Winter Steelhead Redd to Fish conversions,
Spawning Ground Survey Data

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Oregon Adult Salmonid Inventory and Sampling Project (June 2013)

Background:

In 1998 the Oregon Department of Fish and Wildlife (ODFW) began developing a monitoring program for naturally spawning winter steelhead populations (Susac and Jacobs 1998). The goal was to develop field protocols that could produce reliable annual measures of winter steelhead spawner abundance, and could be applied consistently and cost effectively across large geographic scales. Development and evaluation of field methods occurred from 1998 through 2002, and a coast wide monitoring program for naturally spawning winter steelhead was implemented in 2003. Annual monitoring of winter steelhead spawners in Oregon tributaries of the Lower Columbia River was implemented in 2012. In addition, an initial year of monitoring was conducted in the Lower Columbia in 2004, and basin specific monitoring in the Sandy and Clackamas was conducted in 2006, 2007, 2010 and 2011.

Develop and evaluation of field methods occurred above fish passage barriers where a count or mark-recapture estimate of winter steelhead abundance above the barrier was available. Comprehensive spawning ground surveys, or a randomly selected sample of spawning ground surveys, were conducted above the barriers. Metrics of winter steelhead abundance from spawning ground surveys were generated based on live fish and redd counts. These metrics were then compared to the known/estimated abundances from the dam counts and mark-recapture studies. Spawning ground survey estimates of total winter steelhead redds were highly correlated to the dam counts and/or mark recapture estimates and proved to be a reliable and cost effective methodology for monitoring winter steelhead spawner abundance (Jacobs et al. 2002).

Current monitoring of Oregon's Lower Columbia and Coastal naturally spawning adult winter steelhead populations targets providing annual information on: 1) Abundance; 2) Proportion of hatchery origin spawners; 3) Spatial distribution; and 4) Spawning timing. The goal is to provide this information at three geographic scales; Species Management Unit (equivalent to an ESU/DPS), Stratum (group of populations), and Population. A spatially balanced probabilistic sampling design (Stevens 2002) is used to randomly select survey sites across a stream network of winter steelhead spawning habitat. Repeat visits to each site from February through May generate a total redd count for each survey. Redds are marked with colored rocks and flagging to prevent re-counting during subsequent surveys. The survey interval of once every fourteen days is based on prior ODFW research (Susac and Jacobs 1998). Descriptions of protocols can be found in the annual survey procedures manual (ODFW 2012).

Issue:

The use of redds as a metric for monitoring winter steelhead spawner abundance is well established (Johnson et al. 2007). However, monitoring based on estimated redd abundance creates a conflict with harvest management and population viability assessments which are typically conducted based on numbers of fish. Results from the methodology development work in 1998 through 2002 are reported in Table 1. This information was used in a linear regression (Figure 1) to predict total adult winter steelhead from redd counts (Susac and Jacobs 2003).

Although the total steelhead per redd regression shown in Figure 1 is highly significant ($R^2 = 0.97$ $p < 0.001$), there are two areas for concern with the regression. First, the Y intercept is 61.82 fish when no redds are observed. This is unrealistically high and makes no biological sense, partly demonstrated by the regression line passing above all the observed data points near the origin (Figure 2). Second, the slope of the linear regression (1.07 fish/redd, Table 2) is lower than the observed fish / redd quotient for all but 2 of the 14 data points (Table 1), and is not close to the mean or median of the distribution of observed quotients (Figure 3). The Smith River data is the only calibration site with observed fish per redd values close to the regression slope (Table 2). This suggestion of leveraging of the linear regression is supported by an examination of the data for the five calibration sites. The data exists in basically two groupings, 3 points with over 1,200 redds and 11 points with under 350 redds (Table 1). The three points with over 1,200 redds are the three years of Smith River data.

Comparison of adult steelhead per redd across sites and years suggest variation in this metric across years and possibly between sites (Table 1 and Figure 4). In particular fish per redd was generally higher in 1998 and 1999 than in the period 2000 through 2002. Also, Smith River had a lower fish per redd value than any other site, in each of the three years with Smith River data. The differences in methodology development sites conducted each year precludes a more comprehensive evaluation of spatial and temporal patterns in the fish per redd conversions.

Response:

In response to the issues identified with the original fish per redd analysis, and the possible leveraging of the linear regression by the Smith River data, we reanalyzed the data using an Analysis of Covariance (ANCOVA). The analysis included two continuous variables, number of adult steelhead and number of steelhead redds above the counting station, and a categorical variable (Smith River vs. not Smith River). The ANCOVA model included an interaction term between redds and the categorical variable, to allow for a different slope and intercept based on the categorical variable (Smith River vs. not Smith River). Results from the ANCOVA are presented in Table 3, and a comparison of the predicted values versus the observed steelhead and redd data are presented in Figure 5.

Conclusion:

Besides the quality of the fish and redds estimates, development of fish per redd conversions depend on two basic aspects of the data they are based on: the actual number of fish per redd; and the redd detection probability (the proportion of redds actually present that samplers identify). Redd detection probability is influenced by at least two factors. The likelihood of detecting a redd when it is present, influenced by survey conditions such as stream flow and water clarity. The likelihood of a redd created since the last survey visit being detectable during the subsequent survey visit, influenced by the number of days a redd is visible and the number of days between survey visits.

What parameters would be expected in the fish to redd conversion methods? If each female steelhead produces a single redd, and you have a 50:50 sex ratio we would expect a 2.0 fish to redd ratio. If each female steelhead produces two redds (test and/or actual redds) and you have a 50:50 sex ratio we would expect a 1.0 fish to redd ratio. It is likely that female steelhead average somewhere between one and two redds produced per female. If redd detection probability is 100% (samplers identify every redd present), the expected Y intercept would be 0. The vagaries of sampling in a natural environment (weather and stream conditions) preclude perfect redd detection, thus surveyors miss some redds. Generally this undercounting of redds will result in overestimating the fish per redd rate (same number of fish but fewer redds observed). However, it is possible that in some of the surveys were no redds were detected, redds were actually present. While this outcome is a possibility, it seems unlikely that there are many sites where surveyors miss every redd for the year. Therefore, we would still expect the Y intercept should be essentially 0.

The ANCOVA analysis provides a redd to steelhead conversion for non-Smith River sites with variables (slope and intercept) that more closely match the observed data and are more biologically plausible than the linear regression (Table 2). Although, only the slope was statistically significant (Table 3), the Y intercept (3.74) is much closer to the expected value of 0 fish at 0 redds than the linear regression Y intercept of 61.82. Neither the slope or Y Intercept adjustment of Smith River sites was statistically significant (Table 3). The ANCOVA conversion for Non-Smith River sites is:

Total Steelhead = (1.70 * Redds) + 3.74

Future Plans:

The variation in observed redd to fish conversion rates suggests temporal and possibly spatial differences in these rates (Figure 4). Thus, use of average or modeled conversion methods could lead to inaccurate annual estimates of winter steelhead spawners. Developing sites within the area to be monitored, that can provide annual estimates of redd to fish conversions, could address this issue. This type of approach is currently used by ODFW staff in monitoring North East Oregon steelhead (Dobos et. al 2013), and has been proposed for use in California (Gallagher et al. 2010).

Beginning with the 2014 winter steelhead spawning survey season we will conduct annual assessments of adult winter steelhead per redd rates. This will use similar methods and include some of the same locations where the initial methodology development work was done. Sites proposed for this work in 2014 include: Lewis and Clark River (Lower Columbia), North Fork Nehalem River, Mill Creek (Yaquina R.), and West Fork Smith River (Umpqua R.). Our goal is to ultimately have at least one such steelhead per redd annual calibration site in each of the strata where we are conducting randomly selected spawning ground surveys to estimate winter steelhead redd abundance. Other sites will be evaluated and may be add as calibration sites as staff time and funding are available. Current Life Cycle monitoring sites and other ODFW adult steelhead monitoring sites will be the most likely future calibration sites.

References:

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Figures and Tables:

Table 1. Oregon coastal winter steelhead monitoring methodology development sites and results, 1998 to 2002 (as reported in Jacobs et al. 2002 Table 4-5). NH = Fishhawk Cr (Nehalem R); SR = Smith R (Umpqua R); SZ = Mill Cr (Siletz R); WF = W Fk Smith R (Umpqua R); YQ = Mill Cr (Yaquina R).

Year	Site	Spawning Habitat (miles)	Female	Male	Percent Female	Redds	Females / Redd	Fish / Redd
1998	NH	14.6	17	18	48.6%	18	0.94	1.94
	SZ [a]	10.2	86	89	49.1%	75	1.15	2.33
	YQ	2.5	20	27	42.6%	15	1.33	3.13
	Avg.				**46.8%**		**1.14**	**2.47**
1999	NH	11.6	22	33	40.0%	22	1.00	2.50
	SZ [a]	10.2	48	40	54.5%	48	1.00	1.83
	YQ	2.2	28	28	50.0%	27	1.04	2.07
	Avg.				**48.2%**		**1.01**	**2.14**
2000	NH	11.6	29	30	49.2%	41	0.71	1.44
	YQ	2.2	32	21	60.4%	51	0.63	1.04
	SR [a, b]	225.0	881	517	63.0%	1,438	0.61	0.97
	WF [a]	22.4	274	179	60.5%	326	0.84	1.39
	Avg.				**58.3%**		**0.70**	**1.21**
2001	SR [a, b]	225.0	774	566	57.8%	1,224	0.63	1.09
	WF [a]	16.7	162	145	52.8%	241	0.67	1.27
	Avg.				**55.3%**		**0.65**	**1.18**
2002	SR [a, b]	225.0	1,146	985	53.8%	1,829	0.63	1.17
	WF [a]	18.5	409	328	55.5%	327	1.25	2.25
	Avg.				**54.7%**		**0.94**	**1.71**

a = Monitoring site is not a complete barrier. Adult passage estimated using mark-recapture.

b = Redd abundance estimated based on statistical sampling design.

Table 2. Adult winter steelhead redd to fish conversion methods based on ODFW methodology development work in 1998 through 2002 (data reported in Table 1). Note, the Smith River site was also sampled in 2003, but the fish and redd estimates are not currently available for analysis.

Method	Regression Slope or Quotient	Regression Y Intercept
ANCOVA	1.70	3.74
Linear Regression	1.07	61.82
Average Quotient (AQ), All sites and Years	1.75	--
AQ - Fishhawk Cr (NH), n=3	1.96	--
AQ – Mill Cr, Siletz (SZ), n=2	2.08	--

AQ - Mill Cr, Yaquina (SZ), n=3	2.08	--
AQ – W FK Smith (WF), n=3	1.64	--
AQ - Fishhawk Cr (SR), n=3	1.08	--

Table 3. Results for ANCOVA analysis to predict winter steelhead spawners from redd counts. Based on ODFW methodology development work in 1998 through 2002 (Table 1).

	Estimate	Std. Error	T value	P value
Y Intercept	3.74	38.59	0.097	0.925
Slope (fish/redd)	1.70	0.24	7.091	< 0.01
Adjustments to slope and intercept for Smith River				
Y Intercept	-442.04	333.69	-1.325	0.215
Slope (fish/redd)	-0.32	0.32	-0.994	0.344

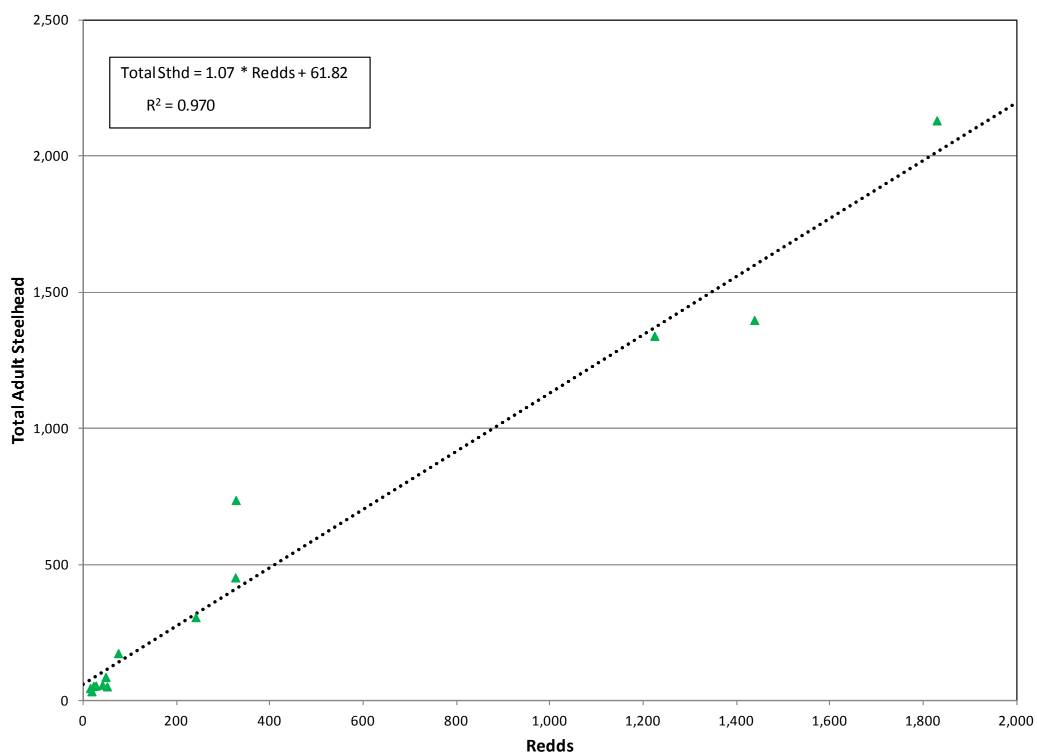

Figure 1. Regression of total adult steelhead and total steelhead redds at all Oregon coastal winter steelhead monitoring methodology development sites for the years 1998 through 2002.

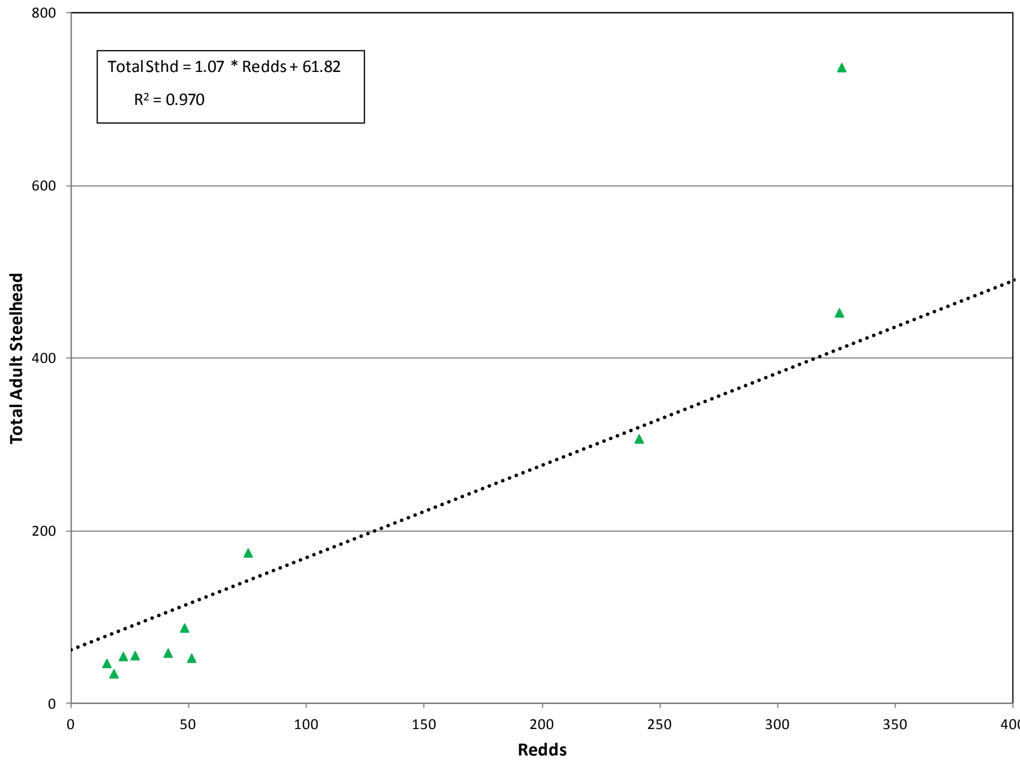

Figure 2. Close up of Figure 1, near origin.

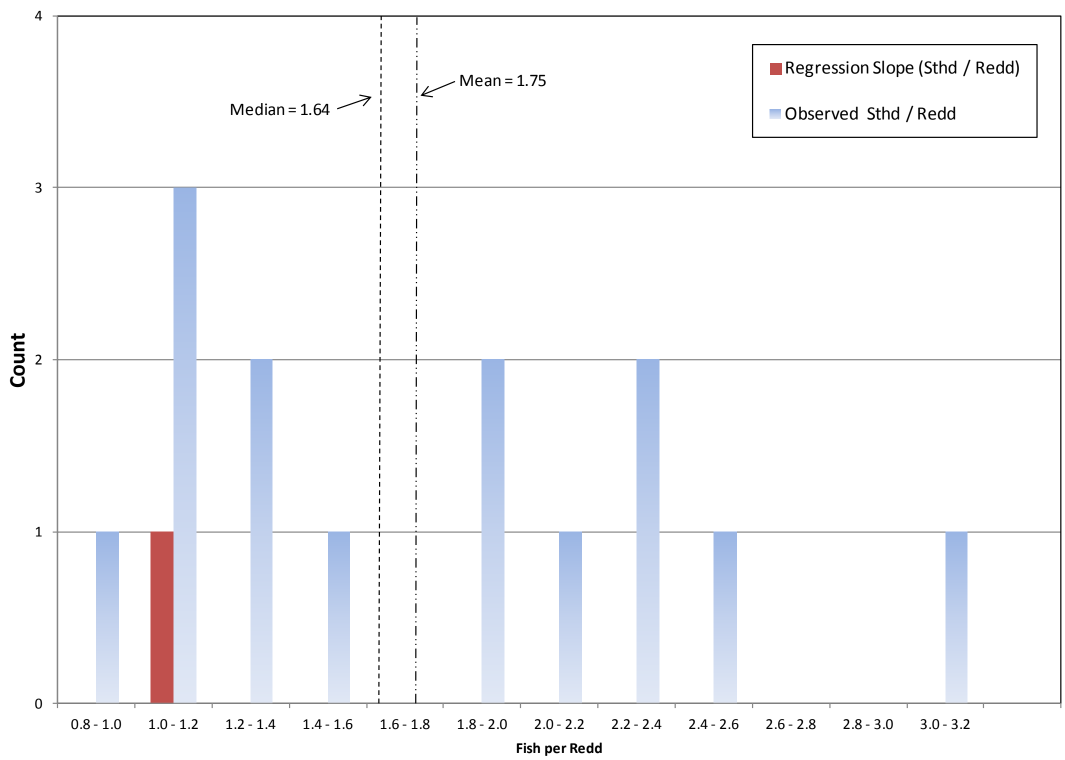

Figure 3. Comparison of regression slope to observed steelhead per redd at all Oregon coastal winter steelhead monitoring methodology development sites for the years 1998 through.

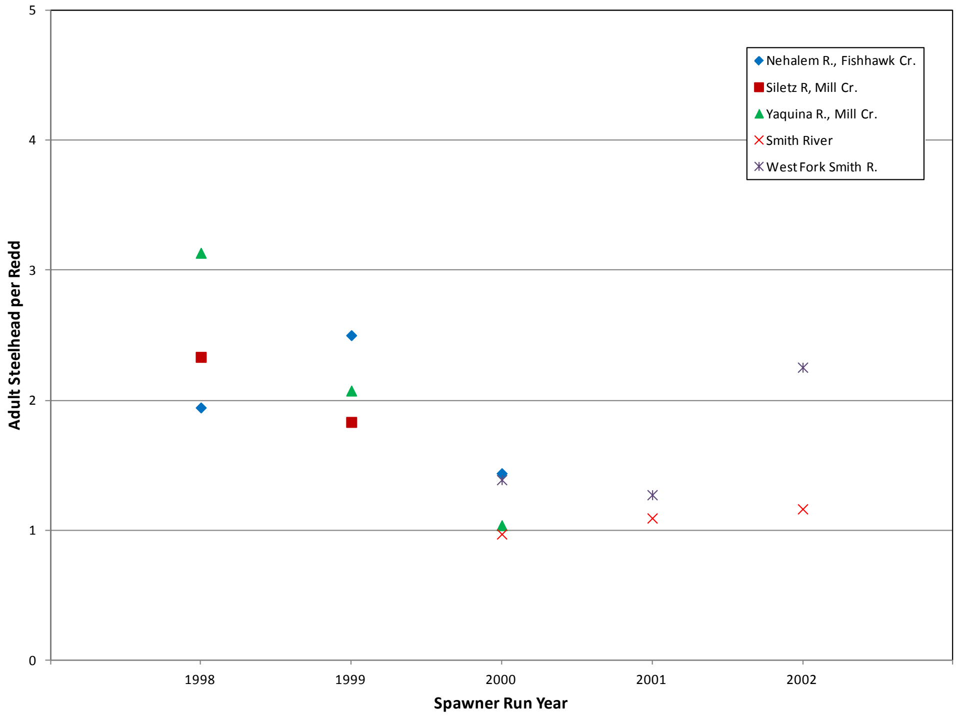

Figure 4. Total adult steelhead per redd at Oregon coastal winter steelhead monitoring methodology development sites for the years 1998 through 2002.

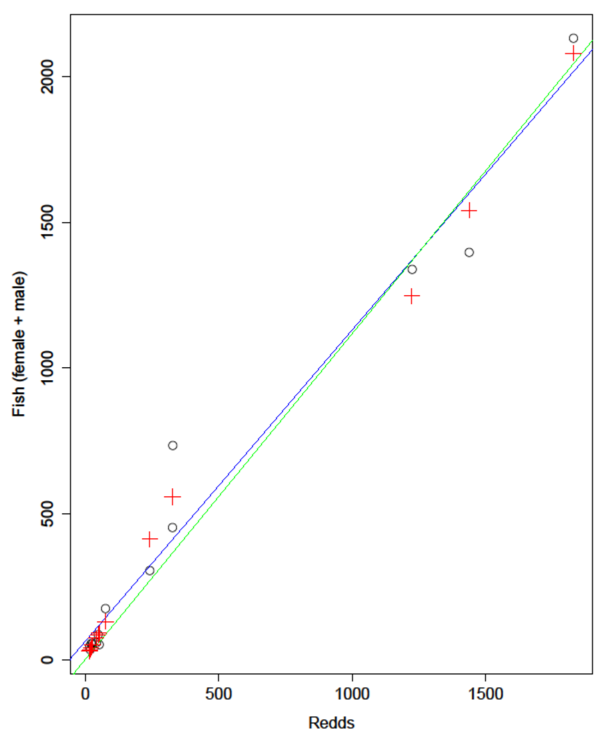

Figure 5. ANCOVA predictions of total steelhead (+) from steelhead redds, compared to actual observed fish and redd abundance data (O) at methodology development sites. Blue line is regression with intercept; green line is forced through origin.