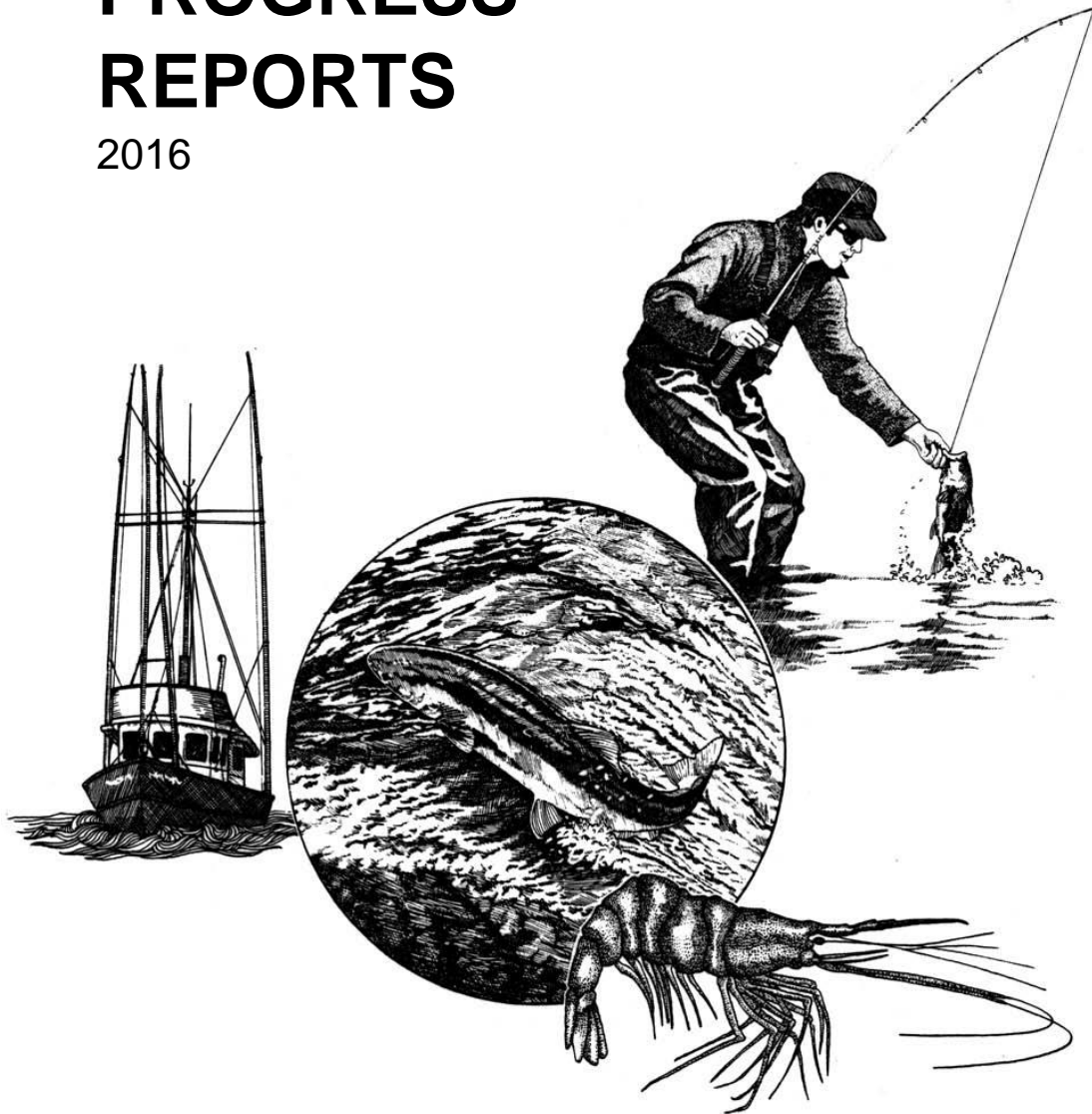


PROGRESS REPORTS

2016



FISH DIVISION **Oregon Department of Fish and Wildlife**

Clackamas River Bull Trout Reintroduction Project:
Monitoring bull trout with census redd counts and PIT tag technology, 2011-2016

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Clackamas River Bull Trout Reintroduction Project: Monitoring bull trout with census redd counts and PIT tag technology, 2011-2016

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Corvallis Research Lab, December, 2016



Abstract

Bull trout were extirpated from the Clackamas River basin by the 1960s. A reintroduction feasibility assessment and an implementation plan were completed in 2007 and 2011, respectively, with the goal of establishing a self-sustaining population of 300-500 adults in the Clackamas River basin. Phase one of the project (2011-2016) involved translocating 2,868 bull trout (80% as age-1 and 2) from the Metolius River basin, tagging each with a passive integrated transponder (PIT tag), releasing them in the upper Clackamas River basin, and monitoring them using a variety of methods. Monitoring methods included census redd counts and detection of PIT-tagged bull trout at a PIT detection site in Pinhead Creek. The number of redds observed and adult PIT-tagged bull trout (defined as age-5 and older) detected have steadily increased from 18 redds and 15 adults in 2013 to 68 redds and 72 adults in 2016. There was a strong linear relationship between the annual redd count and the number of adults detected in Pinhead Creek, suggesting that redd counts may be useful in tracking trend in adult abundance. In 2016, adults detected in Pinhead Creek were translocated mainly at age-1 and 2 (i.e., 70-210 mm), released at locations both in Pinhead Creek and the Clackamas River, and spent a median of 26 d in Pinhead Creek during the spawning period. The second phase of the project begins in 2017 and entails continued monitoring of progress toward the reintroduction goal, at least in part through census redd surveys and the use of PIT tag technology, of producing naturally-reproducing, self-sustaining population of bull trout in the Clackamas River basin.

Introduction

Bull trout (*Salvelinus confluentus*) were extirpated from the Clackamas River basin by the 1960s. A feasibility assessment (Shively et al. 2007) and an implementation plan (US Fish and Wildlife Service [USFWS] 2011) for bull trout reintroduction were completed with the goal of establishing a self-sustaining population of 300-500 adult in Clackamas River basin. The reintroduction was divided into three phases of approximately 6-7 years each (USFWS 2011). The first phase was from 2011-2016 and involved translocating 2,868 bull trout from the Metolius River basin (Table 1), giving each one a unique passive integrated transponder (PIT tag), releasing them at various locations and lifestages (80% of which were between 70-250 mm total length) in the upper Clackamas River basin, and then monitoring them using radio telemetry, PIT tags, electrofishing, and redd surveys. The second phase begins in 2017 and entails continued monitoring of progress toward the reintroduction goal, at least in part through census redd surveys and the use of PIT tag technology.

Redd surveys from 2011 to 2014 were conducted by an *ad hoc* multi-agency group of observers. In 2015 and 2016, census redd surveys were conducted by a crew of five experienced observers from the Oregon Department of Fish and Wildlife (ODFW), with additional help from other agencies and volunteers. In 2015, a long interval (44 d) between censuses may have increased uncertainty and observer error in identifying new bull trout redds and discerning them from redds constructed during a previous season or by other fall-spawning fish species such as Chinook salmon (*Oncorhynchus tshawytscha*) or coho salmon (*O. kisutch*). In 2016, the objectives were to 1) evaluate the effectiveness of a two-week interval between each census conducted throughout the potential spawning period, 2) use thermographs to refine the sampling frame and focus surveys in thermal habitat suitable for bull trout spawning, 3) examine relationships between redd counts and PIT-tagged bull trout detected in the Pinhead Creek watershed, and 4) characterize the spatial and temporal distribution of salmon spawning.

Methods

Census redd surveys

A five-person crew conducted census redd surveys in all potential bull trout spawning habitat in the upper Clackamas River and major tributary basins (Figure 1). Census surveys were generally completed every two weeks (Table 2). The first census survey was conducted in mid-August, prior to the putative start of bull trout and Chinook salmon spawning. This survey was used to familiarize the field crew with bull trout redd identification by analyzing characteristics of old redds from a previous season (i.e., redds constructed prior to August) and flagging areas that could be mistaken for new redds. A new bull trout redd was identified by its pocket-mound structure, smaller gravel size relative to substrate in Chinook salmon redds, and the contrast of brighter disturbed gravel relative to darker surrounding substrate matrix. Chinook and coho salmon redds were distinguished by larger dimensions and substrate size and by identifying the species of adult salmon occupying a redd. The crew flagged new bull trout redds and recorded the following data: GPS location, maximum length and width, species and number of adults occupying redd, and brief descriptions of observer certainty.

Table 1. PIT-tagged bull trout translocated from the Metolius River basin to the Clackamas River basin in the first phase of the reintroduction project. Lifestages were defined by the size classes 70-250 mm (juvenile), 251-450 mm (subadult), 451-650 mm (adult).

Year	Location	Lifestage			Date	
		Juvenile	Subadult	Adult	Min	Max
2011	Clackamas River	0	0	11	30-Jun	30-Jun
	Clackamas River 1	0	14	3	30-Jun	30-Jun
	Clackamas River 2	0	11	21	30-Jun	15-Jul
	Last Creek	42	0	0	30-Jun	15-Jul
	Pinhead Creek	16	0	0	21-Jul	21-Jul
	<i>2011 Subtotal</i>	<i>58</i>	<i>25</i>	<i>35</i>		
2012	Clackamas River 1	0	9	1	14-Jun	14-Jun
	Clackamas River 2	2	34	16	14-Jun	12-Jul
	Last Creek	151	0	0	3-May	28-Jun
	Pinhead Creek	364	0	0	10-May	31-May
	<i>2012 Subtotal</i>	<i>517</i>	<i>43</i>	<i>17</i>		
2013	Clackamas River	3	30	3	6-Jun	13-Jun
	Clackamas River 1	0	60	5	6-Jun	27-Jun
	Last Creek	338	0	0	11-Apr	27-Jun
	Pinhead Creek	283	0	0	2-May	30-May
	<i>2013 Subtotal</i>	<i>624</i>	<i>90</i>	<i>8</i>		
2014	Berry Creek	296	0	0	24-Apr	29-May
	Clackamas River 1	26	45	7	5-Jun	25-Jun
	<i>2014 Subtotal</i>	<i>322</i>	<i>45</i>	<i>7</i>		
2015	Berry Creek	287	1	0	10-Apr	5-Jun
	Clackamas River 1	13	73	7	15-May	5-Jun
	<i>2015 Subtotal</i>	<i>300</i>	<i>74</i>	<i>7</i>		
2016	Clackamas River 1	95	94	6	20-May	13-Jun
	Clackamas River 5	501	0	0	8-Apr	13-May
	<i>2016 Subtotal</i>	<i>596</i>	<i>94</i>	<i>6</i>		
	<i>Total</i>	<i>2417</i>	<i>371</i>	<i>80</i>		
	<i>Grand total</i>		<i>2868</i>			

Salmon redds generally were not treated individually, except in Pinhead Creek and Last Creek, where they were treated like bull trout redds. Elsewhere, the crew usually recorded the number of salmon redds tallied over 100-300 m survey sections and a GPS location for each section mid-point.

Bull trout and salmon redd data were entered in an Access database that contains data from previous bull trout spawning surveys in the upper Clackamas River basin. Each year spawning surveyors recorded observations of some bull trout redds described as “potential”, “possible”, “likely”, “test dig?” or some other variant registering uncertainty in their observations; these descriptions were included in the database. In 2015 and 2016, observers were trained to include a

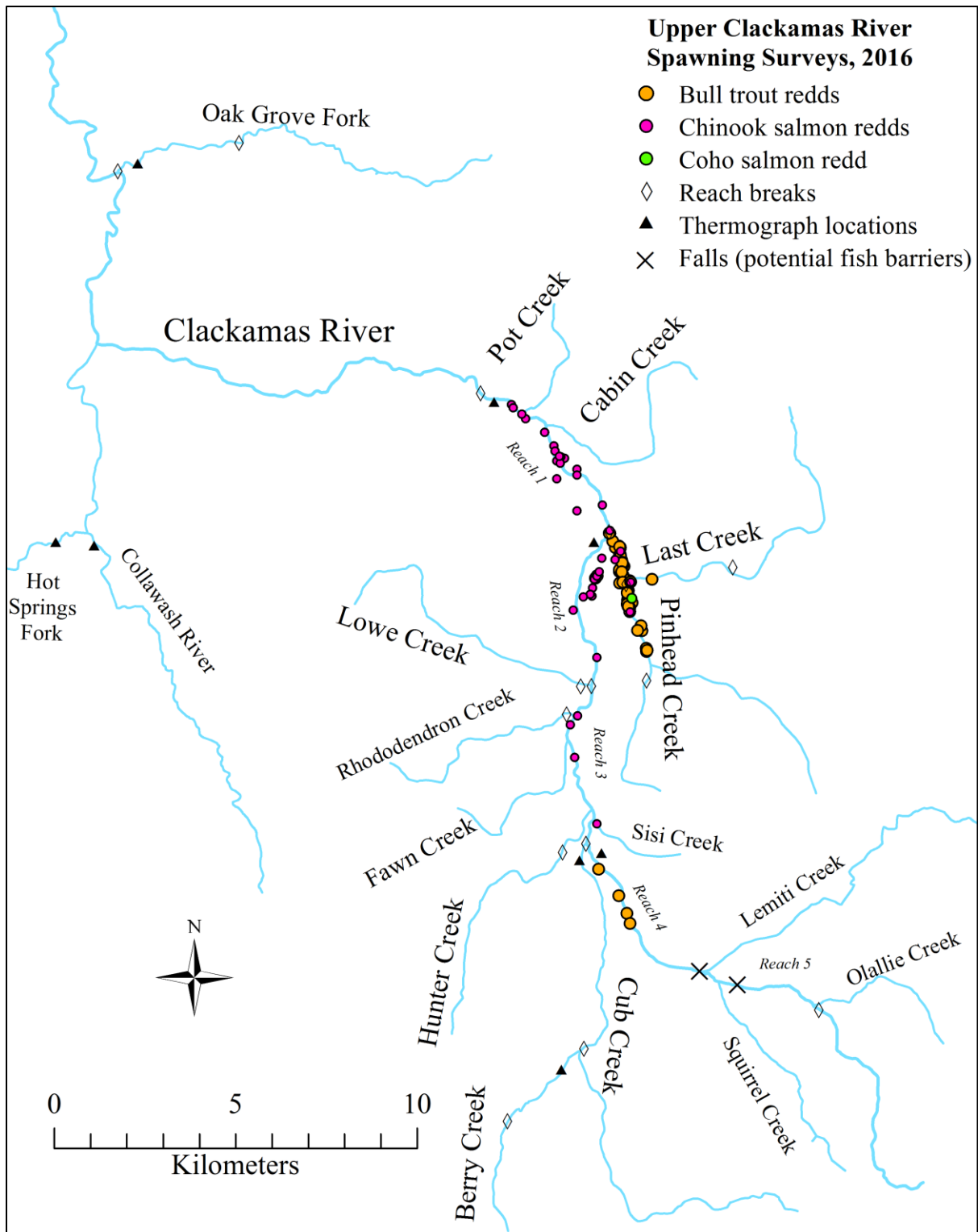


Figure 1. Survey extent, potential natural fish barriers, and salmon and bull trout redds observed during census redd surveys in the upper Clackamas River basin. Each bull trout and coho salmon marker represents a single observed redd. Chinook salmon redds were not individually georeferenced, thus an individual Chinook marker may represent multiple redds (range, 1-30 redds) counted over a survey extent (range, 100-200m). Secondary channels are not shown and redd markers have not been snapped to the stream line.

Table 2. Census survey schedule and reaches and the number of bull trout redds counted in each census. Some reaches were not surveyed (NS) in each census.

Reach	Census					
	1	2	3	4	5	6
Clackamas River 1	18-Aug	30-Aug	13-Sep	27-Sep	NS	NS
Clackamas River 2	16-Aug	1-Sep	15-Sep	28-Sep	12-Oct	NS
Lowe Creek	16-Aug	1-Sep	15-Sep	28-Sep	12-Oct	NS
Clackamas River 3	16-Aug	NS	15-Sep	28-Sep	12-Oct	NS
Hunter Creek	16-Aug	NS	15-Sep	28-Sep	12-Oct	NS
Rhododendron Cr.	16-Aug	NS	15-Sep	28-Sep	12-Oct	NS
Clackamas River 4	15-Aug	31-Aug	14-Sep	29-Sep	12-Oct	NS
Pinhead Creek 1	17-Aug	29-Aug	12-Sep	26-Sep	12-Oct	26-Oct
Pinhead Creek 2	17-Aug	29-Aug	12-Sep	26-Sep	12-Oct	26-Oct
Last Creek	17-Aug	29-Aug	12-Sep	26-Sep	12-Oct	26-Oct
Cub Creek	15-Aug	NS	14-Sep	NS	NS	26-Oct
Berry Creek	15-Aug	NS	14-Sep	29-Sep	NS	26-Oct
Oak Grove Fork	18-Aug	30-Aug	13-Sep	27-Sep	NS	NS
Total bull trout redds	0	6	16	24	14	8

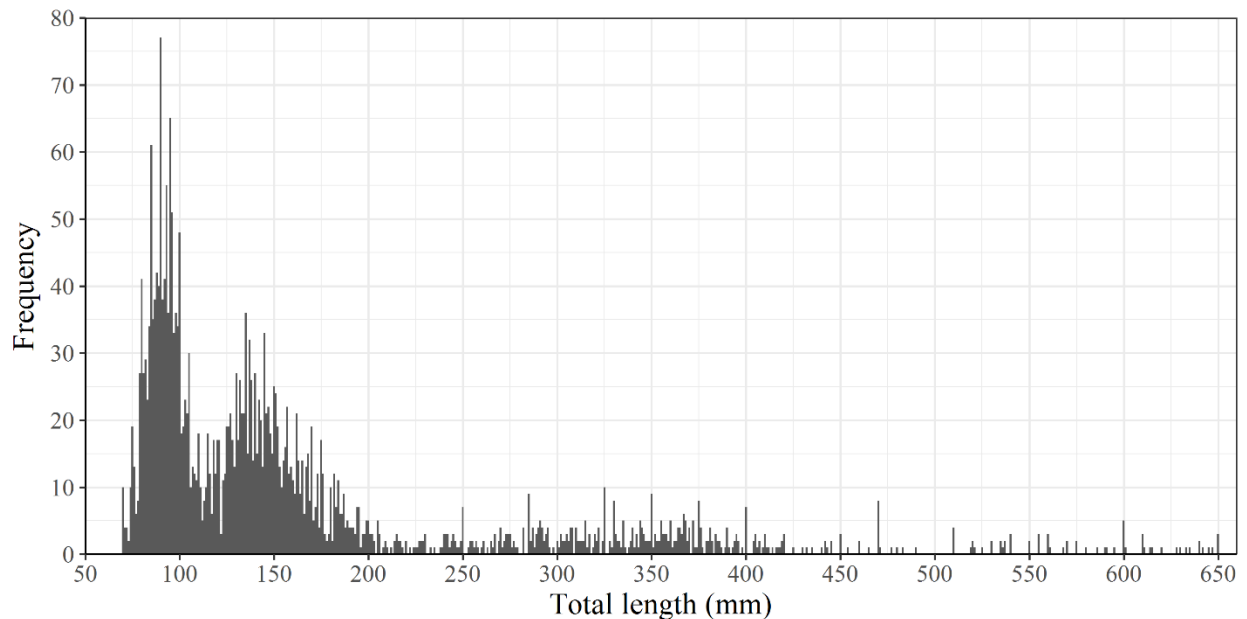


Figure 2. Length-frequency histogram of bull trout captured in the Metolius River basin, PIT-tagged, and translocated to the upper Clackamas River basin, 2011-2016.

brief description of their certainty in each new redd identified and the reason for their uncertainty. These descriptions were entered as a variable in the database. Differing from previous years, only redds identified with descriptors connoting high certainty or likelihood were included in the 2016 count. (See Appendix I for dataset from 2016.)

Stream temperature

Digital temperature data loggers (Onset™ Hobo Water Temp Pro v2 U-22), or thermographs, set to record stream temperature every 30 minutes, were deployed in 8 locations in the upper Clackamas River on August 18 and recovered on October 10 (Figure 1). Thermographs were successfully recovered from Hot Spring Fork, Collawash River, Clackamas River (Reaches 1, 2, and 4), Cub Creek, and Berry Creek. The thermograph in Oak Grove Fork was not found.

Pinhead Creek monitoring

In the first phase of the reintroduction, bull trout translocated from the Metolius River basin and released in the Clackamas River basin were given PIT tags and a 4-antenna PIT tag array was maintained in Pinhead Creek, near its confluence with the Clackamas River, usually from June through November. The PIT detection site and database are maintained by the USFWS. PIT tag detections in Pinhead Creek were used to describe the annual number, duration, timing, lifestage-at-release, and release location of PIT-tagged bull trout present in Pinhead Creek during the spawning season.

As a relative measure of annual adult bull trout abundance, bull trout age-5 and older (hereafter referred to as “adults”) detected at the PIT array were counted by year. This age cutoff was used because migratory bull trout in the Metolius River basin are thought to begin to mature at age-5 (Ratliff et al. 1996), which is similar to bull trout populations in other basins. For example, a study in the Lake Pend Oreille basin showed that at least 50% of age-5 bull trout had reached adulthood (McCubbins et al. 2016). In a study in the Flathead Lake basin, bull trout first matured at age-5 and all individuals age-6 and older were mature (Fraley and Sheppard 1989). Age-1 through age-4 bull trout detected at the PIT array were also counted to show use of Pinhead Creek by immature fish and the potential presence of potentially mature younger fish. To get an annual adult count, age-class at release of PIT-tagged fish and at detection in Pinhead Creek were approximated. Age-class at release was approximated for age-1 and age-2 fish based on a length-frequency histogram of translocated fish (Figure 2) and length-at-age studies of bull trout throughout their range for older fish (Fraley and Sheppard 1989, Ratliff et al. 1996, see Table 2 of Salow 2004). Bull trout ages were approximated as follows: age-1, 70-115 mm; age-2, 116-210 mm; age-3, 211-320 mm; age-4, 321-400 mm; and age-5 and older, >400 mm. Age-class at detection was estimated by summing age-class at release and the interval between the date of release and detection in Pinhead Creek. For example, to estimate the annual number of PIT-tagged bull trout age-5 or older detected in Pinhead Creek, the following detection intervals were used: >1,360 d (i.e., 3 yr and 265 d) for age-1 at release, >995 d for age-2, >630 d for age-3, >265 d for age-4, and >0 d for age-5 and older.

Simple linear regression was used to assess the relationship of the annual number of adult PIT-tagged bull trout detected in Pinhead Creek, the response variable (Y), and the total annual count of bull trout redds in Pinhead and Last creeks, the explanatory variable (X), from 2011-2016 (Ramsey and Schafer 1997). The simple linear regression model used is as follows: $\mu\{Y|X\} = \beta_0 + \beta_1 X$. The parameter β_0 is the y-intercept of the line. The parameter β_1 represents the slope of the line.

Duration of detection of PIT-tagged adult bull trout in Pinhead Creek was calculated as the number of days between the first detection and last detection of each fish in a monitoring season. This was summarized by year using median, maximum, and minimum duration, excluding individuals detected for ≤ 1 d. This exclusion attempted to reduce, likely without eliminating, the influence of short-term non-spawning use on the estimated timing of adult use in Pinhead Creek. Timing of adult use of Pinhead Creek was represented by boxplots of first and last detections of individuals during the monitoring season. The annual adult count was displayed by the lifestage at which these fish were released and by their release location. Lifestage was defined in the PIT tag database by the following categories: juvenile, 70-250 mm; subadult, 251-450 mm; and adult, 451-650 mm.

Results and Discussion

Census redd surveys

In 2016 census redd surveys, 68 bull trout redds were counted in the upper Clackamas River basin (Figure 1, Table 3, Appendix I). This was a 15% increase compared to the number of redds counted in 2015 and an 84% increase compared the redd count in 2014. Similar to previous years, most of the redds were observed in the Pinhead Creek watershed (N=62, Figure 3). The redd count in Pinhead Creek and Last Creek in 2016 exceeded the count in 2015 by 45% (Table 4). Bull trout redds were also observed in reach 2 (Figure 3) and reach 4 (Figure 1) of the Clackamas River. The first bull trout redds were observed in late August, the highest number of new redds were observed in late September census survey, and new redds were observed during the last survey on October 26 (Table 2). Bull trout were seen actively spawning on or occupying three redds. Bull trout redds were distinguished from salmon redds mainly by their dimensions. Chinook and coho salmon redds were on average more than 6 and 4 times larger in area, respectively, than bull trout redds.

Chinook redds were highly abundant in reaches 1 and 2, and present in lower numbers in reach 3, of the Clackamas River (Figure 1). The crew observed three Chinook redds in Pinhead Creek, two of which were occupied by Chinook salmon; a single occupied Chinook redd in Last Creek; and an occupied coho salmon redd in the upper section of Pinhead Creek (Figure 3). The spawning timing of Chinook salmon was the same as bull trout, with the first Chinook redds noted in late August and occupied redds noted during the last survey. The occupied coho redd was recorded during the last survey on October 26.

The temporal and spatial overlap of bull trout and salmon spawning poses challenges to monitoring bull trout abundance with census redd counts. The main challenge is the bull trout redd count could be confounded by a number of factors; some examples include salmon test digs the size of bull

trout redds, small salmon redds counted as large bull trout redds (or vice versa), redd superimposition by salmon may obscure bull trout redds, and higher observer error-rates (depending on variation in observer experience and skill) because observers will be asked to discern redds of multiple salmonid species. This challenge appears to be more acute in reach 1 and 2 of the Clackamas River, where Chinook spawning is highly abundant, than in Pinhead Creek where only five salmon redds were identified. In 2016, census surveys were completed every two weeks throughout the spawning period (August through October), which was more frequent than previous survey intervals. This relatively short interval likely reduced observer uncertainty and error in identifying bull trout redds by increasing the probability of seeing salmon occupying their redds. In 2015, a longer interval led to ambiguity in distinguishing between new redds and some old redds (Starceovich and Clements 2015). This shorter interval likely decreased ambiguity by allowing surveyors to encounter redds sooner after, or during, their construction when redds appear more visible and in higher contrast to undisturbed sediment and redds from a previous season.

Table 3. Bull trout redds counted during census surveys in the upper Clackamas River basin, 2011-2016. In certain years, some stream reaches were not surveyed (NS).

Stream	Reach	Redd count						Reach description
		2011	2012	2013	2014	2015	2016	
Pinhead Creek	1	3	9	10	21	13	34	Mouth to Last Cr.
Pinhead Creek	2	2	5	2	14	34	25	Last Cr. to FS140 Road
Last Creek	1	0	2	3	2	0	3	Mouth to Camp Cr.
Clackamas River	1	NS	NS	NS	NS	2	0	Big Bottom to Pinhead Cr.
Clackamas River	2	NS	NS	NS	NS	5	2	Pinhead Cr. to Lowe Cr.
Clackamas River	3	NS	NS	NS	NS	2	0	Lowe Cr. to Cub Cr.
Clackamas River	4	NS	NS	1	NS	2	4	Cub Cr. to First falls
Clackamas River	5	NS	NS	NS	NS	0	NS	First falls to Ollalie Cr.
Oak Grove Fork	1	NS	NS	2	NS	1	0	First 2.5 km
Lowe Creek	1	NS	NS	NS	NS	0	0	First 1 km
Rhododendron Cr.	1	NS	NS	NS	NS	0	0	First 1 km
Hunter Creek	1	NS	NS	NS	NS	0	0	First 1.5 km
Cub Creek	1	NS	NS	NS	NS	0	0	Mouth to Berry Cr.
Cub Creek	2	NS	NS	NS	NS	0	NS	2.5 km up from Berry Cr.
Berry Creek	1	NS	NS	NS	NS	0	0	First 3 km
TOTAL		5	16	18	37	59	68	

Stream temperature

Bull trout are thought to begin spawning as stream temperature drops below 9°C (see Pratt 1992). This temperature threshold can be used to assess when and where there is potential for bull trout spawning in individual reaches of the sampling frame. In 2015, stream temperature was measured and recorded at the start and end of each survey. These data showed that Pinhead Creek, Last Creek, and reaches 1, 4, and 5 of the Clackamas River were below 9°C throughout the bull trout spawning season. Other reaches were near or exceeded the 9°C threshold during the spawning season. In 2016, thermographs were deployed in several of these borderline survey reaches to gain continuous temperature data and better assess these reaches as suitable spawning habitat (Figure 4). These temperature profiles showed that Hot Spring Fork and the Collawash River, based on the 9°C threshold, likely would be too warm for spawning during the spawning period. Reaches 1 and 2 of the Clackamas River, Cub Creek, and Berry Creek did not reach 9°C until early to mid-September and then bordered and occasionally exceeded the threshold during the remainder of the spawning period. Although maximum and minimum temperature thresholds are not known for bull trout spawning, these temperature profiles suggest that currently these reaches may not be ideal spawning habitat every year and climate warming scenarios suggest that borderline areas like these reaches may become even less thermally suitable in the near future (Rieman et al. 2007, Ruesch et al. 2012, Jones et al. 2014). Cub Creek and Berry Creek also have relatively few patches of spawning gravel (personal observation), which further reduces their relative potential to support bull trout reproduction. Reach 4 of the Clackamas River was below 9°C during the spawning period and four bull trout redds were counted; however, it is relatively high gradient and limited in spawning gravel availability (personal observation). The production of a more detailed thermal habitat map and a predictive stream temperature model of the upper Clackamas River basin are recommended to understand better how the current distribution and availability of thermal habitat may be influencing reintroduction progress and how a warming climate may affect future availability of suitable thermal habitat in this basin and region.

Table 4. Census survey redd counts in relation to the number of PIT-tagged adult bull trout detected in the Pinhead Creek watershed and the estimated duration each PIT-tagged adult spent in this watershed basin. Adulthood was defined as fish estimated to be \geq age-5. Duration was defined as the number of days between the first and last detection at the PIT array in Pinhead Creek.

Census survey		Tagged adult bull trout	Duration (d)		
Year	Redds		Median	Max	Min
2011	5	17	26	78	3
2012	16	17	35	55	12
2013	15	15	25	68	3
2014	37	32	22	93	3
2015	47	53	18	87	2
2016	62	72	26	88	3

Table 5. Age-class and release location of all PIT-tagged bull trout detected in Pinhead Creek during the spawning season. Age-class was approximated from their age-class at release and the number of days between their release and detection dates (see text for more details).

Year	Age (yr)					Release location				
	≥5	4	3	2	1	Lower Clackamas	Clackamas Reach 1	Pinhead/Last creeks	Clackamas Reach 2	Berry Creek
2011	17	1	2	8	7	5	2	11	11	0
2012	17	2	3	2	8	1	2	13	15	0
2013	15	1	16	276	17	0	2	205	11	0
2014	32	12	21	2	8	5	14	38	9	1
2015	53	32	2	2	10	9	30	41	5	5
2016	72	5	2	0	5	0	29	44	2	4

Pinhead Creek monitoring

The number of adult PIT-tagged bull trout using Pinhead Creek during the spawning season has steadily increased from 15 adults in 2013 to 72 in 2016 (Table 4). The adult count is a subset of the total count of PIT-tagged bull trout detected in Pinhead Creek that also includes fish age-1 through age-4 (Table 5). The total count suggests that bull trout may be using Pinhead Creek watershed for spawning prior to age-5 and for reasons other than spawning, such as juvenile rearing and subadult foraging or thermoregulation.

There was a strong linear relationship ($y=1.3x+3.2$, $R\text{-squared}=0.92$, $P\text{-value}=0.002$) between the annual redd count (x) and the number of adults detected (y) in Pinhead Creek (Figure 5). This suggests that redd counts, which were conducted by experienced surveyors familiar with bull trout and salmon spawning surveys in this basin and region, may be useful in estimating the abundance of adult bull trout in the Pinhead Creek watershed. The linear model shows an almost 1:1 relationship between adults detected and redds counted ($\beta=1.03$). More survey effort in census redd counts did not affect this ratio. Even though census redd surveys in 2016 were conducted much more often than in 2015, the adult to redd ratio was similar in both years (1.12 in 2015 and 1.16 in 2016). This adult to redd ratio is low relative to those of other bull trout populations (see Howell and Sankovich 2012) and may be the result of overestimating redd abundance or underestimating adult abundance. It is possible that some of the redds counted may not be actual bull trout redds; for example, the count may include test digs or, despite efforts to limit these sources of error, redds from a previous season or constructed by salmon. There likely has been some tag loss in translocated fish that have reached adulthood (Meyer et al. 2011). In 2011, the first year of translocations, five redds were counted in Pinhead Creek. Recruits from these redds would be age-5 this season, which is the age at which a proportion of Metolius River bull trout first mature (Ratliff et al. 1996), and these recruits may be undetected members of the adult population. Locally spawned bull trout recruiting to adulthood in Pinhead Creek will increasingly affect this ratio in succeeding years; however, local progeny were not detected during recent electrofishing and minnow-trapping efforts (Brian Davis, USFWS, personal communication). As 2016 is expected to be the last year of translocating PIT-tagged bull trout, the proportion of PIT-tagged bull trout in the spawning population will shrink over time as locally spawned fish enter

the adult population and PIT-tagged adults die. As this process occurs, a new method of calibrating adult abundance to redd counts will be needed.

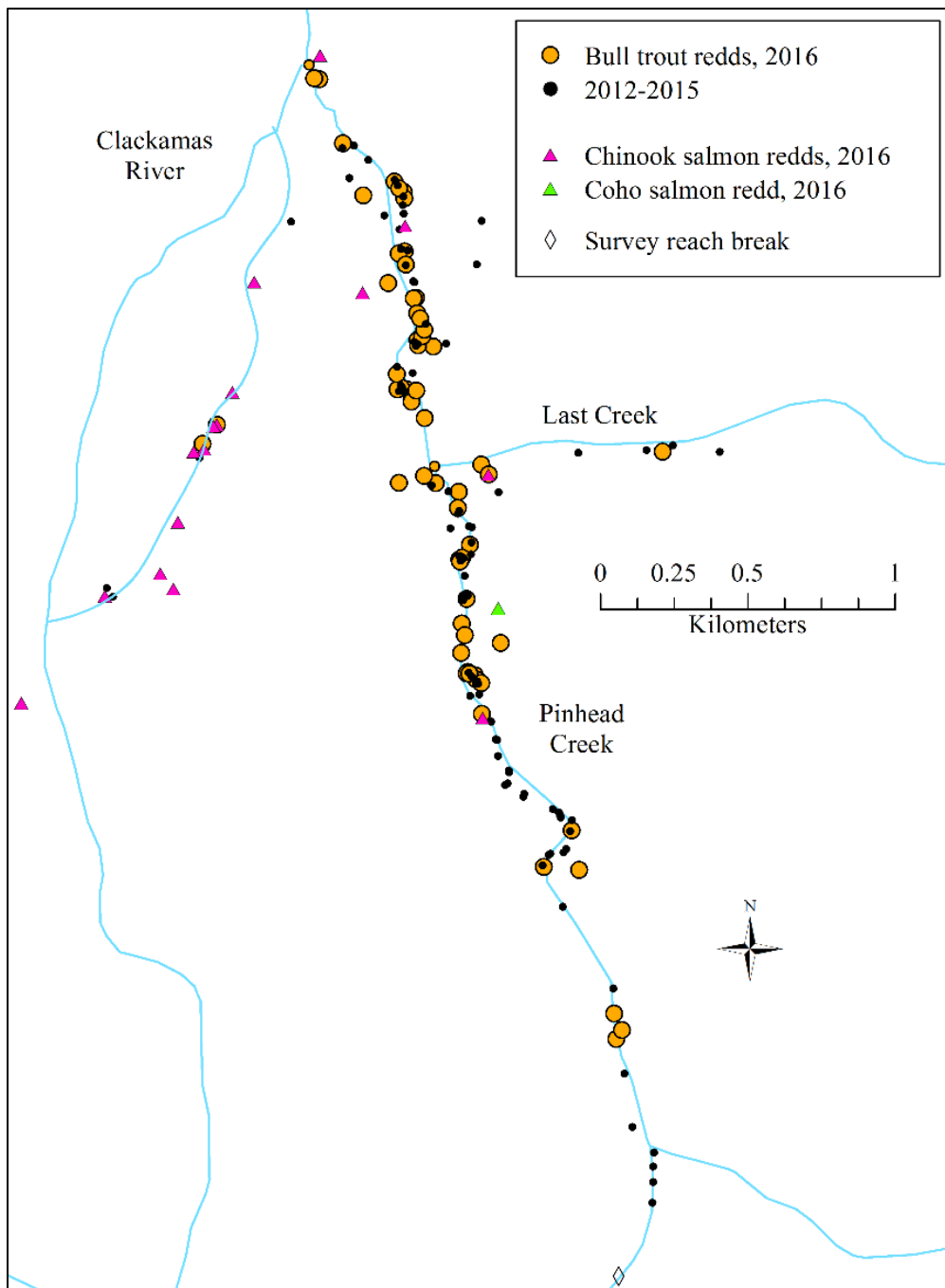


Figure 3. Georeferenced redds in Pinhead Creek, Last Creek, and Reach 2 of the Clackamas River. Each bull trout marker represents a single observed redd. Each Chinook and coho salmon marker represents a single observed redd on Pinhead and Last creeks. In Reach 2 of the Clackamas River, a Chinook marker represent 1 to 15 redds (median, 5). Most secondary channels are not shown and redd markers have not been snapped to the stream line.

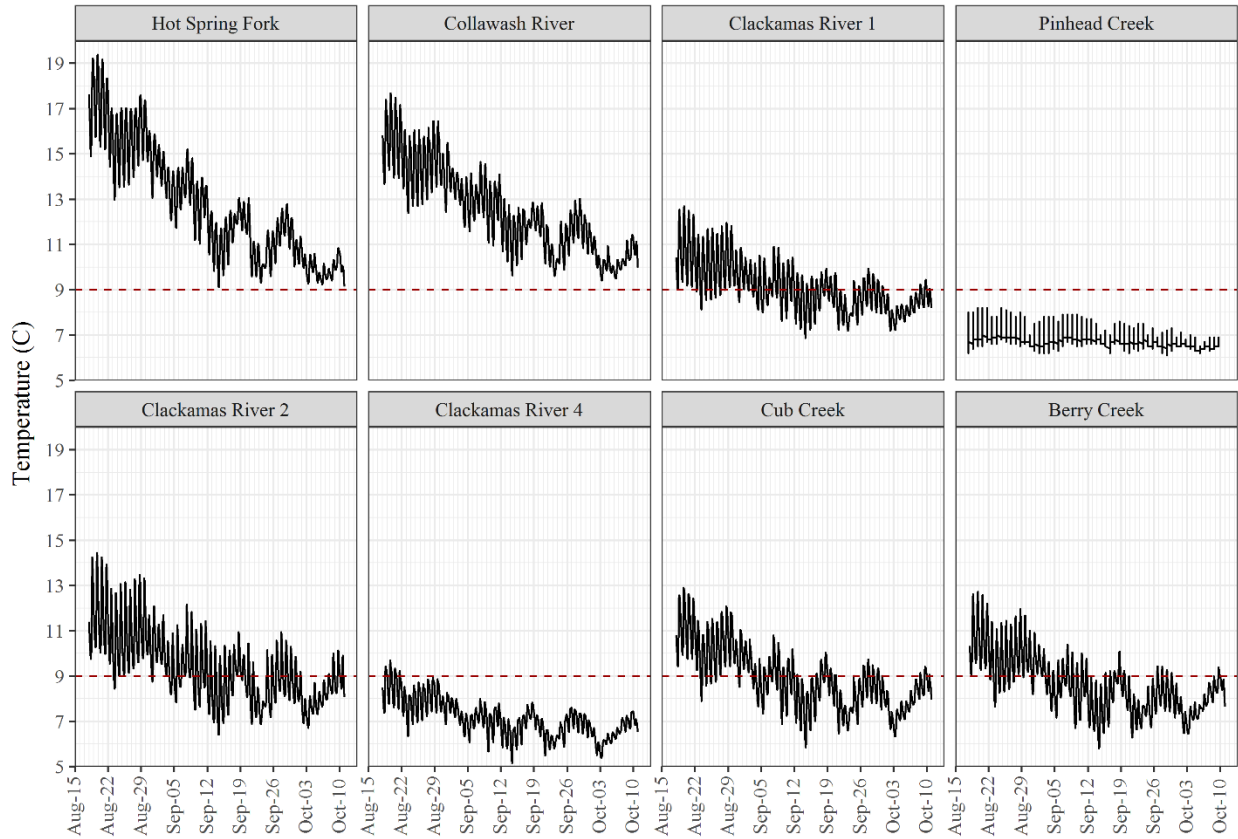


Figure 4. Stream temperatures recorded during bull trout spawning surveys in the upper Clackamas River basin, August 18 to October 10, 2016. Temperature data for Pinhead Creek are from 2011. Red dotted line represents the 9°C threshold considered to be the temperature below which bull trout begin spawning.

The lifestage at which PIT-tagged bull trout were released in the upper Clackamas River basin and subsequently detected at the Pinhead Creek PIT detection site during the spawning season as adults shifted from mostly adult in 2011-2012, to mostly subadult by 2015, and to mostly juvenile by 2016 (Figure 6). The release location of PIT-tagged bull trout (all ages) detected at Pinhead has shifted from mainly the Clackamas River to Pinhead Creek and Last Creek in 2016 and includes fish released as far away as Berry Creek (Table 5). These data show that at least some translocated juveniles and subadults are surviving to adulthood and either returning near their release locations in the Pinhead Creek watershed during the spawning season or finding and using Pinhead Creek during the spawning season even if released in the Clackamas River.

In each year, most PIT-tagged adults were first detected in Pinhead Creek in August and last detected in mid-October (Figure 7), which corresponds to the spawning season seen during redd surveys. It is assumed that adults with detection duration >1 d entered Pinhead Creek to spawn because a high percentage of bull trout redds were observed in this watershed. Based on the detection duration during individual year, adults generally spend 18-35 d in Pinhead Creek during the spawning season (Table 4). This timing information suggests that bull trout have likely completed spawning by mid-October; although, in 2016, eight bull trout redds were counted on

October 26. Adults have been detected in Pinhead Creek as late as November 17; in 2016, the last detection was October 31. This suggest that bull trout could be spawning in the second half of October in Pinhead Creek and may account for at least some of these redds counted during the last survey. It is possible that these redds were constructed by bull trout without PIT tags. Alternatively, these redds may have been missed during previous surveys. These redds were unlikely to be salmon redds because of their relatively small size. PIT tag detection timing at Pinhead Creek provides an approximation of when bull trout are using Pinhead Creek and the Clackamas River and could be useful in designing redd monitoring schedules, training, and protocols that minimize errors in identifying bull trout redds.

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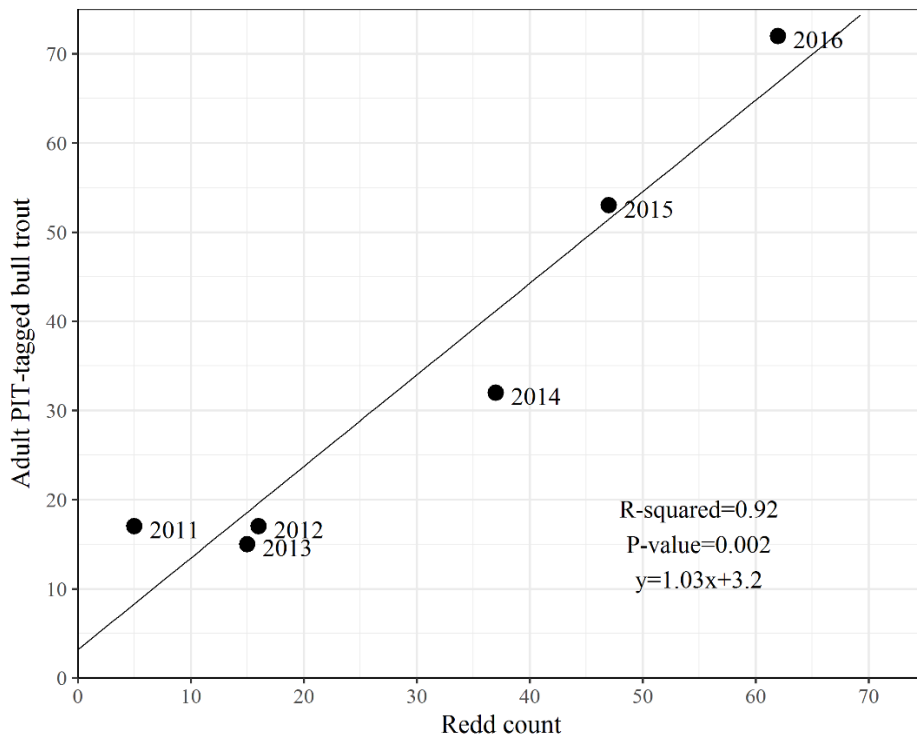


Figure 5. Annual number of adult PIT-tagged bull trout (i.e., age-5 and older) detected in Pinhead Creek during the spawning period as a function of the annual bull trout redd count in Pinhead Creek and Last Creek.

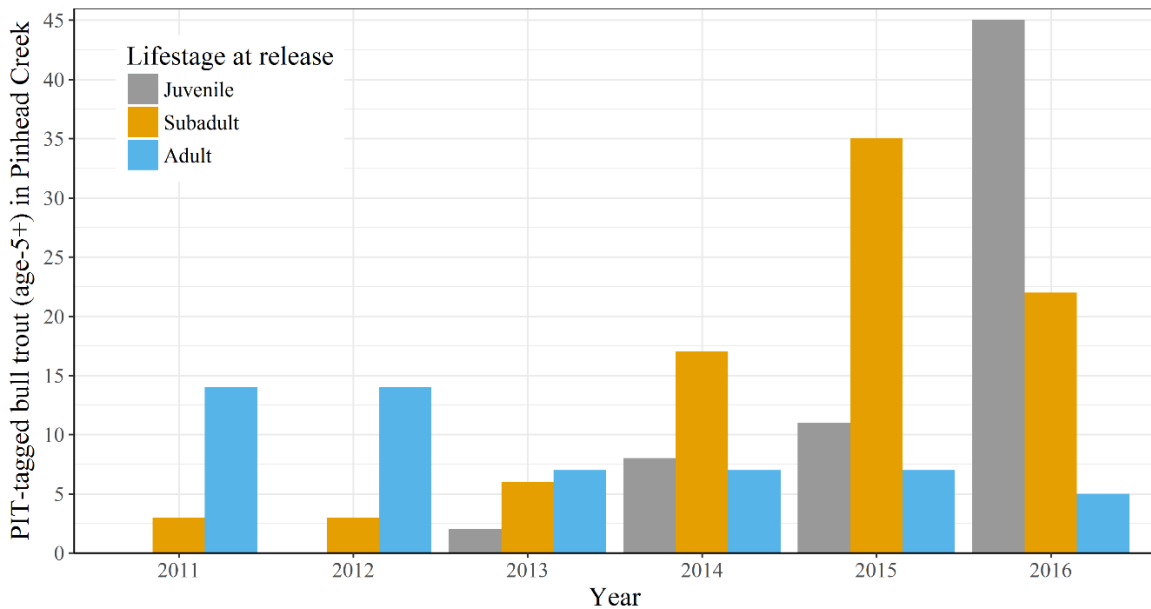


Figure 6. Lifestage at which PIT-tagged bull trout were released into the upper Clackamas River basin and subsequently detected at the Pinhead Creek PIT-array prior to and during the spawning season as adult bull trout (i.e., age-5 and older).

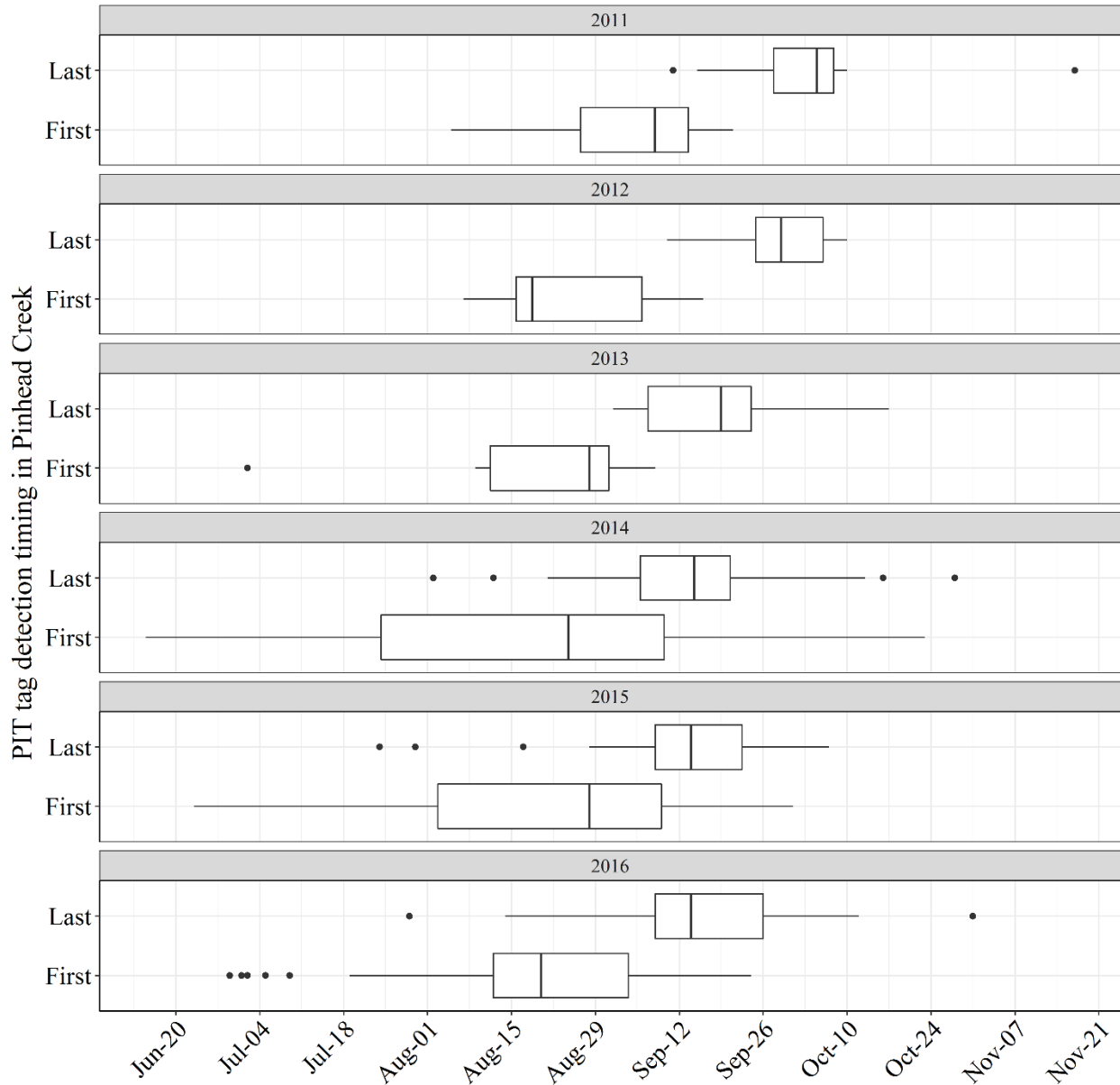


Figure 7. Timing of first and last detection of PIT-tagged bull trout, age-5 and older, at the PIT array near the mouth of Pinhead Creek. The boxplot displays a median line and two middle quartile boxes; the whiskers are defined as 1.5*interquartile range (IQR), outliers are beyond this spread, and together they represent the early and late quartiles. PIT-tagged adults detected ≤ 1 d were not included in timing analyses.

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Appendix I. Bull trout redd count data from the Clackamas River basin, 2016.

Stream	Reach	Date	ID	Easting	Northing	LN (cm)	WD (cm)	Feature note
Clackamas River	2	9/28/2016	C1RH	587700	4980471	140	70	BT redd?
Clackamas River	2	9/28/2016	C2RH	587748	4980536	140	100	BT redd, moderate confidence, SS:side channel, unlikely to be chk redd
Clackamas River	4	9/29/2016	C1TC	588565	4971236	200	140	possible chk redd
Clackamas River	4	9/29/2016	C2TC	587788	4972454	180	90	possible chk redd
Clackamas River	4	10/12/2016	D2TCSS	588342	4971719	70	50	Low uncertainty, not well defined pile of gravel but good undercut wood nearby, flagged
Clackamas River	4	10/12/2016	D4TCSS	588652	4970957	110	80	Nice pile of rocks, low uncertainty
Last Creek	1	9/12/2016	B1DP	588570	4980308	190	140	bull trout redd, possibly 2 redds
Last Creek	1	9/26/2016	C1JW	589262	4980444	230	95	0.5m from left bank
Last Creek	1	10/26/2016	E2SS	588671	4980367	250	100	Maybe old redd, but not flagged previously
Pinhead Creek	1	8/29/2016	A1RH	588351	4981361	130	85	new redd on top of old
Pinhead Creek	1	8/29/2016	A1SS	588646	4980401	65	23	small redd
Pinhead Creek	1	9/12/2016	B1TC	588330	4981016	120	110	
Pinhead Creek	1	9/12/2016	B1RH	588483	4980801	140	120	bt redd, possible old redd
Pinhead Creek	1	9/12/2016	B2RH	588424	4980967	100	80	bt redd, small but fresh
Pinhead Creek	1	9/12/2016	B3RH	588393	4980656	140	100	bt redd (gravel not sorted)
Pinhead Creek	1	9/12/2016	B1SS	588491	4980338	55	70	redd/probably test dig/not well sorted/some algaed rocks
Pinhead Creek	1	9/12/2016	B1GM	588373	4980662	130	100	
Pinhead Creek	1	9/26/2016	C1TC	588383	4981326	140	70	
Pinhead Creek	1	9/26/2016	C2TC	588383	4981326	110	60	
Pinhead Creek	1	9/26/2016	C3TC	588416	4980965	170	60	
Pinhead Creek	1	9/26/2016	C4TC	588429	4980823	120	70	
Pinhead Creek	1	9/26/2016	C5TC	588431	4980805	200	90	BT on redd, confirmed
Pinhead Creek	1	9/26/2016	C2SS	588090	4981711	200	95	definite redd, good pocket/mound
Pinhead Creek	1	9/26/2016	C3SS	588096	4981708	170	90	definite redd
Pinhead Creek	1	9/26/2016	C4SS	588361	4980656	70	70	small, clear digging, test dig?
Pinhead Creek	1	9/26/2016	C1RH	588385	4981304	240	130	BT redd, confident
Pinhead Creek	1	9/26/2016	C3RH	588386	4981124	200	150	BT redd, bull trout on redd

Stream	Reach	Date	ID	Easting	Northing	LN (cm)	WD (cm)	Feature note
Pinhead Creek	1	9/26/2016	C4RH	588446	4980836	180	100	BT redd? Small, fine substrate, small pebbles
Pinhead Creek	1	10/12/2016	D2PL	588245	4981314	180	110	large redd, no fines
Pinhead Creek	1	10/12/2016	D6PL	588365	4981117	80	50	100% certain, small but defined
Pinhead Creek	1	10/12/2016	D7PL	588409	4980614	60	30	SS:new redd?
Pinhead Creek	1	10/12/2016	D8PL	588454	4980558	100	60	confirmed new redd by ss
Pinhead Creek	1	10/12/2016	D1JW	588390	4981079	180	100	best defined redd of day, same loc at 2014
Pinhead Creek	1	10/12/2016	D1RH	588176	4981491	120	60	BT redd, moderate confidence
Pinhead Creek	1	10/12/2016	D1TC	588453	4980858	100	70	Possible BT redd, kind of small
Pinhead Creek	1	10/12/2016	D2RH	588359	4980708	140	60	BT redd, confident
Pinhead Creek	1	10/12/2016	D3RH	588366	4980339	160	80	BT redd, 75% confident
Pinhead Creek	1	10/12/2016	D1SS	588079	4981712	100	60	under log, definite redd
Pinhead Creek	1	10/26/2016	E2TC	588367	4981338	160	150	50/50 redd/test; maybe old chk next to new BT
Pinhead Creek	1	10/26/2016	E3TC	588428	4980914	190	90	90% confident of BT or coho redd (if coho spawn here)
Pinhead Creek	1	10/26/2016	E4TC	588438	4980897	160	100	90% confident of BT redd
Pinhead Creek	1	10/26/2016	E5TC	588425	4980652	130	90	60% confident of BT redd
Pinhead Creek	1	10/26/2016	E6TC	588452	4980362	200	100	75% confident of BT redd
Pinhead Creek	2	8/29/2016	A1RH	588596	4979944	130	80	BT redd?
Pinhead Creek	2	8/29/2016	A2RH	588712	4979795	300	120	confident BT redd
Pinhead Creek	2	8/29/2016	A3RH	588712	4979795	110	90	confident BT redd
Pinhead Creek	2	8/29/2016	A4RH	588978	4979025	240	110	
Pinhead Creek	2	9/12/2016	B1RH	588572	4980079	200	130	bt redd, large redd, gravel sorted
Pinhead Creek	2	9/12/2016	B2RH	588600	4979696	200	130	bt redd, confident
Pinhead Creek	2	9/12/2016	B3RH	588596	4979691	190	100	bt redd, confident
Pinhead Creek	2	9/12/2016	B4RH	588624	4979685	230	130	bt redd, large gravel and cobble kicked up
Pinhead Creek	2	9/12/2016	B5RH	588628	4979671	210	120	
Pinhead Creek	2	9/12/2016	B6RH	588646	4979659	130	60	bt redd, finer gravel substrate
Pinhead Creek	2	9/12/2016	B7RH	588648	4979554	180	110	bt redd
Pinhead Creek	2	9/12/2016	B1SS	589104	4978451	80	40	small redd, distinct digging edge, clean gravel, not well sorted

Stream	Reach	Date	ID	Easting	Northing	LN (cm)	WD (cm)	Feature note
Pinhead Creek	2	9/12/2016	B2SS	589097	4978537	170	60	not fluffed up, some algaed rocks, maybe last seasons redd?
Pinhead Creek	2	9/26/2016	C6TC	588566	4980253	110	80	BT redd, confident
Pinhead Creek	2	9/26/2016	C5RH	588580	4979861	120	60	BT redd, confident
Pinhead Creek	2	9/26/2016	C7TC	588590	4979821	130	90	BT redd, confident
Pinhead Creek	2	9/26/2016	C8TC	588578	4979761	110	80	BT redds side by side
Pinhead Creek	2	9/26/2016	C9TC	588578	4979761	160	90	Bt redds side by side
Pinhead Creek	2	9/26/2016	C10TC	588605	4979690	180	120	
Pinhead Creek	2	9/26/2016	C11TC	588953	4979159	150	80	BT redd?
Pinhead Creek	2	9/26/2016	C1SS	589123	4978481	95	120	95% certain redd, left bank, OHV
Pinhead Creek	2	10/12/2016	D4RH	588607	4980128	120	80	BT redd 90% confident
Pinhead Creek	2	10/12/2016	D5RH	588581	4980085	150	90	BT redd/Chk redd 50/50 call
Pinhead Creek	2	10/26/2016	E7TC	588574	4980071	180	80	80% confident BT/maybe Chk
Pinhead Creek	2	10/26/2016	E1EM	588858	4979035	200	90	90% confident BT redd

