Technical Report 2014-5

MIGRATION BEHAVIOR AND SPAWNING SUCCESS OF SPRING CHINOOK SALMON IN FALL CREEK, THE NORTH FORK MIDDLE FORK WILLAMETTE AND SOUTH SANTIAM RIVERS: RELATIONSHIPS AMONG FATE, FISH CONDITION, AND ENVIRONMENTAL FACTORS, 2013

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For
U.S. Army Corps of Engineers
Portland District, Portland OR

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Executive Summary

Many adult Chinook salmon in the Willamette River basin die prior to spawning (prespawning mortality). While PSM rates appear to vary among years and among subbasins, the exact cause and relationships are not well defined. In 2013 we continued to survey the energetic status and prespawn survival rates of three populations of Willamette River spring Chinook salmon, monitored river environmental conditions, and investigated the relationships among prespawn mortality and a suite of potential causative factors. Carcass recovery rates were lower than in previous years because record rainfall in September made study streams too dangerous to survey during peak Chinook salmon spawning activity.

In 2013, a total of 96 Chinook salmon were sampled at Fall Creek Dam. Fish were collected, assessed for energetic content and overall condition, PIT-tagged and then transported above the dam and allowed to spawn naturally. Four PIT-tagged salmon were recovered during spawning ground surveys on Fall Creek, a recapture rate of 4.2% that was lower than in previous years (10-12%) due to flood conditions. Both of the PIT-tagged females recovered on the spawning grounds were prespawn mortalities. Thirteen unmarked Chinook salmon were also recovered on the spawning grounds, all of which were prespawn mortalities. The average water temperature during the study period was 15.7 °C with a peak of 20.8 °C occurring in late July.

A total of 165 Chinook salmon collected at the Dexter Dam trap were outplanted into the North Fork Middle Fork Willamette River (NFMF) in 2013. Overall, 17 (10.3%) of the PIT and radio-tagged fish were recovered in carcass surveys, a recovery rate within the range of previous years (7-20%). Female prespawn mortality of NFMF outplants was 44.4% (four out of nine females recovered) for PIT and radio-tagged fish combined. Mean water temperature in the NFMF during the study period was 11.7 °C with a peak of 14.8 °C in early-July.

In 2013, we initiated outplanting into the NFMF approximately a month earlier than in previous years. Of the 165 PIT and radio-tagged fish released in the NFMF, 64 (39%) were released between 22-May and 5-June (early release group, hereafter). The remaining 101 fish (61%) were released between 19-June and 17-July (standard release group, hereafter). Overall, 9% (n = 6) from the early release group were recovered on the spawning ground versus 11% (n = 11) for the standard release group. Only one female from the early release group was recovered and it was a prespawn mortality. A total of six females from the 'standard' release group were recovered and three (50%) were prespawn mortalities. Few inferences could be drawn from the small sample affected by the September flood.

We also estimated prespawn mortality in the South Fork Santiam River upstream of Foster Dam and evaluated behavior of adult salmon released in Foster Reservoir. A total of 200 spring Chinook salmon were radio+PIT-tagged (n = 75) or PIT-tagged (n = 125) and then transported upstream from the dam. Twenty-one radio- and PIT-tagged fish (10.5%) were recovered during spawning ground surveys prior to the flood. Ten female PIT- and radio-tagged fish were recovered on the spawning grounds and five (50%) were prespawn mortalities. Of the 75 radio-tagged fish, 50 (67%) were released in Foster Reservoir; 38 (76%) of the 50 fish were last recorded in the South Santiam, 6 (12%) were last recorded in the Middle Fork Santiam, and 6 (12%) passed downstream over Foster Dam. Three radio-tagged adults (6.0%) from the reservoir release group were recovered on the South Santiam spawning grounds compared to

20% for radio-tagged fish released in the river. Median reservoir residence times were 32.3 d for fish last recorded on the South Fork Santiam receiver and 16.1 d for fish last recorded on the Middle Fork Santiam receiver. The one female reservoir-released fish recovered was a prespawn mortality. Mean water temperature in the South Santiam upstream from Foster Dam during the study period was 14.8 °C with a peak of 19.3 °C on 6-Aug.

Although recoveries of PIT- and radio-tagged fish were lower than in previous years and small sample sizes make interannual comparisons challenging, prespawning mortality rates were likely higher in 2013 than in previous study years. In 2013, PSM rates were 100% at Fall Creek and 44% in the NFMF. Across the previous five study years (2008-2012) pre-spawn mortality estimates of PIT and radio-tagged females combined were 44.5% (range 6-82%) for Fall Creek and 29.8% (range 14-44%) for immediate outplants to the NFMF.

We tested for associations between fate and a suite of factors potentially related to prespawn mortality across study years using univariate and multiple logistic regression models and multi-model selection techniques. The models for Fall Creek included 82 females collected over 5 years. Among the univariate logistic regression models, year, tag date, Fulton's K, fork length and standardized breadth at anus (StdBa) were significantly associated with prespawn mortality. In the multi-model logistic regression evaluation, the most parsimonious model included year and tag date. Several additional models had statistical support, including all models that included either year or tag date. The models for the NFMF included 57 females collected over 5 years. Prespawn mortality was not significantly associated with any univariate factors in the NFMF.

During 2013 we collected tissue samples from adults scored as prespawn mortalities or successful spawners for evaluation of contaminant concentrations. Nineteen adults were collected from NFMF, seven from the S. Santiam River, and two adults were collected from Fall Creek (total 16 PSM and 12 successful spawners). To date, three metals previously implicated in prespawn mortality (Pb, Cd, and Ni) have been analyzed and revealed concentrations similar to or below those previously reported for salmon. Concentrations of Pb and Cd were significantly higher from carcasses collected in the S. Santiam River compared NFMF samples ($P <= 0.048$) and concentrations did not differ between successful and unsuccessful spawners. Future analyses will include additional trace elements and organic compounds.

Introduction

The numbers of adult spring-run Chinook salmon (*Oncorhynchus tshawytscha*) returning to the Willamette River, including tributaries managed as part of the USACE Willamette Valley Project (WVP), have fluctuated widely and have been near historic low levels in recent years. Development of the WVP began in 1941 and currently includes 13 dams and reservoirs on the Long Tom, Santiam, McKenzie, Middle Fork Willamette, and Coast Fork Willamette subbasins. The WVP is managed for flood control, recreation, irrigation, fish and wildlife management, and power generation. Upper Willamette Chinook salmon populations in the WVP have declined for a variety of reasons, including habitat degradation, habitat loss associated with dams, land use practices, overharvest, pollution, changes in hydrologic and thermal regimes, and direct and indirect effects of artificial propagation (NMFS 2008). Due in part to these concerns, the upper Willamette River spring Chinook salmon run was listed as threatened under the U.S. Endangered Species Act in 1999 (NMFS 1999).

Due to impassable WVP dams on major tributaries of the Willamette River, , returning adults in many populations cannot reach much of their historic spawning habitat. Therefore an adult trap-and-haul program was initiated in the 1990's to make use of surplus hatchery broodstock with the objectives of restoring a source of marine-derived nutrients and supplementing the prey base of native resident fish and wildlife, including other threatened species (i.e., bull trout, *Salvelinus confluentus*) (Beidler and Knapp 2005; Schroeder et al. 2007). Secondary benefits of outplanting include facilitating natural spawning of these populations above the dams and reconnecting habitats, and these secondary objectives have been elevated in recent years. There has been high prespawn mortality observed in some years since the start of the trap-and-haul program. Rates have been widely variable among years and among sub-basin populations (Schroeder et al. 2007; Kenaston et al. 2009; Keefer et al. 2010; Keefer and Caudill 2010; Roumasset 2012) and underlying mechanisms are not fully understood. Factors most likely to contribute to adult prespawn mortality include environmental stressors (especially water temperature), infectious disease, and poor energetic condition. Importantly, demographic modeling suggests that observed levels of prespawn mortality (e.g. > 50-70%) may strongly negatively affect population growth rates and hinder salmon recovery (Keefer et al. 2010). The importance of prespawn mortality to the dynamics and viability of Willamette tributary populations may increase if future regional climate warming (e.g., Eaton and Scheller 1996; Mote et al. 2003) increases the rate of temperature-related mortality.

The migration corridors of many rivers in the Willamette River basin have been altered by habitat degradation, hydroelectric installations, and climate change. In addition to the direct effects of passage barriers and lost access to spawning habitat, the operation of dam and reservoir systems for power production, recreation, and flood control can affect salmon and their migrations. Some important indirect effects are the alteration of river flow and temperature regimes. In many river systems, operating dams for flood control has resulted in less variable flow regimes during migration. Depending on dam operation, water stored in reservoirs can either warm or cool downstream reaches when it is released (Rounds 2010). In the Willamette system, tributary dams tend to cool downstream reaches in the spring and early summer and tend to increase water temperatures in the late summer and fall compared to the undammed system (e.g., Rounds 2007). The physiological effects of altered water temperatures during Chinook salmon migration, both below dams and in tributaries during holding and spawning, may have negative effects on energy use and gonad development, potentially resulting in lower reproductive fitness for these populations.

Migrating adult Chinook salmon do not feed during their upstream freshwater migration but rely on finite energy reserves accumulated while feeding in the ocean. Adult salmon die within days to weeks of spawning, indicating that energy stores are likely fine-tuned by past selection to maximize reproductive output (spawning and gametes) while also providing adequate energy to fuel upstream migration, summer holding, and spawning. The energetic costs of migration and spawning activities in the Willamette basin may have changed as a result of altered flow and temperature regimes, degradation of main stem and tributary habitats, and the effects of climate change. Thus, it is possible that energy stores in returning Chinook salmon may currently be mismatched to present conditions and possibly insufficient to allow successful spawning for some fish.

Energy is primarily stored as lipids and energy content tends to be higher in populations traveling greater distances or that return to higher elevations (e.g., Crossin et al. 2004b). Within populations, there is evidence that energetic condition depends on growth conditions experienced in the ocean prior to return migration. For example, adult sockeye salmon (*O. nerka*) return with lower reserves in years following relatively poor ocean feeding conditions (Crossin et al. 2004a). More generally, poor energetic condition at river entry (Crossin et al. 2004a; Rand et al. 2006) and temperature regime during migration and on spawning grounds (Mann 2007; Crossin et al. 2008; Keefer et al. 2008, 2010; Mann et al. 2010) has been associated with higher probability of prespawn mortality.

Stress from trapping and transport efforts, in combination with disease, may also contribute to prespawn mortality (Schreck et al. 2001). The role of pathogens in prespawn mortality has frequently been overlooked and underestimated because all salmon and most steelhead die shortly after they spawn and there have been few attempts to document the proportion that die prematurely. Spawning fish are severely immune compromised, and thus even those that survive past spawning often are infected with a variety of pathogens. Therefore, infections and lesions in adult salmon in freshwater are considered normal, and commonly post-spawned fish exhibited a variety of infections and lesions. However, if infections become too severe, fish may succumb days or weeks before spawning, reducing recruitment to the subsequent generation.

Release of outplanted adults to Willamette basin reservoirs downstream of traditional outplant streams is being considered as a management alternative that may reduce exposure to stressful temperatures and depletion of energetic stores. WVP reservoirs offer a potential thermal refuge for adult Chinook salmon during warm summer months if adults select and hold in cooler waters below the thermocline prior to movement into spawning tributaries. Release to reservoirs could also reduce transport distances and handling time.

The primary goal of this study was to evaluate factors potentially associated with prespawn mortality in adult Chinook salmon from the time they were collected at the traps through spawning, including environmental stressors, maturation status, disease, parasites, and initial energetic condition. Adults were collected at Dexter and Fall Creek dams in the Middle Fork

Willamette River basin, assessed and tagged, and released above the dams into spawning habitats. In 2013, we began evaluating prespawn mortality in salmon outplanted to the South Fork Santiam River and continued a feasibility study of releasing fish into Foster Reservoir. Additionally, subsamples of adults from collected at Dexter and Foster were transported to Oregon State University to assess holding benefits and disease prevalence (reported separately by Schreck et al. *in review*). Also new in 2013 was a small-scale comparison of toxins concentrations in carcasses of successful and unsuccessful adult Chinook salmon.

Specific objectives were to:

1) Estimate prespawn mortality rates in two populations of adult Chinook salmon outplanted to WVP tributaries (Fall Creek and the NFMF) as part of a multi-year monitoring program (in collaboration with ODFW).
2) Test for associations between prespawn mortality, individual adult traits evaluated at the time of collection, and environmental conditions encountered during holding.
3) Estimate prespawn mortality rates in populations of adult Chinook salmon outplanted to the South Fork Santiam River (in collaboration with ODFW).
4) Continue evaluating the feasibility of releasing adults in Foster Reservoir on the South Fork Santiam River.
5) Evaluate interannual patterns in prespawn mortality.
6) Screen carcasses recovered on spawning grounds for a broad panel of known toxins and test for associations between concentrations and spawning success.

Methods

Chinook salmon collection and tagging for this study took place at two sites in Middle Fork Willamette River, west of Eugene, OR (Figure 1) and a third site upstream of Albany, OR. The first site was at Fall Creek Dam on Fall Creek, a tributary of the Middle Fork of the Willamette River. The second was at Dexter Dam on the Middle Fork of the Willamette River. Dexter Dam regulates the outflow from Lookout Point Dam just upstream. The third location was Foster Dam, Foster Dam Reservoir and upstream tributaries.

Middle Fork Willamette River: Study Sites and Facilities

The Fall Creek trap included a small ladder that led to a finger weir in front of a large collection area. USACE personnel operated a mechanical sweep to crowd trapped fish and raise them into a chute that dropped the fish into an anesthetic tank containing eugenol. The tank was lifted using a fixed crane and placed on the ground where anesthetized fish were tagged and assessed. Fish were then transported approximately 3 km upstream from the head of Fall Creek Reservoir and released at rkm 505.4.

The Dexter trap was operated by Oregon Department of Fish and Wildlife (ODFW) and sampled fish were provided by ODFW. ODFW primarily uses the Dexter facility to collect broodstock for the Willamette Hatchery (WH) in Oakridge, OR. In 2009-2013, a fish ladder led to a slot weir at the entrance to a holding raceway. At the time of sorting, fish were mechanically crowded into an elevator which lifted them to an anesthetic tank. After fish were sedated with CO_2, they were transferred to a secondary tank with freshwater then transferred to an anesthetic tank with MS-222 where they were assessed and tagged. Fish were transferred to a transportation truck for recovery then transported above Lookout Point or Hills Creek dams for release. No fish were held for late outplant at the Willamette Hatchery in 2013 because the facility was being used to produce broodstock for the Coast Fork of the Willamette River. Only fish above the hatchery's broodstock quota were transported and released for natural spawning. In 2013, we initiated outplanting into the NFMF approximately a month earlier than in previous years. Figure 2 outlines the 2009-2013 study design.

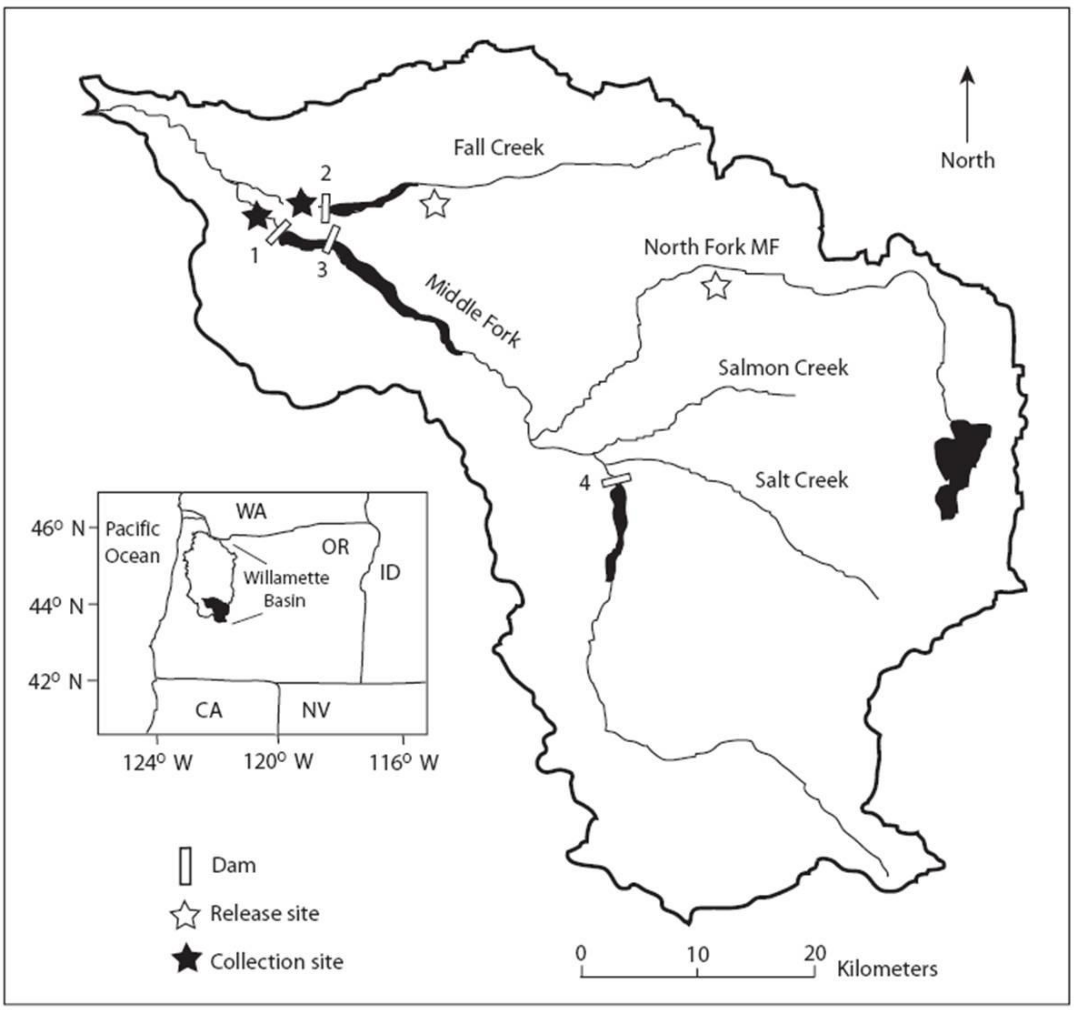

Figure 1. Map of the Middle Fork Willamette River basin showing Chinook salmon collection and outplant sites. Dams are numbered: 1 = Dexter Dam, 2 = Fall Creek Dam, 3 = Lookout Point Dam, and 4 = Hills Creek Dam.

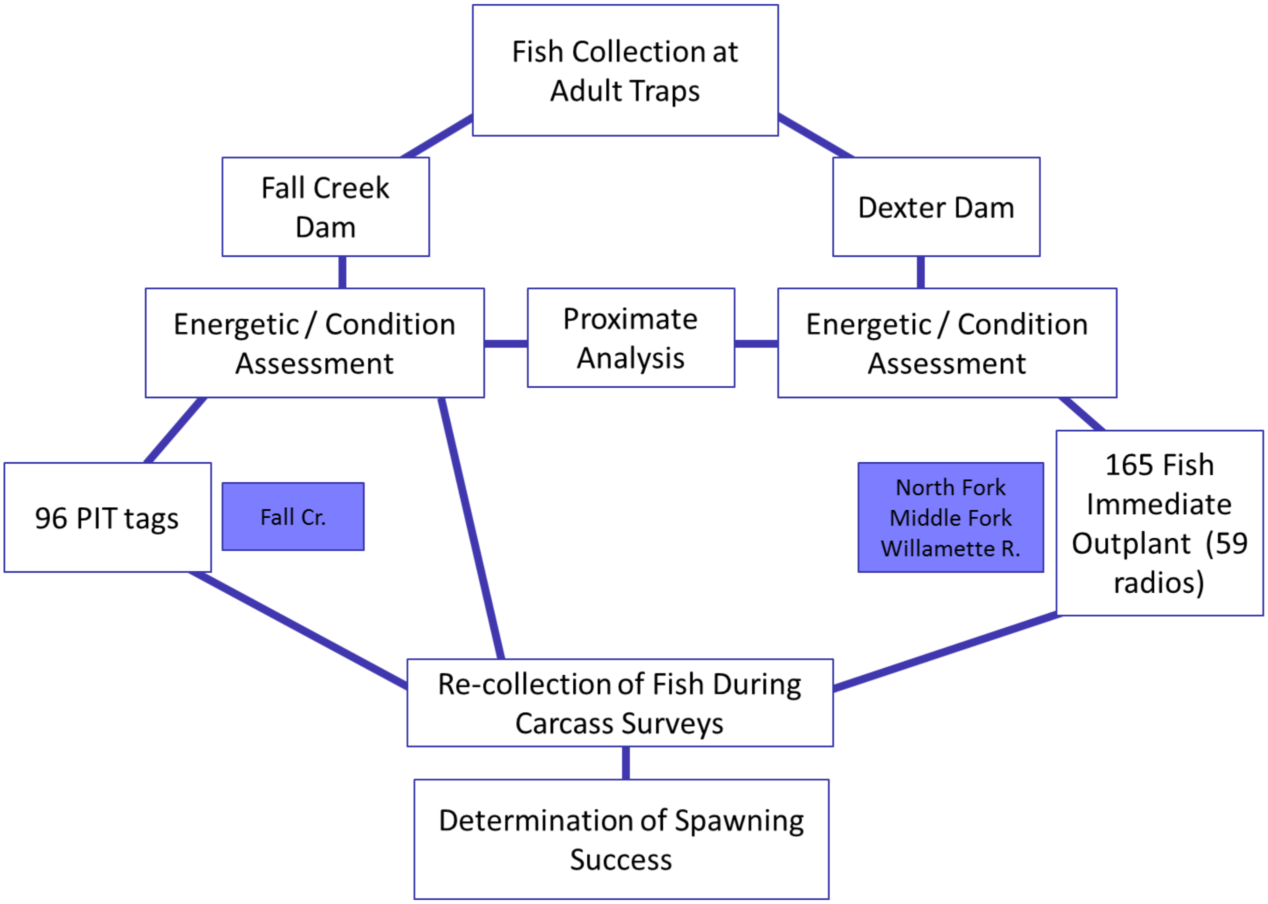

Figure 2. Study design for 2013. All fish tagged at Fall Creek trap were immediately outplanted into Fall Creek. Fish collected and tagged at Dexter Dam were immediately outplanted into the NFMF Willamette River. Additionally, a sub-sample of fish from Dexter Dam was sent to Oregon State University after tagging and assessment.

Tagging and Assessment of Condition

Salmon were fully anesthetized prior to handling at both trap sites. Adults were anesthetized in approximately 60 ppm eugenol at Fall Creek trap. Sampling at Dexter trap used CO_2 during initial trapping followed by MS-222 according to ODFW protocols (approximately 50 ppm with 2.5:1 $NaC0_3$ to MS222 buffer). Following tagging, fish were loaded into a truck filled with fresh river water and transported to an upstream release site. Oxygen was monitored during transportation with a target concentration of 10 ppm. Tagging temperature was recorded and was generally less than 16°C because bottom-draw reservoir water was used for the anesthetic tank and hauling truck at all sites.

While anesthetized, fish were sexed and inspected for clips or markings. A composite condition score was recorded based on injuries, marine mammal marks, headburn, parasites, and descaling. A score of three indicated no obvious damage or minimal healed scrapes, two indicated minor or healed injuries with potential scarring, and one indicated open/severe wounds or multiple minor injuries. Fish were PIT tagged in the dorsal sinus, near the back of the dorsal fin in an effort to increase tag retention on scavenged carcasses. Fork lengths to the nearest 0.5 cm were taken as well as four morphological measures previously used to estimate energetic status (Figure 3) (Mann et al. 2010). Mid-eye to hypural length was defined as the distance along the lateral line from the middle of the eye to the end of the scales on the hypural plate on the caudal peduncle. Hump height was the distance from the anterior origin of the dorsal fin to the lateral line, perpendicular to the lateral line. Depth at anus was the total depth of the fish perpendicular to the lateral line at the anal opening. Breadth at anus was the width of the fish at the intersection of the lateral line and a theoretical line perpendicular to the lateral line at the anus. Morphometric measurements were taken using calipers and recorded to the nearest mm. Fish weights (to the nearest decagram) were collected using a flat table scale (Ohaus Defender bench scale, Ohaus Corp., Pine Brook, NJ).

The percentage of lipids in the muscle tissue was used as the estimation of energy condition because lipids are the primary energy reserve fish use during migration and spawning (Brett 1995). Lipid levels were estimated using a Distell Fatmeter (Distell Industries Ltd., West Lothian, Scotland). The fatmeter was developed in the commercial fish industry to estimate the percent of lipids in a trimmed fillet. The meter uses a low energy microwave sensor to estimate water content in the muscle tissue. Based on the inverse relationship between water and lipid levels in fish tissue (Craig et al. 1978; Higgs et al. 1979), the meter estimates the percent lipid in Chinook salmon muscle tissue using a proprietary algorithm. We used proximate analysis of tissues in each study year (see below) to test the accuracy of fatmeter estimates and correct for any instrument drift among years. Four readings were taken just above the lateral line, progressing toward the posterior of the fish and the average was recorded for each fish.

A sub-sample of 59 fish was radio-tagged prior to outplanting in the NFMF in 2013. A 3-volt transmitter (Lotek Wireless Inc., New Market, Ontario; MCFT-3A, 43 mm × 14 mm diameter, 11 g in air) was inserted gastrically through the mouth. A latex band was placed on each transmitter to reduce regurgitation (Keefer et al. 2004). The purpose of radio tagging was to verify that fish were moving upstream after release, estimate distribution during holding (Naughton et al. 2011; Roumasset 2012), evaluate residence time and fate of reservoir-released adults, and to determine if fish migrated into the reservoir. Additionally, the use of radio tags aided in the collection of carcasses for prespawn mortality assessments.

Blood samples from radio-tagged fish at the Dexter trap were taken from the sub-vertebral caudal vessel posterior to the anal fin. The blood sample was centrifuged for a minimum of four minutes until the red blood cells separated from the plasma. The plasma was transferred to a vial using a pipette, and immediately stored on ice. Samples were frozen as soon as possible and transferred to OSU.

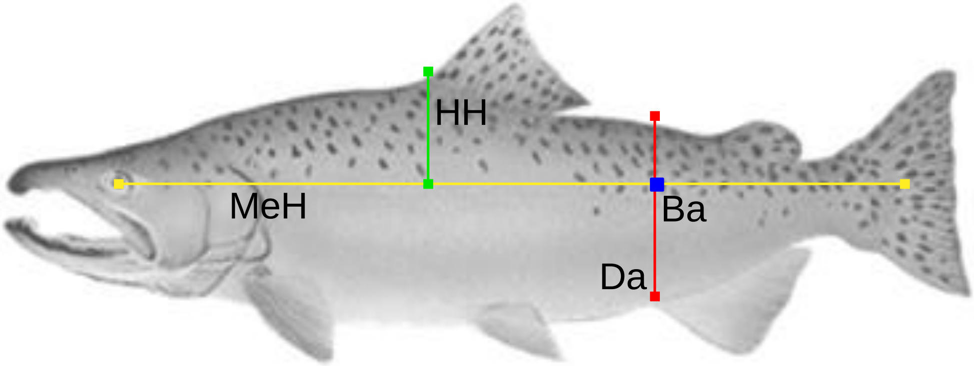

Figure 3. Diagram of morphometrics collected. MeH = Mid-eye to hypural length, HH = Hump height, Da = Depth at anus, Ba = Breadth at anus.

Proximate Analysis

Fifteen additional fish were lethally sampled at the Dexter trap to estimate mean lipid, protein, water, and ash amounts in tissues and to validate the accuracy of the fatmeter estimates of energy condition. Processing fish entailed partitioning the fish carcass into four tissues types; muscle, skin, viscera and gonads (e.g., Mann et al. 2010). Each of the tissues was removed as entirely as possible from a carcass, and weighed to the nearest gram to establish the total weight of each tissue type. Then each tissue was homogenized independently in a Cuisinart® food processor and a 50 gram subsample of the homogenate was taken. The samples were frozen and later transported to Washington State University where they underwent proximate analysis.

Proximate analyses were performed using established methods. Lipid amounts were calculated by passing volatized ether through the 50 g tissue samples which removed all ether-soluble products including lipids. Lipids were then extracted from the ether, dried and weighed (AOAC 1965). Ash content was calculated by combusting weighed samples at 500–600 ºC for 12 hours and reweighing (AOAC 1965; Craig et al. 1978). The percent moisture in the samples was obtained by placing a weighed sample in a freeze drier at -40º C for 24 to 36 hours and reweighing. Protein content was determined by subtraction (% protein =100 - % water - % fat - % ash), as in other studies on salmon energetics (e.g., Berg et al. 1998; Hendry and Berg 1999; Hendry et al. 2000). Carbohydrate content was assumed to be negligible. After lipid weights were calculated for each 50 gram subsample, we calculated total lipid per tissue and total body lipid levels. Energy density or gross somatic energy was calculated as kJ of energy per kg of fish mass, assuming energy equivalents for fat and protein of 36.4 kJ g^{-1} and 20.1 kJ g^{-1}, respectively (Brett 1995). Total energy included gonadal tissues.

Gross somatic energy density (kJ/kg) was used as a second measure of energy condition and was calculated for the lethally sampled fish. Gross somatic energy density represents the energy density contained within somatic tissues of the fish and is a measure of energy contained not only in the muscle tissue, but also the viscera and skin (Crossin and Hinch 2005). Because it is standardized by mass, it can be directly compared among individuals. Gross somatic energy density was regressed on lipid percentage (natural log [$\log_e$] transformed) estimated by the fatmeter (non-standardized values, see below) to examine the relationship between fatmeter estimates and gross somatic energy density (e.g., Colt and Shearer 2001; Crossin and Hinch 2005).

We used linear regression to estimate the relationship between muscle lipid content and fatmeter readings. The relationship was then used to estimate muscle lipid content for each outplanted fish by inverse prediction (Sokal and Rohlf 1995) using fatmeter measurements taken at the time of tagging. Henceforth, we refer to the corrected lipid estimates for outplanted fish as "standardized lipid percentage". Fatmeter readings from 2013 were also collected from fish tagged at Willamette Falls (see Jepson et al. 2013) and compared with readings from fish tagged at Fall Creek and the Dexter Dam trap. We evaluated the relationships between lipid values of fish collected for proximate analysis and morphometrics using multiple regression.

Temperature Monitoring

Temperature recorders were installed in 2013 at four sites in Fall Creek and four in the NFMF. In Fall Creek, loggers were located at the release site (rkm 505.4), the bridge near Johnny Creek (rkm 513.0), near the mouth of Portland Creek (rkm 516.5), and at the unnamed falls that act as a fish barrier (rkm 529.6) (Appendix Figure 1). In the NFMF Willamette River, loggers were placed at the release site (rkm 557.9), below the bridge near Kiahanie campground (rkm 565.4), at the forest road 1944 bridge (rkm 572.5), and above Skookum Creek (rkm 585.9) (Appendix Figure 2). Depth of temperature loggers ranged from approximately 0.5-1.5 m. Temperatures were logged at 15 minute intervals from mid-May to mid-October. Note river kilometers are measured from the mouth of the Columbia River.

We used IBT submersible temperature loggers (Embedded Data Systems, LLC, Lawrenceburg, KY; 17.35×5.89 mm, 3.3g in air) to record internal temperatures on a subsample of radio-tagged fish. The tags were waterproofed (Plasti Dip multipurpose rubber coating; Plasti Dip International, Blaine, Minnesota, see Donaldson et al. 2009) and attached to the bottom of the radio tags with electrical tape then inserted gastrically. The temperature recorders were recovered during carcass surveys and were downloaded.

Spawning Ground Surveys and Spawning Success

After transport to release sites above the dams, salmon were allowed to spawn naturally and spawning areas were monitored to collect carcasses and assess spawning success. Carcass surveys were conducted by both UI and ODFW on a regular basis from the beginning of releases through the spawning period (June through early October). Fish encountered during spawning ground surveys were inspected by UI and/or ODFW personnel for radio and PIT tags. When the carcass of an individual from this study was located, it was inspected to determine spawning status and its general condition was noted (how recently it died, obvious wounds, fungus levels, or other apparent visual cues that caused mortality). In addition, otoliths and scales were collected from non-marked fish. If a fish had recently died (gills were red or pink), the fish was transported on ice to OSU, and tissue samples were collected for histology.

In 2013 spawning success was assessed by inspecting the gonads of females and estimating the proportion of gametes remaining to the nearest 25%. A successfully spawned fish was defined as having less than 25% of gametes remaining in the body cavity (Pinson 2005). Prespawn mortality rates were calculated separately for males and females because the proportion of remaining gametes could not be reliably estimated in males and in some carcasses that had been scavenged. Males that died prior to spawning (based on the date the first redd was counted) were considered prespawn mortalities. Statistical analyses only examined female PSM rate.

Multi-year summary

We performed several statistical analyses to test for associations between prespawn mortality and a suite of potential causative factors for both Fall Creek and the NFMF fish across study years. We used logistic regression and multi-model selection techniques (Burnham and Anderson 2002) and compared fit using Aaike Information Criteria (AIC). Predictor variables included year, tag date, condition, fatmeter percent, Fulton's K ($K = (10^5 * \text{weight}/FL^3)$), fork length(FL), weight, mid-eye-to-hyperal (MeH), depth at anus (Da), breadth at anus (Ba) and hump height (HH). We also calculated standardized morphometric measurements for the four morphometric parameters (StdMeH, StdDA, StdBA, StdHH) to control for differences in body size by dividing each estimate by fork length.

The model set included all univariate models plus eighteen multiple logistic regression models with adult fate (spawned, prespawn mortality) as the dependent variable. The full logistic regression model was:

Prespawn mortality (y/n) = + year + tagdate + condition + fatmeter + Fulton's K + FL + weight + StdMeH + StdDA + StdBA + StdHH.

In addition, to statistical analyses we summarized prespawn mortality rates across study years and streams. We also compared prespawn mortality rates among PIT, radio-tagged, and unmarked fish.

Methods: South Santiam River

Adult Chinook salmon were collected and tagged at the Foster Dam trap on the South Santiam River from 13 June to 4 September 2013. The trap was operated by ODFW and sampled fish were provided as part of routine trap operations. The Foster trap consists of a ladder, a collection area and a mechanical sweep to crowd fish. ODFW personnel sorted fish and transferred fish into an anesthetic tank where they were anesthetized with CO_2 before transfer to a secondary tank containing MS-222. Tagging, handling, and proximate analysis methods were similar to those reported above for salmon trapped at Dexter. Salmon were released in Foster Reservoir near the Calkins boat launch (rkm 421.7; measured from mouth of the Columbia River) and in the South Fork Santiam River at River Bend (rkm 428.3) and Gordon Road (rkm 444.7).

Methods: Toxicology sampling

In 2013, we also collected tissue samples from female spring Chinook salmon carcasses in Fall Creek, the NFMF and the South Fork of the Santiam River to estimate the concentrations of toxins. The primary goal was to screen samples for a broad spectrum of metals (~25 elements) and organic toxins (~100 compounds) to identify potential toxins of concern, while also testing for differences in adults that were either prespawn mortalities or successful spawners. We focused on radio or PIT-tagged fish but unmarked fish were also collected. After determining spawning status, we removed a 2.5×2.5 cm (one inch) square of muscle and skin tissue from the belly about 2.5 cm anterior to the pelvic fin on the left side of the fish. The sample was then placed in a labeled 60 ml amber glass jar. Samples were placed in a freezer at the end of each day then transferred to the University of California, Davis for toxicological screening at the end of the field season using previously described methods (e.g., Greenfield et al. 2008, Hwang et al. 2009a, 2009b, McGourty, et al. 2009). To date, three metals (Cd, Pb, and Ni) have been fully analyzed. We tested for differences in mean concentrations of Cd, Pb, and Ni using individual two-way ANOVAs using the model: Concentration = Site + Spawned

Two samples from Fall Creek were not included in the model. Preliminary models indicated no evidence of a Site X Spawned interaction (P => 0.207) and were dropped.

Results: Middle Fork Willamette River

Fall Creek

Tagging occurred from 16 May to 26 August, 2013. A total of 96 fish (46 females, 50 males) were PIT tagged (Figure 4). Tagging was representative of the overall timing of the run, which peaked in early June followed by another peak in late-July (Figure 4). All fish transported above the dam were non-adipose clipped fish. The mean condition score in 2013 was 2.5, mean fork length was 70.3 cm, mean weight was 3.9 kg, and mean lipid percentage was 5.2% (Table 1).

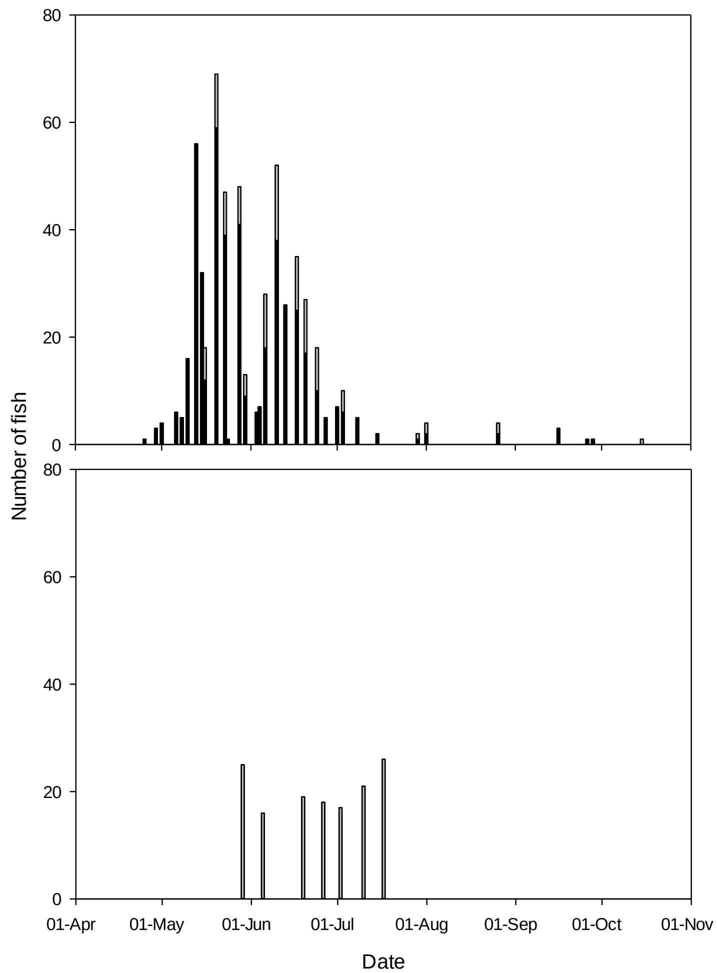

Figure 4. Numbers of adult Chinook salmon tagged in 2013. Top panel: distributions of Chinook salmon that were (open bars) and were not (black bars) tagged at Fall Creek trap. Fall Creek fish were immediately outplanted above Fall Creek Dam and Reservoir. Bottom panel: distributions of Chinook salmon collected and tagged at Dexter Dam and immediately outplanted to the NFMF on the date of tagging (gray bars).

Table 1. Adult Chinook salmon size, lipid content, and condition metrics for fish sampled at Fall Creek trap in 2013. MeH = Mid-eye to hypural length, Da = Depth at anus, Ba = Breadth at anus, HH = Hump height, % Lipid = Standardized % lipid in muscle tissue, wet weight.

Fall Creek (*n* = 96)	Fork Length (cm)	Weight (kg)	MeH (cm)	Da (cm)	Ba (cm)	HH (cm)	% Lipid	Condition Score
Mean	70.3	3.87	59.6	11.3	6	7.8	5.2	2.5
St. Deviation	6.8	1.7	6.0	1.3	1.0	0.9	3.0	0.7
Max	94	9.65	81	16	9.3	10.3	12.7	3
Min	57	2.1	49	9.1	4.1	5.5	0.5	1

Individual lipid concentrations as estimated with the Fatmeter during 2013 were positively correlated with the values estimated from proximate analysis taken from lethally sampled adults (adj. r^2 = 0.680, P = <0.001, n = 15 see Proximate Analysis section below). Mean lipid content of tagged adults arriving to Fall Creek trap early in the run were similar to those estimated for adults at Willamette Falls (Figure 5) and decreased through the 2013 season (Figure 6). This seasonal decline was similar to results in previous years.

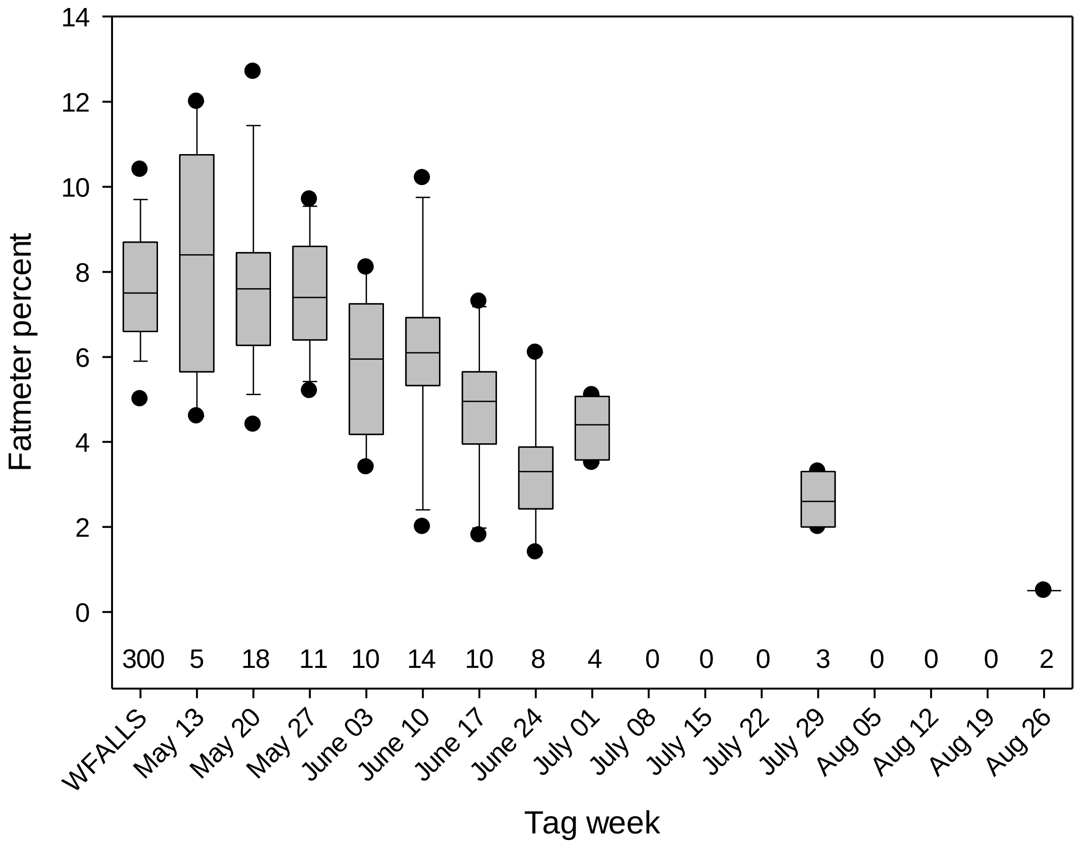

Figure 5. Weekly distributions of fatmeter estimates for Chinook salmon tagged at Fall Creek trap in 2013. Box plots represent median (solid line), 25th and 75th percentiles (ends of boxes), 10th and 90th percentiles (whiskers), and 5th and 95th percentiles (solid circles). Sample size for each date given below each box. First box on left shows data for Chinook salmon sampled at Willamette Falls Dam (WFALLS) from Jepson et al. (2014).

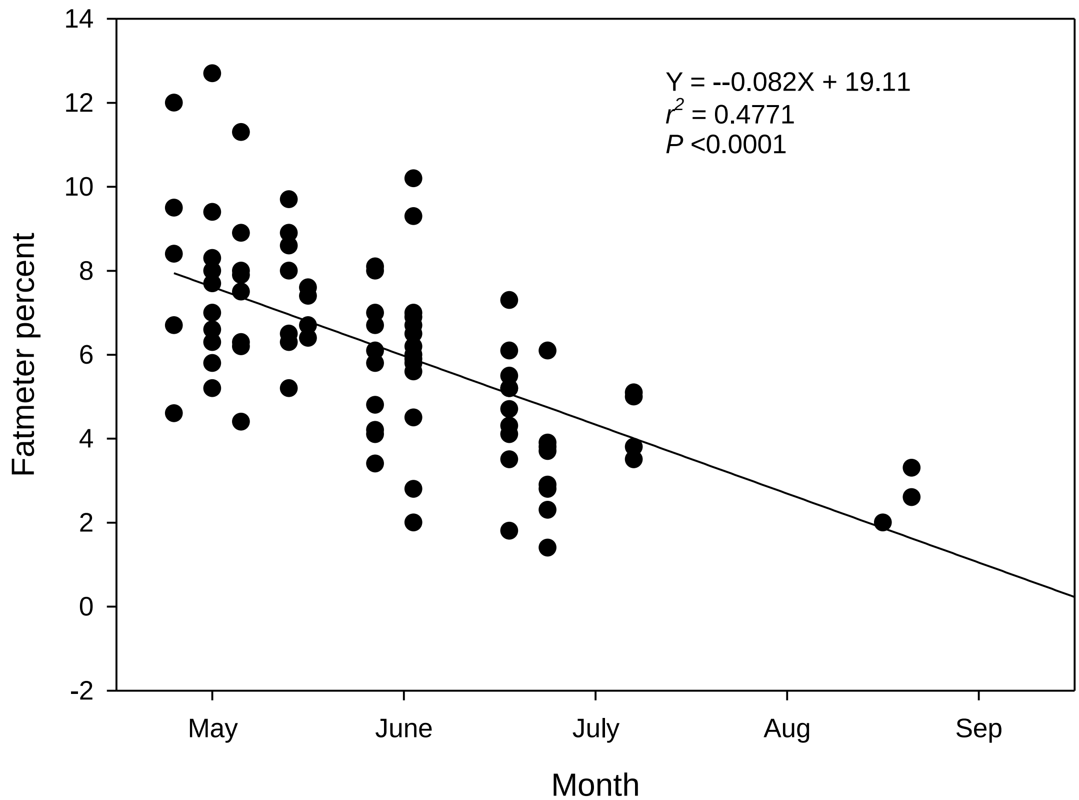

Figure 6. Fatmeter percentages for all fish tagged at arrival at Fall Creek Dam in 2013.

North Fork Middle Fork Willamette River

In 2013, we initiated outplanting into the NFMF approximately a month earlier than in previous years in an attempt to reduce the residence time of adults in the Dexter Dam tailrace. Tagging began on 22 May and continued until 17 July (Figure 6). This group included 165 fish (75 females, 90 males), and had mean length of 74.3 cm, mean weight of 4.7 kg, mean condition score of 2.4, and mean standardized lipid percentage of 2.8% (Table 2). Mean fatmeter readings from fish tagged at the Dexter Dam trap were lower than those for fish tagged at Willamette Falls and decreased across the eight tagging events (Figure 7).

Table 2. Adult Chinook salmon size, lipid content, and condition metrics for fish collected and sampled at Dexter trap and then immediately outplanted in 2013. MeH = Mid-eye to hypural length, Da = Depth at anus, Ba = Breadth at anus, HH = Hump height, % Lipid = Standardized % lipid in muscle tissue, wet weight.

Dexter (*n* = 165)	Fork Length (cm)	Weight (kg)	MeH (cm)	Da (cm)	Ba (cm)	HH (cm)	% Lipid	Condition Score
Mean	74.3	4.7	62.6	11.4	6	7.8	2.8	2.4
St. Deviation	7.0	1.4	6.2	1.5	0.8	1.0	1.4	0.7
Max	90.5	8.6	78.5	19.5	8.1	10.5	7.1	3
Min	57	2.1	47	8.1	4	4.4	0.6	1

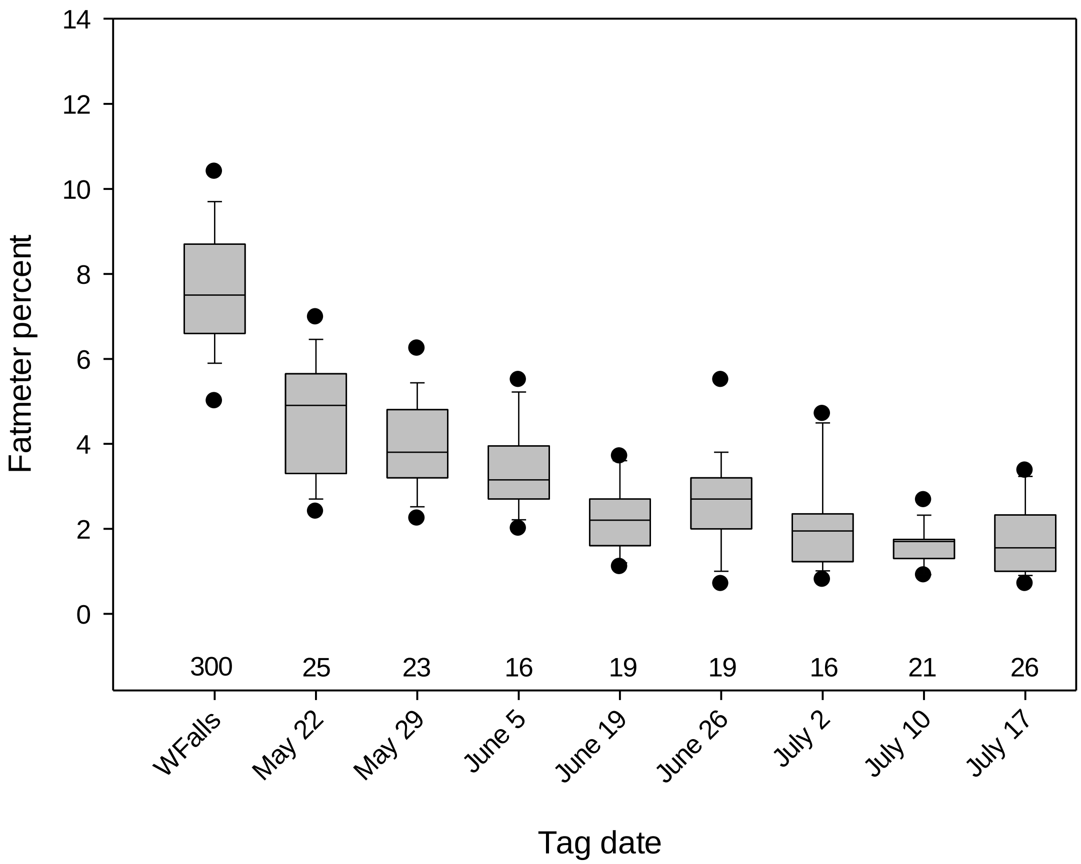

Figure 7. Weekly distributions of fatmeter results for Chinook salmon tagged at Dexter trap in 2013. Box plots represent median (solid line), 25th and 75th percentiles (ends of boxes), 10th and 90th percentiles (whiskers), and 5th and 95th percentiles (solid circles). First box on left shows data for Chinook salmon sampled at Willamette Falls Dam (WFALLS) from Jepson et al. (2014).

Proximate Analysis

In 2013, proximate analysis was performed on 15 salmon collected at Dexter (8 males and 7 females). No fish were sampled from Fall Creek (Table 3) because of concerns over lethally sampling unclipped (presumed natural origin) adults from this location. Lethal takes for proximate analysis were conducted on 29 May (n = 5), 12 July (n = 3), and 6 August (n = 7). The average muscle lipid level was 6.2% (Table 4) and ranged from 3-12%. Females had gonadal lipid compositions of 10.6%, while males were 1.0%, on average (Table 4).

Table 3. Mean tissue composition of Chinook salmon collected at Dexter and used in proximate analysis in 2013.

Tissue	% Moisture	% Crude Lipid	% Total Ash	% Protein
Gonads	71.6	5.5	2.1	20.9
Muscle	73.5	6.2	1.1	19.2
Skin	63.0	8.6	1.0	27.3
Viscera	76.9	4.1	1.6	17.4

Table 4. Tissue composition of Chinook salmon used in proximate analysis by sex.

Tissue	% Moisture	% Crude Fat	% Total Ash	% Protein
Males (n = 8)				
Gonads	80.8	1.0	2.6	15.6
Muscle	72.7	6.7	1.1	19.5
Skin	61.8	9.9	1.0	27.3
Viscera	77.3	3.0	1.6	18.1
Females (n = 7)				
Gonads	61.0	10.6	1.5	26.9
Muscle	74.5	5.6	1.1	18.8
Skin	64.5	7.1	1.0	27.4
Viscera	76.6	5.0	1.7	16.7

Fatmeter readings were taken on proximate analysis fish at the time of trapping to simultaneously assess the accuracy of the fatmeter readings and provide regression equations to calculate standardized values across years. Preliminary multiple regression models provided no evidence of a difference between sexes in the relationship between uncorrected fatmeter and proximate analysis lipid estimates ($P > 0.1$ in all years), but did suggest differences in the relationship among years ($P < 0.05$). Consequently, we performed regression analyses for each year with combined sexes. In all years the relationship was positive. However, the significance and strength of the relationship varied among years (Table 5).

Table 5. Linear regression results that show the relationships between fatmeter percentages (FM) and percent lipid in wet weight muscle tissue calculated in proximate analysis (PA) for combined males and females. These equations were used to obtain standardized fatmeter estimates for individual adults.

Year	*n*	Intercept	Slope	*P*	*adj* r^2
2013	15	-1.348	0.726	<0.001	0.68
2012	15	0.523	0.5137	0.408	0.61
2011	15	1.854	0.46	0.072	0.17
2010	30	0.703	0.413	<0.001	0.65
2009	29	3.097	0.758	<0.001	0.38
2008	11	3.738	0.387	0.090	0.21

We also tested whether the fatmeter provided accurate estimates of total energy in all body compartments combined (muscle, skin, and viscera). Specifically, we estimated whole-body somatic energy density (kJ/kg) using tissue samples, which standardized energy content for differences in fish size. Although the relationship was weak, we found a positive relationship between fatmeter readings and energy density in 2013 (Figure 8). Overall the results suggest that the fatmeter provides a non-lethal method to estimate a relative index of lipid reserves and energy content among individuals within years, but may not provide adequate precision to predict absolute values for individual adult Chinook salmon lipid or energy content.

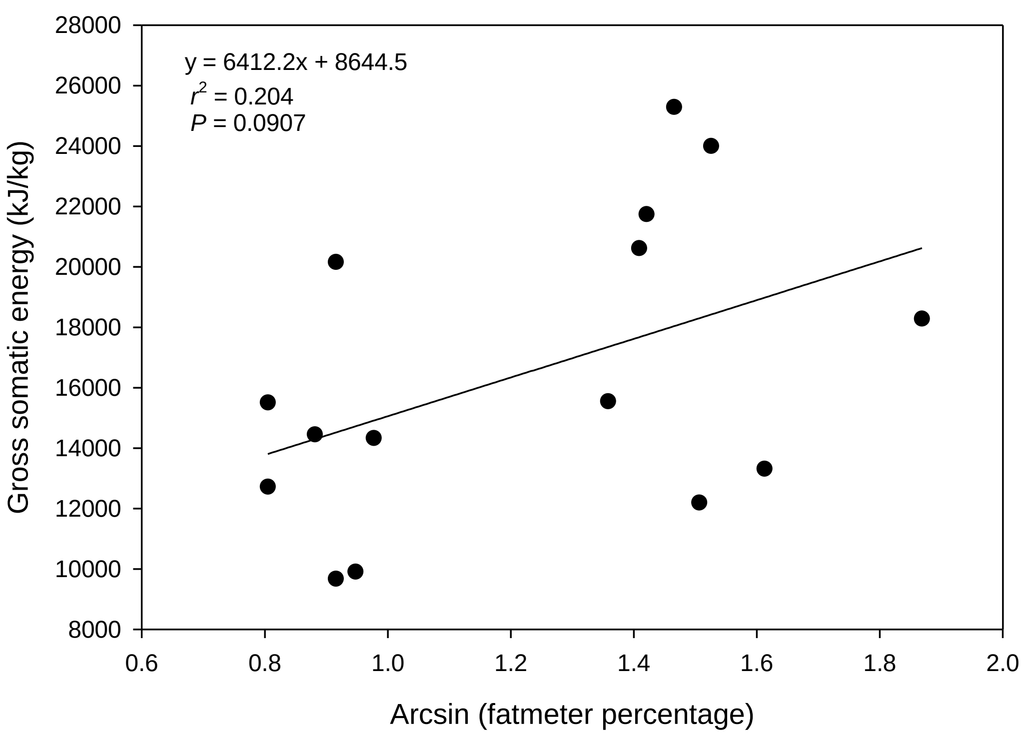

Figure 8. Relationship between Chinook salmon energy density (kJ/kg) estimated using proximate analysis and arcsine square root transformed raw fatmeter percentages, 2013.

River Conditions

The 2013 migration season was characterized low base flow during the early spawning period and by high flows due to record rainfalls in September (Figure 9). Water temperatures were near average throughout the monitoring period (Figure 10). The average water temperature at Fall Creek during the 2013 study period was 15.7 °C with a peak of 20.8 °C in late July (Figure 11). These temperatures were favorable for Chinook salmon holding as they were within the thermal preferendum of this species and were 3-4°C lower than incipient lethal temperatures (Orsi 1971; Coutant 1977; Jobling 1981; Richter and Kolmes 2005). Overall, water temperatures in Fall Creek were cooler in 2011 and 2013 than in 2009 and 2010. Temperatures increased at downstream locations and were highest at the release site in all study year (2009-2013). Mean daily temperatures in 2008 were < 19°C at a single site monitored by the USFS (Mann et al. 2010).

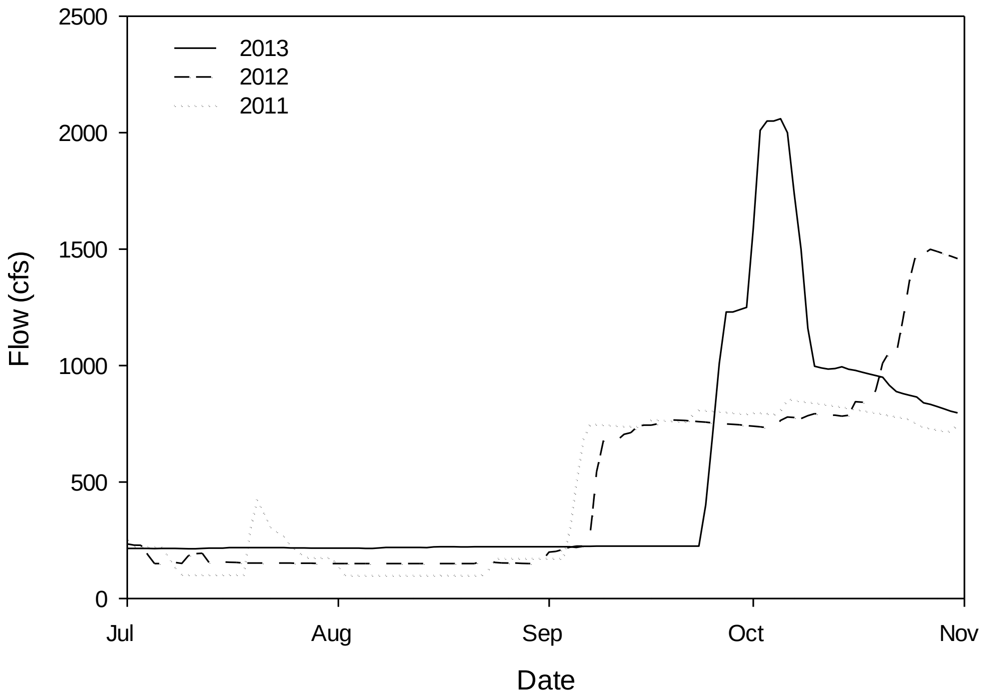

Figure 9. Mean daily discharge (cfs) at Fall Creek 2011-2013. Data is from the USGS Fall Creek gage below Winberry Creek.

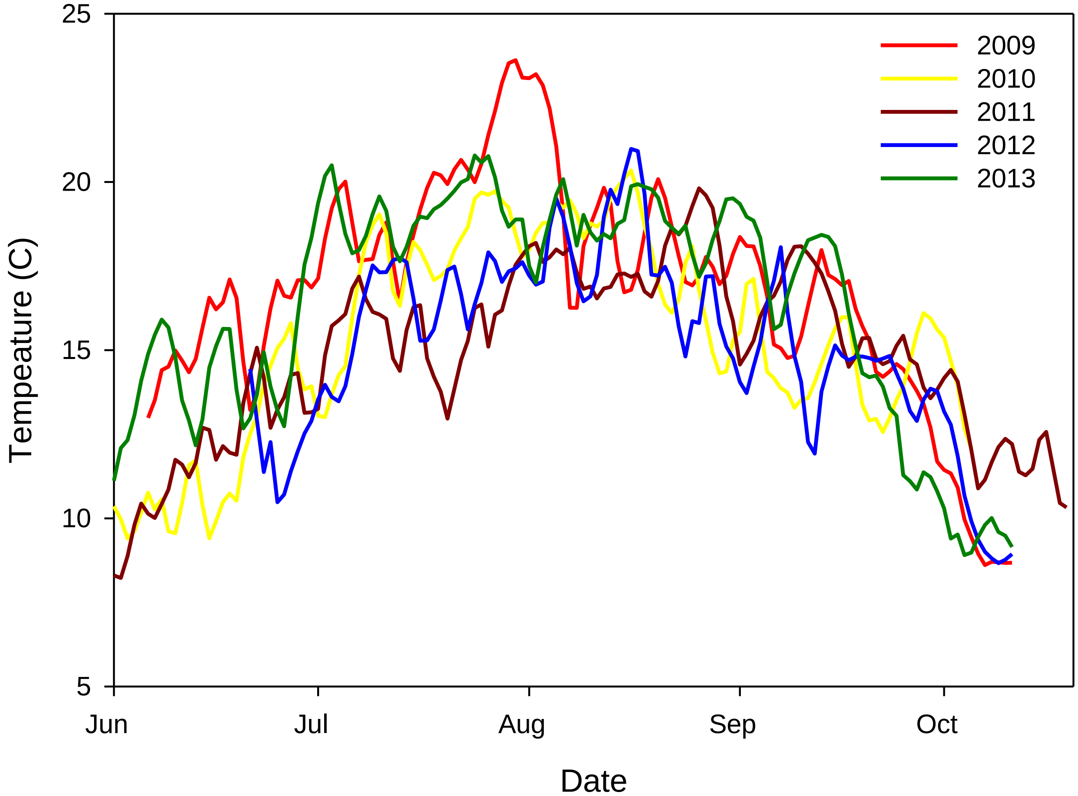

Figure 10. Mean daily water temperatures in Fall Creek in 2009-2013 near the release site (rkm 505.4).

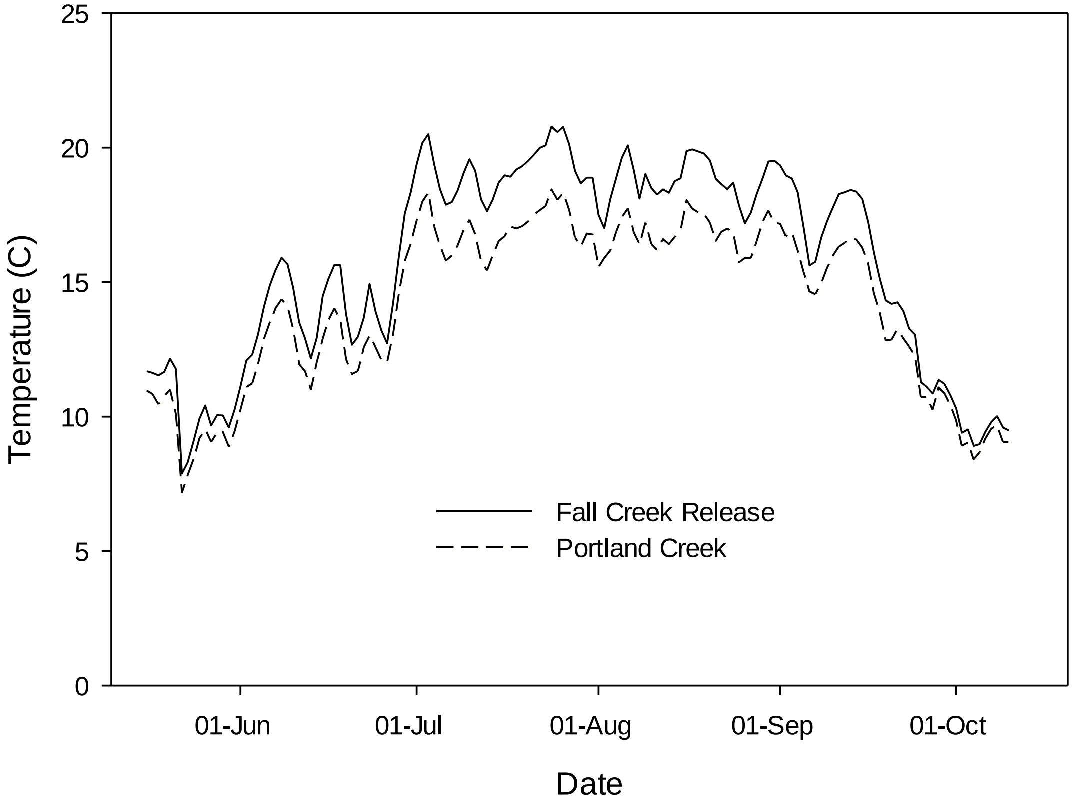

Figure 11. Daily mean water temperatures in 2013 at two sites in Fall Creek. The loggers represent a progression upstream from the release site (rkm 505.4) to the fish barrier (rkm 529.6). Data loggers deployed at Johnny Creek and the barrier falls were damaged or malfunctioned.

Water temperatures in the NFMF in 2013 were similar to previous study years (Figure 12). In the NFMF, daily means did not exceed 15°C at the release site during the monitoring period in 2013 and ranged from 8.1 to 14.8 °C from June through mid-October (Figure 12). NFMF temperatures were generally near or below the Chinook salmon thermal preferendum. Temperatures generally were higher at downstream locations in all years (Figure 13).

Although the release sites at Fall Creek and the NFMF Willamette were located 16.5 miles from each other, the NFMF was consistently cooler than Fall Creek due to differences in elevation and watershed characteristics (Figure 14). Mean water temperature in the NFMF during the 2013 study period was 11.7 °C with a peak of 14.8 °C in early July. Daily mean river temperatures in the NFMF averaged about 3.0 °C lower than in Fall Creek at the release sites throughout the monitoring period and about 4.0 °C lower during the July and August holding period.

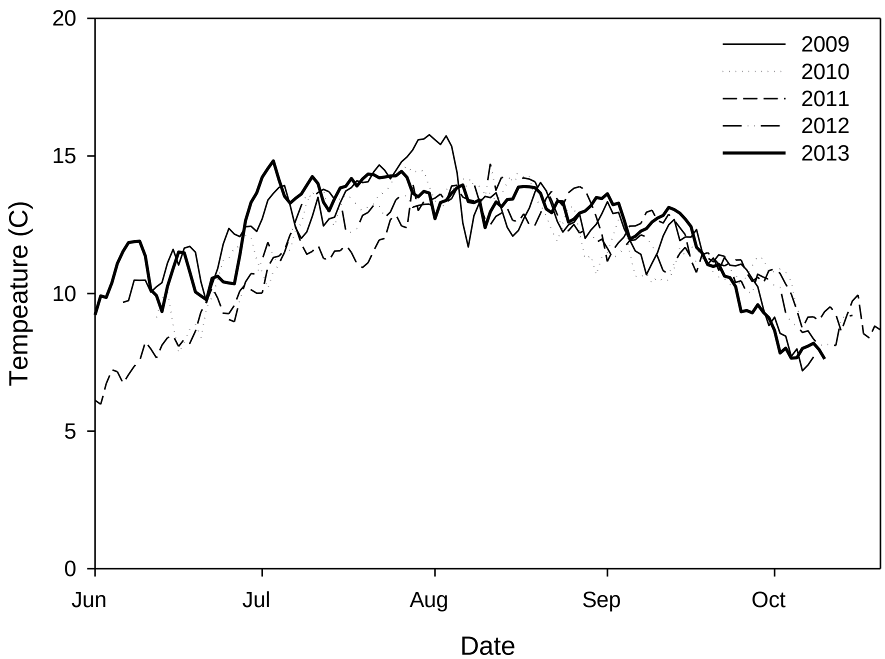

Figure 12. Comparison of mean daily water temperatures collected in the NFMF in 2009-2013 near the release site (rkm 557.9).

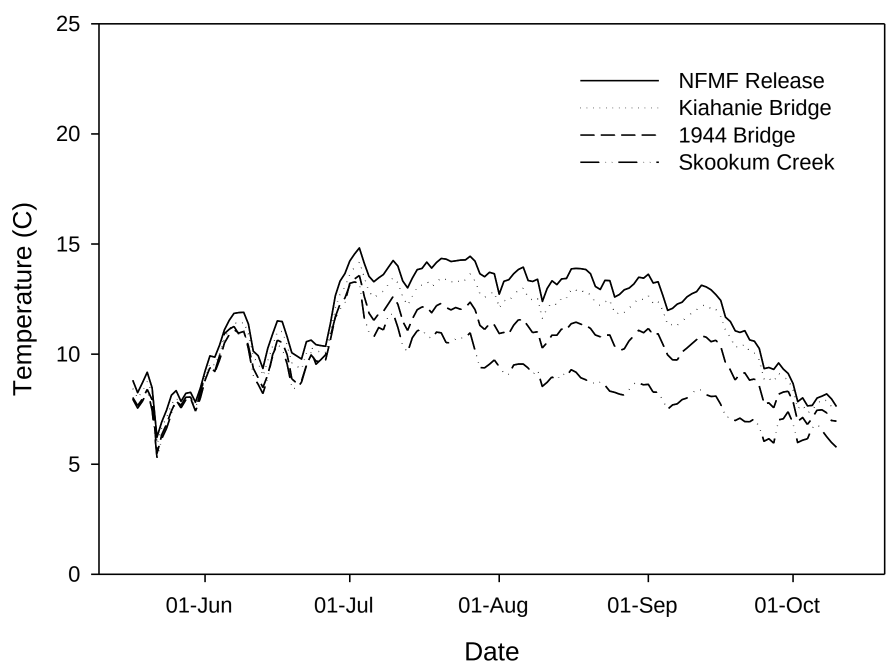

Figure 13. Daily mean water temperatures in 2013 at four NFMF sites. The loggers represent a progression upstream from the release site (rkm 557.9) to Skookum Creek (rkm 585.9). Data gaps at the release site resulted from lost/stolen loggers.

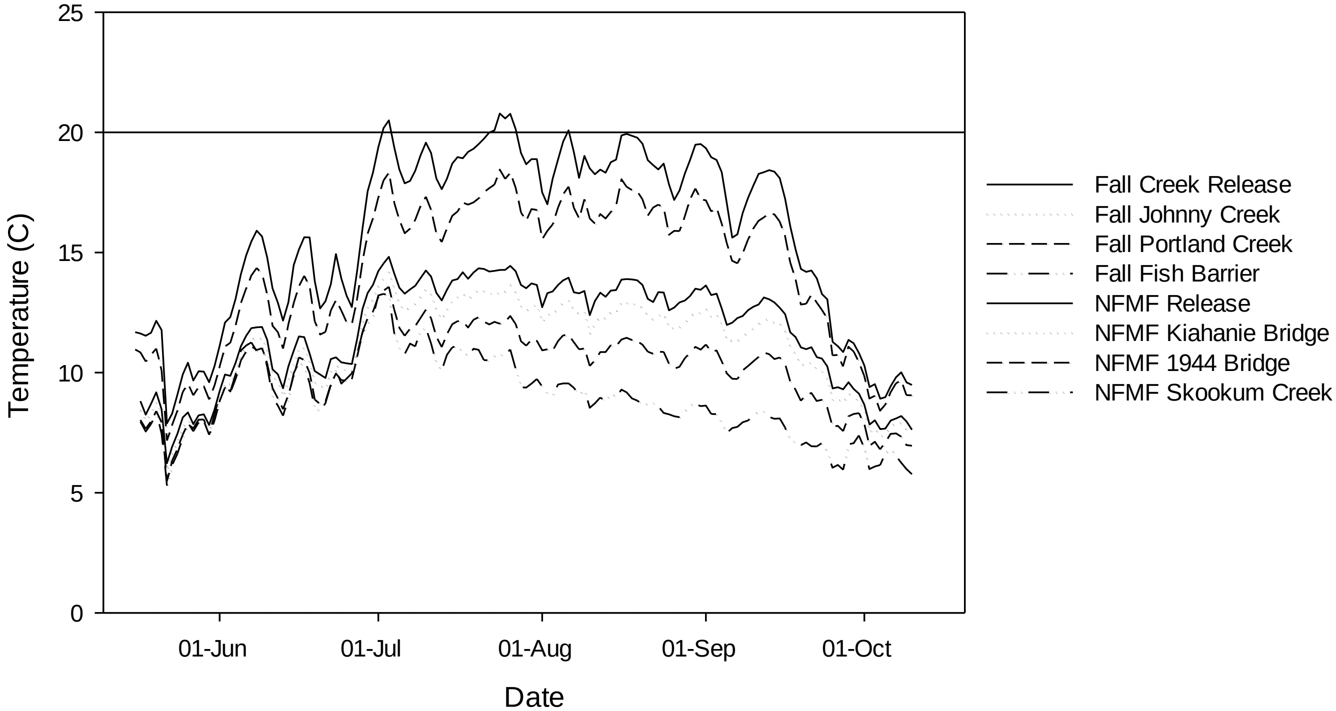

Figure 14. Daily mean water temperatures in Fall Creek and the NFMF Willamette River in 2013. Solid line at 20 °C represents temperature considered to be physiologically stressful for adult salmonids.

Spawning Ground Surveys and Spawning Success: Fall Creek

Carcasses were recovered in Fall Creek from 9 July until 12 October with the first redd observed on 19-September. The recovery rate was 4.2% (4 out of 96 fish) of the PIT-tagged fish. We recovered a higher proportion of unmarked fish in 2013 (8.4%) than PIT -tagged fish (Table 7). The 2013 prespawn mortality estimates in 2013 were the highest in the 2008-2013 period for Fall Creek (Table 7). The prespawn mortality estimate was 100% (13 of 13 females recovered) for untagged carcasses and 100% (2 of 2 females) for PIT-tagged fish (Table 6).

Table 6. Recovery rates and final estimated fates of Chinook salmon that were PIT-tagged or double-tagged (PIT and radio-tagged) and unmarked fish in Fall Creek, 2008-2013. Prespawning mortality (PSM) rates were only calculated for females.

Year	Group	# released	# recovered	% recovered	Females # recovered	Females %PSM
2008	PIT	188	30	16	0	N/A
	Double	7	1	14	0	N/A
	Unmarked	N/A	19	N/A	0	N/A
2009	PIT	175	22	13	10	80
	Double	25	11	44	6	100
	Unmarked	N/A	66	N/A	15	87
2010	PIT	124	30	24	12	42
	Double	75	32	43	15	73
	Unmarked	N/A	148	N/A	46	43
2011	PIT	125	27	22	12	17
	Double	75	22	29	9	44
	Unmarked	128	33	26	13	54
2012	PIT	78	20	26	11	0
	Double	40	11	28	5	20
	Unmarked	192	67	35	28	18
2013	PIT	96	4	4.2	2	100
	Unmarked	371	31	8.4	13	100

The final distribution of PIT-tagged fish indicated that the majority of spawning occurred 15-25 km upstream from the release site (Figure 15). Each of the two PIT-tagged prespawn mortalities was recovered between Portland Creek and the barrier falls.

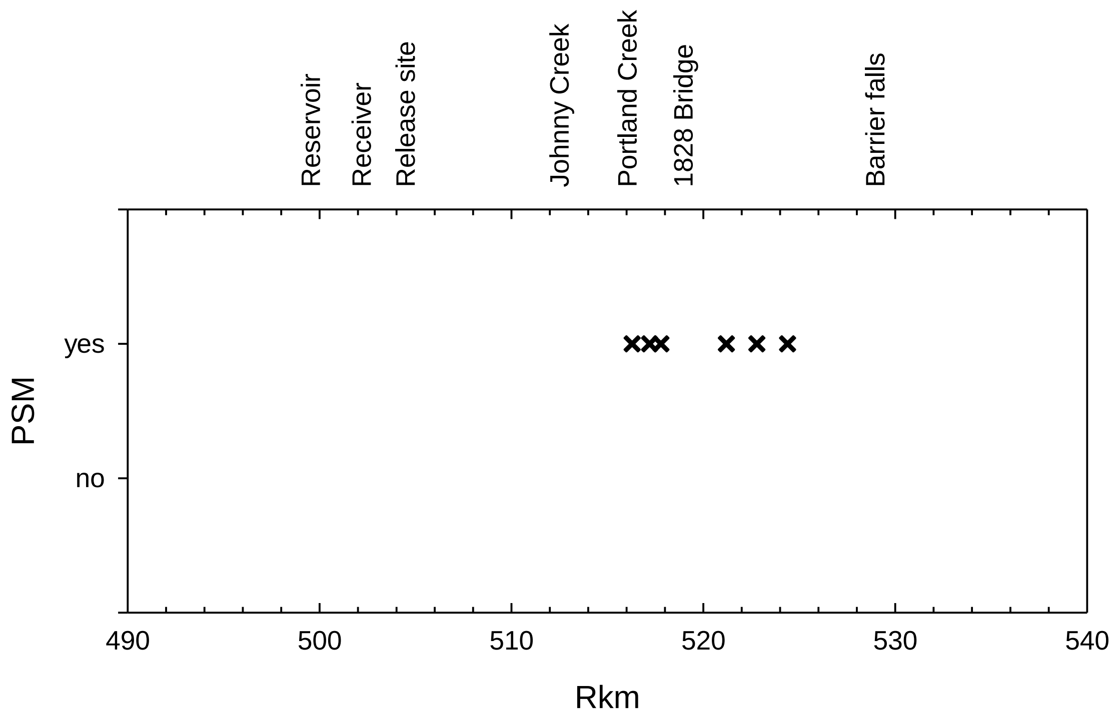

Figure 15. Distribution of PIT-tagged and untagged female Chinook salmon carcasses that were recovered in Fall Creek spawning ground surveys in 2013, including their spawning status.

Spawning Ground Surveys and Spawning Success: NFMF

Carcasses were recovered in the NFMF from 5 June to 8 October from two groups of tagged adults. The recovery rate was 10.4% for adults tagged only with at PIT-tag and released immediately (Table 7), a proportion similar to the recovery rate for radio-tagged adults (10.2%). Approximately 17% of the unmarked fish released in the NFMF were recovered on the spawning grounds.

The prespawning mortality rates in 2013 were 50% (3 of 6 females recovered) for PIT-tagged fish and 33% (1 of 3 females recovered) for radio-tagged fish (Table 8). The prespawn mortality rate for unmarked fish was approximately 29% (Table 7).

Table 7. Final fates of PIT-and radio-tagged and unmarked subsets of the Chinook salmon outplanted in the NFMF Willamette River in 2009-2013. Prespawning mortality (PSM) rates were only calculated for females. DEX = fish tagged at the Dexter Dam trap and immediately outplanted into the NFMF Willamette River. HH = fish held at the Willamette Hatchery then later outplanted into the NFMF Willamette River.

Year	Group	# released	# recovered	% recovered	Females #recovered	Females %PSM
2009 (DEX)	PIT	124	6	5	3	0
	Double	12	3	25	1	100
	Unmarked	N/A	66	N/A	19	47
2009 (HH)	PIT	103	1	1	1	0
2010 (DEX)	PIT	148	30	20	15	47
	Double	43	8	18	3	67
	Unmarked	N/A	266	N/A	102	64
2010 (HH)	PIT	81	8	10	7	0
	Double	18	7	39	6	33
2011 (DEX)	PIT	109	7	6	5	0
	Double	71	11	15	5	60
	Unmarked	1,366	186	14	98	38
2011 (HH)	PIT	79	8	10	5	40
2012 (DEX)	PIT	104	14	13	10	10
	Double	50	11	22	6	17
	Unmarked	2,441	387	16	192	23
2012 (HH)	PIT	71	17	24	10	10
2013	PIT	106	11	10.4	6	50
	Double	59	6	10.2	3	33.3
	Unmarked	2031	336	16.5	153	28.8

In the NFMF, spawning activity was concentrated in a 10 km reach just upstream from the release site (Figure 16), a pattern similar to spawning distributions observed in previous years (Mann et al. 2011; Naughton et al. 2011). A total of 177 redds were counted in 2013 and all were upstream from the release site.

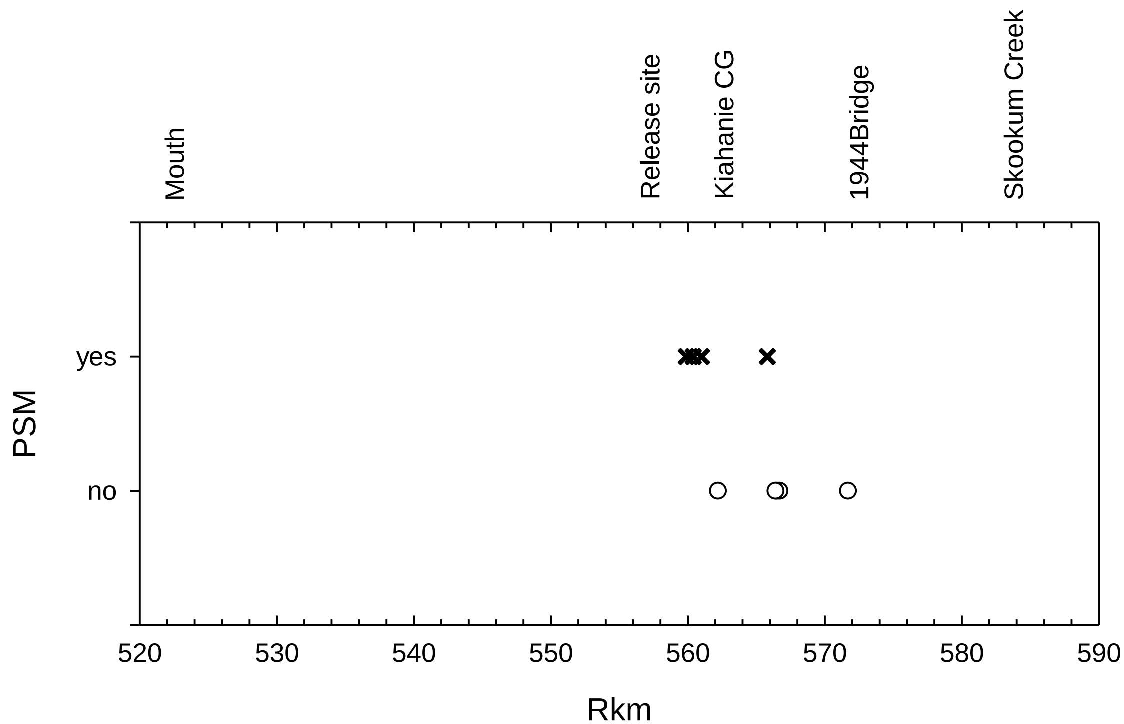

Figure 16. Distribution of PIT- and radio-tagged female Chinook salmon carcasses that were recovered in the NFMF Willamette River spawning ground surveys in 2013, by their spawning status.

In 2013, we initiated outplanting into the NFMF approximately a month earlier than in previous years. Few tagged carcasses were recovered prior to flooding. Only one female from the early release group was recovered and it was a prespawn mortality. A total of 6 females from the standard release group were recovered and three (50%) were prespawn mortalities.

Table 8. Prespawn mortality (PSM) percentages for two groups of spring Chinook salmon tagged at the Dexter trap and released in in the NFMF in 2013.

Release Date	Number Released	Number Recovered	Percent Recovered	Females Recovered	PSM	Percent PSM
22May-5June	64	6	9.4	3	1	33
19Jun-17Jul	101	11	10.9	6	3	50

Multi-year Summary

We tested for associations between fate and a suite of factors potentially related to prespawn mortality across study years using univariate and multiple logistic regression models and multi-model selection techniques. The models for Fall Creek included 82 females over 5 years.

Among the univariate logistic regression models, year, tag date, Fulton's K, fork length and standardized breadth at anus (StdBa) were significantly ($P < 0.05$) associated with prespawn mortality (Table 9). In the multi-model logistic regression evaluation, the most parsimonious model included year and tag date (Table 9). The tag date effect reflected higher prespawn mortality among earlier migrants, on average, while the year effect indicated higher prespawn mortality in the early study years. Several additional models had statistical support, with ΔAIC < 4.0. All but one model that included either year or tag date were significant. These models included various combinations of condition, fork length, Fulton's K, weight and shape. That multiple models produced similar results was not surprising given the inter-correlations among predictor variables.

The models for the NFMF included 57 females over 5 years. Prespawn mortality was not significantly associated with any univariate predictors (all model $P \geq 0.127$), although the fatmeter-only model was the most parsimonious among all models tested (Table 10). In the multivariate models, year plus tag date was the model with the lowest *P* value ($P = 0.115$) and was the most parsimonious (Table 9).

Overall, prespawn mortality rates for PIT and radio-tagged female Chinook salmon were highly variable in Fall Creek ranging from about 6% in 2012 to 100% in 2013 (Figure 17). Prespawn mortality rates for PIT and radio-tagged females combined in the NFMF were also highest in 2013 (44%; Figure 17) versus 14-33% in previous years. In most years, a majority of prespawn mortalities occurred prior to the first redd count in each stream (Figures 18 and 19). Prespawn mortality rates were higher for PIT and radio-tagged fish in Fall Creek compared to untagged fish in 2009 and 2010 but rates were similar for tagged and untagged groups in 2011-2013 (Figure 20). In the NFMF, there were no consistent year-to-year patterns in prespawn mortality rates among untagged, PIT-tagged or radio-tagged groups (Figure 21).

Table 9. Selection statistics for logistic regression models of prespawn mortality in Fall Creek from 2008-2013 that included a variety of predictor variables and mortality as the dependent variable. AIC = Akaike information criteria, $\Delta AIC = AIC_{current} - AIC_{best}$. Models in shaded grey had statistical support (ΔAIC < 4 in multivariate model, $P < 0.05$ in univariate models), and the model in bold text was most parsimonious. Variable definitions: Condition = overall physical condition; TagDate = release date; Fatmeter = fatmeter percentage; StdMeH = standardized mideye to hypural length; StdHH = standardized hump height; StdDa = standardized depth at anus; StdBa = standardized breadth at anus; FL = fork length; Weight, and K = Fulton's K (10^5*weight/L^3).

Model type Univariate	Variables	AIC	ΔAIC	P-value
Timing	Year	91.761	3.22	0.002
	Tag Date	100.159	11.618	<0.001

Table 9. Continued

Condition	Condition				118.899	30.358	0.796
	Fatmeter				112.54	23.999	0.080
	Fulton's K				112.045	23.504	0.036
Shape	StdMeH				116.088	27.547	0.307
	StdHH				115.765	27.224	0.233
	StdDA				117.064	28.523	0.680
	StdBA				111.478	22.937	0.025
Size	FL				111.748	14.286	0.028
	Weight				115.127	17.665	0.157
Multivariate	Variables						
Timing	**Year**	**Tag Date**			**88.541**	**0**	**0.001**
Condition	Condition	Fatmeter			116.49	27.949	0.241
	Year	Condition	Fatmeter		95.056	6.515	0.029
	Condition	Fatmeter	K		114.74	26.199	0.228
	Year	Condition	Fatmeter	K	95.691	7.15	0.042
	Condition	Fatmeter	tagdate		102.377	13.836	0.020
	Year	Fatmeter	tagdate	K	91.852	3.311	0.007
Shape	StdMeH	StdHH	StdDA	StdBA	118.856	30.315	0.393
	Year	Shape			95.925	7.384	0.027
	Condition	Fatmeter	Shape		119.714	31.173	0.523
	Year	Condition	Fatmeter	Shape	99.987	11.446	0.180
	Shape	Tag date			101.779	13.238	0.008
	Year	shape	Tag date		93.408	4.867	0.036
Size	FL	Weight			111.376	22.835	0.043
	Year	FL	Weight		91.032	2.491	0.009
	FL	Weight	Shape		113.364	24.823	0.155
	Year	FL	Weight	Shape	96.937	8.396	0.086
Full					101.934	13.393	0.586

Table 10. Selection statistics for logistic regression models of prespawn mortality in NFMF from 2009-2013 that included a variety of predictor variables and mortality as the dependent variable . AIC = Akaike information criteria, ΔAIC = $AIC_{current}$-AIC_{best}. Models in shaded grey had statistical support (ΔAIC < 4 in multivariate model, $P < 0.05$ in univariate models), and the model in bold text was most parsimonious. Variable definitions: Condition = overall physical condition; TagDate = release date; Fatmeter = fatmeter percentage; StdMeH = standardized mideye to hypural length; StdHH = standardized hump height; StdDa = standardized depth at anus; StdBa = standardized breadth at anus; FL = fork length; Weight, and K = Fulton's K (10^5*weight/L^3).

Model type Univariate	Variables				AIC	ΔAIC	P-value
Timing	Year				76.091	5.607	0.248
	Tag date				76.025	5.541	0.466
	Condition				77.904	7.420	0.720
	Fatmeter				71.113	0.629	0.635
	Fulton's K				73.288	2.804	0.127
Shape	StdMeH				75.721	5.237	0.883
	StdHH				74.513	4.029	0.277
	StdDA				75.742	5.258	0.985
	StdBA				75.567	5.083	0.678
Size	FL				76.421	5.937	0.706
	Weight				75.742	5.258	0.974
Multivariate							
Timing	Year	Tag date			70.484	0.000	0.115
Condition	Condition	Fatmeter			74.808	4.324	0.916
	Year	Condition	Fatmeter		79.527	9.043	0.836
	Condition	Fatmeter	K		75.254	4.770	0.895
	Year	Condition	Fatmeter	K	80.232	9.748	0.885
	Condition	Fatmeter	Tag date		76.699	6.215	0.961
	Year	Fatmeter	Tag date	K	73.655	3.171	0.482

Table 10. Continued.

Shape	StdMeH	StdHH	StdDa	StdBa	75.839	5.355	0.273
	Year	Shape			77.609	7.125	0.368
	Condition	Fatmeter	Shape		77.939	7.455	0.783
	Year	Condition	Fatmeter	Shape	82.173	11.689	0.833
	Year	shape	Tag date		75.778	5.294	0.388
						-70.484	
Size	FL	Weight			76.543	6.059	0.558
	Year	FL	Weight		78.289	7.805	0.443
	FL	Weight	Shape		78.488	8.004	0.384
	Year	FL	Weight	Shape	79.18	8.696	0.475
Full					89.092	18.608	0.909

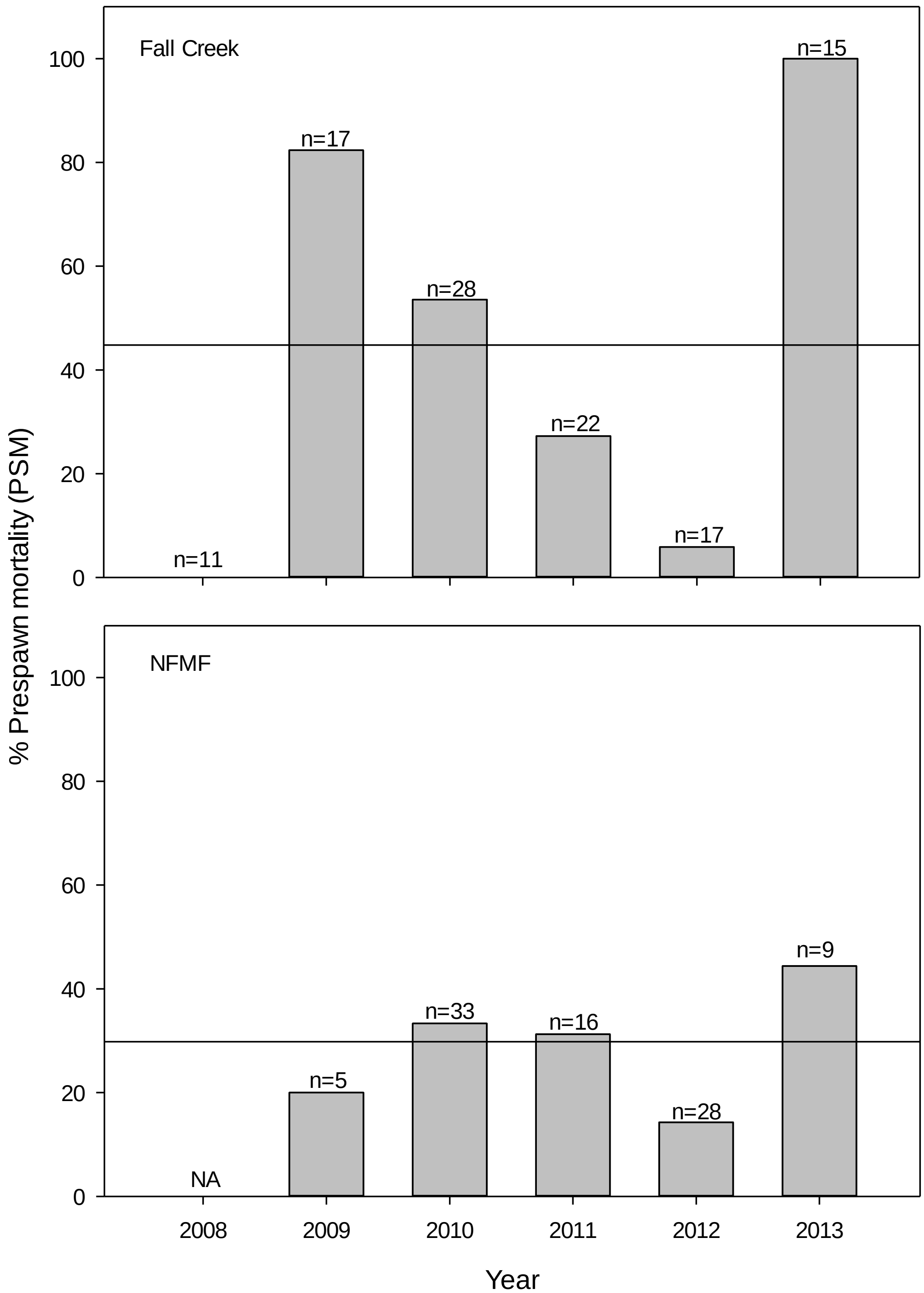

Figure 17. Annual percent prespawn mortality for PIT- and radio-tagged Chinook salmon in Fall Creek (top panel) and the NFMF (bottom panel) in 2008-2013. Horizontal line is the mean prespawn mortality rate across study years. Percentages are for females only.

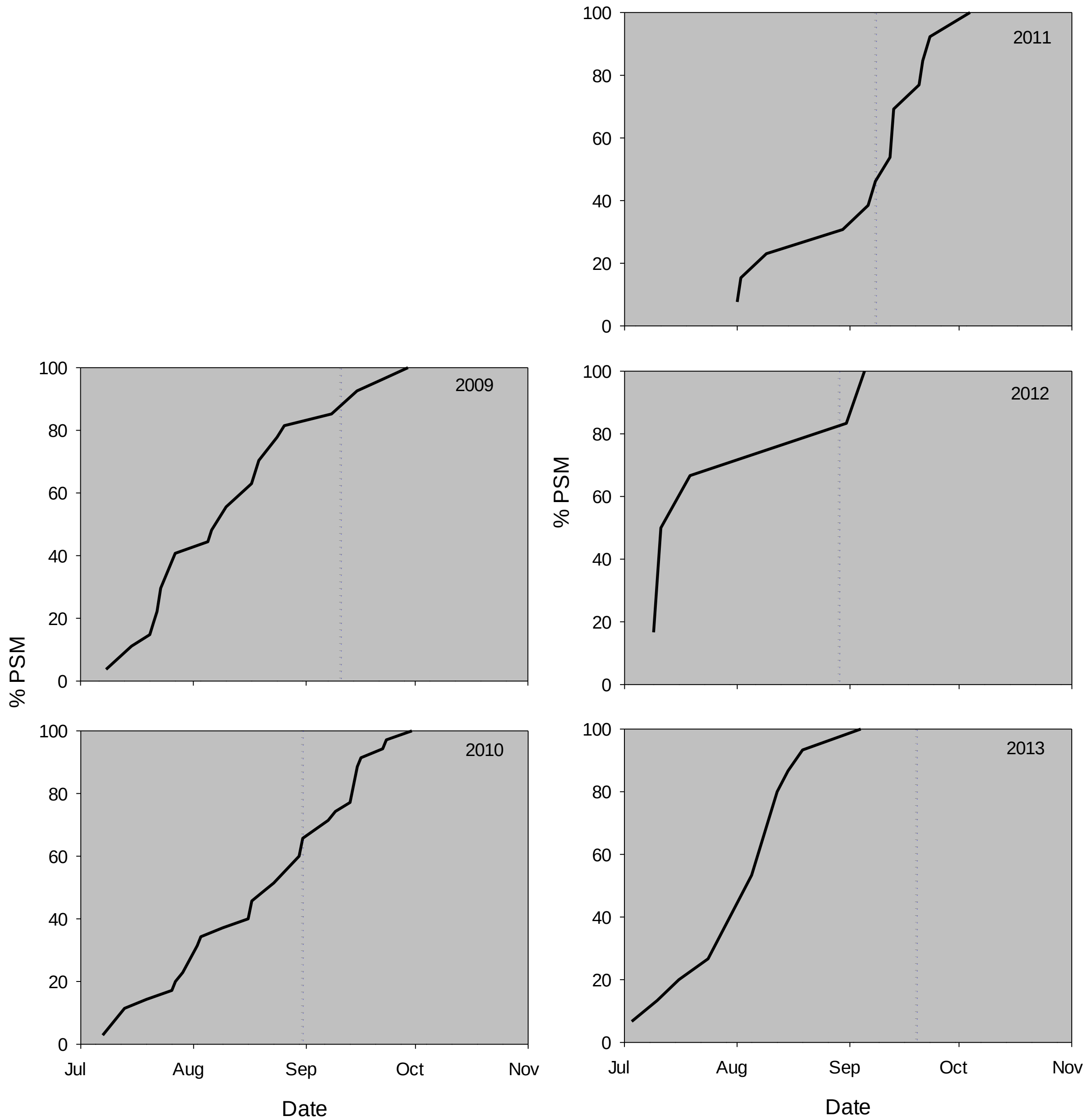

Figure 18. Cumulative percent prespawn mortality events of Chinook salmon in Fall Creek in 2009-2013 by date of carcass recovery. Vertical lines indicate the date that the first redd was observed.

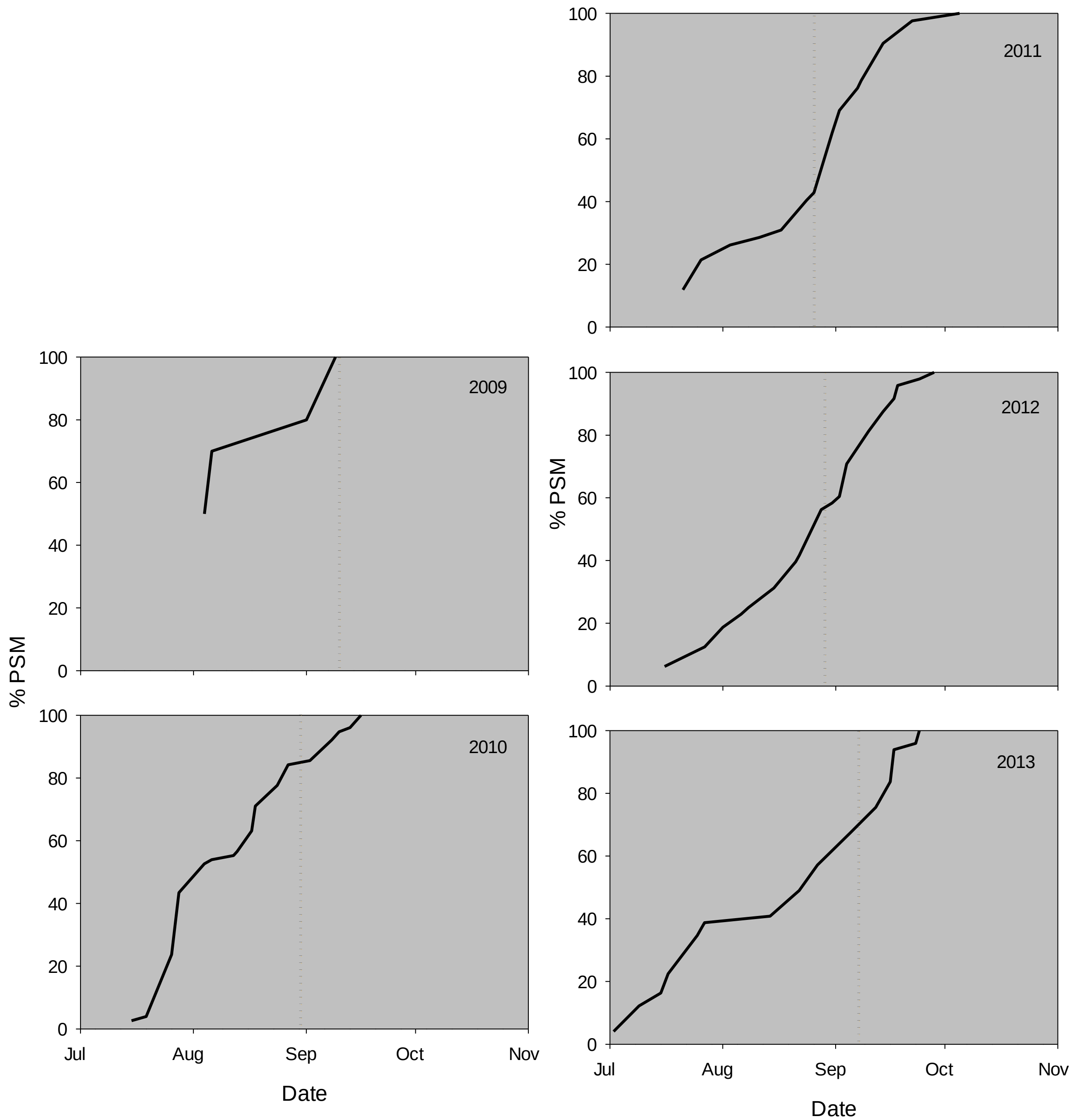

Figure 19. Cumulative frequency of prespawn mortality events of Chinook salmon in the NFMF of the Willamette River in 2009-2013. Vertical lines indicate the date that the first redd was observed.

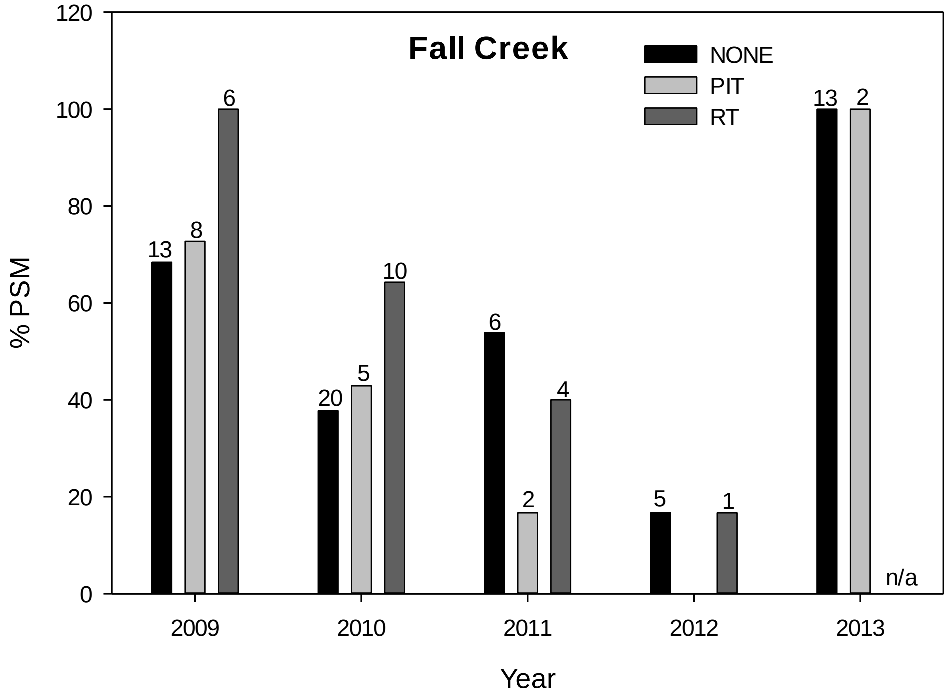

Figure 20. Prespawn mortality rates for Chinook salmon for untagged fish and by tag type in Fall Creek in 2009-2013. Sample sizes are above bars. Percentages are for females only.

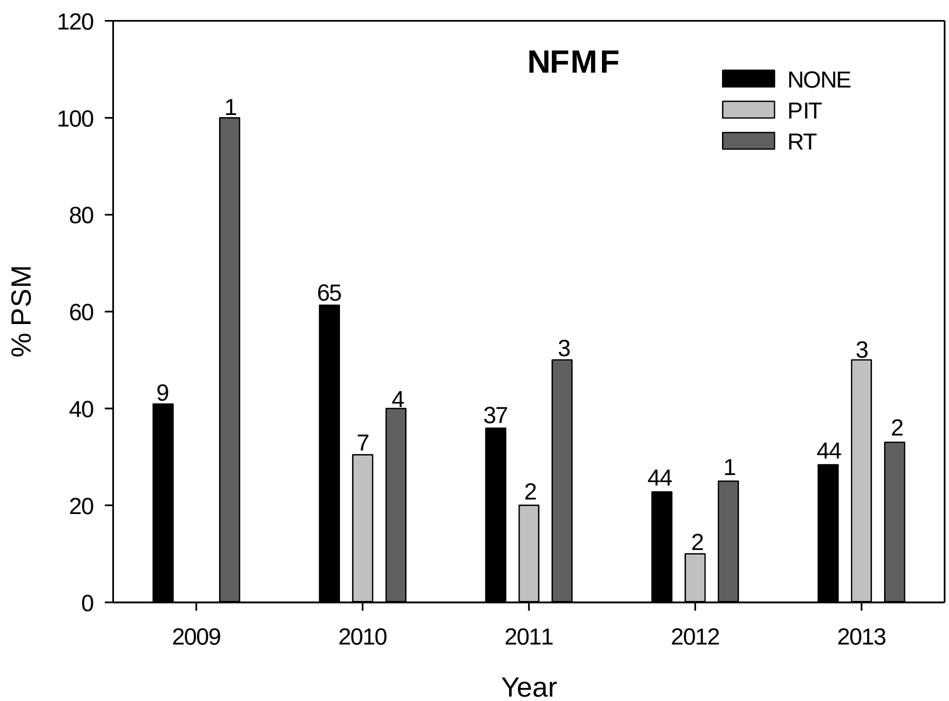

Figure 21. Prespawn mortality rates for Chinook salmon for untagged fish and by tag type for the NFMF in 200902013. Sample sizes are above bars. Percentages are for females only.

We examined the interannual relationship between water temperature and prespawn mortality in the two study areas (Figure 22). In Fall Creek, annual female mortality was strongly associated with mean daily water temperature from 1 July to 15 September ($r^2 = 0.83$) and positively but weakly correlated with the maximum 7-d moving average temperature ($r^2 = 0.27$). The first metric was an indicator of the overall thermal environment in each year and the second metric was an index of potential acute thermal stress. There were no clear patterns in the NFMF (Figure 23). Neither the seasonal mean ($r^2 = 0.08$) nor the 7-d moving average ($r^2 = 0.30$) was strongly associated with prespawn mortality.

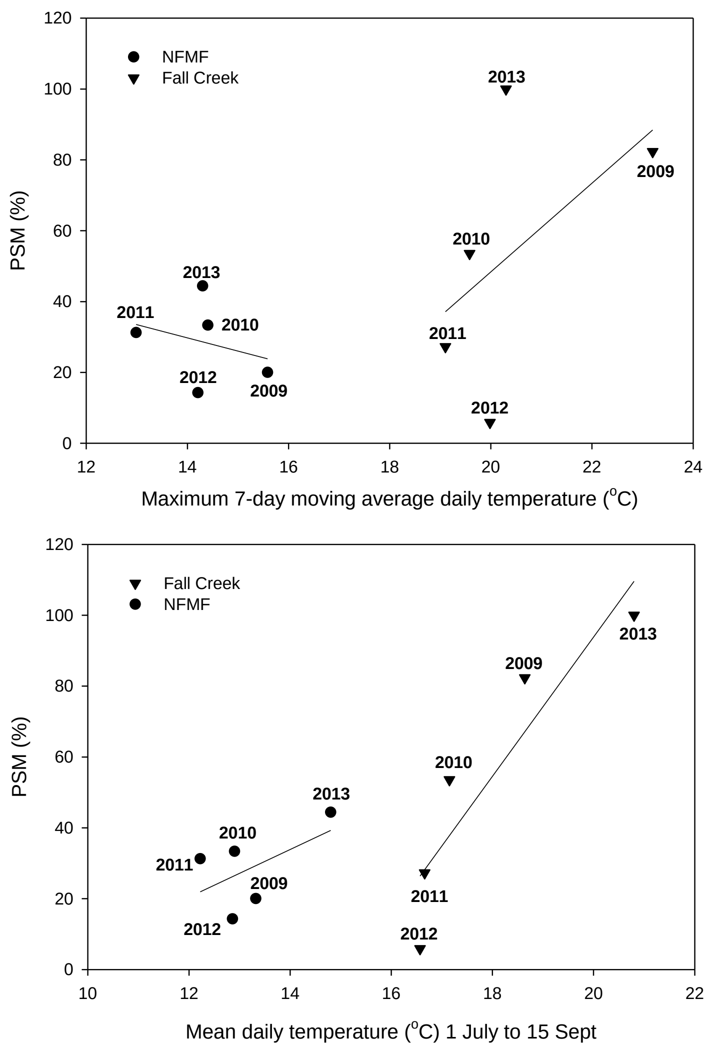

Figure 22. Prespawning mortality rates of female PIT and radio-tagged Chinook salmon in Fall Creek and the NFMF in relation to the maximum 7-d moving average daily temperatures (top panel) and the mean daily temperature from 1 July to 15 September (bottom). Temperatures were recorded at the release sites.

Results: South Fork Santiam

A total of 200 fish (86 females, 114 males) were PIT tagged, and 75 of these were also radio-tagged at Foster Dam and released into the South Fork Santiam River or Foster Reservoir (Figure 23). All fish transported above the dam were non-adipose clipped fish. Fish were released at three sites (Figure 24): River Bend (*n* = 22), Calkins (*n* = 50) and Gordon Road (*n* = 128). Fish released at the Calkins site were used to evaluate reservoir releases. The mean fork length was 77.8 cm in 2013, mean condition score in 2013 was 2.3, mean weight was 5.7 kg, and mean lipid percentage was 2.6% (Table 11). Overall, 12.8% of the PIT-tagged and 20% of the radio-tagged fish released were recovered on the spawning grounds. Prespawn mortality estimates for fish released upstream from Foster Dam were 28.6% (2 of 7 females recovered) for PIT-tagged fish and 100% (3 of 3 females recovered) for radio-tagged fish.

Figure 23. Map of Foster Reservoir including South Fork and Middle Fork Santiam river arms (top panel), radio telemetry and release sites (bottom panel). Note: Gordon Road release site is approximately 16.4 river kilometers upstream of River Bend and is not shown on the map.

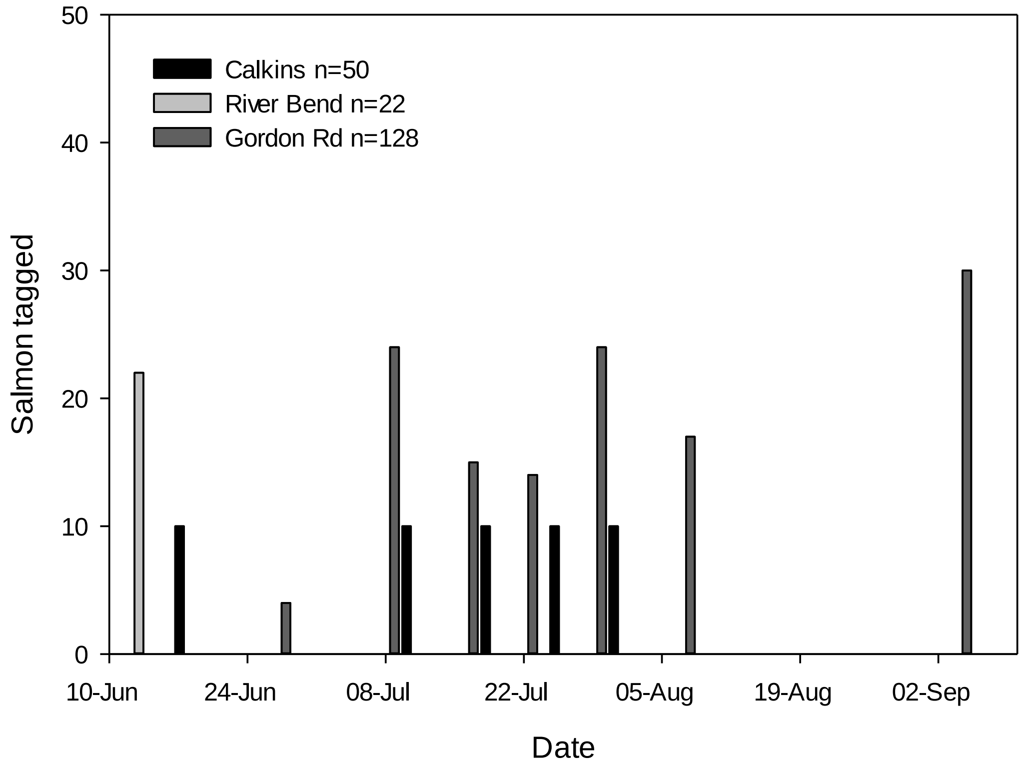

Figure 24. Numbers of adult Chinook salmon tagged at Foster Dam in 2013. Fish were immediately outplanted at three locations above Foster Dam.

Table 11. Adult Chinook salmon size, lipid content, and condition metrics for fish collected and sampled at Foster trap on the South Fork of the Santiam River and then immediately outplanted in 2013. MeH = Mid-eye to hypural length, Da = Depth at anus, Ba = Breadth at anus, HH = Hump height, % Lipid = % lipid in muscle tissue, wet weight.

SF Santiam (n = 200)	Fork Length (cm)	Weight (kg)	MeH (cm)	Da (cm)	Ba (cm)	HH (cm)	% Lipid	Condition Score
Mean	77.8	5.7	64.8	12.8	6.1	8.5	2.6	2.3
St. Deviation	6.6	1.5	5.8	1.4	0.9	0.9	1.7	0.8
Max	92.0	9.6	77.0	18.5	8.5	11.0	13.2	3
Min	51.0	0	41.0	7.7	3.5	5.0	0.4	1

Individual lipid concentrations of fish collected at Foster Dam as estimated with the fatmeter were poorly correlated with the values estimated from proximate analysis taken from lethally sampled adults (adj. r^2 = -0.0740, P = 0.854, n = 15 see Proximate Analysis section below). Negative adjusted r-square values indicate that the mean of the data provides a better fit than the regression equation. Mean estimated lipid content of tagged adults arriving at the Foster trap in June were lower than lipid content estimated for adults at Willamette Falls and generally decreased through the 2013 season (Figure 25).

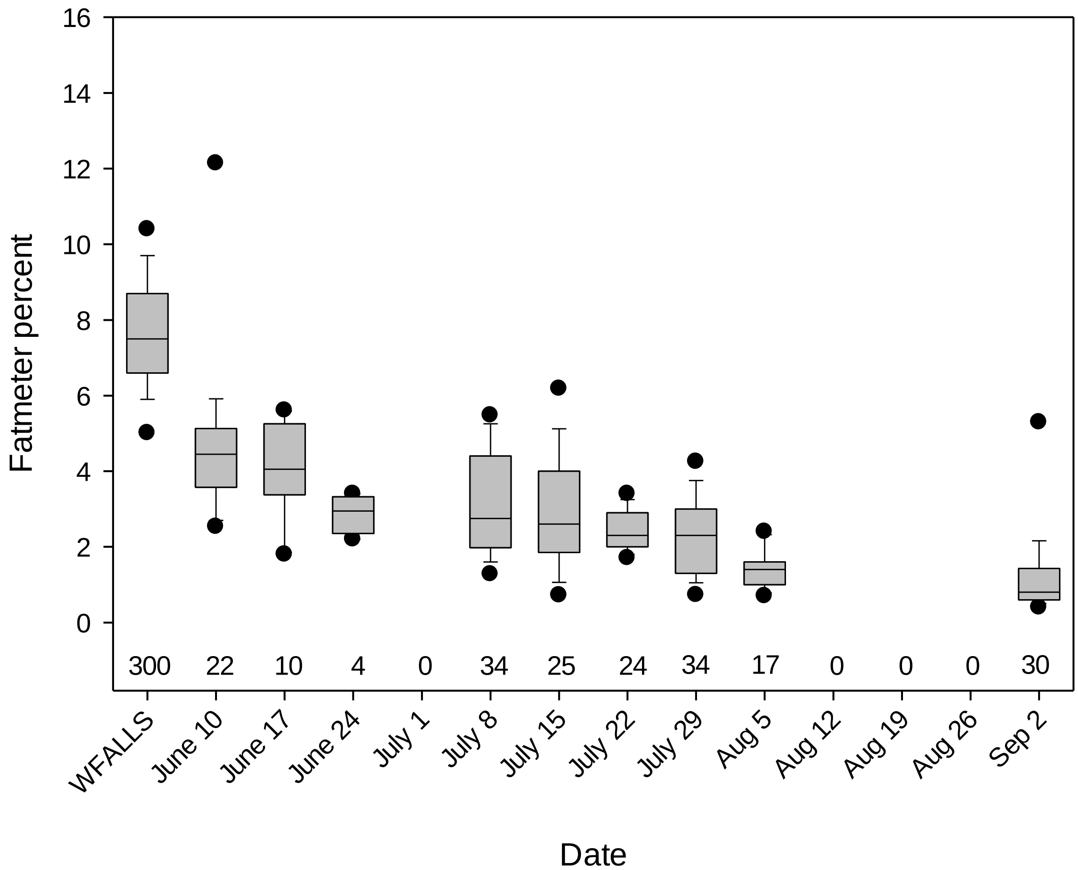

Figure 25. Distributions of fatmeter results for Chinook salmon tagged at the Foster Dam trap in 2013. Box plots represent median (solid line), 25th and 75th percentiles (ends of boxes), 10th and 90th percentiles (whiskers), and 5th and 95th percentiles (solid circles). Sample size for each date given below each distribution. Fat meter readings from Willamette Falls (WFALLS) are from Jepson et al. 2013.

River and Reservoir Environment

Mean water temperature in the South Santiam during the 2013 study period was 14.8 °C with a peak of 19.3 °C on 6 August and tended to be progressively warmer downstream (Figure 26). Water temperatures in the Middle Fork Santiam were approximately 4 degrees cooler (mean = 11.8 °C) than in the South Fork with a maximum temperature of 15.5 °C on 22 July. Mean water temperatures collected at 11 depths in Foster Reservoir ranged from 19.0 °C at 0.2 m from the surface to about 8 °C at 24 m, with a maximum of 23.5 °C in early July (Figure 27). The thermocline was at approximately 4-6 m and temperatures below 6 m remained <= 15°C throughout the summer.

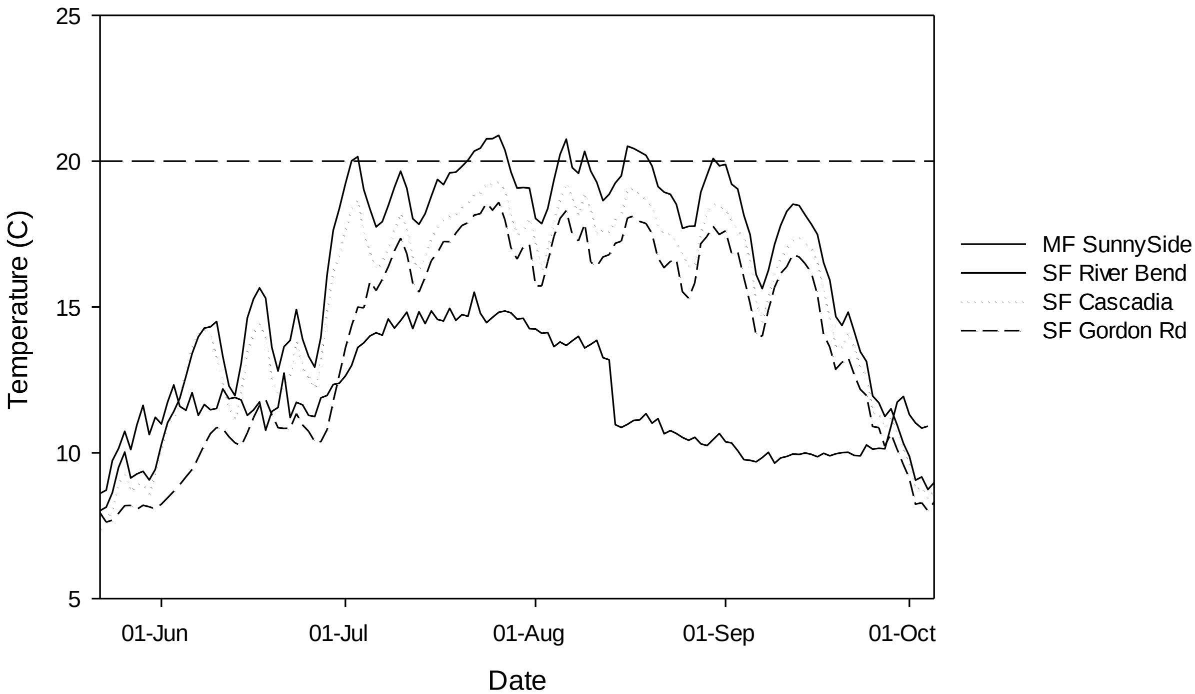

Figure 26. Daily mean water temperatures in 2013 in the Middle Fork Santiam River and three sites in the South Fork Santiam River. The loggers in the South Fork Santiam represent a progression upstream from the River Bend release site (rkm 428.3) to the Gordon Road release site (rkm 444.7).

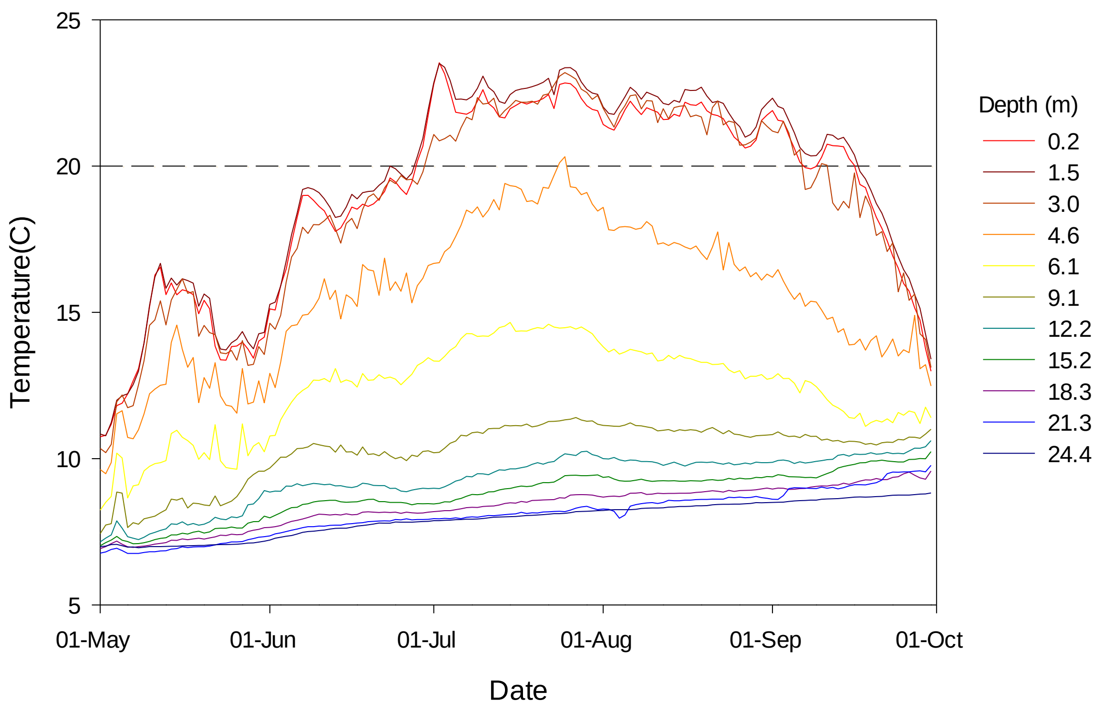

Figure 27. Foster Reservoir temperatures collected at 11 depths between 1-May and 1-October 2103 (US Army Corps of Engineers).

Proximate Analysis

In 2013, proximate analysis was performed on 15 salmon collected at Foster (8 males and 7 females). Lethal takes for proximate analysis were conducted on 13 June (n = 5), 10 July (n = 5) and 7 August (n = 5). The average muscle lipid level was 6.3% (Table 12) and ranged from 3.0-10.4%. Females had gonadal lipid compositions of 10.6%, while males were 6.9%, on average (Table 12).

Table 12. Mean tissue composition of Chinook salmon collected at the Foster Dam trap and used in proximate analysis in 2013.

Tissue	% Moisture	% Crude Lipid	% Total Ash	% Protein
Gonads	68.6	6.3	1.7	23.4
Muscle	73.7	6.3	1.1	18.9
Skin	65.6	5.2	1.0	28.2
Viscera	77.4	3.1	1.3	18.2

Table 13. Tissue composition of Chinook salmon collected at Foster used in proximate analysis by sex.

Tissue	% Moisture	% Crude Fat	% Total Ash	% Protein
Males (n = 8)				
Gonads	77.5	2.5	1.9	18.1
Muscle	73.5	6.9	1.1	18.6
Skin	65.9	5.1	0.9	28.1
Viscera	77.0	2.0	1.3	19.0
Females (n = 7)				
Gonads	58.4	10.6	1.5	29.5
Muscle	74.0	5.6	1.2	19.3
Skin	65.3	5.4	1.1	28.3
Viscera	77.7	2.0	1.3	19.0

Reservoir Releases

Fifty radio-tagged salmon were released into Foster Reservoir in 2013 and 33 (66%) of these were recorded at receivers upstream from the Calkins release site. Median reservoir residence times were 32.3 d for fish last recorded on the South Fork Santiam receiver (SFR), 16.1 d for fish last recorded on the Middle Fork Santiam receiver (MSR; Figure 28). Fish last recorded at the SFR site also included some fish that were detected on the MSR site, including fish that made multiple trips between receivers. Only one female released in Foster Reservoir was recovered on the spawning grounds and it was a prespawn mortality. A thermograph recovered from this female indicated a 23.3% decrease in degree day accumulation during her 46 day residence in

Foster Reservoir (mean 13.8 C temperature, accumulation of 635 degree days) compared to the temperatures during the same period in the S. Santiam at Cascadia (average 18 C, 828 degree days).

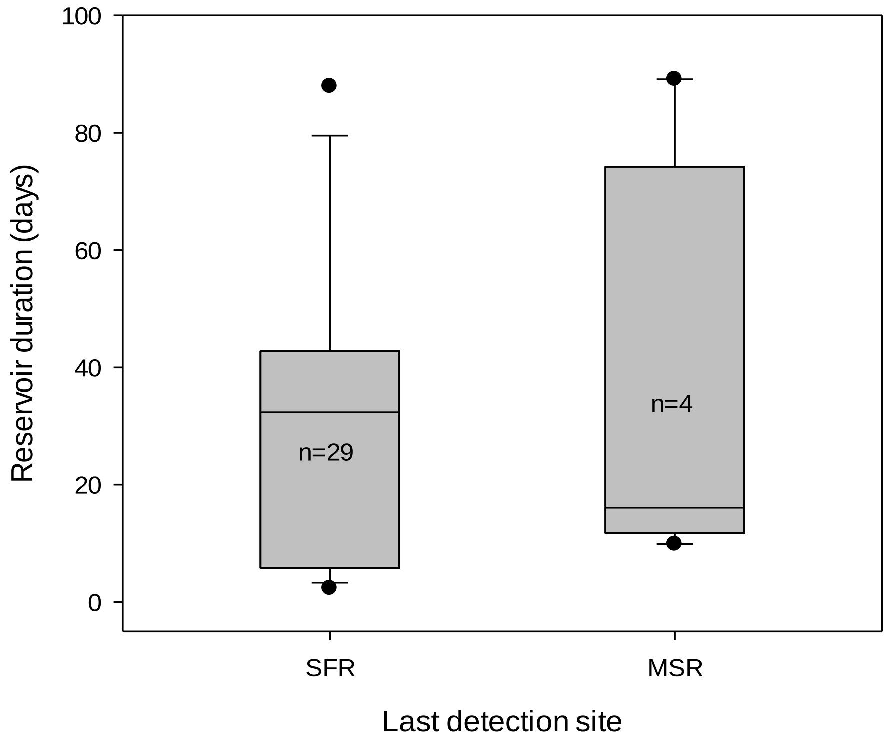

Figure 28. Reservoir residence times (d) of radio-tagged adult Chinook salmon released into Foster reservoir in 2013. Box plots represent median (solid line), 25th and 75th percentiles (ends of boxes), and 10th and 90th percentiles (whiskers). SFR = South Fork Santiam River, MSR = Middle Fork Santiam River.

Toxicology sampling

Overall we collected 28 tissue samples from adult Chinook salmon recovered on the spawning grounds: 19 (68%) from the NFMF, 7 (25%) from the South Fork Santiam and 2 (7%) from Fall Creek. Of the nineteen collected in the NFMF 10 (53%) were from prespawn mortalities and 9 (47%) were from fish that spawned. Four of the seven (57%) samples collected in the South Fork Santiam were from prespawn mortalities while the other three were from fish that spawned. Both of the Fall Creek samples were from prespawn mortalities, had concentrations within the range observed at other sites and are not considered further due to limited sample size.

Mean concentrations across all samples were: Ni: 91.6 ng/g; Cd: 4.2 ng/g; Pb 10.1 ng/g. The concentrations of metals analyzed to-date indicated significant spatial variation in concentration of Cd and Pb but not Ni (Figure 29) and no evidence of differences in concentrations of metals in salmon classified as successful spawners vs. prespawn mortalities (Figure 30; 2-way ANOVA:

Ln([Ni]) F_{site} = 0.047; P_{site} = 0.831; F_{spawn} = 0.036; P_{spawn} = 0.862; Ln([Cd]) F_{site} = 4.450; $\boldsymbol{P_{site}}$ **= 0.047**; F_{spawn} = 0.007; P_{spawn} = 0.935; Ln([Pb]): F_{site} = 9.254; $\boldsymbol{P_{site}}$ **= 0.006**; F_{spawn} = 0.063; P_{spawn} = 0.804).

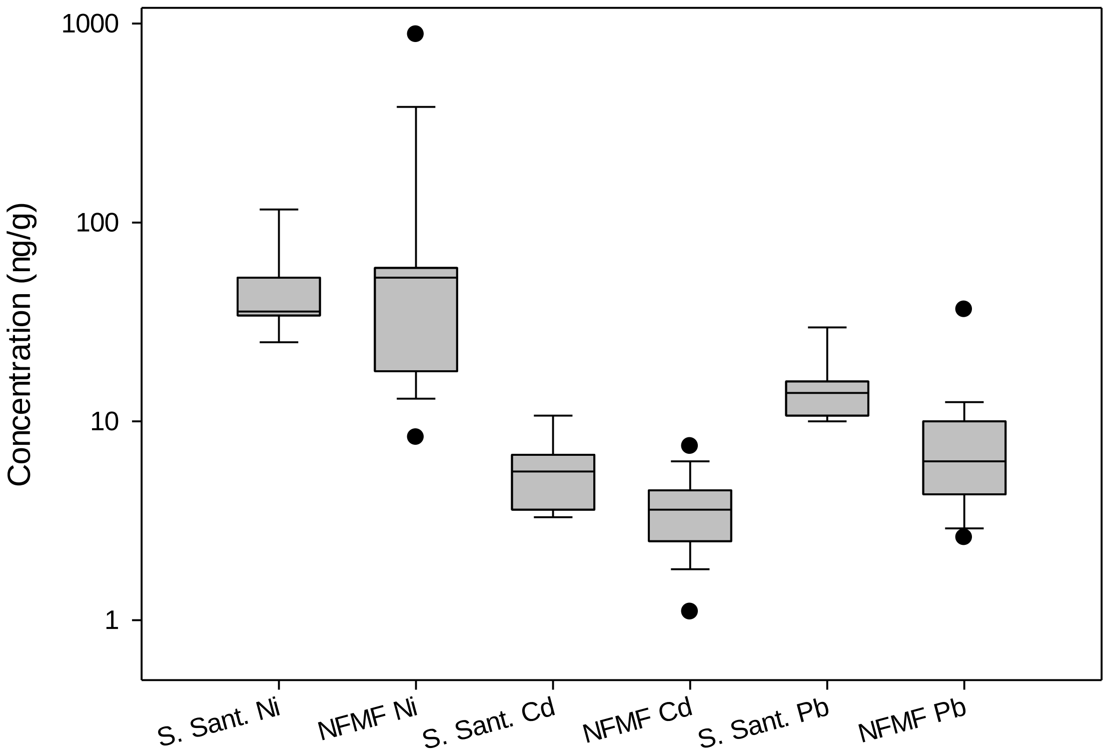

Figure 29. Concentrations of nickel, cadmium and lead in muscle+skin tissue samples from carcasses collected on the S. Santiam and NFMF rivers, 2013. S. Santiam N = 7; NFMF N = 19.

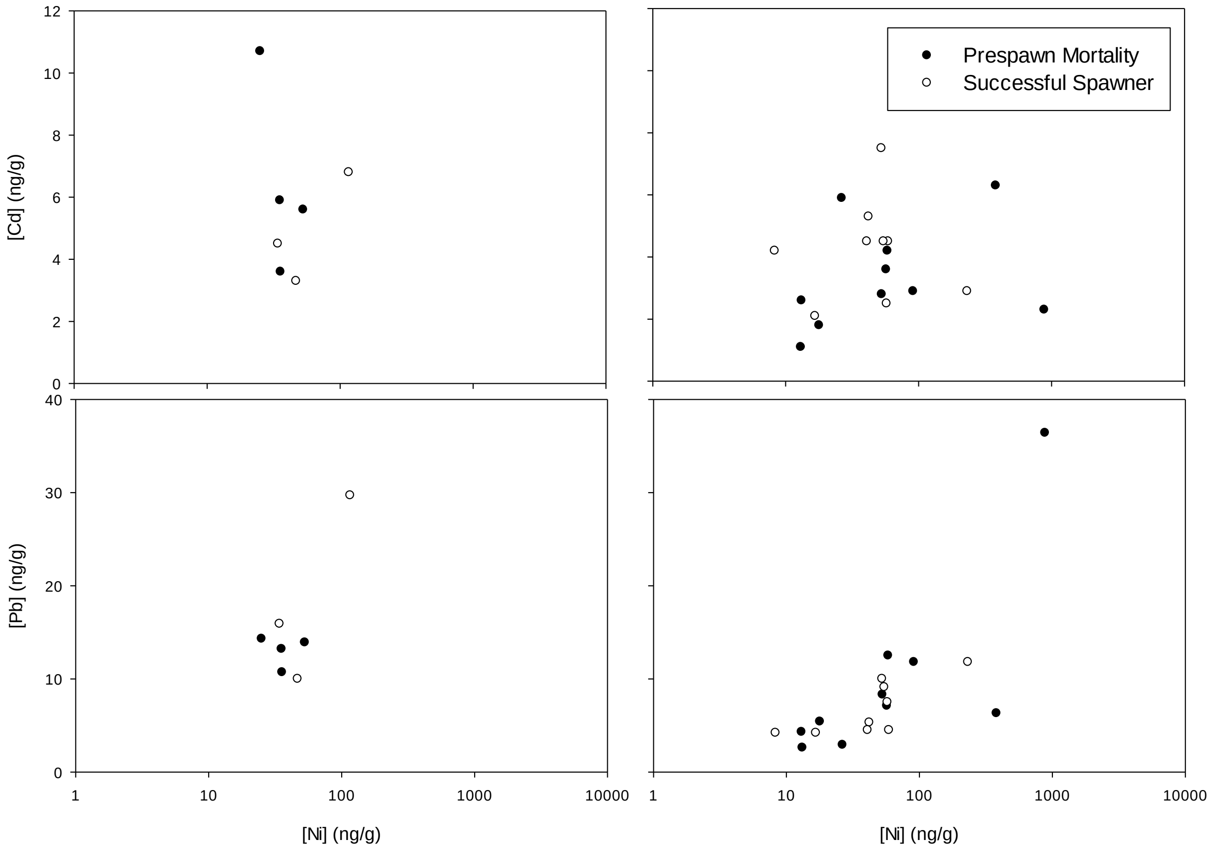

Figure 30. Concentrations of Ni, Cd, and Pb for individual adult Chinook salmon carcasses classified as having successfully spawned or as prespawn mortalities.

Discussion

The primary Middle Fork study objectives were to estimate prespawning mortality rates in the two Middle Fork populations and to examine relationships between prespawn mortality and potential causative agents. Accomplishing these objectives in 2013 was difficult because record rainfall in September made study streams too dangerous to survey during peak Chinook salmon spawning activity. Thus all comparisons regarding 2013 must be viewed with caution because potential biases in the estimates caused by the flood remain unknown as discussed below. Secondary goals included examination of patterns across years, evaluation of behavior of reservoir-released adults at Foster Reservoir, and preliminary screening of toxin concentrations.

Prespawn mortality rates did not differ systematically between groups that were untagged, tagged with PIT tags or double-tagged with PIT- and radio-tags, suggesting that tagging had minimal effect on fate. Notably this result contrasts with a recent study of Chinook salmon in the Yakima River where adults were also tagged relatively late in the migration and displayed strong tagging effects (Corbett et al. 2012). The disparity between locations indicates population-specific differences in response to methodologies or tagging, differences in prior experience and exposure to pathogens, toxins, high temperatures or other carry-over effects prior to tributary entry and tagging, differences in environment during holding, or a combination of the above. Moreover, lower PSM rates of marked groups in recent years may reflect more careful handling, tagging and transport. Regardless, the results for the WVP suggest carefully executed tagging studies can provide reliable estimates of prespawn mortality and fate within the study areas.

Although the sample sizes were low, prespawn mortality rates in Fall Creek in 2013 were the highest among all study years and this result was consistent with the high temperature observed there (also, see below). In 2013, 100% of the females (n = 2 PIT-tagged, n = 13 unmarked) recovered on the spawning grounds were prespawn mortalities. The 2013 rates were similar to the high (40-90%) rates observed in 2009 and 2010 (i.e., mortality as high as 90%, Schroeder et al. 2007; Kenaston et al. 2009; Keefer and Caudill 2010). However, it remains unknown if this estimate is biased high because carcasses of late-spawning adults could not be recovered. Nonetheless, evaluation of the seasonal timing of prespawn mortality events (Figures 18 and 19) reveal that much of the mortality occurs prior to the onset of spawning, suggesting the true rate was high relative to past years.

The 2013 prespawn mortality rate in the NFMF was also the highest in the time series. For this population it is unknown whether the estimate was biased high or biased low by the flood event. The rate would be biased high if adults remaining post flood had high spawning success whereas the estimate would be biased low if remaining adults subsequently died at a higher rate than prior to the flood. The high variability in the seasonal pattern of prespawn mortality expression and the moderate temperatures in the NFMF during 2013 prevent speculation about the true rate. Small sample size and similar issues also render the S. Santiam prespawn mortality rate estimate unreliable.

In 2013, we initiated trapping at Dexter about three weeks earlier than past years (see Appendix tables 1 and 2) in an effort to make the sampled outplants more representative of the actual run timing in the Middle Fork of the Willamette. In previous years, sampling at Fall Creek was more representative of the timing of the run than sampling at Dexter. This was due to limitations in the operation of the Dexter Trap, which is primarily used for broodstock collections for Willamette Hatchery. With the assistance of ODFW the collection of adults at Dexter Dam began on 19 May (approximately two weeks earlier than in 2012), with collections every two to three weeks thereafter until the first week in August. Data from our 2012 study revealed that radio-tagged adults spent about two weeks on average (*range* <1-22 days) in the Dexter Dam tailrace prior to collection (Jepson et al. 2013). This pattern suggested that residence time in the tailrace may be determined by trapping interval. Poor attraction flow from the Dexter trap entrance compared to turbine discharge may also contribute somewhat to tailrace residence time irrespective of trap operations. In 2013, operations were modified to allow adults to enter the trap throughout the run season which could potentially reduce tailrace residence time and densities in the trap during collection of broodstock and adults for outplanting. However, low numbers of carcass recoveries in 2013 due to high flows during spawning ground surveys prevented a rigorous evaluation of associations between prespawn mortality and potential trap timing effects that may be associated with holding in the tailrace and trap operations. Continued early operation of the trap combined with improved collection and handling protocols could reduce the prespawn mortality rate for this population, which is thought to be relatively high given the near optimal temperatures and apparently high quality habitat at the release site.

When combining the results from all five study years, we found an association between annual prespawn mortality rate and summer water temperatures in Fall Creek, though we note this conclusion should be considered preliminary because it is largely driven by results from two years (2009 and the potentially biased 2013 estimate; Figure 23). We have also observed prespawn mortality that directly coincided with increases in water temperatures within year (Mann et al. 2010 and 2011). The 2013 Fall Creek temperatures were cooler in 2013 than in 2009, although daily maximums exceeded 20°C, a range that is considered deleterious to adult Chinook salmon (Richter and Kolmes 2005; Mann 2007). We observed lower mortality rates for fish collected and outplanted in May in 2010, when water was cooler than later in the summer. In 2011 and 2012, river temperatures rarely exceed 20°C throughout the run and lower temperature exposures likely contributed in part to low prespawn mortality rates. In 2013, temperatures were similar to 2011 and 2012, but spawning ground recoveries in 2013 were too low make meaningful comparisons among study years. Moreover, all of the prespawn mortalities occurred prior to the observation of the first redd which was nearly three weeks later than in 2012 (2012 first redd date = 30-August) and two weeks later than in 2011 (first redd date = 8 September). In contrast to Fall Creek, the first redd observed in the NFMF was on 6 September. The low numbers of early redds observed in 2013 at Fall Creek may be partially explained by changes in the distribution of fish in Fall Creek related to warmer late summer and fall temperatures. Fish were observed on several occasions holding in large pools downstream from typical spawning areas two to three weeks after the typical onset of spawning (late-August/early September) but the lack of radio-tagged fish made it difficult to effectively monitor their distributions. Temperatures during this period were among the warmest in the time series (Figure 10).

Fish Condition, Environmental Conditions, and Spawning Success: Middle Fork

The energetic condition of two populations of Willamette River spring Chinook salmon was assessed. The percentage of lipid in the muscle tissue was used as the measure of energetic condition. The mean lipid content at the time of tagging in 2013 was 5.2% % and 2.8% % for Fall Creek and Dexter fish, respectively. These measurements were nearly the same as in 2012 where mean lipid content was 5.3% at Fall Creek and 2.4% at Dexter. Differences in tagging dates among and between years made direct comparison of these means difficult, though after standardization using the proximate analyses, we did not observe significant differences in lipid levels between years or locations.

The lipid levels of fish tagged at Fall Creek and Dexter Dam in 2012 and 2013 were generally lower than in 2009-2011 (Mann et al. 2011). Differences in the locations and timing of these sampling events likely explain some of the among-year and population differences in lipid levels. Lipid levels in Chinook salmon collected at Willamette Falls in 2013 were about 2-5% higher (mean lipid level at Willamette Falls = 7.7%), on average, than those collected at Fall Creek or the Dexter Dam trap. This was not surprising because significant energy is required to migrate the more than 250 km from Willamette Falls to these upstream sites.

Although samples sizes were too low to detect a significant association between physical condition and spawning success in 2013 in Fall Creek, salmon were in generally good condition in 2013 (mean condition score = 2.5). The mean condition in 2013 was slightly lower than 2012 (*mean* = 2.6). The relatively high condition scores suggest initial composite condition and previous injury was not a major factor contributing to the apparently high prespawn mortality. We note that this index was somewhat subjective because there may be some interannual variability in scores because different personnel collected data in some years.

Although prespawn mortality rates for PIT and radio-tagged fish were high (44%) it is unlikely that water temperatures in NFMF near areas used by outplanted Chinook salmon had large impacts on survival. Daily mean water temperatures did not exceed 15°C at the NFMF release site during the monitoring period in 2013 or in previous years except 2009 (max temperature = 15.8°C). It is more likely that prespawn mortality rates were affected by additional factors, including transportation stress, long holding times downstream from Dexter Dam and at the facility, unmeasured factors affecting condition at arrival, and density-dependent issues that were not quantifiable in this study but were potentially important based on field observations. These factors should be a management concern for salmon released into the NFMF, but may be of less importance at Fall Creek where transportation times are shorter and densities are lower.

South Fork Santiam and Foster Reservoir Releases

In 2013, we continued our study to evaluate the feasibility of releasing adults into Foster Reservoir. Release into a reservoir would allow unmarked (presumably natural-origin) adults collected below dams to select and home to their natal tributary. Thus in 2012 and 2013, we conducted reservoir and in-stream releases to evaluate the use of reservoir release for both thermal and homing benefits. In contrast to the relatively short residence times (< 1 d) observed in Fall Creek reservoir in 2011 and 2012, the typical residence time in Foster reservoir ranged from 3 to 8 days in 2012 and was substantially longer in 2013. The mean residence times in 2013 were ~16 d for fish last recorded in the Middle Fork Santiam and ~32 d for fish last recorded in the South Fork Santiam. The single thermograph recovered from a reservoir release fish indicated slightly less than a 25% decrease in thermal exposure during the period of reservoir residence. This was not surprising because temperatures in Foster Reservoir may have provided a cool water refuge (*mean* = 8 °C at 24 m depth) during summer months when temperatures in the South Fork Santiam River often exceeded 18 °C. Telemetry records also indicated that there was some evidence for tributary selection, including fish that made multiple trips between tributary receiver sites. While these behaviors suggest natal site selection, selection could not be confirmed because no fish were of known origin.

In addition to evaluating Foster Reservoir releases we also estimated prespawn mortality rates of adults released into the South Fork Santiam River. While record rainfalls precluded surveys during peaks in spawning in the South Fork Santiam as well as the other study systems, our radio-tag recovery rate was about two times higher in the South Fork Santiam River (20%) than in the NFMF (10.2%), although PIT tag recovery rates were approximately the same (12.8%, SF Santiam, 10.4% NFMF). Due to the low number of tags recovered, conclusions about prespawn mortality remain speculative. Nevertheless, the combined rate for radio and PIT tag fish was 50% which was similar to the NFMF (44%).

Toxicology

We collected samples in 2013 for screening of toxins with two goals: 1) to screen concentrations from a broad panel of known toxins to identify “background” loads and potential toxins of concern, and 2) to directly test for associations between concentrations and spawning success in individual salmon. Complete screening will include evaluation of more than 25 trace elements and metals and more than 100 organic pollutants. We selected three target elements (Pb, Cd, Ni) for initial reporting because elevated concentrations were observed in these metals in gill tissues of prespawn mortality coho salmon compared to successful spawners in non-urban hatchery salmon (Scholz et al. 2011). Concentrations observed in the WVP reported here were lower or similar than those reported for Fraser River Chinook salmon (Kelly et al. 2008, Kelly et al. 2011) for similar tissues (muscle). Observed values from WVP Chinook salmon were also lower or similar to those reported for coho from both non-urban and urban streams by Scholz et al. (2011). We note differences in species and tissue type (muscle+skin vs gill) between our study and the Scholz et al. (2011) study prevent direct comparison. Nonetheless, metal concentrations observed in the WVP are approaching those observed in prespawn mortality salmon by Scholz et al (2011). While we did not observe a clear association between toxins concentrations and fate, we did observe spatial differences in metal concentrations. The mechanisms resulting in spatial variation in Pb and Cd may be related to underlying geology (the natural source of these elements) or differences in exposure to anthropogenic sources encountered during rearing, migration or holding. Overall, the data for three metals analyzed provided little evidence that toxic concentrations of these elements were directly responsible for prespawn mortality in 2013.

Management Implications

The apparent impact that water temperatures had on spawning success across study years suggests that strategies that minimize Chinook salmon exposure to high temperatures should be considered to increase survival of outplanted fish. Development of structured management plans for years with different anticipated river conditions could be used to ensure minimum impacts to outplanted fish, with the costs and benefits depending on biological benefit and economic costs (e.g., Schreck et al 2013). Without the ability to directly manipulate water temperatures in the rivers above impoundments, managers may have to manipulate the timing or location of outplanting, or use cool water holding strategies during summer.

If fish that die pre-spawning do so because of conditions in the Willamette River main stem or in tributaries, then holding them in high quality conditions may increase survival, particularly in years with predicted low discharge and/or high temperatures. Upon trapping, the fish could be held in cool water until river temperatures have dropped to a more favorable level. Results from our previous holding studies (2009-2012) at Willamette Hatchery suggest that this strategy could be useful, particularly in warm years, although this approach entails added risks associated with transport and longer holding times. Schreck et al. 2013 reported that prespawn mortality rates of fish captured at Willamette Fall, Dexter Dam, and Foster Dam and held until sexual maturity in cool (~13 C) were lower for fish collected earlier (0-6%) compared to fish collected later (10-32%) in the run. However, we note that there are potentially serious concerns with extended holding that need to be considered before implementation, including disease transmission, maturation effects, and reduction of condition, as well as logistical issues concerning facility use and personnel demand. Similarly, conditions encountered at collection facilities and during transport and at outplanting may affect prespawn mortality rate. The relatively high prespawn mortality in the cool-water NFMF compared to Fall Creek in cool years suggests differences in experience prior to outplanting may contribute to prespawn mortality in the NFMF. Potential factors include tailrace residence time, collection density, physical differences in the collection and trap facilities, handling procedures including differences in anesthetics, and any differences in transport protocols (densities, travel times, tank structure and conditions, etc.). Improving collection, transport, and release of adults from Dexter into the NFMF is likely to be effective at reducing PSM, however, salmon returning the Middle Fork Willamette tributaries also have the longest travel distances among the Willamette basin spring Chinook populations and may already be physiologically stressed or have higher disease loads when they arrive at Fall Creek and Dexter dams. This migration stress may significantly affect their post-outplant survival.

The short movements of adults prior to spawning in the NFMF relative to Fall Creek suggest that habitat conditions within the NFMF are not limiting near the release site. Experimental tests of alternative collection and handling protocols could identify causative agents and effective management strategies. An alternative management strategy may be to use different outplant release sites in years with different in-river conditions in streams such as Fall Creek (Schreck et al. 2013). For example, release sites further upstream, which are generally cooler, could be used during periods of unfavorable water temperatures.

In contrast to 2010 and 2011 there were no significant mortalities observed following a release event in the NFMF in 2012 or 2013. There was, however, presumably some delayed mortality associated with collection and transportation to the release site. The mechanism for this mortality is unclear, but may have attributable to short-term stress of handling and transport and/or "shipping fever" (Schreck et al. 2012a) rather than to water quality issues during transportation (which would manifest in minutes to hours and would likely have been evident prior to release from the truck). Schreck et al. 2013 suggested minimizing crowding and duration of the stress and possibly using antibiotics to reduce the severity of "shipping fever". Handling protocols at Dexter Dam Trap require use of CO_2 for anesthetization. While CO_2 is known to induce higher stress and mortality in fishes during anesthesia (e.g., Sanderson and Hubert 2007), to what degree differences in collection and handling protocols contributed to prespawn mortality at either site remains unknown. The effects of handling protocol could be tested explicitly by applying alternative protocols or anesthesia treatments to paired release groups through the outplant season at Dexter Dam or other locations.

Demonstrating causal links between prespawn mortality and mechanism(s) (e.g., disease expression or energy) could provide guidance and support for other recovery options proposed for the recovery of the Upper Willamette Chinook ESU (ODFW and NMFS. 2011) and is an on-going goal of this collaborative project (see Schreck et al. 2012a,b, 2013). For example, if temperature is a controlling factor for pathogenesis, then proposed measures that would prevent warming or reduce temperatures that are in the proposed "Conservation and Recovery Plan" could be even more strongly endorsed. Schreck et al. 2013 found a strong positive association between PSM and accumulated degree days and time in the UWR system and suggested that accumulated degree days provided a simple, biologically relevant metric since it is associated with thermal exposure, pathogen dynamics, and energetic status. Results reported here and in Jepson et al. (2013) indicate that Chinook salmon accumulate considerable thermal units before and after collection and outplanting. The possibility of managing water temperatures below the dams during the spring Chinook migration to reduce stress, disease and reduce prespawning mortality should be considered. Active management of temperature regime has been successful below Lost Creek reservoir on the Rogue River (ODFW 1991) and below Dworshak Dam on the Clearwater-Snake rivers (Clabough et al. 2007). Successful management of adults within the WVP and on the spawning grounds above projects will require reliable information on disease prevalence, individual-and population-level energetics, abiotic factors in the migration corridor, and effects of current protocols for handling and transporting fish.

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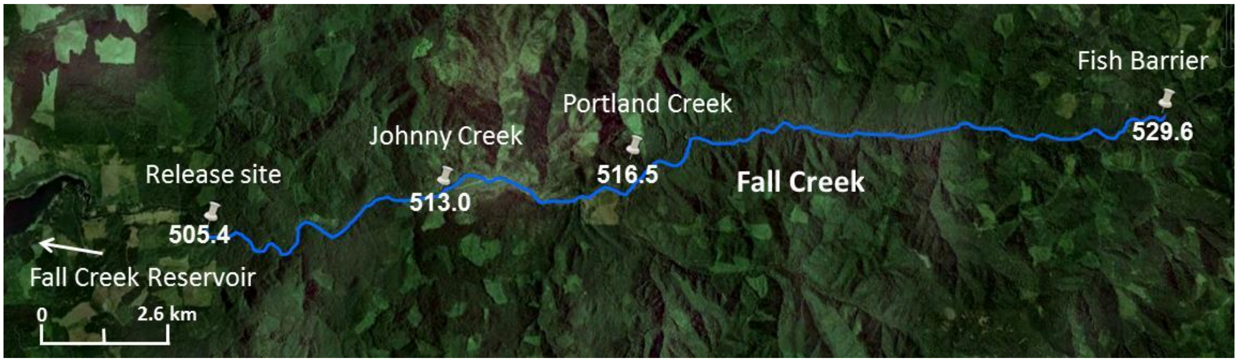
Appendix

Appendix Table 1. Number and date range of Chinook salmon that were PIT-tagged or double-tagged (PIT and radio-tagged) fish in Fall Creek, 2008-2013.

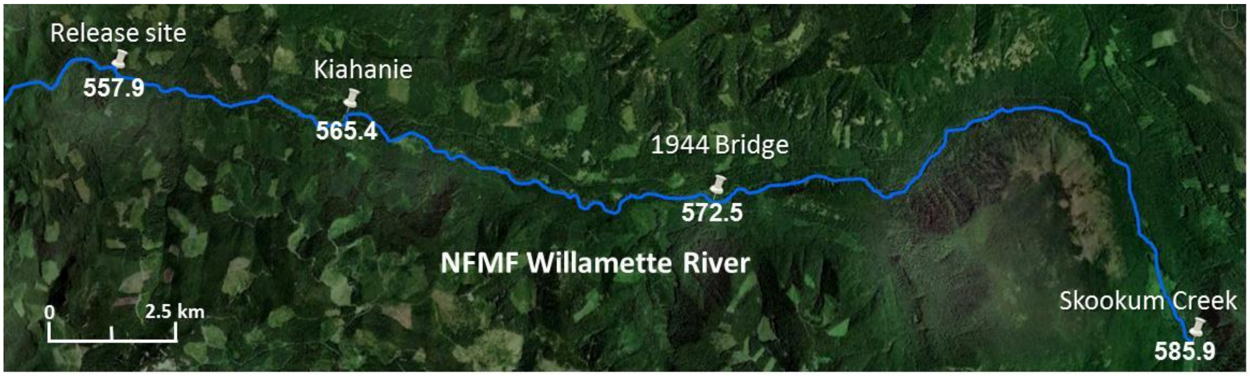
Year	Group	# released	Tag/release date range
2008	PIT	188	15 May – 14 July
	Double	7	26 June – 7 July
2009	PIT	175	26 May – 24 Aug
	Double	25	4-June – 10 Aug
2010	PIT	124	17 May – 26 Aug
	Double	75	7 June – 26 Aug
2011	PIT	125	19 May – 26 Sep
	Double	75	19 May – 26 Sep
2012	PIT	78	17 May – 19 July
	Double	40	17 May – 10 Aug
2013	PIT	96	16 May – 26 Aug

Appendix Table 2. Number and tag date range of PIT-and radio-tagged subsets of the Chinook salmon outplanted in the NFMF Willamette River in 2009-2013. DEX = fish tagged at the Dexter Dam trap and immediately outplanted into the NFMF Willamette River. HH = fish held at the Willamette Hatchery then later outplanted into the NFMF Willamette River with release date shown in parentheses.

Year	Group	# released	Tag/release date range
2009 (DEX)	PIT	124	25-June – 17 Aug
	Double	12	17 July – 17 Aug
2009 (HH)	PIT	103	24 June – 9 July (24 Aug)
2010 (DEX)	PIT	148	13 July – 11 Aug
	Double	43	13 July – 11 Aug
2010 (HH)	PIT	81	18 June – 1 July (1 Sep)
	Double	18	18 June – 1 July (1 Sep)
2011 (DEX)	PIT	109	26 May – 24 Aug
	Double	71	26 May – 24 Aug
2011 (HH)	PIT	79	15 June – 18 Aug (30 Aug)
2012 (DEX)	PIT	104	6 June – 1Aug
	Double	50	6 June – 1Aug
2012 (HH)	PIT	71	19 June – 1Aug (29 Aug)
2013	PIT	106	22 May – 17 July
	Double	59	22 May – 17 July



Appendix Figure 1. Map of temperature monitoring locations in Fall Creek in 2014.



Appendix Figure 2. Map of temperature monitoring locations in NFMF Willamette River in 2014.