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ADULT CHINOOK SALMON MONITORING IN THE SOUTH FORK MCKENZIE RIVER RELATIVE TO WATER TEMPERATURE CONTROL AND UPSTREAM PASSAGE FACILITIES AT COUGAR DAM

Prepared for

***U. S. ARMY CORPS OF ENGINEERS***

***PORTAND DISTRICT – WILLAMETTE VALLEY PROJECT***

333 S.W. First Ave.

Portland, Oregon 97204

Prepared by

Nikolas D. Zymonas

Michael J. Hogansen

**Oregon Department of Fish and Wildlife**

**Upper Willamette Research, Monitoring, and Evaluation**

**Corvallis Research Lab**

**28655 Highway 34**

**Corvallis, Oregon 97333**

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# Executive Summary

 Construction of Cougar Dam in 1963 eliminated Chinook salmon *Oncorhynchus tshawytscha* from more than 85% of former habitat in the South Fork McKenzie River (SFMR) and reduced the productivity of river reaches downstream of the dam.  Resource management agencies have since made several changes to fisheries management practices and modifications to Cougar Dam, including out-planting of adult hatchery-origin Chinook salmon upstream of the dam (beginning in 1993), extreme reservoir drawdown during construction of a water temperature control facility and concurrent use of the diversion tunnel (2002–2004), temperature control operations (2005), and operation of an upstream fish passage facility (2010-2012).  Downstream passage modifications for juvenile salmon are being planned.

 The purpose of this project was to monitor abundance, demographic characteristics, and distribution of adult salmon in the SFMR in 2011, and to assess associations among these attributes and other potentially related variables. We assisted with processing fish collected at the Cougar Dam upstream fish passage facility and at McKenzie Hatchery, and we conducted weekly redd and carcass surveys of the SFMR upstream and downstream from Cougar Dam. We collected data on species, length, apparent condition, presence of adipose fin (hatchery or wild origin), and presence of internal tags, and we collected scales (for ageing) and genetics fin samples (for a separate study) from all handled fish and carcasses. We also determined pre-spawn mortality from female carcasses, and we collected otoliths from carcasses having an intact adipose fin to determine the proportion of those fish that were actually of hatchery origin. We identified and enumerated salmon redds to assess spawning abundance and distribution.

 The upstream fish passage facility collected 388 adult Chinook salmon in 2011, including 163 females and 225 males. Females (mean ± SD = 814 ± 65 mm FL; range = 560–975 mm) were significantly longer than males (791 ± 77 mm; 570–1,050 mm). Most adult salmon collected in the upstream passage facility (92%) had an intact adipose fin, and we estimated that wild-origin fish comprised 81% of all adult salmon collected at the facility. Among unmarked salmon, males were primarily age 4 (70%) or age 5 (28%), whereas more females were age 5 (52%) than age 4 (45%). Unmarked age-5 salmon were significantly longer than unmarked age-4 salmon, both within and across sexes, but length did not significantly differ between sexes within age-4 or age-5 groups. During the period of trap operation from 29 March – 24 October 2011, salmon were collected from 23 June – 27 September 2011 with peaks in abundance in early July, early August (after an unanticipated 18-d closure of the facility), and early to mid-September. Males were notably more abundant than females after the facility was re-opened in August through mid-September, and most adipose-marked salmon were collected in September. Most salmon appeared to be in good condition when processed, with externally apparent injuries noted for 54 fish (13.9%). The ratio of wild-origin adult female salmon collected in the upstream passage facility to the number of parental generation hatchery-origin females out-planted in the upper SFMR (i.e., estimated replacement rate, ignoring post-release pre-spawn mortality) was 0.50: 1 in 2011 and 0.17: 1 in 2010.

 We assisted McKenzie Hatchery staff in processing 345 adult hatchery salmon out-planted in the upper SFMR (i.e., upstream of Cougar Dam) in 2011. Females were significantly longer than males at both McKenzie Hatchery and Cougar Dam, and unmarked salmon collected at the dam were significantly longer than hatchery out-plants, both for females and males. Timing and abundance of hatchery salmon out-planting roughly matched releases of unmarked salmon from the upstream passage facility.

 In total, 730 adult salmon were released in the upper SFMR in 2011, including an estimated 311 wild- and 419 hatchery-origin salmon. Total abundance was similar to that in 2005, 2007, 2008, and 2010, although females constituted a considerably higher proportion in 2011 and wild adults were transported upstream only in 2010 and 2011. Fish were released in the upper SFMR beginning somewhat earlier in 2011 than in 2010 as a result of delayed start to operation of the upstream passage facility in 2010.

 We obtained a peak count of 328 salmon redds for the entire SFMR drainage in 2011. We found no redds in tributary streams. The redd count in 2011 exceeded that of all other years during the period 2005–2011 except 2009. Redds in the SFMR comprised 23% of redds in the upper McKenzie Basin in 2011 and varied from 15–42% during the period 2005–2011. The proportion of SFMR redds located upstream of Cougar Dam in 2011 (0.72) slightly exceeded the average for 2005–2011 (mean = 0.65; range = 0.45–0.80) and was higher in the two years in which the upstream fish passage facility operated (2010 and 2011) than in all other years during the period 2005–2011 except for 2009. Exploratory correlation analyses indicated few significant relationships between variables at the scale of the entire SFMR drainage over the period 2005–2011 and no significant correlations with annual peak redd count. However, we obtained relatively high correlation coefficient values for the correlations of annual peak redd count with proportion of SFMR redds upstream of Cougar Dam (*r* = 0.70; *P* = 0.08) and proportion of all upper McKenzie Basin redds in the SFMR (*r* = 0.70; *P* = 0.08). The proportion of upper McKenzie Basin redds in the SFMR was significantly negatively correlated with Leaburg Dam passage abundance (*r* = -0.84; *P* = 0.02). We found no evidence for a positive relationship between redd count and number of female hatchery-origin salmon out-planted in the upper SFMR 3–6 years earlier (*r* = -0.38; *P* = 0.40). Note, though, that the number of data points for this analysis was relatively small, and factors that may have influenced these results included methodological imprecision, changes to dam infrastructure and management, interactions among factors, and influences of other external factors that may affect survival-to-adult return.

 We found 104 salmon carcasses in the entire SFMR in autumn 2011, all of which were in the main stem. We estimated that 77% of all carcasses were of wild origin. Females comprised 74% of the carcasses that we found, of which 1.4% were considered pre-spawn mortalities. The estimated proportion of wild-origin salmon in the entire SFMR in 2011 (0.51), based on the combination of carcass survey results for the lower SFMR and known composition of females released in the upper SFMR, exceeded that for all other years during the period 2005–2011. The coefficient value for the correlation between estimated proportion wild-origin adult salmon in the South Fork McKenzie River and number of hatchery-origin females out-planted in the upper SFMR was relatively high and negative but not significant (*r* = -0.69, *P* = 0.08).

 In the lower SFMR, we found redds beginning on 8 September 2011 and obtained a peak count of 92 redds. Redds were evenly distributed between the upstream and downstream 2-mi survey sections in the lower SFMR, and the proportion of redds in the upper survey section was less than in any previous year during the period 2001–2011. We found fewer redds in the Cougar Dam tailrace in 2010 and 2011 than in previous years, suggesting that upstream transport of salmon collected in the fish passage facility reduced spawning abundance near the dam. Lower SFMR redd count was not significantly correlated with any other included variable for the period 2001–2011, although we found a relatively high and positive correlation coefficient for the association with abundance of wild-origin salmon passing Leaburg Dam (*r* = 0.58; *P* = 0.06). Results of correlation analyses suggested that higher proportions of redds were located in the upstream section of the lower SFMR in years with higher adult returns to the upper McKenzie Basin, higher proportions of hatchery-origin salmon, and higher abundance of adult females out-planted in the upper SFMR 3-6 years earlier.

 We found 77 salmon carcasses in the lower SFMR from 8 September – 14 October 2011, including 45 carcasses in the upper 2-mi survey section and 32 in the lower 2-mi section. We recovered 0.61 female carcasses per redd. We estimated that 80% of carcasses were of wild origin, which exceeded the mean for 2001–2011. Females comprised 72% of carcasses. We found no pre-spawn mortalities among females, although pre-spawn mortality indicated by carcass recoveries has typically been low in the lower SFMR (mean = 5%). Ages estimated from scales collected from unmarked carcasses in the lower SFMR were similar to those obtained for unmarked salmon collected in the upstream passage facility. Correlation analyses indicated that proportion wild-origin spawners in the lower SFMR was negatively associated with adult abundance at Leaburg Dam and positively associated with abundance of adult females out-planted 3–6 years earlier in the upper SFMR. Proportion of wild-origin carcasses in the lower SFMR increased relative to proportion wild-origin adult salmon passing Leaburg Dam beginning in 2006, corresponding to return of age-4 adults that were progeny of adults that spawned beginning in 2002, when dam operations changed during construction of water temperature control facilities and increased numbers of adult salmon were out-planted.

 For the SFMR upstream of Cougar Dam, we first observed redds on 8 September 2011 and obtained a peak count of 236 redds. The peak redd count in 2011 was relatively high for the period 2005–2011 and the number of redds per female released in the upper SFMR in 2011 (0.70) was the highest among years in this period. The reach from the reservoir upstream 6.5 miles accounted for 78% of all redds in the upper SFMR, probably as a result of releasing all adult salmon about 1 mile upstream from the head of the reservoir. We counted 16 redds within the reservoir drawdown zone and 34 redds downstream of the rotary screw trap site. Annual peak redd count for the upper SFMR was not significantly correlated with number of adult female salmon (both hatchery and wild-origin) released in the upper SFMR, although the correlation coefficient was relatively high and positive (*r* = 0.65, *P* = 0.11).

 We found 27 salmon carcasses in the SFMR upstream from Cougar Dam from 31 August – 20 October 2011. Distribution of carcasses roughly matched redd distribution, with 37% of carcasses in the downstream-most sub-reach and 19% of carcasses in each of the next two sub-reaches upstream to RM 16. Although 49% of salmon released upstream of Cougar Dam were unmarked and 46% were females, corresponding values for carcasses were 77% for each of these categories, indicating that carcass recovery was biased towards unmarked females. We found only one pre-spawn mortality among the 17 recovered female carcasses in the upper SFMR. We estimated that 68% of carcasses were of wild origin. These metrics were probably influenced by the low recovery rate (<4% of all adult salmon released upstream, amounting to 0.07 female carcasses per redd), which stemmed from factors such as large channel width and high discharge, downstream movement of carcasses into the reservoir, and removal of carcasses by scavengers.

# Introduction

 The McKenzie River basin historically produced substantial runs of Chinook salmon *Oncorhynchus tshawytscha*, with the South Fork McKenzie River (SFMR) perhaps supporting the greatest production among streams in the basin (Mattson 1948). Redd counts in the South Fork McKenzie River were as high as 805 in 1956 and 686 in 1958, and the estimated run size was 4,300 adult salmon in 1958 (USFWS 1959; Willis et al. 1960). Within the South Fork McKenzie River drainage, the majority of Chinook salmon spawning historically occurred upstream of the present site of Cougar Dam (USDI 1960; Willis et al. 1960; Ingram and Korn 1969).

 Following construction of Cougar Dam in 1963, the Fish Commission of Oregon evaluated upstream passage of adult salmon and downstream passage of juveniles through the original passage facilities. Studies indicated that few adult salmon moved upstream to Cougar Dam because water temperatures in the South Fork McKenzie River were substantially colder in late spring and summer after completion of the dam (Ingram and Korn 1969). Downstream fish passage facilities provided low collection efficiency, and juvenile salmon that entered the facility incurred high mortality rates. Passage at the dam was discontinued, eliminating production in 25 miles of formerly accessible habitat.

 Changes in the water temperature regime after completion of Cougar Dam also adversely affected salmon production downstream of the dam. Elevated water temperatures associated with reservoir drawdown in autumn and early winter resulted in accelerated early development and emergence (Homolka and Downey 1995). Early emergence was believed to reduce survival of Chinook salmon fry as a consequence of exposure to winter freshets, low stream productivity, and increased vulnerability to predators.

 During the past two decades, a series of fisheries management changes and modifications to Cougar Dam have affected the Chinook salmon population in the SFMR. In 1993 ODFW began out-planting adult hatchery-origin Chinook salmon and subsequently found that progeny of these fish may survive downstream passage and return as adults (Taylor 2000; Beidler and Knapp 2005; Zymonas et al. *in review*). The reservoir was drawn down during construction of a water temperature control facility in 2002–2004, and erosion of accumulated sediment led to extended periods of high turbidity within the residual pool and downstream that may have reduced the suitability of spawning habitat near the dam (USACE 2003; Anderson 2007; Zymonas et al. *in review*). Temperature control operations began in 2005, aligning the temperature regime of the downstream reach with a more natural pattern (Rounds 2007), but the run of adult salmon in 2011 included only the first generation of individuals to hatch under the new temperature regime. Altered thermal regimes and out-planting of hatchery adults may affect salmon populations by means of competition and genetic selection (Ford et al. 2006; Angilletta et al. 2008). Finally, the U.S. Army Corps of Engineers (USACE) constructed an upstream fish passage facility in 2009–2010 and began operating this facility on 27 July 2010. A total of 252 adult Chinook salmon was transported upstream in 2010; 88% lacked an adipose fin-clip and 72% were males. By passing a large number of wild fish upstream of the dam for the first time in more than 40 years, operation of the passage facility altered spawning distribution, abundance, and ratios of wild- to hatchery-origin spawners both upstream and downstream of the project (Zymonas et al. *in review*). Effectiveness monitoring, an essential component of fish passage programs (Calles and Greenberg 2009), was stipulated in ESA planning (NMFS 2008), but a substantial delay in initial operation of the facility precluded collection of monitoring data under conditions representative of normal operating conditions in 2010.

 The primary objective of this investigation was to evaluate status of the Chinook salmon population in the South Fork McKenzie River in relation to the management and structural changes noted above. In this project phase, we addressed this objective by: (1) collecting biological data on fish captured in the upstream fish passage facility and assisting in its operation; and (2) providing information on spawning distribution, abundance, and origin (hatchery or wild) of adult Chinook salmon. We conducted redd counts and carcass surveys that built upon an existing dataset including surveys conducted downstream of Cougar Dam since 2001 and upstream of Cougar Reservoir since 2005 (Kenaston et al. 2009; Zymonas et al. *in review*). We aimed to assess spawning abundance and to evaluate relationships among spawning abundance and various demographic and abundance variables. Results of these investigations will be used to help gauge the status of the Chinook salmon population in the South Fork McKenzie River and guide management decisions regarding the larger goal of establishing a sustainable Chinook salmon population that utilizes the habitat upstream of Cougar Reservoir. Managers expect that interacting influences of water temperature control at Cougar Dam, upstream passage, and controlled levels of hatchery out-planting will continue to affect this population. Collection of biological data and corresponding genetics samples will also support separate studies currently in progress.

# Methods

## Task 1.1 Cooperatively assist with collection of biological data (species, length, weight, condition, presence of marks or tags, insertion of new tags, collection of genetics tissue samples) and disposition of fish captured at the Cougar Dam fish passage facility during the scheduled period of operation (March – October).

 We assisted in processing fish collected at the Cougar Dam upstream fish passage facility in coordination with USACE staff. We conducted daily site visits to visually assess presence, abundance, and species of fish in the pre-sort holding pool located at the top of the fish ladder, and we notified USACE staff of our observations. Surface flow into the holding pool was nonexistent except during fish processing events (flow normally entered at the bottom of the pool), and a finger weir discouraged fish from returning downstream into the ladder. Fish processing and transfer events were typically conducted when at least ten adult salmon or one bull trout *Salvelinus confluentus* were present in the holding pool, and sometimes more often during the salmon run (May–September). An automated crowding gate moved fish to the upstream end of the holding pool, where inflowing spill attracted fish to jump over a false weir into a flume that terminated in an anesthesia tank. We hand-netted any fish that were confined by the crowder but did not volitionally exit the holding pool. Fish were transferred into the tank in small groups and anesthetized using clove oil (9:1 mixture with 95% ethanol). Inflowing fresh water maintained sufficiently cool water temperature in the anesthesia tank, and additional anesthetic was added if necessary to maintain proper concentration.

 We identified species and sex and measured fork length of each fish. Staff from the ODFW McKenzie Fish Hatchery provided expertise in identification of sex of adult Chinook salmon early in the season when secondary sexual characteristics were relatively undeveloped. Sex of most adult salmon was readily apparent by August. We noted any instances in which sex could not be confidently identified. Collection of genetic tissue samples provided a means for later verification of identified sex.

 We inspected fish for external marks and used a handheld reader to scan bull trout for passive integrated transponder (PIT) tags. We implanted a 23-mm half-duplex PIT tag in any untagged bull trout. We collected scales from bull trout and adult Chinook salmon from a key area three rows above the lateral line between the posterior margin of the dorsal fin and the insertion of the anal fin. We placed the scale samples onto ‘gum cards’ and added a unique identification code for each fish. Fin tissue samples for genetic analysis were collected from all bull trout and adult Chinook salmon and stored in individual containers with 100% ethanol. Scales were sent to the ODFW Corvallis Research Laboratory and fin tissue samples were sent to Oregon State University for later genetics analyses. Age assignments considered fish to be age 1 in the calendar year following egg deposition (following the Gilbert–Rich designation method).

 We placed adult salmon and most trout into a post-sort holding pool for recovery after processing. After these fish recovered, they were ‘flushed’ through an orifice at the bottom of the holding pool into the top of a fish transport truck tank located directly below. These fish were transported upstream to the USFS – Hard Rock Group Site at river mile 11. Transported fish were released through a 2-ft diameter discharge tube from the lower portion of the transport truck tank down a pneumatically controlled ramp with ≤ 30 cm vertical drop into the SFMR. Staff remained on site to ensure that released fish either volitionally swam off or otherwise appeared to be in good condition. Two bull trout collected in April were transported and released at the Slide Creek boat ramp at the head of the reservoir. Juvenile salmon, hatchery rainbow trout *O. mykiss*, and hatchery steelhead adults were placed into a separate recovery tank and then returned to the SFMR downstream of Cougar Dam.

 We summarized data for the Cougar Dam upstream fish passage facility according to sex and origin of salmon. We used two-way ANOVA to test for significant length differences between sexes and between wild- and hatchery-origin groups. We used Kruskal–Wallis tests with Dunn’s post-hoc multiple comparisons to assess length differences among groups partitioned according to the eight combinations of sex, origin, and age (ages 4 and 5). Non-parametric procedures such as the Kruskal–Wallis test were used if the data did not meet parametric assumptions of normality and equal variance. We used two-way ANOVA with Holm–Sidak post-hoc multiple comparisons to test for length differences between unmarked salmon collected at the upstream fish passage facility and salmon out-planted in the upper SFMR from McKenzie Hatchery. Collection site and sex were the two included factors. We used graphical methods to describe timing of salmon collection in the upstream fish passage facility and out-planting from McKenzie Hatchery. We estimated replacement rate for out-planted hatchery-origin adult female salmon by dividing the number of females collected in the Cougar Dam upstream fish passage facility by the number of parental generation females, as indicated by ages estimated using scales.

## Task 2.1 Conduct redd count surveys (census) weekly from mid-August through October. Spatial extent includes the South Fork McKenzie River from the mouth to Cougar Dam and from the head of Cougar Reservoir to the Elk Creek confluence. Other potential spawning locations (e.g., upstream from Elk Creek confluence, French Pete Creek, East Fork) will be surveyed at least once. Collect GPS locations to provide information on redd distribution.

 We conducted redd count surveys based on standard protocols (Johnson et al. 2007) to obtain an index of Chinook salmon spawning abundance. Surveyors received training at the start of the season and cooperatively conducted initial surveys with highly experienced ODFW Corvallis Research Laboratory staff to ensure that all surveyors followed standard protocols. During each survey, we counted any identifiable redds while also searching for live fish and carcasses (see Task 2.2). Surveys were performed by hiking and wading in the reach extending from about one mile upstream of the mouth of Elk Creek (RM 26) to the Dutch Oven Campground (RM 16) and via inflatable raft or kayak from RM 16 to the head of Cougar Reservoir (about 19.5 mi total) and from Cougar Dam downstream to the confluence with the main stem McKenzie River (4.2 mi). Two or three surveyors completed each boat-based survey, whereas one or two surveyors conducted each walking survey. Surveyors coordinated to ensure complete coverage of the entire main channel and any side channels.

 We conducted approximately weekly surveys of the SFMR downstream of Cougar Dam (lower SFMR) during the period 7 July – 13 October 2011 and upstream of Cougar Reservoir (upper SFMR) during 11 July – 20 October 2011. We divided the upper and lower SFMR into designated survey reaches to provide information on spawning distribution. The upper SFMR included eight reaches delineated by readily recognizable tributaries or campgrounds. The upstream-most reaches near Elk Creek were surveyed on fewer occasions as a result of logistical constraints. We divided the lower SFMR into two reaches: (1) the 2.2-mi reach from Cougar Dam downstream to the FR 19 bridge, and (2) the 2.1-mile reach from the FR 19 bridge downstream to the confluence with the McKenzie River. We collected GPS locations for all reach boundaries and at sites where redds were concentrated. We maintained reach boundaries that were consistent with those of previous years to facilitate interannual comparisons of distribution and abundance.

 We conducted redd surveys in several tributaries of the upper SFMR on at least one occasion. One survey was conducted in the lower one mile of Augusta Creek, Elk Creek, the E. Fk. S. Fk. McKenzie River, and French Pete Creek. We also conducted six complete surveys of the lower 1.6 mi of Roaring River primarily to document spawning abundance of bull trout as part of a separate project funded by the USACE (Monitoring the Status of Bull Trout Influenced by the Willamette Project). Chinook salmon spawning in Roaring River was documented in 2002 (Zymonas et al. *in review*).

 We summarized redd count data at multiple spatial scales, including the entire SFMR, the segments upstream and downstream of Cougar Reservoir, and designated survey reaches within each segment. Annual total counts for the entire SFMR and upper and lower segments consisted of the sum of peak counts for each designated survey reach. We used Pearson correlation analysis to assess associations among variables pertaining to salmon abundance and demographics and to identify relationships potentially warranting future research and management attention. Although we report significance at α = 0.05, we also point out some non-significant correlations that may deserve consideration, given the influences of small sample sizes (relatively few years of data), methodological imprecision, and process noise (see Gibbs et al. 1998). We also conducted simple linear regression analyses with selected variables that potentially explain variation in spawning abundance.

 Analyses at the scale of the entire SFMR included two key abundance metrics: (1) total number of redds in the SFMR, and (2) SFMR redd count as a proportion of total redds in the upper McKenzie River basin upstream of Leaburg Dam during the period 2005–2011 (redd surveys were consistently conducted in the lower SFMR beginning in 2001 and in the upper SFMR beginning in 2005; redd counts for other areas in the basin were obtained from ODFW –Willamette Spring Chinook Salmon Project). Although various factors affecting survival-to-adult-return complicate assessment of population response to specific management and structural changes in the SFMR, managers anticipate that these actions will result in overall higher abundance of wild-origin adult salmon.

 Additional abundance variables in correlation analyses included counts of adult Chinook salmon passing Willamette Falls (adults and jacks), total and wild-origin adult Chinook salmon passing Leaburg Dam (adults; adjusted for fallback of hatchery fish and for results of otolith analyses), and number of female salmon out-planted in the upper SFMR (hatchery-origin only and total including wild-origin fish in 2010 and 2011; log*e*-transformed to meet parametric assumptions). We also included the estimated number of female salmon out-planted upstream of Cougar Dam 3–6 years earlier (i.e., potential maternal parents) as an index of potential abundance of wild-origin salmon produced in the upper SFMR. Scale analysis indicated that McKenzie River returns in 2001–2006 consisted of 70.8% age-5, 26.7% age-4, 2% age-6, and 0.5% age-3 salmon (Schroeder et al. 2007), and we used these percentages to estimate the number of out-planted adult female potential parents for returning spawners each year. We estimated the proportion of the spawning population consisting of wild-origin salmon as the weighted mean of proportions for the upper and lower SFMR, based on carcass surveys for the lower SFMR (see Task 2.2 for carcass data) and known composition of females released in the upper SFMR during the period 2005–2011 and using number of redds in each segment as the weighting factor. Proportion of SFMR salmon redds located upstream of Cougar Dam was included as a coarse measure of spawning distribution within the SFMR. Simple linear regression analyses used annual peak redd count or proportion of total redds in the upper McKenzie River basin as the response variable and Leaburg Dam passage counts, number of female salmon out-planted in the upper SFMR, and number of female salmon out-planted 3–6 years earlier as explanatory variables. All percentage data were arcsine-transformed for analysis, and the Shapiro–Wilk test was used to test for departure from the normal distribution.

 We separately summarized and analyzed data for the segments downstream and upstream of Cougar Dam. We conducted correlation analyses similar to those described above using data from 2001–2011 for the lower SFMR. These included peak redd count in the lower reach, number of female salmon out-planted 3–6 years earlier, passage of adult salmon at Willamette Falls and Leaburg Dam, proportion of lower SFMR redds that were in the upstream 2 miles from the dam to the FR 19 bridge, proportion of wild-origin carcasses and proportion of female carcasses determined to be pre-spawning mortalities (see Task 2.2 for carcass data). For the upper SFMR, we assessed correlation of annual peak redd count with number of adult female salmon (both hatchery and wild-origin) including data for years 2005–2011.

## Task 2.2 Conduct complete carcass surveys (census) weekly from mid-August through October. Spatial extent includes the South Fork McKenzie River from the mouth to Cougar Dam and from the head of Cougar Reservoir to the Elk Creek confluence. Collect GPS locations to provide information on carcass distribution (coarse indicator of spawning location). To determine hatchery vs. wild origin, record presence or absence of adipose fin and collect otoliths. Collect genetics tissue samples from carcasses encountered downstream of the dam (samples will be collected from all live fish transported upstream).

 We sampled Chinook salmon carcasses to enable characterization of sex ratios, pre-spawning mortality, age structure, and proportion of hatchery- versus wild-origin adult salmon in the South Fork McKenzie River. During each spawning survey described in Task 2.1, we enumerated all adult Chinook salmon carcasses, noted whether the adipose fin was removed or intact, and scanned for implanted coded wire tags using a handheld reader. We collected the snout from each tagged fish for later retrieval of tags and identification of tag code, which indicated the hatchery and release group of origin. We recorded fork length and sex, and we determined whether females had spawned. If necessary, we made an incision in the abdomen to determine sex and assess whether females were pre-spawning mortalities (still contained a majority of expected quantity of eggs). We collected scales from all carcasses for age determination and fin tissue samples for genetic analyses (as described above). We collected otoliths from all carcasses having intact adipose fins, and we contracted with Washington Department of Fish and Wildlife to verify hatchery or wild origin through identification of hatchery-induced thermal marks on otoliths. We removed the caudal fin from all carcasses after processing to prevent re-counting on subsequent surveys. Carcasses that were excessively scavenged, decomposed, or otherwise unrecoverable were recorded as ‘unprocessed’ carcasses.

 We summarized spawning data using summary statistics and correlation analysis. The number of hatchery-origin salmon was estimated as:

(number of unclipped adipose fin adults) \* (proportion of unclipped adults that otolith analyses indicated were hatchery-origin fish) + (number of adipose fin-clipped adults).

We included variables indicating the proportion of wild-origin carcasses and proportion of female carcasses determined to be pre-spawning mortalities in the correlation and regression analyses described in Task 2.1 above to assess relationships among pre-spawning mortality, proportion wild-origin spawners, and other abundance metrics.

# Results and Discussion

## Task 1.1 Cooperatively assist with collection of biological data (species, length, weight, condition, presence of marks or tags, insertion of new tags, collection of genetics tissue samples) and disposition of fish captured at the Cougar Dam fish passage facility during the scheduled period of operation (March – October).

 The upstream fish passage facility collected 671 fish representing five species during the period of operation from 29 March – 24 October 2011 (Table 1). This included 388 adult Chinook salmon and five bull trout. Other fishes included rainbow trout (freshwater resident form and adult summer steelhead), cutthroat trout *O. clarkii*, and mountain whitefish *Prosopium williamsoni*. Adult salmon included 163 females and 225 males (Table 2). Two of the males were jacks (i.e., males < 610 mm) that measured 570 and 587 mm FL. Overall, adult salmon averaged 800 ± 75 mm FL (mean ± SD).

Table 1. Counts of fish collected in the upstream fish passage facility in 2011, by species, life stage, sex, and hatchery mark (adipose fin removed). Bull trout varied from 485–614 mm FL. Count of male salmon includes two jacks. Steelhead were recaptured on three additional occasions.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Life stage | Female | Male |   | Marked  | Unmarked |   | Total |
| Bull trout | Adult | - | - |  | 0 | 5 |  | 5 |
| Chinook salmon | Adult | 163 | 225 |  | 30 | 358 |  | 388 |
|  | Juv. | - | - |  | 0 | 1 |  | 1 |
| Cutthroat trout | - | - | - |  | 0 | 109 |  | 109 |
| Mountain whitefish | - | - | - |  | 0 | 5 |  | 5 |
| Rainbow trout | - | - | - |  | 2 | 156 |  | 158 |
| Steelhead | Adult | 4 | 1 |   | 4 | 1 |   | 5 |

 Most adult salmon in the upstream passage facility (92%) were unmarked (i.e., the adipose fin was intact) (Table 2). Females comprised 43% of unmarked salmon and 27% of marked salmon, suggesting a lower rate of straying to the dam for hatchery-origin females than males in the McKenzie Basin. Females averaged 814 ± 65 mm (range = 560–975 mm) and males averaged 791 ± 77 mm (570–1,050 mm) (). Length was significantly greater for females than males (two-way ANOVA: df = 1, 384; *F* = 4.10; *P* = 0.04). Length did not differ significantly between marked and unmarked salmon (df = 1, 384; *F* = 0.60; *P* = 0.44), although the number of marked male salmon was small (*N* = 8) and some unmarked fish were of hatchery origin. The interaction term was not significant (*df* = 1, 384; *F* = 0.33; *P* = 0.57). Genetic analyses indicated that 88% of *N* = 42 age-4 salmon assigned to at least one previously out-planted parent, indicating that the facility was primarily attracting fish that originated in the upper SFMR (Marc Johnson, ODFW, memorandum dated 29 August 2011).

 Otolith analyses for carcasses collected upstream from Cougar Reservoir indicated that 13% (2 of 15) of unmarked fish were actually of hatchery origin. Based on these data, we estimated that wild-origin fish comprised 81% of all adult salmon collected at the fish passage facility and transferred upstream, including 83% of females and 79% of males (Table 2).

 Ages estimated from scales of salmon collected in the fish passage facility varied from 3 to 6. Ages were estimated for 328 salmon, including 139 females and 189 males, and 304 unmarked and 24 marked salmon. Among unmarked salmon, males were primarily age 4 (70%) or age 5 (28%), whereas more females were age 5 (52%) than age 4 (45%) (Figure 2). Median length of females exceeded that of males for age-4 (females =783 mm, males = 768 mm) and age-5 unmarked salmon (females = 852 mm, males = 848 mm) (Figure 3). Although unmarked age-5 salmon were significantly longer than unmarked age-4 salmon, both within and across sexes (Kruskal–Wallis test: *H* = 83.2, *df* = 3, *P* <0.001; Dunn’s multiple comparisons: all *P* < 0.05), length did not significantly differ between sexes within age-4 or age-5 groups (*P* > 0.05). Small sample sizes precluded inclusion of age-3 or age-6 groups in statistical tests. For marked fish, 13 of 24 salmon were males estimated to be age 4, while the remainder consisted of nearly equal numbers of age-5 males and age-4 and age-5 females (Figure 2).

Table 2. Numbers of adult Chinook salmon transported upstream of Cougar Dam in 2010 and 2011, by hatchery or wild origin, sex, and collection site. Jacks are males < 610 mm FL.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   |   | 2010 |   | 2011 |
| Source | Sex | Cougar Dam Passage Facility | McKenzie Hatchery |  | Cougar Dam Passage Facility | McKenzie Hatchery | Total |
| **Raw Counts** |
| Unmarked | F | 64 | 0 |  | 153 | 0 | 153 |
|  | M | 155 | 0 |  | 200 | 0 | 200 |
|  | J | 3 | 0 |  | 2 | 0 | 2 |
| Marked | F | 6 | 245 |  | 8 | 175 | 183 |
|  | M | 24 | 251 |  | 22 | 166 | 188 |
|   | J | 1 | 1 |  | 0 | 4 | 4 |
| *Sub-Total* | F | 70 | 245 |  | 161 | 175 | 336 |
|  | M | 179 | 251 |  | 222 | 166 | 388 |
|  | J | 4 | 1 |  | 2 | 4 | 6 |
| *Total* | All | 253 | 497 |  | 385 | 345 | 730 |
|  |  |  |  |  |  |  |  |
| % Unmarked | F | 91.4 | 0 |  | 95.1 | 0 | 46 |
|  | M | 86.6 | 0 |  | 90.1 | 0 | 52 |
|  | J | 75 | 0 |  | 100 | 0 | 33 |
| **Estimates (Corrections Based on Otolith Analyses)** |
| Wild | F | - | - |  | 134 | 0 | 134 |
|  | M | - | - |  | 175 | 0 | 175 |
|  | J | - | - |  | 2 | 0 | 2 |
| Hatchery | F | - | - |  | 27 | 175 | 202 |
|  | M | - | - |  | 47 | 166 | 213 |
|   | J | - | - |  | 0 | 4 | 4 |
| *Sub-Total* | F | - | - |  | 161 | 175 | 336 |
|  | M | - | - |  | 222 | 166 | 388 |
|  | J | - | - |  | 2 | 4 | 6 |
| *Total* | All | - | - |  | 385 | 345 | 730 |
|  |  |  |  |  |  |  |  |
| % Wild | F | - | - |  | 83 | 0 | 40 |
|  | M | - | - |  | 79 | 0 | 45 |
|   | J | - | - |  | 100 | 0 | 33 |

 Based on age structure of unmarked adult female salmon in 2011, we estimated the ratio of female salmon collected in the upstream passage facility to parental generation females out-planted in the upper SFMR (i.e., replacement) to be 0.50: 1. For 2010, this ratio was 0.17: 1 (using the 2011 age structure data). Although only two years of data were available, these data indicate that the rate of return from out-planted adult females was considerably less than replacement. Collection of salmon that originated downstream of the dam would inflate this estimate, whereas spawning downstream of the collection facility by salmon produced in the upper SFMR would lead to underestimation of replacement rate.

 Temporal distribution of collection in the fish passage facility included three peaks in abundance (Figure 4). Salmon were first collected on 23 June 2011 and abundance increased beginning the week of 3 July 2011. Unanticipated closure of the facility as a result of mechanical failure strongly affected the temporal distribution of operation in 2011, and no fish were collected for an 18-d period from 19 July – 6 August. Abundance immediately peaked (77 fish) upon re-opening of the facility during the week of 7 August then declined through the remainder of August. A third peak in abundance occurred during the weeks of 5 and 12 September. The last salmon was collected on 27 September, and operations ended for the year on 24 October 2011.

 Temporal distribution varied by sex and origin (Figure 4). Although the seasonal pattern was broadly similar between female and male salmon, females outnumbered males only during the weeks of 4 and 11 July, and males were notably more abundant after the facility was re-opened in August through mid-September. The initial portion of the run consisted entirely of unmarked salmon. Marked salmon were first collected on 9 August, and most marked salmon were collected in September.

 Most salmon appeared to be in good condition when processed. Externally apparent injuries were recorded for 54 fish (13.9%), including 31 having damage to the body, 19 only to the fins, and 4 with relatively minor scrapes. We did not identify the source of these wounds, although some appeared to be claw or bite marks from predators. Head wounds (dorsal surface, excluding jaw) were noticed on 18 salmon, including 13 relatively severe wounds.

 All but three salmon collected at the upstream passage facility in 2011 survived handling and transport at least to their time of release upstream at RM 11. These included only one mortality attributable to normal facility operations. In this instance, the crowding gate crushed an unmarked 845-mm adult female salmon as the gate was being lowered at the downstream end of the holding pool on 27 June 2011. An unmarked 735-mm adult female salmon died on 11 July 2011 as a result of requested removal of an external temperature logger that was gastrically implanted as part of a separate investigation in the basin. Finally, an unmarked 805-mm adult male salmon was found dead in the holding pool on 26 September 2011, but the advanced degenerative condition of this fish suggested that it had probably already spawned and the facility was not the source of mortality.

 We assisted McKenzie Hatchery staff with processing 345 adult hatchery salmon out-planted in the upper SFMR in 2011 (Table 2). All salmon were marked hatchery fish except for one unmarked male. Length of out-planted hatchery salmon averaged 772 ± 67 mm FL (mean ± SD) (Figure 1). Females averaged 790 ± 53 mm (range = 560–975 mm; *N* = 175) and males averaged 754 ± 75 mm (range = 330–1,040 mm; *N* = 170). Length was significantly greater for unmarked salmon collected at Cougar Dam than for out-planted salmon from McKenzie Hatchery (two-way ANOVA: df = 1, 666; *F* = 38.13; *P* < 0.001) and significantly greater for females than males (*F* = 26.18; *P* < 0.001). The interaction term was not significant (*F* = 0.60; *P* = 0.44). Post-hoc multiple comparisons (Holm–Sidak) indicated that females were significantly longer than males at each site and that unmarked salmon at the dam were significantly longer than hatchery out-plants, both for females and males (all *P* ≤ 0.002). Note that our data apply to those salmon out-planted in the upper SFMR and may not be representative of the entire population of hatchery salmon that returned to McKenzie Hatchery in 2011.

 Timing and abundance of hatchery salmon out-planting roughly matched that of releases of unmarked salmon from the upstream passage facility (Figure 5). Differences in temporal distribution between the two groups stemmed largely from the unexpected shutdown of the upstream passage facility from 19 July to 6 August, upstream transport of marked salmon collected at the upstream passage facility (counted towards the total of hatchery-origin salmon), and logistical issues associated with fish collection and processing at McKenzie Hatchery.

 In total, we released 730 adult salmon in the upper SFMR in 2011 (Table 3). This was similar to total numbers in 2005, 2007, 2008, and 2010, although females constituted a considerably higher proportion in 2011 and wild adults were transported upstream only in 2010 and 2011. Also, fish were released in the upper SFMR beginning somewhat later in 2010 than in 2011 as a result of delayed operation of the upstream passage facility. Salmon released in the upper SFMR in 2011 included 358 unmarked and 375 marked adults. Based on otolith analyses, we estimated that 311 wild- and 419 hatchery-origin salmon were released. These expanded estimates should be considered with caution because of the low rate of carcass recovery in the upper SFMR. However, these data demonstrate the need to incorporate ratios of unmarked hatchery fish if management objectives specify achieving target levels of hatchery and wild fish.





Figure 1. Length–frequency histogram for unmarked adult Chinook salmon (intact adipose fin) collected at the Cougar Dam upstream fish passage facility (top) and adult Chinook salmon from McKenzie Hatchery out-planted in the upper SFMR in 2011 (bottom). One additional 330-mm male (omitted here) was out-planted.





Figure 2. Age frequencies for unmarked (top) and marked (bottom) adult salmon collected at the Cougar Dam upstream fish passage facility in 2011. One age-6 unmarked male (omitted here) was also collected.





Figure 3. Median length (mm FL; bars = 25th – 75th percentiles) of unmarked (top) and marked (bottom) adult salmon collected at the Cougar Dam upstream fish passage facility in 2011. See Figure 1 for sample sizes. One fish (age-6, 915-mm unmarked male) omitted here.



Figure 4. Weekly count of marked and unmarked female and male salmon collected at the Cougar Dam upstream fish passage facility in 2011.



Figure 5. Weekly number of salmon from the upstream passage facility and McKenzie Hatchery transported and released upstream of Cougar Reservoir in 2011. Table 3. Adult Chinook salmon released upstream of Cougar Dam, peak redd counts, and carcass counts in 1993–2011. Totals include fish from the Leaburg Dam ladder trap in 2002 (300 M, 312 F, 7 J), 2003 (214 male, 110 female, 9 juvenile), and in 2007–2009 (brought to McKenzie Hatchery and out-planted with fish collected at the hatchery). Redd counts were obtained during a single survey in 2005–2008 but from multiple, repeated surveys in 2009–2011. Sex was identified for carcasses only in 2009–2011.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | Adult ChS Released  |  |  Redds |  | Carcasses |
| Year | Total | Male | Fe-male | Jack |  | Peak count | Redds/F | F/ Redd |  | Total | Fe-male | Pre-spawn mort |
| 1993 | 56 | 22 | 33 | 1 |  |  |  |  |  |  |  |  |
| 1994 | 0 | 0 | 0 | 0 |  |  |  |  |  |  |  |  |
| 1995 | 0 | 0 | 0 | 0 |  |  |  |  |  |  |  |  |
| 1996 | 294 | 127 | 160 | 7 |  |  |  |  |  |  |  |  |
| 1997 | 1038 | 572 | 465 | 1 |  |  |  |  |  |  |  |  |
| 1998 | 327 | 165 | 153 | 9 |  |  |  |  |  |  |  |  |
| 1999 | 549 | 366 | 180 | 3 |  |  |  |  |  |  |  |  |
| 2000 | 1506 | 801 | 695 | 10 |  |  |  |  |  |  |  |  |
| 2001 | 2055 | 1233 | 765 | 57 |  |  |  |  |  |  |  |  |
| 2002 | 4861 | 2767 | 2038 | 56 |  |  |  |  |  |  |  |  |
| 2003 | 3884 | 2140 | 1680 | 64 |  |  |  |  |  |  |  |  |
| 2004 | 3430 | 2143 | 1263 | 24 |  |  |  |  |  |  |  |  |
| 2005 | 863 | 462 | 387 | 14 |  | 110 | 0.28 | 3.5 |  | 9 |  |  |
| 2006 | 1018 | 765 | 243 | 10 |  | 162 | 0.67 | 1.5 |  | 4 |  |  |
| 2007 | 743 | 438 | 297 | 8 |  | 95 | 0.32 | 3.1 |  |  2 |  |  |
| 2008 | 874 | 573 | 288 | 13 |  | 128 | 0.44 | 2.3 |  | 10 |  |  |
| 2009 | 1387 | 651 | 629 | 107 |  | 274 | 0.44 | 2.3 |  | 53 | 31 | 3 |
| 2010 | 749 | 430 | 315 | 4 |  | 175 | 0.56 | 1.8 |  | 32 | 25 | 2 |
| 2011 | 730 | 388 | 336 | 6 |  | 236 | 0.70 | 1.4 |  | 27 | 17 | 1 |

## Task 2.1 Conduct redd count surveys (census) weekly from mid-August through October. Spatial extent includes the South Fork McKenzie River from the mouth to Cougar Dam and from the head of Cougar Reservoir to the Elk Creek confluence. Other potential spawning locations (e.g., upstream from Elk Creek confluence, French Pete Creek, East Fork) will be surveyed at least once. Collect GPS locations to provide information on redd distribution.

Entire SFMR

 We obtained a peak count of 328 redds for the entire SFMR drainage in 2011, including 92 redds downstream and 236 upstream from Cougar Dam (Table 4). We found no redds in tributary streams. The redd count for the SFMR in 2011 exceeded that of all other years during the period 2005–2011 except 2009 (Figure 6) when considerably more female salmon were out-planted and 342 redds were counted (274 in the upper SFMR). Although the slope of the regression line was positive, linear regression indicated no significant trend in redd count across this period (*r*2 = 0.40; *P* = 0.13). Redds in the SFMR comprised 23% of redds in the upper McKenzie Basin in 2011, varying from 15–42% during the period 2005–2011. Linear regression indicated no trend in this proportion during this period (*r*2 = 0.07; *P* = 0.57). The proportion of SFMR redds located upstream of Cougar Dam in 2011 (0.72) slightly exceeded the average for 2005–2011 (mean = 0.65; range = 0.45–0.80). Proportion of SFMR redds upstream of Cougar Dam was higher in the two years in which the upstream fish passage facility operated (2010 and 2011) than in all other years during the period 2005–2011 except for 2009.

 Correlation and regression analyses indicated relatively few strong relationships between variables at the scale of the entire SFMR drainage over the period 2005–2011 (; ; ; Table 6). We obtained relatively high coefficient values for correlations of peak redd count with SFMR proportion of upper McKenzie Basin redds and proportion SFMR redds upstream from Cougar Dam (both *r* = 0.70; *P* = 0.08), although neither correlation was significant at α = 0.05. We found no indication of a positive relationship between redd count and number of female salmon out-planted 3–6 years earlier in correlation (*r* = -0.38; *P* = 0.40) or regression analyses. The SFMR proportion of upper McKenzie Basin redds was significantly negatively correlated with Leaburg Dam passage abundance (*r* = -0.84; *P* = 0.02), suggesting that considerable variation in passage abundance at Leaburg Dam was associated with spawning elsewhere in the upper McKenzie Basin. Regression analysis indicated that Leaburg Dam passage abundance explained 70% of the variation in SFMR proportion of upper McKenzie Basin redds. We also obtained non-significant but relatively high correlation coefficient values for correlations of SFMR proportion of upper McKenzie Basin redds with abundance of only wild-origin salmon passing Leaburg Dam (*r* = -0.71), redd count in the entire SFMR (*r* = 0.70), and proportion of SFMR redds in the upper SFMR (*r* = 0.66). Upstream passage abundance of wild-origin salmon at Leaburg Dam was significantly positively correlated with abundance of all salmon at Leaburg Dam (*r* = 0.91; *P* < 0.01), and number of out-planted hatchery-origin female salmon was significantly positively correlated with total number of female salmon released into the upper SFMR (*r* = 0.91; *P* < 0.01; both variables log*e*-transformed). The significant negative correlation between Willamette Falls passage abundance and number of female salmon out-planted 3–6 years earlier (*r* = -0.82; *P* = 0.02) reflected a positive relationship between Willamette Falls passage abundance and number of female salmon out-planted the same year (typically, high abundance years at McKenzie Hatchery as well as at Willamette Falls).

Table 4. Weekly number of redds counted in designated survey reaches of the SFMR and tributaries in 2011. Peak counts in bold; asterisk indicates slightly higher count not considered as the peak count (see text).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Section | Length (mi) | 3-Jul | 10-Jul | 17-Jul | 24-Jul | 31-Jul | 7-Aug | 14-Aug | 21-Aug | 28-Aug | 4-Sep | 11-Sep | 18-Sep | 25-Sep | 2-Oct | 9-Oct | 16-Oct |
| **S Fk McKenzie R - Upstream of Cougar Dam** |
| RM 25.0 - 26.0 | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | **2** | - | 2 |
| RM 22.2 - 25.0 | 2.8 | - | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - | - | **3** |
| RM 20.0 - 22.2 | 2.2 | - | - | - | - | - | - | - | 0 | - | - | - | 3 | 1 | - | - | **7** |
| RM 18.0 - 20.0 | 2.0 | - | - | - | - | - | 0 | - | 0 | 0 | - | 4 | 2 | 15 | - | - | **29** |
| RM 16.1 - 18.0 | 1.9 | - | - | - | - | - | 0 | - | 0 | 0 | - | 0 | 1 | 7 | - | - | **10** |
| RM 14.1 - 16.1 | 2.0 | - | 0 | 0 | - | - | 0 | - | 0 | 0 | 9 | 26 | **54** | 35 | - | 35 | - |
| RM 11.5 - 14.1 | 2.6 | - | 0 | 0 | - | - | 0 | - | 0 | 0 | 4 | 36 | 59 | **65** | - | 65 | - |
| Reservoir - RM 11.5 | 1.9 | - | 0 | 0 | - | - | 0 | - | 0 | 0 | 8 | 41 | **66** | 65 | - | 65 | - |
| **Tributaries** |
| Augusta Creek  | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Elk Creek  | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | - | - |
| EFSF McKenzie R. | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | - | - |
| French Pete Cr. | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | - | - |
| Roaring River | 1.8 | - | - | - | - | - | - | 0 | - | - | 0 | 0 | - | 0 | 0 | - | 0 |
| **S Fk McKenzie R - Downstream of Cougar Dam** |
| FR 19 Bridge - Dam | 2.2 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | 8 | 22 | 33 | 50\* | 34 | **46** | - |
| Mouth - FR 19 Bridge | 2.1 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | 6 | 7 | 30 | 39 | 37 | **46** | - |
| *Total* | 24.7 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 35 | 136 | 248 | 277 | 73 | 257 | 51 |



Figure 6. Peak count of redds in the entire SFMR, number of adult salmon passing Cougar Dam, and number of female salmon from McKenzie Hatchery and the Cougar Dam upstream fish passage facility released in the upper SFMR in 2005–2011.

 Although it would be reasonable to anticipate annual redd count to be positively related to variables indicating abundance of adults (current year and previous generation), we found no strong evidence that either basin-wide run size or SFMR out-planting abundance influenced redd counts in the entire SFMR during 2005–2011. Several factors may have affected these results. Only seven years of redd count data were available for analyses at the scale of the entire SFMR, and a longer dataset including multiple salmon generations would provide greater statistical power and include a broader representation of environmental and biological conditions. Annual total redd counts varied relatively little during most of this period, being 196–247 redds in five of the seven years and substantially higher (328–342 redds) in two years. Imprecision in redd count data may result from observer and process error in identification of redds and from use of peak redd count as an index of spawning abundance (some number of additional redds may be constructed after the peak survey date). Leaburg Dam passage abundance may provide low precision as a measure of female abundance in the SFMR by including salmon destined for other reaches of the upper McKenzie River basin and because sex ratio may vary among years. Survival to spawning for adult salmon out-planted in the upper SFMR may have varied among years. The relationship between number of parental generation females and subsequent adult abundance may be affected by interannual variation in survival of out-planted fish, various factors affecting survival-to-adult-return, and the inclusion of multiple age classes in the spawning population each year. Inclusion of parental generation redd abundance as a more direct measure of spawning abundance might be appropriate in future analyses, but the temporal extent of spawning surveys to date was insufficient here given the 3–6 year generation time of spring Chinook salmon. Finally, ODFW released an estimated 34,674 adipose-clipped subyearling salmon upstream of Cougar Dam in autumn of 2001 and 21,278 in 2005, potentially leading to increased numbers of redds in the lower SFMR 3-4 years later.

Table 5. Correlation matrix (*r* and *P*) for variables potentially related to entire SFMR spawning abundance in 2005–2011 (*N* = 7 for all pairs). Bold and underlined values indicate significant correlations; normal underlined values indicate non-significant correlations having *r* > 0.50.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | % Upper McKenzie Redds | Up SFMR Females 3–6 yrs prev | Willamette Falls Passage | Leaburg Dam Passage | Leaburg Dam Passage Wild-origin | SFMR % Wild-origin | *ln*(Upper SFMR Hatchery Females) | *ln*(Upper SFMR Hatchery and Wild Females) | % SFMR Redds in Upper SFMR |
|  |  |  |  |  |  |  |  |  |  |
| SFMR | 0.70 | -0.38 | 0.10 | -0.30 | -0.31 | 0.06 | 0.22 | 0.58 | 0.70 |
|  Redds | 0.08 | 0.40 | 0.84 | 0.51 | 0.50 | 0.90 | 0.63 | 0.17 | 0.08 |
|  |  |  |  |  |  |  |  |  |  |
| % of Upper McKenzie | -0.01 | -0.25 | **-0.84** | -0.71 | -0.45 | 0.51 | 0.54 | 0.66 |
|  Basin Redds |  | 0.99 | 0.59 | **0.02** | 0.07 | 0.31 | 0.24 | 0.21 | 0.10 |
|  |  |  |  |  |  |  |  |  |  |
| Up SFMR Female Abundance | **-0.82** | -0.13 | 0.15 | 0.10 | 0.21 | -0.19 | -0.67 |
|  3–6 yrs. previous |  | **<0.01** | 0.78 | 0.75 | 0.84 | 0.65 | 0.68 | 0.10 |
|  |  |  |  |  |  |  |  |  |  |
| Willamette Falls Passage |  |  | 0.28 | -0.11 | -0.11 | -0.34 | -0.07 | 0.53 |
|  |  |  |  | 0.55 | 0.81 | 0.82 | 0.46 | 0.89 | 0.22 |
|  |  |  |  |  |  |  |  |  |  |
| Leaburg Dam Passage – Wild- and  |  |  | **0.91** | 0.54 | -0.43 | -0.34 | -0.54 |
|  Hatchery-Origin |  |  |  | **<0.01** | 0.21 | 0.34 | 0.46 | 0.21 |
|  |  |  |  |  |  |  |  |  |  |
| Leaburg Dam Passage - Wild-origin only |  |  | 0.57 | -0.32 | -0.34 | -0.74 |
|  |  |  |  |  | 0.18 | 0.48 | 0.46 | 0.06 |
|  |  |  |  |  |  |  |  |  |  |
| SFMR % Wild-origin (Out-plant upper, carcasses lower) |  |  |  | -0.69 | -0.47 | -0.41 |
|  |  |  |  |  |  |  | 0.08 | 0.29 | 0.36 |
|  |  |  |  |  |  |  |  |  |  |
| *ln*(Upper SFMR Hatchery-origin Females) |  |  |  |  | **0.85** | 0.19 |
|  |  |  |  |  |  |  |  | **0.01** | 0.69 |
|  |  |  |  |  |  |  |  |  |  |
| *ln*(Upper SFMR Hatchery- and Wild-origin Females) |  |  |  |  |  | 0.48 |
|  |  |  |  |  |  |  | 0.28 |



Figure 7. Bivariate relationships of annual peak redd counts for the entire SFMR with variables pertaining to abundance, origin, and distribution of Chinook salmon.



Figure 8. Bivariate relationships of SFMR proportion of upper McKenzie Basin redds with variables pertaining to abundance, origin, and distribution of Chinook salmon.

Table 6. Results of linear regression analyses using entire SFMR redd count, proportion of the entire Upper McKenzie basin redd count, and proportion SFMR adult salmon of wild-origin as response variables. Explanatory variables include number of adult female hatchery-origin salmon out-planted during the same year as redd surveys [F(same year)] (loge-transformed) and 3–6 yrs earlier [F(3-6 yrs)], and upstream passage abundance of salmon at Leaburg Dam (Leaburg).

|  |  |  |  |
| --- | --- | --- | --- |
| Independent Var. | Coefficient | *r*2 | *P* |
| **SFMR Redds ~** |
| F(3-6 yrs) | -0.037 | 0.143 | 0.403 |
| Leaburg | -0.028 | 0.090 | 0.512 |
| F(same yr) | 0.154 | 0.049 | 0.634 |
| **SFMR Redds % of Upper McKenzie ~** |
| F(3-6 yrs) | 0.0000 | 0.000 | 0.987 |
| Leaburg | -0.0001 | 0.702 | 0.019 |
| F(same yr) | 0.147 | 0.260 | 0.243 |
| **SFMR % Wild-Origin ~** |
| F(3-6 yrs) | 0.00002 | 0.009 | 0.837 |
| Leaburg | 0.0001 | 0.291 | 0.211 |
| F(same yr) | -0.250 | 0.482 | 0.083 |

 Lower SFMR

 We obtained a peak count of 92 redds for the SFMR downstream of Cougar Dam in 2011. We first found redds on 8 September 2011, and counts increased through the final survey on 9 October 2011 (Table 4). We conducted no subsequent survey because no additional salmon in spawning condition were observed. A higher count of 50 redds was obtained for the upper section in this reach on 28 September by a crew that had not previously surveyed the reach, and we used the peak count of 46 based on subsequent surveys and crew experience (i.e., the less-experienced crew probably overestimated the number of redds).

 Redds were evenly distributed between the upstream and downstream 2-mi survey sections in the lower SFMR (Table 7). As in previous years, four sites held the majority of redds in this reach in 2011 (Figure 9). We found 14 redds in the Cougar Dam tailrace and most of the remainder at sites with braided channel morphology. The proportion of redds in the upper survey section was less than in any previous year during the period 2001–2011 and substantially less than the mean (67%). This reduction corresponded to diminished spawning abundance in the Cougar Dam tailrace, similar to the observed distribution in 2010, suggesting that this stemmed from upstream transport of salmon collected in the fish passage facility. Returning salmon of upstream origin may have increased the proportional abundance of spawning in the tailrace prior to 2010, and preliminary results of genetics analyses support this contention (Johnson and Friesen *in prep*).

 Correlation analysis indicated no significant correlations between lower SFMR redd count and any other included variable for the period 2001–2011 (Table 8). However, a relatively high correlation coefficient was obtained for lower SFMR redd count and abundance of wild-origin salmon passing Leaburg Dam (*r* = 0.58; *P* = 0.06). Upstream passage of salmon in 2010 and 2011 constituted a confounding factor in this analysis for the lower SFMR by effectively removing large numbers of fish from the reach, but a similar correlation analysis including only years 2001–2009 also yielded no significant correlations with lower SFMR redd count (Zymonas et al. *in review*).

 Correlation analyses yielded several significant correlations among variables other than lower SFMR redd count (Table 8). Proportion of redds in the upper survey section of the lower SFMR was significantly positively correlated with abundance of all adult salmon (*r* = 0.80, *P* < 0.01) and only wild-origin salmon (*r* = 0.80, *P* < 0.01) passing Leaburg Dam, and a relatively high negative correlation coefficient was obtained for the correlation of proportion of redds in the upper survey section with proportion carcasses of wild-origin recovered in the lower SFMR (*r* = -0.59, *P* = 0.06). Abundance of all salmon and only wild-origin salmon passing Leaburg Dam were strongly positively correlated (*r* = 0.98, *P* < 0.01), but proportion carcasses of wild-origin in the lower SFMR was negatively correlated with passage abundance at Willamette Falls and Leaburg Dam. These results indicate that higher proportions of redds were located in the upper section in years of high returns to the upper McKenzie Basin and in years with higher proportions of hatchery-origin salmon. However, proportion carcasses of wild-origin in the lower SFMR was also positively correlated with abundance of adult females out-planted in the upper SFMR 3-6 years earlier (*r* = 0.75, *P* = 0.01). We found significant negative correlations between number of female salmon out-planted 3–6 years earlier and both Willamette Falls passage abundance (*r* = -0.80; *P* < 0.01) and Leaburg Dam passage abundance (*r* = -0.67; *P* < 0.02), and an inspection of the data indicated that this largely resulted from the co-occurrence of high out-planting abundance and passage abundance during 2001–2004 and considerably lower numbers outside of that period. Thus, intercorrelation and potentially interactions among variables complicate interpretation of these results.

Table 7. Counts of adult Chinook salmon at Willamette Falls (adults and jacks) and Leaburg Dam, and peak redd counts in the lower South Fork McKenzie River in 2001–2011. Leaburg counts indicate estimated number of adults that passed the dam, corrected for fall-back; percent wild fish estimated based on results of otolith analyses.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   |   | Leaburg Dam |  | Lower SFMR Redds |
| Year | W. Falls | Passed | % Wild |  | Total | Upper Reach (Dam – Bridge) | Lower Reach (Bridge – Mouth) | % Upper Reach |
| 2001 | 53,973 | 4,213 | 68.1% |  | 61 | 44 | 17 | 72 |
| 2002 | 83,136 | 5,575 | 64.8% |  | 108 | 84 | 24 | 78 |
| 2003 | 87,749 | 8,082 | 60.5% |  | 85 | 73 | 12 | 86 |
| 2004 | 96,725 | 7,205 | 61.6% |  | 142 | 113 | 29 | 80 |
| 2005 | 36,633 | 2,956 | 82.4% |  | 86 | 51 | 35 | 59 |
| 2006 | 37,041 | 2,371 | 83.1% |  | 85 | 54 | 31 | 64 |
| 2007 | 23,099 | 3,141 | 83.7% |  | 117 | 79 | 38 | 68 |
| 2008 | 14,672 | 1,546 | 84.3% |  | 84 | 61 | 23 | 73 |
| 2009 | 28,514 | 1,551 | 74.4% |  | 68 | 39 | 24 | 57 |
| 2010 | 67,059 | 2,364 | 54.8% |  | 52 | 27 | 24 | 52 |
| 2011 |  45,147 | 2,838 | 77.2% |  | 92 | 46 | 46 | 50 |



Figure 9. Number of Chinook salmon redds at sites of redd concentrations in the lower SFMR in 2011.

Table 8. Correlation matrix (*r* and *P*) for variables potentially related to lower SFMR spawning abundance in 2001–2011 (*N* = 11 for all pairs, except *N* = 10 for all correlations with Lr SFMR Pre-spawn Mortality). Bold and underlined values indicate significant correlations; normal underlined values indicate non-significant correlations having *r* > 0.50.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | *ln*(Up SFMR Females 3-6 yrs. Previous) | Willamette Falls Passage | Leaburg Dam Passage - Wild and Hatchery | Leaburg Dam Passage - Wild Only | SFMR % Wild-Origin Carcasses | % Lr SFMR Redds in Upper Reach (Dam-Bridge) | Lr SFMR Prespawn Mortality -Females |
| Lr SFMR Redds | 0.09 | 0.30 | 0.49 | 0.58 | -0.14 | 0.45 | -0.19 |
|  | 0.80 | 0.37 | 0.12 | 0.06 | 0.68 | 0.16 | 0.60 |
|  |  |  |  |  |  |  |  |
| *ln*(Up SFMR Females 3-6 yrs.  | **-0.80** | **-0.67** | -0.60 | **0.75** | -0.27 | -0.27 |
| Previous) |  | **<0.01** | **0.02** | 0.05 | **0.01** | 0.43 | 0.45 |
|  |  |  |  |  |  |  |  |
| Willamette Falls Passage | **0.87** | **0.78** | **-0.89** | 0.53 | 0.41 |
|  |  |  | **<0.001** | **<0.01** | **<0.001** | 0.09 | 0.24 |
|  |  |  |  |  |  |  |  |
| Leaburg Dam Passage - Wild and Hatchery | **0.98** | **-0.82** | **0.80** | 0.17 |
|  |  |  |  | **<0.001** | **<0.01** | **<0.01** | 0.65 |
|  |  |  |  |  |  |  |  |
| Leaburg Dam Passage - Wild Only |  |  | **-0.75** | **0.80** | 0.06 |
|  |  |  |  |  | **0.01** | **<0.01** | 0.87 |
|  |  |  |  |  |  |  |  |
| SFMR % Wild-Origin Carcasses |  |  |  | -0.59 | -0.44 |
|  |  |  |  |  |  | 0.06 | 0.20 |
|  |  |  |  |  |  |  |  |
| % Lr SFMR Redds in Upper Reach (Dam-Bridge) |  |  | -0.04 |
|   |   |   |   |   |   |   | 0.91 |

Upper SFMR

 We obtained a peak count of 236 redds for the SFMR upstream of Cougar Dam in 2011. We first observed redds on 8 September 2011. We found the largest increases in redd abundance in surveys during the weeks of 11 and 18 September, and we obtained peak counts for the three survey reaches from the reservoir to RM 16.1 (Dutch Oven Campground) during the weeks of 18 and 25 September (Table 4). Gaps in the survey schedule reduced precision of identification of spawn timing after 29 September 2011, but our results indicated that spawn timing in upstream reaches was more protracted than in downstream reaches. In future years, effort should be devoted to completing surveys of the entire system from RM 0–25 every week into mid-October to more precisely define spatio-temporal distribution of spawning.

 Redds in the upper SFMR were concentrated in the lower 6.5 miles from the reservoir upstream to Dutch Oven Campground (Figure 10). The three encompassed reaches accounted for 78% of all redds in the upper SFMR. Highest linear density of redds occurred in the reach from the reservoir upstream to RM 11.5, followed by the next two reaches from RM 11.5 – RM 16.1. Redd distribution was generally more concentrated in the lower 6.5 miles of the upper SFMR in 2011 than it was in 2007–2010 (Figure 11). This may have been a consequence of releasing all adult salmon at RM 11 in 2011, whereas 43–78% of females were released farther upstream at RM 18 each year during 2007–2009 (Figure 12). Wild-origin salmon transferred to the upper SFMR in 2010 and 2011 may have been more inclined than hatchery-origin fish to move greater distances from release locations as a function of homing to natal reaches, although some portion of wild-origin adult females probably originated from redds in the lower reaches of the upper SFMR relatively near the release location. Other noteworthy aspects of redd distribution in this reach included location of 16 redds within the reservoir drawdown zone and 34 redds downstream of the rotary screw trap used for enumerating juvenile downstream migrants and collecting genetics tissue samples for a pedigree study. Survival to hatching and to adult return for eggs in the reservoir drawdown zone compared to eggs in upstream reaches may warrant future investigation.

 We found no redds or live salmon in surveyed reaches of tributary streams. Augusta Creek, Elk Creek, and the East Fork South Fork McKenzie River appeared to provide marginal or insufficient discharge and spawning substrate for adult Chinook salmon. French Pete Creek and Roaring River provided sufficient discharge and spawning substrate, although Roaring River water temperature may be colder (maximum summer temperature < 8°C, September daily mean <6.5°C) than typical Chinook salmon spawning streams in the McKenzie Basin.

 The annual peak redd count in 2011 was relatively high for the period 2005–2011 (Table 3). The number of redds per female released in the upper SFMR in 2011 was the highest among years in this period. We also observed a relatively high number of redds per released female in 2010, potentially providing initial indication that wild-origin adults survive to spawning at a higher rate than out-planted hatchery-origin adults.

 Correlation analysis indicated that annual peak redd count for the upper SFMR was not significantly correlated with number of adult female salmon (both hatchery and wild-origin) released in the upper SFMR, although the correlation coefficient was relatively high and positive (*r* = 0.65, *P* = 0.11, *N* = 7; Figure 13). Factors potentially limiting correlation strength included imprecision of redd counts and interannual variation in pre-spawn mortality among adult female salmon released into the upper SFMR. Also, survey frequency was greater in 2010 and 2011 than in previous years, and uppermost survey reaches were not surveyed in 2007 and 2008.



Figure 10. Chinook salmon redd distribution by designated survey reach in the upper SFMR in 2011. Peak counts and percentage of total are provided for each reach. 

Figure 11. Linear density of Chinook salmon redds in the upper SFMR in 2007–2011. Surveys included only RM 9–20 in 2007 and RM 9–22 in 2008 (points indicate reaches that were not surveyed in 2007 and 2008).



Figure 12. Distribution of adult salmon among three release sites in the upper SFMR in 2007–2011. Data for 2007–2009 includes only fish from McKenzie Hatchery; 2010 and 2011 include fish from the Cougar Dam passage facility and McKenzie Hatchery.



Figure 13. Annual peak redd counts and numbers of female salmon (both hatchery and wild origin) released in the upper SFMR, 2005–2011.

##

## Task 2.2 Conduct complete carcass surveys (census) weekly from mid-August through October. Spatial extent includes the S Fork McKenzie River from the mouth to Cougar Dam and from the head of Cougar Reservoir to the Elk Creek confluence. To determine hatchery vs. wild origin, record presence or absence of adipose fin and collect otoliths.

Entire SFMR

 We found 104 salmon carcasses in the SFMR in autumn 2011, including 77 downstream and 27 upstream of Cougar Dam (Table 9). We found no carcasses in tributary reaches. Most (84%) carcasses were unmarked (intact adipose fin), and we estimated that 77% of all carcasses were of wild origin based on otolith analyses (6 of 76 otoliths from unmarked fish had thermal marks = 7.9%). We detected coded wire tags in 5 of 73 unmarked carcasses that were scanned for tags (6.8%). All of these were in female carcasses in the lower SFMR (*N* = 43 F, 13 M scanned unmarked carcasses), whereas none were in the upper SFMR (*N* = 12 F, 5 M). Females comprised 74% of carcasses, of which 1.4% were considered pre-spawn mortalities. Positive bias toward recovery of females may have resulted from greater tendency for females to remain at spawning sites after spawning. We found carcasses beginning on 31 August and extending through 20 October 2011.

 Estimated ages of salmon encountered as carcasses in the SFMR varied from 4 to 6 years. Nearly all were age 5 (57%) or age 4 (41%). Age was estimated for 61 salmon, including 45 females and 16 males, and although all of these were unmarked, some were of hatchery origin. A majority of females were age 5 (64%) and most of the remainder were age 4 (33%). In contrast, males consisted of more age-4 (63%) than age-5 salmon (38%). Age distributions for carcasses were similar to those obtained for unmarked salmon collected in the upstream passage facility (see above). Overall, estimated ages of all salmon collected in the upstream passage facility and encountered as carcasses downstream of Cougar Dam varied from 3 to 6 years (Table 10). Scales from 376 salmon were suitable for age estimation, while an additional 50 salmon could not be aged because the samples were regenerated, reabsorbed, or damaged.

 The estimated proportion of wild-origin salmon in the entire SFMR in 2011 (0.51), based on the combination of carcass surveys for the lower SFMR and known composition of females released in the upper SFMR, exceeded that for all other years during the period 2005–2011. Fewer hatchery-origin females were released in the upper SFMR in 2011 than in any previous year during 2005–2011 (175 from McKenzie Hatchery plus an estimated 27 unmarked individuals at the upstream passage facility). The coefficient value for the correlation between estimated proportion wild-origin adult salmon in the South Fork McKenzie River and number of hatchery-origin females out-planted in the upper SFMR was relatively high and negative but not significant (*r* = -0.69, *P* = 0.08). Linear regression indicated that the number of adult female hatchery salmon out-planted the same year explained 48% of the variation in the proportion of wild-origin salmon in the entire SFMR (*r*2 = 0.48, *P* = 0.08; Table 6).

 We collected fin tissue samples for genetics analysis from 93 salmon carcasses. This included 75 fish downstream and 18 fish upstream of Cougar Dam. Including the 388 samples collected at the upstream passage facility and 345 at McKenzie Hatchery, we collected fin tissue samples from a total of 808 fish in 2011. An additional 18 samples collected from carcasses in the upper SFMR were duplicate samples from fish sampled prior to upstream transfer, but the lack of unique marks precluded matching multiple samples from individual fish. Results of genetics analyses are presented in a separate report (Johnson and Friesen *in prep*).

Table 9. Number of salmon carcasses recovered in the SFMR in 2011, by reach, adipose-fin mark, sex, and spawning status (females).

|  |  |  |  |
| --- | --- | --- | --- |
|  Section | Length (mi) | Redds | Carcasses |
| Total | Marked |  | Unmarked | Not Processed |
| Male |  | Female |  | Male | Female |
|   | Spawned | Not spawned |   | Spawned | Not spawned |
| **S Fk McKenzie R - Upstream of Cougar Dam** |
| RM 25.0 - 26.0 | 1.0 | 2 | 1 | 0 |  | 0 | 0 |  | 0 | 1 | 0 | 0 |
| RM 22.2 - 25.0 | 2.8 | 3 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| RM 20.0 - 22.2 | 2.2 | 7 | 2 | 0 |  | 0 | 0 |  | 0 | 1 | 0 | 1 |
| RM 18.0 - 20.0 | 2.0 | 29 | 1 | 0 |  | 0 | 0 |  | 0 | 1 | 0 | 0 |
| RM 16.1 - 18.0 | 1.9 | 10 | 3 | 0 |  | 1 | 0 |  | 1 | 0 | 0 | 1 |
| RM 14.1 - 16.1 | 2.0 | 54 | 5 | 0 |  | 2 | 0 |  | 1 | 2 | 0 | 0 |
| RM 11.5 - 14.1 | 2.6 | 65 | 5 | 0 |  | 1 | 0 |  | 0 | 2 | 0 | 2 |
| Reservoir - RM 11.5 | 1.9 | 66 | 10 | 0 |  | 1 | 0 |  | 3 | 4 | 1 | 1 |
| **Tributaries** |
| Augusta Creek  | 1.0 | 0 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| Elk Creek  | 1.0 | 0 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| EFSF McKenzie R. | 1.0 | 0 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| French Pete Cr. | 1.0 | 0 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| Roaring River | 1.8 | 0 | 0 | 0 |  | 0 | 0 |  | 0 | 0 | 0 | 0 |
| **S Fk McKenzie R - Downstream of Cougar Dam** |
| FR 19 Bridge - Dam | 2.2 | 46 | 32 | 3 |  | 4 | 0 |  | 5 | 20 | 0 | 0 |
| Mouth - FR 19 Bridge | 2.1 | 46 | 45 | 1 |  | 3 | 0 |  | 11 | 29 | 0 | 1 |
| *Total* | 26.5 | 328 | 104 | 4 |   | 12 | 0 |   | 21 | 60 | 1 | 6 |

Table 10. Age frequencies for all salmon collected in the upstream passage facility or encountered as carcasses downstream of Cougar Dam in 2011.

|  |  |  |
| --- | --- | --- |
|   | Age |   |
| Mark | 3 | 4 | 5 | 6 | Total |
| **Female** |
| Marked | 0 | 4 | 3 | 0 | 7 |
| Unmarked | 4 | 72 | 91 | 1 | 168 |
| **Male** |
| Marked | 0 | 13 | 4 | 0 | 17 |
| Unmarked | 2 | 127 | 54 | 1 | 184 |

Lower SFMR

 We found 77 salmon carcasses in the lower SFMR in autumn 2011 and processed all except one (). We encountered 45 carcasses in the upper 2-mi survey section and 32 in the lower 2-mi section (Table 9). Most carcasses were unmarked (86%), and we estimated that 80% were of wild origin, based on analyses of otoliths from *N* = 60 unmarked fish. Females comprised 72% of carcasses and we found no pre-spawn mortalities. Although we were unable to determine carcass recovery rate because we lacked data on total abundance of individuals that entered the SFMR, we recovered 0.61 female carcasses per redd, suggesting a considerably higher recovery rate than in the upper SFMR. We estimated that 14% of females and 7% of males were hatchery-origin salmon, based on sex-specific adipose-fin marking ratios and otolith analyses for both sexes combined (because of small sample size for males). We found carcasses beginning on 8 September and extending through 14 October 2011.

 Ages estimated from scales varied from 4 to 6 (Figure 14). Age was estimated for 47 salmon, including 36 females and 11 males, and all of these were unmarked. A majority of females were age 5 (64%) and most of the remainder were age 4 (33%). In contrast, males consisted of more age-4 (55%) than age-5 salmon (45%). These age distributions were similar to those obtained for unmarked salmon collected in the upstream passage facility (see Figure 2).

 Length of carcasses in the lower SFMR averaged 831 ± 76 mm FL (mean ± SD; *N* = 71). Mean length of male carcasses (875 ± 81 mm; *N* = 19) exceeded that of females (831 ± 76 mm; *N* = 52). Mean length of unmarked carcasses (all: 837 ± 76 mm, *N* = 64; females: 818 ± 67 mm, *N* = 48; males: 892 ± 76 mm, *N* = 16; ) exceeded that of marked fish (all: 776 ± 61 mm; *N* = 7; females: 772 ± 81 mm, *N* = 4; males: 782 ± 34 mm, *N* = 3), within each sex and also in aggregate, but the small sample size of unmarked fish precluded meaningful statistical significance testing between marked and unmarked groups within sex. Considering only those unmarked fish for which age was estimated, length differed significantly by sex but not between age-4 and age-5 groups (two-way ANOVA: *df* = 1, 1, 45; sex: *F* = 23.9; *P* < 0.001; age: *F* = 1.8; *P* = 0.19). Post-hoc multiple comparisons (Holm–Sidak) indicated that male carcasses were significantly longer (*P* < 0.05) than females within each age group and that age-5 fish were longer than age-4 fish within females but not within males. Larger size of male carcasses than female carcasses stands in opposition with observations from the upstream fish passage facility and McKenzie Hatchery (see Task 1.1). However, these results should be interpreted with caution because of the small sample size of male carcasses for which age estimates were obtained (age-4: *N* = 6, age-5: *N* = 5).

 The number of carcasses recovered in the lower SFMR and proportion consisting of females in 2011 were near the mean for the period 2001–2011 (). Proportions of unmarked and wild-origin salmon in 2011 exceeded the 2001–2011 mean and were considerably higher than in 2010, and the proportion of hatchery-marked otoliths in unmarked salmon was less than the mean. Pre-spawn mortality indicated by carcass recoveries has typically been low in the lower SFMR (mean = 5%), and previous surveys indicated zero pre-spawn mortality in 2007 and 2008 as well as in 2011. As noted below, biases in carcass recovery suggest cautious interpretation of data based on carcass surveys.

 Data from carcass surveys suggest that abundance of stray hatchery-origin adults and abundance of adult females out-planted 3–6 years earlier in the upper SFMR (a potential surrogate for production of wild-origin juveniles) may have influenced composition of the spawning population in the lower SFMR. Proportion wild-origin carcasses in the lower South Fork McKenzie River was significantly negatively correlated with adult salmon passage abundance at Willamette Falls (*r* = -0.89) and Leaburg Dam (*r* = -0.82) (Table 8), and the four years of highest passage abundance (2001–2004) also had the lowest proportion of wild carcasses in the lower SFMR (0.25–0.41). Adult salmon passage abundances at Willamette Falls (*r* = 0.87) and Leaburg Dam (*r* = 0.61) were positively associated with proportion hatchery-origin salmon passing Leaburg Dam. Data for 2010 constituted an outlier in this relationship, having both moderately high passage abundance at Willamette Falls, low passage abundance at Leaburg Dam, and low proportion of wild-origin carcasses in the lower SFMR. However, 2010 was the first year in which wild adults were transferred upstream at Cougar Dam and it had the lowest proportion of wild-origin salmon passing Leaburg Dam during the period. Significant positive correlation of proportion wild-origin carcasses in the lower South Fork McKenzie River with the number of adult female salmon out-planted upstream of Cougar Dam 3–6 years earlier (*r* = 0.75) suggested that spawning abundance upstream of dam may have noticeably influenced eventual relative abundance of unmarked adults downstream of the dam. However, abundance of out-planted females was also negatively correlated with passage abundance at Willamette Falls (*r* = -0.79) and Leaburg (*r* = -0.57), complicating assessment of independent influence of each variable. Pre-spawning mortality among females was not significantly correlated with any of the included variables (Table 8).

 Proportion of wild-origin carcasses in the lower SFMR increased relative to proportion of Leaburg Dam passage consisting of wild-origin salmon beginning in 2006 (Figure 16). This timing corresponds to return of age-4 adults that were progeny of adults that spawned beginning in 2002, when dam operations changed for construction of water temperature control facilities (extreme drawdown of Cougar Reservoir in 2002–2004 followed by implementation of water temperature control beginning in 2005). Factors that potentially contributed to this relatively large increase in proportion wild-origin salmon in the lower SFMR include increased production of juveniles stemming from substantially larger numbers of adult salmon out-planted in the upper SFMR (Table 3), increased downstream passage survival of wild-origin juveniles through the Cougar Dam diversion tunnel during the drawdown period, and increased early survival of juveniles produced downstream of Cougar Dam as a result of a more natural thermal regime beginning in autumn of 2002 (Zymonas et al. *in review*).

Table 11. Attributes of salmon carcasses in the SFMR downstream from Cougar Dam in 2001–2011. Mean values compare years prior to (2001–2009) and after the start of upstream passage at the dam (2010–2011).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|   |   |   | UnmarkedHatchery- |   |   | Pre-spawn |
| Year | Total | %Unmarked | Origin | %Wild | %Females | Mortality |
| 2001 | 58 | 41 | 0.25 | 41 | 62 | - |
| 2002 | 177 | 61 | 0.33 | 41 | 54 | 0.04 |
| 2003 | 114 | 35 | 0.28 | 25 | 57 | 0.03 |
| 2004 | 103 | 38 | 0.28 | 27 | 59 | 0.10 |
| 2005 | 33 | 52 | 0.00 | 52 | 73 | 0.08 |
| 2006 | 111 | 78 | 0.00 | 78 | 79 | 0.01 |
| 2007 | 67 | 84 | 0.04 | 80 | 76 | 0.00 |
| 2008 | 34 | 88 | 0.10 | 80 | 65 | 0.00 |
| 2009 | 76 | 88 | 0.03 | 86 | 78 | 0.15 |
| 2010 | 29 | 48 | 0.13 | 43 | 72 | 0.10 |
| 2011 | 77 | 86 | 0.07 | 80 | 72 | 0.00 |
| Mean '01-09 | 86 | 63 | 0.14 | 57 | 67 | 0.05 |
| Mean '10-11 | 53 | 67 | 0.10 | 62 | 72 | 0.05 |
| Mean '01-11 | 80 | 64 | 0.14 | 58 | 68 | 0.05 |
| SD '01-11 | 44 | 22 | 0.12 | 23 | 9 | 0.05 |



Figure 14. Age frequencies for unmarked adult salmon collected as carcasses in the lower SFMR in 2011.



Figure 15. Median length (mm FL; bars = 25th – 75th percentiles) of unmarked adult salmon collected as carcasses in the lower SFMR in 2011. See Figure 13 for sample sizes.



Figure 16. Proportions of adult salmon passing Leaburg Dam and carcasses in the lower SFMR consisting of wild-origin fish, and abundance of adult salmon passing Leaburg Dam, 2001–2011.

Upper SFMR

 We found 27 salmon carcasses in the SFMR upstream from Cougar Dam in 2011 (). We processed 22 of these carcasses. Distribution of carcasses roughly corresponded to redd distribution, with 37% of carcasses in the downstream-most sub-reach and 19% of carcasses in each of the next two sub-reaches upstream to RM 16 (Table 9). We found marked and unmarked carcasses upstream as far as the RM 16.1–18.0 reach and three additional unmarked female carcasses as far as RM 25.0–26.0, potentially indicating a tendency for wild-origin salmon to distribute farther upstream from the release site.

 Similar to results from carcass surveys downstream of Cougar Dam, females comprised the majority of carcasses (77%), most carcasses were unmarked (77%), and we found only one pre-spawn mortality among the 17 recovered female carcasses in the upper SFMR. We estimated that 68% of carcasses were of wild origin, after correction based on analysis of otoliths from *N* = 16 unmarked fish. We found carcasses beginning on 31 August and extending through 20 October 2011.

 Complete census data on abundance of adult salmon released into the upper SFMR (from the upstream passage facility and McKenzie Hatchery) provided additional insights on carcass data for that reach. Although 49% of salmon released upstream of Cougar Dam were unmarked and 46% were females, corresponding values for carcasses were 77% for each of these categories, indicating that carcass recovery was biased towards unmarked females. Also, the pre-spawn mortality rate calculated from carcass data (6%) was considerably lower than the 30% pre-spawn mortality rate associated with a hypothetical 1: 1 ratio of females: redds (336 females, 236 redds). These metrics were probably influenced by the low recovery rate (<4% of all adult salmon released upstream; 0.07 female carcasses per redd), which stemmed from factors such as large channel width and high discharge, downstream movement of carcasses into the reservoir, and removal of carcasses by scavengers. Salmon carcasses apparently remain intact within the river channel for a relatively brief period. We speculate that higher recovery rate for females than males may in part stem from lower spawning site fidelity and higher likelihood of transport downstream into the reservoir for post-spawn males. We lack data to explain the bias towards higher recovery rates of unmarked fish. Given the low recovery rate, future surveys should include increased effort devoted to recovering carcasses to increase the likelihood of obtaining data representative of the entire population of adult salmon in the upper SFMR.

 Age of salmon encountered as carcasses in the upper SFMR was estimated to be either age 4 or 5. Sixty-seven percent of females were estimated to be age 5 and 80% of males were estimated to be age 4. These results generally agreed with age structure estimated from scales collected at the Cougar Dam upstream fish passage facility (see above).

Compared to previous years during the period 2005–2011, the number of carcasses counted in the upper SFMR in 2011 was less than in 2009 and 2010 but considerably higher than in 2005–2008 (). The corresponding recovery rate for 2011 was slightly higher than the mean, but the maximum for the period was only 4.8%. Proportions consisting of females and pre-spawn mortalities in 2011 were similar to the previous one or two years, whereas proportion of unmarked carcasses was substantially lower in 2010. Spawning surveys included processing of carcasses only beginning in 2010, and collection of additional years of data will be necessary to assess relationships among attributes.

Table 12. Attributes of salmon carcasses in the SFMR upstream from Cougar Dam in 2011. Asterisk indicates data based on only *N* = 4 otoliths analyzed in 2010 (*N* = 16 in 2011).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|   |   |   | UnmarkedHatchery- |   |   |  Pre-spawn | Recovery |
| Year | Total | %Unmarked | Origin | %Wild | %Females | Mort. | Rate |
| 2005 | 9 | - | - | - | - | - | 0.010 |
| 2006 | 4 | - | - | - | - | - | 0.004 |
| 2007 | 2 | - | - | - | - | - | 0.003 |
| 2008 | 10 | - | - | - | - | - | 0.011 |
| 2009 | 53 | - | - | - | - | 0.10 | 0.038 |
| 2010 | 36 | 36 | 0.25\* | \* | 78 | 0.08 | 0.048 |
| 2011 | 27 | 77 | 0.13 | 68 | 77 | 0.06 | 0.037 |
| Mean | 20 | 57 | 0.19 | 68 | 78 | 0.08 | 0.022 |
| SD | 19 | 29 | 0.08 | - | 1 | 0.02 | 0.019 |

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