FISH RESEARCH PROJECT
OREGON

STEELHEAD ESCAPEMENT MONITORING IN THE UPPER GRANDE RONDE RIVER AND JOSEPH CREEK BASINS

ANNUAL TECHNICAL REPORT

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Objectives

1. Estimate redd density and spawner escapement of summer steelhead in the Upper Grande Ronde River basin.
2. Estimate redd density and spawner escapement of summer steelhead in the Joseph Creek basin, a tributary to the Lower Grande Ronde River.
3. Estimate spawners:redd ratio above adult weir collection points.

Accomplishments and findings

We conducted 119 surveys in the Upper Grande Ronde River (UGRR) basin and 73 surveys in the Joseph Creek basin from 17 March through 11 June 2014 to determine summer steelhead *Oncorhynchus mykiss* redd abundance and adult escapement for these two populations. We sampled 29 random, spatially-balanced sites throughout the UGRR basin encompassing 61.3 km (6.9%) of an estimated 892 km of available steelhead spawning habitat. In Joseph Creek, we surveyed 25 sites encompassing 51.8 km (13.5%) of the 384 km of available spawning habitat. During these surveys we observed 65 steelhead redds and 19 live steelhead in the UGRR basin and 130 redds and 18 live steelhead in the Joseph Creek basin. We observed two carcasses in Joseph Creek basin and no carcasses in the UGRR basin.

On 18.7 km of Deer Creek, 18 redds, five live steelhead, and three carcasses were observed during five survey visits. A total of 48 wild-origin adult steelhead were passed above a permanent weir on Deer Creek, resulting in a 2.67 fish:redd ratio for the 2014 spawning season. Using the fish:redd ratio extrapolated from Deer Creek surveys, adult steelhead escapement estimates for the UGRR and Joseph Creek basins were 2,512 (95% C.I.: 1,538–3,487) and 2,522 (95% C.I.: 1,744–3,300) respectively.

Management recommendations

1. Using the current data of steelhead spawning distribution and geographic landscape variables, refine the sampling universe for the Upper Grande Ronde River and Joseph Creek populations to improve our knowledge of steelhead spawning distribution.
2. Estimate the biologically and statistically significant level of change in steelhead escapement for determining short- and long-term population changes.
3. Improve current methods for standardizing escapement estimates.
4. Manage the Upper Grande Ronde River and Joseph Creek populations exclusively for wild-origin steelhead and determine the extent and distribution of hatchery steelhead in the basin through observations of hatchery fish during the spawning season.

ACKNOWLEDGMENTS

We would like to acknowledge the assistance and cooperation of the many private landowners throughout the area who allowed us access to their property. The cooperation of private landowners was essential in meeting our project objectives. Additionally, we thank the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) for providing data from weir collections on Catherine and Lookinglass creeks and the UGRR. The Nez Perce Tribe provided data from weir collections on Joseph Creek. Further, we would like to acknowledge our field crew members Shannon Skinner, Marcus Anderson, Jess Bohnsack, Chip Andrus and Tyler Warner for their assistance as well as Jeff Yanke and Kyle Bratcher for their expertise and assistance.

INTRODUCTION

Summer steelhead in the Grande Ronde River basin fall within the Snake River Distinct Population Segment (DPS) and are listed as threatened under the Endangered Species Act (62 FR 43937; August 18, 1997). The Upper Grande Ronde River (UGRR) and Joseph Creek basins support two of the four populations in the Grande Ronde Major Population Group (MPG). These populations are segregated based on topographic, genetic, and behavioral evidence of interactions. Historically, the Grande Ronde River was one of the more significant anadromous fish producing rivers in the Columbia River basin. Despite recovery efforts, these populations remain depressed relative to historic levels.

The goal of this project is to annually evaluate summer steelhead population abundance for the UGRR, and recently Joseph Creek, by conducting surveys of redds and spawning activity. These surveys provide those data needed to estimate adult steelhead escapement, improve our understanding of habitat utilization, and contribute to productivity and survival estimates for these populations.

Study area

The Grande Ronde River flows generally northeast 341 km from its origin in the Elkhorn Mountain range to join the Snake River at river kilometer (rkm) 271, about 32 rkm upstream of Asotin, WA and 793 rkm from the mouth of the Columbia River. The UGRR basin (Figure 1) includes the Grande Ronde River and its tributaries from the headwaters to the confluence with the Wallowa River (rkm 131). Major tributaries of the UGRR include Sheep Creek (rkm 312), Meadow Creek (rkm 290), Catherine Creek (rkm 225), and Lookingglass Creek (rkm 138). The UGRR drains approximately 4,200 km^2 and contains 1,475 km of streams (892 km of anadromous salmonid habitat). Elevations in the basin range from 705 m at the confluence of the Grande Ronde and Wallowa rivers to over 2,646 m in the headwater mountains. Stream physiography in headwater areas is similar to other western, inter-mountain systems, with forested uplands, perched meadows, and high to moderate stream gradients. However, the mid-portion of the UGRR flows through large historic wetland complex (approximately 56 x 24 km at its greatest extent), bounded by a geologic pinch point at the downstream end (Rinehart Gap). The main portion of this valley is extremely flat (stream gradient <0.1%), leading to increased stream sinuosity and decreased water velocity. Gradient increases after the UGRR passes downstream through Rinehart Gap (near the town of Elgin) and enters a canyon-dominated landscape. Land use in the headwaters is a mix of timberlands and cattle grazing, while the main valley is in irrigated crop production. Agricultural land use is relatively light downstream of Elgin.

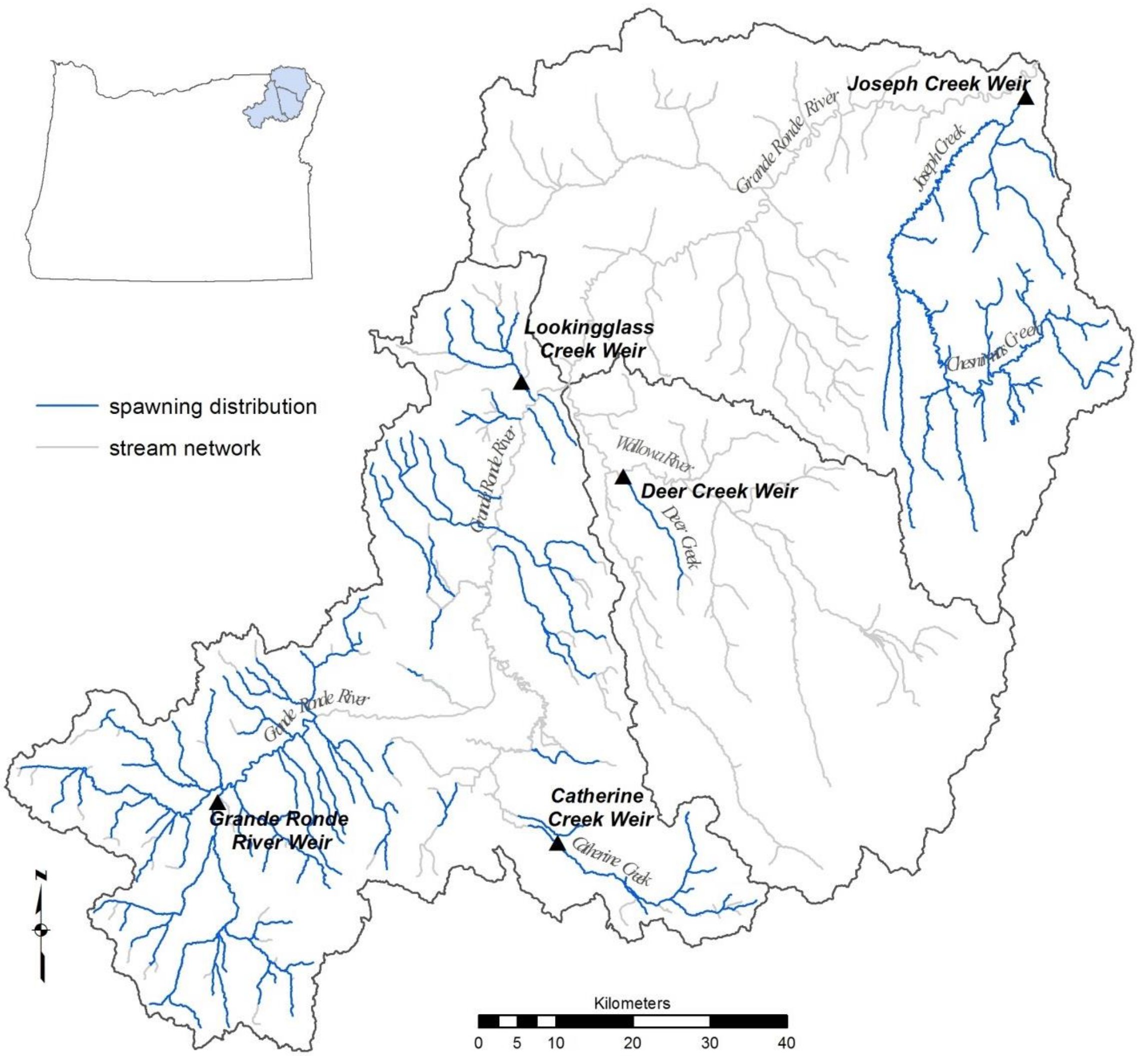

Figure 1. Sampling domains (blue) fall within the current spawning distribution of summer steelhead in Upper Grande Ronde River (UGRR) and Joseph Creek basins. Deer Creek and weir locations are also shown.

Joseph Creek is the most downstream tributary of the Grande Ronde River, entering approximately 7 km upstream of its mouth. Joseph Creek and its tributaries drain 1,420 km^2 originating on a plateau north of the upper Wallowa River valley, and flowing generally north into Washington (Wallace 2011). The Joseph Creek basin contains 536 km of streams, 384 km of which are estimated to be part of steelhead spawning distribution (Figure 1). Major tributaries include Crow and Chesnimnus creeks (which meet forming Joseph Creek at rkm 79), Swamp Creek (rkm 54), and Cottonwood Creek (rkm 7). Elevations in the basin are substantially lower than the UGRR basin, and range from 273 m at its confluence with the lower Grande Ronde River to around 1,673 m in the headwater areas. Physiography within the drainage is a mixture of hills and valleys at the upstream end, and canyonlands in the downstream portion (Figure 1). Land use is primarily cattle grazing in the upper reaches, especially upstream of the origin of Joseph Creek. Some grazing occurs in the lower reaches and tributaries; however, most of lower Joseph Creek flows through federal (US Forest Service) and Nez Perce Tribal property. No significant municipalities exist in the Joseph Creek basin.

Deer Creek flows north from its origin in the Wallowa Mountains until reaching the Wallowa River at rkm 18. It is a narrow, elongated drainage, covering 79 km^2 with elevations ranging from 2,259 m to 787 m. Approximately 18.7 km of stream are considered anadromous fish spawning habitat, and all 18.7 km are surveyed annually. A concrete fish acclimation facility (Big Canyon), with a permanent weir, is located approximately 0.25 km from the mouth of Deer Creek. All wild-origin adult steelhead captured at Big Canyon were marked with an opercle punch and passed above the weir during their spawning migrations. The known number of adult steelhead allowed into the spawning areas enables us to determine the adult fish:redd ratio for extrapolation to the larger UGRR and Joseph Creek populations (Flesher et al. 2005; Gee et al. 2008; James Ruzycki, ODFW, unpublished data). Land use is almost entirely timberlands upstream of the permanent weir.

METHODS

Sampling domain and site selection

Steelhead were monitored using a probabilistic sampling approach that incorporates a sample-site selection procedure created for the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). The Generalized Random Tessellation Stratified (GRTS) design achieves a spatially balanced distribution of sites selected at random from the available spawning habitat to extrapolate an estimate of redd, and therefore, spawner abundance (Jacobs et al. 2009). This method follows the Oregon Plan for Salmon and Basins Monitoring Program approach (Stevens 2002).

This GRTS design was first implemented in the UGRR in 2008 and 2012 for Joseph Creek. Sample sites were limited to the current steelhead spawning distribution, which was defined by redd and fish counts from previous spawning ground surveys and barriers identified during habitat surveys for summer steelhead. This information is annually updated to include newly identified barriers as well as new reaches of spawning habitat. All reaches upstream of known barriers to anadromous fish passage were eliminated from the potential sampling area. Thirty sample sites were targeted in the UGRR for this year. Twenty-five sample sites were targeted in the Joseph Creek basin for this year.

Beginning in 2012, a new survey design implementing sites selected from the Columbia Habitat and Monitoring Program (CHaMP) was integrated into the legacy design that includes the following components for the UGRR:

- 10 sites repeated every year (annual)
- 10 sites repeated once every 3 years on a staggered basis
- 5 sites from UGRR CHaMP frame to be repeated once every 3 years.
- 5 sites new every year (once-only)

Under the new survey design, stream segments were stratified into three classifications (source, transport, and depositional) and sites were evenly distributed among those three strata (logistics allowing). Stream segments were classified using Geographical Information System (GIS) by several attributes including valley width, stream gradient and bankfull width (Tim Beechie, unpublished data). In stratifying the sampling universe, we attempted to identify and isolate areas of habitat differentially utilized for spawning, thereby increasing the precision of future adult escapement estimates.

There were no sites in the Joseph Creek basin integrated from CHaMP because the program is not implemented in that basin. Additionally, GRTS-selected sites were not stratified by stream classification. The initial GRTS draw (2012) was stratified similarly to UGRR, but resulted in significant site clustering in depositional stream reaches. We removed the stratification to promote wider distribution of sites within the basin. Therefore, sites were selected as follows:

- 10 sites repeated every year (annual)
- 15 sites repeated once every 3 years on a staggered basis

Incorporating a 1:100,000 digital stream network, GIS was used to insure an unbiased and spatially balanced selection of sample sites. The GIS site selection process generated geographic coordinates (i.e. latitude and longitude) for each candidate site (Table 1). A two-kilometer reach was established encompassing each candidate site. Topographic maps were produced showing the downstream and upstream ends of each survey reach along with the included GRTS sample point. In the field, crews used a handheld Global Positioning System (GPS) to locate the established survey reaches. Some candidate sites were not sampled due to denial of permission from private landowners or because sites were located upstream of previously unknown fish passage barriers. In such events, replacement sites were drawn from a pre-selected list of over-sample sites.

Steelhead redd surveys

Steelhead redd surveys were based on standard ODFW methods (Susac and Jacobs 1999; Jacobs et al. 2000; Jacobs et al. 2001) and were conducted from March through June, 2014. Individual sites were surveyed up to seven times to quantify the number of redds constructed at each site, with approximately two week intervals between successive surveys to account for the temporal variation in spawning activity. Generally, surveyors walked upstream from the bottom of each sample reach and counted all redds, live fish, and dead fish observed. In some cases the larger streams were surveyed in a downstream direction for safety.

New redds were flagged and locations were marked with a handheld GPS unit. During each visit, surveyors recorded the number of new redds as well as previously identified flagged redds. Redd visibility was rated 0 for newly discovered redds and ranged from 1 (clearly visible) to 5 (no longer visible) for previously observed redds. To reduce bias of surveyor observations, surveyors were rotated through sites and partners if logistics allowed.

Steelhead carcasses were examined to obtain population and life history information by recording fork length (mm), MEPS (middle of the eye to posterior scale) length (mm), sex, egg retention (females), and origin determined by presence (wild) or absence (hatchery) of an adipose fin. For all carcasses, surveyors also collected scale samples from the key scale area (Nicholas and Van Dyke 1982) for age determination. Additional details of the survey protocol can be downloaded from the PNAMP, Monitoring Methods website (https://www.monitoringmethods.org/Protocol/Details/757).

Spawning timing

Weir Counts

Five weirs located on the UGRR, Joseph, and Deer creeks (Figure 1) were used to evaluate timing of steelhead entering the basins prior to spawning. The UGRR weirs, operated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), are located on the mainstem Grande Ronde River (rkm 291), Catherine Creek (rkm 32), and Lookingglass Creek (rkm 3; Figure 1). The weir on Deer Creek, operated by ODFW, is located 0.25 rkm upstream of its confluence with the Wallowa River. Wild adult steelhead trapped at the Deer Creek weir were marked with an opercle punch and released upstream of the weir to spawn naturally. All wild and hatchery-origin adult steelhead were passed above the UGRR weirs to spawn naturally.

The Nez Perce Tribe (NPT) operates the weir on Joseph Creek just upstream of its confluence with the Grande Ronde River. All adult steelhead (wild- and hatchery-origin) were captured and passed above the weir unmarked to spawn naturally (Paul Kucera, NPT, unpublished data).

Discharge and temperature

We attempted to relate redd observations to discharge for the UGRR, Joseph and Deer creeks. We used discharge measurements taken by Oregon Water Resources Department (OWRD) on the mainstem Grande Ronde River (station ID 13318960) by Perry (rkm 263). Unfortunately the Joseph Creek gauge (station ID 35G060, Washington Department of Ecology) lost funding in late 2012, and is no longer operational.

Estimating escapement

A locally weighted neighborhood variance estimator (Stevens and Olsen 2004), which incorporates the pair-wise dependency of all points and the spatially constrained nature of the design, was used to estimate a 95% confidence interval of the escapement estimate using SP Survey for R statistical software (R Development Core Team 2005). The statistical test was ran both with a single weighting value for the total spawning distribution and broken into a matrix of three strata by classification (source, transport, depositional) with weighting values depending on distance and number of surveys for each category (3).

Total escapement of adult steelhead (E_s) was determined by summing the product of the weight value (W), number of redds observed/km surveyed at each site (*i*), and fish:redd ratio determined from Deer Creek Surveys as:

$$E_s = \sum_{i=1}^{n} W_s \left(\frac{\text{Redds}}{\text{km}}\right)_i \left(\frac{\text{Fish}}{\text{Redd}}\right) \qquad (2)$$

Weight equals the distance of available spawning habitat in km (determined from GIS layer) divided by the number of sites surveyed as:

$$W = \left(\frac{km\ avail.}{no.sites}\right) \qquad (3)$$

The proportion of hatchery to wild-origin steelhead was calculated by dividing the total number of fin marked fish by all fish that could be observed for marks (live fish only). The number of hatchery fish straying to the basin was then estimated by multiplying this proportion of hatchery and wild-origin steelhead by our estimate of steelhead escapement.

Table 1. Steelhead spawning ground survey characteristics, location and stream classification for sites in the UGRR basin, 2014.

Site ID	Stream	Panel	Stream Classification	Survey Distance (km)	Upstream Latitude	Upstream Longitude	Downstream Latitude	Downstream Longitude
092986	Fly Creek	Panel 1	Depositional	2.00	45.1949	-118.40397	45.2104	-118.396610
149594	Dark Canyon Creek	Panel 1	Source	2.13	45.3112	-118.40096	45.2969	-118.390200
275866	Meadow Creek	Panel 1	Transport	2.02	45.2938	-118.64340	45.2929	-118.623100
288410	Little Indian Creek	Panel 1	Source	2.15	45.4062	-117.80785	45.4125	-117.826740
316330	South Fork Catherine Creek	Panel 1	Source	2.07	45.1041	-117.59148	45.1005	-117.610700
420954	Grande Ronde River	Panel 1	Depositional	2.04	45.3155	-118.27548	45.3236	-118.258650
514458	Spring Creek	Panel 1	Transport	2.18	45.3955	-118.37271	45.3786	-118.361430
018904	Spring Creek	Annual	Transport	2.39	45.3472	-118.30733	45.3381	-118.286129
030904	McCoy Creek	Panel 1	Transport	2.48	45.3411	-118.55475	45.3488	-118.574785
047598	Rysdam Creek	Panel 1	Transport	2.16	45.6733	-117.83170	45.6918	-117.844200
052824	Five Points Creek	Random	Transport	2.04	45.4219	-118.16232	45.4184	-118.181400
059352	Clark Creek	Annual	Depositional	1.84	45.5002	-117.81994	45.5150	-117.828889
063704	Sheep Creek	Random	Source	1.94	45.3044	-118.15286	45.3042	-118.152980
072200	South Fork Catherine Creek	Random	Depositional	2.26	45.1005	-117.61070	45.1109	-117.629100
075080	Meadow Creek	Random	Transport	2.16	45.2961	-118.70047	45.2964	-118.679210
079752	Grande Ronde River	Annual	Depositional	1.99	45.1793	-118.38937	45.1933	-118.395185
101102	Phillips Creek	Annual	Depositional	2.30	45.5697	-117.99371	45.5669	-117.973246
101560	Meadow Creek	Annual	Transport	1.97	45.2924	-118.61218	45.2832	-118.602238
102872	Dry Creek	Panel 1	Transport	2.07	45.3678	-118.26620	45.3733	-118.288602
104942	Little Lookingglass Creek	Panel 1	Depositional	2.08	45.7535	-117.87833	45.7671	-117.886998
118408	West Chicken Creek	Annual	Source	1.95	45.0268	-118.40358	45.0445	-118.403882
120904	Burnt Corral Creek	Annual	Source	2.13	45.1740	-118.51651	45.1843	-118.499661
123964	Limber Jim Creek	Random	Source	2.09	45.1063	-118.28242	45.1046	-118.299280
125832	Meadow Creek	Annual	Depositional	2.17	45.2636	-118.55147	45.2714	-118.533272
143240	Tybow Creek	Panel 1	Source	2.01	45.2320	-118.46207	45.2145	-118.467850
147928	Five Points Creek	Annual	Depositional	2.36	45.4107	-118.20179	45.4034	-118.222762
163672	Whiskey Creek	Panel 1	Source	1.97	45.2701	-118.21970	45.2872	-118.218650
172104	Meadow Creek	Random	Depositional	2.10	45.2622	-118.40112	45.2511	-118.416320
177134	East Phillips Creek	Annual	Source	2.20	45.6345	-118.05570	45.6230	-118.072221

Table 2. Steelhead spawning ground survey characteristics, location and stream classification for sites in the Joseph Creek basin, 2014.

Site ID	Stream	Panel	Stream Classification	Survey Distance (km)	Upstream Latitude	Upstream Longitude	Downstream Latitude	Downstream Longitude
002175	Crow Creek	Annual	Transport	2.07	45.6902	-117.15030	45.6902	-117.151930
037170	South Fork Chesnimnus Creek	Panel 3	Source	2.14	45.7260	-116.88738	45.7341	-116.870260
051026	Unnamed trib to Alder	Annual	Source	1.69	45.6939	-117.01259	45.7044	-117.021706
067711	Elk Creek	Panel 3	Transport	2.05	45.7002	-117.17113	45.7053	-117.152110
112130	Devils Run Creek	Annual	Source	2.24	45.7826	-116.96899	45.7801	-116.984205
141826	Basin Creek	Annual	Source	2.12	45.9128	-117.05728	45.9323	-117.057503
167426	Chesnimnus Creek	Annual	Depositional	2.44	45.7553	-116.99873	45.7507	-117.018780
169810	Chesnimnus Creek	Annual	Transport	2.08	45.7128	-116.91006	45.6975	-116.922844
192639	Crow Creek	Panel 3	Transport	2.13	45.6524	-117.14371	45.6708	-117.143200
231938	Cottonwood Creek	Panel 3	Source	2.00	45.8861	-116.98510	45.8680	-116.982500
249983	Elk Creek	Panel 3	Transport	2.13	45.6291	-117.19910	45.6478	-117.197230
255490	Billy Creek Tributary	Panel 3	Source	2.20	45.8028	-117.01440	45.8166	-117.021000
274559	Elk Creek	Panel 3	Source	2.13	45.6477	-117.19720	45.6640	-117.190430
301570	Cottonwood Creek	Annual	Source	1.88	45.9325	-117.05344	45.9430	-117.059020
339903	Swamp Creek	Panel 3	Transport	2.12	45.7703	-117.23261	45.7177	-117.229680
389247	Chesnimnus Creek	Annual	Depositional	1.94	45.6984	-117.12101	45.7051	-117.136075
390658	Chesnimnus Creek	Panel 3	Transport	2.18	45.6972	-116.92519	45.7143	-116.934740
427858	Chesnimnus Creek	Panel 3	Depositional	2.13	45.7173	-117.08565	45.7079	-117.090560
434111	Swamp Creek	Panel 3	Depositional	1.96	45.7865	-117.22978	45.8001	-117.229890
436738	Broady Creek	Panel 3	Source	2.10	45.9510	-117.07667	45.9453	-117.095590
471167	Little Elk Creek	Panel 3	Source	1.54	45.0944	-117.19869	45.6947	-117.185210
480514	Cottonwood Creek	Panel 3	Depositional	2.06	45.9826	-117.06148	45.9936	-117.050690
493394	Salmon Creek	Annual	Transport	1.92	45.7048	-117.04924	45.7188	-117.052223
508162	Joseph Creek	Panel 3	Depositional	2.11	45.7834	-117.17880	45.7896	-117.177210
515586	Chesnimnus Creek	Annual	Depositional	2.40	45.7370	-117.03171	45.7318	-117.049554

RESULTS

Sampling domain and site selection

We surveyed 29 sites in the UGRR (Figure 2) encompassing 61.3 km of an estimated 892 km (6.9 %) available steelhead spawning habitat (Table 1). Two sites were not surveyed due to persistent high discharge and were not included in our calculations. Stream classification for the 29 surveyed sites was distributed evenly (10 sites in source classification, 9 in transport, and 10 in depositional). Four sites were located above the Grande Ronde River weir, two above the Catherine Creek weir, and one above the Lookingglass Creek weir.

Twenty-five sites were surveyed in Joseph Creek and tributaries (Figure 3), encompassing 51.8 km of an estimated 384 km (13.5 %) available spawning habitat (Table 2), all of which were above the weir. Stream classification for the 25 sites was random with 10 sites surveyed in source classification, eight in transport, and seven in depositional.

We conducted five surveys on Deer Creek encompassing 18.7 km of utilized spawning habitat from the weir to the USFS road 8270 bridge. In previous years, additional surveys were conducted upstream of these 18.7 km, and no redds or adult steelhead were observed.

Steelhead redd surveys

We conducted 119 surveys in the UGRR basin in 2014, with a mean interval of 16.6 days between surveys. A total of 65 steelhead redds were observed at 17 of the 29 sites (Table 3). Redds were not evenly distributed among stream classifications: twelve (18%) were found in source areas, 31 (48%) in transport, and 22 (34%) in depositional reaches. A total of 19, live adult steelhead were observed in the UGRR (Table 5). Of these fish three had an observable adipose fin clip, six were of wild origin, and 10 were of unknown origin. No carcasses were observed during our surveys in the UGGR basin.

A total of 73 surveys were completed in the Joseph Creek basin, with a mean interval of 10.5 days between surveys. We found 130 steelhead redds at 18 of the 25 sites (Table 4). More redds were found in the depositional stream classification (n=53, 41%), than source or transport reaches (n=40 (31%) and 37 (28%) respectively). Eighteen live adult steelhead were observed at nine sites (Table 6), while two dead, adult steelhead were found at two sites (Table 7). No adipose-clipped hatchery fish were observed during our Joseph Creek surveys.

We observed 18 redds on our visits to Deer Creek, 15 (83.3 %) of which were discovered in the lower 9.6 km. Seven live fish and three carcasses were observed on Deer Creek (Table 7). Three adipose-clipped hatchery fish were also observed during our surveys.

Spawning timing

Based on our redd observations, onset of spawn timing was similar between the UGRR and Joseph Creek basins, but a little later for Deer Creek. We observed the first redds on 25 March in the UGRR, March 19 Joseph Creek basins (Figure 4) and 17 April in Deer Creek (Figure 5). The last redds were observed on 06 June in the UGRR, 03 June in Joseph Creek and 15 May in Deer Creek. By 12 May, 52% of the total redds in the UGRR basin were observed. By 05 May, 61% of the total redds in the Joseph Creek basin were observed. By the third survey on 17 April, 28% of the total redds were observed on Deer Creek. Although onset of redd building was similar among basins, peak redd observations occurred slightly later in Joseph Creek than UGRR (Figure 4), which is similar to the pattern observed in 2012 and 2013 (Dobos et al. 2012, Fitzgerald et al. 2013). Most redds in the UGRR basin were first observed during the descending hydrographs of early May to late June (Figure 4). Surveys on Deer Creek coincided with low discharge periods (Figure 5).

Weir Counts

The Catherine Creek, Lookingglass Creek, and the Grande Ronde River weirs were operable 3 March, 1 March, and 3 March, respectively. During the spring of 2014, 178 wild and two hatchery adult steelhead were passed at the Lookingglass Creek weir, 263 wild adult steelhead at the Catherine Creek weir, and 8 wild adult steelhead at the Grande Ronde River weir (Table 8). The first adult steelhead were passed on 12 March at the Lookingglass Creek, 05 March at Catherine Creek, and 19 March on Grande Ronde River. The last steelhead were passed on 16 April at the Grande Ronde River and 22 June at Lookingglass Creek and 08 June in Catherine Creek (Mike McLean, CTUIR, unpublished data). The Catherine Creek, Lookingglass, and the Grande Ronde River weirs were removed 31 July, 01 July, and 16 September, respectively.

Adult steelhead were captured at the weir operated by Nez Perce Tribe (NPT) near the mouth of Joseph Creek and all fish (wild- and hatchery-origin) were passed above the weir to spawn naturally. High flows on 09 March rendered the trap inoperable for the remainder of the season (Table 8, Paul Kucera, NPT, unpublished data 2014).

At the Deer Creek weir, 48 adult wild-origin steelhead were passed upstream to spawn naturally (Table 8). The weir was installed and operating 19 February and the first fish was captured 28 Feb. The weir was removed 26 May, 10 days after the last wild-origin fish was passed.

Estimating escapement

A fish:redd ratio of 2.67 (48/18) was generated using the number of fish passed above the weir at Deer Creek and the number of redds observed there in 2014. Using this ratio and a single weight value for all stream classifications (30.8), 2,512 adult steelhead (95% C.I.: 1,538–3,487) escaped into the UGRR basin and naturally spawned (Table 9; Figure 6). No adipose-clipped hatchery fish were observed during surveys on the UGRR. Using this same method with a weight value of 15.4, **2,522 adult steelhead (95% C.I.: 1,744–3,300)** escaped into the Joseph Creek basin (Table 9; Figure 6). No adipose-clipped hatchery fish were observed during surveys on Joseph Creek.

Using the weight values for each strata, source (50.1), transport (27.0), and depositional (19.7), we estimated that **2,305 (95% CI, 1,362–3,348)** adult steelhead for the UGRR population (Table 10). For Joseph Creek estimates changed by only one fish: using the weight values for each strata, source (15.9), transport (14.3), and depositional (15.8), we estimated that **2,253 (95% CI, 1,726–3,320)** adult steelhead returned to spawn (Table 11).

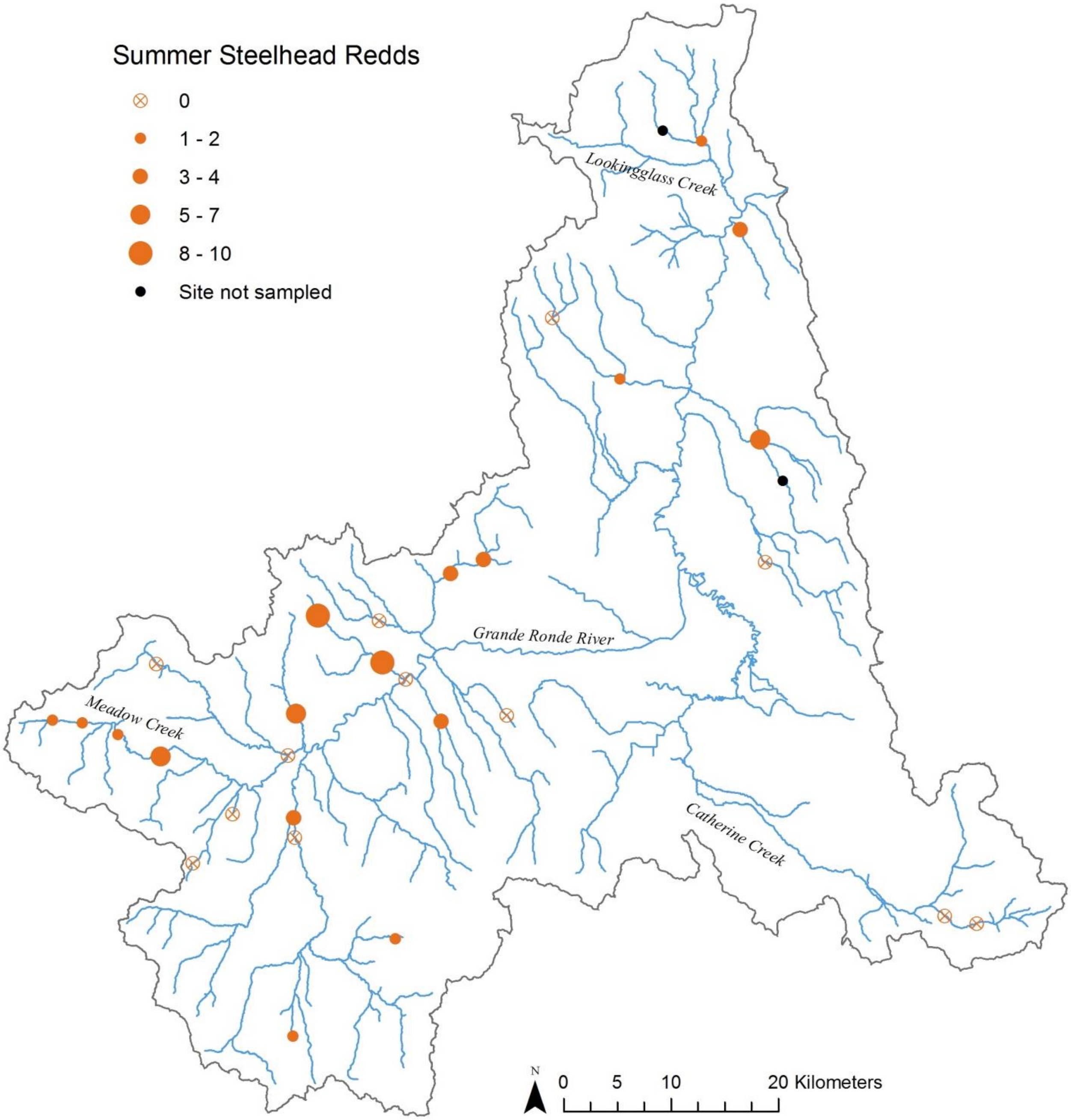

Figure 2. Map of the Upper Grande Ronde River basin displaying count of redds observed at each site in 2014. The two sites not surveyed were due to continual high flows and dangerous wading conditions.

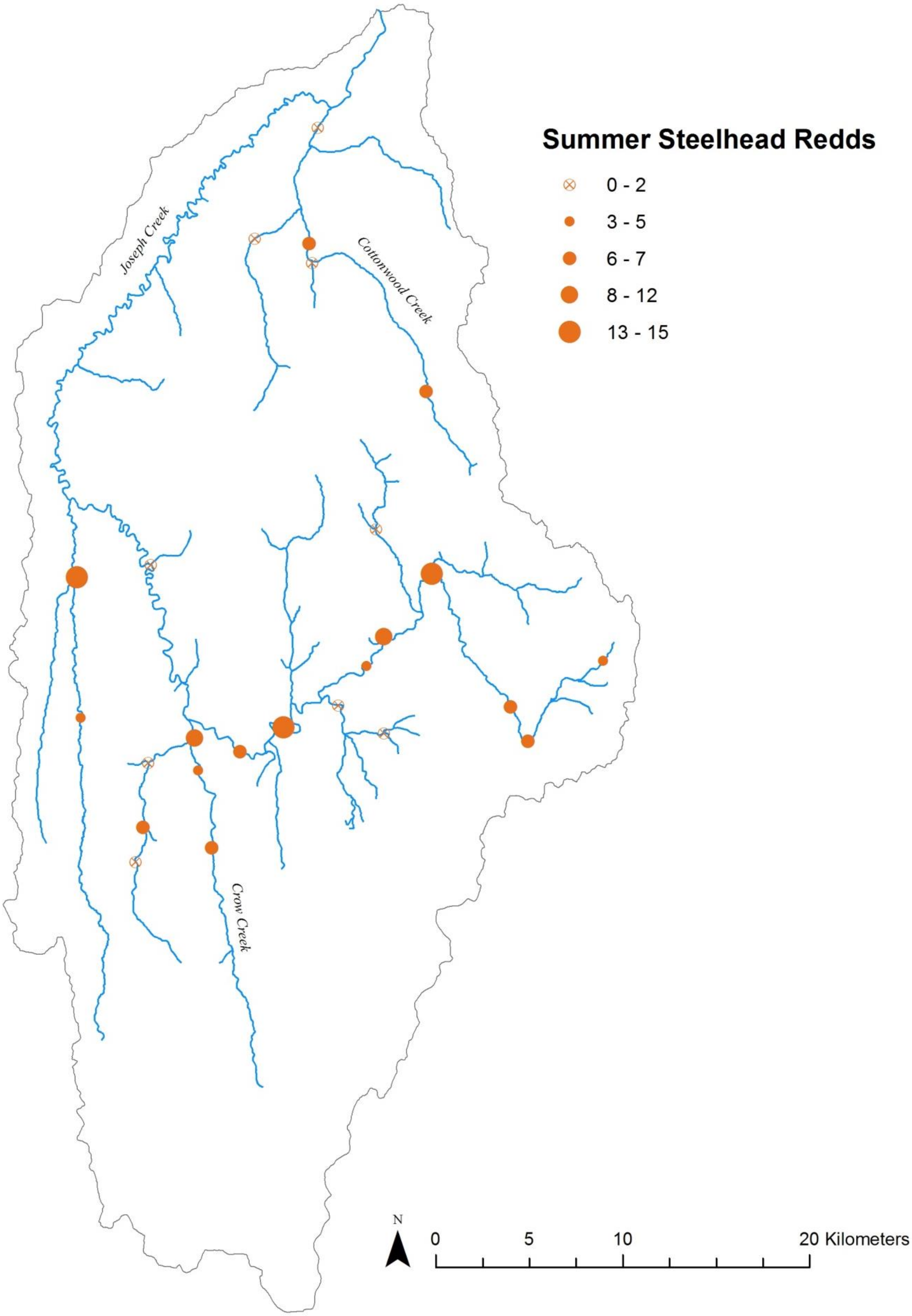

Figure 3. Map of the Joseph Creek basin showing count of redds observed at each site in 2014.

Table 3. Completion dates and general results for redd surveys in the Upper Grande Ronde River basin and Deer Creek, 2014.

Site ID	Stream	No. surveys completed	Mean No. days between surveys	Redd Count	1st Survey	2nd Survey	3rd Survey	4th Survey	5th Survey	6th Survey	7th Survey
018904	Spring Creek	7	14.3	9	3/17/2014	3/31/2014	4/14/2014	4/28/2014	5/12/2014	5/27/2014	6/11/2014
030904	McCoy Creek	6	14.4	0	3/31/2014	4/14/2014	4/28/2014	5/12/2014	5/27/2014	6/11/2014	
047598	Rysdam Creek	5	14.3	4	3/24/2014	4/8/2014	4/23/2014	5/6/2014	5/20/2014		
052824	Five Points Creek	5	15	4	4/7/2014	4/22/2014	5/8/2014	5/22/2014	6/6/2014		
059352	Clark Creek	6	14.4	6	3/18/2014	4/1/2014	4/15/2014	4/29/2014	5/13/2014	5/29/2014	
063704	Sheep Creek	1	NA	0	5/14/2014						
072200	SF Catherine Creek	2	37	0	4/29/2014	6/5/2014					
075080	Meadow Creek	4	10	2	4/24/2014	5/5/2014	5/21/2014	6/3/2014			
079752	Grande Ronde River	3	32	0	3/25/2014	4/16/2014	5/28/2014				
092986	Fly Creek	6	14.4	4	3/25/2014	4/7/2014	4/21/2014	5/6/2014	5/22/2014	6/5/2014	
101102	Phillips Creek	6	14.2	1	3/26/2014	4/8/2014	4/23/2014	5/6/2014	5/20/2014	6/5/2014	
101560	Meadow Creek	5	14	1	4/8/2014	4/21/2014	5/5/2014	5/21/2014	6/3/2014		
102872	Dry Creek	5	13.8	0	3/25/2014	4/7/2014	4/21/2014	5/5/2014	5/19/2014		
104942	Little Lookingglass Creek	5	19.5	2	3/24/2014	4/8/2014	5/15/2014	5/29/2014	6/10/2014		
118408	West Chicken Creek	4	15	1	4/21/2014	5/6/2014	5/22/2014	6/5/2014			
120904	Burnt Corral Creek	5	14.3	0	3/17/2014	3/31/2014	4/14/2014	4/28/2014	5/13/2014		
123964	Limber Jim Creek	4	15	1	4/28/2014	5/14/2014	5/28/2014	6/12/2014			
125832	Meadow Creek	7	13	6	3/19/2014	4/3/2014	4/14/2014	4/30/2014	5/7/2014	5/21/2014	6/5/2014
143240	Tybow Creek	5	14.3	0	3/17/2014	3/31/2014	4/14/2014	4/30/2014	5/13/2014		
147928	Five Points Creek	5	13.8	3	4/15/2014	4/30/2014	5/14/2014	5/30/2014	6/9/2014		
149594	Dark Canyon Creek	5	14.3	7	4/8/2014	4/21/2014	5/7/2014	5/19/2014	6/4/2014		
163672	Whiskey Creek	7	14.2	3	3/17/2014	3/31/2014	4/14/2014	4/28/2014	5/12/2014	5/27/2014	6/10/2014
172104	Meadow Creek	7	13.7	0	3/19/2014	4/3/2014	4/14/2014	4/30/2014	5/13/2014	5/27/2014	6/9/2014
177134	East Phillips Creek	3	14	0	5/15/2014	5/28/2014	6/12/2014				
275866	Meadow Creek	5	14	1	4/8/2014	4/21/2014	5/5/2014	5/21/2014	6/3/2014		
288410	Little Indian Creek	6	14	0	4/1/2014	4/15/2014	4/29/2014	5/13/2014	5/29/2014	6/10/2014	
316330	SF Catherine Creek	2	37	0	4/29/2014	6/5/2014					
420954	Grande Ronde River	1	NA	0	6/5/2014						
514458	Spring Creek	4	0	10	4/22/2014	5/5/2014	5/19/2014	6/4/2014			
3-0	Deer Creek	6	14	10	3/20/2014	4/3/2014	4/17/2014	5/1/2014	5/15/2014	5/29/2014	
6-3	Deer Creek	6	14	5	3/20/2014	4/3/2014	4/17/2014	5/1/2014	5/15/2014	5/29/2014	
8-6	Deer Creek	5	11.2	3	4/3/2014	4/17/2014	5/1/2014	5/15/2014	5/29/2014		
10-8	Deer Creek	3	5.6	0	4/17/2014	5/1/2014	5/15/2014				
12-10	Deer Creek	1	NA	0	5/1/2014						

Table 4. Completion dates and general results for surveys in the Joseph Creek basin, 2014

Site ID	Stream	No. surveys completed	Mean No. days between surveys	Redd Count	1st Survey	2nd Survey	3rd Survey	4th Survey	5th Survey	6th Survey
002175	Crow Creek	4	9.8	5	3/21/2014	4/2/2014	4/15/2014	4/29/2014		
037170	SF Chesnimnus Creek	3	6.0	4	5/6/2014	5/19/2014	6/5/2014			
051026	Unnamed trib to Alder	4	10.5		3/26/2014	4/8/2014	4/22/2014	5/7/2014		
067711	Elk Creek	5	12.2	10	3/21/2014	4/2/2014	4/15/2014	4/29/2014	5/21/2014	
112130	Devils Run Creek	4	10.5	14	4/16/2014	5/5/2014	5/19/2014	5/28/2014		
141826	Basin Creek	4	10.0		3/24/2014	4/7/2014	4/28/2014	5/13/2014		
167426	Chesnimnus Creek	5	12.2	12	4/3/2014	4/21/2014	5/7/2014	5/20/2014	6/3/2014	
169810	Chesnimnus Creek	6	13.0	6	3/31/2014	4/9/2014	4/23/2014	5/6/2014	5/19/2014	6/4/14
192639	Crow Creek	4	8.2	6	3/19/2014	4/2/2014	4/15/2014	4/29/2014		
231938	Cottonwood Creek	2	2.8	7	5/8/2014	5/22/2014				
249983	Elk Creek	4	11.5		3/27/2014	4/9/2014	4/21/2014	5/12/2014		
255490	Unnamed trib to Billy	4	11.5		4/24/2014	5/12/2014	5/23/2014	6/9/2014		
274559	Elk Creek	4	11.5	6	3/27/2014	4/9/2014	4/21/2014	5/12/2014		
301570	Cottonwood Creek	4	9.7	6	3/24/2014	4/7/2014	4/28/2014	5/13/2014		
339903	Swamp Creek	3	8.8	4	4/1/2014	5/1/2014	5/15/2014			
389247	Chesnimnus Creek	4	10.5	6	4/16/2014	4/29/2014	5/14/2014	5/28/2014		
390658	Chesnimnus Creek	6	13.0	7	3/31/2014	4/9/2014	4/23/2014	5/6/2014	5/19/2014	6/4/14
427858	Chesnimnus Creek	4	12.0	15	4/16/2014	5/5/2014	5/20/2014	6/3/2014		
434111	Swamp Creek	3	7.3	13	4/14/2014	5/1/2014	5/13/2014			
436738	Broady Creek	3	12.3		3/25/2014	4/28/2014	5/13/2014			
471167	Little Elk Creek	4	9.0		3/17/2014	3/31/2014	4/15/2014	5/1/2014		
480514	Cottonwood Creek	4	12.5		3/24/2014	4/7/2014	4/29/2014	5/13/2014		
493394	Salmon Creek	5	14.0	2	3/26/2014	4/8/2014	4/22/2014	5/7/2014	5/21/2014	
508162	Joseph Creek	4	7.4	2	5/5/2014	5/14/2014	5/28/2014	6/11/2014		
515586	Chesnimnus Creek	5	16.8	5	4/3/2014	4/24/2014	5/7/2014	5/20/2014	6/9/2014	

Table 5. Locations, dates, and characteristics of live steelhead observations in the UGRR and Deer Creek basins, 2014.

Site ID	Stream	Observation Date	Fin Clip	On/Off Redd
047598	Rysdam Creek	3/24/2014	Yes	Off
047598	Rysdam Creek	3/24/2014	No	Off
052824	Five Points Creek	5/8/2014	Unknown	Off
059352	Clark Creek	4/1/2014	No	On
059352	Clark Creek	4/1/2014	No	On
059352	Clark Creek	4/1/2014	No	On
059352	Clark Creek	4/1/2014	No	On
059352	Clark Creek	4/15/2014	Yes	On
059352	Clark Creek	4/15/2014	Unknown	On
059352	Clark Creek	4/15/2014	Unknown	On
101560	Meadow Creek	4/21/2014	Unknown	On
118408	West Chicken Creek	4/21/2014	Unknown	On
149594	Dark Canyon Creek	4/21/2014	Unknown	On
172104	Meadow Creek	5/27/2014	Unknown	Off
275866	Meadow Creek	4/21/2014	Yes	Off
420954	Grande Ronde River	6/6/2014	Unknown	Off
514458	Spring Creek	4/22/2014	No	Off
514458	Spring Creek	5/19/2014	Unknown	Off
514458	Spring Creek	5/5/2014	Unknown	On
Deer3-0	Deer Creek	4/17/2014	Unknown	Near
Deer3-0	Deer Creek	4/17/2014	Unknown	Off
Deer3-0	Deer Creek	4/17/2014	Yes	Off
Deer3-0	Deer Creek	4/17/2014	Yes	Off
Deer3-0	Deer Creek	4/17/2014	Yes	Off
Deer3-0	Deer Creek	4/17/2014	Yes	Off
Deer3-0	Deer Creek	5/15/2014	Unknown	On

Table 6. Locations, dates, and characteristics of live steelhead observations in the Joseph Creek basin, 2014.

Site ID	Stream	Observation Date	Fin Clip	On/Off Redd
002175	Crow Creek	4/2/2014	Unknown	On
067711	Elk Creek	4/15/2014	Unknown	Off
112130	Devils Run Creek	5/5/2014	Unknown	Off
112130	Devils Run Creek	5/5/2014	Unknown	On
167426	Chesnimnus Creek	4/21/2014	No	On
167426	Chesnimnus Creek	4/21/2014	Unknown	On
167426	Chesnimnus Creek	4/21/2014	Unknown	On
167426	Chesnimnus Creek	4/21/2014	Unknown	On
192639	Crow Creek	3/19/2014	Unknown	On
192639	Crow Creek	4/2/2014	No	On
192639	Crow Creek	4/2/2014	No	On
274559	Elk Creek	4/9/2014	No	Off
274559	Elk Creek	4/9/2014	No	Off
390658	Chesnimnus Creek	4/9/2014	Unknown	Off
390658	Chesnimnus Creek	4/9/2014	Unknown	Off
390658	Chesnimnus Creek	4/9/2014	Unknown	Off
493394	Salmon Creek	3/26/2014	Unknown	Off
508162	Joseph Creek	5/14/2014	Unknown	Off

Table 7. Locations, dates, and characteristics of dead steelhead observations in Joseph and Deer Creek basins, 2014.

Site ID	Stream	Date Observed	Fish Sex	Fork Length	Origin
037170	SF Chesnimnus Creek	5/19/2014	Male	590	Wild
112130	Devils Run Creek	5/19/2014	Male	720	Wild
Deer3-0	Deer Creek	5/15/2014	Male	625	Wild
Deer3-0	Deer Creek	5/15/2014	Male	570	Wild
Deer3-0	Deer Creek	5/15/2014	Male	560	Wild

Table 8. Origin of fish passed above Joseph Creek, UGRR, Catherine Creek, Lookingglass Creek and Deer Creek weirs in 2014.

	Natural Origin	Hatchery Origin	Proportion Hatchery (%)	Total Fish
Joseph Creek*	145	0	0	145
UGRR**	8	0	0	8
Catherine Creek**	263	0	0	263
Lookingglass Creek**	178	2	1.1	180
Deer Creek***	48	0	0	48

*Paul Kucera, Nez Perce Tribe, Department of Fisheries Resources Management, unpublished data, personal communication
**Michael McLean, Confederated Tribes of the Umatilla Indian Reservation, Department of Natural Resources, Fisheries Program, unpublished data, personal communication
***Michael Flesher, Oregon Department of Fish & Wildlife, La Grande Fish Research, unpublished data, personal communication

Table 9. Annual results of steelhead spawning ground surveys, 2008−2014. Available spawning habitat was refined yearly based on previous surveys.

Year	No. of sites	Spawning habitat (km)	Weight value	Redds observed	Distance surveyed (km)	Fish:redd ratio	Total spawner escapement	95% CI	CI as % of escapement
UGRR basin									
2008	29	1,301	44.9	24	64.2	4.07	2,096	±1,142	54.50%
2009	30	1,178	39.3	42	59.9	3.81	3,148	±1,047	33.20%
2010	29	934	32.2	109	56.4	1.6	2,876	±897	31.20%
2011	28	929	33.2	44	59.5	4.75	3,275	±1,028	31.40%
2012	30	897	29.9	70	60.7	3.14	3,261	±1,077	33.00%
2013	29	892	30.8	52	56.1	1.91	1,553	±757	48.70%
2014	29	892	30.8	65	61.3	2.67	2,512	±974	38.77%
Joseph Creek basin									
2012	30	384	12.8	67	58.4	3.14	1,357	±380	28.00%
2013	26	384	14.8	153	51.5	1.91	2,197[a]	±934	42.50%
2014	25	384	15.4	130	51.8	2.67	2,522[b]	±778	30.85%

a. With 2.2% hatchery proportion the total natural spawners is 2,149 (95% CI ±913).
b. With 1.1% hatchery proportion the total natural spawners is 2,494 (95% CI ±769).

Table 10. Survey characteristics and results, grouped by stream classification type for the UGRR basin, 2014.

Stream Classification	No. of sites	Spawning habitat (km)	Weight value	Distance surveyed (km)	Total redds observed	Redds per km	Spawner escapement	Lower 95% CI	Upper 95% CI
Source	10	453	50.29	20.65	12	0.6	779	1	1557
Transport	9	243	26.96	19.46	31	1.6	1015	516	1514
Depositional	10	197	19.67	21.14	22	1.0	562	198	925
Total	**29**	**892**	**96.91**	**61.25**	**65**	1.1	**2,355**	**1,362**	**3,348**

Table 11. Survey characteristics and results, grouped by stream classification type for the Joseph Creek basin, 2014.

Stream Classification	No. of sites	Spawning habitat (km)	Weight value	Distance surveyed (km)	Total redds observed	Redds per km	Spawner escapement	Lower 95%CI	Upper 95% CI
Source	10	159	15.9	20.03	37	1.8	749	230	1267
Transport	8	115	14.3	16.68	40	2.4	732	445	1020
Depositional	7	111	15.8	15.04	53	3.5	1,043	510	1575
Total	**25**	**384**	**14.8**	**51.76**	**130**	**2.5**	**2,523**	**1,726**	**3,320**

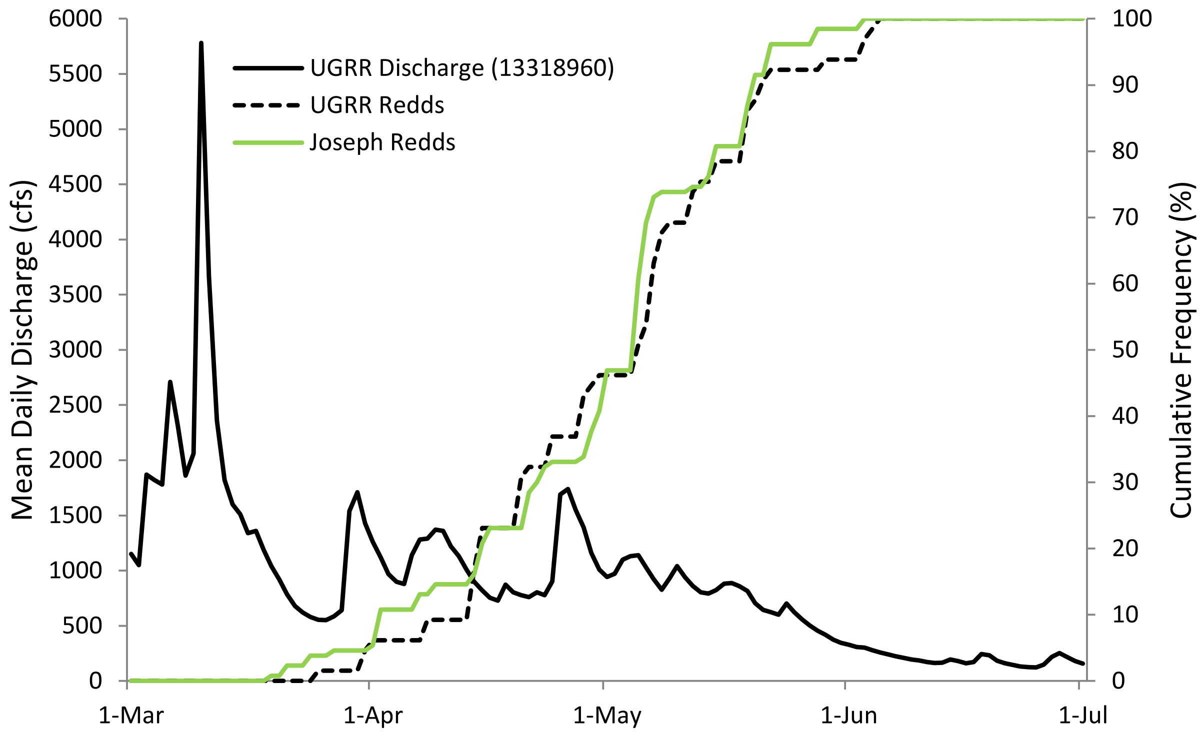

Figure 4. Cumulative frequency of observed redds and mean daily discharge during the spawning period for the UGRR basin (OWRD station #13318960) in 2014.

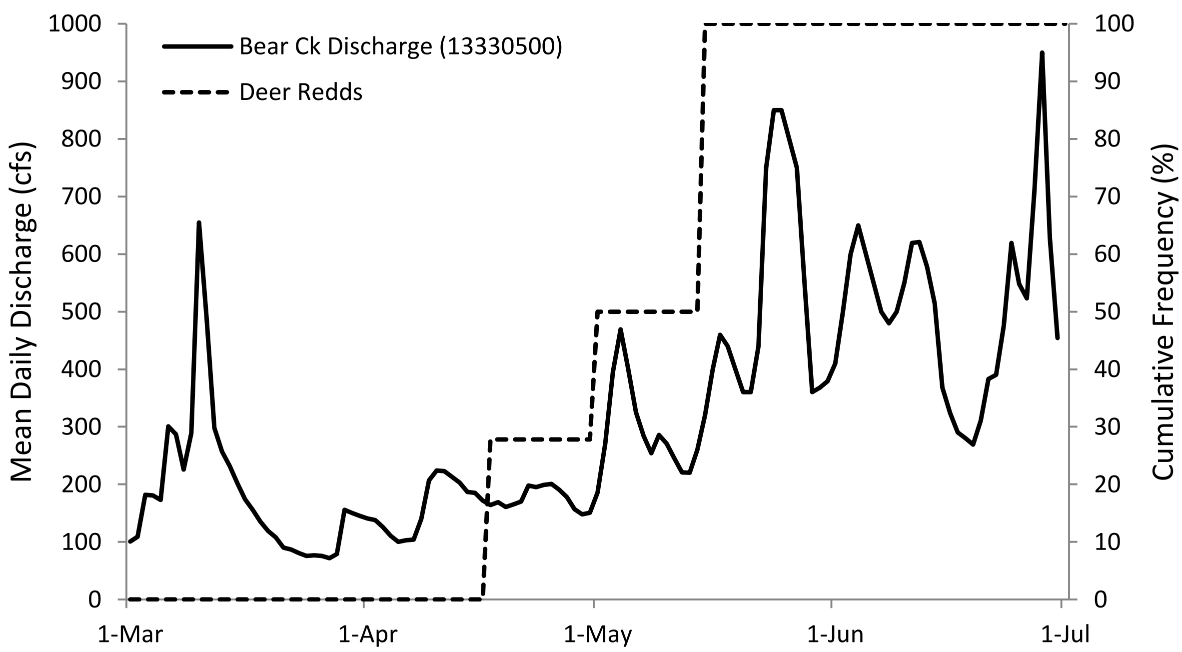

Figure 5. Cumulative frequency of observed redds during the spawning period for Deer Creek and discharge from neighboring Bear Creek (OWRD station #13330500) in 2014.

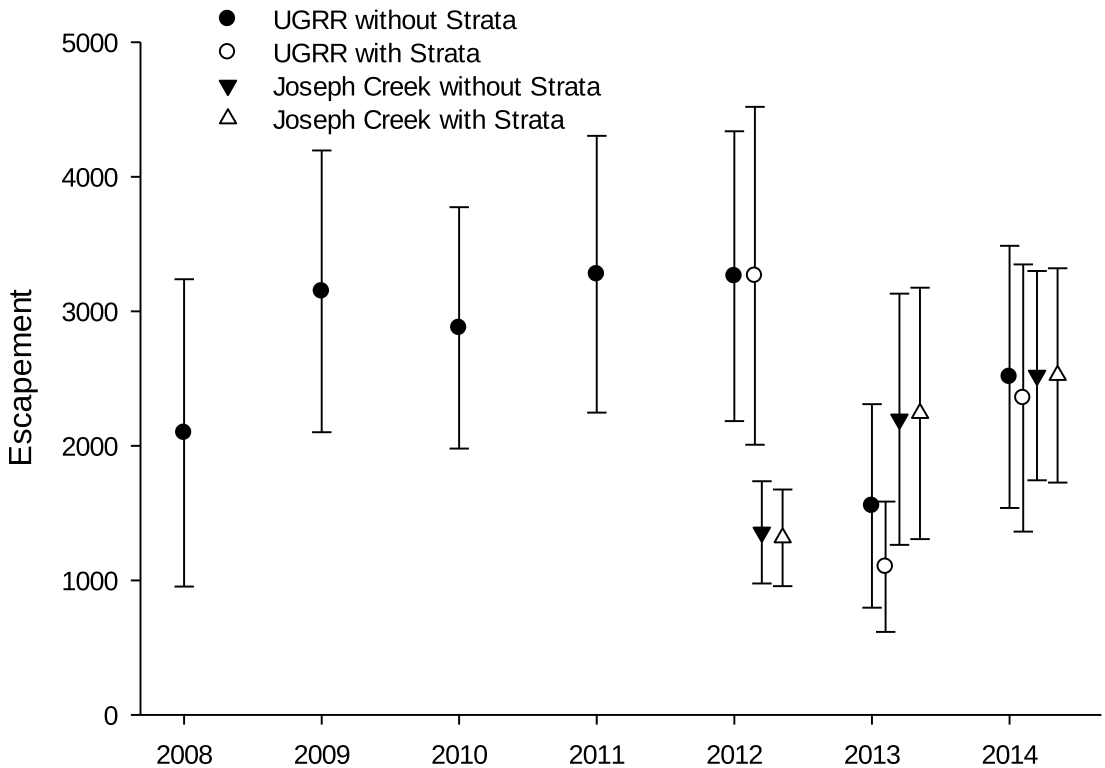

Figure 6. Escapement estimates with 95% confidence intervals for steelhead in the Upper Grande Ronde River basin using a single weight value, 2008−2014 and using strata weights for the three classifications of stream type for UGRR and Joseph Creek, 2012−2014.

DISCUSSION

Steelhead redd surveys

Water clarity during surveys was marginal to good in both the UGRR and Joseph Creek basins throughout most of the season. Water clarity and our ability to observe redds generally improved as the season progressed, especially after April. Restriction of snow to higher elevations, relatively low precipitation, and moderate to low flows in May resulted in early access to most sites and good visibility. Flows were generally higher, and persisted longer in Lookingglass, Deer, Catherine creeks, and other tributaries flowing from the Wallowa Mountains due to their high elevation headwaters. Our protocol indicates that surveys should be conducted at two week intervals and we achieved this in the UGRR.

The efficiency of our surveys on larger tributaries (i.e. Lookingglass and Catherine creeks) was poor. Even when we were able to survey the stream, we were often unable to cross or even walk in the channel for significant stretches. This may explain why zero redds were observed in Catherine and Lookingglass creeks, despite hundreds of steelhead being captured at their respective fish weirs (Table 8).

Not surprisingly, seasonal stream discharge appears to play a significant role in our ability to observe steelhead redds. The fish:redd ratio from Deer Creek correlated strongly with the total water volume from UGRR (Figure 7). This suggests that the use of fish:redd is an appropriate method to compensate for our ability to successfully observe redds throughout the basin based on water conditions.

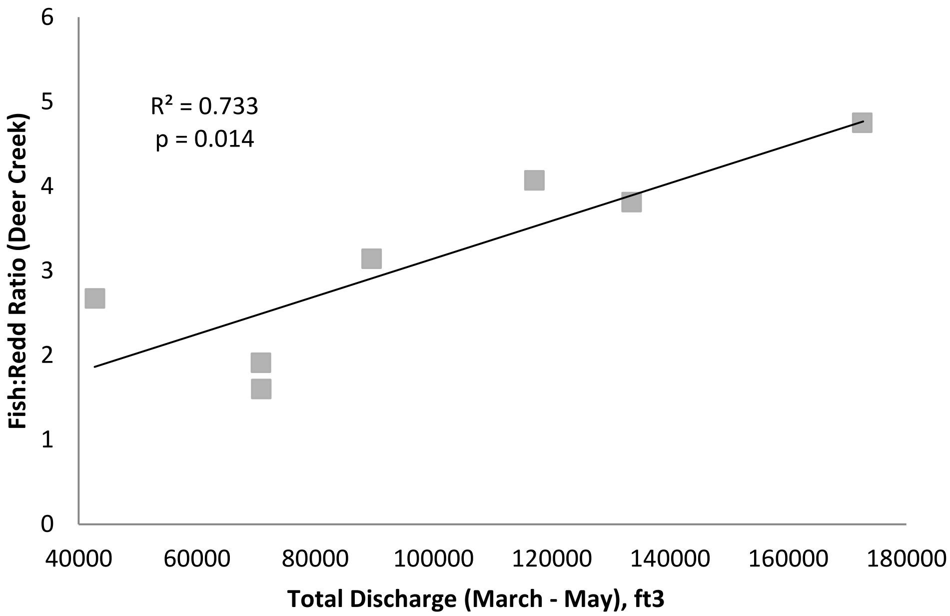

Figure 7. Relationship between total discharge in UGRR (Perry Station) and the fish:redd ratio derived from Deer Creek surveys, 2008−2014.

Spawning timing

Most redds were first observed during descending limbs of the hydrograph. However, any relationship of spawning to stream flow may be obscured by artifacts of our sampling technique. Our ability to observe redds is strongly influenced by water clarity, which is generally better on the descending limb of hydrographs than on rising limbs. Even though our observations of redds were during these descending periods, they do not indicate exactly when the redd was made. Deer creek surveys illustrate this point. We were only able to survey during the low water periods between peaks in the hydrograph (Figure 5). However, redds were likely built during the high water periods between surveys. Our surveys cannot determine or estimate when redds were built (unless we observe fish actively spawning) limiting our ability to infer a relationship between flow and spawning activities.

Timing of initial redd observations was similar across both basins and in Deer Creek. However, the progression of redd building appeared to be slower in Joseph Creek. This seems counterintuitive, as Joseph Creek is lower in elevation, and generally warmer than UGRR or Deer Creek. We observed a two week lag (early April) between redd building in UGRR and Joseph Creek (Figure 4). This was also observed in 2012 and 2013 (Dobos et al. 2012, Fitzgerald et. al 2013), the first two years of Joseph Creek surveys. We were unable to determine if this is a real discrepancy in spawn timing, or an inability to effectively survey Joseph Creek tributaries during early April. Surveyors recorded water clarity (scale 1-3) at each survey event, and water clarity did improve substantially in Joseph Creek by mid- April. However, if water clarity/redd visibility was limiting our counts, one would expect a rapid increase in redd counts once water clarity improved. This was not the case, as redd observations climbed steadily after mid-April, but not faster than UGRR or Deer Creek.

Estimating escapement

Population-scale escapement estimates had relatively poor precision for both Joseph Creek and UGRR (95% CI ~38% of the estimate). This is better than last year's precision estimate of ~45% of estimate. Confidence intervals have consistently been 30–35% of the UGRR escapement estimate since 2009 (Table 9). This is despite our refinement of known steelhead spawning distribution, which has been reduced in length by 31% since 2008. It appears that the variable distribution of redds throughout the spawning distribution inflates the confidence intervals. In particular, observations of zero redds substantially increase the confidence interval, and certain streams are not likely to produce redds regardless of the number of adults returning. In 2014 we observed zero redds at 41% of our UGRR basin sites, and 28% of those in Joseph Creek. With continued observations of zero redds at some survey sites, it seems unlikely that precision will improve unless some other method of identifying appropriate spawning habitat can be found.

This is our third year of attempting to correlate redd locations with stream classifications. Redd observations were highest in transport reaches for UGRR and highest in depositional reaches for Joseph basins. This distribution is similar to Joseph Creek observations in 2012 and 2013, but far different for UGRR streams (Dobos et. al 2012, Fitzgerald et. al 2013). There seems to be only minor utility in attempting to relate stream classification generated from landscape level variables to redd locations. Steelhead are likely not choosing appropriate spawning sites at the landscape scale. With the overlap of CHaMP sites and steelhead spawning ground surveys, we are exploring other potential relationships between redd building and small-scale habitat characteristics.

We will continue to define the extent of these identified stream reaches deemed unsuitable for spawning and locate similar reaches when they are selected in our sample draw. As the spawning distribution is refined, precision in our escapement estimates should increase. We will also continue to monitor trends of both methods and relate redd locations to immediate habitat to gain better understanding of how spawning habitat is utilized.

REFERENCES

Dobos, M.E., J.R. Ruzycki, C.D. Horn, E.R. Sedell, K. L. Bleisner and R.W. Carmichael. 2012. Steelhead escapement monitoring in the upper Grande Ronde River and Joseph Creek basins. Annual Technical Report. Oregon Dept. of Fish and Wildlife, La Grande, Oregon.

Fitzgerald, A.M, J.R. Ruzycki, C.D. Horn, E.R. Sedell, K. L. Bleisner and R.W. Carmichael. 2013. Steelhead escapement monitoring in the upper Grande Ronde River and Joseph Creek basins. Annual Technical Report. Oregon Dept. of Fish and Wildlife, La Grande, Oregon.

Flesher, M. W., G. R. Vonderohe, G. C. Grant, D. L. Eddy, and R. W. Carmichael. 2005. Lower Snake River Compensation Program: Oregon Summer Steelhead Evaluation Studies. Oregon Dept. of Fish and Wildlife, Salem, Oregon, http://www.fws.gov/lsnakecomplan/Reports/ODFW/Eval/LSRCP%20Oregon%20Steelhead%20Evaluation%20Studies%2001%20and%2002%20annual.pdf

Gee, S.A., M.W. Flesher, D.L. Eddy, L.R. Clarke, J.R. Ruzycki, and R.W. Carmichael. 2008. Lower Snake River Compensation Plan: Oregon Summer Steelhead Evaluation Studies. http://www.fws.gov/lsnakecomplan/Reports/ODFW/Eval/04%20Annual%20STS%20final.pdf

Jacobs, S., J. Firman, G. Susac, E. Brown, B. Riggers, and K. Tempel. 2000. Status of Oregon coastal stocks of anadromous salmonids. Monitoring program report number OPSW-ODFW-2000-3, Oregon Department of Fish and Wildlife, Portland, Oregon.

Jacobs, S., J. Firman, and G. Susac. 2001. Status of Oregon coastal stocks of anadromous salmonids, 1999-2000. Monitoring program report number OPSW-ODFW-2001-3, Oregon Department of Fish and Wildlife, Portland, Oregon.

Jacobs, S.E., W. Gaeuman, M.A. Webber, S.L. Gunckle, and S.J. Starcevich. 2009. Utility of a probabilistic sampling design to determine bull trout population status using redd counts in basins of the Columbia River Plateau. North American Journal of Fisheries Management 29: 1590 – 1604.

Mclean, Mike, Confederated Tribes of the Umatilla Indian Reservation, Department of Fisheries Resources Management, unpublished data, personal communication.

Kucera, Paul, Nez Perce Tribe, Department of Fisheries Resources Management, unpublished data, personal communication.

Nicholas, J. W., and L. Van Dyke. 1982. Straying of adult coho salmon to and from private hatchery at Yaquina Bay, Oregon. Oregon Department of Fish and Wildlife, Information report (fish) 82-10, Portland, Oregon.

R Development Core Team. 2005. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.Stevens, D. L. 2002. Sampling design and statistical analysis methods for the integrated biolgocial and physical monitoring of Oregon streams. Report No. OPSW-ODFW-2002-07, The Oregon Plan for Salmon and Basins, Oregon Department of Fish and Wildlife, Corvallis, OR.

Stevens, D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Susac, G. L., and S. E. Jacobs. 1999. Evaluation of spawning ground surveys for indexing the abundance of adult winter steelhead in Oregon coastal basins. Oregon Department of Fish and Wildlife. Annual Progress Report F145-R-08. Portland, Oregon.