Staircase Rapids from April to November 1996 (Appendix E). The density of adult bull trout was highest in river section two upon the onset of the primary spawning migration (October 9), and then steadily declined in that section after October 12, 1996 (Figs. 3 and 8). In river section three, adult bull trout densities were nearly constant throughout the spawning migration, whereas relatively high densities were found in section four during the migration. Relatively high densities of bull trout in river section five occurred on October 19 and December 7 which was the section closest to Lake Cushman (Fig. 8).

Physical habitat variables were described for river sections one to five. River section one was an unconstrained, predominately single channel characterized by a low percentage of rapid habitats. In that section, habitat units (e.g.-pools, riffles, glides) were relatively shallow in depth, contained few large boulders, and were comprised of high percentages of gravel and cobble substrates (Table 2). The stream channel in river sections two and three generally was constrained by hillslopes, and the total length of each section was predominately riffle habitat (Table 2). Habitat units within river section three typically were deep, and the stream channel was high gradient.

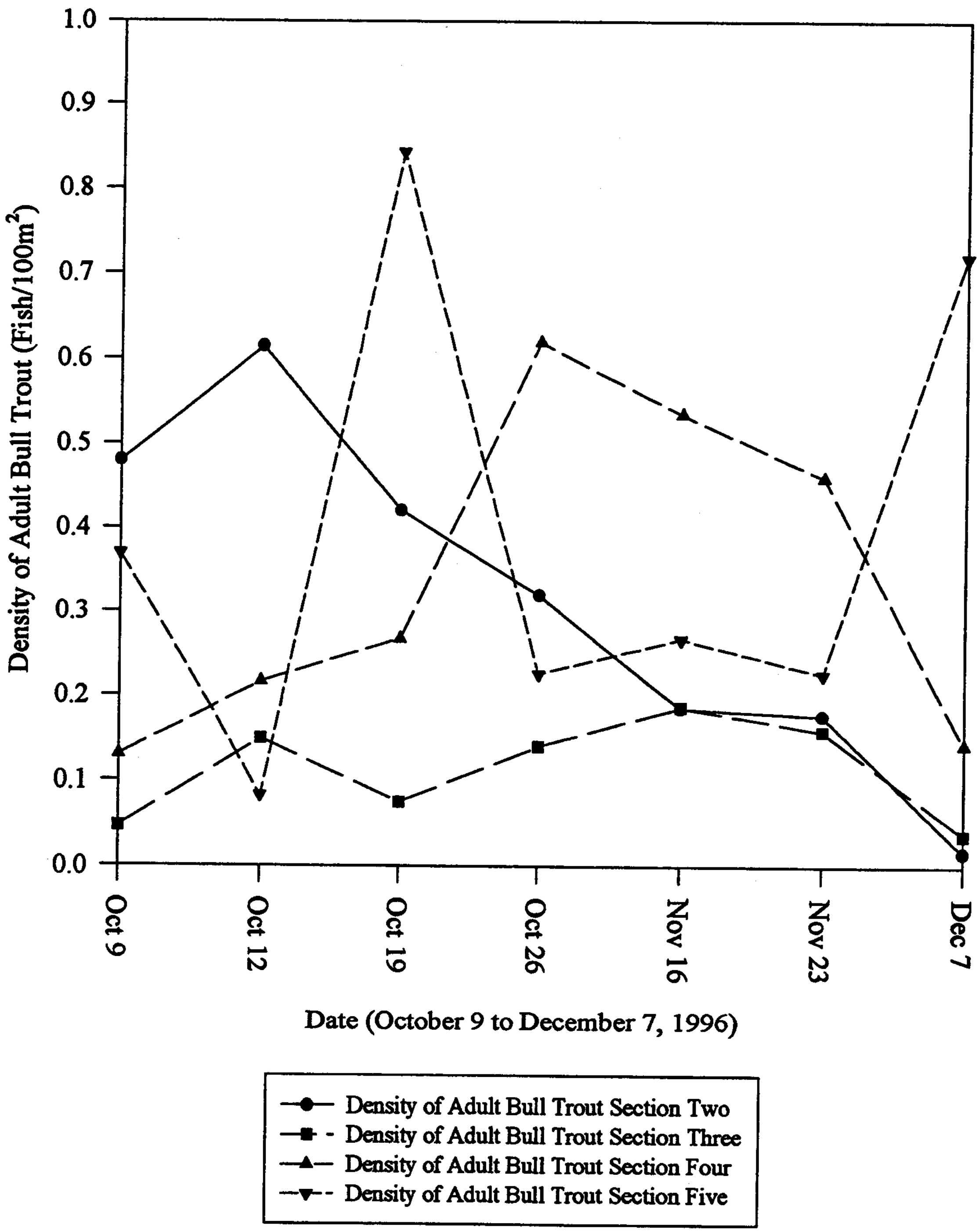

Figure 8. Density of adult bull trout in North Fork Skokomish River sections two to five (downstream of Staircase Rapids) from October 9 to December 7, 1996. Depicting temporal movements of bull trout spawners among river sections.

Table 2. Mean measurements and descriptions of physical habitat variables in North Fork Skokomish River sections one to five from August 5 to 7, 1996. Maximum and minimum values of selected habitat parameters denoted in parentheses.

Habitat Parameter	River Section 1	River Section 2	River Section 3	River Section 4	River Section 5
Total Length (m)	2,444	685	472	1,433	243
Mean Width (m)	15.3 (5.2-27.0)	17.3 (11.8-27.6)	22.7 (14.5-37.3)	20.6 (8.0-29.1)	20.0 (20)
Estimated Wetted Area (m^2)	37,393	11,872	10,722	29,518	4,862
Mean Water Depth (m)	0.8 (0.1->4.0)	0.9 (0.3->3.0)	1.4 (0.3-3.5)	0.6 (0.2-1.6)	1.5 (1.5)
Mean Gradient (%)	1.6 (0.5-6.0)	2.2 (2.0-3.0)	2.5 (1.0-5.0)	2.5 (1.0-6.0)	1.0 (1.0)
Channel Form	Unconstrained	Constrained by Hillslope	Constrained by Hillslope	Unconstrained	Constrained by Road
Pools/Riffles	1.1	1.0	1.5	1.0	0.0
Pool Habitat (% of section length)	28 n=11	14 n=2	35 n=3	15 n=4	0 n=0
Riffle Habitat (% of section length)	24 n=10	62 n=2	54 n=2	23 n=4	0 n=0
Glide Habitat (% of section length)	41 n=10	12 n=1	0 n=0	57 n=4	100 n=1
Rapid Habitat (% of section length)	7 n=3	12 n=1	11 n=1	5 n=2	0 n=0
Number of Boulders per 100 m of river	4	43	25	6	1
Gravel and cobble (combined mean % substrate)	85	50	55	66	60
Number of Habitat Units	34	6	6	14	1

The river channel in section four was unconstrained, relatively shallow in depth, and comprised of gravel and cobble substrates. River section five, located immediately upstream from Lake Cushman, was relatively short in length and low gradient.

Spawning was observed upstream and downstream of Staircase Rapids in the NFSR, and in the lower sections of Elk Creek and Slate Creek (Fig. 9) from mid-September to early December. In 1996, the first bull trout redd was observed on October 19 upstream of Staircase Rapids, although spawning primarily occurred downstream of the rapids. An additional seven redds were counted on November 9, 1996 near rkm 46 (section four) downstream of the rapids. Weekly spawning surveys from 1991 and 1993 indicated that redds were constructed as late as December 2 and December 6, respectively (unpublished files, OLYM). Two adult bull trout carcasses were found in the river from November 23 to December 7, 1996. No adult bull trout were observed in the river during a walking survey conducted on January 3, 1998.

During weekly spawning surveys conducted in tributaries in 1996, five adult bull trout were observed in Slate Creek on November 8, 1996, and redds were found on November 22 and 25. The last observation of an adult bull trout in Slate Creek was on December 6, 1996. Although Elk Creek was dry late in the summer of 1996, streamflow resumed in October. Three adult bull trout were observed on November 15, 1996, and two redds were found on November 25. No adult bull trout or newly constructed redds were observed in Elk Creek in subsequent weekly surveys.

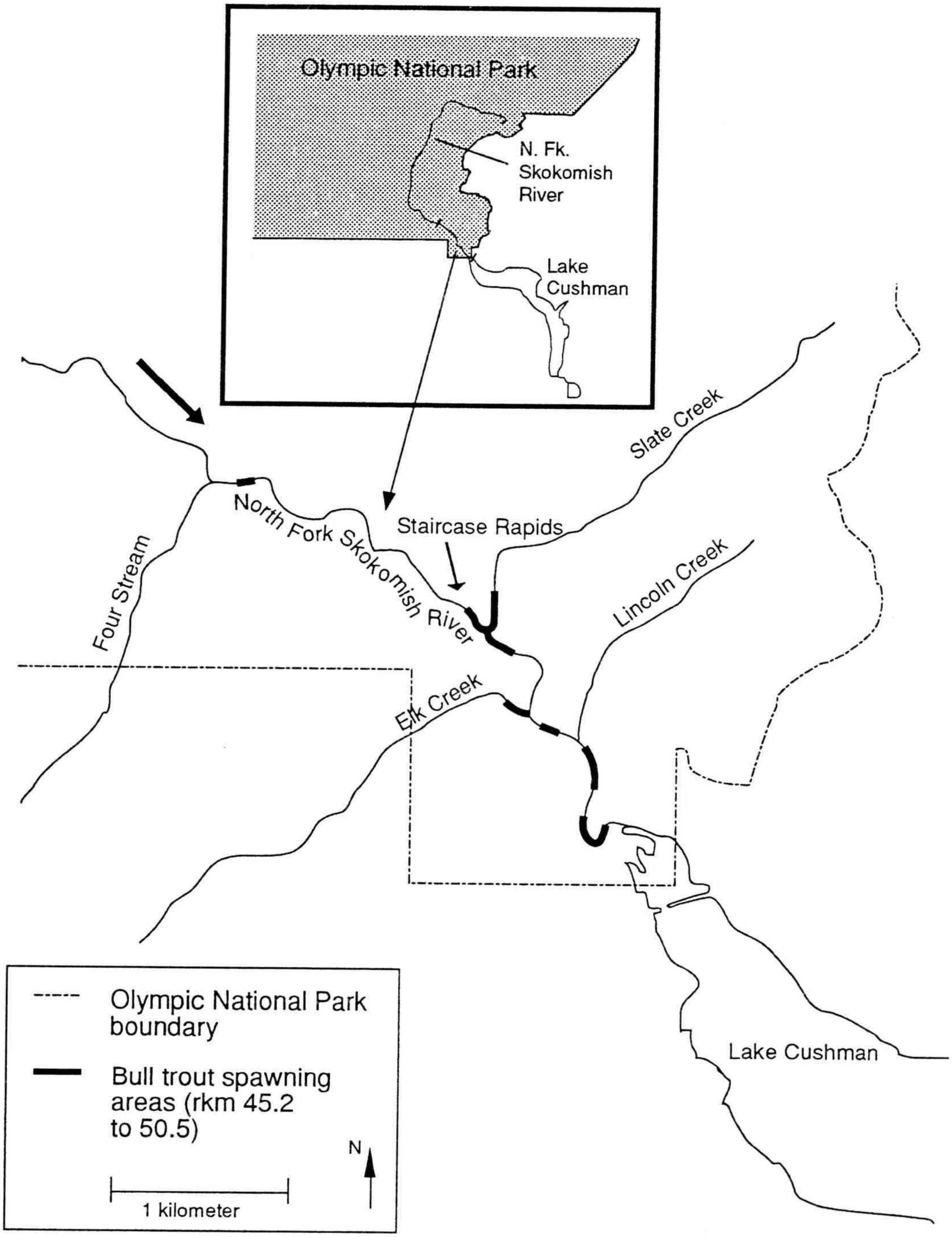

Figure 9. Bull trout spawning areas in the North Fork Skokomish River Basin.

Lengths of Bull Trout Spawners:

Based on analysis of length-frequency distributions, bull trout entering the river prior to September 26 were shorter than those fish that entered after this date ($p<0.05$; Kolmogorov-Smirnov test) (Fig. 10). Mean lengths of bull trout spawners consistently increased from June 18 to December 7 (Fig. 11). Mean estimated lengths of adult bull trout upstream of Staircase Rapids were shorter than those fish observed downstream of the rapids on each sample date from July 17 (first observation upstream of rapids) to October 26, 1996 (Fig. 12). Maximum estimated lengths of adult bull trout upstream and downstream of Staircase Rapids were 63.5 cm and 81.3 cm, respectively. Overall, bull trout spawners in the NFSR had an mean estimated total length of 54.8 cm (n=283; range 25.4 to 81.3 cm) in 1996.

Young-of-the-Year and Juvenile Bull Trout:

Observations of young-of-the-year (defined as <70 mm in TL) and juvenile bull trout were limited in this study despite 9 months of weekly snorkel surveys throughout 5.6 km of river and extensive electrofishing throughout the drainage. Young-of-the-year bull trout were found in the river and in Elk Creek and Slate Creek in 1996 (Fig. 5). Twenty-nine bull trout were collected from Elk Creek on June 27, and these fish averaged 40 mm in length (range 24-119 mm). Similarly, 13 bull trout fry found in Slate Creek on July 3 averaged 42 mm (range 33-47 mm). Three bull trout captured in section four on July 10 averaged 46 mm (range 44-50 mm).

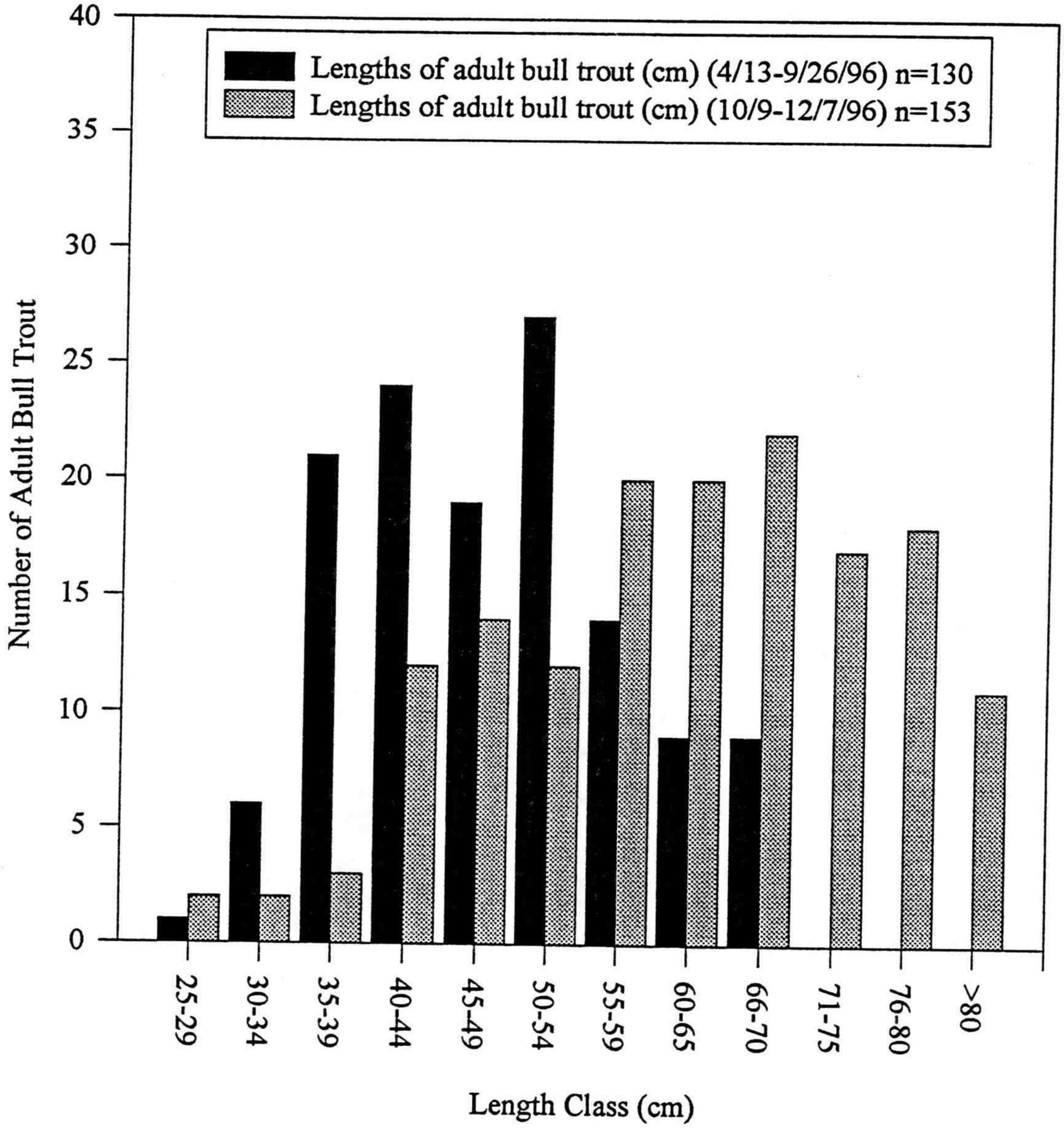

Figure 10. Length distributions (cm) of early (4/13/96-9/26/96; n=130) and late (10/9/96-12/7/96; n=153) migrating adult bull trout. Based on length estimates from total number of observations during day snorkel surveys in North Fork Skokomish River.

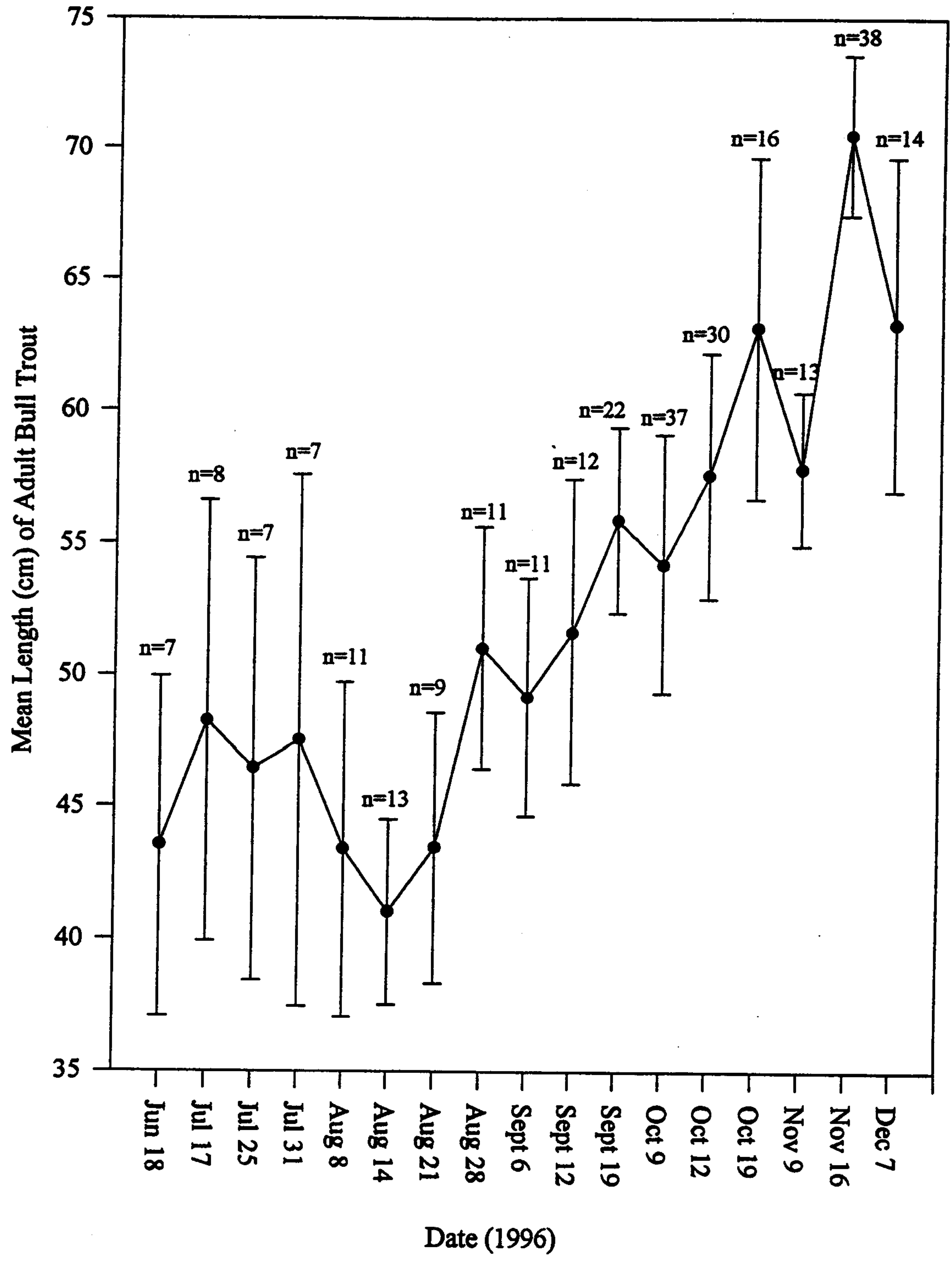

Figure 11. Mean lengths (cm) of adult bull trout in the NFSR between June 18 and December 7, 1996 based on estimates from total number of observations from day snorkel surveys. Vertical bars represent 95% confidence intervals for the mean. Sample dates with n>4.

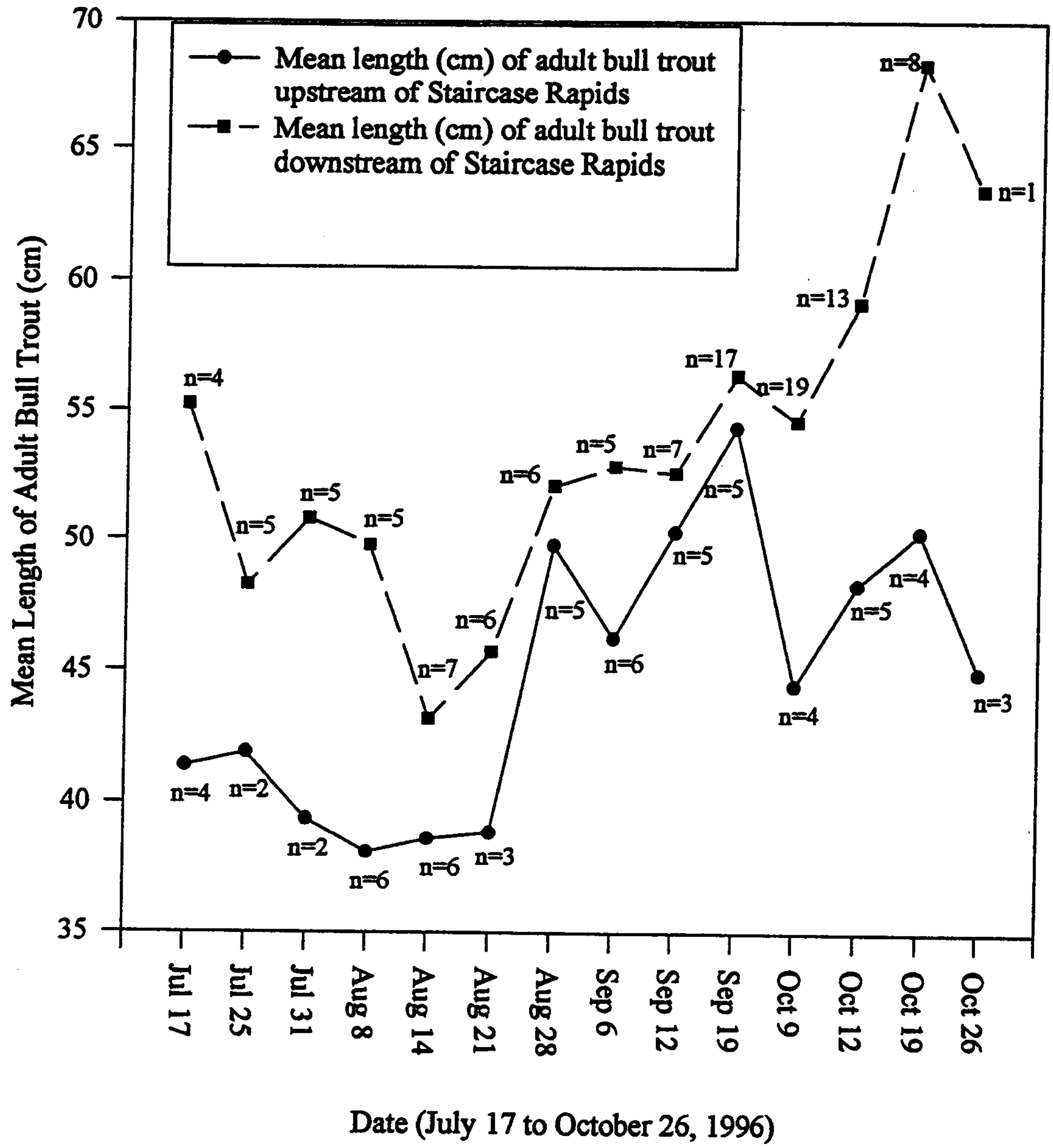

Figure 12. Mean lengths of adult bull trout upstream and downstream of Staircase Rapids from July 17 to October 26, 1996. Based on length estimates from day snorkel surveys in river sections one to five. Sample sizes denoted.

Juvenile bull trout (127 to 180 mm) were only only detected during night snorkel surveys on September 10 and September 17 (Table 3); none were detected in 34 day snorkel surveys from 1994 to 1996. Night snorkel surveys revealed that juvenile bull trout were present in river sections upstream and downstream of Staircase Rapids (Fig. 5). These fish were observed lying on the river substrate. Night snorkel surveys also resulted in higher numbers of cutthroat/rainbow trout than those counts conducted during the day (Table 3).

Influence of Photoperiod, River Discharge, and Water Temperature on Migration and Spawning of Bull Trout:

Abundances of adult bull trout in the river increased with shortened day lengths during 1994, 1995, and 1996 (Fig. 13). Similarly, the primary period of upstream migration from 1994 to 1996 and the onset of spawning were associated with the descending limb of the day length curve in 1996 (Fig. 14).

Mean daily river flows recorded during this study (1996) were consistent with long-term discharge records from water year 1970 to 1995 (Fig. 15). Peak flows typically occurred during winter and minimum flows occurred during summer. Mean daily discharges exhibited similar seasonal patterns of low and high flows between 1994 and 1996 (Appendix D). Mean annual discharge of the river between water years 1970 and 1995 was 14.8 cms. In 1996, mean discharge of the river was 13.9 cms.

Table 3. Comparison of day versus night snorkel counts and estimated lengths of bull trout, whitefish, and cutthroat/rainbow trout on September 10 (section four) and September 17 (section one), 1996 in North Fork Skokomish River.

Fish Species	September 10, 1996 Day Snorkel Section 4	Night Snorkel Section 4	September 17, 1996 Day Snorkel Section 1	Night Snorkel Section 1
No. of Bull Trout	1 adult 0 juvenile	0 adult 1 juvenile	3 adults 0 juvenile	1 adult 4 juveniles
Estimated Lengths	(61 cm)	(15 cm)	(43, 53, 56 cm)	(1 at 51cm; 4 at 12 to 18 cm)
No. Cutthroat/ Rainbow Trout	2	34	13	124
Estimated Lengths	(2 at >30 cm)	(28 at <30 cm; 6 at >30 cm)	(5 at < 12 cm; 8 at > 12 cm)	(113 at <30 cm;11 at >30 cm)
No. Whitefish	2	10	Do not inhabit section 1	Do not inhabit section 1
Estimated Lengths	(2 at 5 cm)	0	---------	---------

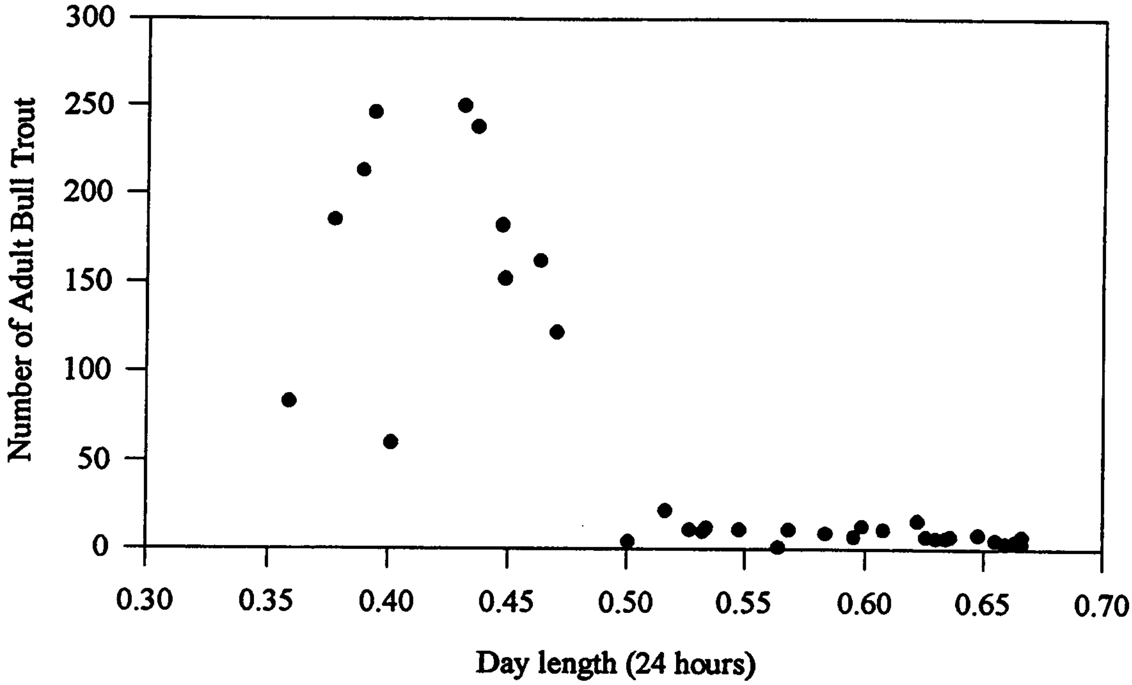

Figure 13. Relationship between number of adult bull trout and day length in the North Fork Skokomish River (47° 30' N). Based on number of adult bull trout observed during snorkel counts from 1994 to 1996.

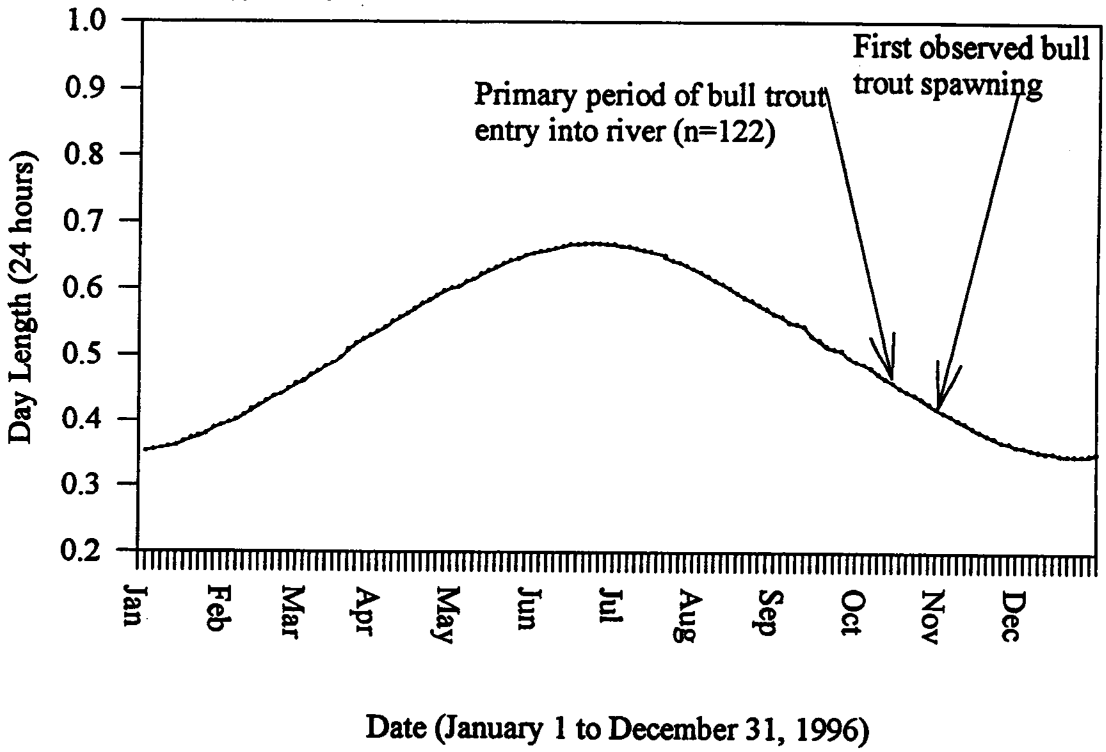

Figure 14. Day length at 47° 30'N latitude (North Fork Skokomish River) from January 1 to December 31, 1996. Timing of bull trout migration and first observed spawning denoted.

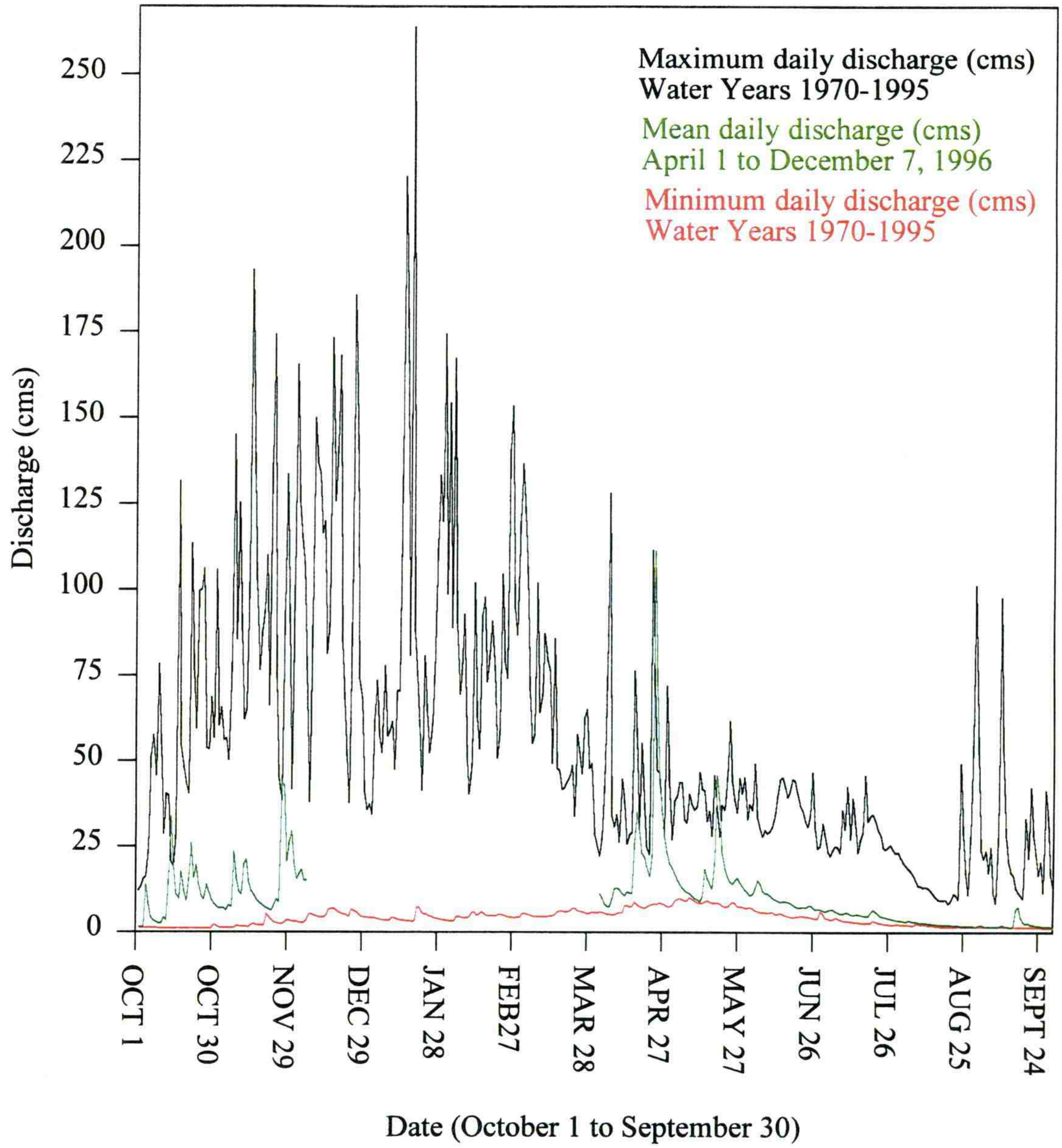

Figure 15. Maximum (black) and minimum (red) daily discharge (cms) of North Fork Skokomish River for water years 1970 to 1995 in relation to mean daily discharge (green) of river from April 1 to December 7, 1996.

From July 1 to October 2, 1996, mean daily river discharge was 3.2 cms (ranged from 1.3 to 7.4 cms), and during this period less than 22 adult bull trout were counted in the river. On October 4, following high precipitation, river discharge increased to 14.0 cms (850% increase from October 3), and 122 adult bull trout were observed in the river on October 9. Comparison of mean daily river flow data dating back to 1970 revealed that the frequency of equaling or exceeding a discharge of 10 or 20 cms greatly increased in October and November (Fig. 16). The high frequency of exceeding an event of 10 or 20 cms during that period corresponded to the month of primary upstream migration of adult bull trout which also occurred in October or November from 1987 and 1996 (Appendix C). Although mean daily flow values were not available for tributaries, streamflows were 0.23 cms in Elk Creek and 0.16 cms in Slate Creek on November 25 during which time adult bull trout were present in the creeks.

During summer low-flow conditions, mean lengths of adult bull trout generally were shorter than those fish that entered after increased river discharge in October (Fig.17). Bull trout appeared to move directly upstream from river sections five through two, and observations of bull trout first occurred in section one (upstream of Staircase Rapids) on July 17 (Table 4). Snorkel counts revealed that abundances of adult bull trout did not increase in section one after August 8, but numbers of adult bull trout downstream of Staircase Rapids remained high (sections two to five) (Table 4).

River discharge was negatively associated with water temperature in 1996 (Fig. 18). High discharges in October and November coincided with declining water temperatures.

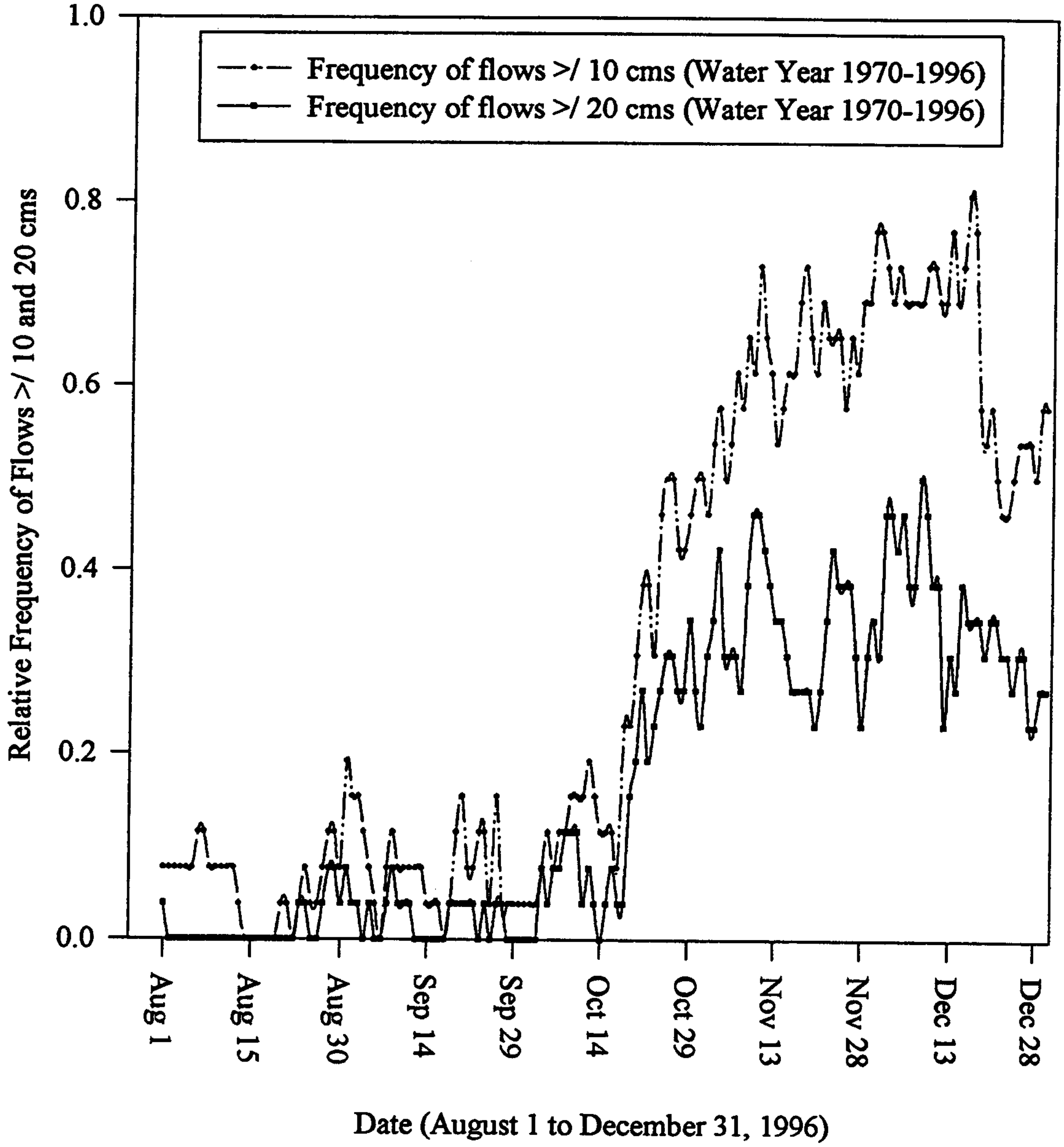

Figure 16. Frequency of equaling or exceeding a river discharge of 10 (circle; dashed line) or 20 (square;solid line) cms between August 1 and December 31 in North Fork Skokomish River. Based on mean daily discharge from water years 1970 to 1996.

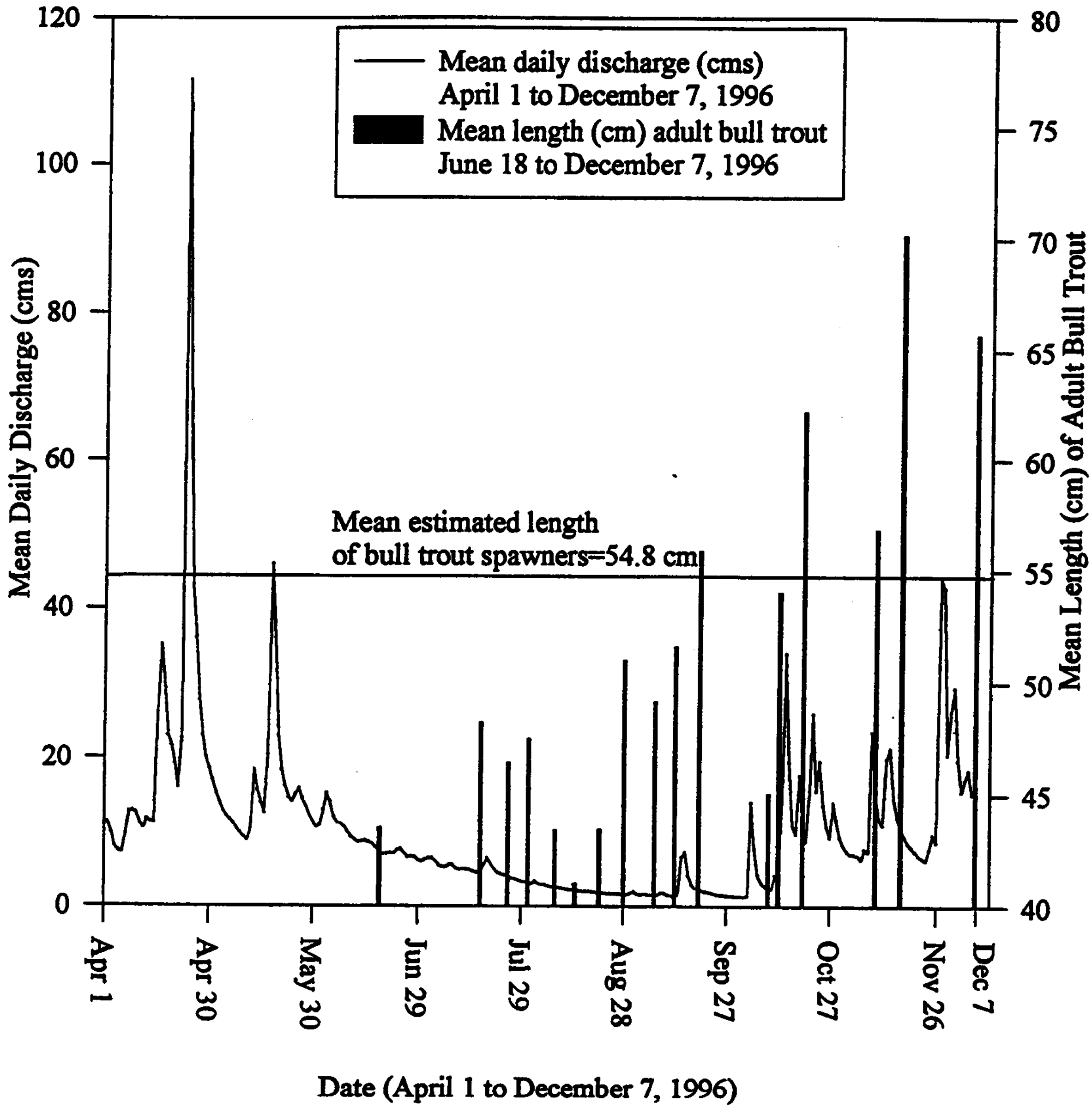

Figure 17. Mean length (cm) of adult bull trout in relation to river discharge (cms). Mean lengths shorter during periods of low flow and longer during higher autumn flows. Line represents estimated mean length of adult bull trout spawners.

Table 4. Number of adult bull trout in river sections one to five from April 13 to October 26, 1996. Depicting fish movements among river sections. Section one located upstream and sections two to five located downstream of Staircase Rapids. Numbers of adult bull trout did not increase in river section one after August 8.

	-UPSTREAM- OF RAPIDS	---------------DOWNSTREAM OF RAPIDS---------------			
Date	**Number of Adult Bull Trout-Section 1**	**Number of Adult Bull Trout-Section 2**	**Number of Adult Bull Trout-Section 3**	**Number of Adult Bull Trout-Section 4**	**Number of Adult Bull Trout-Section 5**
4/13/96	0	0	0	1	0
5/15/96	0	0	5	1	0
6/5/96	0	0	2	1	0
6/18/96	0	1	4	2	0
7/1/96	0	0	2	2	0
7/17/96	4	0	2	2	0
7/25/96	2	1	4	0	0
7/31/96	2	0	4	0	1
8/8/96	6	0	4	1	0
8/14/96	6	0	5	2	0
8/21/96	3	1	4	1	0
8/28/96	5	1	4	1	0
9/6/96	6	0	4	1	0
9/12/96	5	2	5	0	0
9/19/96	5	13	3	1	0
9/26/96	1	1	2	0	0
Increase in river flow					
10/9/96	4	57	5	38	18
10/12/96	5	73	16	64	4
10/19/96	4	50	8	79	41
10/26/96	3	38	15	183	11

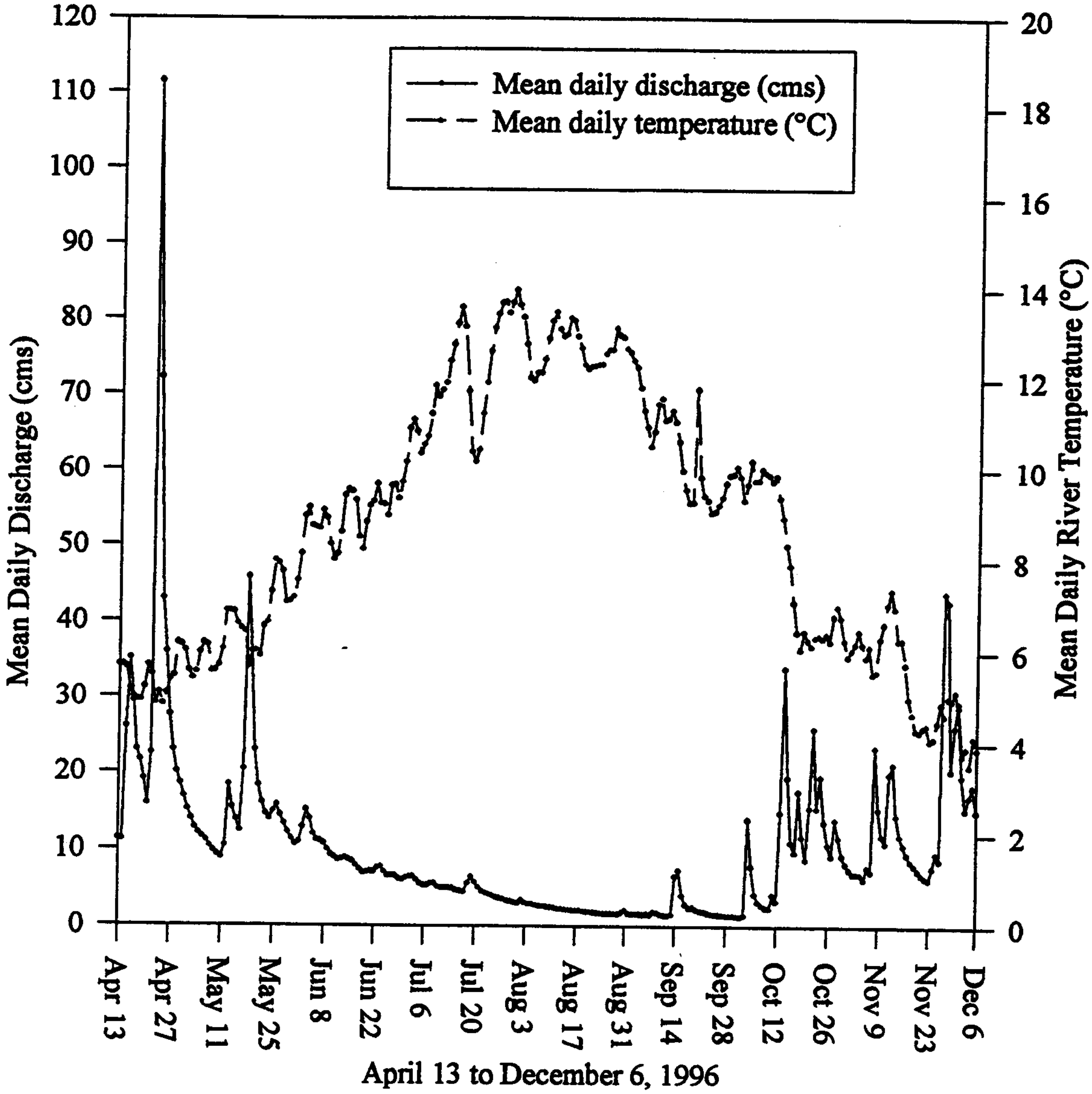

Figure 18. Mean daily river discharge (cms) and mean daily river temperature (°C) from April 13 to December 6, 1996 in the North Fork Skokomish River.

The upstream migration of bull trout was associated with the high-flow event on October 4 during which time mean daily river temperatures began to decline (Fig. 19).

In 1996, the onset of bull trout spawning in the NFSR and Slate Creek corresponded to declines in water temperature. Despite high abundances of bull trout in the river in early October, spawning did not begin until October 19 when river temperatures had declined to 6.3°C (Fig. 19). Mean daily river temperatures ranged from 3.5°C to 7.4°C during the remainder of the bull trout spawning period.

The onset of spawning in Slate Creek also appeared to be influenced by declines in water temperature. Although bull trout were first observed in the creek on November 8, 1996, redds were not found until November 22 after water temperatures declined to 2.2°C. Mean daily water temperatures remained at less than 5.2°C during the bull trout spawning period (November 22 and December 6) (Fig. 20).

From June through September when most bull trout inhabited the reservoir, Lake Cushman was thermally stratified (Fig. 21). During that period, the maximum near-surface water temperature in summer was 22.9°C, and the minimum temperature was 6.9°C at a depth of 31 m on July 26. At the lake sampling stations, the metalimnion in the reservoir extended to a depth of 20 to 25 m. In October 1996, the temperature of the near-surface water decreased to 14.5°C, and remained nearly constant throughout the water column (Fig. 21). The reservoir remains cold and well mixed between November and April (Hosey and Associates 1990).

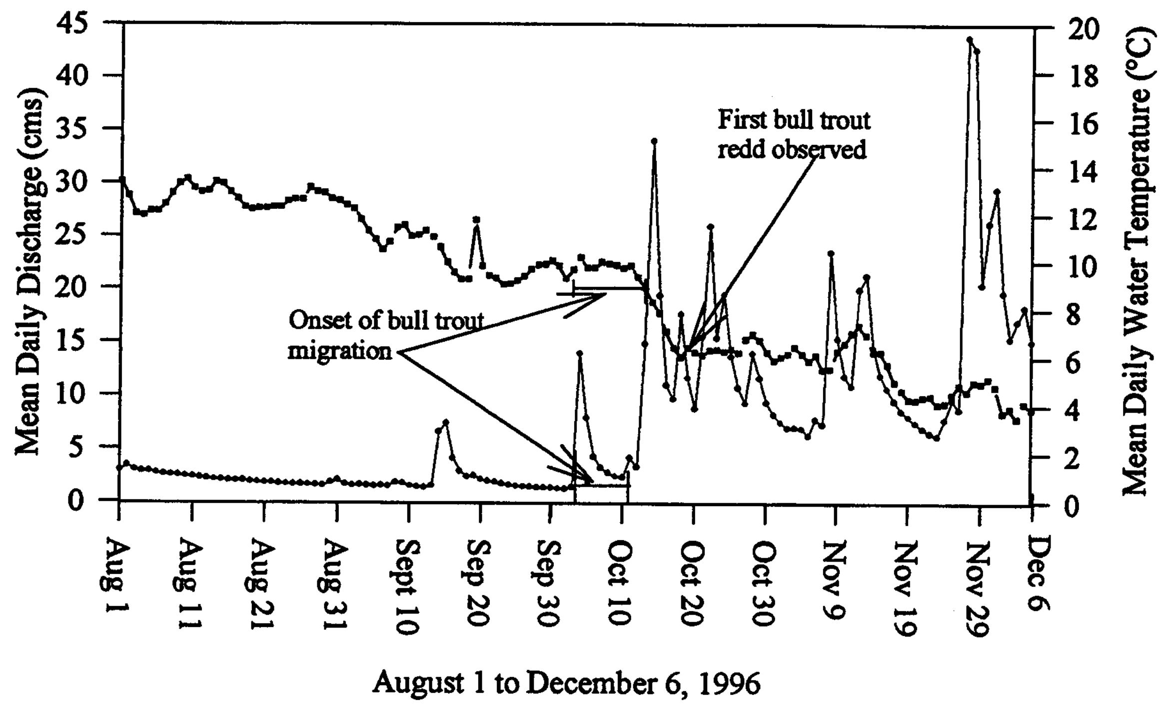

Figure 19. Mean daily river discharge (cms;circle) and mean daily river temperature (°C;square) from August 1 to December 6, 1996 in the North Fork Skokomish River in relation to bull trout migration and onset of spawning.

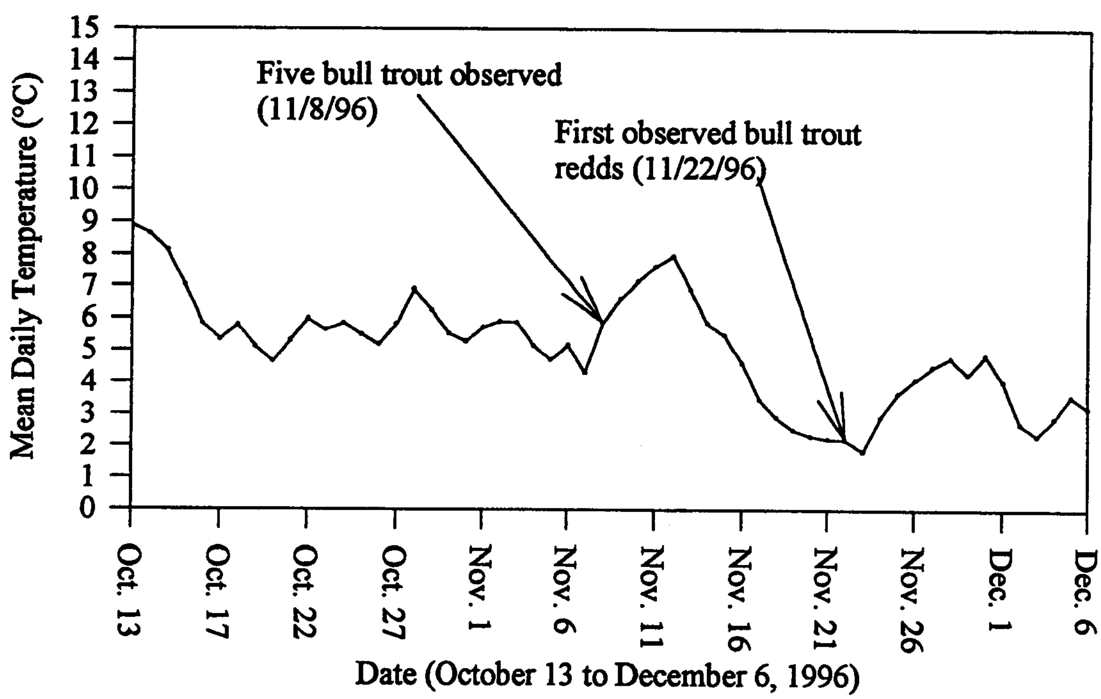

Figure 20. Mean daily water temperature (°C) in relation to bull trout entry and spawning in Slate Creek from October 13 to December 6, 1996.

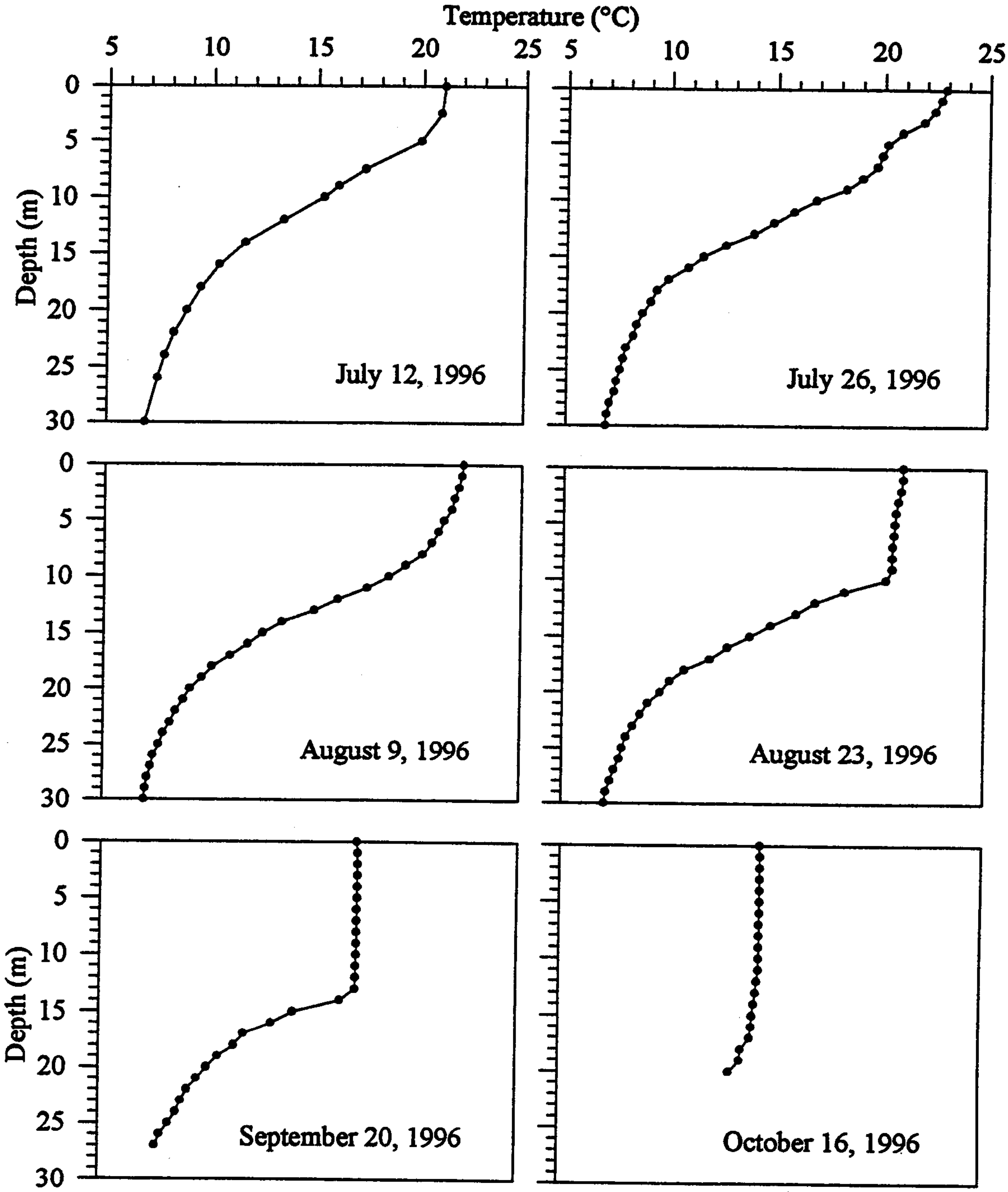

Figure 21. Mean water temperature (°C) as a function of depth (m) in Lake Cushman from July12 to October 16, 1996. Values averaged for limnological stations one and two.

Temporal Shifts in Abundances of Bull Trout, Whitefish, and Cutthroat/Rainbow Trout:

From 1994 to 1996, there were temporal shifts in relative abundance and percent composition of bull trout, whitefish, and cutthroat/rainbow trout in the NFSR (Figs. 22 and 23). Changes in abundance of bull trout and whitefish corresponded to fish migrations between the reservoir and river. Based on monthly (1994 and 1995) and weekly (1996) snorkel counts, each fish species was prevalent in the river for a specific period of time.

Adult whitefish were the most abundant species in river (sections two to five) from June to August in 1994 and 1995 and from May to August 1996 (Figs. 22 and 23). Total abundances of whitefish differed among years but peak counts occurred in August in all sample years (Fig. 22). The peak whitefish count (of 493) occurred on August 21, 1996, followed by drastic declines in abundance by September 6. It was assumed that most whitefish returned to Lake Cushman by September 19 (Fig. 22). Whitefish comprised only a small percentage of the total fish abundance in the river between October and December (Fig. 23).

Cutthroat/rainbow trout were the most abundant salmonids upstream of Staircase Rapids and comprised the highest density of any salmonid from April to November in river section one (Appendix E). Abundances of cutthroat/rainbow trout exhibited considerable temporal variation between 1994 and 1996, and the highest counts occurred in August 1994 and 1996 and in July 1995 (Fig. 22). Similar to whitefish, cutthroat/rainbow trout exhibited drastic declines in abundance in the river in late September, but cutthroat/rainbow trout were more abundant than bull trout and whitefish in river sections two to five in September of 1994 and 1996 (Fig. 23). From September to December, cutthroat/rainbow trout generally made up a greater percentage of the total fish abundance than did whitefish but comprised less of the total fish abundance than did adult bull trout.

From October to December (1994 to 1996), adult bull trout were more abundant than other salmonids in the river but were least abundant between May and September (1994 to 1996) (Fig. 22). Clearly, bull trout comprised the highest percentage of total fish abundance in autumn (Fig. 23). Upstream migration of adult bull trout from Lake Cushman in October followed drastic declines in abundances of whitefish and cutthroat/rainbow trout.

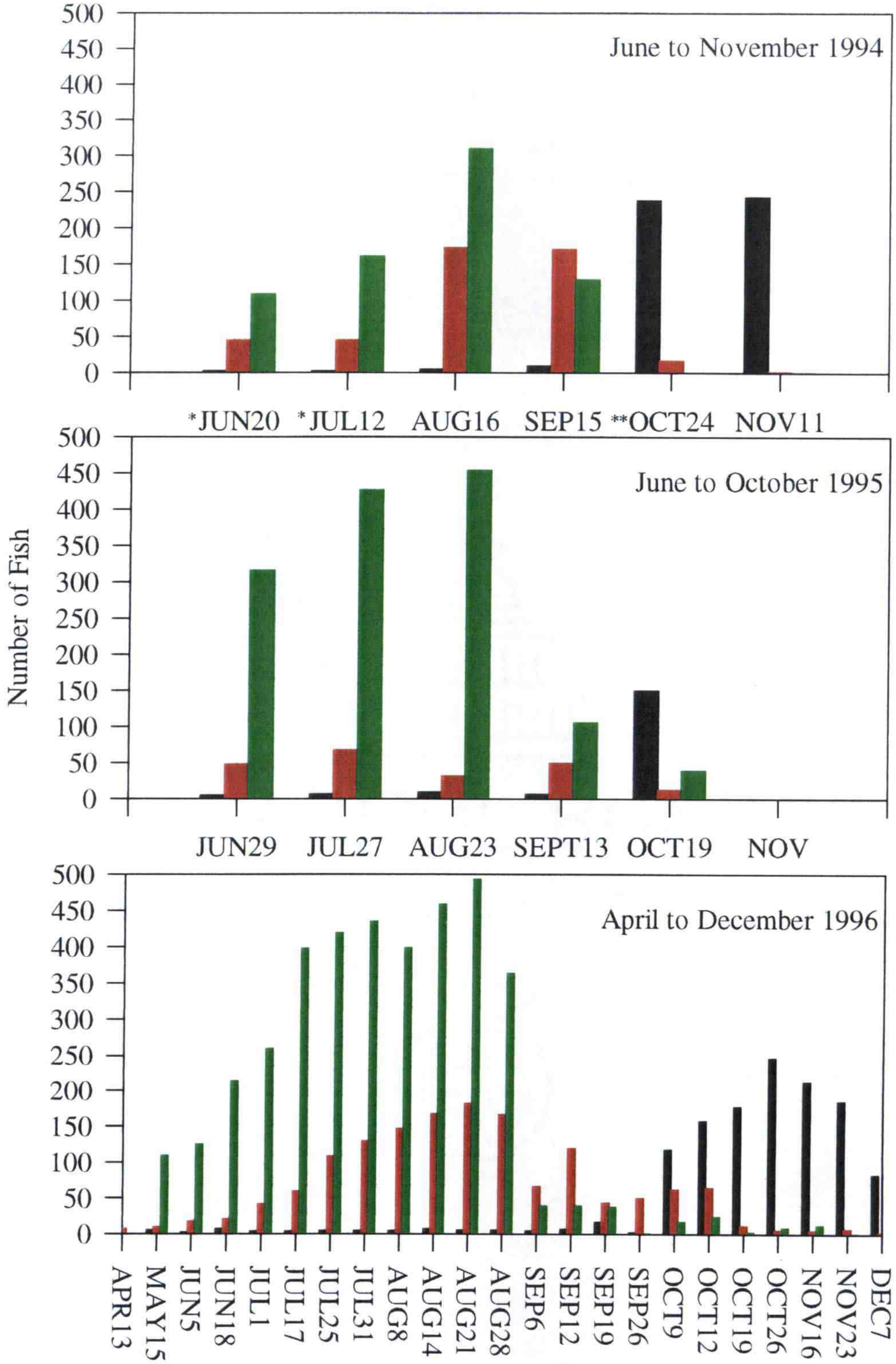

Figure 22. Temporal shifts in abundances of adult bull trout (black), adult whitefish (green), and cutthroat/rainbow trout (red) in N. Fk. Skokomish River sections 2-5 from 1994 to 1996. Based on day snorkel counts of each species. *river sections 2-4 **WDFW sections 2-6.

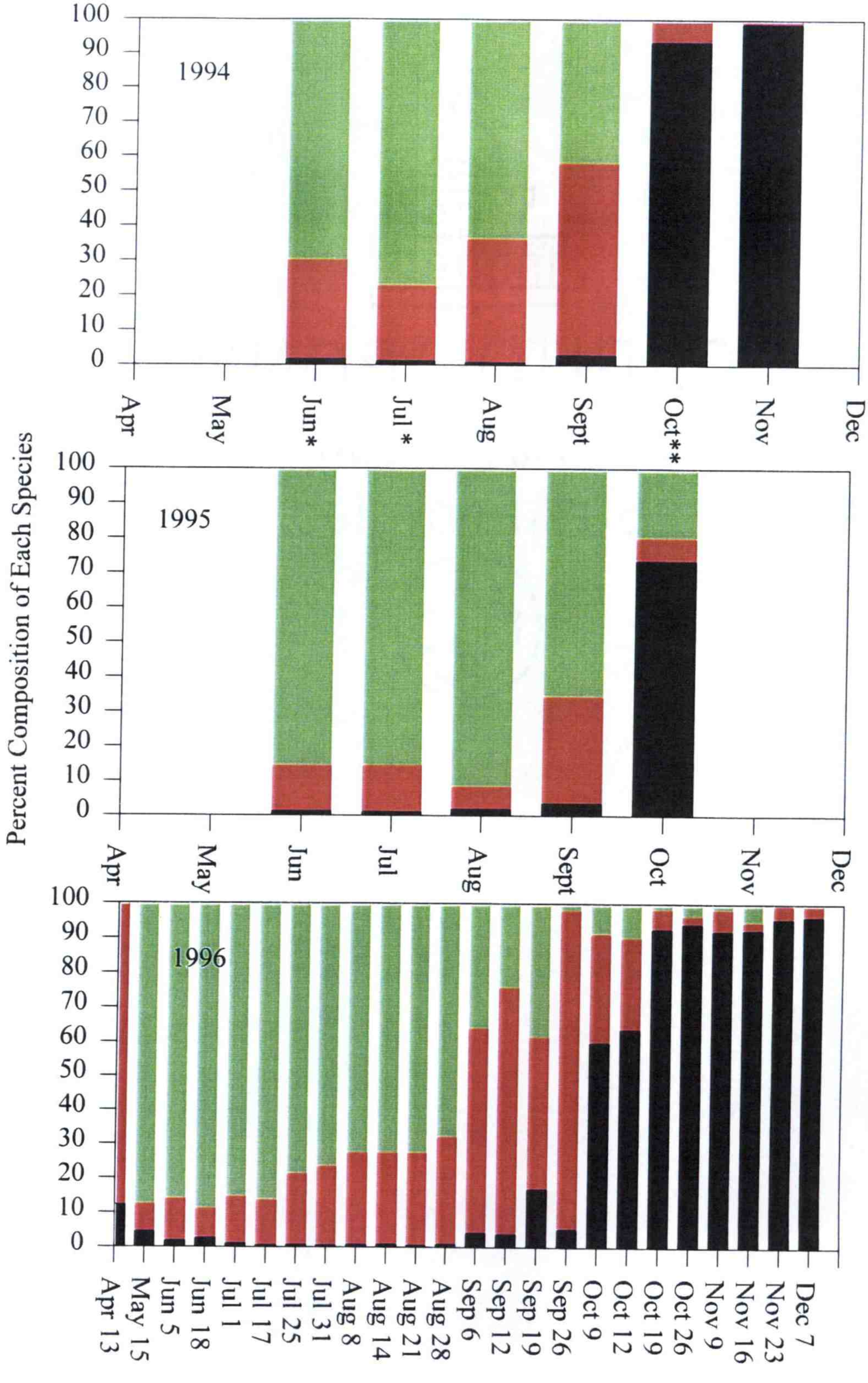

Figure 23. Percent composition of adult bull trout (black), adult whitefish (green), and cutthroat/rainbow trout (red) in the N. Fk. Skokomish River sections 2 to 5 from 1994 to 1996.*river sections 2-4**WDFW 2-6. Based on counts from day snorkel surveys.

DISCUSSION

The presence of bull trout in the NFSR was confirmed by results from genetic analysis. These results supported a past study in the NFSR that identified bull trout through morphological measurements and meristic counts (Appendix F) (WDFW 1997). Recently, there has been much confusion in distinguishing bull trout from Dolly Varden, particularly from the Olympic Peninsula where the two species are often sympatric near the southern range of Dolly Varden (Morton 1970; Mongillo 1992; unpublished ONP files 1993-1996; Leary and Allendorf 1997). The large size of the lacustrine-adfluvial form in the NFSR also supported the hypothesis that these fish were bull trout and not Dolly Varden. Bull trout in the river attained estimated lengths up to 81.3 cm and were comparatively longer than other native char at OLYM (Table 5). Further evidence from genetic and morphological studies of 25 native char from the South Fork Skokomish River confirmed the presence of bull trout in that river (WDFW 1997). To date, there has been no evidence of Dolly Varden inhabiting the Skokomish River drainage.

Distribution of Bull Trout:

Lacustrine-adfluvial bull trout were the only observed life history form in the NFSR. Bull trout primarily were found in the river downstream of Staircase Rapids, and in the lower sections of Elk Creek and Slate Creek (Fig. 5). There was no evidence of non-migratory bull trout in the NFSR Basin despite extensive electrofishing and day snorkel surveys throughout the basin. Bull trout were not detected in the river upstream of the

Table 5. Comparison of fish lengths among identified bull trout and Dolly Varden populations at Olympic National Park. **Lengths were not available by species.

River/Creek	Species and Date of Sample	Total Length (mm)	Mean Length (mm)	Method and Sample Size
N. Fk. Skokomish River	Bull Trout (4/13-12/7/96) Bull Trout (10/19-20/96)	254 to 813 533 to 635	548 591	Snorkel n=283 and Hook-and-Line n=4
Elk Creek	Bull Trout (6/27/96)	27 to 119	40	Electrofishing n=29
Slate Creek	Bull Trout (7/3/96)	33 to 47	42	Electrofishing n=13
Queets River	Bull Trout (9/11-14/95)	123 to 515	222	Hook-and-Line n=20
Elwha River	Bull Trout (9/12/95)	196 to 222	209	Hook-and-Line n=3
E. Fk. Quinault River	**Bull Trout/Dolly Varden (7/20/95) (9/11-14/95)	100 to 365	175	Hook-and-Line and Electrofishing n=22
Upper Soleduck River	Dolly Varden (9/29/94) (Identified by Cavendar 1978)	105 to 205	142	Electrofishing n=18
	Dolly Varden (8/28/95)	43 to 203	N/A	Electrofishing n=31

confluence of Four Stream (rkm 50.7), and an impassable barrier probably exists in the river canyon near the confluence of Six Stream (Eric Volk, personal communication, WDFW). Based on this distributional information, bull trout likely do not inhabit the river and its tributaries upstream of rkm 52.

The presence of large bull trout (up to 63.5 cm) upstream of Staircase Rapids during the spawning period from 1994 to 1996 suggested that Staircase Rapids was not a barrier to bull trout migration as had been previously presumed (WDFW 1957; Hosey and Associates 1990; and WDFW 1997). Future trapping or tagging studies could determine whether Staircase Rapids is indeed passable to migratory bull trout.

Migration and Spawning of Bull Trout:

In the NFSR, elements of the life history of bull trout were described relative to the initiation of migration, distribution of spawners, and duration of spawning. Understanding temporal variation of migration and spawning among populations of bull trout may be critical in the management and conservation of this species. Intraspecies variability is likely important in species persistence and evolution (Healey et al. 1995; Gresswell et al. 1997). Maintenance of diversity of life history characteristics among populations, such as variability in timing of migration and spawning, may increase the ability of fish to adapt to environmental changes (den Boer 1968; Gresswell et al. 1994).

Monthly timing of migration and spawning of bull trout has been shown to be variable among different river and lake systems. In the present study, bull trout typically migrated in September and October and spawned from September to December. Timing of upstream migration was consistent among years in the NFSR (Appendix C), but differed from earlier migrating populations in the Flathead River Basin, Montana (April), Metolius River, Oregon (May), and Mackenzie Creek, British Columbia (June) (Table 6). In Mackenzie Creek, British Columbia, 90% of all migrating adults had entered the stream by August 20 (McPhail and Murray 1979), but only 73 % of all adults had entered the NFSR by October 19, 1996.

Typically, upstream migrations of bull trout in the NFSR occurred over short distances (less than 6 rkm), and spawning was confined to lower sections of the river and tributaries (Fig. 9). High densities of bull trout in river section four coupled with the presence of redds in that river section indicated that it may be an important spawning area (Figs. 3 and 6). River section four contained high percentages of gravel and cobble substrates (Table 2). In the Flathead River, Montana, bull trout spawners selected stream channels characterized by gravel substrates (Fraley and Shepard 1989). In contrast, high densities of bull trout in river section five on October 19 and December 7, 1996 were directly related to migration periods from and to the reservoir and likely were not prominent spawning areas (Fig. 8).

At present, it is not known whether all mature adults returning to the river actually spawned or how long each adult inhabited the river after spawning. McPhail and Murray (1979) reported that not all migratory adults spawned in Mackenzie Creek despite having entered the stream. Based on the absence of adult fish in the river in January 1998, spawners presumably returned to Lake Cushman after spawning. Snorkel surveys or

Table 6. Comparison of lacustrine-adfluvial bull trout spawning migrations and spawning periods in Washington, Oregon, Idaho, Montana, and British Columbia.

Lake and River System	**Upstream Migration**	**Spawning Period**	**Source**
-Lake Cushman and North Fork Skokomish River, WA	September to November	September to December 6	Present study
-Chester Morse Lake and Cedar River, WA	N/A	October to December 7	Reiser et al. 1997
-Lake Billy Chinook and Metolius River, OR	May to August	July 13 to mid-October	Ratliff 1992
-Flathead Lake and River, MT	April to July	Late August to early October	Fraley and Shepard 1989
-Upper Arrow Head Lakes, Mackenzie Creek, B.C.	June to August	September 14 to October 29	McPhail and Murray 1979
-Clark Fork River, ID	N/A	September 18 to October 20	Heimer 1965

trapping and tagging studies that extend into January could assess fish movements in the river during December and January.

Although the frequency of repeat spawning in the NFSR was unknown, migrations that occurred over short distances may serve as an energy-conserving mechanism in iteroparous spawners. Furthermore, the existence of confined spawning areas in the NFSR (Fig. 9) may increase the likelihood of adult fish locating a mate during the spawning period. Post-spawning mortality was assumed to be low considering that only two adult carcasses were observed in the river, and no carcasses were found in Elk Creek and Slate Creek.

There were considerable differences in spawning periods among lacustrine-adfluvial bull trout populations (Table 6) and (Fig. 24). Based on available literature, the NFSR and Cedar River, Washington contain bull trout populations with the longest spawning periods and latest known spawning times throughout the range (Table 6). In this study, the relative duration of spawning from the first observed spawning to the last snorkel survey was 49 days in 1996. McPhail and Murray (1979) reported a spawning period of at least 45 days (Mackenzie Creek, British Columbia), and Heimer (1965) observed spawning for 32 days (Clark Fork River, Idaho).

Length of Bull Trout Spawners:

Mean estimated total length (54.8 cm; range 25.4 to 81.3 cm; n=283) of adult bull trout in the NFSR was comparable to fish measured in 1990 (mean 57.0 cm; range 35.5 to 75.7 cm; n=30) (Appendix F, unpublished files, WDFW). Additionally, mean lengths of

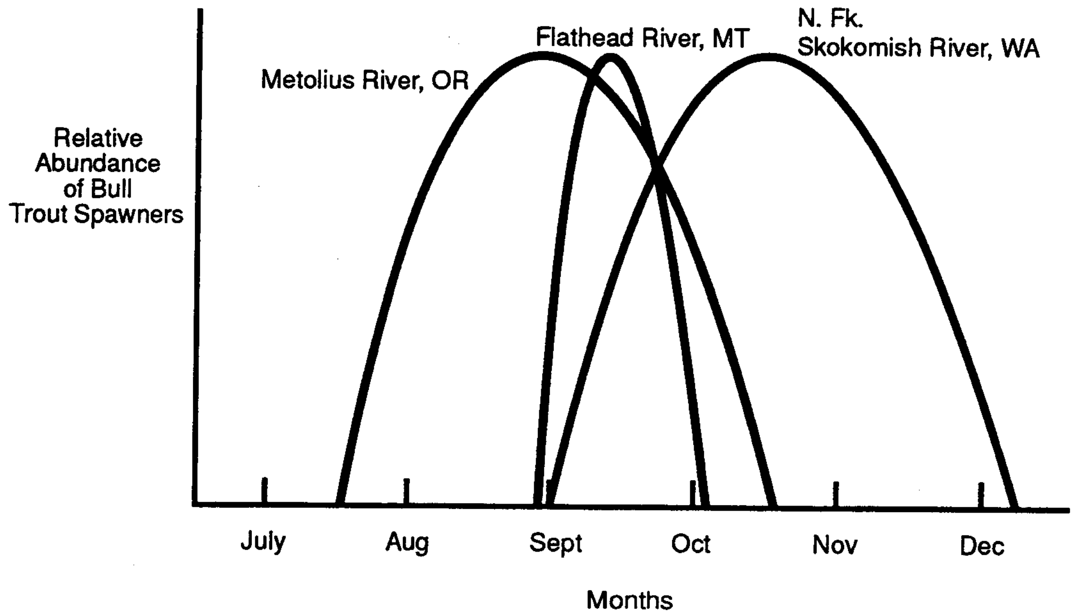

Figure 24. Lacustrine-adfluvial bull trout spawning periods in the North Fork Skokomish River, WA; Flathead River, MT; and Metolius River, OR.

bull trout in the NFSR were comparable to bull trout in watersheds of Idaho and Montana (averaged 44.0 to 60.0 cm) and the Metolius River, Oregon (51.8 cm) (Pratt 1992; Riehle et al. 1997). Preliminary results suggested that bull trout upstream of Staircase Rapids were shorter in length than those fish observed downstream of the rapids (Fig. 12), although sample sizes were small, and there was a lack of independence between snorkel counts on subsequent dates (e.g.-same fish may have been counted on subsequent dates).

Overall, mean length of spawners in the NFSR consistently increased throughout the migration from June to December (Fig. 11). Increases in mean lengths of bull trout spawners suggest that there are two phases to the spawning migration in the NFSR (Fig. 10). One possible explanation for the smaller sizes of early migrants is that these fish are precocious males. In the Flathead and Pend Oreille Basins (1992), precocious males comprise a portion of the spawning population, and these smaller males may enter the spawning area prior to the upstream migration of larger adult fish.

Alternatively, the presence of two phases of the spawning migration may be indicative of two populations spawning in the NFSR. Variable timing of migrations has been shown to occur within and among populations of other salmonids (Schaffer and Elson 1975; Jonsson et al. 1990; Gresswell et al. 1994). For instance, Arctic char (*Salvelinus alpinus*) exhibit great variability in life history including differences in growth, age, and size at sexual maturation among forms both within and among localities. Such differences in Arctic char result in spatial and temporal variability in spawning (Nordeng 1983; Smith and Skúlason 1996). Similarly, mean size and migratory timing of cutthroat trout (*Oncorhynchus clarki bouvieri*) vary among spawning populations in tributaries of

Yellowstone Lake (Gresswell et al. 1994). Further research on bull trout in the NFSR could address the likely occurrence of differences in the size of early versus late migrating bull trout.

Differences in the timing of upstream migration between small and large bull trout may be related to discharge in the NFSR. Generally, early migrating bull trout of shorter lengths enter the NFSR during periods of low-flow and larger fish enter at higher river flows (Figs. 10 and 17). McPhail and Murray (1979) also found that the smallest and youngest bull trout enter Mackenzie Creek, British Columbia during minimum streamflow conditions. Similarly, older and larger Atlantic salmon (*Salmo salar*) are more dependent on high water levels than are smaller and younger adult salmon (Jonsson et al. 1990), and large female coho (*Oncorhynchus kisutch*) have been shown to enter a creek at peak discharge while progressively smaller fish enter as discharge recedes (van den Berghe and Gross 1989).

Results of this study indicated that early migrants in the NFSR moved the farthest upstream and ascended Staircase Rapids (section one of the study area). Low numbers of bull trout were observed upstream of the rapids from July to October, and analysis of counts by river section indicated that these fish moved upstream from section five (near Lake Cushman) to section one (Table 4). Late migrating bull trout did not appear to ascend Staircase Rapids after increased river discharge in October (Table 4). For instance, despite high numbers of fish downstream of Staircase Rapids in October, the number of adults upstream of the rapids did not increase during that month (Table 4). Therefore, it was assumed bull trout that entered the river after increased river discharge remained in river sections downstream of the rapids. In British Columbia, early migrating bull trout move farthest upstream and late migrants remain near a reservoir (McPhail and Murray 1979). Similarly, early migrating cutthroat trout tend to move farthest upstream into tributaries of Yellowstone Lake (Gresswell et al. 1994).

In the NFSR, there may be a selective advantage for smaller bull trout to migrate during low discharges when migration of larger fish may be inhibited. By entering the river during low-flow conditions, smaller bull trout may minimize intraspecific competitive interactions with larger spawning fish. Conversely, upstream migration that occurs during periods of high-flow may minimize the risk of injury and exposure to predation despite increased energetic costs (Jonsson 1991). Large bull trout may be partially exposed during spawning in low waters (McPhail and Murray 1979) and therefore require higher flows to remain submerged in water.

From an evolutionary perspective, a population comprised of early and late migrating fish of small and large sizes increases the likelihood that reproduction will occur in a particular year even under adverse flow conditions. For instance, in years of low-flow conditions throughout autumn, small bull trout could safely migrate to spawning areas. Also, early migrants followed by late migrants may serve as a means of extending the duration of the spawning period in autumn. By extending the duration of reproduction, eggs or fish of the same age class will be exposed to different environmental factors at different times. Such increased temporal variation in spawning may enhance the chance of survival of a population in a variable environment (den Boer 1968). In cases of high winter flows that can decimate developing embryos of fall spawning char (Seegrist and

Gard 1972; Erman et al. 1988), a longer period of reproduction in autumn may increase the likelihood of population persistence and may minimize the effects of stochastic events related to high discharges. New research in the NFSR should be directed toward spawning success of bull trout. Any information of spawning success derived from this relatively intact system may be useful as a means of comparison to degraded systems inhabited by bull trout.

Young-of-the-Year and Juvenile Bull Trout:

Generally, there is a paucity of information on the life history of juvenile bull trout in the NFSR. Young-of-the-year bull trout were captured in Elk Creek and Slate Creek during electrofishing surveys in 1996. These fry were found in the vicinities of known bull trout spawning areas and were believed to be progeny of fish that spawned in 1995. We failed to detect juvenile bull trout during extensive day snorkeling conducted from 1994 to 1996. Failure to detect juvenile bull trout indicated that day snorkeling was an inadequate means of attaining information about their life history in the NFSR. Night snorkel surveys on two different dates revealed low numbers of bull trout upstream (n=4) and downstream (n=1) of Staircase Rapids (Table 3). Night snorkeling was determined to be more effective than day surveys for counting juvenile bull trout in small streams in Washington and Idaho (Goetz 1994; Bonneau et al. 1995).

The absence of juvenile bull trout in the NFSR, despite extensive electrofishing and snorkel surveys, may prove to be useful information for future research and management in the NFSR. For instance, the small number of juvenile bull trout suggests that these fish may emigrate from the river to the reservoir soon after emergence from the gravel. Typically, juvenile bull trout emigrate from tributaries to large lakes or reservoirs between the ages of one to six in British Columbia, Idaho, and Montana (Fraley and Shepard 1989; Goetz 1989; Pratt 1992). However, unlike some reservoir and river systems containing lacustrine-adfluvial populations, spawning areas in the NFSR are close to the reservoir (less than 6 rkm). The close proximity of the spawning areas to the reservoir and the lack of juvenile rearing habitat in intermittent and high gradient tributaries may result in immediate emigration from the river to the reservoir. In contrast, immediate emigration does not occur in the Flathead Basin presumably because spawning occurs up to 250 km upstream from Flathead Lake. In that river and lake system, juveniles reside in tributaries for one to four years before moving downstream to the lake (Fraley and Shepard 1989). Future research in the NFSR could focus on life history of juvenile bull trout including age and size of emigration. Downstream migrant traps may be useful to document juvenile bull trout movements. In the Metolius River and Lake Billy Chinook system, downstream migrant traps were successfully used for information on life history of juvenile bull trout (Riehle et al. 1997).

Influence of Photoperiod, River Discharge, and Water Temperature on Migration and Spawning of Bull Trout:

Northcote (1984) and Jonsson (1991) discussed the notion that a hierarchy of environmental factors stimulated fish migration in rivers although a suite of physical variables may influence spawning movements of adfluvial fish (Gresswell et al. 1997). In the NFSR, timing of upstream migration and spawning of bull trout was associated with declining photoperiod, increased river discharge, and declining water temperature. These results were in agreement with previous reports that photoperiod, water flow, and temperature influence upstream migration of bull trout (Fraley and Shepard 1989; Rode 1990). The role of each of these factors in influencing migration appeared to differ throughout geographic regions.

Timing of upstream migration of fish depends on the interaction between the physiological state of fish and environmental cues such as changes in river discharge and water temperature (Northcote 1984). Because seasonal changes in photoperiod are consistent among years, day length likely serves as a predictable environmental factor that indicates season of migration to the fish (Jonsson 1991). Henderson (1963) provides evidence that the gonad maturation of brook trout is regulated by seasonal changes in day length.

Changes in photoperiod likely serve as a primary environmental cue that increases the likelihood of reproduction of bull trout in the Metolius River, Oregon. In that system, spring-fed tributaries result in stable river discharges and temperatures throughout the year (Fig. 25) (Ratliff 1992). As a result, changes in photoperiod likely influence upstream migration of bull trout in the Metolius River (Fig. 26). In the NFSR, upstream migration occurs under conditions of declining day length in autumn (Fig. 14), however, river discharge is believed to be influential in triggering migration of bull trout in that river.

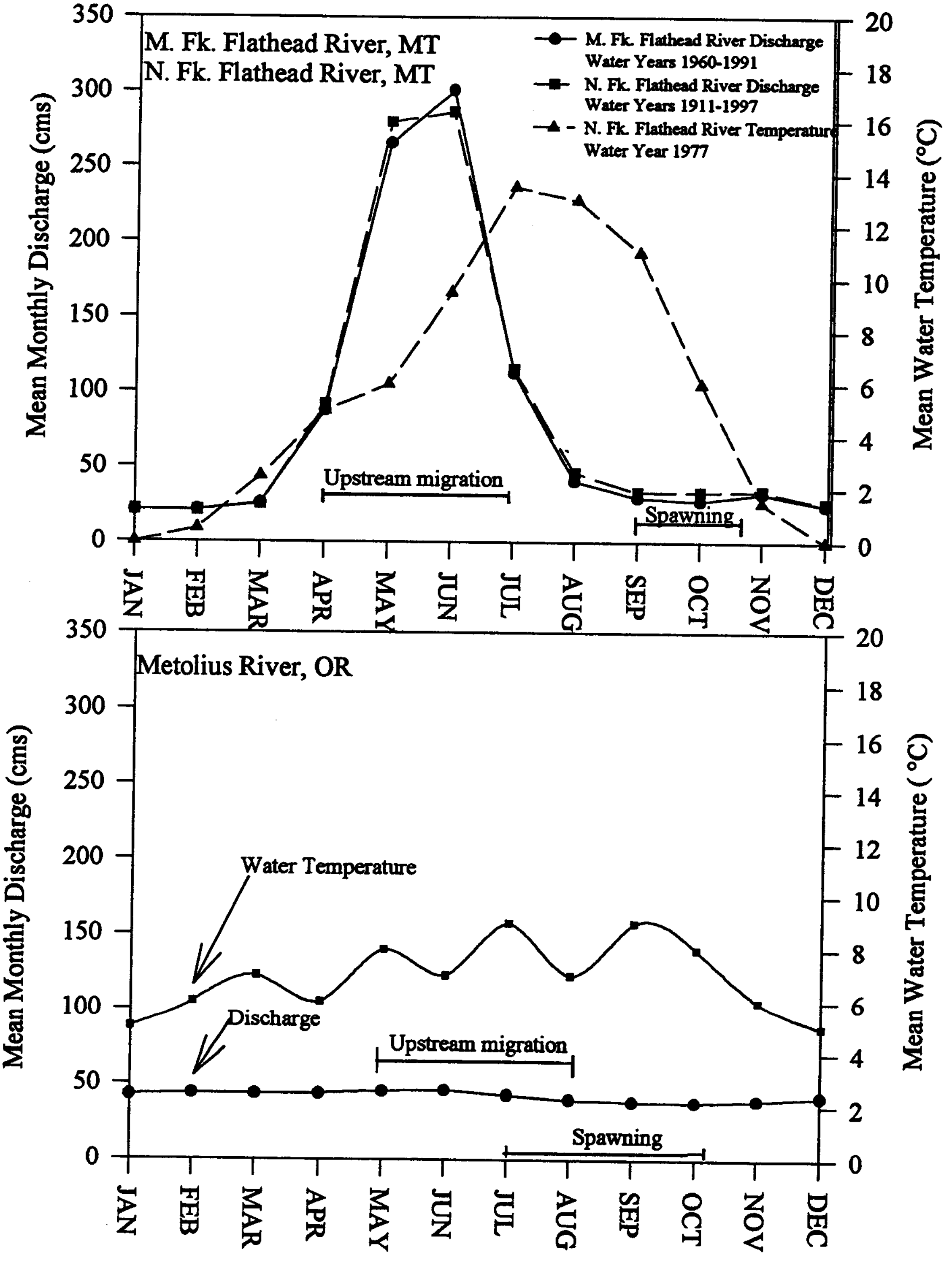

Figure 25. Mean monthly discharges (cms) and water temperature (° C) in M. Fk.(WY 1960-1991) and N. Fk. (WY 1911-1997) Flathead Rivers, MT and Metolius River (WY 1913-1995;), OR in relation to bull trout migration and spawning. Metolius River temperature (Scott Lewis, personal communication, Portland General Electric).

Figure 26. A hierarchical model of the influences of photoperiod on initiation of migration and spawning of lacustrine-adfluvial bull trout in the Metolius River, Oregon. Diagram shows the relative influence of photoperiod on spawning migration of bull trout in that system. Changes in day length likely stimulate upstream migration, and not river discharge and water temperature which remain stable throughout the year. Relatively high base flows appear to provide adequate discharges that enable large bull trout to remain submerged throughout the spawning migration.

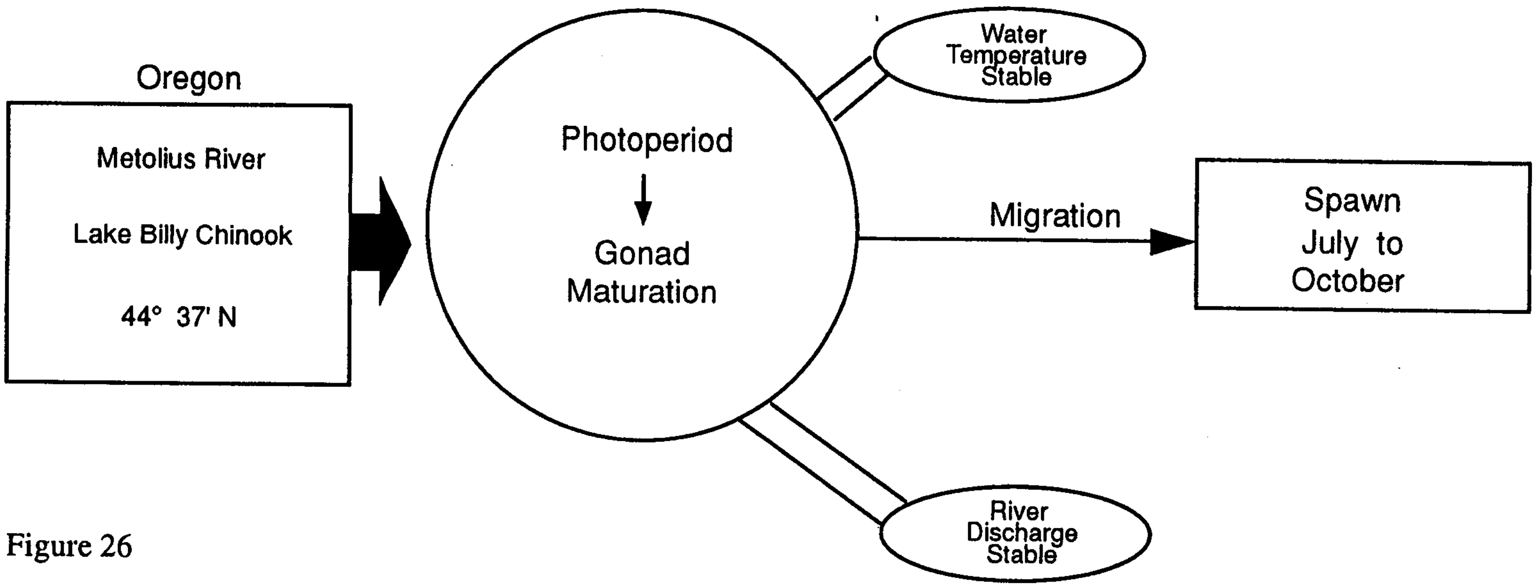
Oregon
Metolius River
Lake Billy Chinook
44° 37' N
Photoperiod
Gonad
Maturation
Water
Temperature
Stable
Migration
Spawn
July to
October
River
Discharge
Stable

Figure 26

Increased river discharge is believed to be an important, if not prominent, factor in initiating upstream migration of numerous species of salmonids (Banks 1969; Northcote 1984; van den Berghe and Gross 1989; Jonsson et al. 1990; Jonsson 1991). Timing of spawning migrations of lacustrine-adfluvial bull trout appear to be related to increases in river flow. Generally, seasonal patterns of river flow in the Pacific Northwest exhibit high-flow and flood predictability (Poff and Ward 1989). Analysis of historic flow data suggested that increased river discharge in October is a predictable environmental cue to migrating bull trout in the NFSR (Fig. 15). In the NFSR and Cedar River Washington, river discharge is characterized by low-flows in summer and subsequent increases in river flow in October and November that correspond to upstream migration of bull trout (Figs. 27 and 28). Overall, these river discharge patterns in the NFSR are consistent with historic records of streamflow patterns over the past 25 years (Fig. 15), and therefore appear to be representative of this system.

In the Middle Fork and North Fork Flathead Rivers, Montana, river discharge patterns also appear to influence timing of migration of lacustrine-adfluvial bull trout (Figs. 25 and 28). In that system, increases in river discharge in May and June correspond to upstream migrations of adult bull trout (Pratt 1992). Because snowmelt systems such as the Flathead Drainage have high flood and flow predictability (Poff and Ward 1989), spring run-off may serve as a prominent environmental cue to migratory bull trout. Generally, bull trout in the Flathead River migrate earlier in the year than bull trout in western Washington (Table 6). This temporal variation in migration of bull trout among systems

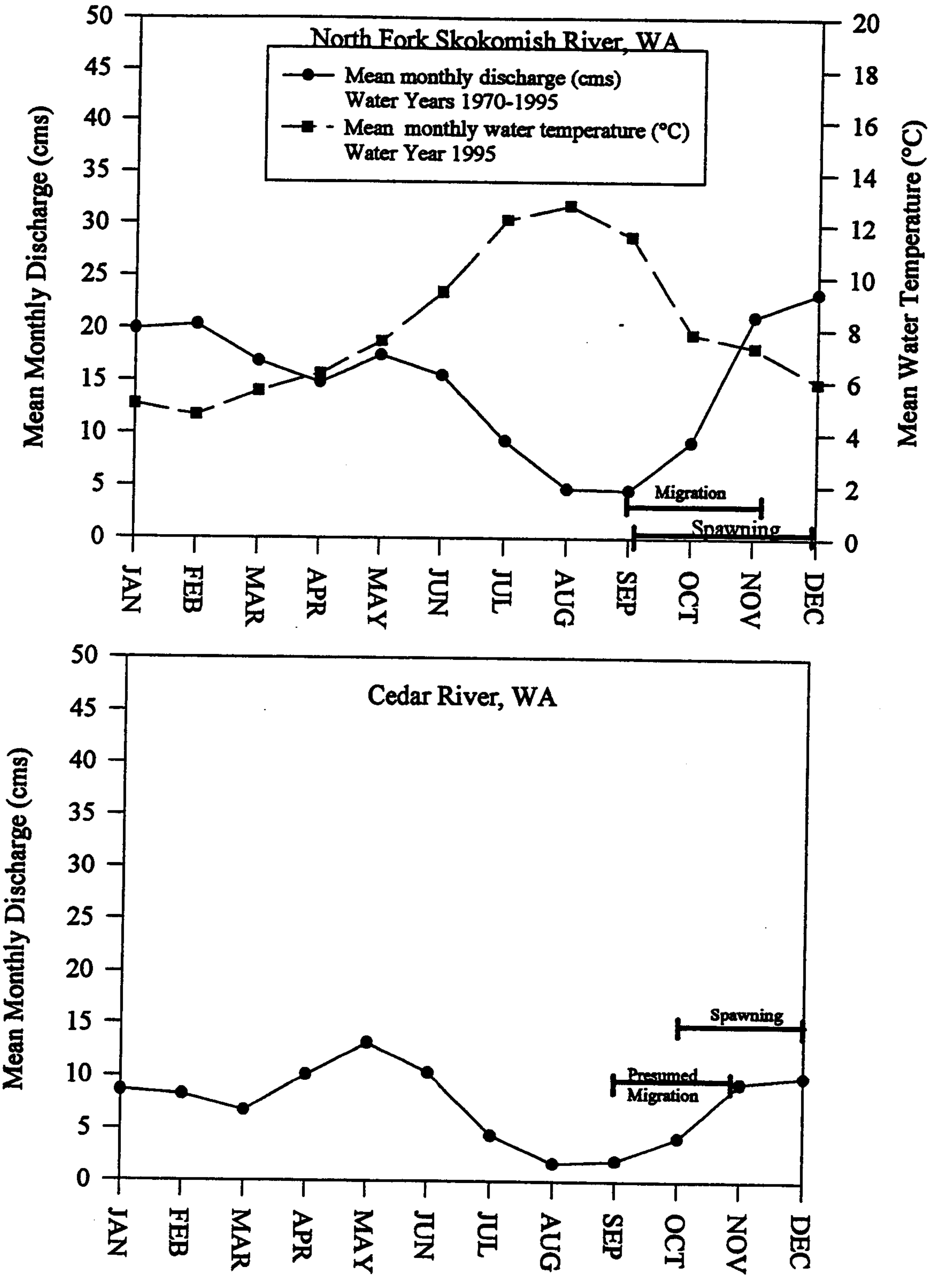

Figure 27. Comparison of mean monthly discharge (cms) in N. Fk. Skokomish River (WY 1970-1995;circle) and Cedar River (WY 1945-1992) WA in relation to bull trout migration and spawning. N. Fk. Skokomish River temperature (WY1995;square) denoted.
Data from unpublished USGS files.

Figure 28. A hierarchical model of the influences of photoperiod, river discharge, and water temperature on initiation of migration and spawning of lacustrine-adfluvial bull trout in the North Fork Skokomish and Cedar Rivers, Washington and Middle Fork and North Fork Flathead Rivers, Montana. Diagram shows that changes in photoperiod likely are important to gonad maturation of bull trout, and increases in river discharge are a prominent stimulus to upstream migration. In the North Fork Skokomish River, increased river discharge and declining water temperatures may interact to initiate migration and spawning of bull trout.

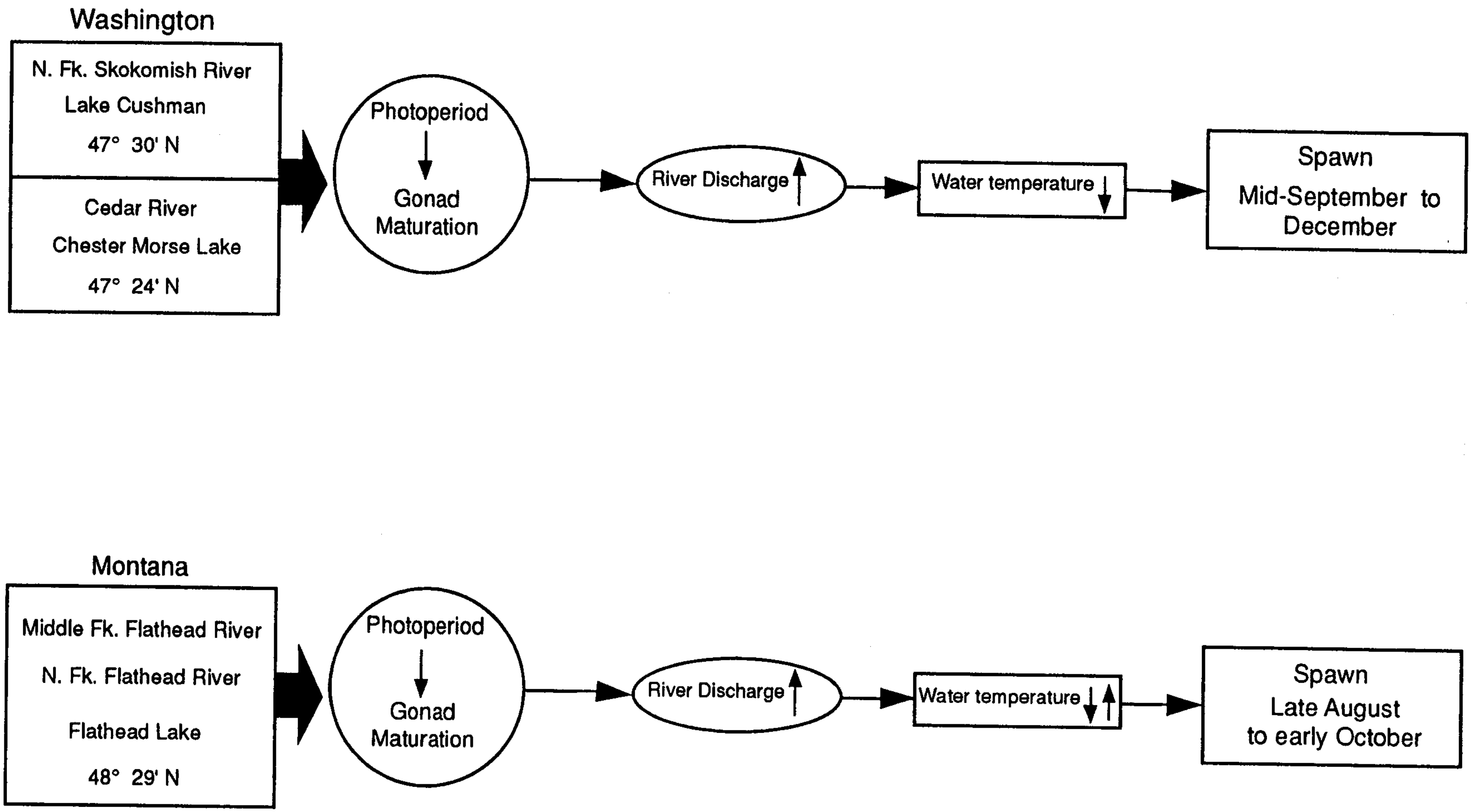
Washington
N. Fk. Skokomish River
Lake Cushman
47° 30' N
Cedar River
Chester Morse Lake
47° 24' N
Photoperiod
Gonad Maturation
River Discharge
Water temperature
Spawn
Mid-September to December
Montana
Middle Fk. Flathead River
N. Fk. Flathead River
Flathead Lake
48° 29' N
Photoperiod
Gonad Maturation
River Discharge
Water temperature
Spawn
Late August to early October

Figure 28

in Washington and Montana may be explained by the earlier seasonal occurrence of increased river flows in Montana (Figs. 25 and 27).

Reservoir conditions were not believed to initiate upstream migration of bull trout. In 1996, water temperatures were monitored from June to October in Lake Cushman. The reservoir was thermally stratified from June to September 1996 (Fig. 21) when bull trout inhabited the reservoir. In October, the temperature of the near-surface water declined and remained constant throughout the water column. These uniform temperatures in the reservoir coincided with adult bull trout moving upstream into the NFSR. Similar periods of thermal stratification and fall circulation occurred in Flathead Lake, Montana and Lake Billy Chinook, Oregon. However, in those reservoir and river complexes, upstream migration of bull trout occurred prior to fall circulation (personal communications, Jack Stanford, University of Montana and Scott Lewis, Portland General Electric). Consequently, the onset of migration of bull trout in those systems was likely not influenced by fall circulation.

Although river discharge was believed to stimulate upstream migration, declining water temperatures likely were the impetus for spawning in the NFSR Basin. Timing of river entry and the onset of spawning of bull trout have been associated with declining temperatures (Fraley and Shepard 1989). Despite differences in timing of the onset of reproduction in the river and Slate Creek, both systems exhibited drastic declines in water temperature prior to bull trout spawning (Figs. 19 and 20). Bull trout spawned in the river in October after temperatures dropped to 6.3°C, whereas declines in temperature and subsequent spawning occurred in November in Slate Creek. These results were consistent with findings in British Columbia, Montana, and Oregon where bull trout spawned when temperatures declined or were less than 9°C (McPhail and Murray 1979; Fraley and Shepard 1989; Ratliff 1992).

Temporal Shifts in Abundances of Bull Trout, Whitefish, and Cutthroat/Rainbow Trout:

From 1994 to 1996, distinct temporal segregation among bull trout, whitefish, and cutthroat/rainbow trout was observed in the NFSR upstream from Lake Cushman. Temporal changes in abundance of fish indicated that adult bull trout and adult whitefish remain temporally segregated in the river between May and December (Fig. 22). Generally, bull trout, whitefish, cutthroat/rainbow trout, and other salmonids exhibited different spawning periods in the NFSR (Appendix G).

Adult whitefish clearly were the most abundant salmonid in the river downstream of Staircase Rapids between May and September (Fig. 22), and adults presumably returned to the reservoir by September. Spawning migrations of whitefish in the NFSR occurred earlier than other whitefish populations in Alberta and Wyoming where fish spawned from September to November (Northcote and Ennis 1994). The return of whitefish to Lake Cushman occurred immediately prior to the upstream migration of bull trout.

As a result of temporal differences in migration between bull trout and whitefish, these two species reduce spatial overlap in the limited spawning habitats downstream of Staircase Rapids. Similarly, adult bull trout and whitefish co-occur in the reservoir during only four months of the year (January to April), and therefore, interspecific competitive interactions in Lake Cushman may be reduced. Sharp declines in abundance of whitefish that occurred in September of 1996 may be in response to the upstream movements of large lacustrine-adfluvial bull trout. Whitefish are an important food source for bull trout (Carl 1985; Fraley and Shepard 1989), and selective pressures resulting from predation and competition likely favor their return to the reservoir before migratory bull trout enter the river.

From April to September 1996, cutthroat/rainbow trout exhibited higher abundances than bull trout, but were less abundant than whitefish in the NFSR. Temporal shifts in abundances of cutthroat/rainbow trout were similar to those of whitefish with the exception being that drastic declines in abundance of cutthroat/rainbow trout occurred in October (Fig. 23). Interpretation of temporal changes in abundance of cutthroat/rainbow trout relative to other salmonids was less clear due to the likely presence of both migratory and non-migratory life history forms. Generally, resource partitioning between bull trout and cutthroat trout has been demonstrated in streams (Nakano et al. 1992), and the two species remain spatially segregated at the habitat unit scale (Pratt 1984). Information related to temporal segregation among bull trout, whitefish, and cutthroat/rainbow trout may be useful as agencies move from species management to community and ecosystem management.

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APPENDICES

Appendix A. WDFW annual fish stocking records of rainbow trout, cutthroat trout, and kokanee salmon at Lake Cushman from 1935 to 1989. Catchable trout are defined as 10 fish/pound or bigger, subcatchable trout are smaller than 10 fish/pound, and subcatchable kokanee are fry. Adopted from Hosey and Associates 1990.

Year	Subcatchable Rainbow Trout	Catchable Rainbow Trout	Subcatchable Cutthroat Trout	Catchable Cutthroat Trout	Subcatchable Kokanee Salmon
1935		5,000			
1936		11,000			40,000
1937					294,520
1938					140,000
1939		9,997			221,350
1940		11,788			203,000
1941		5,400			699,550
1942	11,767	7,497			800,048
1943	9,995				1,071,868
1944	46,021	9,994			974,581
1945	38,800				723,468
1946	25,040	18,796			919,950
1947					1,374,276
1948		19,559			865,258
1949		44,415			902,500
1950					379,972
1951					1,062,500
1952			1,300		969,062
1953					1,923,700
1954			60,905		600,000
1955					1,451,890
1956			4,956		1,201,200
1957					
1958			6,176		1,950,500
1959	3,900				3,991,968
1960					1,700,000
1961	383,845				860,000
1962	302,543				1,129,940
1963	92,758				900,560
1964	374,890				
1965	199,875		33,000		
1966	128,256	2,259	56,970		
1967	62,603	3,960	196,557		
1968	383,566		50,183		
1969	322,525	9,453	97,363	3,328	

(Appendix A, Continued). WDFW annual fish stocking records of rainbow trout, cutthroat trout, and kokanee salmon at Lake Cushman from 1935 to 1989. Catchable trout are defined as 10 fish/pound or bigger, subcatchable trout are smaller than 10 fish/pound, and subcatchable kokanee are fry. Adopted from Hosey and Associates 1990.

1970	255,444		196,406	146,910	
1971	101,864		15,012	117,871	
1972	120,630	8,500	15,902	19,243	
1973	424,610			73,790	
1974	60,434	3,515	109,044	72,344	
1975		7,003		67,782	
1976				10,897	
1977		7,002		75,893	1,629,320
1978				74,594	140,000
1979				37,630	
1980	21,105			50,500	
1981		6,000		36,216	
1982				44,809	
1983		16,631	10,200	13,334	120,640
1984					
1985				69,825	
1986	72,974		190,500		
1987			15,600	3,666	
1988			271,329	25,302	
1989			126,680		

Appendix B. Replicate snorkel counts comparing number of adult bull trout, adult whitefish, and cutthroat/rainbow trout in pass one versus pass two (1.6 rkm) in the North Fork Skokomish River. Day snorkel surveys conducted on July 11 and 13, August 13 and 27, and September 18, 1996.

Date	**Fish**	**Pass 1-Number of Fish in 1.6 km river section**	**Pass 2-Number of Fish in 1.6 km river section**
July 11, 1996		Duration=10:05-12:00	Duration=13:15-14:40
	Adult bull trout	6	7
	Adult whitefish	141	124
	Cutthroat/ rainbow Trout	48	38
July 23, 1996		Duration=10:35-11:50	Duration=13:00-14:20
	Adult bull trout	5	5
	Adult whitefish	199	168
	Cutthroat/ rainbow trout	61	74
August 13, 1996		Duration=11:30-13:10	Duration=14:30-16:10
	Adult bull trout	4	4
	Adult whitefish	121	136
	Cutthroat/ rainbow trout	97	133
August 27, 1996		Duration=11:10-12:50	Duration=14:30-16:20
	Adult bull trout	3	4
	Adult whitefish	102	100
	Cutthroat/ rainbow trout	104	122
September 18, 1996		Duration=12:15-13:10	Duration=13:55-15:00
	Adult bull trout	5	5
	Adult whitefish	39	28
	Cutthroat/ rainbow trout	27	33

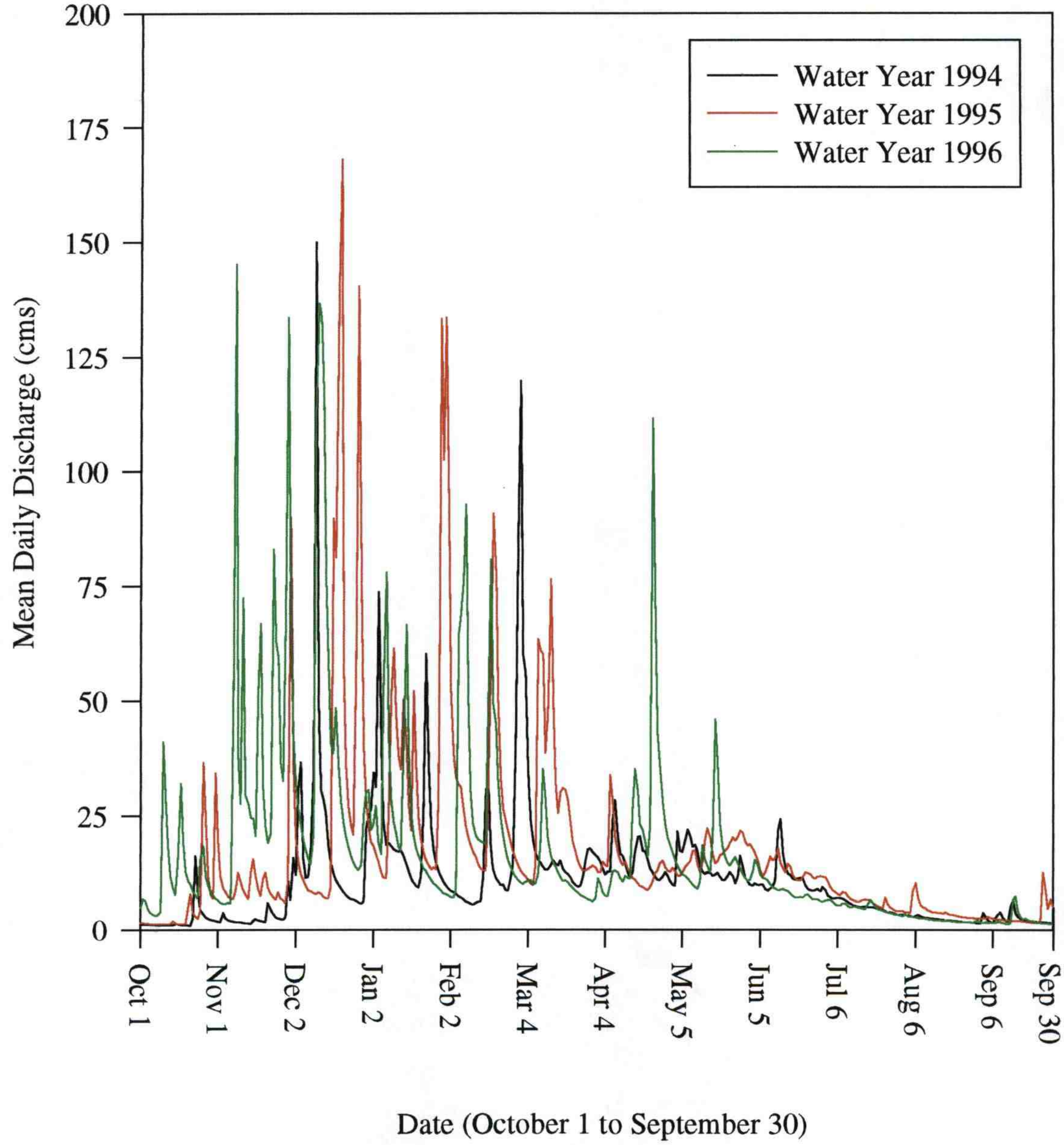
Appendix C. Estimated month of primary upstream migration and month of peak count of adult bull trout in the North Fork Skokomish River from 1985 to 1996. WDWF snorkel surveys approximately corresponds to river sections 2 to 5 in present study but also includes an additional section 6.

Date	Number of Bull Trout	Estimated Month of Primary Upstream Migration (1985-96)	Month of Peak Count	Agency and Method of Survey
9/18/85	3	September	September	WDW/Foot
9/20/85	4			WDW/Foot
9/26/85	0			WDW/Foot
10/31/85	0			ONP/Foot
11/20/85	0			ONP/Foot
10/9/86	0	November	December	WDW/Foot
10/23/86	0			WDW/Foot
11/3/86	7			WDW/Foot
12/4/86	11			WDW/Snorkel
9/25/87	4	October	October	WDW/Snorkel
10/30/87	14			WDW/Snorkel
9/30/88	120	September	October	WDW/Snorkel
10/7/88	101			WDW/Snorkel
10/20/88	152			WDW/Snorkel
8/22/89	5	October	November	WDW/Snorkel
9/22/89	3			WDW/Snorkel
10/18/89	32			WDW/Snorkel
11/22/89	174			WDW/Snorkel
12/15/89	22			WDW/Snorkel
9/27/90	6	October	November	WDW/Snorkel
10/8/90	55			WDW/Snorkel
10/24/90	222			WDW/Snorkel
11/7/90	299			WDW/Snorkel
9/25/91	242	September	October	WDW/Snorkel
10/10/91	243			WDW/Snorkel
10/29/91	299			WDW/Snorkel
11/12/91	0			WDW/Snorkel
10/2/92	108	September	October	WDW/Snorkel
10/21/92	285			WDW/Snorkel
11/10/92	251			WDW/Snorkel
11/24/92	29			ONP/Foot
11/1/93	~200-225	October	November	ONP/Foot
11/8/93	~253			ONP/Foot
11/15/93	~193			ONP/Foot
12/1/93	8			ONP/Foot

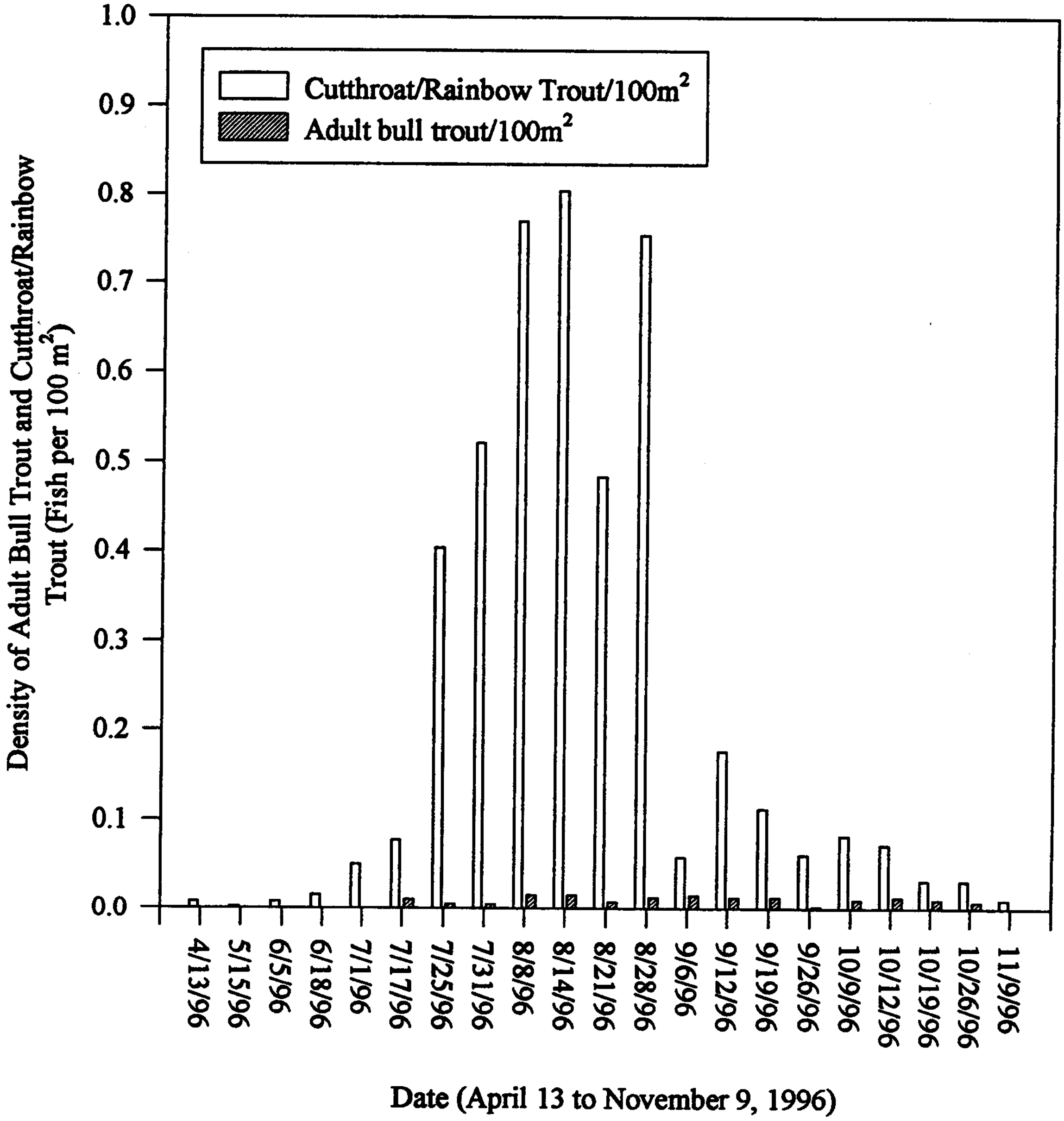
(Appendix C, Continued). Estimated month of primary upstream migration and month of peak count of adult bull trout in the North Fork Skokomish River from 1985 to 1996. WDWF snorkel surveys approximately correspond to river sections 2 to 5 in present study but also include an additional section 6. *River sections 1 to 5.

Date	Number of Bull Trout	Estimated Month of Primary Upstream Migration (1985-96)	Month of Peak Count	Agency and Method of Survey
6/20/94	3 *	October	November	ONP/Snorkel
7/12/94	5 *			ONP/Snorkel
8/16/94	7			ONP/Snorkel
9/15/94	11			ONP/Snorkel
10/24/94	238			WDFW/ Snorkel
11/10/94	246			ONP/Snorkel
6/29/95	5	October	October	ONP/Snorkel
7/27/95	6			ONP/Snorkel
8/23/95	16			ONP/Snorkel
9/13/95	10			ONP/Snorkel
10/19/95	152			ONP/Snorkel
4/13/96	1	October	October	ONP/Snorkel
5/15/96	6			ONP/Snorkel
6/5/96	3			ONP/Snorkel
6/18/96	7			ONP/Snorkel
7/1/96	4			ONP/Snorkel
7/17/96	8			ONP/Snorkel
7/25/96	7			ONP/Snorkel
7/31/96	7			ONP/Snorkel
8/8/96	11			ONP/Snorkel
8/14/96	13			ONP/Snorkel
8/21/96	9			ONP/Snorkel
8/28/96	11			ONP/Snorkel
9/6/96	11			ONP/Snorkel
9/12/96	12			ONP/Snorkel
9/19/96	22			ONP/Snorkel
9/26/96	4			ONP/Snorkel
10/9/96	122			ONP/Snorkel
10/12/96	162			ONP/Snorkel
10/19/96	182			ONP/Snorkel
10/26/96	250			ONP/Snorkel
11/9/96	60 (Low visibility)			ONP/Snorkel
11/23/96	213			ONP/Snorkel
12/7/96	185			ONP/Snorkel

Appendix D. Mean daily river discharge (cms) of North Fork Skokomish River for water years 1994 to 1996. Depicting similar patterns of high and low flow among years.



Appendix E. Density of cutthroat/rainbow trout and adult bull trout upstream of Staircase Rapids (section one) from April 13 to November 9, 1996. Whitefish were not found in river section one. November 9 was date of last survey in section one.



Appendix F. Bull trout identification using unweighted linear discriminant (0.63 x Branchiostegal Ray Number) + (0.18 x Anal Fin Ray Number) + (37.31 x Maxillary Length/Standard Length Ratio)] - 21.8 adopted from Haas and McPhail 1991. Bull trout have values > 0 and Dolly Varden have values < 0. Sample dates from September 27 to November 7, 1990 (unpublished files, WDFW 1990). * Maxillary Length/Standard Length.

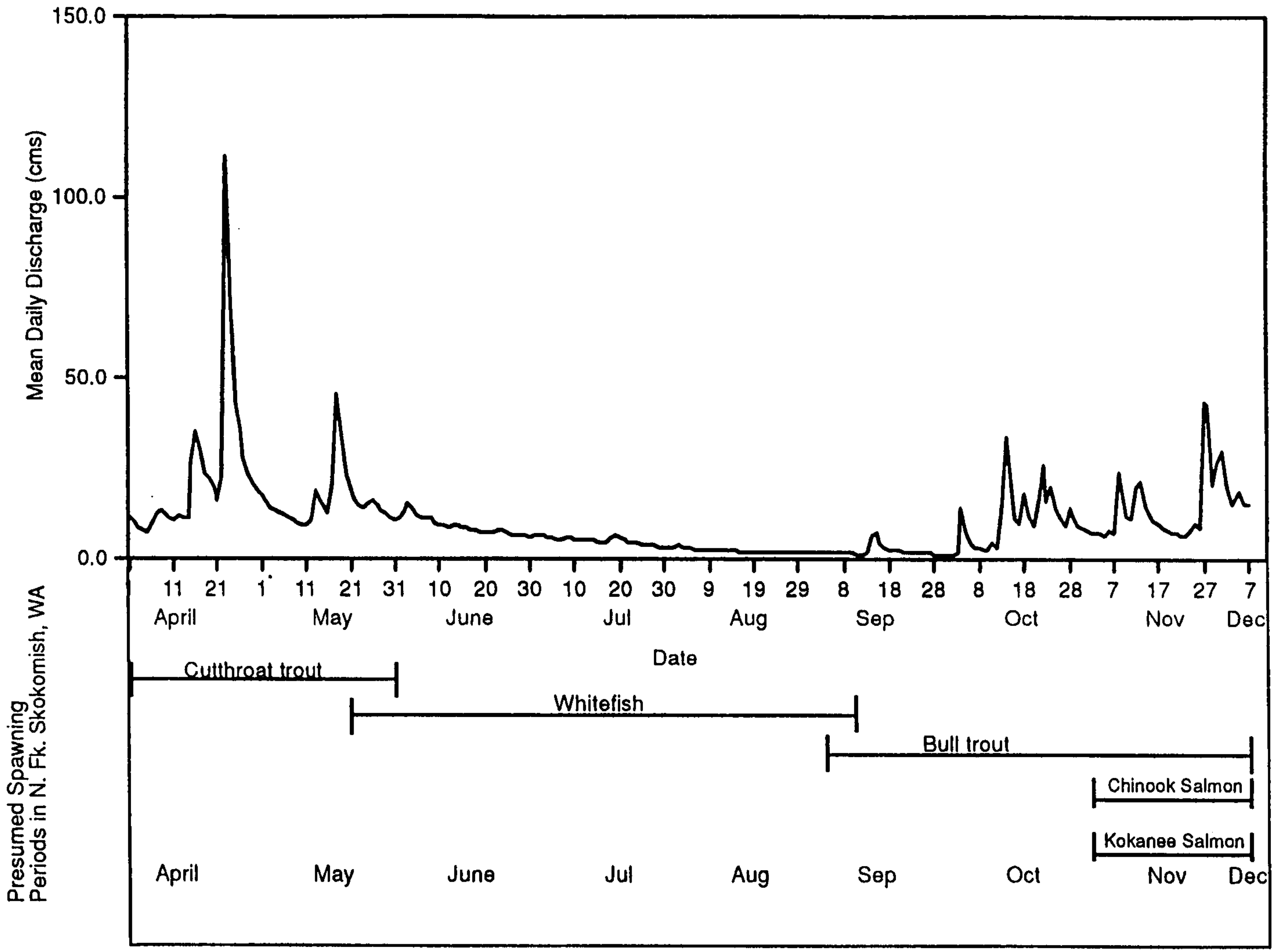
Date	Sex	# of Branchio-stegals	Anal Fin Rays	Maxillary Length (mm)ML	Standard Length (mm)SL	*ML/SL Ratio	Haas Value	Spp
10/24/90	F	25	9	71	521	0.136	0.65	Bull Trout
10/24/90	F	26	9	50	355	0.141	1.45	Bull Trout
10/24/90	F	26	10	93	638	0.146	1.82	Bull Trout
11/7/90	F	26	9	80	530	0.151	1.83	Bull Trout
10/8/90	F	27	10	72	515	0.140	2.23	Bull Trout
11/7/90	F	27	9	78	550	0.142	2.12	Bull Trout
10/24/90	F	27	9	110	755	0.146	2.27	Bull Trout
11/7/90	F	27	10	75	513	0.146	2.46	Bull Trout
10/24/90	F	27	10	81	550	0.147	2.50	Bull Trout
9/27/90	F	27	9	68	460	0.148	2.35	Bull Trout
11/7/90	F	28	9	69	506	0.136	2.55	Bull Trout
9/27/90	F	28	10	90	639	0.141	2.89	Bull Trout
11/7/90	F	28	10	70	480	0.146	3.08	Bull Trout
10/8/90	F	28	11	99	650	0.152	3.50	Bull Trout
10/24/90	F	28	9	109	715	0.152	3.15	Bull Trout
11/7/90	F	28	10	80	515	0.155	3.44	Bull Trout
10/24/90	F	29	10	69	499	0.138	3.43	Bull Trout

(Appendix F, Continued). Bull trout identification using unweighted linear discriminant (0.63 x Branchiostegal Ray Number) + (0.18 x Anal Fin Ray Number) + (37.31 x Maxillary Length/Standard Length Ratio)] - 21.8 adopted from Haas and McPhail 1991. Bull trout have values > 0 and Dolly Varden have values < 0. Sample dates from September 27 to November 7, 1990 (unpublished files, WDFW 1990). * Maxillary Length/Standard Length.

11/7/90	F	29	9	80	553	0.145	3.49	Bull Trout
10/8/90	F	29	9	86	563	0.153	3.79	Bull Trout
10/24/90	M	26	9	100	670	0.149	1.77	Bull Trout
10/24/90	M	26	10	75	480	0.156	2.21	Bull Trout
11/7/90	M	26	10	91	575	0.158	2.28	Bull Trout
10/24/90	M	26	10	95	585	0.162	2.44	Bull Trout
10/24/90	M	26	10	100	588	0.170	2.73	Bull Trout
10/24/90	M	27	10	83	520	0.160	2.97	Bull Trout
10/24/90	M	27	10	109	645	0.169	3.32	Bull Trout
10/24/90	M	27	10	107	613	0.175	3.52	Bull Trout
10/8/90	M	27	10	102	568	0.180	3.71	Bull Trout
10/24/90	M	28	9	114	663	0.172	3.88	Bull Trout
10/8/90	M	28	9	123	688	0.179	4.13	Bull Trout

Morphometric measurements and meristic counts were used to identify native char captured by hook-and-line in the NFSR (unpublished files, WDW 1990). These measurements and counts were taken by WDW employees on 30 native char captured between September 27 and November 7, 1990 and included measurements of maxillary and standard lengths and counts of branchiostegal rays and anal fin rays. An unweighted linear discriminant function (Haas and McPhail 1991) was later applied to identify each fish. Morphometric measurements, meristic counts, and genetic analysis also were conducted on 25 native char collected from the South Fork Skokomish River in 1995 (WDFW 1997).

Appendix G. Bull trout spawning period and presumed whitefish, cutthroat trout, chinook salmon, and kokanee salmon spawning periods in relation to river discharge in 1996.



Mean Daily Discharge (cms)
150.0
100.0
50.0
0.0
11 21 1 11 21 31 10 20 30 10 20 30 9 19 29 8 18 28 8 18 28 7 17 27 7
April May June Jul Aug Sep Oct Nov Dec
Date
Presumed Spawning Periods in N. Fk. Skokomish, WA
Cutthroat trout
Whitefish
Bull trout
Chinook Salmon
Kokanee Salmon
April May June Jul Aug Sep Oct Nov Dec