BULL TROUT LIFE HISTORY, GENETICS, HABITAT NEEDS, AND LIMITING FACTORS IN CENTRAL AND NORTHEAST OREGON

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Introduction

For restoration and protection of bull trout habitats, conservation strategies depend on determining the distribution of bull trout. However, that distribution may vary seasonally depending on the age and life history type of the fish. Most juvenile bull trout distributions in Oregon have been determined during summer, and consequently, little is known about the distributions and movements of bull trout of any life stage during other seasons. Most bull trout life history information comes from fluvial or adfluvial populations (Pratt 1992; Ratliff 1992). Evidence of migratory fish is minimal or lacking for many bull trout populations in Oregon and the Columbia Basin, and they are assumed to be resident forms. Knowledge of life history patterns, in addition to aiding habitat management, also has important implications for gene conservation. Migratory life histories are vital for the resilience of bull trout metapopulations (Rieman and McIntyre 1993; Dunham et al. 1997). If migratory forms are identified, their maintenance and persistence are dependent on protection of all habitats along migratory corridors.

To address these management and conservation issues, we identified two objectives: 1) determine the distribution of juvenile and adult bull trout and habitats associated with that distribution and 2) determine fluvial and resident bull trout life history patterns. We intend to complete these objectives through study of certain populations of bull trout in the Grande Ronde, Walla Walla, and John Day basins. Selection of these basins permits comparisons of relatively depressed and robust populations as well as relatively degraded and pristine habitats.

Study areas

The Grande Ronde River originates in the Blue Mountains and Wallowa Mountains of northeast Oregon. It flows north for 241 km before joining the Snake River in Washington. In the lower Grande Ronde basin, we captured and tagged adult bull trout in the Wenaha River. Juvenile bull trout were captured and tagged in the upper Grande Ronde River, the Lostine River, Catherine Creek, and Lookingglass Creek in the upper Grande Ronde basin. The Walla Walla River originates in the Blue Mountains and flows westward in northeast Oregon and southeast Washington to the Columbia River. Within the Walla Walla basin, we captured and tagged adult bull trout in Mill Creek. Mill Creek originates in the Blue Mountains of Oregon and flows west for 56 km before joining the Walla Walla River. The John Day basin encompasses 28,000 square km and is the third largest basin east of the Cascade Range. The John Day River, largest free-flowing tributary of the Columbia River in Oregon, originates in the Strawberry Wilderness of the Malheur National Forest, then flows 458 km and joins the Columbia River at river kilometer (Rkm) 352. In the John Day basin, we captured and tagged adult and juvenile bull trout from the upper mainstem John Day River and its tributaries Call Creek, Deardorff Creek, and Roberts Creek.

Methods

Radio telemetry has been used effectively in bull trout investigations (McLeod and Clayton 1997; Swanberg 1997; Thiesfield et al. 1996), and we chose it as the primary means to determine movements and habitat use of migratory bull trout. We limited radio tag size to a maximum weight of 3 percent of the host fish weight, as suggested by Winter (1996). Battery size primarily determines tag weight and the duration of time the transmitter operates. Therefore, since large fish can accommodate heavier, larger tags, movements of large bull trout were defined for longer time periods than those of small fish. The shortest duration tags we used (20 days minimum) could be implanted in bull trout no less than 43 g (about 160 mm fork length). We wanted to track some fluvial bull trout for two successive spawning seasons. Radio tags that accomplished this (18 – 24 months duration) required bull trout at least 900 g (about 450 mm fork length). Radio tags were manufactured by Advanced Telemetry Systems and operated at signal frequencies from 150 to 151 MHz. Some tags used on large bull trout had the capability to measure ambient temperatures by sending a signal that pulsed at a rate that varied with water temperature.

In the Wenaha River and Mill Creek, large bull trout were caught with barbless-hooked lures during June through August. We used fishing line of 5.5-kg strength to quickly capture fish and lessen stress. In the John Day Basin, weir traps placed in Call, Deardorff, and Roberts creeks as well as the upper mainstem John Day River captured downstream migrant bull trout. Weir panels 1.2 m long and 0.9 m high were built with wood (5 cm X 10 cm dimensions) and covered with 0.6-cm mesh screen. Panels were anchored to the streambed with 1.6-cm diameter reinforcing rods after erosion-control cloth was added to the bottom frame. Panels directed downstream migrant fish into a 0.9-m long de-watering trap anchored with reinforcing rods at the upstream end. The trap entrance was 0.6 m wide and 0.8 m high and tapered to a square exit opening with 18-cm sides. Traps were framed with aluminum stock and covered on all sides with perforated aluminum. A 15-cm diameter perforated pipe, attached to the trap exit, transported fish to a wooden holding box that measured 0.6 m wide, 0.6 m deep, and 0.9 m long. The holding box was anchored in a pool with steel fence posts. These weir traps were placed in Call Creek at Rkm 0.7, Deardorff Creek at Rkm 5.3, Roberts Creek at Rkm 1.3, and in the upper mainstem John Day River at Rkm 449.6. To provide access by upstream-migrant fish to stream reaches upstream of the weir, openings were provided between the end of the weirs and the stream banks. When upstream-migrant traps were put in place, these openings were closed with sandbags. All traps were located within U.S. Forest Service boundaries. A 1.5-m diameter screw trap, constructed by E.G. Solutions, Inc, was placed in the mainstem John Day River at Rkm 436.8, downstream of Deardorff Creek (Fig. 1). With this trap, we intended to recapture bull trout with PIT (passive integrated transponder) tags applied at weir sites. In the Grande Ronde basin, weir or screw traps operated by personnel from the ODFW Chinook Life History Study captured juvenile bull trout.

All traps were sampled daily except for times of high flows early in the season. Fish of most species captured were measured to fork length; weight and scale samples were additionally collected from all bull trout. Bull trout that were 150 mm or longer were identified individually with 14-mm PIT tags at 125 KHz (Avid). PIT tags were usually implanted in the fish's abdominal cavity, but were implanted in the dorsal sinus of most radio-tagged bull trout. PIT tags permit us to obtain growth data, age validation, and some distribution data from future recaptured fish. Radio tags were implanted in the fish's abdominal cavity through an incision made anterior and ventral to the pectoral fins. Incisions were sutured and sealed with surgical glue. Radio-tagged bull trout were released into pools near their capture sites after recovery from anesthesia.

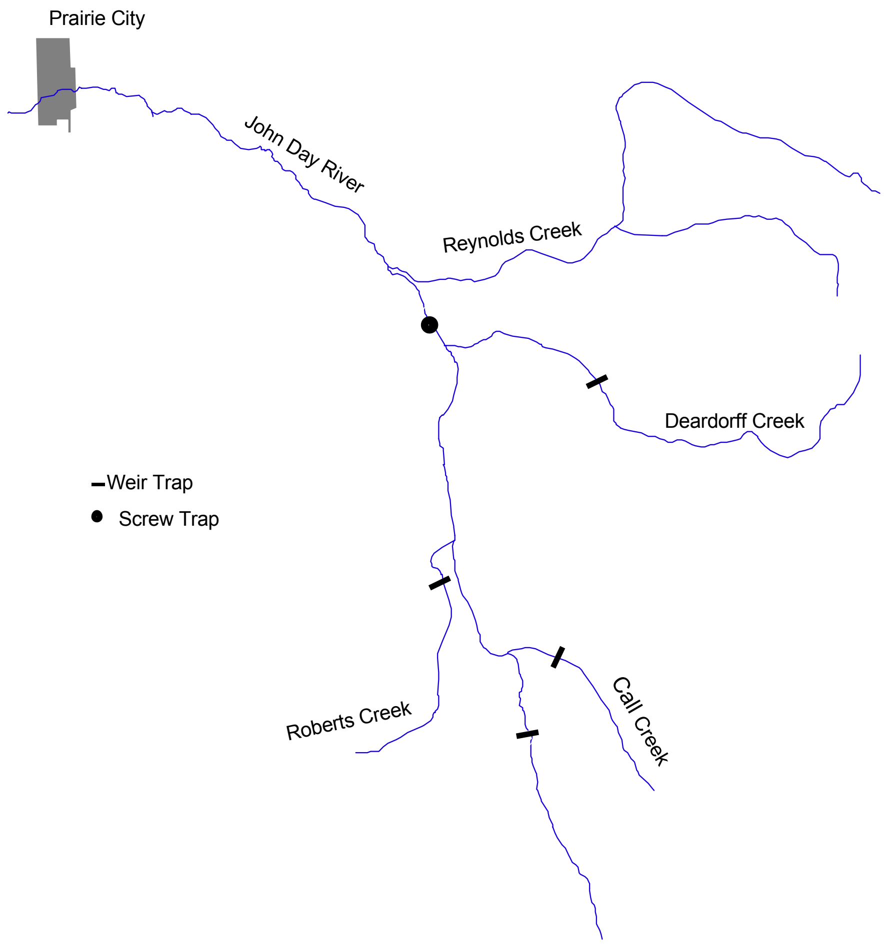

Figure 1. Locations of traps in the upper mainstem John Day River subbasin.

Radio-tagged fish were tracked from both the ground and the air. From the ground, tag signals were captured using a receiver (Lotek, model SRX 400) and antennae carried on foot or mounted to a vehicle. Sometimes, fish were directly located by hiking, depending on stream accessibility. Where possible, we used a vehicle to detect the strongest signal location from a road adjacent to the stream. We determined the azimuth to the stream from that location and estimated the position of the fish as the point where the azimuth intersected the stream. Aerial tracking was conducted from a high-wing monoplane (Cessna 180) operated by the Oregon State Police. We flew above the river until the strongest signal was detected with an "H" antenna under each wing. That position was recorded in degrees and minutes by a global positioning receiver, part of the plane's navigational system. Later, positions were plotted on maps. If the plotted position did not appear on the stream, it was relocated at the shortest distance to the stream and therefore represented the estimated bull trout position.

Results and discussion

We radio tagged a total of 81 bull trout, including 45 in the Grande Ronde basin, 11 in Mill Creek (Walla Walla basin), and 25 in the John Day basin. Overall, we observed one mortality, at Mill Creek, as a consequence of capture and surgery. Signals from tags used in large bull trout were detectable to about nine km when tracked from the ground and to about 14 km when tracked from the air. Signals from tags used in small bull trout were detectable to about one km when tracked from the ground and to about five km when tracked from the air. These estimates were determined by moving away from a tag placed at a known position, until the signal was no longer received.

In the Grande Ronde basin, we radio tagged 21 bull trout from the Wenaha River (Table 1). These fish ranged from 45 to 65 cm long and were assumed to be adults. Their estimated age based on scale analysis ranged from five to seven years with a mean of 5.7. After being released these fish showed little movement until September, when 14 of them moved upstream into headwater spawning tributaries. They began moving back downstream by late September, and none stayed in spawning areas for more than two weeks. No upstream movement was detected in seven of 21 fish. Movement downstream was relatively rapid. We found tagged bull trout in the Grande Ronde River on 01 October, and most had moved there by November. The tagged bull trout moved rapidly down the Grande Ronde River and then stopped at positions throughout this river between its confluences with the Wallowa River and the Snake River. Fish generally remained at these locations through the duration of 1997. One fish continued into the Snake River and ranged 108 km from its upstream location in the Wenaha River basin. From analysis of 21 tagged bull trout, the average distance ranged was 47 km.

A few fish apparently remained in the Wenaha River. Without confirmation, we cannot be sure that the tags remained in live fish. One radio tag was recovered on the riverbank near the confluence of Milk Creek on the South Fork Wenaha River on 9 September, 1997. The fish carrying the tag was tracked upstream to and downstream from spawning areas; we assume it was a post-spawning mortality or victim of predation.

We PIT-tagged a total of 102 bull trout in the Grande Ronde basin, including the 45 radio-tagged bull trout shown in Table 1.

Table 1. Bull trout of the Grande Ronde basin implanted with radio tags during 1997. Bull trout of the Wenaha River were captured by angling; all others were captured by screw trap.

Location, Date tagged	L (cm)	W (g)	Tag life (mo)	Frequency (MHz)
Wenaha R:				
16 Jul	48.5	1217	18	150.913
16 Jul	47.5	1126	18	150.853
16 Jul	51.0	1297	18	150.594
16 Jul	45.5	989	13	150.373
16 Jul	56.5	1923	18	150.754
16 Jul	58.3	>2500	18	150.653
16 Jul	58.8	>2500	18	150.953
16 Jul	46.0	1021	13	150.334
16 Jul	49.4	1383	18	150.713
17 Jul	64.5	>2500	18	150.795
17 Jul	48.0	1198	18	150.833
17 Jul	50.5	1263	18	150.974
17 Jul	44.7	966	13	150.293
30 Jul	49.5	1284	18	150.774
30 Jul	51.0	1400	18	150.634
12 Aug	53.8	1980	13	150.192
12 Aug	46.1	1049	13	150.094
12 Aug	51.0	1215	13	150.393
12 Aug	49.5	1000	13	150.172
12 Aug	46.0	900	18	150.673
13 Aug	51.5	1200	13	150.154
Lookingglass Cr:				
9 Oct	25.1	158	< 6	151.161
9 Oct	24.7	153	< 6	151.132
13 Oct	30.7	257	< 6	150.142
27 Oct	31.0	314	3.3	150.172
Upper Grande Ronde R:				
08 Apr	19.4	72	1.2	150.493
21 Oct	33.3	-	< 6	150.092
Lostine R:				
22 Apr	19.2	75	1.2	150.453
25 Apr	17.6	56	1.2	150.412
28 Apr	19.0	64	1.2	150.473
30 Apr	17.2	49	0.7	150.274
23 May	16.4	43	0.7	150.013
09 Jul	17.7	54	< 6	151.053

Table 1, continued.

Location, Date tagged	L (cm)	W (g)	Tag life (mo)	Frequency (MHz)
Catherine Cr:				
30 Apr	17.2	44	< 6	150.152
30 Apr	18.7	58	< 6	150.393
30 Apr	17.7	45	< 6	150.032
03 May	20.7	51	< 6	150.373
03 Jun	17.5	-	< 6	150.252
04 Jun	21.4	-	< 6	150.292
09 Jun	18.0	56	< 6	150.190
19 Sep	22.5	129	4.7	151.161
19 Sep	22.0	108	3.3	151.142
23 Sep	21.8	88	3.3	151.121
24 Sep	21.4	86	3.3	151.152
03 Oct	24.2	124	4.7	151.181

From Mill Creek during June and July, we radio tagged 11 bull trout that ranged from 45 to 53 cm fork length (Table 2). These fish were captured in the pool formed by the dam that supplies Mill Creek water to the city of Walla Walla, WA. Like adult bull trout of the Wenaha River, those of Mill Creek showed little movement after being tagged until they began moving upstream to spawning areas in September. Downstream movement occurred in October, presumably after spawning. Most tagged fish reached their furthermost downstream locations by the end of November, where they remained through winter. The greatest distance that any tagged bull trout ranged was 35 km, and the average was 25 km.

Table 2. Bull trout of Mill Creek implanted with radio tags during 1997.

Date tagged	L (cm)	W (g)	Tag life (mo)	Frequency (MHz)
10 Jun	52.0	-	18	150.933
11 Jun	47.0	-	13	150.054
12 Jun	50.4	-	18	150.893
18 Jun	50.5	-	18	150.694
18 Jun	52.6	-	18	150.514
25 Jun	52.2	1444	18	150.613
8 Jul	53.0	1320	18	150.871
8 Jul	48.0	1182	18	150.732
8 Jul	52.0	1425	18	150.574
25 Jul	45.0	953	13	150.313
25 Jul	52.0	1317	18	150.813

No radio-tagged fish were observed downstream of Walla Walla, WA. Mill Creek is highly channelized near Walla Walla and is constrained by a concrete channel that passes underground in several places on its course through the city. In the past, some bull trout have been observed near springs in this area (Glen Mendel, Washington Department of Fish and Wildlife, personal communication).

We recovered one radio tag in a hole in the riverbank near the city of Walla Walla, and assume that the fish that had carried it was a victim of predation. This was the only likely mortality of all radio-tagged bull trout released in Mill Creek. Movements of large bull trout that we observed in the Grande Ronde and Walla Walla basins generally agree with those described by Swanberg (1997) for fluvial bull trout populations in Montana. They are also similar to reported movements of adfluvial bull trout (Thiesfield et al. 1996; Fraley and Shepard 1989).

Weir traps intended to capture downstream migrant bull trout in streams of the upper mainstem John Day subbasin were mostly in place by late May, and all operated through early October. A trap to capture upstream-migrant bull trout was designed and built during summer. It was installed near the downstream-migrant trap at the upper mainstem John Day River site (Rkm 449.6) during late August and also operated through early October. Since it effectively captured upstream migrant fish, similar traps will be installed at other weir sites in 1998. Bull trout were captured in all downstream-migrant traps soon after weirs were in place (Fig. 2). The numbers captured are minimum estimates of the number of migrants since some fish could have passed around the ends of weirs most of the sampling period. The data suggest that additional bull trout likely moved downstream at weir sites before traps were in place, but high stream flows prevented sampling prior to the dates indicated.

The screw trap was placed in the upper mainstem John Day River on 04 April and captured only four bull trout during the two weeks that followed. However, after the third week of April through the end of June, the catch of bull trout was consistently much higher (Fig. 3a). Although bull trout were captured less frequently after June, they continued to appear in the trap throughout September, as they did in three of the four weir traps.

Most bull trout captured in all traps throughout the sampling period were 200 mm or less in length. Some bull trout larger than 250 mm were captured in August and September, possibly spawners moving to or from tributaries and upper reaches of the mainstem John Day River. Of 99 bull trout captured in the four weir traps, we PIT-tagged 43 fish, including 20 from the upper mainstem John Day River, seven from Call Creek, five from Roberts Creek, and 11 from Deardorff Creek. The screw trap captured 169 bull trout; measurements from 158 of these produced a length range from 89 to 520 mm, with a mean of 177 mm (Fig. 3b). We PIT-tagged 118 bull trout caught in the crew trap. We radio-tagged 11 bull trout captured in weir traps in the upper John Day subbasin (Table 3), and 14 bull trout captured in the screw trap (Table 4).

We thought that bull trout captured in downstream migrant traps in lower reaches of headwater streams would be directed towards habitats in the mainstem John Day River. While that may occur, our limited data suggest that these habitats exist primarily upstream of the mouth of Deardorff Creek since none of the bull trout PIT-tagged at weirs were re-captured in the screw trap. Telemetry data gathered to date suggest that movements downstream in the John Day River are of relatively small magnitude, since few observations of tagged bull trout occurred in the vicinity of Prairie City, OR and none occurred as far downstream as the city of John Day. However, most downstream migrants were small and consequently, most radio tags implanted in them were relatively short (0.3 – 4.7 months) in duration. In 1998 we intend to include more large bull trout so that locations of individual fish can be tracked for a longer time period.

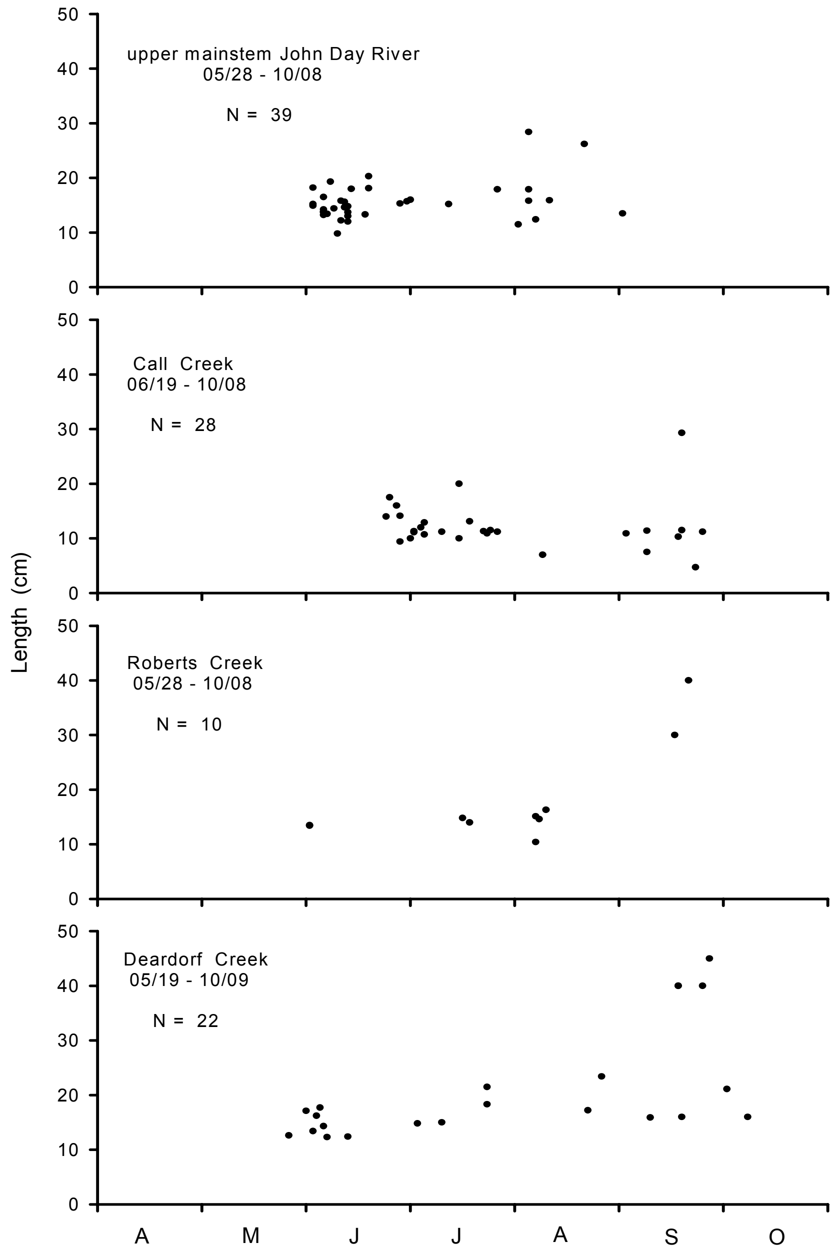

Figure 2. Bull trout of the upper John Day River subbasin captured in downstream migrant weir traps in 1997.

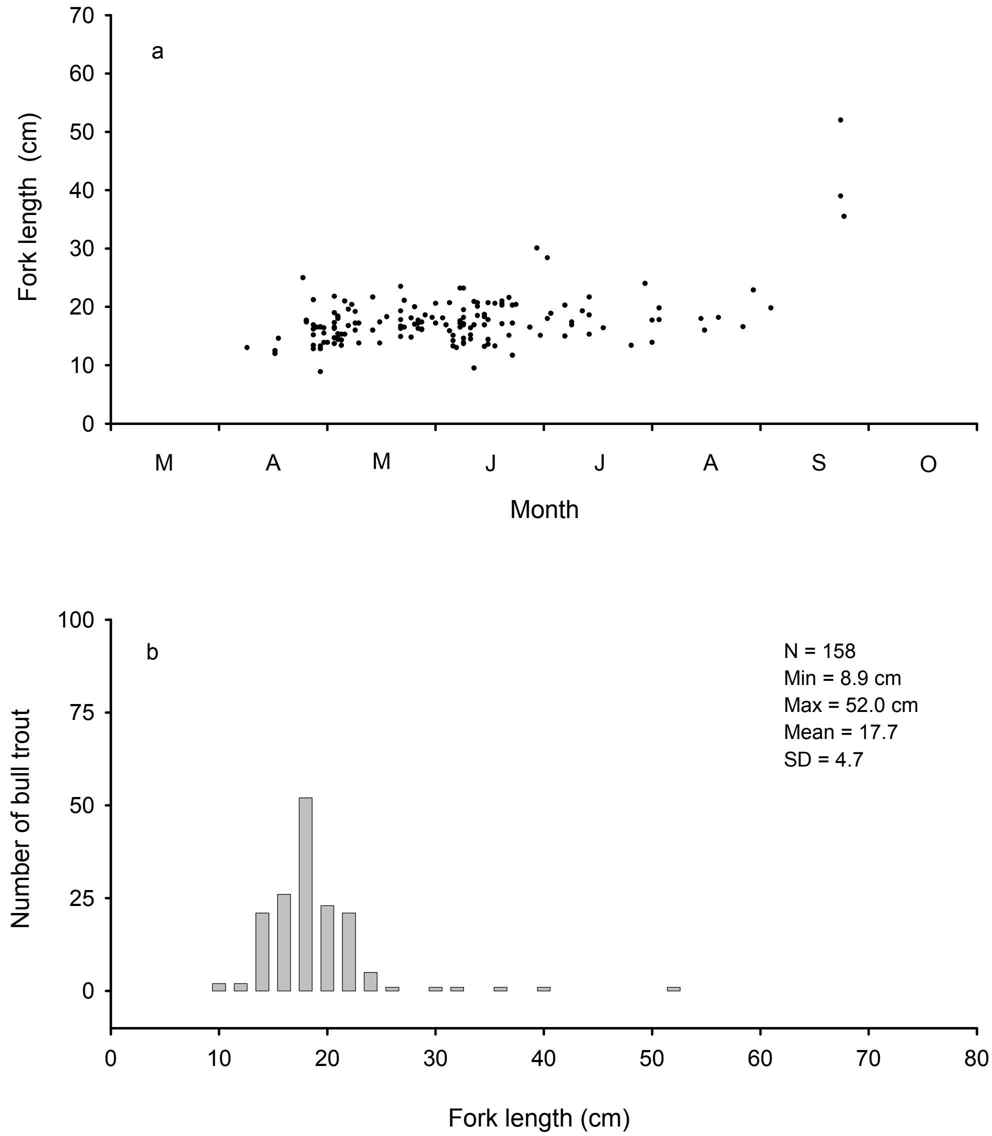

Figure 3. John Day River bull trout captured by screw trap in 1997 between 04 April and 12 October (a), and corresponding length frequencies (b).

Table 3. Bull trout captured in upper John Day subbasin weir traps and radio-tagged in 1997.

Trap location	Date tagged	L (cm)	W (g)	Tag life (mo)	Frequency (MHz)
Downstream weirs:					
John Day R. (Rkm 449.6):	31 May	18.2	59	0.7	150.322
	16 Jun	20.3	93	0.7	150.211
	01 Aug	28.4	247	4.7	151.182
Roberts Creek (Rkm 1.3)	12 Sep	>30.0	>300	1.2	151.032
Deardorff Creek (Rkm 5.3):	20 Jul	18.3	61	0.7	151.132
	20 Jul	21.5	93	3.3	151.022
	22 Aug	23.4	-	3.3	151.062
	03 Oct	16.0	44	0.7	151.152
Upstream weirs:					
John Day R. (Rkm 449.6):	19 Sep	28.5	209	0.7	151.171
	30 Sep	48.5	947	18	150.011
	30 Sep	21.9	103	3.3	151.082

Table 4. Bull trout captured in the upper John Day River screw trap (km 436.8) and radio-tagged in 1997.

Date tagged	L (cm)	W (g)	Tag life (mo)	Frequency (MHz)
25 Apr	25.0	181	0.7	150.353
28 Apr	21.2	113	0.7	150.172
01 May	16.4	146	0.7	150.073
04 May	21.8	103	0.7	150.052
04 May	19.0	65	0.7	150.232
19 May	18.3	69	0.7	150.092
23 May	19.3	74	1.2	150.423
23 May	23.5	124	0.7	150.312
27 May	20.0	92	0.7	150.133
09 Jul	20.3	79	0.7	150.114
05 Aug	17.8	55	0.7	151.112
05 Aug	19.8	78	2.0	151.272
01 Sep	22.9	116	2.0	151.212
27 Sep	39.0	507	4.7	151.202

II. Distribution and habitat use of bull trout and brook trout in streams containing both species.

Introduction

In streams where native bull trout and nonnative brook trout co-occur, a distinct distribution pattern is evident. Typically, a zone of allopatric bull trout exists upstream of a zone of allopatric brook trout and a zone of sympatry occurs between them. This pattern varies in some streams, particularly where brook trout were introduced in headwater lakes.

The objectives of this study are to identify habitat characteristics associated with bull trout and brook trout distributions. This is a continuation of research started in 1996 (Bellerud et al., 1997). In 1997, fish distribution and habitat surveys were conducted on Hurricane Creek and Bear Creek, and Goat Creek, all in the Wallowa Basin.

Methods

To assess fish distribution, we used a systematic sampling strategy beginning at the mouth of the stream, or 2 km downstream of the lower limit of bull trout distribution determined from existing survey data. From there, we electrofished a 100-m reach per kilometer of stream so that a ten percent sampling rate was achieved. This rate had been suggested for the detection of a species at low densities (Hillman and Platts 1993). When no individuals of a given species were detected in two successive reaches sampled, an additional 100-m section was included midway between the sampled reach where the species was last observed and the sampled reach where they were first absent. This allowed estimation of species distribution to a precision of ± 500 m. Sampling was conducted in one pass without blocknets. Electroshocker settings were selected to minimize chances of injury to bull trout based on data from sampling conducted in 1995 (Hemmingsen et al. 1996). Captured fish were identified and measured to length, then released back into the sampled reach.

Throughout the range of fish distributions identified, habitat surveys were conducted using the protocol established by the ODFW Aquatic Inventory Project (Moore et. al, 1996). These surveys included measurements of habitat type, substrate, gradient, in-stream cover, woody debris, and bank condition. The protocol was slightly modified by eliminating detailed riparian zone analysis, and sampling a portion of the stream rather than its entire length. Approximately 2 km of stream was surveyed, in evenly distributed 500-m reaches, within distributions of allopatric bull trout and brook trout. One 500-m reach was surveyed in the distribution of sympatry of both species.

Electronic temperature loggers ("hobo-temp", Onset Computer Co.) were placed in zones of distribution identified by electrofishing. We placed temperature loggers in all of the streams sampled in 1996 (Bellerud et al., 1997) as well as Hurricane, Bear, and Goat creeks. The temperature loggers remained in the streams from June or July through September.

Data were compiled and summarized using spreadsheets. Comparisons of more than two groups were made with analysis of variance, and comparisons of two groups were made with t-tests. A significance level of P=0.05 was used for all tests.

Results and Discussion

Habitat

Preliminary analysis showed no statistically significant differences between reaches allopatric for bull trout, allopatric for brook trout, and sympatric for both species for 36 of 37 habitat variables measured. However, comparisons were of low statistical power due to high variability of the data. Stream gradient was the only habitat variable to show statistical significance, but only when brook trout reaches that originate in headwater lakes were excluded from the analysis. Without these, the overall mean gradient of reaches allopatric for bull trout was significantly higher than the overall mean gradients of reaches allopatric for brook trout or sympatric for both species (Table 5). However, brook trout did occupy high (5-25%) gradient reaches when these originated in headwater lakes. Adams et al. (1998) also found brook trout in gradients up to 17%. In addition, we found brook trout at higher gradients when they were allopatric rather than sympatric with bull trout. Our results suggest that the presence of bull trout may limit the ability of brook trout to occupy high gradient reaches, but other factors (e.g. velocity and temperature) may be involved.

Dambacher and Jones (1997) identified seven factors that indicated quality bull trout habitat: shade, undercut, riffle gravel, bank erosion, riffle fines, number of pieces of large woody debris and volume of large woody debris. We evaluated these factors to identify possible differences in habitat quality between bull trout, brook trout and sympatric reaches. Within reaches of streams, each factor received a score of 0, 1, or 2 to reflect qualities of poor, moderate, or high, respectively. Scores were summed and standardized to give a composite habitat quality between 0 (all factors poor) and 1 (all factors high) for each reach. In streams with both allopatric brook trout and sympatric bull trout and brook trout reaches, habitat quality scores were lower in the former than in the latter in six of seven cases (Table 6). In streams with both allopatric bull trout and sympatric reaches, habitat quality scores were higher in the former than in the latter in six of 10 cases.

Table 5. Mean gradient of stream reaches occupied by bull trout, brook trout, and both species in sympatry. All grand means were significantly different ($P<0.05$).

Basin: stream	Allopatric reaches: bull trout	Allopatric reaches: brook trout	Sympatric reach
John Day:			
Crane Cr	-	2.9	4.6
Baldy Cr [a]	3.8		5.0
Crawfish Cr [a]		4.9	0.9
Upper mainstem John Day R	3.4		2.0
Upper N. F. John Day R	3.2		2.0
Metolius:			
Canyon Cr [a]	1.6	7.0	1.9
Roaring R	4.0		
Malheur:			
Big Cr	4.3	0.8	2.6
Meadow Fork Big Cr	6.5		4.2
Powder:			
N. F. Anthony Cr	5.7	3.6	6.4
Indian Cr	9.8	2.9	2.0
North Powder R	7.7	3.3	1.0
Lake Cr [a]	9.9	25.0	
Little Cracker Cr	12.9		9.3
Grande Ronde:			
Hurricane Cr	3.0		2.8
Grand mean [b]	5.8	2.5	3.4

[a] Streams with lakes at the headwaters.
[b] Excludes streams with lakes at the headwaters.

Table 6. Habitat quality scores for bull trout, sympatric and brook trout reaches.

Basin: stream	Allopatric reaches		Sympatric reach
	bull trout	brook trout	
John Day:			
Crane Cr		0.57	0.64
Baldy Cr	0.57		0.50
Cunningham Cr	0.43		
Crawfish Cr		0.43	0.57
Mainstem John Day R	0.64		0.50
N. F. John Day R	0.50		0.79
Metolius:			
Canyon Cr	0.79	0.57	0.71
Roaring Cr	0.50		
Malheur:			
Big Cr	0.57	0.43	0.64
Meadow Fork Big Cr	0.86		0.93
Powder:			
N. F. Anthony Cr	0.36	0.57	0.29
Indian Cr	0.64	0.43	0.71
North Powder R	0.79	0.64	0.71
Lake Cr	0.58	0.57	
Little Cracker Cr			0.21
Grande Ronde:			
Hurricane Cr	0.57		0.21

Temperature

We conducted preliminary analysis on data collected during 13 July through 30 August, the period of warmest water in the streams sampled. During this period, water temperatures were significantly cooler in allopatric bull trout reaches than in reaches allopatric for brook trout or sympatric for both species (Table 7). We also calculated the cumulative percentage of hourly measurements at various temperatures for the same time period. Results showed that reaches allopatric for bull trout had a greater proportion of temperatures below 9^{o} C than did those reaches allopatric for brook trout or sympatric for both species (Table 8). At temperatures of 9^{o} C or higher, the cumulative percentage of hourly values were very similar for reaches allopatric for bull trout and sympatric for both species. Allopatric brook trout reaches had greater proportions of higher temperatures than did those allopatric for bull trout or sympatric for both species. Temperatures above 12^{o} C accounted for 23% of the total in allopatric brook trout reaches whereas in allopatric bull trout or sympatric reaches such temperatures accounted for only 9% of the respective totals.

Table 7. Mean hourly temperatures (^{o}C), 13 July – 30 August 1997.

Basin: stream	Allopatric reaches: bull trout	Allopatric reaches: brook trout	Sympatric reach
John Day:			
Crane Cr	-	13.8	8.7
Baldy Cr	10.0	11.5	-
Cunningham Cr			
Crawfish Cr	-	10.2	10.8
Mainstem John Day R	9.0	-	10.0
N. F. John Day R	9.8	-	11.0
Metolius:			
Canyon Cr	7.1	8.8	10.1
Roaring Cr	5.4	-	-
Malheur:			
Big Cr	-	10.8	7.1
Meadow Fork Big Cr	7.3	-	8.4
Powder:			
N. F. Anthony Cr	10.5	11.7	10.9
Indian Cr	9.7	10.3	9.4
North Powder R	9.7	9.9	10.1
Lake Cr	10.9	-	-
Little Cracker Cr	-	-	9.9
Grande Ronde:			
Hurricane Cr	8.0		
Bear Cr / Goat Cr	9.8	-	10.1

Table 8. Cumulative percentage of hourly temperatures pooled for each reach type, 13 July – 30 August 1997.

Temperature (°C)	Allopatric reaches: bull trout	Allopatric reaches: brook trout	Sympatric reach
≤4	0	0	0
≤5	5	0	0
≤6	12	0	2
≤7	22	3	9
≤8	32	9	20
≤9	47	24	41
≤10	63	43	64
≤11	80	61	80
≤12	91	77	91
≤13	97	85	96
≤14	99	90	99
≤15	100	94	100
≤16		96	
≤17		98	
≤18		99	
≤19		100	
≤20			

Maximum weekly average temperatures (MWAT) calculated from a 7-day moving average during the comparison period are presented in Table 9. The highest MWAT observed in any reach that contained bull trout was 15.5° C, and this value occurred in only three of 24 cases. Buchanan and Gregory (1997) suggested that the maximum MWAT acceptable for bull trout is 15° C. Our data closely support this value. In three of eight reaches allopatric for brook trout, the MWAT exceeded 16 ° C.

Table 9. Maximum weekly average temperature (°C) based on a 7-day moving average, 13 July – 30 August 1997.

Basin: stream	Allopatric reaches		Sympatric reach
	bull trout	brook trout	
John Day:			
Crane Cr	-	19.0	11.0
Baldy Cr	14.8	13.8	-
Cunningham Cr	-	-	-
Crawfish Cr	-	20.3	14.9
Mainstem John Day R	11.7	-	12.3
N. F. John Day R	14.2	-	15.5
Metolius:			
Canyon Cr	12.4	10.8	12.5
Roaring Cr	6.9	-	-
Malheur:			
Big Cr	-	16.9	10.1
Meadow Fork Big Cr	9.2	-	11.7
Powder:			
N. F. Anthony Cr	13.4	15.5	13.7
Indian Cr	15.5	13.4	11.2
North Powder R	13.4	13.0	13.4
Lake Cr	13.5	-	-
Little Cracker Cr	-	-	13.3
Grande Ronde:			
Hurricane Cr	11.3	-	-
Bear Cr / Goat Cr	15.5	-	13.6

III. Bull trout and brook trout interactions

Introduction

One of the greatest threats to the persistence of native bull trout populations is the presence of nonnative brook trout *Salvelinus fontinalis*. Hybridization between brook trout and bull trout has been documented (Kitano et al. 1994, Markle 1992), and the two species are thought to be direct competitors (Brown 1992, Dambacher et al. 1992). However, the mechanism by which competition occurs is not well understood and poorly documented. To identify and describe possible competition between these species, we conducted an experiment to examine the influence of brook trout on the feeding behavior and diet of bull trout.

Snorkel observations, growth measurements, and stomach content analysis were used to explore evidence of possible competitive interactions of bull trout with brook trout. Pens were built in sympatric bull trout and brook trout reaches of the North Powder River and the Meadow Fork of Big Creek in northeastern Oregon (see Bellerud et al. 1997 for site description). Each pen received one of three treatments differing in density of bull trout and presence of brook trout. Changes in feeding behavior, number of interactions between fish, and growth were documented for bull trout in various densities and the presence and absence of brook trout.

Methods

We built six fish pens in the sympatric zones of each stream. The pens were constructed from wood frame panels that were 1.2 m per side and covered with 1.9-cm mesh nylon screen. The panels were secured with wood braces (5 cm x 10 cm x 2.4 m) and sealed at the base with erosion cloth and sandbags. Average pen size was 3.1 square meters. All pens were built in pools and slow water habitats. In most cases the stream bank served as one side of the pens to provide elements of natural cover. Three of the 12 pens were fully enclosed by panels. Each pen contained a variety of microhabitats including slow water refuges, portions of the thalwag, and areas with physical cover.

Each pen received two bull trout, four bull trout, or a combination of two bull trout and two brook trout, assigned at random. We captured all fish used in the experiment by fly-fishing. Each individual was weighed after stomach evacuation, measured, and uniquely marked with a photonic dye injected in the caudal fin to ensure positive identification throughout the experiment. We attempted to equalize sizes of fish in each pen to prevent the development of a dominance hierarchy.

Over a six-week period, each pen was monitored by snorkeling up to eight times weekly. During each monitoring session, focal animal observations were conducted on each fish for five minutes (Altmann 1974). The feeding rate, food source utilized, number and type of interactions, and the location of the focal feeding point were recorded during the observation period. Food source utilized was determined by counting the number of times the subject fed from the substrate, water column, and surface. Interactions were counted and scored as positive, negative, or neutral. When a focal fish gained or maintained feeding territory through aggression, the interaction was defined as positive. A negative interaction occurred when the focal fish lost feeding territory or was displaced by another fish. Neither fish was dominant in a neutral interaction. After all observations were completed in each pen, the physical characteristics of the focal points were measured. These characteristics included depth at focal point, holding depth, type and percent of cover, velocity, and velocity gradient. The velocity gradient was defined as the difference between the velocity of the focal point and the greatest velocity within 60 cm of the fish (Everest and Chapman 1972, Fausch and White 1981). Generally, fish occupy positions where energy expenditure is the least, but where fast currents carrying high food volume are within reach (Fausch and White 1981). At the end of six weeks all fish were removed from the pens, weighed, measured, and released back into the stream.

Before we started the experiment, baseline data were collected on the feeding behavior of bull trout and brook trout in their unconfined natural environment. A snorkel diver entered the stream at the downstream end of the sympatric zone and slowly moved upstream. Focal animal observations were conducted for five minutes on every undisturbed fish the diver encountered. All fish disturbed by the divers presence were ignored. Species, length, focal feeding point location, foraging rate, food source utilized, and interactions with other fish were recorded during the observation period. Fish length was estimated by measuring the distance between two objects located at both ends of the fish. A marker was placed at the focal feeding position of each fish and the physical characteristics at each point were measured. These data were used to compare the behavior of fish in the pens to that of fish outside the pens.

In addition to this behavior experiment, we repeated the diet study conducted in 1996 (See Bellerud et al. 1997 for methods). Laboratory work continued on that study, primarily the identification and categorization of invertebrates.

Results and Discussion

<u>Growth</u>

Bull trout in all treatments experienced weight loss. Bull trout in the low-density treatment (2 bull trout) lost an average of 7.4 % of their body weight. Bull trout in the high density allopatric treatment (4 bull trout) lost an average of 14.1 % of their body weight. Bull trout in the high density sympatric treatment (2 bull trout, 2 brook trout) lost an average of 17.5% of their body weight. In contrast, brook trout in the high-density sympatric treatment lost an average of 3.1% body weight (Fig. 4). Preliminary analysis indicated that bull trout at low-density lost less weight than bull trout at either allopatric or sympatric high-density (two way ANOVA, one sided $p= 0.05$ and $p< 0.02$, respectively).

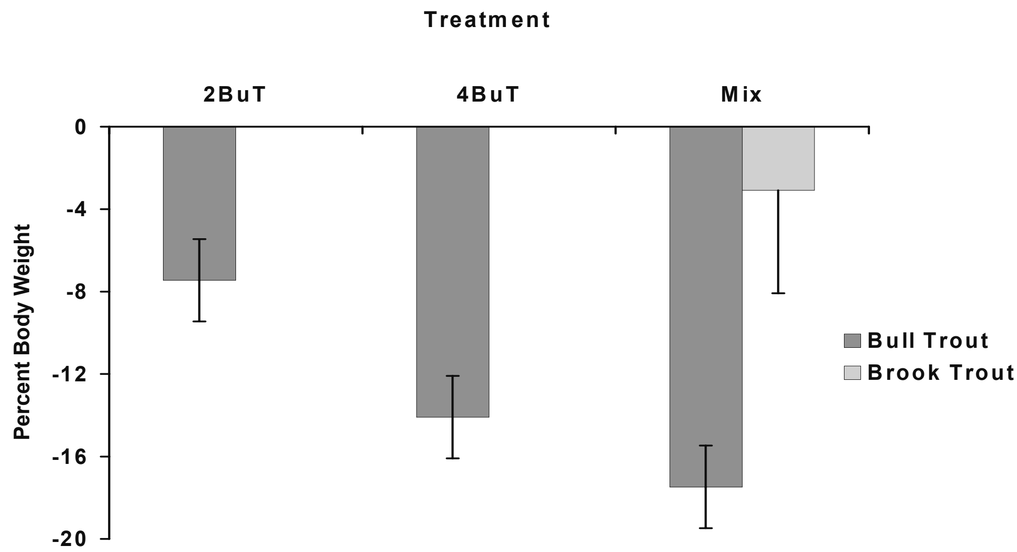

Figure 4. Mean change in body weight for fish in all treatments after six weeks. 2BuT=low density bull trout treatment; 4BuT=high density bull trout treatment; Mix=high density bull trout and brook trout treatment.

Since weight loss occurred to fish in all pens, an artifact due to the pens was indicated. Feeding rates of fish outside of the pens was significantly greater than those of fish in the pens (t-test, p= 0.0001 for both streams). This result suggested that food was limited within the pens (Fig. 5).

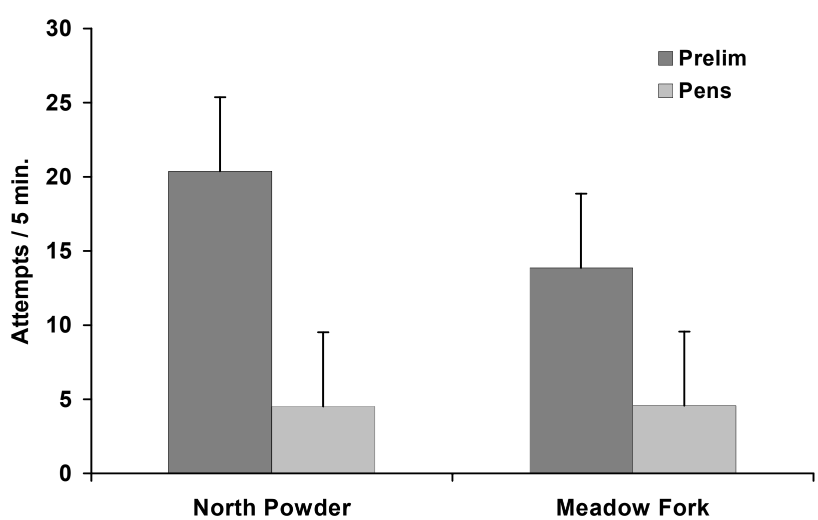

Figure 5. Average feeding rate for all fish observed during preliminary snorkeling in the natural environment (prelim) compared to that for all fish in pens in North Powder River and Meadow Fork of Big Creek.

Feeding Rate

Preliminary analysis indicated no difference in the feeding rates of bull trout between treatments (two way ANOVA, one sided p= 0.46). Within a five-minute period, bull trout in the low-density treatment fed an average of 6.3 times. Likewise, high density fed an average of 5.8 times and sympatric bull trout fed an average of 4.5 times (Fig. 6). Brook trout fed an average of 3.8 times in five minutes.

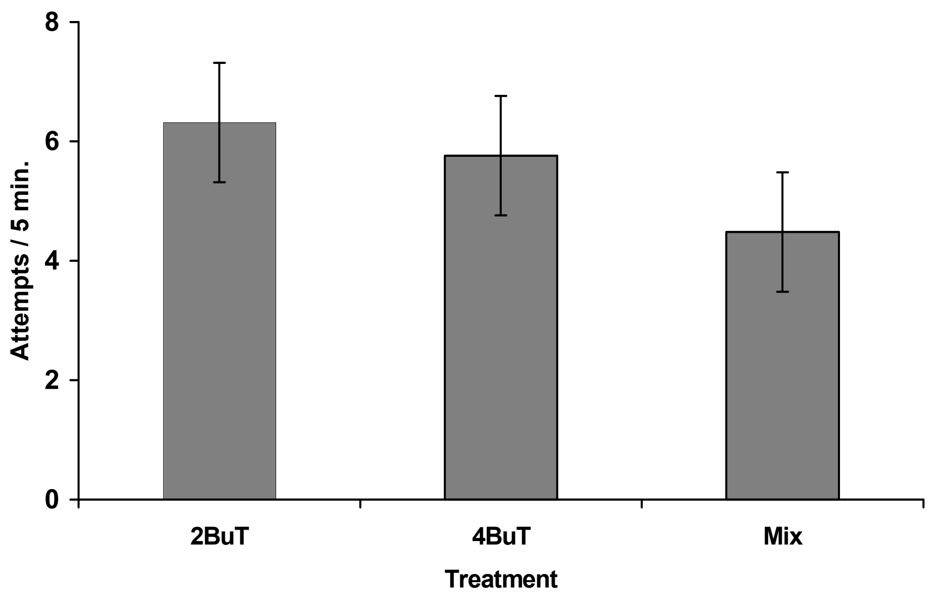

Figure 6. Average feeding rates for bull trout in all treatments.

Negative Interactions

In Meadow Fork of Big Creek, bull trout in sympatric pens had more negative interactions, mostly with brook trout, than did allopatric bull trout at low or high density (Fig. 7). In the North Powder River, bull trout in the high-density allopatric treatment had more negative interactions than did bull trout in either the low-density allopatric treatment or the high-density sympatric treatment (Fig. 8). That result was caused by one bull trout, which consistently chased and nipped the other three bull trout in the pen. The aggressive bull trout was 5 to 15 mm larger than the others in the pen. When the interactions of this particular fish are excluded from the analysis, the pattern of negative interactions for bull trout in the North Powder River closely resembles those of Meadow Fork of Big Creek. However, preliminary analysis suggested the differences between treatments were not statistically significant (Big Creek: Kruskal-Wallis, p=0.85, Powder: Kruskal-Wallis, p=0.15).

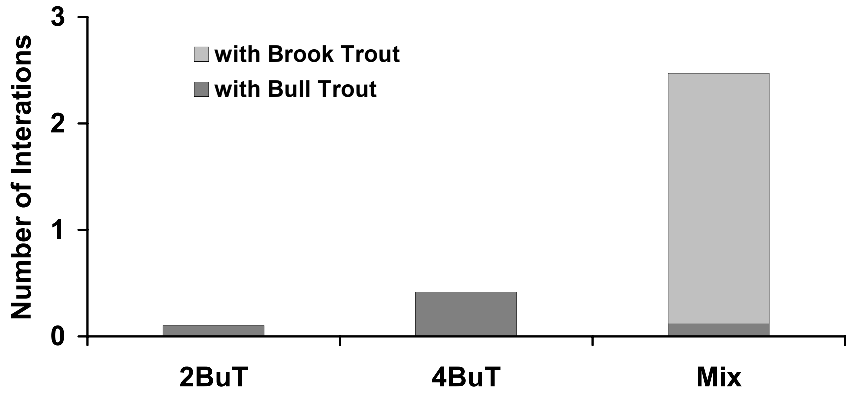

Figure 7. Average number of observed negative interactions for bull trout in all treatments in Meadow Fork of Big Creek.

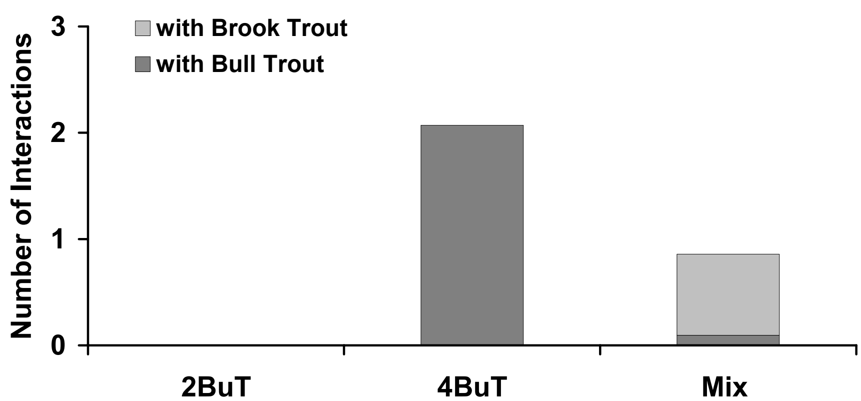

Figure 8. Average number of observed negative interactions for bull trout in all treatments in North Powder River.

Habitat Variables

No differences were evident in focal feeding points occupied by all fish among treatments. Velocity and depth measurements were equivalent between bull trout in all treatments and bull trout and brook trout in the mixed treatment. This suggests that competition for focal feeding points was minimal and that bull trout and brook trout used similar focal points.

Food Source

Bull trout in all treatments and those observed outside the pens utilized the water column in 80 to 90 percent of their feeding attempts, regardless of the presence or absence of brook trout (Fig. 9). Bull trout rarely fed from the surface or the benthos. There was no evidence of a niche shift by bull trout in the presence of brook trout. Similarly, there was no resource partitioning observed between bull trout and brook trout in the mixed treatment. Brook trout also utilized the water column in 80 to 90 percent of their feeding attempts (Fig. 10). Although bull trout will switch from feeding in the water column to the benthos in the presence of cutthroat trout (Nakano et al. 1992), we did not observe this switch in our experiment.

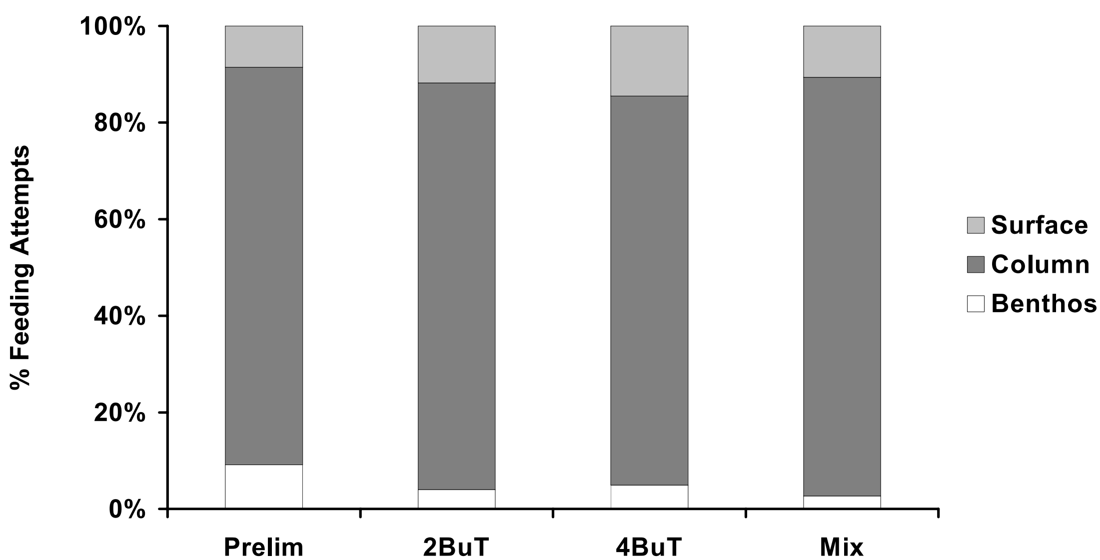

Figure 9. Percent food source utilized by bull trout in all treatments, including the preliminary snorkel (prelim).

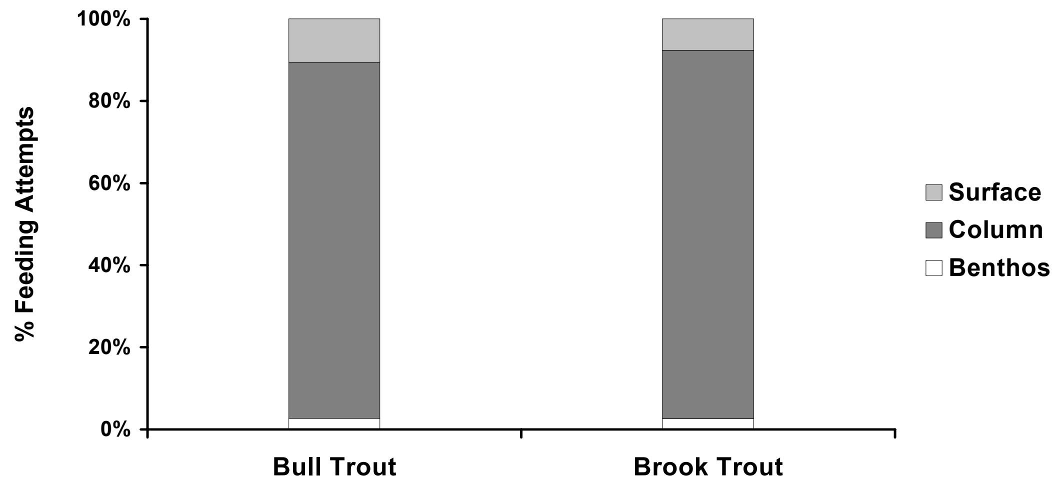

Figure 10. Percent of food source utilized by bull trout and brook trout in the mixed treatment.

IV. Bull trout spawning surveys

Introduction

Little specific data are available on bull trout abundance and population trends (Rieman and McIntyre 1993), particularly in Oregon with the exception of the Metolius River population. This was identified as a research need by Rieman and McIntyre (1993) and Buchanan et al. (1997). Spawning surveys are beginning to be used with increasing frequency by management agencies attempting to fill this need. Aside from the potential of surveyors to unknowingly walk on redds and momentary disturbance of adults near redds, it is an attractive technique because its potential impacts on the population are relatively low compared to potential injuries when making population estimates based on multiple-pass removal or mark-recapture techniques using electrofishing (see Hemmingsen et al. 1996). Also, since it measures reproductive adults, it likely has less inherent variability than population estimates that represent multiple age classes that have unknown survival rates to spawning adults.

However, there has been no systematic evaluation of the utility of spawning surveys to precisely estimate the abundance of spawning bull trout. The variability and reliability of spawning survey data may be influenced by many factors, including differences in population size, spawning distribution from year to year, time of spawning, redd characteristics of migratory versus resident life history forms, spawning habitat characteristics, and surveyor bias. Our objectives are to determine the amount of variability due to these factors so that spawning survey design can be improved and its effectiveness as a monitoring tool can be evaluated.

Study Sites

We conducted multiple surveys on the same three streams surveyed in 1996: Mill Creek, in the Walla Walla basin; Silver Creek, in the Powder basin; and the Little Minam River, in the Grande Ronde basin. Spawning populations in Mill Creek are mostly large fluvial adults. Forest Service personnel had previously conducted spawning surveys in 1994 and 1995 that suggested Mill Creek had a substantial number of spawners (191 redds in 1994). Ratliff and Howell (1992) classified the Mill Creek population as ‘low risk of extinction’. It was downgraded by Buchanan et al (1997) to “of special concern” because of an apparent downward trend in numbers of spawners, based on redd counts for 1994-96.

Silver Creek is a second order tributary of Cracker Creek in the Upper Powder basin. There has been some impact from logging and mining. The potential spawning substrate contains a high percentage of finely decomposed granite. Silver Creek spawners are presumed to be resident fish, generally smaller than 300 mm, with suspected low abundance. The silver Creek population was classified as ‘moderate risk of extinction’ (Ratliff and Howell 1992; Buchanan et al. 1997).

The Little Minam River is a tributary of the Minam River. It is located within a designated wilderness area and has experienced little human impact other than angler harvest. There is a suspected barrier to upstream passage located approximately 8 km upstream from the mouth. The spawning population was thought to be relatively abundant. Ratliff and Howell (1992) and Buchanan et al. (1997) classified the Little Minam population as ’low risk of extinction’. Reaches of the Little Minam River and Lookingglass Creek were used to measure observer bias. The Little Minam has resident bull trout less than 300 mm in length whereas Lookingglass Creek has larger, fluvial fish.

Methods

Redd Counts

All suspected bull trout spawning areas in Mill Creek, Silver Creek, and the Little Minam River were surveyed 3 or 4 times during September and October. Stream reaches were designated before surveying and marked on each surveyor's map. Reaches corresponded with changes in stream character. Upstream and downstream limits of reaches, chosen to correspond with terrain features easily identifiable by surveyors, were flagged (Table 10). Reach lengths were measured from USGS topographic maps (1:24,000) using TerrainNavigator software (MAPTECH, Inc). Surveyors counted the number of bull trout redds and the number of bull trout on, or near, a redd in designated reaches. Surveyors moved upstream when possible to increase the potential to see fish associated with redds. Unique numbers for each redd, survey, and reach were assigned in order of discovery. These data and the survey date were marked on plastic flagging tied on streamside vegetation near the redd to evaluate visibility of the redd on subsequent surveys.

The length of the redd was measured from the front edge of the pocket to the back edge of the mound. Width was measured at the widest portion of the redd. Water depth was measured with a wading staff in the deepest part of the pocket and from the stream bottom beside the redd. Substrate composition was evaluated by counting the number of stones in a 50-cm portion of redd measured by a wading staff laid parallel to the redd. Lengths of patches of sand or silt along the staff were also recorded. The type of habitat unit in which the redd occurred along with a general description of redd location were also recorded.

Redd Visibility

Bull trout redds identified and flagged during spawning surveys were subsequently re-examined. Their visibility was scored on the following scale:

Class 1: a redd has no algal growth or silt deposition; the pocket and mound are sharply defined.
Class 2: a redd has some algal growth and silt deposition, but less than the adjacent stream bottom; the mound and pocket are slightly eroded.
Class 3: redd with algal growth and silt deposition similar to the surrounding stream bottom; the pocket and mound are indistinct.

We assumed that the probability of detecting a category-1 redd to be the same as the probability of detecting a new redd, the chances of detecting a category-2 redd to be half the probability of detecting a new redd, and that it would be very unlikely that a surveyor would be able to detect a category-3 redd.

Table 10. Spawning survey reach descriptions.

Stream, reach	Reach boundaries		Length (km)
	Downstream	Upstream	
Little Minam R:			
1	Boulder Cr	Threemile Cr	2.1
2	Threemile Cr	Whiskey Flat Cr	1.8
3	Whiskey Flat Cr	Horseshoe Cr	1.1
4	Horseshoe Cr	Fireline Cr	1.7
5	Fireline Cr	Dobbin Cr	1.3
6	Dobbin Cr	Tributary on right	2.6
7	Tributary on right	End of fish distribution	2.0
Dobbin Cr:			
1	Mouth	1st tributary on right	2.2
2	1st tributary on right	2nd tributary on right	0.9
3	2nd tributary on right	Steep cascade 50 m long	2.1
Mill Cr:			
1	Intake dam	Low Cr	1.1
2	Low Cr	Broken Cr	0.6
3	Broken Cr	Paradise Cr	1.7
4	Paradise Cr	N.F. Mill Cr	2.9
5	N.F. Mill Cr	Deadman Cr	3.7
6	Deadman Cr	Bull Cr	1.0
7	Bull Cr	Springs	1.6
Low Cr	Mouth	Springs	2.1
Paradise Cr	Mouth	Tributary on left	2.3
N.F. Mill Cr	Mouth	Springs	1.3
Deadman Cr	Mouth	--	1.5
Burnt Fork	Mouth	--	1.5
Bull Cr	Mouth	--	0.9
Silver Cr:			
1	Mouth	Snell Hollow Rd	1.2
2	Snell Hollow Rd	Tributary on left	1.3
3	Tributary on left	--	1.6
4	--	1st tributary ds Erin Cr	1.5
5	1st tributary ds Erin Cr	Tributary on left	2.2
6	Tributary on left	Fence across creek	0.8

Results and Discussion

Redd Counts

Bull trout redds were found in all surveyed reaches of the Little Minam River (Fig. 11), while suspected spawners were observed in two small tributaries, Fireline Creek and an unnamed creek near Whiskey Flats. These results were somewhat different from those of 1996, when no redds were observed in survey reach one of the Little Minam River or reaches three and four of Dobbin Creek (Bellerud et al. 1997). Since we found redds in reach one of the Little Minam River this year, we suspect that some bull trout may have spawned downstream from Boulder Creek, the downstream boundary of survey reach one. Of the 306 redds observed in the Little Minam River, 52% occurred in reaches six and seven. These reaches also had the highest proportion of redds observed in 1996 (Bellerud et al. 1997).

In addition to those in the Little Minam River, 71 redds were observed in Dobbin Creek for a total of 377 (Fig. 11). This is a seven-fold increase of the 54 total redds observed in 1996 (Bellerud et al. 1997). Some of the increase might be due to more experience by the surveyors. However, we detected a three-fold increase in observed bull trout, which supports the suggestion that there was a substantial increase in the number of spawning bull trout in 1997. This is indicative of the need for several years of survey data to help determine the variation in annual redd numbers.

Fifty-six percent of redds in the Little Minam River were newly observed on the second survey during 24-25 September. During this survey we also observed 59% of redds in Dobbin Creek, although reaches two and three were not surveyed a fourth time because of snowfall. However, we think that few if any new redds were missed since only two redds were observed in these sections on the previous survey (08-10 October).

We observed 83 bull trout redds in Mill Creek and 29 in its tributaries for a total of 112 redds in the watershed (Fig. 12). Although new redds were observed in Mill Creek during each survey, 42% were observed on the second survey during 22-23 September. As in 1996, most redds in Mill Creek occurred in survey reach five. In slight contrast, no redds were observed in Mill Creek tributaries until the second survey, and of the 29 redds, 59% were observed on the third survey during 6-7 October. These tributaries accounted for 27% of all redds observed in the watershed, slightly less than the proportion (35%) observed in 1996 (Bellerud et al. 1997). Some spawning may have occurred after October since new redds were observed in Mill Creek and tributaries on the final survey. Snowfall in the watershed prohibited surveys after October.

Redds in Silver Creek totaled 18, although that may be a conservative estimate since only three surveys were conducted (Fig. 13). Of these 72% were observed on the second survey (29-30 September). During 1997, redds were observed in survey reaches four and six whereas none had been detected in these reaches during 1996 (Bellerud et al. 1997).

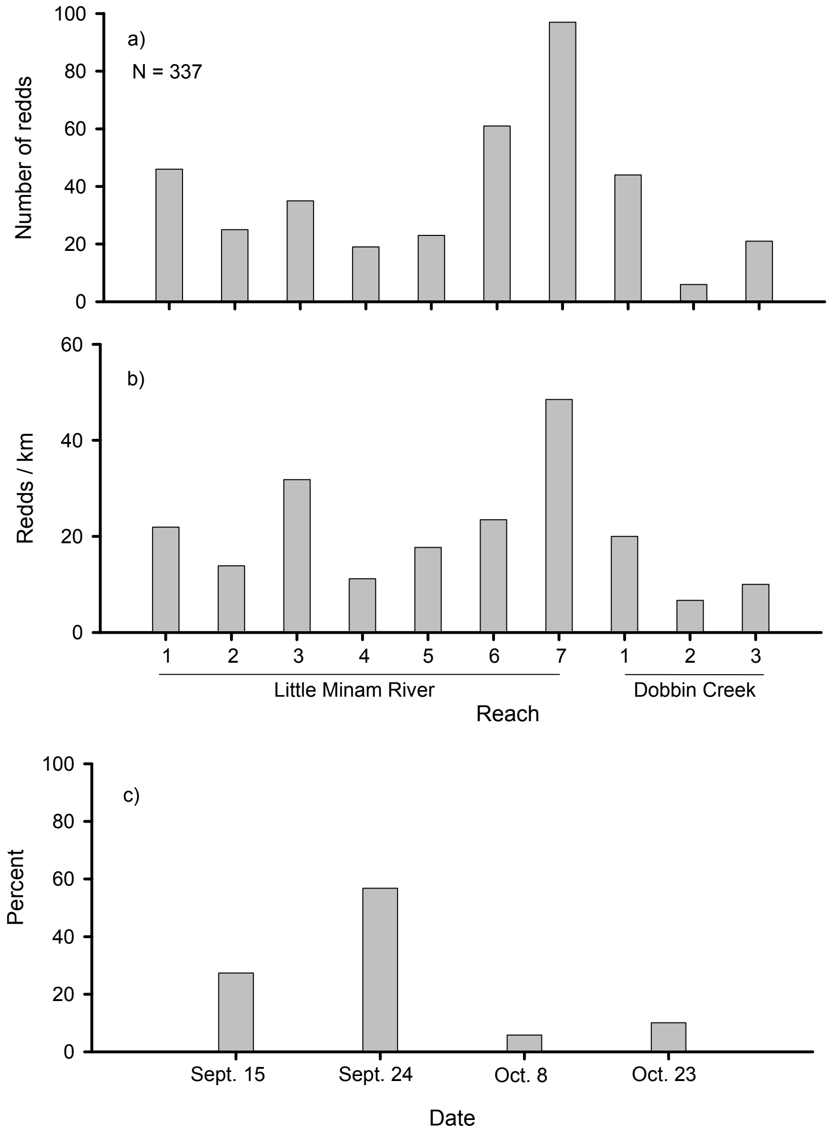

Figure 11. Spawning ground surveys on Little Minam River and Dobbin Creek, 1997; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey.

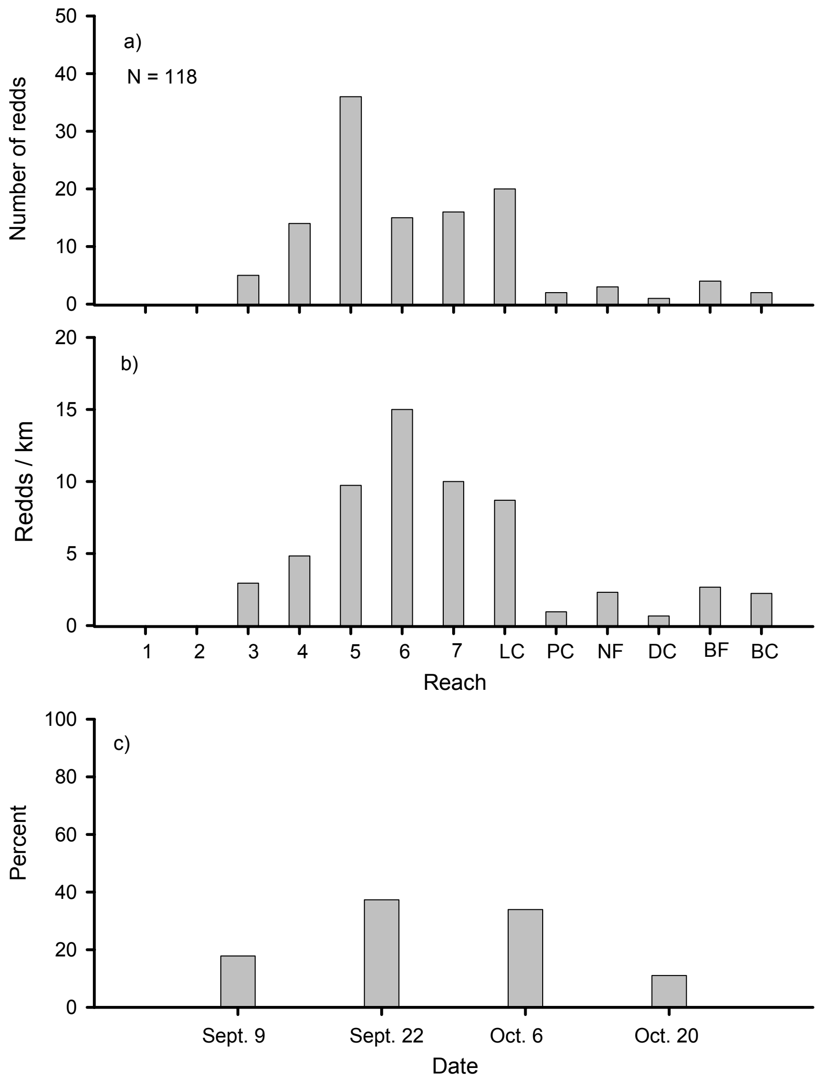

Figure 12. Spawning ground surveys on Mill Creek and tributaries, 1997; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey. LC = Low Creek, PC = Paradise Creek, NF = North Fork Mill Creek, DC = Deadman Creek, BF = Burnt Fork and BC = Bull Creek

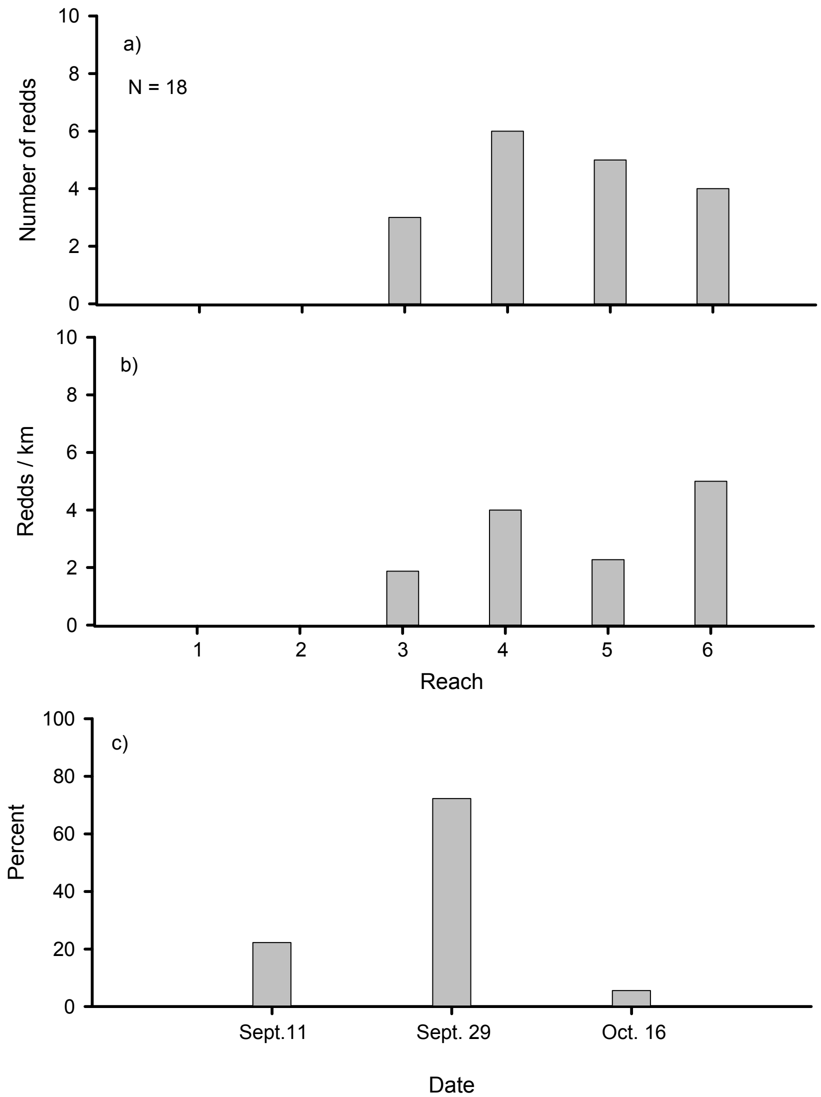

Figure 13. Spawning ground surveys on Silver Creek, 1997; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey.

Redd Visibility

Results showed that redd visibility is highly variable among steams. After four weeks, 10% of redds counted in Mill Creek were given a visibility score of three (undetectable from surrounding substrate) whereas this score was given to 40% of redds in the Little Minam River and 75% to those in Silver Creek (Table 14). Visibility of redds made by resident fish decreased more rapidly over time than visibility of redds made by larger fluvial fish. Bull trout in Mill Creek construct larger redds (mean length = 1.2 m, SD = 0.5) than those in the Little Minam River (mean length = 0.7 m, SD = 0.3) and Silver Creek (mean length = 0.4, SD = 0.3). Thus redd size partially accounts for the relatively long time that Mill Creek redds remain visible.

Redd visibility is also affected by substrate type and algal growth. Typically, a new redd is detected by the shape (pocket and mound), orientation to water current and cover, and lighter color of disturbed substrate. The surrounding substrate is usually covered with algae, whereas the new redd is not and therefore is brighter. The spawning substrate in Silver creek is primarily fine “decomposed granite”, roughly the diameter of very coarse sand. Algal growth is not noticeable on this type of substrate. Redds in Mill Creek were constructed primarily in gravel-sized substrate. Redds in Little Minam River were constructed of substrate with size that was generally intermediate to that of the other streams. Small redd size, small substrate size, and no visible algae make redds in Silver Creek hard to detect and account for the relatively short time that these redds remained visible.

Table 14. Proportions of bull trout redds at each visibility category through time.

Stream: Visibility category	Weeks since first redd observation		
	2	4	6
Little Minam River:			
1	21	7	4
2	73	53	60
3	6	40	36
Mill Creek:			
1	54	34	35
2	40	56	26
3	6	10	39
Silver Creek:			
1	0	0	0
2	57	25	0
3	43	75	0

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