November 2001

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

Annual Report 2000

DOE/BP-34342-4

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, Paul M. Sankovich - Oregon Department of Fish and Wildlife, Philip J. Howell - USDA Forest Service, Pacific Northwest Research Station, 2001, Bull Trout Life History, Genetics, Habitat Needs, And Limiting Factors In Central And Northeast Oregon 2000 Annual Report, Report to Bonneville Power Administration, Contract No. 1994BI34342, Project No. 199505400, 34 electronic pages (BPA Report DOE/BP-34342-4)

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

2000 ANNUAL REPORT

Prepared by:

Alan R. Hemmingsen
Stephanie L. Gunckel
Paul M. Sankovich

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 94B134342

November 2001

Table of Contents

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

Introduction

This section describes work accomplished in 2000 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 continued to monitor the movements of bull trout with radio transmitters applied in 1998 (Hemmingsen, Bellerud, Gunckel and Howell 2001) and 1999 (Hemmingsen, Gunckel and Howell 2001). No new radio transmitters were applied to bull trout of the upper John Day River subbasin, Mill Creek (Walla Walla Basin), or the Grande Ronde Basin in 2000. We did implant radio transmitters in two bull trout incidentally captured in the John Day River near the confluence of the North Fork John Day River.

In Mill Creek, we used traps to capture migrant bull trout to obtain data for the third successive year in this stream. With these traps, we intended to determine the timing of bull trout movements both upstream and downstream, and to determine the relative abundance, size and age of migrant fish. Because we captured migrant bull trout with traps for three years in the upper John Day River and its tributaries (Hemmingsen, Bellerud, Buchanan, Gunckel, Shappart and Howell 2001; Hemmingsen, Bellerud, Gunckel and Howell 2001; Hemmingsen, Gunckel and Howell 2001) and traps were no longer needed to capture bull trout for radio-tagging, no traps were operated in the John Day Basin in 2000.

Methods

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. 7, page 23), as described in Hemmingsen, Bellerud, Gunckel and Howell (2001). Downstream migrant bull trout were captured using a 1.5-meter diameter rotary screw trap, constructed by E.G. Solutions, Inc, located upstream of the dam at the same site (Rkm 41.5) used in 1998 and 1999.

We sampled both traps daily during their operation from late March through 20 October. Fish of most species captured were anesthetized and measured to fork length; all bull trout were weighed, and scales were collected from a sub-sample of individuals. Bull trout that were 150 mm fork length or longer were checked for the presence of 14-mm, 125 KHz, Avid PIT (passive integrated transponder) tags applied during angling in 1997, and during angling and trapping in 1998 or 1999. Many of the bull trout that had not previously received PIT tags were subsequently implanted with them. 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 112 m upstream of the screw trap. 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.

In the John Day River system, two bull trout were implanted with radio transmitters manufactured by Advanced Telemetry Systems, Inc. As in previous years, 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, Bellerud, Buchanan, Gunckel, Shappart and Howell (2001). These bull trout also received PIT tags implanted in the dorsal sinus. We tracked radio transmitter signals of tagged bull trout from both the ground and air. In addition to signals new in 2000, we tracked signals from some transmitters implanted in 1998 and 1999; all transmitters implanted in 1997 had expired prior to 2000. Aerial tracking was conducted from a plane operated by either the Oregon State Police or by personnel from Baker Aircraft, Inc, Baker City, OR.

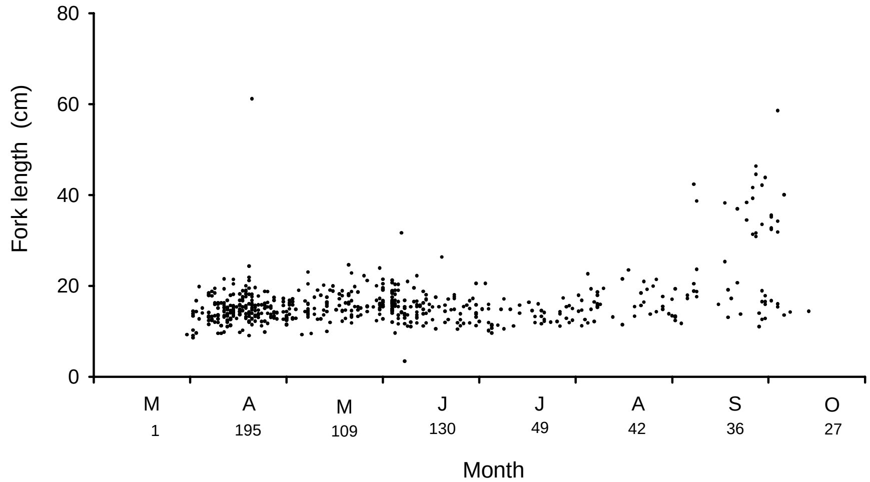
Results and discussion

Mill Creek

Bull trout captured by traps can be divided into two groups, those captured for the first time in each trap, or those recaptured one or more times in either trap. Recaptured individuals were identified by a fin mark or tag. Figures presented here describe individuals captured for the first time in 2000 in either trap. Recaptured bull trout are discussed in the text or identified in tables.

Both traps were set in Mill Creek on 24 March 2000, although the cone of the screw trap was not lowered until 30 March, when it captured one bull trout. Both traps operated continuously until 20 October. The screw trap captured 589 bull trout during its operation. This number is similar to the 615 bull trout captured at this site in 1999 (Hemmingsen, Gunckel and Howell 2001). Seventy-four percent of the total captured in 2000 appeared during April, May and June; all but two of these were less than 250 mm. Of the 63 bull trout captured during September and October, 40% were larger than 250 mm. Fork lengths of all bull trout captured by screw trap ranged from 34 to 611 mm. The overall mean fork length was 162 mm; the median fork length was 151 mm, and 95% of all bull trout captured were less than 250 mm (Fig. 1).

The efficiency at which the Mill Creek screw trap captured bull trout averaged 38% (Table 1). This average is less than estimated average in 1998 (43%) or 1999 (48%); however, the monthly variation in efficiency tended to be less in 2000 than in either year previous (Hemmingsen, Bellerud, Gunckel and Howell 2001; Hemmingsen, Gunckel and Howell 2001). 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 1,580 and 2,280 (1,930 $\pm$ 350). 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. Calculation of the estimated number also assumes that all marked bull trout placed upstream move back downstream past the trap. Marked bull trout that do not move back downstream cause under-estimation of the total number.



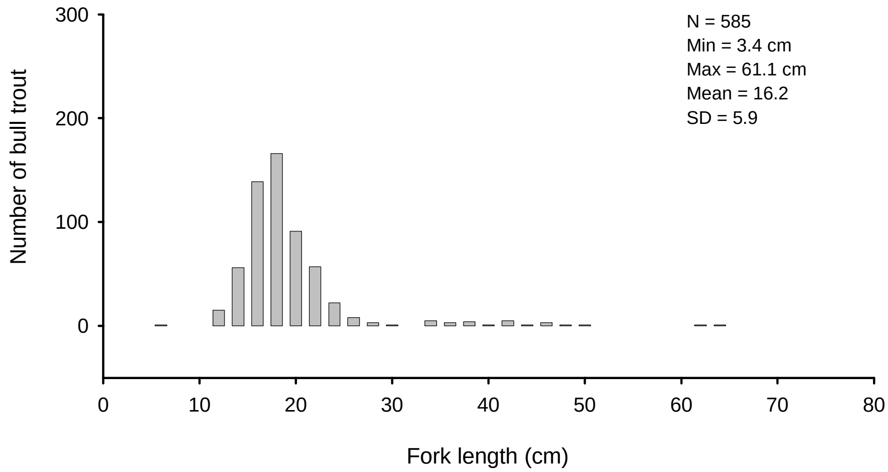


Figure 1. Numbers and lengths of bull trout in Mill Creek captured in the screw trap in 2000. Monthly totals are shown under corresponding months.

Table 1. 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]	48	47	34	37	38	19
Estimated number of bull trout	664	237	382	138	118	391
95% confidence interval	167	61	111	67	57	270

[a] Proportion of fin-marked fish released upstream of the trap and recaptured.

The upstream migrant trap captured 210 bull trout, seven more than were captured in 1999; none was captured prior to June. Sixty-seven percent of the captured upstream migrant bull trout appeared during July and August while only three appeared during October. For 204 of the bull trout captured in this trap, fork lengths ranged from 210 to 700 mm with a mean of 415 mm (Fig. 2).

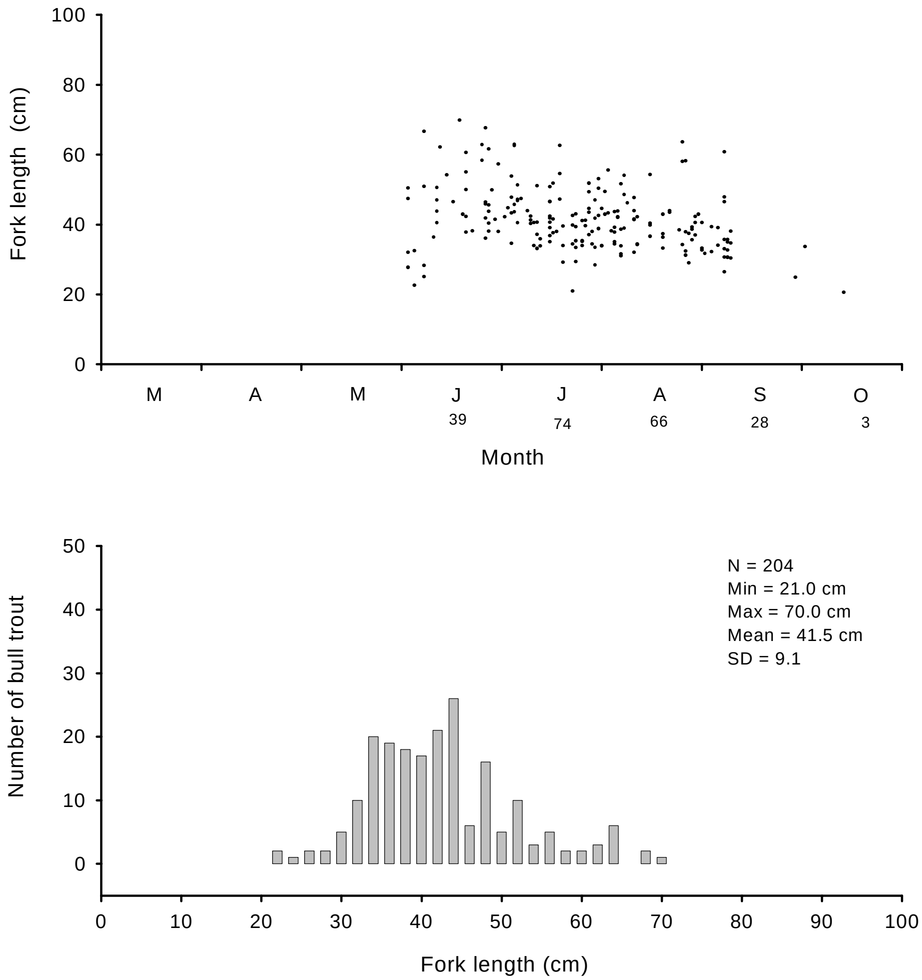


Figure 2. Numbers and lengths of bull trout in Mill Creek captured in the upstream migrant trap in 2000. Monthly totals are shown under corresponding months.

We compared the average fork lengths of bull trout captured monthly in the Mill Creek screw trap (downstream migrants) and found relatively little variation from March through August each year (Fig. 3). Both the average size and the variation in size increased during September and October each year. This was caused by the presence of more large bull trout that likely were moving downstream after spawning. Few bull trout were captured in the ladder trap (upstream migrants) prior to June each year, and these were relatively small. Some bull trout of similar small size were again present during October in two of three years. Although the largest upstream migrant bull trout (830 mm) appeared during July 1998, the average size of upstream migrant bull trout tended to decrease monthly from June through October each year.

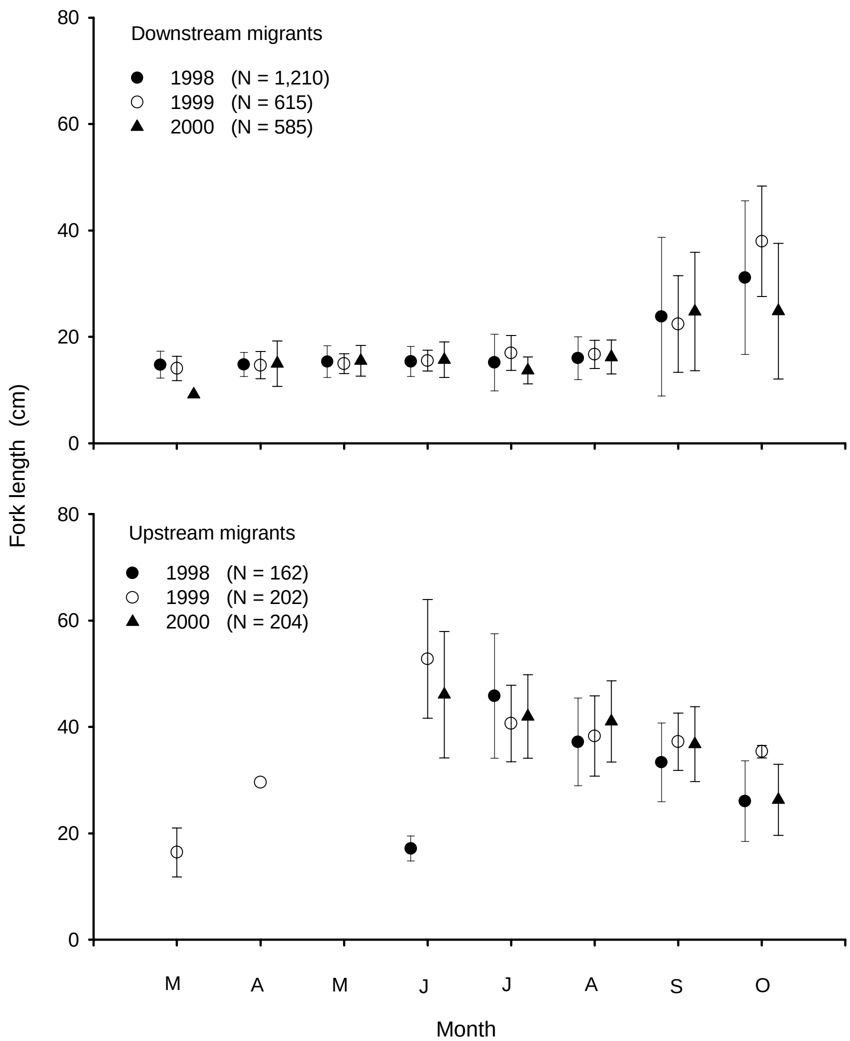


Figure 3. Monthly mean fork lengths (± SD) of Mill Creek bull trout captured in traps during three years.

We conducted 66 telemetry surveys in Mill Creek during 2000, of which 63 were by foot and three were by truck. These surveys occurred during January (3), February (5), March (4), April (4), May (6), June (9), July (9), August (7), September (4), October (7), November (4), and December (4). We continued to track 11 of 32 bull trout that received radio transmitters in 1998, and 11 of 16 bull trout that received radio transmitters in 1999 (Table 2). Of the 22 transmitters active at the beginning of 2000, 12 were located throughout the year. Seven of these 12 transmitters were in bull trout, shown with bold-faced in Table 2, which moved at least 1 km. These seven bull trout ranged between Rkm 20.0 and 51.0 in Mill Creek, and all reached their highest locations in the watershed in September or early October.

Table 2. Radio-tagged bull trout of Mill Creek that were tracked in 2000. Bolded records indicate bull trout which moved at least 1 km.

L (mm) [a]	MHz	LU	TU	LD	TD
Tagged in 1998:					
605	150.073	37.7	04 Jan	37.7	26 Dec [b]
535	**150.105**	**48.5**	**04 Oct**	**29.8**	**27 Oct**
520	150.123	25.0	04 Jan	25.0	26 Dec [b]
485	150.124	35.1	18 Jan	34.3	01 Jul [c]
545	**150.134**	**50.1**	**23 Sep**	**20.3**	**11 Apr**
470	150.146	21.1	08 Apr [c]	20.8	04 Jan
630	**150.192**	**48.3**	**13 Sep**	**30.9**	**04 Jan**
510	150.343	37.2	05 Sep	37.2	27 Oct [d]
555	**150.713**	**48.5**	**13 Sep**	**20.0**	**04 Jan**
580	150.993	32.5	14 Mar [e]	32.5	04 Jan
300	151.811	35.4 [f]	04 Jan	34.9	08 Apr
Tagged in 1999:					
282	**151.052**	**47.0**	**23 Sep**	**40.9**	**04 Jan**
330	**151.151**	**46.7**	**05 Sep**	**40.9**	**04 Jan**
378	151.192	34.1	11 Jan [e]	34.1	04 Jan
365	151.222	38.5 [g]	28 Apr	37.8	04 Jan
329	151.241	38.2	26 Jul [e]	38.2	11 Jan
360	151.273	39.1	04 Jan	39.1	26 Dec [b]
315	151.312	40.9	04 Jan	40.9	26 Dec [b]
358	151.343	37.2 [h]	02 Feb	36.9	04 Jan
290	151.561	41.2	28 Mar [e]	41.2	04 Jan
395	**151.681**	**48.6**	**04 Oct**	**28.3**	**15 Feb**
338	151.702	31.9	04 Jan	31.4 [i]	07 Mar

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 2000.
TD = earliest date of maximum downstream location.
[a] Length when implanted with radio transmitters.
[b] Located here all year.
[c] Signal lost after this date.
[d] Signal detected only during September and October.
[e] Stationary signal lost after this date.
[f] Signal lost near this location on 27 June.
[g] Signal lost at this location on 04 July.
[h] Signal stayed at this location through 26 December.
[i] Signal lost at this location on 02 September.

Of the five transmitters that were active all year but moved <1 km, four stayed at the same locations (Table 2) while one (frequency 151.343) moved 0.3 km. Ten transmitters expired or were otherwise lost during 2000. Four of these were located last between Rkm 32.5 and 41.2 at positions they had maintained since the beginning of the year, and one was only detected at Rkm 37.2 in September and October. Bull trout with the remaining five transmitters with signals that ended during 2000 had individual movements of 0.3 – 0.8 km between Rkm 20.8 and 38.5.

The downstream range limit for any Mill Creek bull trout tracked in 2000 (Rkm 20.0) was less than that shown by bull trout with transmitters in 1998 (Rkm 19.3) or 1999 (Rkm 19.5). The upstream range limit (Rkm 51.0) was the same as in 1999 (Hemmingsen, Gunckel and Howell 2001) but less than the location (Rkm 52.8) observed in 1998 (Hemmingsen, Bellerud, Gunckel and Howell 2001). 2000 was the fourth consecutive year that no radio-tagged bull trout was detected downstream of Walla Walla, WA.

John Day River Basin

In spring of 2000, personnel of the Chinook Life History Project (Oregon Department of Fish and Wildlife) captured several bull trout while seining for juvenile chinook salmon (*Oncorhynchus tshawytscha*) in the John Day River. Since we had two radio transmitters unused from 1999, we implanted them in two of these bull trout, which were captured at Rkm 273 near Spray, OR, downstream of the confluence with the North Fork John Day River at Rkm 295 (Table 3). One of these bull trout, 248 mm on 19 April, was tracked to Rkm 107 of the North Fork John Day River by 05 July. During this time of 77 days, it had traveled about 181 km upstream from its capture location in the mainstem John Day River. The transmitter was eventually found near a tree with an inhabited osprey nest. The second bull trout, 234 mm on 24 April, was tracked to Rkm 6.1 of Granite Creek, tributary to the North Fork John Day River at Rkm 140, on 26 July. During this time of 93 days, it had traveled about 220 km upstream from its capture location in the mainstem John Day River. The transmitter was never located again after 26 July.

Table 3. Bull trout of the John Day River implanted with radio transmitters in 2000.

Capture location, date tagged	L (mm)	MHz	Signal life (mo)	LU	TU	LD	TD
John Day R (km 273)**:**							
19 Apr	248	150.015	9	107.0 [a]	05 Jul	--	--
24 Apr	234	150.042	9	6.1 [b]	26 Jul	--	--

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum known downstream location (Rkm) in 2000. Dashes = capture location.
TD = earliest date of maximum downstream location. Dashes = date tagged.
[a] Location is in N.F. John Day River.
[b] Location is in Granite Creek, tributary to the N.F. John Day River.

We conducted 27 telemetry surveys in the upper John Day River watershed during 2000, of which 26 were by truck and one was by plane. These surveys occurred during January (2), February (3) March (3), April (2), May (3), June (2), July (2), August (4), September (1), October (3), November (1), and December (1). We continued to track 13 of 37 bull trout that received radio transmitters in 1998 and all 11 bull trout that received radio transmitters in 1999. These 24 bull trout were first located on 13 January, and 11 of them continued to be located throughout 2000 (Table 4). Nine of these 11 bull trout moved a maximum of 3.4 km. The remaining two fish (frequencies 151.343 and 151.301) ranged 6.1 and 4.3 km, respectively. Ten of these 11 bull trout remained in the John Day River. One bull trout (frequency 150.604), first located in the John Day River at Rkm 439.0, moved downstream to the confluence of Deardorff Creek (438.1) then up it 1.5 km by 20 April. The transmitter stayed at this location and was eventually located in the brush near the creek.

Table 4. Radio-tagged bull trout of the upper John Day River watershed that were tracked throughout 2000. All locations are in the John Day River unless otherwise noted.

Capture location	L (mm) [a]	MHz	1st location [b]	LU	TU	LD	TD
Tagged in 1998:							
Call Cr. (km 0.7):	465	150.472	431.6	433.0	03 Feb	429.6 [c]	20 Apr
	530	150.493	445.7	--	--	444.3 [c]	08 Mar
	520	150.554	424.4	426.7	03 Feb	--	--
Deardorff Cr. (km 5.3):	502	150.604	439.0	1.5 [d]	20 Apr	--	--
Roberts Cr. (km 1.3):	560	150.623	400.1 [e]	NA	NA	NA	NA
John Day R. (km 449.2)	501	150.354	433.0	--	--	429.6	16 May
John Day R. (km 436.8):	482	150.453	436.8	--	--	435.3	08 Mar
Tagged in 1999:							
Call Cr. (km 0.7)	285	151.302	448.3	--	--	447.8	03 Mar
Roberts Cr. (km 1.3)	362	151.343	434.2	--	--	428.1	31 May
John Day R. (km 450.1):	495	151.582B	450.1	452.6	18 Aug	449.6	14 Mar
	360	151.301	450.1	453.9	05 Oct	449.6	03 Aug

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 2000.
TD = earliest date of maximum downstream location.
[a] Length when implanted with radio transmitters.
[b] Located on 13 January. Dashes = first location.
[c] Signal stayed at this location through December.
[d] Located in Deardorff Creek.
[e] Stationary at this location all year.

Signals from the remaining 13 transmitters were located for part of 2000. All of these signals were lost by late August, and all were located only in the John Day River. Two of these 13 transmitters (frequencies 150.982 and 150.534) were located only once during January (Table 5). Another two of these transmitters (frequencies 150.952 and 151.313) were not located until March, but we continued to locate them through early July; the transmitter with signal 151.313 remained at the same location. The transmitter with signal 151.601B remained at its initial location through early July; it was found 0.4 km downstream, outside its host fish, on 22 August. The transmitter with signal 151.222 remained at its initial location through May. Eight of the 13 bull trout in Table 5 were apparently alive while their signals were tracked. Of these eight fish, four moved downstream 0.3 to 21.5 km from their initial locations. Two of the eight bull trout moved upstream 2.6 or 3.3 km from their initial locations. Of the remaining two bull trout, one (frequency 151.582A) moved downstream 1.9 km, then moved upstream 4.0 km; the other (frequency 151.562) moved downstream 0.9 km, then moved upstream 3.4 km.

Table 5. Radio-tagged bull trout of the upper John Day River watershed that were tracked through part of 2000. All locations are in the John Day River unless otherwise noted.

Capture location	L (mm) [a]	MHz	1st location [b]	LU	TU	LD	TD
Tagged in 1998:							
Call Cr. (km 0.7):	510	150.433	417.2	--	--	416.6 [c]	04 May
	465	150.982	421.1 [d]	NA	NA	NA	NA
Deardorff Cr. (km 5.3):	459	150.534	422.2 [d]	NA	NA	NA	NA
Roberts Cr. (km 1.3):	240	150.932	443.2	--	--	421.7 [e]	17 Mar
	420	150.992	446.1	--	--	445.1 [f]	07 Mar
John Day R. (km 436.8):	320	150.952	421.7 [g]	425.0	06 July [h]	--	--
Tagged in 1999:							
Roberts Cr. (km 1.3)	360	151.582A	434.2	436.3	18 May [h]	432.3	17 Mar
John Day R. (km 434.2)	247	151.703	434.2	436.8	25 Aug [h]	--	--
	319	151.313	432.4 [g i]	NA	NA	NA	NA
	285	151.601B	434.2	--	--	433.8 [j]	22 Aug
	305	151.222	435.8 [k]	NA	NA	NA	NA
	400	150.541	442.3	--	--	442.0 [l]	21 Jan
John Day R. (km 449.2)	318	151.562	449.2	451.7	20 Jul [h]	448.3	03 Feb

[a] Length when implanted with radio transmitters.
[b] Located on 13 January. Dashes = first location.
[c] Last located here 20 July.
[d] Signal located only once.
[e] Last located here on 12 April.
[f] Last located here on 18 August.
[g] First located in March.
[h] Signal lost after this date.
[i] Remained at this location.
[j] Transmitter found alone.
[k] Remained at this location through 30 May.
[l] Last located here on 22 February.

Grande Ronde Basin

We conducted 24 telemetry surveys, of which 21 were by plane and three were by truck. These surveys occurred during January (1), March (3), April (2), May (3), June (4), July (2), August (3), September (1), October (3) and November (2). On these surveys, we tracked 19 of 25 bull trout that received radio transmitters in 1998, and all 13 bull trout that received radio transmitters in 1999. During 2000, these 32 bull trout were located through 35 km of the Snake River, 131 km of the Grande Ronde River, 12 km of Lookingglass Creek, much of the Wenaha River including the North Fork, South Fork, and three tributaries (Fig. 4).

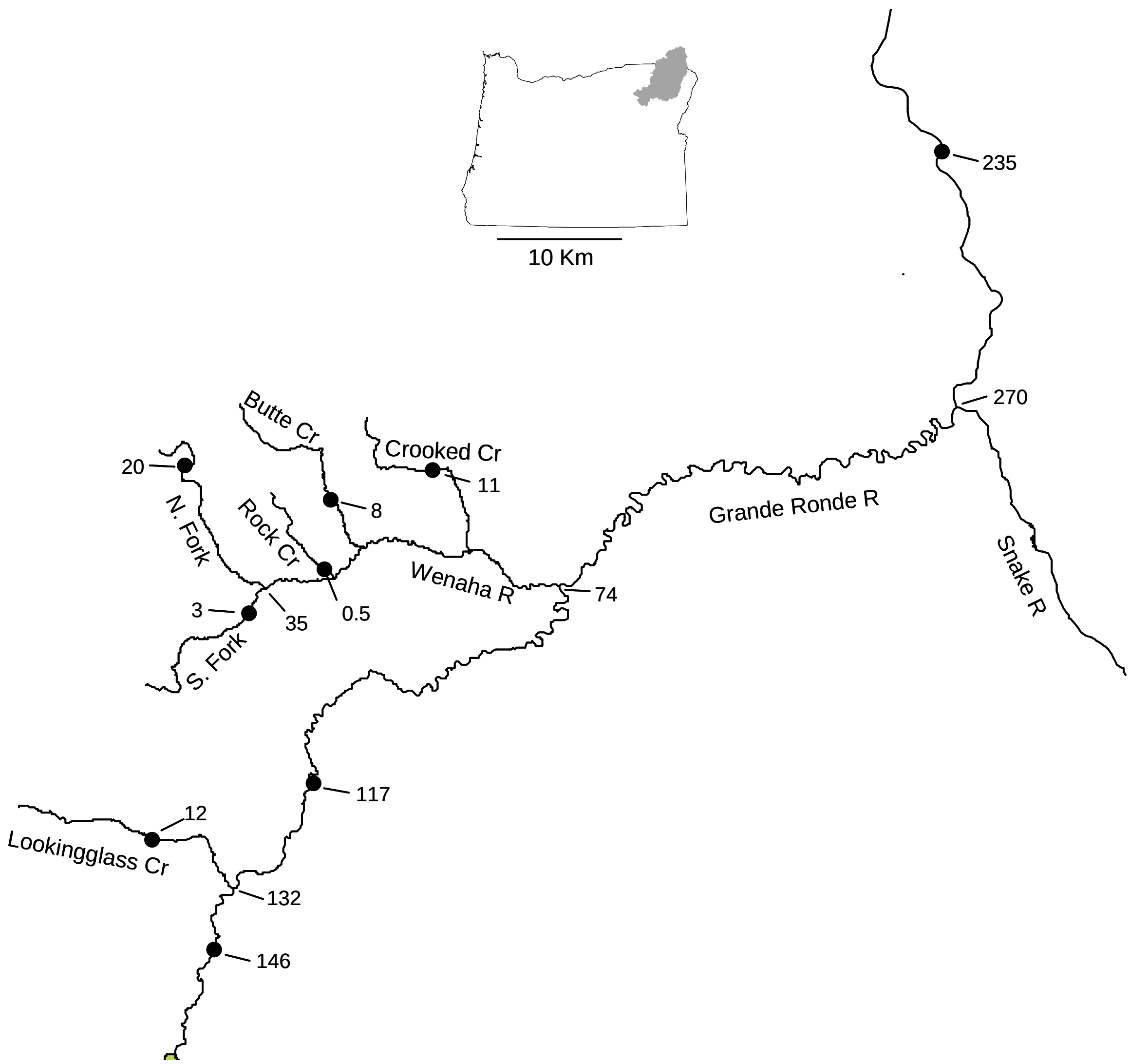


Figure 4. Maximum bounds (circles) of ranges (Rkm) of radio-tagged bull trout in the lower Grande Ronde Basin and the Snake River observed in 2000. No bull trout was tracked in the Snake River upstream of the Grande Ronde River confluence. Locations without circles indicate Rkms at confluences of major streams. Note that the Grande Ronde River continues upstream from the bottom of this figure.

These 32 bull trout of the Grande Ronde Basin with radio transmitters were originally captured from either Lookingglass Creek or the Wenaha River. To summarize their movements during this report period, they are grouped first by stream where they were captured and tagged, then by their locations when first detected in 2000.

Three of these 32 bull trout were captured from Lookingglass Creek in 1998. Two of these three bull trout were in the Grande Ronde River (Rkm 143) upstream of the Lookingglass Creek confluence (Rkm 132, Fig. 4) on 19 January 2000 (Table 6). By late January, one of these two bull trout (frequency 151.262) was located upstream in the Grande Ronde River at Rkm 146. This bull trout slowly moved downstream, entered Lookingglass Creek by early May, and ascended to Rkm 12 by mid-July. This bull trout remained in Lookingglass Creek throughout the remainder of our surveys; during August and September it was located between Rkm 11 and 4, and during October and November it was between Rkm 3 and 2. The second bull trout (frequency 151.234) moved slowly downstream in the Grande Ronde River and entered Lookingglass Creek in mid-May. This bull trout ascended to Rkm 3 by 20 June and was back in the Grande Ronde River (Rkm 135) by early July, when its signal was lost. In both these cases, the maximum downstream locations (LD) in Table 6 are relative to their locations in Lookingglass Creek and do not reflect the actual directions the fish traveled in the Grande Ronde River. The third bull trout was detected in Lookingglass Creek only in mid-June.

Upstream locations of bull trout in the Grande Ronde River and Lookingglass Creek during 2000 were less extensive than those observed in previous years. During 1999, one radio-tagged bull trout moved from Rkm 158 of the Grande Ronde River to Rkm 18 of Lookingglass Creek (Hemmingsen, Gunckel and Howell 2001).

Table 6. Observed locations of radio-tagged bull trout captured from Lookingglass Creek in 1998 and tracked in 2000. Locations are in the Grande Ronde River unless otherwise noted.

		1st location in 2000					
MHz	L (mm) [a]	Rkm	Date	LU	TU	LD	TD
151.262	444	143	19 Jan	12 [b]	12 Jul	146	26 Jan
151.234	541	143	19 Jan	3 [b]	19 Jan	143	19 Jan
150.105	520	4.5 [b]	15 Jun [c]	NA	NA	NA	NA

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 2000.
TD = earliest date of maximum downstream location.
[a] Length when implanted with radio transmitters in 1998.
[b] Located in Lookingglass Creek.
[c] Signal lost after this date.

Twenty-nine of the 32 bull trout with active transmitters were captured from the Wenaha River in 1998 and 1999. During January or March (winter) 2000, we located 22 of these bull trout in the Grande Ronde River (Rkm 1 – 117), two in the Snake River (RKm 244 and 265) and two in the Wenaha River (Rkm 24 and 34). Three transmitters were undetected during these early surveys. Of the 22 bull trout located during winter in the Grande Ronde River, 12 were between

Rkm 1 and 67, downstream of the Wenaha River confluence (Rkm 74, Fig. 4). The other 10 of these 22 bull trout were between Rkm 77 and 117, upstream of the Wenaha River confluence (Table 7). Transmitters in eight of the 22 bull trout were detected during at least eight months. Five of these eight bull trout entered the Wenaha River between mid-April and mid-July, then ascended to either Crooked Creek (29 September), Rock Creek (23 August), SF Wenaha River (20 June), or the mainstem Wenaha River (28 June, 09 August). Only one of these five bull trout (frequency 150.053) moved back down the Wenaha River and into the Grande Ronde River by mid-November. Three of the eight bull trout detected for at least eight months stayed in the Grande Ronde River and ranged between 6 and 16 km from their first location of the year.

Signals from nine of the 22 transmitters were located during four to seven months (Table 7), but most of these were lost from mid-June through mid-October. Five of the nine bull trout with these transmitters moved from the Grande Ronde River into the Wenaha River between late April and mid-July and ascended to Rkm 25 (12 July), Rkm 29 (12 July), Butte Creek (26 July), Crooked Creek (20 June), or the NF Wenaha River (02 August). When their signals were last detected, three of these five bull trout remained in the Wenaha River while two individuals had returned to the Grande Ronde River (one at Rkm 83 on 04 October, one at Rkm 95 on 22 November). Three of the nine bull trout located four to seven months were always found in the Grande Ronde River. One bull trout (frequency 151.092) left the Grande Ronde River and was located in the Snake River (Rkm 263-245) from mid-March to mid-June; this bull trout was not found again until mid-November, when it was back in the Grande Ronde River (Rkm 40).

Signals from five of the 22 transmitters were located less than four months. One bull trout was located only once. Signals from four transmitters were located two or three months and were lost by mid-April (Table 7). Bull trout with these four transmitters moved downstream 79 km ending in the Snake River (frequency 150.703), remained near the mouth of the Grande Ronde River (frequency 151.722), moved to Rkm 7 of the Wenaha River (frequency 150.273) or stayed within three km of the first location of the year (frequency 151.072). The maximum downstream locations (LD) in Table 7 are relative to their locations in the Wenaha River and do not reflect the actual directions the fish traveled in the Grande Ronde River.

Signals from four of the 32 bull trout originally captured in the Wenaha River were located in either the Snake or Wenaha rivers during March 2000 (Table 8). One bull trout in the Snake River (frequency 150.922) moved nine km further downstream, then moved 138 km upstream into the Wenaha River (Rkm 29) by late May, when its signal was lost. This distance is the longest one way by any bull trout that we observed in the Grande Ronde Basin during 2000. The second bull trout in the Snake River early in 2000 (frequency 151.701) moved upstream into the Grande Ronde River (Rkm 9) by late May, when its signal was also lost. One bull trout in the Wenaha River early in 2000 (frequency 150.114) was located between Rkm 34 and 37 from March to mid-July, then between Rkm 13 and 15 through late November. The second bull trout in the Wenaha River (frequency 150.115) was located between Rkm 24 and 32 throughout our surveys.

Signals from three transmitters were not located until much later in the year. One of these bull trout (frequency 150.146) was first located 02 August at Rkm 32 of the Wenaha River, three km downstream of the confluence of the North Fork and South Fork Wenaha River. From late September through late November the transmitter was located in the North Fork Wenaha River between Rkm 53 and 55, and may not have been in a live fish when it was last located. The second of these three bull trout (frequency 151.245) was first located 20 June at Rkm 105 of the Grande Ronde River. By 12 July, this transmitter was located in the North Fork Wenaha River at Rkm 16. On 12 October it was in West Fork Butte Creek (Rkm 14), then on 15 November it

Table 7. Observed locations of radio-tagged bull trout that were captured from the Wenaha River, tracked in 2000, and located in the Grande Ronde River during winter 2000. Locations are in the Grande Ronde River unless otherwise noted.

		1st location in 2000					
MHz	L (mm) [a]	Rkm	Date	LU	TU	LD	TD
			Downstream of Wenaha R. during winter				
Located >7 months:							
150.053	530	42	19 Jan	10 [b]	29 Sep	36	28 Mar
150.133	630	39	19 Jan	45	02 Aug	38	11 Nov
150.343	483	52	19 Jan	68	02 Aug	49	15 Nov
150.743	565	65	19 Jan	65	19 Jan	58	26 Apr
150.032	340	48	19 Jan	35 [c]	09 Aug	48	19 Jan
Located 4-7 months:							
151.092	375	42	19 Jan	40	15 Nov	246 [d]	15 Mar
150.881	370	42	19 Jan	29 [c]	12 Jul	42	19 Jan
150.972	378	45	19 Jan	45	19 Jan	41	09 May
151.381	310	48	19 Jan	25 [c]	12 Jul	56	19 Apr
151.513	260	8	15 Mar	11	26 Apr	5	09 May
Located <4 months:							
150.703	470	67	01 Mar	67	01 Mar	258 [d]	19 Apr [e]
151.722	405	1	15 Mar	1.3	15 Mar	270 [d]	19 Apr [e]
			Upstream of Wenaha R. during winter				
Located >7 months:							
151.223	546	117	19 Jan	0.5 [f]	23 Aug	115	09 May
151.622	330	103	19 Jan	14 [c]	28 Jun	103	19 Jan
151.642	320	77	19 Jan	3.0 [g]	26 Jul	82	07 Jun
Located 4-7 months:							
150.869	350	98	15 Mar	8.0 [h]	26 Jul	94	24 May
150.902	365	104	19 Jan	104	19 Jan	55	07 Jun
151.613	350	85	01 Mar	11 [b]	20 Jun	88	15 Mar
151.672	350	112	19 Jan	17 [l]	02 Aug [e]	112	19 Jan
Located <4 months:							
150.273	630	77	15 Mar	7 [c]	19 Apr [e]	77	15 Mar
151.072	340	94	19 Jan	95	28 Mar [e]	91	15 Mar
150.891	360	86	19 Jan [e]	NA	NA	NA	NA

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 2000.
TD = earliest date of maximum downstream location.
[a] Length when implanted with radio transmitters in 1998 or 1999.
[b] Located in Crooked Creek, tributary of the Wenaha River.
[c] Located in the Wenaha River.
[d] Located in the Snake River.
[e] Signal lost after this date.
[f] Located in Rock Creek, tributary of the Wenaha River.
[g] Located in the South Fork Wenaha River.
[h] Located in Butte Creek, tributary of the Wenaha River.
[i] Located in the North Fork Wenaha River.

was back in the North Fork Wenaha (Rkm 14). The third of these bull trout (frequency 150.613) was located once at RKm 95 in the Grande Ronde River on 22 November.

Table 8. Observed locations of radio-tagged bull trout that were captured from the Wenaha River, tracked in 2000, and located in the Snake River or Wenaha River during winter 2000. Locations are in the Wenaha River unless otherwise noted.

		1st location in 2000					
MHz	L (mm) [a]	Rkm	Date	LU	TU	LD	TD
150.992	422	244 [b]	15 Mar	29	24 May [c]	235 [b]	28 Mar
151.701	435	265 [b]	28 Mar	9	24 May [c]	258 [b]	19 Apr
150.114	520	34	15 Mar	37	12 Jul	21	12 Oct
150.115	535	24	15 Mar	32	15 Nov	22	17 Oct

LU = maximum known upstream location (Rkm) in 2000.
TU = earliest date of maximum upstream location.
LD = maximum downstream location (Rkm) 2000.
TD = earliest date of maximum downstream location.
[a] Length when implanted with radio transmitters in 1998 or 1999.
[b] Located in the Snake River.

II. Stream temperature monitoring

Introduction

Bull trout are stenothermic, requiring cold water temperatures to rear and reproduce. Consequently, the distribution of bull trout is directly determined, in part, by the stream temperature regime. Elevated water temperature is considered to be a significant factor in the decline of bull trout in Oregon and the Pacific Northwest (Buchanan and Gregory 1997). Although bull trout have been observed in water >20°C, temperatures >16°C are considered unsuitable for long term survival (Selong *et al*. 2001). Rieman and Chandler (1999) showed that bull trout of the Pacific Northwest were most likely to be found in streams where the summer maximum temperatures were <14°C. In laboratory conditions, the fundamental thermal niche of juvenile bull trout was 10.2 - 14.2°C (Selong *et al*. 2001).

Our objective is to describe the relationship between stream temperature and distribution of bull trout in Oregon's portion of the Columbia River Basin. This section describes efforts to measure the thermal characteristics of the upper John Day River watershed, Mill Creek (Walla Walla Basin), and the Grande Ronde Basin, where we are monitoring bull trout movements.

Methods

Twenty-eight temperature data loggers (Onset Computer, Inc.) were deployed in the study basins; 18 in upper John Day River, four in Mill Creek, and six in Grande Ronde watersheds (Table 9). In the upper John Day River watershed, data collection efforts were completed in cooperation with Confederated Tribes of Warm Spring Reservation of Oregon (CTWRO) and the US Forest Service (USFS). Temperature data loggers were launched between 03 May and 05 July. Data loggers were collected September through December and the data were downloaded. In most cases data loggers were re-launched for winter monitoring.

Temperature data loggers were programmed with a recording interval of either one hour or 48 minutes. Data loggers were placed in a sock or mesh bag with a few heavy stones. The bag was placed on the substrate on the edge of the thalweg to ensure its location in an area of adequate mixing. In large rivers, the data loggers were suspended in the water column with a cable secured at the water surface to large rocks or rip-rap.

Results and Discussion

Five temperature loggers malfunctioned or were lost. Of these, two were in Mill creek, one was in the Grande Ronde River, and two were in the upper John Day River (Table 9). Three data loggers in the upper John Day River watershed are still operational and will not be collected until late summer 2001. A summary of results only is reported during the summer months for the upper John Day River watershed when coverage was most thorough.

Upper John Day River watershed

Of the 13 temperature data loggers collected from the upper John Day River watershed, six were located in the river upstream of the town of John Day, and seven were located in four tributary streams, including Indian Creek (2), Reynolds Creek (2), Deardorff Creek (1), and Call Creek (2) (Fig. 5).

The seven hottest consecutive days occurred between 30 July and 05 August. For these days, the average maximum stream temperature in the mainstem John Day River above RKm 435 did not exceed 20°C (Fig 6a). Only at RKm 444 did maximum temperatures remain below 15 C. River temperatures downstream of RKm 422 (Prairie City) exceeded 15°C for > 23 hours of the day, whereas temperatures at RKm 437 and 435 exceeded 15°C for an average of 8 and 10 hours, respectively (Fig 6b).

Of the four tributary streams, Call Creek was coolest at its mouth. On 05 August, the 7-day average maximum temperature for Call Creek was 10.7°C, whereas Deardorff and Reynolds were 14.5°C and 16.3°C, respectively (Fig 6a). Temperatures in Call Creek and Deardorff Creek never exceeded 15°C. During July and August, the mouth of Reynolds creek averaged 2.7 hour/day above 15°C and North Fork Reynolds Creek remained below 15°C all summer.

Water temperature at the mouth of Indian Creek was consistently the highest of all sites, including RKm 399 on the John Day River. The 7-day average maximum temperature for Indian Creek averaged 2.4°C higher than the mainstem John Day River at the mouth of Indian Creek (RKm 414). The temperature logger at the mouth of Indian Creek was out of the water between 29 Jul and 04 Aug, the seven hottest days of the summer. Upper Indian Creek was cooler than the mouth, but was warmest of all tributaries monitored. Stream temperatures averaged 7.5 hours over 15°C during the seven hottest days at the upper Indian Creek site.

The average daily fluctuation in temperature increased longitudinally downstream (Fig 6c). Daily fluctuation at RKm 444 ranged between 1.7 to 5.8 degrees during July and August. At RKm 399 daily fluctuation ranged from 2.5 to 10.8 degrees during the same time period. The mouth of Indian creek showed the greatest daily fluctuation ranging from 4.9 to 16.5, however upper Indian Creek fluctuated less than both Deardorff Creek and Reynolds Creek at the mouth. The temperature regime of Call Creek was the most stable, with temperatures fluctuating within a range of 3 degrees.

Table 9. Location and duration of temperature data loggers deployed in 2000.

Basin	Stream	Launch Date	Recovery Date	River Kilometer	Location Description
Grande Ronde	Grande Ronde R.	27-Jun	30 Oct	42	1.6 km upstream of Hwy 3 bridge
	"	18-Jun	08 Dec	87	1.2 km upstream of Wildcat Cr.
	"	18-Jun	**	107	at Bear Cr. confluence
	"	23-Jun	29 Oct	138	400m downstream of Lookingglass Cr.
	Wenaha R.	27-Jun	29 Nov	0.4	400m upstream from mouth
	SF Wenaha R.	11-Jun	29 Oct	36.2	at Elk Flat Trail crossing
John Day	John Day R.	05-Jul	12 Oct	399 [a]	at the mouth of Dog Cr.
	"	05-Jul	12 Oct	414 [a]	at the mouth of Indian Cr.
	"	04-Jul	22 Feb [b]	422 [a]	in Prairie City
	"	03-May	10 Sep	435	at 1999 screw trap site
	"	05-Jul	12 Oct	437 [a]	upstream of Reynolds Cr.
	"	05-Jul	12 Oct	444 [a]	upstream of Roberts Cr.
	"	19-Jun	**	455	end of fish distribution
	Indian Cr.	05-Jul	12 Oct	0.1 [a]	at the mouth
	"	27-Jun	04 May [b]	12.5	12m upstream from Sheep Cr.
	Dixie Cr.	21-Jun	**	0.1	at the mouth
	"	21-Jun	--	15	2/3 distance to headwaters
	Reynolds Cr.	19-Jun	19 Oct	1 [a]	1 km upstream of the mouth
	NF Reynolds Cr.	25-Jun	24 Sep	10.5 [c]	100 m downstream of Mossy Gulch
	Deardorff Cr.	07-Jul	12 Oct	0.1 [a]	at the mouth
	Rail Cr.	21-Jun	--	0.1	at the mouth
	"	20-Jun	--	5	2/3 distance to headwaters
	Call Cr.	19-Jun	28 Nov	0.1	at the mouth
	"	21-Jun	01 Aug	3	2/3 distance to headwaters
Walla Walla	Mill Cr.	13-Jun	12 Dec	5	at Wallula Ave bridge
	"	13-Jun	**	21	at Five Mile Road bridge
	"	13-Jun	**	31	at Wickersham bridge
	"	13-Jun	03 Nov	42	at screw trap site

[a] Data collected by CTWSRO.
[b] In 2001.
[c] Data collected by USFS.
** Malfunctioned or lost data logger.
-- Data logger not collected until summer 2001.

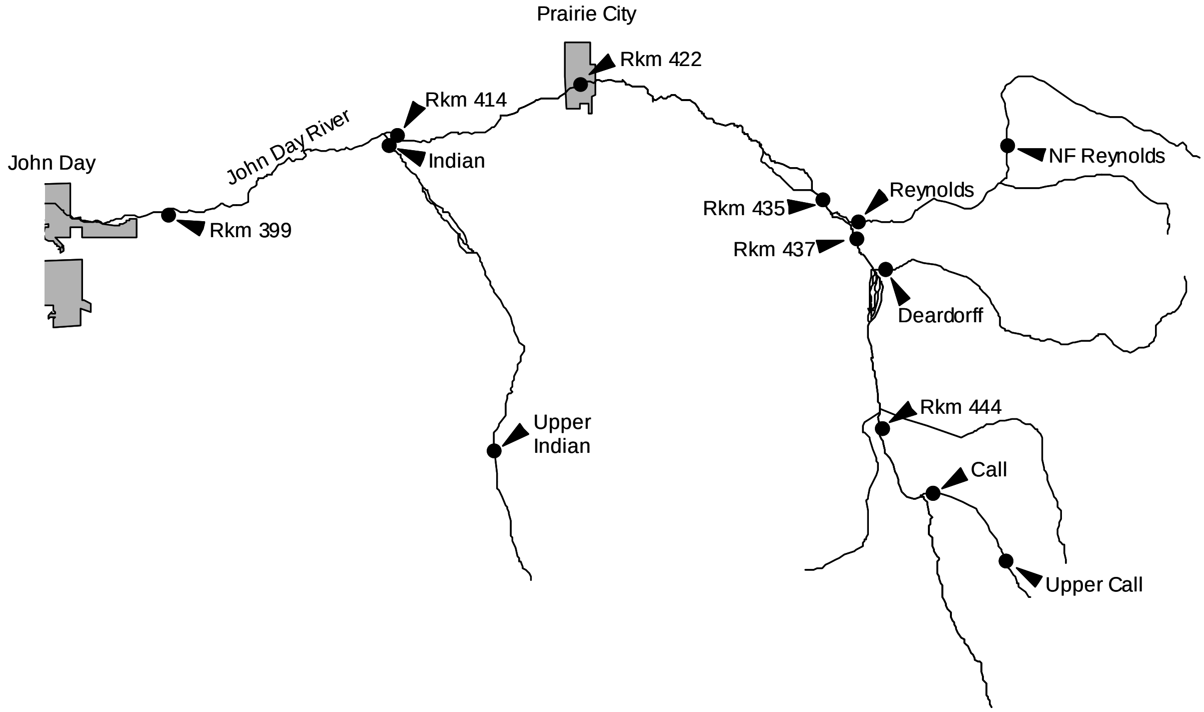


Figure 5. Location of temperature data loggers in upper John Day watershed in 2000.

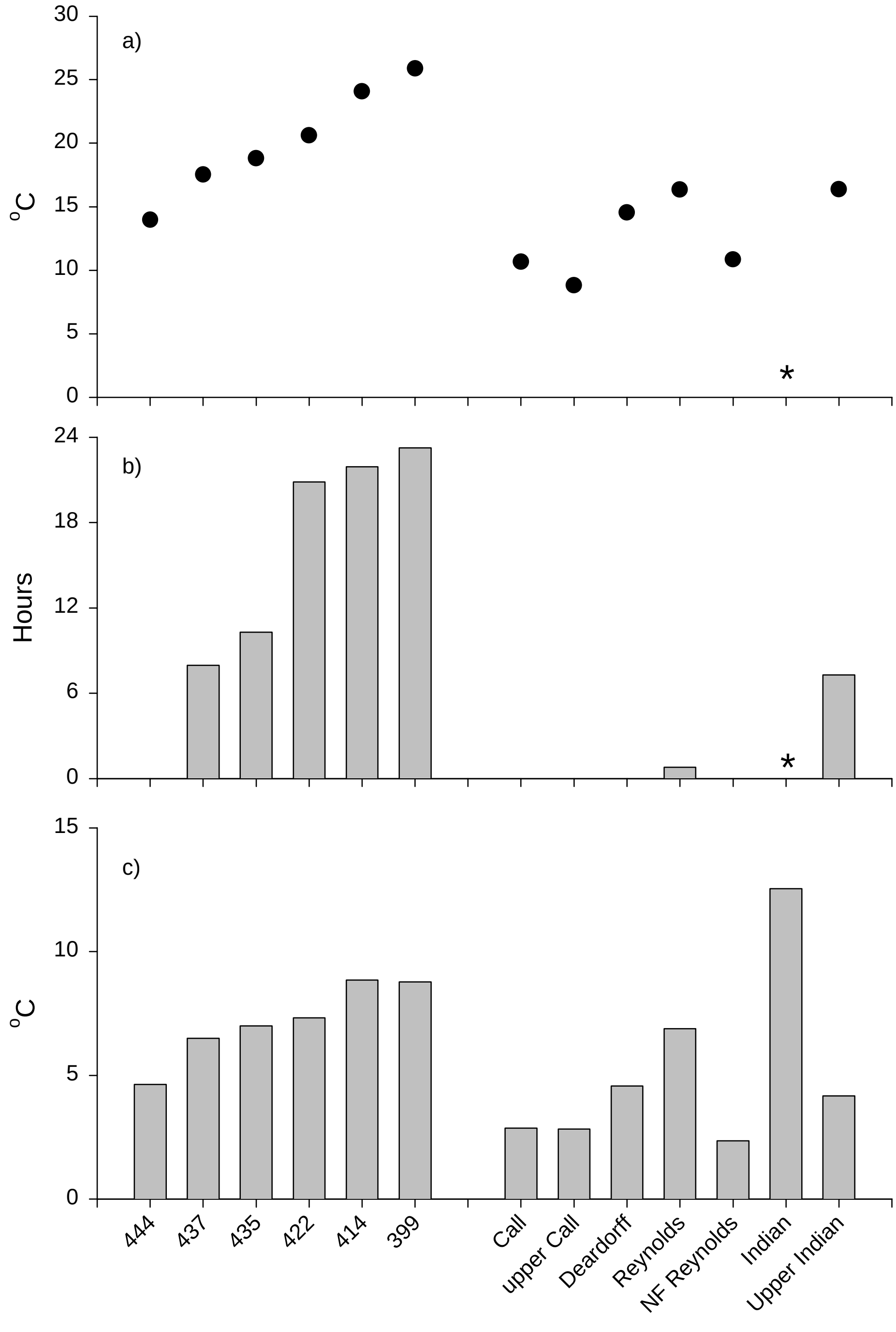


Figure 6. Seven day average a) maximum temperature and b) number of hours > 15° C during 30 July and 05 August, 2000 in the upper mainstem John Day basin. C) Average degrees of fluctuation during July and August 2000. * - temperature data logger at the mouth of Indian Creek was out of the water during this time.

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 Mill Creek (Walla Walla Basin) and the Little Minam River (Grande Ronde Basin). These surveys provided additional data to better estimate the spatial and annual variation in observed numbers of bull trout redds. In previous years, we conducted similar surveys in Silver Creek (Powder Basin). 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, Bellerud, Buchanan, Gunckel, Shappart and Howell 2001; Hemmingsen, Bellerud, Gunckel and Howell 2001; Hemmingsen, Gunckel and Howell 2001). Because counts of redds in Silver Creek did not reflect the estimated abundance of mature bull trout (Hemmingsen, Gunckel and Howell 2001), spawning surveys were dropped from Silver Creek in 2000.

Methods

We conducted four spawning surveys of Mill Creek and its tributaries upstream of the water intake dam (Fig. 7). Two surveys occurred in September (11, 12 and 14; 26-28) and two occurred in October (10, 11 and 13; 18-21). We also conducted four spawning surveys of the Little Minam River upstream from the confluence of Boulder Creek, and Dobbin Creek (Fig. 8). Two surveys occurred in September (7 and 8; 20 and 21) and two occurred in October (3-5; 18 and 19). Survey reach numbers shown in Figs. 7and 8 coincide with reach boundaries and lengths described by Hemmingsen, Bellerud, Buchanan, Gunckel, Shappart and Howell (2001). 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), 1997 (Hemmingsen, Bellerud, Buchanan, Gunckel, Shappart and Howell 2001), 1998 (Hemmingsen, Bellerud, Gunckel and Howell 2001), and 1999 (Hemmingsen, Gunckel and Howell 2001).

Results and Discussion

We observed 193 bull trout redds in the Mill Creek watershed during 2000. Of these redds, 110 were in Mill Creek and 83 were in its tributaries (Fig. 9a). The tributaries contained 43% of redds observed in the watershed, which was slightly more than in previous years. Tributaries to Mill Creek have contained 27 to 35% of the redds observed in the watershed each year from 1996 through 1999. In 2000, as in all years we conducted surveys, most of the redds in tributaries were in Low Creek (N=39). Of the 110 redds observed in Mill Creek, 70 were in reach five, between North Fork Mill Creek and Deadman Creek. Reach five of Mill Creek contained 36% of all redds observed in the watershed during 2000. No bull trout redd was observed in reaches one and two of Mill Creek. In 2000, densities of redds (Fig. 9b) were highest in reach five of Mill Creek (18.9/km) and Low Creek (18.6/km). While relatively few bull trout had spawned in Mill Creek and its tributaries before the middle of September, 66% of all redds observed were counted by late September and 93% were counted by 11 October (Fig. 9c).

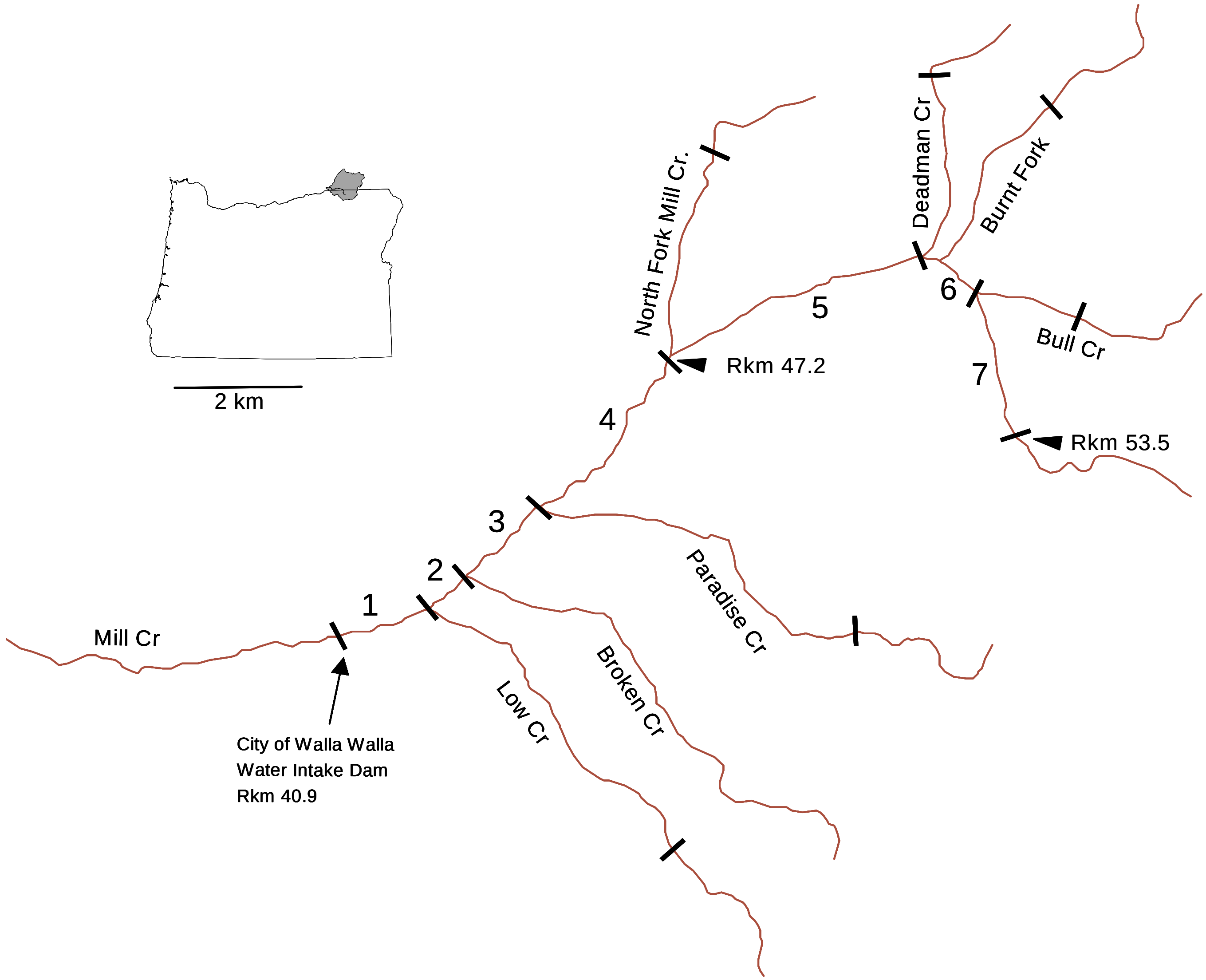


Figure 7. Locations of bull trout spawning survey reaches in Mill Creek and tributaries.

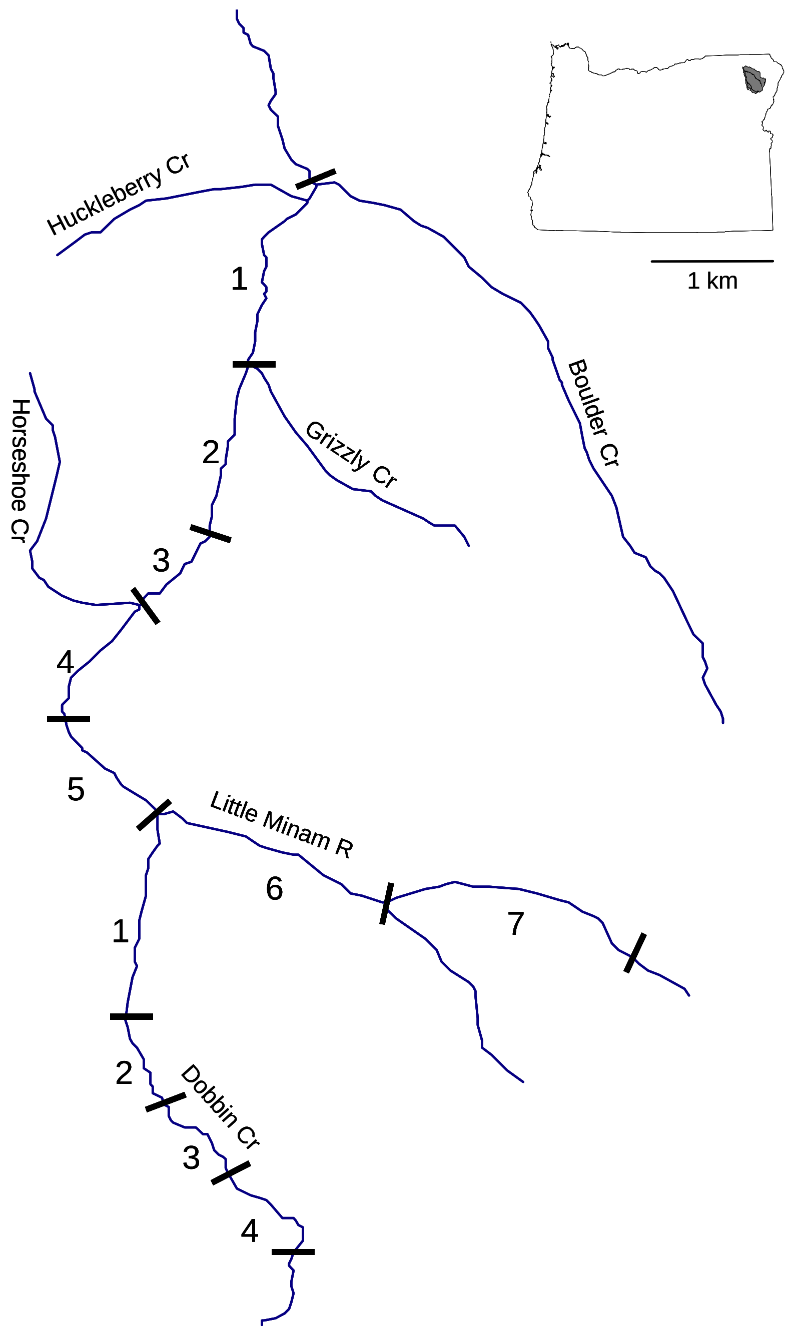


Figure 8. Locations of bull trout spawning survey reaches in the Little Minam River and Dobbin Creek.

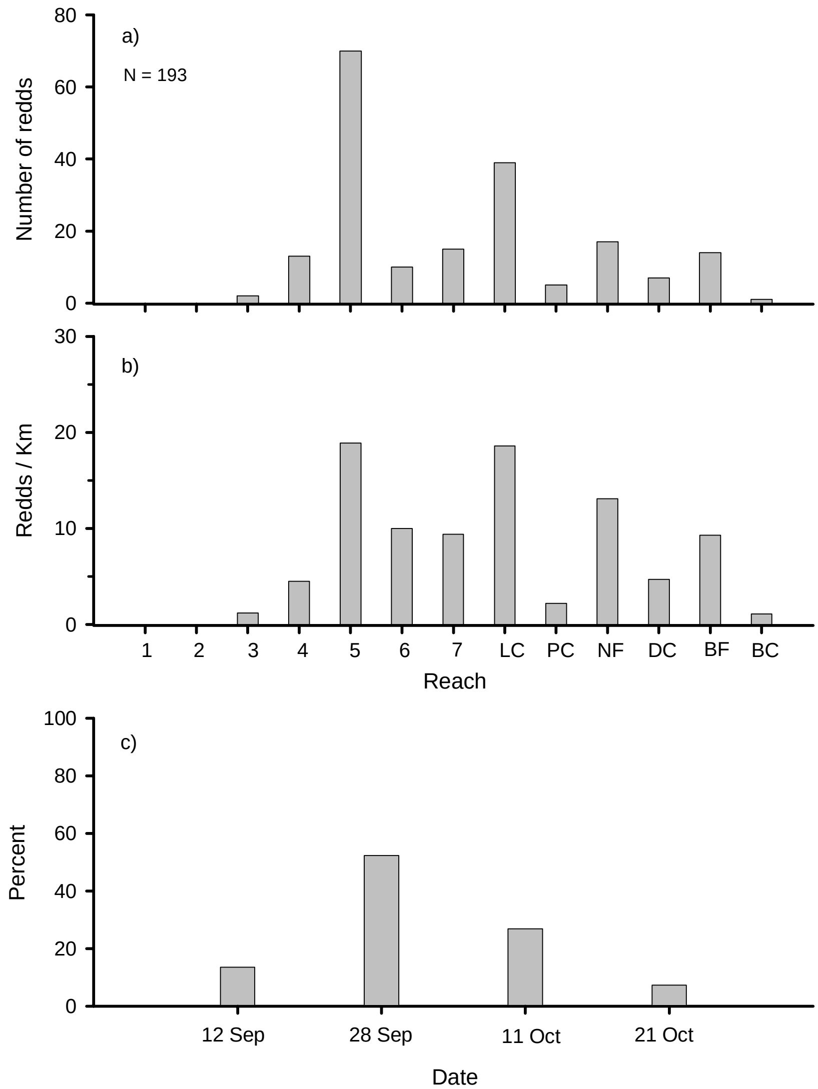


Figure 9. Spawning ground surveys on Mill Creek and tributaries, 2000; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey. LC = Low Creek, PC = Paradise Creek, NF = North Fork Mill Creek, DC = Deadman Creek, BF = Burnt Fork and BC = Bull Creek

We observed 270 bull trout redds in the Little Minam River watershed in 2000. Of these, 237 were in the Little Minam River and 33 were in its tributary Dobbin Creek (Fig. 10a). No redds were found in reaches two or four of Dobbin Creek. The proportion of redds produced in Dobbin Creek (12%) was similar to the proportion (11%) produced there in 1999 (Hemmingsen, Gunckel and Howell 2001). Reaches six and seven of the Little Minam River, upstream of the confluence with Dobbin Creek, contained 137 redds, or 51% of the total observed in the watershed. Bull trout redds were also concentrated in these two reaches in 1996, 1997 and 1998. In 2000, densities of redds in the Little Minam River exceeded 20 per km in reaches three, six and seven (Fig. 10b). Most bull trout in Little Minam River and Dobbin Creek spawned by the third week of September (Fig 10c). Seventy-nine percent of redds observed were counted by 21 September and 99% were counted by 05 October.

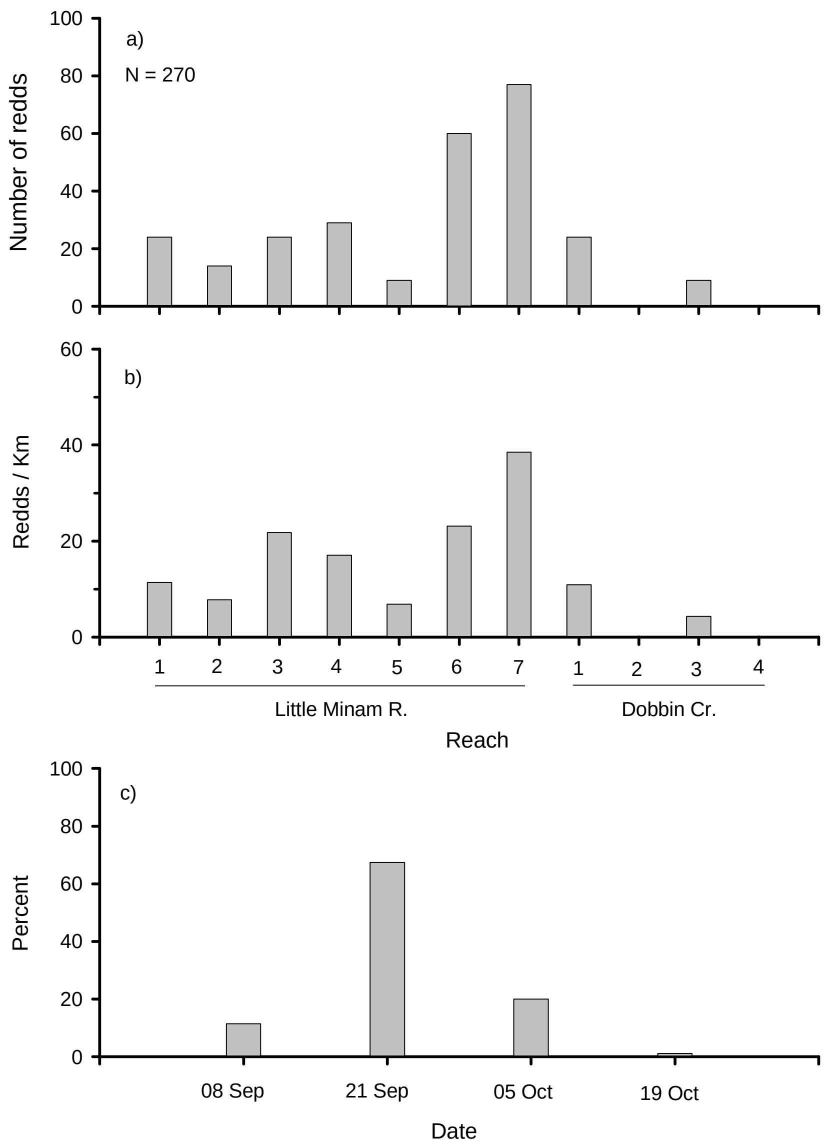


Figure 10. Spawning ground surveys on the Little Minam River and Dobbin Creek, 2000; a) number and b) density of bull trout redds in each reach, c) proportion of N observed during each survey.

The number of bull trout redds observed in the Mill Creek watershed in 2000 was the highest total observed in recent years. Numbers of redds in 1994 and 1995 are not directly comparable since these surveys, conducted by the U.S. Forest Service, were not as extensive or frequent as surveys since 1996. In contrast, the number of bull trout redds observed in the Little Minam River and Dobbin Creek in 2000 was the lowest number observed since 1996, when surveyors struggled to detect redds made by small bull trout (Fig. 11).

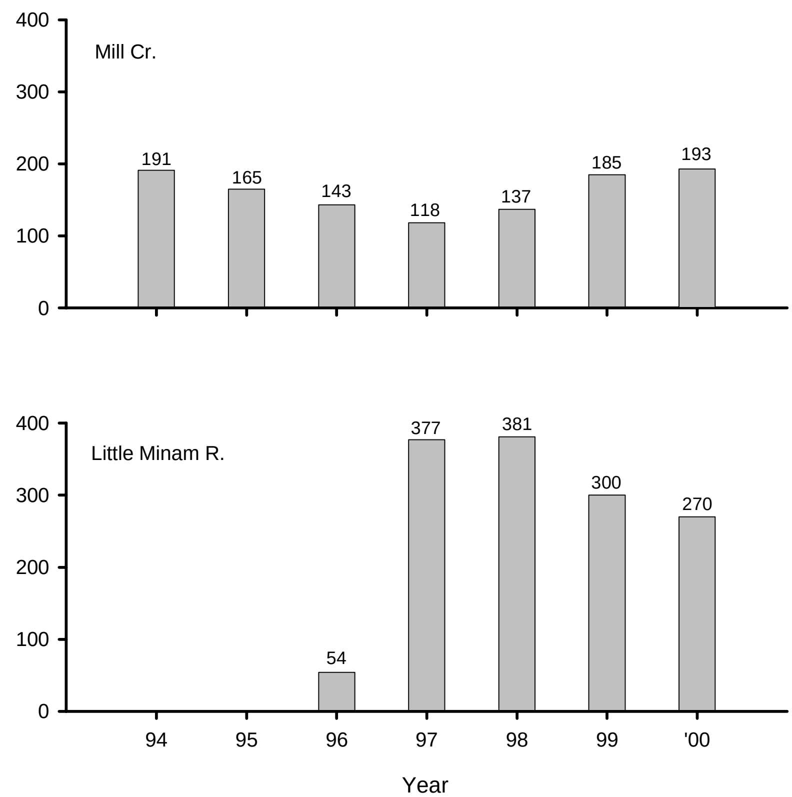


Figure 11. Numbers of bull trout redds observed annually from 1994 -2000. Data from Mill Creek in 1994 and 1995 are courtesy of the USDA Forest Service, Walla Walla, WA. Little Minam River was not surveyed in 1994 and 1995.

Because we have systematically counted redds for five years, we may begin to examine the variation in distribution of bull trout redds within watersheds. We calculated the variation in the proportion of redds contained in each reach of Mill Creek and the Little Minam River from 1996 through 2000. We then examined the relationships between proportions of redds in stream reaches and the total number of redds in respective watersheds. In Mill Creek, for example, reach five contained the greatest proportion of redds (30 to 37%; $\bar{x}$ = 33.7) observed annually in the watershed, with the lowest coefficient of variation (CV = 9%) among all reaches (Table 10). To see how well the number of redds in reach five estimated the total number of redds in the watershed annually, we divided the number of redds counted annually in reach five by its five-year mean proportion (0.337). We then calculated the percentage error by which these estimates differed from the total number of redds counted. In this analysis, the numbers of redds in reach five alone over-estimated the total redds observed in 1996 and 2000 by 10.8% and 7.6%, respectively. For the remaining three years, numbers of redds in reach five alone under-estimated the observed totals in the watershed by 2.5 to 9.5% (Table 11).

In a second examination, we included the numbers of redds counted in Low Creek because it also had relatively low variation (CV = 20%, Table 10). Redds in Low Creek tend to be smaller and possibly more difficult to observe than those in reach five of Mill Creek. However, this analysis contains no assumptions about difficulties in observation; it is a statistical exercise that examines correlations between redds counted in selected reaches and those counted throughout the watershed. Together, reach five of Mill Creek and Low Creek produced 48 to 57% ($\bar{x}$ = 52.0%) of redds observed annually in the watershed. Compared to reach five alone, counts in both survey reaches more closely reflected total numbers observed in all years except 2000 (Table 11).

Table 10. Proportion of bull trout redds observed each year in various survey reaches of Mill Creek and tributaries, and the estimated variation among years.

Survey reach	1996	1997	1998	1999	2000	*mean*	*SD*	*CV*
Mill Cr:								
1	0.7	0.0	0.0	0.0	0.0	0.1	0.3	224
2	0.0	0.0	0.7	0.0	0.0	0.1	0.3	224
3	0.0	4.2	2.2	2.2	1.0	1.9	1.6	82
4	16.9	11.9	10.9	20.5	6.7	13.4	5.4	40
5	37.3	30.5	32.8	31.4	36.3	33.7	3.0	9
6	7.7	12.7	10.2	7.0	5.2	8.6	2.9	34
7	2.1	13.6	12.4	7.6	7.8	8.7	4.6	52
Low Cr	12.7	16.9	19.7	22.2	20.2	18.3	3.7	20
Paradise Cr	7.7	1.7	0.7	3.2	2.6	3.2	2.7	85
NF Mill Cr	4.2	2.5	4.4	3.2	8.8	4.6	2.5	53
Deadman Cr	2.1	0.8	2.9	0.0	3.6	1.9	1.5	78
Burnt Cr	8.5	3.4	1.5	2.2	7.3	4.5	3.1	69
Bull Cr	0.0	1.7	1.5	0.5	0.5	0.8	0.7	84

Table 11. Comparison of total bull trout redds observed and estimated using selected survey reaches in the Mill Creek watershed as index areas.

Index reach, Year	Total redds in watershed		% error [a]
	Observed (x)	Estimated (y)	
Reach 5:			
1996	142	157	10.8
1997	118	107	-9.5
1998	137	134	-2.5
1999	185	172	-7.0
2000	193	208	7.6
Reach 5 and Low Cr:			
1996	142	137	-3.9
1997	118	108	-8.7
1998	137	138	1.1
1999	185	190	2.9
2000	193	210	8.6

[a] ((y-x)/x)*100.

In the Little Minam River, reach seven has produced 21 to 29% ($\bar{x}$ = 25.3%, CV = 11%) of redds observed annually in the watershed (Table 12). Using the five-year mean proportion for reach seven, we calculated the estimated number of redds in the Little Minam watershed as we did for Mill Creek. This analysis showed that the numbers of redds counted in reach seven alone over-estimated the total numbers observed in 1996, 1997 and 1998 only slightly (Table 13). However, numbers of redds in reach seven alone under-estimated the total observed in 1999 by 18.3% and over-estimated the total observed in 2000 by 12.7%. In a second examination for this watershed, we included the numbers of redds counted in reach three of the Little Minam River (CV = 19%) with those counted in reach seven. Together, these survey reaches produced 30 to 37% ($\bar{x}$ = 33.4%) of redds observed annually in the watershed. Compared to reach seven alone, the addition of counts of redds in reach three slightly reduced the magnitude of error in 1996 and 2000, and slightly increased the error in 1997 and 1998 (Table 13). The greatest benefit occurred when the error associated with the total number of redds in 1999 decreased from 18.3% to 12.0%.

Table 12. Proportion of bull trout redds observed each year in various survey reaches of the Little Minam River and Dobbin Creek, and the estimated variation among years.

Survey reach	1996	1997	1998	1999	2000	*mean*	*SD*	*CV*
L. Minam R:								
1	0.0	12.2	7.9	16.3	8.9	9.1	6.1	67
2	7.4	6.6	6.6	14.0	5.2	8.0	3.5	44
3	7.4	9.3	5.8	9.3	8.9	8.1	1.5	19
4	7.4	5.0	9.7	14.3	10.7	9.4	3.5	37
5	5.6	6.1	11.3	4.7	3.3	6.2	3.0	49
6	18.5	16.2	17.1	10.0	22.2	16.8	4.5	26
7	25.9	25.7	25.7	20.7	28.5	25.3	2.9	11
Dobbin Cr:								
1	22.2	11.7	3.9	3.3	8.9	10.0	7.7	77
2	5.6	1.6	2.4	2.0	0.0	2.3	2.0	88
3-4	0.0	5.6	9.7	5.3	3.3	4.8	3.5	74

Table 13. Comparison of total bull trout redds observed and estimated using selected survey reaches in the Little Minam River watershed as index areas.

Index reach, Year	Total redds		% error [a]
	Observed (x)	Estimated (y)	
Reach 7:			
1996	54	55	2.5
1997	377	383	1.7
1998	381	387	1.7
1999	300	245	-18.3
2000	270	304	12.7
Reaches 7 and 3:			
1996	54	54	0.0
1997	377	395	4.8
1998	381	359	-5.7
1999	300	269	-10.2
2000	270	302	12.0

[a] ((y-x)/x)*100.

Results presented here indicate that surveys of selected stream reaches can correlate with the total number of bull trout redds counted in these watersheds with relatively small error (± 9% in Mill Creek; ± 12% in the Little Minam River). Depending on the objectives of spawning surveys, this precision may be acceptable in lieu of the effort required for annual surveys of entire spawning areas in a watershed. We emphasize that the identification of these reaches required systematic surveys throughout all spawning areas in both watersheds, conducted four times annually for five years. Similar efforts may be required to confidently identify candidate index reaches in other watersheds.

If index reaches are selected to estimate the total abundance of bull trout redds in the Mill Creek and Little Minam River watersheds, managers must accept the risk that the correlations seen in 1996-2000 may not be as precise in future years. We have demonstrated variation in surveyors' abilities to detect bull trout redds; these abilities are influenced by life history and size of the fish as well as physical characteristics of the spawning substrates in the watersheds (Bellerud *et a*l. 1997; Hemmingsen, Bellerud, Buchanan, Gunckel, Shappart and Howell 2001; Hemmingsen, Bellerud, Gunckel and Howell 2001; Hemmingsen, Gunckel and Howell 2001). Such variation in the detection of redds will apply whether surveys are conducted throughout the watershed or in selected index reaches. Furthermore, habitat changes in the watershed may significantly affect the proportion of bull trout that spawn in a given reach. For example, a high flow event prior to spawning in 1999 altered habitat in reach six of the Little Minam River. The proportion of the total number of redds in the watershed represented by reach six in 1999 declined by 41% from the previous 3-year average (Table 12). Changes in redd distribution may be undetected unless surveys throughout the watersheds are made periodically so that the proportions and variation of redds in index reaches can be verified.

IV. Acknowledgments

This project is grateful to D. Gaudette, L. Gaudette and J. Shappart, and S. Starcevich, for their dedication in the field, including deployment and collection of temperature data loggers, telemetry, and spawning surveys. We are also grateful to L. Boe and M. Northrup with the US Forest Service, Walla Walla Ranger District for assistance with trapping, telemetry and spawning surveys in Mill Creek. We thank S. Robertson with the Confederated Tribes of Warm Springs Reservation of Oregon and J. Soupir with the US Forest Service, Prairie City Ranger District for assistance with temperature data collection in the upper John Day Basin. We appreciate the assistance with spawning surveys in the Grande Ronde basin provided by J. Zakel. Finally, we thank the Oregon State Police and Baker Aircraft, Inc for successful telemetry flights.

V. References cited

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.

Buchanan, D. V. and S. V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pages 119-126 *in* Mackay, W. C., M. K. Brewin, and M. Monita, editors. Friends of the bull trout conference proceedings. Bull trout task force (Alberta), C/O Trout Unlimited Canada, Calgary.

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.

Hemmingsen, A. R., S. L. Gunckel and P. J. Howell. 2001. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1999 Annual Report. Project Number 199405400, Bonneville Power Administration, Portland, Oregon.

Reiman, B.E. and G.L. Chandler. 1999. Empirical evaluation of temperature effects on bull trout distribution in the Northwest. Final repot to Environmental Protection Agency, Boise, Idaho.

Selong, J. H., T. E. McMahon, A. V. Zale, and F. T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026-1037.