Chinook Salmon (*Oncorhynchus tshawytscha*) Spawning Ground Surveys in the South Fork Salmon River and Big Creek, 1996-2016

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EXECUTIVE SUMMARY

This report documents adult Chinook salmon (Oncorhynchus tshawytscha; Nacó'x in Nez Perce) monitoring activities in the South Fork Salmon River (SFSR) associated with hatchery effectiveness monitoring of the LSRCP McCall Hatchery Chinook salmon program and natural-origin Chinook salmon status and trends monitoring in Big Creek, a tributary of the Middle Fork Salmon River (MFSR). This report includes data and analyses obtained through adult Chinook salmon spawning ground surveys (SGS), focusing on surveys conducted from 2012 – 2016 in the SFSR and 2008 – 2013 in Big Creek. Intensive multiple-pass spawning ground surveys were discontinued in 2014 in Big Creek. Data and results were added to the long-term trend analysis for both streams.

Data was collected through multiple-pass, ground count spawning ground surveys to obtain Chinook salmon redds and population demographic information from carcasses. Annual surveys were conducted in the SFSR covering a total of 19.1 kilometers (km), Big Creek covering a total of 10.3 km and the East Fork South Fork Salmon River (EFSFSR) above a passage barrier where adult Chinook salmon were outplanted. Performance measures derived from redd count data included 1) index of spawner abundance (redd counts); 2) progeny-per-parent ratio (derived from a ratio of progeny redds to parent redds); 3) spawn timing and; 4) adult spawner distribution. Performance measures derived from carcass survey data included 1) adult spawner sex ratio; 2) age structure; 3) age at return; 4) size-at-return; 5) hatchery fraction; 6) pre-spawn mortality and; 7) stray rate. Additionally, temperature data was collected and analyzed at five sites dispersed throughout the Chinook salmon spawning habitat of the upper SFSR.

In the most recent 5-year period from 2012 – 2016 the index of spawner abundance measured by redd counts averaged 270 redds per year in the four sections surveyed in the SFSR. This was lower than the previous five-year period (2007 – 2011 = 472) and the long-term trend of 306 redds per year from 1990 – 2016. Annual counts from 2012 – 2016 were all within the observed range for the SFSR from 40 redds in 1996 to 748 redds in 2010. Big Creek index of spawner abundance averaged 77 from 2009 – 2013, nearly double the long-term trend period of 46 redds per year. From 1986 – 2013 the Big Creek index of spawner abundance ranged from 1 in 1995 to 105 in 1988. Recent counts have been near the high end of the range, with a maximum of 102 counted in 2012. Long-term redd count trends were positive for both rivers. Spawner distribution and spawn timing were also relatively stable over that time period for both rivers. Within the SFSR, we identified significant differences in female prespawn mortality, age at return, and adult spawner sex ratio for natural-origin (natural) compared with hatchery-origin (hatchery) Chinook salmon. Although minor, these differences potentially indicated a slight life history divergence of the hatchery fish.

Excess Chinook salmon adults from the McCall Hatchery Program released into a rehabilitated section of Meadow Creek in the EFSFSR drainage to supplement natural spawning in the SFSR basin. This section is inaccessible to migrating adults and contains significant amounts of good to excellent spawning habitat. Since 2010 an average of 285 adults were released to spawn naturally. Redd counts averaged 81 and ranged from 41 in 2013 to 135 in 2016. Based on redd counts this program was successful at boosting natural production. However, an evaluation of juvenile emigrant survival or adult returns was not conducted making it impossible to determine if adult returns increased as a result of the outplants.

Temperature monitoring revealed that August 15 – 31 average daily temperature increased as water moves downstream through the mainstem SFSR. This temperature gradient likely explained the spawn timing differences with fish spawning upstream spawning earlier relative to fish exposed to higher temperatures lower in the system. In addition, relatively high late August water temperatures may limit or prevent significant spawning below the lowest SGS section (below Phoebe Creek), as redd densities decrease significantly in areas below this point.

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ACKNOWLEDGMENTS

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INTRODUCTION

The Lower Snake River Compensation Plan (LSRCP) was conceived in 1976 to mitigate for steelhead and spring, summer and fall Chinook salmon losses to streams in the Snake River basin due to construction of the Lower Snake River Dams. In 1985 the Nez Perce Tribe (NPT) Department of Fisheries Resource Management participation in the program began and developed goals that emphasize elements important to the NPT principles; 1) reestablish and/or enhance production in all anadromous fish streams within the reservation, in the ceded area of the NPT, throughout the Snake River Drainage, and other historic areas of use and influence where feasible; 2) reestablish and/or establish tribal fisheries when and where opportunities exist and to assist in establishing sport fisheries; 3) monitor LSRCP hatchery facilities in an effort to maintain a quality production program which will meet LSRCP goals and; 4) demonstrate at what point in time the LSRCP meets the identified adult return mitigation goals.

As part of the LSRCP, the McCall Hatchery program was developed to mitigate for summer Chinook salmon losses in the South Fork Salmon River (SFSR). LSRCP created adult return objectives for each hatchery program and estimated smolt to adult survival (SAR) in setting juvenile production numbers, which for the McCall Hatchery Program corresponded to a production goal of one million smolts with a goal of returning 8,000 summer Chinook salmon back to the Snake River basin (Hutchinson, 1982). Chinook salmon smolts reared at McCall Hatchery are direct stream released into the South Fork Salmon River drainage at the Knox Bridge (river kilometer - 522.303.215.118), which is approximately one kilometer upstream of the MHT. From 1980 - 1989 both adipose fin clipped (AD) and unclipped hatchery juveniles were released. Tagging consisted of the application of coded wire tags (CWT) and PIT tags for harvest estimation and run reconstruction. Since 1989 100% of the hatchery fish were AD marked and a portion were CWT. Returning hatchery adult salmon captured at the MHT and used for broodstock, released downstream for sport and Tribal fisheries enhancement, distributed to Tribes or foodbanks, or outplanted to various locations in the SFSR or the East Fork South Fork Salmon River (EFSR) to spawn naturally.

The McCall Hatchery program has a complex management history, with various levels of natural/hatchery interbreeding both in the hatchery and in nature. Relative large numbers of hatchery fish spawn below the MHT and directed and undirected (weir inefficiencies) passage of hatchery fish above the create opportunities for interbreeding above the MHT. In addition, natural fish have been integrated into the hatchery program at various times over the course of the program, such as the Idaho Salmon Supplementation Project where hatchery fish were passed above the weir to naturally spawn with natural fish and natural fish were brought into the hatchery and spawned with hatchery fish (Bowles and Leitzinger, 1991). These management actions have effectively created an integrated population in the SFSR. The presence of a single genetically unique stock in the upper SFSR was confirmed by genetic diversity analysis demonstrating that the current SFSR Chinook salmon population likely represented the historic stock and is distinct from the nearby populations in Johnson Creek and the Secesh River (Matala, et al. 2012).

Data and analyses included in this report were obtained from multiple-pass spawning ground surveys on the SFSR and Big Creek. Surveys enumerate Chinook salmon redds to estimate an index of abundance and spawn timing and distribution. Spawned-out carcasses provide spawner population composition information. Objectives of the evaluations described in this report will provide data to monitor and evaluate adult returns to the McCall Hatchery

Program and understand the magnitude of hatchery interactions in the SFSR. Objectives include 1) estimating the index of abundance, distribution, productivity and life history performance measures for hatchery salmon spawning in the SFSR downstream of the MHT; 2) document the distribution and level of hatchery/natural interactions downstream of the MHT; 3) evaluate stream temperatures in the SFSR downstream of the MHT and; 4) evaluate the performance of hatchery adults released to spawn naturally in the East Fork South Fork Salmon River. An additional objective included evaluating natural Chinook salmon spawner abundance and population composition in the unsupplemented population in upper Big Creek (tributary of the Middle Fork Salmon River) as a reference population of the SFSR. Incorporating natural population of Big Creek as a control stream uninfluenced by hatchery fish can reveal positive or negative changes from hatchery/natural interactions, such as changes in age composition or productivity. Evaluations in Big Creek by this project were subsequently suspended in 2013 as they were not critical to the objectives of the LSRCP hatchery M&E program.

New information found in the report includes data collected from 2009 – 2016 and 1986 – 1995. A previous report covered NPT M&E activities from 1996 – 2008 (Young and Blenden, 2011). These data provide a longer time series with which to evaluate status and trends of these populations.

DESCRIPTION OF STUDY AREAS

The SFSR drainage encompasses an area of 3,382 square km (1,306 square miles) and includes two major tributaries, the Secesh River and the East Fork South Fork Salmon River (EFSFSR). The primary Chinook salmon spawning areas within the SFSR are located upstream of the confluence with the EFSFSR extending beyond the MHT to the upper reaches in Stolle Meadows. Spawning ground survey index sections surveyed by this project included four stream reaches comprising a total of 19.1 kilometers (Figure 1). The survey areas were established in 1991 and include a majority of the high quality Chinook salmon spawning habitat in the upper SFSR below the MHT. Idaho Department of Fish and Game surveys the major spawning areas above the MHT. SFSR index sections surveyed annually included a 5.0 km section from MHT to the confluence with Dime Creek (WD); a 6.3 km section from the confluence with Dime Creek to approximately 580 m above the confluence with Roaring Creek at GPS point N44.74033 W115.68914 (DC); a 1.1 km section encompassing the Poverty Flat area from the confluence with Blackmare Creek downstream to where the river narrows at GPS point N44.83606 W115.70423 (PF) and; a 6.7 km section from Lodgepole campground to the Phoebe Creek bridge (LP). In addition, a single peak count survey was performed in 2000 – 2003, 2005 and 2007 on a section beginning at the end of the DC section at GPS point N44.74033 W115.68914 and ending at the confluence with Sisters Creek (GC).

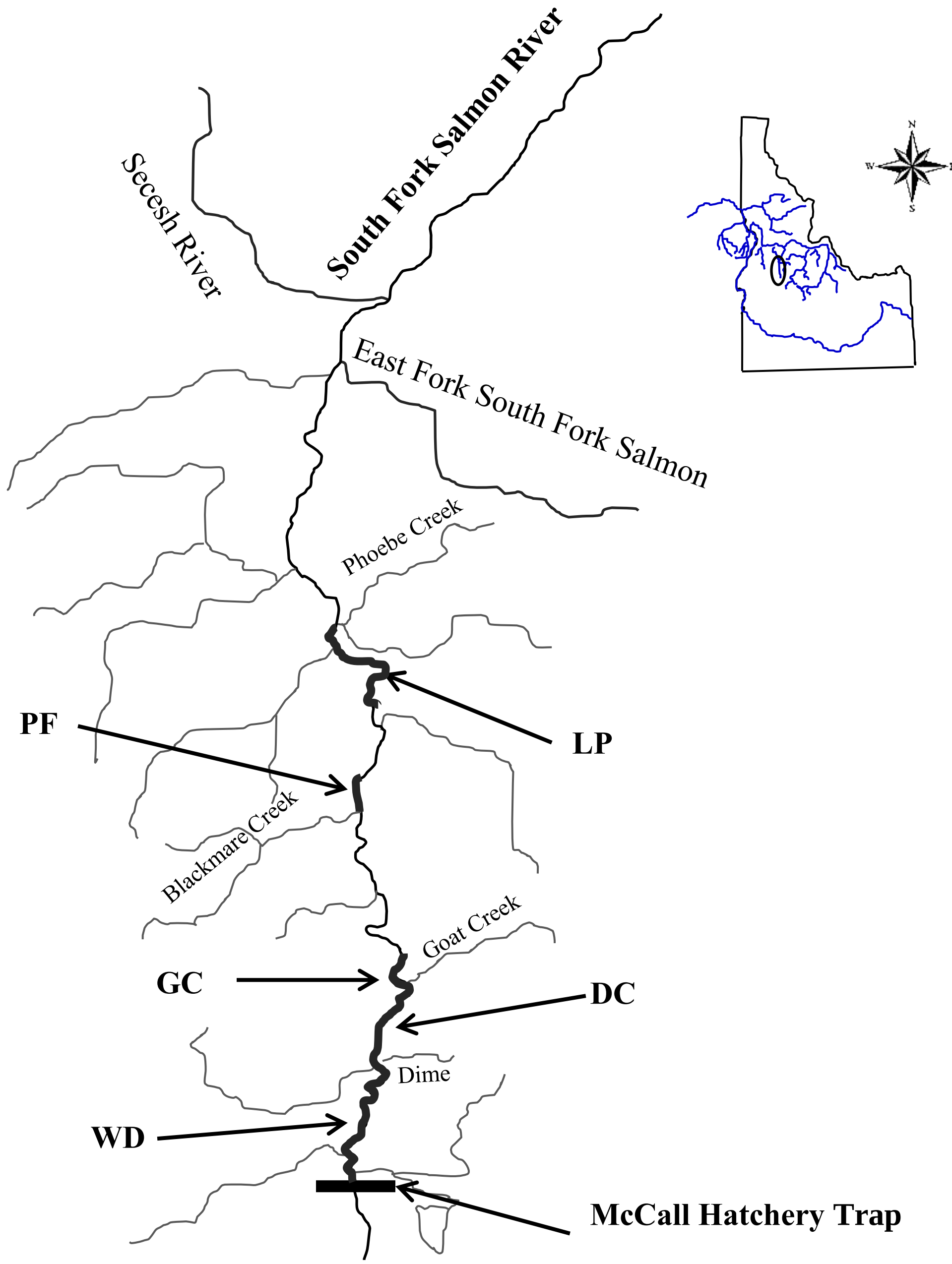


Figure 1. Map showing the South Fork Salmon River basin and stream sections surveyed during annual spawning ground surveys. Surveys where completed on four index areas; Weir to Dime Creek section (WD); Dime Creek section (DC); Poverty Flat (PF) and; Lodgepole Campground to Phoebe Creek (LP). The supplemental section (GC) was not surveyed every year.

Big Creek is approximately 67 km in length (Figure 2) and enters the Middle Fork Salmon River at river kilometer 28.9. A majority of the drainage is located within the Frank Church River of No Return Wilderness area. Access to the system is limited to a road in the headwaters and a hiking trail from the Smith Creek wilderness boundary trailhead to the mouth where it enters the Middle Fork Salmon River. Big Creek sections surveyed annually included a 4.7 km section from the bridge near the mouth of Jacobs Ladder Creek to the confluence with Logan Creek (JC) and a 5.6 km section from the confluence with Logan Creek to the confluence with Smith Creek (LC; Figure 2).

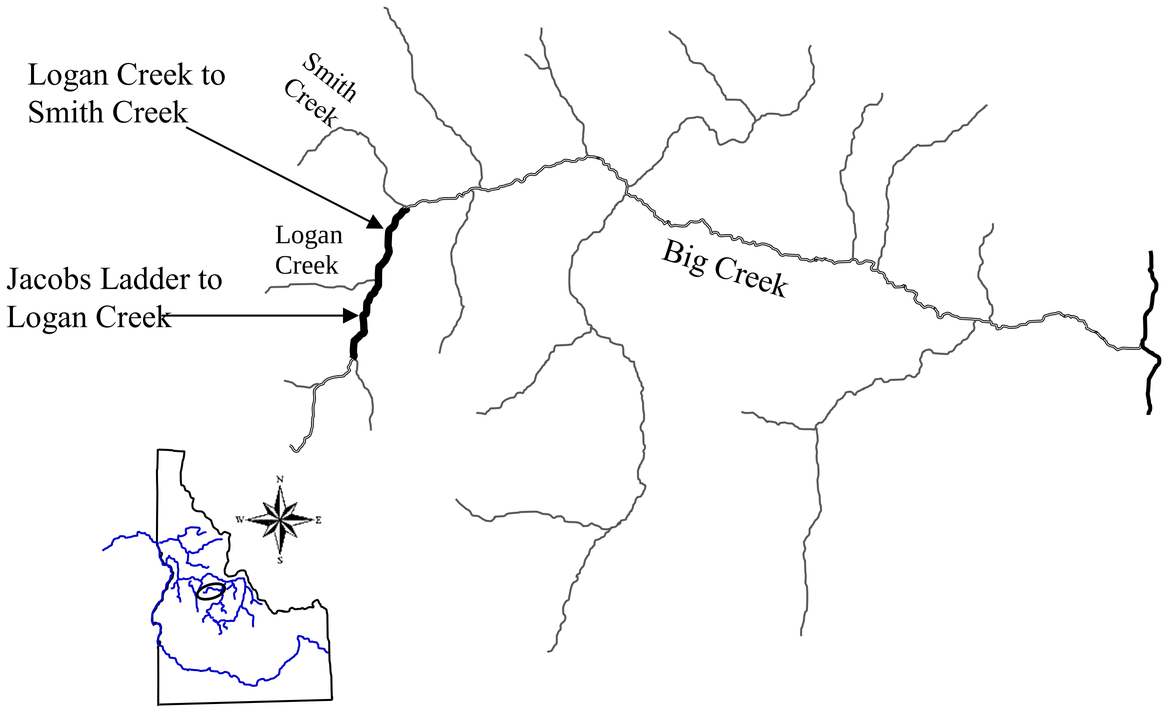


Figure 2. Map showing the Big Creek basin and stream sections surveyed during annual spawning ground surveys. Index area survey sections indicated included Jacobs Ladder to Logan Creek (JC) and Logan Creek to Smith Creek (LC).

METHODS

Spawning Ground Surveys

Data for this report were collected from multiple-pass, ground-based spawning ground surveys in the South Fork Salmon River and Big Creek. Generally, four surveys were completed on the SFSR and three were completed on Big Creek each year. Multiple-pass surveys more accurately enumerated salmon redds, effectively delineated spawn timing and distribution (Schwartzberg, 1987) and allow enumeration of carcass composition over the entire spawning period. During each pass surveyors enumerated redds, live fish and collected biological information from carcasses. Beginning in 2006 the location of all redds was marked with a

Global Positioning System (GPS) waypoint in World Standard Group (WSG) 84 in degree decimal format.

Data collected from carcasses included recovery location (GPS waypoint), fork length, presence/absence of marks and tags and sex (determined by an internal examination of the gonads). Tissue samples were collected from individuals for DNA analysis and scale samples were collected from unmarked (presumed natural-origin) fish until 2011. Scales were removed from a preferred area located two to three rows above the lateral line on a diagonal scale column running from the posterior base of the dorsal fin to the anterior base of the anal fin (Schwartzberg, 1987). Starting in 2012 the dorsal fin rays were removed for aging as it was determined to be more accurate that scale pattern analysis for post-spawn salmon carcasses (Tim Copeland, IDFG, personal communication). The second through seventh fin ray were removed by cutting through the fin ray joints, leaving the fin ray heads intact for aging. All fish were scanned using a coded wire tag (CWT) detector and snouts were removed from all fish containing a CWT. Passive Integrated Transponder (PIT) tags were identified and codes determined using a handheld PIT tag reader. Carcasses were cut open for positive identification of sex and to determine egg retention in females (measure of spawning success). Finally the caudal fin was removed from all carcasses to prevent duplicative sampling on subsequent surveys.

Carcass collections are often biased and don't accurately represent the spawning population. In general, jacks are underrepresented (Zhou, 2002) in carcass collections, resulting in a slightly skewed sex ratio favoring females and inflated estimates for average size-at-return. Hatchery fish also tend to be underrepresented (Murdoch et al. 2010), potentially affecting pHOS estimates. We did not correct for collection bias in this study but will explore correction methods in future reports.

Chinook Salmon Age Determination

Carcass age was determined through proportional assignment and length frequency analysis using age/length tables constructed using lengths of known age fish. Age/length tables constructed using the known age fish determined by CWT (for hatchery fish) or estimated ages determined by dorsal fin ray pattern analysis (for natural fish). Fin ray age determination was completed by the Idaho Department of Fish and Game age laboratory from unmarked Chinook salmon carcasses collected in the SFSR above the MHT and from Big Creek. Separate age/length tables were constructed for female and male Chinook with lengths in five cm bins. The proportion of age 4 and age 5 females and age 3, age 4 and age 5 males at each length bin was used to estimate age proportion of unknown age fish in the same length bin. Uncertain age determination based on lengths and small female carcass sample sizes during some years was a concern.

Performance Measure Calculations

Performance measures calculations followed definitions developed by the Collaborative Systemwide Monitoring and Evaluations Project (CSMEP) and adopted by the Ad Hoc Supplementation Work Group (Beasely et al. 2008). Data collected from spawning ground surveys were limited to redd counts and adult spawner composition and this determined which performance measures could be calculated. No juvenile or adult trapping or tagging was done under this project. Performance measures derived from redd counts included 1) index of spawner abundance; 2) progeny-per-parent ratio; 3) spawn timing and; 4) adult spawner distribution. Performance measures calculated from carcass recoveries included; 1) adult spawner sex ratio; 2) age class structure; 3) age at return; 4) size-at-return; 5) hatchery fraction; 6) female pre-spawn mortality and; 7) stray rate. A summary results for all performance measures calculated from the SFSR and Big Creek are presented in Appendix A.

Index of spawner abundance

Calculated from the raw measure of counts of redds in spawning areas using extensive area, multiple-pass surveys. Estimated hatchery fraction from each survey section was used to estimate an index of natural spawner abundance. Each section was surveyed from 1 to 5 times starting in late July or early August and finishing in late August for Big Creek and starting in mid-August and finishing in mid-September for the SFSR. This generally encompassed the entire spawning period for each stream.

Progeny-per-parent ratio

Progeny-per-parent ratios (P:P) were estimated using redd counts and female age and origin compositions determined from carcasses. The median of the annual P:P estimates represents the population growth rate (λ). Parent redds were the same as the total redds for a given brood year since redds constructed by both hatchery and natural females would be expected to produced progeny and contributed to natural adult returns. Progeny redds only included redds constructed by natural females, with contributions from hatchery fish removed by multiplying total redds by *1 – hatchery fraction*. Redds constructed by hatchery fish in the progeny redd calculation were subtracted because they did not originate from naturally spawning fish. Progeny redds were apportioned to a brood year by multiplying the total natural redd count estimate by the proportion of age 4 and age 5 natural female carcasses. The total progeny redds from a given brood year was equal to the sum of age 4 natural redds from one year and age 5 natural redds the following year. During years where few carcasses were recovered the mean annual age composition was used to estimate progeny redds to reduce small sample size variability.

Spawn timing

Estimated by two measures, 1) median – date where 50% of the cumulative redds were counted summed across years; 2) date that the 10^{th} and 90^{th} percent of total redds were counted. Differences in spawn timing among sections were tested using a chi-square test with the null hypothesis that Julian day distributions were equal for redd counts from all sections.

Adult spawner distribution

Estimated as the redd count distribution by section for both hatchery and natural fish.

Estimated female hatchery fraction was used to estimate the number of hatchery and natural adults spawning in each section.

Adult spawner sex ratio

Estimated as the proportion of female carcasses recovered from each stream, section and year. Comparisons among groups were made using a chi-square test with the null hypothesis of equal sex ratios.

Age-at-return

Describes the relative distribution of spawner age for a single brood year (cohort). This involves run-reconstruction for each cohort based on age class specific adult abundance estimates (ages 3-5) over multiple years. The resulting adult abundance estimate by age for each cohort is expressed as a proportional distribution. No adjustments were made to the estimates for disproportional harvest or carcass recoveries across years. Age proportions were determined using age/length tables as described above. Differences in age-at-return for hatchery and natural groups were tested using a chi-square test with a significance level of $P = 0.05$.

Age class structure

Describes the annual age distribution of the spawning population estimated from the carcass sample for hatchery and natural returns. Age proportions were determined using age/length tables as described above. Differences in age class structure for hatchery and natural groups were tested using a chi-square test with a significance level of $P = 0.05$.

Size-at-return

Size-at-return of a population is greatly affected by age composition differences when comparing hatchery and natural adults. Age composition differences between hatchery and natural Chinook salmon returning to the SFSR make any observed size-at-return differences a reflection of age rather than size. Comparing size-at-return of a single age class more accurately captures growth or size differences among adults of the same age that experiences similar freshwater and ocean environments. Size-at-age estimates were calculated for male and female spawning adults in order to avoid sex differences. Statistical tests comparing natural and hatchery carcasses in the SFSR were made using at t-test of means.

Hatchery fraction – pHOS

Hatchery fraction or proportion of hatchery-origin spawners (pHOS) was estimated by dividing the total number of hatchery carcasses by the total number of carcasses for the entire stream and within each section. Hatchery fraction for each section was compared using a chi-square test with the null hypothesis that the hatchery fraction was equal in all sections and a significance level of $P = 0.05$.

Pre-spawn mortality

Calculated by dividing the total number of females that retained $\leq$ 25% of their eggs by the total number of female carcasses recovered by origin and by section (SFSR only). Significant differences in percent female pre-spawn mortality between hatchery and natural carcasses were tested using a two-way Analysis of Variance (ANOVA) with year and origin as factors.

Stray rate

In the SRSR the stray rate was calculated as the proportion of tagged hatchery fish, identified by CWT, originating from outside the SFSR. Total strays were determined by expanding tag recoveries by the tag rate at release. In Big Creek the stray rate was calculated as the proportion hatchery Chinook salmon as identified by an adipose fin clip.

Spawner abundance

In previous reports (Young and Blenden, 2011; Kucera and Blenden, 1999) the performance measure *spawner abundance* was not estimated because it was impossible to directly enumerate the spawning populations in the SFSR or Big Creek. Alternative approaches such as expanding the number of redds by a standard value (Plan for Analyzing and Testing Hypotheses; PATH; Beamesderfer et al. 1998) would provide estimates spawner abundance estimates. However, this method provides added uncertainty associated with the selected expansion value and increased variability given the potential for differences between origin-types or among stream reaches. Utilizing a standard expansion factor results in trends identical to that estimated from the redd count data (*Index of Spawner Abundance*), further limiting its effectiveness as a monitoring parameter. Consequently, lacking a fish enumerating station, alternative methods will need to be developed in order to directly measure Chinook salmon abundance in the SFSR and Big Creek.

The existence of in-stream Passive Integrated Transponder (PIT) tag detection arrays currently operating in the SFSR (SFG - SFSR at Guard Station Bridge, 522.303.215.030 and; KRS – SFSR at Krassel Creek, 522.303.215.065;http://www.ptagis.org/sites/map-of-interrogation-sites) allow for an estimate of PIT tags in the SFSR. Combined with the systematic tagging of natural Chinook salmon at Lower Granite Dam by the Integrated Status and Effectiveness Monitoring Project (ISEMP; http://southforkresearch.net/wp/), estimates of natural Chinook salmon above the KRS array can be determined. Subtracting fish trapped at the MHW, Tribal and sport harvest estimates and prespawn mortality from the total estimate of natural Chinook at KRS, the total number of natural fish spawning below the MHW can be determined.

RESULTS AND DISCUSSION

South Fork Salmon River Chinook Salmon Redd Counts

Index of spawner abundance

An index of spawner abundance was estimated using multiple pass index area redd counts in four sections below the MHT. The five-year annual average redd count was 270 (S.D. = 56.2) enumerated from 2012 – 2016, ranging from a low of 191 in 2013 to a high of 330 in 2012. Redd counts decreased compared to the previous five-year period (2007 – 2011 = 472; S.D. = 193.9). From 1990 - 2016 the annual redd counts ranged from a minimum of 16 in 1996 to a maximum of 748 in 2010 (Table 1). Total annual redd counts from 1990 – 2016 combined from each of the four sections revealed high year-to-year variability and a positive linear trend (slope =8.9; Figure 3). The coefficient of variation (C.V.) across years was relatively high for all sections with the highest variation observed in the WD and DC sections. The average redd distribution determined by the proportion of redds counted in each section indicated an even distribution of spawning across the four sections (Table 1).

Table 1. Redd counts from four sections in the South Fork Salmon River determined from annual multiple-pass spawning ground surveys from 1990 – 2016. WD – weir to Dime Creek; DC – Dime Creek section; PF – Poverty Flat; LP – Logdepole Campground to Phoebe Creek.

Year	WD	DC	PF	LP	Total
1990	4	26	137	146	313
1991	22	23	39	117	201
1992	60	30	27	2	119
1993	82	39	108	135	364
1994	21	23	22	26	92
1995	1	2	5	8	16
1996	6	4	13	17	40
1997	59	71	51	72	253
1998	31	19	33	51	134
1999	18	18	17	44	97
2000	62	107	37	66	272
2001	108	134	74	130	446
2002	78	171	73	164	486
2003	81	85	58	146	370
2004	146	285	122	162	715
2005	67	195	44	60	366
2006	53	105	44	72	274
2007	47	118	41	38	244
2008	249	70	90	78	487
2009	123	71	64	83	341
2010	201	163	159	225	748
2011	170	115	126	131	542
2012	99	91	51	89	330
2013	55	35	42	59	191
2014	41	32	131	113	317
2015	61	66	52	67	246
2016	61	75	48	81	265
5-year Proportion	0.23	0.22	0.25	0.29	1.00
5-year Mean	63.4	59.8	67.8	78.8	269.8
St. Dev.	21.5	25.6	36.5	24.4	56.2
CV	0.34	0.43	0.54	0.31	0.21

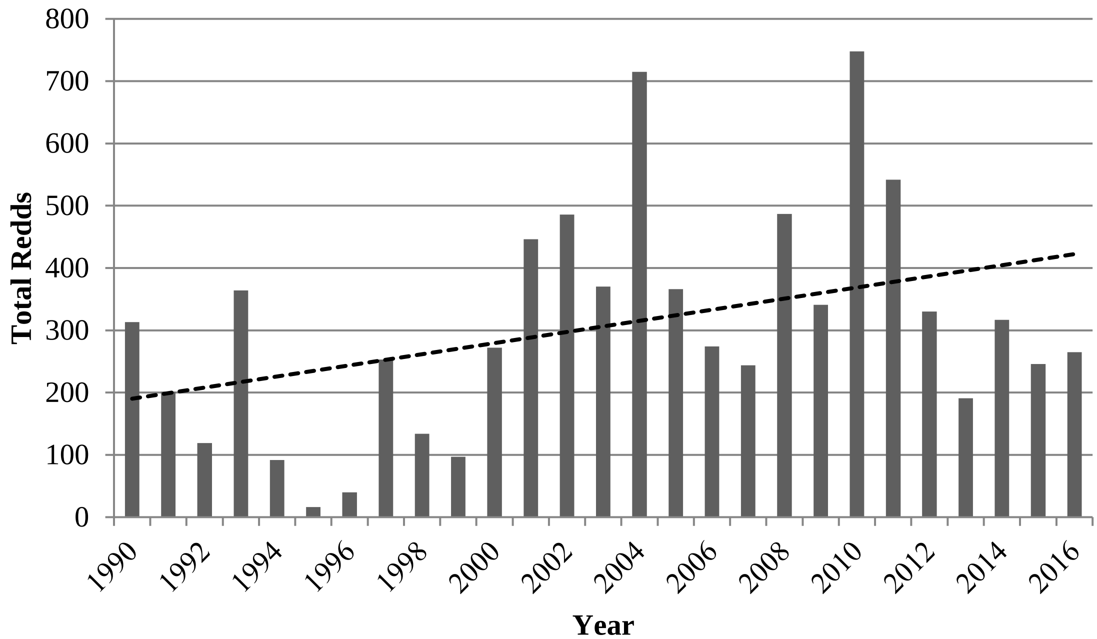
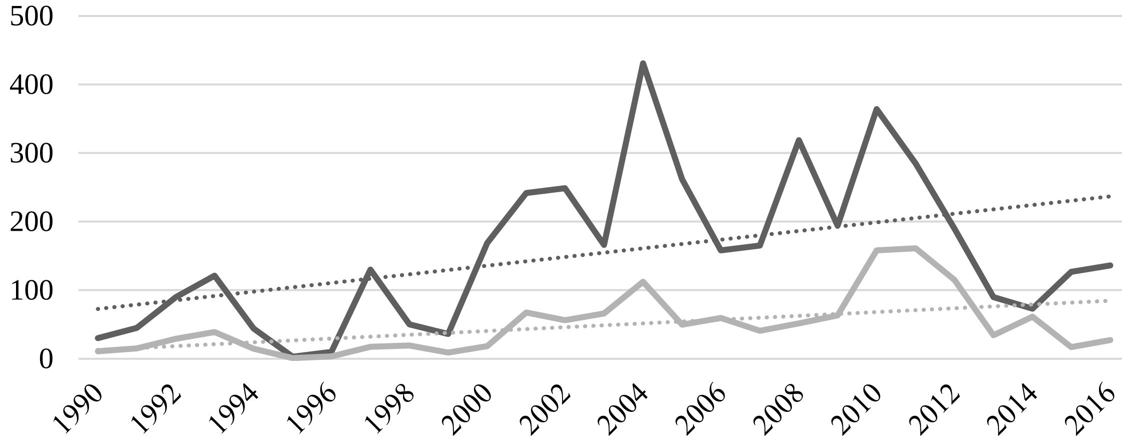


Figure 3. Total redds counted from four sections of the South Fork Salmon River below the McCall Hatchery Weir from 1990 – 2016. Dashed line demonstrates the linear trendline for the data series.

The estimated number of redds constructed by natural fish (index of natural fish abundance) was estimated by multiplying the total redds by one minus the estimated female hatchery fraction after subtracting female prespawn mortality. Because the hatchery fractions differences in the WD and DC sections and in the PF and LP sections were not significantly different (T-test, $P < 0.05$), the four sections were combined into two regions, an upper (WD and DC) and lower (PF and LP), for the estimation of natural-origin redds (Figure 4). Trend line slopes for the estimated natural redds were similar in the upper and lower SFSR, suggesting consistent increases in natural abundance in both areas (WD + DC natural redd slope = 2.76; PF + LP natural redd slope = 2.61). Comparing slopes of total redds and estimated natural redds demonstrated that the steepest slope was observed for total redds in the WD + DC sections (WD + DC total redd slope = 6.32). These results suggested that the increasing number of total redds observed in the WD and DC sections were largely the result of an increase in hatchery spawning in the area just below the MHT.

a.



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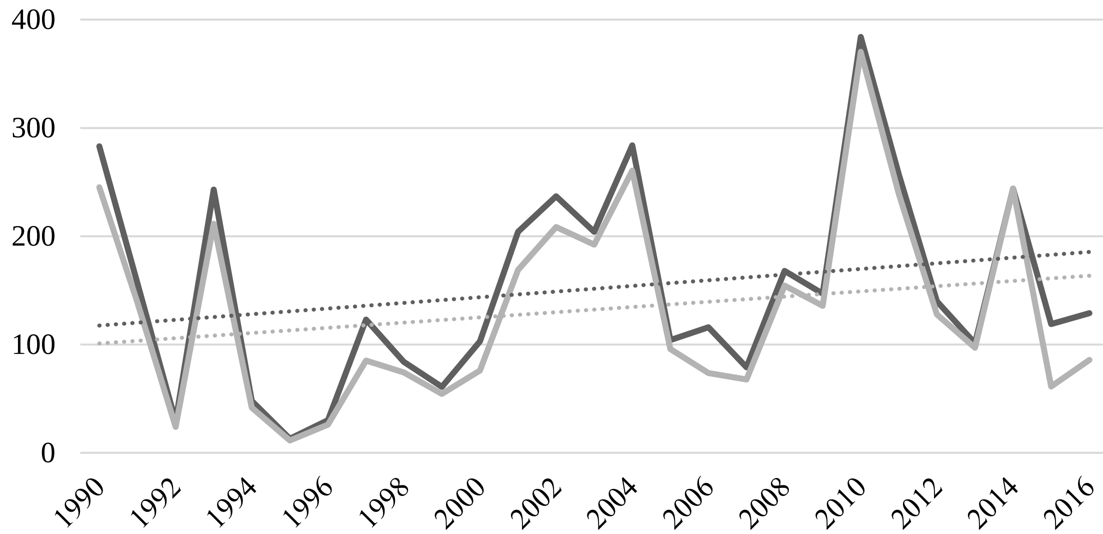


Figure 4. Total Chinook salmon redds (black) and estimated number of Chinook salmon natural origin redds (gray) counted from 1990 – 2016. Natural redds were estimated using the proportion of natural female carcasses recovered in each section after subtracting the hatchery and natural female prespawn mortalities. Solid and dashed trendlines demonstrate the linear trends in abundance for total redds and natural redds, respectively. a. Combined annual counts from the Weir to the confluence with Dime Creek (WD) and Dime Creek (DC) sections. b. Combined annual counts from the Poverty Flat (PF) and Lodgepole Campground to Phoebe Creek Bridge (LP) sections.

Progeny-per-parent ratio

Similar to the estimation of adult spawner abundance, a redd count index of abundance was used to estimate annual progeny-per-parent ratios (P:P), and the median annual value represented the population growth rate (λ). In this analysis redd counts were used as an index of female spawner abundance, assuming that each female constructed a single redd. Although relying on a measure of female abundance did not account for total abundance, a relatively consistent sex ratio among years with a coefficient of variation (C.V.) of less than 15% for natural fish (including jacks) provided a reasonably accurate estimate of P:P with enough confidence to provide status and trend information on the naturally spawning population of Chinook salmon in the SFSR below the MHT. Small female carcass sample sizes resulting in uncertain age compositions were a concern for some years (1990 – 1995). To reduce uncertainty, a mean annual age composition was used in years with fewer than ten female carcass recoveries.

An analysis using combined data from all four sections collected from 1990 – 2016 provided P:P estimates for brood years 1990-2011. Overall lambda was estimated at 0.68 (Table 2) indicating that the population was not reaching replacement over this time period. Annual P:P values ranged from a low of 0.08 in brood year 1991 to a high of 3.88 in brood year 1996 and was characterized by two periods with consistently low P:P from 1990 – 1994 and from 2001 – 2005) and one period with consistently high P:P from 1995 – 2000. Although not all hatchery fish were marked prior to 1995, the impact of misidentifying hatchery fish as natural had a minimal impact on the analysis because redds constructed from 1990 – 1993 were all parent redds, so misidentifying origin did not affect the calculations since all females, regardless of origin, combined in the parent redd value. Progeny redd estimates in 1994 and 1995 would have been affected by the presence of unmarked hatchery fish. However, very low adult returns and low P:P estimates for those years indicated that if unmarked hatchery fish did contribute to the progeny redd estimate, their effect was minimal.

Table 2. Chinook salmon parent redds, progeny redds and Progeny:Parent (P:P) ratio estimated using total parent redds (natural and hatchery) and estimated natural-origin progeny redds in the upper mainstem South Fork Salmon River. Natural redds were estimated based on the proportion of female natural carcasses recovered each year. Lamda (λ) was estimated as the median progeny-per-parent value.

Brood Year	Parent Redds	Return Redds	P:P
1990	313	45	0.14
1991	201	15	0.08
1992	119	77	0.65
1993	364	65	0.18
1994	92	82	0.89
1995	16	65	4.06
1996	40	155	3.88
1997	253	307	1.21
1998	134	167	1.24
1999	97	341	3.51
2000	272	261	0.96
2001	446	160	0.36
2002	486	105	0.22
2003	370	155	0.42
2004	715	153	0.21
2005	366	348	0.95
2006	274	468	1.71
2007	244	331	1.36
2008	487	213	0.44
2009	341	245	0.72
2010	748	193	0.26
2011	542	79	0.15
		λ	0.68

Spawn timing

Chinook salmon redd count data from 1990 – 2016 was used to estimate spawn timing for four sections in the SFSR to compare the most recent five-year period (2012 – 2016) with the long term average (Table 3). Median, 10th percentile and 90th percentile values indicated that the earliest spawn timing occurred in the WD section, and got progressively later moving downstream. Median spawn timing in all four sections was slightly earlier for the recent five-year period compared to the long term data.

Table 3. Chinook salmon spawn timing including Median, 10th percentile and 90th percentile dates for 4 sections of the South Fork Salmon River below the McCall Hatchery Trap from a. 2012 – 2016 and; b. 1990 – 2016.

a.

Section	Median	10th percentile	90th percentile
WD	8/31	8/23	9/9
DC	9/1	8/25	9/9
PF	9/6	8/28	9/11
LP	9/7	8/30	9/14

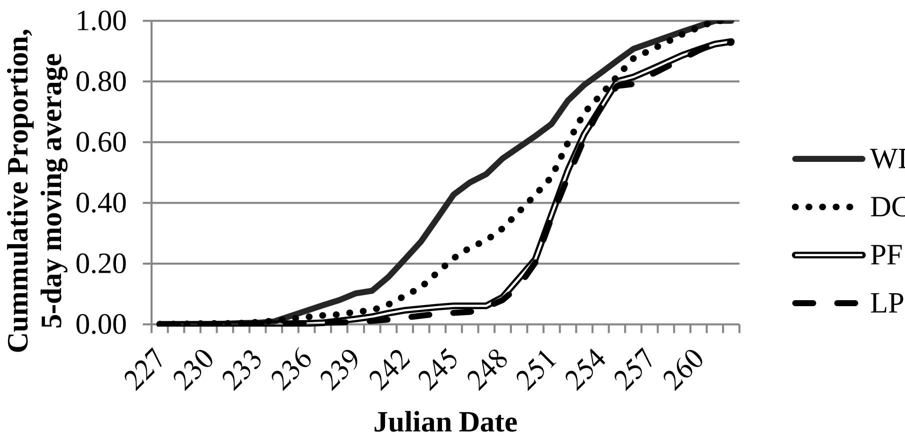
b.

Section	Median	10th percentile	90th percentile
WD	9/1	8/24	9/9
DC	9/3	8/26	9/10
PF	9/6	8/25	9/13
LP	9/7	8/29	9/15

Graphing the cumulative redd counts pooled for years 2012 – 2016 and 1990 - 2016 (Figure 5) revealed similar patterns of spawn timing with females spawning earliest in the WD section and the latest in the LP section. All-section pairwise comparisons of spawn timing distributions using a Kolmogorov-Smirnov two-sample test (K-S test) revealed that spawn timing in the WD section was significantly earlier ($P < 0.05$) than both the PF and LP sections for the most recent ten-year period and the long term data set and spawn timing in the DC section was significantly earlier than that in the LP section for the most recent ten-year period. No other comparisons were significant.

Although the differences were not large, the slightly earlier spawning in the upper two sections may be the result of selection in the hatchery or environmental temperature differences (Quinn et al. 2002). If spawn timing of hatchery fish was altered by hatchery broodstock selection protocols (non random selection for early or late spawning individuals) then the significantly higher proportion of hatchery fish in the upper two sections (WD and DC) may have skewed the overall spawning timing earlier in those sections. Selection in the hatchery has been demonstrated to significantly alter spawn timing in many salmonid species (Quinn et al. 2002). However, spawning of broodstock at the McCall Hatchery weir has not changed over the life of the program, with the first spawn occurring on the same approximate date from 1980 – 2007 (Hutchinson, 1982; McPherson et al. 2008). There is evidence for altered spawn timing in another Snake River basin Chinook salmon population. Hatchery Chinook salmon in the Imnaha River spawn significantly later and in predominantly downstream sections of the river compared to natural fish and the authors suggested that inadvertant hatchery selection for later spawn timing was responsible (Hoffnagle, et al. 2008). A second and more likely reason was that earlier spawn timing in upstream locations resulted from a physical temperature gradient forming throughout the system, with adults spawning later in the lower two sections (PF and LP) due to warmer water temperatures experienced early in the spawning period. Our data did indicated that average August temperatures increased as you move downstream from the McCall Hatchery weir (see *Environmental Monitoring* section below) and this may have contributed to to later spawn timing. The relationship between warmer temperatures and later spawn timing has been demonstrated for numerous salmon species (Quinn, 2005).

a.



b.

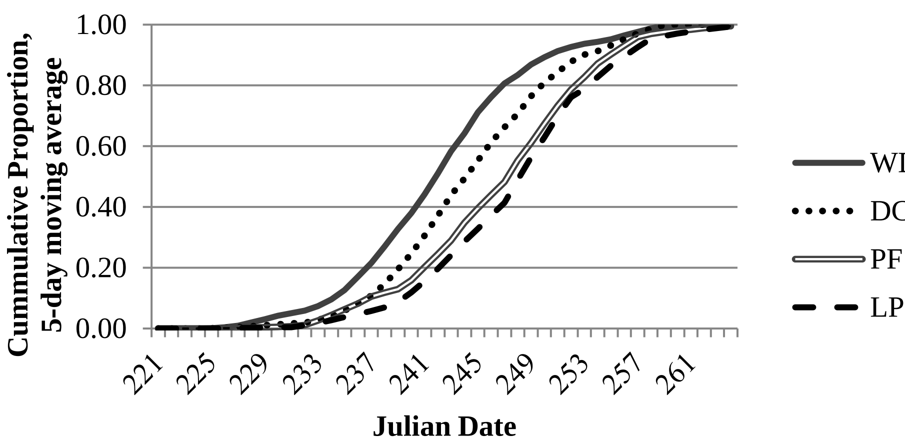


Figure 5. Five day moving average cumulative Chinook salmon redd counts from four sections in the South Fork Salmon River determined from annual multiple-pass spawning ground surveys from a. 2012 – 2016 and; b. 1990 – 2016. WD – weir to Dime Creek; DC – Dime Creek section; PF – Poverty Flat; LP – Lodgepole Campground to Phoebe Creek.

Adult spawner distribution

Chinook salmon adult spawner distribution was investigated by analyzing the proportion of redds in each section using combined data from 1990 – 2016. Comparing the most recent five-year period with the long-term average distribution by section revealed no change in distribution. However, results suggest that the long-term trend in redd distribution has shifted. In this analysis we combined the redd count distributions for the WD and DC sections (WD +

DC group) and the PF and LP sections (PF + LP group) because of similar spawn timing, hatchery fraction and geographic proximity. Results demonstrated that long-term trends were positive, indicating that the spawner distribution has shifted with higher proportions of both total and natural redds constructed in the upper two sections (Figure 6).

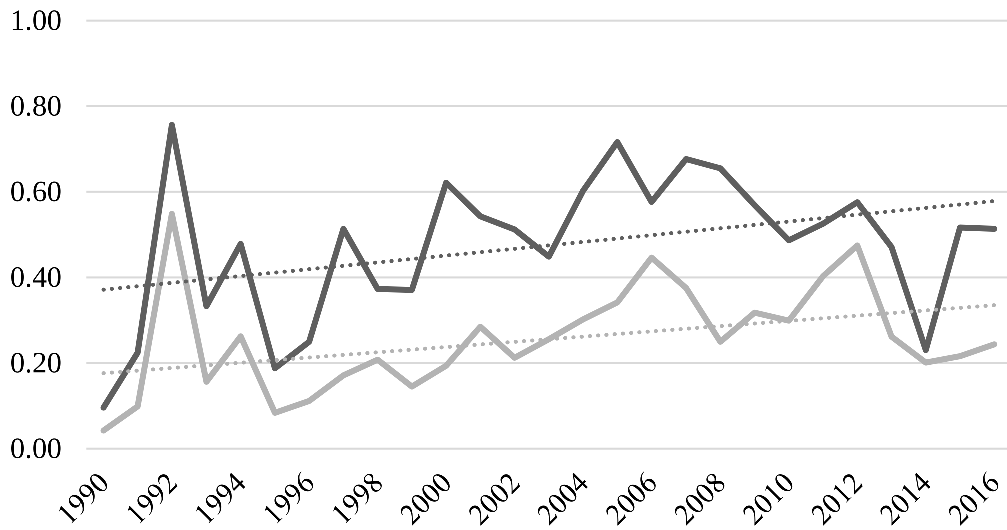


Figure 6. Chinook salmon spawner distribution estimated as the proportion of total redds (solid line) and natural redds (dashed line) observed in the weir to Dime Creek (WD) and Dime Creek (DC) sections from 1990 – 2016. Linear trend line over this time period for all (solid trend line) and natural (dashed trend line) redds.

South Fork Salmon River Carcass Surveys

Sex ratios

From 1990 – 2016 a total of 7,431 carcasses were recovered where sex and origin could be determined including 2,142 hatchery females, 1,141 hatchery males and 546 hatchery jacks, 1,788 natural females, 1,587 natural males and 227 natural jacks (Table 4). For all carcasses, including jacks, the average proportion female was 0.60 (S.D. = 0.09) for hatchery carcasses and 0.49 (S.D. = 0.07) for natural carcasses, similar to the most recent five-year average (hatchery = 0.60, S.D. = 0.11; natural = 0.50, S.D. = 0.09). Without jacks, the proportion of female hatchery carcasses averaged 0.68 (S.D. = 0.01) and female natural carcasses averaged 0.53 (S.D. = 0.05). A Z-test used to evaluate the average annual difference in proportion female between hatchery and natural carcasses revealed significant differences between the proportion of hatchery and natural female carcasses for all carcasses ($Z = 10.2$; $P = 0.001$) and adults only ($Z = 8.24$; $P = 0.001$). Prior to 1995 not all hatchery adults were marked making it difficult to determine origin. This limited the number of known origin carcasses and made it impossible to compare hatchery and natural fish for metrics such as sex ratio. Consequently, a majority of the carcasses recovered from 1990 – 1995 were designated as unknown origin and the proportion female from those years were not included in Table 4 or in the statistical analysis.

Table 4. Hatchery and natural female, male and jack carcasses recovered in the South Fork Salmon River from 1990 – 2016 and proportion female hatchery and natural from 1997 – 2016. S.D. – standard deviation; C.V. – coefficient of variation.

Year	Hatchery Female	Hatchery Male	Hatchery Jacks	Natural Female	Natural Male	Natural Jack	Proportion Female Hatchery	Proportion Female Natural
1990	1	0	0	3	1	0	N/A	N/A
1991	4	1	0		0	0	N/A	N/A
1992	9	6	2		0	0	N/A	N/A
1993	5	0	0	14	5	1	N/A	N/A
1994	5	2	1	11	6	1	N/A	N/A
1995	1	0	0	4	3	1	N/A	N/A
1996	2	8	4	8	10	2	N/A	N/A
1997	105	82	0	46	48	1	0.56	0.48
1998	15	6	2	55	43	3	0.65	0.54
1999	17	10	8	34	35	11	0.49	0.43
2000	201	105	86	44	44	48	0.51	0.32
2001	305	238	70	164	221	18	0.50	0.41
2002	272	176	94	245	188	24	0.50	0.54
2003	96	95	37	201	170	17	0.42	0.52
2004	131	41	21	98	73	5	0.68	0.56
2005	98	31	12	30	28	0	0.70	0.52
2006	35	10	5	26	29	1	0.70	0.46
2007	28	9	5	11	8	1	0.67	0.55
2008	229	78	85	70	93	6	0.58	0.41
2009	116	48	50	116	105	24	0.54	0.47
2010	141	37	14	168	144	6	0.73	0.53
2011	71	12	18	168	109	19	0.70	0.57
2012	55	12	2	83	72	3	0.80	0.53
2013	32	23	2	34	39	25	0.56	0.35
2014	48	26	18	112	78	8	0.52	0.57
2015	61	42	9	16	11	3	0.54	0.53
2016	59	43	1	27	23	0	0.57	0.54
Totals	2142	1141	546	1788	1587	227		
						Mean	0.60	0.49
						S.D.	0.10	0.07
						C.V.	0.17	0.15

Age-at-return

Spawning ground surveys conducted from 1990 – 2016 recovered a total of 6,084 Chinook salmon carcasses of known origin. Data prior to 1993 was not used in the analysis because marking strategies and poor returns limited data usefulness for comparing hatchery and natural returns from carcass. Based on known-age fish, the length bins were relatively accurate at determining fish age by fork length. However, the relatively high error rate for determining age 5 fish indicated that these results should be viewed with caution.   The analysis of age-at-return as determined by aging individual fish with tags (CWT or PBT) and fin rays would provide a more accurate estimate for this performance measure.

Analyzing trends for brood years 1993 through 2011 revealed relatively stable age-at-return ratios for both hatchery and natural fish (Figure 7). Nearly all slopes were near zero, with a slight positive trend for age 3 fish and a corresponding negative trend for age 5 fish for both hatchery and natural populations.

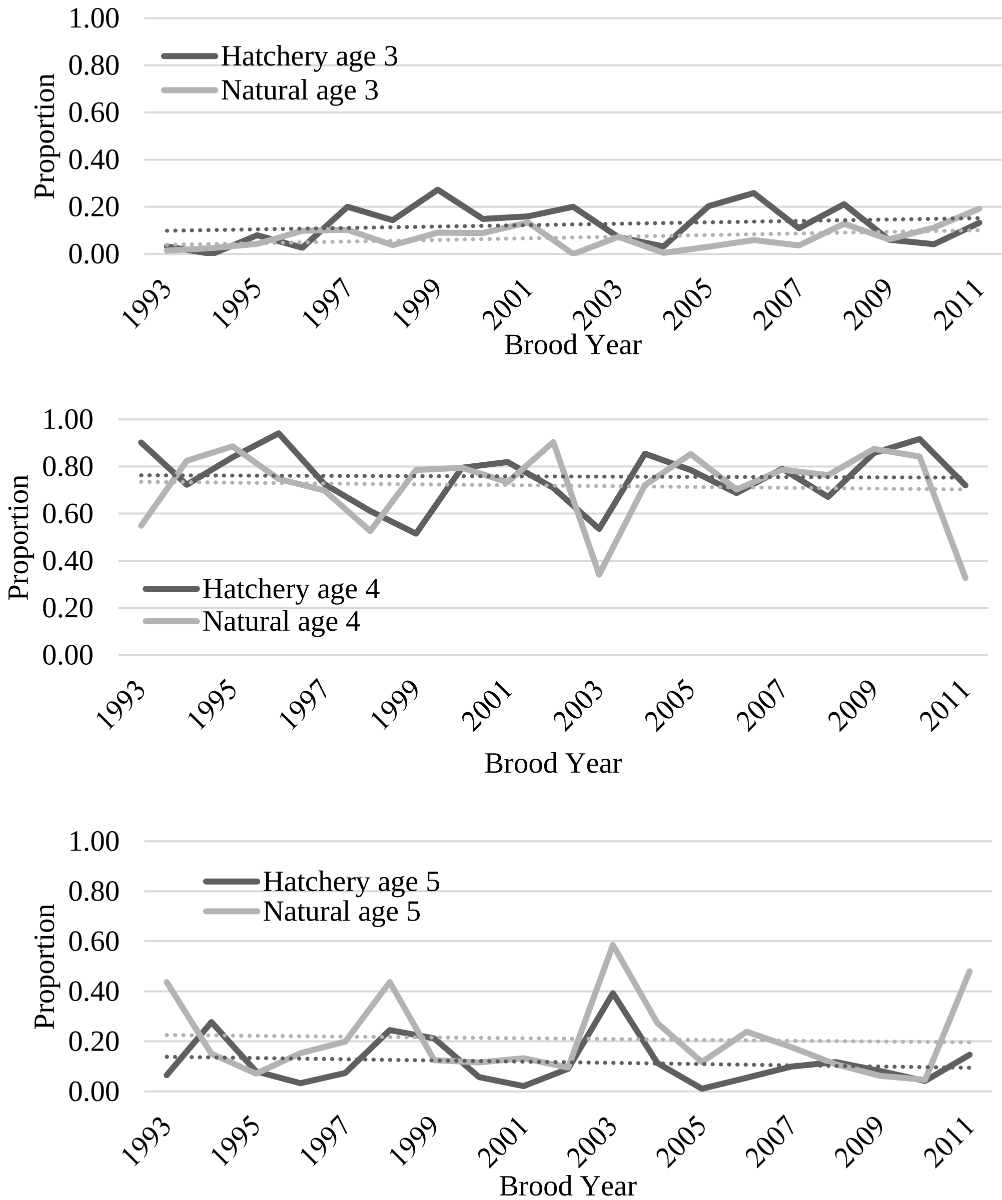


Figure 7. Annual trends in age 3 (top), age 4 (middle) and age 5 (bottom) hatchery (solid line) and natural (dashed line) Chinook salmon estimated from carcasses recovered in the South Fork Salmon River for brood years 1993 through 2011. Dotted and dashed lines demonstrate the linear trend line for natural and hatchery carcasses, respectively.

Age Structure

The age structure metric measures the age composition of the spawning population. Spawning ground surveys conducted from 1990 – 2016 recovered 6,205 carcasses with identifiable origin including 1,663 hatchery females, 1,159 hatchery males, 1,683 natural females and 1,700 natural males. The age structure was adjusted by removing female prespawn mortalities since these fish did not contribute to the spawning population. Results demonstrated that the composition of hatchery and natural populations was dominated by age 4 spawners (Figure 8). The natural population had a higher proportion of age 5 spawners compared to the hatchery population.

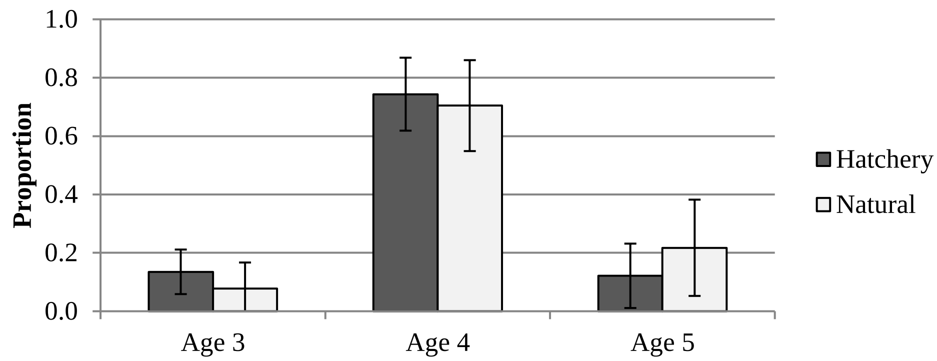


Figure 8. Age structure of the South Fork Salmon River Chinook salmon presented as the average proportions of age 3, age 4 and age 5 fish in the spawning population from 1997 – 2016. Error bars represent standard deviations.

Size-at-return

Size-at-return is greatly affected by age composition differences when comparing populations. The hatchery and natural age composition differences presented above make any observed size-at-return differences influenced more by age than growth. A more accurate comparison is size-at-return comparisons by age class, which reveals actual growth differences between origin-type.

Size-at-return comparisons as estimated by average fork lengths were completed for hatchery and natural jacks and age four adults (Table 5). The low numbers of returning age 5 adults combined with the relatively high error rate associated with length-based age determination of fish in this age class invalidated this comparison. A non-parametric t-test comparison of median fork length between hatchery and natural females and males revealed significant differences between the origins of each sex (Kruskal-Wallis rank test; $P < 0.005$). The observed mean fork length differences were small (Table 5), and though statistically significant, were likely not biologically significant and resulted mainly from the large sample size used in the test.

Annual average fork lengths of age 4 female and male Chinook salmon have decreased from 1997 to 2016 for both origin types (Figure 9). The average female size decreased at a steeper rate compared to males for both types. These results indicate that the average size-at-return has decreased in the SFSR population over the past 20 years. The negative trend line was influenced by the spike in average size observed in 1998. However, starting the time series in

1999 still resulted in a negative size trend for all origin/sex types except hatchery males (data not shown), suggesting that the size decrease is genuine.

Table 5. Number (N) mean, standard deviation (S.D.) and coefficient of variation (C.V.) for size-at-return measured by fork length (centimeters) for hatchery and natural Chinook salmon carcasses recovered in the South Fork Salmon River from 1990 – 2016.

	Hatchery			Natural		
	Age 4		Jack	Age 4		Jack
	Female	Male		Female	Male	
N	1501	643	372	1277	1110	213
Mean	79.4	80.5	58.7	79.8	79.8	58.9
S.D.	2.2	2.0	2.3	2.6	1.9	3.0
C.V.	0.03	0.02	0.04	0.03	0.02	0.05

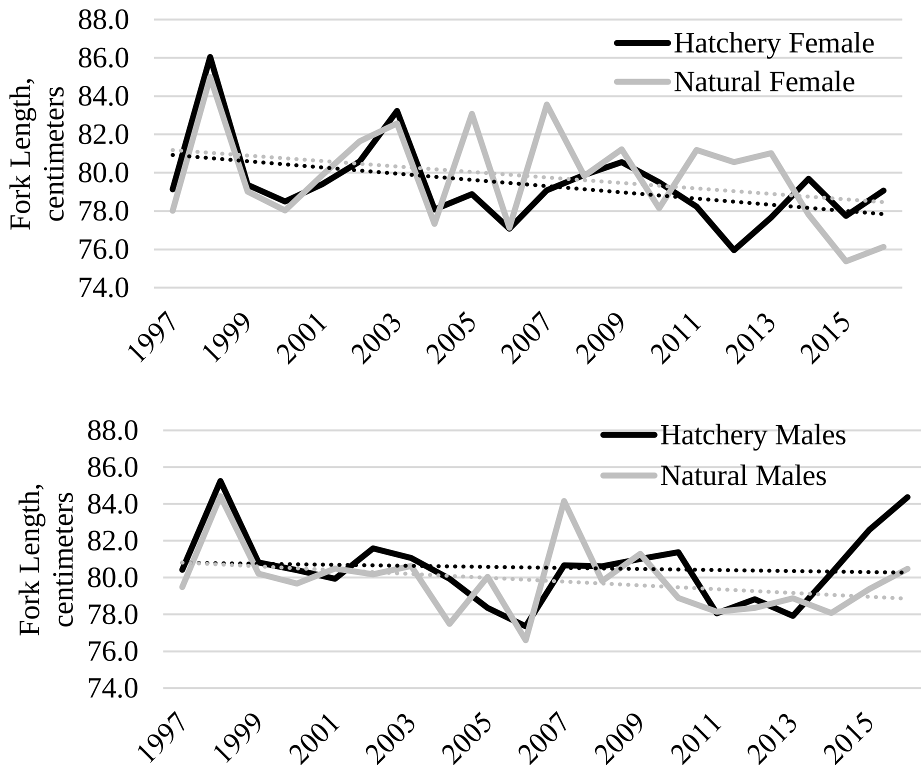


Figure 9. Annual average fork lengths of age 4 female (top) and male (bottom) hatchery and natural Chinook salmon carcasses recovered in the South Fork Salmon River from 1997 – 2016.

Hatchery fraction - pHOS

A total of 7,409 known-origin Chinook salmon carcasses were recovered from 1990 – 2016 including 3,824 hatchery and 3,585 natural for an overall combined hatchery fraction (pHOS) equal to 0.52. Annual pHOS estimates ranged from a low of 0.18 in 1998 to a high of 0.73 in 2000 with an annual average equal to 0.49 (S.D. = 0.18). Prior to 1997 poor returns, low carcass recovery rates and the presence of unmarked hatchery fish limited data usefulness, making it impossible to estimate annual pHOS.

The pHOS estimate for the entire survey area was relatively high. Separating by section revealed highly variable pHOS rates, ranging from an average of 0.68 (S.D. = 0.16) the upper two sections just below the MHW to an average of 0.18 (S.D. = 0.16) in the lower two sections (Figure 10). Recent changes in pHOS demonstrated a significant decrease in hatchery interactions in the DC section offset by increased hatchery interactions in the PF section, with the WD and LP sections at levels similar to the long-term averages. Relatively high hatchery fractions in the most recent five year period (Table 6), especially for the lower sections (PF and LP) were not solely caused by increasing hatchery fish spawning in these areas, but rather, a from reduced natural returns combined with a small increase in hatchery fish. For example, from 2012 – 2016 recoveries of hatchery carcasses in the LP section ranged from 0 (2013) to a maximum of 6 (2015). Recoveries of hatchery carcasses did increase in the PF section, especially for unclipped integrated hatchery fish.

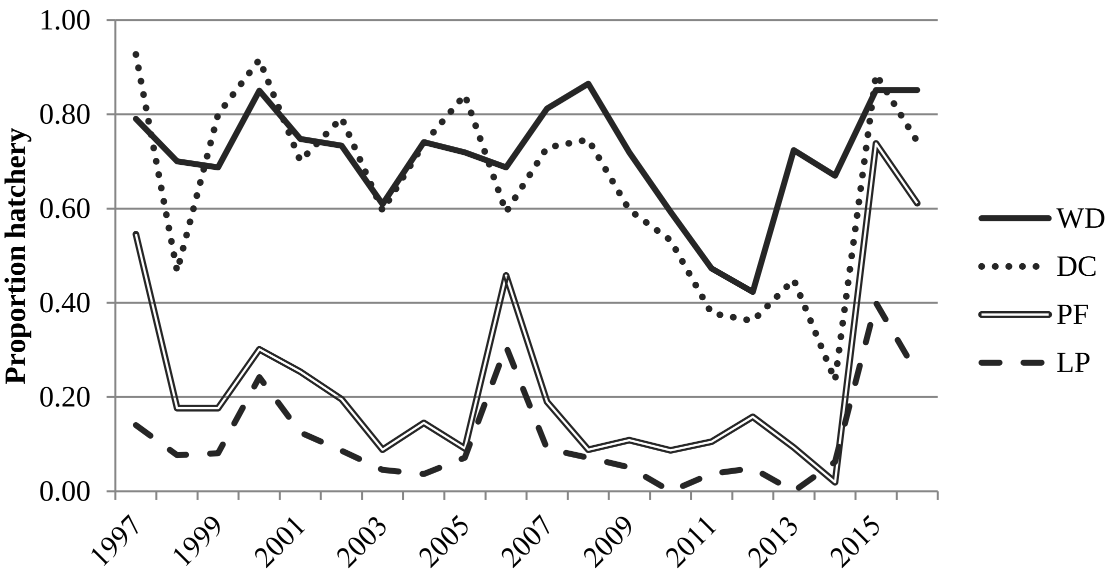


Figure 10. Annual hatchery fraction estimates measured as the proportion hatchery carcasses recovered from four sections of the South Fork Salmon River. WD – weir to Dime Creek; DC – Dime Creek section; PF – Poverty Flat; LP – Lodgepole Campground to Phoebe Creek.

Table 6. Hatchery fraction measured as the mean proportion of hatchery carcasses recovered from four sections of the South Fork Salmon River from 1997 – 2016 and from 2012 – 2016. S.D. – standard deviation; WD – weir to Dime Creek; DC – Dime Creek section; PF – Poverty Flat; LP – Lodgepole Campground to Phoebe Creek.

	Section			
	WD	DC	PF	LP
1997 - 2016				
Mean	0.71	0.63	0.18	0.11
S.D.	0.12	0.20	0.20	0.11
2012-2016				
Mean	0.70	0.53	0.32	0.15
S.D.	0.18	0.27	0.33	0.17

Excess hatchery fish returning to the MHW were often outplanted to downstream sites to increase harvest opportunities and augment natural spawning. All outplanted fish were marked with an opercle tag or punch so they could be identified at the weir or during carcass surveys. Fish that were outplanted multiple times were marked with additional opercle punches. From 1996 – 2016 adult outplants comprised 27% of the recovered hatchery carcasses, with a range of 0 in 1998 to 0.58 in 2005 (Table 7). There was no difference in the proportion of male compared to female outplants (data not shown). Although the release sites varied, fish were generally released at Dollar Creek Bridge or at a site approximately ½ mile above Roaring Creek. Both sites are in or just below the DC section. As expected, a majority of the marked carcasses were recovered in the DC or WD sections with less than 3% of the marked carcasses recovered in the PF and LP sections (34/1,053). These results suggested that in the absence of adult outplants the overall hatchery fraction would be reduced by approximately ten percent in the upper two sections and assuming that the outplant release location remains the same, outplants did not significantly increase pHOS or hatchery/natural interactions in the lower two sections.

Table 7. Total hatchery, number marked outplanted and proportion outplanted carcasses recovered during South Fork Salmon River Chinook salmon spawning ground surveys from 1996 – 2016. The number of right opercle punches (ROP) or left opercle punches (LOP) represented the number of punches which corresponds to the number of times the fish was captured at the weir and released downstream.

Year	Hatchery carcasses	Marked outplant	Proportion outplanted	Mark type
1996	14	4	0.29	1 ROT
1997	189	91	0.48	1LOP 1ROT 1ROP ROT
1998	23	0	0.00	
1999	35	15	0.43	1LOP
2000	393	228	0.58	1LOP 1ROP 2LOP 2ROP
2001	723	69	0.10	1LOP 1ROP 2ROP
2002	546	220	0.40	ROP
2003	228	17	0.07	1ROP
2004	193	92	0.48	1LOP 1ROP 2LOP 2ROP 3ROP
2005	145	56	0.39	1LOP 1ROP 2ROP
2006	50	11	0.22	1ROP
2007	42	12	0.29	1LOP 1ROP
2008	392	51	0.13	1LOP
2009	221	39	0.18	1ROP 2ROP
2010	189	88	0.47	1LOP 1ROP 2LOP
2011	101	15	0.15	1LOP 1ROP
2012	69	17	0.25	1LOP 1ROP
2013	58	9	0.16	1LOP
2014	92	6	0.07	1LOP 2ROP
2015	106	14	0.13	1LOP 1ROP
2016	91	8	0.09	1LOP 1LOP/1ROP
Total	3,900	1062	0.27	

[1]ROT – right opercle tag; 1LOP – one left opercle punch; 1ROP – one right opercle punch; 2LOP – two left opercle punches; 2ROP – 2 right opercle punches; 3ROP – three right opercle punches.

Female pre-spawn mortality

All Chinook salmon carcasses were cut open to determine sex and, for females, percent spawned. Females judged to have retained greater than 75% of their eggs were categorized as pre-spawn mortalities (PM). From 1990 – 2016 a total of 3,789 female carcasses were assessed for egg retention with 525 (13.9%) determined to be PM (Table 8). Annual female PM averaged 0.11 (S.D. = 0.09) and ranged from zero (1995 and 1996) to 0.40 in 2001. Carcass recoveries from 1990 through 1999 were combined because low annual sample sizes prevented the estimation of annual PM rates.

Table 8. Hatchery- and natural-origin female pre-spawn mortality and spawned carcass recoveries from 1990 – 2016 from the South Fork Salmon River. Pre-2000 included combined carcass recoveries from 1990 – 1999. PM – pre-spawn mortality.

	Hatchery-origin			Natural-origin		
	PM	Spawned	Proportion PM	PM	Spawned	Proportion PM
Pre-2000	14	147	0.09	5	163	0.03
2000	3	191	0.02	0	43	0.00
2001	146	154	0.49	37	126	0.23
2002	26	243	0.10	8	233	0.03
2003	36	57	0.39	16	184	0.08
2004	41	88	0.32	3	94	0.03
2005	2	89	0.02	0	28	0.00
2006	3	30	0.09	2	23	0.08
2007	3	22	0.12	0	10	0.00
2008	30	184	0.14	4	63	0.06
2009	10	89	0.10	4	109	0.04
2010	21	113	0.16	4	158	0.02
2011	11	53	0.17	9	157	0.05
2012	9	39	0.19	2	78	0.03
2013	3	24	0.11	2	29	0.06
2014	42	4	0.91	8	104	0.07
2015	14	45	0.24	0	14	0.0
2016	6	47	0.11	1	2	0.04
Totals	358	1523	0.24	96	1498	0.06

Female PM rates were significantly higher in hatchery compared to natural adults (t-test; t = 3.14; P = 0.004). The mean annual female PM rate for hatchery fish was 0.24 (S.D. = 0.22) and ranged from 0.02 (2000 and 2005) to 0.91 (2014). The mean annual female PM mortality rate for natural fish was 0.05 (S.D. = 0.05) and ranged from zero (2000, 2005 and 2007) to 0.23 (2001). The abnormally high rate of PM observed in the hatchery population in 2014 largely resulted from a flash flood that occurred on August 7, 2014. A thunderstorm in the upper SFSR rapidly increased flows and washed sediment into the River. In addition to killing most of the broodstock being held at the MHT, a large number of carcasses were recovered by survey crews in the upper SFSR. Surveys occurred during a period when water visibilities were near zero (Figure 11). It was likely that many carcasses were missed, likely underestimating total prespawn mortality.

Figure 11. The South Fork Salmon River on August 14, 2014 following a thunderstorm and flash flood in the upper basin.

Annual fluctuations in female PM rates were highly variable with a consistently higher annual PM rate in hatchery compared to natural females (Table 8). In spite of the annual variation, regression analysis demonstrated a significant positive relationship between annual rates of hatchery and natural female PM ($R^2 = 0.57$; P = 001). The significant correlation between PM rates of hatchery and natural females suggested that common biological or physical factors unrelated to origin influenced the annual magnitude of female PM. Results from a previous report suggested that high adult abundance and high water temperatures during the peak spawning period were positively correlated with PM. Both of these results were largely driven by the 2001 return year, which saw the highest adult abundance, water temperatures and PM. The additional years of data added to the analysis since the previous report (Young and Blenden, 2011) resulted in these correlations no longer being significant. However, high water temperatures were believed to contribute to higher prespawn mortality observed in Willamette River Chinook (Keefer, et al., 2010) and Frasier River sockeye populations (Quinn et al. 2007). Data collected under this project have been provided as part of a Columbia River basin analysis of female PM of which the result will describe the factors contributing to PM in a more robust analysis (Bowerman et al. 2016).

To determine if the significantly higher PM observed in hatchery fish resulted from having been previously trapped at the MHT and outplanted, we compared PM rates between outplanted and non-outplanted females. A total of 17.4% of recovered hatchery female carcasses exhibited opercule marks indicating that they had been captured at the McCall Hatchery weir and outplanted downstream (see "*Hatchery fraction*" section). Comparing PM rates between outplanted and non-outplanted females revealed that 9.5% of the outplanted females and 24.3% of the non-outplanted females were PM, suggesting that being outplanted did not significantly influence the rate of PM during the mid-August to mid-September spawning period. However, a significant portion of the fish were outplanted in July, one to two months prior to spawning ground surveys and mortality occurring in this period would not have been identified. Completing surveys during this time period may reveal higher PM for outplanted fish.

A total of 61 of 3,475 carcasses exhibited signs of injuries, many consistent with fishing activities such as puncture wounds, gashes, hooks in mouth or body and fresh abrasions (Appendix C). Of the 61 carcasses exhibiting injuries, 39 were female and 30 of these were PM. At this rate it was evident that visible injuries significantly increased the chances that a female carcass was a PM. Although the rate of injuries noted over the years was minimal, it was likely that the survey schedule where the first survey didn't occur until mid-August did not adequately evaluate mortality prior to spawning. Harvest activities generally occurred in July and it was possible that mortalities happened earlier in the summer and the resulting carcasses were eaten by scavengers or naturally decomposed before our surveys began. Given the possibility that spawning ground survey dates didn't overlap the likely peak mortality periods resulting from both being outplanted or subject to a harvest related injury, earlier surveys should be considered in the future.

These analyses suggest that both biological and physical factors influenced female PM in the SFSR. The significantly higher rates in hatchery compared to natural females indicated clear survival advantage for natural fish. Additional research to determine the cause of this difference will be important given the large numbers of hatchery fish that spawn naturally or are outplanted to other rivers with a goal of supplementing natural returns. In addition, understanding the effects of temperature on PM will be critical given the potential for climate change induced increases in water temperatures expected in the future. Underlying mechanisms causing PM are unknown but may be tied to altered energy balance or increased disease load associated with prolonged exposure to high water temperatures. High water temperatures appeared to adversely affected survival of migrating sockeye salmon in the Columbia River (Keefer, et. al. 2008; Naughton et. al. 2005).

Stray rate

The presence of hatchery strays could only be determined from CWT, PIT or other tag recoveries. From 1990 – 2016 a total of 596 CWTs were recovered including 578 originating from McCall Hatchery releases, 15 known stray origin and three tagged and released as juveniles with no known origin (McNary Dam or Columbia River; Table 9). The overall stray rate to the SFSR area below the MHT was estimated at 2.5%. The distribution of the stray tags was relatively even, with five recovered in the WD section, two in the DC section, five in the PF section and three in the LP section. Marking information obtained from the Regional Mark Information System (RMIS; http://www.rmpc.org/) was used to expand for untagged fish from each CWT release group. All stray CWT codes recovered in the SFSR were from 100% marked groups (actual tagging rates were 94% - 100%) so no expansion was needed and the sum of the recovered tags divided by the total tags equals the estimated stray rate. Only six PIT tags were interrogated from carcasses over this timeframe, with none being from out of basin fish. These results indicated that hatchery stray rates were low in the survey areas.

Table 9. The number of coded wire tag recoveries by release site for tags recovered from 1991 – 2016 in the South Fork Salmon River (SFSR) below the McCall Hatchery Trap.

Year	Imnaha River	Lostine River	Johnson Creek	SFSR, Knox Bridge	McNary Dam	Columbia River	Upper Grande Ronde River	total CWT
1991				2	1	1		4
1992				16				16
1993				6		1		7
1994				7				7
1995				1				1
1996				3				3
1997				14				14
1998				3				3
2000				39				39
2001				30				30
2002				20				20
2003		1		29				30
2004			1	25				26
2005		1		49			1	51
2006				17				17
2007		1		11				12
2008		1		67				68
2009	1	1		40				42
2010		1		43				44
2011		2		14				16
2012				14				14
2013				7				7
2014				30				30
2015			2	54			1	57
2016			1	37				38
Totals	1	8	4	578	1	2	2	596

Big Creek

Big Creek Redd Counts

Index of spawner abundance

Annual redd counts from two sections in Big Creek from 1986 – 2013 revealed high year-to-year variability, ranging from a low of one redd observed in 1995 to a high of 104 in 2001 (Table 10). The most recent ten-year geometric mean redd count was 45.8. From 1986 through present the linear trend in redd counts exhibited a positive trend line (Figure 12).

Table 10. Redd counts from two sections in Big Creek determined from annual multiple-pass spawning ground surveys from 1986 – 2013. JC – Jacobs Ladder Creek to Logan Creek; LC – Logan Creek to Smith Creek.

Year	JC	LC	Total
1986	41	4	45
1987	24	3	27
1988	94	11	105
1989	25	10	35
1990	13	1	14
1991	12	1	13
1992	23	7	30
1993	46	5	51
1994	2	0	2
1995	1	0	1
1996	1	1	2
1997	26	0	26
1998	13	3	16
1999	4	0	4
2000	10	3	13
2001	95	9	104
2002	89	6	95
2003	63	15	78
2004	32	17	49
2005	11	10	21
2006	12	3	15
2007	18	7	25
2008	32	12	44
2009	69	15	84
2010	40	16	56
2011	75	12	87
2012	86	16	102
2013	40	17	57
10-year geomean	33.4	11.3	45.8

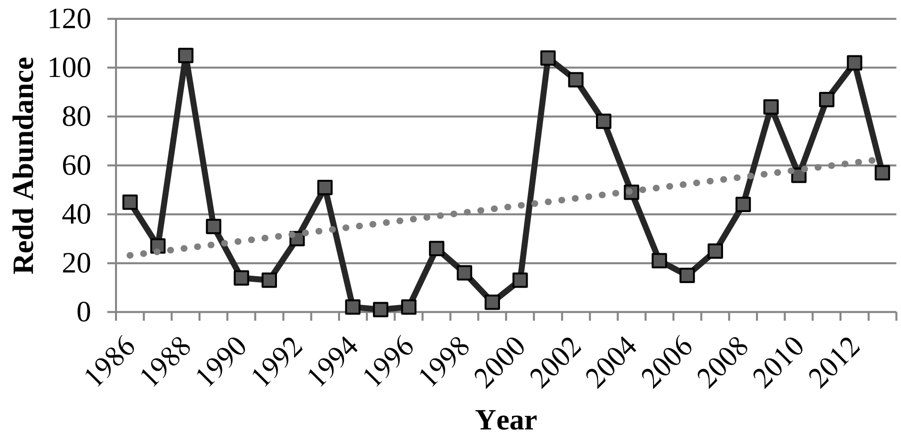


Figure 12. Total annual redds counted in the Jacobs Ladder Creek to Logan Creek and Logan Creek to Smith Creek sections of Big Creek from 1986 - 2013. Dashed line demonstrates the linear trendline for the data series.

Progeny-per-parent ratio

Similar to the SFSR, methods to determine actual adult abundance in Big Creek were not available. Consequently, progeny-per-parent ratio (P:P) was calculated using parent redds and progeny redds estimated using female *age structure*. Actual calculated female *age structure* was used when greater than eight female carcasses were recovered and an average *age structure* was used when fewer than eight female carcasses were recovered. Actual female *age structure* was applied to 12/28 years, with the remaining years relying on the long-term average. P:P estimates were calculated annually and the median value provided an estimate of λ (Table 11). Estimated λ of 0.83 indicated that the population was not replacing itself over this time period. P:P rations ranged from a low of 0.11 in brood years 1990 and 1991 to a high of 8.38 in 1998.

Table 11. Brood year, parent redds, progeny redds and progeny:parent ratio estimated from female carcass recoveries and redd counts in Big Creek for brood years 1986 - 2008. Lamda (λ) was calculated as the median progeny-per-parent value.

Brood year	Parent Redds	Progeny Redds	Progeny :Parent
1986	45	15	0.34
1987	27	19	0.70
1988	105	52	0.50
1989	35	17	0.48
1990	14	2	0.11
1991	13	1	0.11
1992	30	12	0.42
1993	51	22	0.42
1994	2	11	5.39
1995	1	8	7.92
1996	2	15	7.52
1997	26	125	4.80
1998	16	134	8.38
1999	4	32	7.94
2000	13	37	2.83
2001	104	18	0.18
2002	95	19	0.20
2003	78	33	0.43
2004	49	41	0.83
2005	21	88	4.21
2006	15	90	5.97
2007	25	87	3.48
2008	44	82	1.87
		λ	0.83

Overall the population in Big Creek has undergone extreme variations in population size, from near extirpation to relatively high abundance, leading to the extremely wide range in P:P estimates. However, P:P values didn't randomly fluctuate from year to year but rather demonstrated periods of relatively low values (brood years 1988 – 1993 and 2001 - 2003) followed by periods of relatively high values (1994 – 2000 and 2005 - 2008; Figure 13). The most recent 5 brood years (2004 – 2008) exhibited a λ = 3.48 with 4/5 P:P ratios greater than one, indicating increased levels of productivity.

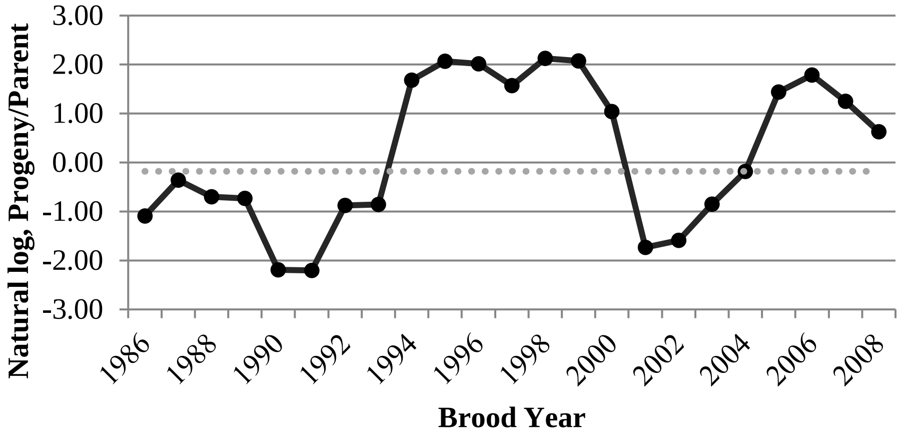


Figure 13. Natural log progeny:parent estimates from brood years 1986 – 2008 calculated from redd counted in Big Creek from Jacobs Ladder Creek to Smith Creek. Dashed line represents the median progeny:parent ratio (λ) across all brood years.

Spawn timing

Spawn timing was determined by the median, 10^{th} percentile and 90^{th} percentile redd counts for the JC and LC sections. Spawn timing was significantly earlier for the JC section, with the median being five days and the 10^{th} percentile nine days earlier compared to the LC section (Table 12).

Table 12. Spawn timing for two sections in Big Creek from 1996 – 2013 with median, peak, 10^{th} percentile and 90^{th} percentile dates. Peak indicated the date with the highest number of redds summed over all years.

Section	Median	Range	10^{th} percentile	90^{th} percentile
JC	8/14	7/6-8/31	8/2	8/29
LC	8/19	7/28-9/1	8/11	8/29

Cumulative redd counts pooled for years 1986 – 2013 (Figure 14) revealed that the distribution of spawn timing was significantly earlier in the JC compared to the LC section. The maximum difference between cumulative spawn timing distributions was 0.34 on August 18 (Kolmogorov-Smirnov two-sample test: $P < 0.05$).

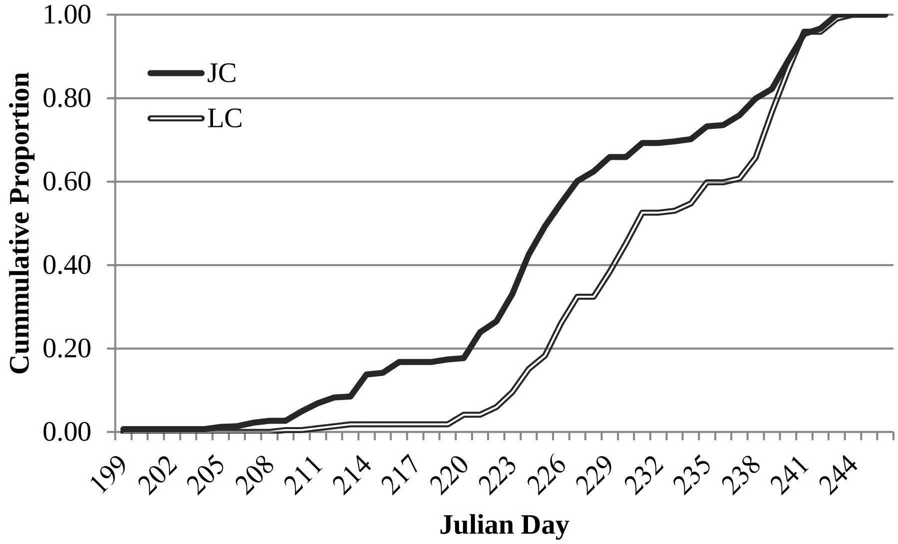


Figure 14. Cumulative redd counts from two sections in Big Creek determined from annual multiple-pass spawning ground surveys from 1986 – 2013. JC – Jacobs Ladder Creek to Logan Creek; LC – Logan Creek to Smith Creek.

Adult spawner distribution

Adult spawner distribution was investigated by comparing the redd count distribution in the JC section with that observed in the LC section. From 1986 - 2013 the average proportion of redds in the JC section was 0.82 (S.D. = 0.13). The annual proportion of redds in the JC section ranged from 0.52 in 2005 to a high of 1.0 in multiple years. For the most recent five-year period (2009 – 2013) the proportion of redds in the JC section equaled 0.79 (S.D. = 0.10), similar to the long-term average, indicating no change in spawner distribution.

Big Creek Carcass Surveys

Sex ratios

From 1986 – 2013 a total of 541 carcasses were recovered where sex could be identified, including 274 females and 267 males for an overall sex ratio of nearly 1:1 (0.51 female). Removing jacks (males $\leq$ 57 cm) resulted in an adult female proportion of 0.55. Small numbers of carcass recoveries for most years (see Table 12) made it impossible to estimate annual sex ratios.

Age Structure

Ages of Big Creek carcasses were determined by total fork length and length frequency analysis. A length frequency histogram of male and female carcasses is presented in Figure 15. Male and female age proportions were determined using a length/age key constructed using known age carcasses collected from the SFSR and Big Creek. Applying the age key resulted in estimated male age proportions of 0.16 age three, 0.64 age four and 0.20 age five males and estimated female proportions of 0.37 age four and 0.63 age five.

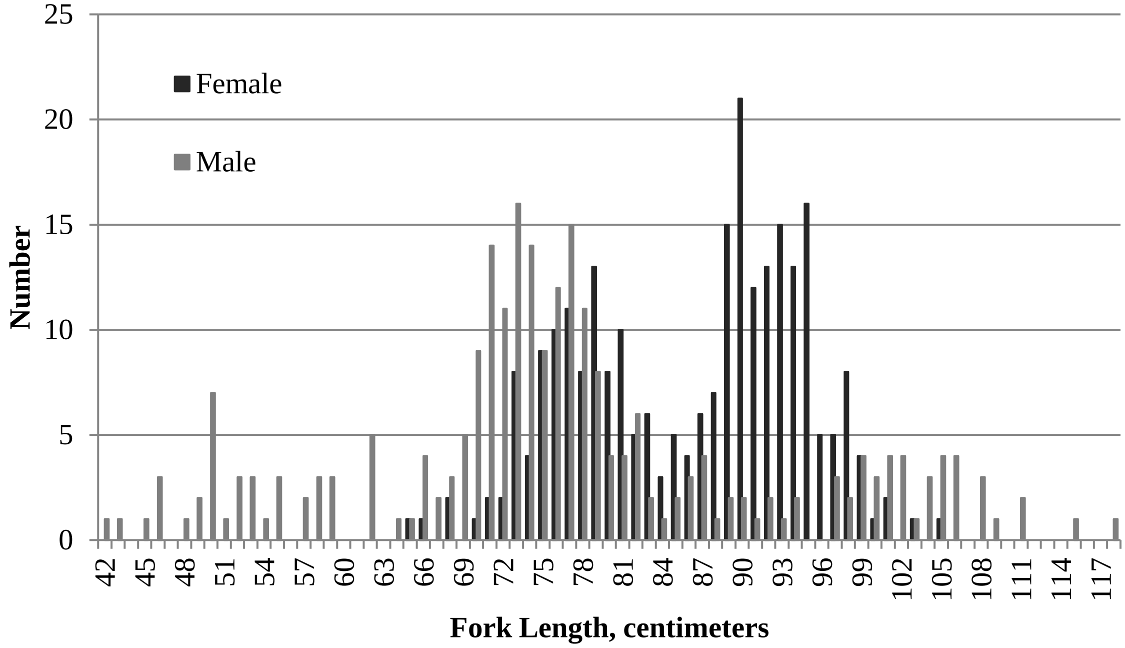


Figure 15. Fork length frequency histograms from Big Creek female and male carcasses recovered from 1986 – 2013. Fork lengths were measured in mm.

The average carcass age declined from 1986 – 2013 (Figure 16), indicating that the population composition of spawning fish has changed to a predominance of younger age fish. The change was more pronounced in males, with a drastic age reduction starting in 2001 and persisting until today. An investigation of annual carcass compositions revealed that prior to 2001 annual carcass sample sizes were relatively small, with 2 years (1988 and 1993) dominated by age 5 male carcasses. Since then no years have be dominated by age 5 males, likely explaining the male trend. In contrast, age 5 females were dominant both before (1988, 1991, 1993) and after 2000 (2002, 2003, 2011). In addition, the recovery of jacks was significantly more frequent since 2009. These results suggest that continued carcass surveys and monitoring of the age structure in Big Creek is warranted.

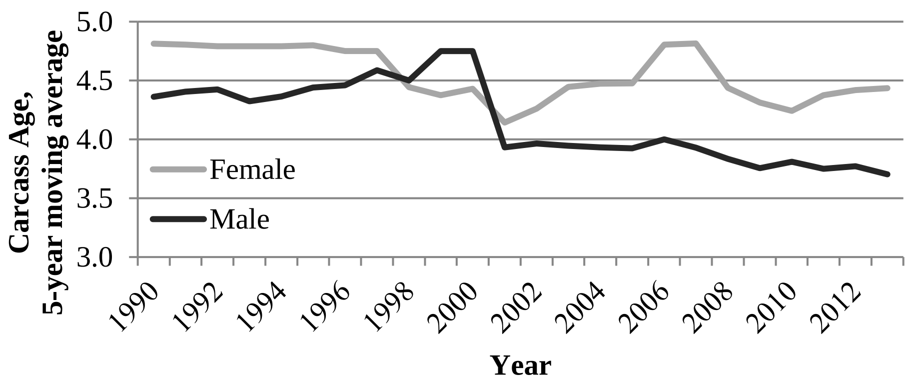


Figure 16. Five year average age from 1990 – 2013 for Big Creek Chinook salmon carcasses.

Age-at-return

Carcass recoveries representing brood years 1983 – 2008 indicated that the overall age-at-return calculated from carcasses recovered in Big Creek was 0.07 age 3, 0.53 age 4 and 0.40 age 5. Plotting the five-year moving average annual age-at-return demonstrated that the proportion of age 3 and age 4 fish increased whereas the proportion of age 5 fish decreased (Figure 17). Changes in the brood year age proportions were heavily influenced by the high proportion of age 5 fish observed from 1983 – 1988. Since 1989 age compositions have been relatively stable at 0.10 age 3, 0.65 age 4 and 0.25 age. This also corresponded with the significant population declines observed in the mid 1990's. This pattern suggested that the population collapse may have altered the historic age composition that has resulted in the younger average age composition currently in the population. However, it is not possible to determine if the initial six brood years in this study represented the historic age composition or were the result of cyclical or environmentally induced changes in age composition.

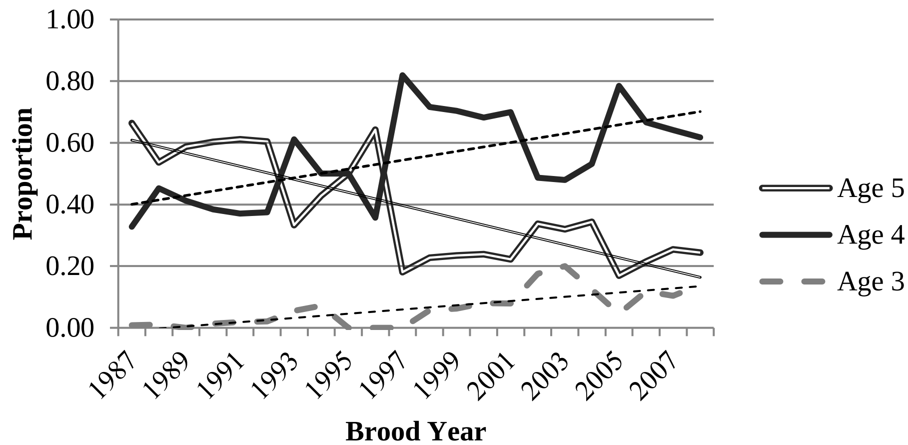


Figure 17. Five-year moving average proportions of age 3, age 4 and age 5 carcasses recovered in Big Creek representing returns from brood years 1983 – 2008.

Size-at-return

An analysis of fork length measurements obtained from carcasses recovered in Big Creek from 1986 – 2013 (Table 13) demonstrated that the mean adult carcass fork length (excluding jacks) was significantly greater for females compared to males (P<0.001). It was not possible to compare size at return from one year to the next because few carcasses were recovered for most years. This limited the effectiveness of the performance measure by not allowing an evaluation of annual size difference or changes over time.

Table 13. Male, female and jack fork lengths including the number (n), mean, standard deviation (S.D.) and coefficient of variation (C.V.) determined from carcasses recovered in Big Creek from 1986 – 2013. All values were lengths in centimeters (cm).

	Female	Male	Jack
n	258	205	47
Mean	85.9	81.7	54.9
S.D.	8.5	12.2	6.8
C.V.	0.10	0.15	0.12

Hatchery fraction

Big Creek is managed as a natural fish population with no hatchery releases. Since 1992 all marked or tagged hatchery fish are identified as strays. Prior to 1992 origin was not determined because a high proportion of hatchery fish released in the Snake River basin were not marked. Consequently, the data presented here only estimated hatchery fraction from 1992 – 2013. For the combined years 1992 – 2013 a total of 368 carcasses were recovered, of which 10 were marked hatchery fish (Table 14). This represented an average hatchery fraction of 2.7% in upper Big Creek. Hatchery fraction for individual years ranged from zero (13 different years) to 50% in 2006 (four carcasses were recovered, 2 were hatchery). However, small sample sizes in some years, including 2006, limited our ability to estimate annual hatchery fraction rates. Five marked hatchery carcasses were female and five were male. Estimated age composition of strays included three age 3 males (jacks), four age 4 females and two age 4 males and one age 5 male. Of the ten marked hatchery carcasses recovered, a single carcass recovered in 2006 possessed a CWT indicating that it was an age 3 male (jack) released from Rapid River Hatchery.

Table 14. Hatchery/Natural composition, percent female carcasses and number and percent hatchery carcasses recovered in Big Creek from 1992 through 2013. No carcasses were recovered in 1996.

	Female		Male		
Year	Hatchery	Natural	Hatchery	Natural	Hatchery Fraction
1992		8		9	0.00
1993		17		16	0.00
1994		4		1	0.00
1995		1			0.00
1997		4			0.00
1998		2		3	0.00
1999		2		1	0.00
2001	1	28	1	55	0.02
2002		10		26	0.00
2003		16	2	8	0.08
2004	1	5		1	0.14
2005		4		3	0.00
2006	2	1		1	0.50
2007		1		1	0.00
2008		5		6	0.00
2009		21	1	30	0.02
2010		9		9	0.00
2011	1	12		10	0.04
2012		8		6	0.00
2013		5	1	9	0.07
Totals	5	163	5	195	0.027

Female prespawn mortality

For the combined years 1986 – 2013 a total of 258 female carcasses were recovered that were assessed for prespawn mortality. Of these, five retained greater than 75% of their eggs indicating that they were prespawn mortalities. Two female prespawn mortalities were recovered in 1988 and one in 1991, 1994 and 2003. Although these results suggested that prespawn mortality was not a significant issue for the Big Creek population, surveys didn't begin until late July or early August making it impossible to fully evaluate prespawn mortality prior to the initiation of spawning.

Stray rate

Only the presence of adipose fin-clipped hatchery carcasses could be used to determine stray rate to Big Creek. It was not possible to estimate a natural stray rate from carcass recoveries. Therefore, the overall stray rate was equal to the proportion of hatchery carcasses recovered. See section "*Carcass surveys – hatchery fraction*" for an estimated stray rate in Big Creek.

East Fork South Fork Salmon River

Meadow Creek outplants

Index of spawner abundance

Historically Meadow Creek and the upper East Fork South Fork Salmon River (EFSFSR) was a highly productive Chinook salmon spawning area that was destroyed and degraded by mining activity starting in the 1940's. In the mid-1990s the National Forest Service rehabilitated approximately 2 kilometers of Meadow Creek just above the confluence with the EFSFSR, creating an area of good to excellent Chinook salmon spawning habitat. Although the rehabilitated area is inaccessible to anadromous fish due to a large waterfall cascading into a lake formed by historic open mine pit, the Nez Perce Tribe promoted the release of excess hatchery Chinook salmon from the MHT to restore natural production to the rehabilitated section of Meadow Creek. Field crews conducted spawning ground surveys to assess the success of the outplanted fish in a transect from the confluence of Fiddle Creek and the EFSFSR to the bottom of a rip rap area at the top of the rehabilitated stream area of Meadow Creek.

Spawning ground surveys demonstrated that outplanted adults successfully spawned following their release in the Meadow Creek area (Table 15). Annual redds counted ranged from 41 to 135, with an average of 2.1 females/redd. The inflated female/redd estimate likely resulted from the combination of a relatively high prespawn mortality of outplanted females and density dependence resulting from the limited available spawning area. High female prespawn mortality was not unexpected since the releases occurred late in the year when fish were ready to spawn and an extended transporting time of approximately 2 hours from the MHT to the release site likely contributed to the mortality. Density dependence was suggested by the fact that lower female/redd estimates occurred during years when fewer females (or total adults) were released (2013 and 2015; Table 15). However, the relationship between redd counts and females/redd estimates was not strongly supported and, given the small sample size (7 years of data), insufficient for drawing conclusions about density dependence. With additional years of release and redd count data it might be possible to calculate an optimal female release number that maximizes redd production for this outplant program.

Related to the objective of increasing natural production in the SFSR, the presence of significant number of redds and high numbers of juveniles observed in the rehabilitated area (observational, data not shown) suggests that releasing hatchery adults from the MHT has successfully contributed to production through the juvenile life history stage. Juvenile emigrant survival or adult returns evaluations were not completed. A small number of PIT tags or parentage-based tagging of adults would be required to conclusively evaluate success of this release program from outplants to adult returns.

Timing of the outplants was important. Very few fish from the early release of 2010 spawned in the target location, with numerous outplanted fish documented in the EFSFSR below Stibnite mine, at the Johnson Creek weir or even returning to the MHT (unpublished data). Future outplants should occur in late August or early September to avoid dispersal from the release site.

Table 15. Outplants of McCall Hatchery Chinook salmon to Meadow Creek from 2009 - 2016 and redd counts determined by spawning ground surveys in the upper East Fork South Fork Salmon River and Meadow Creek.

Year	Date[1]	Female	Male	Jack	Total Released	Redds	Female/ redd
2009						41	NA
2010	19-Aug	58	76	0	534	82	6.5
	25-Aug	100	89	11			
	26-Aug	101	89	10			
2011	25-Aug	114	70	37	459	102	4.5
	2-Sep	133	15	90			
2012	5-Sep	140	122	32	294	57	5.2
2013	8/29/2013	25	25	0	130	41	3.2
	9/4/2013	40	40	0			
2014	NA						
2015[2]		80	80		160	67	2.4
2016[2]		268	268		536	135	4.0

[1]Dates, female, male jack and total release data was obtained from McCall Hatchery Run Reports (Folsum, 2014; Folsum, 2013; Patterson, 2012 and; Patterson, 2011).
[2]sex of outplanted fish were unknown, assumed a 50:50 ratio of females:male

Environmental monitoring

Water temperatures are monitored on a year-round basis using five temperature loggers deployed throughout the upper mainstem SFSR including Stolle Meadows, Penny Springs, Poverty Flat mid-stream, Poverty Flat near-shore and Darling Cabins. In addition, sites operated by other organizations monitor temperatures at Knox Bridge (NOAA-Fisheries), KRS PIT tag array (ISEMP) and SFSR Guard Station (ISEMP). Together these sites provide a complete profile of water temperature of the SFSR. The temperature profile presented in Figure 18 demonstrated that average August 15 - 31 temperatures increase as water flows downstream, with the coldest temperatures in Stolle Meadows and the warmest temperatures at the SFSR Guard Station. The period selected (August 15 – 31) represent the first half of the Chinook salmon spawning period that coincides with the highest temperatures and thus has the greatest effect on spawning Chinook salmon. Earlier spawn timing in higher elevation areas coincides with cooler water temperatures, with spawn timing occurring later as you move downstream through the system. Higher temperatures early in the season likely delayed spawning in the lower river and may even limit the downstream extent of suitable spawning in the SFSR. IDFG conducts annual single pass index redd counts downstream from the lowest NPT transect that includes the Darling Cabin temperature monitoring site and typically observed limited Chinook salmon spawning activity (Kim Apperson, personal communication). This is in spite of the fact that there appears to be extensive areas of suitable spawning habitat in that region, including one of the main spawning areas for spring spawning B-run steelhead just below the Krassel Guard Station (William Young, personnel communication).

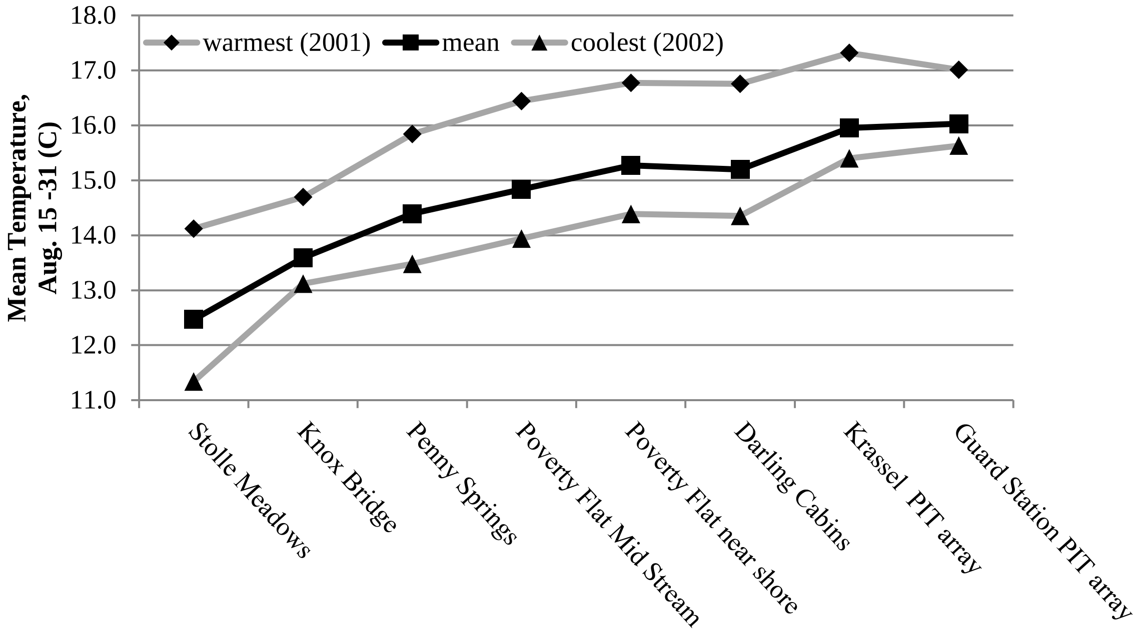


Figure 18. Mean August 15 – 31 water temperature for the 2001 – 2013 average (■), 2001 (warmest; ♦) and 2002 (coolest; ▲) for eight sites in the South Fork Salmon River. Sites are in order from upstream (Stolle Meadows) to downstream (SFSR Guard Station).

A single temperature logger deployed in Big Creek near the middle of the survey area demonstrated cold August water temperatures suitable to Chinook salmon spawning.

All temperature data were sent to the Rocky Mountain Research Station to be included in the NorWeST Stream Temp database (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html).

Conclusions and Management Recommendations

Significant numbers of hatchery Chinook salmon spawned below the MHT.

High numbers of hatchery Chinook salmon in the SFSR spawned below the MHT. This was especially evident in the two sections just below the trap (WD and DC), with hatchery recoveries making up nearly 70% of the carcasses. This indicated that hundreds of hatchery fish per year stopped and spawned naturally without ever making it to the trap. Approximately 28% of the hatchery carcasses were trapped and outplanted below the weir, but spawned naturally without being harvested or reaching the weir a second time. As you move downstream from the trap the proportion of hatchery carcasses recovered on the spawning grounds decreased with a relatively small number of outplanted fish. The high degree of hatchery/natural interactions in this area allows for interbreeding that supplements natural productivity, although juvenile abundance or adult returns resulting from naturally-spawning hatchery fish in this are has not been evaluated. Hatchery/natural interactions are significantly lower in the lower two sections (PF and LP) as determined by the relatively low pHOS results. However, pHOS has increased in the past three years compared to earlier years. The reason for this is not clear, but it may be related to the integrated production program that releases unclipped juveniles. Disproportionately high numbers of integrated production carcasses were recovered in the lower two sections that, combined with weak returns of natural adults, contributed to the increased pHOS estimates in recent years. Sport harvest in the SFSR selectively removes adipose-clipped fish resulting in a higher proportion of unclipped integrated fish in the naturally spawning population below the MHT. We recommend continued monitoring of pHOS in these sections.

SFSR hatchery and natural Chinook salmon demography

Comparing demographic parameters of hatchery and natural Chinook salmon carcasses recovered in the SFSR revealed significant differences for sex ratios, age at return, and female prespawn mortality. Most of these differences resulted from a younger average age for hatchery compared to natural fish, producing greater numbers of jacks in the hatchery population. Reasons behind the significantly greater rates of female prespawn mortality in the hatchery population were not evident. Possibilities include biologically-based decline in physiological capacity to survive until spawning or a behavioral difference related to the ability to locate thermally hospitable holding locations prior to spawning. Detection results from the KRS PIT array indicated that a majority of the adults that eventually spawned below the MHT migrated passed that location in late June or early July and held somewhere between there and the MHT. Surviving the months-long interval between migration and spawning likely requires locating and holding in an environmentally favorable area or pool. Limited environmentally-suitable areas may contribute to the observed prespawn mortality in the hatchery population.

Over 25 years of carcass recovery data revealed that the average size and age are decreasing for both the hatchery and natural populations of Chinook salmon spawning in the SFSR. This trend has been occurring all across the range of Pacific salmon in all species (Ohlberger et al., 2017; McPhee et al., 2016; Lewis et al. 2015) and suggests ecosystem-wide effects on age-at-maturity and size-at-maturity.

Environmental monitoring

The deployment of five temperature loggers and other in-stream temperature monitoring stations provide an accurate profile of water temperatures in the SFSR. Water temperatures progressively increased downstream from the MHT and this affects spawn timing and may even limit or prevent spawning in the lowest reaches of the SFSR. Continued monitoring is essential to fully understand Chinook salmon survival and productivity given the effects increasing temperatures predicted from global climate change.

Recommended Future Activities

- Continue multiple-pass, index-area spawning ground surveys in the SFSR.
- Continue to monitor redd count trends in SFSR to assess spawner abundance, timing and distribution.
- Continue carcass recoveries from SFSR to assess important Chinook salmon demographic attributes.

- Monitor female prespawn mortality rates and investigate contributing factors.
- Continue temperature monitoring in the SFSR and assess the effects of temperature changes on spawning success and distribution.
- Utilize the currently functioning PIT tag arrays to better enumerate Chinook salmon escapement and spawning in the SFSR basin.

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APPENDICIES

Appendix A. Performance measure table for South Fork Salmon River and Big Creek Chinook salmon spawning aggregates.

Table A1. Performance measures for SFSR and Big Creek Chinook salmon spawning aggregates. Data was obtained from annual redd counts and carcass surveys from 2012 – 2016.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Performance Measure</th><th colspan="3">SFSR</th><th>Big Creek</th></tr>
<tr><th>Natural</th><th>Hatchery</th><th>Combined</th><th>Natural</th></tr>
<tr><td rowspan="13">Abundance</td><td>Adult Escapement to Snake Basin</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Fish per Redd Estimate</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Index of Spawner Abundance -
redd counts,
Mean (S.D.)
Range
SFSR - 2012-2016
Big Creek – 2009-2013</td><td>164 (89)
65 – 272</td><td>106 (60)
45 – 181</td><td>270 (56)
191 - 330</td><td>77 (20)
56 – 102</td></tr>
<tr><td>Spawner Abundance
redds x 2.31
Mean
Range
SFSR - 2012-2016
Big Creek – 2009-2013</td><td>379
151 – 629</td><td>244
103 – 417</td><td>623
441 – 762</td><td>178
129 – 236</td></tr>
<tr><td>Hatchery Fraction
percent hatchery
SFSR - 2012-2016
Big Creek – 2009-2013</td><td>NA</td><td>NA</td><td>WD = 70.4%
DC = 53.5%
PF = 32.4%
LP = 15.2%
All sections = 44.4%</td><td>2.6%</td></tr>
<tr><td>Ocean/Mainstem Harvest</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Harvest Abundance in Tributary</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Index of Juvenile Abundance (Density)</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Juvenile Emigrant Abundance</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Hatchery Production Abundance</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Smolt Equivalents</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Run Prediction</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td rowspan="10">Survival - Productivity</td><td>Smolt-to-Adult Return Rate</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Progeny-per- Parent Ratio
Lamda-progeny redds/parent redds, Brood years</td><td>Ukn</td><td>Ukn</td><td>1990 – 2011 = 0.68
2007 – 2011 = 0.44</td><td>1990 – 2008 = 0.83
2004 – 2008 = 3.48</td></tr>
<tr><td>Recruit/spawner (Smolt Equivalents per Redd or female)</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Pre-spawn Mortality
Percentage of females 0-25% spawned
SFSR - 2012-2016
Big Creek – 2009-2013</td><td>4.0%</td><td>31.2%</td><td>15.4%</td><td>0%</td></tr>
<tr><td>Juvenile Survival to Lower Granite Dam</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Juvenile Survival to all Mainstem Dams</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>In-hatchery Life Stage Survival</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Post-release Survival</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Relative Reproductive Success (Parentage)</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
</table>

	Performance Measure	SFSR			Big Creek
		Natural	Hatchery	Combined	Natural
Distribution	**Adult Spawner Spatial Distribution** Percentage of redds in each section, 2012-2016	**WD&DC – 27.9%** **PF&LP – 72.1%**	**WD&DC – 77.5%** **PF&LP – 22.5%**	**WD&DC – 46.1%** **PF&LP – 56.9%**	**JC – 78.9%** **LC – 21.1%**
	Stray Rate[1] Percentage of out of basin carcasses, SFSR -2012-2016 Big Creek – 2009 - 2013	**Ukn**	**1.6%**	**Unk**	**2.6%**
	Juvenile Rearing Distribution	NA	NA	NA	NA
	Disease Frequency	NA	NA	NA	NA
Genetics	Genetic Diversity				
	Reproductive Success (Nb/N)	NA	NA	NA	NA
	Effective Population Size (Ne)	NA	NA	NA	NA
Life History	Age Class Structure	NA	NA	NA	NA
	Age–at–Return Percentage of carcasses of each age class by brood year SFSR – 2007 - 2011 Big Creek - 2004-2008	**Males:** **age 3 = 18.9%** **age 4 = 65.4%** **age 5 = 15.7%** **Females:** **age 3 = 2.4%** **age 4 = 78.1%** **age 5 = 19.5%**	**Males:** **age 3 = 29.4%** **age 4 = 59.7%** **age 5 = 10.9%** **Females:** **age 3 = 1.6%** **age 4 = 80.6%** **age 5 = 8.7%**	**NA**	**Males:** **Age 3 = 22.2%** **Age 4 = 71.4%** **Age 5 = 6.4%** **Females:** **Age 4 = 58.6%** **Age 5 = 41.4%**
	Age–at-Emigration	NA	NA	NA	NA
	Size-at-Return Mean mm (S.E.) SFSR - 2012-2016 Big Creek – 2009 - 2013	**Jack = 594** **Male = 790** **Female = 782**	**Jack = 609** **Male = 808** **Female = 780**		**Jack = 534** **Male = 801** **Female = 837**
	Size-at-Emigration	NA	NA	NA	NA
	Condition of Juveniles at Emigration	NA	NA	NA	NA
	Adult Spawner Sex Ratio Percent adult females SFSR - 2011-2016 Big Creek – 2009-2013	**53.4%**	**74.0%**	**61.5%**	**47.4%**
	Fecundity by Age	NA	NA	NA	NA
	Adult Run-timing	NA	NA	NA	NA
	Spawn-timing, all years Median date 10th percentile 90th percentile	**Ukn**	**Ukn**	**9/7** **8/29** **9/14**	**8/17** **8/2** **8/29**
	Juvenile Emigration Timing	NA	NA	NA	NA
	Mainstem Arrival Timing (Lower Granite)	NA	NA	NA	NA
Habitat	Instream Flow	NA	NA	NA	NA
	Water Temperature	NA	NA	NA	NA

[1]hatchery stray rate was the proportion of out of basin CWTs divided by the total CWT recoveries; Big Creek stray rate was the proportion of adipose fin clipped carcasses recovered.

Appendix B. Injuries noted from carcasses collected in the SFSR from 1996 - 2016.

Table C1. South Fork Salmon River carcasses recovered that exhibited of visible injuries. Data includes the section, year, sex, percent spawned, origin and a description of the injuries. Percent spawn (% spawn) was not assessed on male carcasses.

section	Year	FL (mm)	Sex	% spawn	Origin	Remarks
DC	1994	93.5	M		N	puncture wounds in belly
WD	1997	815	F	100	H	single hook in mouth
WD	1997	1030	F	100	N	Treble hook in side
LP	1998	910	F	100	N	Puncture wound
DC	1998	975	F	0	H	Open flesh on dorsal; not puncture wound
WD	1998	590	J		N	Large stick through mouth
DC	2001	760	F	0	H	1/2" puncture wound left side by dorsal
DC	2001	765	F	0	H	Abrasion right side
WD	2001	785	F	0	H	Picket marks on body
DC	2001	790	F	0	H	Deep abrasions on right side
DC	2001	835	F	0	N	3 Puncture wound right side
DC	2001	850	F	0	N	Large chunk out of dorsal, gash by right opercle
DC	2001	730	M		N	Puncture wound right side
WD	2001	755	M		N	Puncture wound
DC	2001	760	M		N	Fishing line in mouth
LP	2001	815	M		N	2 Puncture wound right side
DC	2001	850	M		H	Puncture wound right hand side
DC	2001	870	M		H	puncture wound right side
DC	2002	760	F	0	H	Puncture wound above ventral fin
DC	2002	775	F	0	H	Puncture wound
PF	2002	925	F	0	N	Several puncture wounds on left side
DC	2002	940	F	0	H	Puncture wound
PF	2002	960	F	0	N	Puncture wound (2" hole) on right side
DC	2002		F	0	H	Puncture wound
WD	2002		F	100	H	Hook in mouth
WD	2002	470	J		H	Abrasion right side
DC	2002	800	M		H	Puncture wound
PF	2002	965	M		H	Puncture wounds on left side
DC	2002	1080	M		N	Puncture wound
WD	2002		M		H	Gash on right side
WD	2003	820	F	0	N	Puncture wound
LP	2003	820	F	0	N	Entire belly bruised swollen
WD	2003	830	F	100	N	Puncture wound right side
PF	2003	915	F	0	H	4 deep abrasions on tail
GC	2003	950	F	0	H	Puncture wound
LP	2003	790	M		N	2 open wounds/tumors on side below dorsal fin

WD	2003	825	M		H	2 Large circular abrasions
DC	2003	860	M		H	Hook in side and other puncture wounds
DC	2004	1000	F	50	H	Wound on side
PF	2004	840	M		N	Bite wound
DC	2004	870	M		H	Gash on head
WD	2005	760	F	100	H	Puncture wound
WD	2008	820	F	0	H	Puncture wound
WD	2008	830	F	0	H	Puncture wound
WD	2008	950	F	0	H	Puncture wound
WD	2008	750	M		N	Puncture wound
WD	2008	845	M		H	wound
WD	2008	995	M		H	Puncture wound
WD	2009	81	F	75	H	hook in side
WD	2009	75.5	F	100	H	hook in mouth
WD	2010	85	F	0	H	Possible puncture on side, head eaten
PF	2011	84	F	0	H	Puncture hole in belly
DC	2011	83	F	0	H	Puncture wound
DC	2011	87	F	0	N	Puncture wound
PF	2011	93	F	0	N	hook in mouth
DC	2011	90	F	0	N	bite or talon marks
LP	2011	77	F	0	N	small hole near dorsal fin
LP	2012	73.5	F	0	N	puncture wounds in abdomen
WD	2012	104	M		N	hook in mouth, spawned out
LP	2013	76	F	0	N	puncture wound above right ventral
PF	2013	84	F	0	H	bite mark on back, puncture on lower side mid body

[1]Sections: WD – McCall Hatchery weir to Dime Creek; DC – Dime Creek to 1 km below Mirror Creek; PF – Poverty Flats; LP – Lodgepole Campground to Phoebe Creek.
[2]Percent spawned was estimated from females only.
[3]Origin: H – hatchery-origin; N – natural-origin.