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Spring Chinook Salmon in the Willamette and Sandy Basins

Sandy River Basin Spring Chinook Salmon Spawning Surveys – 2016

Compliance Monitoring for Sandy Hatchery Biological Opinion – April 2017

ANNUAL PROGRESS REPORT

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KEY FINDINGS

1. The proportion of hatchery origin spawners (pHOS) for spring Chinook salmon *Oncorhynchus tschwytscha* in the Sandy River Basin was 4.8%.
2. The estimated number of spawners in the Sandy River Basin was 3,615.
3. A total of 44 hatchery fish were removed at the weirs, reducing pHOS from 7.8% to 2.8% in the upper Sandy River Basin.
4. Peak spawn timing occurred from September 27 to October 4, within the range of dates from 2002-2015.
5. Spawning distribution was similar to 2002-2007, suggesting that weirs did not affect distribution.
6. Prespawn mortality of wild fish in the Salmon and Zigzag River basins was lower than in 2003–2011 in the absence of weirs.

INTRODUCTION

Spring Chinook salmon *Oncorhynchus tshawytscha* from the Sandy Basin were listed as threatened under the Endangered Species Act in 1999 (NOAA 1999). All hatchery spring Chinook salmon in the Sandy River basin were released with adipose fin clips and thermally marked otoliths beginning with the 1997 brood year. All fin-clipped hatchery spring Chinook salmon were trapped and removed at Marmot Dam in 2002–2007. After Marmot Dam was removed in 2007, it could no longer be used to exclude hatchery fish from spawning areas in the upper Sandy River basin. Following the dam's removal, the percentage of hatchery-origin spawners (pHOS) in spring Chinook salmon increased to 23–77% of the spawning population in 2008–2012, compared to a mean of 11% (4–18%) in 2002–2007, when Marmot Dam was used to sort returning fish. A detailed history of management for Chinook salmon in the Sandy Basin can be found in Schroeder et al. (2013) and Taylor (1998).

Beginning in 2011, the Oregon Department of Fish and Wildlife (ODFW) implemented several measures to reduce the proportion of hatchery Chinook spawning in the wild. These actions included operating weirs and traps to remove adult hatchery Chinook salmon, reducing the number of hatchery smolts released, and acclimating juvenile hatchery Chinook in the Bull Run River with the objective of increasing the number of hatchery fish that home back to their release location, where they can be trapped and removed. In 2013, ODFW began operating a weir near the mouth of the Bull Run River to trap and remove hatchery adults homing back to this river. Also, ODFW began conducting spawning surveys in the Bull Run River in 2013.

This report summarizes data collected during spawning surveys and an assessment of the Sandy hatchery program pertaining to spring Chinook salmon. We report on the following selection of performance standards and monitoring requirements from the Hatchery Genetics Management Plan for the Sandy River basin. Those activities or analyses in bold italics are ongoing and will be reported later as noted.

1. Reduce straying of hatchery spring Chinook in the upper Sandy River (above the confluence of the upper Sandy and Salmon rivers) through construction of off-station acclimation ponds, weirs/traps, and other stray reduction measures.
2. Performance standard for a three-year running average pHOS is of 0.10 of the spawning population in spring Chinook salmon.
3. ODFW will monitor the presence of hatchery fish on the spawning grounds to verify compliance with this standard.
4. Complete census conducted by ODFW, across the Sandy Basin, of the location, number, and timing of naturally spawning hatchery fish.
5. Life-history characteristics of hatchery origin and wild spring Chinook will be monitored through analysis of hatchery returns (***run timing and age composition***), spawning ground surveys, and juvenile out-migrants.
6. Determine distribution and spawning success of naturally-produced spring Chinook salmon. ***Assessment of productivity is long-term because of the generational overlap in returning adults; some analyses require age composition data to assess brood year returns and adult-to-adult survival (see #5).***
7. Monitor the number of mortalities in all adult collection facilities and on spawning grounds for each species to assess the potential effect of trap operation, with an emphasis on prespawn mortality in the naturally produced population.
8. Monitor changes in spawning distribution and estimate prespawn mortality**.**

METHODS

Spawning surveys for spring Chinook salmon in the Sandy River basin consist of carcass recovery and redd counts, following the methods used in previous years (Schroeder et al. 2013). These surveys are designed to provide a complete census of redds in all areas with spawning habitat for spring Chinook salmon and to recover all observed carcasses. Data collected from carcasses include prespawn mortality (based on females), hatchery:wild composition (based on the presence or absence of fin clips or thermal marks in otoliths), and age composition and freshwater life history in wild fish (based on analysis of scales). Redd counts are used to estimate spawner escapement (the number of adult fish that reach the spawning grounds), total run size when combined with other metrics, and to describe spawning distribution. Weirs were used to exclude hatchery spawners from the upper Sandy Basin.

Redd Counts

All spawning areas for spring Chinook in the upper Sandy River basin were surveyed on a 7–10 day cycle, with increased effort during peak spawning to survey all areas. This schedule is designed to ensure weekly coverage of the primary spawning areas in the Salmon and Zigzag rivers and Still Creek, which have historically accounted for 80–90% of all spring Chinook redds in the upper Sandy Basin (the area of the Sandy Basin above the site of the former Marmot Dam, Figure 1). In 2016, we surveyed the Bull Run River, a tributary in the lower Sandy Basin and the mainstem Sandy River upstream of the Marmot Dam site biweekly (Figure 1). All redds observed were counted in each survey. The same surveyors generally covered the same survey sections so they could better follow changes in spawning activity.

Redds were tallied on a personal digital assistant (PDA) and coordinates of redds were recorded with a global positioning system (GPS) receiver connected to the PDA. Comments were recorded on the PDA to help interpret data at the end of the season.

For purposes of surveys and analysis, streams were divided into "survey sections" based on geographical landmarks such as bridge crossings or campgrounds (Figure 2). These survey sections have been used by ODFW since 1996. As described below, in 2016 we split the traditionally used survey sections in the lower sections of the Salmon, Zigzag, and Bull Run rivers at the location of the weirs to allow additional analyses of potential effect of trapping on distribution of spawners and prespawn mortality.

Surveys cannot distinguish redds produced by hatchery fish from redds produced by naturally produced fish. Thus, in our analysis, we used a surrogate indicator to estimate the percentage of redds in each survey section that are produced by clipped, versus unclipped fish. For each survey section, we calculated the percentage of clipped versus unclipped carcasses found in that section. That percentage was then used to estimate the contribution of clipped and unclipped spawners to redds found in that section.

For the Bull Run River surveys, we used standard sections that were used in previous years by the Portland Water Bureau (PWB). These surveys were added in 2013 because ODFW began operating a weir on the Bull Run River and have continued to do so. ODFW did not conduct these surveys previously because they were being done by PWB and the data was shared for our reports. Surveys by PWB documented little spawning activity and ODFW biologists noted limited available spawning habitat (Schroeder et al. 2013).

Carcass Recovery

We processed all recovered carcasses of spring Chinook salmon for which we could determine the presence of an adipose fin. Carcasses were cut open to verify sex, and retention of eggs in females was used to determine spawning success (prespawn mortality). We scanned all fin-clipped fish with a hand-held detector to check for coded-wire tags (CWT), and collected the snout and biological data (fork length, sex, spawning success) from those with a CWT. Snouts were put into a plastic bag with a waterproof tab providing a unique identifier for each sample. All data were entered into PDAs.

We collected otoliths from all carcasses with an adipose fin (and those with questionable fin clips). We collected scales and tissue samples from all unclipped fish. Otoliths and tissues were put into individually numbered vials, and scales were put into numbered waterproof envelopes. Data were recorded on scale envelopes and entered into a PDA, including references to otolith, tissue vial numbers, and survey section. Biological information included fork length (cm), sex, and spawning success. After processing the carcasses, tails were removed to identify fish that have already been counted and processed, and carcasses were returned to the stream channel.

Composition of Spawning Population

We used carcass sampling to identify hatchery and wild fish based on fin clips and to produce preliminary estimates of pHOS. Otoliths are being analyzed to apportion the unclipped or unknown fish (with a partial adipose fin clip or with an indeterminate fin clip status) into wild and hatchery categories. These results will be ready in March 2016 and will be used to correct pHOS estimates. In the last few years, hatchery fish have accounted for about 3% of the unclipped carcasses, increasing pHOS accordingly. Banding patterns are induced in the otoliths of all hatchery spring Chinook during incubation by raising or lowering the water temperature on a set schedule, which results in increases or decreases in the growth rings of otoliths and creates a pattern that can be used to differentiate between hatchery and wild fish (Volk et al. 1999). Composition of the spawning population was estimated for survey sections, subbasins, and the Sandy River Basin.

Age was determined by reading scales to count annuli following the methods described by Borgerson et al. (2014). Age composition was estimated by return year and by brood year from scales collected from wild fish recovered during spawning ground surveys.

Trapping

District biologists from ODFW installed weirs and fish traps in the lower Salmon and Zigzag rivers to capture and remove hatchery spring Chinook salmon migrating to spawning areas. Traps were checked once a day in the early part of the season. Beginning September 10, traps were monitored throughout the evening and night to process fish more frequently. All fish caught in the trap were counted daily by category (fin-clipped or unclipped). Fish with a fin clip were transported to the Clackamas Hatchery for gamete collection or to the Sandy Hatchery to be euthanized and used for nutrient enrichment in the upper Sandy Basin.

We incorporated additional elements to our surveys to monitor the potential effects of operating weirs in the lower Salmon and Zigzag rivers to remove fin-clipped Chinook salmon:

1. Identified weir locations in our standard survey sections to monitor counts upstream and downstream of the weirs
2. Recorded live fish, carcasses, prespawn mortality, hatchery:wild composition, and redds upstream and downstream of weirs
3. Analyses designed to evaluate potential weir effects included
    a. Distribution and timing of live fish relative to weir locations
    b. Distribution of redds within the Salmon and Zigzag watersheds and within the upper Sandy River basin
    c. Passage timing and subsequent distribution of spawners
    d. General timing of spawning compared to previous years
    e. Hatchery:wild composition of spawning population upstream and downstream of weirs, and within the upper Sandy River basin
    f. Comparison of pHOS among years
    g. Prespawn mortality within watersheds and in the upper Sandy River basin

Data Management and Analysis

All carcass and redd data were recorded on a PDA and these data were uploaded to a database daily. Data checks were conducted in-season and at the end of the season to identify and correct data entry errors or to verify questionable data. Data were summarized by survey section, including survey sections downstream of weirs. The highest redd counts for each section were reviewed to follow the progression of spawning activity during the season. We report peak redd counts, the highest number of redds observed during a single spawning survey for a given section.

When Marmot Dam was in place, the counting station at the dam allowed ODFW to count all adult spring Chinook salmon returning to the upper Sandy River basin. The dam was removed in November 2007; complete counts are no longer available. Simple linear regression of Marmot Dam count to redds counted upstream of the dam was used to estimate run size for 1996–1998 (early surveys) and 2002–2006 (Figure 3). We did not use 2007 because of unknown effects of dam deconstruction, operation of a temporary weir, and additional handling of adult Chinook salmon in a trap-and-haul operation to move fish upstream of the cofferdam. For 2007-2016, run size was estimated from peak redd counts and 2.5 fish per redd. The number of fish per redd is reviewed by Gallagher et al. (2007). The estimate of 2.5 fish per redd is supported by Boydstun and McDonald (2005) and has been used previously to estimate run size in the Sandy and Willamette basins.

Tissue samples are being stored for possible genetic studies on composition of spring and fall Chinook salmon if funding becomes available. These samples may also provide the basis of future studies on the rate and magnitude of genetic change in a population where hatchery fish are successfully excluded from the population.

RESULTS

We conducted spawning surveys for spring Chinook salmon in the Sandy River basin in 2016 from August 10 to October 26. Primary spawning areas in the Salmon and Zigzag watersheds were surveyed 6–9 times through the season, including surveys for prespawn mortality, and generally on a weekly rotation. These are the sections that have historically accounted for most of the redds in the upper basin. Secondary spawning areas in the upper Zigzag River, Little Sandy River, Lost, Clear Fork, Sixes and Cheeney creeks were surveyed 1–4 times depending on water levels. These secondary areas have contained few, if any, redds historically and depend on early rain events if they are to have enough water for Chinook salmon to spawn. Also, we surveyed the Sandy River upstream of the old Marmot Dam site (4 times) and the Bull Run River (4 times).

Composition of the Spawning Population

The estimate of pHOS in the Sandy River Basin, including the Bull Run River, in 2016 was 4.8% (Figure 4). For the upper Sandy River Basin (upstream of the old Marmot Dam site), the estimated pHOS in 2016 was 3.9 % (Table 1). The percentage of hatchery origin spawners

was lowest in the Salmon (1.0%) and Zigzag rivers (2.4%) and Lost Creek (0.0%), and highest in the Bull Run River (52.9%), Clear Fork Creek (14.1%) and Clear Creek (25.0%) (Tables 1 and 2). The percentage of hatchery spawners in 2016 was 1.2% and 1.3% upstream of weirs in the Salmon and Zigzag rivers, whereas 0% and 5.6% of the spawners downstream of the Salmon and Zigzag weirs were hatchery origin (Table 2).

Estimated abundance of spawning spring Chinook salmon in the Sandy Basin was 3,615, with 3,441 wild spawners and 174 hatchery spawners. The number of wild fish returning to the upper Sandy River Basin in 2016 was 25% higher than in 2015 (Figure 5).

Wild adult spawners returning in 2016 were 66.2% age 4 and 26.9% age 5 (Table 3). Each year, a small percentage of spawners will be age 3 and age 6. Wild adults from the 2010 brood year were 68.7% age 4 and 28.6% age 5 (Table 4). Wild adults from the 2011 brood year were 69.5% age 4 and 27.4% age 5, although we expect a small percentage of age 6 adults to return in 2017 (Table 4).

Effect of Trapping

Weirs and fish traps were installed by ODFW biologists in the lower Salmon and Zigzag rivers to capture and remove hatchery Chinook salmon migrating upstream to primary spawning areas. In 2016, the Zigzag River trap was in the same location as in 2013-2015. The Salmon River trap has been in the same location since 2013 just below the Highway 26 Bridge.

Trapping began June 23, 2016 in the Salmon and Zigzag Rivers (Table 5). Weir traps were checked at least once a day in the early part of the season. Traps were inspected daily to insure they were functioning properly and to remove fish that entered the trap. All fish with an intact adipose fin were passed upstream. Adult salmon were trapped at the weirs at a fairly steady rate from late July to early October (Figure 8). Weirs were removed on October 5 on the Zigzag and Salmon Rivers, because of increasing river levels (Figure 16), after peak spawning activity occurred in most areas (Figure 11).

A total of 44 hatchery Chinook were removed at the traps on the Salmon and Zigzag rivers, and 1,352 unclipped Chinook were trapped and passed upstream (Table 5, Figure 8). In addition, 75 clipped Chinook were removed and 22 unclipped Chinook were passed upstream at the weir on the Bull Run River.

We estimated that removing fin-clipped fish at the weirs reduced the percentage of hatchery fish in the spawning population from 7.8% to 2.8% for the primary spawning areas upstream of the Marmot Dam site (Table 6, Figure 9). The percentage of fin-clipped fish upstream of the weirs on the Salmon and Zigzag rivers was low overall (Table 1). These results indicate that trapping in the primary spawning tributaries continues to reduce the number of hatchery spawners.

Timing of Spawning

The date of first spawning in 2016 was September 7 in the Salmon River and September 6 in the Zigzag River (Figure 10). The first date of spawning in the Salmon River and Zigzag River were within the observed range from 2002-2009, when weirs were not present (Figure 10). The date of first spawning in 2016 in the lower Salmon River was September 8, similar to the mean from 2002–2009 (Figure 10).

Peak spawning date in the Zigzag River Basin occurred between September 28 and October 4, within the range from 2002-2010 before weirs were in place (Figure 11). In the Salmon River, peak spawning occurred from September 27 and October 1. This date was within the range from 2002-2010 (pre-weir) in all areas of the Salmon River.

Redd Counts and Distribution

The number of redds counted on all surveys in the upper Sandy Basin (above the old Marmot Dam site) was 1,435 in 2016, which was 20% higher than the number counted in 2015. Additionally, 11 redds were counted in the Bull Run River (including Little Sandy River), upstream of the weir.

Density of redds above the weirs was highest in the upper sections of the Salmon River and in Still Creek (Table 7). Redd densities in the upper sections of the Salmon River were similar to 2015 (88.8 redds/mile) and higher than 2013-2014 (Table 7). Redd densities in the lowest survey sections of the Salmon and Zigzag Rivers (weir to mouth) were high as well this year, possibly from delayed upstream migration or trap avoidance resulting in displacing fish downstream. Salmon and Zigzag rivers below the weirs had 151.7 and 80.7 redds/mi respectively. Still Creek continued to have high redd densities overall (87.0 redds/mi), as this tributary is where most spawning takes place in the Zigzag River watershed (Table 7). Variation in redd densities by section may be attributed to a number of causes, such as natural variation and changing habitat.

We compared the redd distribution among several survey sections in the Salmon and Zigzag watersheds. Redd distribution in 2015 was compared to 2002–2007 as a baseline for distribution of natural origin spawners because fin-clipped fish were removed at Marmot Dam. However, in the Salmon River, data from 2004 and 2006 were not used because redd counts were combined for the lower sections when section breaks were not noted on the data sheets.

In the Salmon River, the percentage of total redds increased in the section farthest upstream (Final Falls-Forest Rd 2618) and in the lowest section (Wildwood-mouth) when compared to 2002–2007, especially from unclipped spawners (Figure 12). The percentage of redds decreased in the two middle sections compared to 2002-2007. These data suggest an overall decrease in the percentage of redds in the middle survey sections.

In the Zigzag River watershed, the percentage of total redds in Still Creek and Zigzag River above Still creek increased from 2015 and when compared to 2002-2007 (Figure 13). The

percentage of redds in the section farthest downstream (Still Creek – mouth) and Camp Creek decreased in 2016 compared to 2015 and was lower compared to 2002–2007.

Overall redd distribution in the Salmon and Zigzag rivers in 2016 remained similar to those observed in 2002-2007, suggesting that weirs did not affect the distribution of spawning salmon (Figures 12 and 13). Redd locations were mapped for the Salmon and Zigzag rivers using GPS coordinates collected on spawning surveys (Figures 14 and 15).

Prespawn Mortality

We compared prespawn mortality in 2016 to that in 2003–2007 to detect any effects the weirs may have on prespawn mortality in wild fish. Data from 2003-2007 was chosen as an appropriate baseline to compare, because the spawning population in the upper basin was primarily wild fish migrating directly to the spawning grounds. We did not use 2002 or 2010 in our comparisons because spawning surveys in those years were not started until September, which reduced the probability of recovering carcasses of fish that died before spawning. One limitation of using the 2003–2007 period as a baseline for mortality in natural origin spawners is that all unclipped spring Chinook salmon were subject to handling at Marmot Dam where they were trapped and passed upstream.

Overall prespawn mortality in the upper Sandy River basin was 1.2 % (Table 8). Additionally, prespawn mortality in the upper basin in 2016 was lower for fin-clipped salmon (0.0%) than for unclipped salmon (1.3%), although very few hatchery fish were recovered. Among specific watersheds, prespawn mortality in the Salmon and Zigzag River basins was low in 2016 compared to 2003–2007 and 2011-2016 (Table 8). In the Salmon River, prespawn mortality was 3.7% for all fish and unclipped fish (0.0% for clipped; only 1 female carcass collected). In the Zigzag River, prespawn mortality was 0.0% for both clipped and unclipped fish, even though 208 female carcasses were recovered. Recovery of carcasses early in the spawning survey season is often low in the Zigzag River because of poor visibility caused by glacial melt. This can be a problem each year, but this area is surveyed frequently and good numbers of carcasses are still collected.

DISCUSSION

During the 2016 spawning season, survey conditions were favorable until the end of the season. Several rain storms occurred in October (Figure 16), with the heaviest rainfall occurring during the week of October 8-15. River levels were above average for the rest of the month (Figure 16). We obtained accurate peak redd counts before the first major rainstorm and recovered large numbers of carcasses, with over 45% of the carcasses obtained after peak spawning. In addition, live fish and redd counts declined soon after we observed peak redd counts, indicating that we surveyed peak spawning activity before the high flow events. However, we were unable to complete one late survey on the mainstem Sandy River because of high, turbid water. The last survey on the Sandy River occurred on October 3rd.

Estimated pHOS in the Sandy River basin, including Bull Run, was the lowest since 2002 at 4.8%. From 2002-2007, the mean pHOS was 11% (range 4-18%) when hatchery fish were removed at Marmot Dam. Following the removal of Marmot Dam in 2007, pHOS ranged from 9.3% in 2013 to as high 76.3% in 2010, with an average of 33.3% from 2008-2016. In the upper Clackamas River basin, pHOS in 2016 was 3%, the lowest since 2002. All fin-clipped fish are removed at North Fork Dam and pHOS is consistently low in the upper Clackamas basin. Since 2011, ODFW has taken measures to reduce the proportion of hatchery Chinook spawning in the upper Sandy Basin. The number of hatchery smolts released in the Sandy Basin was reduced starting in 2011. Weirs were installed on the lower Salmon and Zigzag rivers to exclude hatchery fish from the primary spawning areas used by wild fish upstream. In addition, hatchery smolts were acclimated in the lower Bull Run River to reduce straying to the upper Sandy Basin. A third weir was installed on the Bull Run River to exclude hatchery fish from spawning upstream and to remove returning hatchery adults for brood stock. As of 2016, most hatchery fish returning to the Sandy basin are from broods acclimated in Bull Run. Because of these efforts and the declining number of hatchery spawners, we expect pHOS to remain low in the Sandy Basin.

The estimated abundance of wild spring Chinook spawning in the upper Sandy basin in 2016 was 3,615, the highest since 2002. In the Clackamas River basin upstream of North Fork Dam, the number of wild spring Chinook salmon spawners was 3,376, the highest count since 2004 and 34% higher than in 2015. Wild populations of spring Chinook salmon continue to increase in these basins in recent years. In the McKenzie River, upstream of Leaburg Dam, the estimated number of wild spring Chinook spawners in 2016 was 1,659, which was 6% higher than in 2015. The average number of spawners in this area from 2002-2016 was 2,198 (Sharpe et al. 2017). The estimated number of hatchery spawners (174) in the upper Sandy was the lowest since 2008. Likewise, the number of hatchery fish counted at North Fork Dam (983) was the lowest since 2002. The continued reduction in hatchery spawners in the Sandy Basin is most likely the result of the management actions taken by ODFW to reduce pHOS.

Timing of peak spawning in the upper Sandy basin was similar to past years. The average peak spawning date from 2002-2016 is October 1 with a range of September 16 to October 17. In the upper Clackamas basin, peak spawning from 2002-2016 on average took place on October 5 with a range from September 24 to October 23. In the McKenzie River basin, peak spawning from 2008-2014 on average took place on September 25 with a range from September 21 to October 12. The median peak spawning date in the Salmon and Zigzag rivers from 2002-2015 was October 2 and September 28, respectively. In 2016, the first redds were observed during the first week of September on the Salmon and Zigzag rivers, which is the case most years.

Total redd counts in the upper Sandy basin in 2016 were the second highest (1,435) since comprehensive surveys began in 2002. Redd counts have averaged over 800 redds in the past 15 years. Redd counts have ranged from a low of 186 redds in 2003 to a high of 1,636 redds in 2010. In 2016, redd counts in the Bull Run and Little Sandy Rivers were the lowest since 2002. Redd counts in these rivers have averaged over 45 redds from 2002-2016. Redd density (redds/mile) in the upper sections of the Salmon River have consistently been the highest in the Sandy River basin. From 2002-2007 the average redd density was 33 redds/mile before Marmot Dam was removed from 2002-2007 and 80 redds/mile after Marmot Dam was removed from 2008-2016. In the Zigzag River basin, Still Creek has had the highest density of redds/mile in

most years. Still Creek averaged 19.5 redds/mile from 2002-2007 and 60.1 redds/mile 2008-2016.

The distribution of redds in the primary spawning areas has changed little in recent years. The distribution of redds in the Salmon River in 2016 was similar to previous years, with the upper survey sections having the highest percentage of redds. The section from Final Falls to USFS Rd. 2618 has had 48% of all redd in this river from 2011-2016. The percentage of redds from Wildwood park to the mouth of the Salmon River has changed little overall since the weirs started being used in 2011, with an average of 23% of all redds from 2011-2016. Redd distribution in the Zigzag River basin has varied less since surveys began in 2002. Still Creek has consistently has the highest percentage of redds in the Zigzag basin with 58% of all redds from 2011-2016. The section of the Zigzag River from Still Creek to the mouth has the second highest percentage of redds, with 25% of all redds in the Zigzag basin from 2011-2016. The percentage of redds in this section, which has the weir, has increases some in recent years, however the distribution is now similar to what was observed in the years before Marmot Dam was removed. The small tributaries of Lost Creek, Clear Fork and Clear Creek continue to have a low percentage of the total redds in the upper Sandy basin. The weirs seem to have had little effect on the distribution of redds in the Salmon and Zigzag rivers.

Prespawn mortality has remained low in the Sandy River basin since surveys began in 2002. From 2002-2009, before weirs were used, the average prespawn mortality was 7.4%. From 2011-2016, with weirs in use, average prespawn mortality has been 4.6%. Prespawn mortality in the Salmon River in 2016 was 3.7%, lower than the average from 2011-2016 (5.2%) and 2003-2009 (6.1%). No female prespawn carcasses were recovered from the Zigzag river in 2016. Average prespawn mortality in the Zigzag River from 2004-2008 was 1.8% and 3.9% from 2011-2016. Prespawn mortality is typically higher for clipped hatchery spawners. From 2008-2016 average prespawn mortality for unclipped fish was 4.0% (range 1.0-10.9%) and was 6.4% (range 0.0-11.1%) for clipped fish. Overall, these results suggest that the weirs do not increase prespawn mortality.

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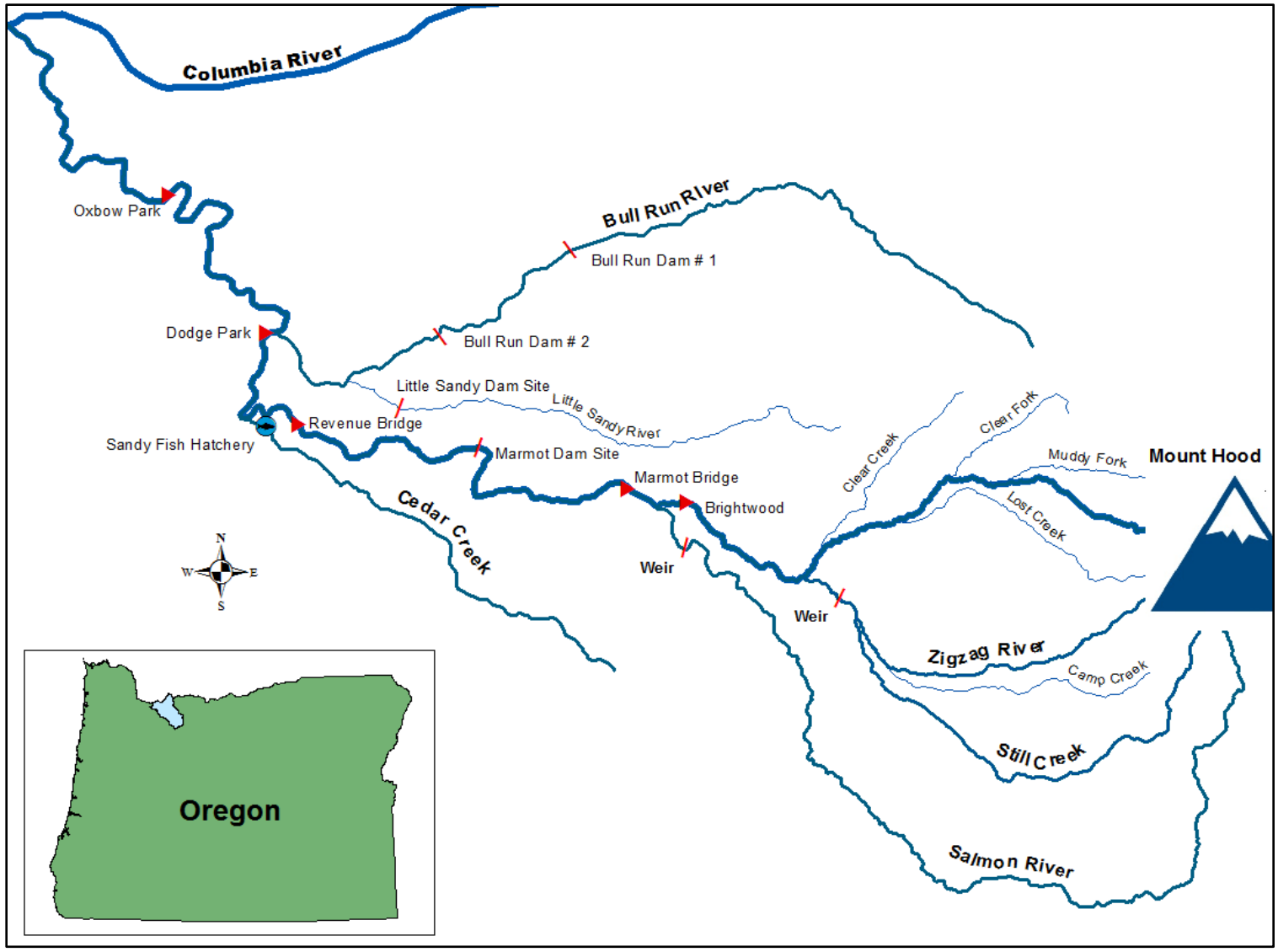

Figure 1. The Sandy River Basin including tributaries with spawning populations of spring Chinook salmon.

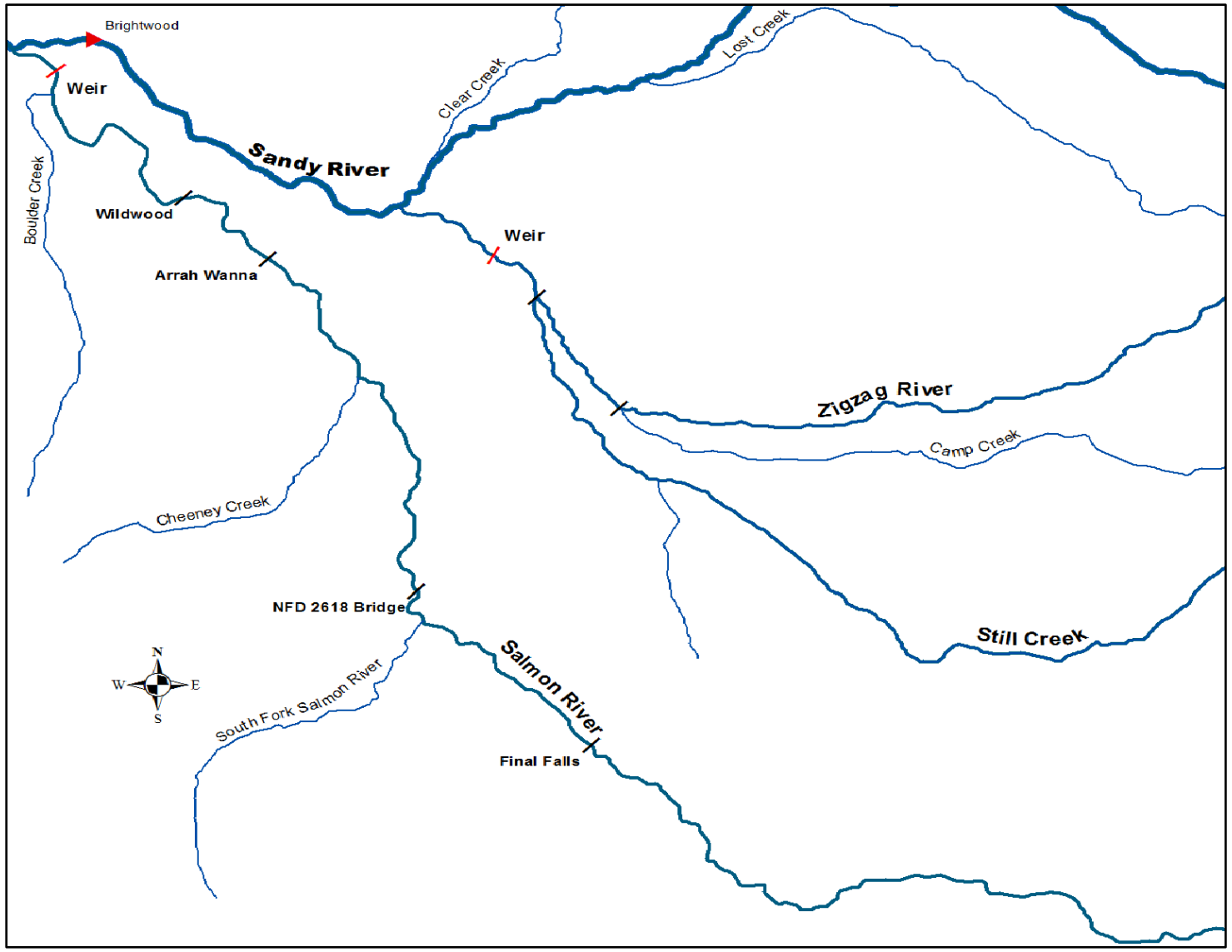

Figure 2. The upper Sandy River Basin with weirs locations and some section breaks on major spawning tributaries.

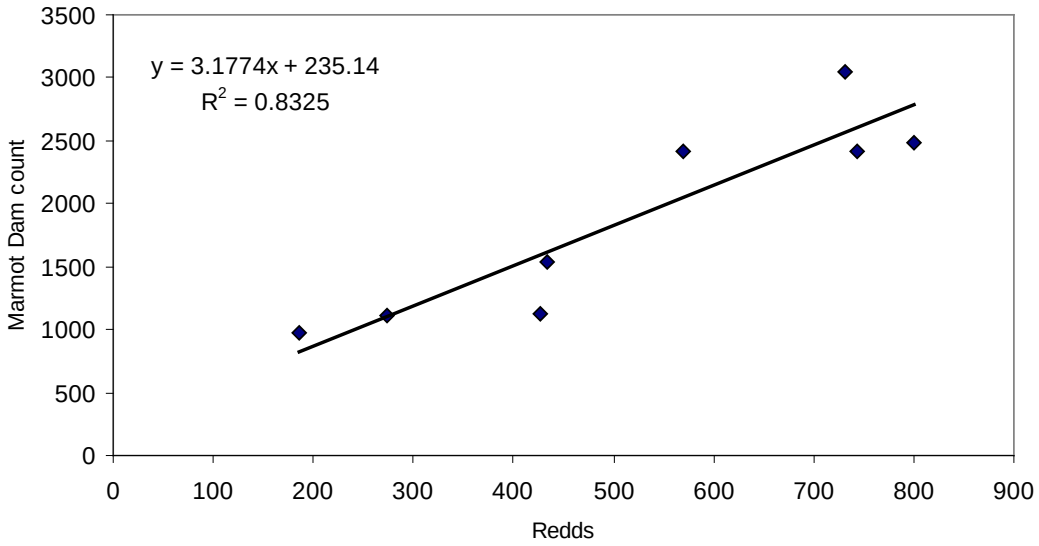

Figure 3. Relationship between count of adult spring Chinook salmon at Marmot Dam and the number of Chinook redds counted upstream of the dam, 1996–1998 and 2002–2006.

Table 1. Percentage of spring Chinook salmon carcasses with fin-clips that were recovered in spawning areas of the Sandy River Basin, 2016.

River/stream	Section	Percent clipped	Sample size
Salmon River	Final Falls - NFD 2618 Br.	1	134
	NFD 2618 Br. - Arrah Wanna	3	61
	Arrah Wanna - Weir	0	51
	Weir - Mouth	0	54
	Cheeney Creek	0	0
Salmon Basin Total		**1**	**301**
Zigzag River	Above Camp Creek	0	5
	Camp Creek - Still Creek	9	11
	Still Creek - weir	2	48
	Weir - mouth	6	124
Zigzag River Total		**5**	**188**
Still Creek	Above Rd 20 Bridge	0	150
	Below Rd 20 Bridge	2	147
Still Creek Total		**2**	**297**
Camp Creek	Campground - mouth	0	12
Zigzag Basin Total		**2**	**497**
Lost Creek	Riley Campground - mouth	0	4
Clear Fork	Mouth area	14	71
Clear Creek	E. Barlow Rd to mouth	25	4
Bull Run River	Dam - mouth	53	17
Sandy River	Zigzag River to Marmot Dam	0	5
GRAND TOTAL		**4.8**	**899**

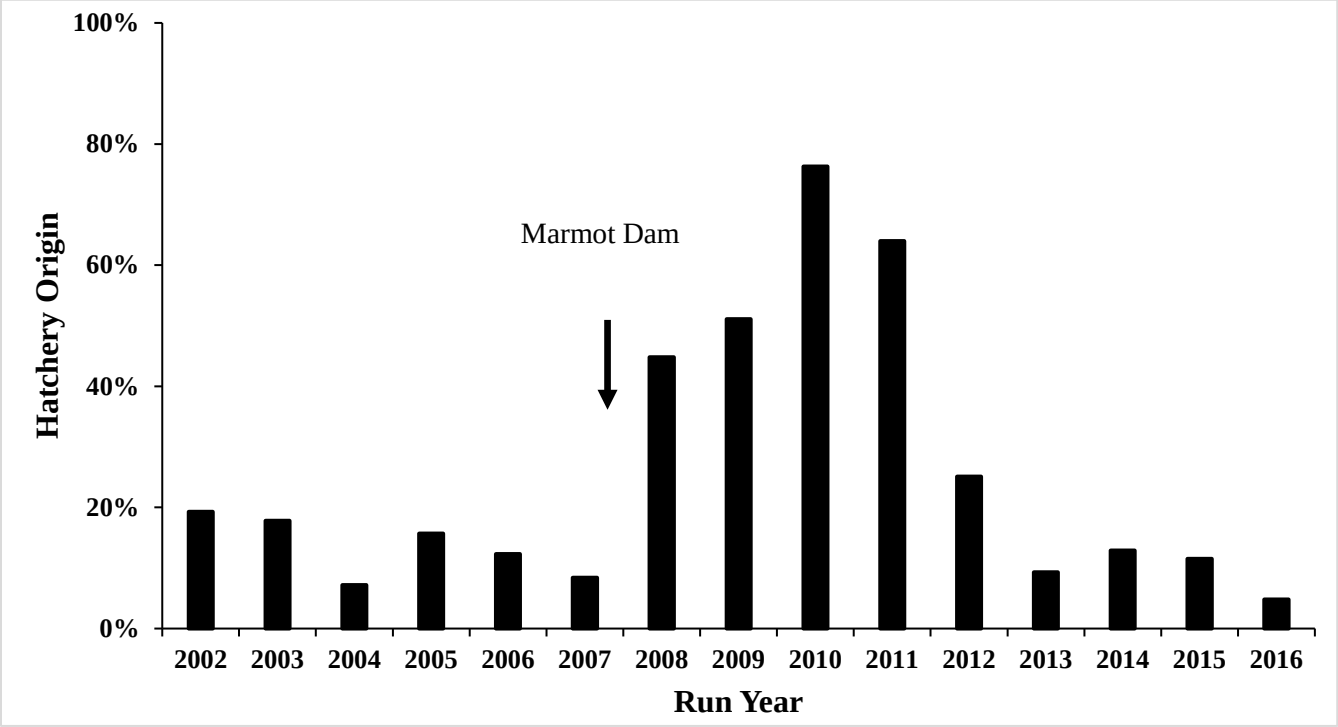

Figure 4. Percentage of hatchery-origin spring Chinook salmon in the spawning population of Sandy River basin upstream of the Marmot Dam site, 2002–2016.

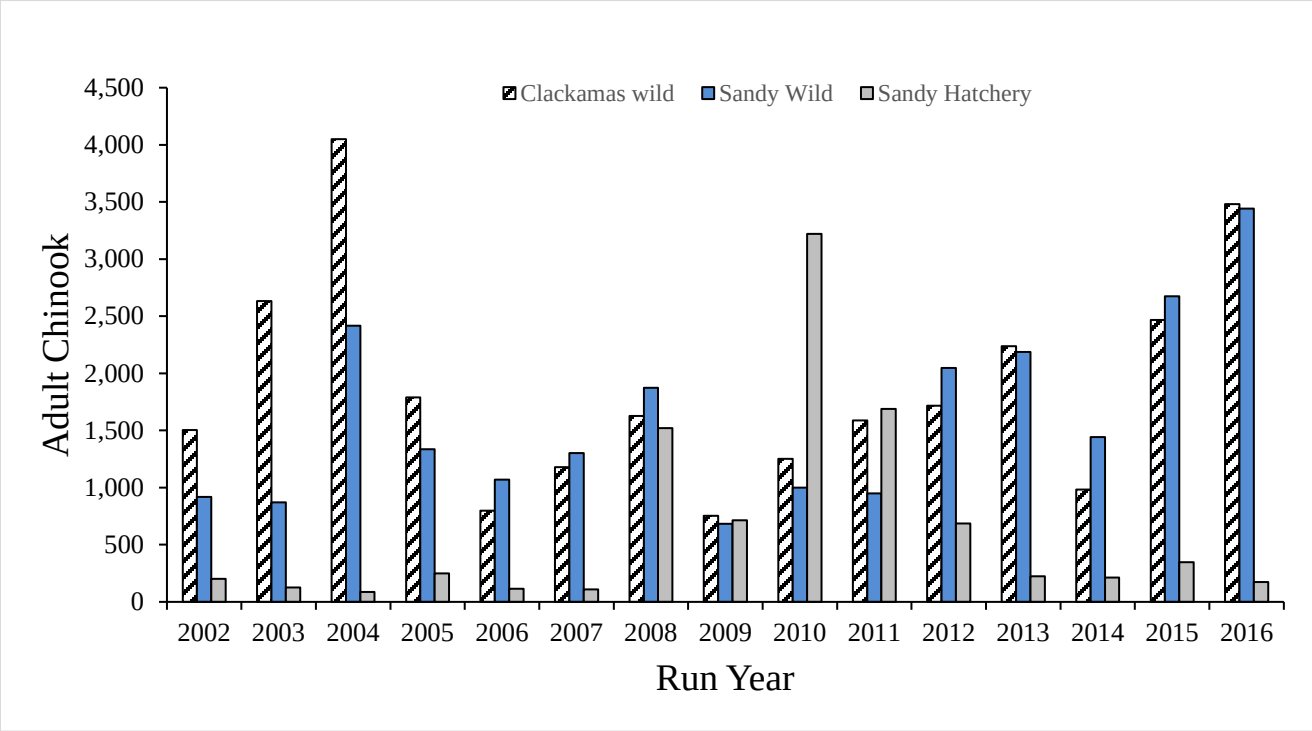

Figure 5. Number of spring Chinook salmon spawning in the Sandy River basin (hatchery and wild), and in the Clackamas Basin upstream of North Fork Dam (wild), 2002–2016. Number of fish in the Sandy River basin in 2008–2016 was estimated from redd counts. For 2002–2006, the number of fish was estimated with the relationship of counts at Marmot Dam to redd counts. The proportion of wild and hatchery fish was estimated from recovery of carcasses.

Table 2. Percentage of spring Chinook salmon carcasses that were hatchery origin in six areas of the Sandy River Basin, 2016.

Basin	Area	Percent hatchery	Sample size
Salmon	Upstream of weir	1.2	247
	Downstream of weir	0.0	54
	Total	**1.0**	**301**
Zigzag	Upstream of weir	1.3	373
	Downstream of weir	5.6	124
	Total	**2.4**	**497**
Sandy R, Lost,& Clear Fork creeks	All surveyed areas	13.1	84
Bull Run River	Dam–mouth	52.9	17

Table 3. Age composition (%) by return year of wild spring Chinook salmon in the Sandy River basin. Origin of fish was determined by presence of the adipose fin and absence of induced thermal marks in otoliths.

RETURN YEAR (N)	AGE 3	AGE 4	AGE 5	AGE 6
2002 (74)	0.0%	45.9%	51.4%	2.7%
2003 (40)	2.5%	25.0%	67.5%	5.0%
2004 (226)	0.4%	73.9%	25.2%	0.4%
2005 (162)	0.0%	23.5%	74.7%	1.9%
2006 (180)	1.1%	41.1%	56.7%	1.1%
2007 (216)	0.9%	23.1%	74.1%	1.9%
2008 (290)	0.3%	42.8%	54.8%	2.1%
2009 (91)	0.0%	41.8%	54.9%	3.3%
2010 (265)	4.9%	43.4%	51.3%	0.4%
2011 (242)	2.9%	58.7%	36.4%	2.1%
2012 (649)	0.3%	55.0%	43.1%	1.5%
2013 (611)	1.6%	32.2%	64.2%	2.0%
2014 (488)	2.5%	51.2%	45.7%	0.6%
2015 (399)	5.8%	67.4%	26.1%	0.8%
2016 (394)	6.6%	66.2%	26.9%	0.3%

Table 4. Age composition (%) by brood year of wild spring Chinook salmon in the Sandy River basin. Origin of fish was determined by presence of the adipose fin and absence of induced thermal marks in otoliths.

BROOD YEAR (N)	AGE 3	AGE 4	AGE 5	AGE 6
1998 (62)	--	54.8%	43.5%	1.6%
1999 (70)	0.0%	14.3%	81.4%	4.3%
2000 (291)	0.3%	57.4%	41.6%	0.7%
2001 (145)	0.7%	26.2%	70.3%	2.8%
2002 (240)	0.0%	30.8%	66.7%	2.5%
2003 (214)	0.9%	23.4%	74.3%	1.4%
2004 (177)	1.1%	70.1%	28.2%	0.6%
2005 (180)	0.6%	21.1%	75.6%	2.8%
2006 (213)	0.0%	54.0%	41.3%	4.7%
2007 (447)	2.9%	31.8%	62.6%	2.7%
2008 (759)	0.9%	47.0%	51.6%	0.4%
2009 (425)	0.5%	46.4%	52.5%	0.7%
2010 (364)	2.7%	68.7%	28.6%	0.3%
2011 (365)	3.1%	69.5%	27.4%	—

Table 5. Number of spring Chinook salmon counted at traps in the Salmon and Zigzag Rivers, 2011-2016. Fin-clipped fish were removed and unclipped fish were passed upstream. Traps were installed by ODFW district biologists to capture and remove fin-clipped salmon.

Zigzag	2011	2012	2013	2014	2015	2016
Dates	Aug 19-Sep 29	Jul 14-Oct 14	Jul 8-Sep 27	Jun 20-Oct 10	May 21–Oct 12	Jun 23-Oct 5
Fin-clipped	183	177	154	302	46	18
Not clipped	91	399	721	597	573	359

Salmon	2011	2012	2013	2014	2015	2016
Dates	Sep 14-Oct 4	Jun 18-Oct 14	Jul 8-Sep 28	Jul 7-Oct 10	Jul 1-Oct 21	Jun 23-Oct 5
Fin-clipped	229	247	88	156	70	26
Not clipped	94	1,108	684	579	972	993

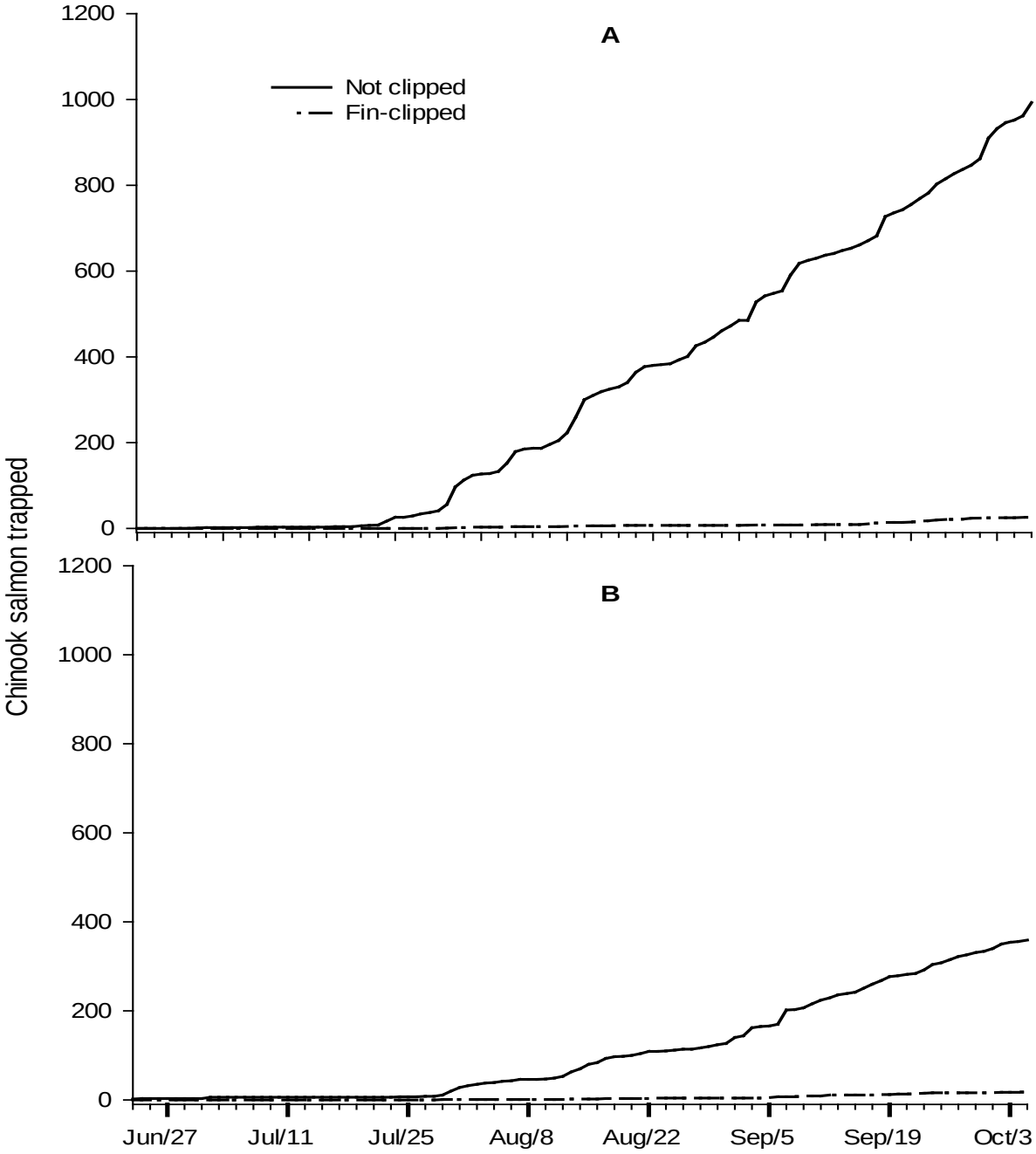

Figure 8. Cumulative number of spring Chinook salmon handled at weirs in the lower Salmon (A) and Zigzag (B) rivers, for fish with an adipose fin clip (dashed line) and without a fin clip (solid line), 2016.

Table 6. Effect of trapping and removing fin-clipped spring Chinook salmon at weirs in the lower Zigzag and Salmon Rivers on the proportion of hatchery spawners in the Zigzag and Salmon rivers and in the upper Sandy River basin, 2016.

		Fin-clipped spawners (%)	
	Number removed	With trapping	Without trapping
Zigzag	21	3.8	13.7
Salmon	26	1.0	9.0
Upper Sandy River basin	47	2.8	7.8

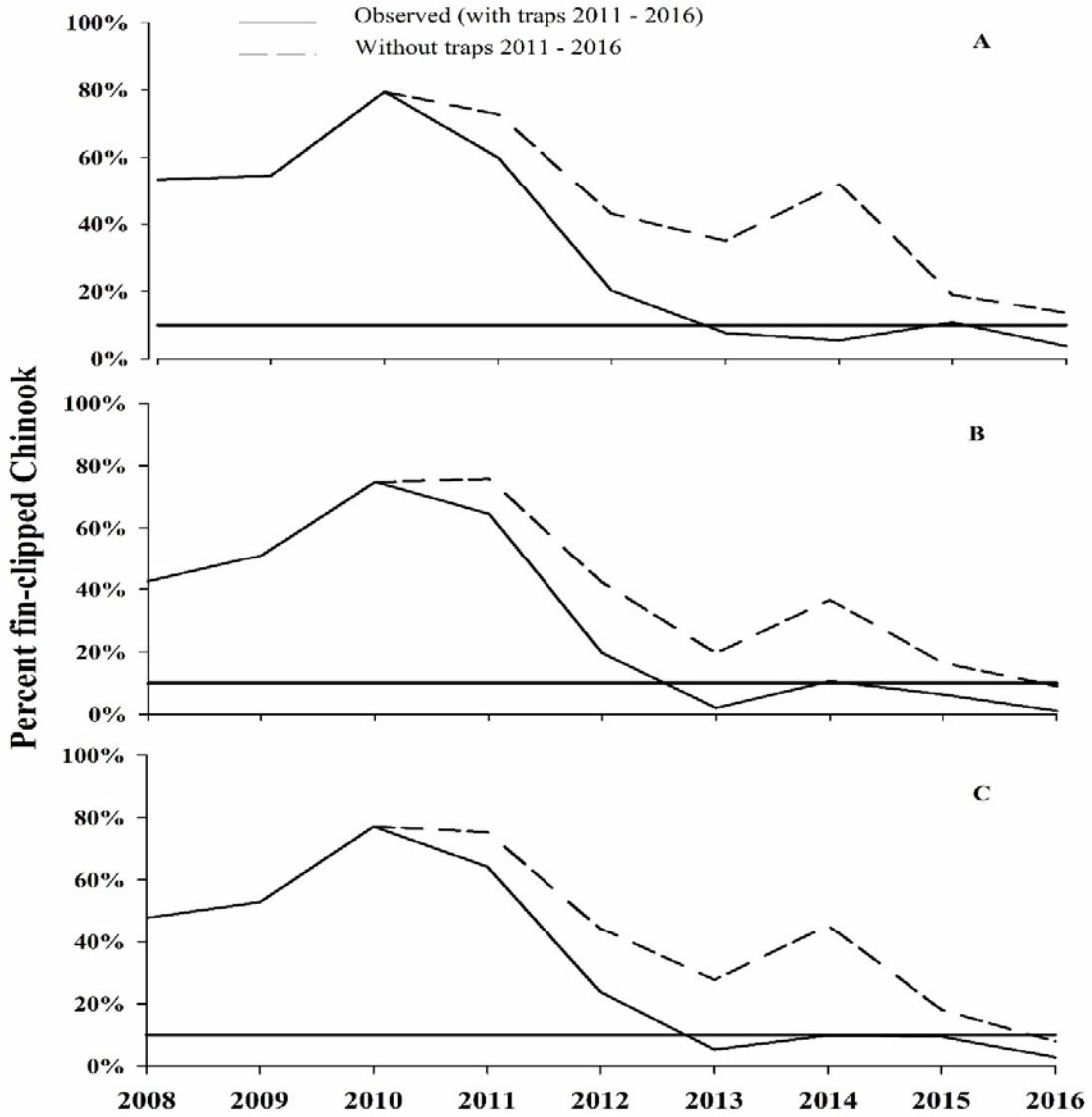

Figure 9. Percentage of fin-clipped spring Chinook salmon in the Zigzag (A) and Salmon (B) rivers, and in the upper Sandy River basin (C). Traps were operated in the lower Salmon and Zigzag rivers in 2011–2016 to remove fin-clipped fish. Estimated percentage of fin-clipped spawners without trapping is shown by dashed line. The 10% line represents the conservation and recovery objectives for proportion of hatchery-origin spawners.

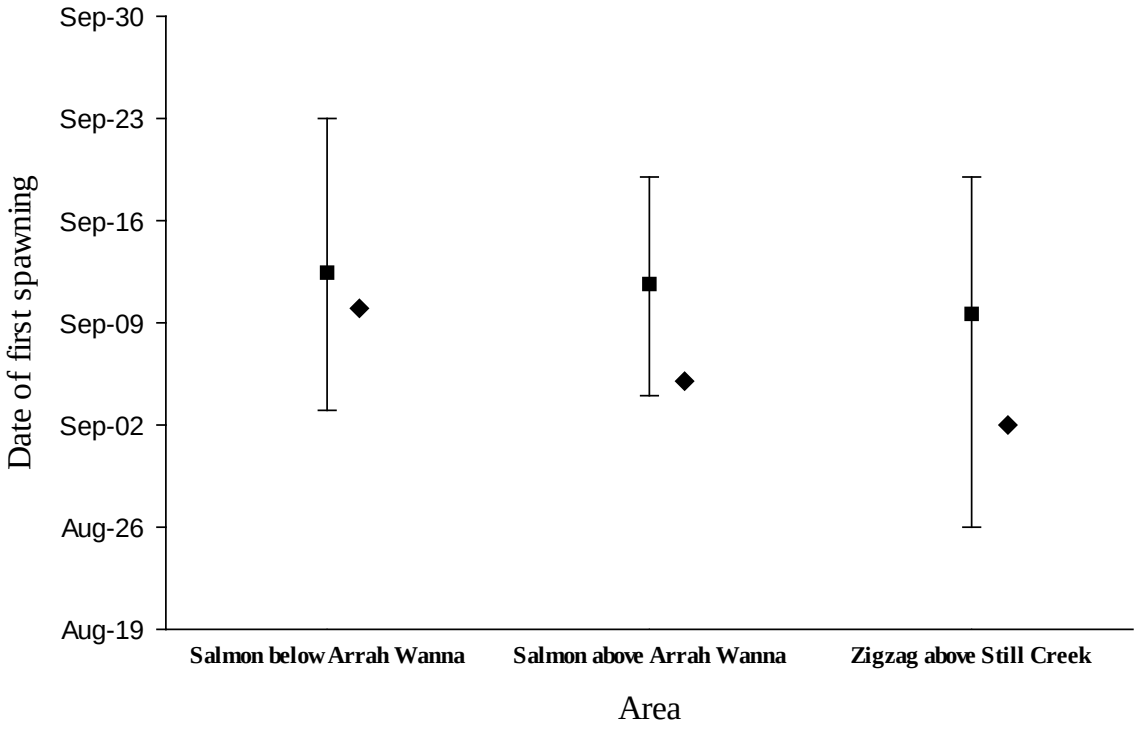

Figure 10. Date of first spawning for spring Chinook salmon in the Salmon and Zigzag River Basins for 2002–2009 (mean, ■), and in 2016 (♦). The capped vertical lines are the range and the numbers above the lines are years in the data set. Data for 2010 were not included because surveys started late. Does not include 2003 for the Zigzag River Basin because surveys were more than two weeks apart between early and late September.

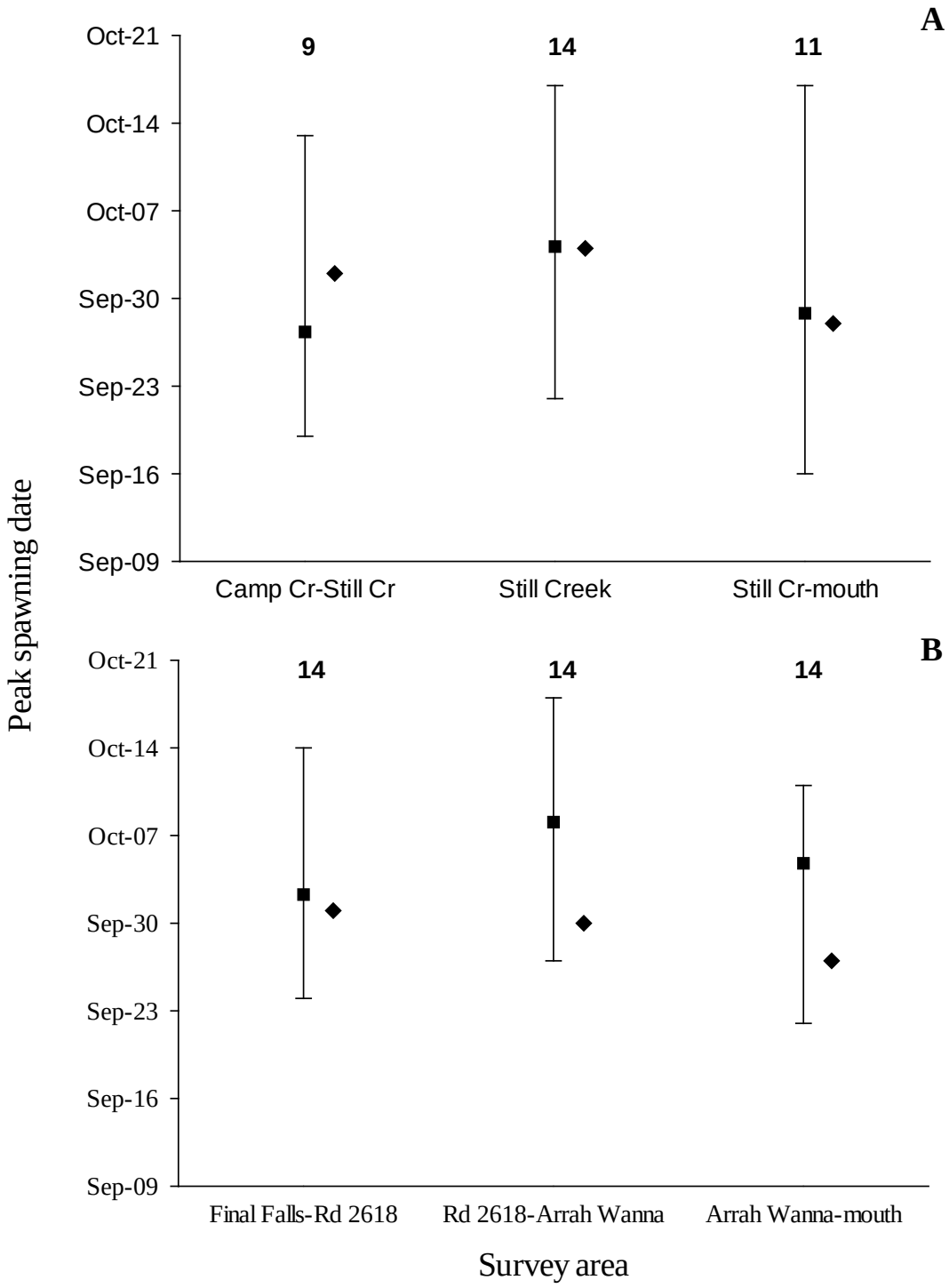

Figure 11. Peak spawning dates of spring Chinook salmon in the Zigzag (A) and Salmon (B) river basins in 2002–2010 (mean, ■) and in 2016 (♦). The capped vertical lines are the range and the numbers above the lines are years in the data set. Years were excluded when only a single survey was conducted (Zigzag River) or when no late surveys were conducted (lower Salmon River).

Table 7. Count of spring Chinook salmon redds and redd density (redds/mi) in standard survey areas of the upper Sandy River basin (upstream of the old Marmot Dam site), 2005-2016. Areas include those that were consistently surveyed in all years, which accounted for 94–100% of all redds in the upper basin.

Basin, section	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
						Redds						
Salmon River:												
Final Falls–Forest Rd 2618	84	139	79	395	139	387	173	314	179	189	284	284
Forest Rd 2618–ArrahWanna	62	45	54	181	61	299	151	87	79	60	99	148
ArrahWanna–Wildwood	65	67	22	60	14	70	48	32	19	25	41	31
Wildwood-mouth	81	67	36	61	25	98	113	135	46	82	191	150
Salmon R tributaries	--	--	--	1	0	53	0	2	34	0	0	10
Zigzag River:												
Still Creek	79	117	28	405	162	550	152	291	291	185	238	435
Camp Creek	8	5	0	--	2	55	19	22	19	9	1	11
Above Still Creek	13	7	13	75	50	80	89	33	77	25	52	97
Still Creek–mouth	31	36	27	109	36	59	122	80	86	48	201	151
Other streams:												
Lost Creek	11	9	9	27	9	5	32	45	15	14	30	32
Clear Fork Creek	--	--	--	1	1	2	10	24	18	9	35	55
Clear Creek	0	2	3	0	0	3	--	--	1	0	1	2
TOTAL	**434**	**427**	**271**	**1315**	**499**	**1661**	**909**	**1065**	**864**	**646**	**1173**	**1406**
						Redds/mi						
Salmon River:												
Final Falls–Forest Rd 2618	26.3	43.4	24.7	117.2	43.4	114.8	54.1	98.1	55.9	59.1	88.8	88.8
Forest Rd 2618–ArrahWanna	11.5	8.3	10.0	33.5	8.2	40.4	28.0	16.1	14.6	11.1	18.3	27.4
ArrahWanna–Wildwood	40.6	41.9	13.8	37.5	8.8	43.8	30.0	20.0	11.9	15.6	25.6	19.4
Wildwood-mouth	23.8	41.9	10.6	17.9	7.4	28.8	33.2	39.7	13.5	24.1	56.2	44.1
Salmon R tributaries	--	--	--	0.4	0.0	21.2	0.0	0.8	13.8	0.0	0.0	4.5
Zigzag River:												
Still Creek	15.8	35.5	8.5	81.0	32.4	109.2	30.4	58.2	58.2	37.0	47.6	87.0
Camp Creek	3.5	2.2	0.0	--	0.9	23.9	8.3	9.6	8.3	3.9	0.4	4.8
Above Still Creek	6.8	3.7	6.8	39.5	13.5	21.6	24.1	8.9	20.8	6.8	14.1	26.2
Still Creek–mouth	14.1	16.4	12.3	49.5	16.4	26.8	55.5	36.4	39.1	21.8	91.4	68.6
Other streams:												
Lost Creek	5.5	4.5	4.5	13.5	4.5	2.5	16.0	22.5	7.5	7.0	15.0	16.0
Clear Fork Creek	--	--	--	1.7	1.7	3.3	16.7	40.0	30.0	15.0	58.3	91.7
Clear Creek	0.0	4.0	6.0	0.0	0.0	6.0	--	--	2.0	0.0	2.0	4.0

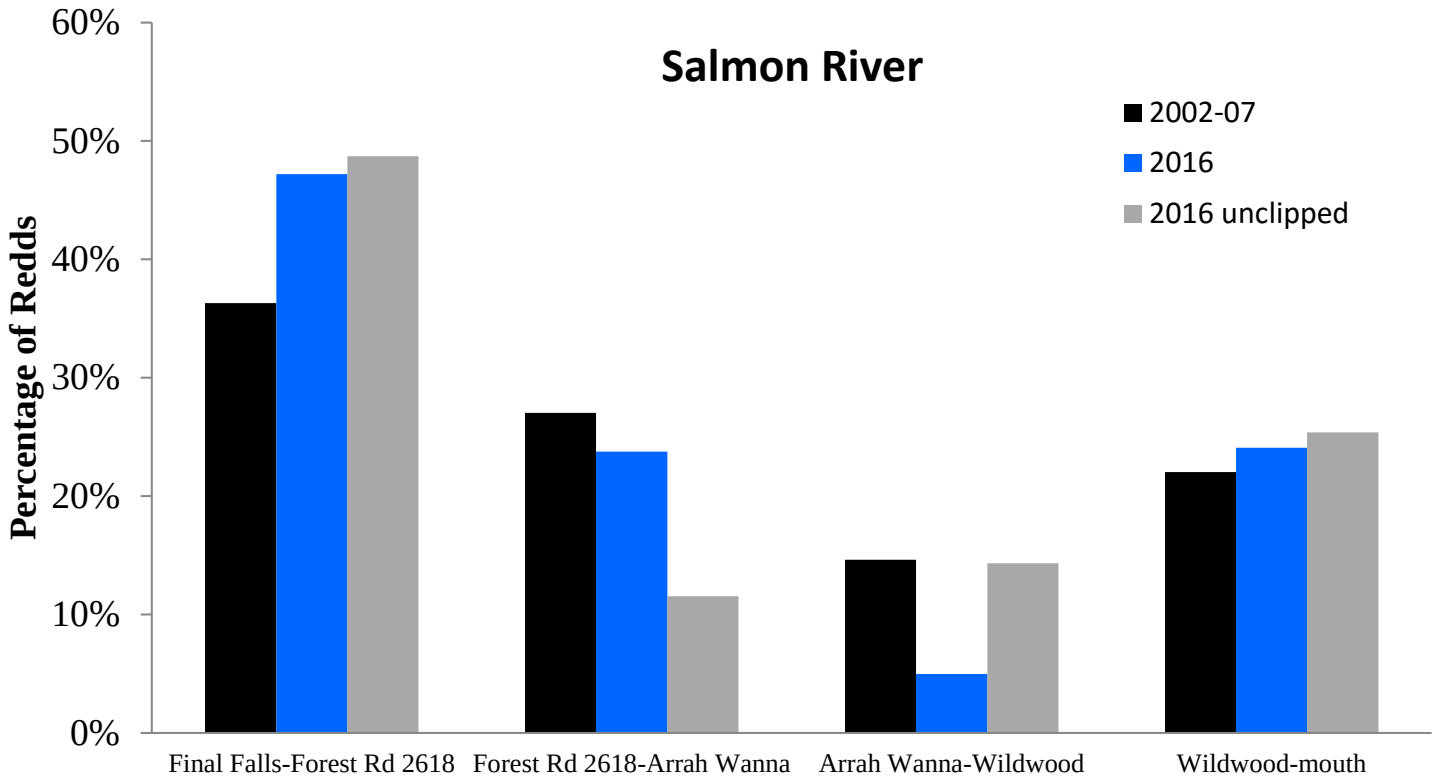

Figure 12. Percentage of spring Chinook salmon redds in four sections of the Salmon River, 2002–2007 and 2016. The 2002–2007 data did not include 2004 and 2006 because redd counts were combined for the lower two sections. The estimated redd distribution of unclipped fish in 2016 was based on the proportion of unclipped carcasses in each section.

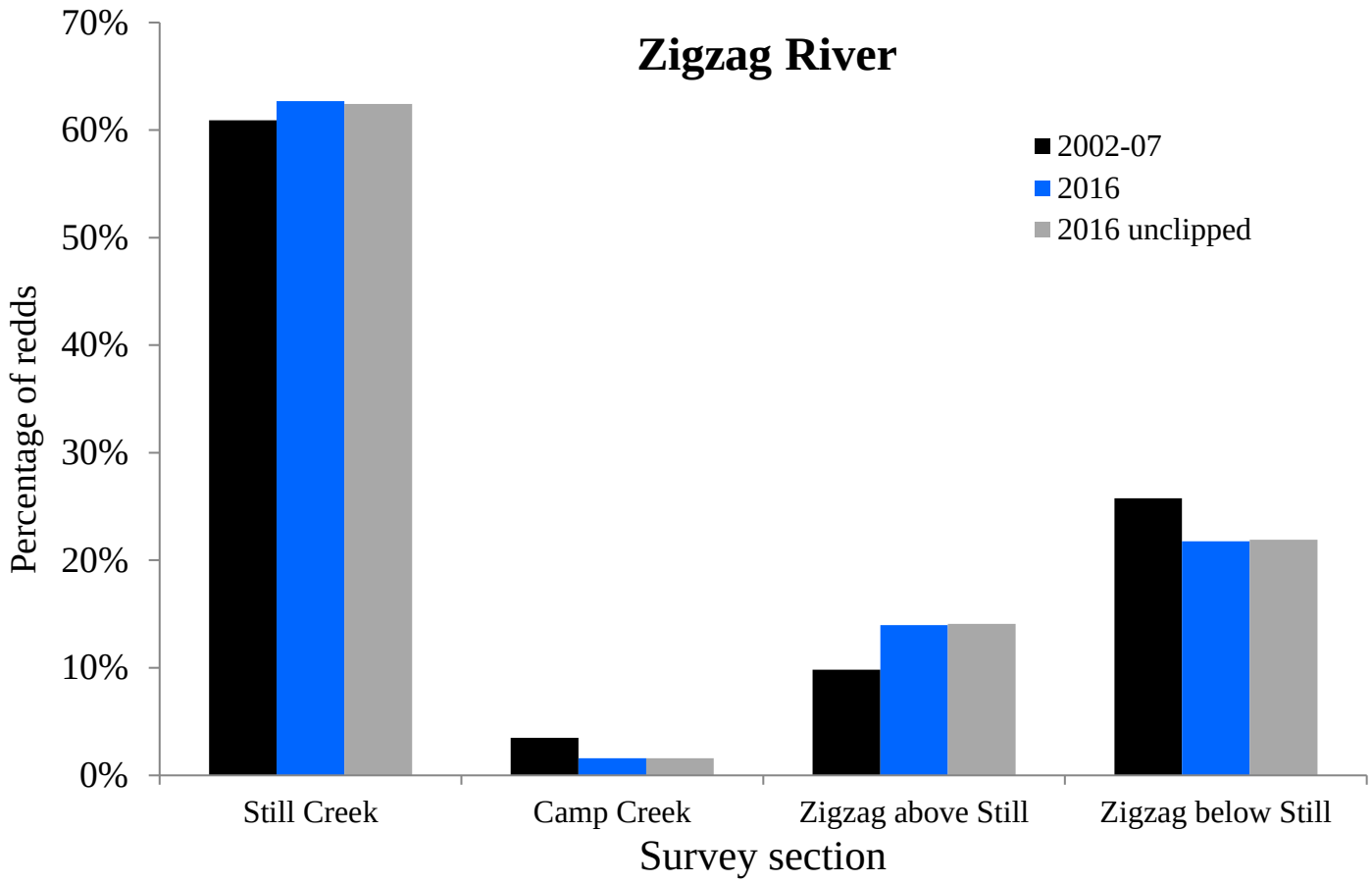

Figure 13. Percentage of spring Chinook salmon redds in four sections of the Zigzag River watershed, 2002–2007 and 2016. The estimated redd distribution of unclipped fish for 2016 is based on the proportion of unclipped carcasses recovered in each section.

Table 8. Percentage of spring Chinook salmon females that died prior to spawning as determined by presence of eggs (sample size in parentheses) for the Salmon and Zigzag watersheds, and for the upper Sandy River basin. Fin-clipped fish were removed at Marmot Dam in 2003–2007, no weirs were operated in 2008–2009, and weirs were operated in the lower Salmon and Zigzag rivers in 2011-2016 to trap and remove fin-clipped fish.

Watershed	2003–2007[a]	2008–2009[a]	2011	2012	2013	2014	2015	2016
Salmon	9.8 (376)	2.7 (225)	3.9 (281)	7.4 (285)	5.1 (216)	5.4 (202)	4.7 (254)	3.7 (136)
Zigzag	1.1 (95)	0.0 (158)[b]	5.5 (91)	5.0 (201)	3.6 (166)	5.8 (138)	5.3 (208)	0.0 (228)
Upper Sandy	7.0 (585)	3.3 (484)	4.7 (408)	5.6 (550)	4.6 (395)	5.7 (348)	5.2 (501)	1.2 (403)

[a] 2002 and 2010 in the Salmon River and ’02,’03,’09 and ’10 in the Zigzag River were excluded because surveys did not begin until mid-September. [b] Only 2008.

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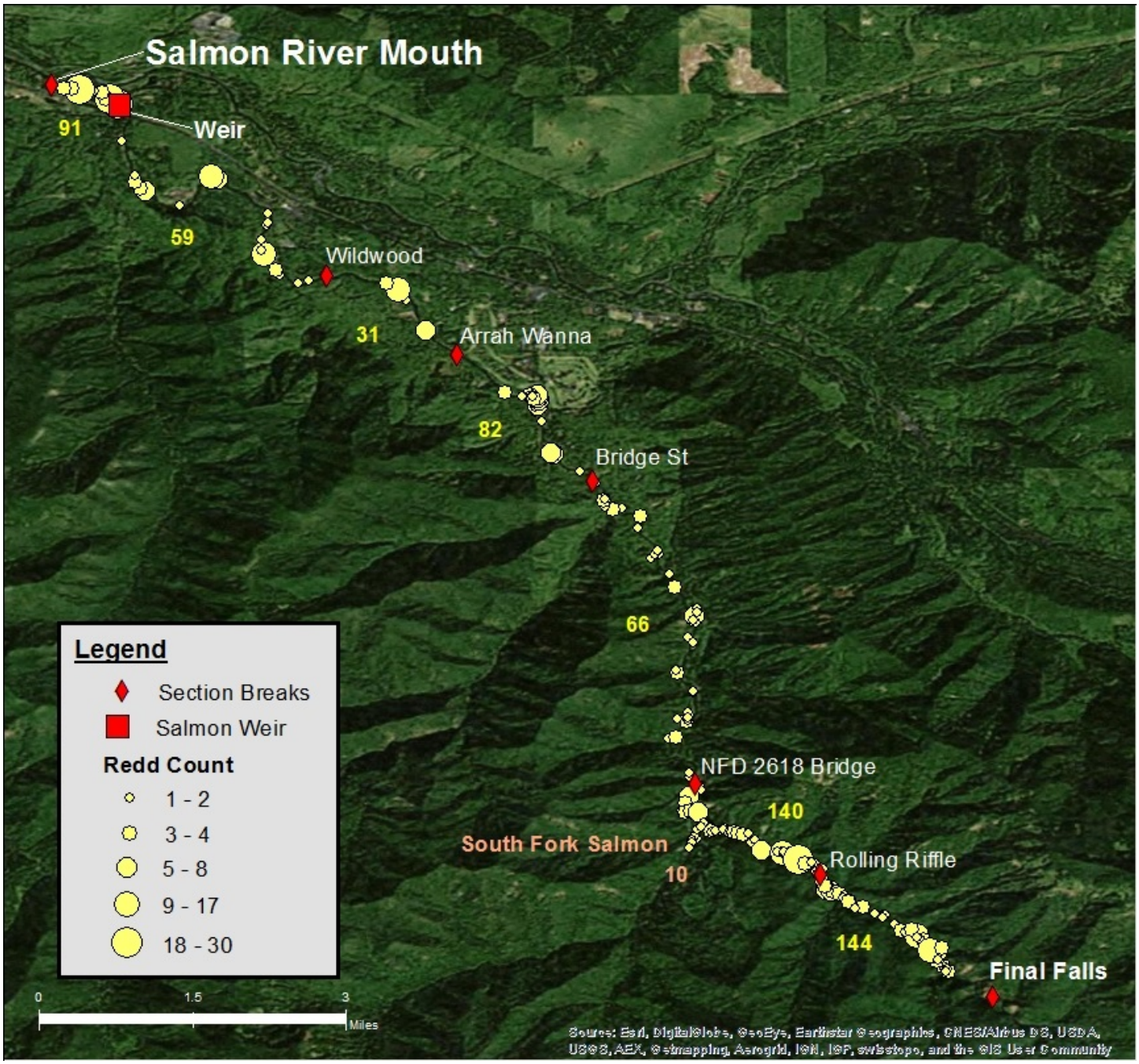

Figure 14. Location of redds in the Salmon River watershed, 2016. Redd locations were marked with GPS receivers synchronized with PDAs. Numbers are peak counts of redds for survey sections indicated by red markers.

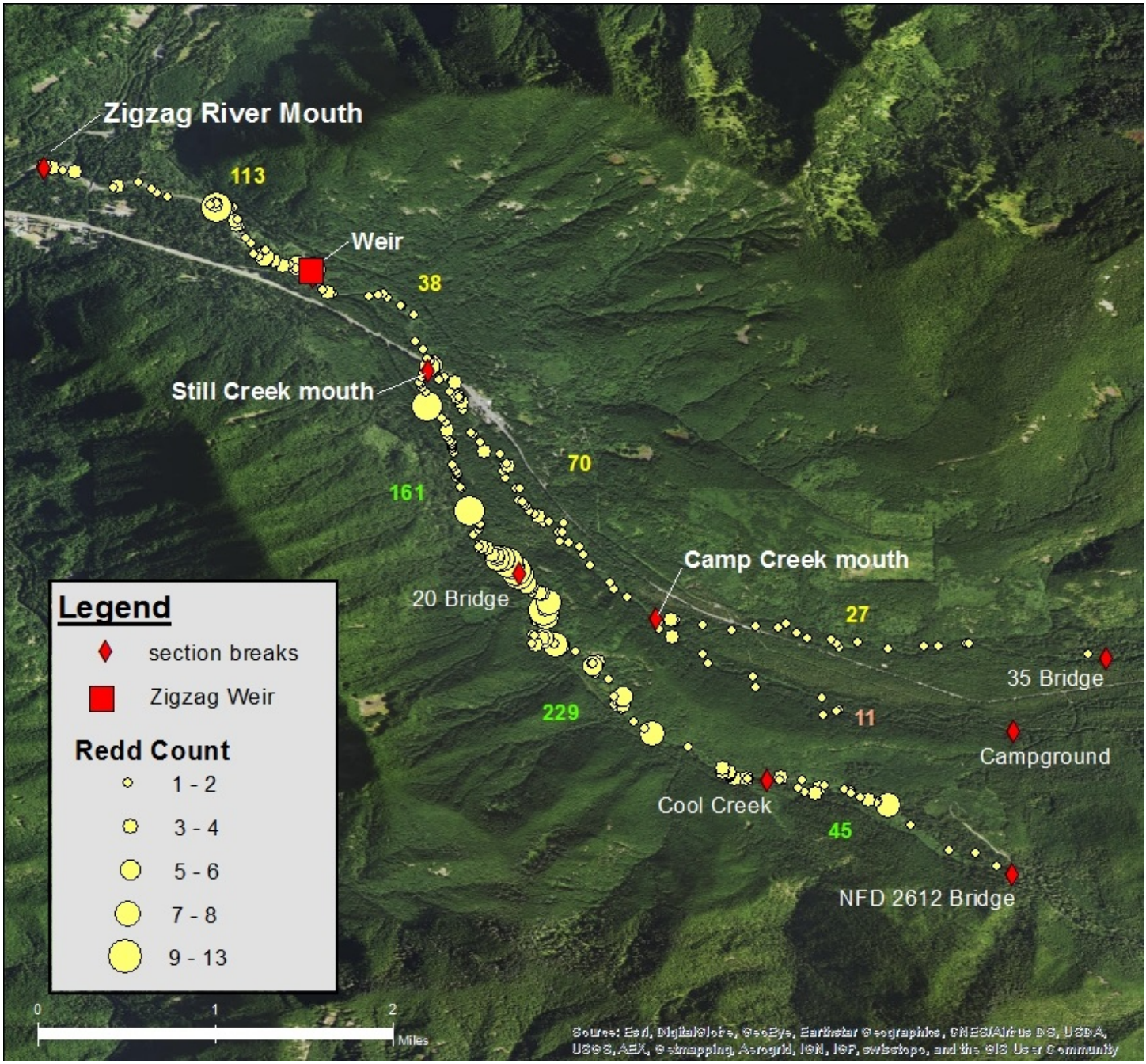

Figure 15. Location of redds in the Zigzag River watershed, 2016. Redd locations were marked with GPS units synchronized with field data collectors PDAs. Numbers are peak counts of redds for survey sections (indicated by red markers) where redd location data are available.

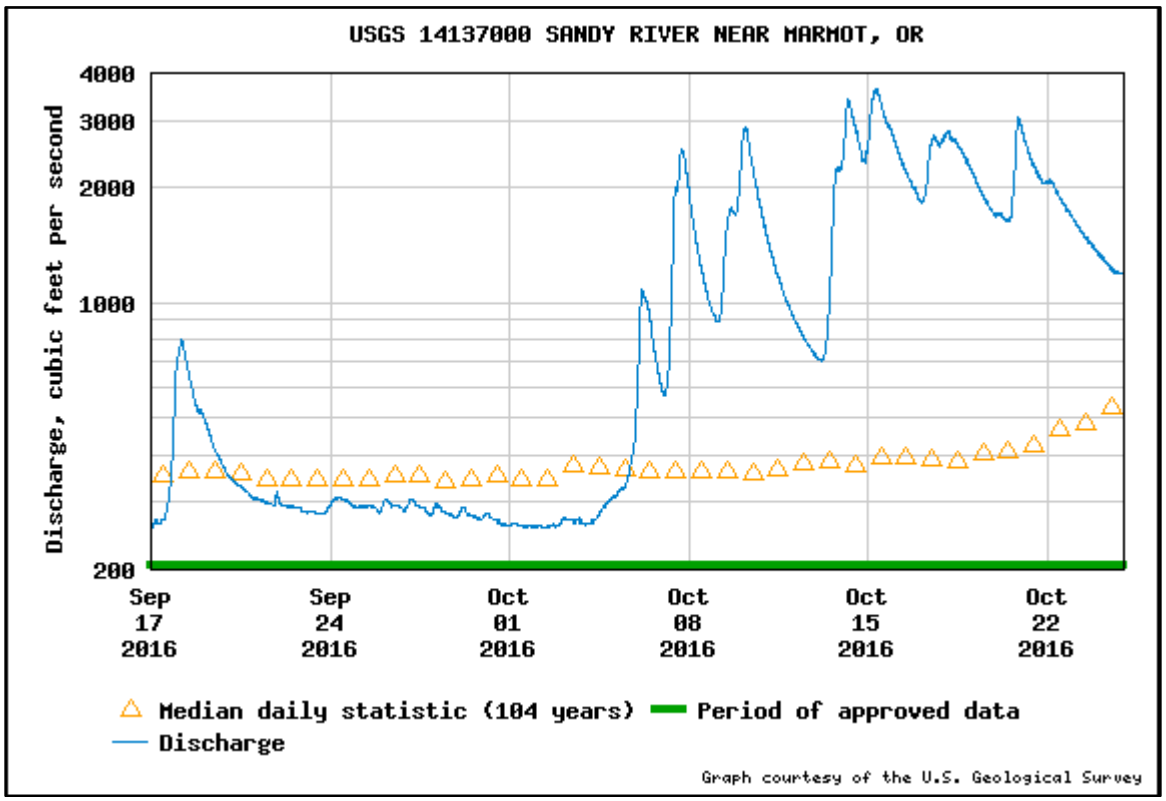

Figure 16. Sandy River discharge (ft^3/s) at Marmot OR gage station from September 17 to October 24, 2016.