Migratory Patterns, Structure, Abundance, and Status of Bull Trout Populations from Subbasins in the Columbia Plateau and Blue Mountain Provinces

2006 Annual Report

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Introduction

This study began in 2002. Background, methods, and results from prior years are presented in previous annual reports (Sankovich et al. 2003; Sankovich et al. 2004; Starcevich et al. 2005; Moore et al. 2006).

Methods

This study was conducted in the upper Mill Creek watershed (Walla Walla subbasin), upstream from a dam and intake structure in Mill Creek that supplies water to the city of Walla Walla, Washington (Figure 1). A ladder on the dam allows passage for upstream migrants. We operated a trap, designed as described in Hemmingsen et al. (2001b), at the head of the dam's ladder from 3 May through 31 October 2006. The trap was usually checked daily when bull trout began to move up the ladder, which occurred on 11 June. As in previous years, bull trout trapped at the ladder were anesthetized, measured, weighed, interrogated for a PIT tag, and, if no PIT tag was present, injected with one. Each fish was also inspected for maturity using ultrasound, and mature females were identified. All bull trout were marked by hole-punching the top of the caudal fin to distinguish fish marked with a mid-caudal punch in 2005. The punch was used to mark fish for the mark-recapture estimate to determine the number of adult-sized (> 299 mm) bull trout residing above the trap that did not pass through the trap. As in previous years, we installed a net across the stream near the base of the dam to eliminate the possibility of fish avoiding the trap by jumping the dam so we could fully enumerate the number of fish that migrated upstream from below the dam.

To account for any fluvial-sized females that might have over-wintered upstream from the dam, we snorkeled the study area from 7-8 September, 2006. A single diver snorkeled all the pools and a portion of the other habitats capable of holding fluvial adult-sized fish. The diver recorded the number of marked (caudal fin punch) and unmarked bull trout ≥ 300 mm fork length (FL) that were observed. Since 2002, only four adult females < 300 mm have been identified at the trap. All four of those fish were ≥ 289 mm. We estimated the number of unmarked bull trout ≥ 300 mm FL by incorporating the number of marked and unmarked bull trout observed snorkeling and the number of marked bull trout released upstream of the trap at the time of snorkeling into Bailey's (1951) mark-recapture estimator:

$$\hat{N} = \frac{(C+1)M}{R+1}$$

where *N* is the population size, *M* is the number of bull trout marked, *C* is the number of marked and unmarked bull trout observed snorkeling, and *R* is the number of marked bull trout observed snorkeling. The Bailey estimate accounts for the possibility a marked bull trout may be observed multiple times in the snorkel count. Since the percentage of marked fish in the snorkel count exceeded 10% of the total snorkel count, confidence intervals were based on a binomial distribution (Seber 1982).

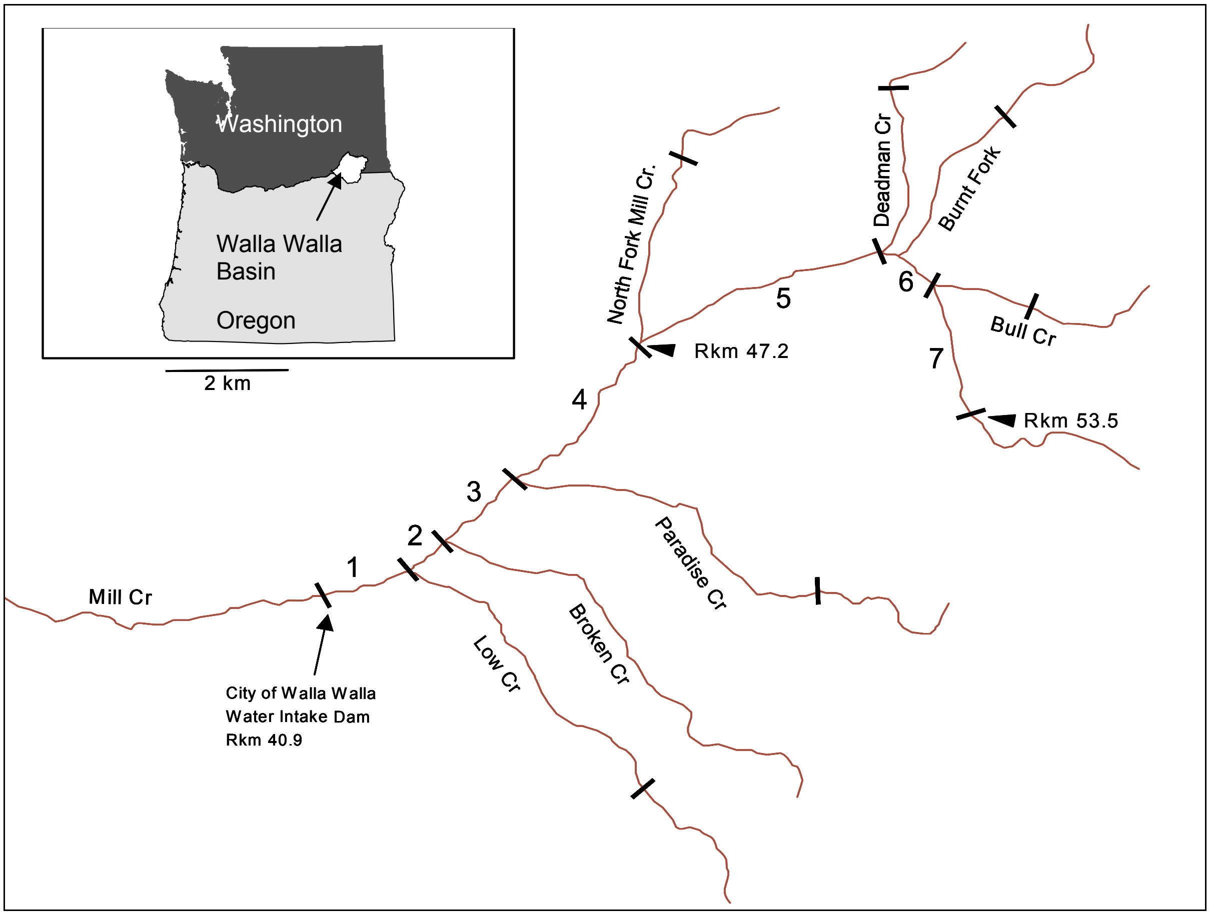

Figure 1. Map of the Mill Creek study area showing landmarks and reach units in which redds were counted during spawning ground surveys.

The number of unmarked fish (N_U), therefore, equals the population estimate (N) minus the number of fish marked at the trap (M), and the number of unmarked mature females equals N_U multiplied by the fraction of mature females $\geq$ 300 mm observed at the trap, assuming the female fraction of the unmarked fish was the same as that of the fish inspected at the trap. The overall estimate for mature fluvial females in the study area, then, was calculated as the sum of the unmarked females above the trap plus the females counted at the trap. The confidence interval assumes all of the error is from the estimate of unmarked females.

Redd counts in the study area were conducted three times between mid-September and early November throughout the entire spawning distribution. During each survey, we flagged newly observed redds, identified them with a unique number, measured their length (from the beginning of the pit to the end of the mound) and width (at the widest part of the mound), and noted all fish observed within 1 m of the redd.

Results and Discussion

We captured 93 bull trout in the upstream trap, 48 of which were identified as mature females (Table 1). All bull trout were ≥ 320 mm FL, including one mortality. None of the bull trout captured recycled through the trap.

Table 1. Number, sex, and maturity status of bull trout captured in an upstream migrant trap in Mill Creek, 2006. Female maturity was determined using ultrasound. Counts of other species are also included.

Species	Mature females	Mature males and immature males and females	Total
Bull trout	48	44	92[a]
Whitefish	--	--	2
Rainbow trout	--	--	1

a. *Does not include one mortality.*

We marked and released 65 bull trout above the trap before the study area was snorkeled. The diver located 23 marked and 10 unmarked bull trout $\geq$ 300 mm. Thus, we estimated there were a total of 27 unmarked fluvial adults, of which 14 were assumed to be mature females based on the female fraction (0.52) at the trap. Combining these females with the 48 released at the trap yielded an estimate of 62 (95% CL = 60-67) mature fluvial females in the study area.

Fifty-six fluvial bull trout redds were counted during regular census surveys in mainstem Mill Creek and North Fork Mill Creek (Table 2). An additional 35 resident bull trout redds were counted in Low Creek.

Table 2. Bull trout redd counts from regular surveys in Mill Creek, 2006. Survey sections are shown in Figure 1.

Survey section	Number of redds
Fluvial	
0 (below dam)	2
1	0
2	0
3	0
4	8
5	29
6	7
7	7
N.F. Mill Cr.	5
Total above dam	56
Resident	
Low Cr.	35
Paradise Cr.	0

Female estimates and redd counts in 2006 were the lowest observed in the last nine years (Table 3). Adjusting the estimated error in the redd count due to bias among surveyors (Starcevich et al. 2005) increased the redd:female ratio to 1.0, similar to other years, with the exception of 2001 and 2002. The relationship between mature females and redds has low power (R^2=0.37) and is not statistically significant (Figure 2). The low correlation is primarily due to disproportionately high redd:female ratios observed in 2001and 2002.

Table 3. The number of redds and mature females in Mill Creek and Low Creek, 1998-2006. Females for 1998-2002 in Mill Creek were calculated by applying mean female ratio at the trap during 2002-2005 (0.50) to the upstream trap count and also applying the mean proportion of unmarked females above the trap during 2003-2005 (0.29).

				Redd count		Redds/female	
Population	Year	Females	95% CL	Raw	Adjusted	Raw	Adjusted
Mill Creek	1998	95	--	104	--	1.1	--
	1999	127	--	138	--	1.1	--
	2000	129	--	142	--	1.1	--
	2001	98	--	184	--	1.9	--
	2002	117	--	176	--	1.5	--
	2003	96	88-114	110	--	1.1	--
	2004	89	80-105	97	97	1.1	1.1
	2005	116	102-143	95	107	0.8	0.9
	2006	62	60-67	56	62	0.9	1.0
Low Creek	2003	48	27-69	28	51	0.6	1.1
	2005	97	69-125	43	78	0.4	0.8

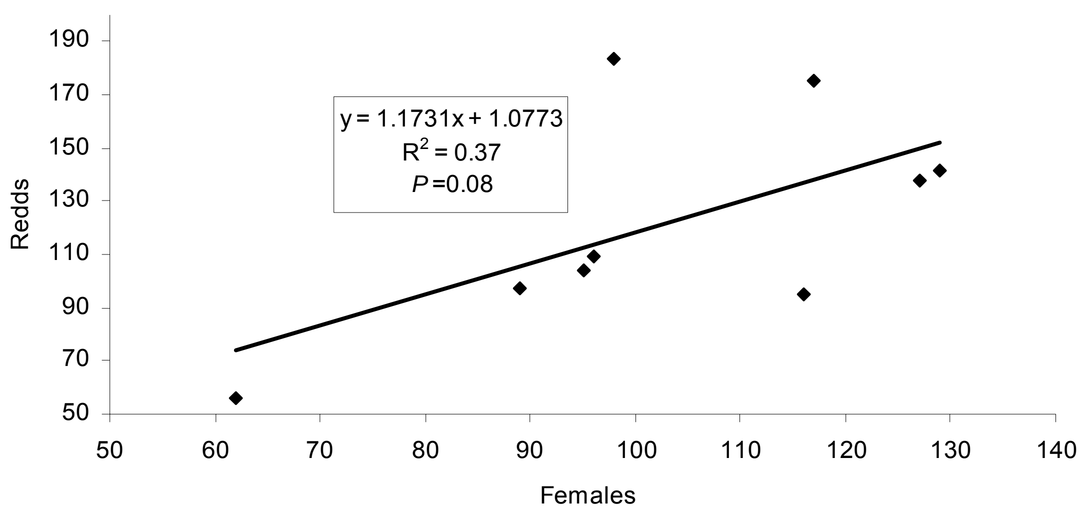

Figure 2. Regression of redds on mature female bull trout in Mill Creek, 1998-2006.

II. Seasonal Movements of Subadult Fluvial Bull Trout in Mill Creek (2006)

Introduction

Bull trout (*Salvelinus confluentus*) exhibit many life history strategies. Stream-resident bull trout complete their life cycles in or near natal tributaries. Migratory bull trout typically spend 1-4 years rearing in natal streams and then migrate downstream to more productive feeding areas. Migratory "subadult" bull trout may spend several years foraging in the lower reaches of their natal streams, a larger river, or a lake before returning to natal streams to spawn (Rieman and McIntyre 1993). Resident and migratory forms may occur together and either form can produce resident or migratory offspring (Rieman and McIntyre 1993). Migratory forms may be particularly important to the persistence of bull trout populations (Rieman and McIntyre 1993). Therefore, understanding the movement patterns and associated habitat requirements of fluvial bull trout is critical to developing appropriate habitat protection measures for this species. For example, subadults may inhabit the lower reaches of a stream for long periods of time. In many watersheds, the lower reaches have been extensively altered and degraded by anthropogenic activities. However, studies of fluvial bull trout to date have focused almost exclusively on adults.

Therefore our objective for 2006 was to continue the investigation started in 2005, evaluating the seasonal movement of subadult fluvial bull trout. To accomplish this, a rotary screw trap was installed in upper Mill Creek, a tributary to the Walla Walla River, to capture migrating subadult bull trout for PIT tagging. A series of PIT tag detector arrays were installed at two downstream sites to assess movement timing and abundance. In addition, in 2006 we radio-tagged a subsample of the subadults PIT-tagged to provide finer scale data on movement patterns, and systematically sampled lower Mill Creek between the City of Walla Walla's diversion dam and upstream of Bennington Dam using night snorkeling to estimate subadult abundance, distribution, and water temperature relationships during late July-early August when summer water temperatures peak.

Methods

PIT Tagging

In March 2006, a 1.5 m rotary screw trap was installed in Mill Creek at Rkm 42. According to screw trap data collected at this location from 1998 through 2002, most subadult bull trout in Mill Creek migrate downstream between April and June but some movement occurs nearly every month of the year (Hemmingsen et al. 2001c). Therefore, we operated the screw trap five days per week from 6 March through 21 December to compare movement patterns of PIT tagged fish over a broad range of flow and temperature conditions.

All captured bull trout were anesthetized with a diluted mixture of tricaine methanesulfonate (MS-222) and measured to the nearest millimeter fork length (FL). Other species were counted and tallied according to predetermined size categories. All bull trout were interrogated for the presence of PIT tags. Untagged bull trout ≥100 and ≤ 299 mm were surgically implanted with one full-duplex PIT tag. Two tag sizes (23 or 11.5 mm) were used in 2006 based on tag availability. The 23 mm tags were inserted into the body cavity through a small incision on the left side, just above and anterior to the pelvic fins. The incision area was then swabbed with isopropyl alcohol, dried with sterile absorbent gauze and a small drop of veterinary grade tissue adhesive was applied to the wound. The 11.5 mm SGL tags were inserted in the abdominal cavity using a syringe and hypodermic needle. After processing, all fish were allowed to recover in buckets filled with fresh, cold stream water. Recovered fish were released into a quiet backwater pool downstream of the screw trap.

A 5-antenna PIT tag detector array was installed at Rkm 34.9 (identified as KCB (Kiwanis Camp Bridge) in the PTAGIS database (http://www.ptagis.org/ptagis/)) in June 2005. The U.S. Fish and Wildlife Service (USFWS) installed two detector arrays at Bennington Dam (Rkm 18.5) (identified as MCD in the PTAGIS database): one in the downstream low flow outlet and another in the upstream ladder. Locations of the screw trap and PIT tag detection arrays are shown in Figure 3.

To relate stream temperatures to subadult movements and habitat, we installed thermographs at the rotary screw trap, the Kiwanis and Bennington PIT tag detector arrays, and near the mouth of Blue Cr. (Rkm 27.4).

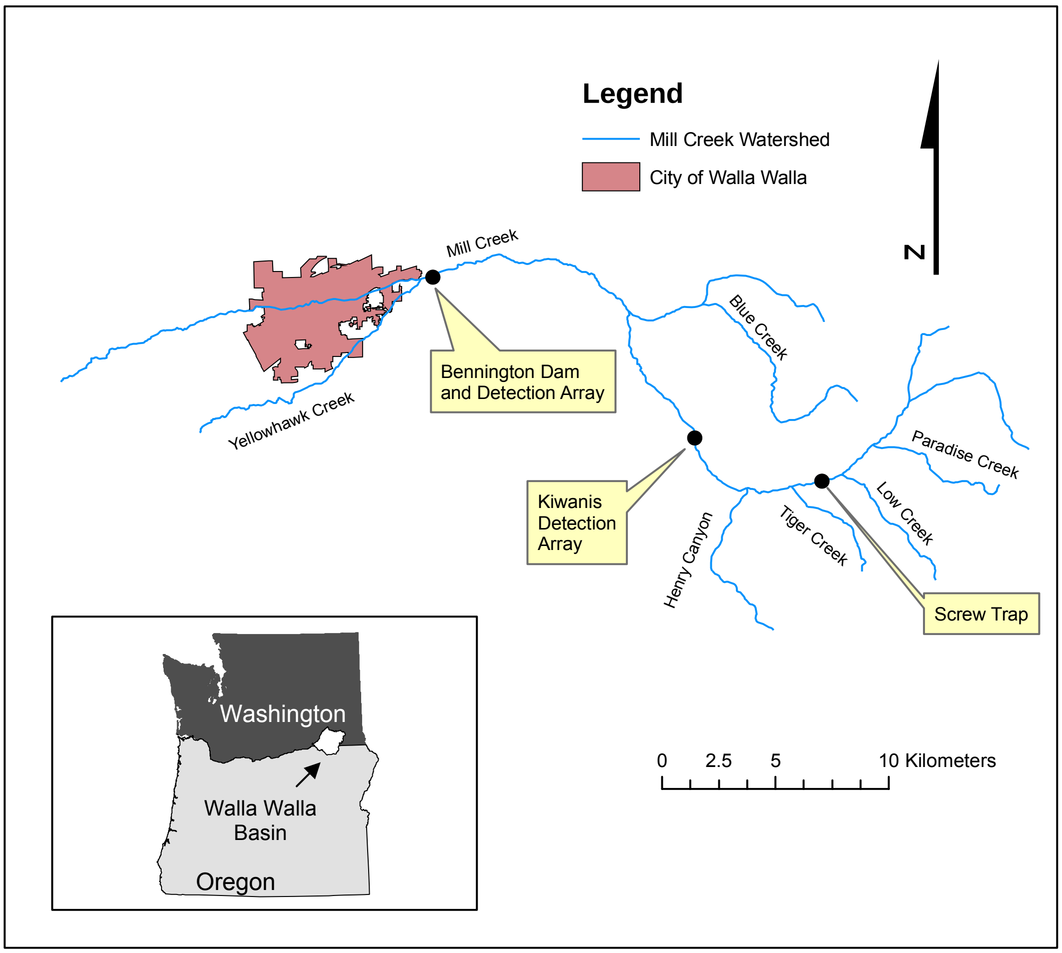

Figure 3. Map of Mill Creek showing the location of the screw trap used to capture subadult bull trout for PIT tagging and the locations of PIT tag detection arrays. Mill Creek is located in the eastern portion of the Walla Walla River Basin near the Oregon-Washington border.

Radio-tagging

Subadults captured at the screw trap were radio-tagged following the procedures described in Hemmingsen et al. (2001a). Lotek model NTC-3-2-KMF with a 12 hour duty cycle and 15 second burst rate were used. All radio-tagged fish were implanted with a 11.5 mm PIT tag. The manufacturer's estimated life of the radio transmitters was 193 days. We limited the minimum potential size range of tagged fish to 164 mm FL to keep the tag weight within a maximum of 3% of the tagged fish's body weight. This length was based on a length-weight relationship of bull trout previously trapped in Mill Creek. Locations of tagged fish were tracked weekly by vehicle and on foot. The USFWS also tracked by fixed-wing plane during July from the mouth of the Walla Walla River upstream throughout the length of Mill Creek to check for fish in locations that were inaccessible.

Summer Distribution and Abundance

Subadult bull trout distribution and abundance in lower Mill Creek was examined using night snorkeling in a systematic sample of reaches. Sampling was scheduled during late July through early August when maximum temperatures typically occur. Night snorkeling has been shown to be substantially more efficient than day snorkeling (Thurow et al. 2006), and the width and depth of some portions of lower Mill Creek limit the effectiveness of electrofishing. Night snorkeling has been used effectively in the past to capture subadult bull trout (Moore 2005). We therefore intended to capture subadults, and interrogate them for PIT tags.

Using a random starting point, potential sample sites were identified on a map at a frequency of one site per km of stream between the diversion dam and Bennington Dam. One section of Mill Creek near Bennington Dam is bordered by private ownership and was therefore not included in the sample frame. Sample reaches were designed to be 100-200 m in length. Lengths of individual reaches depended on the extent of access to private property and natural breaks between habitat unit types at the upper and lower ends of the reach. Each reach was classified into fast and slow water habitat unit types. Dimensions (thalweg length, widths at 3 transects, depths at 25%, 50%, and 75% of the width transects) of each unit were recorded. Thermographs with a 30 minute recording interval were deployed at the upper and lower ends of each reach the day prior to snorkeling to record water temperatures for the 24 hr period at the time of sampling.

Each unit was snorkeled by two divers with dive lights at night working in an upstream direction. Crepuscular periods were avoided for sampling. Counts of fish species within estimated length intervals (50 mm increments) were recorded. Divers attempted to capture all bull trout observed with hand nets. Captured bull trout were anesthetized with MS 222, measured for FL, interrogated for PIT tags, allowed to recover, and released.

Results and Discussion

Screw trap captures

From 6 March through 21 December 2006, we captured 1,760 subadult (< 300 mm) bull trout. Four untagged and 21 previously tagged adult (> 300 mm) bull trout were also captured. In addition to bull trout, we also captured two sculpin (*Cottus spp.*), two lamprey (*Lampetra spp.*), 16 rainbow trout (*Oncorhynchus mykiss*) between 50–200 mm, and two rainbow trout > 200 mm.

Subadult bull trout ranged in size from 106 to 299 mm, with a mean FL of 153 mm (SD 18) (Table 4). The trap was not fished during the month of November due to high water conditions. Peak capture of subadults occurred in August (Table 4, Figure 4). Compared with trap data collected in 2005, a marked increase in the number of out migrating subadult bull trout was observed in 2006 (Figure 4). However, it should be noted that the trap was not fished during August, 2005. The mean fork length of subadults captured in 2006 was similar to that occurring during 2005 (Figure 4).

Table 4. Length and abundance data for all subadult bull trout (< 300 mm) captured in the Mill Creek screw trap, 2006.

Month	No. Days Checked	No. Fish Captured	Fork Length (mm) Min	Max	Mean	SD
March	7	44	108	185	143	16
April	19	149	114	202	144	15
May	31	311	120	217	148	16
June	30	485	118	250	156	18
July	26	191	108	299	157	19
August	31	530	106	232	155	17
September	29	25	126	203	156	19
October	24	16	121	245	168	38
November	--	--	--	--	--	--
December	12	9	125	221	161	35
Totals	209	1,760	106	299	153	18

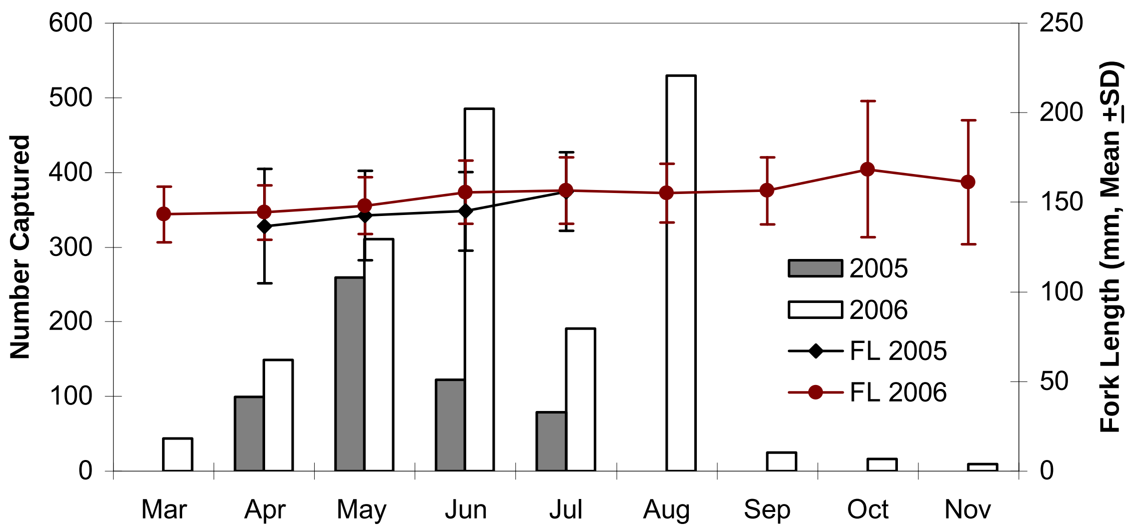

Figure 4. The number of captures (bars) and average size (lines) of subadult bull trout collected in the Mill Creek screw trap, grouped by month. In 2005, the screw trap was only fished during mid-April through July.

Of the 1,760 subadult bull trout captured in the trap, 68% (n = 1,198) were implanted with PIT tags (n = 227 with 11 mm tags, n = 971 with 23 mm tags). The mean FL of PIT tagged fish was 152 mm (SD 19). Length-frequency data for PIT tagged subadult bull are displayed in Figure 5.

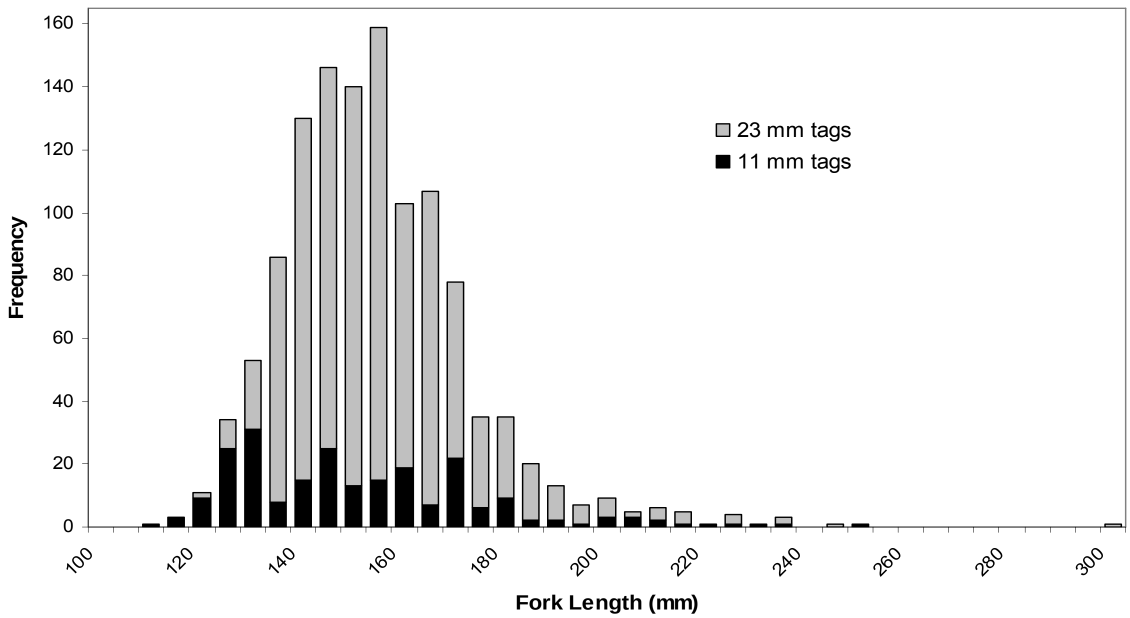

Figure 5. Length frequency distribution for subadult bull trout PIT tagged at the Mill Creek screw trap, 2006.

Movement of PIT tagged subadults

From 25 March through 27 December, 446 (37%) of the subadult bull trout PIT tagged at the screw trap during 2006 were detected by the Kiwanis antenna array (Table 5). Detection rates at the Kiwanis array did not vary appreciably between the two tag sizes. We detected 38% of the 23 mm tags versus 33% of the 11.5 mm tags. This similarity in detection rates between the two tag sizes was also observed in 2005. A Chi-squared test of independence revealed no evidence that tag size and detection rate were dependent ($p > 0.15$). This suggests that subadult bull trout stayed close to the stream bottom and consequently close to the antenna during the time they passed through the antenna field.

Of the 446 fish detected at the Kiwanis array, 31 were subsequently detected at the Bennington antenna array (Table 5). None of the fish detected at the Bennington array were detected a third time at the Kiwanis array, however nine fish were detected at the Kiwanis array twice. Additionally, there were seven detections at the Bennington array that were not detected at the Kiwanis array and two of those fish were detected more than once. With unknown detection efficiency at the instream arrays, it is difficult to draw conclusions regarding the downstream distribution of subadult bull trout; however, the large discrepancy in the number of detections at the two arrays suggests that the vast majority of these fish rear in Mill Creek upstream from Bennington Dam. Since the detection efficiency of the Kiwanis array is <100%, our results also suggest that at least 37% of subadult bull trout migrate downstream past the Kiwanis Camp for rearing.

Our results further suggest that fish migrating downstream from the Kiwanis array remain downstream of this location at least throughout mid winter. The evidence for this behavior was demonstrated by the pattern of detections at the Kiwanis array. Most detections occurred relatively soon after tagging and only nine fish were detected at the array more than once (Table 5). This finding suggests that a substantial portion of subadult bull trout may use the portion of the Mill Creek watershed downstream of their natal area for foraging and/or overwintering habitat.

Table 5. Travel time (days) between tagging site and locations first and last detected for subadult bull trout PIT tagged at the Mill Creek screw trap during 2006. Values in parenthesis are standard deviations.

Location detected	Number	Travel time 1[a]				Travel time 2[b]			
First / Last	detected	Min	Max	Median	Mean	Min	Max	Median	Mean
Kiwanis	446	0	227	5	13 (26)	-	-	-	-
Kiwanis/Kiwanis[c]	9	0	103	6	28 (42)	5	156	20	53 (60)
Kiwanis/Bennington	31	1	24	3	5 (5)	2	242	17	61 (72)
Bennington only	7	4	250	70	74 (85)	-	-	-	-

a Travel time (days) from tagging location to location first detected.
b Travel time (days) from location first detected to location last detected.
c Excludes two fish detected on two consecutive days.

In 2005, 538 subadult bull trout were implanted with PIT tags at the screw trap. Only nine of those fish were subsequently detected at the downstream antenna arrays in 2006. Two of the nine fish had been detected before in 2005, however the remaining seven fish were detected for the first time in 2006. One fish tagged on 13 June 2005 has been detected three times. It was detected for the first time at the Bennington array 348 days after being tagged, then for a second time at the Kiwanis array 59 days later, and it was last detected at the Kiwanis array 92 days after its previous detection. This movement pattern is consistent with a subadult migration downstream to Bennington Dam and a first upstream spawning migration approximately a year later.

As was observed in 2005, fish size did not appear to influence distance traveled in 2006. The average size-at-tagging for bull trout detected at Bennington Dam (distance traveled = 23.5 Rkm) was 147 mm (SD 15). The average size-at-tagging for bull trout detected at the Kiwanis array (distance traveled = 7 Rkm) was 150 mm (SD 15). Furthermore, there was no apparent relationship between size-at-tagging and travel duration for detections at either array (Figure 6).

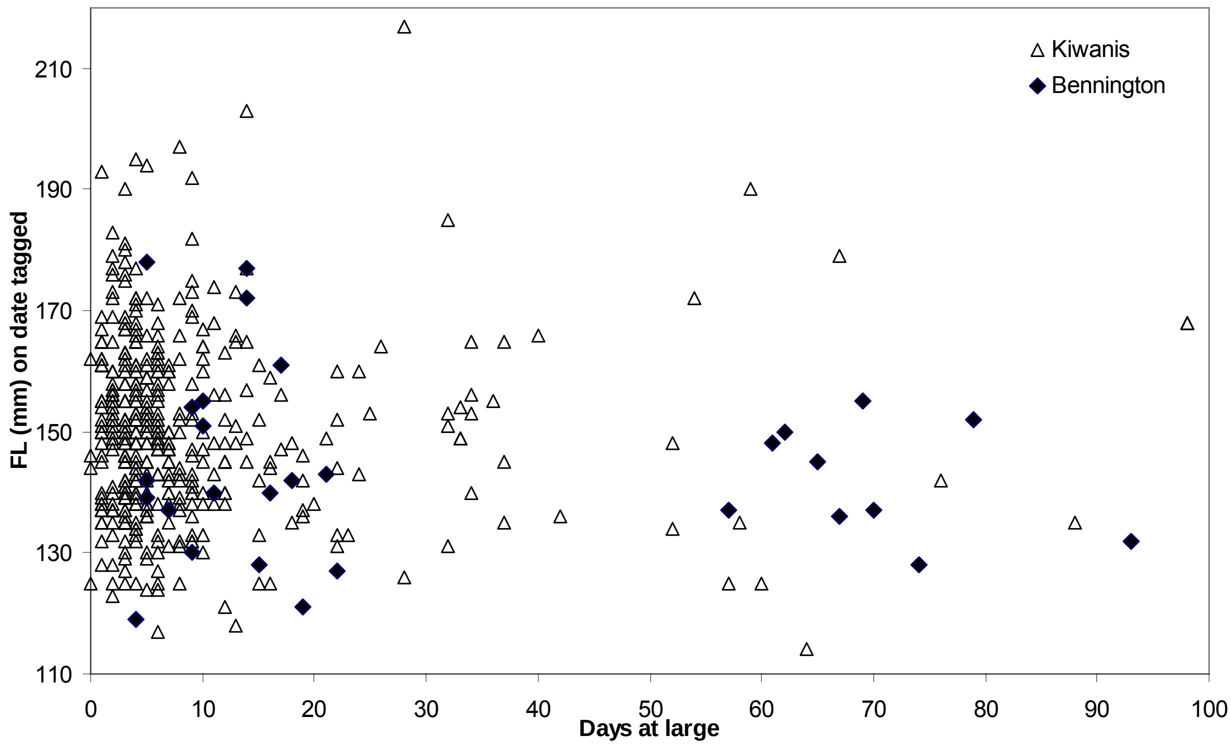

Figure 6. Fish length vs. travel time to first detection at downstream arrays for subadult bull trout PIT tagged in 2006. Fish having travel times > 100 days are not included.

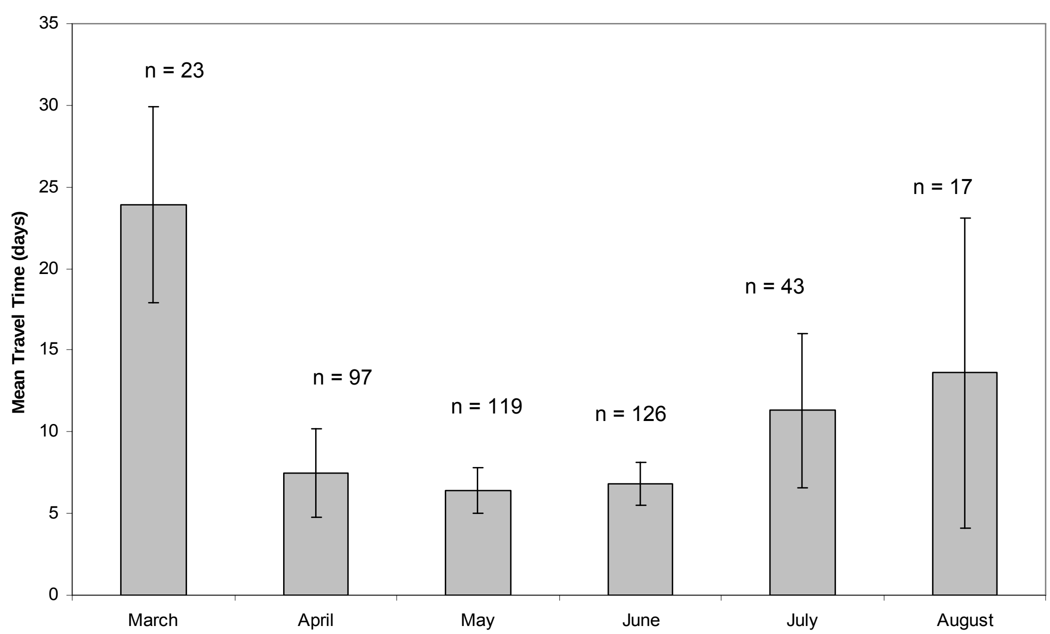

Figure 7. Mean travel time between the screw trap and the Kiwanis array for subadult bull trout PIT tagged during the months of March through August. Fish having travel times > 100 days are not included. Error bars represent 95% confidence intervals.

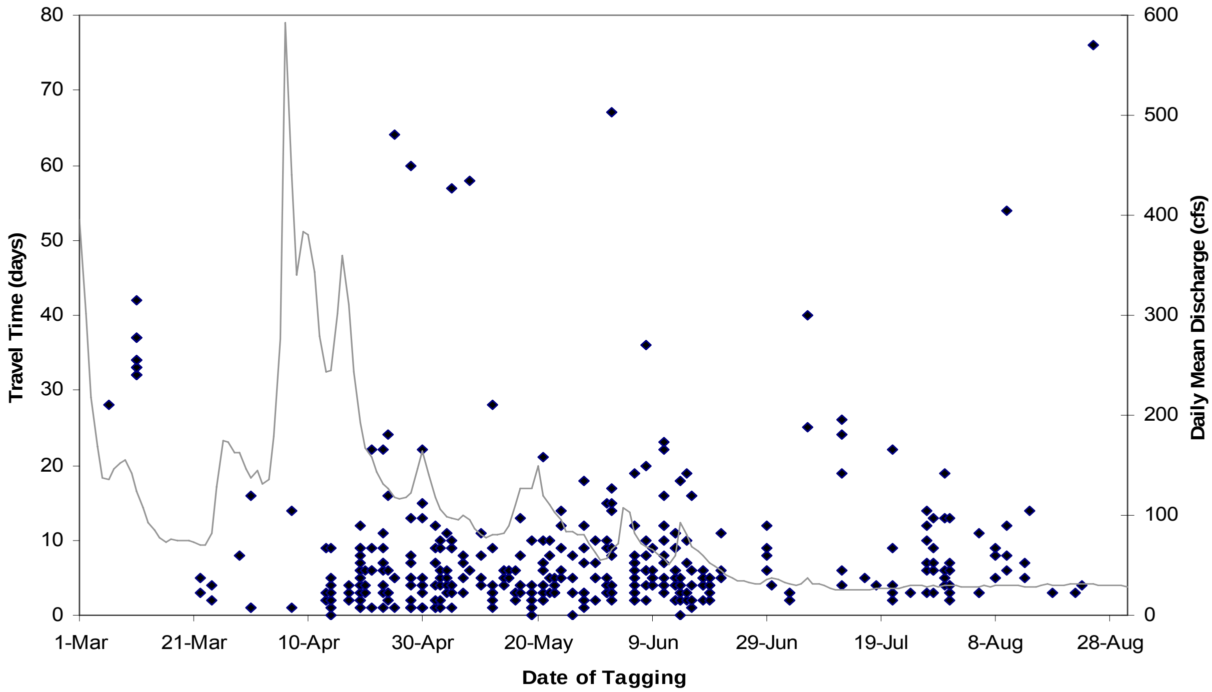

Figure 8. Relationship between date of tagging, stream discharge, and travel time between the screw trap and the Kiwanis array for subadult bull trout PIT tagged in Mill Creek, 2006. Fish having travel times > 100 days are not included. Flow data derived from USGS gauge number 14013000 near Walla Walla, WA (http://waterdata.usgs.gov/wa/nwis/current/?type=flow).

There appeared to be a relationship between the date a fish was tagged and rate of travel to the Kiwanis array. Subadult bull trout PIT tagged in April, May, and June took approximately half as long to reach the array than those tagged earlier (March) and later (July and August) in the season (Figure 7). Stream discharge could contribute to this difference. The majority of the fish tagged in April, May, and June were traveling during the descending limb of the hydrograph (Figure 8).

The 7-day average daily maximum temperature for subadult fish foraging and migration recommended by the EPA is 16 °C (EPA 2003). As was observed in 2005, daily maximum water temperature downstream of the Kiwanis array routinely exceeded 16 °C during June through August, 2006 (Figure 9). Peak summer daily maxima downstream from the Kiwanis array were 18–26 °C during mid-July through the end of August. These data, along with our findings of subadult summer distribution indicate that at least a portion of the subadult bull trout in Mill Creek encounter summer temperatures well above recommended criteria.

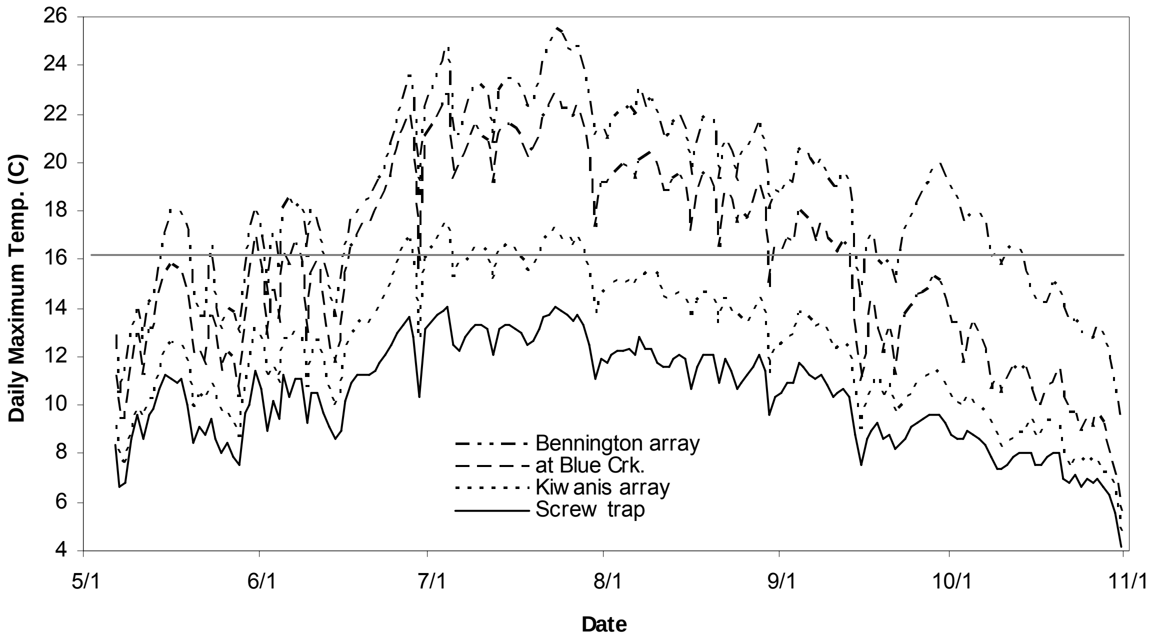

Figure 9. Daily maximum water temperatures at four sites on Mill Creek, 2006. Horizontal line shows the 7-day average daily maximum temperature for subadult fish foraging and migration recommended by the EPA.

Radio-tagging

We radio-tagged 38 bull trout (165-250 mm FL, Figure 10) from late April through early August, 2006. A range of 1 to 6 fish were tagged per week over the 16 week period.

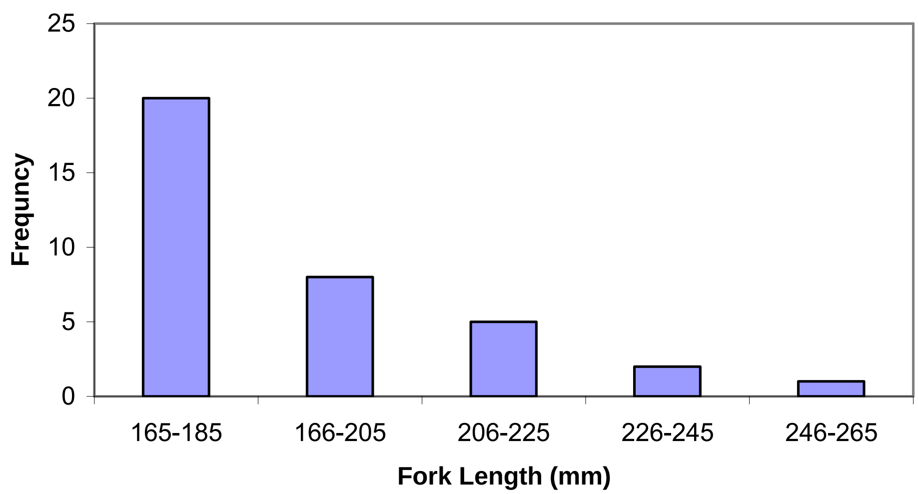

Figure 10. Frequency distribution of the lengths (FL) of bull trout radio-tagged in Mill Creek, 2006.

We found that the maximum trackable tag life of the transmitters was 190 days; however, tag life of 53% of the transmitters was less than 100 days (Table 6). Also, we located 35 of the tagged fish multiple times (2-25 detections, Table 7).

Table 6. Frequency distribution of radio tag life as measured by tracking duration for subadult bull trout radio-tagged in Mill Creek, 2006.

Days	Frequency	Cumulative %
0-10	7	18
11-25	3	26
26-50	6	42
51-75	1	45
76-100	3	53
101-125	3	61
126-150	4	71
151-175	8	92
176-200	3	100

Table 7. Frequency distribution of the number of detections of radio-tagged bull trout in Mill Creek by tracking, 2006.

Detections	Frequency	Cumulative %
0-5	15	39
6-10	4	50
11-15	8	71
16-20	6	87
21-25	5	100

During the duration of tracking, 18 tagged fish remained within 1.6 km of the tagging site. This suggests that a substantial proportion of the bull trout ≤ 250 mm trapped in the screw trap are not downstream migrants but at least initially continue to remain in the upper watershed. Because of size restrictions needed to accommodate the weight of the transmitter, radio-tagged fish represent the larger potential subadult bull trout captured in the screw trap. Thus, the fish remaining in the upper watershed are not limited to smaller, presumably younger individuals.

Sixteen radio-tagged fish migrated downstream of the diversion dam; two of these fish initially moved upstream of the trap prior to moving downstream of the diversion dam. All but one of these fish moved below the diversion dam within a month of tagging, and most reached the downstream extent of their distribution within about a week after moving below the dam (Table 8). Note: these represent maximum times due to tracking intervals and gaps in locating individual fish. The maximum downstream distribution of the radio-tagged fish below the diversion dam ranged from Rkm 18, 1 km downstream of Bennington Dam, to Rkm 38, about 3 km downstream of the diversion dam (Figure 11). Most of the fish moved within a few km upstream of the mouth of Blue Creek. None of these fish moved upstream from those locations as water temperatures increased in lower Mill Creek during the summer.

Table 8. Number of days after tagging when radio-tagged bull trout were first detected downstream of the diversion dam and additional days to their furthest downstream detection in Mill Creek, 2006.

Below diversion		Downstream location	
Days	Frequency	Days	Frequency
5-10	3	0	6
11-20	8	1-10	4
21-30	3	11-30	4
143	1	85	1

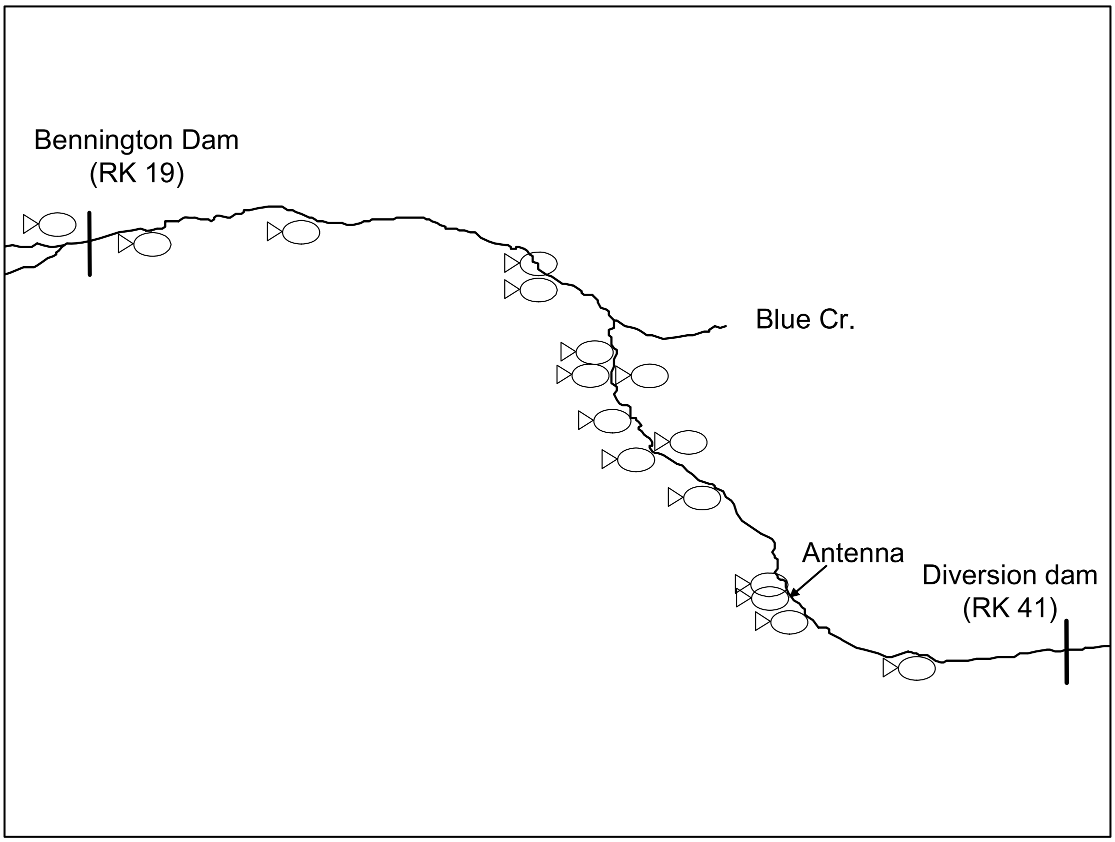

Figure 11. Extent of downstream distribution of radio-tagged bull trout below the diversion dam in Mill Creek, 2006.

Summer Distribution and Abundance

We sampled 13 reaches in the study area. In portions of Washington we were limited to approximately 1 site per 2 km and had to adjust 2 sites because of access restrictions; we were also not permitted to sample reaches adjacent to private land downstream of Rkm 24.

We observed a total of 29 subadult bull trout, of which 19 were captured and interrogated for PIT tags. Of the 19 captured fish, three were previously PIT-tagged at the screw trap in 2006. All of the PIT tag fish were captured at site 8 on 27 July. Date of tagging of the recaptured fish ranged from 11 March to 16 June and corresponding increases in size between tagging and recapture ranged from 8-57% of the length at tagging. Although the sampling efficiency of snorkeling was not estimated, the high capture ratio of fish observed suggests that subadults were highly approachable using this technique. Relative to other species of salmonids bull trout were relatively rare. Counts of juvenile chinook were generally 10-fold higher and over 1,000 juvenile steelhead/rainbow trout were observed (Table 9). These results suggest that during the summer subadult bull trout are a small fraction of the fish fauna in this portion of Mill Creek.

Table 9. Maximum daily temperatures (°C) of upper and lower thermographs at sampling sites on the day of snorkeling and numbers of salmonids encountered during night snorkel surveys in Mill Creek, 2006.

			Maximum Daily Temperature (°C)			Number (>60mm and <300mm F. L.)			
							Observed		
Site ID	Snorkel Date	Site Length (M)	Upper	Lower	Differ-ence	Captured Bull Trout	Bull Trout	Chinook	Rainbow/ Steelhead
1	26-Jul	129.5	13.5	13.6	0.1	1	0	0	10
2	25-Jul	182.1	-	14.1	-	3	1	33	66
3	26-Jul	129.0	14.7	14.7	0	0	1	3	40
4	25-Jul	198.8	15.2	15.0	-0.2	3	2	52	99
5	24-Jul	163.0	17.0	17.1	0.1	2	1	26	86
6	24-Jul	117.0	16.0	16.1	0.1	3	0	0	69
7	27-Jul	136.0	17.8	-	-	0	0	5	41
8	27-Jul	209.0	20.3	20.0	-0.3	5	0	42	98
9	26-Jul	232.0	20.8	21.0	0.3	0	1	49	114
10	1-Aug	110.0	19.5	19.4	-0.1	2	0	57	116
11	31-Jul	176.0	19.3	19.6	0.3	0	1	5	116
12	1-Aug	147.0	19.8	20.0	0.1	0	1	46	87
13	31-Jul	146.0	20.3	20.7	0.4	0	2	18	82
Total						19	10	335	1,024

Differences between the maximum temperatures recorded at the upper and lower thermographs in most of the sampling reaches were within the error of the thermographs reported by the manufacturer (±0.2°C) (Table 9). At only one site was the temperature of the lower thermograph lower (-0.3°C) than this error. Consequently, these data do not suggest that the bull trout observed were occupying reaches where ground water cooled ambient stream temperatures.

Subadult densities from upstream to downstream sites were variable despite generally increasing water temperatures (Figure 12, Table 9). However, densities averaged higher in the upper six sites than in the lower seven sites. The lower temperatures reported for the lower four sites are likely a result of sampling those sites a week later than the other sites. We maintained continuously recording thermographs throughout the spring through fall at sites 6 and 10 (Figure 12). At site 10 maximum daily temperature was 19.4°C at the time of sampling (2 August), whereas it was 22.2-22.4°C (25-28 July) the prior week when the sites upstream were sampled; maximum daily temperature at that site during the summer was 22.9°C (4 July). Similarly, at site 5 maximum daily temperature at the time of sampling was 17.1°C (25 July), whereas the following week when the lower four sites were sampled (1-2 August), the maximum daily temperature dropped to 14.9°C; maximum daily temperatures at that site during the summer was 17.7°C (4 July). Thus, the distribution of subadults at the time of sampling occurred when temperatures were comparable to their maximum summer values. These data combined with the telemetry data indicate subadults that migrate downstream more than 6 km below the diversion dam experience temperatures greater than 16°C for extended periods during most of the summer and daily maxima of 20-24°C (Moore et al. 2006). The 7-day average daily maximum temperature for subadult foraging and migration recommended by EPA is 16°C (EPA 2003).

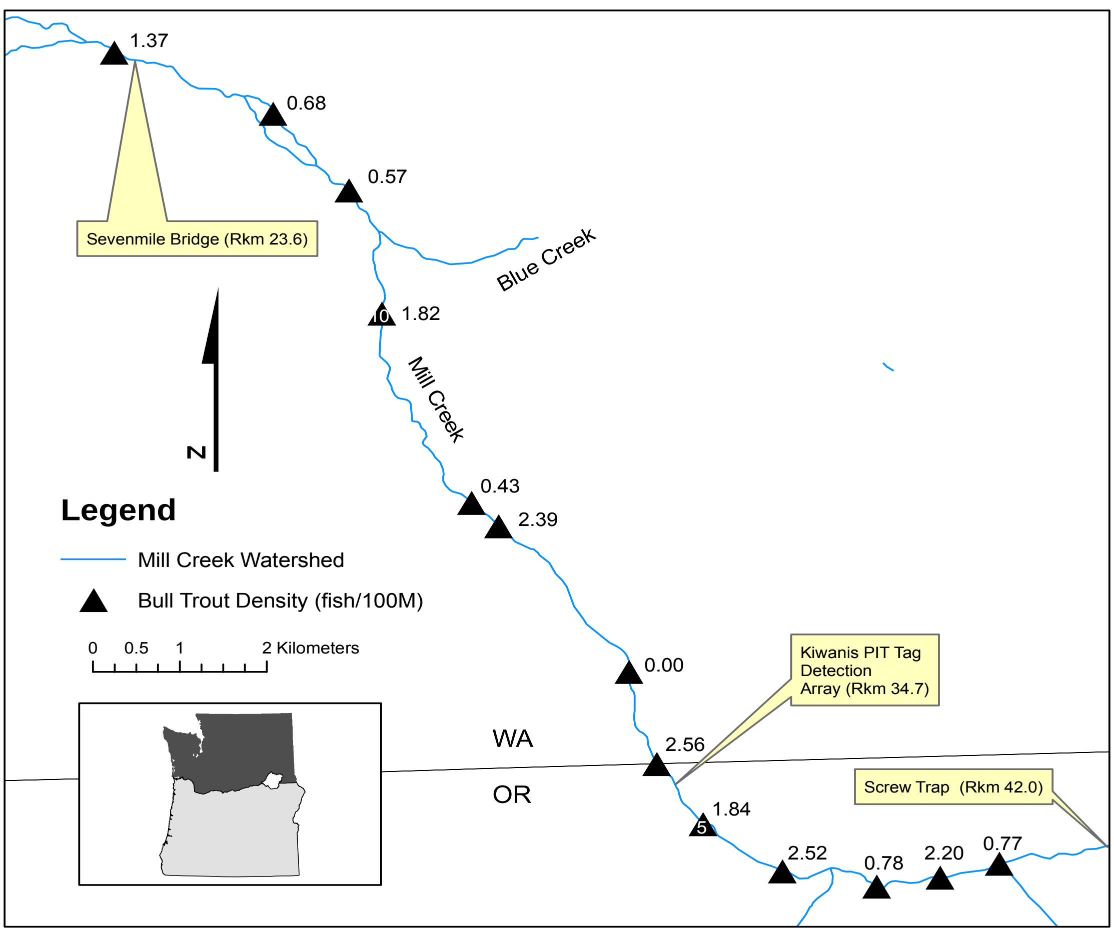

Figure 12. Locations of snorkel sites and associated subadult bull trout densities (fish/100 m) in Mill Creek during the summer of 2006. Snorkel sites 5 and 10 are labeled.

III. Analysis and Synthesis of Project Results

The intent of this objective is to progress towards scientific publications or summary reports from results of past work of this project.

A manuscript on the use of endoscopy to determine sex and maturity of small, resident forms of bull trout and other salmonids was written, submitted, and accepted for publication in *Transactions of the American Fisheries Society*. The technique was developed over the course of this project.

Swenson, E. A., A. E. Rosenberger, and P. J. Howell. In press. Validation of endoscopy for determination of maturity of small salmonids and sex of mature individuals. Transactions of the American Fisheries Society 136:994-998.

A draft manuscript for submission to a peer reviewed journal on the thermal habitat of adult bull trout in the Lostine River was prepared.

During FY 2006 project staff have worked principally on the following data sets:

- Analysis of migration patterns of fluvial bull trout from NE Oregon using radio telemetry.
- Life history of Mill Creek fluvial bull trout using PIT tags and cohort analysis-development of database and initial analysis.
- Reliability of using redd counts to monitor bull trout abundance
- Application of the EMAP sampling design to monitor bull trout through redd counts.

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