Mackay, W.C., M.K. Brewin, and M. Monita. 1997.
Friends of the Bull Trout Conference Proceedings. 371 - 380.

Bull Trout Distributions Related to Temperature Regimes in Four Central Idaho Streams

Susan B. Adams[1] and Theodore C. Bjornn

Cooperative Fish and Wildlife Research Unit, University of Idaho
Moscow, Idaho 83843, USA

Abstractt - Bull trout *Salvelinus confluentus* distributions and water temperature regimes were studied in four streams of the Weiser River basin, Idaho, in 1992 and 1993. Bull trout occurred at elevations ranging from 1,472 m to 2,182 m and at densities up to 9.5 fish per 100 m^2. Bull trout were sympatric with rainbow trout *Oncorhynchus mykiss* in all streams and with brook trout *S. fontinalis* and brook trout x bull trout hybrids in two streams.

Summer temperatures were continuously recorded in 1992 and 1993. The 1993 temperature monitoring sites were at the upstream and downstream distribution limits of juvenile bull trout, the upstream limits of either the brook trout or the rainbow trout distribution, and six additional locations. Temperatures recorded from June through September 1993 varied from 0.8 to 18.2°C. In 1992, juvenile and adult bull trout were found in 20.5 °C water where no other species were present. Some bull trout occupied a cool water refugium, which may have been critical to their survival in one stream reach.

Cumulative temperature units were similar among the downstream distribution limits of bull trout in three of the four streams. Temperature units may be more indicative than maximum temperatures of the downstream limits of bull trout distribution. Apparently, summer water temperature is an important, but not singular, factor determining bull trout distributions in the Weiser River basin.

Temperature regimes in four central Idaho streams containing bull trout *Salvelinus confluentus* were characterized in relation to fish distributions in the summers of 1992 and 1993. We compared temperatures at the upstream and downstream distribution limits of bull trout within and amongst streams. We also compared temperatures at the limits of the bull trout distributions to those at the upstream distribution limits of brook trout *S. fontinalis* or rainbow trout *Oncorhynchus mykiss*, whichever species ranged the farthest upstream.

Bull trout are a cold water species that moved north and into higher elevations after the last glacial period (Power 1980; McPhail and Lindsey 1986; Donald and Alger 1993). Their current distribution extends from about 42° to 61° N latitude (Haas and McPhail 1991). Bull trout apparently decrease in abundance and in occurrence in the more southerly portions of their range (Haas and McPhail 1991). Maximum temperatures in which juvenile bull trout occur may vary but are usually below 18.0°C (Goetz 1989). Increasing temperatures were a factor in the elimination of bull trout from the lower reaches of the McCloud River, California, after construction of a dam (Cavender 1978; Rode 1989).

Identification of factors that limit a population's distribution is an essential first step in efforts to improve the status of the population. The streams we studied are located in the southern fifth of the historic bull trout range. We suspected, for three reasons, that temperature regimes limited bull trout distributions in the Weiser River basin. First, the likelihood that high summer temperatures limit bull trout distributions in the southern portion of the range is greater than it would be farther north. Second, 1992 maximum summer temperatures downstream of bull trout distributions in three study streams ranged from 17.2 to 20.6°C (Adams 1994) which are near or above the maximum temperatures at which bull trout normally occur (Shepard et al. 1984; Fraley and Shepard 1989; Goetz 1989; Buckman et al. 1992; Dambacher et al. 1992; Ziller 1992). Third, road construction, timber harvest and grazing in the study area have all contributed to losses in riparian canopy cover. Reductions in canopy cover can lead to increased stream temperatures and increased fluctuations in daily temperatures (Gibbons and Salo 1973).

Study Area

The Weiser River drainage has undergone considerable physical and biological alteration since the early 1900's. Historically, chinook salmon *O. tshawytscha* and steelhead trout *O. mykiss* used the basin for spawning and rearing. Although the construction of Brownlee Dam in 1958 eliminated anadromous fish from the Weiser Basin, smaller irrigation diversion dams on the Weiser River and its tributaries had already reduced runs in the basin (Parkhurst 1950). Before 1937, the lower end of the Little Weiser River was often completely dry in the summer (Parkhurst 1950). After 1937, low flows were maintained at the river mouth throughout the summer. Rainbow and brook trout have been stocked in many Weiser River basin streams. We suspect that all bull trout in the study area are now headwater residents. However, anecdotal reports of 50 cm bull trout in two of the streams in the 1950's (J. Morris, Indian Valley, Idaho, personal communication) suggest that fluvial bull trout once inhabited the streams.

[1] Current contact address: Flathead Lake Biological Station, University of Montana, 311 Bio Station Lane, Polson, Montana 59860, USA.

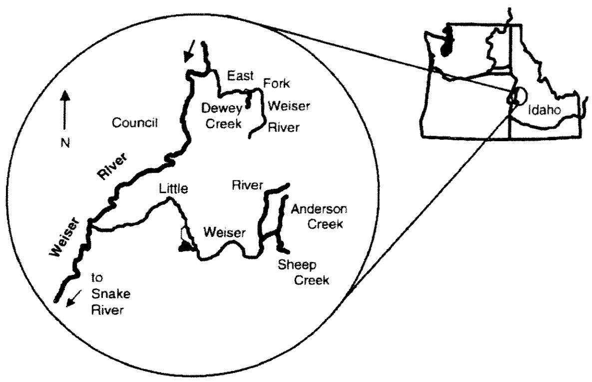

Figure 1. Weiser River basin, Idaho, including the four study streams: Little Weiser River, Anderson Creek, Sheep Creek and Dewey Creek.

The Weiser River flows into the Snake River upstream from Brownlee Dam in west, central Idaho (Figure 1). The four study streams lie on the east side of the Weiser River Basin in the Payette National Forest (PNF). Anderson and Sheep creeks are in the Little Weiser River basin. Dewey Creek flows into the East Fork Weiser River. The study area extended from 44° 30' to 44° 48' north latitude. Study site elevations ranged from approximately 1,250 m at Big Flat Campground to 2,262 m near the headwaters of the Little Weiser River. The streams lie primarily in Columbia River Basalt land types, but the headwaters of Anderson Creek and the Little Weiser River are composed of Idaho Batholith granitics. Land uses in the study area included timber harvest and concomitant road construction, sheep and cattle grazing, and recreation.

The streams flow through a variety of terrain and vegetation. The Little Weiser River and Anderson Creek parallel each other, originating from springs on an open grassy ridge and flowing into forested canyons. Roads are adjacent to portions of the streams, and clearcuts with stream buffers exist in both drainages. Sheep Creek originates in a forested area. Approximately half way down its length, Sheep Creek flows through a 0.6 km long, open meadow. The low gradient, meadow stream reach was a unique site in the study area. Unstable, sloping banks, a widened stream channel and lack of riparian canopy cover allowed more solar radiation into the stream here than in most other reaches. Historic and current cattle grazing is presumably the cause of the altered channel morphology and the lack of riparian vegetation.

Dewey Creek begins as multiple, small, spring-fed channels. The headwaters were logged, and in places clearcut across the stream. Four closed logging roads traverse the headwater spring areas, and in 1993 at least 13 malfunctioning culverts diverted water from or introduced sediment to the stream channels. Downstream of the clearcuts, Dewey Creek flows through a forested area with buffer zones along the road and the logged areas. Dewey Creek is smaller than the other three streams. The predominant instream cover is woody debris, as opposed to the cobble/boulder substrate cover abundant in the Little Weiser River basin streams.

Methods

Fish densities and distribution limits were estimated by snorkeling. We snorkeled Anderson and Sheep creeks in 1992 and confirmed the fish distribution limits in 1993. The Little Weiser River and Dewey Creek were snorkeled in 1993. Most snorkeling was conducted during daylight periods when water temperatures ranged from 9.0 to 18.0°C. Exceptions included three days of snorkeling in the Little Weiser River when water temperatures were below 7.5 °C and all snorkeling in Dewey Creek where water temperatures were between 6.0 and 9.0°C. We chose 9.0°C as the minimum temperature for daytime snorkeling based on observations of bull trout hiding behavior and information from R. Thurow (later published in Thurow 1994). In Dewey Creek, where temperatures never exceeded 10°C in 1993, no differences in bull trout hiding behavior were observed at water temperatures between 6.0 and 10.0°C. Snorkel counts of bull trout were as effective in the day as at night; in both Dewey Creek and the Little Wieser River; water temperatures during the comparisons ranged from 6.0 to 12.5°C in the day and from 5.5 to 9.5°C at night (Adams 1994).

In Anderson and Sheep creeks, subsets of all stream habitats were snorkeled throughout the length of each stream. In Dewey Creek, every fifth pool was snorkeled throughout the stream. In the Little Weiser River, bull trout distribution limits were found by snorkeling every fifth pool near the expected distribution limits. Additional habitat units were snorkeled near the suspected distribution limits of each species in all four streams to ensure that the actual limits were identified. All distributions were determined for fish less than approximately 150 mm total length; the most upstream and downstream sightings of bull trout less than 150 mm marked the limits of the relatively continuous distributions of bull trout in all study streams. Contiguous stream reaches were delineated based on channel type, migration barriers, major tributaries, and angler accessibility.

Temperatures were recorded at four locations in 1992 and at 18 in 1993 (Figures 2 and 3). During the summer of 1992, three Omnidata Datapod 112's and one Ryan Tempmentor recorded hourly temperatures near the upper road access in each study stream. In 1993, Omnidatas recorded hourly temperatures at the 1992 locations in all streams except Dewey Creek. Also in 1993, Hobo-Temp-XT miniature temperature loggers recorded temperatures every 48 minutes at the upstream and downstream limits of bull trout less than approximately 150 mm and at the upstream limits of rainbow or brook trout, whichever extended the farthest upstream (Figures 2 and 3). The temperature recording locations at fish distribution limits were selected after snorkeling was completed. We placed additional Hobo-Temps immediately upstream and downstream of Sheep Creek meadows. A Hobo-Temp at the PNF boundary on the Little Weiser River recorded temperatures every 1.6 hours.

Daily maximum, minimum and mean temperatures were calculated for each site. Cumulative temperature units were calculated by summing the average daily temperatures, in degrees Celsius, over a given time period. The time periods chosen for each comparison were based on availability of data for the sites. Because some data were missing due to high spring flows and technical difficulties, temperature comparisons were not made throughout the entire summer. We had data for at least one site in each stream from July 16 to September 29, 1993. Consequently, we were confident that our comparisons included the warmest temperatures of the summer, but not the entire peak temperature period. All comparisons made over longer intervals than those reported here corroborated the reported results.

Results

Species Composition and Distribution

We observed six fish species as well as bull trout x brook trout hybrids (hereafter referred to as hybrids) and tailed frogs Ascaphus truei in the study area. Bull trout were sympatric with rainbow trout in all four study streams and with brook trout and hybrids in Dewey Creek and the Little Weiser River (Figures 2 and 3). We visually distinguished among the chars with 94 percent accuracy (Adams 1994). Mountain whitefish Prosopium williamsoni and two sculpin species Cottus sp. resided downstream of the chars in the Little Weiser River and Anderson Creek. Tailed frogs ranged throughout most of the area inhabited by bull trout in the three Little Weiser River basin streams.

The distribution of species relative to one another was similar among streams. In both streams where they resided, brook trout extended farther downstream than bull trout. Hybrids existed wherever the two species were sympatric. In the Little Weiser River, brook trout extended upstream almost as far as rainbow trout. In Dewey Creek, brook trout extended upstream slightly farther than rainbow trout. Bull trout occoured farther upstream than any other fish species in all four streams.

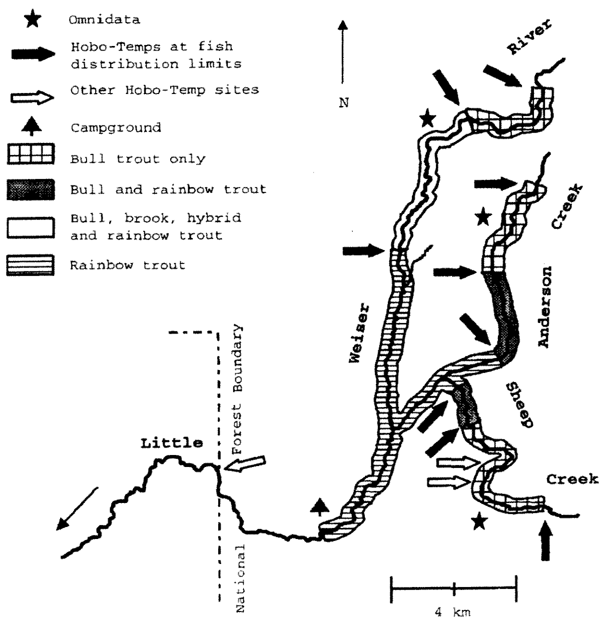

Figure 2. Temperature recording sites and salmonid distributions in the Little Weiser River basin, Idaho, study streams. Distributions shown are for fish less than 150 mm total length. Omnidata and Hobo-Temp continuous temperature recorder sites are shown. Black arrows indicate Hobo-Temps at fish distribution limits. White arrows along Sheep Creek are the meadow Hobo-Temp sites. The white arrow on the Little Weiser River is the Payette National Forest boundary Hobo-Temp site. The uppermost portion of each stream was devoid of fish.

Table 1. Densities of bull trout and of all fishes in pools and in all habitat types for segments of streams occupied by bull trout less than 150 mm total length. Percent of all fish that were bull trout is shown.

Stream	Habitat type	Densities(fish/100 m2)		Percent bull trout
		Bull trout	All fishes	
Anderson	pools	8.2	12.2	67.5
	all	5.7	9.0	63.8
Sheep	pools	8.6	12.0	71.7
	all	5.6	7.9	71.5
Dewey	pools	3.0	4.3	

The uppermost section of each stream contained no fish. A waterfall was a migration barrier at the upstream bull trout limit in Anderson Creek. A culvert created a migration barrier lower in Anderson Creek, but bull trout densities were the same for 100 m upstream and downstream of the culvert. In Dewey Creek, a culvert marked the upstream limit of bull trout, but may not have been a migration barrier.

Bull trout densities (number/100 m^2) calculated by reach ranged from 0.0 to 9.5. Fish densities in the section of stream occupied by bull trout less than 150 mm were calculated for three streams (Table 1). Densities of bull trout in Anderson and Sheep creeks were more than 2.5 fold greater than the densities in Dewey Creek. Densities were not estimated in the Little Weiser River, but based on snorkeling observations, we suspect that densities were similar to those in Anderson and Sheep creeks.

Elevations and stream widths varied among the downstream and among the upstream bull trout distribution

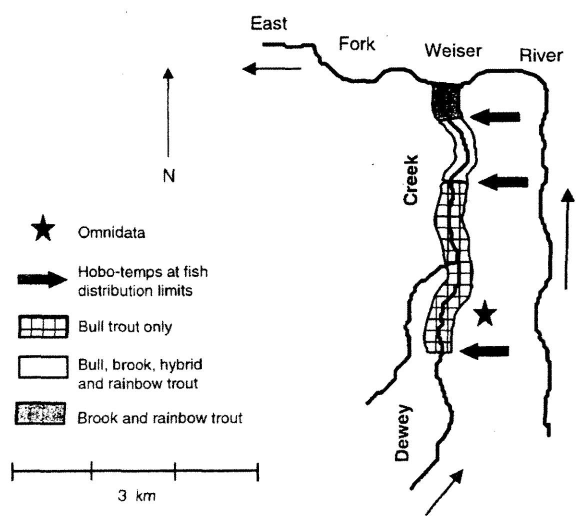

Figure 3. Temperature recording sites and distributions of fishes less than 150 mm total length in Dewey Creek, Idaho. Omnidata and Hobo-Temp continuous temperature recorder sites are shown.

limits. Elevations where bull trout occurred ranged from 1,472 m in Sheep Creek to 2,182 m in the Little Weiser River (Figure 4). Dewey Creek, which had the lowest bull trout densities, also had the narrowest range of elevations sustaining bull trout. Average stream widths within 200 m of bull trout distribution limits varied from 2.4 to 4.5 m (Table 2). Stream width did not correlate with summer stream discharge and did not appear to determine downstream distribution limits, although it could be a factor.

Temperature

In 1992, the study streams had exceptionally low spring flows. In 1993, high spring flows preceded a cool, rainy summer. Average daily temperatures at Omnidata recorder sites were warmer overall in the summer of 1992 than in 1993, although for some dates, temperatures were higher in 1993. During 52 summer days, Anderson Creek and Sheep Creek had 23 and 33 more temperature units, respectively, in 1992 than in 1993. The warmest week of 1992 was not included in the interval due to missing data in 1993.

Maximum daily temperatures recorded where bull trout were found between August 1 and September 29, 1993 ranged from 3.6 to 18.2°C, the latter occurring in Sheep Creek meadows. Minimum temperatures during the period varied from 0.8 to 10.8°C. Daily temperature fluctuations ranged from 0.8 to 10.6°C per day, with the greatest fluctuations occurring in Sheep Creek meadows. Peak temperatures occurred between August 4 and August 21.

Reporting only maximum temperatures can give a one-dimensional view of stream temperature regimes. For example, maximum daily temperatures in Dewey Creek were highest at the upstream site, but minimum temperatures indicate that the upstream site was the coolest site (Figure 5). The upstream site had slightly cooler average daily temperatures than the other sites.

Comparisons of average daily temperatures among sites can be confused by changing relationships among the sites over time. In 1993, the middle Little Weiser River site had higher average daily temperatures than the upstream site until September 22, when the relationship reversed. In order to overcome this difficulty, we compared cumulative temperature units among sites. In Dewey Creek, the upstream site had the fewest and the downstream site had the most temperature units accumulated over 47 days from August 14 to September 29, 1993 (Figure 6).

The temperatures at the downstream sites in all four streams provide another example of the utility of temperature units. Maximum daily summer temperatures at downstream sites in 1993 were similar among the Little Weiser basin streams, but were much lower in Dewey Creek (Figure 7). The Little Weiser River site had maximum daily temperatures that were approximately 2°C warmer than the Sheep Creek site. If temperatures at the Little Weiser River site were consistently 2°C warmer than at the Sheep Creek site, we would expect that over 47 days, the former site would have 94 more temperature units than the latter site. However, temperature units at the two sites were similar despite different maximum temperatures; the

Table 2. Average stream widths within 200 m of the upstream and downstream bull trout distribution limits and of the upstream brook or rainbow trout distribution limits. Widths in Dewey Creek are for pools only.

	Stream width (m)		
Stream	Upper bull trout limit	Upper brook or rainbow limit	Lower bull trout limit
Little Weiser	3.0	4.5	4.2
Anderson	2.4	3.8	4.0
Sheep	2.7	4.2	4.0
Dewey	2.8	4.0	4.0

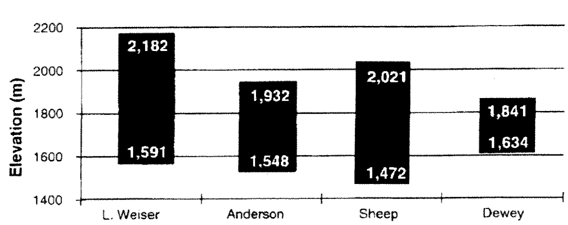

Figure 4. Elevation ranges where bull trout less than 150 mm occurred in the summers of 1992 and 1993. White numbers indicate elevations at bull trout distribution limits.

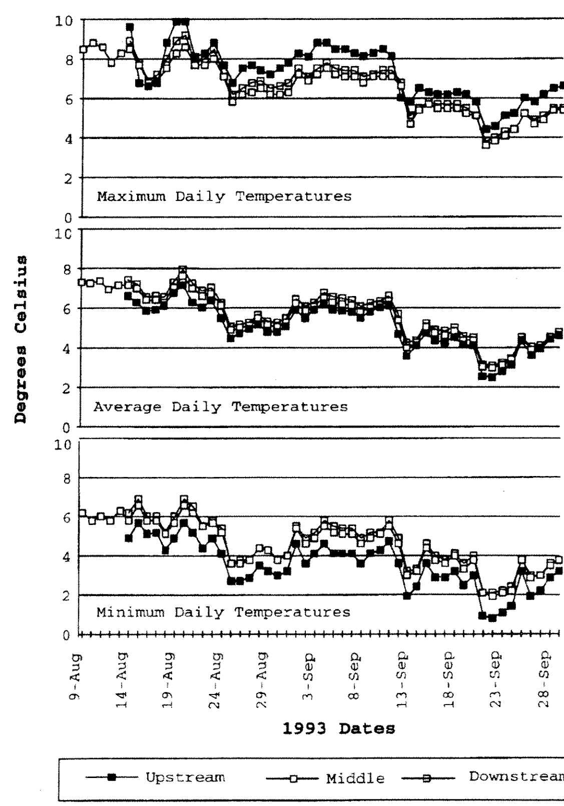

Figure 5. Maximum, minimum and average daily temperatures at the upstream and downstream bull trout limits and the upstream brook trout limit (middle site) in Dewey Creek from August 9 to September 29, 1993.

downstream Little Weiser River site had only 6 more temperature units than the downstream Sheep Creek site over 47 days (Figure 8). The Little Weiser River had a slightly larger range of daily temperatures and had steeper thermal peaks than Sheep Creek (Figure9).

If high summer temperatures determine the downstream distribution limits of bull trout, we would expect to find similar temperatures at the downstream distribution limits in each stream. Since the downstream sites in the Little Weiser River, Anderson Creek and Sheep Creek had similar temperature units but different elevations, stream widths, and species compositions, we conclude that temperature units may be a primary determinant of the downstream bull trout distribution limits in those streams. The downstream Dewey Creek site, however, had 123 fewer temperature units than the downstream Little Weiser River site. Therefore, temperature apparently did not determine the downstream distribution limit of bull trout in Dewey Creek.

Temperatures at the middle and upstream sites were not as clearly indicative of fish distribution limits as at the downstream sites. Temperature units at the upstream distribution limits of bull trout were similar among the four streams, with Dewey Creek slightly cooler. The upstream distribution limits, however, could also be a function of other factors such as stream size and migration barriers (as in Anderson and possibly Dewey creeks). The temperature units at the middle sites in the Little Weiser basin were less similar, suggesting that temperature did not determine the upstream limits of rainbow trout there.

Age 0, juvenile and adult bull trout were present in the upstream end of Sheep Creek meadows when the water temperature, measured at bull trout focal points, was 20.5°C on

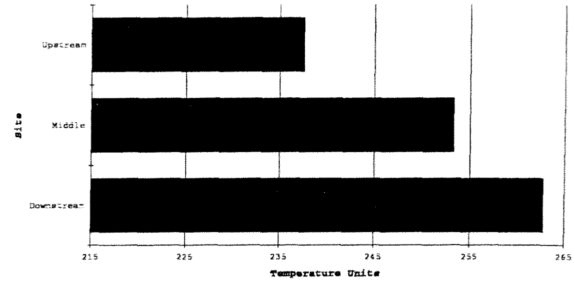

Figure 6. Temperature units for 47 days from August 14 to September 29, 1993 at fish distribution limits in Dewey Creek.

at least three hot summer afternoons in 1992. In 1993, the downstream meadow site had higher maximum daily temperatures (Figure 10) and more temperature units than any other temperature recording site where bull trout occurred (Figures 8 and 11).

Surface water temperatures in the downstream end of the meadow were often approximately 2°C warmer than those recorded by the Hobo-Temp, which was several meters downstream of the meadow. A group of adult bull trout held in a 1.2 m deep pool at the downstream end of the meadows throughout the summer and fall of 1992 and 1993. When the surface water in the pool was 20.5°C, the temperature at 1 m depth was 17.0°C due to colder groundwater entering the pool. Bull trout remained in the cooler water near the bottom of the pool. Two factors distinguished the meadow site from the downstream bull trout distribution limit sites, which had the next warmest temperatures; first, in the meadow, bull trout were the only fish species present, and second, the meadow

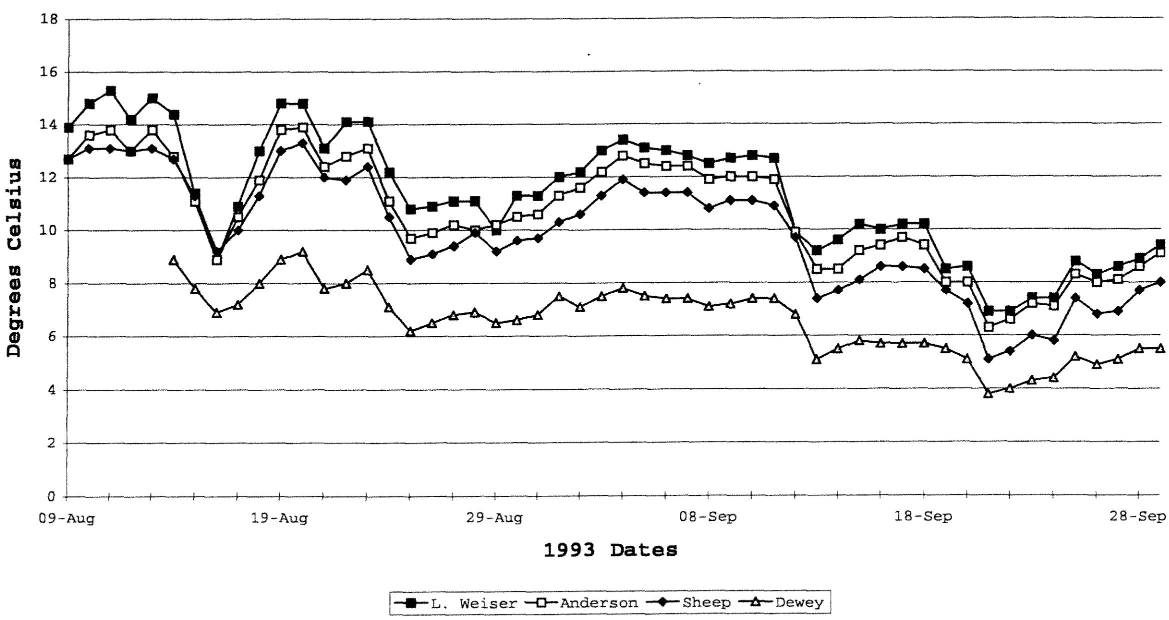

Figure 7. Maximum daily temperatures at the downstream limits of bull trout distributions in each stream from August 9 to September 29, 1993.

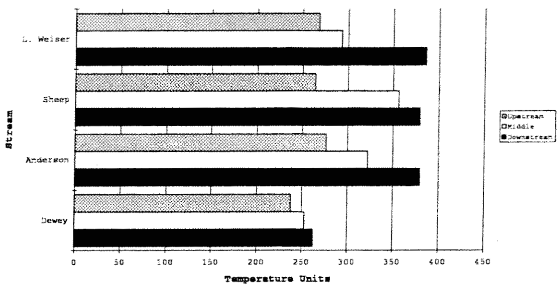

Figure 8. Temperature units for 47 days from August 14 to September 29, 1993, at the limits of fish distributions in all four streams.

reach had a low gradient.

Temperature units increased rapidly from the upstream to downstream ends of the meadow. From the upstream bull trout limit in Sheep Creek heading downstream, temperatures: increased in the narrow, somewhat exposed, high gradient channel; increased more rapidly in the slow flowing, exposed, low gradient channel in the meadows; decreased in the narrow, high gradient channel downstream of the meadows; and slowly increased downstream towards the PNF boundary. The change in temperature units per stream km from the upstream distribution limit of bull trout in Sheep Creek to the PNF boundary on the Little Weiser River illustrates the rate of warming in the various stream sections (Figure 12). The rate of warming in the meadow was 2.5 times higher than in any other section of the creek.

The temperatures in the meadows and at the PNF boundary provide another example of the different conclusions, regarding the relative warmth of two sites, that can be reached depending on whether maximum temperatures or temperature units are compared. The maximum temperatures in the meadows were as high as those in the Little Weiser River at the PNF boundary, 12.4 km downstream of the lower bull trout limit in Sheep Creek (Figure 10). However, at the PNF boundary 135 more temperature units accumulated than at the lower meadow site in Sheep Creek during 52 days.

Low minimum daily temperatures may have allowed the bull trout at the upstream end of Sheep Creek meadows to tolerate high maximum daily temperatures. While the minimum daily temperatures in the meadows rarely exceeded 8°C in 1993, minimum temperatures at the PNF boundary often exceeded 10°C and occasionally exceeded 12°C (Figure 13). The minimum daily temperatures at the PNF boundary were higher than the minimums at any site containing bull trout. The cool water at night throughout the meadows and the cool water refugia at the downstream end of the meadow, are likely the critical factors that allowed bull trout to persist there.

Discussion

The various measures used to assess temperature regimes each reflect different aspects of the influence that temperature can have on biological systems. Maximum daily temperatures, if high enough for a long enough period, may cause fish to emigrate or die. Lethal temperature limits vary depending on the duration of exposure and the acclimation temperature of the fish (Power 1980). Minimum temperatures and the duration of maximum temperatures apparently influence the summer distribution of westslope cutthroat trout (*O. clarki lewisi*) (Hunt 1992). Temperature units represent an accumulation of the temperature history over a given time and may influence

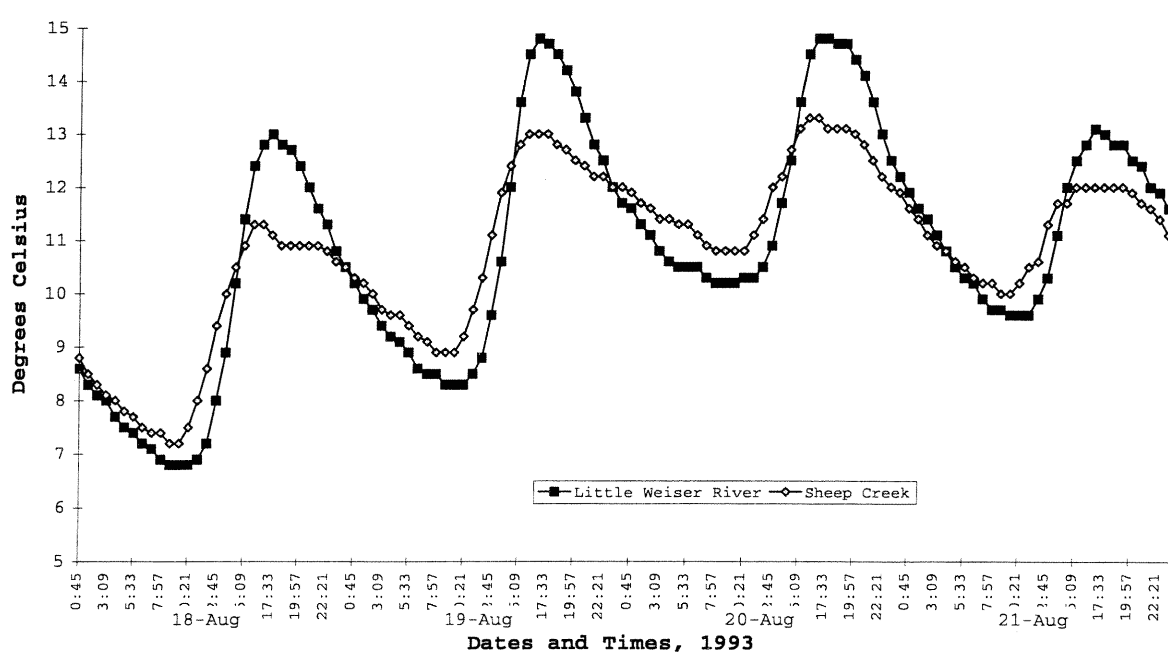

Figure 9. Temperatures recorded every 48 minutes from August 18 to 21, 1993, at the downstream bull trout distribution limits in the Little Weiser River and Sheep Creek.

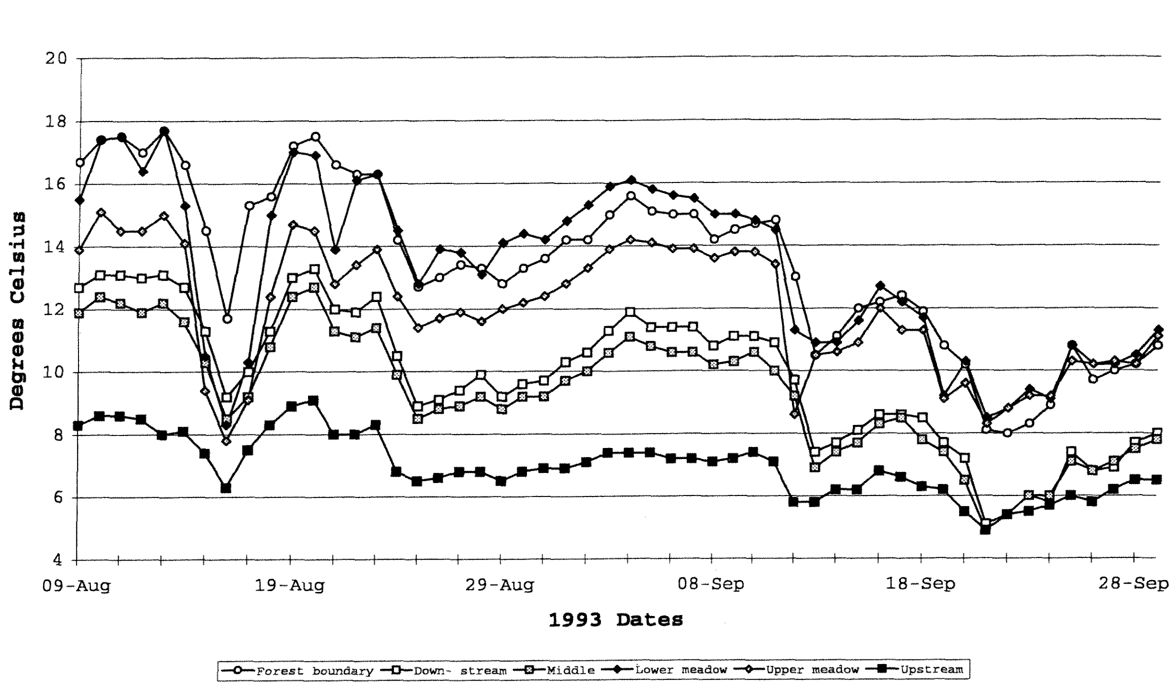

Figure 10. Maximum daily temperatures at the five Sheep Creek temperature recording sites and downstream at the Payette National Forest (PNF) boundary site on the Little Weiser River. No bull trout were present at the PNF boundary.

development, metabolic rates, growth, condition and behavior of fish, as well as disease prevalence and food availability (Gibbons and Salo 1973). Temperature units apparently influenced the downstream distribution limits of bull trout in the study streams. Maximum temperatures and temperature units are both likely to have biological significance for bull trout, and should thus both be examined in a complete temperature evaluation. The physiological and behavioral effects of extreme temperatures and temperature fluctuations on bull trout are relatively unknown. Some bull trout lived in the upstream end of Sheep Creek meadows where they were exposed to daily temperature fluctuations exceeding 10.5°C.

We could not determine what factors likely influenced the downstream limit of bull trout in Dewey Creek. Temperatures at the downstream bull trout distribution limit in Dewey Creek were cooler than what bull trout tolerated with the same species composition in the Little Weiser River. Temperatures did not increase between the downstream limit of bull trout and the mouth of Dewey Creek; therefore, high temperatures probably did not prevent bull trout from utilizing the lower section of Dewey Creek. Gradient and stream width were also similar between the mouth and the downstream bull trout limit. Rieman and McIntyre (1995) found that within occupied habitat patches, neither gradient nor stream width (greater than 2 m) explained much of the distribution pattern of bull trout among reaches.

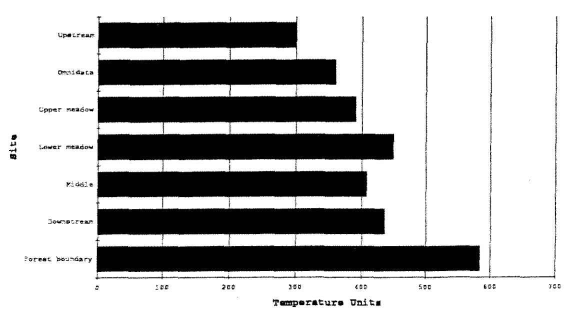

Figure 11. Cumulative temperature units for 52 days, from August 9 to September 29, 1993, at all Sheep Creek temperature recording sites and downstream at the Payette National Forest (PNF) boundary site on the Little Weiser River. No bull trout were present at the PNF boundary.

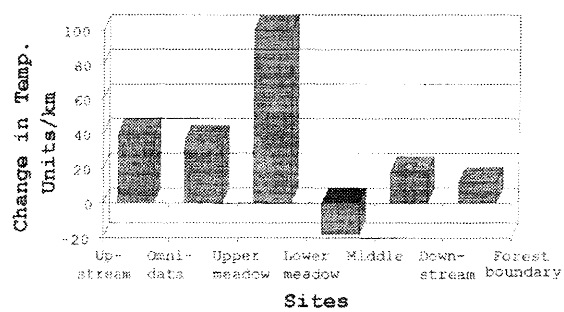

Figure 12. Change in cumulative temperature units per km between temperature recording sites, starting at the upstream Hobo-Temp site in Sheep Creek and proceeding downstream to the Payette National Forest boundary in the Little Weiser River. Temperature units are cumulative from August 9 to September 29, 1993.

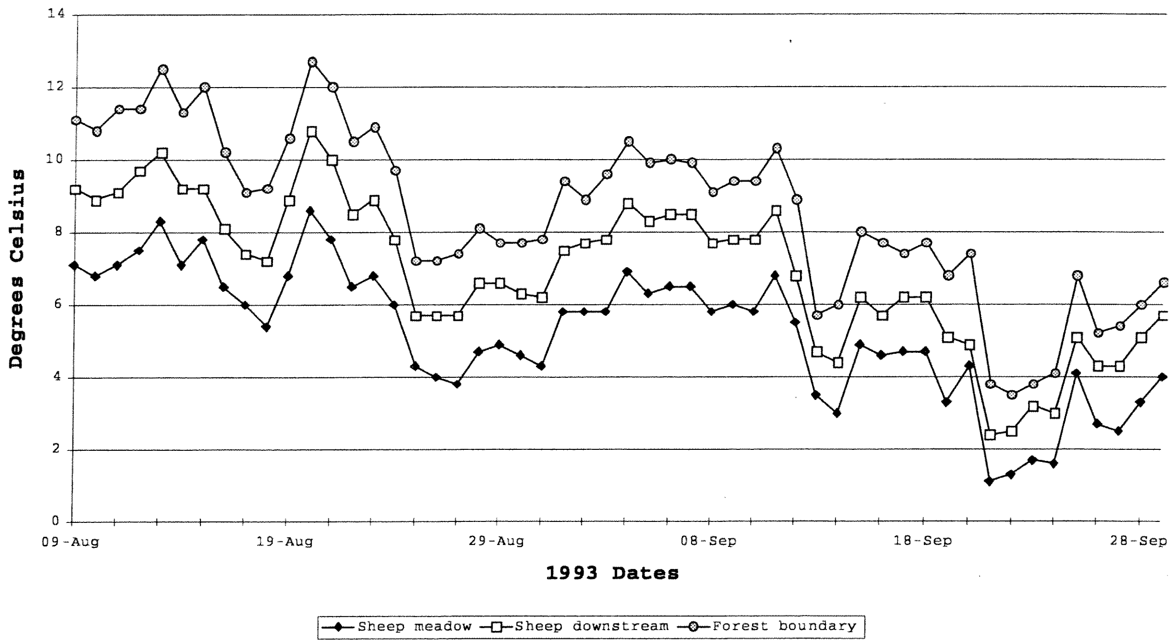

Figure 13. Minimum daily temperatures immediately downstream from Sheep Creek meadows, at the downstream bull trout distribution limit in Sheep Creek and at the Payette National Forest boundary in the Little Weiser River, from August 9 to September 29, 1993.

Summer temperatures were not the only factor influencing the upstream distribution limits of bull trout in the study area. A migration barrier determined the upstream limit of bull trout in at least one stream. Temperature units and stream widths were similar at the upstream sites among the Little Weiser basin streams. Either or both factors could influence the upstream distribution limits. Also, winter temperatures and overwinter habitat may have influenced the upstream winter and summer distributions of bull trout. In the small, headwater reaches, winter mean daily temperatures occasionally fell below 0°C and anchor ice formed (Adams 1994). Hokanson et al. (1973) suggested "that the entire seasonal temperature cycle limits the natural occurrence of self-sustaining brook trout populations". Studies including winter temperatures and distributions are necessary to evaluate the complete temperature regimes utilized by bull trout.

Stream gradient and species composition may interact with temperature to influence the distribution of bull trout. The stream section with the highest temperatures where we found bull trout was Sheep Creek meadows. If temperature, alone, determined the distribution of bull trout, we would expect to find them downstream in Sheep Creek to where the temperature units were as high as those in the meadows. However, the meadow section was low gradient and contained no other fish species. Gradient and velocity can alter the energetic requirements of fish and the availability of food. Food availability in the meadow site may also influence the ability of bull trout to withstand high summer temperatures there.

The temperature range in which bull trout normally occur is lower than that for brook trout and rainbow trout. Bull trout commonly occur in streams with maximum summer temperatures ranging from 10.1 to 15.0°C (Fraley and Shepard 1989; Buckman et al. 1992; Dambacher et al. 1992; Ziller 1992). Shepard et al. (1984) reported summer maximum temperatures of 18.0°C in several sites with low bull trout densities. We observed bull trout in 20.5°C water. The maximum temperatures where brook trout normally occur are between 19.0 and 21.0°C (Burton and Odum 1945; Power 1980). Eaton et al. (1995) found that the 95th percentile of weekly mean temperatures for brook trout (180 sites) was 22.3°C and for rainbow trout (442 sites) was 24°C.

Temperature may affect the ability of bull trout to compete with other species. Pratt (1984) found bull trout in warmer water in allopatry rather than in sympatry with westslope cutthroat trout and hypothesized that the distribution of bull trout with respect to temperature was partially dependent on the presence or absence of westslope cutthroat trout. Shepard et al. (1984) proposed that increasing water temperatures could shift species composition to favor cutthroat trout over bull trout in the Flathead basin. Cunjak and Green (1986) found that brook trout dominated rainbow trout at 8.0 and 13.0°C, but at 19.0°C neither species was clearly dominant. Individuals established their dominance in a shorter time when the water temperature was near their thermal optimum.

In the Weiser River basin, warmer water temperatures may favor rainbow and brook trout over bull trout. Small, forested, headwater streams, as found in this study, are more susceptible than larger streams to extreme summer and winter temperatures when the riparian canopy is removed (Gibbons and Salo 1973). In the Little Weiser River basin, increased summer temperatures, resulting from reduced riparian cover or decreased stream flow, may reduce bull trout habitat and allow expansion of the distribution of brook and rainbow trout.

The presence of a cool water refugium at the downstream end of Sheep Creek meadows probably aided in the persistence of bull trout in the reach, even though not all bull trout in the meadow utilized the cool water. Bonneau (1996) found bull trout congregating near a cold water inflow in a northern Idaho river. The presence of cool water refugia and their use by bull trout necessitates extra care in placing temperature recording devices in streams. If a recorder is placed far from cool water inflows, a biologist may conclude that bull trout are using water warmer than they actually are. If a recorder is located in a cold inflow, the conclusion may be that stream temperatures are generally colder than they really are. Either conclusion could result in management decisions that are detrimental to bull trout.

Payette National Forest personnel initiated several stream restoration projects in response to the findings in this study. In 1993, Sheep Creek meadows was fenced to exclude cattle and to allow recovery of riparian vegetation. The temperature monitoring at fish distribution limits in the study streams continued in 1994. Temperature monitoring upstream and downstream of the meadows was scheduled to continue for five years.

Acknowledgments

C. Colter and T. Murray (U. of Idaho) assisted with field data collection. R. Skinner and K. Golden (U.S.F.S.) also provided field assistance. R. Strach, D. Burns, and T. Page (U.S.F.S.) arranged funding and logistic support from the Payette National Forest. M. Radko (U.S.F.S. Intermountain Research Station, Boise) provided temperature data from the PNF boundary site. J. Morris (independent cowboy), F. Edwards (Idaho Department of Fish and Game, retired) and D. Anderson (Idaho Department of Fish and Game) saved us many weeks of work by providing invaluable clues as to where bull trout might be found in the Weiser River basin. R. Leary (Wild Trout and Salmon Genetics Laboratory, U. of Montana) conducted genetic analyses for species identification of chars.

References

Adams, S. B. 1994. Bull trout distribution and habitat use in the Weiser River drainage, Idaho. Master's thesis. University of Idaho, Moscow.

Beamish, F. W. H. 1980. Swimming performance and oxygen consumption of the charrs. Pages 739-748 in E. K. Balon, editor. Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk bv Publishers, The Hague, The Netherlands.

Bonneau, J, and J. L. Scarnecchia. 1996. Distribution of juvenile bull trout in a thermal gradient of a plunge pool in Granite Creek, Idaho. Transactions of the American Fisheries Society 125:628-630.

Buckman, R. C., W. E. Hosford, and P. A. Dupee. 1992. Malheur River bull trout investigations. Pages 45-57 *in* P.J. Howell and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.

Burton, B. W., and E. P. Odum. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. Ecology 26:182-194.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout, Salvelinus confluentus (Suckley), from the American Northwest. California Fish and Game, 64(3):139-174.

Cunjak, R. A., and J. M. Green. 1986. Influence of water temperature on behavioral interactions between juvenile brook charr, Salvelinus fontinalis, and rainbow trout, Salmo gairdneri. Canadian Journal of Zoology 64:1288-1291.

Dambacher, J. M., M. W. Buktenica, and G. L. Larson. 1992. Distribution, abundance and habitat utilization of bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon. Pages 30-36 in P.J. Howell and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Covallis, OR.

Donald, D. B., and D. J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Eaton, J. G., and six coauthors. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4):10-18.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake and River system, Montana. Northwest Science 63(4):133-143.

Gibbons, D. R., and E. O. Salo. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-10, Portland, Oregon.

Goetz, F. 1989. Biology of the bull trout; a literature review. U.S.D.A. Forest Service, Willamette National Forest, Eugene, Oregon.

Haas, G.R., and J.D. McPhail. 1991. Systematics and distributions of Dolly Varden (Salvelinus malma) and bull trout (Salvelinus confluentus) in North America. Canadian Journal of Fisheries and Aquatic Sciences 48:2191-2211.

Hokanson, K. E. F., J. H. McCormick, B. R. Jones, and J. H. Tucker. 1973. Thermal requirements for maturation, spawning, and embryo survival of the brook trout, Salvelinus fontinalis. Journal of the Fisheries Research Board of Canada 30:975-984.

Hunt, J. P. 1992. Catchability and vulnerability of westslope cutthroat trout to angling and movements in relation to seasonal changes in water temperatures in northern Idaho. Master's Thesis. University of Idaho, Moscow.

McPhail, J. D., and C. C. Lindsey. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north to the Stikine). Pages 615-637 in C.H. Hocutt and E.O. Wiley, editors. The zoogeography of North

American Freshwater Fishes. John Wiley and Sons, New York.

Parkhurst, Z.E. 1950. Survey of the Columbia River and its tributaries, part 7. U.S. Fish and Wildlife Service, Special Scientific Report - Fisheries number 40.

Power, G. 1980. The brook charr, Salvelinus fontinalis. Pages 141-203 in E. K. Balon, editor. Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk bv Publishers, The Hague, The Netherlands.

Pratt, K.L. 1984. Habitat use and species interactions of juvenile cutthroat (Salmo clarki lewisi) and bull trout (Salvelinus confluentus) in the upper Flathead River basin. Master's thesis. University of Idaho, Moscow.

Rieman, B. E., and J. D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124:285-296.

Rode, M. 1989. Bull trout, Salvelinus confluentus (Suckley), in the McCloud River, status and recovery recommendations. California Department of Fish and Game, Inland Fisheries Administrative Report 89.

Shepard, B.B., K.L. Pratt, and P.J. Graham. 1984. Life histories of westslope cutthroat and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Thurow, R. F. 1994. Underwater methods for study of salmonids in the Intermountain West. U.S.D.A. Forest Service, Intermountain Research Station, General Technical Report INT-GTR-307, Ogden, Utah.

Ziller, J.S. 1992. Distribution and relative abundance of bull trout in the Sprague River Subbasin, Oregon. Pages 18-29 in P.J. Howell and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.