Salmon and Steelhead Spawning Survey Methods
Stratification of Estimates

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Oregon Adult Salmonid Inventory and Sampling Project
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Introduction:

Conservation and management of Oregon's native fish requires monitoring status and trend for a variety of habitat and fish population metrics. In Western Oregon, much of the monitoring of naturally spawning salmon and steelhead populations is conducted by the Oregon Department of Fish and Wildlife's (ODFW) Oregon Adult Salmonid Inventory and Sampling Project (OASIS). Results of OASIS monitoring include annual estimates of; abundance (hatchery and wild), distribution, timing and occupancy. This information is used in management of Oregon's native fish populations and hatchery programs. The Hatchery Scientific Review Group (HSRG) conducted a review of all Columbia River Basin hatchery programs and made recommendations for how these programs should be managed to ensure the recovery of Endangered Species Act (ESA) listed fish (HSRG 2009). The HSRG used a model they developed to determine how much influence a hatchery program should have on a wild population. This model was based on a theoretical model of genetic introgression of hatchery genes into a wild population. The HSRG used the proportion of natural origin (pNOS) and hatchery origin (pHOS) spawners on the natural spawning grounds to estimate the allowable level of introgression that would not significantly impair the productivity of the wild population. The model assumes that wild and hatchery fish are equally distributed and randomly spawning with each other, and thus uses pHOS is a measure of introgression.

ODFW has been conducting spatially balanced random spawning surveys for coho salmon since 1998 along the Oregon Coast. This monitoring was expanded to include Lower Columbia River coho in 2002, Oregon coastal winter steelhead in 2003, Lower Columbia River fall Chinook in the 2009, and Lower Columbia steelhead in 2012. This approach utilized the randomness and spatial balance of the surveys to estimate the numbers of both wild and hatchery fish on the spawning grounds. Consistent with HSRG model assumptions all fish sampled for determining rearing origin, for a year and basin, were used without regard to spatial or temporal distribution of the recoveries (Jacobs et.al. 2002).

After years of surveys, it became apparent that wild and hatchery fish were not typically equally distributed throughout a basin. In years with random survey sites close to hatchery release locations the estimate of pHOS for the population was higher than in years without random sites close to a hatchery release location. This resulted in large fluctuations in the annual estimate of pHOS which were a result of random sampling

and not actual changes in the basin pHOS. In this case, a multi-year average could provide a more accurate pHOS estimate, as is called for in recent ODFW conservation plans. In addition, survey sites can have different probabilities of being able to sample fish for use in pHOS calculations. Thus sites can be over or under represented in the pHOS calculation in comparison to their contribution to the abundance calculation. These observations led to biased estimates of pHOS which would not be corrected by a multi-year average. These disparities made it clear that the current approach for estimating pHOS was not accurately estimating introgression. It was this realization that led ODFW to identify in the Coastal Multi-species Conservation and Management Plan (ODFW 2014) a need to refine the process for estimating pHOS to adjust for the bias that occurs when survey sites over-represent the distribution of hatchery fish.

The purpose of this document is to:
1. Discuss issues with the current method of estimating abundance and pHOS of naturally spawning salmon and steelhead populations
2. Describe an improvement to the current method.

Need for Analysis Method Change:

The current method of including data from all fish sampled throughout the spawning season in a single pHOS estimate is simple and maximizes sample size for the calculation. If done correctly this method of calculating pHOS does provide an estimate of the total number of hatchery and wild fish that spawned in a population for a year. However, this method ignores spatial and temporal structure in the naturally spawning population. While abundance data are important in management, the pHOS calculation is often used as a surrogate measurement of the level of interbreeding between hatchery and wild fish. Several assumptions are necessary for pHOS to be an appropriate metric for interbreeding.

- Hatchery and wild fish would have to have the same spatial distribution within the naturally spawning population.
- Hatchery and wild fish would have to have the same temporal distribution within the naturally spawning population.
- Hatchery and wild fish would have to have equal probability of successful natural mate selection.
- Hatchery and wild fish would have to have equal probability of successful mating.

Using pHOS as a metric of interbreeding is based on each fish having an equal likelihood of mating with every other fish of the opposite gender. Therefore, failure to meet the assumptions listed above would result in pHOS overestimating interbreeding. It is unlikely that any of the assumptions listed above are routinely met within Western Oregon naturally spawning salmon and steelhead populations. Documenting when, if ever, these assumptions are met is an area in need of further analysis and reporting.

The need for a better metric to monitor interbreeding has been recognized in various venues, and work has begun by several ODFW projects. The Coastal Multi-Species Conservation and Management Plan (CMP) was developed to guide management of native populations of Chinook, Chum, Steelhead and Cutthroat in Oregon coastal basins (ODFW 2014). The CMP recognized the importance of spatial structure in evaluating and managing hatchery fish interactions with wild fish. As a step in improving the currently used pHOS metric the CMP called for a stratified approach to calculating pHOS based on the location of hatchery release sites. In the Willamette Basin, the ODFW Hatchery Research, Monitoring and Evaluation project monitors the spawning abundance of ESA listed spring Chinook. That program is now implementing stratification and differential weighting in the calculation of pHOS as a means to eliminate bias resulting from uneven distribution of hatchery and wild fish (Sharpe et al. 2015). In Oregon coastal and Lower Columbia basins the OASIS project conducts monitoring of salmon and steelhead spawning populations using a random site selection procedure. However, uneven distributions of survey sites and hatchery fish in conjunction with differential fish sampling probabilities resulted in biased estimates of abundance and/or pHOS, and stratification was used to address those biases.

This analysis change is a result of work looking into the question of whether pHOS is an appropriate metric for introgression, but does not directly address that question. Review of the existing OASIS spawning survey data has demonstrated differences in the spatial and temporal distribution of hatchery and wild salmon and steelhead in Oregon's naturally spawning populations. Beginning with the 2010 OASIS annual report (Lewis et al. 2011) inclusion of two distribution metrics ($P_{80\%}$ and AOC) described by Peacock and Holt (2012) have consistently shown large differences in the spatial distribution of wild and hatchery coho spawners. Random sampling should be able to adequately represent these differences. However, our review of the data showed that the distributional differences also appeared to result in a biased sample for calculating pHOS. In some cases, areas where hatchery fish are concentrated contributed disproportionally to the season-long total sample for calculating pHOS (many more carcasses sampled than in any other survey). The result was a bias in the estimate of hatchery and wild fish, and thus pHOS.

Example of Stratified Estimation:

The Clatskanie coho population is one of eight Oregon populations in the Lower Columbia River Coho Evolutionarily Significant Unit (Meyers et al. 2006). Currently, spawning ground surveys based on a random spatially balance sampling design are used to monitor the abundance and pHOS of naturally spawning salmonid populations in this basin. This methodology has been in use since 2002 for coho, 2009 for fall Chinook and 2012 for winter steelhead. The population is composed mostly of the Clatskanie River, but also includes generally small direct tributaries to the Columbia River (Figure 1). Westport slough enters the Columbia River about 3.5 miles downstream from the Clatskanie River. The up-stream end of Westport slough likely connected with the lower Clatskanie River, but currently appears to be at least partially

blocked by a road. Plympton Creek is the first tributary of Westport slough that contains salmon and steelhead spawning habitat (Figure 1).

A pattern of large abrupt changes in pHOS (10% or less versus 50%) was evident over the first seven years of monitoring spawning coho in the Clatskanie population (Figure 2). Closer examination of the data showed the abrupt changes were related to whether or not there was a random survey site in Plympton Creek. Plympton Creek is now in our annual survey panel (site surveyed every year). This has resulted in less volatility in the annual pHOS estimate (Figure 2), but little change in the multi-year average pHOS (16% from 2002 through 2008, and 14% from 2009 through 2015).

Based on implementation of stratified estimates under the CMP data for other species and areas was reviewed to determine if this technique was warranted. Stratified estimation procedures were already being used in the Clatskanie for fall Chinook because of very large differences in abundance and pHOS between Plympton Creek and the rest of the population. Survey results for Clatskanie coho showed similar patterns to those of fall Chinook (Table 1). Our annual coho spawning survey site goal in the Clatskanie is 18 so each site represents 5.6% of the sample. Plympton Creek contains 1.8% of the coho spawning habitat in the population (Figure 1). As an annual survey Plympton Creek is 5.6% of the yearly sample, and is thus slightly overrepresented in the monitoring effort.

This is not necessarily an issue if there aren't other differences between Plympton Creek and the rest of the population. The results of our review showed there are actually substantial difference (Table 1). The density of coho spawning in Plympton Creek is higher (26.8 versus 15.8 coho per mile), pHOS is much higher in Plympton Creek (87.3% versus 4.3%), and the rate of carcass recovery for use in calculating pHOS is much higher in Plympton Creek (0.27 versus 0.03 coho carcasses per coho spawner). The result is that on average Plympton Creek represents 3.3% of the estimated coho abundance in the Clatskanie population but accounts for 25.6% of the sample used to calculate pHOS (Table 1). To visualization this bias the change in the Clatskanie coho pHOS estimate (stratified – un-stratified) was plotted against a metric of the degree to which Plympton Creek coho are over represented in the pHOS calculation (Plympton Creek: percent pHOS sample – percent of abundance). The result was a strong negative relationship between over representation of Plympton Creek and the stratified pHOS estimate for Clatskanie (Figure 3). Because of these results the abundance and pHOS for Clatskanie coho were recalculated for the monitoring period, 2002 through present. This resulted in a slight decrease in the average total adult coho spawning abundance, from 1,236 to 1,189, and a large reduction in the average estimated pHOS, from 22% to 7% (Table 2).

Analysis Method Change:

In regards to the example discussed above, we changed the method of estimating abundance and pHOS in the Clatskanie Basin from a single spatial scale (whole basin) to a stratified two scale approach, (Plympton Creek, and Clatskanie basin

excluding Plympton Cr.). This will continue to use all the same data (nothing will be excluded) and use the standard estimation procedure (Jacobs et al. 2002) used in all other basins, except stratified by the two sub-basins. We will be using a stratified estimation procedure in the Clatskanie basin for all three species currently monitored; fall Chinook, coho and winter steelhead. We have been using this stratification method for our fall Chinook estimates since that monitoring began in 2009. We have recalculated the coho spawning abundance and pHOS estimates using this method for the entire duration of our coho monitoring, 2002 through 2015 (Table 2). We will recalculate winter steelhead estimates in the near future.

In a broader context we are evaluating the need to use stratified estimation in other basins and for other species. Stratification of spawning abundance and pHOS estimates for Oregon Coastal winter steelhead in relation to hatchery steelhead release areas was called for in the ODFW Coastal Multi-Species Conservation and Management Plan (ODFW 2014). We are in the process of developing the methods and implementing this change for the 2016 winter steelhead spawning season. We will review the data needs and availability for recalculating estimates for prior years of monitoring, 2003 through 2015. We began using a stratified estimate procedure in the Clackamas basin for coho in the 2014/15 spawning season. We are in the process of re-calculating prior Clackamas coho estimates and reviewing the need for stratification of salmon and steelhead estimates in other Lower Columbia populations.

References:

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Clatskanie Population

Columbia River

Plympton Creek

※ Westport

※ Clatskanie

Westport Slough

※ Goble

Clatskanie Coho Population

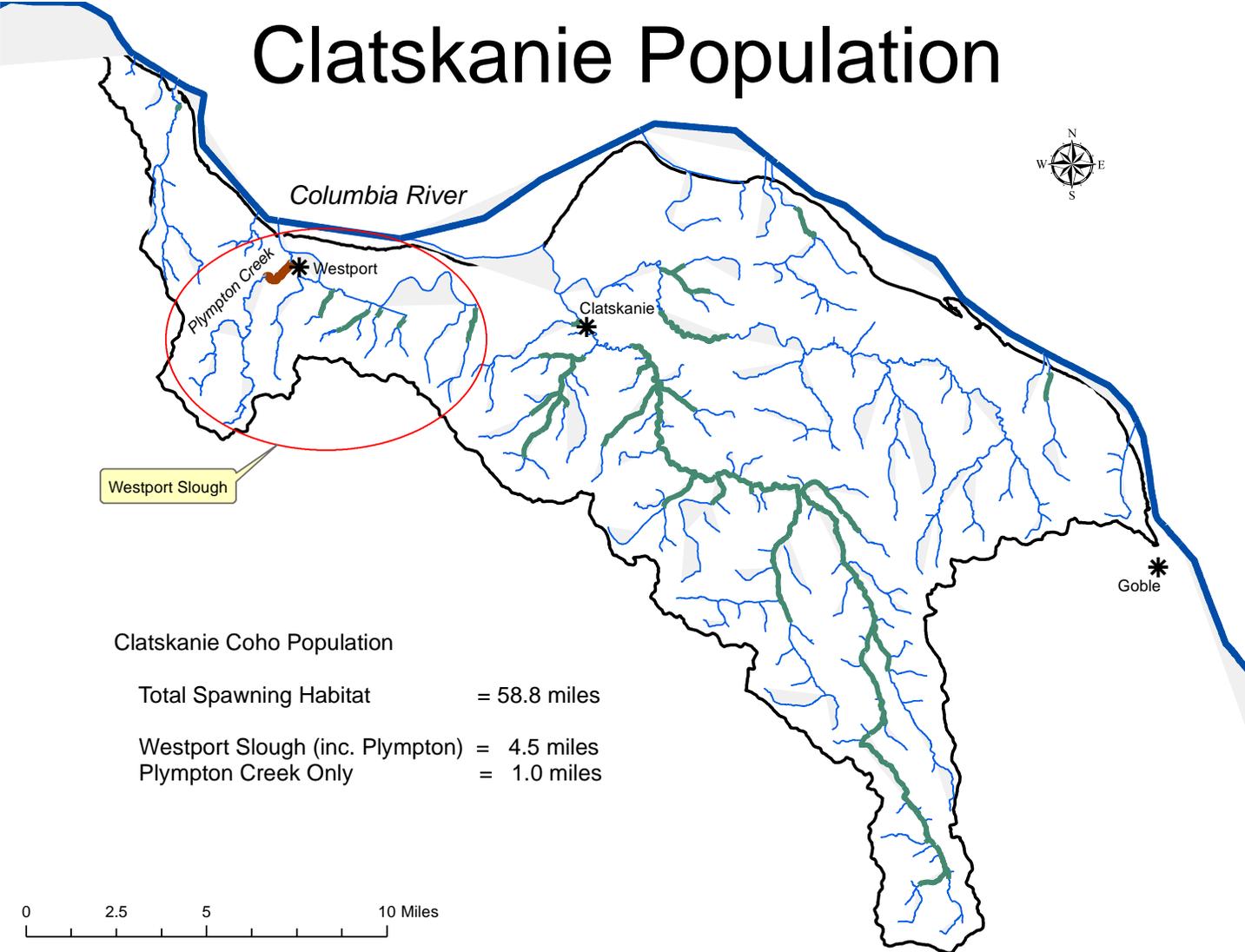|		
Total Spawning Habitat	=	58.8 miles
Westport Slough (inc. Plympton)	=	4.5 miles
Plympton Creek Only	=	1.0 miles

0   2.5   5   10 Miles

Figure 1. Map of the Clatskanie Basin in Oregon showing coho salmon spawning habitat (bold streams) and the proportion in Westport Slough (red Circle) and in Plympton Creek (Bold Red).
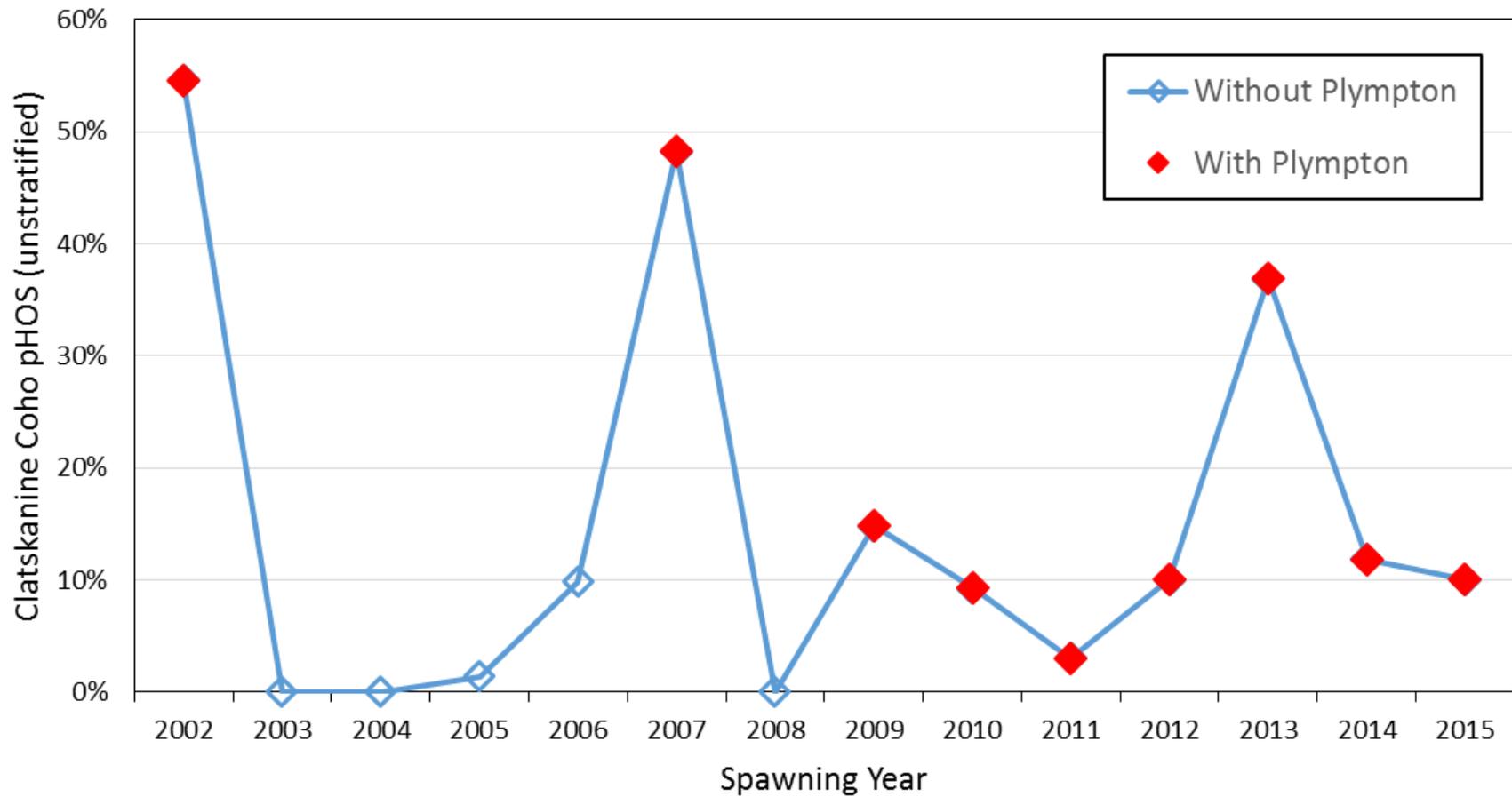
Figure 2. Clatskanie coho population proportion hatchery origin spawners (pHOS) based on the original un-stratified estimation methodology. Years when Plympton Creek was sampled are in red. Beginning in 2009 Plympton Creek was selected as part of the annual panel, which are sites that will be surveyed every year.

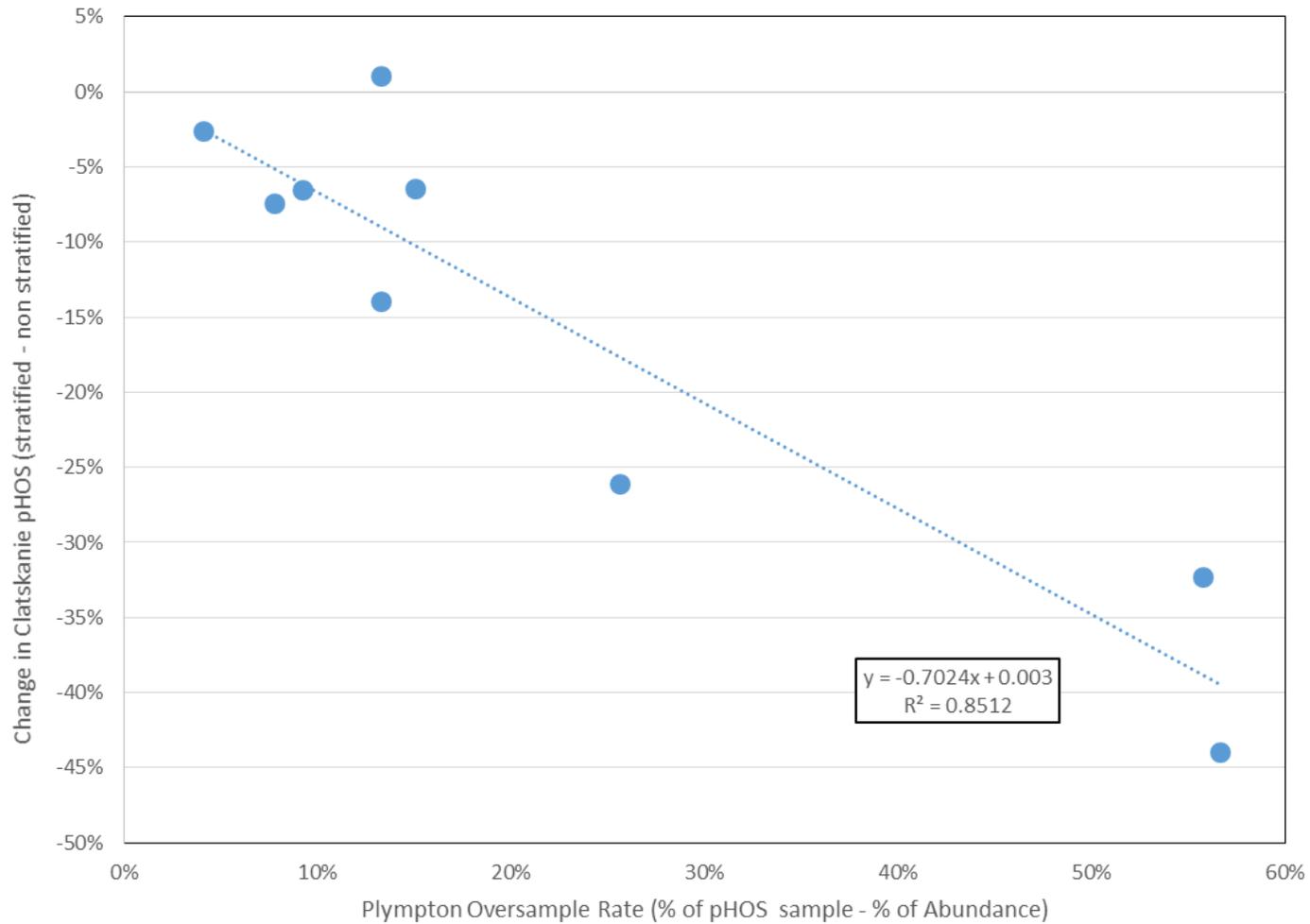Figure 3. Change in the Clatskanie coho population proportion hatchery origin spawners (pHOS) between the original un-stratified and new stratified estimation methodology. Change in pHOS (stratified – un-stratified) compared to the degree to which Plympton Creek fish are overrepresented in the sample for calculating pHOS (percent of the pHOS sample from Plympton Cr. – percent of the Clatskanie coho abundance in Plympton Cr.).

Table1. Comparison of spawning survey data and results for Plympton Creek and the rest of the Clatskanie coho population.

	Plympton Creek					Clatskanie Pop. (-Plympton Cr.)					Plympton as a Percent of	
		Samples for pHOS[2]			Est. Coho		Samples for pHOS[2]			Est. Coho	Samples	Est. Coho
Year	Density[1]	Number	per Capita	pHOS[3]	Abund.[4]	Density[1]	Number	per Capita	pHOS[3]	Abund.[3]	for pHOS[2]	Abund.[3]
2002	12.6	7	0.41	85.7%	17	4.1	4	0.02	16.7%	198	63.6%	7.9%
2003	n.a.	n.a.	n.a.	n.a.	n.a.	11.2	17	n.a.	0.0%	563	n.a.	n.a.
2004	n.a.	n.a.	n.a.	n.a.	n.a.	6.3	23	n.a.	0.0%	398	n.a.	n.a.
2005	n.a.	n.a.	n.a.	n.a.	n.a.	7.7	2	n.a.	1.4%	501	n.a.	n.a.
2006	n.a.	n.a.	n.a.	n.a.	n.a.	6.8	10	n.a.	9.9%	467	n.a.	n.a.
2007	36.9	18	0.34	77.8%	53	16.8	11	0.01	0.0%	915	62.1%	5.5%
2008	n.a.	n.a.	n.a.	n.a.	n.a.	12.2	38	n.a.	0.0%	995	n.a.	n.a.
2009	14.6	4	0.21	100.0%	19	15.3	23	0.02	0.0%	1,187	14.8%	1.6%
2010	28.2	10	0.27	70.0%	37	22.2	78	0.05	1.3%	1,697	11.4%	2.1%
2011	10.7	7	0.50	57.1%	14	19.3	133	0.09	0.0%	1,539	5.0%	0.9%
2012	10.7	2	0.13	100.0%	15	8.4	11	0.02	10.0%	681	15.4%	2.2%
2013	22.3	6	0.20	100.0%	30	8.6	14	0.02	7.6%	655	30.0%	4.4%
2014	101.9	19	0.14	94.7%	135	44.3	143	0.04	0.7%	3,262	11.7%	4.0%
2015	2.9	1	0.25	100.0%	4	3.2	5	0.02	2.4%	245	16.7%	1.6%
Avg.	26.8	8	0.27	87.3%	36	15.8	47	0.03	4.3%	1,153	25.6%	3.3%
(2002, 2007, and 2009 through 2015)												

Coho Spawning Habitat				Miles	Percent				Miles	Percent		
				1.03	1.8%				57.70	98.2%		

1 = Average density of live coho (live adult coho / mile) from GRTS surveys used in abundance estimates. Live coho estiamted using the Area-Under-Curve methodology.

2 = Number of coho carcasses with known adipose fin clip status avaialblr for pHOS calculation. Per capita is the number of carcasses colelcted devided by the abundance estimate.

3 = Proportion hatchery origin spawners based on carcasses, and live observations when less than 10 carcasses available. Adjusted for proportion of hatchery fish with and adipose fin clip.

4 = Estimated total abundance of adult coho spawners for the year, includes both ahtchery and wild fish.

Table 2. Comparison of abundance and pHOS estimates in the Clatskanie coho population. Current, un-stratified, estimates are highlighted in yellow, and whole basin estimates based on stratification are highlighted in blue. Estimates for each of the two strata are in white.

	Clatskanie Current				Clatskanie (No Plympton)				Plympton Only				Clatskanie Stratified			
	Total	Wild	Hatch	pHOS	Total	Wild	Hatch	pHOS	Total	Wild	Hatch	pHOS	Total	Wild	Hatch	pHOS
2002	229	104	125	55%	198	165	33	17%	17	2	15	88%	215	167	48	22%
2003	563	563	0	0%	563	563	0	0%					563	563	0	0%
2004	398	398	0	0%	398	398	0	0%					398	398	0	0%
2005	501	494	7	1%	501	494	7	1%					501	494	7	1%
2006	467	421	46	10%	467	421	46	10%					467	421	46	10%
2007	1,126	583	543	48%	915	915		0%	53	12	41	77%	968	927	41	4%
2008	995	995	0	0%	995	995	0	0%					995	995	0	0%
2009	1,256	1,070	186	15%	1,187	1,187	0	0%	19	8	11	58%	1,206	1,195	11	1%
2010	1,774	1,609	165	9%	1,697	1,675	22	1%	37	11	26	70%	1,734	1,686	48	3%
2011	1,553	1,506	47	3%	1,539	1,539	0	0%	14	7	7	50%	1,553	1,546	7	0%
2012	688	619	69	10%	681	613	68	10%	15	6	9	60%	696	619	77	11%
2013	702	443	259	37%	655	605	50	8%	30	6	24	80%	685	611	74	11%
2014	3,547	3,126	421	12%	3,262	3,239	23	1%	135	7	128	95%	3,397	3,246	151	4%
2015	249	224	25	10%	245	239	6	2%	4	1	3	75%	249	240	9	4%
Avg.	1,003	868	135	15%	950	932	18	4%	36	7	29	73%	973	936	37	5%
Avg. Yrs in Common	1,236	1,032	204	22%	1,153	1,131	22	4%	36	7	29	73%	1,189	1,137	52	7%

= Not Sampled