# EVALUATION OF THE TRAP AND TRANSPORT OF ADULT STEELHEAD ABOVE USACE PROJECT DAMS IN THE UPPER WILLAMETTE BASIN

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# Summary

Wild, winter-run steelhead are trapped and transported above US Army Corps dams in the Willamette River basin in an effort to reintroduce these fish into historical habitats as part of federal mitigation obligations. The goal of this project was to provide information on spawning distribution of winter steelhead above and below Foster Dam considering the influence of upstream fish passage and outplanting procedures. Data were collected by conducting spawning ground surveys throughout the South Santiam subbasin using a spatially-balanced design during the 2015/2016 and 2016/2017 spawning seasons. During the 2016/2017 season additional surveys were conducted explicitly to determine the amount of overlap between winter-run and non-native, hatchery summer-run steelhead on the spawning grounds. Generally, both summer- and winter-run steelhead spawned in the upper reaches of streams and near Foster Dam. There was a six-week separation between the end of summer-run spawning and the onset of winter-run spawning. Outplanting methods for both runs have been consistent since at least 2006 and we found no evidence of negative impacts of the program on prespawn mortality. The spatially-balanced survey design resulted in a threefold increase in miles surveyed compared to traditional index surveys and provided information regarding the distribution of spawning activity in the South Santiam subbasin that was lacking. The South Santiam River does not have any fish counting stations and, other than fish volitionally entering the trap at Foster Dam, there is no way to know how many fish enter the subbasin. Continued spawning ground surveys, a video monitoring system at Lebanon Dam, or both are needed to monitor these ESA-listed fish in the subbasin and evaluate the possible negative effects of the hatchery program and outplanting procedures.

# Introduction

Native winter-run steelhead (*Oncorhynchus mykiss*) in the Willamette River Basin (Basin) were listed as threatened under the Endangered Species Act (ESA) in 1999 (NMFS 1999). Historically, this was the only steelhead run in the South Santiam subbasin until the 1960s when the Oregon Department of Fish and Wildlife (ODFW) began stocking summer-run steelhead as part of the US Army Corps (USACE) mitigation obligation and to provide a recreational fishery (Tinus and Friesen 2010). The introduction of non-endemic hatchery conspecifics to the system has the potential to negatively impact wild populations and hinder recovery efforts (Anderson et al. 2000; Weber and Fausch 2003; Simpson et al., 2009; Van Doornik and Teel 2010). Negative impacts include reduced fitness due to genetic introgression (Van Doornik and Teel 2010), increased competition for resources (Simpson et al. 2009), and disease transmission (Anderson et al. 2000). The goal of this project was to characterize spawning by winter-run steelhead; and this information will serve as a baseline for future research evaluating the status of native steelhead in the Basin considering management activities including hatchery programs and outplanting protocols. This report presents data from an intensive survey effort in the South Santiam River subbasin during the 2015/2016 and 2016/2017 run years and will summarize previously collected data in an effort to provide a baseline of the status of the distinct population segment (DPS).

Adult winter-run steelhead migrate into the Basin and spawn during winter and spring months when weather conditions and high flow events make surveying difficult, resulting in a paucity of data on their spatial distribution, spawn timing, prespawn mortality, and other relevant metrics. Counts of fish passing over dams have been used to estimate abundance, but little data exist on spawning distribution above those sites. Furthermore, adult, unmarked steelhead collected at the Foster Dam fish trap have been outplanted above Foster Dam on the South Santiam River since the 1960s with the goal of re-introducing native steelhead into habitat blocked by the dam. This outplanting program has not yet been evaluated in relation to prespawn mortality (PSM) or use of historic habitat. In an effort to address these knowledge gaps, ODFW implemented an intensive field surveying effort during the 2015/2016 and 2016/2017 run years to characterize spawning in the South Santiam subbasin.

Most of the historical (1960s to present) spawning data collected for winter steelhead in the Basin was derived from index surveys conducted in locations known to have high spawning densities and easy stream access for surveyors. The index counts are useful because of the long time series but, because the use of index reaches is not necessarily representative of the actual spawner distribution, they have the potential to skew estimates of abundance and provide little information on actual spatial distribution for the watershed as a whole. During the 2015/2016 and 2016/2017 spawning surveys, we implemented a generalized random tessellation stratified (GRTS) -based survey design, drawing on experience from other steelhead monitoring programs in the state (i.e. ODFW/OASIS project). This design incorporates a spatially-balanced distribution of survey reaches across a subbasin and provides a more robust estimate of spawner abundance than traditional index surveys for a given geographic area of interest, referred to as the 'sample frame' (Gallagher et al. 2007). We compared data collected from GRTS surveys to index surveys conducted in the same streams to compare the methods. Although the hypothesized distribution of steelhead spawning habitat has been modeled and mapped in the past, this report represents one of few comprehensive, empirical studies describing the actual spawning distribution of winter steelhead in the S. Santiam subbasin (see Hutchison et al. 1966; Firman et al. 2005; Jepson et al. 2015). Implementation of a GRTS-based survey design is thought to be an improvement on previous monitoring efforts because it incorporates spatial distribution into the design (Stevens 2002). Additionally, data from index surveys may not represent population dynamics at the basin level due to the spatial heterogeneity of spawning and are not considered a robust method of estimating spawner abundance (Rieman and McIntyre 1996; Dunham et al. 2001). However, conducting index site surveys in the short term for the purpose of continuing the long term dataset and generating a relationship between redd counts obtained from index surveys and GRTS surveys could provide value to future research projects.

## Background

Winter steelhead spawner abundance has generally been on a declining trajectory in the Basin since at least the early 1980s based on annual index surveys (Figure 1). The exception to this trend is the Calapooia subbasin where spawner abundance appears to be stable, albeit at low densities (Figure 1). Multiple factors are thought to be contributing to the continuing decline of this DPS, including loss of habitat above Willamette Project dams (NMFS 2008), increased pinniped predation (Stansell et al. 2010; Walker 2015; Falcy 2017), climate change (Wade et al. 2013; Crozier 2015), and interactions with hatchery conspecifics (Harnish et al. 2014). The USACE is responsible for mitigating the loss of access to important spawning habitat above Project dams in the Basin (NMFS 2008). A combination of hatchery production (using non-endemic summer steelhead) and a trap and haul program to reintroduce winter steelhead into blocked habitats are two strategies being used to accomplish this mitigation.

The first comprehensive spawning surveys to describe steelhead spawning distribution and magnitude took place in 1966; little is known about the species in the Basin prior to those surveys (Hutchison et al. 1966). The 1966 study used expert knowledge to identify all streams above Willamette Falls having substantial spawning potential for steelhead and divided these into "good" and "fair" categories. All “good” stream miles were surveyed either on foot or by air near the peak of spawning season in April and May. One-mile sample areas in the “fair” streams were randomly selected and 73 of these sections were also surveyed. A total of 3,965 redds were counted in the Santiam subbasin, resulting in an escapement estimate of 8,261 fish and accounting for 33.2% of the estimated Willamette Basin total, based on counts at Willamette Falls (Hutchinson et al. 1966).

The 1960s were also an emerging time for the production of hatchery fish in the Basin. Beginning in 1961, winter steelhead from the North Santiam subbasin were produced at the Marion Forks Hatchery for release mostly in the Santiam Basin; however, some fish were also released into other subbasins (Table 2). Between 1960 and 2000, the majority of fish were released near the Minto Fish Collection Facility into the North Santiam river (>1.5 million; Table 2, ODFW unpublished data). Hatchery production of winter-run steelhead ceased during the late 1990s in response to poor fishery performance and potential negative impacts of the hatchery program on native stocks; the ESA listings were pending at this time. Also during the late 1960s, a hatchery program was implemented by ODFW using summer-run Skamania stock originally from Washington (Tinus and Friesen 2010). The Skamania stock was selected because the timing of their migration was more desirable to anglers. Furthermore, it was thought the temporal separation of run timing between the two stocks could aid in mitigating negative impacts of non-native conspecifics by reducing genetic introgression and competitive interactions between adults. Prior to 1975, returning summer-run fish that volunteered to the fish ladder at Foster Dam were outplanted into the forebay of Foster Lake; however, it is thought that most of these fish either fell back over Foster Dam or were killed by turbines (Buchanan 1977).

Currently, the majority (~70%) of winter steelhead that migrate into the Basin enter the Santiam River system (ODFW 2011). Generally, more fish enter the North Santiam River (~43%) than the South Santiam River (~27%) and both subbasins currently contain areas where summer-run hatchery fish are excluded. In the North Santiam River an adequate wild fish sanctuary location is not available because of total dissolved gas (TDG) concerns between the Minto Fish Collection Facility and Big Cliff Dam. Unmarked adult steelhead collected at the Minto Fish Collection Facility are released upstream into the proposed wild fish sanctuary between Minto and Big Cliff dam when TDG levels are below 120%; but when TDG levels are above this threshold fish are released into the mainstem North Santiam downstream of the Minto facility where there is potential to interact with summer-run hatchery fish. Additionally, no steelhead are currently passed above any Willamette Project dams in the North Santiam subbasin because of a lack of downstream juvenile passage. It is possible that considerable numbers of winter-run steelhead spawn below Minto but the authors know of no data to confirm this possibility. In the absence of data on spawning distribution and PSM in the North Santiam it is impossible to evaluate this outplant procedure.

The South Santiam River has a wild fish sanctuary located above Foster Dam where non-native, hatchery-origin summer steelhead are excluded. Wild fish are collected at Foster and driven in trucks above the reservoir where they are released. Since outplanting has shifted to only occur above the reservoir, there have not been problems with fallback or juvenile passage as evidenced by consistent wild fish returns to the Foster Fish Collection Facility. Establishing wild fish sanctuaries and providing downstream juvenile passage are critical first steps towards reintroducing the species into habitat blocked by Willamette Project dams and achieving recovery.

Steelhead abundance in the North Santiam River is estimated by counts at Upper and Lower Bennett dams and fixed index surveys conducted annually in the subbasin, resulting in a lack of knowledge about the spatial distribution of redds. In addition to numbers of fish and timing of migration in the subbasin, video monitoring systems at the Bennett dams allow for the differentiation of marked and unmarked fish and comparisons between the two. During 1997-2005, unclipped (natural-origin) and clipped (hatchery-origin) fish followed similar abundance trends that fluctuated from year to year. After changes to the Bennett Dam fish ladder and monitoring system (2006-2010), numbers of unclipped fish appeared to stabilize around 850 fish per year from 2011-2016, whereas numbers of clipped fish continue to fluctuate during the same period (Figure 2). Numbers of summer and winter steelhead passing Willamette Falls during 2011-2016 also reflected a similar trend. Furthermore, the coefficient of variation (CV) of each run of fish over Bennett Dams during their peak migration months (March/April for winter steelhead, May/June for summer steelhead) also suggests that summer steelhead numbers are more variable than winter steelhead (Figure 3). Numbers of summer steelhead passing over Willamette Falls were more variable than winter steelhead during 2011-2016, suggesting that this trend occurs Basin-wide. Numbers of winter steelhead passing Willamette Falls and the Bennett Dams in 2017 were the lowest on record (n=822 at Willamette Falls, n=169 at Bennett Dams).

## Methods

We conducted redd count surveys in the South Santiam River and its major tributaries by boat and on foot beginning February 3, 2016 and ending July 13, 2016 during the 2015/2016 spawning season. Survey reaches include previously established index sites and a set of GRTS sites selected from a sample frame that encompassed the known distribution of spawning steelhead in the S. Santiam River (indicated by green lines in Figure 4). During the 2016/2017 season, we began surveying on December 1, 2016 to capture spawning activity by hatchery summer steelhead and continued until the end of May 2017. We surveyed all reaches on a 14-day sample interval except during episodic high flow events when effective surveys were not possible. Work closely followed the established steelhead survey protocols as described in the ODFW/OASIS Project Manual (available online at: http://oregonstate.edu/dept/ODFW/spawn/pdf%20files/reports/STWManual2015-Final.pdf). All surveyors were thoroughly trained in redd identification, carcass sampling procedures, equipment operation, and safety procedures by experienced field staff. We identified GRTS survey reaches and presumed winter steelhead spawning distribution after consultation with ODFW District staff for below-dam surveys and the USFS for above-dam surveys. In total, we surveyed 56 GRTS sites in addition to the nine traditional index sites during 2016 (Figure 4). Inclement weather and persistent high flows resulted in some sites becoming inaccessible for the 2016/2017 survey season and these sites were removed from analysis. We noted the presence and relative abundance of live spawners in holding areas and spawning grounds in all survey reaches. In surveys below Foster Dam particular care was given to noting the presence/absence of adipose fins on all live fish encountered to assess the amount of temporal overlap between summer-run (adipose clipped) and winter-run (unclipped) steelhead on the spawning grounds.

The few carcasses that we recovered during the spawner surveys were sexed and percentage of eggs remaining was used to differentiate post- and pre-spawn mortality for females. Spawning success was determined by inspecting the gonads and estimating the percentage of eggs remaining to the nearest 25%. Fish with greater than 25% of eggs remaining were classified as pre-spawn mortalities. Biological samples such as scales and otoliths were taken from all carcasses recovered for archival records and other monitoring projects in the Basin. All biological samples were sent to the appropriate parties for processing in a timely manner.

## Results

Since 2006, most adult unmarked steelhead that swam into the trap of their own volition have been outplanted at Riverbend Campground on the South Santiam River upstream of Foster Reservoir. Of 3,011 winter steelhead outplanted in the South Santiam basin since 2006, 2,977 were outplanted at Riverbend, seven were released into the forebay of the reservoir, 18 were outplanted at Gordon Rd., and nine were outplanted at Calkins Park near the head of reservoir (Table 1). Most of the outplanting at locations other than Riverbend occurred late in the season when water temperatures at Riverbend were warmer than optimal. No formal protocol describing steelhead outplant locations exists, and during times when Riverbend is unsuitable (due to water temperatures or flow), an alternative outplanting location is chosen based on the expert opinion of the hatchery staff.

Distribution and abundance of redds in the South Santiam subbasin was derived from spawning ground surveys above and below Foster Dam. Overall, 320 redds were counted across 56 miles of habitat surveyed during the 2015/2016 run year (Table 3). We first observed redds on March 23, 2016 below the dam and March 22, 2016 above the dam (Figure 5). Peak spawning activity (inferred from the maximum number of new redds observed in any survey interval) was between April 11 and April 24 (sample interval 6), 2016 below Foster and between May 9 and May 22, 2016 above Foster (sample interval 8, Figure 5). Redd density was highest in the survey section directly below Foster Dam, near the South Santiam Hatchery (Figure 6). No redds were observed below Waterloo Falls on the mainstem South Santiam River or below OR-226 on Crabtree Creek (Figure 6). There were some redds observed in Thomas Creek near the confluence with the South Santiam River during one survey; however, this section is known to have high lamprey spawning densities and possible lamprey redd superimposition may have resulted in misidentification of the redds. Otherwise, no redds were observed below Hanna Bridge on Thomas Creek (Figure 6).

The number of winter steelhead counted at Willamette Falls during 2016/2017 (n=822) was seven times lower than during 2015/2016 (n=5,778) resulting in fewer redds being counted during the 2016/2017 run year. The 822 fish passing over Willamette Falls represents the lowest return of winter steelhead since counts began during the 1950s. Additionally, unusually rainy weather throughout the winter and spring limited access to some survey reaches; these reaches were excluded from analysis. During 2017, 51 miles of habitat were surveyed and 28 redds were counted (Table 4). Half of the observed redds were located above Foster Dam and the majority of redds below Foster Dam were located in the uppermost reach of Thomas Creek (Figure 7). The first redd was observed on April 4 and the final redd was observed on the last survey day, May 31 (Figure 8). Peak redd counts, both above and below Foster Dam, were obtained between May 1 and May 14 (sample interval 4, Figure 8), which was a few weeks later than during 2016. Similar to 2015/2016, no redds were found in the lower stretches of any river (Figure 7).

During the 2016/2017 run year, hatchery-origin, summer steelhead were also surveyed to measure the amount of temporal and spatial overlap of steelhead spawning in the wild. Due to large stretches of inclement weather and high water levels during winter, much of the lower river was not surveyed during the summer steelhead spawning period. Since there was no spawning by winter steelhead in these reaches during either run year it is unlikely that we missed any significant spawning or overlap between the two steelhead runs. Overall, 61 redds were counted across 28 miles of habitat surveyed (Figure 9). The majority of spawning occurred in the Wiley Creek complex that includes Wiley Creek, Little Wiley Creek, and Jackson Creek (Figure 9). Spawning was observed in Crabtree Creek in low densities between Richardson Gap and Weyco Bridge (Figure 9). In Thomas Creek, summer steelhead spawning was only observed in the uppermost survey reach, an area also used consistently by winter steelhead during both 2016 and 2017 (Figures 6, 7, and 9). The first redd was observed on December 22, 2016 and the final redd was observed on February 15, 2017 (Figure 8).

The total number of spawners in the S. Santiam subbasin can only be estimated from spawning ground surveys followed by fish/redd expansions because there are no counting or video monitoring programs in this subbasin. In 2016 there were an estimated 1,480 ± 721 (mean ± 95% CI) winter steelhead that returned to the S. Santiam or one of its tributaries, and during 2017 an estimated 157 ± 60 winter steelhead returned to the subbasin. An average of ~27% of the winter steelhead that pass over Willamette Falls enter and spawn in the S. Santiam basin annually (ODFW 2011). Based on that average we would expect 1,560 fish returned to the S. Santiam in 2015/2016 (5,778 winter steelhead over Willamette Falls) and 222 fish returned in 2016/2017 (822 winter steelhead over Willamette Falls). The expected number of fish returning to the S. Santiam was close to our estimate and within the confidence intervals during both years.

Data collected from index sites and GRTS sites during 2015/2016 were compared to evaluate differences between the two methods. Data collected from GRTS and index sites during 2016/2017 were not compared because the historically low returns resulted in no redds being found in index sites. During 2015/2016, spawner abundance estimates from index surveys in Thomas and Crabtree Creeks were lower than but within confidence intervals of GRTS surveys; however, index sites in Wiley Creek were much higher and outside the confidence intervals of GRTS surveys (Table 5). Redd densities were higher in index surveys than in nearby GRTS surveys in Wiley Creek, but densities were similar between GRTS and index surveys in Crabtree and Thomas Creeks (Figure 10). Redd density, measured as redds/mile, between GRTS surveys and index surveys were correlated during 2015/2016; however because of small sample size this correlation was not significant (Pearson correlation: 0.757, $p = 0.081$, Figure 11). The single year of data does not permit development of a statistically robust relationship between GRTS and index surveys but if redd density remains correlated after the addition of more years of data then it may be possible to use the relationship between the two survey methods to extrapolate useful information.

Carcass recoveries of steelhead are uncommon due to post-spawn kelting behavior and seasonal high flows that wash carcasses into inaccessible and unobservable areas. A total of four steelhead carcasses were recovered during 2015/2016 surveys. Of those, three were female and one was male. Two of the females were post-spawn mortalities and spawning condition of the other female was undetermined. One female steelhead was recovered above Foster Dam and the other three carcasses were recovered below the dam. No carcasses were recovered during 2016/2017 spawning surveys. Too few carcasses were recovered to provide a robust PSM estimate during either year.

## Discussion

This was the first time GRTS-based sampling was implemented in the Basin for monitoring winter-run steelhead. The GRTS design resulted in more than a threefold increase in miles of habitat surveyed compared to index surveys that have previously been the only systematic monitoring method employed by ODFW in the basin (GRTS: 56.0 miles surveyed; Index: 17.8 miles surveyed). Index locations were also surveyed during both run years with the goals of maintaining the long-term dataset and collecting data using the two methods concurrently in an effort to build a mathematical relationship. Index sites in Wiley Creek had the highest redd densities of any surveyed location, and GRTS sites that were located in tributaries of Wiley Creek near the index sites had no redds observed, which highlights the spatial heterogeneity in the distribution of redds across a relatively small system (Figure 10). Using GRTS or another spatially-balanced survey design is required to capture this heterogeneity across large systems; even though in this case the GRTS sites would have missed an important spawning area. The rotating panel strategy of GRTS surveys, where some sites are surveyed annually and others are surveyed in a rotation across multiple years, is designed to capture this spatial heterogeneity. If there are unidentified sites with consistently high spawning densities, then it is assumed that the rotating panel will capture this eventually. Surveying only fixed index sites makes this type of flexibility impossible and also prevents reliable expansion of redd density outside the sampled area.

The spatial distribution of redds in the South Santiam subbasin indicated steelhead selected the upper reaches of streams to spawn. No habitat measurements were taken during surveys so we were unable to quantitatively determine which environmental factors drive the selection of spawning locations in the subbasin. Lower reaches have areas with suitable spawning substrate but temperature, flow, gradient, or some other factor, such as spawning site fidelity, likely cause fish to forego these locations and continue into the upper reaches to spawn. This was observed across both years and for both winter and summer steelhead. Further research is needed to identify causal mechanisms and characterize use of previously mapped habitat. The current body of knowledge has identified impassable barriers to migration and the next steps are to compare the distribution of actual steelhead spawning to the distribution of available spawning habitat. This comparison can then be used to identify areas where suitable, connected habitat is not being used (under-seeded) and thus target restoration efforts in those areas.

In the North Santiam River, wild winter steelhead numbers were relatively stable between 2011 and 2016 based on counts at the Bennett Dam complex. Counts of both clipped (summer-run hatchery) and unclipped (winter-run wild) fish trapped at Bennett Dam during 1997-2005 showed substantial year-to-year variation; however, after construction of a new fish ladder and new video monitoring system the numbers of unclipped fish exhibited reduced variation across years. Comparing the CV between presumed winter and summer steelhead indicated that numbers of summer steelhead passing over Bennett Dam are almost twice as variable as winter steelhead (Figure 3). This is not an artifact of the fish ladder or video monitoring system because the counts of summer and winter steelhead counted at Willamette Falls during the same time period had similar trends in CV (winter steelhead = 0.252; summer steelhead = 0.439). Further research is needed to determine the cause of this pattern but some possible explanations include differential responses to environmental conditions and differences in summer steelhead hatchery operations, in addition to other possible causes.

Unmarked, presumably wild, adult steelhead volunteering to the trap at Foster Dam have been outplanted almost exclusively at Riverbend Campground since 2006. This outplant location provides fish with suitable flow and temperature for most of the run of winter steelhead during most years. During four of the past five years a small number of fish have been outplanted at other locations. Most of these outplants have been late in the season when water temperatures at Riverbend were warmer than optimal; however, in 2016 all fish outplanted in February were released at Gordon Rd. Continued increases in water temperature as predicted by climate change models (Littell et al. 2009) may require increased use of other outplant locations such as Calkins Park. The Calkins Park outplant location provides fish with the option to swim upstream if conditions are suitable or to seek thermal refuge in the deeper waters of the reservoir during warm water years. There is currently no standard protocol for determining outplant location for winter steelhead, and even though >99% of all outplanted fish are released at Riverbend it may be worthwhile to create a protocol to aid in decision making for times when conditions make Riverbend unsuitable for outplanting and to standardize outplant procedures. Unfortunately, even with thorough spawner and prespawn mortality surveys, carcass recoveries of steelhead are rare. The paucity of carcass recoveries and the relative stability of outplant methods are not conducive to determining if PSM is a problem for winter steelhead. Ongoing genetic pedigree work (Caudill et al. 2017) may inform this uncertainty in the future.

Spawning by summer- and winter-run steelhead in the South Santiam subbasin were separated temporally based on our redd observations, even though fish of both runs spawned in the same locations. Summer-run hatchery strays constructed redds mostly in the Wiley Creek complex likely because of the proximity to the South Santiam Fish Hatchery. If fish are unable to find or are not sufficiently attracted to the ladder at the fish collection facility, then Wiley Creek offers the closest alternative for spawning. The river reach just below Foster Dam also had relatively high rates of redd construction during both years. The Wiley Creek complex was not used by winter-run steelhead during 2017, but was used extensively by winter-run fish during 2016. Generally, summer-run (hatchery) and winter-run (wild) fish are spawning in the same locations throughout the South Santiam subbasin, but hatchery fish have finished spawning before wild fish begin spawning. A temporal gap between February 15, 2017 and April 4, 2017 when no new redds were found suggested that during the 2016/2017 run year there were at least six weeks between the end of spawning by hatchery fish and the onset of spawning by wild fish. However, we could not explore the possibility that male summer-run steelhead held over long enough to eventually spawn with incoming winter-run fish and the low density of winter steelhead present may have caused underestimation of the spawning period. Winter steelhead are migrating to the spawning grounds during this time and this could lead to other interactions between summer- and winter-run adult steelhead, but this was beyond the scope of this project. Previous work comparing the spawn timing of summer- and winter-run steelhead also found no evidence of temporal spawning overlap (Firman et al. 2002; Firman et al. 2003; Firman et al. 2005). These results contrast with genetic data from the same populations indicating some hybridization between winter and summer steelhead in the Willamette Basin (Johnson et al. 2013) and Santiam River (Caudill et al. 2016). While temporal separation is likely to reduce competition between adults and genetic introgression, use of the same spawning locations could result in juveniles emerging into the same environment and competing for resources (e.g,. Harnish et al. 2014).

Information about juvenile steelhead of both hatchery and natural origin is lacking even though this knowledge gap has been identified in the past (Tinus and Friesen 2010). Juvenile hatchery steelhead are generally larger and more aggressive than wild counterparts which could lead to competitive exclusion from high quality rearing habitat (Berejikian et al. 1996). Arguably, interactions between wild and hatchery fish during the juvenile stage could impact populations more than interactions as adults (Harnish et al. 2014). In the Willamette Basin, steelhead generally spend two years in freshwater as juveniles prior to smoltification (Clemens 2015) and this creates an extended period of time for possible negative interactions to manifest. The lack of juvenile steelhead data continues to be an important knowledge gap that needs to be addressed to identify any negative impacts of the hatchery program and mitigate them.

Video monitoring at fish passage structures is commonly used to count salmonids as they migrate upstream (Collins et al. 1991; Irvine et al. 1991; Hatch et al. 1998; McCormick et al. 2015). Video monitoring systems are a relatively cost effective method for determining migratory fish abundance, especially in mixed stock communities (McCormick et al. 2015). Computer programs have made video monitoring efficient for obtaining accurate counts of fish with minimal effort, and data storage capabilities have increased allowing for review of video to determine species and identify marks that differentiate between natural and hatchery produced fish without handling them. The video monitoring system in place in the North Santiam River at the Bennett Dams complex has allowed ODFW to collect data on numbers and migration timing of steelhead even though spawning surveys are not regularly conducted in that subbasin. Implementing a video monitoring system at Lebanon Dam on the South

Santiam River could allow for similar data collection and result in a valuable addition of data to those collected during spawning surveys conducted in the subbasin. During the 2015/2016 run year, 71% of all spawning activity occurred upstream of Lebanon Dam and no redds were observed in the mainstem South Santiam River below Lebanon Dam. Video monitoring would not provide any additional data on spatial distribution and continued spawning surveys would still be required to effectively monitor steelhead in the subbasin; however, counts of fish at Lebanon Dam would provide managers with valuable data regarding abundance and migration timing in the most heavily used spawning area of the subbasin. Additionally, video monitoring at Lebanon Dam would provide data on other ESA-listed species such as Chinook salmon (*O. tshawytscha*).

Results from this study represent the only spatially-balanced sampling data identifying the current distribution of spawning by winter steelhead in the South Santiam subbasin but is not enough data to make long-term predictions. A continued monitoring effort is required to understand how steelhead are using their environment and effectively target recovery efforts in areas with the highest chance for success. Additionally, research into why recent winter steelhead population levels appear to be less temporally variable than summer steelhead is warranted, especially if this is related to hatchery operations. Outplanting procedures have not changed in the South Santiam basin for at least eleven years and possibly longer, with no detectable negative consequences. The Riverbend release site is convenient and available for most of the winter steelhead spawning season making this outplant location suitable for continued releases; however, it is worthwhile to develop a plan for secondary release sites late in the season, especially in the face of climate change. While summer- and winter-run appear to be temporally segregated for spawning, additional research is needed to determine if protracted holding by male summer-run fish results in introgession despite the lack of temporal overlap. Data on relative abundance, distribution, disease, survival, and diet of juvenile steelhead, both natural and hatchery origin, is still lacking and is necessary for effective management of the DPS and hatchery programs.

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## Tables

Table 1. Winter steelhead outplanted above Foster Dam, 2006-2016.

| | Outplanted at Riverbend | | | | | |
|---|---|---|---|---|---|---|
| Year | Total | Male | Female | Outplanted Other | Total Outplanted | F:M ratio |
| 2006 | 419 | 193 | 226 | 0 | 419 | 1.17 |
| 2007 | 209 | 98 | 111 | 0 | 209 | 1.13 |
| 2008 | 256 | 129 | 127 | 0 | 256 | 0.98 |
| 2009 | 192 | 86 | 106 | 0 | 192 | 1.23 |
| 2010 | 426 | 155 | 271 | 0 | 426 | 1.75 |
| 2011 | 315 | 117 | 198 | 0 | 315 | 1.69 |
| 2012 | 317 | 138 | 179 | 9 | 326 | 1.30 |
| 2013 | 283 | 115 | 168 | 3 | 286 | 1.46 |
| 2014 | 214 | 86 | 128 | 0 | 214 | 1.49 |
| 2015 | 122 | 44 | 78 | 7 | 129 | 1.77 |
| 2016 | 206 | 73 | 133 | 15 | 221 | 1.82 |
| 2017 | 18 | 8 | 10 | 0 | 18 | 1.25 |

Table 2. Releases of juvenile late-run hatchery winter steelhead in the Willamette Basin, 1963-1999. Brood for these releases were natural-origin winter-run steelhead.

| Number Released | Release site | Date |
|---|---|---|
| 10,000 | Ammsville Pond | Jan-81 |
| 104,159 | Below Fall Creek Dam | Apr-99 |
| 10,000 | Fall Creek Reservoir | Mar-67 |
| 5,133 | Fall Cr. Reservoir | Apr-68 |
| 3,475 | Fall Creek Reservoir | Apr-69 |
| 23,075 | Foster Reservoir | Apr-84 |
| 30,795 | Foster Reservoir | Apr-82 |
| 3,136 | Foster tail race | May-70 |
| 9,408 | Green Peter Reservoir | Apr-68 |
| 15,500 | Green Peter Reservoir | Apr-69 |
| 2,225 | Green Peter Reservoir | May-70 |
| 22,435 | Green Peter Reservoir | Apr-80 |
| 28,931 | Green Peter Reservoir | Jan-81 |
| 15,174 | Green Peter Reservoir | Apr-82 |
| 17,922 | Green Peter Reservoir | Apr-83 |
| 13,014 | Green Peter Reservoir | Apr-84 |
| 20,200 | Green Peter Reservoir | Apr-85 |
| 31,232 | Green Peter Reservoir | Apr-86 |
| 664 | Horn Creek | Jan-81 |
| 3,221 | Horn Creek | Mar-85 |
| 11,690 | Horn Creek | Mar-86 |
| 6,534 | Lost Creek & Hills Creek | Apr-83 |
| 1,999 | Middle F. Santiam | Apr-84 |
| 281 | Middle Santiam | Apr-85 |
| 140,334 | Minto | Mar-63 |
| 135,513 | Minto | Apr-67 |
| 40,890 | Minto | May-67 |
| 99,654 | Minto | Apr-68 |
| 43,966 | Minto | Apr-69 |
| 80,121 | Minto | Apr-71 |
| 20,936 | Minto | Apr-72 |
| 82,795 | Minto | Apr-72 |
| 84,368 | Minto | Apr-73 |
| 9,972 | Minto | Apr-74 |
| 60,661 | Minto | Mar-75 |
| 72,779 | Minto | Apr-76 |
| 50,420 | Minto | Apr-80 |
| 39,456 | Minto | Apr-82 |
| 22,898 | Minto | Apr-84 |
| 45,390 | Minto | Apr-85 |
| 48,060 | Minto | Apr-86 |
| 19,988 | Minto | Apr-89 |
| 47,918 | Minto | Apr-90 |
| 30,056 | Minto Acclimation | Mar-92 |
| 54,733 | Minto Acclimation | Mar-93 |
| 60,334 | Minto Acclimation | Apr-94 |
| 70,605 | N. Santiam | Apr-81 |
| 19,972 | N. Santiam | Mar-87 |
| 91,949 | N. Santiam | Apr-87 |
| 117,262 | N. Santiam | Apr-88 |
| 65,509 | N. Santiam | Apr-89 |
| 94,640 | N. Santiam | Apr-91 |
| 96,486 | N. Santiam | Apr-92 |
| 112,284 | N. Santiam | Apr-93 |
| 103,473 | N. Santiam | Mar-96 |
| 3,920 | N. Santiam @ Downing Creek | Mar-83 |
| 17,118 | N. Santiam @ Minto | Apr-95 |
| 107,024 | N. Santiam @ Minto | Apr-97 |
| 41,247 | N. Santiam @ Minto | Apr-98 |
| 69,479 | N. Santiam @ Minto, Greens Bridge | Apr-78 |
| 77,737 | N. Santiam @ Minto, Greens Bridge | Apr-79 |
| 76,771 | N. Santiam @ Packsaddle, Mehama | Apr-83 |
| 78,641 | N. Santiam @ Stayton, Minto | Apr-77 |
| 271 | Quartzville Creek | Apr-85 |
| 15,618 | S. Santiam @ Moose Cr. | Apr-82 |
| 11,268 | S. Santiam @ Moose Cr. | Apr-84 |
| 5,287 | S. Santiam | May-70 |
| 12,619 | S. Santiam @ base of dam | Apr-86 |
| 9,018 | S. Santiam @ Moose Cr. | Apr-85 |
| 13,472 | S. Santiam @Hatchery Outlet | Apr-85 |
| 33,422 | S. Santiam Below Foster Dam | Apr-83 |
| 44,902 | S. Santiam Res. | Apr-80 |
| 13,074 | Sandy Hatchery | May-76 |
| 45,531 | Stayton | Apr-90 |
| 19,832 | S. Santiam Hatchery | Apr-81 |
| 9,752 | Walter Wirth Lake | Mar-82 |

Table 3. Raw redd count data for winter-run steelhead spawning surveys in the South Santiam subbasin, 2016.

| Site ID | Tributary | Above/Below Foster Dam | Sampling Interval and Date Range | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 2/1/16-2/14/16 | 2 2/15/16-2/28/16 | 3 2/29/16-3/13/16 | 4 3/14/16-3/27/16 | 5 3/28/16-4/10/16 | 6 4/11/16-4/24/16 | 7 4/25/16-5/8/16 | 8 5/9/16-5/22/16 | 9 5/23/2016-6/5/16 | 10 6/6/16-6/19/16 | 11 6/20/16-7/3/16 | 12 7/4/16-7/17/16 |
| 002 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 2 | 1 | 0 |
| 080 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 093 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 0 | 0 | 0 |
| 154 | Canyon Creek | Above | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 9 | 0 | 9 | 12 | 3 |
| 162 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 174 | Canyon Creek | Above | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 2 | 2 | 0 | 0 |
| 001 | Crabtree Creek | Below | 0 | 0 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 003 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 3 | 3 | 9 | 18 | 20 | 22 | 1 | 0 |
| 012 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 013 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 |
| 014 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 015 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 023 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 7 | 6 | 4 | 2 | 0 | 0 | 0 | 0 |
| 024 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 076 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 5 | 8 | 5 | 0 | 0 | 0 | 0 | 0 |
| 077 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 2 | 0 | 0 | 0 |
| 079 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 3 | 0 | 0 | 0 | 0 |
| 083 | Mainstem Below | Below | 0 | 0 | 0 | 1 | 1 | 0 | 5 | 1 | 0 | 0 | 0 | 0 |
| 084 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 086 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 090 | Crabtree Creek | Below | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 097 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 4 | 1 | 3 | 4 | 0 | 0 | 0 | 0 |
| 098 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 156 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 157 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 158 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 1 | 2 | 1 | 0 | 0 |
| 159 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 165 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 4 | 0 | 0 | 0 | 0 |
| 171 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 1 | 0 | 0 |
| 172 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 11 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |

Table 4. Raw redd count data for winter-run steelhead spawning surveys in the South Santiam subbasin, 2017.

| Site ID | Tributary | Above/Below Foster Dam | Sampling Interval and Date Range | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 3/20/17-4/2/17 | 2 4/3/17-4/16/17 | 3 4/17/17 - 4/30/17 | 4 5/1/17-5/14/17 | 5 5/15/17-5/28/17 |
| 002 | Canyon Creek | Above | 0 | 0 | 0 | 0 | 0 |
| 007 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 |
| 018 | Mainstem Above | Above | 0 | 0 | 0 | 2 | 0 |
| 022 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 |
| 080 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 1 |
| 093 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 |
| 154 | Canyon Creek | Above | 0 | 0 | 0 | 0 | 0 |
| 162 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 |
| 169 | Mainstem Above | Above | 0 | 0 | 0 | 0 | 0 |
| 083 | Mainstem Above | Above | 0 | 0 | 0 | 8 | 3 |
| 174 | Canyon Creek | Above | 0 | 0 | 0 | 0 | 0 |
| 001 | Crabtree Creek | Below | 0 | 0 | 0 | 1 | 0 |
| 003 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 1 |
| 004 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 005 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 008 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 009 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 010 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 012 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 013 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 014 | Crabtree Creek | Below | 0 | 1 | 0 | 0 | 0 |
| 015 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 017 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 021 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 023 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 024 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 076 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 077 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 078 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 079 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 082 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 081 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 084 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 086 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 088 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 089 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 090 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 094 | Wiley Creek | Below | 0 | 1 | 0 | 0 | 0 |
| 095 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 097 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 098 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 151 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 153 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 155 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 156 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 157 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 158 | Thomas Creek | Below | 0 | 2 | 0 | 8 | 0 |
| 159 | Thomas Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 165 | Wiley Creek | Below | 0 | 0 | 0 | 0 | 0 |
| 171 | Mainstem Below | Below | 0 | 0 | 0 | 0 | 0 |
| 172 | Crabtree Creek | Below | 0 | 0 | 0 | 0 | 0 |

Table 5. Steelhead spawner estimates using index and GRTS-based survey designs for three tributaries of the South Santiam river, 2016.

| Stream | Index Estimate | Index CI | GRTS Estimate | GRTS CI |
|---|---|---|---|---|
| Crabtree Creek | 82.52 | 65.96 | 153.75 | 88.91 |
| Thomas Creek | 196.41 | 120.91 | 293.88 | 232.79 |
| Wiley Creek | 675.67 | 406.95 | 174.99 | 148.99 |

## Figures

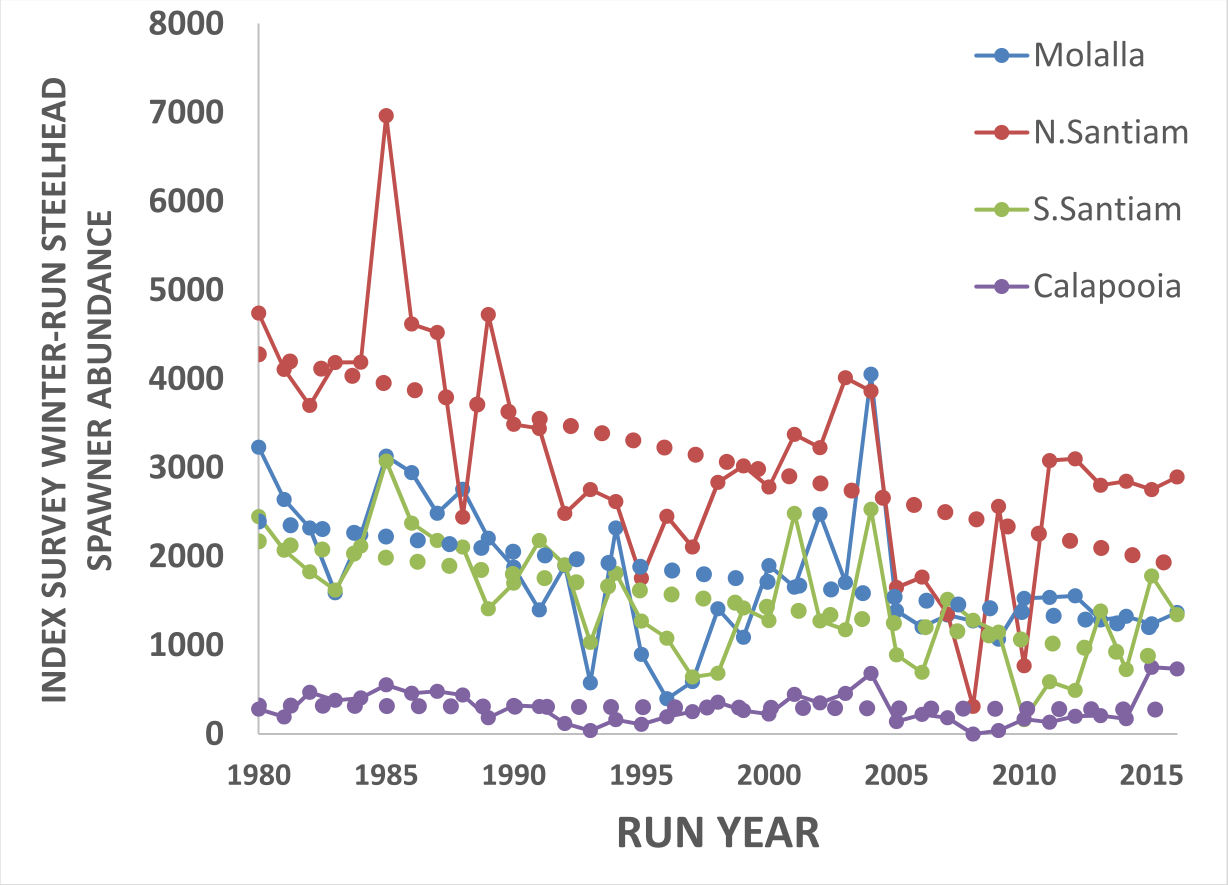

Figure 1. Winter steelhead spawner abundance as estimated from annual index surveys across four subbasins (Molalla, N. Santiam, S. Santiam, Calapooia) in the Willamette River Basin, 1980 – 2015. Dotted lines are linear fits to the series in each subbasin.

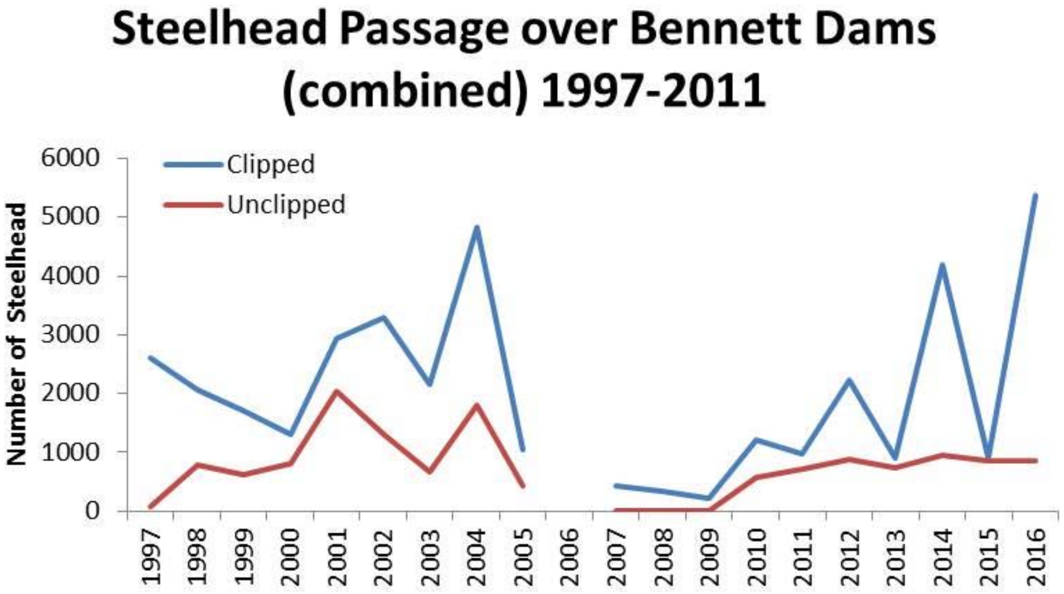

Figure 2. Number of steelhead passing over upper and lower Bennett dams in the North Santiam River, 1997–2016. Unclipped fish are natural origin, presumably winter steelhead; whereas clipped fish are hatchery origin summer steelhead.

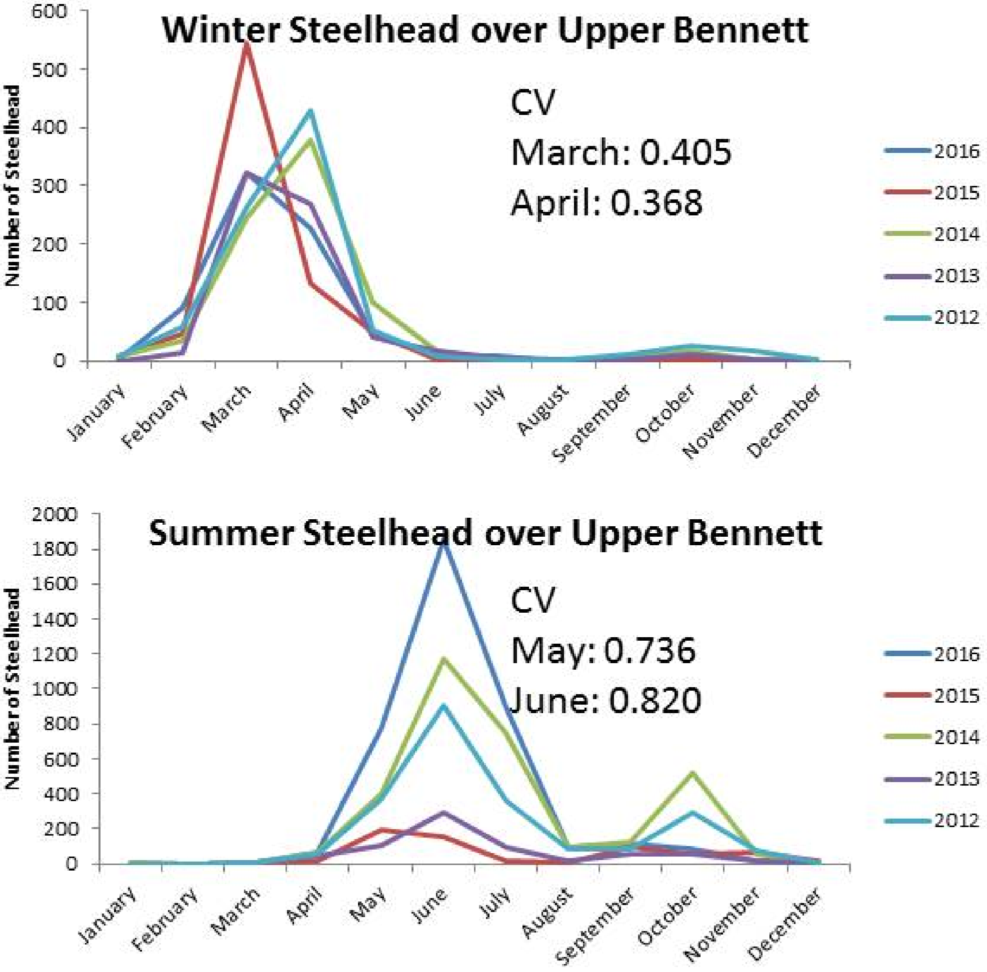

Figure 3. Numbers of steelhead passing over Upper Bennett Dam in the North Santiam River, 2012-2016. Coefficient of variation (CV) is reported for the peak migration months for both runs (winter: March/April; summer: May/June). Note the y-axis scales are different.

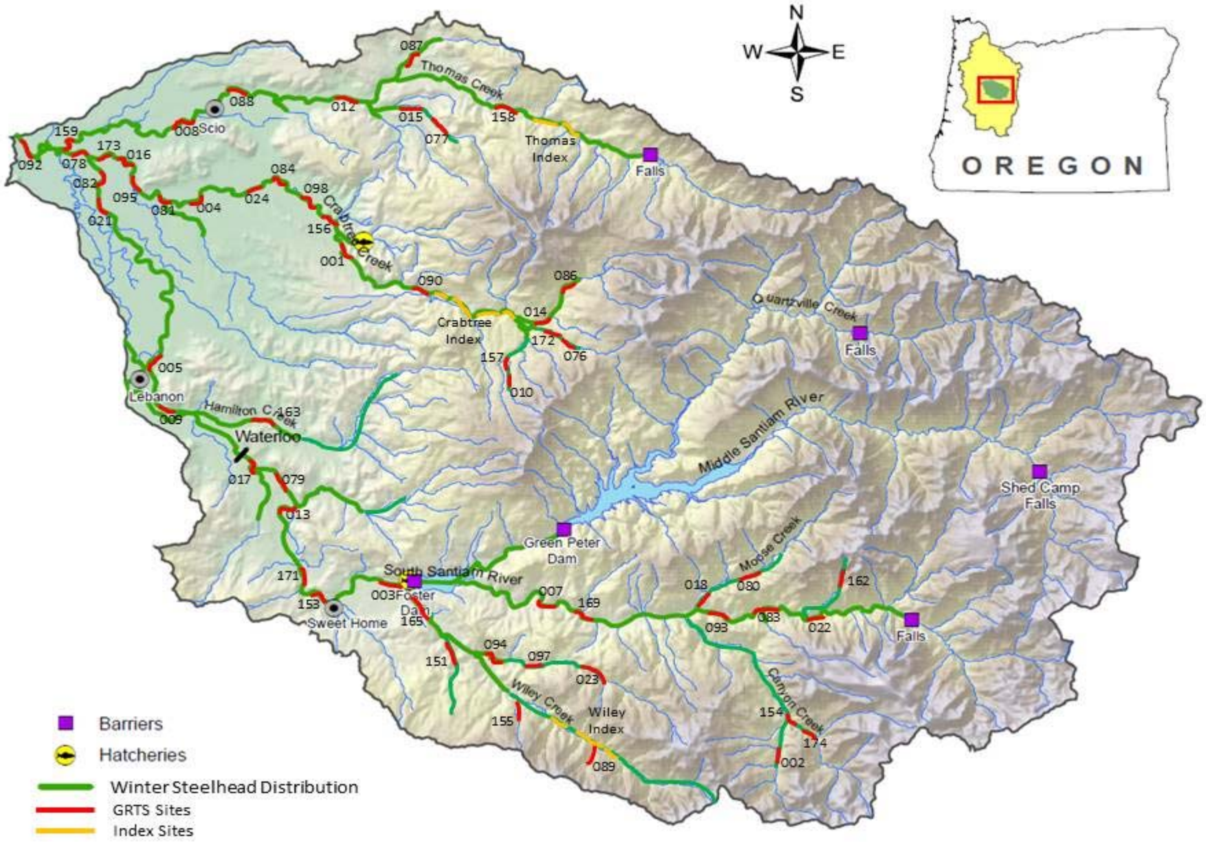

Figure 4. Map of survey locations for both GRTS-based and index survey sites in the South Santiam subbasin, 2015/2016 and 2016/2017. GRTS sites are colored red and index sites are colored orange.

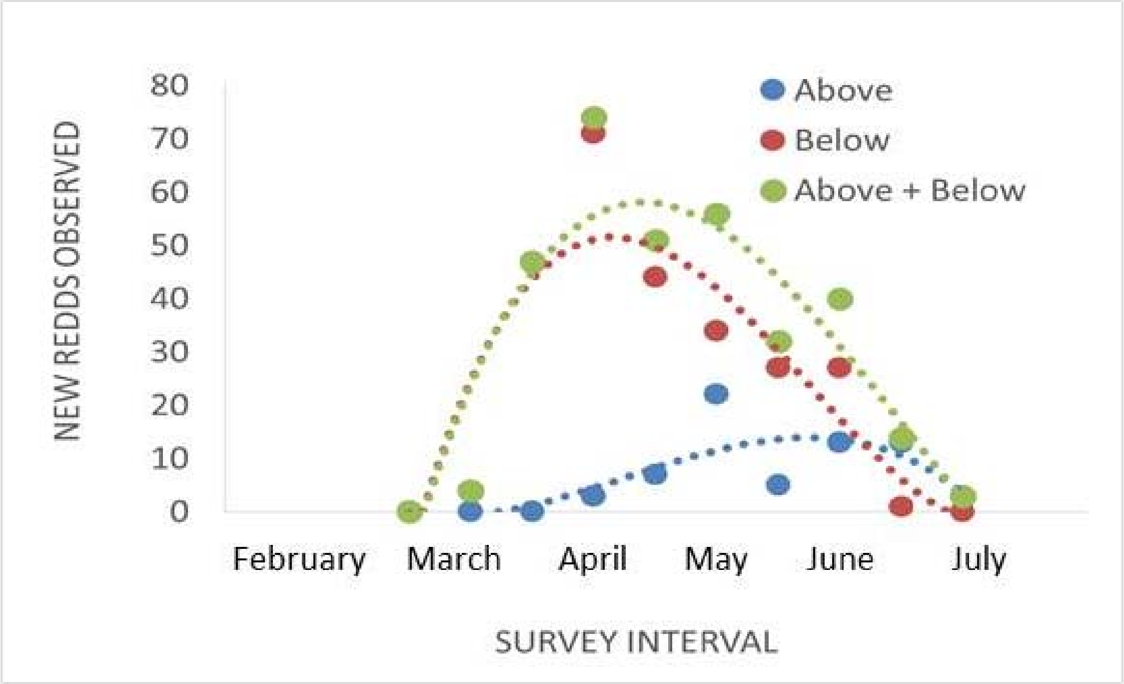

Figure 5. Winter steelhead redds observed by survey interval in the South Santiam subbasin above and below Foster Dam, 2015/2016. Survey intervals were 14-day periods starting on February 3, 2016 and continuing until July 13, 2016. Dotted lines are the second-order polynomial fits to each series.

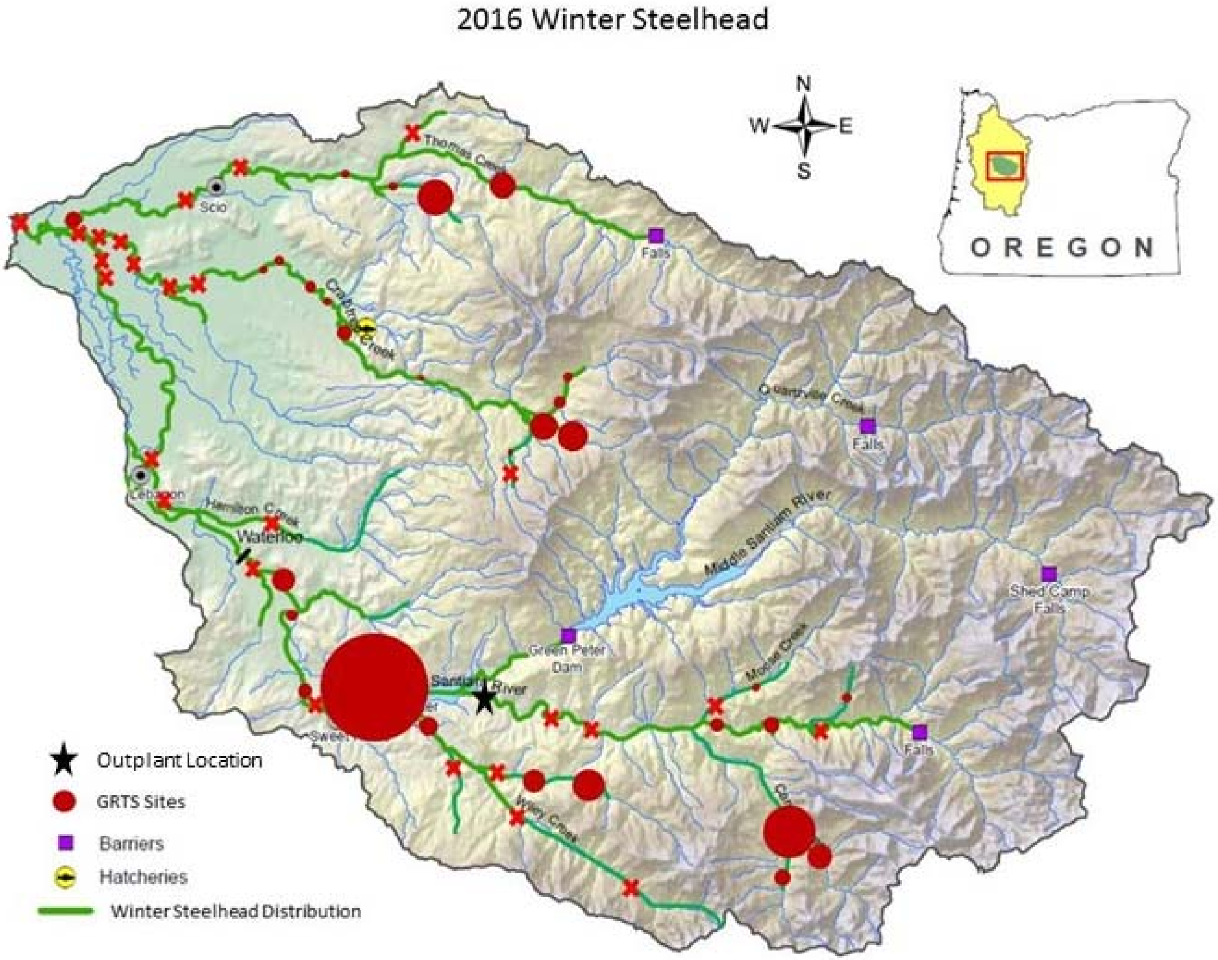

Figure 6. Distribution of winter steelhead redds in the South Santiam subbasin,2015/2016. Circles represent GRTS sites where redds were found and circle size is proportional to the density of redds in each location. Xs represent GRTS locations where no redds were observed during any survey. The max redd density was 22 redds/mile.

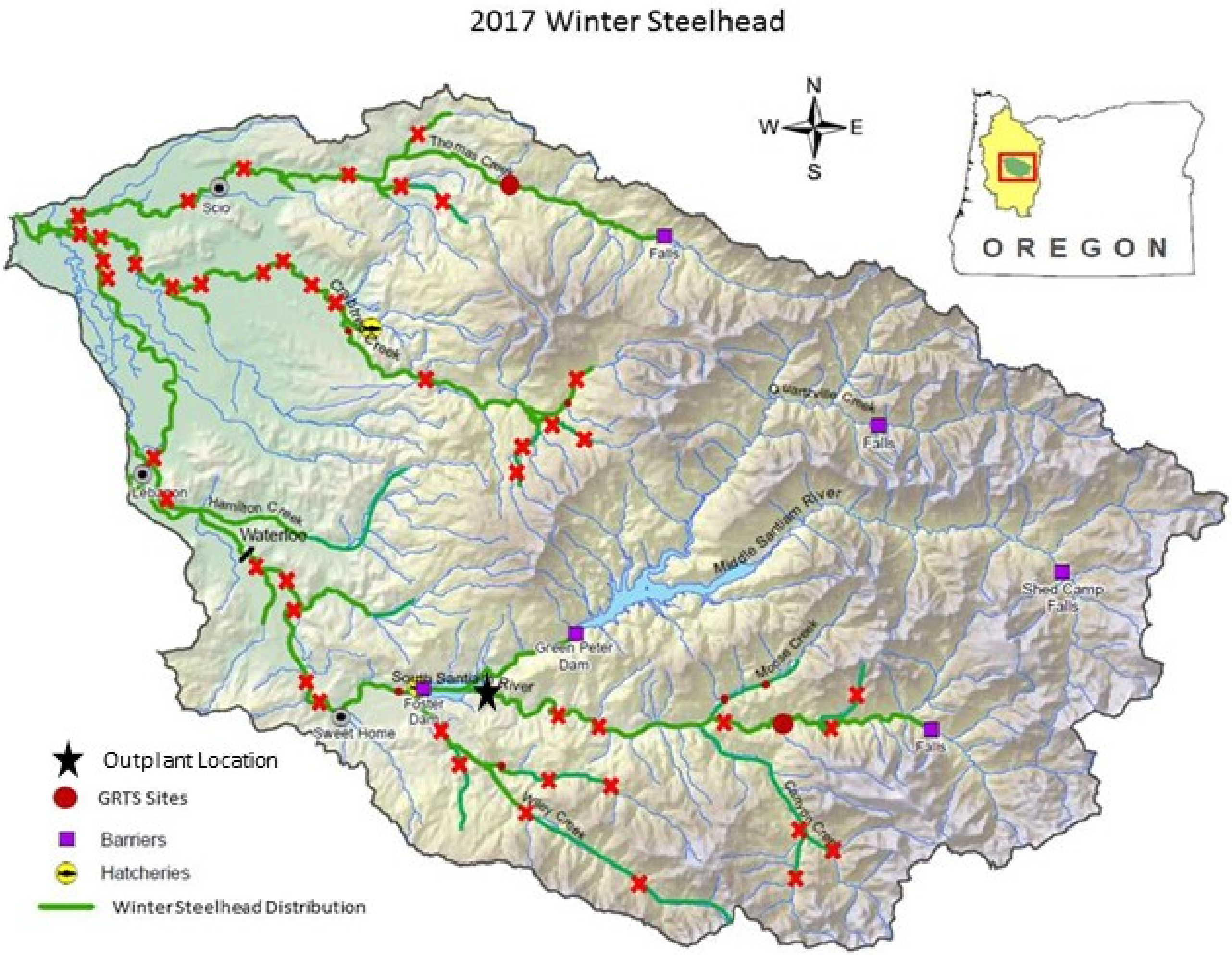

Figure 7. Distribution of winter steelhead redds in the South Santiam subbasin,2016/2017. Circles represent GRTS sites where redds were found and circle size is proportional to the density of redds in each location. Xs represent GRTS locations where no redds were observed during any survey. The max redd density was 8 redds/mile.

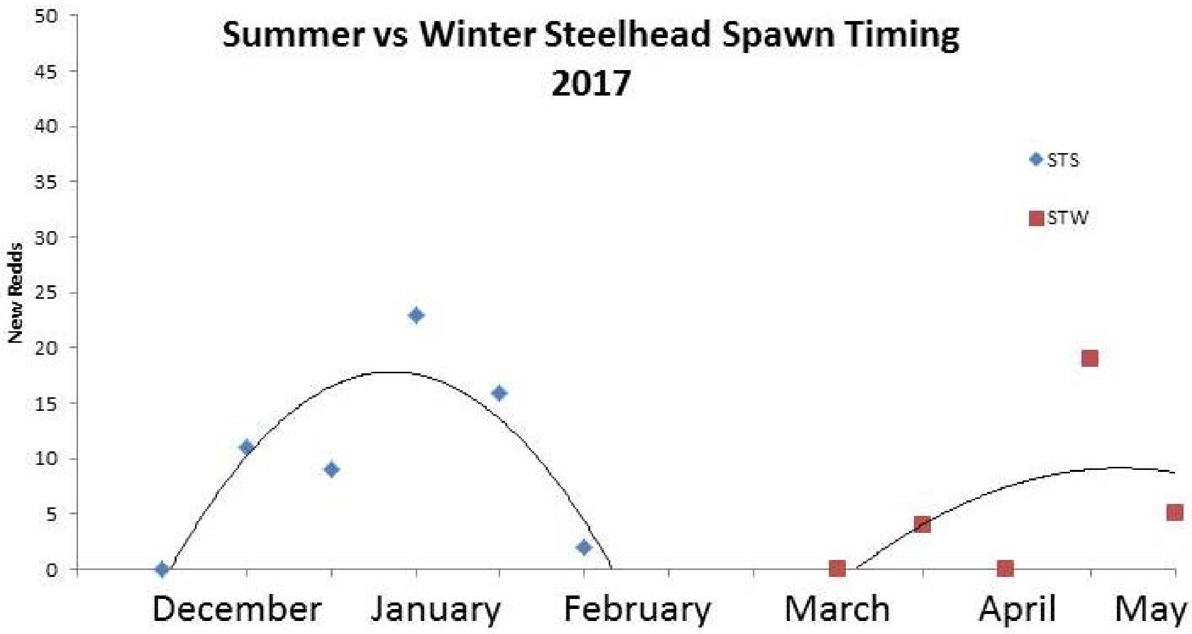

Figure 8. Spawn timing of summer (STS) and winter (STW) steelhead in the South Santiam subbasin during the 2016/2017 spawning season. Solid lines are the second-order polynomial fits to each series and illustrate the temporal separation between redd construction by summer- vs. winter-run fish.

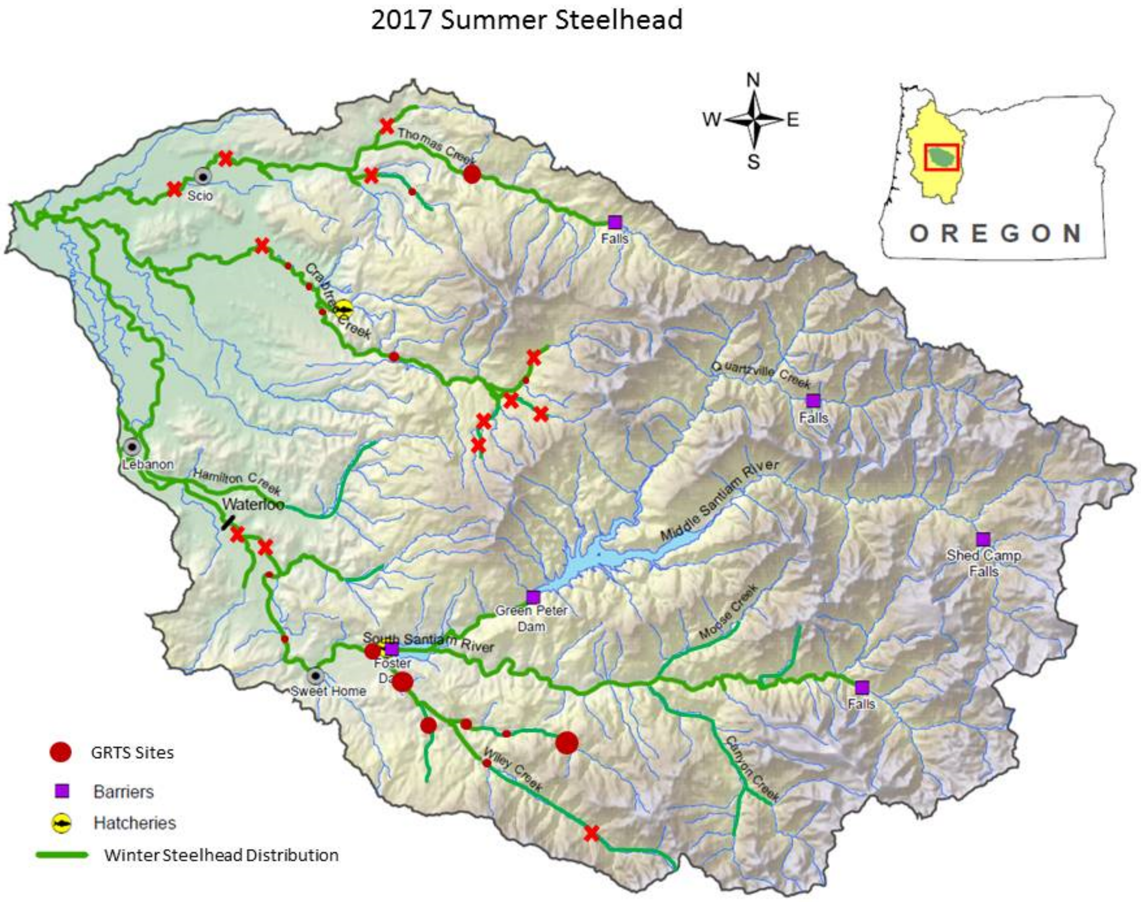

Figure 9. Distribution of summer steelhead redds in the South Santiam subbasin, 2016/2017. Circles represent GRTS sites where redds were found and circle size is proportional to the density of redds in each location. Xs represent GRTS locations where no redds were observed during any survey.

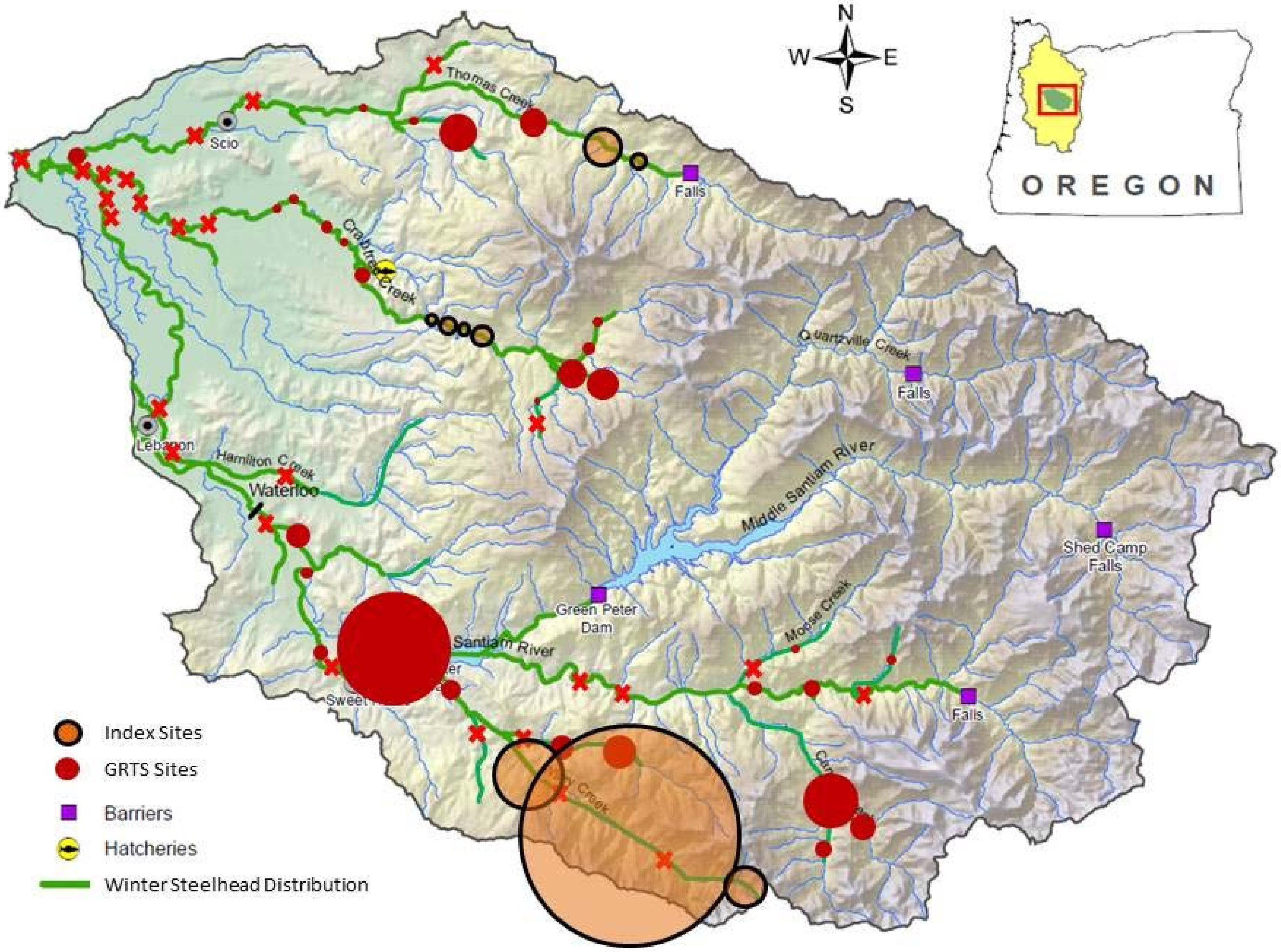

Figure 10. Comparison of redd density between GRTS sites and index surveys in the South Santiam subbasin, 2015/2016. Circles represent sites where redds were found and circle size is proportional to density of redds in each location. Red circles represent GRTS sites and orange circles represent index sites. Xs represent GRTS locations where no redds were observed during any survey.

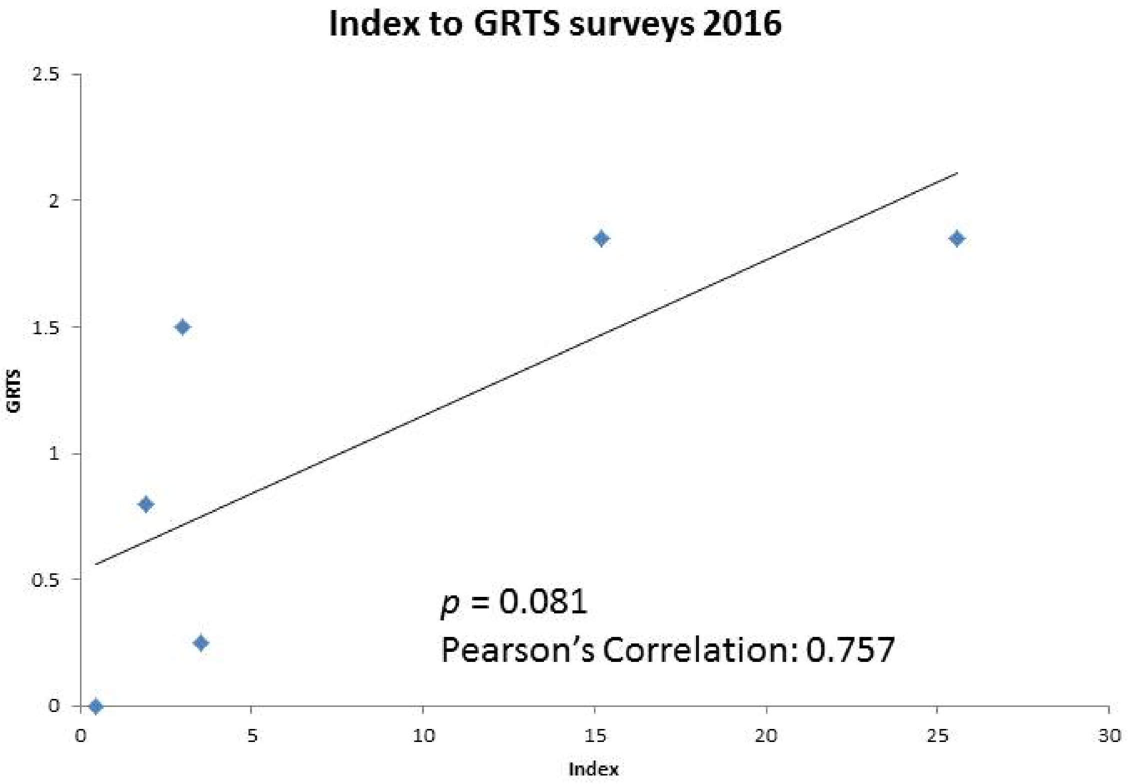

Figure 11. Redds/mile observed and correlation statistics for GRTS and index survey sites in the South Santiam subbasin, 2016.