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Spawning Migration of Lacustrine-Adfluvial Bull Trout in a Natural Area

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Abstract.—We investigated the spawning migration of lacustrine-adfluvial bull trout *Salvelinus confluentus* in the North Fork Skokomish River in Olympic National Park (Washington State) during 1996. Day-snorkeling and electrofishing were conducted to determine timing and duration of the migration and the distribution and abundance of bull trout. The primary spawning migration began in early October and was waning by December. Bull trout migrated 6 km or less up the river from Lake Cushman. Increased river discharge and decreased water temperature appeared to be the primary environmental variables corresponding to the initiation of the migration. Mean length of migratory bull trout increased from June to December. Comparisons with other lacustrine-adfluvial bull trout populations in Oregon, Montana, Idaho, and British Columbia suggested that these populations exhibit specific migratory strategies related to local environmental conditions.

Bull trout *Salvelinus confluentus* were not taxonomically differentiated from closely related Dolly Varden *S. malma* until 1978 (Cavender 1978), and two decades after its description, bull trout were recognized to be at risk of local and regional extirpations (Rieman and McIntyre 1993). Substantial declines in distributions and abundances of this species were attributed to habitat degradation (Fraley and Shepard 1989; Rieman and McIntyre 1993), overfishing (Carl et al. 1989; Ratliff and Howell 1992), dams and irrigation projects (Rode 1990; Rieman and McIntyre 1993), and displacement by nonnative fish species (Markle 1992; Leary et al. 1993). On November 1, 1999, bull trout were listed as a threatened species in Puget Sound and coastal Washington (Federal Register 1999).

Although the majority of bull trout populations exhibit potamodromous life history patterns (Northcote 1997), anadromy has been suspected (Cavender 1978). Spawning-migration patterns across the range of this species include fluvial, fluvial-adfluvial, and lacustrine-adfluvial life histories (Northcote 1997). Lacustrine-adfluvial bull trout reside in lakes and reservoirs and emigrate to lotic systems to spawn. Spawning may occur either annually or in alternate years. Lacustrine-adfluvial bull trout attain the largest body size of the three potamodromous life history forms (Fraley and Shepard 1989; Ratliff 1992) and represent one of the largest bodied native salmonids inhabiting lakes and reservoirs in the Pacific Northwest.

In recent years, interest in the temporal and spatial variability of life history attributes within and among populations of potamodromous salmonids has been increasing (Rieman and McIntyre 1993; Gresswell et al. 1994, 1997). Although researchers have described life history characteristics of lacustrine-adfluvial bull trout (Fraley and Shepard 1989; Goetz 1989; Ratliff 1992), few have studied the environmental variables that influence the timing and duration of spawning migrations across the range of the species (Pratt 1992). Evidence suggests, however, that changes in river discharge, water temperature, and declining photoperiod coincide with spawning migrations by lacustrine-adfluvial bull trout (Fraley and Shepard 1989; Goetz 1989).

The goal of this study was to describe the migration of lacustrine-adfluvial bull trout in the wilderness area of the North Fork Skokomish River, Olympic National Park. Specific objectives were to (1) determine the time of initiation and duration of the spawning migration, (2) determine the distribution and abundance of bull trout in the river basin, and (3) assess if changes in river discharge and water temperature were correlated with the migration.

Study Area

The study area, the North Fork Skokomish River Basin, includes Lake Cushman (a reservoir) in

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Olympic National Forest and the river system upstream from the reservoir in Olympic National Park (Figure 1). The river (47°30′N, 123°22′W) flows in a southeasterly direction from its headwaters in the park to its confluence with the reservoir.

Lake Cushman was a small, natural, oligotrophic lake with a maximum depth of 61 m, but the completion of a dam in 1926 increased the size of the lake to 1,620 ha (maximum depth = 82 m). An additional dam was constructed downstream from the first dam in 1930. The dams, which are operated by Tacoma City Light, have prevented migration of fish between Puget Sound and the North Fork Skokomish River. The eastern and western shorelines of the reservoir have been developed for residential and recreational purposes (Brenkman 1998).

The river basin upstream from Lake Cushman drains 126 km^2 (Figure 1). Discharge is strongly influenced by rainfall in fall and early winter and snowmelt runoff in spring. During summer, river discharge is generally less than 10 m^3/s (Brenkman 1998). By mid-October, however, the frequency of mean daily discharges that exceed 10 m^3/s drastically increases (Figure 2).

From its headwaters (1,622 m elevation), the North Fork Skokomish River flows through forests of mature Douglas fir *Pseudotsuga menziesii* and western red cedar *Thuja plicata* to its confluence with Lake Cushman (225 m elevation). Steep montane topography in basaltic bedrock is associated with high-gradient tributaries in the upper basin. A waterfall in the river canyon near the confluence of Six Stream is also believed to be an impassable barrier to upstream fish migration (Figure 1; Eric Volk, Washington Department of Fish and Wildlife, personal communication).

Distinguishing bull trout and Dolly Varden inhabiting the Olympic Peninsula has been a difficult problem (Morton 1970; Mongillo 1992; Leary and Allendorf 1997). Recent results from genetic analyses, however, indicate that only bull trout inhabit the North Fork Skokomish River (Brenkman 1998).

Methods

Daytime snorkeling was conducted to determine relative distributions and changes in abundance and size distribution of bull trout in the North Fork Skokomish River. This technique is logistically feasible in a roadless area and is known to produce reliable and duplicable counts in large rivers (Northcote and Wilkie 1963; Schill and Griffith 1984; Thurow 1994). Furthermore, the large size of adult lacustrine-adfluvial bull trout makes it unlikely that an observer would miss counting individual fish during daylight hours.

The spawning migration of lacustrine-adfluvial bull trout was monitored by weekly snorkel counts conducted in the river from April 13 to December 7, 1996, between the confluence of Four Stream and Lake Cushman (river kilometer [rkm] 50.7 to rkm 45.1; Figure 1). The entire study area was snorkeled on each sampling date. 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 boundary of Olympic National Park (Figure 1). The portion of the river between sections one and two consisted of a series of rapids known as Staircase Rapids (Figure 1), which could not be snorkeled.

Before each snorkel survey, the diver assisting the author in this study was trained to estimate bull trout body lengths under water by viewing fish replicas of known lengths (Thurow 1994). During a survey, the two divers, one on each side of the river, proceeded downstream counting and estimating the total length of individual bull trout to the nearest inch (later converted to metric units). When fish occurred in large aggregations, however, only the number of fish was recorded. A two-sample Kolmogorov–Smirnov test was used to detect significant differences in length-frequency distributions of migrating bull trout from early (before October 9) and late surveys. October 9 was chosen as a reference point because it enabled comparison of length distributions of migratory bull trout before and after increased river flows (see below).

Electrofishing was conducted in the tributaries of the river throughout the basin from June 7 to August 26, 1996, to determine the presence of migratory and nonmigratory bull trout. Single-pass electrofishing was performed without block-nets (Brenkman 1998).

Daily discharge data for the North Fork Skokomish River from 1970 to 1996 were obtained from a stream gauge (number 12056500) located downstream of Staircase Rapids at an elevation of 232 m (U.S. Geological Survey, unpublished data). Daily fluctuations of water temperature (°C) in 1996 were recorded by data loggers (Onset Computer Corporation) placed in river section five and in Slate Creek.

Results

In 1996, adult lacustrine-adfluvial bull trout moved 6 km or less (sections 1–5) up the North Fork Skokomish River. Individuals also were ob-

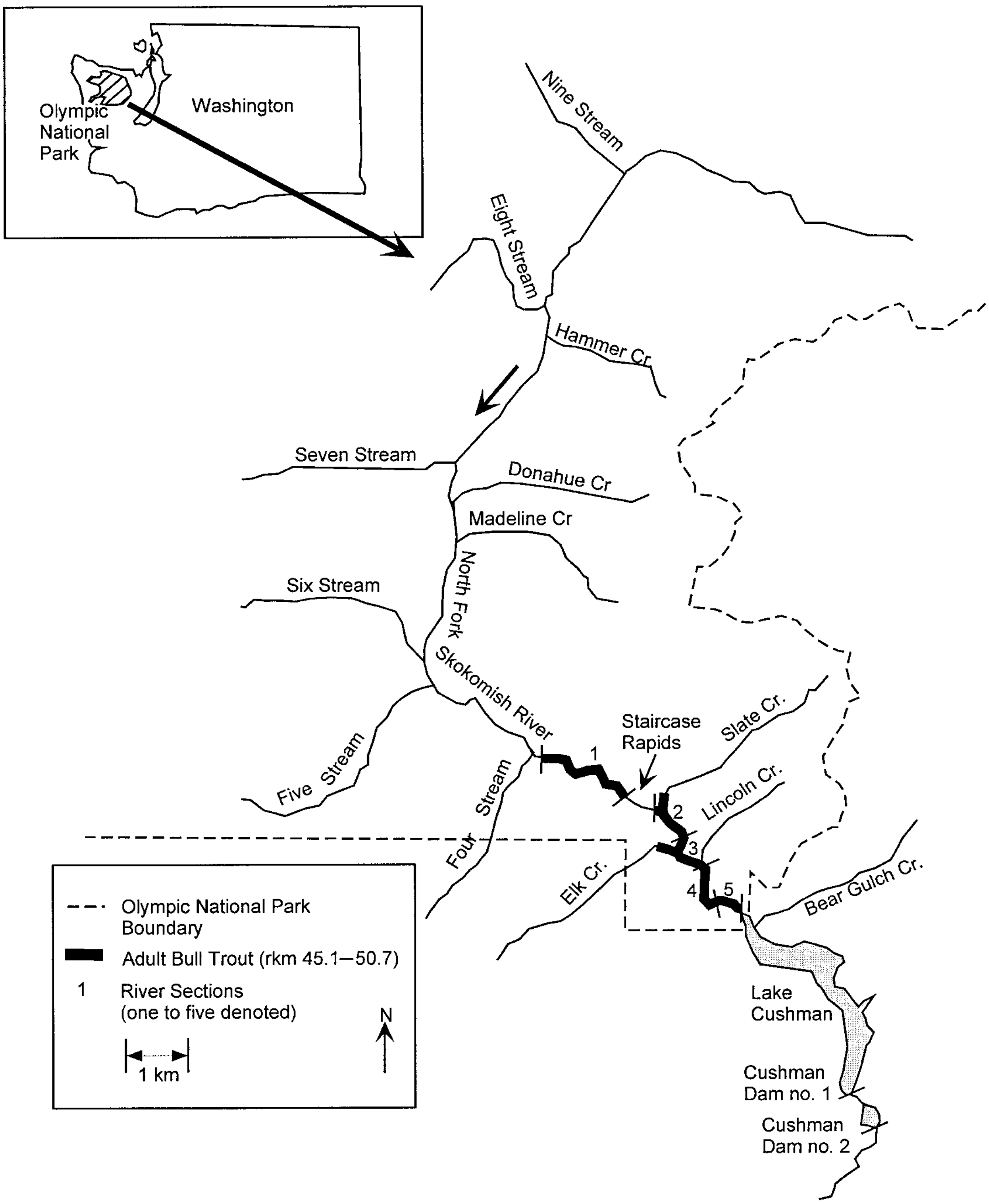

FIGURE 1.—Map of study area in the North Fork Skokomish River Basin, Olympic National Park, Washington, including location of sampling stations (1–5) and Staircase Rapids. The distribution of adult bull trout is also depicted.

served in the lower portions of Slate Creek and Elk Creek (Figure 1). No bull trout were observed in the basin upstream from section one (Brenkman 1998).

Bull trout were found in the study area during all of the snorkel surveys, but the numbers remained low until early October. On October 9, weekly counts increased to 122 adult bull trout,

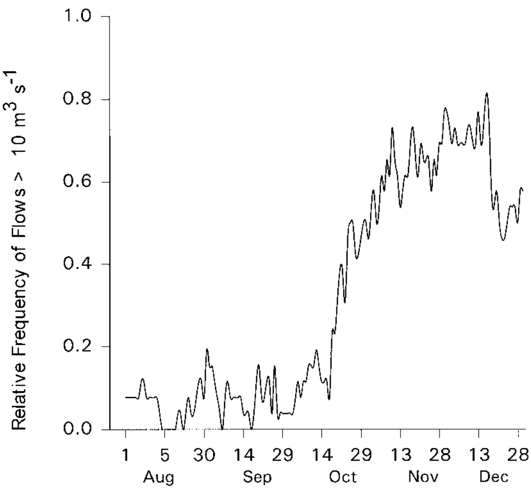

FIGURE 2.—Relative frequency of equaling or exceeding a river discharge of 10 m^3/s between August 1 and December 31 in North Fork Skokomish River (1970–1996).

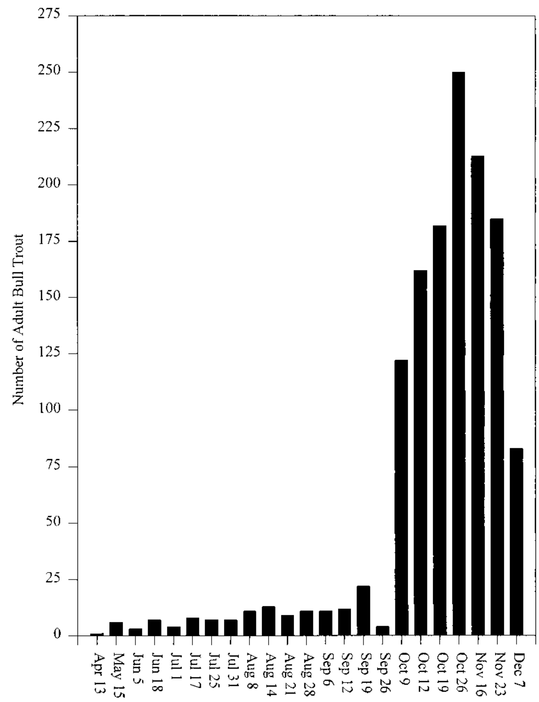

FIGURE 3.—Total number of adult bull trout in the North Fork Skokomish River sections 1–5 from April to December 1996.

and numbers peaked on October 26 (250 adult bull trout). During the period of peak abundance, most of the fish were located in section four (Brenkman 1998). The number of adults declined steadily in November and December. During the last survey (December 7), only 83 bull trout were present (Figure 3).

The mean total length of migratory bull trout in the North Fork Skokomish River was 55 cm (n = 283; range, 25–81 cm). The mean length of bull trout in the river between October 9 and December 7 was greater than those in the river before this period ($P < 0.05$; Figure 4).

From July 1 to October 2, 1996, the mean daily river discharge was 3.2 m^3/s (range, 1.3–7.4 m^3/s); during this period fewer than 22 bull trout were counted on any given sampling date. The increase in upstream migration of bull trout was associated with the sharp increase in discharge to 14.0 m^3/s on October 4 (8.5 times greater than on October 3; Figure 5). River discharge was variable but remained high during the remainder of the study.

During fall (October to December), river discharge was negatively correlated with water temperature (r = 0.748). Mean daily water temperature declined to 10°C when the migration of bull trout surged. Thereafter, water temperatures were less than 8°C (Brenkman 1998). Photoperiod also was decreasing during this period, and the peak count of bull trout in the river occurred when there were 10–11 h of daylight (Brenkman 1998).

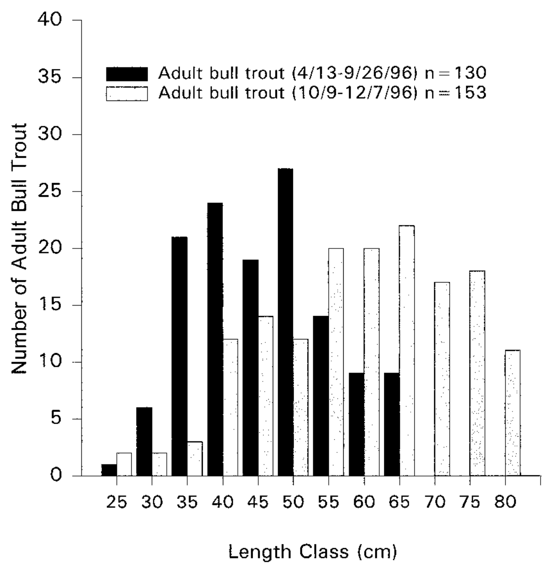

FIGURE 4.—Length distributions (cm) of early- and late-migrating adult bull trout. River discharge increased on October 4, 1996.

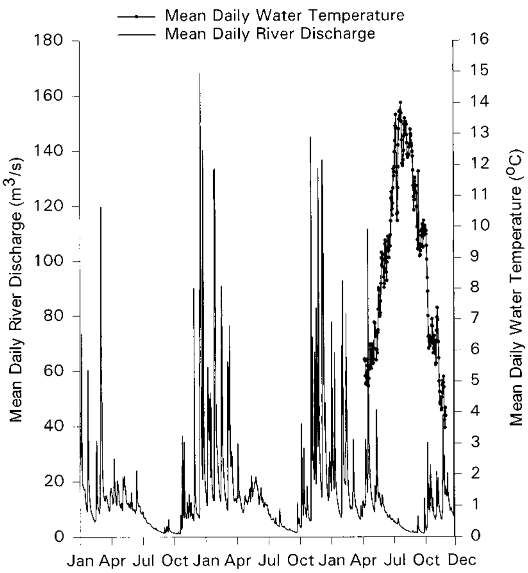

FIGURE 5.—Mean daily river discharge (1994–1996) and water temperature (1996) in the North Fork Skokomish River.

Discussion

Most of the bull trout observed in the North Fork Skokomish River in 1996 were putatively lacustrine-adfluvial individuals from Lake Cushman. Those fish in the river before the primary migration of lacustrine-adfluvial fish were probably early migratory lacustrine-adfluvial fish, but they may have been residuals or fluvial fish. Use of tributary streams by adult bull trout was minimal in that only a few fish were found in the lower sections of Elk Creek and Slate Creek.

A hierarchy of environmental cues stimulates fish migration in rivers (Northcote 1984; Jonsson 1991). For instance, the timing and duration of spawning migrations of fish are related to the interaction of gonad maturation (Henderson 1963) and physical factors such as changes in river discharge and water temperature (Northcote 1984). Thus, among-population variations in the timing and duration of lacustrine-adfluvial bull trout spawning migrations are probably related to local differences in environmental characteristics (Goetz 1989). As in the case of the North Fork Skokomish River lacustrine-adfluvial bull trout, the majority of bull trout spawners in Cedar River, Washington, migrate between October and early December (Edward Connor, Seattle City Light, personal communication). In contrast, migration occurs from April to early October in the Flathead River, Montana (Fraley and Shepard 1989); from May to October in the Metolius River, Oregon (Ratliff 1992; Thiesfeld et al. 1996); from June to late October in Mackenzie Creek, British Columbia (McPhail and Murray 1979); and from July to October in the South Fork Tieton River, Washington (WDFW 1998).

Timing of the primary spawning migration in October by lacustrine-adfluvial bull trout in the North Fork Skokomish River was correlated with increased river discharge. The increase in river discharge was associated with declining water temperatures. Similar decreases of water temperature have been observed during bull trout migrations in Mackenzie Creek, British Columbia (McPhail and Murray 1979).

Nevertheless, declining water temperature may not always be a factor influencing upstream migration of spawning bull trout. For instance, Swanberg (1997) found that migration occurred after water temperatures increased to 17.7°C in the Blackfoot River, Montana. At the Metolius River, Oregon, the bull trout migration appeared to be influenced by declining photoperiod because river discharge and temperature were stable throughout the year (Thiesfeld et al. 1996).

Bull trout in the North Fork Skokomish River attained larger lengths (up to 81 cm) than other bull trout populations in Olympic National Park (Brenkman 1998). Mean lengths of bull trout (55 cm) in the North Fork Skokomish River were comparable with those of bull trout in Idaho and Montana (average, 44–63 cm) and in the Metolius River (52 cm; Fraley and Shepard 1989; Pratt 1992; Riehle et al. 1997).

Differences in the timing of upstream migration between small and large bull trout may have been related to discharge in the North Fork Skokomish River. Generally, early migrating bull trout spawners entered the North Fork Skokomish River during periods of low flow rates and high water temperature, but larger fish entered at high river flows and low water temperatures. McPhail and Murray (1979) also found that the smallest and youngest bull trout entered Mackenzie Creek, British Columbia, during minimum streamflow conditions. Large female coho salmon *Oncorhynchus kisutch* entered streams at peak discharge, and smaller fish entered as discharge receded (van den Berghe and Gross 1989).

Differences in initiation and duration of the spawning migration among lacustrine-adfluvial bull trout populations appear to be adaptations to physical factors (Quinn and Adams 1996; Gresswell et al. 1997). Consequently, bull trout appear to exhibit specific migratory strategies related to local environmental conditions. An understanding and appreciation of the complexity and variation of the life histories of lacustrine-adfluvial bull trout will be essential to the establishment of appropriate management and conservation strategies.

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