THE OREGON PLAN *for Salmon and Watersheds*

Juvenile Salmonid Monitoring In Coastal Oregon and Lower Columbia Streams, 2016

Report Number: OPSW-ODFW-2017-1

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Oregon Plan for Salmon and Watersheds

Annual Monitoring Report No. OPSW-ODFW-2017-1

Ronald J. Constable, Jr., and Erik Suring
Western Oregon Rearing Project
Oregon Department of Fish and Wildlife
28655 Highway 34
Corvallis, OR 97333

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SUMMARY

This report analyzes monitoring data for juvenile Coho Salmon in three Evolutionarily Significant Units (ESUs) and juvenile steelhead in four Distinct Population Segments (DPSs) in western Oregon. Monitoring data are used to evaluate trends in salmonid distribution and abundance, which inform conservation and recovery decisions. The analysis in this report spans the years 1998-2016. Previous annual reports can be found at: https://nrimp.dfw.state.or.us/crl/default.aspx?pn=WORP.

Juvenile Coho Salmon:

For both the Oregon Coast Coho (OCC) and Lower Columbia River (LCR) ESUs, abundance estimates were lower in 2016 relative to the average from the 2013-2015 broods. The 2016 LCR abundance estimate was the lowest recorded in the 11 years of monitoring in this ESU. In the Southern Oregon Northern California Coho (SONCC) ESU the 2016 abundance estimate was similar to the average of the estimates for the 2013-2015 broods. The 2016 estimate of site occupancy, relative to the estimate for the 2013-2015 broods, was lower in the LCR, and similar in the OCC and the SONCC. As with the abundance estimate for the LCR, the 2016 estimate of site occupancy was the lowest recorded since monitoring began in the ESU.

In the OCC there is some indication from Coho Salmon survey data that freshwater productivity rates are regulated by compensatory density dependence at one or several early life stages. In the OCC metapopulation, the spawner:summer parr (recruit) curve is sigmoidal in years of higher female spawner abundance, suggesting some factor (or combination of factors) that sets juvenile carrying capacity. A density dependent pattern has not been observed in the LCR, likely due to relatively low seeding levels in the ESU. For the SONCC there are insufficient adult data to perform these analyses.

Juvenile Steelhead:

For the Oregon Coast (OC) and the Klamath Mountains Provence (KMP) DPSs, the average of the abundance estimates for the 2014-2016 broods was similar to the average for the 2010-2013 broods. The 2016 abundance estimate was similar to the average of the 2006-2015 estimates in the South West Washington (SWW) DPS and lower than the average of the 2006-2015 estimates in the Lower Columbia River (LCR) DPS. Site occupancy estimates in the OC and KMP in the 2014-2016 broods were similar to the estimates for the 2010-2013 broods. Site occupancy estimates in 2016, relative to the average of the 2006-2015 estimates, were similar in the SWW and lower in the LCR.

From 1998 to 2009 pools were required to be ≥40cm in maximum depth to meet survey protocols. This was changed to ≥20cm in maximum depth in 2010. Analyses based on the ≥20cm maximum depth criteria, relative to the ≥40cm maximum depth criteria, typically produce increases in site occupancy rates and larger abundance estimates with proportionately smaller confidence intervals. Abundance estimate trends that included shallow pools tracked with those based on the former pool criteria.

BACKGROUND AND METHODS

This project was initiated by Oregon Department of Fish and Wildlife (ODFW) in 1998 as part of larger monitoring program supporting the Oregon Plan for Salmon and Watersheds (State of Oregon 1997). The primary objective of the project is help guide conservation and recovery decisions related to Coho Salmon (*Oncorhynchus kisutch*) by providing data on trends in the abundance and distribution of Coho Salmon parr in coastal Oregon streams. The project uses principally snorkel surveys at randomly selected sites to meet this objective.

The project's original sampling frame was 1st-3rd order streams within the putative summer rearing distribution of Coho Salmon in the Oregon Coast Coho (OCC) and Southern Oregon Northern California Coho (SONCC) Evolutionarily Significant Units (ESUs) (Figure 1). In 2002 the sampling frame was expanded to include both (*i*) 4th-6th order streams within the rearing distribution of Coho Salmon in these ESUs and (*ii*) 1st-6th order streams within the rearing distribution juvenile steelhead (*Oncorhynchus mykiss*) in in the Klamath Mountain Province (KMP) and Oregon Coast (OC) Distinct Population Segments (DPS). In 2006, 1st-6th order streams within the rearing distribution of Coho Salmon and steelhead in the Oregon portions of the Lower Columbia River (LCR) Coho Salmon ESU and South West Washington (SWW) and LCR steelhead DPSs were included. Surveys in 4th-6th order streams were phased out by 2013. Analyses for all years and in all ESUs/DPSs are now based on data from 1st-3rd order streams.

The scale of the sampling frame has changed over time. The original sampling frame was based on a 100k stream layer. The 100k layer was replaced by a 24k layer in 2007. The 24k layer provided a refinement and expansion of the rearing distribution in the original frame. Analyses for all years in the ESUs/DPSs for the Oregon Coast and Lower Columbia River regions are currently based on the 24k layer. In 2012 a sampling frame based on a 24k stream layer was developed for the SONCC/KMP. This 24K-based frame also refined and expanded the original Coho Salmon and steelhead rearing distribution within the SONCC. Until the 2012 (24k) frame is corroborated by field surveys, analyses in the SONCC/KMP will be based the assumed former distribution. Our sampling frame and survey design are described in detail by Jepsen and Rodgers (2004) and Jepsen and Leader (2007).

Field Sampling

A Generalized Random Tessellation Stratified (GRTS, Stevens 2002) design was used to select sample sites in a spatially balanced, random fashion from our sampling frame. Sample sites were stratified by strata within the ESUs/DPSs and surveyed by field crews using daytime snorkeling during the base flow period (mid-July to mid-October). Sample sites were 1km in length and encompassed the GRTS point (x, y coordinates) provided by the selection process. Field crews were trained in fish ID and snorkel survey protocols described by Rodgers (2000). Surveys began at the downstream end of the sample site and proceeded upstream (Thurow 1994). The length of the sample site, and the length and average width of pools within the sample site, were measured with a hip chain, open reel tape, or range finder. Pool depth was measured using a depth staff. All pools ≥6m^2 in surface area and ≥20cm in maximum depth were snorkeled with a single pass to identify and count juvenile salmonids. Dive lights were used to improve visibility in shaded areas. Visibility was rated by considering factors that could impede the ability to observe fish (Rodgers 2000; Crawford 2011). Hard counts were made of Coho Salmon parr regardless of length, of juvenile steelhead ≥90 mm in fork length (FL, visually estimated), and cutthroat trout (*O. clarki*) ≥90 mm FL. Due to difficulties discerning O. mykiss and *O. clarki* when under 90mm FL, all trout in this range were assumed to be age 0 and were not identified to species or used in analysis (Hawkins 1997, Roni and Fayram 2000). Fish presence was noted for dace, shiners, and trout <90 mm FL. Freshwater mussel presence and relative abundance and beaver activity were also noted. Sample sites that could not be snorkeled due to poor water clarity or quality were electrofished using a single pass without block nets to determine occupancy in each pool for Coho Salmon and occupancy at the sample site for steelhead and cutthroat.

Our goal is to produce distribution and abundance estimates with confidence intervals ≤30% of the estimate. Analysis of our data has shown that completing 40 sample site per stratum (Figure 1) is typically sufficient to reach this goal. For quality control and to evaluate observational differences among snorkelers approximately 15% of sample sites were resurveyed by supervisory staff.

Data Analysis

Data are summarized by ESU or DPS and stratum. Cumulative Distribution Function (CDF) graphs, variances, and confidence intervals were created using tools developed by the EMAP Design and Analysis Team (EPA 2009). In comparison tests a p-value ≤ 0.05 was considered to indicate a significant difference. The following metrics of fish distribution and abundance were calculated for each of the two target species (Coho Salmon and steelhead):

- Site occupancy: The percent of sample sites where the target species was found; calculated by dividing the number of sample sites where the target species was observed by the number of sampled sites that were surveyed for each stratum, ESU, or DPS. Site occupancy has also been calculated for cutthroat trout.

- Pool frequency: The average percent of pools in a sample site that contain the target species. Pool frequency was first calculated at each sample site by dividing the number of pools where the target species was observed by the total number of surveyed pools. The resulting percent at each sample site was then averaged to obtain the pool frequency estimate within the stratum, ESU, or DPS.

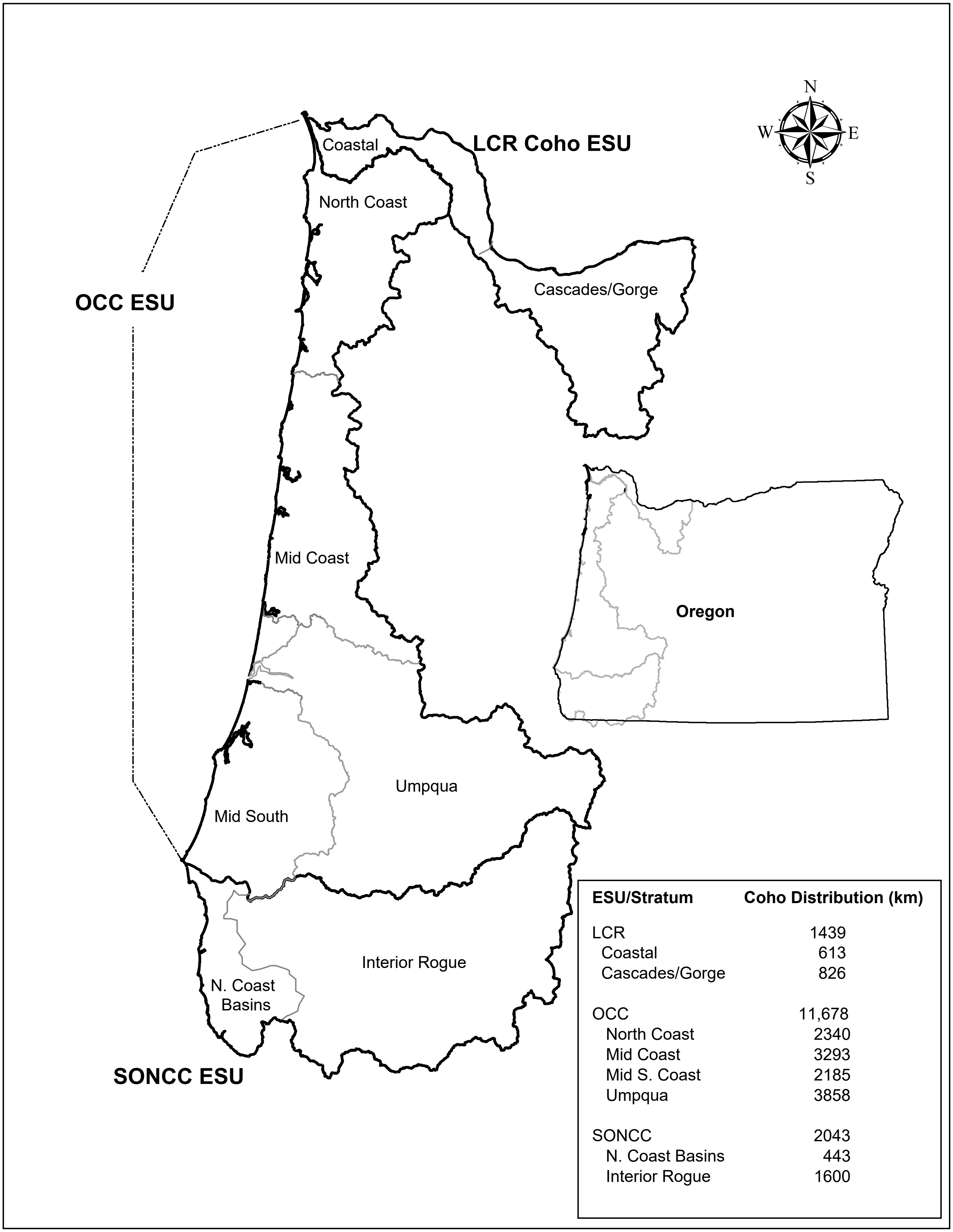
- Density: The number of target species individuals divided by the surface area of the pool in which they were observed. Density was first calculated in each pool. Second, it was calculated for each sample site by averaging the pool densities within the respective sample sites. Lastly, it was calculated for each stratum, ESU, and DPS by averaging the site densities within the respective areas.

- Estimates of abundance in pools: The estimate of the abundance of the target species in pools for each stratum, ESU, or DPS. Pool abundance estimates are calculated by multiplying the count of target species individuals per kilometer at each sample site by the sample site weight. Target species individuals per kilometer is the sum of the snorkel count at the sample site divided by the length (in km) of the sample site. Sample site weight is the total length of the rearing distribution in the stratum, ESU, or DPS divided by the number of surveyed sample sites in the area. The sample site weight is adjusted for sample sites that were non-target, i.e. sample sites that were dry, in tidal zones, or above fish passage barriers, (Stevens 2002). Pool abundance estimates provided in this report are based on un-calibrated snorkel counts in pools that meet size criteria. As such they do not represent total abundance estimates, but are appropriate for assessing trends.

- Percent full seeding: This metric is the percent of sample sites within a stratum or ESU with average density $\geq$0.7 Coho Salmon/m^2. This value is regarded as full seeding following Nickelson et al. (1992) and Rodgers et al. (1992). Nickelson et al. estimate full seeding to be 1.0 coho/m^2 from electrofishing removal estimates and Rodgers et al. report that snorkelers observed 70% of the Coho Salmon in electrofishing removal estimates.

With the completion of the 2016 field season, there are now 19 years of monitoring data for juvenile Coho Salmon in the OCC and SONCC. To compare metrics across this time span, we partitioned the first 18 years of the data into three-year intervals, based on the conventional three-year Coho Salmon life cycle (reviewed by Weitkamp et al., 1995). This resulted in six successive brood groups from 1998-2015 (2016 is analyzed as an individual year in this report, but will be pooled with 2017 and 2018). Juvenile steelhead data were partitioned into brood groups based on a presumptive four-year life cycle (reviewed by Busby et al., 1996). This resulted in three successive brood groups from 2002-2013 and a partial brood group from 2014-2016. The Lower Columbia River Coho Salmon data were partitioned following the 2015 field season, resulting in three successive brood groups from 2007-2015 (2016 is analyzed in this report as a single year). Steelhead data in the LCR and SWW will be partitioned into brood groups following the 2017 season. A brood group contains one iteration of each of the three Coho Salmon brood lines (likewise, a brood group for steelhead contains one iteration of each of the four brood lines), and thus is one complete cycle of the summer rearing segment of the Coho Salmon population. The use of brood groups as an analysis unit, as opposed to individual cohorts or years, can provide a useful way to monitor trends in distribution and abundance. We compared estimates of site occupancy and fish abundance among these brood groups.

Initially only pools that were ≥40cm in maximum depth were snorkeled. This maximum depth criterion was lowered to ≥20cm in 2010 when data from the Smith River Verification Study (Constable and Suring, unpublished report) suggested the lower criterion would allow surveyors to sample larger and more consistent portions of Coho Salmon and steelhead summer rearing abundances. In order to compare current data to that from previous years, reports following the 2010 field season primarily provide an analysis of data based on pools meeting the ≥40cm maximum depth criterion and a secondary analysis of data based on pools meeting the ≥20cm maximum depth criterion.



ESU/Stratum	Coho Distribution (km)
LCR	1439
Coastal	613
Cascades/Gorge	826
OCC	11,678
North Coast	2340
Mid Coast	3293
Mid S. Coast	2185
Umpqua	3858
SONCC	2043
N. Coast Basins	443
Interior Rogue	1600

Figure 1. The project area showing Western Oregon Coho ESUs and strata. The table gives the length of Coho Salmon rearing distribution in 1st-3rd order streams in each area.

RESULTS
2016 Survey Effort and Resurveys

In 2016, 588 sample sites were selected by the GRTS process. Sixty-six of these were determined to be non-target sites (beyond the potential rearing distribution of Coho Salmon and steelhead). Of the remaining 522 sample sites, 120 were not surveyed because of landowner access restrictions, 30 could not be surveyed due to poor visibility or safety issues, 13 were inaccessible, and 48 were not visited due to time restrictions. Sample sites that were not surveyed were defined as target, non-response.

A total of 311 sample sites were surveyed. Of these 299 were snorkeled and 12 were electrofished. A total of 4,205 pools were surveyed within 310.6km of streams. We met our goals for survey effort in the North Coast, Cascades/Gorge, and Interior Rogue stratum (Table 1). Both the Interior Rogue stratum and the Coast stratum of the LCR had a high proportion of sample sites that were dry or where access was denied by landowners. Lack of visibility accounted for the high number of sites that could not be surveyed in the LCR.

Table 1. Survey effort goals and status of sample sites for 2016.

ESU	Stratum	Survey Goal	Snorkeled	Electrofished	Target -Non response	Non-Target
OCC	North Coast	40	36	5	19	1
	Mid Coast	40	38	1	20	6
	Mid-South Coast	40	31	1	18	10
	Umpqua	40	35	0	21	3
LCR	Coast	40	34	0	34	15
	Cascades/Gorge	40	37	4	32	8
SONCC	Interior Rogue	60	59	1	48	18
	N. Coast Basins	40	29	0	19	5

The goal of a 95% confidence interval ≤30% of the density estimate was only met in the Mid Coast stratum (Table 2) for Coho Salmon and was not met in any of the strata for steelhead (Table 3). Variance partitioning has indicated low precision in most years has been due to the high variation of Coho Salmon pool abundance among the survey sites (Anlauf-Dunn, unpublished data).

Thirty-five (12%) of the snorkeled sample sites were resurveyed by supervisory staff. Five of the resurveys were an extension of training for less experienced crew members and were not used to examine the precision of our methodology. Counts of Coho Salmon in the remaining 30 sites had a significant relationship with counts from the resurveys (Figure 2, top left panel, R^2 = 0.995). These results were similar to previous years (bottom left panel, R^2 = 0.956) and indicated our snorkel counts of Coho Salmon were precise and repeatable. Resurvey counts of steelhead were more variable (top right panel, R^2 = 0.754) than Coho Salmon in 2016, and this was similar to previous years (bottom right panel, R^2 = 0.773).

Table 2. Distribution and density estimates of Coho Salmon parr in the four strata of the Oregon Coast Coho ESU and in the LCR and SONCC. Estimates are from snorkel surveys in 1st-3rd order streams from 2016.

	Distribution			Density		
Stratum or ESU	Site Occupancy	Mean Pool Frequency	95% CI	Percent Sites > 0.7 coho/m^2	Mean Average Pool Density (coho/m^2)	95% CI
North Coast	80%	60%	± 16%	6%	0.219	± 32%
Mid Coast	92%	79%	± 10%	18%	0.423	± 29%
Mid-South Coast	84%	76%	± 14%	16%	0.293	± 31%
Umpqua	74%	54%	± 21%	6%	0.174	± 45%
SONCC	32%	21%	± 31%	1%	0.060	± 42%
LCR	24%	14%	± 37%	0%	0.011	± 57%

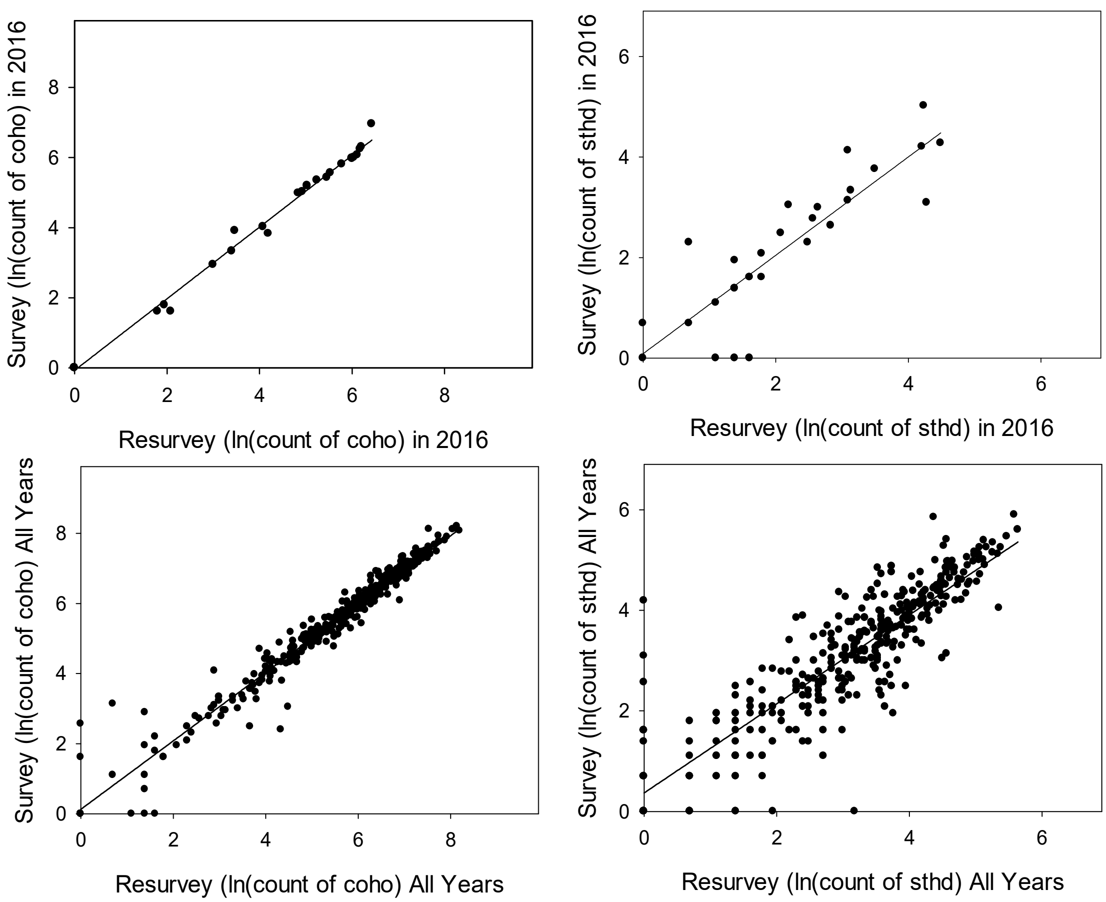


Figure 2. The relationship of Coho Salmon parr and steelhead (≥90mm in fork length) counts from surveys and resurveys of the same sampling sites for 2016 (top panels, n = 30) and for all years (bottom panels, n = 440 for Coho Salmon and n= 386 for steelhead, respectively). Data are log transformed to satisfy regression assumptions.

Trends in Salmonid Distribution and Abundance

Coho Salmon

CDF curves, based on density, the percent of sample sites occupied, and the percent of sample sites fully seeded, were lower in 2016 compared to the average condition from 1998-2015 in 3 out of the 4 OCC strata (Figure 3). From 2015 to 2016 both density and the percent of sites fully seeded declined in most strata, with the exception of the Mid Coast (Figure 4), and this decline was observed for the ESU as a whole (Figure 5). In both the LCR and the SONCC, the percent of sample sites fully seeded remained at or near zero for 2016. Density estimates in 2016 were lower than in 2015 for the LCR, but higher than in 2015 for the SONCC (Figure 5).

Estimates of abundance in pools in 2016 were lower than the average for the 2013-2015 brood group in the OCC and in the LCR (Figure 6). In the LCR, the estimate of abundance in pools in 2016 was under 20% of the average of the annual estimates since monitoring started in the ESU in 2006. In the OCC, the estimate of abundance in pools in 2016 was lower than the average for the three preceding brood groups, but higher than the 1998-2000 brood group. In the SONCC, the estimate of abundance in pools in 2016 was similar to the average for the 2013-2015 brood group, but lower than the average for all of the preceding brood groups with the exception of 1998-2000. The estimate of abundance in pools in 2016 for the strata in the OCC were similar to the averages for the 2013-2015 brood group, with the exception of the Mid South Coast, where the 2016 estimate was lower (Figure 7). Spawner abundance in 2015 (see http://odfw.forestry.oregonstate.edu/spawn/cohoabund.htm) was the lowest recorded in the LCR and at 16 year low for the OCC, which likely contributed to the relatively lower parr abundance estimates in these regions in 2016.

Site occupancy estimates in 2016 were lower in the LCR compared to the 2013-2015 brood group but, in the OCC and the SONCC, the 2016 estimate was similar to the respective 2013-2015 brood groups (Figure 8). In the LCR site occupancy in 2016 was just over 50% of the average of the annual estimates since monitoring started in the area in 2006. Site occupancy estimates in 2016 for the strata in the OCC were similar to the averages for the 2013-2015 brood groups (Figure 9). While the abundance of Coho Salmon spawners was relatively low in 2015 for the OCC, Coho Salmon parr occupancy from the brood (in 2016) exceeded 80%, which was similar to the occupancy rate since 2004 (Figure 8). Site occupancy estimates in 2016 for the SONCC were lower than the first four (1998-2009) brood groups and similar to the last two (2010-2015) brood groups.

Plots of Coho Salmon parr abundance against the abundance of female spawners which produced them suggest parr production was limited in the OCC at current spawner levels (Figure 10). In brood years when female spawner abundance was 80,000 or less (1997-2001, 2005-2007, 2012-2013, and 2015), an increase in spawner abundance was typically correlated with an increase in parr abundance (R^2 = 0.549). However, in years when female spawner abundance exceeded 80,000 (2002-2004, 2008-2011, 2014), increases in spawner abundance appear to be unrelated to parr abundance (R^2 = 0.065). For the OCC, the number of parr produced per female increased when female spawner abundance decreased and, conversely, decreased when female spawner abundance increased, suggesting a compensatory effect (Figure 11). The number of parr per female ranged from 20 in brood year 2011 (which had the highest female abundance) to 113 in brood year 1999 (which had the 3rd lowest female abundance). It is important to note that parr abundance given here was from un-calibrated visual estimates conducted only in pools meeting protocol criteria. Actual parr abundance was likely higher; the range is estimated to be 58-324 parr per female; (Constable et al., in prep.), We assume that the lack of a corresponding increase in parr abundance as female spawner abundance increases above 80,000 was not an effect of parr “spilling over” into less optimal habitats, such as riffles, where they would not be observed with our protocols. Supporting this assumption are data that indicate pool densities have been relatively low to moderate (<0.7 Coho Salmon/m^2) in the majority of sites, even in high spawner abundance years. We also assume that the bias of snorkeler counts of parr in pools is similar at low and high parr abundance. Initial work of testing these assumptions began in the 2016 field season.

In the LCR, there is a much weaker relationship between Coho Salmon female spawner abundance and parr abundance when female spawner levels are relatively low ($R^2 = 0.148$). The number of parr produced per female spawner in the LCR appears more random than in the OCC, and is, on average, 30% lower than the number of parr produced per female in the OCC. We did not observe a compensatory effect in the LCR (Figure 13). Differences between the ESUs are perhaps due to later start of monitoring in the LCR and lower spawner densities in the ESU as compared to the OCC. There is only one data point (2014) where the number of female spawners exceeded 6,000 fish in the LCR (Figure 12). Assuming the factors controlling parr production are similar in the two ESUs, then, based on the density of female spawners (female spawner abundance/length of Coho Salmon distribution), limits to parr production in the LCR would not be expected until female spawner abundance exceeded approximately 10,000 fish (the LCR has 1/8 of the Coho Salmon distribution found in the OCC, Figure 1).

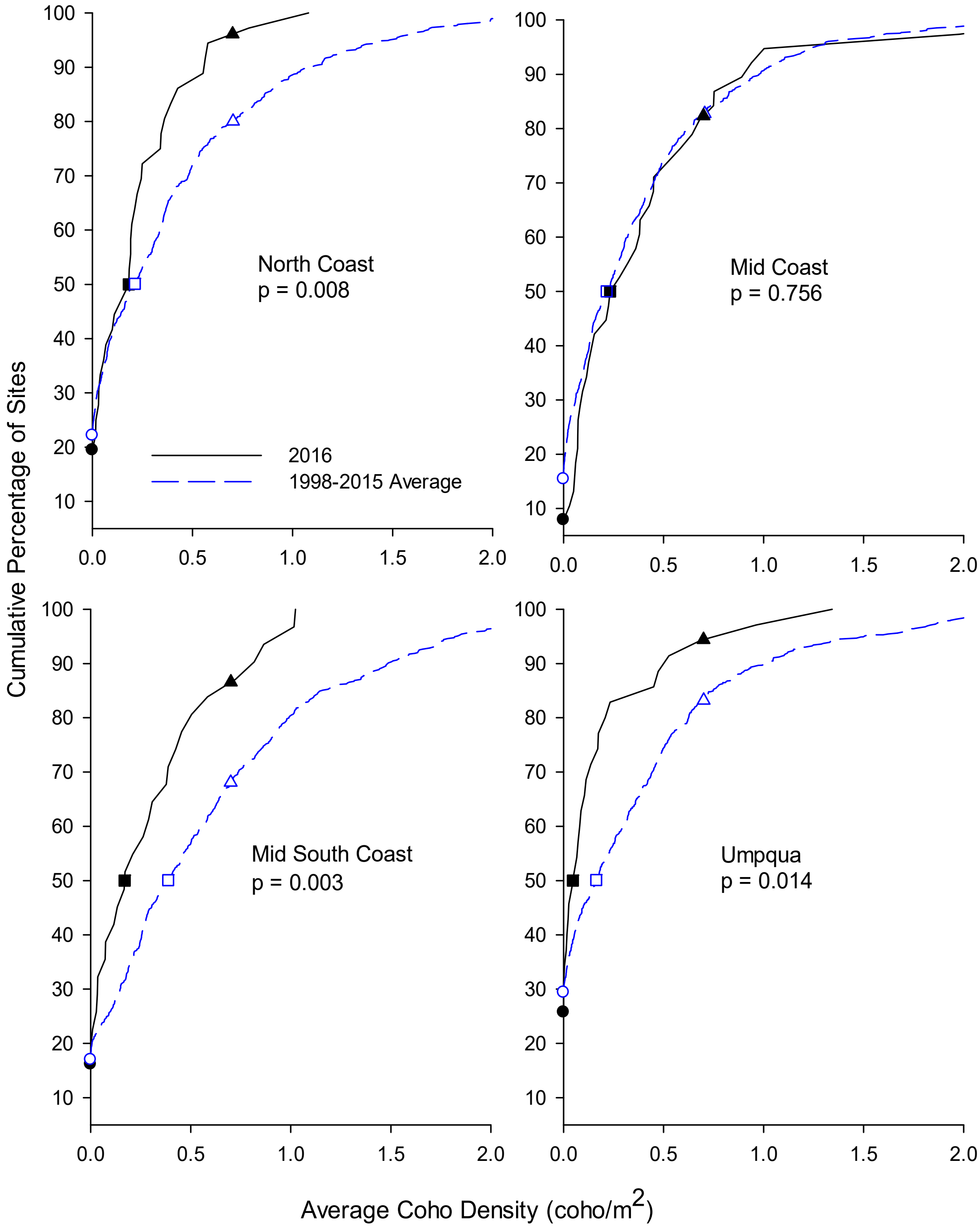


Figure 3. Average Coho Salmon parr density CDFs based on snorkel surveys in 1st-3rd order streams in the four strata of the Oregon Coast Coho ESU. The points shown on the curves are the percentage of unoccupied sites (circles), the median density (squares), and the percentage of sites below full seeding (triangles). The average condition of each stratum based on the CDF of these three metrics (blue, dashed line) is compared to the condition in 2016 (black, solid line). P values are from the comparison test of the two curves.

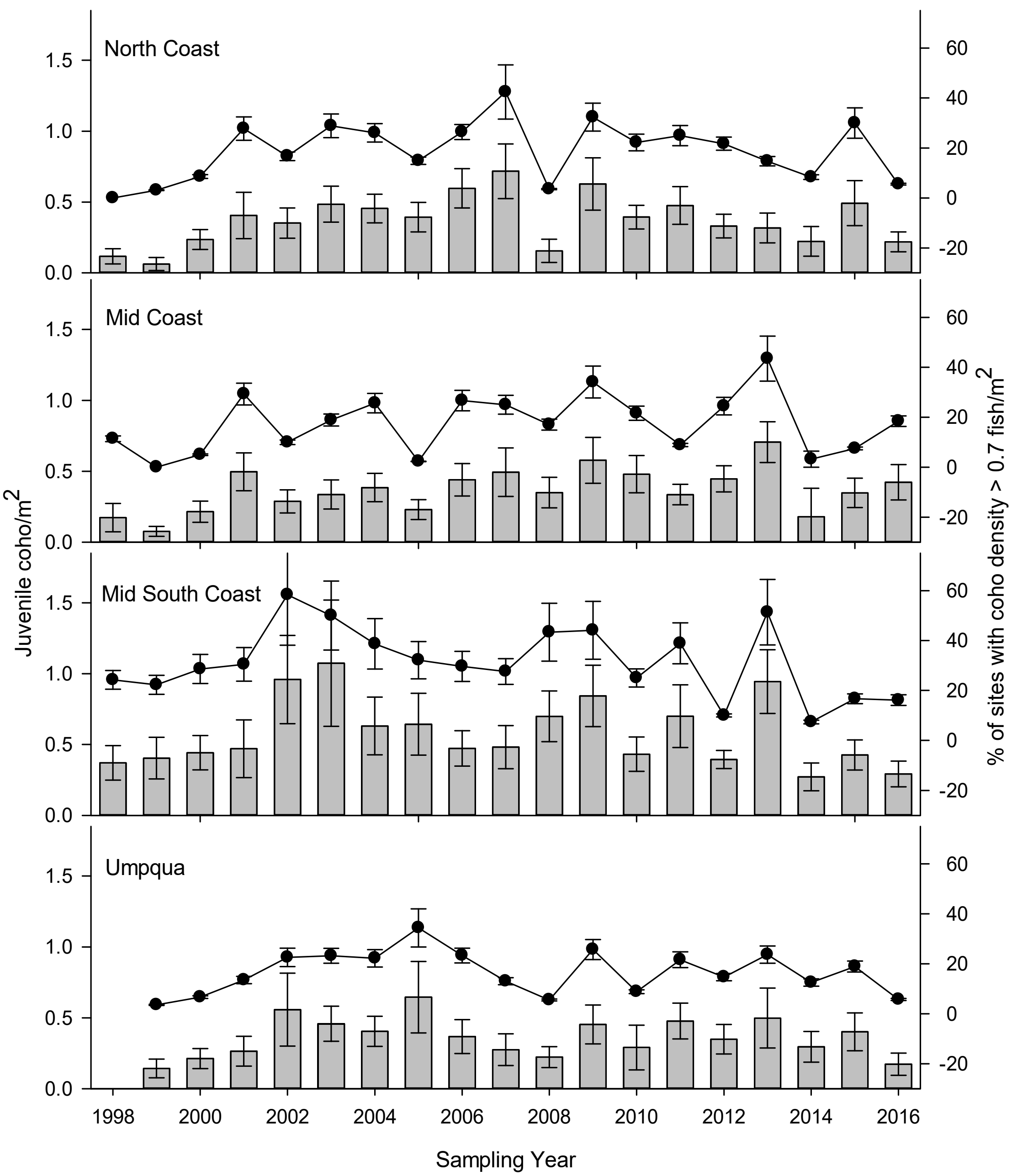


Figure 4. Annual time series of Coho Salmon parr density and full seeding estimates in the four strata of the Oregon Coast Coho ESU, based on snorkel surveys in 1st-3rd order streams. Gray bars are the mean average density (Coho Salmon /m^2 in pools) and black dots are the percent of sites that were fully seeded (density ≥0.7 Coho Salmon/m^2 in pools). Error Bars are the 95% CI.

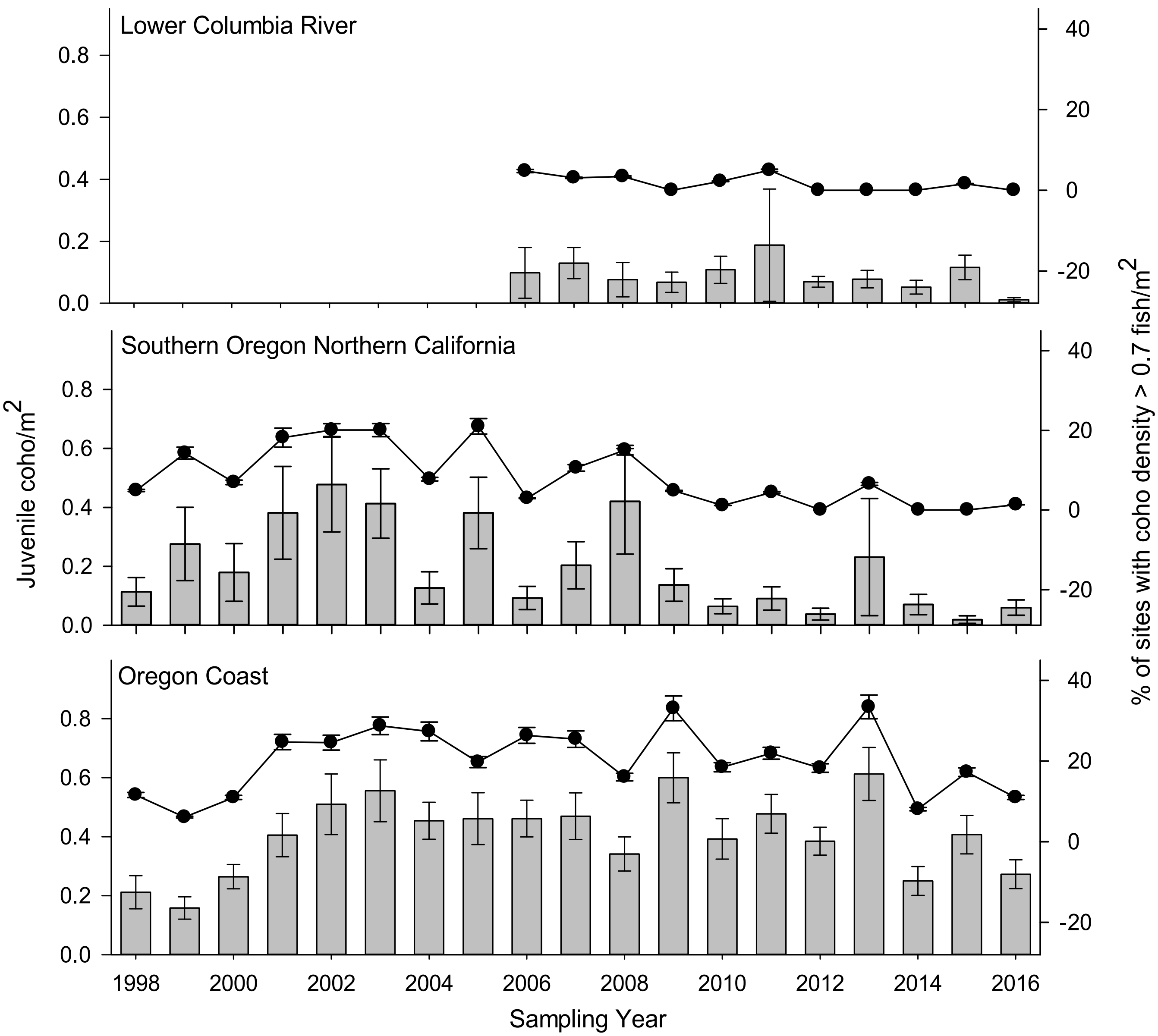


Figure 5. Annual time series of Coho Salmon parr density and full seeding estimates in the three Western Oregon Coho ESUs, based on snorkel surveys in 1st-3rd order streams. Gray bars are the mean average density (Coho Salmon /m^2 in pools) and black dots are the percent of sites that were fully seeded (density ≥0.7 Coho Salmon/m^2 in pools). Error Bars are the 95% CI.

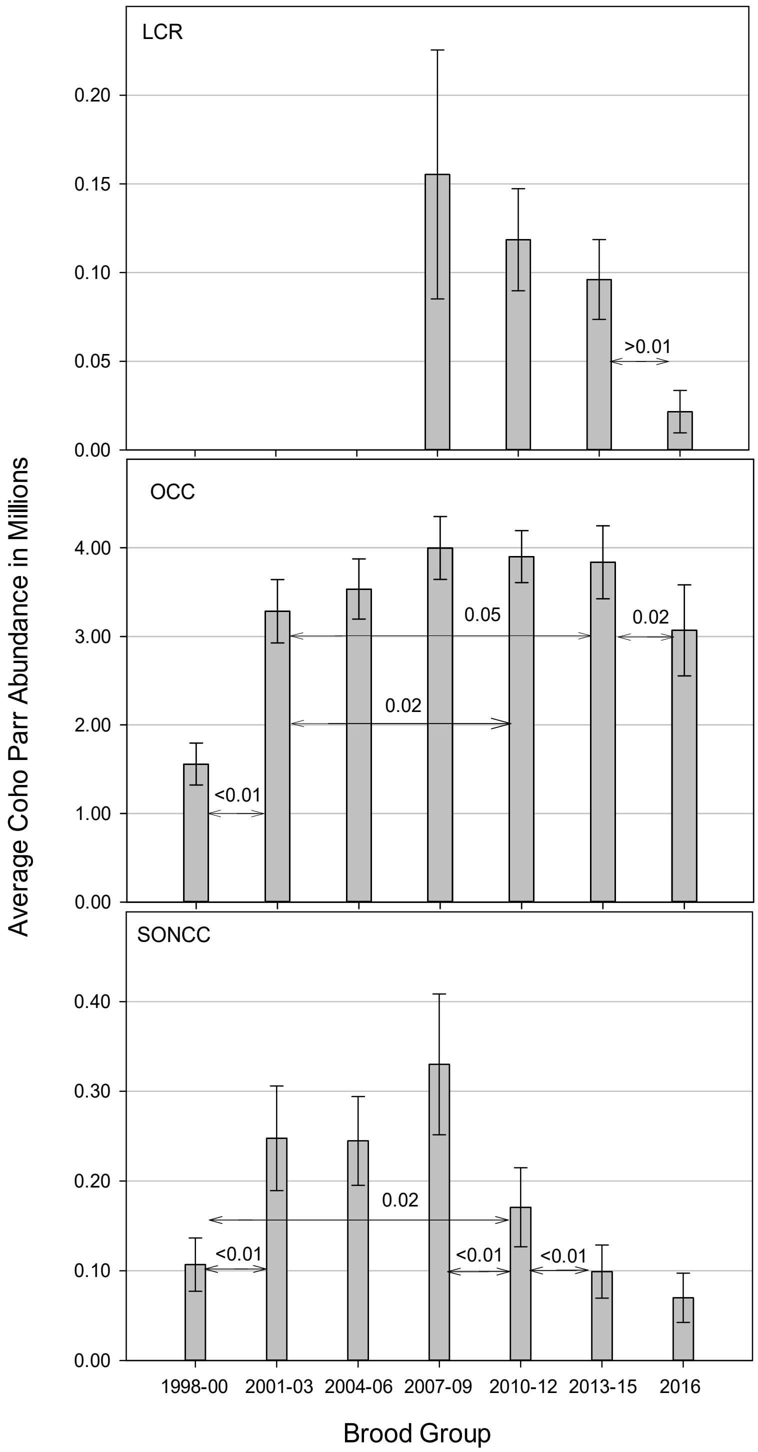


Figure 6. Three year (brood group) trends of Coho Salmon parr abundance estimates in the three Western Oregon Coho ESUs, based on snorkel surveys in 1st-3rd order streams. Note the differences in Y-axis scales among panels. Gray bars and error bars show the abundance estimate with the 95%CI. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$.

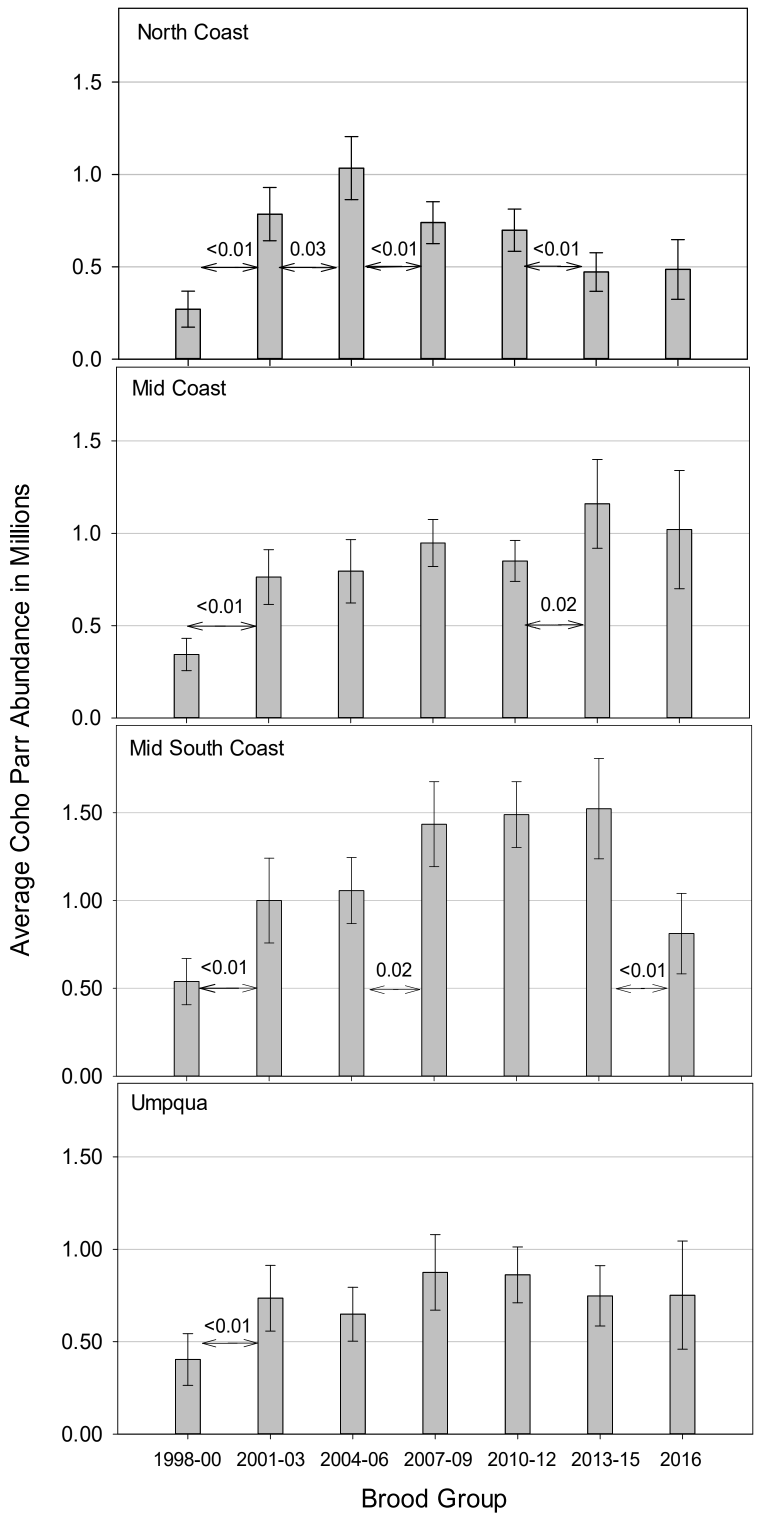


Figure 7. Three year (brood group) trends of Coho Salmon parr abundance estimates in the four strata of the Oregon Coast Coho ESU, based on snorkel surveys in 1st-3rd order streams. Gray bars and error bars show the abundance estimate with the 95%CI. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$.

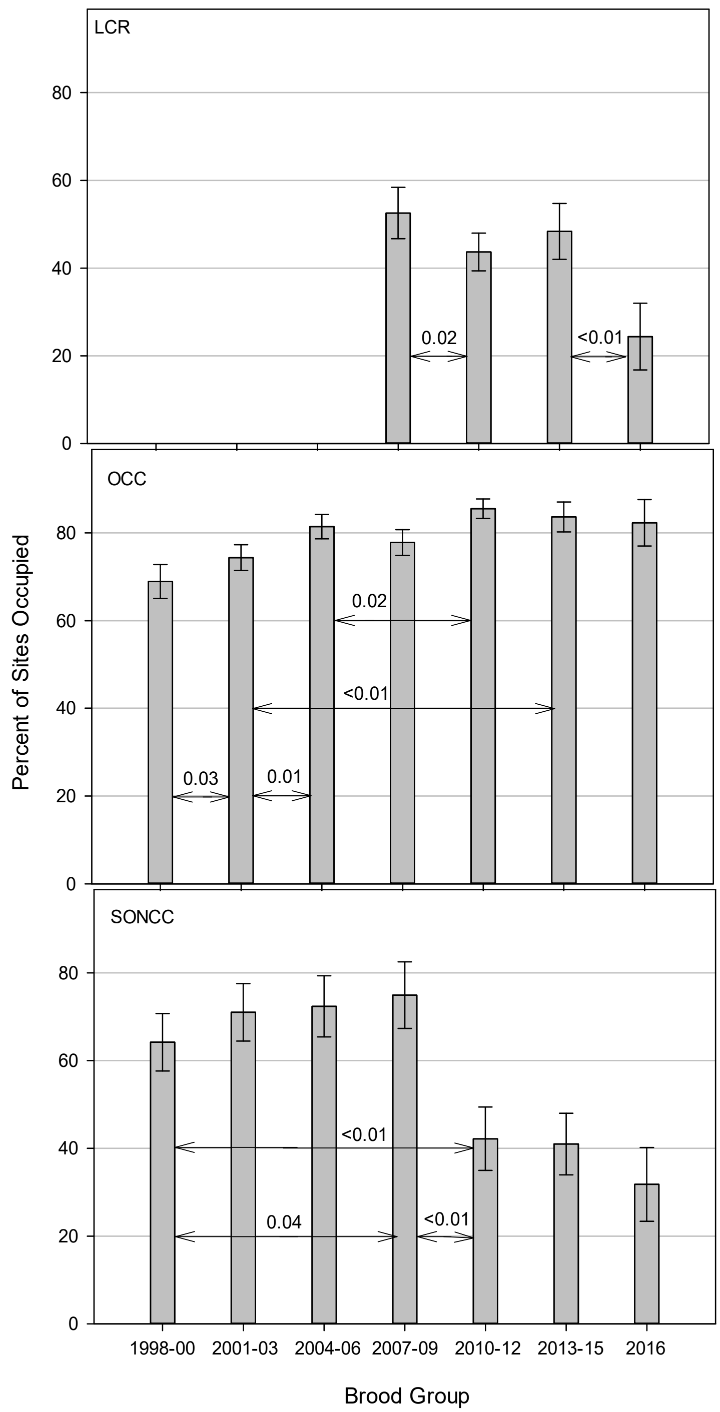


Figure 8. Three year (brood group) trends of Coho Salmon parr site occupancy in the three Western Oregon Coho ESUs based on snorkel surveys in 1st-3rd order streams. Gray bars and error bars show the percent of sites occupied with the 95%CI. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$.

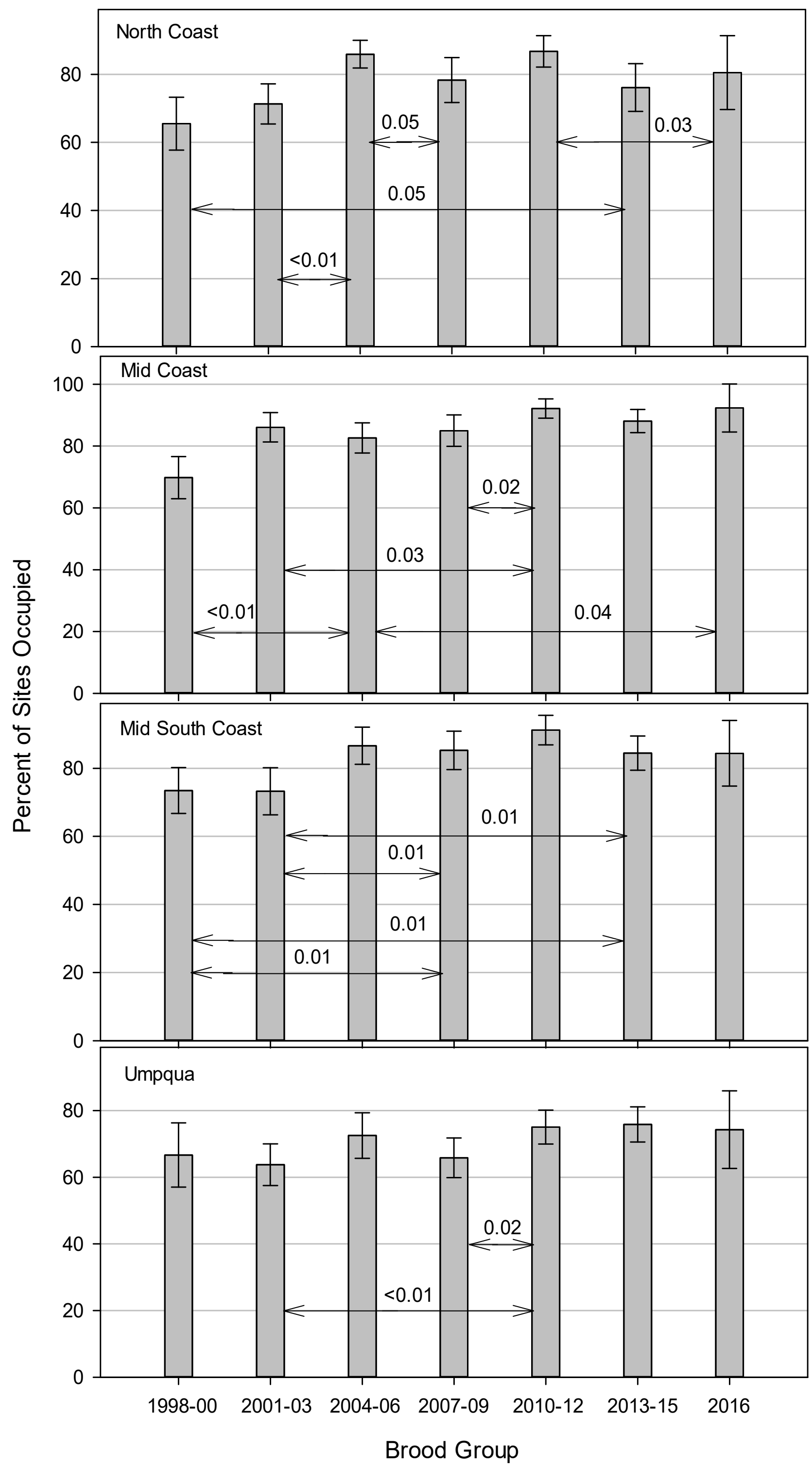


Figure 9. Three year (brood group) trends of Coho Salmon parr site occupancy in the four strata of the Oregon Coast Coho ESU, based on snorkel surveys in 1st-3rd order streams. Gray bars and error bars show the percent of sites occupied with the 95%CI. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$.

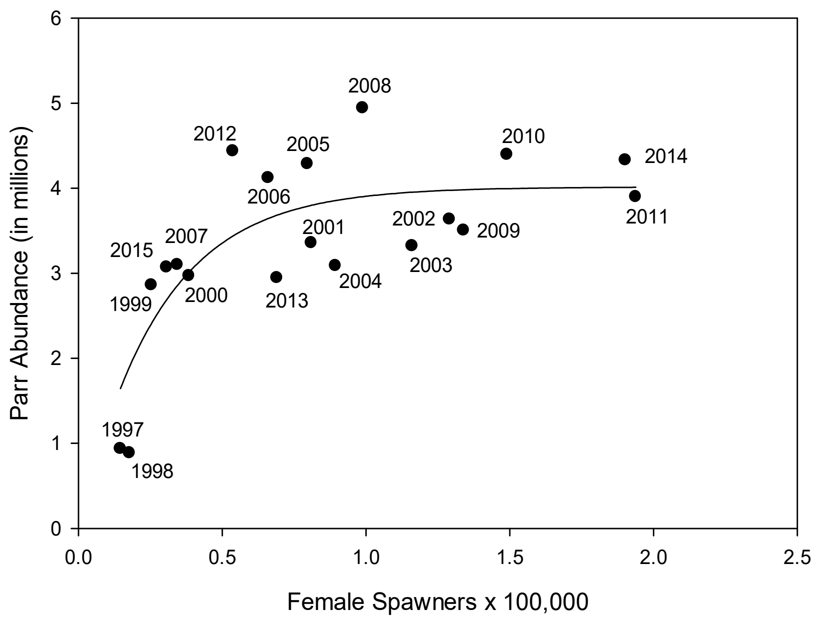


Figure 10. The relationship between the abundance of Coho Salmon parr and the abundance of female spawners that produced them in the Oregon Coast Coho ESU. Parr abundance is from un-calibrated snorkel surveys in 1st-3rd order streams. Spawner abundance is from spawning ground surveys. The brood year is given for each data point.

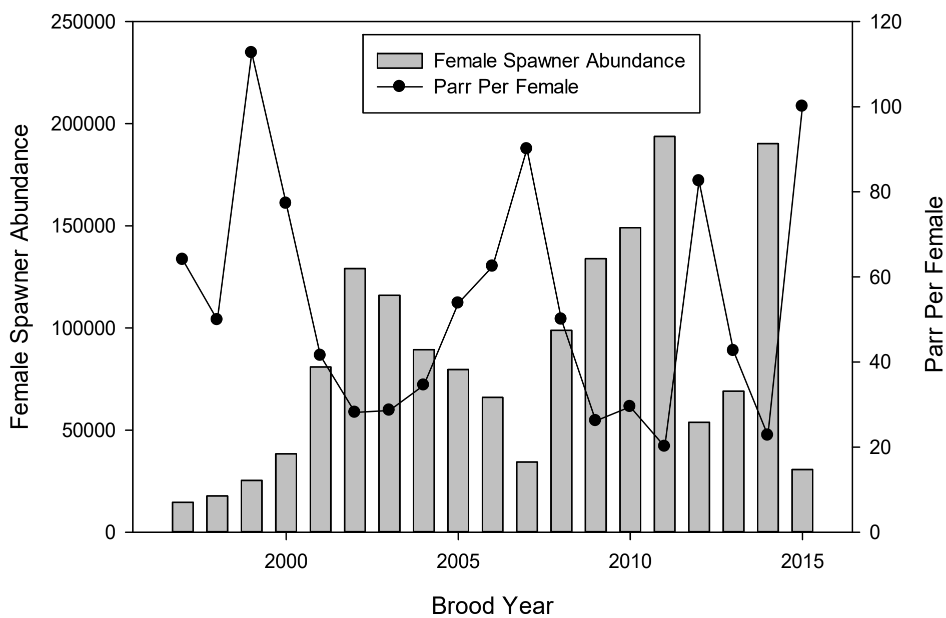


Figure 11. The abundance of female spawners (gray bars) and the number of Coho Salmon parr produced per female spawner (black dots and line) by brood year in the Oregon Coast Coho ESU. Parr abundance is from un-calibrated snorkel surveys in 1st-3rd order streams. Spawner abundance is from spawning ground surveys.

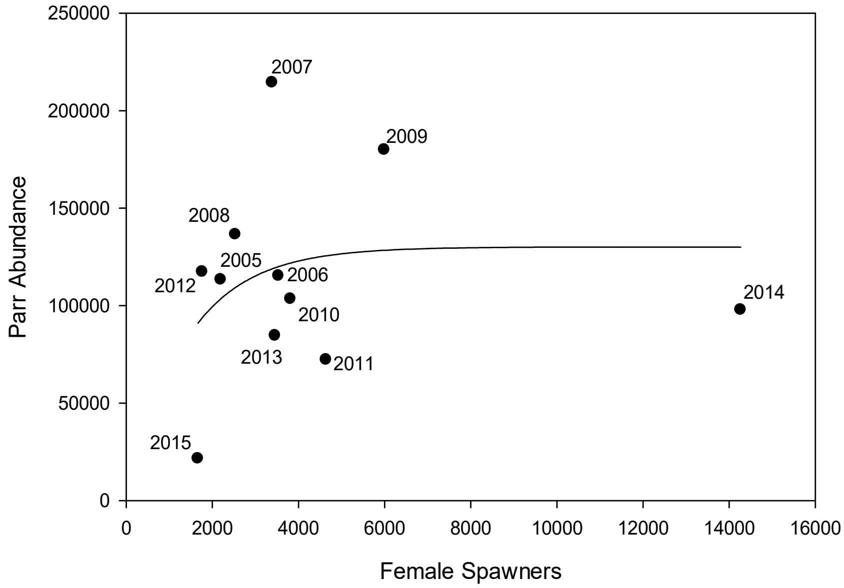


Figure 12. The relationship between the abundance of Coho Salmon parr and the abundance of female spawners that produced them in the Lower Columbia River ESU. Parr abundance is from un-calibrated snorkel surveys in 1st-3rd order streams. Spawner abundance is from spawning ground surveys. The brood year is given for each data point.

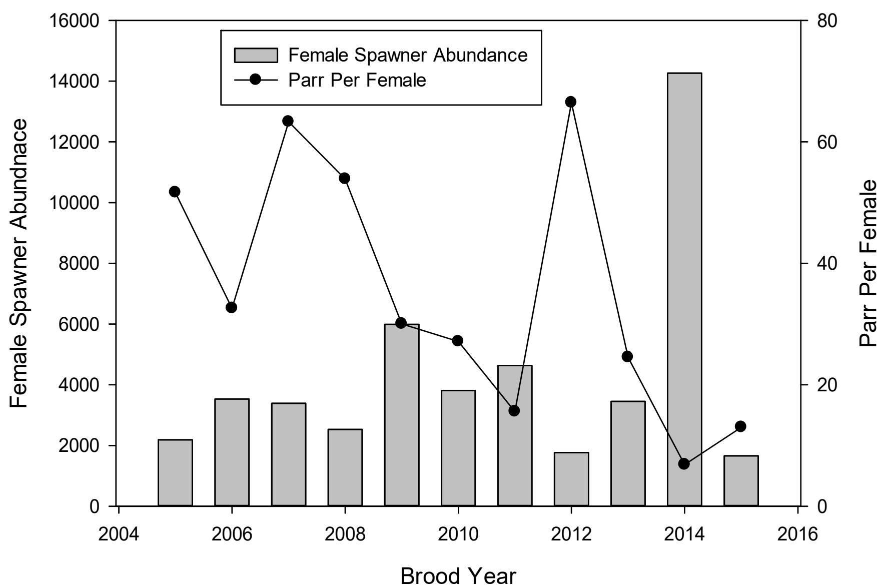


Figure 13. The abundance of female spawners (gray bars) and the number of Coho Salmon parr produced per female spawner (black dots and line) by brood year in the Lower Columbia River ESU. Parr abundance is from un-calibrated snorkel surveys in 1st-3rd order streams. Spawner abundance is from spawning ground surveys.

Steelhead

Density estimates in 2016 were similar to the 2015 estimates in the four DPSs, except in SWW, where the 2016 estimate was higher (Figure 14). Pool Frequency was also higher in 2016 than in 2015 in SWW. Pool Frequency in 2016 was similar to the 2015 estimate in the LCR, lower than the 2015 estimate in the KMP, and higher than the 2015 estimate in the OC

Abundance estimates for the partial brood group from 2014-2016 were similar to the 2010-2013 brood group in the OC, but lower than the 2010-2013 brood group in the KMP (Figure 15). Site occupancy estimates from 2014-2016 were similar to the 2010-2013 brood group in both the OC and KMP (Figure 16). However, in the KMP, the site occupancy estimate from 2014-2016 is lower than the 2002-2005 brood group. In SWW abundance and site occupancy estimates in 2016 were higher than the 2015 estimates but similar to the respective average estimates for the DPS (Figure 17). In the LCR both abundance and site occupancy estimates in 2016 were similar to the 2015 estimates but lower than the respective average estimates for the DPS.

Table 3. Distribution and density estimates for juvenile steelhead (≥90cm in fork length) in the four strata of the Oregon Coast Steelhead DPS, based on snorkel surveys in 1st-3rd order streams for 2016.

Stratum	Distribution			Density	
	Site Occupancy	Mean Pool Frequency	95% CI	Mean Average Pool Density (sthd/m^2)	95% CI
North Coast	49%	20%	± 35%	0.012	± 51%
Mid Coast	79%	55%	± 15%	0.033	± 27%
Mid-South	84%	50%	± 20%	0.013	± 53%
Umpqua	77%	48%	± 18%	0.018	± 24%
KMP Rogue	65%	33%	± 19%	0.02	± 35%
KMP South Coast	85%	64%	± 18%	0.06	± 35%
Lower Columbia	46%	20%	± 34%	0.006	± 39%
Southwest WA	69%	33%	± 28%	0.022	± 28%

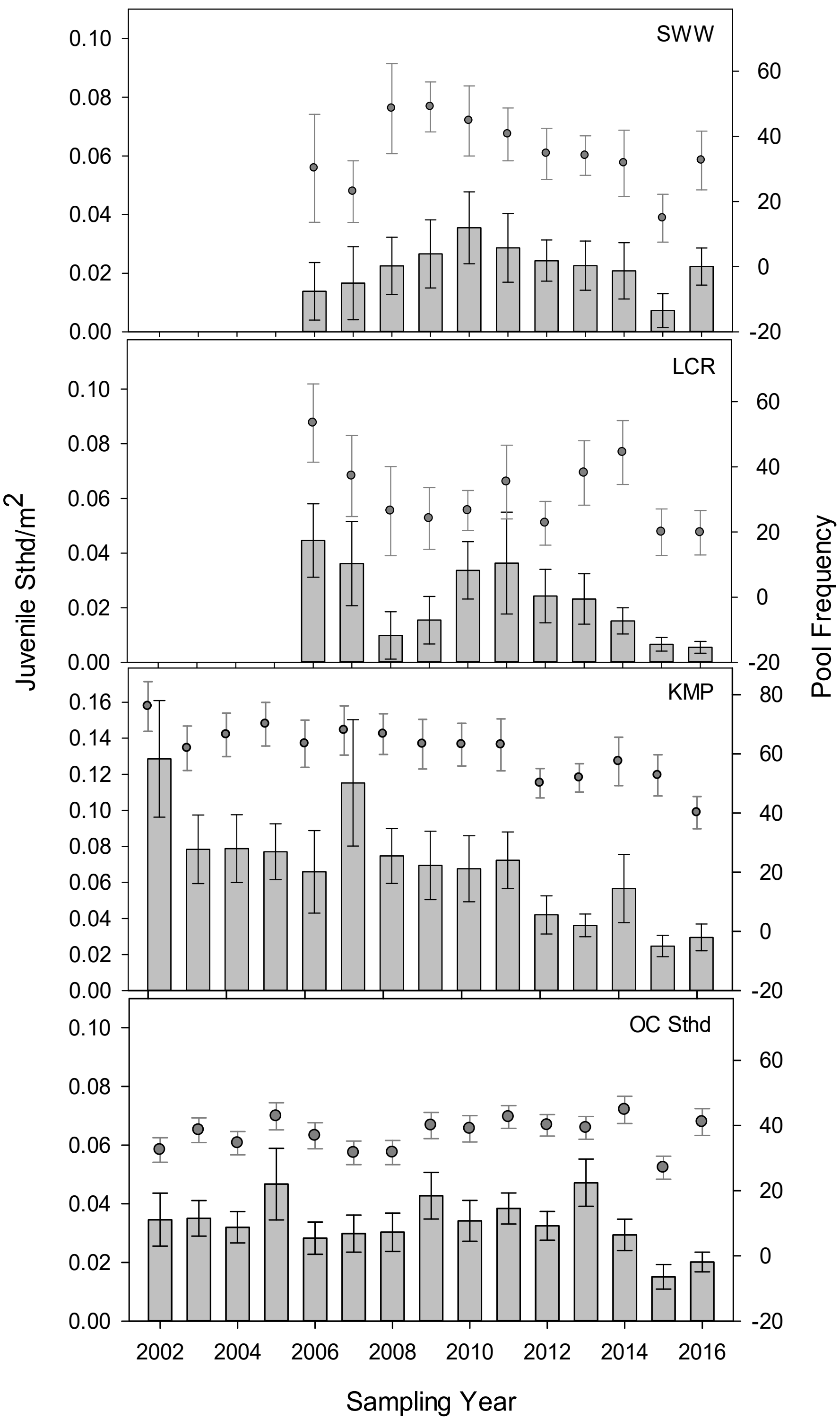


Figure 14. Annual time series of density and pool frequency for juvenile steelhead (≥90mm in fork length) in the four Western Oregon DPSs, based on snorkel surveys in 1st-3rd order streams. Gray bars are for mean average density (sthd/m^2 in pools) and gray dots are for pool frequency (number of sample sites with juvenile steelhead/number of surveyed sample sites). Note the difference in the y-axis scale for the KMP.

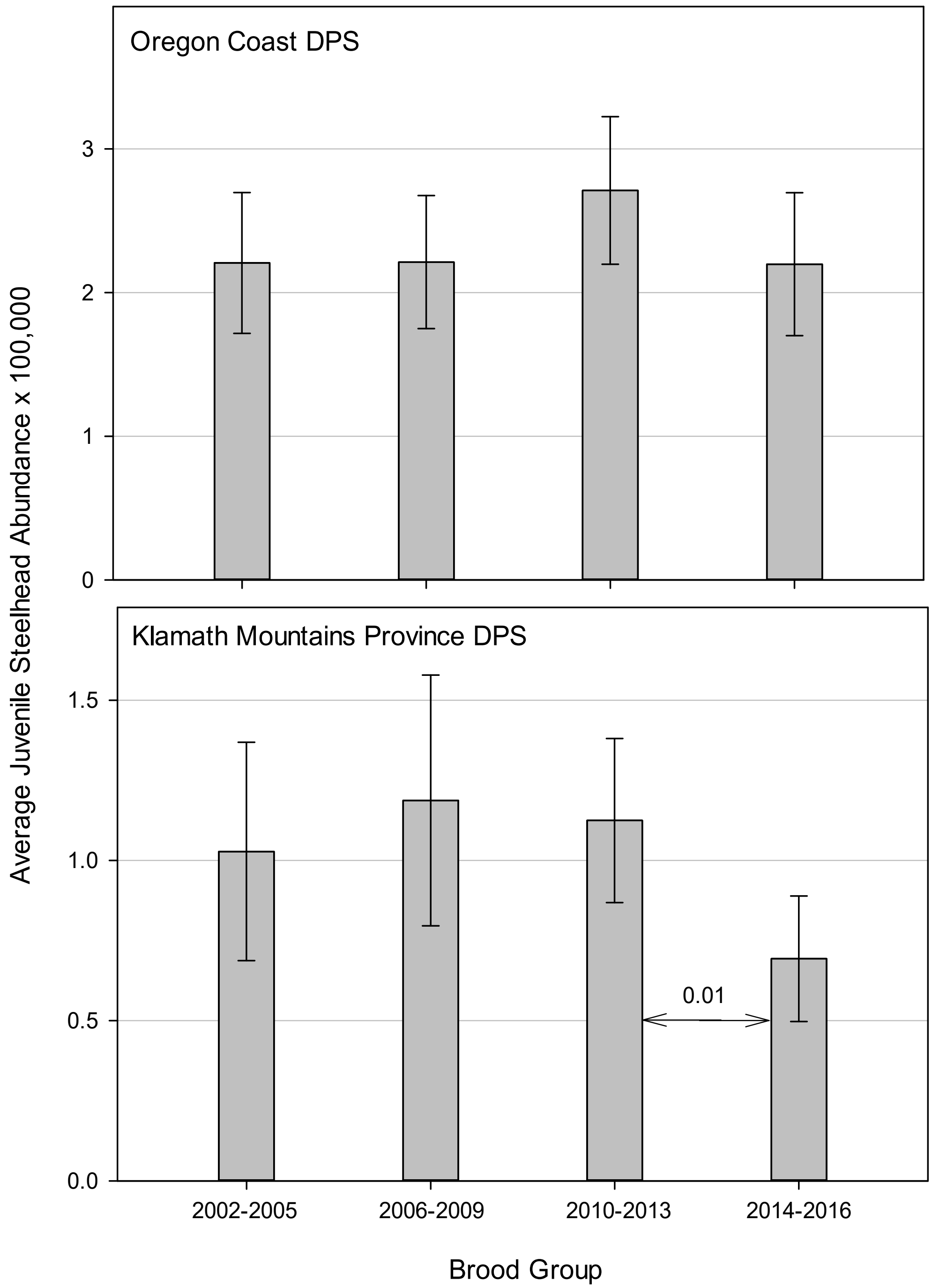


Figure 15. Four year (brood group) trends of juvenile steelhead (≥90cm in fork length) abundance estimates in the Oregon Coast DPS (top panel) and the Klamath Mountains Province DPS (bottom panel), based on snorkel surveys in 1st-3rd order streams. Gray bars and error bars show the abundance estimate with the 95% CI for the brood group. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$

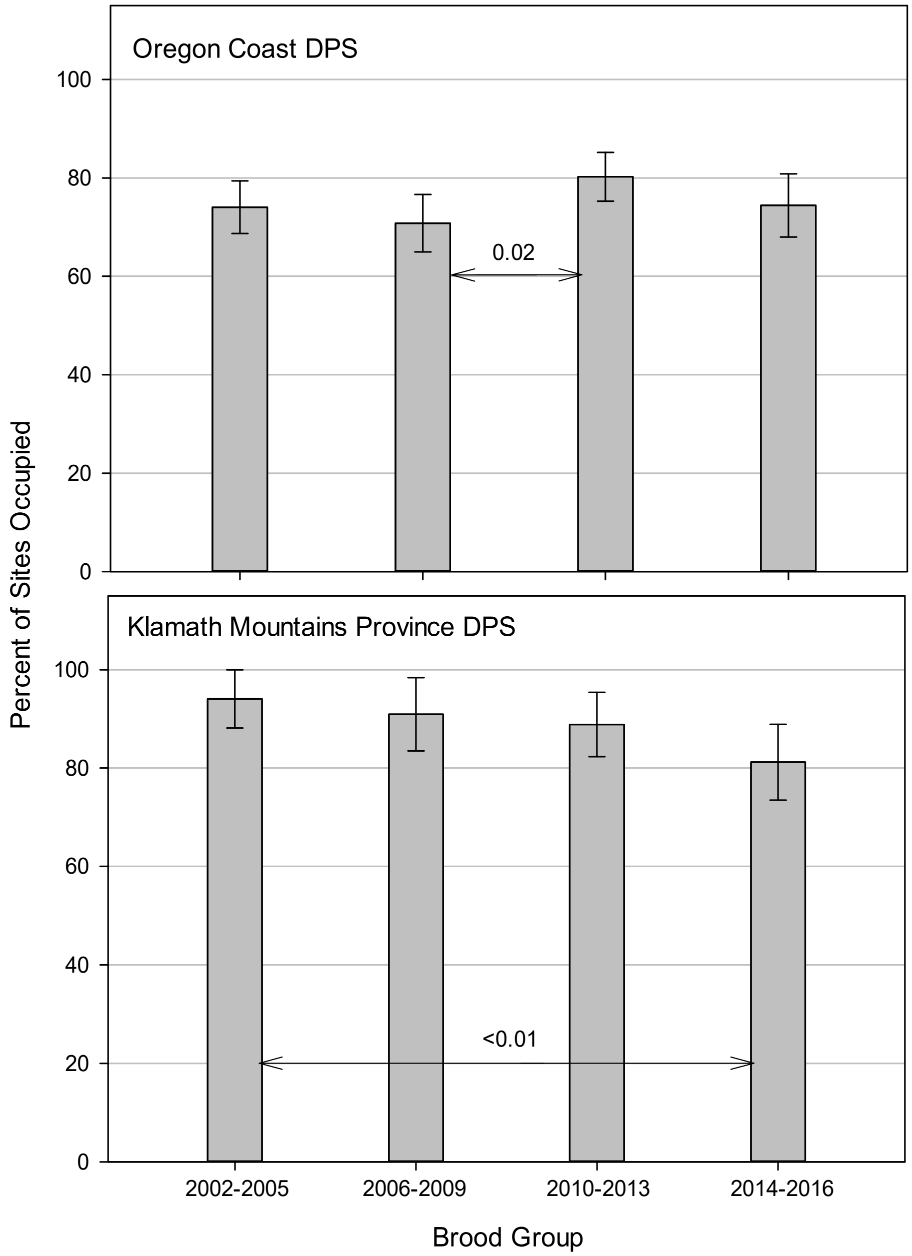


Figure 16. Four Year (brood group) trends of juvenile steelhead (≥90cm in fork length) site occupancy in the Oregon Coast DPS (top panel) and Klamath Mountains Province DPS (bottom panel), based on snorkel surveys in 1^{st}-3^{rd} order streams. Gray bars and error bars show the percent of sites occupied with the 95%CI for each brood group. P-values for selected comparisons among brood groups are given above the horizontal arrows where $p \leq 0.05$.

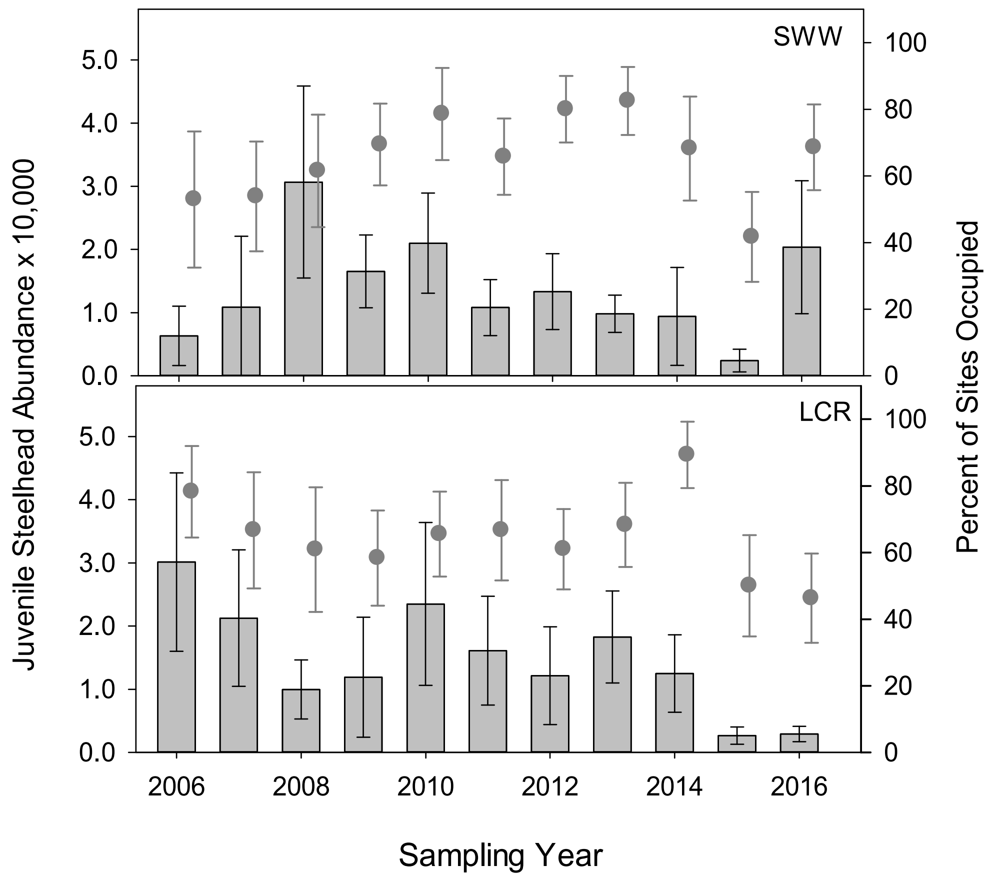


Figure 17. Annual trends of juvenile steelhead (≥90cm in fork length) abundance and site occupancy estimates in the lower Columbia River DPSs, based on surveys in 1st-3rd order streams. Gray bars show the abundance estimate and gray dots show the percent of sites occupied. Error bars are the 95%CI for the estimate.

Effects of Pool Depth on Snorkel Counts

Initially, only pools that were ≥40cm in maximum depth were surveyed. The Smith River Verification Study (Constable and Suring, in prep.) used electrofishing removal estimates (Amour et al. 1983) to determine the portion of the total (from all habitats) summer rearing abundances of Coho Salmon and steelhead that was contained in pools that met this criterion. In the Smith River study area results indicated pools ≥40cm maximum depth contained an average of 46% of the Coho Salmon and 68% of the steelhead summer rearing abundances. The percentage varied annually over the six-year study; ranging from 31-61% for Coho Salmon and from 49-82% for steelhead. Pools in the Smith River study area that were ≥20cm in maximum depth, the lowest depth recommended for snorkel surveys (O'Neal 2007), contained an average of 74% of the Coho Salmon and 79% of the steelhead summer rearing distribution. The annual variation in pools this size was 61-82% for Coho Salmon and 54-91% for steelhead. Abundance estimates in pools ≥40cm in maximum depth related moderately to abundance estimates in all habitats for Coho Salmon ($R^2 = 0.791$, $p = 0.007$) and strongly to abundance estimates in all habitats for steelhead ($R^2 = 0.918$, $p = 0.001$). Abundance estimates in pools ≥20cm in maximum depth related strongly to abundance estimates in all habitats for both species (Coho Salmon $R^2 = 0.974$, $p < 0.001$; steelhead $R^2 = 0.936$, $p < 0.001$). Due to these results, the maximum depth criterion was lowered to ≥20cm in 2010.

Results from resurveys indicate lowering the criteria has had little impact on the precision of Coho Salmon and steelhead counts between surveyors. The lower criterion has produced differences in survey effort and estimates of distribution and abundance. Lowering the maximum depth criterion allowed an additional 937 pools (a 22% increase) to be surveyed in 2016. Eleven survey sites in 2016 did not have pools that were ≥40cm in maximum depth, but did have pools that were ≥20cm in maximum depth. This improved our survey effort over the results presented in Table 1. Coho Salmon and/or steelhead were observed in six of the eleven sites for which all pools were <40cm in maximum depth. Additionally, there were nine survey sites that contained pools that were ≥40cm in maximum depth, but where Coho Salmon and steelhead were only observed in pools that were <40cm in maximum depth. These added survey sites and pools changed site occupancy estimates. For Coho Salmon, the estimates increased by <2% in OCC and SONCC and decreased <2% in the LCR over those given in Table 2. For steelhead, site occupancy estimates also increased by 5% in the KMP, decreased by 4% in the SWW, and changed by <1% in the OCC over those given in Table 3.

From 2010-2013 and in 2016 Coho Salmon density estimates decreased in most strata when the lower depth criterion was applied. In most cases this was less than a 10% decrease. In 2014 Coho Salmon densities increased by 1-5% in most strata when the lower criterion was applied. In 2015 densities did not change by more than 2% except in the SONCC, where they increased over 60% (this was primarily due to extremely high densities in one site with a single pool <40cm in maximum depth. In the past 5 years, steelhead density estimates decreased by <10% with the lower depth criterion in each DPS. For 2016 a similar decrease was observed in the KMP and in the OC, but the LCR increased by 16% and the SWW decreased by 12%.

Paired t-tests from abundance estimates in 2016 from pools ≥40cm and pools ≥20cm indicate that including the shallower pools produced significant differences in the abundance estimates of Coho Salmon parr (Table 4), but not for steelhead parr (Table 5) in the Oregon Coast ESU/DPS. Based on snorkel survey observations from 2010 to 2014, paired t-tests indicated there were significant differences in abundance estimates from pools ≥40cm and pools ≥20cm in the ESU/DPS for both Coho Salmon and steelhead parr. As in past years, abundance estimates including pools that met the 20cm depth criterion produced proportionally smaller 95% confidence intervals for Coho Salmon and steelhead estimates in most strata (Tables 4 and 5).The yearly variability for Coho Salmon abundance in each stratum and ESU estimated by surveys in pools ≥40cm in depth has tracked with the variability estimated by surveys in pools ≥20cm in depth (Figure 16).

Table 4. Comparison of estimates of Coho Salmon abundance in pools using a maximum depth of ≥20 cm and in pools using a maximum depth of ≥40 cm.

Stratum	2016 Coho Estimates				
	Pools ≥ 20cm Max Depth		Pools ≥40cm Max Depth		95% CI Difference
	Estimate	95% CI	Estimate	95% CI	
North Coast	535,536	34%	485,460	33%	0.2%
Mid Coast	1,134,875	31%	1,019,727	31%	0.6%
Mid-South Coast	866,777	28%	812,154	28%	0.8%
Umpqua	820,287	37%	751,757	39%	1.7%
SONCC	72,601	39%	69,839	39%	0.2%
Lower Columbia	22,854	53%	21,627	55%	2.4%

Table 5. Comparison of estimates of steelhead abundance in pools using a maximum depth of ≥20 and in pools using a maximum depth of ≥40 cm.

Stratum	2016 Steelhead Estimates				
	Pools ≥ 20cm Max Depth		Pools ≥ 40cm Max Depth		95% CI Difference
	Estimate	95% CI	Estimate	95% CI	
North Coast	22,685	39%	21,794	39%	0.1%
Mid Coast	76,986	27%	70,337	30%	3.2%
Mid-South Coast	45,006	29%	44,131	34%	0.3%
Umpqua	114,867	33%	111,676	34%	0.3%
KMP Rogue	31,625	44%	30,410	44%	0%
KMP South Coast	47,307	39%	46,652	39%	0.1%
Lower Columbia DPS	2,993	42%	2,905	42%	0%
Southwest WA DPS	20,365	52%	20362	52%	0.5%

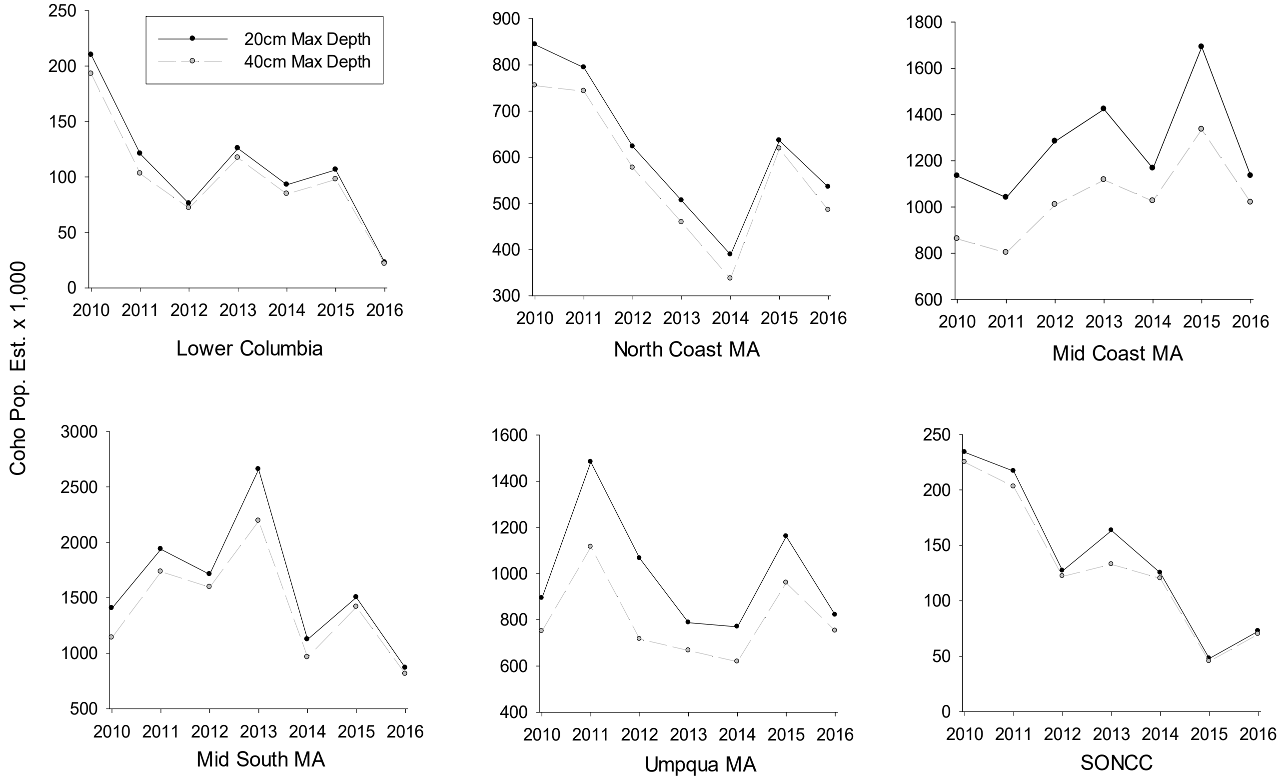


Figure 18. Annual differences in estimates of Coho Salmon parr abundance in Western Oregon strata from 2010 to 2015 based on snorkel surveys using (*i*) a ≥20cm pool depth criteria (solid black line) and (*ii*) a ≥40cm pool depth criteria (dashed gray line). Note differences in the y-axis scale for each graph.

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