August 2001

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

Annual Report 1999

DOE/BP-34342-3

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:

Whitesel, Tim, Alan R. Hemmingsen, Stephanie L. Gunckel - Oregon Department of Fish and Wildlife, Philip J. Howell - USDA Forest, Bull Trout Life History, Genetics, Habitat Needs and Limiting Factors in Central and Northeast Oregon, Annual 1999, Report to Bonneville Power Administration, Contract No. 1994BI343421, Project No. 199405400, 44 electronic pages (BPA Report DOE/BP-34342-3)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

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

1999 ANNUAL REPORT

Prepared by:

Alan R. Hemmingsen
Stephanie L. Gunckel

Oregon Department of Fish and Wildlife
Portland, OR

and

Philip J. Howell

USDA Forest Service
Pacific Northwest Research Station
La Grande, OR

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 199405400
Contract Number 94BI34342

August 2001

Table of Contents

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 1999 that continued to address two objectives of this project. These objectives are 1) determine the distribution of juvenile and adult bull trout *Salvelinus confluentus* and habitats associated with that distribution, and 2) determine fluvial and resident bull trout life history patterns. Completion of these objectives is intended 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, from relatively degraded to pristine, and bull trout populations were thought to vary from relatively depressed to robust. In all three basins we used radio telemetry to determine the seasonal movements of bull trout. In the John Day and Walla Walla basins we also used traps to capture migrant bull trout. With these traps, we intended to determine the timing of bull trout movements both upstream and downstream, determine the relative abundance, size and age of migrant fish, and capture bull trout to be implanted with radio transmitters. In the John Day basin, we captured adult and juvenile bull trout from the upper John Day River and its tributaries, Call Creek, Reynolds Creek, and Roberts Creek. In the Walla Walla basin, we captured adult and juvenile bull trout from Mill Creek.

Methods

In the upper John Day River subbasin, downstream and upstream migrants were captured in weir traps (Hemmingsen et al. 2001a) in Call Creek at river kilometer (Rkm) 0.7, Roberts Creek at RKm 1.3, and the upper John Day River at Rkm 449.2 (Fig. 1); these locations were the same as in 1998. In 1999, traps previously used in Deardorff Creek were relocated to Reynolds Creek at Rkm 7.9. Downstream migrants were captured in traps placed a few meters upstream of traps that captured upstream migrants at all four locations. A 1.5-m diameter screw trap was placed in the John Day River at Rkm 434.2, downstream of the confluence with Reynolds Creek. With the screw trap, we intended to capture fish whose movements originated downstream of any weir, and to recapture bull trout that had been captured at weirs and implanted with 14-mm, 125 KHz, passive integrated transponder (PIT) tags. The location of the screw trap in 1999 was different from the site used the previous two years (Rkm 436.8 of the John Day River) because a landowner denied access to the location used in 1997 and 1998. Since the screw trap was relocated, there was an opportunity for it to capture downstream migrant bull trout from Reynolds Creek. Traps used in Deardorff Creek in 1997 and 1998 were relocated to Reynolds Creek in 1999 because we had caught few bull trout in Deardorff Creek and weirs there required excessive maintenance. Although we lost one year of repetition from the original screw trap location as well as Deardorff Creek, we were able to obtain information from bull trout in another tributary in the subbasin.

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 (Fig. 11, page 29), as described in Hemmingsen et al. (2001b). Downstream migrant bull trout were captured using a 1.5-meter diameter rotary screw trap located upstream of the dam at the same site (Rkm 41.5) used in 1998.

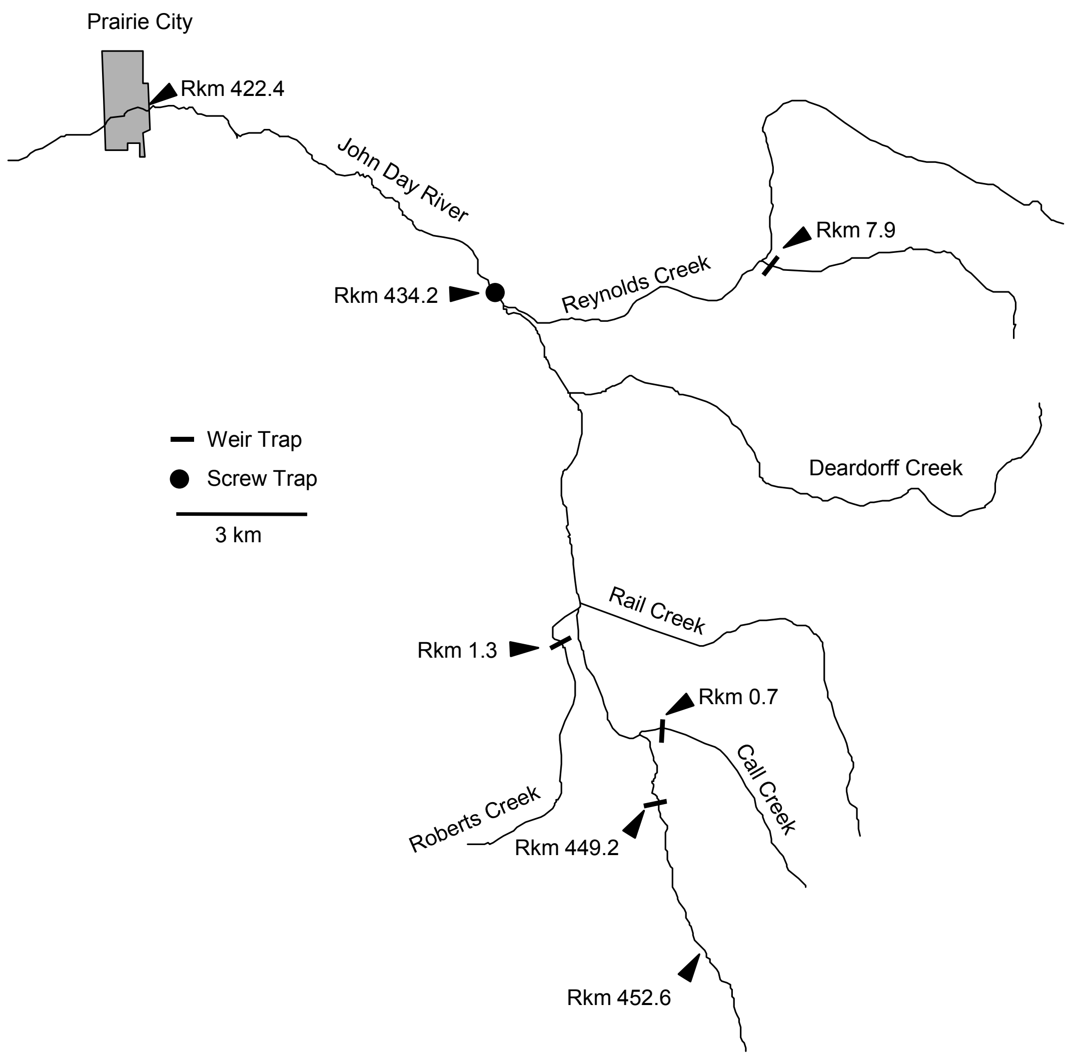


Figure 1. Locations of traps in the upper John Day River subbasin during 1999.

We sampled all traps daily during their operation through October. Fish of most species captured were anesthetized and measured to fork length; weight and scale samples also were collected from all bull trout. Bull trout that were 150 mm fork length or longer were checked for the presence of PIT tags applied during 1997 or 1998. Many of the bull trout that had not previously received PIT tags were subsequently implanted with PIT tags. A portion of the bull trout captured in the Mill Creek screw trap received a caudal fin mark to identify them for trap efficiency calculations. A maximum of three 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 or PIT-tagged bull trout. Estimated numbers of bull trout that may have passed downstream were calculated by bootstrap methods.

Some bull trout from all traps were implanted with radio transmitters. As in 1997 and 1998, we limited transmitter size to a maximum weight of three percent of the host fish. Procedures for surgically implanting radio transmitters and tracking locations of fish are described in Hemmingsen et al. (2001a). Bull trout with transmitters also received PIT tags implanted in the dorsal sinus. We tracked transmitter signals from both the ground and air. Aerial tracking was conducted from a plane operated by the Oregon State Police.

Results and discussion

Bull trout captured by traps in the John Day and Walla Walla basins 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 a fin mark or tag and could originate from several sources. Figures presented here 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

Installation of all weir traps was delayed in 1999 because of low mountain snow levels and high stream flows. Weir traps were placed in Reynolds Creek on 11 May but were ineffective because of high water through the following week. On 21 May, one stream bank collapsed and three trees fell onto the weir. Conditions in Reynolds Creek did not allow effective operation of traps until the first week of July. Traps were placed in Call Creek on 12 May, about one month later than in 1998. Both traps in Call Creek functioned well until high water from 24 May to 07 June. During the subsequent week, flow of Call Creek was relatively low and stable. Call Creek flow increased again in mid-June, and we removed both traps from 19 to 28 June. High stream flows prevented placement of weirs in the upper mainstem John Day River until 10 July and in Roberts Creek until 15 July. After flows subsided, weir traps in these four streams operated through mid-October.

Thirty-eight bull trout were captured in all upstream migrant traps in 1999 (Fig. 2), although traps did not operate before July in three of four streams. The upstream migrant trap in Call Creek operated during part of May and June and all of July, but captured no bull trout until August. This differed from results in 1998, when about half the upstream migrant bull trout captured in Call Creek appeared during July (Hemmingsen et al. 2001b). In spite of the early-season difficulties in 1999, numbers of upstream migrant bull trout captured in Roberts Creek and upper John Day River were nearly identical to those in 1998. In both of these years, the number of upstream migrant bull trout captured in Call Creek was similar to the total captured in all three other streams. In 1999, no bull trout were captured in upstream migrant traps after the third week of September. Fork lengths from 33 of 38 bull trout captured in all upstream migrant traps ranged from 180 to 450 mm (Fig. 3).

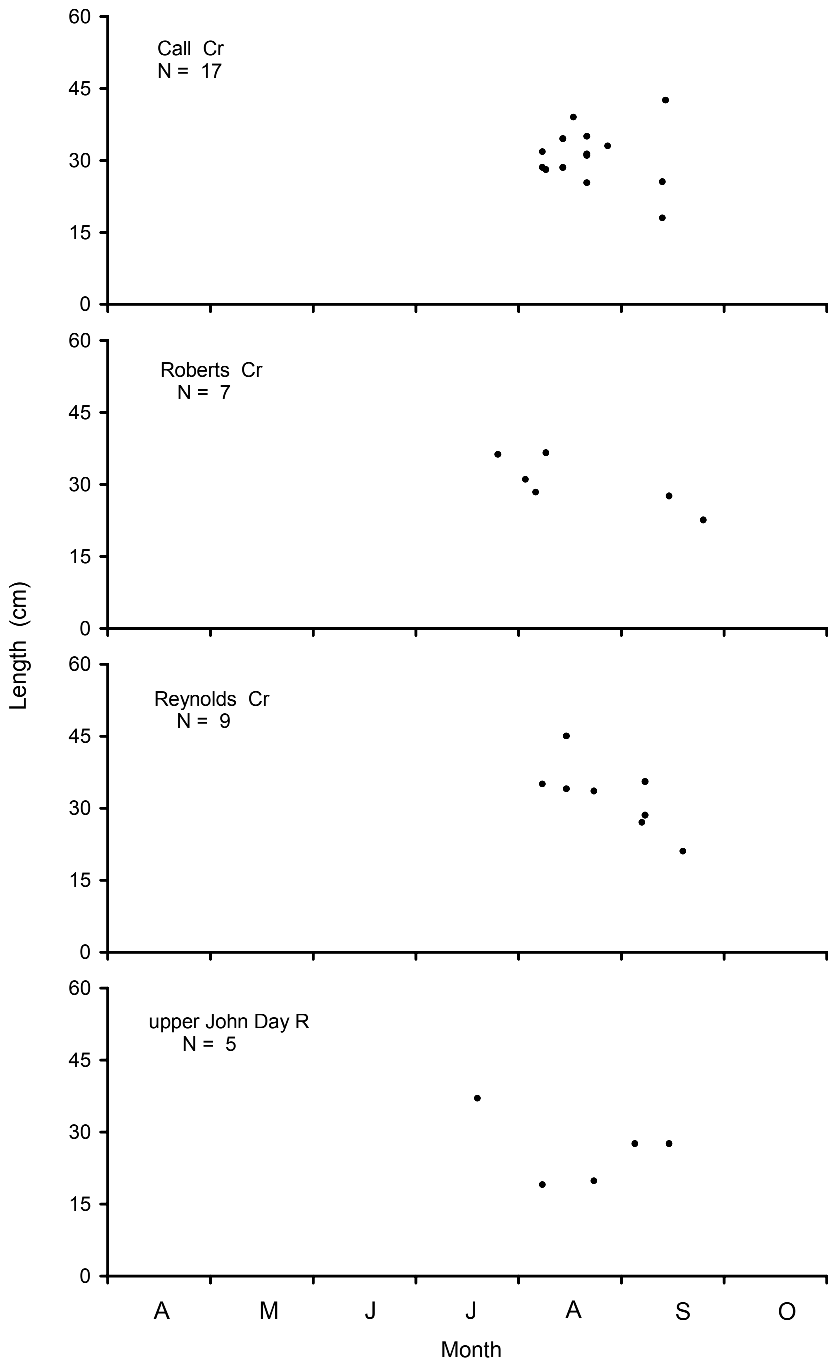


Figure 2. Bull trout of the upper John Day River subbasin captured in upstream migrant weir traps during 1999.

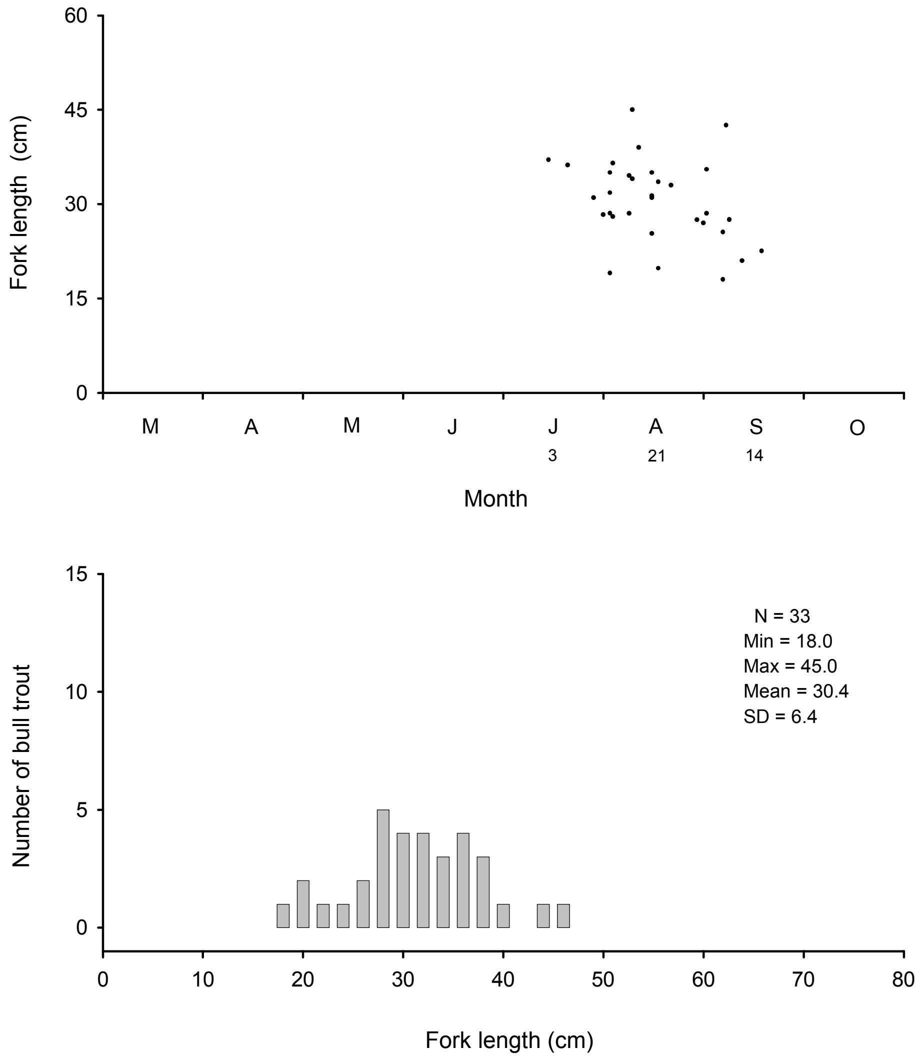


Figure 3. Numbers of bull trout of the upper John Day River subbasin captured in all upstream migrant traps in 1999, and their frequency by length. Monthly totals are shown under corresponding months.

Four of these 38 bull trout had PIT tags that identified them as recaptured individuals, and all four appeared in Call Creek. One of these four had been captured in the downstream migrant trap in the upper John Day River on 13 July, 23 days before arrival in the Call Creek trap. Two bull trout had been captured in the downstream migrant trap in Call Creek in September and October 1998; these fish were recaptured in Call Creek 341 and 343 days later, respectively. The fourth bull trout had been first captured in the upstream migrant trap in Call Creek in July 1998, 416 days before being recaptured in this same trap (Table 1).

Table 1. Bull trout recaptured in upstream migrant traps in the upper John Day River subbasin in 1999.

Recapture site	Date	Length (mm)	Previous site	Previous date	Days elapsed
Call Cr	05 Aug	318 [a]	John Day R [b]	13 Jul	23
“	18 Aug	N/a	Call Cr [c]	10 Sep, ‘98	341
“	10 Sep	425	Call Cr [d]	22 Jul, ‘98	416
“	13 Sep	N/a [e]	Call Cr [c]	05 Oct, ‘98	343

[a] Radio frequency 151.562.
[b] Downstream migrant trap of the upper John Day River.
[c] Downstream migrant trap of Call Creek.
[d] Upstream migrant trap of Call Creek.
[e] Was 465 mm on 05 Oct ’98 when radio-tagged (frequency 150.982).

We captured 173 bull trout in downstream migrant traps. Bull trout appeared in all four traps soon after they began operation, but because of high flows in three streams only the Call Creek trap captured bull trout prior to July (Fig. 4). Twenty-nine percent of the bull trout captured in Call Creek appeared before 07 July. From this date through 27 October, the Call Creek trap captured 67 bull trout, nearly as many as the other three traps combined during the same period. In Call, Roberts and Reynolds creeks, most bull trout captured before September were less than 250 mm fork length; most bull trout captured during September and October were larger than 250 mm. In the upper John Day River, however, bull trout larger than 300 mm fork length were captured before mid-August; one of these, as discussed above, was recaptured later in the upstream migrant trap in Call Creek (Table 1). In 1998, we also found that some large bull trout move from the headwaters of the John Day River into Call Creek, presumably to spawn. In both 1998 and 1999 however, we were unable to document any bull trout moving from the headwaters of the John Day River into traps in tributaries other than Call Creek.

Fork lengths ranged from 50 to 540 mm for 161 of 173 bull trout captured in downstream migrant traps. These bull trout comprised two primary groups, those smaller and those larger than 240 mm (Fig 5). Many in the latter group appear to be pre- or post-spawning individuals. Twelve of the 94 bull trout captured in the downstream migrant trap in Call Creek had PIT tags that identified them as recaptured individuals. These 12 bull trout, ranging in fork length from 257 to 425 mm, were previously captured in the upstream migrant trap in Call Creek and spent an average of 32 days (range 3 to 72 days) between capture in both Call Creek traps (Table 2). Three of the 32 bull trout captured in the downstream migrant trap in Roberts Creek were identified as recaptured individuals. Two of these three bull trout were captured one or 10 days earlier in the upstream migrant trap in Roberts Creek. The third recaptured bull trout was first captured 454 days earlier in the screw trap in the upper John Day River. Two bull trout of Reynolds Creek had been captured 32 and 36 day earlier in the upstream migrant trap there. One of two bull trout recaptured in the downstream migrant trap of the upper John Day River had been captured in the upstream migrant trap Call Creek on 10 July 1998. The other recaptured bull trout had first appeared in the downstream migrant trap of the upper John Day River nearly two years earlier; it had gained 84 mm in length during that time.

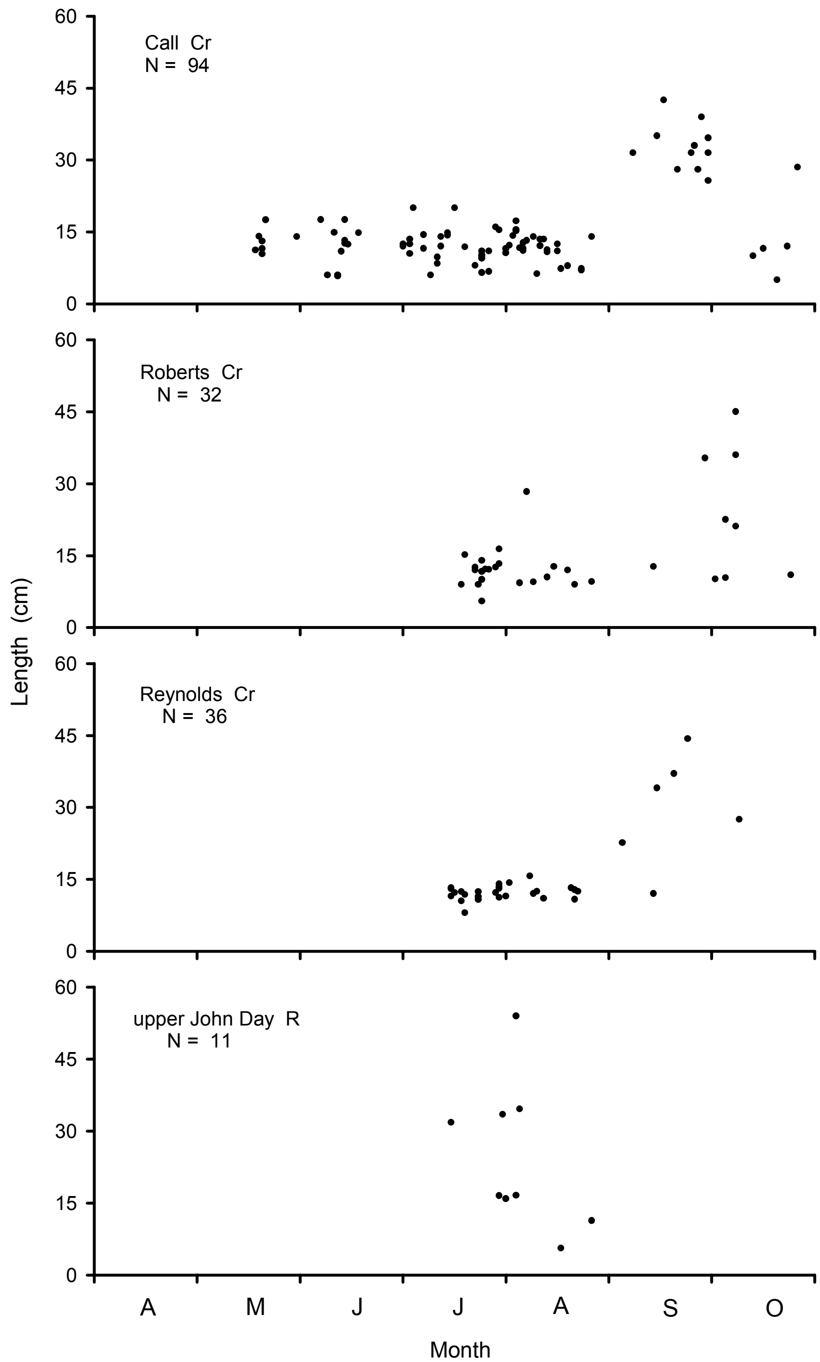
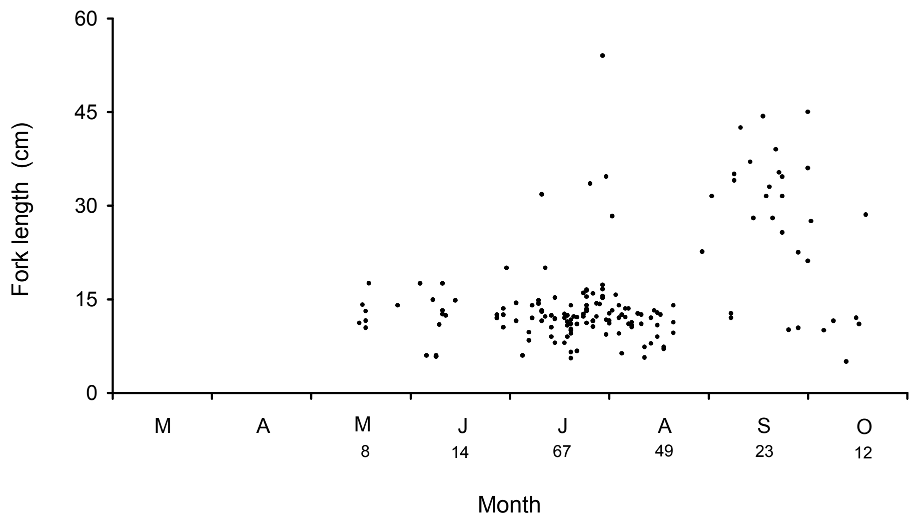


Figure 4. Bull trout of the upper John Day River subbasin captured in downstream migrant weir traps during 1999.



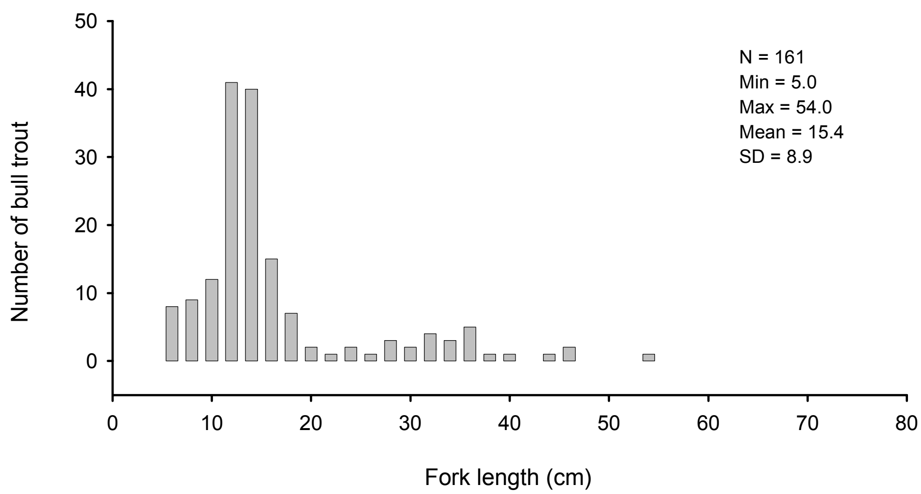


Figure 5. Numbers of bull trout of the upper John Day River subbasin captured in all downstream migrant traps in 1999, and their frequency by length. Monthly totals are shown under corresponding months.

The screw trap was placed in the upper John Day River (Rkm 434.2) on 06 May. It operated through 25 October and captured 61 bull trout. This number was about 40% of the number of bull trout captured by screw trap during either 1997 or 1998. We suspect this reduction in numbers captured was influenced by the location of the trap. The trap site in 1999 was 2.6 km downstream of the site in earlier years, and lacked some physical characteristics of the earlier site that should have increased the probability of capturing bull trout.

Table 2. Bull trout recaptured in downstream migrant traps in the upper John Day River subbasin in 1999.

Recapture Site	Date	Length (mm)	Previous site[a]	Previous date	Days elapsed
Call Cr	04 Sep	315	Call Cr	18 Aug	17
“	11 Sep	350	“	18 Aug	24
“	13 Sep	425	“	10 Sep	3
“	17 Sep	280	“	18 Aug	30
“	21 Sep	315	“	05 Aug	47
“	23 Sep	330	“	24 Aug	29
“	23 Sep	280	“	05 Aug	49
“	24 Sep	N/a [b]	“	13 Sep	11
“	24 Sep	390	“	14 Aug	41
“	26 Sep	257	“	09 Sep	17
“	26 Sep	346	“	11 Aug	46
“	22 Oct	285	“	11 Aug	72
Roberts Cr	04 Aug	283	Roberts Cr	03 Aug	1
“	01 Oct	225	“	21 Sep	10
“	04 Oct	360	Screw trap	08 Jul ‘98	454
Reynolds Cr	20 Sep	443	Reynolds Cr	12 Aug	32
“	05 Oct	275	“	03 Sep	36
Upper John Day R	28 Jul	335	Call Cr	10 Jul ‘98	383
“	02 Aug	346	John Day R [c]	17 Aug ‘97	716

[a] Upstream migrant trap of the stream listed unless otherwise noted.
[b] Was 465 mm on 05 Oct ’98 when radio-tagged (frequency 150.982).
[c] Downstream migrant trap.

Fork lengths from 60 of the bull trout captured by screw trap ranged from 114 to 460 mm, and averaged 232 mm. Most bull trout less than 250 mm fork length were captured during May and June, and none were captured after mid-September. While bull trout 250 mm fork length or larger appeared in all months, most were captured from August through mid-October (Fig. 6). Six of the 61 bull trout captured in the screw trap were identified from PIT tags as recaptured individuals. Five of these six had appeared in the screw trap from one to 67 days earlier (Table 3). The bull trout recaptured on 17 August had previously been captured in the screw trap mid-June 1998, when the trap was located 2.6 km upstream. In 1999, no bull trout captured and identified at any of the four weir sites was recaptured in the screw trap.

Table 3. Bull trout recaptured in the screw trap in the upper John Day River in 1999.

Date recaptured	Length (mm)	Previous site	Previous date	Days elapsed
08 May	206	Screw trap	07 May	1
30 Jul	213	“	12 Jun	48
31 Aug	300	“	25 Jun	67
03 Sep	308	“	07 Jul	58
12 Oct	344	“	14 Sep	28
17 Aug	333	“	15 Jun ‘98	428

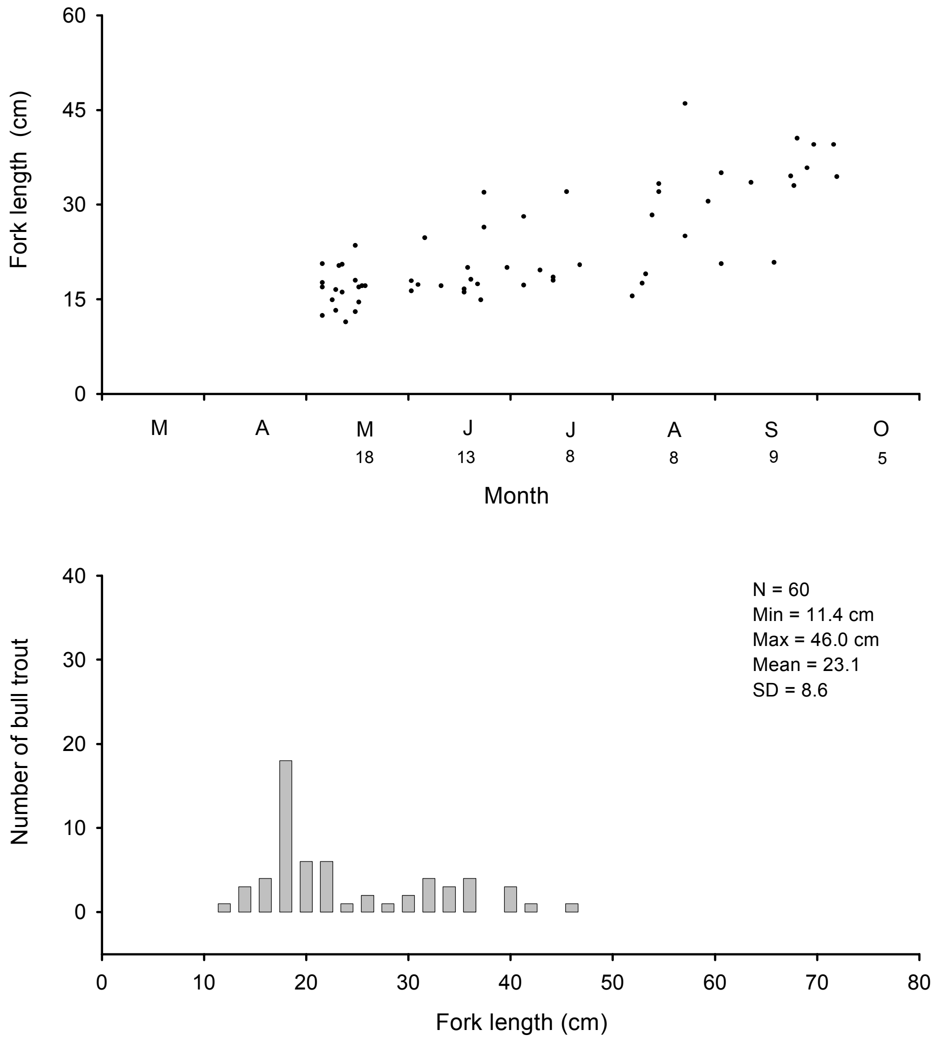


Figure 6. Numbers of bull trout of the upper John Day River captured by screw trap in 1999, and their frequency by length. Monthly totals are shown under corresponding months.

In the upper John Day watershed, we implanted radio transmitters in nine bull trout with fork lengths that ranged from 247 to 400 mm (mean = 320 mm). Four of these bull trout were captured in weir traps, five were captured by screw trap, and most received transmitters with expected durations of 18 months (Table 4). Details for some of these bull trout show a variety of movements. The downstream migrant from Call Creek (151.302) moved to the John Day River around 01 November, then continued upstream to Rkm 450.1 of the John Day River by 12 November. The downstream migrant bull trout from Roberts Creek (151.582A) moved into the John Day River at Rkm 440.6 one day after it was tagged, then continued downstream also to a location near the screw trap. Downstream migrant 151.562, captured in the upper John Day River trap 13 July, moved 2.5 km into lower Call Creek by 29 July. In Call Creek, this fish moved to Rkm 1.5 by 20 Aug and stayed within a 0.4-km reach of stream through 20

September; it likely spawned during this time. This bull trout then moved to Rkm 447.5 of the John Day River by 05 October and to Rkm 448.3 by 14 October. It stayed at the latter location through mid-November.

The bull trout captured earliest in the screw trap (151.703) moved downstream 1 km in the John Day River in four days, then back upstream 5.4 km by 07 August. It was located in Deardorff Creek at Rkm 0.1 on 10 September and was back in the John Day River on 20 September. We do not know how far this fish ascended Deardorff Creek. By 12 November it was 1.6 km upstream of the screw trap site. The second bull trout captured by screw trap in June (151.313) continued downstream 0.4 km where it stayed from late July through 02 September. One month later it was located 0.6 km upstream of the screw trap, but 10 days later (on 15 October) it was downstream at Prairie City (RKm 422.4). By 29 October this bull trout had moved 10.6 km back upstream in the John Day River, where it stayed through 18 November.

Table 4. Bull trout of the upper John Day River subbasin captured in traps and implanted with radio transmitters in 1999.

Trap type, Trap location, date tagged	L (mm)	MHz	Signal life (mo)	LU	TU	LD	TD
Upstream migrant traps:							
Roberts Cr (km 1.3)							
23 July	362	151.343	18	2.2	04 Aug	434.3	03 Nov
Downstream migrant traps:							
Call Cr (km 0.7):							
23 Oct	285	151.302	18	450.1	12 Nov	447.0 [a]	01 Nov
Roberts Cr (km 1.3)							
13 Oct	360	151.582A	18	--	--	434.3	03 Nov
John Day R (km 449.2):							
13 Jul	318	151.562	18	--	--	1.5 [b]	20 Aug
Screw trap (km 434.2):							
08 Jun	247	151.703	9	438.6	07 Aug	433.2	12 Jun
25 Jun	319	151.313	18	434.8	06 Sep	422.4	15 Oct
09 Jul	285	151.601B	9	450.1	28 Jul	--	--
01 Sep	305	151.222	18	436.3	13 Oct	433.0	03 Sep
13 Oct	400	150.541	36	438.1	16 Nov	426.6	20 Dec

LU = maximum known upstream location (Rkm) in 1999. Dashes = trap location.
TU = earliest date of maximum upstream location. Dashes = date tagged.
LD = maximum known downstream location (Rkm) in 1999. Locations are in John Day River unless otherwise noted.
TD = earliest date of maximum downstream location.
[a] The actual location on 01 November was Rkm 447.5, but the fish had to pass the mouth of Call Creek (Rkm 447.0) between 23 Oct and 01 November.
[b] Location in Call Creek.

The bull trout captured by screw trap on 09 July (151.601B) moved upstream 15.9 km by 28 July and stayed at this location through 16 August. This fish was not located again until 06 September, when it was back downstream in the pool where the screw trap was located. It was still in this pool on 16 November. This bull trout provides another example that not all those captured by screw trap are headed downstream.

We also continued to track 26 bull trout in the upper John Day River watershed that were implanted with radio transmitters during 1998. In 1998, the downstream extent of radio-tagged bull trout in the John Day River that we detected was Rkm 428.9, about 6.5 km upstream of Prairie City (Hemmingsen et al. 2001b). During 1999, however, we tracked seven bull trout radio-tagged in 1998 to locations farther downstream. These locations included 4.6 and 4.3 km upstream of Prairie City; 0.2, 1.3, 5.2, and 14 km (Rkm 408.4) downstream of Prairie City; and at the city of John Day (Rkm 400.1). Three of these bull trout had been captured in Call Creek, one had been captured in each of Deardorff and Roberts creeks, and two had been captured in the upper John Day River. These seven bull trout ranged in fork length from 320 to 560 mm (mean = 476 mm) at the times they were captured in 1998.

The highest locations in the upper John Day watershed that we detected any radio-tagged bull trout in 1999 were Rkm 2.2 in Call Creek, Rkm 9.7 in Deardorff Creek, and Rkm 452.6 in the John Day River. We located one bull trout at Rkm 2.4 in Roberts Creek, although it could have moved higher onto private land where we did not have access. The bull trout located at the city of John Day (mentioned above) moved from there to lower Rail Creek on 14 September, then back to Rkm 400.1 by 26 November; it had originally been captured and radio-tagged in Roberts Creek in September 1998. No bull trout with transmitters were found in Reynolds Creek.

Mill Creek

Stream flows of Mill Creek during 1999 permitted operation of both traps from 17 March to 30 October. The upstream migrant trap captured 203 bull trout, 39 more than were captured in 1998. During 1999, only three bull trout were captured prior to June, but these included the smallest and largest individuals (Fig. 7). Seventy-three percent of the captured upstream migrant bull trout appeared during July and August while only one appeared during October. For 202 of the bull trout captured in this trap, fork lengths ranged from 270 to 880 mm with a mean of 413 mm (Fig. 7).

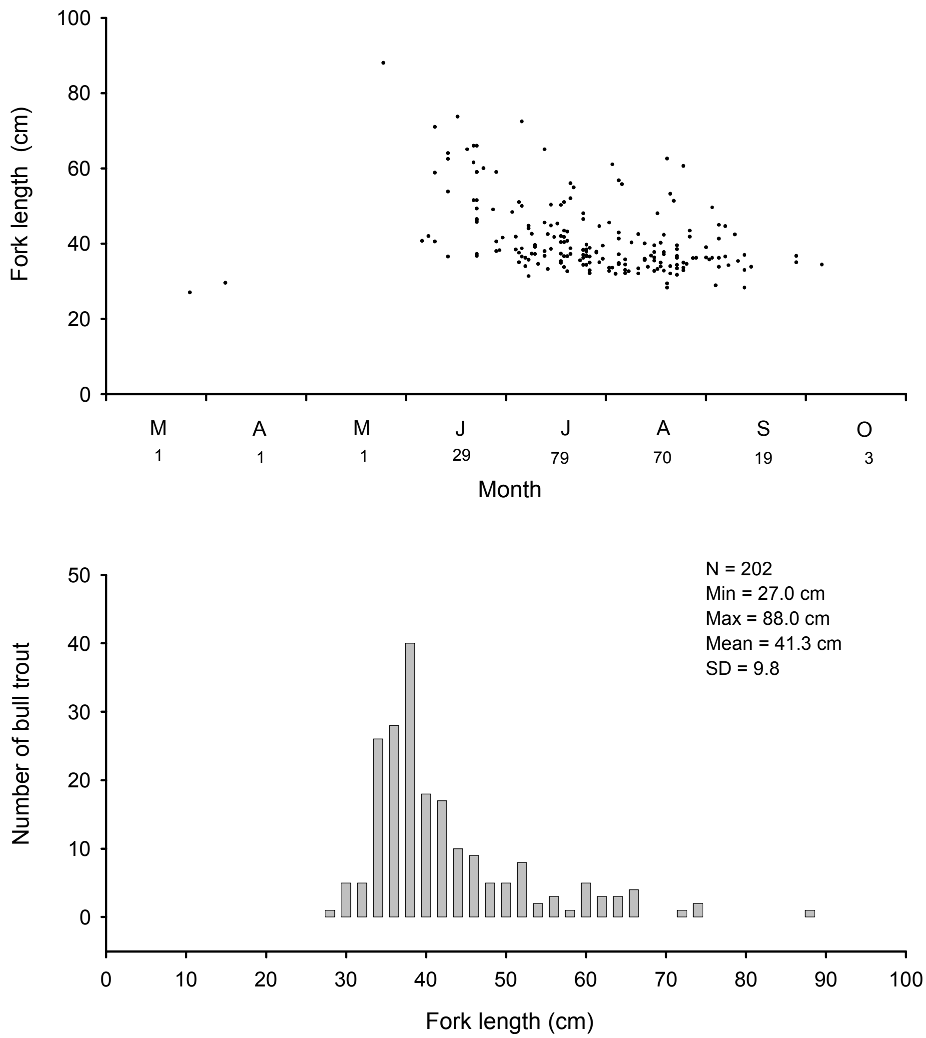


Figure 7. Numbers of bull trout of Mill Creek captured in the upstream migrant trap in 1999, and their frequency by length. Monthly totals are shown under corresponding months.

The screw trap began to catch bull trout soon after it was set in place, and captured 615 of them throughout its operation. This number is 50% of the number captured at this site in 1998 (Hemmingsen et al. 2001b). Fifty-nine percent of the total number captured appeared during April, May and June, and all of these were less than 250 mm (Fig. 8). Most of the 75 bull trout captured during September and October were larger than 250 mm, and likely were moving downstream after spawning. Fork lengths of all bull trout captured by screw trap ranged from 47 to 652 mm. The overall mean fork length was 175 mm; however, the median fork length was 155 mm, and 90% of all bull trout captured were less than 250 mm.

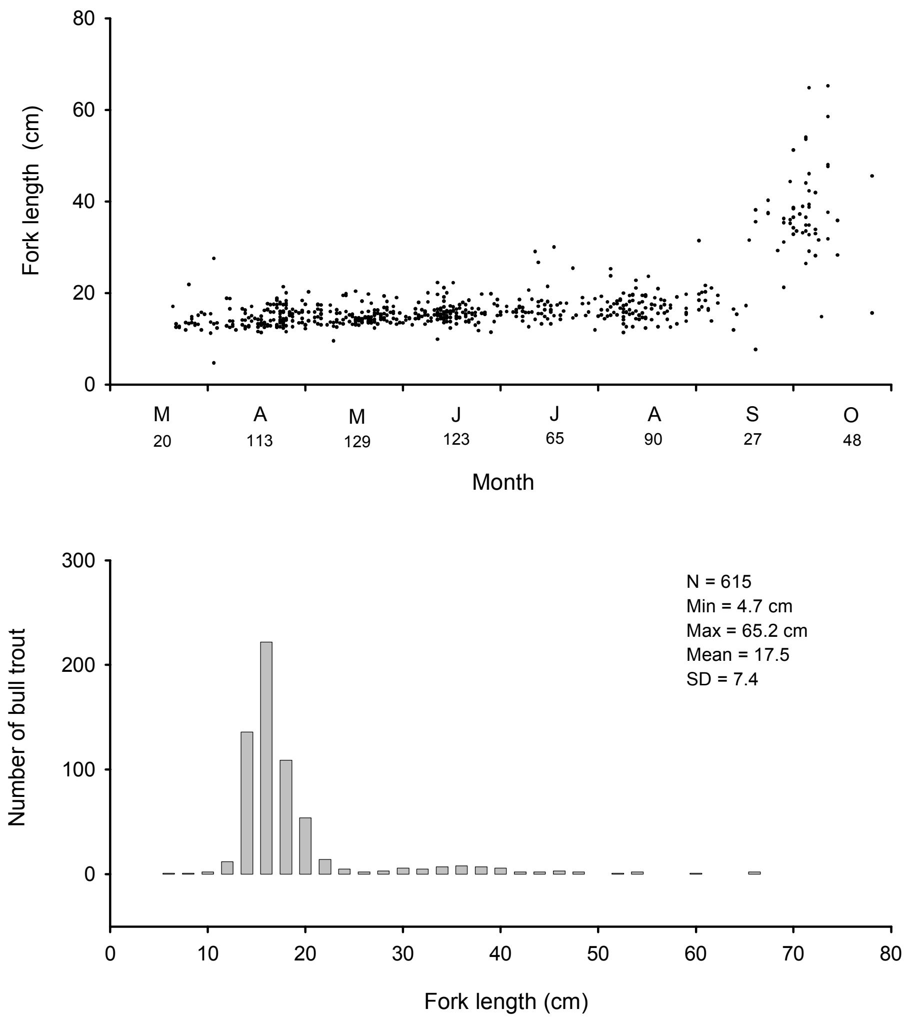


Figure 8. Numbers of bull trout of Mill Creek captured in the screw trap in 1999, and their frequency by length. Monthly totals are shown under corresponding months.

From March through October, the efficiency at which the Mill Creek screw trap captured bull trout averaged 54%, although there was considerable monthly variation (Table 5). Based on these measures of capture efficiency, we estimated the number of bull trout that may have passed downstream at this location to be between 1,126 and 1,526 (1,326 $\pm$ 200). It should be noted that the estimated number of bull trout assumes that these fish pass the trap only once. Based on evidence from PIT tags however, some bull trout can be recaptured more than once and thereby cause over-estimation of the actual number that passed downstream. It also assumes that all marked bull trout placed upstream move back downstream past the trap, and data from both Mill Creek and the upper John Day River show that is not always the case. This condition would cause under-estimation of the number that passed downstream.

Table 5. Efficiencies at which the Mill Creek screw trap captured bull trout, and the estimated numbers of bull trout that passed downstream in 1999.

	Mar-Apr	May	Jun	Jul	Aug	Sep-Oct
Trap efficiency (%)[a]	63	60	64	45	33	32
Estimated number of bull trout	217	225	192	149	293	250
95% confidence interval	38	42	33	53	106	147

[a] Proportion of fin-marked fish recaptured.

Average fork lengths of bull trout captured monthly in the Mill Creek screw trap were very similar from March through August (Fig. 9). Average fork lengths of bull trout captured in the John Day River screw trap tended to increase from May through August, and tended to be greater than those of bull trout captured in downstream migrant traps. Monthly average fork lengths of upstream migrant bull trout in Mill Creek tended to be greater than those of the upper John Day River watershed. In Mill Creek, the largest upstream migrant bull trout appeared during June.

In 1999, we implanted 16 Mill Creek bull trout (fork lengths from 282 to 395 mm) with radio transmitters with expected durations of at least 18 months. Eight of these bull trout were captured in the upstream migrant trap, four of which reached locations farthest upstream by mid-September (Table 6). Three of the eight bull trout, all captured on 12 October, were not located upstream farther than the pool adjacent to the trap. The signal of the eighth bull trout was not detected after implantation of the transmitter.

Four of the 16 bull trout implanted radio transmitters were captured in the screw trap in July and October. Two of these bull trout moved downstream no farther than the water intake dam (Rkm 40.9), while another moved downstream to Rkm 36.7 by early November. The signal of the fourth transmitter was not detected after implantation. Because we had four radio transmitters left after traps were removed, we captured four additional bull trout during November by angling in pools adjacent to the water intake dam. By the end of 1999, two of these bull trout remained near the dam while two had moved downstream 3 km or less.

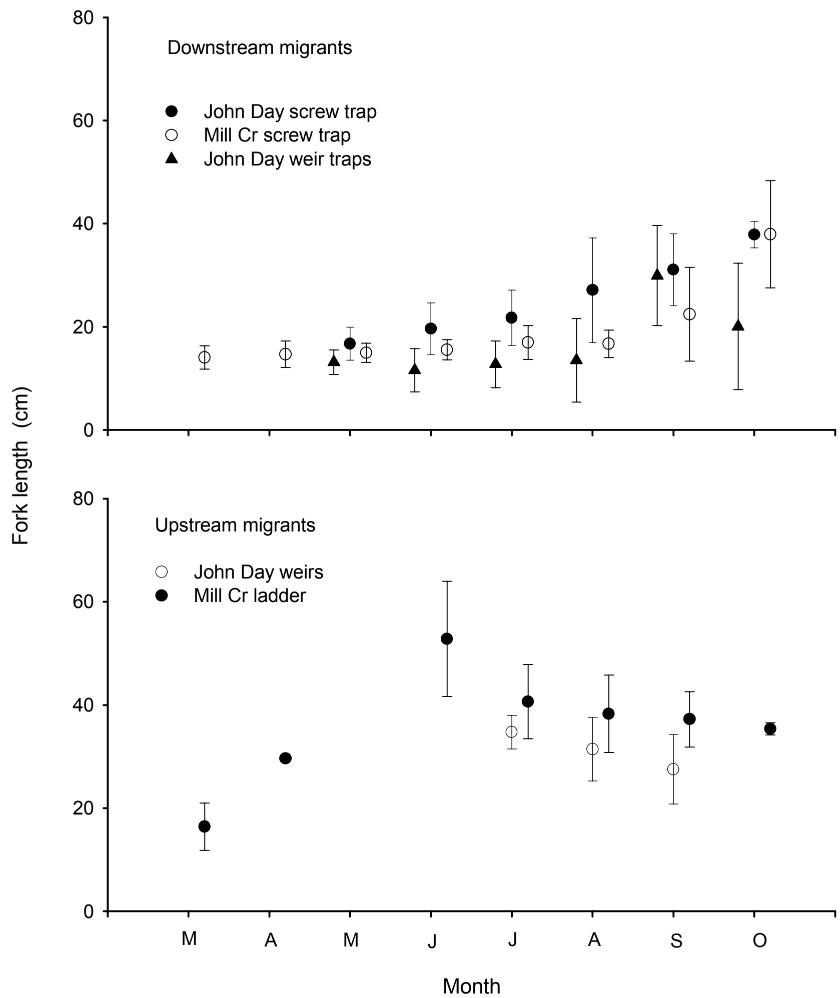


Figure 9. Fork lengths (mean ± SD) of bull trout captured monthly during 1999.

We continued to track four bull trout with transmitters applied in 1997 and 19 bull trout with transmitters applied in 1998. Twelve of these transmitters expired at various times during 1999, often early in the year when little movement occurred. However, we were able to track 11 bull trout with transmitters applied in 1998 throughout 1999. Nine of these 11 bull trout were at their farthest downstream locations in January or February (Table 7). All bull trout in Table 7 were at their most upstream locations in September or October, when they likely were spawning. For all Mill Creek bull trout tracked in 1999, the lowest downstream location (Rkm 19.5, Table 7) was similar to that described for bull trout with transmitters in 1998 (Rkm 19.3). The highest upstream location (Rkm 51.0, Table 6) exceeded the upstream range described for bull trout between 300 and 400 mm fork length with transmitters in 1998 by 0.8 km. However, this upstream range is less than that (Rkm 52.8) reached by a 470-mm radio-tagged bull trout in 1998 (Hemmingsen et al. 2001b). 1999 was the third consecutive year that no radio-tagged bull trout was detected downstream of Walla Walla, WA .

Table 6. Bull trout of Mill Creek implanted with radio transmitters in 1999.

Capture method, date tagged	L (mm)	MHz	Tag life (mo)	LU	TU	LD	TD
Upstream migrant trap (km 40.9):							
07 Jul	375	151.102	18	47.5	25 Sep	--	--
"	350	151.282	"	-- [a]		--	--
31 Jul	375	151.062	"	46.9	28 Sep	--	--
"	378	151.192	"	46.5	28 Sep	34.0	09 Nov
03Aug	335	151.233	"	51.0	18 Sep	--	16 Oct
12 Oct	338	151.702	"	--	--	31.2	31 Dec
"	329	151.241	"	--	--	38.0	17 Dec
"	315	151.312	"	--	--	40.9	13 Oct
Screw trap (km 41.5):							
14 Jul	290	151.561	"	--	--	41.1	03 Aug
20 Jul	300	151.662	"	-- [a]	--	--	--
18 Oct	282	151.052	"	--	--	40.9	24 Oct
"	358	151.343	"	--	--	36.7	09 Nov
Angling (km 40.9)							
15 Nov	360	151.273	"	--	--	39.0	28 Dec
22 Nov	330	151.151	"	--	--	--	--
"	365	151.222	"	--	--	38.0	21 Dec
"	395	151.681	"	--	--	--	--

LU = maximum known upstream location (Rkm) in 1999. Dashes = site tagged.
TU = earliest date of maximum upstream location. Dashes = date tagged.
LD = maximum downstream location (Rkm) through 1999. Dashes = site tagged.
TD = earliest date of maximum downstream location. Dashes = date tagged.
[a] Not located after tagging.

Table 7. Bull trout of Mill Creek implanted with radio transmitters in 1998 and tracked through 1999.

L (mm) [a]	MHz	LU	TU	LD	TD
520	150.123	49.3	18 Sep	25.1	05 Jan
470	150.146	44.8	11 Sep	20.6	05 Jan
555	150.713	48.9	11 Sep	19.5	12 Jan
535	150.105	45.6	11 Sep	40.6	27 Jan
485	150.124	46.5	02 Oct	34.9	05 Jan
630	150.192	49.1	14 Sep	30.6	19 Jan
580	150.993	50.2	12 Sep	33.0	05 Jan
545	150.134	49.9	18 Sep	20.4	02 Feb
300	151.811	41.4	13 Oct	35.3	05 Jan
195	151.282	45.1	04 Sep	40.9	07 Jul [b]
207	151.662	50.7	13 Oct	41.2	24 Jul [b]

LU = maximum known upstream location (Rkm) in 1999.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 1999.
TD = earliest date of maximum downstream location.
[a] Length when radio-tagged in 1998.
[b] Not located between January and July.

Grande Ronde Basin

We implanted radio transmitters and PIT tags in 13 bull trout from the Grande Ronde Basin during 1999. All of these bull trout were captured from the Wenaha River by angling during July and released at the location captured after surgery. These 13 bull trout ranged in fork length from 260 to 375 mm, but only one was less than 300 mm (Table 8). All these fish moved into the Grande Ronde River and reached their maximum distances from the Wenaha River (listed under LD in Table 8) between late October and mid-December. Five of these 13 bull trout were located in the Grande Ronde River downstream of the mouth of the Wenaha River, which joins the Grande Ronde River at Rkm 74. The other nine bull trout had traveled upstream in the Grande Ronde River for distances up to 40.3 km from the confluence of the Wenaha River.

Table 8. Bull trout of the Grande Ronde basin implanted with radio transmitters during 1999; all were captured in the Wenaha River.

Date tagged	Location (Rkm) [a]	L (mm)	MHz	Tag life (mo)	LU [a]	TU	LD [b]	TD
01 Jul	1	340	150.032	18	29	18 Aug	53	01 Dec
30 Jul	15	320	151.642	"	8	18 Aug	85	01 Dec
"	15	330	151.622	"	19	18 Aug	107	03 Nov
"	15	310	151.381	"	19	07 Sep	58	11 Dec
"	15	340	151.072	"	19	07 Sep	96	11 Dec
"	15	375	151.092	"	25	07 Sep	68	01 Dec
"	15	360	150.891	"	18	18 Aug	86	27 Oct
"	16	350	151.613	"	28	18 Aug	87	12 Nov
"	17	350	151.672	"	21	07 Sep	114	12 Nov
"	15	350	150.869	"	23	07 Sep	98	01 Dec
31 Jul	24	370	150.881	"	26	07 Sep	40	27 Oct
"	24	365	150.902	"	26	18 Aug	106	11 Dec
"	24	260	151.513	9	28	18 Aug	37	01 Dec

LU = maximum known upstream location (Rkm).
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm).
TD = earliest date of maximum downstream location.
[a] Locations in Wenaha River.
[b] Locations Grande Ronde River.

We continued to track 15 bull trout whose transmitters had been applied in 1997. These transmitters expired by summer of 1999, so we lack upstream locations of these fish when they spawned in the fall. However locations early in the year describe the downstream limits to ranges observed. One of these 15 bull trout was in the Snake River (Rkm 257.6) early in February and had moved upstream to Rkm 261 by early May (Table 9). Three of the 15 bull trout remained in the Wenaha River; we determined their downstream range limits to be between Rkm 8.2 and 21.2 during February or May. The remaining 11 bull trout had spent the winter and spring in the Grande Ronde River between Rkm 32.2 and 99.5. Four of these 11 fish moved into the Wenaha River by early August. The remaining seven bull trout were still in the Grande Ronde River between Rkm 72.9 and 35.9 when last located (May-July).

Table 9. Bull trout of the Grande Ronde Basin implanted with radio transmitters in 1997 and tracked in 1999.

L (mm) [a]	MHz	LU	TU	LD	TD
485	150.913	23 [b]	02 Aug	21 [b]	26 May
475	150.853	261 [c]	05 May	258 [c]	03 Feb
510	150.594	67 [d]	26 May	63 [d]	03 Feb
588	150.953	12 [b]	02 Aug	38 [d]	04 Jan
460	150.334	10 [b]	07 Jul	80 [d]	03 Feb
494	150.713	1 [b]	09 Jun	72 [d]	17 Feb
645	150.795	19 [b]	29 Jun	8 [b]	17 Feb
480	150.833	73 [d]	07 Jul	100 [d]	17 Feb
505	150.974	47 [d]	26 May	41 [d]	19 May
447	150.293	42 [d]	09 Jun	39 [d]	17 Feb
510	150.634	18 [b]	07 Jul	12 [b]	10 May
538	150.192	36 [d]	04 Jan	32 [d]	19 May
510	150.393	67 [d]	09 Jun	63 [d]	03 Feb
495	150.172	29 [b]	02 Aug	82 [d]	19 May
515	150.154	71 [d]	26 May	69 [d]	19 May

LU = maximum known upstream location (Rkm) in 1999.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 1999.
TD = earliest date of maximum downstream location.
[a] Length when radio-tagged in 1997.
[b] Location in Wenaha River.
[c] Location in Snake River.
[d] Location in Grande Ronde River.

We also continued to track 20 bull trout whose transmitters had been applied in 1998. Of these, 11 had signals that extended throughout most of 1999. These 11 bull trout were 378 to 630 mm fork length when they were radio-tagged in 1998. One of these 11 bull trout moved from the Grande Ronde River (Rkm 158) in February, to Lookingglass Creek (Rkm 18) by early September, then back to the Grande Ronde River (Rkm 138) by December. Lookingglass Creek joins the Grande Ronde River at Rkm 132. Another bull trout that was in the Snake River (Rkm 245) in February moved to the Wenaha River (Rkm 7) by early July, then back to the Grande Ronde River (104) by November. Four of the 11 bull trout were in the Grande Ronde River (Rkm 77 – 118) upstream of the confluence of the Wenaha River (Rkm 74) in February. These four bull trout also moved into the Wenaha River. The detected locations farthest upstream in the Wenaha River of two of these bull trout were Rkm 19 and 29 early in July. The other two bull trout reached Rkm 16 or 48 of the Wenaha River in September. All four of these fish returned to the Grande Ronde River by November or December; two were upstream (Rkm 88 and 118) of the confluence with the Wenaha River while two were downstream (Rkm 43 and 68) of the confluence. Another three bull trout remained in the Grande Ronde River between Rkm 37 and 54 throughout 1999. Finally, frequencies of two bull trout were never detected beyond the Wenaha River since they were implanted with transmitters in 1998. These bull trout had reached Rkm 36 or 37, and we suspect they died or shed their transmitters.

II. Bull trout and brook trout interactions

Introduction

One of the most significant threats to declining native bull trout populations is the presence of non-native salmonids (Howell and Buchanan 1992). Brook trout *Salvelinus fontinalis* particularly cause great concern because they are widely distributed throughout the range of bull trout (Rieman and McIntyre 1993) and the two species readily hybridize (Markle 1992; Leary *et al.* 1993). Competition with brook trout for habitat and prey resources also has been implicated in the decline of bull trout populations (Dambacher *et al.* 1992; Ratliff and Howell 1992). Our previous work shows bull trout and brook trout occupy similar feeding microhabitats, feed primarily from the water column, and exhibit common foraging behaviors; thus demonstrating a high potential for direct interaction (Hemmingsen et al. 2001a; 2001b). Additionally, knowledge of the specific diet of sympatric brook trout and bull trout is fundamental to fully comprehending the potential for direct interspecific competition. However, the diet of sympatric bull trout and brook trout has received minimal attention in the literature except the work of Wallis (1948).

We conducted an observational study of the diets of bull trout and brook trout in two eastern Oregon streams. Our objectives were to 1) describe the diet of allopatric bull trout, sympatric bull trout and brook trout, and 2) determine the dietary overlap between sympatric bull trout and brook trout.

Methods

<u>Study Site</u>

The study was conducted in two streams in eastern Oregon, Meadow Fork of Big Creek and the North Powder River. In both streams bull trout were allopatric in the upper segments and sympatric with brook trout in the middle segments (Fig. 10). These streams were selected for their relatively high densities of trout species, zones of trout allopatry and sympatry, and relative ease of access.

Meadow Fork of Big Creek is a tributary of the Malheur River. The sympatric reach was 2.6 km long where bull trout, brook trout, rainbow trout *Oncorhynchus mykiss*, and shorthead sculpin *Cottus confusus* were present. Immediately upstream was the 4.3 km allopatric reach with bull trout only (Fig. 10a). The allopatric and sympatric study sites were separated by 2.0 km. North Powder River is a headwater stream in the Powder River Basin. The 1.0 km long sympatric reach had bull trout and brook trout. The allopatric bull trout reach extended 2.6 km upstream of the sympatric reach (Fig. 10b). The allopatric and sympatric study sites were separated by about 0.5 km.

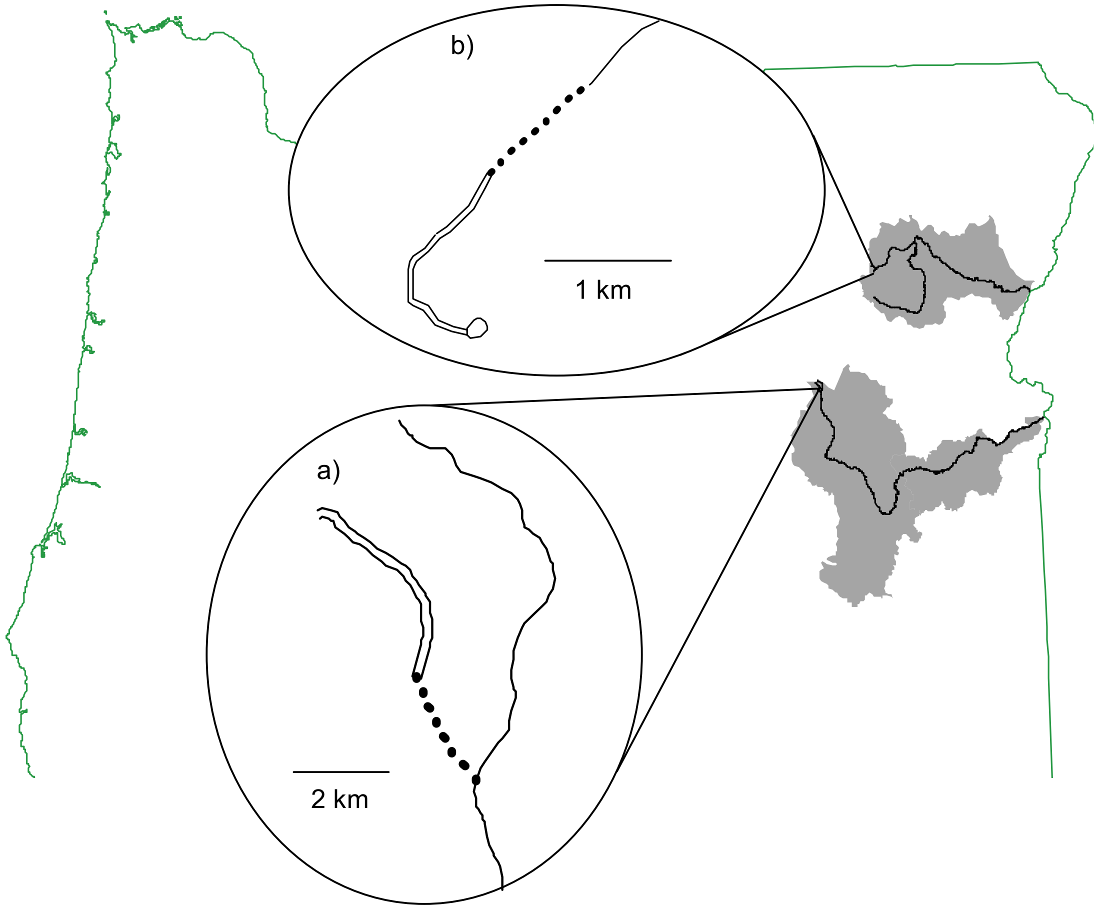


Figure 10. Relative distribution of allopatric bull trout (══) and sympatric bull trout and brook trout (▪ ▪ ▪) in a) Meadow Fork of Big Creek in the Malheur River Basin and b) North Powder River in the Powder River Basin, Oregon.

Fish and Prey Collection

Fish and macroinvertebrate samples were collected during summers of 1996 and 1997. We collected stomach contents from allopatric bull trout, and from sympatric bull trout and brook trout. We also sampled drifting and benthic macroinvertebrates to describe the available prey community. Insects from all samples were identified and counted in the laboratory during 1998 and 1999.

All fish were caught between 0700 and 1200 hours in order to describe the diet following the dawn peak in macroinvertebrate drift. In 1996, all fish were captured by angling with insect-mimicking flies. During 1997, equal sample sizes were captured using insect-mimicking flies, fish-mimicking flies, and an electrofisher to test for bias in capture method. Diets were similar regardless of the methods used to capture fish. Fish were anesthetized, weighed, and measured. Stomach contents were flushed into a 250 μm sieve (sensu Meehan and Miller 1978), and preserved in 95% ethanol. Fish were held in a recovery tank until fully recovered from anesthesia and returned to the stream. To calculate the efficiency of the stomach flushing technique a sub-sample of 10 brook trout were killed; their stomachs were removed and preserved in 95% ethanol.

To quantify prey availability, three macroinvertebrate drift samples were collected at dawn during peak drift one day prior to sampling fish in each study reach. Peak drift was roughly determined by measuring the volume of macroinvertebrates in 10-minute intervals for the hour before and during sunrise. A 250-μm drift net with an opening of 0.1 m^2 was set for 30 minutes in the thalwag just upstream from the head of three randomly selected pools. The height of the drift net was greater than water depth, effectively sampling the entire water column. Depth and water velocity were measured at each net using a flow meter. In addition, six benthic samples were collected in pools in each study reach using a 0.095-m2 surber sampler with a 250 μm net. Sites within each pool were randomly selected. Drift and benthic samples were preserved in 95% ethanol.

Invertebrates from stomach, drift, and benthic samples were sorted, identified to genus, categorized by lifestage (larvae, pupae, or adult), and enumerated in the laboratory using a dissecting microscope (10-40x). In some cases sub-samples of 50% were used to speed processing of drift and benthic samples with a high volume of silt, sand, or fine organic material. Drift and benthic samples were split using a plankton splitter and Caton tray (Caton 1991) respectively. Identification of invertebrates was determined from Merritt and Cummins (1996), Borror *et al*. (1989), Stewart and Stark (1993), Thorp and Covich (1991) and Wiggins (1995).

Analysis

Often, the condition of insects in the stomach samples allowed taxonomic identification only to family or order. Thus all descriptive statistics and analysis were conducted using family level and life stage classification. The average numeric proportions of prey taxa in the diet of all allopatric bull trout and sympatric bull trout and brook trout were compared using the log-likelihood ratio test (G-test)(Sokal and Rohlf 1981). Empty stomachs were not included in the analysis.

Dietary overlap of sympatric bull trout and brook trout on each date samples were collected was calculated using Schoener's overlap index (D):

$$D = 1 - 0.5\left(\sum_{i=1}^{s}\left|p_{ij} - p_{ik}\right|\right),$$

where, P_{ij} and P_{ik} are the proportions of the resource category (*i*) used by species (*j)* and (*k)*, while (*s)* is the total number of resource categories used by both species (Schoener 1968). Values of *D* range from 0, representing no overlap, to 1, for complete overlap. The index provides a comparative measure rather than a statistical measure (Townsend and Hildrew 1976) where values greater than 0.60 are generally considered to indicate biologically significant overlap in the resource use of two species (Wallace 1981; Wilhelm *et al.* 1999).

Results and Discussion

Stomach contents of 82 allopatric bull trout, 78 sympatric bull trout, and 73 sympatric brook trout were examined (Table 10). Fish ranged from 85-238 mm (fork length) and did not differ statistically among groups (3-way ANOVA, f = 0.48, p=0.6). One allopatric bull trout, three sympatric bull trout, and two brook trout had empty stomachs.

Table 10. Dates, number of fish sampled, and Schoener's Index of Overlap (D) for bull trout and brook trout in the sympatric reach for each sample period.

Stream	Date	Reach	Bull Trout	Brook Trout	D
Meadow Fork	20 Aug '96	Allopatric	11	-	-
	21 Aug '96	Sympatric	10	11	0.46
	03 Jul '97	Sympatric	27	20	0.65
	05 Jul '97	Allopatric	19	-	-
North Powder	23 Jul '96	Sympatric	10	10	0.61
	24 Jul '96	Allopatric	18	-	-
	23 Jul '97	Sympatric	28	30	0.68
	24 Jul '97	Allopatric	33	-	-

Of the ten brook trout stomachs dissected after stomach flushing, seven were completely empty. For the remaining three with partially flushed stomachs, 23% of the insects ($\bar{x}$ = 3 insects) remained in the cardiac stomach.

Bull trout and brook trout fed on a wide variety of prey. Both years, each species in each stream consumed an average of 85 (range 67-94) prey families and life stages. No one family averaged more than 13% of the diets, and only 13% of the 85 families exceeded an average of 2% of the diets. Relative proportions of specific prey varied between individual fish; however, larval stages of Ephemeroptera, aquatic Diptera and Trichoptera, and terrestrial insects dominated the stomach samples. Together, these prey groups averaged 72 - 74% of the diets for trout in the study.

For this analysis, prey comprising less than 1% of the diets were combined into groups of similar taxa. The terrestrial stages of aquatic insects were combined into respective groups by order (e.g. Ephemeroptera adults, Plecoptera adults, etc.). Ostracods, copepods, clams, mites, oligochaetes and platyhelminthes comprised 'other aquatic insects'. All insects without an aquatic life stage, including families of Hymenoptera, Hemiptera, Homoptera, Collembola, Thysanoptera, and Chilapoda comprised 'terrestrial insects'.

Diet composition of bull trout was consistent between allopatric and sympatric reaches ($G_{H(34)}$ = 23.21, $p>0.90$). Both allopatric and sympatric bull trout diets were dominated by Baetidae, Heptageniidae, Rhyacophilidae, Chironomidae larvae and terrestrial insects (Table 11). Sympatric bull trout also consumed a large proportion of Ephemerellidae larvae.

A shift in bull trout diet in the presence and absence of brook trout also was not apparent. Diet of sympatric bull trout did not differ qualitatively or statistically from allopatric bull trout. Though this observation may suggest brook trout do not cause a change in bull trout diet, this causal inference is not justified by our study because of its observational nature. Composition of the prey community differed between the allopatric and sympatric reach of both study streams (Gunckel 2001), affecting the overall diet and the electivity for fish. The difference in prey resources impedes direct comparison of the diets and electivity of bull trout in both reaches. A removal experiment would provide the added rigor necessary to demonstrate a change in diet for bull trout in the presence of brook trout (Fausch 1988; 1998).

Sympatric bull trout diet did not differ statistically from the diet of brook trout ($G_{H(34)}$ = 35.85, $p>0.10$). However, compared to sympatric bull trout, brook trout diet had a greater proportion of terrestrial insects (21%) and total Trichoptera families (23% compared to 9% for sympatric bull trout). Brook trout also had a smaller proportion of Ephemeroptera (21% compared to 37% for sympatric bull trout) (Table 11).

Evidence of resource partitioning and interactive segregation was minimal. The diets of bull trout and brook trout were statistically similar. Even though brook trout more frequently consumed larvae of Trichoptera families, they were not exclusive to the diet of brook trout (Table 11). Both bull trout and brook trout commonly preyed upon Trichoptera larvae.

Sympatric bull trout and brook trout diets overlapped considerably in each stream each year. Schoener's index of overlap (D) for sympatric bull and brook trout ranged between 0.46 and 0.68. The only sample when $D < 0.60$ was Meadow Fork of Big Creek 1996 (Table 10). Values of the index for sympatric bull trout and brook trout in this study were equivalent to those calculated for bull trout and lake trout *S. namaycush* sympatric in two lakes (0.69 and 0.53) in Alberta, Canada (Donald and Alger 1993). Substantial overlap in diet and resulting potential for competition in the latter study was suggested as the primary mechanism of bull trout displacement by lake trout. Three size classes of Colorado River cutthroat trout *O. clarki pleuriticus* also demonstrated a similar degree of overlap (0.64 - 0.87) in a high-elevation stream (Bozek *et al.* 1994). The authors concluded food may be limiting in those unproductive streams and the high degree of overlap suggested strong intraspecific competition among size classes.

Table 11. Percent composition of total diet for allopatric bull trout, sympatric bull trout and sympatric brook trout. Only macroinvertebrate families >1% of the diet for either group are shown.

	Allopatric bull trout N = 81	Sympatric bull trout N = 75	Sympatric brook trout N = 71
Larvae			
Baetidae	12.16	10.73	5.33
Ameletidae	3.23	3.95	1.16
Heptageniidae	10.61	10.65	5.63
Ephemerellidae	4.78	11.52	8.30
Plecoptera sp.	1.56	1.26	0.73
Nemouridae	4.79	2.46	1.67
Chloroperlidae	1.96	1.02	0.30
Perlidae	0.22	1.14	0.12
Peltoperlidae	2.79	1.56	1.87
Glossosomatidae	0.48	0.32	2.73
Brachycentridae	0.22	0.10	2.13
Rhyacophilidae	9.00	5.26	5.58
Limnephilidae	1.88	0.99	6.50
Hydropsychidae	0.68	2.83	1.21
Uenoidae	0.04	0.04	3.35
Aquatic Diptera sp.	0.55	1.44	1.19
Chironomidae	11.37	7.79	8.17
Simuliidae	5.24	4.34	3.46
Lepidoptera sp.	0.35	0.97	1.21
Pupae			
Trichoptera sp.	0.07	0.03	1.61
Chironomidae	0.90	2.46	2.44
Adults			
Ephemeroptera sp.	1.27	3.48	4.14
Plecoptera sp.	3.12	2.21	1.39
Trichoptera sp.	0.86	1.30	0.87
Aquatic Diptera sp.	2.81	3.15	5.11
Terrestrials	16.04	15.61	20.58

Vertebrate prey were rare; two brook trout from Meadow Fork of Big Creek each consumed one shorthead sculpin. No bull trout in this diet analysis were found to be piscivorous. Although these findings contradict other bull trout diet studies (Boag 1987), our many snorkel observations (Bellerud *et al.* 1997; Hemmingsen et al. 2001a; 2001b) documented bull trout will prey on smaller fish when available. The degree of piscivory depends on the abundance and accessibility of small forage fish. In montane streams young-of-the-year fish reside frequently near stream margins and are not found often in the same microhabitat with large fish (Mundie 1969; Moore and Gregory 1988; Hubert and Rhodes 1992). The difference in microhabitat use between size classes decreases the likelihood of predation on small trout by larger trout.

III. Bull trout spawning surveys

Introduction

This section describes results of studies that have continued since 1996. We conducted four surveys of bull trout spawning grounds in each of Mill Creek (Walla Walla Basin) and Silver Creek (Powder Basin), and three surveys in the Little Minam River (Grande Ronde Basin). In previous years, we have conducted studies on these streams to determine the variability in the numbers of redds observed by surveyors and the influence of physical characteristics on the probability of detecting redds. Surveys in 1999 provided additional data to better estimate the spatial and annual variation in observed numbers of bull trout redds.

Methods

We surveyed Mill Creek and its tributaries upstream of the water intake dam (Fig. 11). We surveyed the Little Minam River, and tributary Dobbin Creek, upstream from the confluence of Boulder Creek with Little Minam River (Fig. 12). We surveyed Silver Creek upstream from its confluence with Little Cracker Creek (Fig. 13). Survey reach numbers shown in Figs. 11-13 coincide with reach boundaries and lengths described by Hemmingsen et al. (2001a). Surveys in each watershed were conducted at two-week intervals during September and October with protocols consistent with surveys conducted in 1996 (Bellerud *et a*l. 1997) and 1997 (Hemmingsen et al. 2001a).

Results and Discussion

We observed 185 bull trout redds in the Mill Creek watershed during 1999. Of these redds, 127 were in Mill Creek and 58 were in its tributaries (Fig. 14a). No redds were observed in reaches one and two of Mill Creek. Reach five, between North Fork Mill Creek and Deadman Creek, contained the highest proportion of redds (32%), as it did in the previous three years (Bellerud *et al*. 1997; Hemmingsen et al. 2001a; 2001b). Tributaries to Mill Creek contained 31% of the redds observed in the watershed, and most of these were in Low Creek. In 1996 through 1998, tributaries to Mill Creek have produced 27 to 35% of the number of redds observed in the watershed each year from 1996 through 1999. In 1999, densities of redds (Fig. 14b) were highest in Low Creek (19.5/km) and reach five of Mill Creek (15.7/km).

Few bull trout had spawned in Mill Creek and its tributaries by 08 September, however Low Creek was not surveyed on 08 September and Paradise Creek was not surveyed either time in September. Thirty-one percent of all redds observed were counted by 23 September, and 81% were counted by 07 October. Spawning in Mill Creek and its tributaries peaked between the second and third surveys, which occurred on 21-23 September and 4-7 October (Fig. 14c). Spawning also peaked between mid September and early October in 1996 and 1997, while in 1998 it peaked between middle and late September (Hemmingsen et al. 2001b).

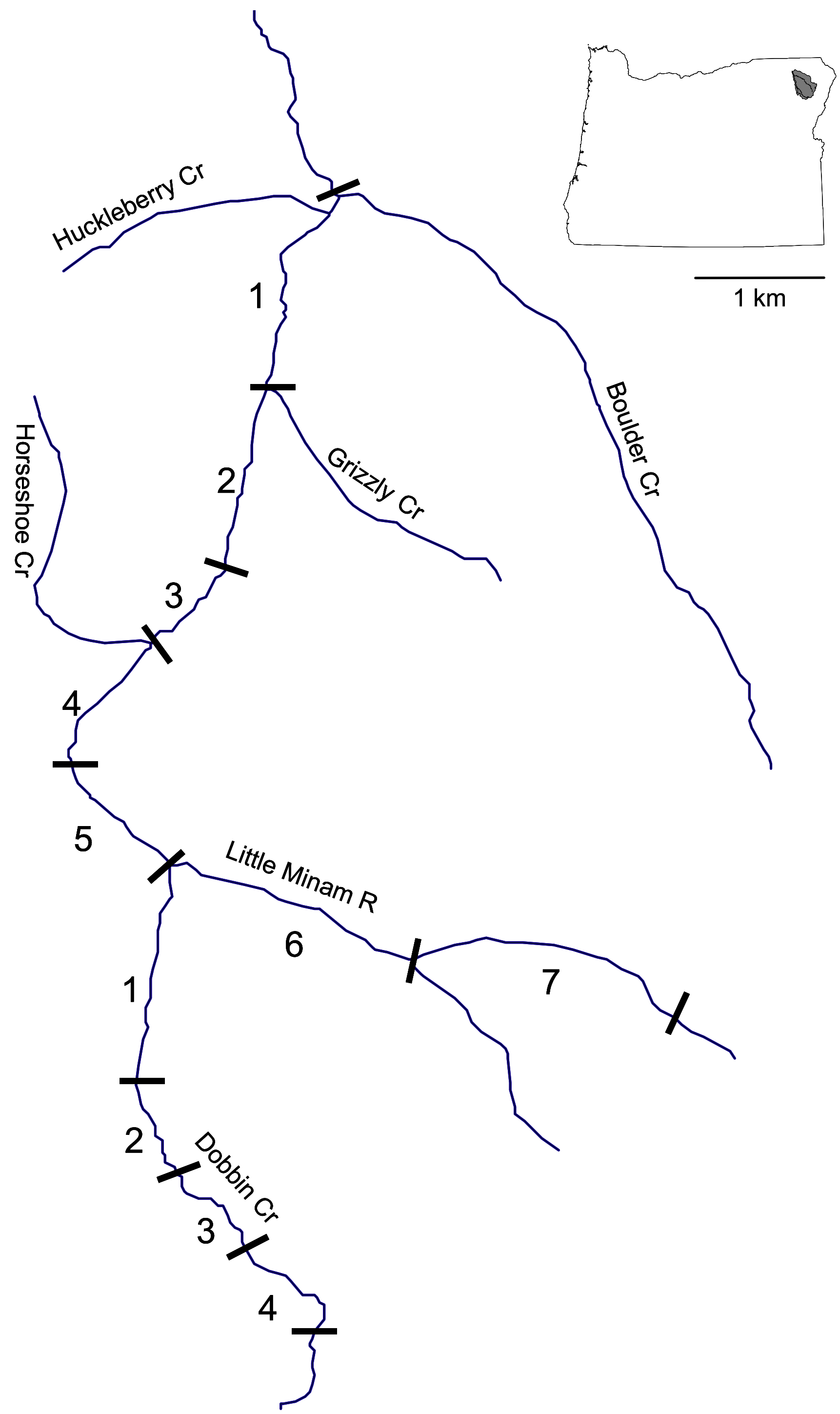


Figure 12. Locations of bull trout spawning survey reaches in Little Minam River and Dobbin Creek.

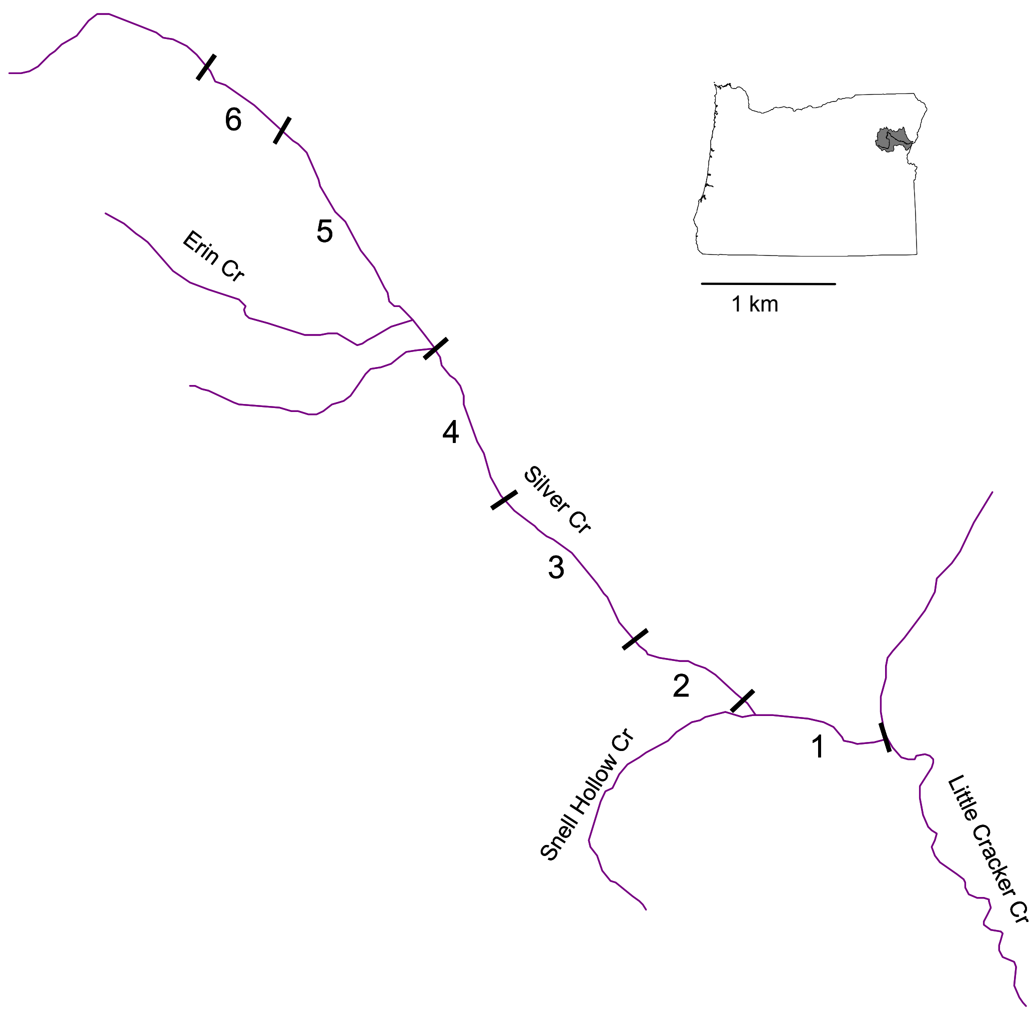


Figure 13. Locations of bull trout spawning survey reaches in Silver Creek

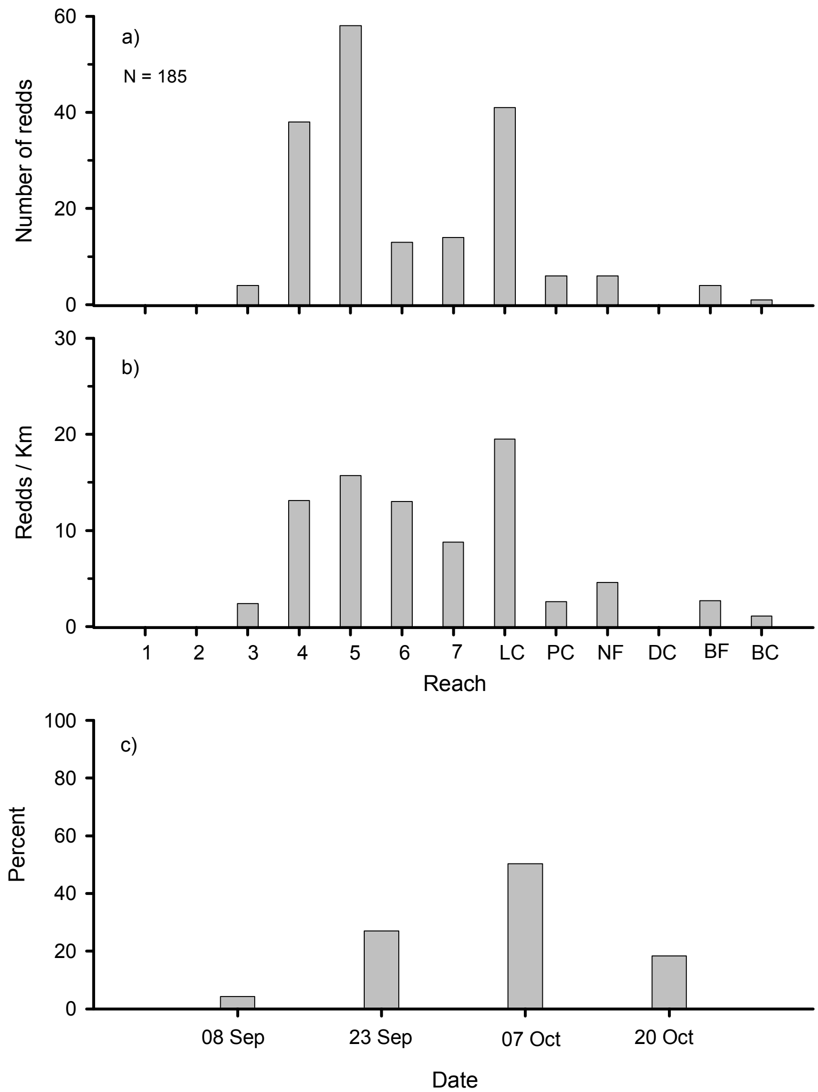


Figure 14. Spawning ground surveys on Mill Creek and tributaries, 1999; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey. LC = Low Creek, PC = Paradise Creek, NF = North Fork Mill Creek, DC = Deadman Creek, BF = Burnt Fork and BC = Bull Creek

We observed 300 bull trout redds in the Little Minam River watershed in 1999, although we did not conduct a fourth survey because of snowfall. Of the redds observed, 268 were in Little Minam River and 32 were in its tributary Dobbin Creek (Fig. 15a). Redds were less heavily concentrated in reaches six and seven and more evenly distributed throughout the survey area than they were in 1996 through 1998. In 1999, densities of redds in Little Minam River exceeded 20 per km in all reaches except five and six (Fig. 15b). Most bull trout in Little Minam River and Dobbin Creek spawned between 15 September and 01 October, when the first and second surveys were completed (Table 15c). Thirty-one percent of the redds observed were counted by 15 September and 74% were counted by 01 October. Bull trout spawning also peaked between middle September and early October in 1996 and 1997 (Bellerud *et al*. 1997; Hemmingsen et al. 2001a). In 1998, however, half of the redds were observed by mid-September (Hemmingsen et al. 2001b).

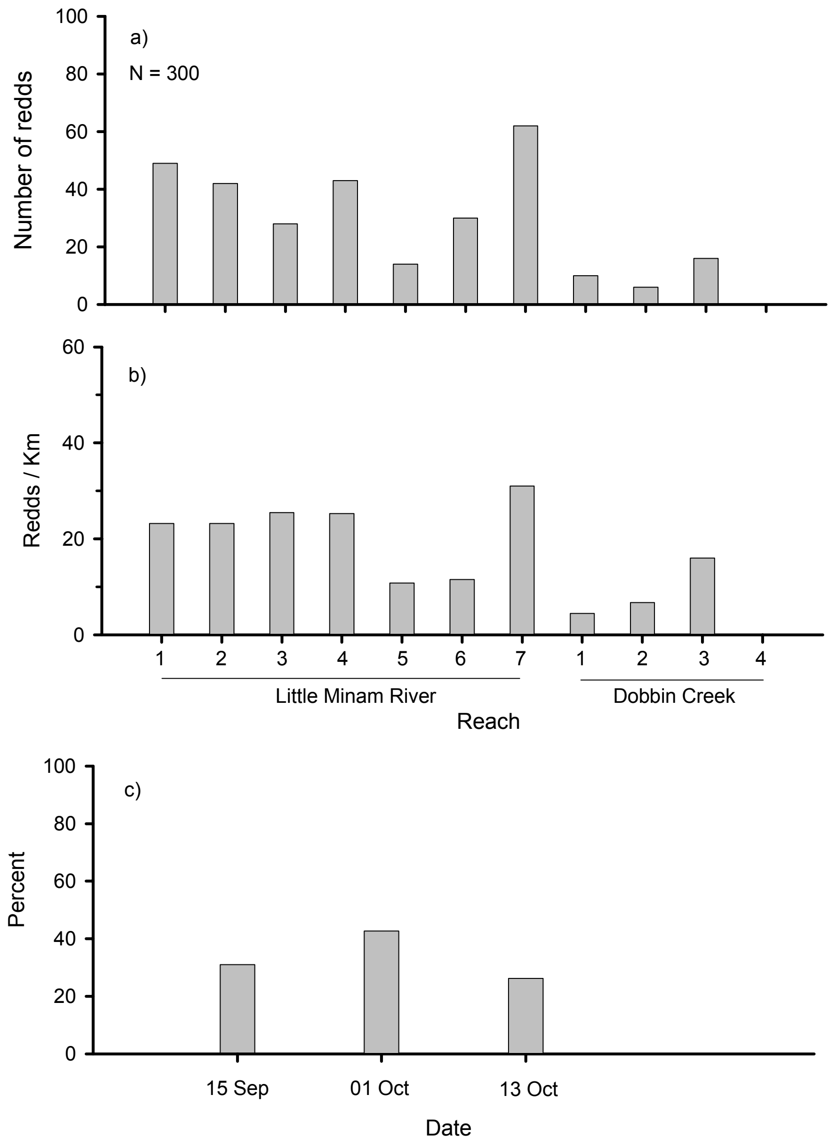


Figure 15. Spawning ground surveys on the Little Minam River and Dobbin Creek, 1999; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey.

To expedite surveys of Silver Creek, reach six (0.8 km) was eliminated in 1999 because few redds had been seen there in previous years (Fig 13). Through the remaining survey reaches of Silver Creek, we observed 21 bull trout redds, all in reaches four and five (Fig. 16a) at densities of 2.0 and 8.2/km, respectively (Fig. 16b). Redds were distributed among more reaches in the three previous years, but reach five contained a vast majority of the redds in 1999, as it did in 1996 (Bellerud *et al*. 1997) and 1998 (Hemmingsen et al. 2001b). Most redds were observed during late September through mid-October, and no new redds were seen on the fourth survey (28 October).

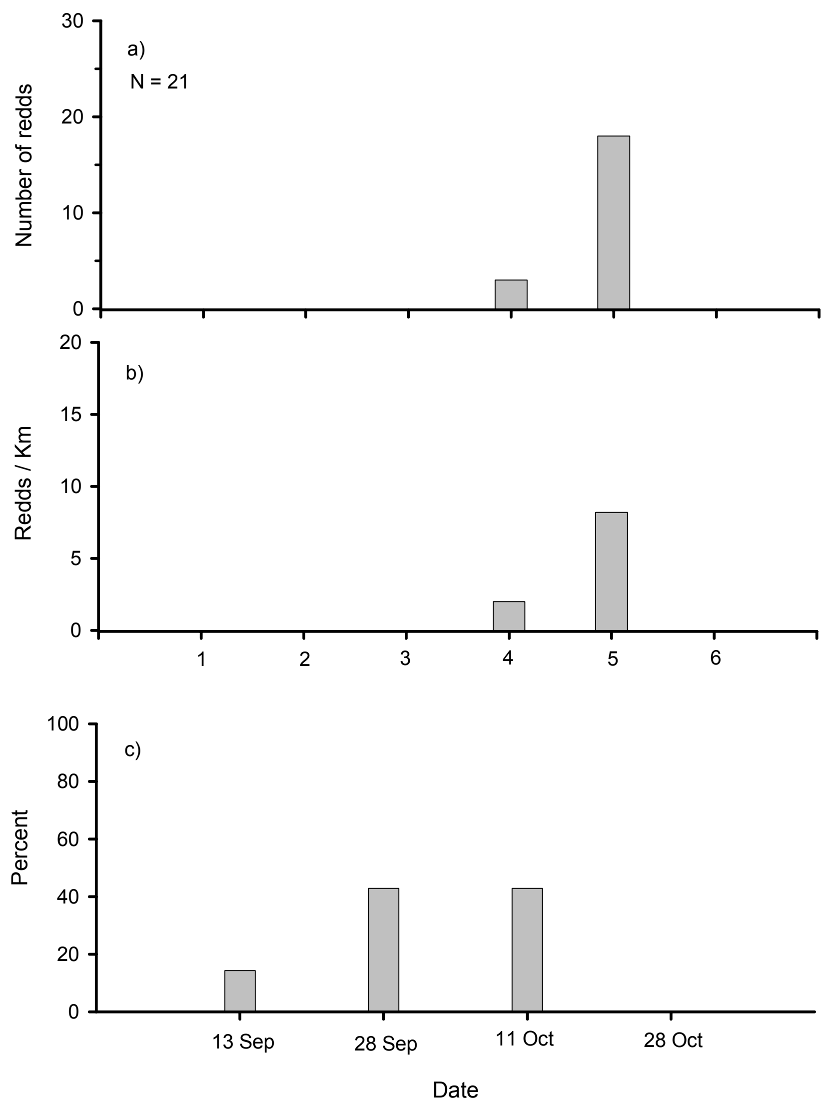


Figure 16. Spawning ground surveys on Silver Creek, 1999;
a) number and b) density of bull trout redds in each reach,
c) proportion of N observed during each survey.

The total number of bull trout redds observed in the Mill Creek watershed in 1999 was the second highest total observed since surveys began in 1994 (Fig. 17). The total in Little Minam River and Dobbin Creek was slightly lower than in 1997 and 1998, but considerably higher than in 1996. Again, a late-October survey was not conducted in the watershed. The low number (54) counted in 1996 may be attributed to the inability of inexperienced surveyors to detect redds made by small resident bull trout (see Hemmingsen et al. 2001b). Any trend in counts of Silver Creek redds is difficult to determine because of similar consequences of inexperienced surveyors in 1996, difficulty of detecting redds in Silver Creek's fine granitic substrate (Hemmingsen et al. 2001a; 2001b), and an increase in the number of surveys from three in 1996 and 1997 to four in 1998 and 1999.

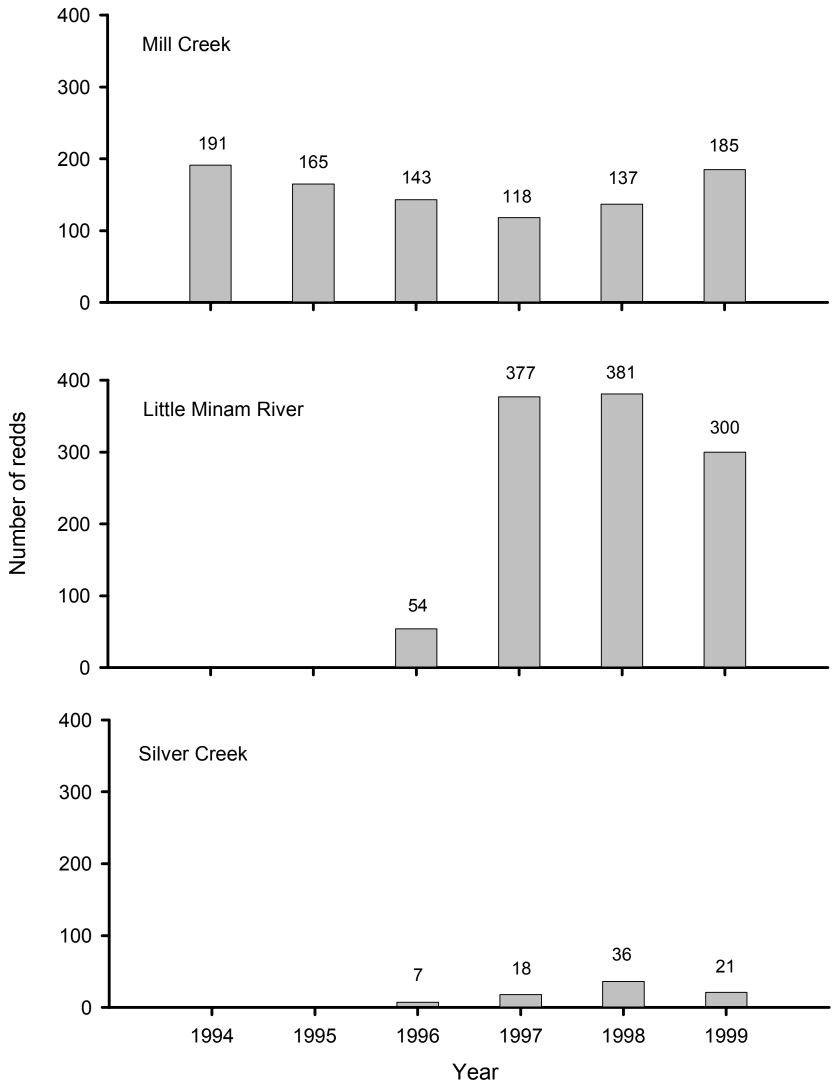


Figure 17. Numbers of bull trout redds observed annually from 1994 -1999. Data from Mill Creek in 1994 and 1995 are courtesy of the USDA Forest Service, Walla Walla, WA. Little Minam River and Silver Creek were not surveyed in 1994 and 1995.

IV. Age and abundance of mature bull trout

Introduction

This section describes results of studies that began in 1999, but are closely related to the spawning surveys described in Section 3. Bull trout redds in Silver Creek are difficult to detect and counts of redds since surveys began in 1996 have been very low (Bellerud *et a*l. 1997; Hemmingsen et al. 2001a; 2001b). If counts of redds in Silver Creek reflect precisely the abundance of spawners, then the bull trout population there is seriously threatened. Therefore, we estimated the abundance of adult bull trout in Silver Creek for comparison with counts of redds. In order to estimate the abundance of adult bull trout, we also estimated of their size at maturity.

Methods

Abundance of bull trout

We calculated the number of bull trout in Silver Creek using a combination of calibrated snorkel counts of fish in pool habitats and expansions of electrofishing removal estimates in shallow, fast water habitats. Pools were snorkeled from the mouth of Silver Creek to the upstream limit of fish distribution. The stream was divided into four reaches and sampled simultaneously by four snorkelers. Bull trout observed in pools were counted and recorded in 50-mm size classes. To increase the precision of estimating lengths, snorkelers had previously trained using underwater artificial silhouettes of bull trout of various sizes.

To estimate sampling efficiencies, each snorkeler made independent counts of bull trout in four groups of 3-4 successive pools randomly distributed throughout the distribution of bull trout in Silver Creek. Nets were installed at the downstream and upstream ends of the groups of pools to block movement of fish. After the groups of pools were snorkeled, bull trout were removed by multiple-pass electrofishing to estimate their abundance following the methods of Armour and Platts (1983). To estimate bull trout abundance in pools, the total number that each snorkeler observed in all of Silver Creek was expanded by his respective mean sampling efficiency in the four sets of pools described above.

In areas not snorkeled, bull trout were removed and enumerated from six 30- to 50-m riffles randomly selected throughout the distribution of bull trout in Silver Creek by multiple-pass electrofishing. Surface areas of these riffles were measured and mean densities (fish/m^2) of bull trout were calculated. To estimate bull trout abundance in all unsnorkeled areas, these densities were applied to total riffle area within the bull trout distribution in Silver Creek determined from previous surveys.

Size and age at maturity

We collected 47 bull trout at least 100 mm fork length from four reaches in August. Fish were anesthetized and scales were collected for aging. Sex of each fish and the development of gonads were examined internally with an optical endoscope and fiber-optic light source. A small (3-4 mm) lateral incision was made slightly anterior and dorsal to the insertion of the pelvic fin to access the abdominal cavity. After examination, this incision was closed with one or two sutures and veterinary surgical glue. The fish were allowed to recover, then returned to the stream. Errors in classification of sex and maturity were estimated using a sample of 10 brook trout. These brook trout were similarly examined, then dissected for verification.

Results and Discussion

Size and age at maturity

Verification by dissection indicated no errors in determination of the sex and maturity of brook trout when they were examined with an endoscope. Although only 10 brook trout were sampled, endoscopic examination may accurately determine the sex and maturity of bull trout.

Bull trout examined ranged in length from 100 to 214 mm fork length. Of these, all bull trout 150 mm or larger and 30% of those less than 150 mm were mature (Table 12). The smallest mature males were 132 or 135 mm while the smallest mature females were 142 or 143 mm, respectively. Two females in the 140-149 mm size class contained a few small, early developing ova. These fish likely would not spawn in 1999 since they were examined about a month prior to the start of spawning.

Table 12. Length and associated numbers of mature and immature bull trout sampled from Silver Creek in 1999.

Length (mm)	Immature	Mature	
		Males	Females
100-109	5		
110-119	2		
120-129	1		
130-139	1	2	
140-149	5	2	2
150-159		5	1
160-169		3	3
170-179		1	3
180-189		2	2
190-199		3	1
200-209		1	
210-219		2	

Analysis of scales from sampled fish indicates that bull trout in Silver Creek mature first at age three (Table 13). All bull trout aged four and older were mature. The largest bull trout examined (204-214 mm) were also the oldest at age six or seven (Figure 18). All Silver Creek bull trout observed during snorkel and redd surveys during this study were estimated to be less than 300 mm fork length, and all measured from electrofishing for population estimation were less than 250 mm.

Table 13. Age and associated numbers of mature and immature bull trout sampled from Silver Creek in 1999.

	Age					
	2	3	4	5	6	7
Immature	7	7				
Mature:						
Male		7	5	3	1	3
Female		5	3	1	3	

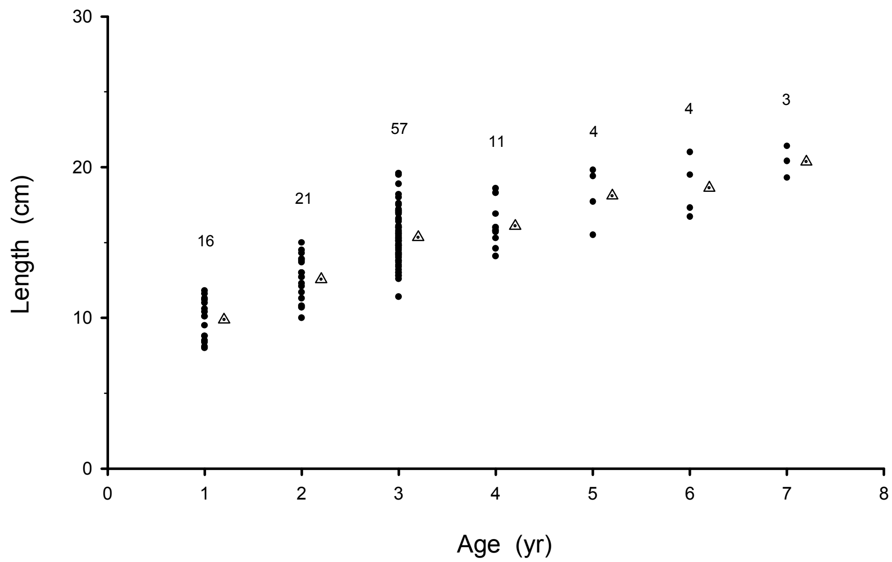


Figure 18. Fork length at age of Silver Creek bull trout estimated by analysis of scales from fish captured for studies in 1999 and for genetic analysis in 1995. Mean lengths at age (triangles) and numbers of bull trout analyzed are shown.

<u>Abundance of bull trout</u>

We estimated the potential bull trout spawning population in Silver Creek to be 885 fish (150 mm or larger). This may be a conservative estimate since the data indicate that about one-third of the bull trout included in the 100-149 mm size class from snorkel surveys could be mature; most of these would be males. Comparison of this estimate to the numbers of redds counted in 1999 (21) strongly suggests that counts of redds in Silver Creek are a poor indicator of the abundance of spawners. This is likely due to the small size of mature bull trout and redds in Silver Creek in combination with substrate that reduces the detection of redds (Bellerud *et al*. 1997; Hemmingsen et al. 2001a; 2001b). There is much less disparity between counts of redds in the Mill Creek watershed and numbers of adult bull trout (300 mm or larger) that moved upstream of the diversion dam prior to spawning, even though these numbers did not include bull trout 300mm or larger that stayed above the diversion dam or possible resident adults less than 300 mm. However, 80% of the fish observed spawning or adjacent to redds in Mill Creek were greater than 300 mm (Bellerud *et al*. 1997). Redds in Mill Creek are larger, composed of larger substrate, and more visible than redds in Silver Creek; consequently, they are more likely to be observed (Hemmingsen et al. 2001a; 2001b).

IV. Acknowledgments

This project is grateful to L. Boe, D. Gaudette, J. Shappart, L. Gaudette (formerly L. Sommerfeld), and S. Starcevich, for their dedication in the field. We appreciate the assistance with spawning surveys in the Grande Ronde basin provided by J. Zakel and T. Walters, and the assistance with Mill Creek studies provided by M. Northrup. We thank the Oregon State Police for successful telemetry flights. Also, thanks to C. Abbes, B. Bellerud, K. Chamberlain, S. Chamberlain, J. Dambacher, R. French, J. Jebousek, C. Steigerwald and A. Talabere, for help with field work related to diet studies, and to B. Gerth for assistance with insect identification. Thanks to P. Sankovich for help with data summarization.

V. References Cited

Armour, C.L. and W.S. Platts. 1983. Field methods and statistical analyses for monitoring small salmonid streams. Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, USDI, Washington, D.C.

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.

Boag, T. D. 1987. Food habits of bull char, *Salvelinus confluentus*, and rainbow trout, *Salmo gairdneri*, coexisting in a foothills stream in Northern Alberta. Canadian Field Naturalist 101: 56-62.

Borror, D. J., C. A. Triplehorn, and N. F. Johnson. An introduction to the study of insects. 1989. San Francisco, Saunders College Publication.

Bozek, M. A., L. D. DeBrey, and J. A. Lockwood. 1994. Diet overlap among size classes of Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in a high-elevation mountain stream. Hydrobiologia 273: 9-17.

Caton, L. W. 1991. Improved subsampling methods of the EPA "rapid bioassessment" benthic protocols. North American Benthological Society Bulletin 8: 317-319.

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.

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

Fausch, K. 1998. Interspecific competition and juvenile Atlantic salmon (*Salmo salar*): on testing effects and evaluating the evidence across scales. Canadian Journal of Fisheries and Aquatic Sciences 55 (Suppl. 1): 218-231.

Fausch, K. 1988. Tests of competition between native and introduced Salmonids in streams: what have we learned? Canadian Journal of Fisheries and Aquatic Sciences 45: 2238-2246.

Gunckel, S.L. 2001. Feeding behavior and diet of native bull trout *Salvelinus confluentus* and introduced brook trout *S. fontinalis* in two eastern Oregon streams. Masters of Science Thesis. Oregon State University, Corvallis, Oregon.

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. Project Number 199405400, Bonneville Power Administration, Portland, Oregon.

Hemmingsen, A. R., B. L. Bellerud, S. L. Gunckel, and P. J. Howell. 2001. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1998 Annual Report. Project Number 199405400, Bonneville Power Administration, Portland, Oregon.

Howell, P. J. and D. V. Buchanan. 1992. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Hubert, W. A. and H. A. Rhodes. 1992. Sizes of prey consumed by age-0 brown trout in Douglas Creek, Wyoming. Journal of Freshwater Ecology 7: 277-282.

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.

Meehan, W. and R. Miller. 1978. Stomach flushing: effectiveness and influence on survival and condition of juvenile salmonids. Journal of the Fisheries Research Board of Canada 35: 1359-1363.

Merritt, R. W. and Cummins, K. W. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company. Dubuque, Iowa.

Moore, K. M. and S. V. Gregory. 1988. Response of young-of-year cutthroat trout to manipulation of habitat structure in a small stream. Transactions of the American Fisheries Society 117: 162-170.

Mundie, J. H. 1969. Ecological Implications of the Diet of Juvenile Coho in Streams. Pages 135-152 *in* T. G. Northcote, editor. Symposium on Salmon and Trout in Streams. Institute of Fisheries, The University of British Columbia, Vancouver.

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.

Rieman, B. E. and J. McIntyre. 1993.U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-302, Ogden, UT.

Schoener, T. 1968. The *Anolis* lizards of Bimini: resource partitioning in a complex fauna. Ecology 49: 704-726.

Sokal, R. R. and Rohlf, F. J. 1981. Biometry, second ed. W.H. Freeman and Company. New York.

Stewart, K. W. and Stark, B. P. 1993. Nymphs of North American Stonefly Genera (Plecoptera). University of North Texas Press. Denton, Texas.

Thorp, J. H. and Covich, A. P. 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press. San Diego, CA.

Townsend, C. and A. Hildrew. 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. Journal of Animal Ecology 45: 759-772.

Wallace, R. K. 1981. An assessment of diet-overlap indexes. Transactions of the American Fisheries Society 110: 72-76.

Wallis, O. L. 1948. Trout studies and a stream survey of Crater Lake National Park, Oregon. Masters of Science Thesis. Oregon State College, Corvallis, Oregon.

Wiggins, G. B. 1995. Larvae of the North American caddisfly genera (Trichoptera), 2nd edition ed. University of Toronto Press. Toronto.

Wilhelm, F. M., B. R. Parker, and D. W. Schindler. 1999. Seasonal food habits of bull trout from a small alpine lake in the Canadian Rocky Mountains. Transactions of the American Fisheries Society 128: 1176-1192.