March 2001

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

Annual Report 1998

DOE/BP-00000228-2

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

*Hemmingsen, Alan R., Stephanie L. Gunckel, Blane L. Bellerud - Oregon Department of Fish and Wildlife, Philip J. Howell - U.S. Forest Service, Bull Trout Life History, Genetics, Habitat Needs, And Limiting Factors In Central And Northeast Oregon, 1998 Annual Report, Report to Bonneville Power Administration, Contract No.00000228, Project No. 199405400, 49 electronic pages* (BPA Report DOE/BP-00000228-2)

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

## 1998 ANNUAL REPORT

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Project Number 199405400
Contract Number 00000228

March 2001

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## I. Movement and life history of bull trout in the John Day, Walla Walla and Grande Ronde basins

### Introduction

This section describes work accomplished in 1998 that continued to address two objectives of this project. These objectives are 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. Completion of these objectives was approached through studies of bull trout in the Grande Ronde, Walla Walla, and John Day basins. These basins were selected because they provide a variety of habitats that range from relatively degraded to pristine, and bull trout populations thought to vary from relatively depressed to robust. In all three basins we used radio telemetry to describe the seasonal movements of bull trout. In two of these basins we also used traps to collect biological information and to provide insights to bull trout life histories. In the John Day basin, we captured adult and juvenile bull trout from the upper mainstem John Day River and its tributaries Call Creek, Deardorff Creek, and Roberts Creek. In the Walla Walla basin, we captured adult and juvenile bull trout from Mill Creek. In the Grande Ronde basin, we captured adult bull trout from the Wenaha River and Lookingglass Creek. Some juvenile bull trout were also captured from Catherine Creek.

### Methods

We continued to operate traps to capture migrant bull trout in both the upper mainstem John Day River subbasin and Mill Creek of the Walla Walla basin. With these traps, we intended to determine the timing of bull trout movements both upstream and downstream, determine the relative abundance and size of migrant fish, and capture fish to be implanted with radio tags. In the upper mainstem John Day River subbasin, downstream and upstream migrants were captured in weir traps placed in Call Creek at river kilometer (Rkm) 0.7, Deardorff Creek at Rkm 5.3, Roberts Creek at RKm 1.3, and the upper mainstem John Day River at Rkm 449.2 (Figure 1). This latter site in the upper mainstem John Day River was 0.4 km downstream of the site in 1997 because it had more stable substrate and was more effective at high stream flows. These weir traps, described in Hemmingsen et al (2001), were set in place from 03 to 09 April. A 1.5-m diameter screw trap was placed in the mainstem John Day River at Rkm 436.8 downstream of the confluence with Deardorff Creek during the same time period. With this trap, we intended to recapture bull trout with 125 KHz, 14-mm Passive Integrated Transponder (PIT) tags applied at weir sites, and to capture fish whose movements originated downstream of any weir.

In Mill Creek, upstream migrant bull trout were trapped as they exited the fish ladder at the dam (Rkm 40.9) associated with the water intake for the city of Walla Walla. The trap was a cube approximately one meter per side built of metal screen with 10-mm mesh that was bolted to the gate valve on the fish ladder. Fish entered the trap through an inverted cone that was intended to prevent their escape back down the ladder. We occasionally snorkeled the pools adjacent to the dam for indications of interference of bull trout movement by the trap. This trap was later modified when we discovered that bull trout would avoid entry, or would enter then escape back down the ladder. Modification involved attachment of a 1-meter diameter hoop net to the upstream end of the trap. A small door allowed passage from the trap to the hoop net. This modification effectively captured and held bull trout until they could be sampled. Downstream migrant bull trout were captured using another 1.5-meter diameter rotary screw trap. We located the screw trap in the first adequate pool (Rkm 41.5) upstream of the dam. Both Mill Creek traps were set in place on 25 March.

We sampled all traps daily during their operation, which generally occurred through mid-October. By this time, bull trout occurrence had decreased, and accumulating leaves and debris made traps ineffective without constant maintenance. Fish of most species captured were anesthetized and measured to fork length; weight and scale samples were additionally collected from all bull trout. Bull trout that were 150 mm or longer were checked for the presence of PIT tags applied during 1997. Many of the bull trout not tagged in 1997 were given PIT tags in 1998. Bull trout captured in screw traps also received a caudal fin mark to identify them for trap efficiency calculations. A maximum of 3 mm was cut from either the top or bottom lobe of the caudal fin, alternating between lobes weekly. After recovery from anesthesia, these fish were released in a pool about 200 m upstream of the traps. Efficiency of the screw trap was determined monthly from the number of recaptured, fin-marked bull trout. Estimated numbers of bull trout that may have passed downstream were calculated by bootstrap methods. Some bull trout of the Grande Ronde Basin were captured in weir or screw traps operated by personnel from the ODFW Chinook Life History Study.

At all trap locations, some bull trout were implanted with radio transmitters. The duration of these transmitters ranged from 0.3 – 2 years. As in 1997, we limited transmitter size to a maximum of three percent of the host fish's weight. Bull trout with transmitters also received PIT tags implanted in the dorsal sinus. We tracked transmitter signals from both the ground and from the air. Aerial tracking was conducted from a plane operated by the Oregon State Police. Procedures for surgically implanting radio transmitters and tracking locations of fish are described in Hemmingsen et al. (2001).

## Results and Discussion

Bull trout captured by these traps can be divided into two groups, those captured for the first time in each trap, or those recaptured one or more times in any trap. Recaptured individuals were identified by some fin mark or tag and originated from several sources. Figures presented here that summarize bull trout captured in traps describe individuals captured for the first time in a given trap. Recaptured bull trout are discussed in the text or identified in tables.

### Upper John Day River subbasin

From 01-16 May, the screw trap and weir traps in Call and Roberts creeks operated intermittently because of high stream flows. Weir traps in Deardorff Creek and the upper John Day River were completely disabled during that period. All traps were functional by 19 May, but high flows returned four days later. From 23 May to 01 June, only the screw trap and weirs in Call Creek operated; they remained functional throughout the sampling season. Another high-water event that began the last week of May prevented operation of weir traps in the upper John Day River and Deardorff Creek until 14 June, and prevented operation of weir traps in Roberts Creek until 24 June. Thereafter, traps in these three streams operated throughout the sampling season.

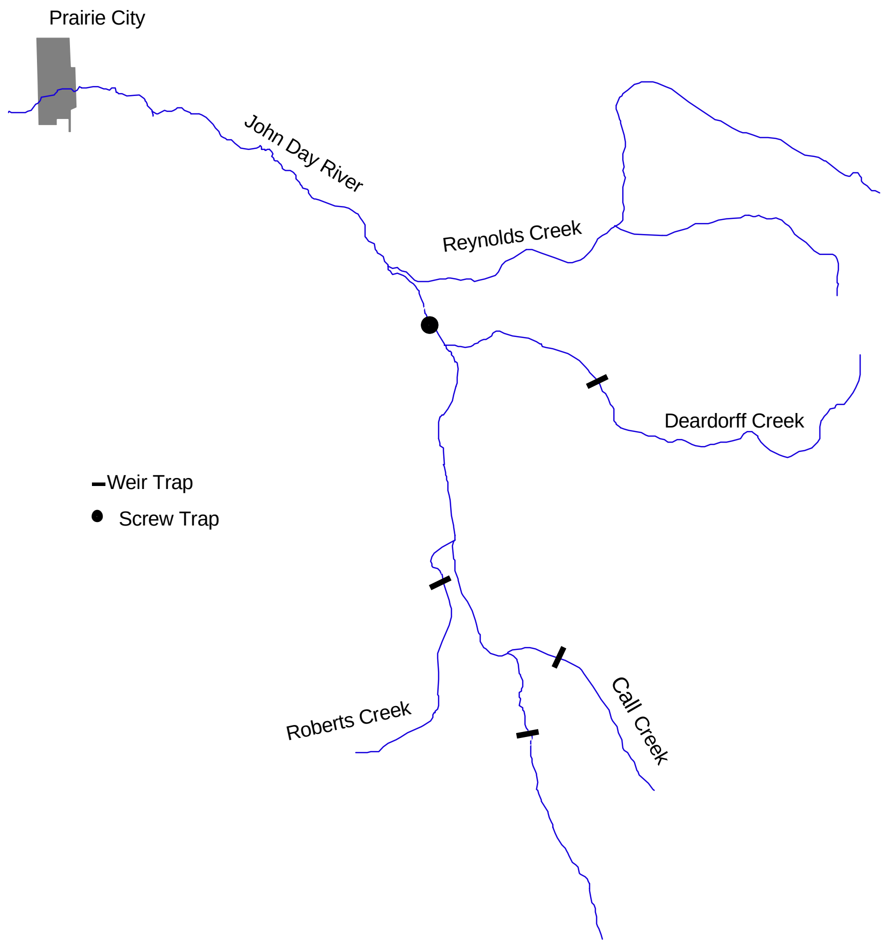



Figure 1. Locations of traps in the upper mainstem John Day River subbasin.

Although in 1997 we operated four downstream migrant weir traps in this subbasin, 1998 was the first year we operated four upstream migrant traps. Fifty-six bull trout were captured in all upstream migrant traps (Figure 2). Prior to July, only two bull trout were captured. The trap in Call Creek captured 34 of the total number of bull trout, none before July, and the trap was functional since installation in early April. The traps in Call and Roberts creeks remained in operation until 13 October, yet only one bull trout was captured in them after 15 September. We removed both upstream and downstream migrant traps in Deardorff Creek on 21 September. Therefore, some bull trout could have passed up Deardorff Creek undetected in October. The upstream migrant trap in the John Day River was removed on 12 September. However, the downstream migrant trap remained in place until 12 October, and no large bull trout were observed at this weir attempting to pass upstream.

Overall, bull trout captured in upstream migrant traps ranged from 186 to 560 mm fork length, and most were 300 mm or larger (Figure 3). Two PIT-tagged bull trout captured in the upstream migrant traps were previously captured in our screw trap located in the upper John Day River. One of these appeared in Call Creek (03 September) 33 days after being captured in the screw trap (Table 1). The second appeared in the Deardorff Creek trap (31 July) 44 days after being captured in the screw trap. This bull trout and the remaining three fish previously captured in the upper John Day River trap were radio-tagged at their original capture sites.

Table 1. Bull trout recaptured in upstream migrant traps in the upper John Day River subbasin in 1998.

| Recapture site | Date | Length (mm) | Previous capture site | Date | Days elapsed |
|---|---|---|---|---|---|
| Deardorff Cr. | 31 Jul | 482 | Screw trap | 17 June | 44 |
| Call Cr. | 03 Sep | 240 | Screw trap | 01 Aug | 33 |
| Call Cr. | 28 Jul | 355 | John Day R [a] | 24 Jun | 34 |
| Call Cr. | 15 Aug | 470 | John Day R [a] | 28 Jul | 18 |
| Call Cr. | 03 Sep | 314 | John Day R [a] | 31 Jul | 35 |

[a] Downstream migrant trap of the upper John Day River.

We surgically implanted radio transmitters in 13 bull trout captured in the upstream migrant traps (Table 2). Of the four Call Creek bull trout, two were less than 400 mm and had transmitters of 4.7 months expected duration. These individuals moved upstream past the weir either 0.4 or 0.8 km, stayed at those locations about one month, then returned downstream. Although we lost one signal after 03 September, the other moved into the mainstem John Day River (Rkm 447.5) by 29 September and eventually to Rkm 447.0, where it stayed until its signal expired. The two Call Creek bull trout larger than 400 mm stayed near the weir site 52 or 55 days, then moved to the John Day River. Between 03 and 17 September, one reached Rkm 440.9 (6.8 km traveled). Between 14 and 29 September, the other reached Rkm 444.3 (2.7 km traveled). They remained at these locations through October.

Although four bull trout of Roberts Creek received transmitters, we were unable to locate three of them during much of the summer and fall. We assume that these fish moved upstream in the Watershed; however, we did not have access to track them by foot, and

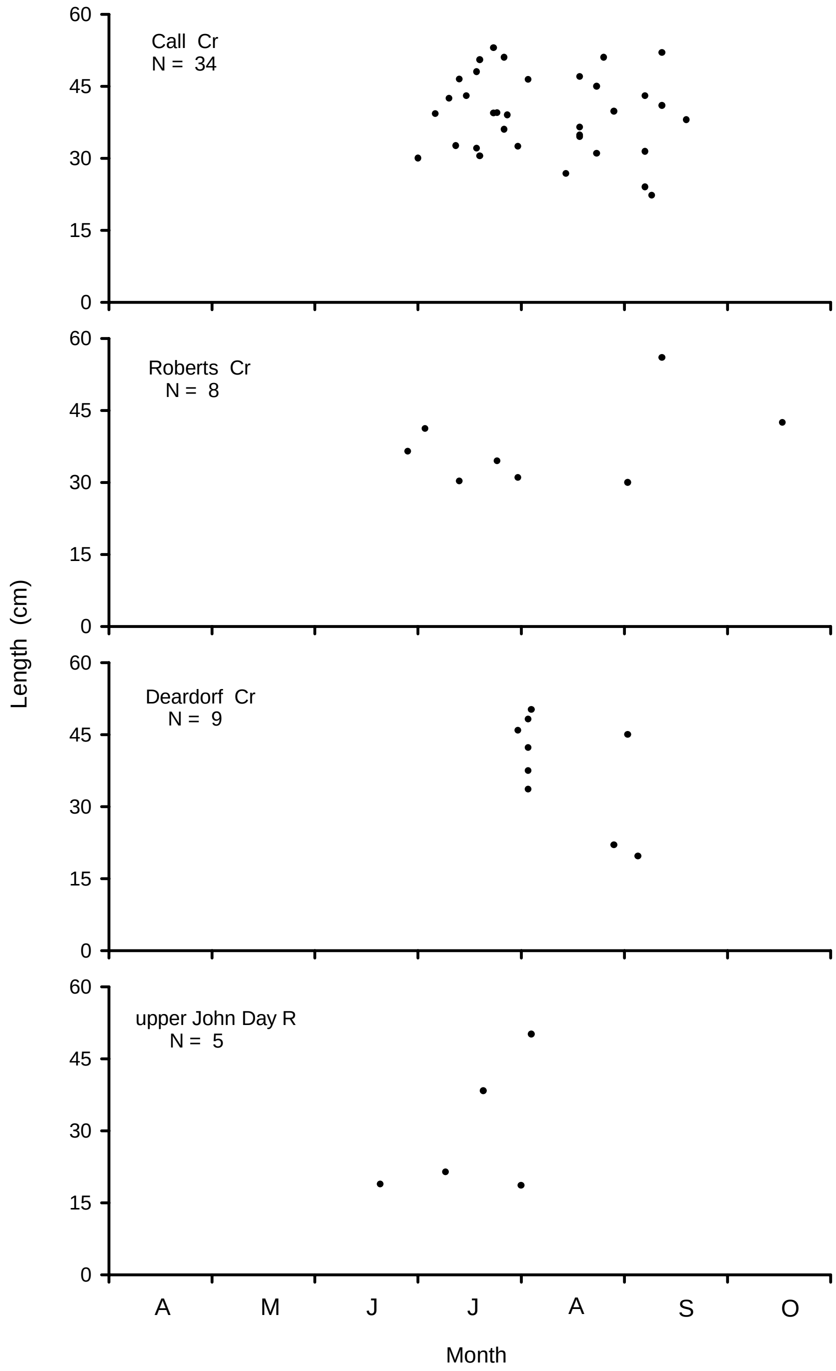



Figure 2. Bull trout of the upper John Day River subbasin captured in upstream migrant weir traps during 1998.

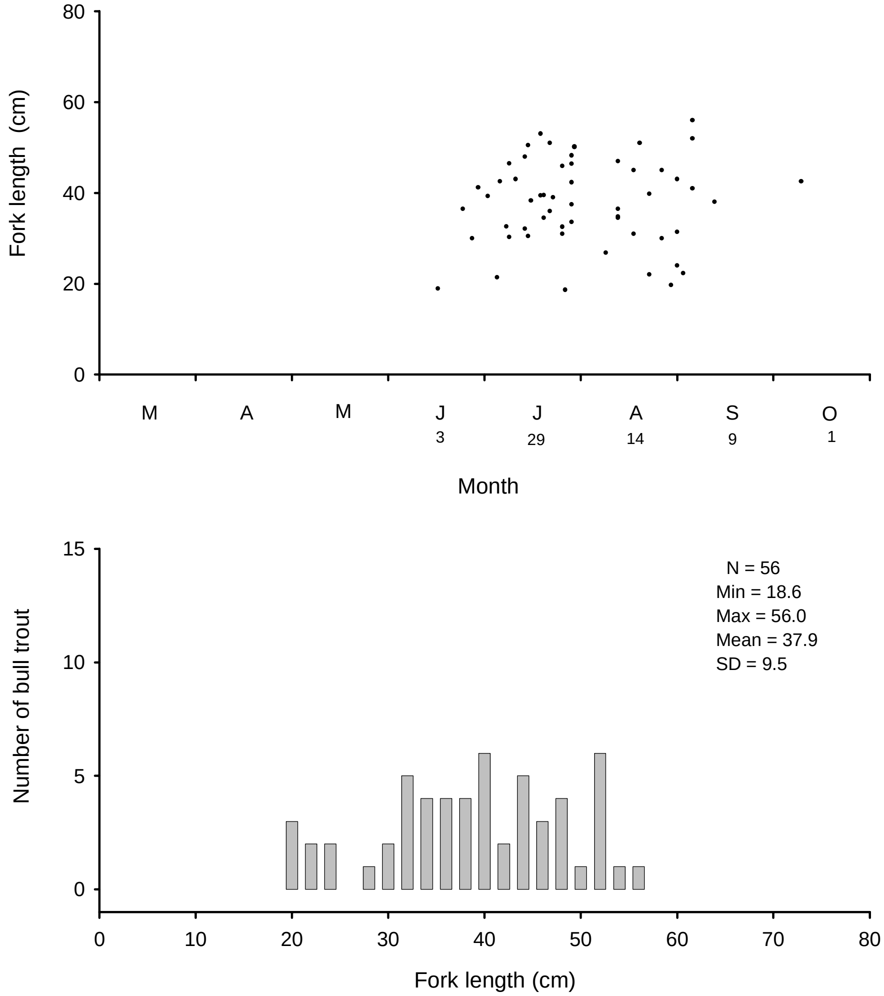



Figure 3. Combined numbers of bull trout of the upper John Day River subbasin captured in upstream migrant traps in 1998, and their frequency by length. Monthly totals are shown under corresponding months.

telemetry flights were canceled. Two of these bull trout were eventually located in the upper John Day River (Rkm 444.7 and 433.0) late in September and October, respectively. The third fish radio-tagged 22 July, was recaptured in the downstream migrant trap on 04 Oct and tracked to the John Day River (Rkm 433.0) on 10 Dec. The fourth Roberts Creek fish, tagged 08 September, moved upstream to Rkm 2.2 and stayed there through most of October.

Both bull trout in Deardorff Creek were captured near the end of July. In nearly one month, they moved upstream 0.4 or 5.4 km. By 14 Sep, they were back to Rkm 1.0 or 1.5, respectively. While one bull trout moved into the John Day River by 21 October, the other remained in Deardorff Creek.

All three radio-tagged bull trout of the upper John Day River continued upstream. Two went to the same locality 4.7 km from the weirs, but at different times. Two fish stayed above the weir site through much of October while the third moved downstream to Rkm 440.7 after the traps were removed. The furthest downstream location in the John Day River that we detected any bull trout was Rkm 428.9 (Table 2), which was about 8 km downstream of our screw trap and 6.5 km upstream of Prairie City.

Table 2. Bull trout captured in upper John Day subbasin upstream migrant weir traps and implanted with radio transmitters in 1998, and the range of their locations.

| Trap location, date tagged | L (mm) | MHz | Signal life (mo) | LU[a] | TU[d] | LD[c] | TD[d] |
|---|---|---|---|---|---|---|---|
| **Call Cr**. (km 0.7): | | | | | | | |
| 29 Jun | 300 | 151.102 | 4.7 | 1.5 | 09 Jul | 0.7 | 03 Sep |
| 04 Jul | 393 | 151.112 | 4.7 | 1.1 | 18 Aug | 447.0 | 21 Oct |
| 13 Jul | 465 | 150.472 | 24 | 0.7 | 03 Sep | 440.9 | 17 Sep |
| 21 Jul | 530 | 150.493 | 24 | 0.7 | 14 Sep | 444.3 | 21 Oct |
| **Roberts Cr**. (km 1.3): | | | | | | | |
| 26 Jun | 365 | 150.852 | 18 | -- | -- | 444.7 | 30 Sep |
| 01 Jul | 412 | 151.251 | 4.7 | -- | -- | 428.9 | 17 Dec |
| 22 Jul | 345 | 151.503 | 3.3 | -- | -- | 433.0 | 10 Dec |
| 08 Sep | 560 | 150.623 | 36 | 2.2 | 29 Sep | 2.2 | 21 Oct |
| **Deardorff Cr**. (km 5.3): | | | | | | | |
| 28 Jul | 459 | 150.534 | 24 | 10.7 | 03 Sep | 440.0 | 21 Oct |
| 01 Aug | 502 | 150.604 | 24 | 5.7 | 03 Sep | 1.0 | 14 Sep |
| **John Day R** (km 449.2): | | | | | | | |
| 10 Jul | 186 | 151.043 | 3.3 | 453.9 | 31 Jul | 453.5 | 21 Oct |
| 18 Jul | 383 | 151.012 | 3.3 | 453.1 | 03 Sep | 449.6 | 21 Oct |
| 01 Aug | 501 | 150.354 | 24 | 453.9 | 03 Sep | 440.7 | 21 Oct |

[a] LU = maximum known upstream location (Rkm) in 1998.
[b] TU = date of maximum upstream location.
[c] LD = maximum known downstream location (Rkm) in 1998 since receiving transmitters.
[d] TD = earliest date of maximum downstream location.
-- = not known.

We captured 159 bull trout in downstream migrant traps, each located a few meters upstream of their respective upstream migrant traps. Bull trout appeared in all four traps soon after they began operation in early April (Figure 4). Only two bull trout in Call Creek and one in Deardorff Creek were captured during May and early June, but this was the time when most traps were affected by high stream flows. Downstream migrant traps remained in Call and Roberts creeks until 13 October, when few bull trout appeared. As was the case for upstream migrants, about half the number of bull trout captured appeared in Call Creek. In three of four traps shown in Figure 4, most bull trout captured before mid-August were less than 250 mm fork length, and fish of this size continued to be captured during October in Call Creek. In the upper John Day River, however, eight bull trout larger than 300 mm were captured before mid-August. Three of these eight bull trout were recaptured later in the upstream migrant trap in Call Creek, and are also represented in Figure 2. The time elapsed between captures in these two traps was 18, 34

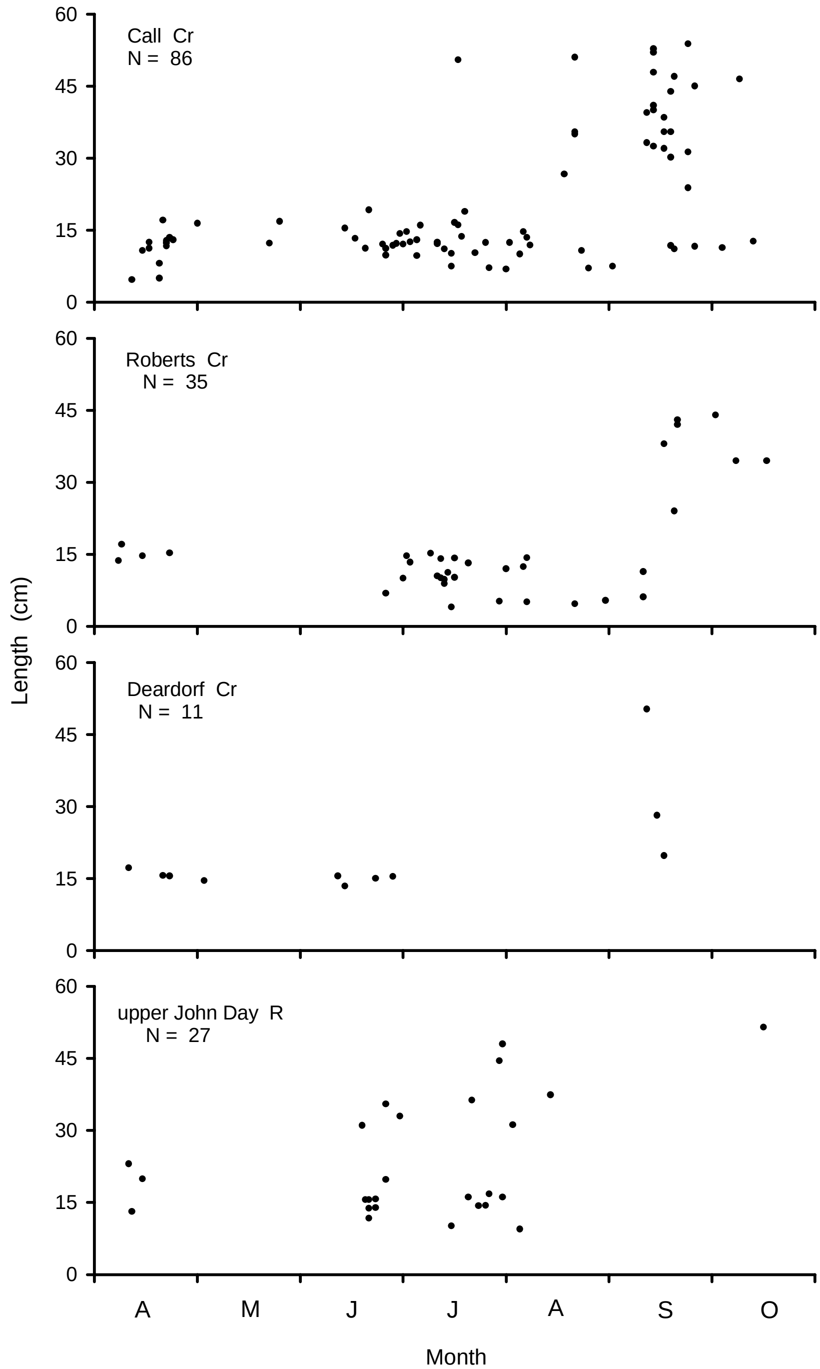



Figure 4. Bull trout of the upper John Day River subbasin captured in downstream migrant weir traps during 1998.

35 days for these three fish (Table 1). Presently, we assume that most large bull trout captured in upstream migrant traps are intercepted while headed to spawn in locations upstream. Although bull trout spawn in the John Day River upstream of traps there, these three bull trout apparently moved out of headwaters of the John Day River to spawn in Call Creek.

Other than in the upper John Day River, most bull trout larger than 300 mm appeared in the downstream migrant traps after mid-August, and the majority of these were captured in Call Creek during September (Figure 4). Of these, seven had previously been captured in the upstream migrant trap in Call Creek, as had another bull trout not shown in Figure 4 because its length had not been recorded. This fish was 393 mm when captured 75 days earlier as it headed upstream. For these eight recaptured bull trout, the time elapsed between captures in both Call Creek traps ranged from 17 to 75 days, with an average of 50 days (Table 3). Another bull trout (300 mm) recaptured in Call Creek was dead and not included in elapsed time calculations. Two additional bull trout larger than 300 mm were recaptured in downstream migrant traps in Deardorff and Roberts creeks after previously being captured in their respective upstream migrant traps. The elapsed time for these two fish fell into the range for those recaptured in Call Creek (Table 3). We assume that all these bull trout had spawned in respective streams during the elapsed time. Telemetry data indicated that some bull trout move from headwater locations rather quickly after spawning. These trap data, however, indicate that bull trout can spend relatively long times going to these headwater locations and staging to spawn.

Table 3. Bull trout recaptured in downstream migrant traps in the upper John Day River subbasin in 1998.

| Recapture Site | Date | Length (mm) | Previous capture site[a] | Date | Days elapsed |
|---|---|---|---|---|---|
| Call Cr. | 08 Sep | 332 | Call Cr. | 28 Jul | 42 |
| Call Cr. | 10 Sep | 325 | Call Cr. | 10 Jul | 62 |
| Call Cr. | 10 Sep | 400 | Call Cr. | 22 Jul | 50 |
| Call Cr. | 10 Sep | 528 | Call Cr. | 21 Jul | 51 |
| Call Cr. | 15 Sep | 439 | Call Cr. | 08 Jul | 69 |
| Call Cr. | 16 Sep | 470 | Call Cr. | 15 Aug | 32 |
| Call Cr. | 17 Sep | --[b] | Call Cr. | 04 Jul | 75 |
| Call Cr. | 20 Sep | 313 | Call Cr. | 03 Sep | 17 |
| Call Cr. | 17 Sep | 300 | Call Cr. | 29 Jun | --[c] |
| Deardorff Cr. | 08 Sep | 502 | Deardorff Cr. | 01 Aug | 38 |
| Roberts Cr. | 04 Oct | 345 | Roberts Cr. | 22 Jul | 74 |

[a] Upstream migrant traps of each site.
[b] Length was 393 mm when captured in the upstream migrant trap.
[c] Mortality that drifted into the trap; days elapsed were therefore not calculated.

Overall, bull trout captured in downstream migrant traps ranged from 40 to 538 mm fork length (Figure 5). The number measured (156) is three less than the subtotals shown in Figure 4 (158) because one bull trout captured in the upper John Day River on 03 July and two bull trout captured in Call Creek on 13 and 17 September escaped unmeasured. Bull trout length-frequency distributions were not normally distributed. Two size categories of fish seemed to exist, those shorter than 240 mm and those longer than 280 mm. Presently, we assume that the latter group consists mostly of fluvial, post-spawning individuals. We are uncertain of the minimum length at maturity of fluvial bull trout in the upper mainstem John Day River subbasin, but data from 1998 suggest that it is probably less than 300 mm and may be around 240 mm.

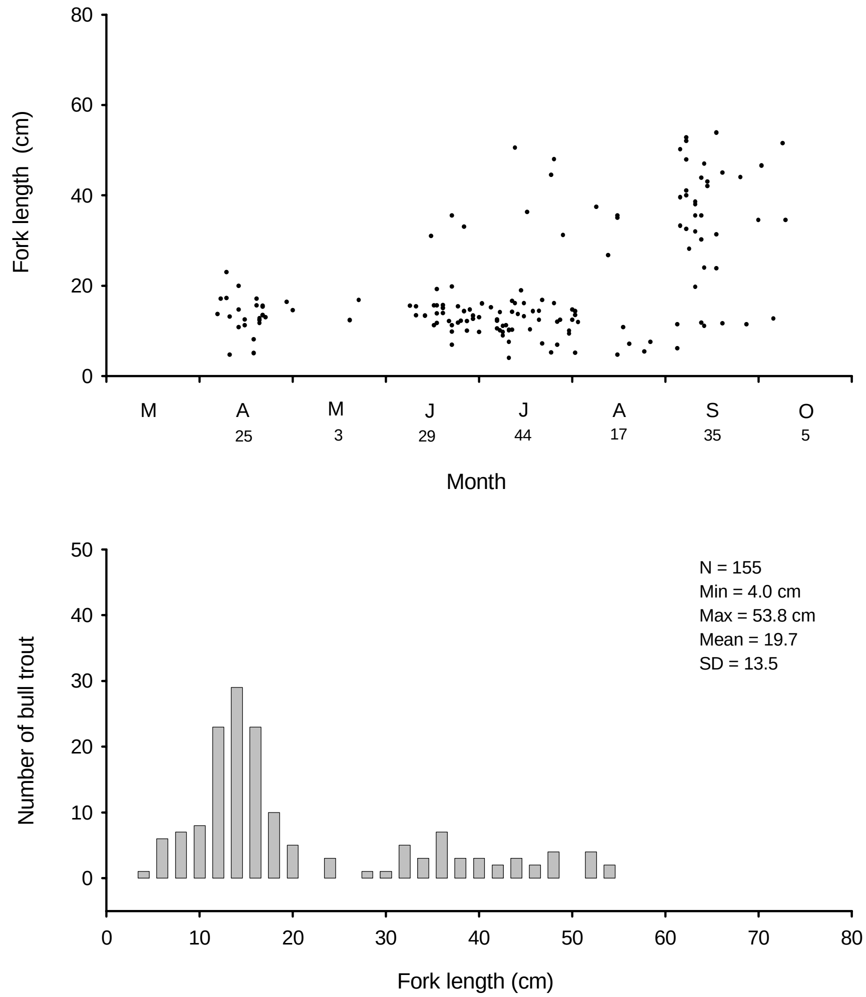



Figure 5. Combined numbers of bull trout of the upper John Day River subbasin captured in downstream migrant traps in 1998, and their frequency by length. Monthly totals are shown under corresponding months.

We implanted radio transmitters in 18 bull trout captured in the downstream migrant traps, mostly from Call Creek (Table 4). Most of the Call Creek fish moved downstream and into the John Day River by late September or October, although the smallest individual (171 mm) did so by 09 July. The lone exception was the 355-mm bull trout tagged on 18 August. It moved to the John Day River at the mouth of Call Creek (Rkm 447.0) on 14 September, then was located back near the Call Creek weir site by 29 September. It remained there through 21 October, the last time it was located in 1998.

One bull trout of Roberts Creek, implanted 16 September, moved downstream to near the confluence with the John Day River and stayed there through October. The other Roberts Creek bull trout remained near the weir site through 21 October. Likewise, the 172-mm bull trout of Deardorff Creek remained near the weir site through 18 June when the transmitter presumably expired. Four of five bull trout at the upper John Day River site, implanted in June and July, moved downstream then up into Call Creek to their highest locations by early September. One of these fish remained near the weir site, whereas the other three individuals moved back to the John Day River by early October. None of these three had returned to its original capture location (Rkm 449.2). A relatively small bull trout, implanted on 10 April, moved downstream to km 441.4 of the John Day River. It eventually moved back upstream to the mouth of Roberts Creek (Rkm 443.0) where it remained through 21 October. The furthest downstream location in the John Day River that we detected any bull trout was Rkm 421.1, which was 0.6 km downstream of the confluence of Dixie Creek (Table 4).

Table 4. Bull trout captured in upper John Day subbasin downstream migrant weir traps and implanted with radio transmitters in 1998, and the range of their locations.

| Trap location, date tagged | L (mm) | MHz | Signal life (mo) | LU[a] | TU[b] | LD[c] | TD[d] |
|---|---|---|---|---|---|---|---|
| **Call Cr**. (km 0.7): | | | | | | | |
| 20 Apr | 171 | 151.732 | 1.3 | -- | -- | 444.3 | 09 Jul |
| 18 Aug | 355 | 151.053 | 3.3 | 0.7 | 29 Sep | 447.0 | 14 Sep |
| 18 Aug | 350 | 151.542 | 3.3 | -- | -- | 441.4 | 29 Sep |
| 18 Aug | 510 | 150.433 | 24 | -- | -- | 421.1 | 27 Oct |
| 10 Sep | 325 | 151.520 | 3.3 | -- | -- | 449.2 | 09 Oct |
| 10 Sep | 520 | 150.554 | 24 | -- | -- | 445.1 | 21 Oct |
| 15 Sep | 302 | 151.022 | 3.3 | -- | -- | 446.5 | 29 Sep |
| 15 Sep | 355 | 151.002 | 3.3 | -- | -- | 443.6 | 21 Oct |
| 22 Sep | 450 | 150.971 | 18 | -- | -- | 439.0 | 30 Sep |
| 05 Oct | 465 | 150.982 | 18 | -- | -- | 447.0 | 09 Oct |
| **Roberts Cr**. (km 1.3) | | | | | | | |
| 16 Sep | 240 | 150.932 | 9 | -- | -- | 0.1 | 09 Oct |
| 17 Sep | 420 | 150.992 | 18 | -- | -- | 1.3 | 21 Oct |
| **Deardorff Cr**. (km 5.3): | | | | | | | |
| 10 Apr | 172 | 151.742 | 1.3 | -- | -- | 5.3 | 18 Jun |
| **John Day R** (km 449.2): | | | | | | | |
| 10 Apr | 230 | 150.814 | 6.7 | -- | -- | 441.4 | 18 Aug |
| 17 Jun | 310 | 150.860 | 18 | 0.7 [e] | 19 Aug | -- | -- |
| 24 Jun | 355 | 151.291 | 4.7 | 1.5 [e] | 19 Aug | 448.3 | 14 Sep |
| 28 Jul | 480 | 150.613 | 36 | 1.1 [e] | 03 Sep | 447.8 | 03 Oct |
| 31 Jul | 312 | 151.601 | 3.3 | 0.7 [e] | 19 Aug | 448.3 | 30 Sep |

[a] LU = maximum known upstream location (Rkm) in 1998 since receiving transmitters. Dashes = trap location.
[b] TU = date of maximum upstream location. Dashes = date tagged.
[c] LD = maximum known downstream location (Rkm) through October 1998.
[d] TD = earliest date of maximum downstream location.
[e] Locations in Call Creek.

The screw trap in the upper mainstem John Day River operated through the second week of October in 1998. During this time it captured 158 bull trout, mostly during April through July. Of these, we measured 144 individuals. No bull trout less than 250 mm were captured after mid-August, and only three bull trout were captured thereafter (Figure 6). Fork lengths of captured bull trout ranged from 199 to 506 mm, and averaged 175 mm. These results are quite similar to those obtained at this location in 1997 (Hemmingsen et al 2001). Two bull trout were recaptured individuals identified by PIT tags. A 151-mm bull trout captured on July 29 in the screw trap was captured 69 days earlier in the downstream migrant trap in Call Creek. A 405-mm bull trout captured on 29 September in the screw trap was captured 92 days earlier in the upstream migrant trap in Roberts Creek. Based on recaptures of fin-clipped bull trout from 19 May to 30 June, the overall efficiency of the screw trap was 25%. However, this efficiency varied with fish size. Bull trout between 120 and 160 mm were recaptured at a proportion of 38%, whereas those larger than 160 mm were recaptured at a proportion of 14%.

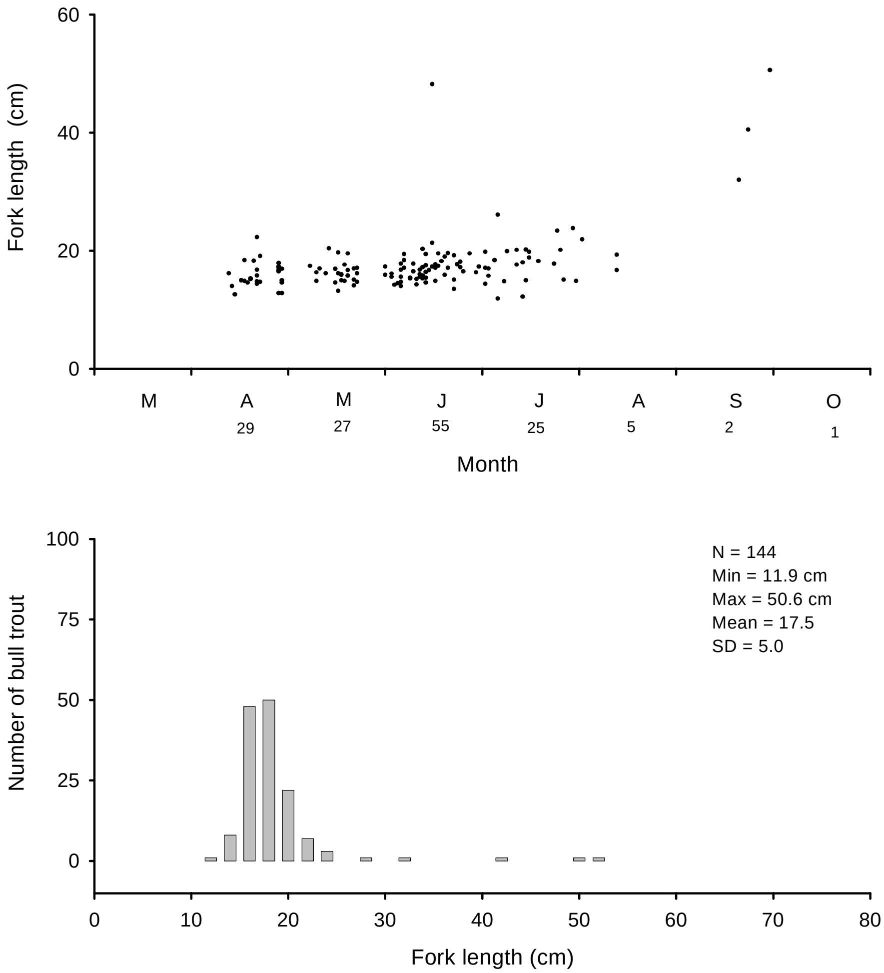



Figure 6. Numbers of bull trout of the upper John Day River captured by screw trap in 1998, and their frequency by length. Monthly totals are shown under corresponding months.

We implanted radio transmitters in six bull trout captured in the screw trap during 1998 (Table 5). One of these fish, 482 mm long and implanted 17 June, moved to Rkm 8 of Deardorff Creek by 14 September, then returned to the pool where the screw trap was located and remained there from late September through October. The 320-mm bull trout implanted 23 September also remained in this pool through October. The other four bull trout moved farther downstream in the John Day River. The lowest location for any of these fish (Rkm 432.0) was 3 km downstream of the confluence with Reynolds Creek.

We also continued to track four bull trout captured in upper John Day River weir traps or the screw trap and implanted in between 01 August and 30 September 1997. These fish remained in the John Day River above Rkm 430.7 until no tag signals were detected, which ranged from 21 January to 12 May 1998.

Table 5. Bull trout captured in the upper John Day River screw trap (km 436.8) and implanted with radio transmitters in 1998, and the range of their locations.

| Date Tagged | L (mm) | (MHz) | Signal life (mo) | LU[a] | TU[b] | LD[c] | TD |
|---|---|---|---|---|---|---|---|
| 22 Apr | 223 | 151.773 | 6.7 | -- | -- | 435.8 | 03 Jun |
| 17 Jun | 482 | 150.453 | 24 | 8[e] | 14 Sep | 436.8 | 30 Sep |
| 08 Jul | 261 | 151.081 | 4.7 | -- | -- | 432.9 | 27 Oct |
| 29 Jul | 234 | 151.033 | 3.3 | -- | -- | 435.3 | 30 Sep |
| 21 Aug | 288 | 151.551 | 3.3 | -- | -- | 432.0 | 09 Oct |
| 23 Sep | 320 | 150.952 | 18 | -- | -- | 436.8 | 21 Oct |

[a] LU = maximum known upstream location (Rkm) in 1998 since receiving transmitters. Dashes = Rkm 436.8.
[b] TU = date of maximum upstream location. Dashes = date tagged.
[c] LD = maximum known downstream location (Rkm) through October 1998.
[d] TD = earliest date of maximum downstream location.
[e] Rkm of Deardorff Creek .

## Mill Creek

Stream flows of Mill Creek permitted operation of both upstream and downstream traps from 25 March to 20 October 1998. The upstream migrant trap captured only two bull trout before July, both less than 200 mm fork length. By early July we had captured no large bull trout, although we observed several of them in the pool at the base of the fish ladder. On 07 July we modified the trap as previously described, and on 08 July the trap captured 18 large bull trout. The upstream migrant trap captured 164 bull trout during its operation, and 47 percent of these were captured during July (Figure 7). Although the trap operated until 20 October, only five bull trout were captured during the month and three of these were captured during the first week of October. We measured 162 individuals of the total number captured. These bull trout ranged in fork length from 137 to 830 mm with a mean of 399 mm (Figure 7).

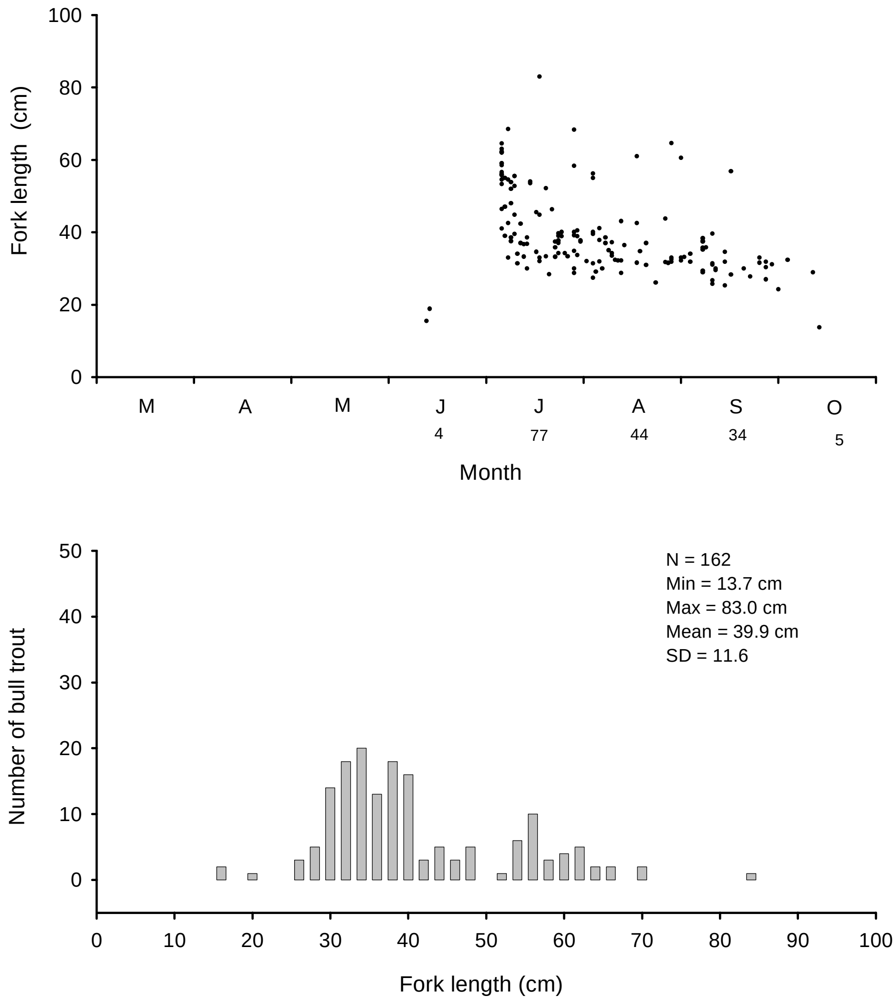
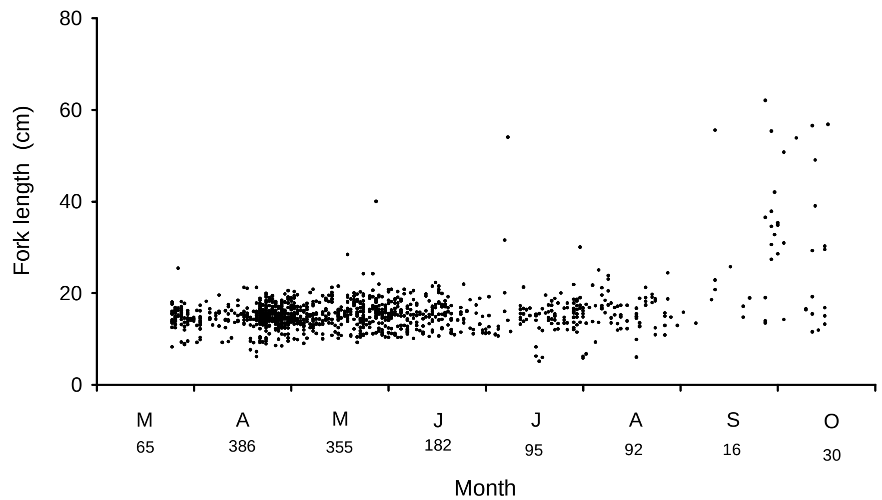



Figure 7. Numbers of bull trout of Mill Creek captured in the upstream migrant trap in 1998, and their frequency by length. Monthly totals are shown under corresponding months.

The screw trap captured 1,221 bull trout, and began catching them soon after the trap was set in place (Figure 8). Most (59%) of these fish appeared during April and May. Measurements on 1,210 bull trout captured produced a range in fork length from 51 to 620 mm. The median fork length was 151 mm and 97% of all bull trout captured were less than 250 mm.



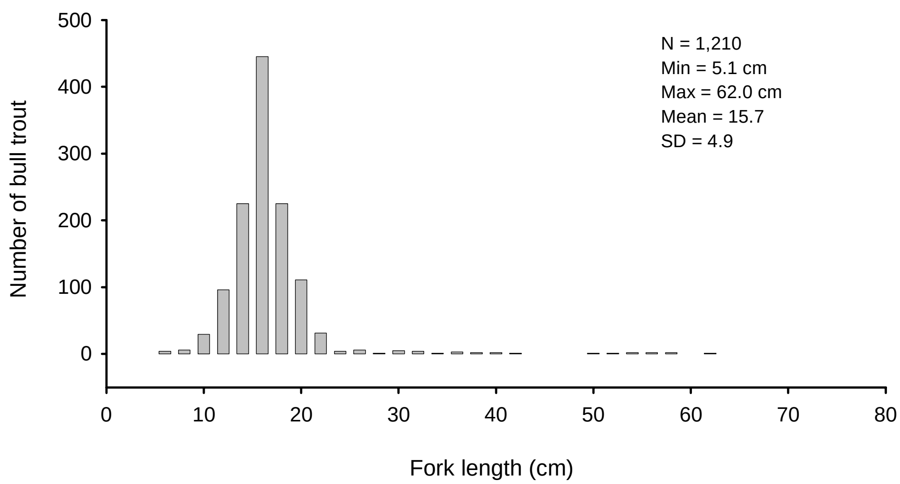




Figure 8. Numbers of bull trout of Mill Creek captured in the screw trap in 1998, and their frequency by length. Monthly totals are shown under corresponding months.

Table 6. Efficiencies at which the Mill Creek screw trap captured bull trout, and the estimated numbers of bull trout that passed downstream in 1998.

| | 25 Mar-Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|
| Trap efficiency (%)[a] | 52 | 35 | 56 | 42 | 51 | 25 |
| Estimated number of bull trout | 854 | 940 | 386 | 175 | 166 | 69 |
| 95% confidence interval | 124 | 165 | 62 | 23 | 24 | 45 |

[a] Proportion of fin-marked fish recaptured.

From March through September, the efficiency at which the screw trap captured bull trout averaged 43%, although there was considerable monthly variation (Table 6). The number captured during October was too small to be included in the expanded estimate. Based on the efficiencies in Table 6, we estimated the number of bull trout that may have passed downstream at this location to be between 2,500 and 3,400.

Eleven bull trout captured in the screw trap had previously been captured and PIT-tagged elsewhere, either in the upstream migrant trap or near the dam by angling (Table 7). These fish ranged from 285 to 620 mm fork length. The elapsed time between captures in both traps ranged from 68 to 101 days, with an average of 82 days. We assume all had spawned during this period, and as was the case in the upper John Day River subbasin, the time doing so was relatively long. Also notable is that all these recaptured fish were first captured in July. We presently do not know whether all bull trout that moved upstream in July returned downstream after October or remained upstream through the winter.

Table 7. Mill Creek bull trout recaptured in the screw trap during 1998. All but one were previously captured in 1998.

| Date Recaptured | Length (mm) | Previous capture site | Date | Days Elapsed |
|---|---|---|---|---|
| 14 Sep | 555 | Upstream migrant trap | 17 Jul | 59 |
| 30 Sep | 620 | Upstream migrant trap | 20 Jul | 72 |
| 02 Oct | 378 | Upstream migrant trap | 26 Jul | 68 |
| 03 Oct | 420 | Upstream migrant trap | 14 Jul | 81 |
| 04 Oct | 285 | Upstream migrant trap | 23 Jul | 73 |
| 06 Oct | 309 | Upstream migrant trap | 16 Jul | 82 |
| 10 Oct | 538 | Upstream migrant trap | 12 Jul | 90 |
| 15 Oct | 565 | Upstream migrant trap | 08 Jul | 99 |
| 16 Oct | 390 | Upstream migrant trap | 16 Jul | 92 |
| 16 Oct | 490 | Mill Cr dam [a] | 07 Jul | 101 |
| 02 Oct | 553 | Mill Cr dam [a] | 07 Jul | 87 |

[a] Angling below dam to capture and radio tag.

From late March through August, the mean lengths of bull trout captured monthly in the Mill Creek screw trap were consistent. The size of these fish was also similar to those of bull trout from the upper John Day River subbasin (Figure 9). Although large bull trout were observed in September and October, we also continued to observe small bull trout during these months (Figure 8). Upstream migrant bull trout in both the John Day River and Mill Creek watersheds were similar in length, particularly during the months of July through September (Figure 9).

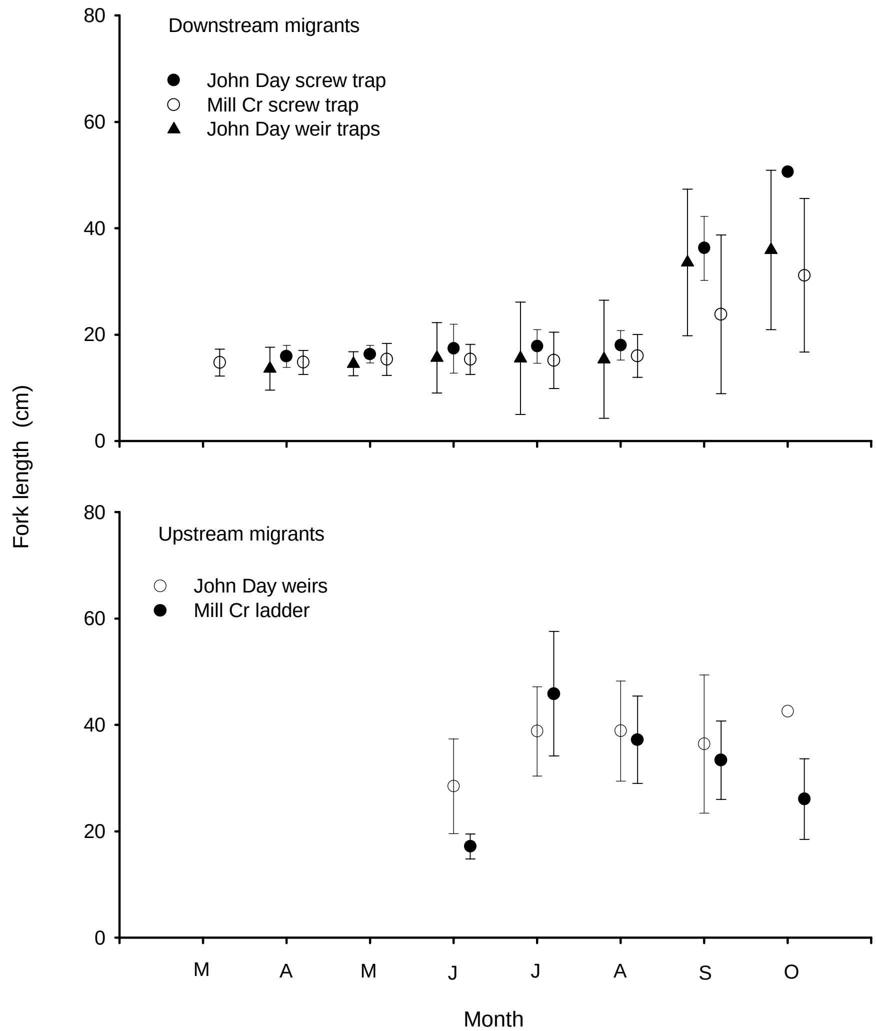



Figure 9. Fork lengths (mean ± SD) of bull trout captured monthly during 1998.

Analysis of scales from 415 Mill Creek bull trout captured in 1998 indicated the presence of fish through nine years in age (Figure 10). There is considerable variation in length at each age, particularly at ages three and four. From this analysis, most bull trout captured by screw trap were age 4 or younger, whereas most bull trout captured in the upstream migrant trap were age 5 or older.

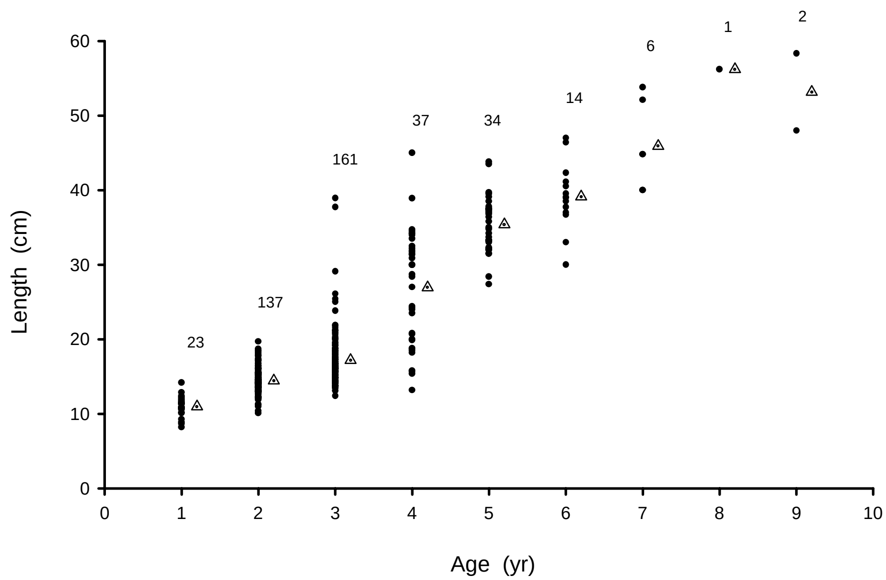



Figure 10. Fork length at age of Mill Creek bull trout estimated by analysis of scales from fish captured in 1998. Mean length at age (triangles) and numbers of bull trout analyzed are shown.

From Mill Creek, we implanted radio transmitters in 32 bull trout from 170 to 630 mm fork length (Table 8). Eleven of these bull trout were captured during July by angling in pools adjacent to the dam (Rkm 40.9) associated with the water intake for the city of Walla Walla. All these bull trout received transmitters with a minimum expected duration of 18 months, so they could be tracked for two spawning seasons. Eight implanted bull trout were captured in the upstream migrant trap. The two captured earliest were also large enough to receive 18-month transmitters. Twelve of 13 bull trout 470 mm or larger were captured by 17 July; 10 of these 12 fish reached their farthest upstream locations by 12 September. For bull trout 470 mm or larger, the farthest upstream location in 1998 ranged between Rkm 41.2 and 52.8 (mean 48.3).

The other six bull trout captured in the upstream migrant trap received shorter duration transmitters, because of their smaller size (300-383 mm), and were tracked through one spawning season. These bull trout were captured between 10 and 23 September, and five reached their farthest upstream locations after mid-September. One bull trout stayed in the vicinity of the pool in which it was released until 01 December. For bull trout between 300 and 400 mm, the farthest upstream location in 1998 ranged between Rkm 40.9 and 50.2 (mean 45.1).

We implanted radio transmitters in 13 bull trout captured in the screw trap throughout the season. These fish were 195-212 mm (fork length) and had small transmitters that produced signals for a relatively short length of time. Three of these bull trout traveled upstream to locations between km 43.3 and 45.1. The other ten of these bull trout continued downstream, although none was located lower than Rkm 36.5. If this location describes the possible extent of downstream movement of bull trout less than 300 mm, nearly 3,000 bull trout may have resided in about 5 km of Mill Creek. However, limitations of transmitter battery size and signal duration prohibited us from accurately determining the extent of downstream locations of relatively small bull trout.

Table 8. Bull trout of Mill Creek implanted with radio transmitters in 1998, and the range of their locations.

| Capture method, date tagged | L (mm) | MHz | Tag life (mo) | LU[a] | TU[b] | LD[c] | TD[d] |
|---|---|---|---|---|---|---|---|
| **Angling** (km 40.9): | | | | | | | |
| 07 Jul | 520 | 150.123 | 18 | 48.6 | 12 Sep | 25.1 | 22 Dec |
| 07 Jul | 470 | 150.146 | 18 | 49.6 | 12 Sep | 20.6 | 16 Dec |
| 07 Jul | 510 | 150.343 | 18 | 52.8 | 05 Sep | 36.2 | 29 Dec |
| 07 Jul | 590 | 150.703 | 18 | 48.5 | 05 Sep | 40.9 | 08 Oct |
| 07 Jul | 555 | 150.713 | 18 | 49.6 | 12 Sep | 19.3 | 29 Dec |
| 17 Jul | 535 | 150.105 | 18 | 47.8 | 05 Sep | 40.9 | 08 Oct |
| 17 Jul | 540 | 150.115 | 18 | 48.3 | 12 Sep | 40.9 | 20 Sep |
| 17 Jul | 485 | 150.124 | 18 | 47.8 | 05 Sep | 35.1 | 16 Dec |
| 17 Jul | 630 | 150.192 | 18 | 51.4 | 01 Oct | 30.6 | 01 Dec |
| 17 Jul | 630 | 150.274 | 18 | 42.8 | 27 Sep | 39.4 | 16 Dec |
| 17 Jul | 580 | 150.993 | 18 | 51.8 | 12 Sep | 33.0 | 29 Dec |
| **Upstream migrant trap** (km 40.9): | | | | | | | |
| 10 Jul | 545 | 150.134 | 18 | 47.5 | 05 Sep | 20.6 | 01 Dec |
| 02 Sep | 605 | 150.073 | 18 | 41.2 | 23 Oct | 35.4 | 23 Nov |
| 10 Sep | 383 | 151.410 | 4.7 | 50.2 | 01 Oct | 19.3 | 29 Dec |
| 10 Sep | 375 | 151.424 | 4.7 | 45.4 | 27 Sep | 40.9 | 04 Oct |
| 10 Sep | 374 | 151.643 | 1.2 | 40.9 | 10 Sep | 35.4 | 29 Dec |
| 17 Sep | 346 | 151.701 | 9 | 44.9 | 27 Sep | 40.9 | 17 Sep |
| 17 Sep | 318 | 151.722 | 9 | 45.1 | 16 Oct | 40.9 | 29 Dec |
| 23 Sep | 300 | 151.811 | 9 | 43.8 | 28 Oct | 35.4 | 29 Dec |
| **Screw trap** (km 41.5): | | | | | | | |
| 27 Mar | 254 | 151.632 | 1.2 | -- | -- | 37.4 | 05 Jun |
| 11 Apr | 212 | 151.703 | 3.3 | 43.3 | 27 Jun | 40.9 | 21 Apr |
| 24 Apr | 196 | 151.292 | 2.0 | -- | -- | 36.7 | 07 May |
| 24 Apr | 182 | 151.652 | 1.2 | -- | -- | 40.9 | 28 Apr |
| 24 Apr | 199 | 151.691 | 2.0 | 43.3 | 27 Jun | 41.5 | 24 Apr |
| 27 Apr | 180 | 151.572 | 0.7 | -- | -- | 39.1 | 26 May |
| 14 May | 195 | 151.282 | 2.0 | 45.1 | 04 Sep | 40.6 | 05 Jun |
| 19 May | 160 | 151.271 | 2.0 | -- | -- | 40.9 | 02 Jul |
| 29 May | 187 | 151.591 | 1.2 | -- | -- | 36.5 | 05 Jun |
| 02 Jun | 207 | 151.662 | 1.2 | -- | -- | 41.2 | 29 Aug |
| 29 Jun | 235 | 151.562 | 0.7 | -- | -- | 40.9 | 27 Sep |
| 23 Sep | 171 | 150.992 | 0.7 | -- | -- | 40.9 | 20 Oct |
| 30 Sep | 190 | 151.533 | 0.7 | -- | -- | 40.6 | 18 Oct |

[a] LU = maximum known upstream location (Rkm) in 1998 since receiving transmitters. Dashes = Rkm 41.5.
[b] TU = date of maximum upstream location. Dashes = date tagged.
[c] LD = maximum downstream location (Rkm) through October 1998.
[d] TD = earliest date of maximum downstream location.

For radio-tagged bull trout 300 mm or larger, the farthest downstream location in Mill Creek during 1998 varied between Rkm 40.9 and 19.3 (mean 33.2). No radio-tagged bull trout was detected downstream of Walla Walla, WA (Rkm 14.5), as was the case in 1997. The greatest detectable range, defined as the distance between the farthest upstream and downstream locations, by any bull trout radio-tagged in 1998 was 31 km. This range was accomplished by a 383 mm individual. The maximum range in 1998 is similar to the 35-km maximum range we observed in 1997. We continued to track some bull trout with transmitters applied in 1997, and their movements were similar to those reported here.

### Grande Ronde Basin

We implanted radio transmitters and PIT tags in 25 bull trout from the Grande Ronde Basin during 1998. Due to several flights cancellations, we lack information to accurately estimate the limits of upstream movements of these bull trout. We were able to determine limits of downstream movements from the time they were captured through the end of 1998.

Nineteen of the 25 bull trout were from the Wenaha River, all captured by angling and, all but one, larger than 400 mm (Table 9). One of these fish was located in the North Fork Wenaha River and not located again. The signals from four additional fish were never found after transmitters were implanted. Of the remaining 14 bull trout, only three remained in the Wenaha River (Rkm 23.8 and 34.6) at the end of the year. Eight bull trout were located in the Grande Ronde River from Rkm 115.1 to 42.3. While six of these fish were located downstream of the mouth of the Wenaha River (Rkm 74 of the Grande Ronde River), two had traveled upstream from the Wenaha River mouth either 4.4 or 41.1 km. Three bull trout, from 400 to 445 mm, were located in the Snake River between Rkm 249 and 245. All these Wenaha River bull trout reached these downstream locations from mid-November 1998 to early January 1999.

Five bull trout 440 mm or larger were captured by angling from Lookingglass Creek. One of these fish was not located again after receiving its transmitter. The other four fish all reached their farthest downstream locations by 03 December. While one had remained in Lookingglass Creek, three were located in the Grande Ronde River between Rkm 176.6 and 148.8. These three bull trout were all upstream of the mouth of Lookingglass Creek (Rkm 132).

Table 9. Bull trout of the Grande Ronde basin implanted with radio transmitters during 1998, and their farthest downstream locations.

| Capture location, Date tagged | L (mm) | MHz | Tag life (mo) | LD[a] | TD[b] |
|---|---|---|---|---|---|
| **Wenaha R:** | | | | | |
| 01 Jul | 470 | 150.703 | 18 | 69.4 [c] | 14 Dec |
| 01 Jul | 510 | 150.146 | 13 | --[d] | -- |
| 21 Jul | 445 | 150.981 | 9 | 247.1[e] | 04 Jan'99 |
| 21 Jul | 528 | 150.245 | 13 | -- [f] | -- |
| 21 Jul | 422 | 150.992 | 9 | 245.4[e] | 04 Jan'99 |
| 21 Jul | 630 | 150.273 | 13 | 80.3 [c] | 14 Dec |
| 21 Jul | 530 | 150.053 | 13 | 42.3[c] | 19 Nov |
| 21 Jul | 405 | 151.722 | 9 | 58.3 [c] | 03 Dec |
| 21 Jul | 400 | 151.811 | 9 | 248.9 [e] | 04 Jan'99 |
| 21 Jul | 520 | 150.114 | 13 | 23.8 | 03 Dec |
| 22 Jul | 435 | 151.701 | 9 | 34.6 | 03 Dec |
| 22 Jul | 450 | 150.613 | 18 | --[d] | -- |
| 22 Jul | 495 | 151.634 | 18 | --[d] | -- |
| 22 Jul | 378 | 150.972 | 9 | 41.5 [c] | 04 Jan'99 |
| 22 Jul | 546 | 151.223 | 13 | 115.1[c] | 03 Dec |
| 22 Jul | 535 | 150.115 | 13 | 34.6 | 03 Dec |
| 22 Jul | 630 | 150.133 | 13 | --[d] | -- |
| 04 Aug | 565 | 150.743 | 18 | 78.4 [c] | 14 Dec |
| 04 Aug | 483 | 150.343 | 13 | 53.9 [c] | 14 Dec |
| **Lookingglass Cr:** | | | | | |
| 27 May | 541 | 150.234 | 13 | 176.6 [c] | 03 Dec |
| 27 May | 470 | 151.253 | 13 | 167.6 [c] | 03 Dec |
| 27 May | 444 | 151.262 | 13 | 148.8 [c] | 03 Dec |
| 12 Jun | 520 | 150.105 | 13 | --[d] | -- |
| 17 Jun | 540 | 151.203 | 13 | 16.4 | 03 Dec |
| **Catherine Cr:** | | | | | |
| 21 Mar | 252 | 151.681 | 2 | 74.1 [j] | 30 Mar |

[a] LD = maximum downstream location (Rkm) through December 1998 or January 1999, since receiving transmitters.
[b] TD = earliest date of maximum downstream location.
[c] Location in the Grande Ronde River.
[d] Not located after tagging.
[e] Location in Snake River.
[f] Located at Rkm 45.1 in NF Wenaha River, the only known location after tagging, on 12 Aug.
[g] The only known location after tagging.
-- = not determined.

## II. Bull trout and brook trout interactions

### Introduction

One of the greatest threats to native bull trout populations is the presence of nonnative brook trout *Salvelinus fontinalis*. Hybridization (Leary et al. 1993) and competition with brook trout (Ratliff and Howell 1992; Dambacher et al.1992) have been cited as reasons for the decline of bull trout. While hybridization has been thoroughly documented (Kitano et al. 1994; Markle 1992), competition between bull trout and brook trout has not been demonstrated clearly and the effect of potential agonistic interactions on bull trout is unknown. The objective of this study was to examine the effect of brook trout on bull trout feeding behavior, focusing on microhabitat use, forging behavior, agonistic interactions, and growth.

In 1998 we modified and repeated the in-stream experiment conducted in 1997 (Hemmingsen 2001). Eight enclosures were constructed in the sympatric reach of Meadow Fork of Big Creek. Because the comparison of bull trout behavior in the 4Bull (four bull trout) treatment to that of bull trout in the Mix (2 bull trout and 2 brook trout) treatment was of greatest interest and importance, the 2Bull treatment of 1997 was eliminated from the experimental design. In 1998, there were four replicates of the 4Bull and Mix treatments. In addition, macroinvertebrate drift was collected to compare food availability inside to outside the enclosures. The behavior and growth of bull trout and brook trout in their natural environment (hereafter free-ranging fish) also were given more emphasis in 1998.

### Methods

We built eight fish enclosures in the sympatric zone of Meadow Fork of Big Creek at sites described by Bellerud et al. (1997). Each enclosure was constructed with four to six wood frame panels that were 1.2 $m^2$ and covered with 1.9-cm mesh nylon screen. An erosion-proof cloth was attached to the underside of the panels, which were secured to the stream bottom with re-bar and stabilized with wood braces (5 cm x 10 cm x 2.4 m). Substrate was piled on top of the cloth to prevent fish from escaping, and sandbags were placed on the downstream edge of the panels to minimize undercutting. In most cases the stream bank served as one side of the enclosures to provide elements of natural cover and input of terrestrial insects. Each enclosure contained a variety of microhabitats including slow water refuges, portions of the thalweg, and areas with cover.

Experimental fish were collected from the sympatric reach by angling. Each animal was weighed, measured, and uniquely marked with phototonic dye injected between the caudal rays to ensure positive identification during the experiment. One of two treatments was randomly assigned to each enclosure: 4 bull trout (hereafter 4Bull), or a combination of 2 bull trout and 2 brook trout (hereafter Mix).

Experimental animals were introduced to enclosures simultaneously, and fish in each enclosure were of similar size to minimize size-structured dominance hierarchies. Fish acclimated in the enclosures for seven days before the first observations were conducted. Behavior in the enclosures was observed by snorkeling 1-3 times per week for a period of six weeks. Observations were systematically scheduled to ensure each enclosure was observed during all periods of the day. Behavior of free-ranging fish was observed by snorkeling the sympatric reach and two segments of the allopatric reach weekly during the experiment.

During a snorkel dive, focal animal observations (Altman 1974) were conducted on each fish for five minutes. Foraging attempts were counted and classified as directed at 1) surface macroinvertebrate drift, 2) water column drift, or 3) benthic invertebrates on the substrate. Because prey items were not always visible, all foraging attempts were counted regardless of capture success. Interactions between fish were counted and categorized as dominant or subordinate. An interaction was considered dominant when an observed fish gained or maintained feeding territory through aggression. An interaction was subordinate when a fish was displaced or lost feeding territory by aggression from another.

After observations were completed, physical characteristics of the focal feeding points were measured. Locations of focal points were marked with a bobber attached to a fishing weight with monofilament line. The bobber was positioned at the height of the focal feeding point. The distance from the bobber to the substrate defined the holding depth. Water velocity at the focal point and maximum velocity within 0.6 m from the focal point were measured using a flow meter. The difference between the two values defined the velocity differential (Fausch and White 1981). The percent of the feeding territory with cover was recorded in categories of 0, 1-25, 26-50, 51-75, or 76-100%. After six weeks, fish in the enclosures were weighed, measured, and released.

To measure the volume of macroinvertebrate drift, one drift net (250$\mu$m mesh) was set directly upstream of each enclosure, and one inside each enclosure at the upstream end. The average distance between the inside and outside drift net was approximately 1.5 meters. Drift was collected inside the enclosures on 03 and 05 August and outside on 04 and 06 August at 0450 to 0520 hours each day. Samples were preserved in 95% ethanol. In the laboratory, insects were sorted from the exuviae and detritus, dried at 55$^{o}$ C, and weighed for measures of biomass.

We captured free-ranging fish by angling during the first week of the experiment. These fish were weighed, measured and identified with a phototonic dye injected between the caudal rays. We re-captured some of these fish six weeks later then measured, weighed and released them. Growth was determined by differences in measurements of identified fish.

## Results and Discussion

Free-ranging fish

A total of 238 free-ranging fish were observed during 14 days of observation (Table 10). The physical characteristics of focal feeding positions of these fish were similar among allopatric bull trout, sympatric bull trout, and brook trout. On average, fish in all groups held positions in the lower third of the water column (Figure 11). Average focal point velocity did not differ among allopatric and sympatric bull trout, or among sympatric bull trout and brook trout. Likewise, there were no differences between the average maximum velocities and hence the velocity differential, defined as the difference between velocity and maximum velocity (Fig 12.).

Table 10. Number and size of free-ranging fish observed during 1998.

| Group | N | Length (mm) $\bar{x}$ | min | Max |
|---|---|---|---|---|
| Allopatric bull trout | 114 | 186.8 | 120 | 310 |
| Sympatric bull trout | 78 | 176.3 | 90 | 240 |
| Sympatric bull trout | 46 | 170.0 | 100 | 230 |

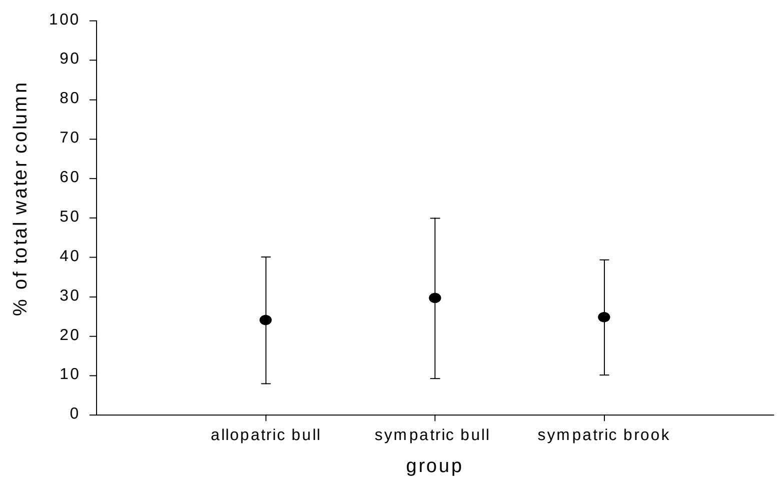



Figure 11. Percent of total depth of focal feeding points occupied by free-ranging fish. Values are means ± 1 SD.

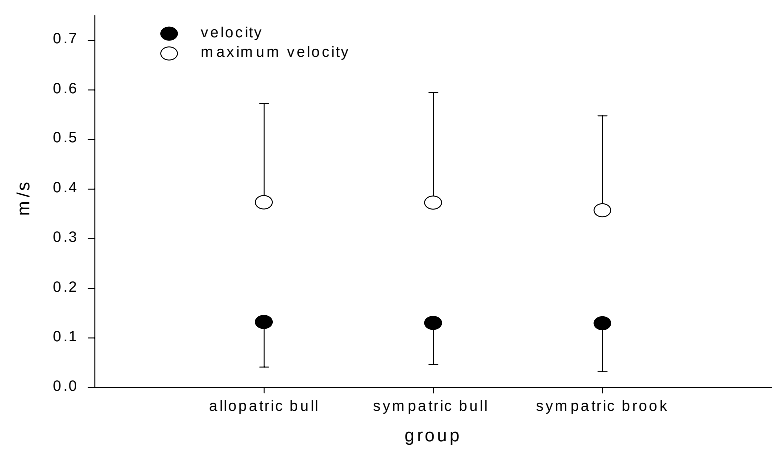



Figure 12. Velocity and maximum velocity of focal feeding points for free-ranging fish. Values are means ± 1 SD.

Allopatric bull trout, sympatric bull trout, and brook trout fed primarily from the water column (Figure 13). Seldom did they feed from the benthos or directly from the surface. Even though sympatric bull trout fed from the surface more frequently than brook trout and allopatric bull trout, the difference was not sufficient to ameliorate competitive interactions or suggest a niche shift for bull trout.

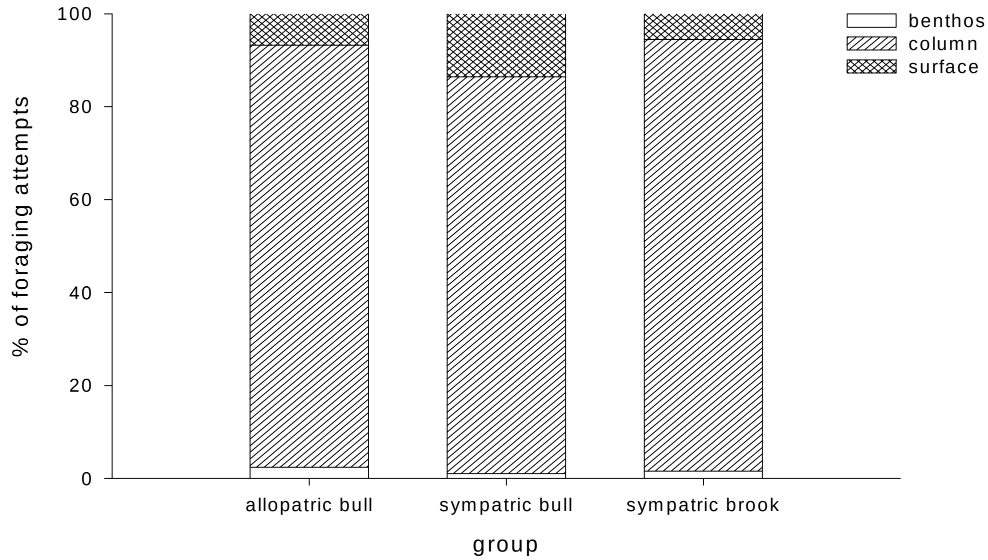



Figure 13. Mean percent of foraging attempts directed at the benthos, water column, and surface for free-ranging fish.

Sympatric bull trout experienced a greater average number of subordinate interactions than did allopatric bull trout or brook trout (Figure 14). Eighty-eight percent of these interactions were instigated by brook trout. However, 87% of all interactions observed were size-dominant interactions. Therefore, it is difficult to distinguish size-specific interactions from species-specific interactions.

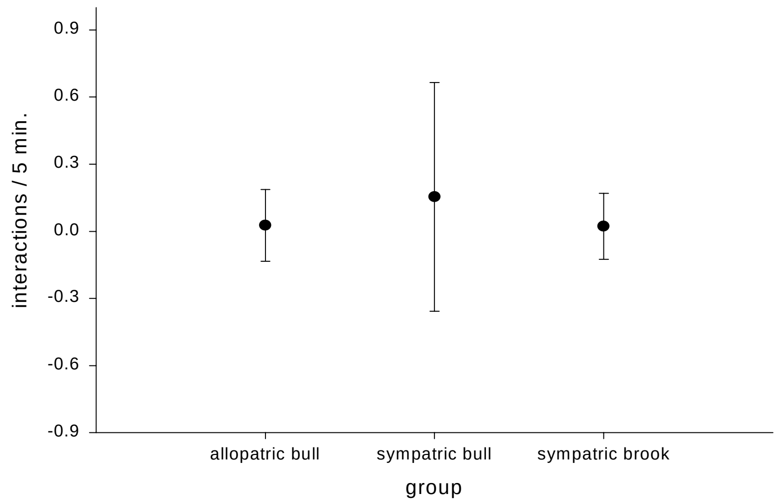



Figure 14. Mean (± 1 SD) number of subordinate interactions for free-ranging fish.

To determine growth of free-ranging fish, we captured and marked 33 allopatric bull trout, 28 sympatric bull trout and 16 brook trout. Six weeks later, we recaptured 11 allopatric bull trout, seven sympatric bull trout and two brook trout. Because yellow and green photonic dyes in the thick tissue of larger bull trout were difficult to distinguish, the identity of three re-captured sympatric bull trout was uncertain. Therefore, these three bull trout were not included in the analysis. Of the remaining individuals, allopatric bull trout grew the least with an average gain in body weight of 10.1%. Sympatric bull trout had an average weight gain of 9.5%. Brook trout had the greatest average weight gain of 28.7%, but only two were measured (Figure 15).

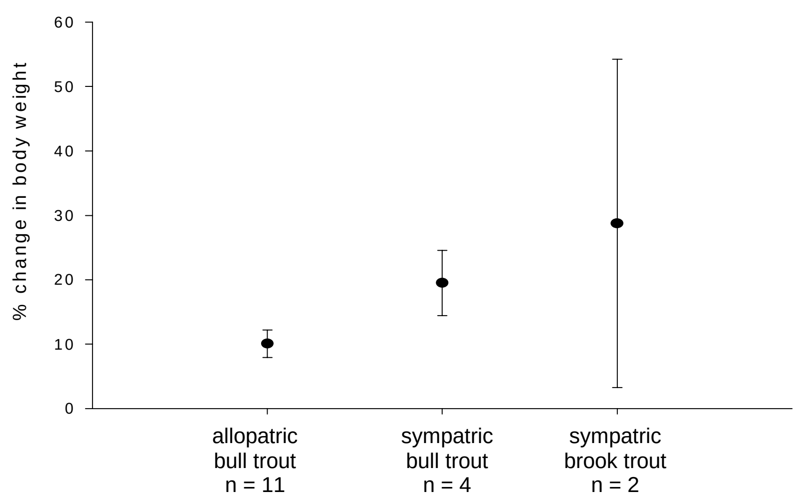



Figure 15. Growth of free-ranging fish measured over a six week period. Values are means ± 1 SD.

Experimental Enclosures

Fish in all enclosures ranged from 142 to 270 mm fork length. Fish within each enclosure were of similar size; the difference between the largest and smallest fish averaged 14 mm. Over the course of the experiment, one bull trout escaped, one brook trout suffered a fungal infection, and one bull trout died. The brook trout was removed and replaced with another of similar size. This replacement fish was introduced to maintain proper density, and its behaviors and growth were not included in the analysis. For enclosures with missing bull trout, growth of those that remained was the measure of overall growth for the enclosure.

On average, fish in all enclosures held similar positions in the lower third of the water column (Figure 16). Average focal point velocity did not differ among all bull trout or among sympatric bull trout and brook trout. Likewise, there were no differences between the average maximum velocities and hence the velocity differential (Figure 17).

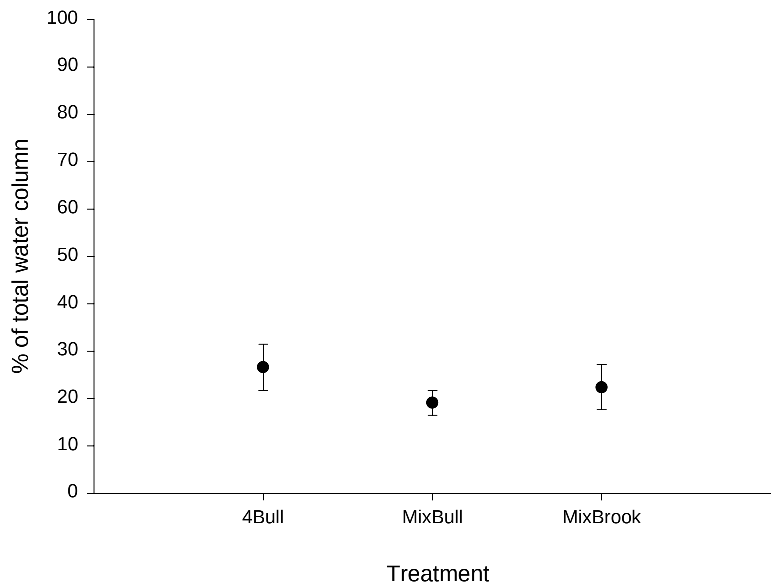



Figure 16. Percent of total depth of focal feeding points occupied by fish in enclosures. Values are treatment means ± 1 SD.

All fish fed primarily from the water column and rarely from the benthos (Figure 18). However, bull trout in the 4Bull treatment fed more frequently from the surface than fish in the Mix treatment. The similarity in microhabitat selection and foraging behavior for all groups of fish does not provide evidence of habitat partitioning by sympatric bull trout and brook trout or a niche shift for bull trout in the presence of brook trout.

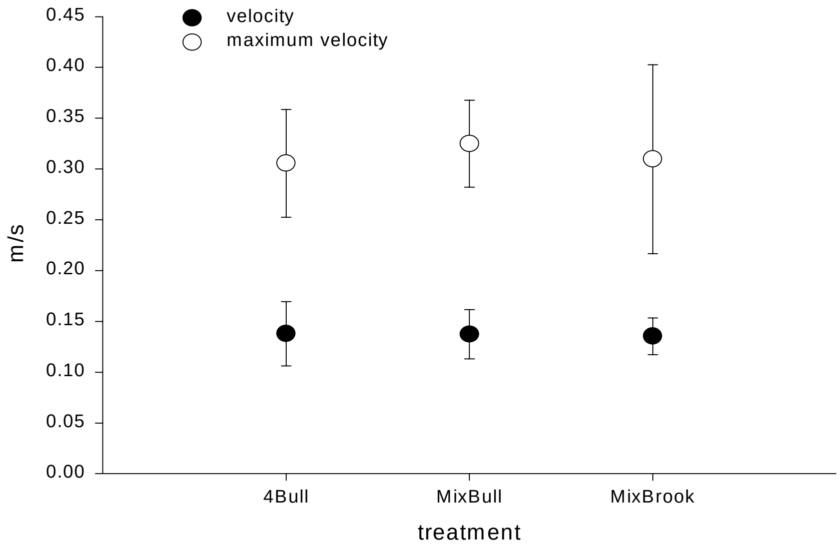



Figure 17. Velocity and maximum velocity of focal feeding points for fish in enclosures. Values are treatment means ± 1 SD.

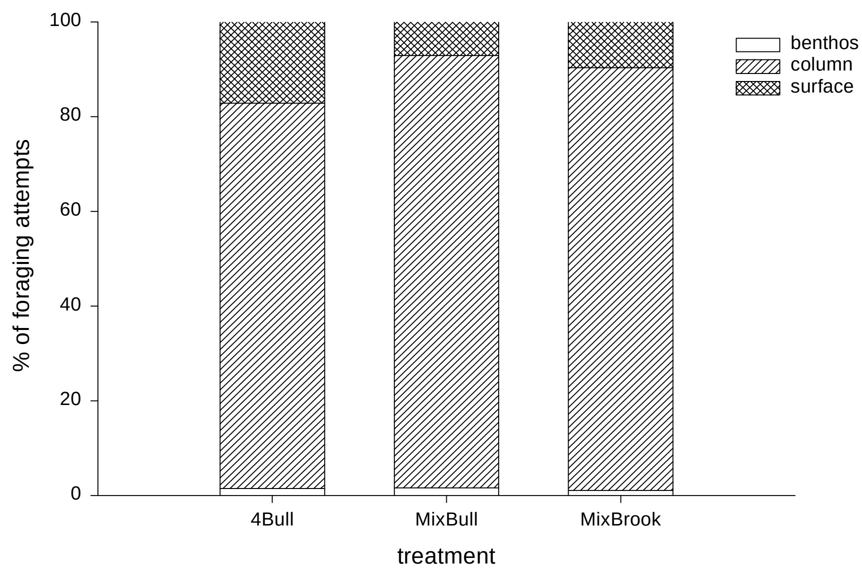



Figure 18. Average percent of foraging attempts directed at the benthos, water column, and surface for fish in enclosures.

Brook trout were more dominant and aggressive than bull trout in all four of the Mix treatment enclosures. In these enclosures, the dominant brook trout consistently maintained feeding territories in the upstream third of each pool. Subordinate fish typically resided in the rear, visually isolated from the dominant brook trout. Brook trout initiated a significantly greater number of dominant interactions than did bull trout (Figure 19). In contrast, bull trout in the Mix treatment were displaced more frequently than brook trout (Figure 20). Rarely did bull trout successfully defend their feeding territory from intruding brook trout or displace brook trout. Furthermore, compared to bull trout in the 4Bull treatment, bull trout in the presence of brook trout experienced a greater average number of subordinate interactions (Figure 20) and fewer dominant interactions (Figure 19).

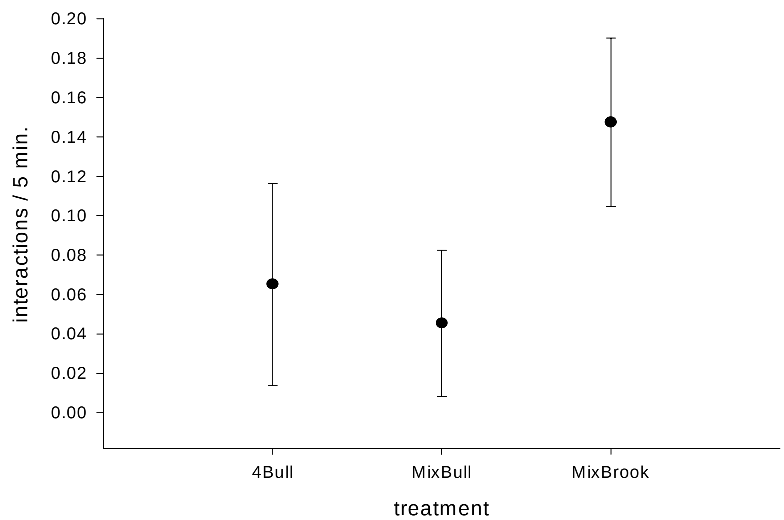



Figure 19. Mean (± 1 SD) number of dominant interactions for fish in enclosures.

Twenty of 24 bull trout in the enclosures lost weight over the duration of the experiment. Growth of bull trout was similar in the 4Bull and Mix treatments; they lost an average of 10.7% and 8.5% of their body weight, respectively. Six of eight brook trout grew during the experiment. On average, brook trout gained 9.8% of their body weight (Figure 21).

The availability of prey in the enclosures was restricted. Biomass of invertebrate drift inside ($\bar{x}$ = 0.015 g) the enclosures was on average 52.5% (SD = 20.1%) less than outside ($\bar{x}$ = 0.029 g) the enclosures. The decrease in growth may be related to the restricted macroinvertebrate availability within the enclosures, but may also reflect the stress of confinement and higher densities of fish.

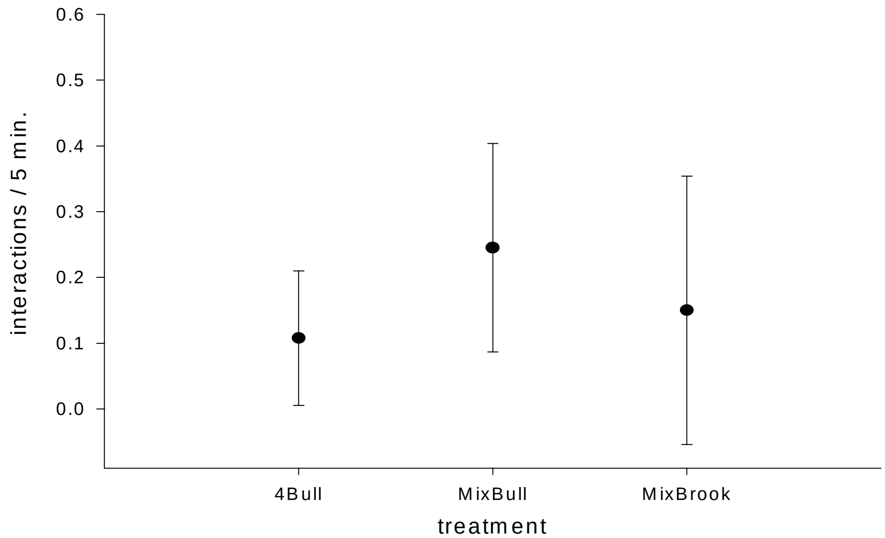



Figure 20. Mean (± 1 SD) number of subordinate interactions for fish in enclosures.

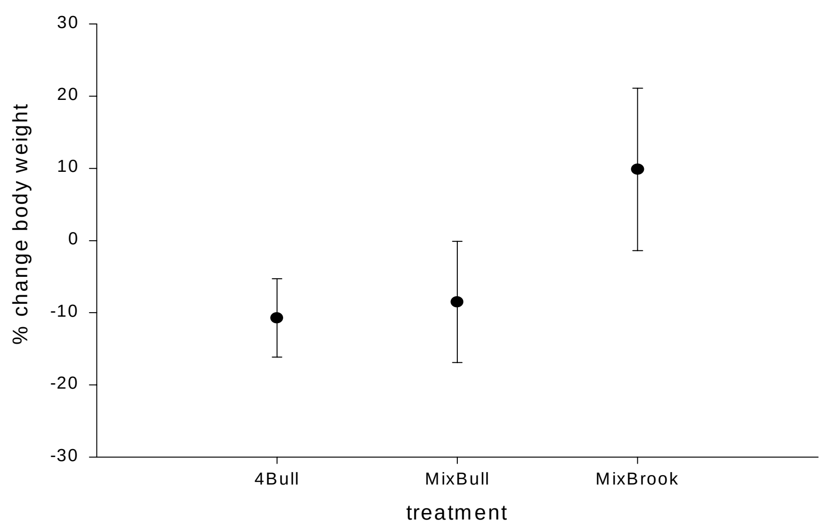



Figure 21. Percent change in body weight for fish in enclosures. Values are treatment means ± 1 SD.

## III. Bull trout spawning surveys

### Introduction

This section describes results of studies that have continued since 1996. We conducted four spawning ground surveys of bull trout in Mill Creek (Walla Walla River basin), Silver Creek (Powder River basin), as well as Lookingglass Creek and the Little Minam River (Grande Ronde River basin). In both Little Minam River and Lookingglass Creek, we estimated the variability in the observed numbers of redds that may occur among surveyors. These streams provided a relatively large range in the size of redds. Mill Creek, Silver Creek, and Little Minam River also have different physical characteristics that can influence the probability the any redd can be observed. We continued to measure these characteristics and describe their possible influences on the outcomes of spawning ground surveys.

<u>Abundance of redds</u>

### Methods

We surveyed Mill Creek and its tributaries upstream of the dam that shunts Mill Creek water to the city of Walla Walla (Figure 22). We surveyed the Little Minam River upstream from the confluence with Boulder Creek and Dobbin Creek, a tributary to the Little Minam River (Figure 23). We surveyed Silver Creek upstream from its confluence with Little Cracker Creek (Figure 24). Survey reach numbers shown in Figs. 22-24 coincide with reach boundaries and lengths described by Hemmingsen et al. (2001). Surveys in each watershed were conducted at approximately two-week intervals during September and October, in a manner similar to that used for surveys conducted in 1996 (Bellerud et al. 1997) and 1997 (Hemmingsen et al. 2001).

### Results and Discussion

We observed 137 bull trout redds in the Mill Creek watershed during 1998. Of these, 95 redds were in Mill Creek itself while 42 redds were in tributaries (Figure 25). No redds were observed in reach number one, downstream of the confluence with Low Creek. Reach number five, between North Fork Mill Creek and Deadman Creek, contained 33% of the number of redds observed during 1998. This reach also contained the highest proportion of redds observed in each of the two previous years. Tributaries to Mill Creek contained 31% of the number of redds observed in the watershed during 1998, and Low Creek contained most of these. In 1996 and 1997, tributaries produced 35 and 27 percent, respectively, of the total number of redds observed. Low Creek and reaches five through seven of Mill Creek contained bull trout redds at densities between 10 and 15 per km, which was at double the densities of redds in other locations.

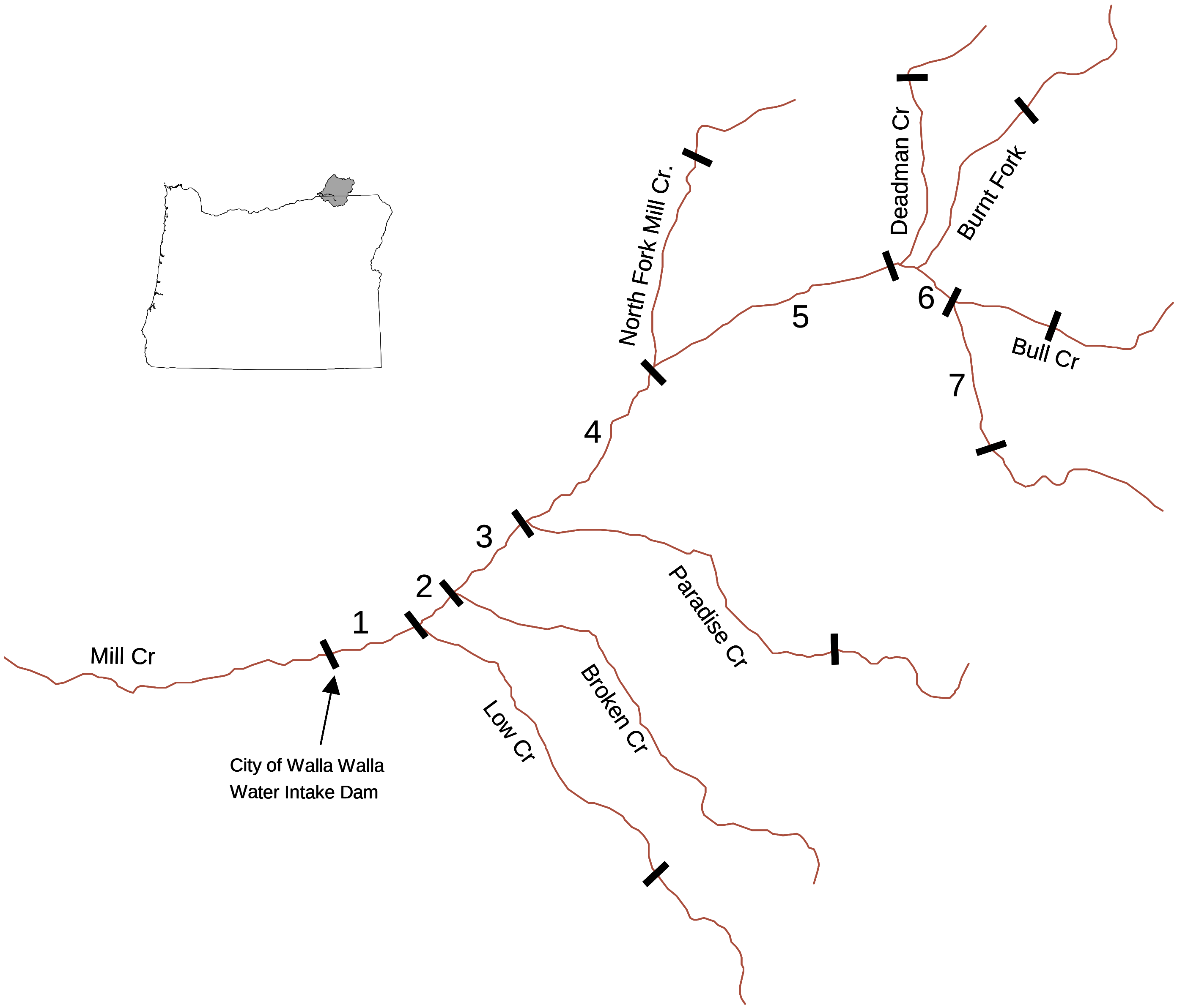



Figure 22.  Locations of bull trout spawning survey reaches in Mill Creek and tributaries.

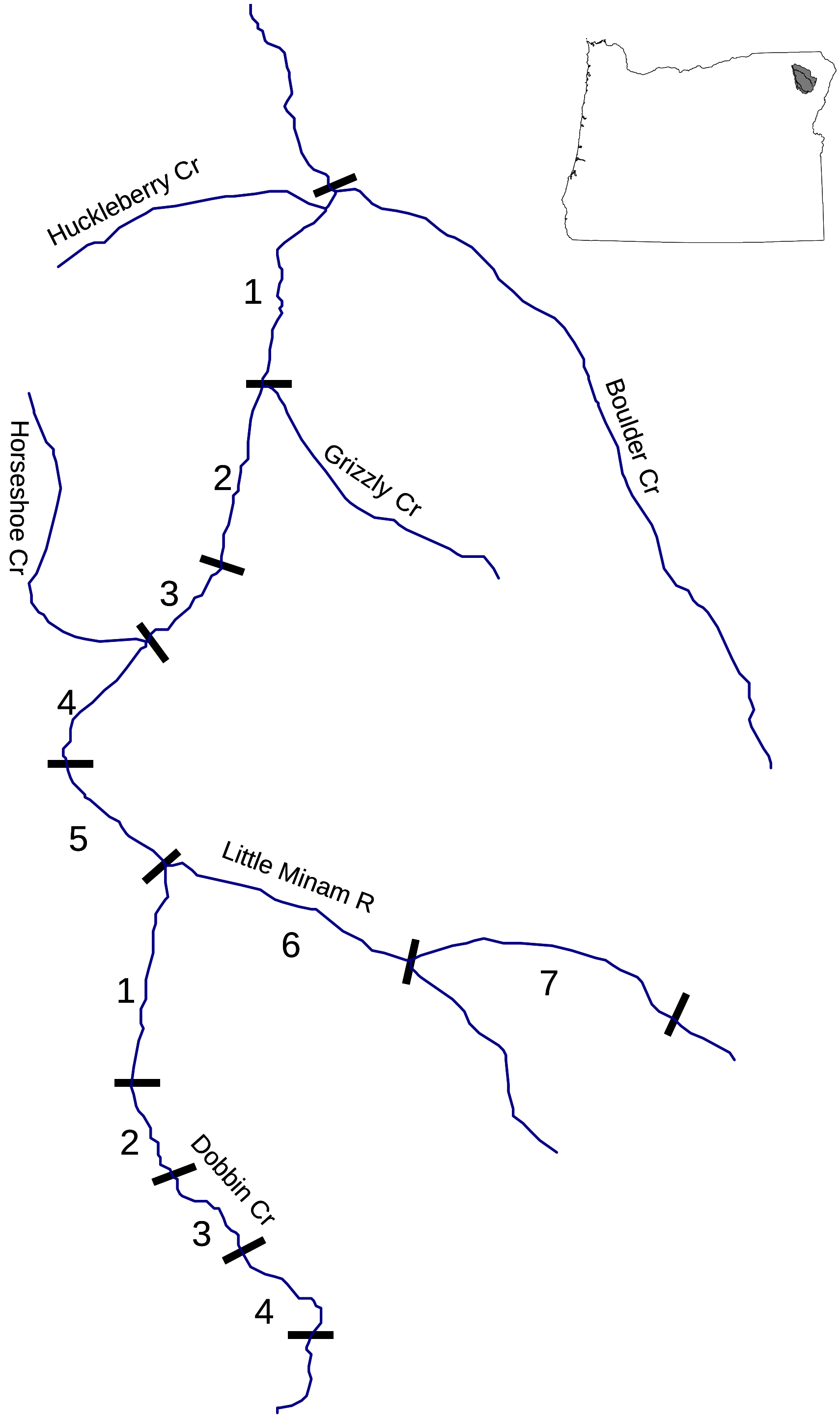



Figure 23.  Locations of bull trout spawning survey reaches in Little Minam River and Dobbin Creek

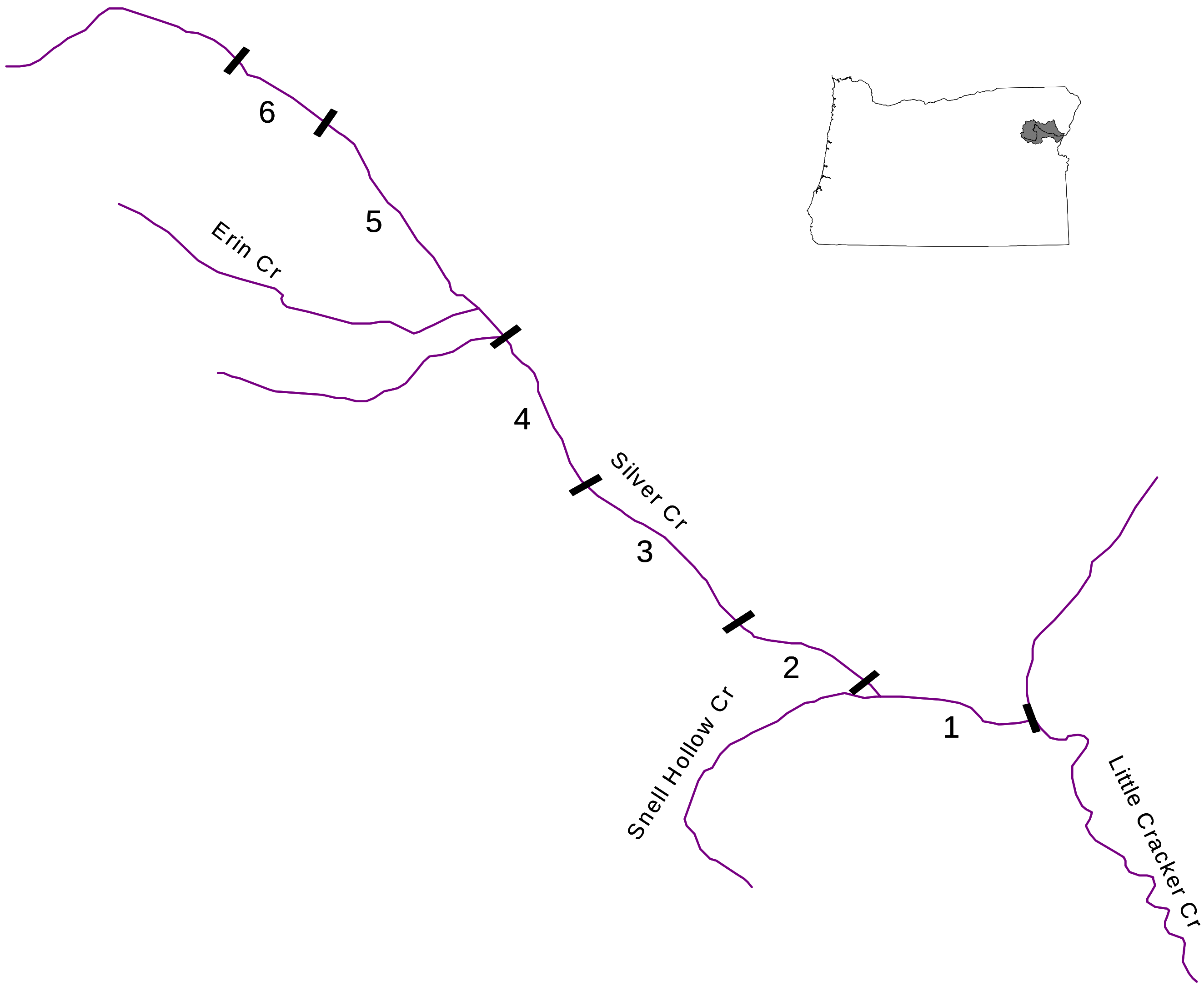



Figure 24.  Locations of bull trout spawning survey reaches in Silver Creek

Few bull trout had spawned in Mill Creek and tributaries by 09 September. However, 58% of all redds were observed between 09 an 23 September, and 81% were observed by 07 October. In 1996 and 1997, most redds were observed between middle September and early October.

We observed 320 bull trout redds in the Little Minam River and 61 redds in Dobbin Creek, for a total of 381 redds in this watershed during 1998 (Figure26). Fifty-one percent of the number of redds observed in Little Minam River were in reaches six and seven, upstream of the confluence with Dobbin Creek. These two reaches also contained most of the redds observed during 1996 and 1997. Reaches three through seven of Little Minam River and reach three of Dobbin Creek all contained bull trout redds at densities greater than 20 per km. Fifty-one percent of all redds observed in Little Minam River and Dobbin Creek were counted on the first survey, 15 and 16 September. In 1996 and 1997, most redds were observed between middle September and early October.

We observed 36 bull trout redds in Silver Creek during 1998 (Figure27). As in 1996 and 1997, all redds were observed in reaches three through six; most were contained in reach five at a density of about 12 redds per km. Although we observed new redds during all surveys, nearly 60% had been made by 28 September.

The total number of bull trout redds observed in the Mill Creek watershed during 1998 was within the range of totals observed annually since surveys began in 1994 (Figure 28). Total numbers of redds observed in Little Minam River and Dobbin Creek were nearly identical during both 1997 and 1998. The low number of redds observed in Silver Creek and the Little Minam River during 1996 may have resulted from the surveyors' inexperience at detecting redds made by small bull trout. In addition, the characteristics of the substrate where bull trout spawn in Silver Creek make it difficult to detect any redd.

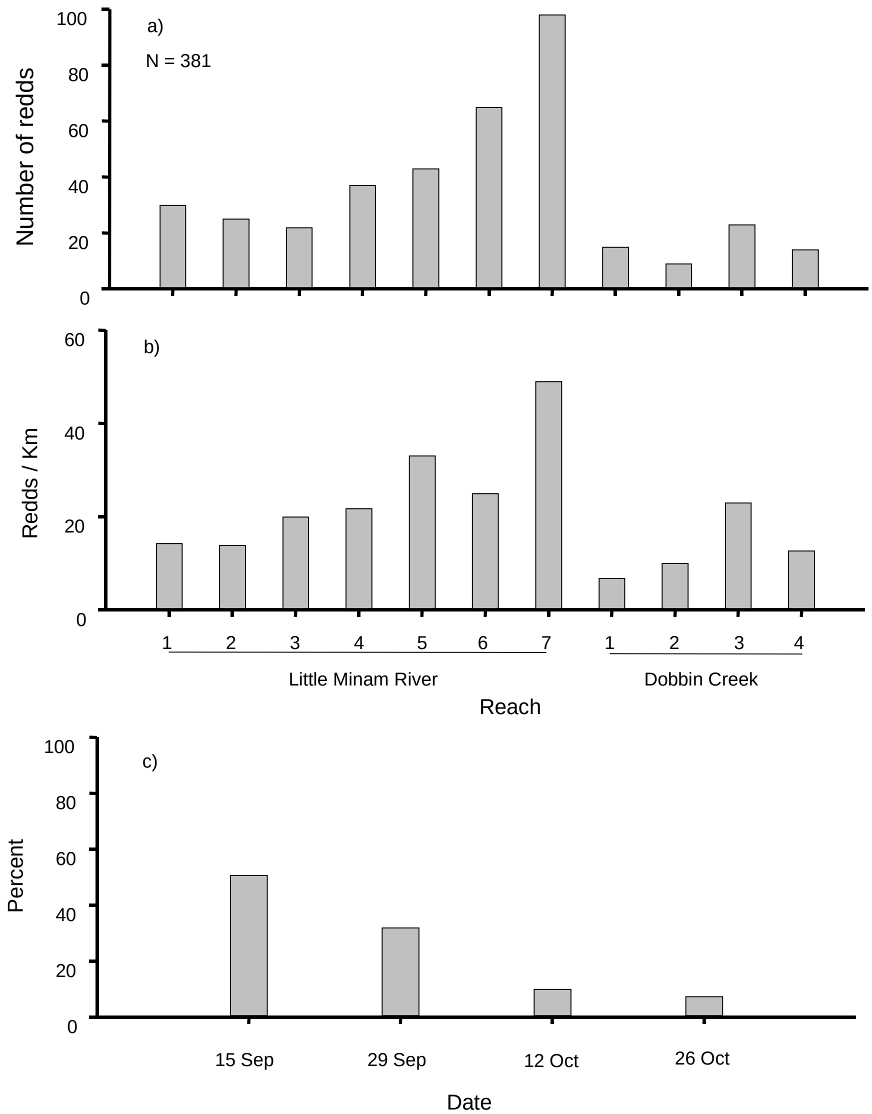



Figure 26. Spawning ground surveys on Little Minam River Dobbin Creek, 1998; a) number, b) density of bull trout redds in each reach, and c) proportion observed during each

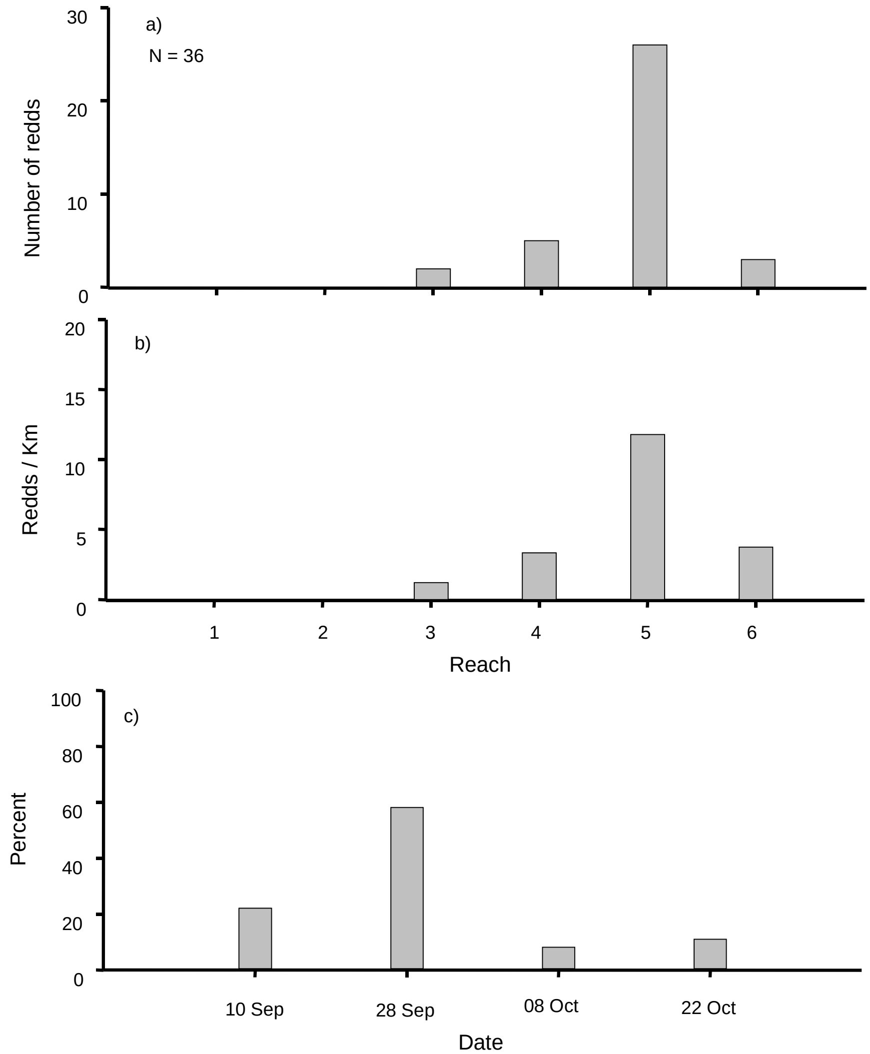



Figure 27. Spawning ground surveys on Silver Creek,
a) number, b) density of bull trout redds in each reach,
and c) proportion observed during each survey.

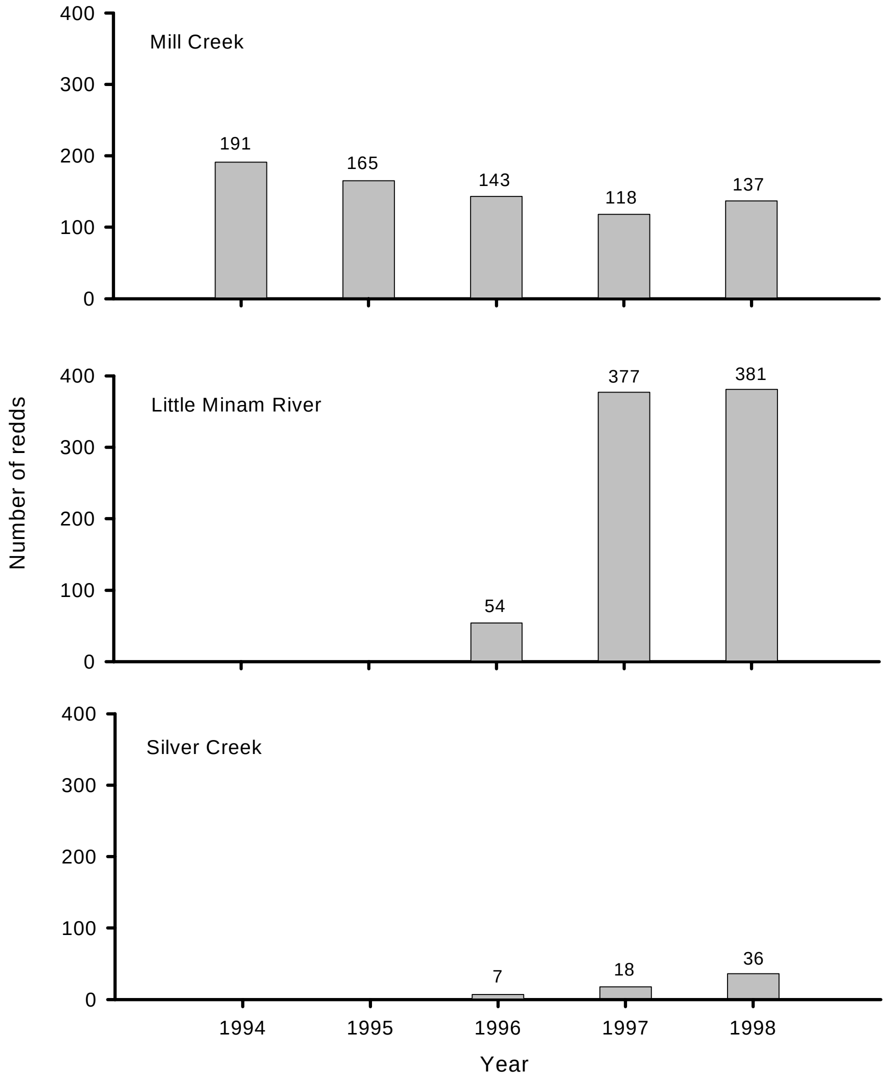



Figure 28. Numbers of bull trout redds observed annually from 1994 to 1998. Little Minam River and Silver Creek were not surveyed in 1994 and 1995.

Surveyor variability

## Methods

In both 1997 and 1998, we estimated the variability in numbers of redds that surveyors may count by comparing the results of five to 10 surveyors who counted redds in two streams. Participants surveyed four reaches, each nearly one km long, of the Little Minam River and Lookingglass Creek. These surveyors had not surveyed any of these reaches prior to the study each year. Surveyors were classified as “experienced” or “novice “. Experienced surveyors had previously counted bull trout redds several times during one or more seasons. Novice surveyors had not previously counted bull trout redds, although some had counted salmon redds (Table 11). Novices were briefed on general redd characteristics and shown a bull trout redd in a different reach of each stream before the evaluation. In 1998, novices accompanied experienced surveyors in a different reach of each stream one or two days before the evaluation.

Table 11. Number of surveyors in the evaluations of bull trout redd numbers.

| | Little Minam R. | | Lookingglass Cr. | |
|---|---|---|---|---|
| Year | Novice | Experienced | Novice | Experienced |
| 1997 | 2 | 3 | 2 | 5 |
| 1998 | 3 | 5 | 5 | 5 |

Generally, redds in reaches of streams used in the evaluation were first counted by an additional three to five experienced individuals. By consensus, these individuals determined the best estimated number of redds in each reach, hereafter termed the base number. These base numbers became the totals to which the results of each evaluated surveyor were compared. Each surveyor in the evaluation counted bull trout redds in each reach, and classified each observed redd as definite or possible. We used an analysis of variance to describe overall variation in numbers of redds, and compared results among surveyors with the Student-Newman-Keuls test.

## Results and Discussion

In most cases, variance among surveyors and stream reaches was large and highly significant (Table 12). Generally, variance among stream reaches was greater than variance among surveyors. Estimates of redds in the Little Minam River were more variable than those in Lookingglass Creek. When redds classed "possible" were included in the analysis, they increased the variance only slightly (Table 13).

Table 12. Coefficients of variation (CV) and observed significance levels (P) among surveyors and stream reaches.

| | Little Minam R. | | Lookingglass Cr. | |
|---|---|---|---|---|
| Statistic | 1997 | 1998 | 1997 | 1998 |
| CV among samplers (%) | 1364 | 453 | -7 | 58 |
| P | 0.0001 | 0.0001 | 0.5559 | 0.014 |
| CV among reaches (%) | 577 | 749 | 522 | 75 |
| P | 0.0049 | 0.0001 | 0.0001 | 0.0001 |
| Grand mean | 45.1 | 19.6 | 4.8 | 4.3 |

Table 13. Coefficients of variation (%) in numbers of redds classified two ways.

| | Little Minam R. | | Lookingglass Cr. | |
|---|---|---|---|---|
| Source of variation | definite | both [a] | Definite | both [a] |
| Surveyor | 453 | 463 | 58 | 53 |
| Stream reach | 749 | 804 | 75 | 81 |

[a] Includes redds classed as definite and possible.

Novice surveyors generally tended to have more variation in the numbers of redds they observed (Figure 29). The numbers of redds observed by experienced surveyors were generally closer to the base numbers than were those observed by novice surveyors, although there were notable exceptions in both groups (Table 14). Novice surveyors tended to count more redds than did experienced surveyors. Compared to results from the Little Minam River, the mean numbers of redds observed in Lookingglass Creek by all surveyors were closer to the respective base numbers.

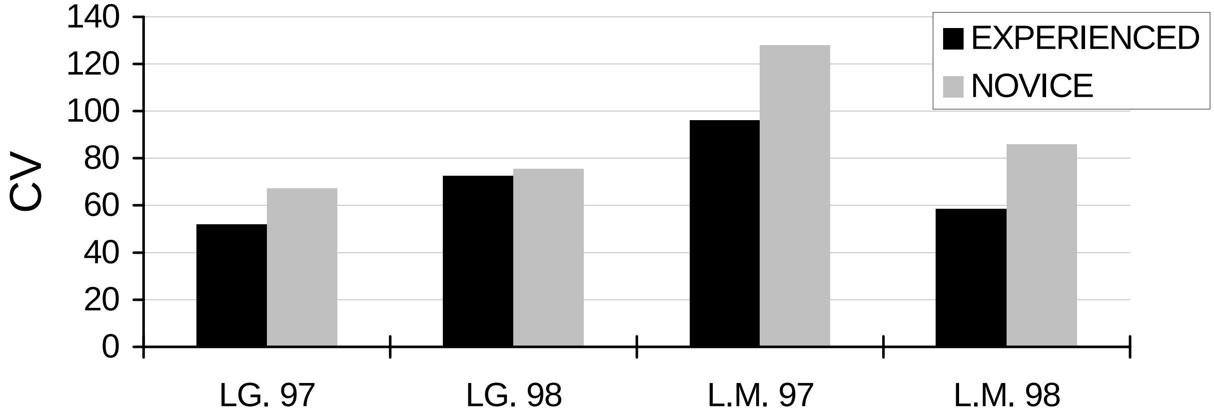



Figure 29. Coefficients of variation for experienced and novice surveyors in Lookingglass Creek (LG) and Little Minam River (LM), 1997-98.

Table 14. Means and ranges of the number of bull trout redds observed by experienced and novice surveyors, expressed as a percentage of base numbers.

| Statistic | Little Minam R. 1997 | Lookingglass Cr. | |
|---|---|---|---|
| | | 1997 | 1998 |
| **Experienced:** | | | |
| Mean | 133 | 121 | 86 |
| Minimum | 55 | 93 | 38 |
| Maximum | 216 | 180 | 104 |
| **Novice:** | | | |
| Mean | 205 | 160 | 89 |
| Minimum | 110 | 120 | 50 |
| Maximum | 300 | 200 | 158 |

Redd characteristics

## Methods

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 class-1 redd to be the same as the probability of detecting a new redd, the chances of detecting a class-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 class-3 redd. Methods for estimation of the size of stream substrates, redds and spawning bull trout are provided in Hemmingsen et al. (2001).

## Results and Discussion

The visibility of bull trout redds varied among streams. Compared to redds in Mill Creek or Little Minam River, the visibility of redds in Silver Creek was relatively low. In Silver Creek, after two weeks there were almost no redds with class-1 characteristics and after six weeks nearly 75% would have been undetected if they had not been flagged (Figure 30). After two weeks in Mill Creek, nearly half the redds counted looked newly made; after six weeks nearly a third of them retained class-1 characteristics. Redds in the Little Minam River generally maintained their visibility longer than those in Silver Creek but not as long as those in Mill Creek.

Physical characteristics likely influence visibility of redds among streams. In Little Minam River and Silver Creek, substrates that composed redds were smaller than those in Mill Creek (Figure 31). Particularly in Silver Creek, redds had a high percentage of decomposed granite. This made disturbance to the substrate by spawning bull trout less apparent.

Bull trout redds in Silver Creek and Little Minam River were smaller than redds in the Mill Creek watershed other than Low Creek (Figure 32). Size of redds appeared to correspond to the size of fish that were observed spawning or holding near redds. Bull trout spawners 300 mm or larger were not observed in Silver Creek, Little Minam River or Low Creek. In survey reaches of the Mill Creek watershed other than Low Creek, however, 80% of the spawners were bull trout 300 mm or larger.

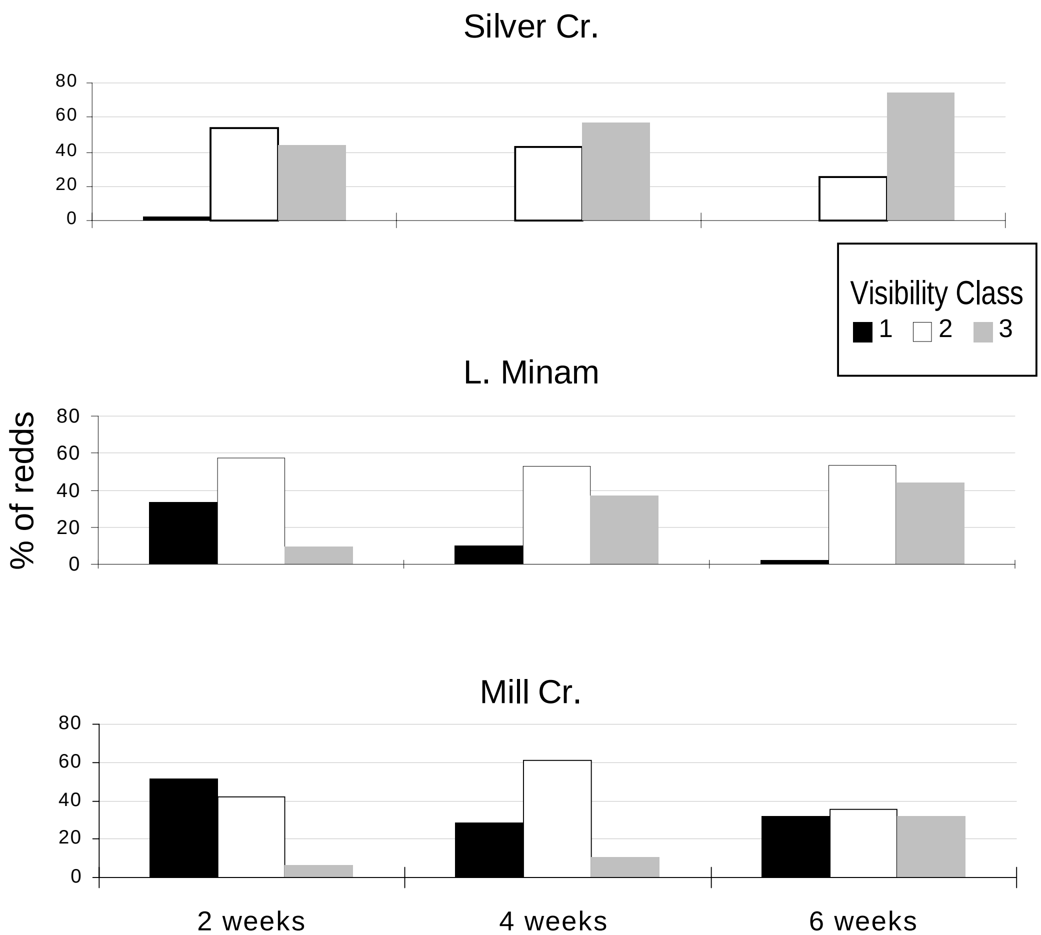



Figure 30. Visibility classes of bull trout redds from two to six weeks after first observation in either the 1997 or 1998 spawning season. See test for description of visibility classes.

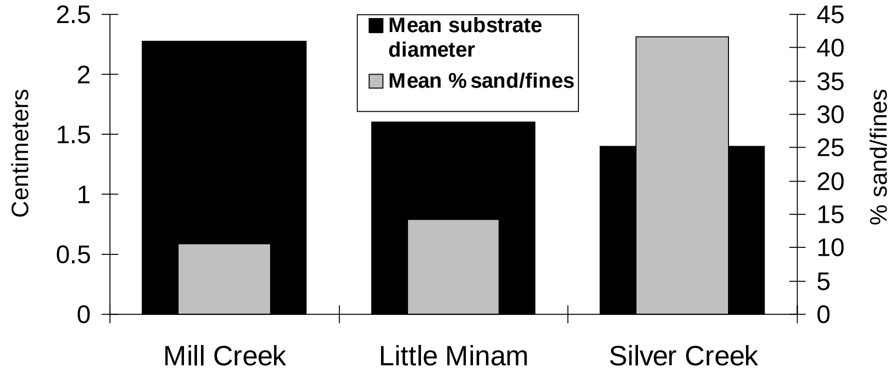



Figure 31. Mean size of substrate and the percentage of small particles in bull trout redds of three streams during 1997 and 1998.

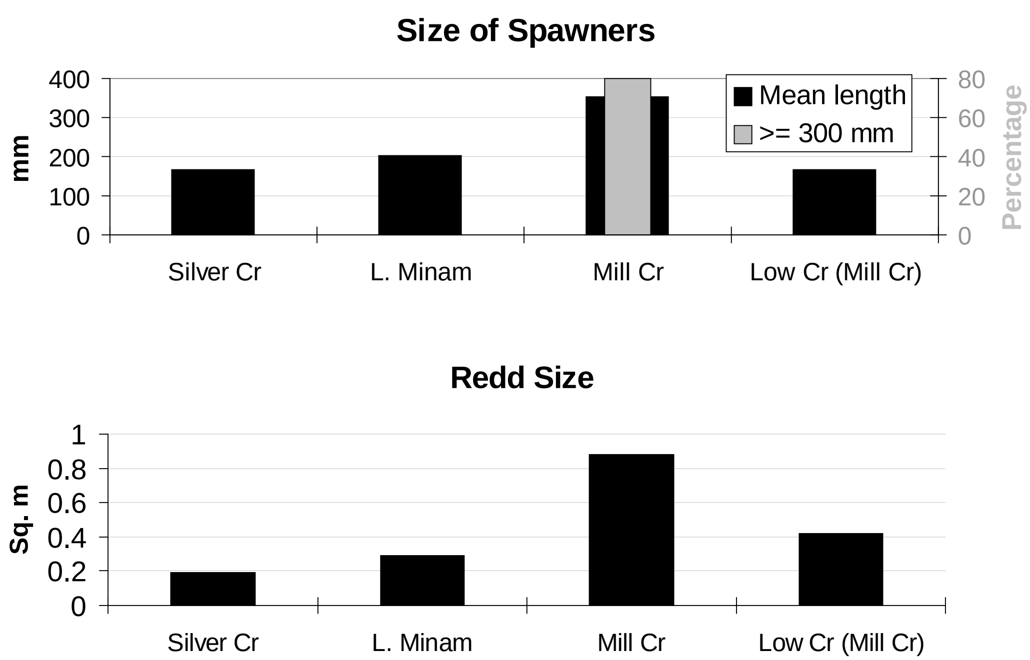



Figure 32. Mean size of redds and bull trout observed near them in 1997 and 1998.

## Acknowledgments

This project is grateful to Christian Abbes, Sarah Chamberlain, Bradley Lovatt, Jason Shappart, Lisa Sommerfeld, and Steven Starcevich for their dedication in the field, and also to Lisa for analysis of scales. Thanks to Dave Buchanan for his moral support and occasional help in the field. We appreciate the assistance with spawning surveys in the Grande Ronde basin that Jeff Zakel and Tim Walters provided. Thanks to Paul Sankovich for help with data summaries. We thank the Oregon State Police for providing telemetry flights.

## IV. References Cited

Altman, J. 1974. Observational study of behavior: sampling methods. Behavior 49: 226-267.

Bellerud, B. L., S. L. Gunckel, A. R. Hemmingsen, D. V. Buchanan, and P. J. Howell. 1997. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1996 Annual Report. Bonneville Power Administration, Portland, Oregon.

Dambacher, J., M. Buktenica, and G. 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* Howell, P. J. and D. V. Buchanan, Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter American Fisheries Society, Corvallis.

Fausch, K. and R. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Sciences 38: 1220-1227.

Hemmingsen, A. R., B. L. Bellerud, D. V. Buchanan, S. L. Gunckel, J. S. Shappart, and P. J. Howell. 2001. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1997 Annual Report. Bonneville Power Administration, Portland, Oregon.

Kitano, S., K. Maekawa, S. Nakano, and K. Fausch. 1994. Spawning behavior of bull trout in the Upper Flathead drainage, Montana, with special reference to hybridization with brook trout. Transactions of the American Fisheries Society 123: 988-992.

Leary, R., F. Allendorf, and S. Forbes. 1993. Conservation genetics of bull trout in Columbia and Klamath River drainages. Conservation Biology 7: 856-865.

Markle, D. 1992. Evidence of bull trout x brook trout hybrids in Oregon. Pages 58-67 *in* Howell, P. J. and D. V. Buchanan, Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter American Fisheries Society, Corvallis.

Ratliff, D. and P. Howell. 1992. The status of bull trout populations in Oregon. Pages 10-17 *in* Howell, P. J. and D. V. Buchanan, Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter American Fisheries Society, Corvallis.