ODFW PROGRESS REPORT Series

2018

Oregon Department of Fish and Wildlife

Clackamas River Bull Trout Reintroduction Project:
Characterizing status and thermal habitat suitability in 2017 with census redd counts, PIT tag technology, eDNA surveys, and water temperature data loggers

ODFW-Native Fish Investigations and Portland General Electric (Agreement #2018-08)

ANNUAL PROGRESS REPORT
FISH RESEARCH PROJECT
OREGON

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PROJECT NUMBER: Portland General Electric Agreement # 2016-08

PROJECT PERIOD: 2017

Prepared by: Steven J. Starcevich

Oregon Department of Fish and Wildlife
4034 Fairview Industrial Drive SE
Salem, OR 97302

This project was funded in part by Portland General Electric and the ODFW-Native Fish Investigations Program

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Clackamas River Bull Trout Reintroduction Project: Characterizing status and thermal habitat suitability in 2017 with census redd counts, PIT tag technology, eDNA surveys, and water temperature data loggers

Steven J. Starcevich, ODFW Native Fish Investigations Program
Corvallis Research Lab, May, 2018

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. The first phase of the project (2011-2016) involved translocating 2,868 Bull Trout 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. The second phase of the project began in 2017 and continued monitoring progress toward the reintroduction goal, through census redd surveys, the use of PIT tag technology, night snorkel surveys, water temperature monitoring, and eDNA surveys. Redd abundance in Pinhead Creek basin steadily increased from 16 redds in 2012 to 85 redds in 2017. In 2017, 62 PIT-tagged adults (estimated age at detection ≥ age-5) were detected in Pinhead Creek, a decline from 73 PIT-tagged adults in 2016. The abundance of PIT-tagged adults is expected to decline over time as translocated fish are replaced by locally produced adults. PIT-tagged adults spent a median of 17 d in Pinhead Creek during the spawning period; these fish were translocated mainly at age-1 and 2 (i.e., 70-210 mm) and released at locations primarily in Pinhead Creek and the Clackamas River. Most Bull Trout spawning occurred in September and the last PIT-tagged adult detection was in mid-October. Temperature monitoring revealed extensive high quality thermal habitat for juvenile Bull Trout (maximum <14°C) in the Clackamas River upstream of the Collawash River confluence. Thermal habitat quality for spawning (daily mean <9°C in September) was high in the Clackamas River upstream of the Cub Creek confluence, Pinhead Creek, and Last Creek; and medium in the Clackamas River between the confluences of Cub Creek and Collawash River and a few tributaries of the Clackamas River. No Bull Trout were observed during night snorkeling surveys in 1.5 km of Pinhead Creek. Surveys for eDNA occurred in 31 sample sites within 11 streams. The eDNA samples have not been analyzed yet. Census spawning surveys, eDNA and night snorkel surveys, and temperature monitoring will continue in 2018.

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 implementation plan was divided into 3 phases of approximately 6-7 years each (USFWS 2011). The first phase was from 2011 through 2016 and involved translocating 2,868 Bull Trout from the Metolius River basin (Figure 1, 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 began in 2017 and entailed 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 in 2011 through 2014 were conducted by an *ad hoc* multi-agency group of observers. In 2015 and 2016, census redd surveys were conducted in all potential spawning habitat in the upper Clackamas River basin 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 2017, the redd survey sampling frame was reduced to areas where Bull Trout spawning was consistently observed in 2015 and 2016, which were Pinhead Creek, Last Creek, and the upper Clackamas reach. The census surveys were conducted with four ODFW surveyors of varying experience, with additional help from two experienced surveyors from the U.S Forest Service (USFS) and U.S. Fish and Wildlife Service. The areas dropped from the sampling frame in 2017 were either confounded by high density Chinook Salmon (*Oncorhynchus tshawytscha*) spawning with few to no Bull Trout redds observed in previous surveys or consisted of relatively poor spawning habitat with no redds observed previously. Bull Trout occupancy in these areas will be monitored from 2017 through 2020 using environmental DNA (eDNA) surveys and water temperature data loggers were deployed to evaluate thermal habitat suitability throughout the upper Clackamas River basin. In 2017, the specific objectives were to 1) characterize Bull Trout abundance using census spawning surveys in known or high potential spawning areas, 2) examine relationships between redd counts and PIT-tagged adults detected in the Pinhead Creek watershed, 3) document juvenile Bull Trout rearing in Pinhead Creek using night snorkel surveys, and 4) refine the sampling frame using water temperature data loggers to focus spawning and eDNA surveys in thermal habitat suitable for Bull Trout spawning and rearing, and 5) characterize Bull Trout distribution using eDNA surveys in potential spawning and rearing areas. Funding for objectives 1 and 5 was provided by Portland General Electric (Agreement # 2016-08). Funding for additional objectives was provided by ODFW – Native Fish Investigations Program.

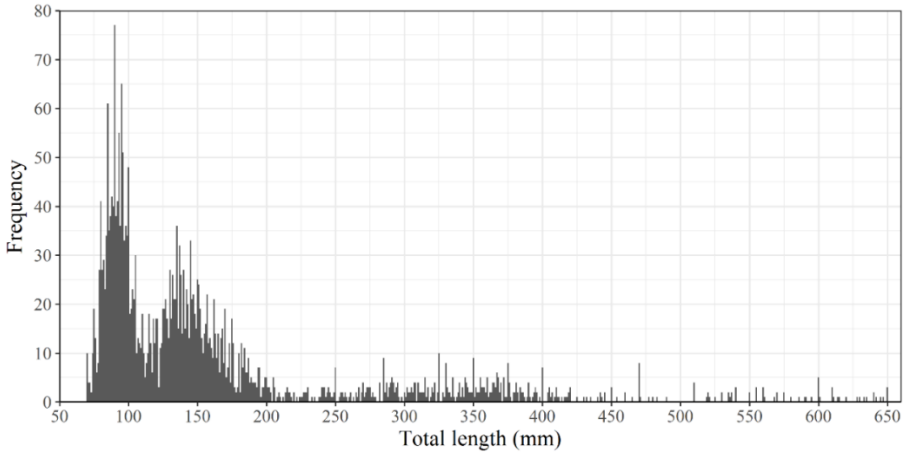

Figure 1. Length-frequency histogram of Bull Trout captured in the Metolius River basin, PIT-tagged, and translocated to the upper Clackamas River basin, 2011-2016.

Methods

Census redd surveys

A five-person crew conducted census redd surveys in Pinhead Creek, Last Creek, and Reach 4 of the upper Clackamas River (Figure 2). 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 their relatively large surface area 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: geographic location, maximum length and width of the redd, species and number of adults occupying the redd, and brief descriptions of the redd and surveyor confidence in the redd observation. Welch's t-test was used to compare redd surface area (i.e., redd length * redd width) of Chinook Salmon and Bull Trout.

Bull Trout and salmon redd data were entered in an Access database that contained data from previous Bull Trout spawning surveys in the upper Clackamas River basin. From 2011-2014, some spawning surveyors recorded observations of some redds described as "potential", "possible", "likely", "test dig?" or some other variant registering uncertainty in their observations; these descriptions were included in the database. From 2015-2017, observers were trained to include a brief description of their certainty in each new redd identified and the reason for their uncertainty. These descriptions were entered as a comment in the database. Differing from 2011-2014, only features described as redds (i.e., as opposed to test dig) and with descriptors connoting relatively high certainty (e.g., >50%) were included in the 2017 count. (See Appendix I for dataset from 2017.)

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. Lifestage was defined by the size classes 70-250 mm (juvenile), 251-450 mm (subadult), 451-650 mm (adult). Annual translocations occurred from 2011 through 2016.

		Lifestage			Date	
Year	Location	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
	2011 Subtotal	*58*	*25*	*35*		
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
	2012 Subtotal	*517*	*43*	*17*		
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
	2013 Subtotal	*624*	*90*	*8*		
2014	Berry Creek	296	0	0	24-Apr	29-May
	Clackamas River 1	26	45	7	5-Jun	25-Jun
	2014 Subtotal	*322*	*45*	*7*		
2015	Berry Creek	287	1	0	10-Apr	5-Jun
	Clackamas River 1	13	73	7	15-May	5-Jun
	2015 Subtotal	*300*	*74*	*7*		
2016	Clackamas River 1	95	94	6	20-May	13-Jun
	Clackamas River 5	501	0	0	8-Apr	13-May
	2016 Subtotal	*596*	*94*	*6*		
	Total	*2417*	*371*	*80*	*Grand total*	2868

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

	Census					
Reach	1	2	3	4	5	6
Clackamas River 4	5-Sep	17-Sep	NS	NS	16-Oct	NS
Pinhead Creek 1	28-Aug	19-Sep	27-Sep	3-Oct	17-Oct	31-Oct
Pinhead Creek 2	28-Aug	18-Sep	27-Sep	2-Oct	16-Oct	31-Oct
Last Creek	29-Aug	18-Sep	27-Sep	3-Oct	17-Oct	30-Oct
Total Bull Trout redds	1	35	15	15	13	10
Total Chinook Salmon redds	0	0	1	1	4	24

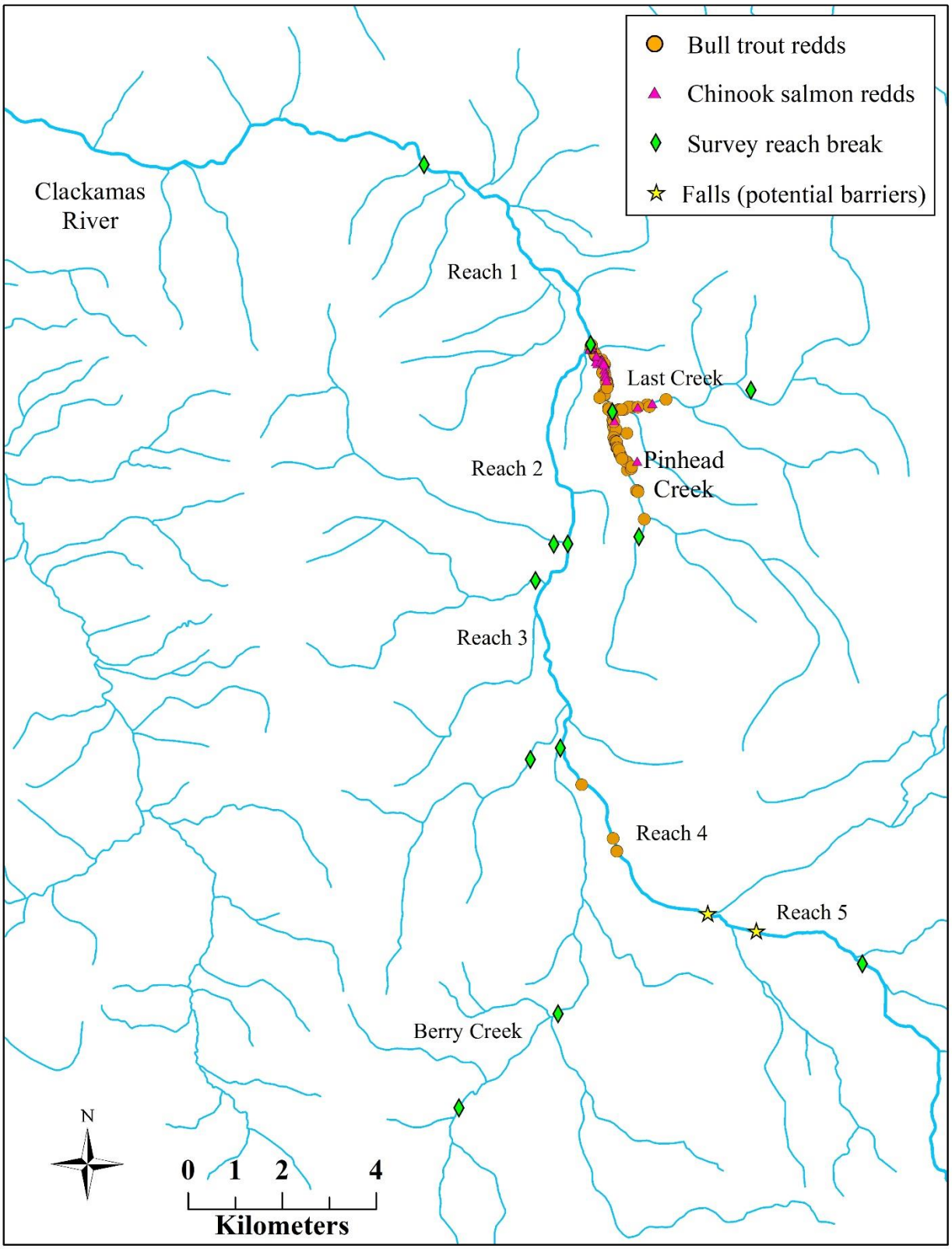

Figure 2. Census survey extent for all survey years and Pinhead Creek, Last Creek, and Reach 4 of the Clackamas River and redd distribution in 2017.

Pinhead Creek PIT-tagged adult monitoring

In the first phase of the reintroduction, Bull Trout translocated from the Metolius River basin were given PIT tags and released in the Clackamas River basin. A solar-powered, 4-antenna PIT array has been installed in Pinhead Creek, near its confluence with the Clackamas River, to monitor PIT-tagged Bull Trout use of this watershed. The PIT array is usually activated by early April and maintained 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, age-5 and older fish (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 either immature fish or mature younger fish. To count the number of PIT-tagged fish using Pinhead Creek annually, 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 1) 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 in the Clackamas River basin and date of 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 quantify the relationship between 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 at the Pinhead Creek PIT array in a single 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 by the following categories: juvenile, 70-250 mm; subadult, 251-450 mm; and adult, 451-650 mm.

eDNA surveys

The eDNA surveys were conducted according to the field collection protocol and sampling equipment suggested by Carim et al. (2016). The peristaltic pump (Geopump, Geotech, Colorado, USA) was powered by either a lithium ion battery or cordless drill (DeWalt, Maryland, USA). At each study site, the pump pulled 5 L of stream water through a 1.5-µm-pore fiberglass filter. The filters were immediately stored in a plastic bag with silica dessicant. Within 10-48 hours, these samples were placed in a -20°C freezer for storage until they can be analyzed for the presence of Bull Trout eDNA by the National Genomics Center for Fish and Wildlife Conservation (USFS Rocky Mountain Research Station, Fort Collins, Colorado).

Candidate eDNA survey streams were classified by two priority levels for monitoring Bull Trout distribution. The highest priority streams were known to be thermally suitable (i.e., maximum <16°C), lacked fish barriers, and were within the suitable patches identified in the reintroduction feasibility study (Shively et al. 2007). Other candidate streams were identified either through historical anecdotes as occupied streams outside of the identified suitable habitat patches (Shively et al. 2007) or by survey gaps in the range-wide Bull Trout distribution research effort led by the USFS Rocky Mountain Research Station (see McKelvey et al. 2016). These streams, currently lacking stream width and thermal habitat data, will be surveyed in the future if thermal habitat monitoring shows these areas to be suitable. Probability of detection of eDNA presence in streams is positively related to fish density and negatively related to stream discharge (Wilcox et al. 2016). Therefore, the number of sample sites allocated to a survey stream depended on estimated stream baseflow discharge and total stream detection probability >0.85, assuming a minimum Bull Trout density of 1 fish per 100 m. Sample site allocation was based on detection probability estimates from simulations using parameterized models from Wilcox et al. (2016).

Night snorkel surveys

Night snorkeling surveys were conducted by 4-person crews on September 21-22 and October 30-31, 2017, between 10 PM and 2 AM. Each snorkeler used a dive light and all habitat in two high density spawning reaches was snorkeled, including side channels and backwaters. On the first night, the 1 km of Pinhead Creek was snorkeled moving upstream from the mouth. On the second night, the crew surveyed 0.5 km of Pinhead Creek, starting at the mouth of Last Creek.

Stream temperature

Digital temperature data loggers (Onset™ Hobo Water Temp Pro v2 U-22) were set to record stream temperature every 30 minutes and deployed in 30 locations in the upper Clackamas River basin in June and downloaded in October. Four data loggers were lost because of bed scour or human tampering; these were replaced in October with new data loggers. An additional 6 data

loggers were deployed in October. Juvenile rearing habitat was evaluated with two maximum daily temperature criteria used to delineate suitable habitat patches (Table 3). Bull Trout are generally thought to initiate spawning when stream temperature declines below 9°C (McPhail and Murray 1979; Weaver and White 1985; Fraley and Shepard 1989; Kitano 1994). More specifically, Bull Trout initiated spawning at mean daily stream temperatures between 9.3 and 11.5°C in Pine Creek, Oregon (Chandler et al. 2001), and 9.4 and 11.7°C in the Lostine River, Oregon (Howell et al. 2010). As peak Bull Trout spawning in Pinhead Creek and elsewhere in northeast Oregon (Starcevich et al. 2012) generally occurs in September, we used mean daily temperatures of <9°C, 9-12°C, >12°C in September to respectively classify spawning habitat as high, medium, and low thermal suitability (Starcevich et al. 2017).

Table 3. Stream temperature metrics used to delineate Bull Trout habitat patches (from Isaak et al. 2009). Italicized temperatures are delineations for Bull Trout patches with sympatric Redband Trout reported in Haas (2001).

Thermal suitability	Summer maximum (°C)	
High	≤16	*≤12*
Medium	>16 to ≤19	*>12 to ≤16*
Low	>19	*>16*

Table 4. Bull Trout redds counted during census surveys in the upper Clackamas River basin, 2011-2017. In certain years, some stream reaches were not surveyed (NS).

		Bull Trout redd count							
Stream	Reach	2011	2012	2013	2014	2015	2016	2017	Riverscape marks
Pinhead Creek	1	3	9	10	21	13	34	33	Mouth to Last Cr.
Pinhead Creek	2	2	5	2	14	34	25	40	Last Cr. to FS140 Road
Last Creek	1	0	2	3	2	0	3	12	Mouth to Camp Cr.
Clackamas River	1	NS	NS	NS	NS	2	0	NS	Big Bottom to Pinhead Cr.
Clackamas River	2	NS	NS	NS	NS	5	2	NS	Pinhead Cr. to Lowe Cr.
Clackamas River	3	NS	NS	NS	NS	2	0	NS	Lowe Cr. to Cub Cr.
Clackamas River	4	NS	NS	1	NS	2	4	4	Cub Cr. to First falls
Clackamas River	5	NS	NS	NS	NS	0	NS	NS	First falls to Ollalie Cr.
Oak Grove Fork	1	NS	NS	2	NS	1	0	NS	First 2.5 km
Lowe Creek	1	NS	NS	NS	NS	0	0	NS	First 1 km
Rhododendron Cr.	1	NS	NS	NS	NS	0	0	NS	First 1 km
Hunter Creek	1	NS	NS	NS	NS	0	0	NS	First 1.5 km
Cub Creek	1	NS	NS	NS	NS	0	0	NS	Mouth to Berry Cr.
Cub Creek	2	NS	NS	NS	NS	0	NS	NS	2.5 km up from Berry Cr.
Berry Creek	1	NS	NS	NS	NS	0	0	NS	First 3 km
TOTAL		5	16	18	37	59	68	89	

Results and Discussion

Census redd surveys

During 2017 census redd surveys, 85 putative Bull Trout redds were counted in Pinhead Creek and Last Creek and 4 redds were counted in reach 4 of the upper Clackamas River (Figure 2, Table 4, Appendix I). Bull Trout redd numbers increased in Reach 2 of Pinhead Creek and Last Creek relative to census counts in 2016. Overall, the census count from Pinhead and Last creeks increased 37% from the previous year (Table 5). The first Bull Trout redd was observed in late August and 74% of the redds were counted by early October (Table 2). Bull Trout were seen occupying or actively spawning on 8 redds (9% of total). Bull Trout redds were 58% the surface area of Chinook Salmon redds ($t = -3.21$, $df = 35.7$, $P = 0.003$).

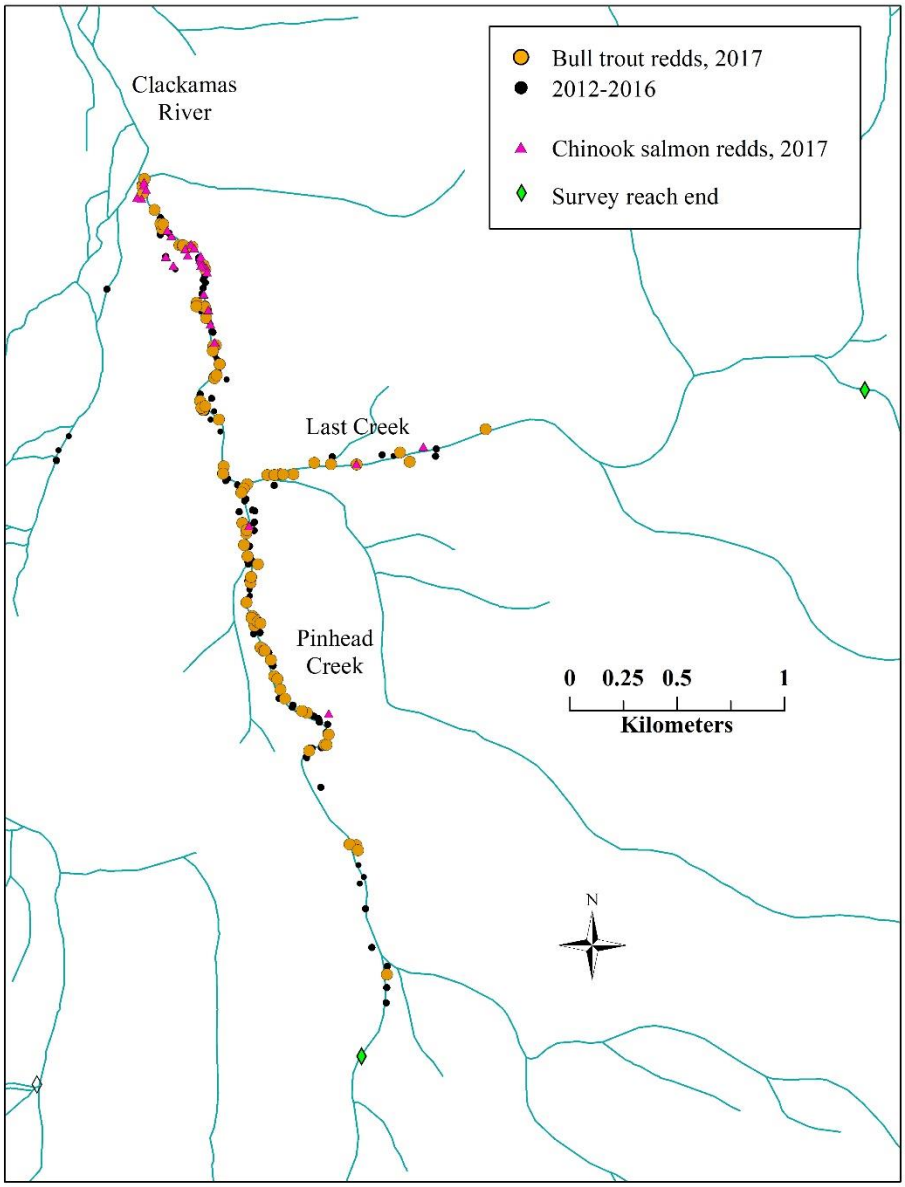

Figure 3. Georeferenced redds in Pinhead Creek and Last Creek from 2012-2017. Redds were georeferenced in secondary channels; these channels are not shown.

Table 5. 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. Adulthood was defined as fish estimated to be ≥ age-5. Duration was defined as the number of days between the first and last detection (>1 day) at the PIT array in Pinhead Creek.

Census Survey			Tagged Adults	Duration		
Year	Redds	Annual Increase		Median	Min	Max
2011	5	NA	5	20	3	26
2012	16	220%	17	35	12	55
2013	15	-6%	13	30	3	68
2014	37	147%	32	22	3	93
2015	47	27%	53	18	2	87
2016	62	32%	73	26	3	88
2017	85	37%	62	17	2	91

In Pinhead and Last creeks, 30 Chinook Salmon redds were counted, 87% of which were observed in Reach 1 of Pinhead Creek (Figure 3, Appendix I). The first salmon redd was observed in late September and salmon spawning increased substantially in the latter half of October (Table 2). Chinook Salmon were observed actively spawning on or occupying 6 redds (20% of total). Most of the Bull Trout redds had been constructed prior to the increase in salmon spawning in Pinhead Creek and therefore did not act as a confounding variable until the final round of surveys.

Pinhead Creek PIT-tagged adult monitoring

The number of adult PIT-tagged Bull Trout using Pinhead Creek during the spawning season steadily increased from 13 adults in 2013 to 72 in 2016 and declined to 62 in 2017 (Table 5). There was a still strong linear relationship ($y=0.85x+3.9$, $R^2=0.83$, $P=0.003$) between the annual census redd count (x) and the number of adults detected (y) in Pinhead Creek (Figure 4). Prior to 2017, the linear model shows an almost 1:1 relationship between adults detected and the census redd count ($\beta_1=1.03$). For individual years, the adult to redd ratio was similar in 2015 (1.12 adults:redd) and 2016 (1.16). In 2017 the adult to redd ratio declined to 0.73 and the relationship no longer appears linear. This was expected at some point because 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. Recruits from the 21 redds observed in Pinhead Creek in 2011 and 2012, the first two years of translocations, would be age-5 or 6 this season, which is the age at which a proportion of the donor population first matures in the Metolius River basin (Ratliff et al. 1996), and these recruits may contribute undetected members to the adult population. Tag loss is also expected to contribute to the proportional decline of tagged adults in the population, especially among repeat spawning females (Meyer et al. 2011).

Although the adult to redd ratio was low relative to other Bull Trout populations (see Howell and Sankovich 2012), the census redd count was a useful monitoring tool from 2012-2016 because it was a consistent proxy for PIT-tagged adult abundance in the Pinhead Creek watershed. This

suggests that the 2017 increase in the census redd count likely reflected an increase in adult abundance even though abundance of PIT-tagged adults declined. If census redd counts continue to be used as an abundance monitoring tool in this basin, then periodic calibration to adult abundance may be necessary to ensure that redd counts are tracking actual adult population trend. Given the diminishing number of translocated adults with PIT tags, new calibration methods may need to be considered.

In 2016 and 2017, 75% of PIT-tagged adults were first detected in Pinhead Creek by early September and last detected by late September (Figure 5), which corresponded to the spawning peak observed during redd surveys (Table 2). PIT-tagged adults generally spend 17-35 d in Pinhead Creek during the spawning season (Table 5). Similar to 2015 and 2016, this timing information suggests that Bull Trout likely have completed spawning by mid-October; although, 10 new Bull Trout redds were counted on October 30-31, 2017. 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; however, this last round of census surveys was most confounded by salmon spawning (Table 2). 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.

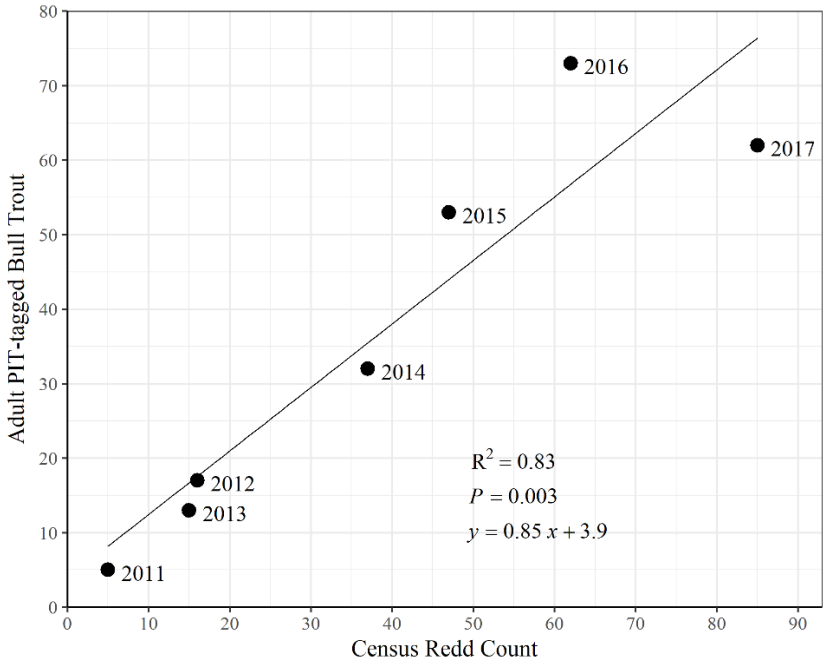

Figure 4. Annual number of adult PIT-tagged Bull Trout (i.e., age-5 and older) detected in Pinhead Creek during the spawning period as a function of the annual Bull Trout redd count in Pinhead Creek and Last Creek. The line and its equation were estimated using simple linear regression.

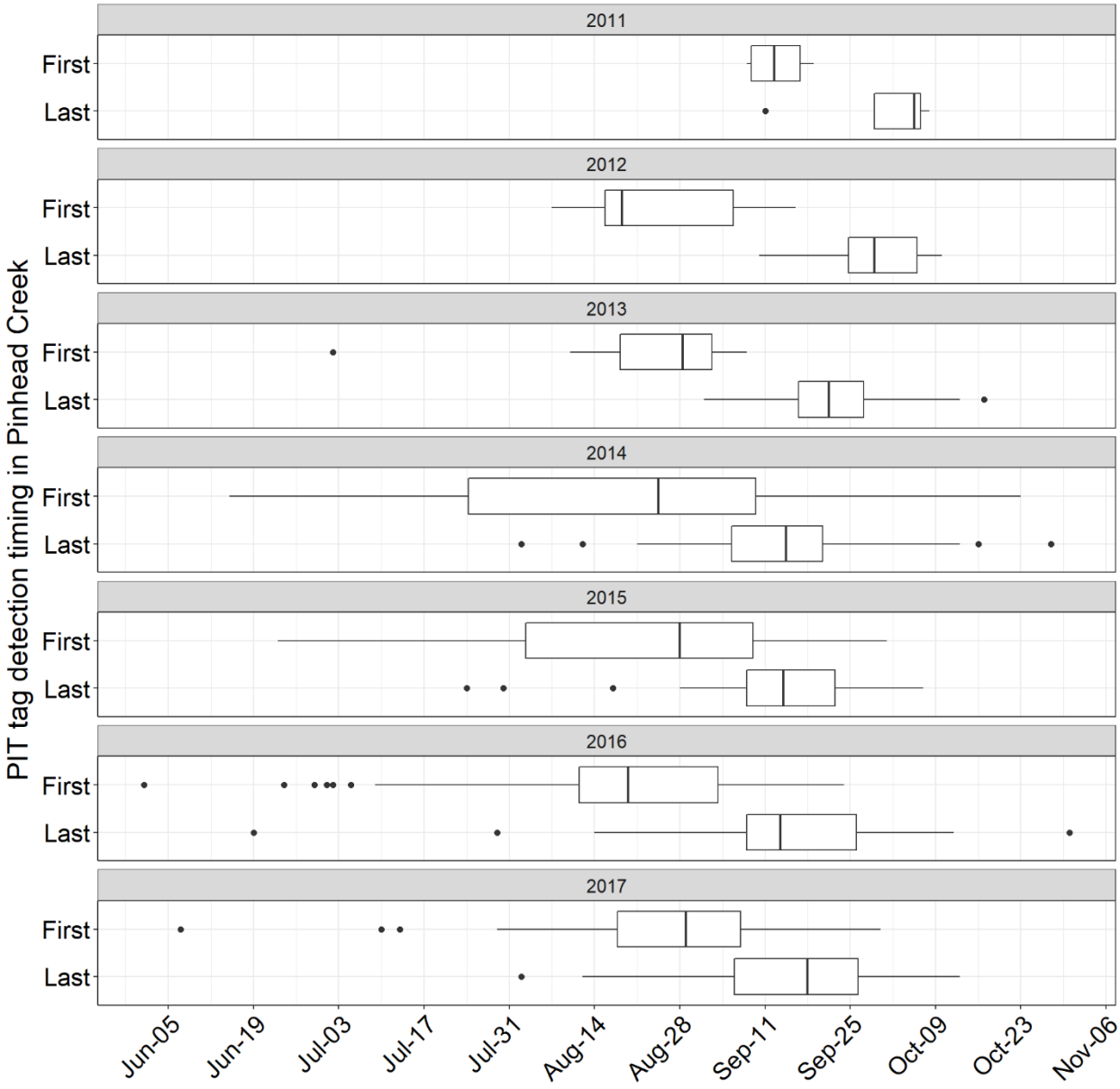

Figure 5. Timing of first and last detection of PIT-tagged Bull Trout, age-5 and older, at the PIT array near the mouth of Pinhead Creek. The boxplot displays a median line and two middle quartile boxes; the whiskers are defined as 1.5*interquartile range (IQR), outliers are beyond this spread, and together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

Table 6. 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 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	Clackamas Reach 5	Berry Creek
2011	5	1	2	8	0	1	0	11	5	0	0
2012	17	2	3	2	7	1	2	13	15	0	0
2013	13	1	16	177	9	0	1	206	10	0	0
2014	32	12	21	2	0	5	14	38	9	0	1
2015	53	32	2	2	1	9	30	41	5	0	5
2016	73	5	2	0	0	0	30	44	2	0	4
2017	62	1	2	3	0	1	29	32	0	3	3

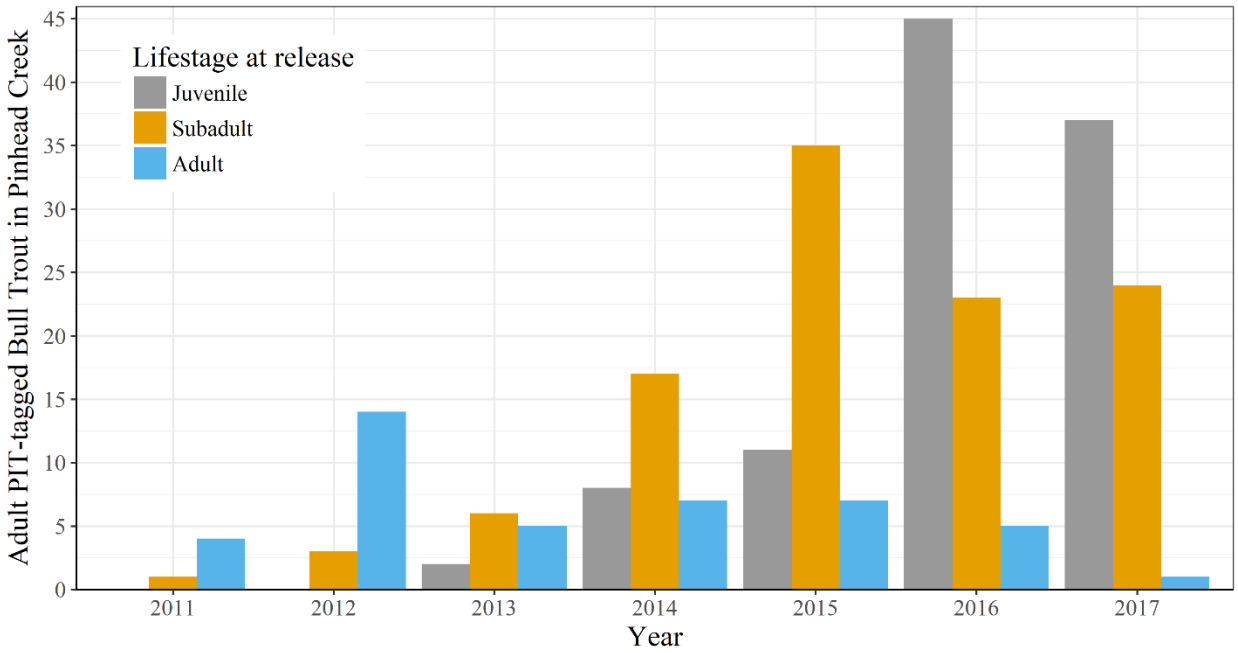

Figure 6. Lifestage at which PIT-tagged Bull Trout were released into the upper Clackamas River basin and subsequently detected at the Pinhead Creek PIT-array prior to and during the spawning season as adult Bull Trout (i.e., age-5 and older).

The total count of PIT-tagged Bull Trout detected in Pinhead Creek also included some PIT-tagged fish between age-1 and 4 (Table 6). The number of younger PIT-tagged fish using Pinhead Creek during the spawning season was low in 2016 and 2017 relative to previous years. The release location of PIT-tagged Bull Trout (all ages) detected at Pinhead Creek in 2017 was mainly Reach 1 of the Clackamas River and Pinhead and Last creeks and included a few fish released as far away as Berry Creek, Reach 5 of the Clackamas River, and the Lower Clackamas River (Table 6). The lifestage at which PIT-tagged Bull Trout were released in the upper

Clackamas River basin and subsequently detected at the Pinhead Creek PIT array as an adult during the spawning season shifted from mostly adult in 2011-2012, to mostly subadult in 2015, and to mostly juvenile and subadult by 2017 (Figure 6). 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 predominantly from Reach 1 of the Clackamas River.

Night snorkel surveys

Even though translocated age-1 and age-2 Bull Trout are surviving to adulthood in the upper Clackamas River basin, extensive juvenile fish surveys in 2016 using a variety of capture methods did not detect locally produced juvenile Bull Trout in Pinhead Creek (Barrows et al. 2017). Night snorkel surveys were not used in 2016 but have been shown to be an effective way to document juvenile Bull Trout rearing (Thurow et al. 2006). The night snorkel surveys in 2017 in Pinhead Creek did not detect juvenile Bull Trout. Juvenile Chinook Salmon was the dominant fish species observed; for example, within a single complex pool in Pinhead Creek as many as 22 salmon juveniles were counted. Other species observed included juvenile Coastal Cutthroat Trout (*O. clarki clarki*), juvenile Rainbow Trout or steelhead (*O. mykiss*), and sculpins (*Cottid sp*). Several areas within the Pinhead Creek survey reaches appeared to be high quality Bull Trout rearing habitat. These areas included low velocity pockets and pools with complex structure such as cobble, large wood and organic debris, and undercut banks. Recent genetic confirmation of Bull Trout alevins sampled from redds identified during census surveys in 2017 in Pinhead and Last creeks (Chris Allen, USFWS, personal communication) suggest that Bull Trout are successfully spawning and eggs are developing into alevins in redds, but it is still unknown if juvenile early rearing is successfully occurring in Pinhead Creek.

Stream temperature

Maximum daily temperatures recorded on 26 temperature data loggers distributed throughout the upper Clackamas River basin (Figure 7, left panel) suggest there is extensive medium and high quality thermal habitat for juvenile Bull Trout rearing. Upstream of the Collawash River confluence, maximum temperatures in the Clackamas River and most of its tributaries were between 12-14°C, well below the 16°C criterion for high quality thermal habitat patches (Isaak et al. 2009). Pinhead Creek is the coldest stream and primary Bull Trout spawning area in the basin so it is surprising that juveniles have not been detected rearing in this stream.

High quality thermal habitat for spawning (i.e., <9°C in September) occurred in Pinhead Creek, Last Creek, and the upper reaches of the Clackamas River (Figure 7, upper right panel); and medium quality spawning habitat (i.e., <12°C in September) existed in the Clackamas River upstream of the Collawash River confluence, Hunter Creek, Berry Creek, Rhododendron Creek, and lower Oak Grove Fork (Figure 7, lower right panel). Low quality spawning habitat occurred in the Collawash River basin, the Clackamas River downstream of the Collawash River, lower Roaring Creek, and Lowe Creek (Figure 7). In 2018, temperature monitoring will be extended to include the tributaries of the upper Collawash River and these data will aid in selecting and prioritizing streams for future distribution sampling using night snorkeling and eDNA surveys.

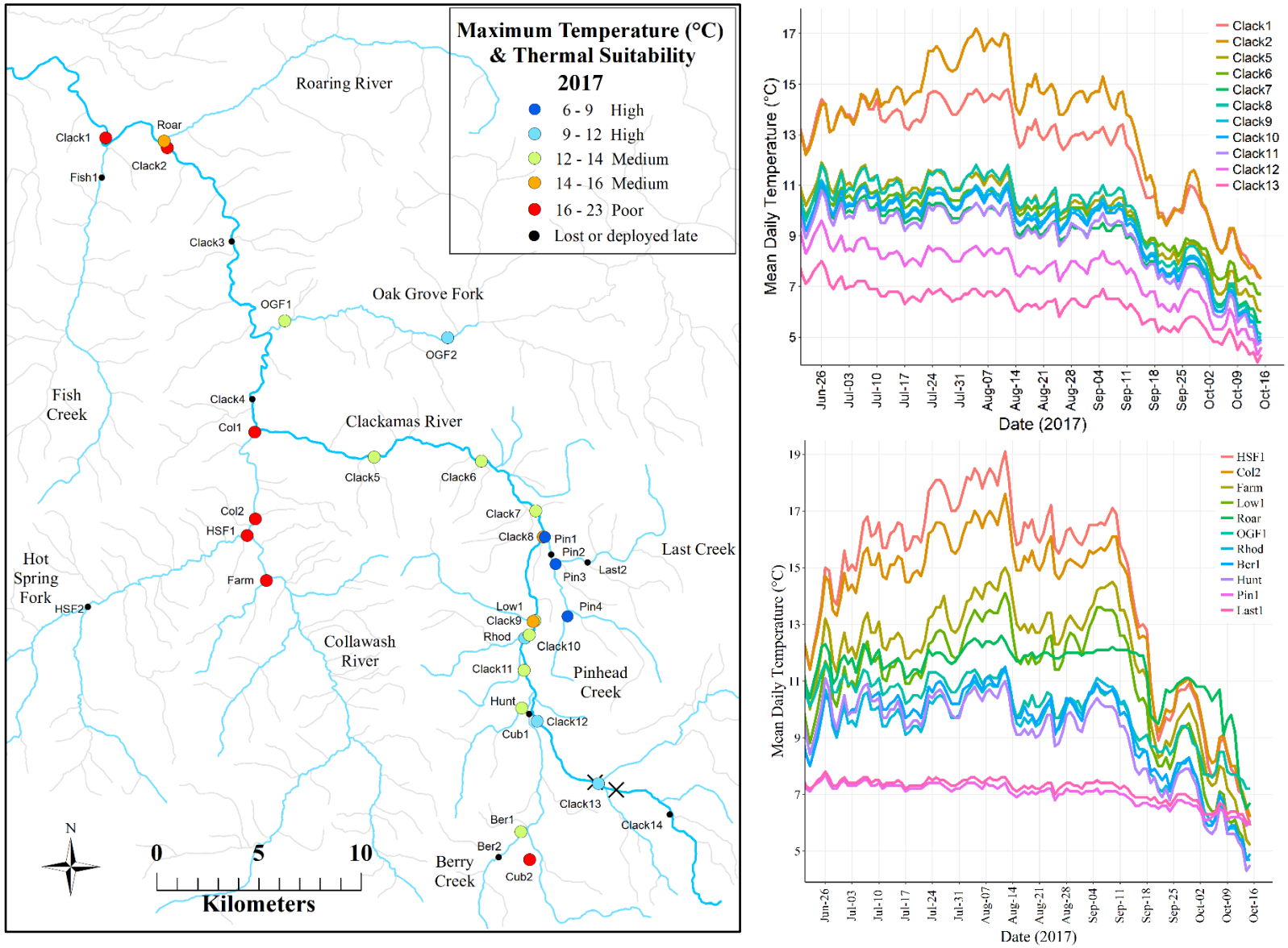

Figure 7. Maximum daily water temperatures recorded with data loggers in the upper Clackamas River basin, June 20 to October 15, 2017.

eDNA surveys

Environmental DNA surveys were conducted to determine the extent and degree of Bull Trout use in Pinhead Creek and Last Creek, to determine if Bull Trout were still rearing in or near reintroduction areas in the upper Clackamas River and Berry Creek, and to monitor potential increase in distribution in Roaring River, Fish Creek, Oak Grove Fork, Pot Creek, Lowe Creek, Rhododendron Creek, and Cub Creek (Figure 8). These samples will be analyzed in 2018.

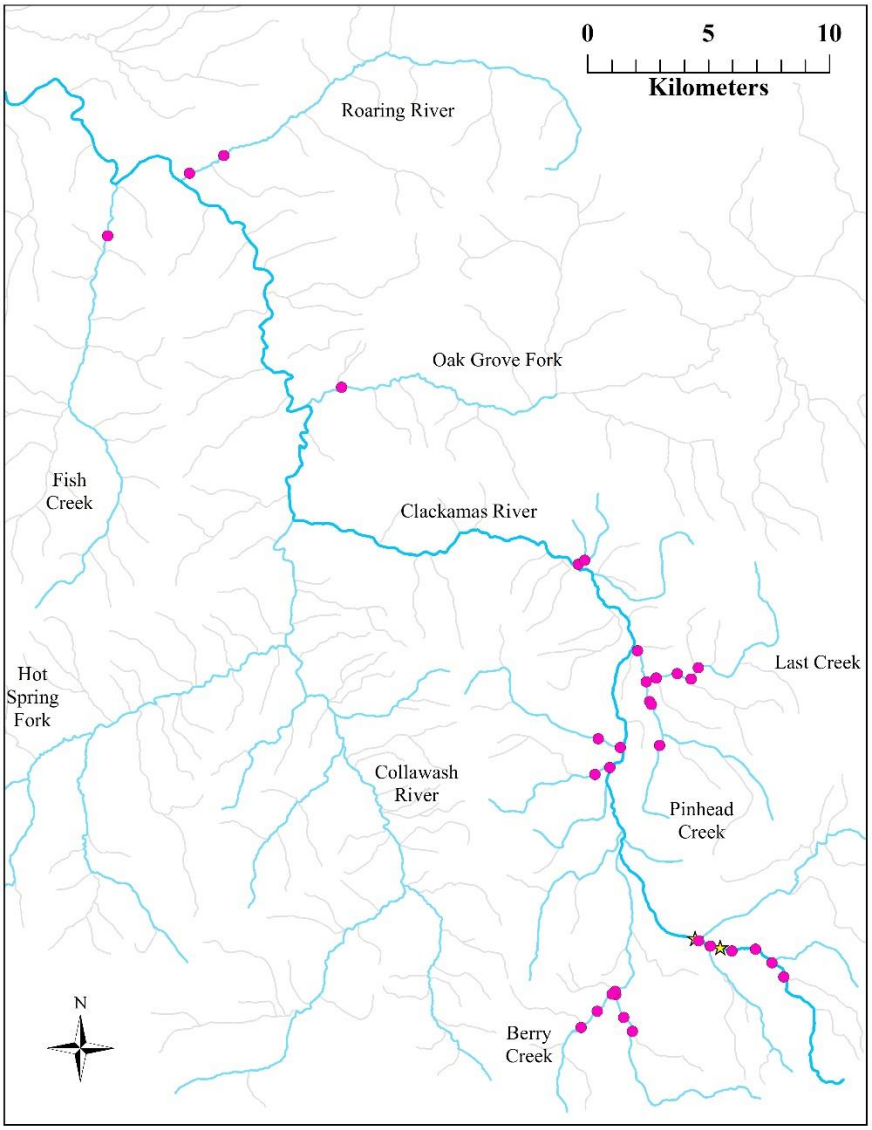

Figure 8. Environmental DNA survey sites (pink dots) and natural falls (yellow stars) that potentially act as fish passage barriers.

Acknowledgements
Thanks to Homan Hamedanizadeh (ODFW) and Adam Kostick (ODFW) for conducting most of the surveys; Jack Williamson (USFS), Chris Allen (USFWS), and Beth Bailey (ODFW) for assistance with surveys; volunteers from the annual meeting of the *Salvelinus confluentus* Curiosity Society for assistance with eDNA, spawning, and snorkel surveys; Mike Meeuwig (ODFW) for a helpful review of a draft report; and Brian Davis and Marshal Barrows (USFWS) for providing PIT tag data.

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Appendix I. Bull Trout and Chinook Salmon redd count data from the upper Clackamas River basin, 2017.

Stream	Reach	Date	Species	Redd ID	Easting	Northing	LN (cm)	WD (cm)	Comment
Last Creek	1	10/30/2017	CHK	G2HH	589400	4980487	200	100	chinook redd on old redd
Last Creek	1	10/30/2017	CHK	G3HH	589076	4979259	300	150	chinook redd on this year's Bull Trout redd!
Last Creek	1	10/30/2017	CHK	G1AK	589088	4980408	150	40	chinook redd by large substrate
Pinhead Creek	1	10/31/2017	CHK	G8HH	588369	4981334	150	80	100% redd
Pinhead Creek	1	9/27/2017	CHK	D1TH	588387	4981323	120	130	*probably B2BB, two small mounds closes together
Pinhead Creek	1	10/3/2017	CHK	E2AK	588096	4981706	100	280	Chinook on redd
Pinhead Creek	1	10/17/2017	CHK	F1HH	588098	4981720	250	120	chinook redd; most likely chinook 18" fish on, couldn't make out species
Pinhead Creek	1	10/17/2017	CHK	F1AK	588087	4981643	140	100	lg substrate, mostly chinook redd
Pinhead Creek	1	10/17/2017	CHK	F2AK	588226	4981470	170	250	chinook redd, larger substrate huge redd
Pinhead Creek	1	10/17/2017	CHK	F1CA	588234	4981331	350	180	chinook redd, fish on
Pinhead Creek	1	10/31/2017	CHK	G2HH	588290	4981410	260	100	chinook redd
Pinhead Creek	1	10/31/2017	CHK	G3HH	588317	4981431	300	140	chinook redd
Pinhead Creek	1	10/31/2017	CHK	G5HH	588332	4981413	130	40	50/50 bt redd, obvious digging
Pinhead Creek	1	10/31/2017	CHK	G7HH	588365	4981351	140	90	100% redd
Pinhead Creek	1	10/31/2017	CHK	G1AK	588108	4981685	170	90	chinook redd
Pinhead Creek	1	10/31/2017	CHK	G5SS	588363	4981331	220	130	chinook redd, 2 chk on redd
Pinhead Creek	1	10/31/2017	CHK	G4SS	588362	4981376	290	90	chinook redd, femal chk 5 m upstream
Pinhead Creek	1	10/31/2017	CHK	G3SS	588302	4981379	120	50	chinook redd, gravel large
Pinhead Creek	1	10/31/2017	CHK	G1SS	588207	4981495	250	250	chinook redd, 2 chinook on redd
Pinhead Creek	1	10/31/2017	CHK	G1CA	588065	4981649	200	100	chinook redd, high probability
Pinhead Creek	1	10/31/2017	CHK	G6HH	588359	4981359	130	80	nice redd
Pinhead Creek	1	10/31/2017	CHK	G2AK	588201	4981372	250	60	chinook redd
Pinhead Creek	1	10/31/2017	CHK	G7SS	NA	NA	200	170	chk redd
Pinhead Creek	1	10/31/2017	CHK	G13HH	588427	4980974	170	80	100% redd
Pinhead Creek	1	10/31/2017	CHK	G12HH	588407	4981058	230	60	50/50 redd, obvious digging
Pinhead Creek	1	10/31/2017	CHK	G11HH	588398	4981125	160	90	100% redd

Stream	Reach	Date	Species	Redd ID	Easting	Northing	LN (cm)	WD (cm)	Comment
Pinhead Creek	1	10/31/2017	CHK	G10HH	588376	4981198	150	80	fresh digging on old redd
Pinhead Creek	1	10/31/2017	CHK	G9HH	588391	4981301	140	60	100% redd
Pinhead Creek	1	10/31/2017	CHK	G3AK	588199	4981373	800	300	chinook redd
Pinhead Creek	2	10/31/2017	CHK	G2AK	588569	5980094	260	200	chinook redd on old redd
Clackamas River	5	9/5/2017	BT	B1HH	588646	4970964	170	70	<50% certainty, fresh digging observed, some algaed gravels in mound, not well fluffed
Pinhead Creek	1	9/19/2017	BT	B1SS	588183	4981503	120	70	
Pinhead Creek	1	9/19/2017	BT	B2SS	588433	4980961	70	50	fish digging, small pocket mound, maybe too small for eggs
Pinhead Creek	1	9/19/2017	BT	B3SS	588450	4980872	140	90	nice redd, a little dark
Pinhead Creek	1	9/19/2017	BT	B4SS	588426	4980812	NA	NA	active digging, 2 large Bull Trout on redds, 1 sneaker?
Pinhead Creek	1	9/19/2017	BT	B5SS	588427	4980807	NA	NA	3 fish active digging nice redd
Pinhead Creek	1	9/19/2017	BT	B6SS	588469	4980396	140	100	nice redd
Pinhead Creek	1	9/19/2017	BT	B1AK	588175	4981527	95	80	100% redd, side channel
Pinhead Creek	1	9/19/2017	BT	B1BB	588264	4981428	100	100	60% redd, fresh dig on old redd
Pinhead Creek	1	9/19/2017	BT	B2BB	588383	4981315	50	150	fresh dig on old redd
Pinhead Creek	1	9/19/2017	BT	B4BB	588375	4980660	170	200	100%redd
Pinhead Creek	1	9/19/2017	BT	B1CA	588421	4980956	140	70	definite redd, high confidence
Pinhead Creek	1	9/19/2017	BT	B2CA	588419	4980935	140	100	2 Bull Trout on redd
Pinhead Creek	2	9/18/2017	BT	B1AK	588705	4979418	100	80	fresh redd, bt carcass on site, otter kill
Pinhead Creek	2	9/18/2017	BT	B2AK	588720	4979405	90	50	fresh redd, under log
Pinhead Creek	2	9/18/2017	BT	B3AK	588940	4979098	100	60	reused site, new redd
Pinhead Creek	2	9/18/2017	BT	B4AK	588867	4979070	120	70	nice redd
Pinhead Creek	2	9/18/2017	BT	B5AK	589088	4978631	100	150	poorly formed, possible test redd
Pinhead Creek	2	9/18/2017	BT	B6AK	589230	4978027	80	140	little gravel, 40%
Pinhead Creek	2	9/18/2017	BT	B1BB	588949	4979098	100	160	100% redd
Pinhead Creek	2	9/18/2017	BT	B2BB	589056	4978634	120	100	75% redd, loks small but good mound
Last Creek	1	9/18/2017	BT	B1BB	588794	4980359	310	130	huge redd
Last Creek	1	9/18/2017	BT	B2BB	588580	4980312	230	120	nice redd

Stream	Reach	Date	Species	Redd ID	Easting	Northing	LN (cm)	WD (cm)	Comment
Pinhead Creek	2	9/19/2017	BT	B7AK	588574	4980084	170	70	50% redd on old redd, some fresh digging
Pinhead Creek	2	9/19/2017	BT	B8AK	588564	4980030	110	20	50% redd, lacks mound, narrow width, test?
Pinhead Creek	2	9/19/2017	BT	B9AK	588581	4979976	150	50	50% redd, lacks mound, narrow width, test?
Pinhead Creek	2	9/19/2017	BT	B10AK	588594	4979854	160	160	90% redd, circle cleared debris
Pinhead Creek	2	9/19/2017	BT	B11AK	588858	4979855	160	40	100%, two Bull Trout on redd, under cutbank
Pinhead Creek	2	9/19/2017	BT	B12AK	588631	4979666	240	140	Huge redd
Pinhead Creek	2	9/19/2017	BT	B13AK	588631	4979665	150	50	80%, small, possible test
Pinhead Creek	2	9/19/2017	BT	B14AK	588629	4979940	210	120	large redd 2m ds of 7B, under log, 100%
Pinhead Creek	2	9/19/2017	BT	B2HH	588557	4980132	60	100	85% confidence
Pinhead Creek	2	9/19/2017	BT	B3HH	588614	4979687	160	210	nice redd
Pinhead Creek	2	9/19/2017	BT	B4HH	588610	4979677	40	100	small redd, 50-50
Pinhead Creek	2	9/19/2017	BT	B5HH	588614	4979653	160	220	nice redd, 400mm Bull Trout on redd
Pinhead Creek	2	9/19/2017	BT	B6HH	588652	4979547	160	150	nice redd
Pinhead Creek	1	9/27/2017	BT	D1CW	588147	4981592	150	80	just upstream of weir, nice redd
Pinhead Creek	1	9/27/2017	BT	D2CW	588359	4980701	150	150	nice new redd
Pinhead Creek	1	9/27/2017	BT	D3CW	588366	4980669	160	180	big redd, 2 tails touching
Pinhead Creek	1	9/27/2017	BT	D1SS	588344	4981160	70	45	small redd, obvious digging, p/m clear
Pinhead Creek	1	9/27/2017	BT	D2SS	588378	4981143	150	145	nice redd
Pinhead Creek	1	9/27/2017	BT	D3SS	588383	4980676	70	40	minimal mound, clear digging, borderline, 50% confidence
Last Creek	1	9/27/2017	BT	D1NS	588673	4980355	230	100	Bull Trout on redd
Last Creek	1	9/27/2017	BT	D2NS	588970	4980406	190	100	Bull Trout on redd
Last Creek	1	9/27/2017	BT	D3NS	589291	4980461	100	60	75% sure
Last Creek	1	9/27/2017	BT	D4NS	589336	4980417	150	90	maybe, 50-50 call
Pinhead Creek	2	9/27/2017	BT	D1PB	588576	4979762	120	60	mound ln 70cm, on previous redd site
Pinhead Creek	2	9/27/2017	BT	D2PB	588602	4979698	80	60	mound ln 45cm, on previous redd site
Pinhead Creek	2	9/27/2017	BT	D3PB	588600	4979689	100	35	mound ln 35cm
Pinhead Creek	2	9/27/2017	BT	D4PB	588627	4979671	90	70	mound ln 65cm
Pinhead Creek	2	9/27/2017	BT	D5PB	588858	4979247	90	75	mound ln 70cm
Last Creek	1	10/3/2017	BT	E1HH	588733	4980359	130	80	small redd

Stream	Reach	Date	Species	Redd ID	Easting	Northing	LN (cm)	WD (cm)	Comment
Pinhead Creek	1	10/3/2017	BT	E1HH	588371	4981143	220	120	possible digging, 50-50, fresh redd
Pinhead Creek	1	10/3/2017	BT	E2HH	588382	4981138	130	70	pocket under log
Pinhead Creek	1	10/3/2017	BT	E1AK	588188	4981525	50	180	
Pinhead Creek	1	10/3/2017	BT	E3AK	588090	4981702	120	170	possibly three redds at one loc
Pinhead Creek	1	10/3/2017	BT	E4AK	588387	4981088	130	170	nice redd
Pinhead Creek	1	10/3/2017	BT	E1BB	588437	4980821	200	100	certain, mid-chan rel, compared to other two redds
Pinhead Creek	2	10/2/2017	BT	E1AK	588563	4980293	80	50	Classic redd
Pinhead Creek	2	10/2/2017	BT	E2AK	588640	4979664	120	190	90% certainty, on old redd
Pinhead Creek	2	10/2/2017	BT	E3AK	588641	4979552	160	170	50% fresh mound under log
Pinhead Creek	2	10/2/2017	BT	E4AK	588655	4979537	160	220	100% large redd, classic
Pinhead Creek	2	10/2/2017	BT	E5AK	588661	4979537	50	130	100%, 5 m us of E4 between logjam
Pinhead Creek	2	10/2/2017	BT	E6AK	588734	4979356	120	230	large redd, double mound
Pinhead Creek	2	10/2/2017	BT	E1SS	589095	4978606	210	75	nice redd, under log
Pinhead Creek	2	10/2/2017	BT	E2SS	588834	4979256	170	110	nice redd
Pinhead Creek	2	10/16/2017	BT	F1HH	588552	4980273	140	70	90% confident bt redd
Pinhead Creek	2	10/16/2017	BT	F1AK	589217	4798067	150	60	on top of flagged 2015 redd
Clackamas River	5	10/16/2017	BT	F1AK	587900	4972376	90	160	confluence of main/left chans
Clackamas River	5	10/16/2017	BT	F1SS	588645	4970962	160	65	nice redd, at previous location
Clackamas River	5	10/16/2017	BT	F2SS	588566	4971231	160	150	nice redd, bt gravel
Pinhead Creek	1	10/17/2017	BT	F2HH	588093	4981667	140	50	small good redd, under with pocket under log
Pinhead Creek	1	10/17/2017	BT	F3AK	588279	4981423	140	130	100% bt redd, previously marked, no ink, check GPS coords with B survey
Pinhead Creek	1	10/17/2017	BT	F4AK	588279	4980607	80	60	90% small redd, fines filled in when sediments above disturbed
Pinhead Creek	1	10/17/2017	BT	F1JW	588281	4981426	120	50	75% confidence, near submerged log
Last Creek	1	10/17/2017	BT	F1AK	588706	4980356	180	100	Nice redd under log
Last Creek	1	10/17/2017	BT	F2AK	588892	4980412	170	120	50% nice redd, no algae surrounded by algae, could be last year but fresh digging
Last Creek	1	10/17/2017	BT	F3AK	589691	4980569	100	80	100% small redd, above small debris jam, nice redd

Stream	Reach	Date	Species	Redd ID	Easting	Northing	LN (cm)	WD (cm)	Comment
Last Creek	1	10/17/2017	BT	F1HH	588746	4980358	60	40	50% bt redd, very small, obvious pocket mound. Lg redd upstream
Last Creek	1	10/30/2017	BT	G1HH	589089	4980405	170	90	clearly fresh digging around pocket bu mound is not bright. 75% bt redd
Pinhead Creek	2	10/31/2017	BT	G1AK	588577	4980099	60	90	100%, small bt redd, nice mound
Pinhead Creek	2	10/31/2017	BT	G3AK	588689	4979494	90	50	100% bt redd, deep pool
Pinhead Creek	2	10/31/2017	BT	G4AK	588755	4979313	110	70	100% bt redd, nice mound!
Pinhead Creek	2	10/31/2017	BT	G1HH	588958	4979146	150	80	100% bt redd
Pinhead Creek	1	10/31/2017	BT	G1HH	588101	4981736	180	60	100% bt redd
Pinhead Creek	1	10/31/2017	BT	G4HH	588323	4981420	140	40	100% bt redd
Pinhead Creek	1	10/31/2017	BT	G4AK	588342	4981142	150	90	small bt redd 90%
Pinhead Creek	1	10/31/2017	BT	G6AK	588467	4980362	130	70	100% bt redd and gravel
Pinhead Creek	1	10/31/2017	BT	G6SS	588376	4981333	150	100	50/50 bt/chk redd, gravel maybe too small for chk

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