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Mainstem Trinity River Chinook Salmon Spawning Survey, 2015 and 2016

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Abstract.— Salmon redds and carcasses were surveyed on the mainstem Trinity River, from Lewiston Dam to the confluence with the Klamath River, during the 2015 and 2016 spawning seasons to map spawning abundance and distribution, evaluate pre-spawn mortality, and characterize redds by species and spawner origin. Redd counts were 2,162 in 2015 and 1,671 in 2016. We applied generalized additive models to the spatiotemporal distribution of unmarked and hatchery-marked spawned female salmon carcasses to apportion these redd counts by natural- and hatchery-origin Chinook Salmon *Oncorhynchus tshawytscha* and Coho Salmon *O. kisutch*. This methodology only allows for the partitioning of redds constructed by hatchery- and naturally produced females and does not account for the origin of the male spawners. In 2015, we estimated that 1,772 redds were constructed by natural-origin Chinook Salmon, 331 by hatchery-origin Chinook Salmon, and the remaining 59 were attributed to Coho Salmon. In 2016, we estimated that 1,516 redds were constructed by natural-origin Chinook Salmon, 91 by hatchery-origin Chinook

Salmon, and the remaining 64 were attributed to Coho Salmon. Natural-origin Chinook Salmon spawned throughout the mainstem river while the distribution of redds constructed by hatchery-origin Chinook Salmon were highly skewed toward Lewiston Dam and the Trinity River Hatchery (83% and 87% were within 10 km of the dam in 2015 and 2016, respectively). Long-term trend analyses from 2002 to 2016 showed no significant change in the abundance of natural-origin Chinook Salmon redds constructed in the mainstem; while, the number of hatchery-origin Chinook Salmon redds decreased. The proportion of total annual natural-origin Chinook Salmon redds decreased in the reaches nearest to Lewiston Dam and increased in the mid-river reaches from 2002 to 2016 while the proportional distribution of hatchery-origin Chinook Salmon redds remained almost completely within the two reaches nearest to Lewiston Dam. Pre-spawn mortality of female Chinook Salmon was low in both 2015 (0.8%) and 2016 (0.7%).

Introduction

The Trinity River once supported large populations of naturally produced anadromous salmonids, including spring- and fall-run Chinook Salmon *Oncorhynchus tshawytscha* (USFWS and HVT 1999). Prior to the construction of Trinity and Lewiston dams, the spawning of spring- and fall-run Chinook Salmon was separated temporally and spatially due to the timing of adult upstream migration of each race and the hydrology of the river. In 1940s, Moffett and Smith (1950) noted that “almost without exception, Trinity River salmon migrating above the South Fork spawn in the 72 miles of river between the North Fork and Ramshorn Creek.”

Following construction of Lewiston Dam, spring- and fall-run Chinook Salmon spawning in the mainstem Trinity River exhibited considerable spatial and temporal overlap due to lack of access to historic spawning areas for the spring-run. High redd densities became frequent within the upper-most portions of the river below this barrier, where presumably hatchery-origin salmon and their progeny comingled and spawned with naturally produced fish. Trinity River Hatchery (TRH), located at the base of Lewiston Dam, is operated to mitigate the loss of Chinook Salmon, Coho Salmon *O. kisutch*, and steelhead *O. mykiss* production upstream of the dam. Rogers (1972) documented that in 1970 more than 50% of Chinook Salmon spawned in the two miles (3.2 km) below Lewiston Dam and 80% spawned above Douglas City. Redd surveys in the 1980s and 1990s between North Fork Trinity River and Cedar Flat documented variable spawning use in these reaches with redd counts ranging from a low of 187 redds in 1998 to a high of 928 in 1997 (USFWS 1986, 1987; Quihillalt 1999). Chamberlain et al. (2012) noted that the mean distance from Lewiston Dam of natural-origin Chinook Salmon redds upstream of Cedar Flat increased from 2002 to 2011. Rupert et al. (2017) noted that when the mainstem Trinity River was divided into reach-scale sections, natural origin Chinook Salmon spawning activity decreased near Lewiston Dam and increased in the mid-river sections of the river.

In an effort to restore the fishery resources of the Trinity River, the Secretary of the Interior signed the Trinity River Mainstem Fishery Restoration Record of Decision (ROD) in 2000 (USDOJ 2000), establishing the Trinity River Restoration Program (TRRP). The goal of the

TRRP is to:

“...restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels, to facilitate dependent tribal, commercial, and sport fisheries’ full participation in the benefits of restoration via enhanced harvest opportunities” (TRRP and ESSA 2009).

To achieve this goal, the TRRP implements a suite of actions (flow management, mechanical channel rehabilitation, coarse sediment augmentation, and watershed restoration) to restore riverine habitats and restore some habitat-creating alluvial processes (USFWS and HVT 1999; USDOJ 2000). Collectively, these actions are intended to increase and maintain salmonid habitats in the 64-km section of the Trinity River from Lewiston Dam downstream to the North Fork Trinity River (restoration reach) which was severely degraded due the operation of the Trinity River Division (TRD) of the Central Valley Project. Downstream of the North Fork Trinity River, valley narrowing and accretions of flow and sediment from tributaries attenuate many of the morphological impacts that have occurred in the restoration reach (USFWS and HVT 1999).

The Integrated Assessment Plan (IAP; TRRP and ESSA 2009) sets forth a list of objectives to evaluate the effectiveness of TRRP restoration actions. Salmon spawning surveys are preformed to provide data to address Objective 3, specifically sub-objectives 3.1 and 3.3:

Objective 3: Restore and maintain natural production of anadromous fish populations.

Sub-objective 3.1: Increase spawning, incubation, and emergence success of anadromous spawners.

Sub-objective 3.3: Minimize impacts of predation and genetic interactions between and among hatchery and natural anadromous fish.

The IAP proposes assessing spawning at three spatial scales: system, reach, and site scales. Each of these spatial scales evaluates the effects of restoration efforts on Chinook Salmon spawning at different resolutions. System-scale analysis evaluates the response to all restoration activities combined over time. Reach-scale analysis evaluates the response to management actions within sections of the river that have unique hydrology and sediment supplies. Finally, site-scale analysis provides insight on changes in spawning distribution/abundance within restoration sites and the localized effects of mechanical channel rehabilitation. The IAP also states that “increased spawner success will likely occur within 3–4 brood cycles following completion of channel rehabilitation and subsequent fluvial and geomorphic evolution.”

This report details the results from salmon spawning survey data collected in 2015 and 2016 on the mainstem Trinity River. Collection of salmon carcasses provides information on pre-spawn mortality, carcass estimates, and reflects the species and origin composition of spawned salmon. Delineating individual salmon redds provides the location and timing of spawning. When analyzed together, each year’s data produces a spatially and temporally explicit set of observed redd locations, with each redd having an associated probability of construction by female natural-origin Chinook Salmon, hatchery-origin Chinook Salmon, natural-origin Coho Salmon, and hatchery-origin Coho Salmon. We define ‘hatchery-origin’ as fish produced and released from Trinity River Hatchery (TRH), and ‘natural-origin’ as

fish that emerge from a redd, regardless of parental origin. These data sets facilitate an array of analyses over a range of spatial and temporal scales, which we use to investigate spawning distribution and abundance. Where applicable, we use the performance measures set forth by the IAP to evaluate changes in spawning as responses to the restoration actions of the TRRP.

Methods

Survey Area and Timing

The Trinity River from Lewiston Dam [182.2 river kilometer (rkm)] to its confluence with the Klamath River was delineated into 14 survey reaches ranging in length from 3.3 to 21.3 km (Figure 1, Table 1). Reach breaks were based on river access locations and channel distances that could be surveyed in a day. Two whitewater sections were not surveyed: the 9.7-km Pigeon Point run (Reach 8) and the 15.6-km section that includes the Burnt Ranch Gorge (Reach 11). In 2016, the boundary separating Reaches 5 and 6 was moved from Roundhouse (rkm 135.7) to Evan’s Bar (rkm 137.4) because of a change in private landowner permission to use their river access.

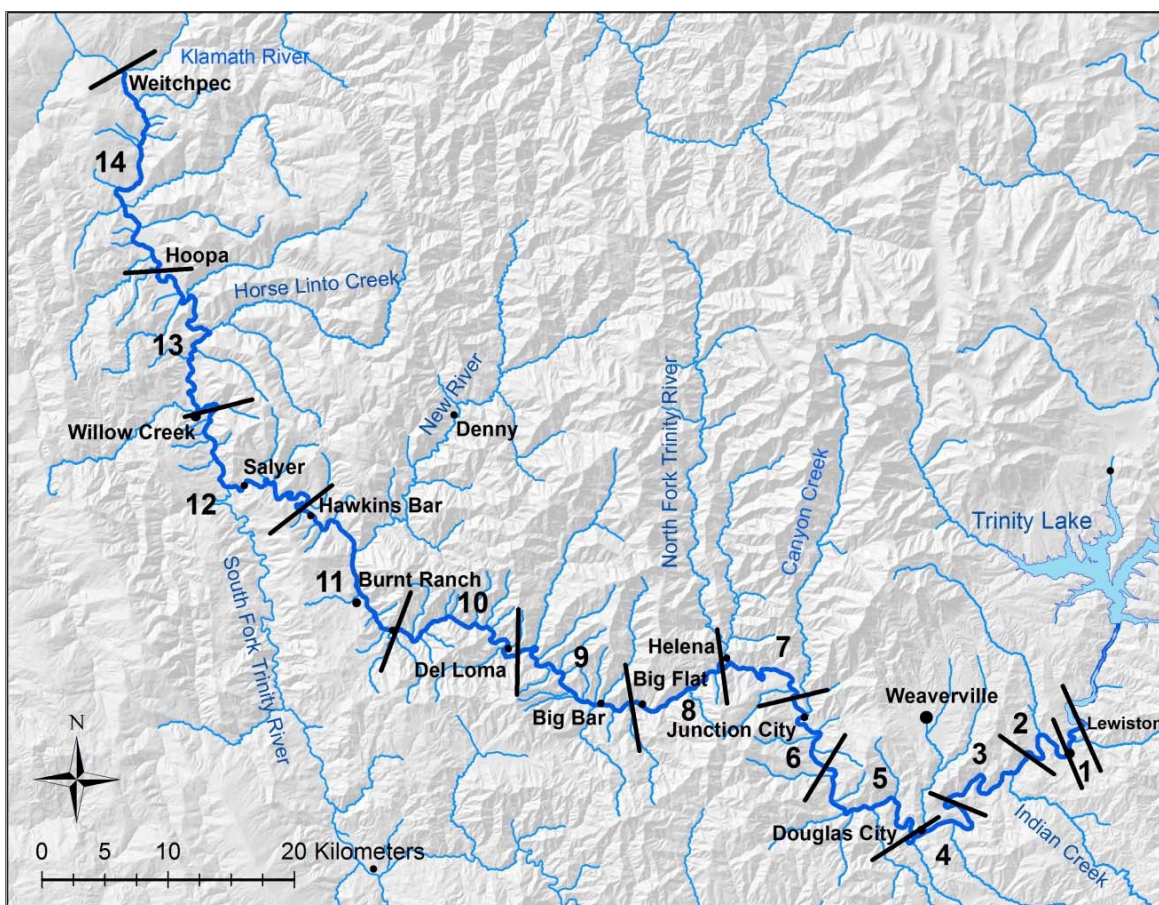


Figure 1. Survey Reaches 1–14 (Lewiston Dam to Weitchpec) on the mainstem Trinity River. Dangerous whitewater conditions precluded surveys in Reaches 8 and 11.

Table 1. Reach boundaries [and river kilometer (rkm)] for the mainstem Trinity River salmon spawning surveys. Agencies involved in data collection include California Department of Fish and Wildlife (CDFW), Shasta–Trinity National Forest (USFS), U.S. Fish and Wildlife Service (USFWS), Yurok Tribal Fisheries Program (YTFP), and Hoopa Valley Tribal Fisheries Department (HVT).

Reach	Boundaries		Surveying agency
	Upstream	Downstream (rkm)	
1	Lewiston Dam (rkm 182.2) ^a	Old Lewiston Bridge (178.7)	USFS, YTFP, CDFW
2	Old Lewiston Bridge	Bucktail River Access (171.6)	CDFW, YTFP
3	Bucktail River Access	Steel Bridge River Access (160.7)	CDFW, YTFP
4	Steel Bridge River Access	Douglas City Campground (150.1)	CDFW, YTFP
5	Douglas City Campground	Evan's Bar (137.4) ^b	CDFW, YTFP
6	Evan's Bar ^b	Junction City Campground (127.1)	USFWS, HVT
7	Junction City Campground	Pigeon Point Campground ^c (117.4)	USFWS, HVT
8	Pigeon Point Campground ^c	Big Flat River Access (107.6)	NOT SURVEYED
9	Big Flat River Access	Del Loma River Access (93.8)	USFWS, HVT
10	Del Loma River Access	Cedar Flat River Access (79.1)	USFWS, HVT
11	Cedar Flat River Access	Hawkins Bar (63.4)	NOT SURVEYED
12	Hawkins Bar	Camp Kimtu in Willow Creek (42.6)	USFWS, HVT
13	Camp Kimtu in Willow Creek	Roland's Bar in Hoopa Valley (21.3)	USFWS, HVT
14	Roland's Bar in Hoopa Valley	Weitchpec (Trinity mouth; 0.0)	USFWS, HVT

^a The spillway and pool directly downstream of Lewiston Dam was not surveyed and presumed to have no redds.

^b In 2015 and earlier the river access separating Reaches 5 and 6 was at Roundhouse (rkm 135.7).

^c Pigeon Point Campground access is 0.8 km downstream of the North Fork Trinity River confluence (rkm 118.2). The primary area where Trinity River Restoration Program actively manages to improve channel morphology and salmon habitat are in Reaches 1–7.

Reaches 1–7 were surveyed weekly and Reaches 9–14 (excluding Reach 11) were surveyed every other week, as conditions permitted, for salmon carcasses and redds as described in Rupert et al. (2017). Surveys in 2015 began September 1 and concluded December 12. Surveys in 2016 began August 29 and concluded December 14. This period was intended to encompass the majority of Chinook Salmon spawning activity.

Redd Identification

Chinook and Coho salmon spawning periods temporally overlap and natural- and hatchery-origin salmon spawn in the same locations in the mainstem Trinity River. Redds are not visually distinguishable by these species and origin types. We used the estimated proportion and spatial distribution of fresh female carcasses of hatchery- and natural-origin Chinook and Coho salmon to infer the probability of redd construction by species and origin. Since only female carcasses are used in the hatchery–natural analysis, the estimates of redds constructed by natural–origin females do not account for hatchery-produced males spawning with naturally produced females. Therefore these estimates should be considered maximum values of natural-origin spawning when not accounting for the hatchery–natural interaction. Generalized Additive Models (GAM) were used with the spatiotemporal distribution of carcasses to estimate the longitudinal gradient in proportional distribution of spawned females by species (Chinook or Coho salmon) and origin (hatchery or natural) along the river channel and over time (Rupert et al. 2017). Cumulative redd counts were arranged by survey day within reach boundaries and season total estimates of redds by species and origin were calculated by summing predicted probabilities of construction for each species/origin category (Rupert et al. 2017).

Carcasses Estimation

Carcass abundance estimates for Reaches 1 and 2 were generated via a hierarchical latent variables model as described in Rupert et al. (2017). This model assumes a latent (unobservable) ecological process interacts with a detection process to produce the observed counts of carcasses (Kery and Schaub 2012). For this survey, the latent process is the true abundance of carcasses. As not all carcasses are observed (imperfect detection), a separate observation process links the unobserved latent process to the observed data. In essence, annual carcass estimates were generated by first estimating weekly detection probabilities. Next, weekly counts of fresh carcasses (those arriving since the prior survey) were assumed to arise from a binomial process (Kery and Schaub 2012), which allows the estimation of weekly abundances. Finally, weekly estimates were summed to create an annual abundance estimate as a derived parameter (Kery and Schaub 2012).

Pre-Spawn Mortality

Fresh carcasses were described as spawned ($\leq 1/3$ eggs retained), partially spawned ($1/3$ – $2/3$ eggs retained), or unspawned ($\geq 2/3$ eggs retained). These spawning condition data were used to assess levels of pre-spawn mortality. Female carcasses designated as ‘spawned’ and ‘partially spawned’ were considered successful spawners. Unspawned carcasses were considered pre-spawn mortalities. Measurement of pre-spawn mortality is limited to occurrence within the time and space of the surveys. Therefore, pre-spawn mortality in the lower Klamath River of Trinity River-bound fish and pre-spawn mortality of spring-run Chinook Salmon prior to the first survey are not reflected in our data and analyses.

Redd–Carcass Relationship

Spawning density was hypothesized to affect the crews' ability to observe redds and carcasses with equal efficiency, especially in the high spawning density areas of Reaches 1 and 2 (Bradford and Hankin 2012). This hypothesis would be supported if the number of redds surveyed in an area was not proportional to the number of fresh spawned female carcasses found in that same area. To determine if this occurred, the estimates of fresh spawned female Chinook Salmon carcasses were compared with corresponding counts of Chinook Salmon redds from Reaches 1 and 2. These values were log-transformed and analyzed using linear regression. These two variables were considered proportional if the slope of their linear relationship was not significantly different than '1'. If the slope was significantly different than '1', these variables may not be proportional and some density dependent observer error could be inferred.

Trends in Redd Abundance and Distribution

Data from 2015 and 2016 were combined with the preceding thirteen years (2002–2014) of mainstem Trinity River redd data from Chamberlain et al. (2012) and Rupert et al. (2017) for long-term analyses of redd abundance and distribution. Past years' data availability was sometimes limited since not all variables analyzed were previously collected (i.e., spatially explicit redd data are not available for Reaches 12–14 prior to 2007). Redd abundance and distribution was analyzed at three spatial scales: the system (~50–100 km sections), reach (~10–20 km sections), and site (~1–2 km sections) scales. The 2015 and 2016 data were examined and, when applicable, included with previous years' data for multi-year trend analyses.

For spatial analyses, the river was partitioned into individual segments based on morphology that we refer to as 'riffle units'. We define riffle unit as a section of river that corresponds to a singular pool-riffle-pool sequence that typically range from 0.1 to 0.5 km long. We chose to delineate these units by this sequence for redd abundance analyses because Chinook Salmon typically build redds in patches proximate to riffle crests. Therefore, riffle units generally contain a group of redds. Riffle unit designations were based on the 'morphological units' delineated by Gaeuman et al. (2016). Where Gaeuman et al. (2016) used hydraulic controls (i.e., riffles) to delineate morphological units, we used the deepest locations (i.e., pools) between these hydraulic controls to split riffle units. As a result, the morphological units from Gaeuman et al. (2016) were shifted slightly upstream. Aerial photography was used to construct riffle units downstream of the restoration reach (excluding Reaches 8 and 11) because the morphological units developed by Gaeuman et al. (2016) were limited to the restoration reach. In total, the mainstem Trinity River was divided into 482 riffle units.

The riffle unit method described in this report differs from the method used for partitioning the river in Rupert et al. (2017). In Rupert et al. (2017), the smallest spatial units were based on contiguous 400-m (and occasionally 200-m) sections of the Science Advisory Board dataframe (SAB units; Buffington et al. 2014). This change in methodology is an improvement over that used in Rupert et al. 2017 because redd groupings are no longer split and the three spatial scale sections better reflect local spawning habitat and TRRP channel rehabilitation sites or suites of sites (Appendix A). The upstream and downstream site-, reach-, and system-scale section boundaries changed slightly to reflect the new riffle unit

divisions. The complete 2002–2016 data set was re-analyzed using the new riffle unit-based divisions at each spatial scale.

Contiguous groups of riffle units were combined to create the sections used for the site-scale analysis (Table 2). These site designations were generally based on the TRRP site designations of the Science Advisory Board dataframe (Buffington et al. 2014). However, the total count of site-scale units was reduced from 57 to 44 by merging the smallest sites-scale sections of the SAB dataframe into the most appropriate adjacent site-scale sections. This spatial scale was used to evaluate changes in natural- and hatchery-origin Chinook Salmon redd abundance at a scale similar to TRRP restoration sites or suites of sites. Changes in spawning abundance within these sites was analyzed using linear regression of the annual proportion (number of redds in the site / sum of redds in the restoration reach) of redds.

Ten reach-scale sections were also used to evaluate long-term trends in natural- and hatchery-origin Chinook Salmon redd abundance (Figure 2, Table 3). These reaches consisted of groups of sites and were intended to evaluate redd abundance at a spatial scale that was an intermediate between the system and site scales. Our reach-scale designations closely resemble those defined by HVT et al. (2011), who partitioned the restoration reach into five ‘rehabilitation reaches’ that were delineated by differences in hydrology and sediment supply characteristics. Downstream of the restoration reach we set the boundaries of the other five river sections similarly to reflect partitioning of the rehabilitation reach. Changes in spawning abundance within these reaches was analyzed using linear regression of both the annual number and proportion (number of redds in reach / sum of redds in all reaches) of natural- and hatchery-origin Chinook Salmon redds.

Changes in redd abundance and distribution at the system scale were evaluated over the entire mainstem and then separately for the restoration reach (Reaches 1–7) and remaining river downstream of the restoration reach (Reaches 9–14). Linear models were used to detect trends in redd abundance. Mean distance from Lewiston Dam of natural- and hatchery-origin Chinook Salmon redds built upstream of Cedar Flat were evaluated using linear regression models.

Table 2. The reach- and site-scale sections used for redd abundance and distribution analysis within the restoration reach. Sites are listed with the approximate location of their upstream boundary, shown as distance from the Klamath River confluence (rkm).

Reach	Site (rkm)	TRRP Rehabilitation	Length (km)
Lewiston	Hatchery (182.20)	2006	0.69
	Sven Olbertson (181.51)	2008	1.28
	Old Bridge (180.22)	2008	1.75
	Sawmill (178.47)	2009	1.60
	Upper Rush Creek (176.87)		1.46
Limekiln	Lower Rush Creek (175.41)		1.33
	Dark Gulch (174.08)	2008	2.81
	Lowden Ranch (171.27)	2010	1.73
	Trinity House Gulch (169.54)	2010	0.72
	Tom Lang Gulch (168.82)		1.48
	Poker Bar (167.34)		2.30
	China Gulch (165.05)		1.47
	Limekiln Gulch (163.57)	2015	2.38
	Steel Bridge (161.20)		1.67
	McIntyre Gulch (159.53)		1.53
	Vitzthum Gulch (158.00)	2007	2.02
	Upper Indian Creek (155.98)	2007	0.56
	Douglas City	Lower Indian Creek (155.42)	2007
Upper Douglas City (153.90)		2007, 2015	0.83
Douglas City (153.07)		2013	1.30
Reading Creek (151.77)		2010	1.77
Upper Steiner Flat (150.00)			1.26
Lower Steiner Flat (148.74)		2012	1.90
Lorenz Gulch (146.83)		2013	1.49
The Canyon (upstream) (145.34)			2.17
Junction City	The Canyon (downstream) (143.18)		2.23
	Dutch Creek (140.95)		2.56
	Evan's Bar (138.38)		1.28
	Soldier Creek (137.11)		0.89
	Chapman Ranch (136.22)		1.10
	Deep Gulch (135.13)		1.11
	Sheridan Creek (134.02)		1.15
	Oregon Gulch (132.87)		0.76
	Sky Ranch (132.12)		1.20
	Upper Junction City (130.91)	2012	0.89
	Lower Junction City (130.01)	2014	0.67
North Fork	Hocker Flat (129.34)	2005	1.88
	Upper Conner Creek (127.46)		1.12
	Conner Creek (126.34)	2006	1.71
	Wheel Gulch (124.63)	2011	1.05
	Valdor Gulch (123.58)	2006	1.84
	Elkhorn (121.74)	2006	1.50
	Pear Tree Gulch (120.24)	2006	1.33
	Bagdad (118.92) ^a		1.52

^a the downstream boundary of the Bagdad site was at rkm 117.4

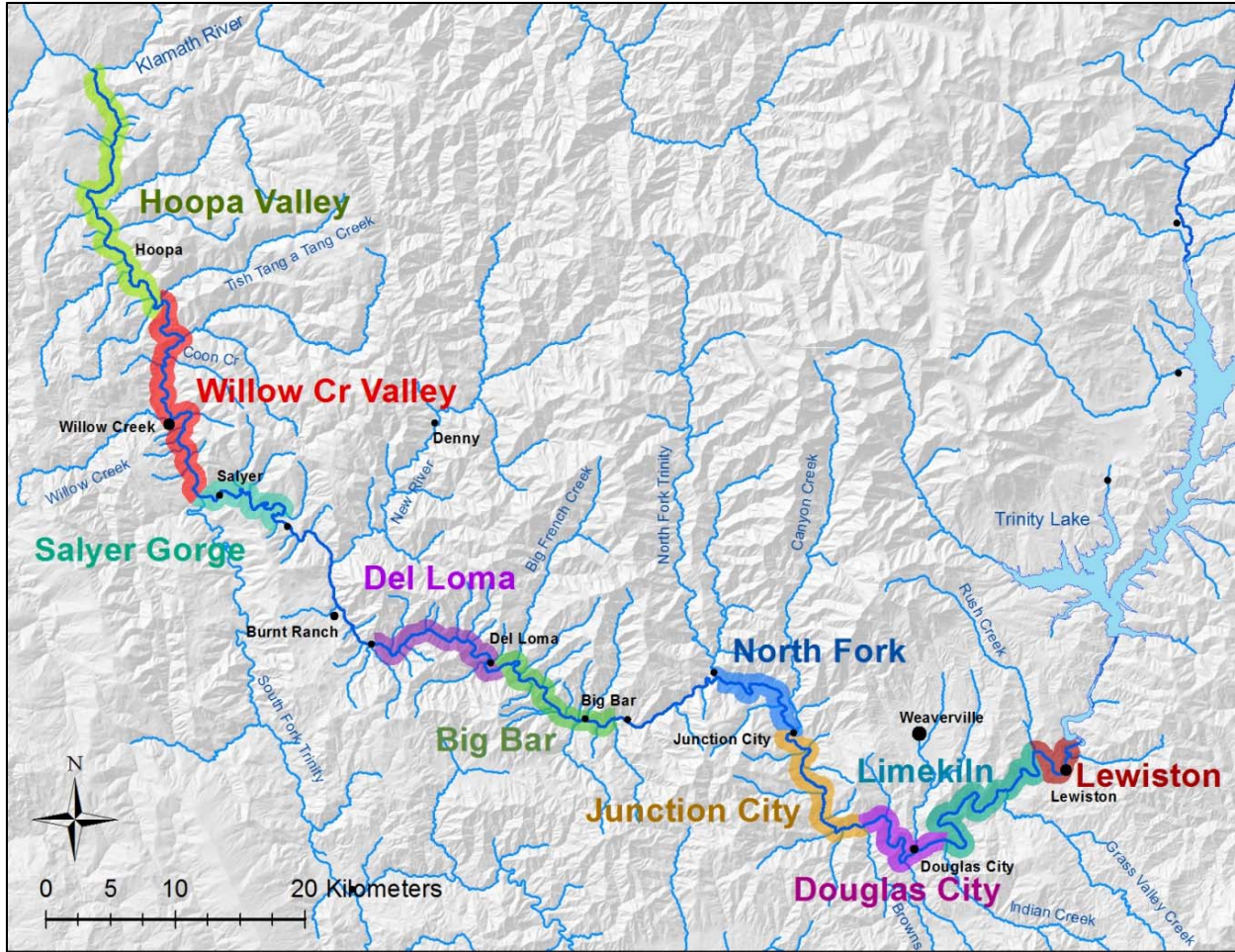


Figure 2. The ten sections of the mainstem Trinity River used for reach-scale analyses of Chinook Salmon redd distribution.

Table 3. River sections [with river kilometer (rkm)] used for the reach-scale analysis of redd abundance.

Section	Boundaries		Length (km)
	Upstream (rkm)	Downstream (rkm)	
Lewiston Rehab	Lewiston Dam (182.20)	Rush Creek (175.41)	6.79
Limekiln Rehab	Rush Creek	Indian Creek (155.42)	19.99
Douglas City Rehab	Indian Creek	Browns Creek (143.18)	12.25
Junction City Rehab	Browns Creek	Canyon Creek (129.34)	13.84
North Fork Rehab	Canyon Creek	North Fork Trinity River (117.40)	11.94
Big Bar	Big Flat access riffle unit (107.82)	Del Loma access riffle unit (94.03)	13.79
Del Loma	Del Loma access riffle unit	Cedar Flat access riffle unit (79.31)	14.72
Salyer Gorge	Hawkins Bar river access (63.76)	South Fork Trinity River (50.33)	13.41
Willow Creek Valley	South Fork Trinity River	Tish Tang a Tang Creek (26.95)	23.40
Hoopa Valley	Tish Tang a Tang Creek	Weitchpec (Trinity River mouth; 0.0)	26.95

Results

Sampling Success

Crews were able to complete 91% of the planned surveys in 2015 and 80% in 2016 (Appendix B and Appendix C, respectively). In 2015, precipitation caused high flows in late-November and December which inhibited 7 of the 20 late-season surveys downstream of Reach 9. In 2016, relatively early precipitation in mid-October caused elevated flows and turbid water, which inhibited most of the scheduled surveys (15 of 18) in Reaches 12–14.

During both 2015 and 2016, the early portions of the survey seasons were affected by flow augmentation releases of greater than 28 m³/s from Lewiston Dam that were intended to reduce the chances of fish disease in the lower Klamath River (USBOR 2015, 2016; TRRP 2016). These high flows, which lasted through mid-September, made locating redds and carcasses more challenging during the first few weeks of the surveys. Discharge from Lewiston Dam dropped to 12.7 m³/s following these events and dropped in again mid-October to 8.5 m³/s for the remainders of the survey seasons (Appendix D, Appendix E).

During the 2015 surveys, unusually high water turbidity was common throughout the mainstem Trinity River. Crews reported water visibility between 0.9 and 1.5 m during most (80%) of the surveys and less than 0.9 m during the rest (Appendix B). Water visibility was particularly poor in the upstream-most reaches in 2015 where visibility was less than 0.9 m for approximately half of the surveys in Reaches 1 and 2. Visibility in 2016 was generally better than in 2015. Crews reported water visibility between 0.9 and 3.0 m during all surveys in 2016; about half of the surveys were conducted when visibility was 0.9–1.5 m and half when visibility was 1.5–3.0 m (Appendix C).

Salmon Carcasses

During the 2015 and 2016 surveys, 763 and 616 Chinook Salmon carcasses were examined, respectively (Table 4, Table 5; excludes marked recaptures and those not identified to species). Of these examined carcasses, 619 and 389 were fresh (Conditions 1 and 2 as described in Rupert et al. 2017) and of these, 19 (3.1%) and 12 (3.1%) were ad-clipped, respectively. In addition, one ad-clipped Chinook Salmon carcass in 2015 and three in 2016 were recovered in an advanced state of decay (i.e., beyond Condition 2).

Crews recovered 392 fresh female Chinook Salmon carcasses in 2015 and 274 in 2016. Of the fresh female carcasses, 15 (3.8%) and 7 (2.6%) were ad-clipped in 2015 and 2016, respectively. CWTs were recovered from 50% of the ad-clipped Chinook Salmon carcasses in 2015 and from 60% in 2016 (Table 4, Table 5). Data from Chinook Salmon carcass CWT recoveries yielded an average annual production multiplier (i.e., tagging rate) of 0.221 in 2015 (Table 6) and 0.234 in 2016 (Table 7). The CWTs from the ad-clipped Chinook Salmon revealed that 90% and 100% of spawned female hatchery-origin Chinook Salmon carcasses (spring- and fall-run combined) were recovered within 10 km of Lewiston Dam in 2015 and 2016, respectively (Figure 3).

Table 4. Summary of Chinook Salmon carcass data by survey reach, 2015.

Reach	Total observed ^a	Fresh ^b males	Fresh ^b females	Male–female ratio	Ad-clipped	Weir-tagged
1	62	13	43	0.30	9	2
2	121	41	61	0.67	7	3
3	59	15	30	0.50	1	0
4	75	17	39	0.44	3	1
5	94	31	48	0.65	0	2
6	129	44	59	0.75	0	2
7	78	23	38	0.61	0	0
9	36	8	19	0.42	0	0
10	33	13	17	0.76	0	0
12	35	11	15	0.73	0	4
13	37	10	20	0.50	0	1
14	4	1	3	0.33	0	0
Total	763	227	392	0.58	20 ^c	15

^a contains only carcasses identified as Chinook Salmon; may contain small number of individuals observed more than once in subsequent weeks

^b only carcasses found in conditions 1 and 2 were considered 'fresh'

^c includes 19 fresh carcasses and 1 decayed carcass

Table 5. Summary of Chinook Salmon carcass data by survey reach, 2016.

Reach	Total observed ^a	Fresh ^b males	Fresh ^b females	Male–female ratio	Ad-clipped	Weir-tagged
1	83	10	37	0.27	8	0
2	185	29	49	0.59	6	5
3	70	14	35	0.40	1	1
4	28	7	15	0.47	0	0
5	82	23	46	0.50	0	3
6	104	16	63	0.25	0	1
7	46	8	23	0.35	0	1
9	8	3	2	1.50	0	0
10	8	3	4	0.75	0	0
12	2	2	0	NA	0	0
13	0	0	0	NA	0	0
14	0	0	0	NA	0	0
Total	616	115	274	0.42	15 ^c	11

^a contains only carcasses identified as Chinook Salmon; may contain small number of individuals observed more than once in subsequent weeks

^b only carcasses found in conditions 1 and 2 were considered 'fresh'

^c includes 12 fresh carcasses and 3 decayed carcasses

Table 6. Coded-wire tag (CWT) information retrieved from adipose fin-clipped Chinook Salmon carcasses, 2015 Trinity River surveys.

Carcasses	CWT	Brood Year	Run type	Release type	Production multiplier
1	068838	2011	Spring	fingerling	0.208
1	060491	2012	Spring	fingerling	0.240
1	060490	2012	Spring	fingerling	0.239
1	068846	2011	Spring	yearling	0.219
1	068773	2010	Spring	fingerling	0.237
1	068847	2011	Fall	yearling	0.231
1	060495	2012	Fall	fingerling	0.223
1	068847	2011	Fall	yearling	0.231
2	068841	2011	Fall	fingerling	0.197
10		--Missing CWT/head --			NA
					Mean = 0.222

Table 7. Coded-wire tag (CWT) information retrieved from adipose fin-clipped Chinook Salmon carcasses, 2016 Trinity River surveys.

Carcasses	CWT	Brood Year	Run type	Release type	Production multiplier
1	068846	2011	Spring	yearling	0.219
1	060491	2012	Spring	fingerling	0.240
1	060606	2013	Spring	fingerling	0.241
1	060492	2012	Spring	fingerling	0.237
1	060612	2013	Spring	yearling	0.237
1	060691	2014	Spring	fingerling	0.242
1	060504	2012	Fall	yearling	0.225
1	060608	2013	Fall	fingerling	0.243
1	060504	2012	Fall	yearling	0.225
6		--Missing CWT/head --			NA
					Mean = 0.234

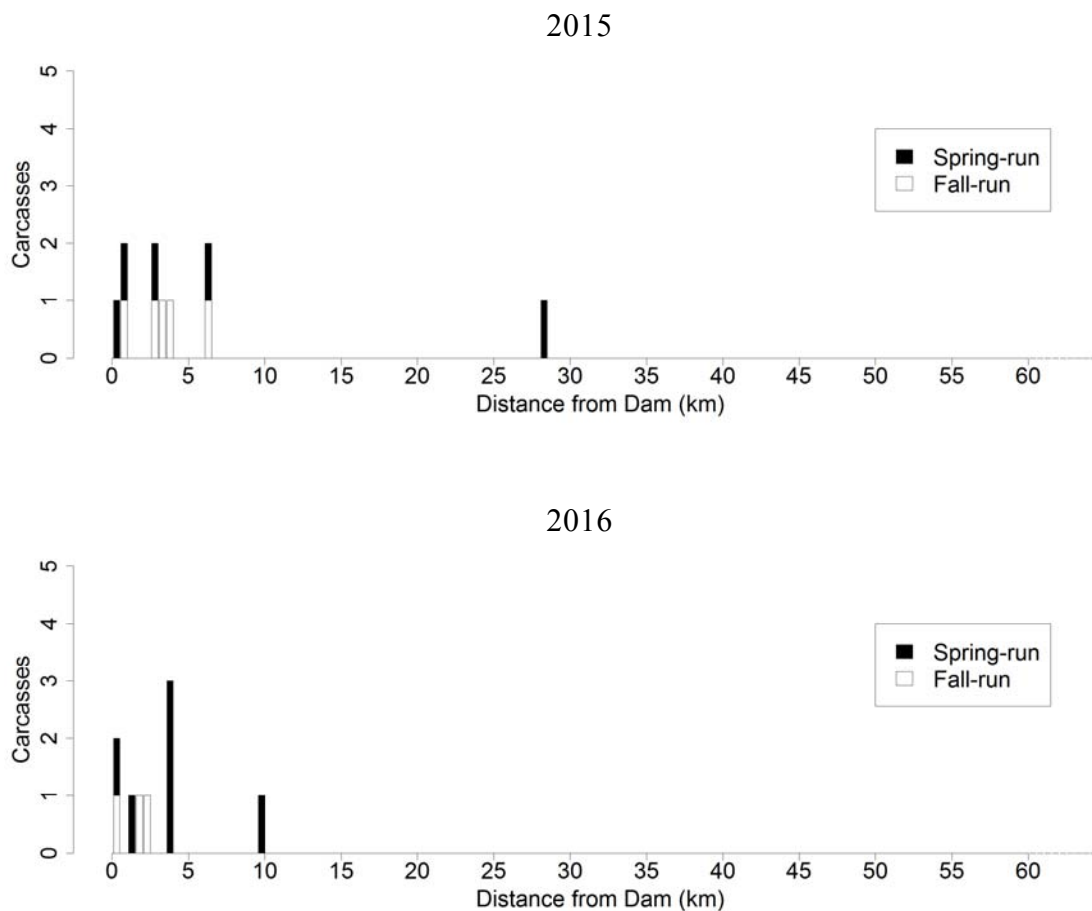


Figure 3. Distribution of coded-wire-tagged (CWT) spring- and fall-run spawned female Chinook Salmon carcasses located in the mainstem Trinity River downstream of Lewiston Dam in 2015 and 2016.

Relatively few (11 and 7, respectively) Coho Salmon carcasses were recovered during the 2015 and 2016 surveys (Table 8, Table 9; excludes marked recaptures and those unidentifiable to species). Of these, 10 and 6 were fresh and of these, 3 (30%) and 4 (67%) were right maxillary-clipped in 2015 and 2016, respectively. Three fresh spawned female Coho Salmon carcasses were collected in 2015, of which one was right maxillary-clipped. Two fresh spawned female Coho Salmon carcasses were collected in 2016, of which one was right maxillary-clipped. The limited number of spawned female Coho Salmon carcasses recovered in 2015 and 2016 inhibited the ability to differentiate Coho Salmon redds by origin.

Table 8. Summary of Coho Salmon carcass data by reach, 2015 Trinity River surveys.

Reach	Total observed	Fresh ^a males	Fresh ^a females	Male–female ratio	Ad-clipped	Weir-tagged
1	1	0	0	-	0	0
2	7	4	3	1.33	1	1
3	1	0	1	0.00	1	0
4	0	0	0	-	0	0
5	0	0	0	-	0	0
6	0	0	0	-	0	0
7	1	0	1	0.00	1	0
9	1	1	0	NA	0	0
10	0	0	0	-	0	0
12	0	0	0	-	0	0
13	0	0	0	-	0	0
14	0	0	0	-	0	0
Total	11	5	5	1.00	3	1

^a only carcasses found in conditions 1 and 2 were considered 'fresh'

Table 9. Summary of Coho Salmon carcass data by reach, 2016 Trinity River surveys.

Reach	Total observed	Fresh ^a males	Fresh ^a females	Male–female ratio	Ad-clipped	Weir-tagged
1	1	0	1	0.00	1	0
2	4	3	0	NA	2	1
3	2	1	1	1.00	1	0
4	0	0	0	-	0	0
5	0	0	0	-	0	0
6	0	0	0	-	0	0
7	0	0	0	-	0	0
9	0	0	0	-	0	0
10	0	0	0	-	0	0
12	0	0	0	-	0	0
13	0	0	0	-	0	0
14	0	0	0	-	0	0
Total	7	4	2	2.00	4	1

^a only carcasses found in conditions 1 and 2 were considered 'fresh'

Carcass Estimates

The hierarchical latent variables model yielded 336 (95% CI: 182–618) Chinook Salmon carcasses in Reach 1 and 495 (95% CI: 333–731) in Reach 2 in 2015. Estimates of fresh spawned female Chinook Salmon carcasses were 267 (95% CI: 143–485) in Reach 1 and 288 (95% CI: 190–435) in Reach 2.

In 2016, the model yielded 236 (95% CI: 128–437) Chinook Salmon carcasses in Reach 1 and 469 (95% CI: 280–757) in Reach 2. Estimates of fresh spawned female Chinook Salmon carcasses were 185 (95% CI: 98–346) in Reach 1 and 292 (95% CI: 172–492) in Reach 2.

Pre-spawn Mortality

Only three unspawned female Chinook Salmon carcasses were found in 2015 and only two in 2016, all without a hatchery mark, which yielded pre-spawn mortality rates among female Chinook Salmon throughout the mainstem Trinity River of 0.8% in 2015 and 0.7% in 2016 (Table 10). These pre-spawn mortality rates were both lower than the previous range of 2.4%–11.5% from 2009 to 2014 (Rupert et al. 2017). Weekly pre-spawn mortality rates ranged from 0.0% to 4.2% in 2015 and from 0.0% to 5.6% in 2016 (Figure 4). Annual pre-spawn mortality of female Chinook Salmon in the Trinity River restoration reach was 0.0% in 2015 and 0.8% in 2016.

Of the five fresh female Coho Salmon carcasses encountered in 2015 (three natural-origin and two hatchery-origin), two were unspawned (one natural-origin and one hatchery-origin; Table 11). Both fresh female Coho Salmon carcasses encountered in 2016 (one natural-origin and one hatchery-origin) had spawned. Note that pre-spawn mortality rates were based on data collected through late December, while Coho Salmon are still spawning.

Table 10. Pre-spawn mortality rates of Chinook Salmon in the Trinity River below Lewiston Dam (Reaches 1–14) and in the restoration reach (Reaches 1–7), 2009–2016 surveys. Pre-spawn mortalities by week and reach for unmarked and ad-clipped Chinook Salmon are presented in Appendix F.

	Reaches 1-14	Reaches 1-7
Year	(Lewiston Dam to Klamath River)	(Lewiston Dam to North Fork)
Year	Combined	Combined
2009	7.9%	6.8%
2010	10.2%	9.5%
2011	4.6%	4.6%
2012	2.4%	2.4%
2013	5.1%	6.1%
2014	11.5%	9.1%
2015	0.8%	0.0%
2016	0.7%	0.8%

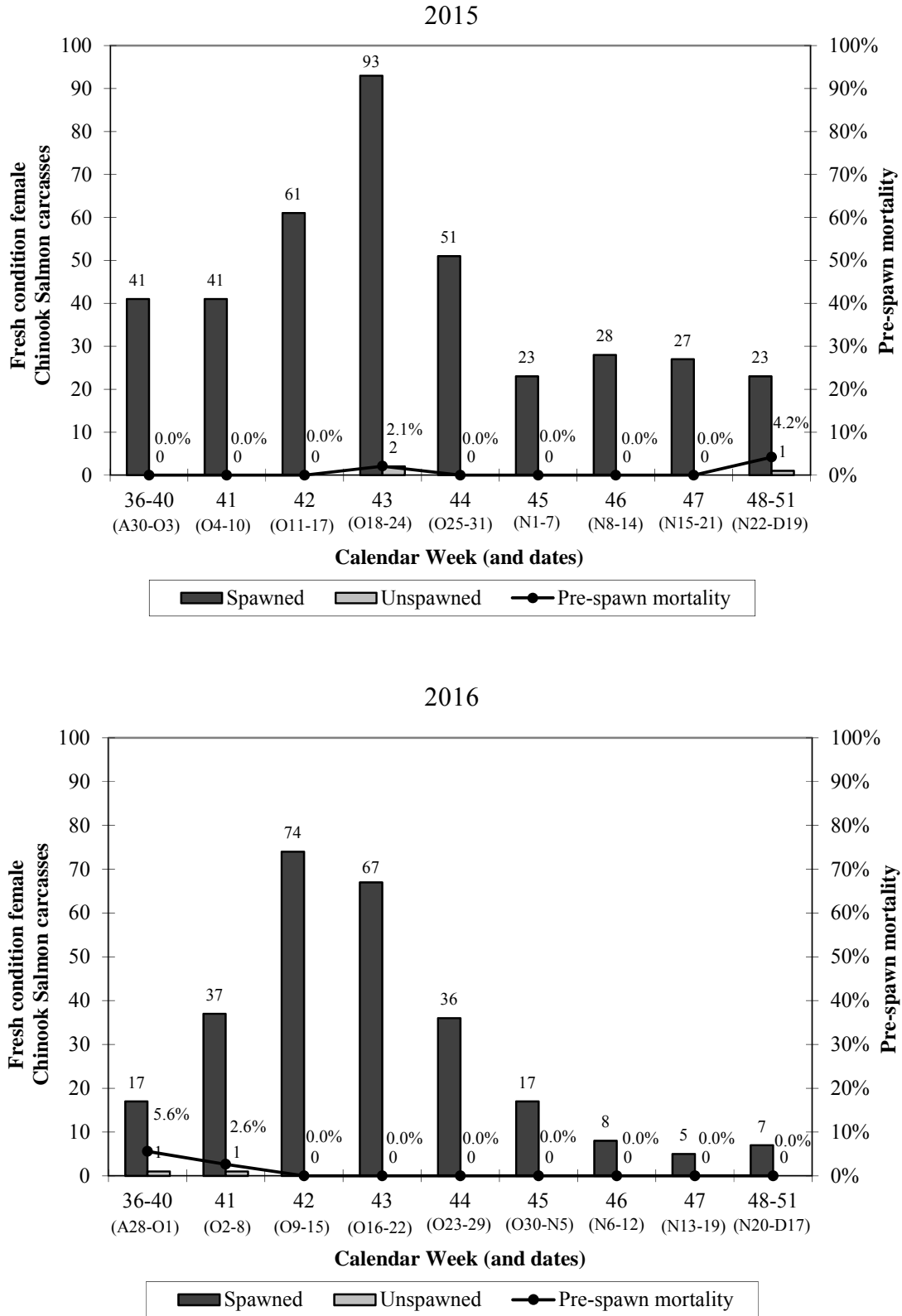


Figure 4. Weekly pre-spawn mortality from fresh (Conditions 1 and 2) female Chinook Salmon carcasses, Trinity River surveys 2015 and 2016. Calendar weeks 36–40 and 48–51 were combined because sample sizes were low in at least one of those weeks.

Table 11. Pre-spawn mortality rates of natural- and hatchery-origin Coho Salmon, Trinity River surveys, 2009–2016. Note that these pre-spawn mortality rates were based on data only collected through late December. Spawning success often varies, typically improving over time, and our surveys did not extend over the entire Coho Salmon spawning period. Pre-spawn mortalities by week and reach for natural- and hatchery-origin Coho Salmon are presented in Appendix G.

Year	Coho Salmon		
	Natural-origin	Hatchery-origin	Combined
2009	7.1%	20.3%	16.1%
2010	21.9%	16.2%	17.0%
2011	6.1%	15.1%	11.6%
2012	3.6%	11.8%	10.4%
2013	10.7%	6.1%	6.6%
2014	35.1%	28.5%	29.8%
2015	33.3% ^a	50.0% ^a	40.0% ^a
2016	0.0% ^b	0.0% ^b	0.0% ^b

^a the sample size for Coho Salmon was only five carcasses in 2015

^b the sample size for Coho Salmon was only two carcasses in 2016

Salmon Redds

During the 2015 and 2016 surveys, 2,162 and 1,671 salmon redds were identified, respectively (Table 12, Table 13). A majority of the 2015 (1,772; 82%) and 2016 (1,516, 91%) redds were estimated to have been constructed by natural-origin female Chinook Salmon, while hatchery-origin female Chinook Salmon accounted for 331 (15%) and 91 (5%) of the total redd count, respectively (Table 14). Coho Salmon redds accounted for 59 (3%) and 64 (4%) of the surveyed redds. The low numbers of spawned female Coho Salmon carcasses collected in 2015 and 2016 inhibited the differentiation of hatchery- and natural-origin Coho Salmon redds. Note that Coho Salmon spawning continued beyond our survey season, and our estimates of Coho Salmon redds are included only to differentiate them from Chinook Salmon redds.

Natural-origin Chinook Salmon redds were constructed throughout most of the mainstem Trinity River in 2015 and 2016 (Figure 5). Hatchery-origin Chinook and Coho (both origin types) salmon redds were consistently skewed toward Lewiston Dam. We detected little to no spawning by hatchery-origin Chinook Salmon or Coho Salmon downstream of Reach 7.

Table 12. Redd counts (before species differentiation) by week and reach, Trinity River surveys 2015. NS = No Survey for scheduled surveys that were missed. Dashes (-) represent days when surveys were not scheduled.

Week start	Reach													Total
	1	2	3	4	5	6	7	9	10	12	13	14		
8/31	0	-	-	-	-	-	-	-	-	-	-	-	-	-
9/7	0	0	0	NS	NS	0	0	-	-	-	-	-	-	-
9/14	0	0	0	0	0	0	0	1	0	-	-	-	-	1
9/21	12	24	9	9	25	19	15	-	-	-	-	-	-	113
9/28	13	34	13	28	30	37	38	24	13	-	-	-	-	230
10/5	19	42	66	34	49	30	39	-	-	5	0	0	-	284
10/12	10	44	19	15	32	43	29	115	64	-	-	-	-	371
10/19	26	24	31	11	14	44	28	-	-	24	7	1	-	210
10/26	43	27	6	5	28	24	25	74	61	-	-	-	-	293
11/2	43	17	2	0	10	6	4	-	-	52	37	15	-	186
11/9	20	9	5	NS	2	5	2	38	20	-	-	-	-	101
11/16	23	12	3	0	3	1	1	-	-	49	52	41	-	185
11/23	18	NS	NS	NS	NS	1	0	7	NS	-	-	-	-	26
11/30	24	18	12	4	2	2	0	-	-	57	7 ^a	NS	-	126
12/7	2	9	0	1	NS	0	0	NS	NS	-	-	-	-	12
12/14	5	10	7	0	2	0	0	-	-	NS	NS	NS	-	24
Total	258	270	173	107	197	212	181	259	158	187	103	57	-	2,162

^a partial count due to technical difficulties

Table 13. Redd counts (before species differentiation) by week and reach, Trinity River surveys 2016. NS = No Survey for scheduled surveys that were missed. Dashes (-) represent days when surveys were not scheduled.

Week start	Reach												Total	
	1	2	3	4	5	6	7	9	10	12	13	14		
8/29	1	-	-	-	-	-	-	-	-	-	-	-	-	1
9/5	0	0	0	0	0	0	0	-	-	-	-	-	-	0
9/12	1	1	7	0	1	1	1	0	0	-	-	-	-	12
9/19	11	18	17	2	13	7	0	-	-	-	-	-	-	68
9/26	18	43	35	39	62	28	14	7	4	-	-	-	-	250
10/3	10	41	41	14	85	90	41	-	-	0	0	0	0	322
10/10	12	28	32	13	54	96	63	NS	NS	-	-	-	-	298
10/17	10	18	13	27	35	42	20	126	72	NS	NS	NS	NS	363
10/24	12	3	2	NS	10	13	10	NS	NS	-	-	-	-	50
10/31	11	12	5	2	11	7	8	-	-	NS	NS	NS	NS	56
11/7	15	14	0	3	4	9	13	34	28	-	-	-	-	120
11/14	0	4	4	1	1	3	1	-	-	40	NS	NS	NS	54
11/21	15	10	NS	NS	NS	0	0	NS	NS	-	-	-	-	25
12/28	4	9	3	2	4	0	0	1	3	NS	NS	NS	NS	26
12/5	0	8	5	0	0	NS	NS	NS	NS	-	-	-	-	13
12/12	4	7	2	NS	NS	NS	NS	-	-	NS	NS	NS	NS	13
Total	124	216	166	103	280	296	171	168	107	40	0	0	0	1,671

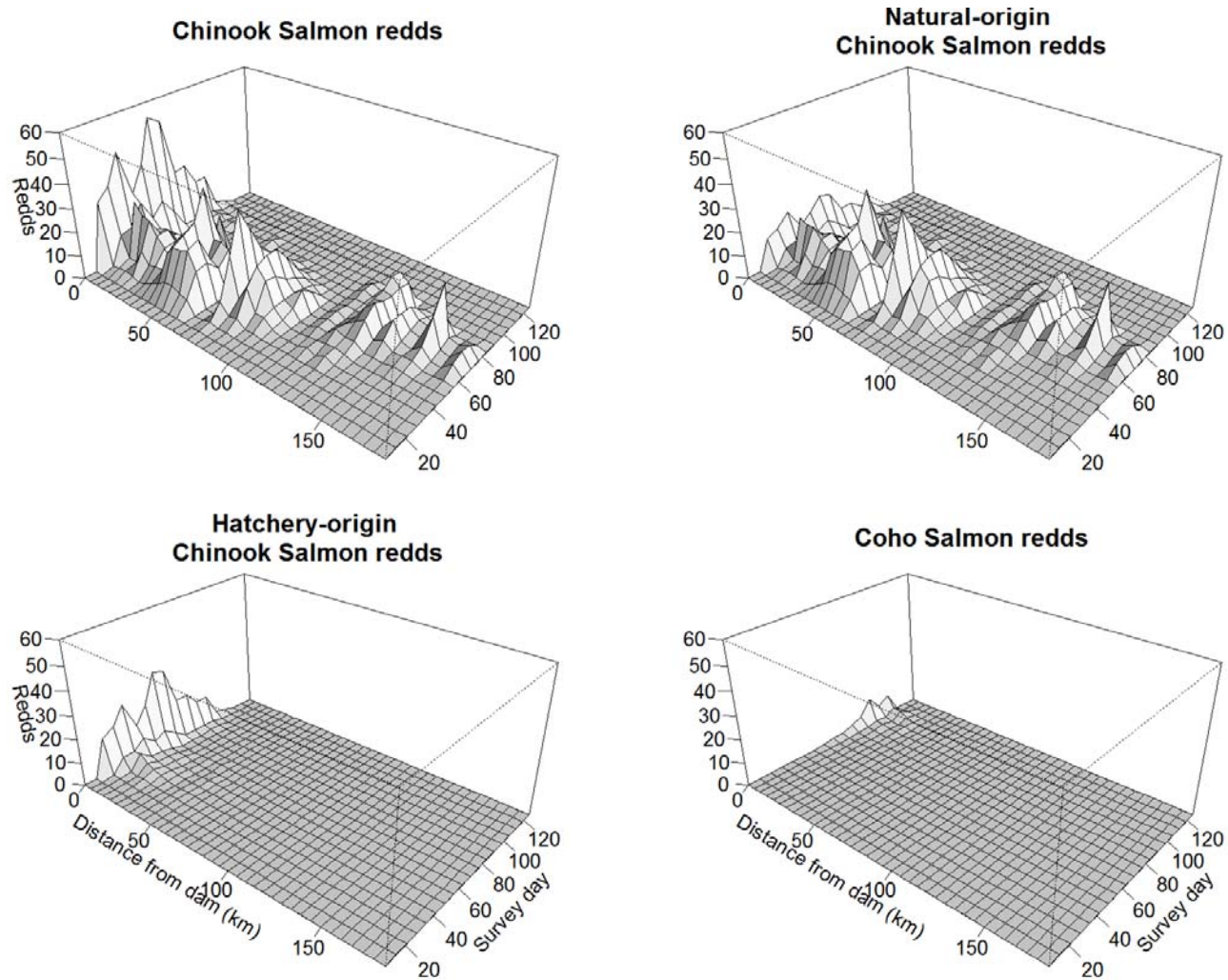
Table 14. Mapped and estimated salmon redds by species and origin observed in the mainstem Trinity River, 2015 and 2016. Hatchery- and natural-origin estimates are for the maternal first generation only. Bootstrap-generated 95% confidence intervals are in parentheses.

Species	Origin	Redd estimates	
		2015	2016
Chinook Salmon	All	2,103 (1,994–2,162)	1,607 ^b
	Natural	1,772 (1,632–1,948)	1,516 (1,453–1,580)
	Hatchery	331 (155–471)	91 (27–154)
Coho Salmon ^a	All	59 (0–168)	64 ^b
	Natural	NA	NA
	Hatchery	NA	NA

^a Our survey season only partially covers the Coho Salmon spawning period

^b Confidence intervals are generated with both Chinook and Coho salmon data. Not enough Coho Salmon female carcasses were found in 2016 to calculate a confidence interval here.

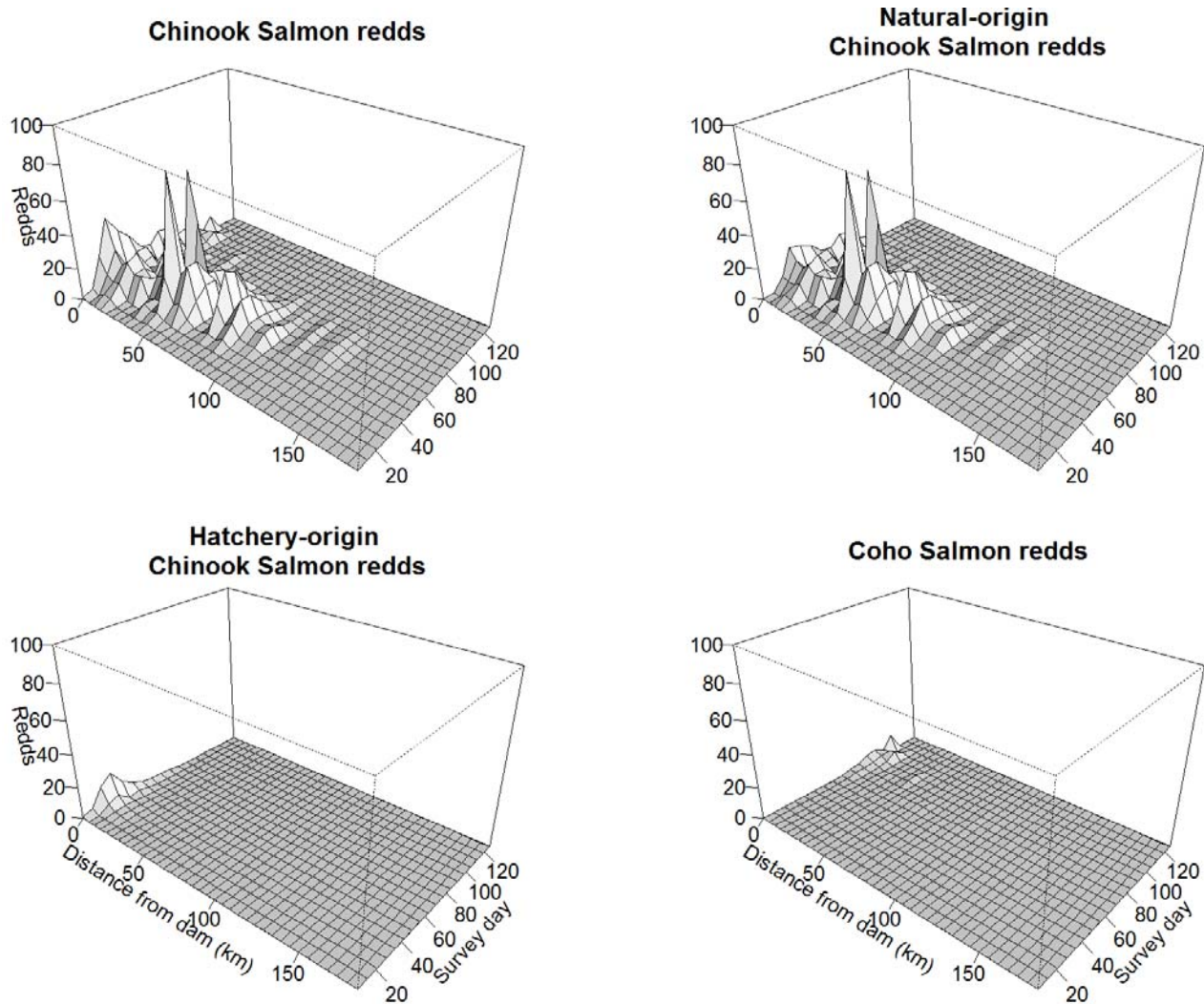
2015



22

Figure 5. Spatiotemporal distribution of mainstem Trinity River salmon redds from Lewiston Dam to Weitchpec, 2015 and 2016. Surveys were not conducted in Reaches 8 (rkm 107.6–117.4) and 11 (rkm 63.4–79.1). The Coho Salmon carcass data precluded the differentiation of hatchery- and natural-origin groups. Survey day 1 = September 1.

2016



23

Figure 5 (continued). Spatiotemporal distribution of mainstem Trinity River salmon redds from Lewiston Dam to Weitchpec, 2015 and 2016. Surveys were not conducted in Reaches 8 (rkm 107.6–117.4) and 11 (rkm 63.4–79.1). The Coho Salmon carcass data precluded the differentiation of hatchery- and natural-origin groups. Survey day 1 = September 1.

Redd–Carcass Relationship

Chinook Salmon redds [natural log-(*ln*-)transformed] and fresh spawned female Chinook Salmon carcasses (*ln*-transformed) in Reaches 1 and 2, 2012–2016, had a positive linear correlation ($R^2 = 0.825$, $p < 0.001$; Figure 6). A significant difference was detected between a slope of ‘1’ and the slope of the linear regression between log-transformed Chinook Salmon redd estimates and Chinook Salmon carcass estimates (slope = 0.635, 95% CI: 0.398–0.872;).

Redd Abundance and Distribution: System Scale

From 2002 to 2016, the number of mainstem salmon redds ranged between 1,671 and 7,588 redds, with no significant trend ($R^2 = 0.208$, $p = 0.087$; Figure 7). The number of redds constructed by natural-origin Chinook Salmon in the mainstem Trinity River varied with no significant trend ($R^2 = 0.012$, $p = 0.694$), while the number of redds constructed by hatchery-origin Chinook Salmon declined over this time frame ($R^2 = 0.545$, $p = 0.002$).

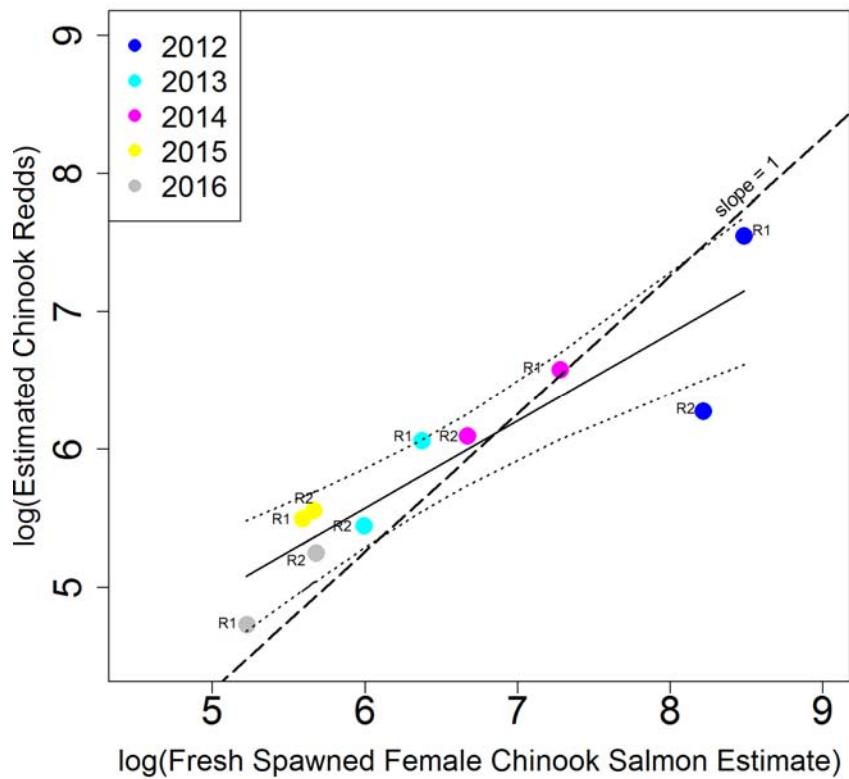


Figure 6. Relationship between counts of *ln*-transformed Chinook Salmon redds and *ln*-transformed estimates of spawned female Chinook Salmon carcasses in Survey Reaches 1 and 2 (solid line), 2012–2016. Data points are labeled by reach (R1 = Survey Reach 1, R2 = Survey Reach 2). The dashed line is included to represent a slope of ‘1’, which would be the slope of two perfectly proportional variables. Dotted lines represent 95% confidence limits of the linear model.

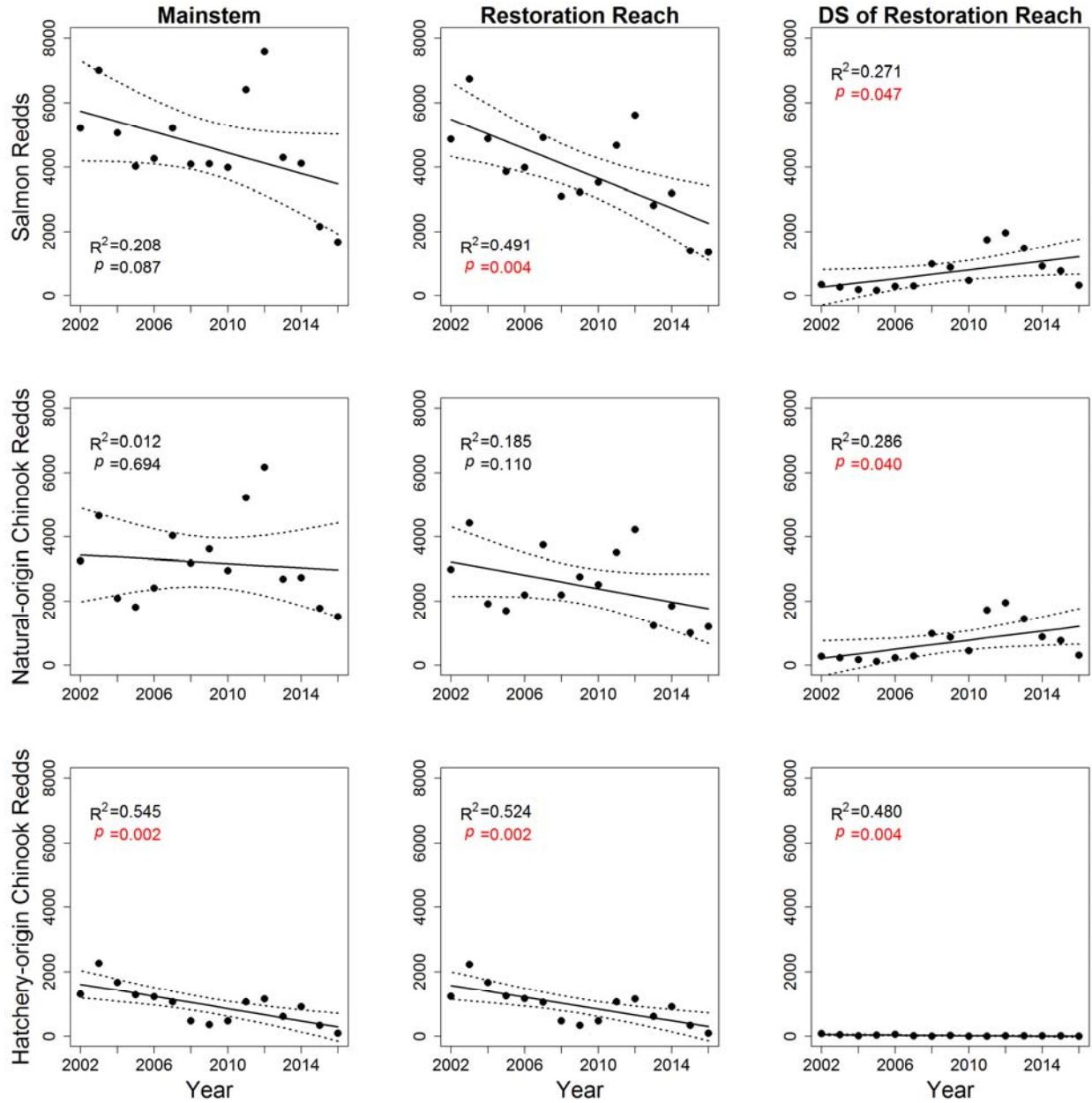


Figure 7. Estimated number of redds constructed in the entire mainstem Trinity River (left), within the restoration reach (center), and downstream of the restoration reach (right) by all Chinook Salmon (top), natural-origin Chinook Salmon (middle), and hatchery-origin Chinook Salmon (bottom) from 2002 to 2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines).

The trends in redd abundance within the restoration reach were similar to the mainstem-wide data (Figure 7). From 2002 to 2016, the number of redds constructed annually by natural-origin Chinook Salmon in the restoration reach varied with no significant trend ($R^2 = 0.185$, $p = 0.110$) while the number of redds constructed by hatchery-origin Chinook Salmon within the restoration reach declined over the same time frame ($R^2 = 0.524$, $p = 0.002$).

Downstream of the restoration reach the number of natural-origin Chinook Salmon redds constructed from 2002 to 2016 increased significantly ($R^2 = 0.286$, $p = 0.040$; Figure 7). A significant decrease in hatchery-origin Chinook Salmon redds was detected downstream of the restoration reach ($R^2 = 0.479$, $p = 0.004$), but this may not be meaningful since few to no redds were constructed by hatchery-origin Chinook Salmon in this section of river (mean = 14 redds/year).

In the section of river from Lewiston Dam to Cedar Flat, the mean distance from Lewiston Dam of natural-origin Chinook Salmon spawning shifted downstream from 2002 to 2016 ($R^2 = 0.721$, $p < 0.001$; Figure 8). This trend was not evident for redds constructed by hatchery-origin Chinook Salmon, which consistently spawned near Lewiston Dam ($R^2 = 0.091$, $p = 0.274$).

Redd Abundance and Distribution: Reach Scale

Long-term changes in natural-origin Chinook Salmon redd distribution were detected at the reach scale (~10–20 km). Redds by natural-origin Chinook Salmon most drastically decreased in the Lewiston reach ($R^2 = 0.472$, $p = 0.005$) and generally decreased in the Limekiln and Douglas City reaches from 2002 to 2016. The number of redds between the Junction City and Del Loma reaches generally increased over this time period. No changes in the number of redds were detectable in the Salyer Gorge, Willow Creek Valley, and Hoopa Valley reaches over the shorter time period from 2007 to 2016. (Figure 9). To account for annual variation in run size we compared the proportions of natural-origin Chinook Salmon redds within each of the ten reach-scale segments relative to the annual total in the entire mainstem river (Figure 10). This analysis revealed a shift in spawning distribution, where natural-origin Chinook Salmon redds decreased in the upstream-most reaches [Lewiston ($R^2 = 0.789$, $p < 0.001$) and Limekiln ($R^2 = 0.475$, $p = 0.004$)], did not significantly change in the Douglas City reach, and increased in the mid-river reaches [Junction City ($R^2 = 0.521$, $p = 0.002$), North Fork ($R^2 = 0.480$, $p = 0.004$), Big Bar ($R^2 = 0.663$, $p < 0.001$), and Del Loma ($R^2 = 0.766$, $p < 0.001$) reaches]. The proportion of redds in the downstream-most reaches (Salyer Gorge, Willow Creek Valley, and Hoopa Valley) have not changed significantly (p -values: 0.706–0.982).

Most hatchery-origin Chinook Salmon redds were constructed in the Lewiston rehabilitation reach (mean = 809 redds/year) and, to a lesser degree, in the Limekiln rehabilitation reach (mean = 83 redds/year) from 2002 to 2016. The abundance of hatchery-origin Chinook Salmon redds significantly decreased in the Lewiston ($R^2 = 0.520$, $p = 0.002$) and Limekiln ($R^2 = 0.520$, $p = 0.002$) reaches from 2002 to 2016 (Figure 11). Few hatchery-origin Chinook Salmon redds were found downstream of the Limekiln reach where their redd numbers averaged between 0.0 and 7.0 per year in each reach with no significant change over this time period.

To account for annual variation in run size we compared the proportions of hatchery-origin Chinook Salmon redds within each of the reaches to the annual total in the entire mainstem river (Figure 12). The Lewiston reach consistently contained the vast majority of hatchery-origin Chinook Salmon (mean = 84.4%), and to a smaller degree the Limekiln reach (mean = 14.3%), from 2002 to 2016. Although the proportion of hatchery-origin Chinook Salmon redds in the Lewiston reach did not significantly change, the proportion of redds in

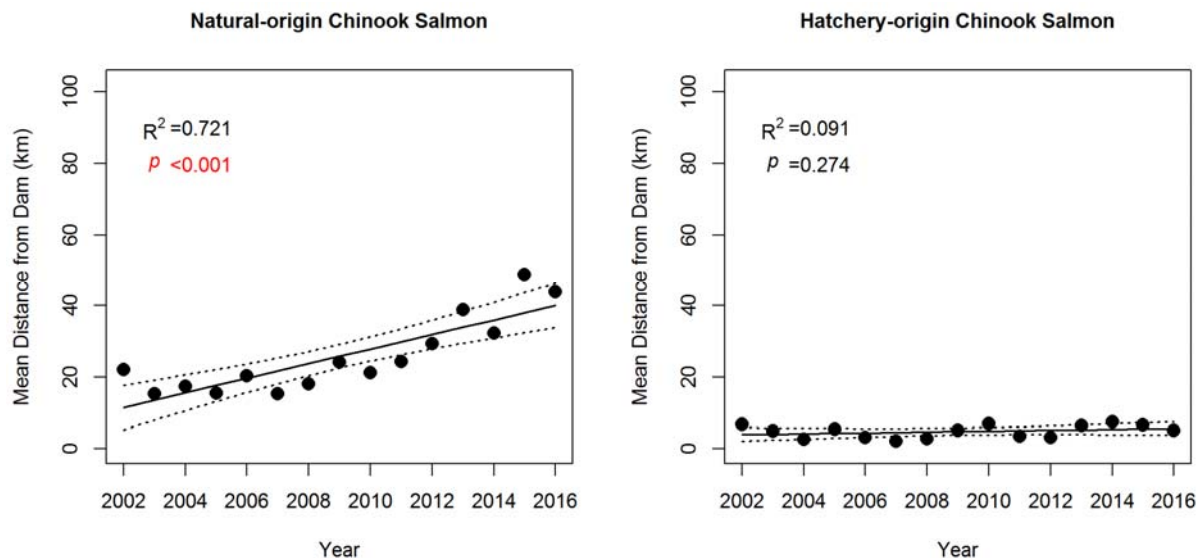


Figure 8. Mean distance from Lewiston Dam of redds constructed by natural- (left) and hatchery-origin (right) Chinook Salmon females between Lewiston Dam and Cedar Flat (0–102.8 km from Lewiston Dam) on the mainstem Trinity River, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines).

the Limekiln reach significantly increased ($R^2 = 0.302$, $p = 0.034$). We also detected a significant decrease in the Del Loma reach ($R^2 = 0.278$, $p = 0.044$); however, few redds by hatchery-origin Chinook Salmon were found in this reach (mean $< 0.01\%$). The proportion of hatchery-origin Chinook Salmon redds were at or close to 0.0% and other than the Del Loma reach, did not significantly change in any of the reaches downstream of the Limekiln reach (Figure 12).

Redd Abundance and Distribution: Site Scale

The proportional abundance of natural-origin Chinook Salmon within the 44 site-scale river sections show a range of long-term (2002–2016) trends. Most sites (23) did not show a significant change in the proportion of natural-origin Chinook Salmon redds, 14 sites showed an increasing trend, and 7 sites showed a decreasing trend (Appendix H). Of the mechanical channel rehabilitation sites with at least five years of post-construction data, 3 of 20 (15%) trended upward, 4 of 20 (20%) trended downward, and 13 of 20 (65%) displayed no significant change in the proportional abundance of natural-origin Chinook Salmon redds (Appendix I).

Hatchery-origin Chinook Salmon redds were not distributed throughout the restoration sites and were too few or absent to merit statistical analysis at the site scale. Like at the reach scale, the proportion of hatchery-origin fish were at or close to 0.0% at most sites below the Limekiln reach from 2002 to 2016.

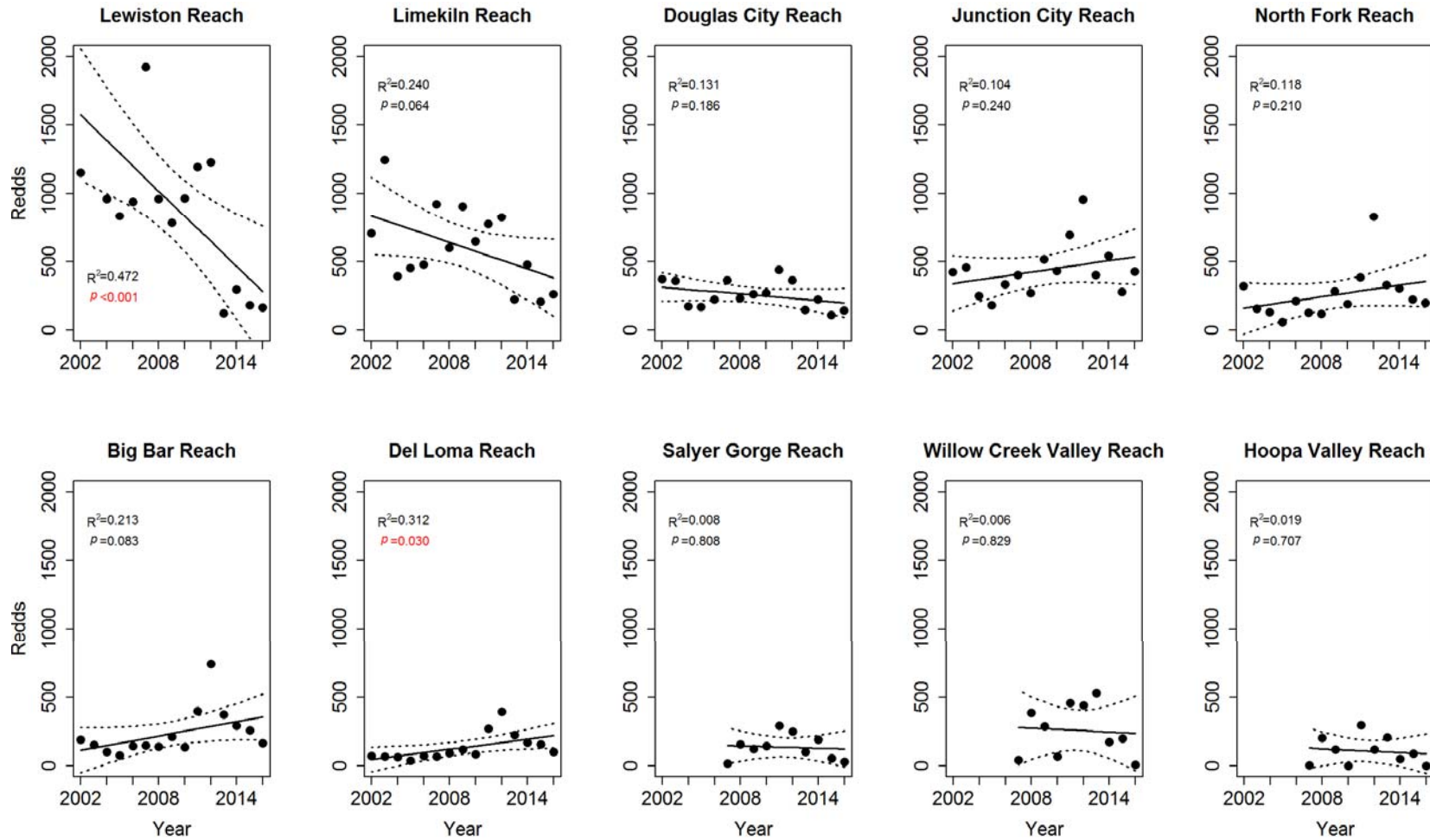


Figure 9. Estimated number of mainstem Trinity River natural-origin Chinook Salmon redds within ten reach-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines).

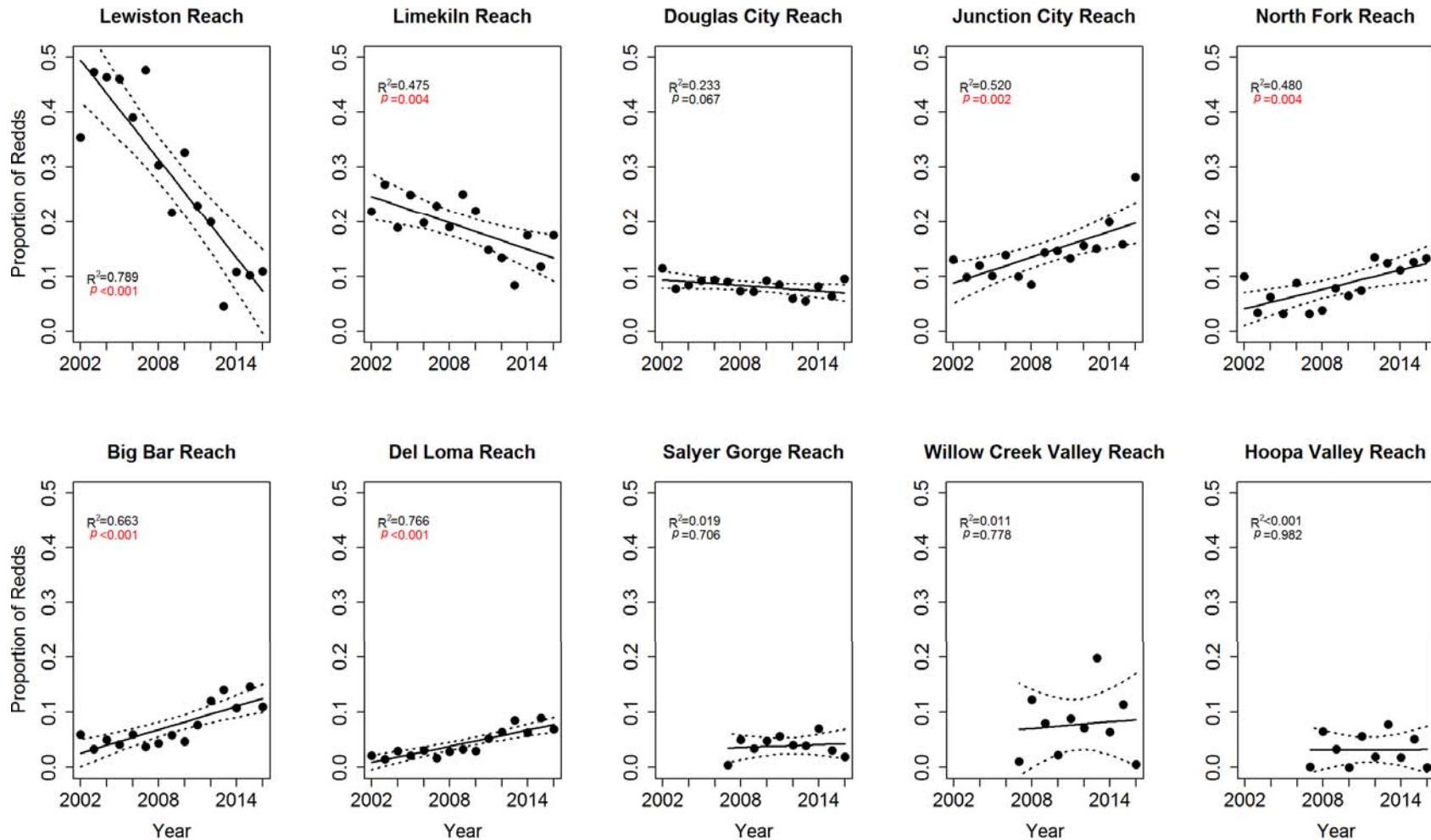


Figure 10. Proportions of mainstem Trinity River natural-origin Chinook Salmon redds relative to the total mainstem count of natural-origin Chinook Salmon redds within ten reach-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if < 0.05), and 95% confidence limits (dotted lines).

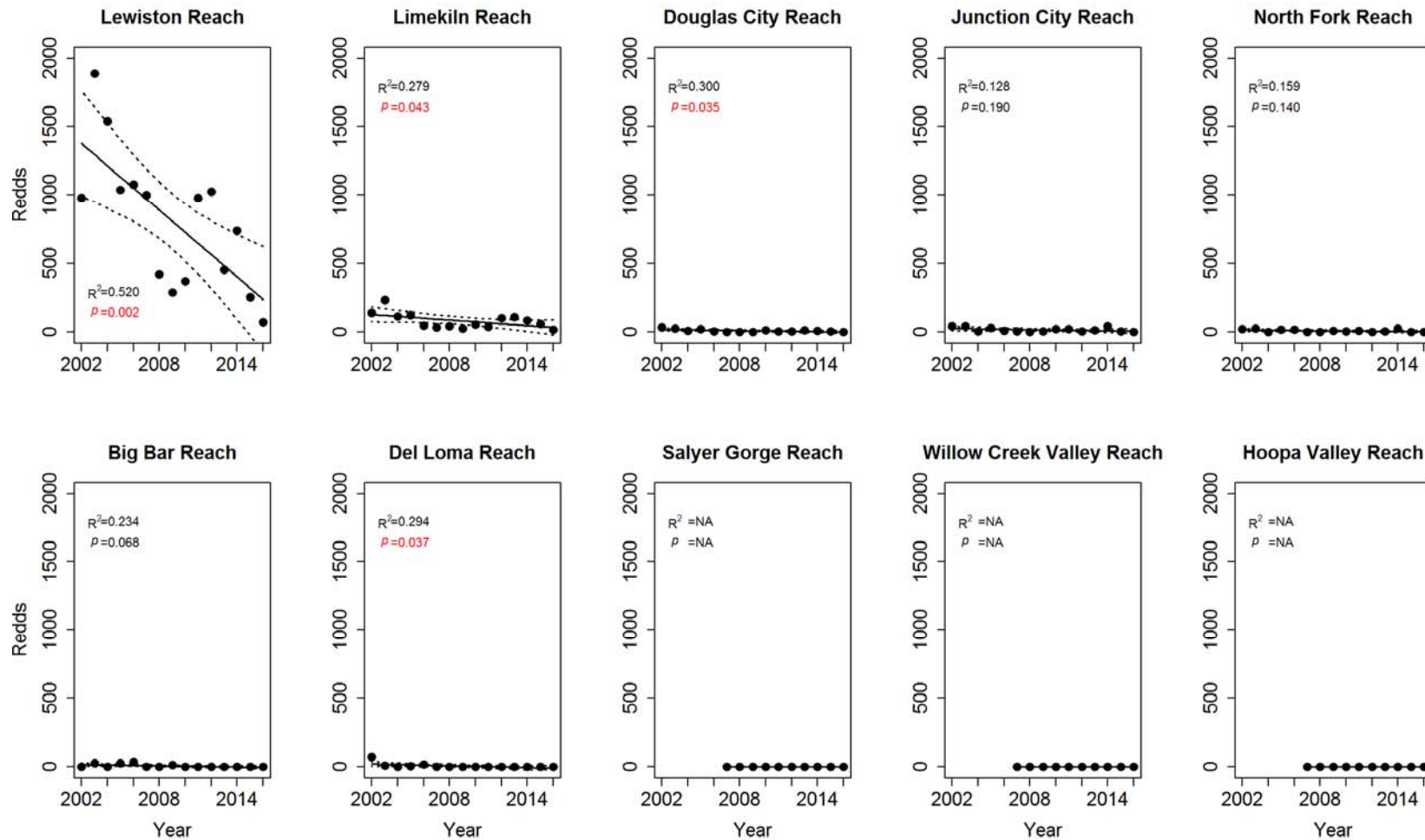


Figure 11. Estimated number of mainstem Trinity River hatchery-origin Chinook Salmon redds within ten reach-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if < 0.05), and 95% confidence limits (dotted lines).

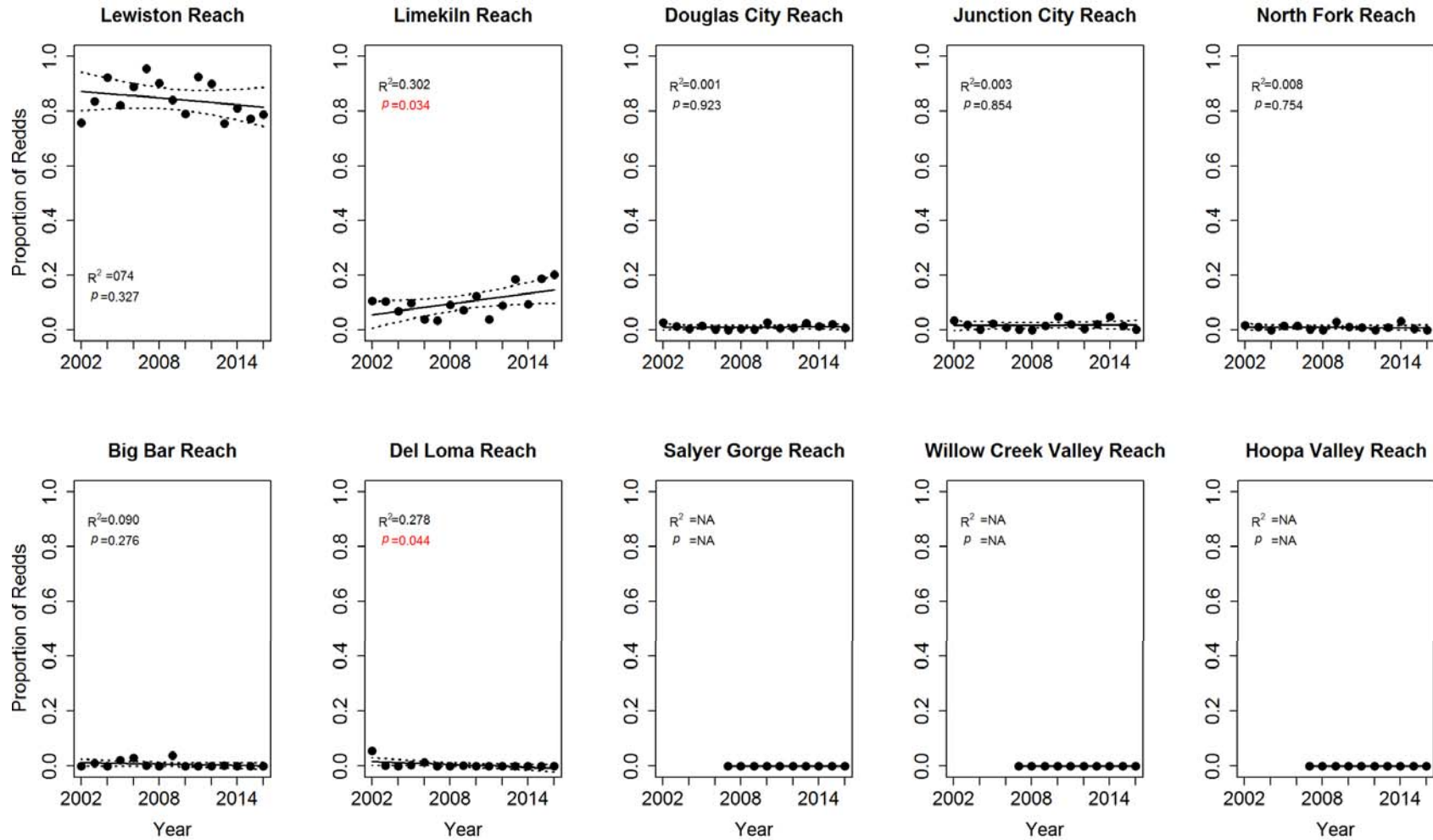


Figure 12. Proportions of mainstem Trinity River hatchery-origin Chinook Salmon redds relative to the total mainstem count of hatchery-origin Chinook Salmon redds within ten reach-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if < 0.05), and 95% confidence limits (dotted lines).

Discussion

Redd counts and salmon carcass estimates from the 2015 spawning season were the second lowest and were the lowest in 2016 since this survey's inception in 2002. Our 2016 results are consistent with the California Department of Fish and Wildlife Chinook Salmon natural spawner escapement estimates for the Trinity River Basin, which estimated the lowest number of spring-run Chinook Salmon since 1995 and a record low number of fall-run Chinook Salmon (CDFW 2017a, 2017b).

Extending through the first few weeks of the survey season, high flows from the Flow Augmentation Releases for the Lower Klamath River stemming from Lewiston Dam, elevated water turbidity impaired visibility and the ability to detect redds and carcasses during 2015 and 2016. Though many of the scheduled lower river (Reaches 12–14) surveys were cancelled due to high flow and poor visibility in 2016, spawning is typically sparse in these reaches and any missed redds from this section would likely have only been a minor contribution to the total redd count.

The analyses of long-term data from our spawning surveys provide insight into the dynamics of Chinook Salmon spawning activity on the Trinity River. The main themes that emerge are 1) the overall abundance of natural-origin Chinook Salmon redds did not change significantly from 2002 to 2016, 2) straying and spawning of hatchery-origin salmon is generally confined to areas near the hatchery (Lewiston Dam), 3) natural-origin Chinook Salmon spawning continues to exhibit spatial changes in distribution, 4) pre-spawn mortality has been relatively low in recent years.

The annual natural-origin Chinook Salmon redd count from 2002 to 2016 ranged between 1,772 (in 2016) and 6,170 (in 2012). Spawner abundance was hypothesized to increase following restoration actions (TRRP and ESSA 2009), but the abundance of natural-origin Chinook Salmon redds from 2002 to 2016 did not significantly change (Figure 7). We acknowledge that other factors (e.g., harvest, ocean conditions, in-river conditions, etc.) influence escapement and may mask responses of spawning activity to river restoration. Shifts in abundance are common to Chinook Salmon populations (Mantua et al. 1997; Brown 2002) and are evident in the Klamath basin (CDFW 2017a, 2017b). The estimates of 2015 and 2016 mainstem Trinity River natural spawner adult escapement (2015: 2,055 spring-run and 4,727 fall-run; 2016: 1,331 spring-run and 3,444 fall-run; CDFW 2017a, 2017b) were notably below the TRRP annual river escapement goal of 68,000 natural-origin Chinook Salmon spawners (6,000 spring-run adults and 62,000 fall-run adults).

Although the abundance of natural-origin Chinook Salmon redds did not show a significant trend from 2002 to 2016, the spatial distribution of redds shifted downstream. The increase in mean distance from Lewiston Dam of natural-origin Chinook Salmon redds was previously documented (Chamberlain et al. 2012; Rupert et al. 2017) and the 2015–2016 data continue this trend. Notably, the 2015 redd data exhibited the highest mean distance of redds from the dam to date (Figure 8). This shift is consistent with the IAP's suggestion that changes in longitudinal redd distribution would happen within three to four brood cycles following restoration activities (TRRP and ESSA 2009).

The abundance of hatchery-origin Chinook Salmon redds (redds constructed by hatchery-produced females regardless of male origin) decreased significantly from 2002 to 2016. In the Lewiston reach alone, estimated number of redds constructed by hatchery-origin Chinook Salmon ranged between a maximum of 1,888 redds in 2003 and a minimum of 72 redds in 2016 (Figure 11). However, the distribution of hatchery-origin Chinook Salmon redds remained relatively constant, spawning in close proximity to the TRH (Figure 12). The number and release timing of hatchery-reared juvenile Chinook Salmon has remained relatively constant over these years, so the reason for the decrease in abundance of hatchery-origin Chinook Salmon redds is unclear. While IAP objectives advocate limiting the genetic interaction of hatchery- and natural-origin Chinook Salmon, and having fewer hatchery-origin Chinook Salmon redds on the spawning grounds does support these objectives, further investigations are suggested to examine the causes for this precipitous decrease in hatchery-origin Chinook redds.

Reach-scale analyses revealed the clearest resolution for analyzing spawning distribution shifts of natural-origin Chinook Salmon. The trend from 2002 to 2016 shows that fewer natural-origin Chinook Salmon spawned near TRH and Lewiston Dam (Lewiston and Limekiln reaches) and more spawned in the mid-river sections (Junction City–Del Loma reaches; Figure 10). This shift is contrary to the IAP hypothesis that redd abundance in the reaches below the North Fork Trinity River would not increase until escapement began to approach “restoration goals” (TRRP and ESSA 2009). TRRP restoration actions may therefore be influencing a larger portion of the Trinity River than expected. Presumably, flow management is the primary factor for the spawning distribution shift of natural-origin Chinook Salmon since the effects of flow extend downstream much further than the generally localized effects of mechanical channel rehabilitation, course sediment augmentation, and watershed (tributaries) restoration.

Changes in redd abundance at the site scale was specifically used to evaluate the effect of TRRP channel rehabilitation activities. Our analysis revealed no clear post-construction response at rehabilitation sites. As reported in Rupert et al. (2017), despite being the smallest scale used in our analyses, the site scale may still be too spatially broad and too few years have passed since construction to detect responses to restoration. A positive response in the abundance of Chinook Salmon redds specific to channel rehabilitation may take many generations, after many years of geomorphic change and maturation. TRRP channel rehabilitation sites only secondarily affect spawning habitat since many constructed features are intended to increase and diversify juvenile rearing habitats and/or change the geomorphology of the site. The long-term effects of flow management however are intended to increase spawning habitat, though this would presumably affect all sites, regardless of channel rehabilitation treatments (TRRP and ESSA 2009).

Evaluation of the relationship between redd counts and the estimated number of spawned female Chinook Salmon following inclusion of the redd and carcass data from 2015 and 2016 into the 2012–2014 data set indicated a density-dependent redd observation bias (Figure 6). This is contrary to the result that Rupert et al. (2017) found with just the 2012–2014 data set. The Reach 2 data point from 2012, the largest run year, appears to have a negative influence on the slope of the regression line which suggests that redds in Reach 2 may be undercounted. Large spawning runs in the future may help validate or refute the density-dependent observation bias in the upper reaches.

The importance of describing pre-spawn mortality has increased in recent years with ongoing drought conditions and associated higher risks of epizootic events. Aguilar et al. (1996) reported that pre-spawn mortality for Chinook Salmon ranged between 1.1% and 44.9% in the mainstem Trinity River above the North Fork confluence from 1978 to 1982 and 1987 to 1995. In comparison, pre-spawn mortality rates that we measured were relatively low (between 2.4% and 9.5% from 2009 to 2014, 0.0% in 2015, and 0.7% in 2016) in this section of the river. Salmon pre-spawn mortality rates are typically highest at the beginning of the spawning season and decrease as the season advances (Aguilar et al. 1996; Gough and Williamson 2012). Too few pre-spawn mortality Chinook Salmon carcasses were observed in 2015 (three) and 2016 (two) to conduct a temporal analysis these years. Aguilar et al. (1996) also reported a positive correlation between pre-spawn mortality and run size for Trinity River Chinook Salmon from 1978 to 1995. After adding the 2015 and 2016 data, the lowest run sizes and pre-spawn mortality rates since 2009, to the data from 2009 to 2014, we detected no correlation between pre-spawn mortality and redd counts in the restoration reach ($p = 0.72$; Appendix J). The lack of correlation suggests that other factors beyond run size (i.e., river conditions, run timing, etc.) may be influencing pre-spawn mortality rates. The 2015 and 2016 Coho Salmon run sizes were notably small and carcasses sample sizes ($n = 5$ and 2 , respectively) were inadequate to assess pre-spawn mortality for this species. Interpretation of results pertaining to spawning success should take into account that pre-spawn mortality goes beyond what we observe on the spawning ground surveys. Pre-spawn mortality fish are available to our carcass survey because they expired prior to spawning. The spatiotemporal location of their recovery is unlikely to be an accurate depiction of when and where they were destined to spawn had they survived. For instance, pre-spawn mortality occurring in the Lower Klamath River for Trinity River-bound fish would not be detectable during our Trinity River spawn surveys. Likewise, spring-run Chinook Salmon that expired well before the first surveys in September would also not be detectable.

Acknowledgements

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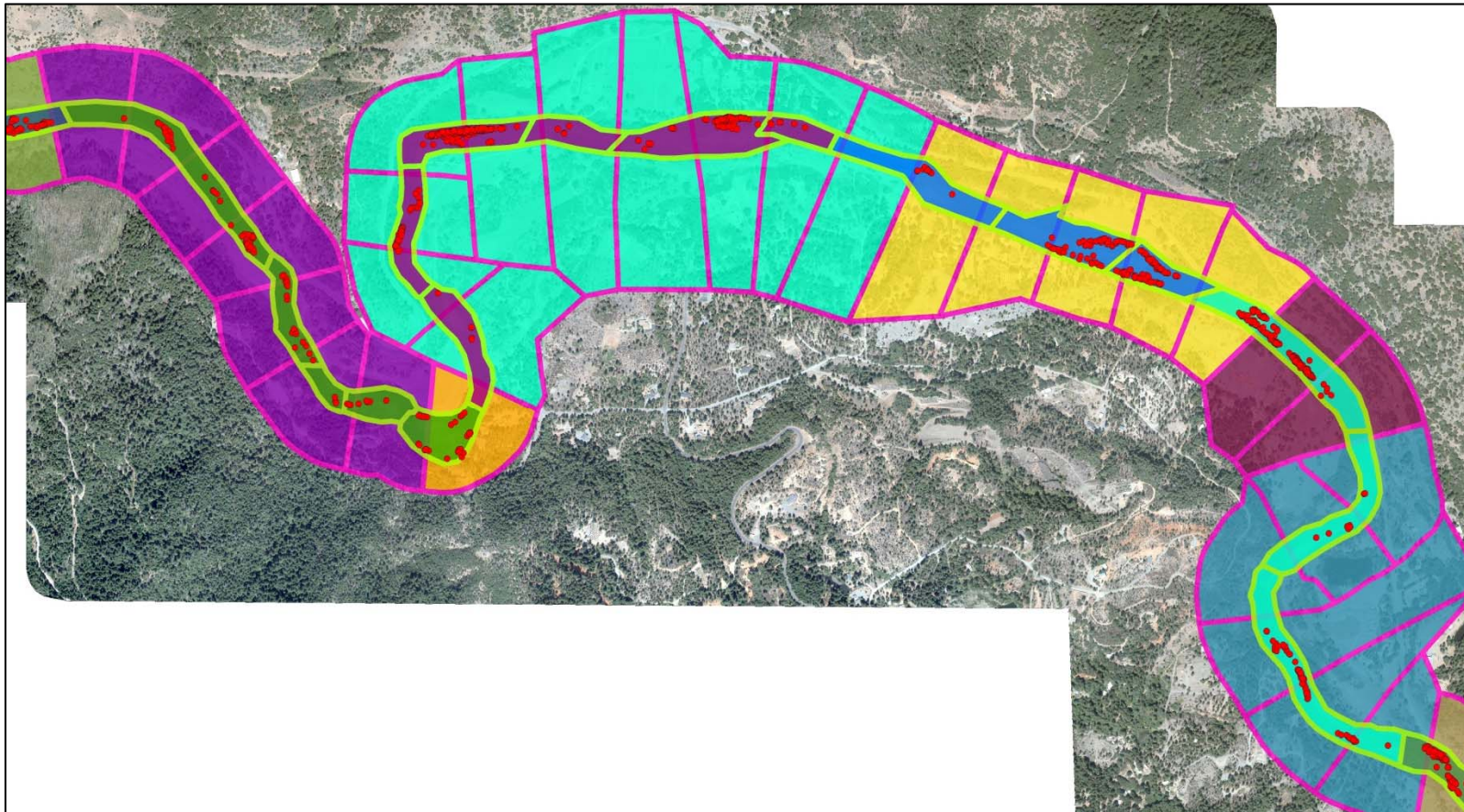
Literature Cited

- Aguilar, B., L. D. Davis, B. W. Collins, L. Hanson, W. Sinnen, M. Zuspan, and M. Dean. 1996. Annual Report: Trinity River Basin salmon and steelhead monitoring project, 1994–1995 season. R. M. Kano, editor. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California. 223 p.
- Bradford, M., and D. Hankin. 2012. Trinity River Restoration Program adult salmonid monitoring evaluation. Prepared for TRRP. Weaverville, California. 47 p.
- Brown, E. M. 2002. 2000 salmon spawning ground surveys. Pacific Salmon Treaty Program, 538 Award Number NA77FP0445. Idaho Fish Game Report 02-33, Boise, Idaho.
- Buffington, J., C. Jordan, M. Merigliano, J. Peterson, and C. Stalnaker. 2014. Review of the Trinity River Restoration Program following Phase 1, with emphasis on the Program's channel rehabilitation strategy. Prepared by the Trinity River Restoration Program's Science Advisory Board for the Trinity River Restoration Program with assistance from Anchor QEA, LLC, Stillwater Sciences, BioAnalysts, Inc., and Hinrichsen Environmental Services.
- CDFW (California Department of Fish and Wildlife). 2017a. Klamath River Basin Spring Chinook Salmon Spawner Escapement, In-river Harvest and Run-size Estimates, 1980-2016. California Department of Fish and Wildlife, Arcata, Californian.
- CDFW (California Department of Fish and Wildlife). 2017b. Klamath River Basin Fall Chinook Salmon Spawner Escapement, In-river Harvest and Run-size Estimates, 1978-2016. California Department of Fish and Wildlife, Arcata, Californian.
- Chamberlain, C. D., S. Quinn, and W. Matilton. 2012. Distribution and abundance of Chinook Salmon redds in the mainstem Trinity River 2002 to 2011. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report TR 2012-16, Arcata, California.
- Gaeuman, D., R. Stewart, and T. Buxton. 2016. First steps towards a river corridor management strategy. Technical report: TR-TRRP-2016-1. Trinity River Restoration Project, Weaverville, California.
- Gough, S. A., and S. C. Williamson. 2012. Fall Chinook Salmon run characteristics and escapement for the main-stem Klamath River, 2001–2010. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2012–14, Arcata, California.
- HVT (Hoopa Valley Tribe), McBain and Trush, and Northern Hydrology and Engineering. 2011. Channel rehabilitation design guidelines for the mainstem Trinity River. Prepared for the Trinity River Restoration Program, Hoopa, California.
- Kery, M., and M. Schaub. 2012. Bayesian population analysis using WinBUGS. Academic Press, Oxford, United Kingdom.

- Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, R. C. Francis. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78(6):1069–1079.
- Moffett, J. W., and S. H. Smith. 1950. Biological investigations of the fishery resources of the Trinity River, California. Special Scientific Report No. 12, U.S. Fish and Wildlife Service. 71 p.
- Quihillalt, R. R. 1999. Mainstem Trinity River fall Chinook Salmon spawning redd survey, 1996 through 1998. U.S. Fish and Wildlife Service, Arcata, California.
- Rogers, D. W. 1972. King Salmon (*Oncorhynchus tshawytscha*) and Silver Salmon (*Oncorhynchus kisutch*) spawning escapement and spawning habitat in the upper Trinity River, 1970. California Fish and Game, Region 1, Anadromous Fisheries Branch Administrative Report Number 73-10.
- Rupert, D. L., C. D. Chamberlain, S. A. Gough, N. A. Som, N. J. Davids, W. C. Matilton, A. M. Hill, and E. R. Wiseman. 2017. Mainstem Trinity River Chinook Salmon Spawning Distribution 2012–2014. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2017–52, Arcata, California.
- TRRP (Trinity River Restoration Program). 2016. Restoration flow releases on the Trinity River Water Year 2015. Workgroup report: WR-TRRP-2016-1. Trinity River Restoration Project, Weaverville, California.
- TRRP and ESSA (Trinity River Restoration Program and ESSA Technologies Ltd.). 2009. Integrated Assessment Plan, Version 1.0 – September 2009. Draft report prepared for the Trinity River Restoration Project, Weaverville, California. 285 p.
- USBOR (U.S. Bureau of Reclamation). 2015. Environmental Assessment, 2015 Lower Klamath River Late-Summer Flow Augmentation from Lewiston Dam. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.
- USBOR (U.S. Bureau of Reclamation). 2016. Environmental Assessment, 2016 Lower Klamath River Late-Summer Flow Augmentation from Lewiston Dam. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.
- USDOI (U.S. Department of Interior). 2000. Record of Decision: Trinity River mainstem fishery restoration final Environmental Impact Statement / Environmental Report.
- USFWS (U.S. Fish and Wildlife Service). 1986, 1987. Trinity River flow evaluation study, 2 reports. Annual Report, U.S. Fish and Wildlife Service, Sacramento, California.
- USFWS (U.S. Fish and Wildlife Service) and HVT (Hoopa Valley Tribe). 1999. Trinity River flow evaluation, Final Report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California and Hoopa Valley Tribe, Hoopa, California.

Appendices

Appendix A. Example riffle units (chartreuse-outlined polygons) compared to 400-m Science Advisory Board (SAB) dataframe units (pink-outlined polygons) at the Conner Creek, Wheel Gulch and Valdor sites. For comparison at the Wheel Gulch site, riffle-units are shown as dark blue polygons and the SAB units are shown as yellow polygons. Salmon redds from 2011 to 2016 (red dots) are displayed to highlight how riffle units split redd groupings based on habitat. Both types of site-scale sections that represent the same TRRP restoration site may have different start and end points.

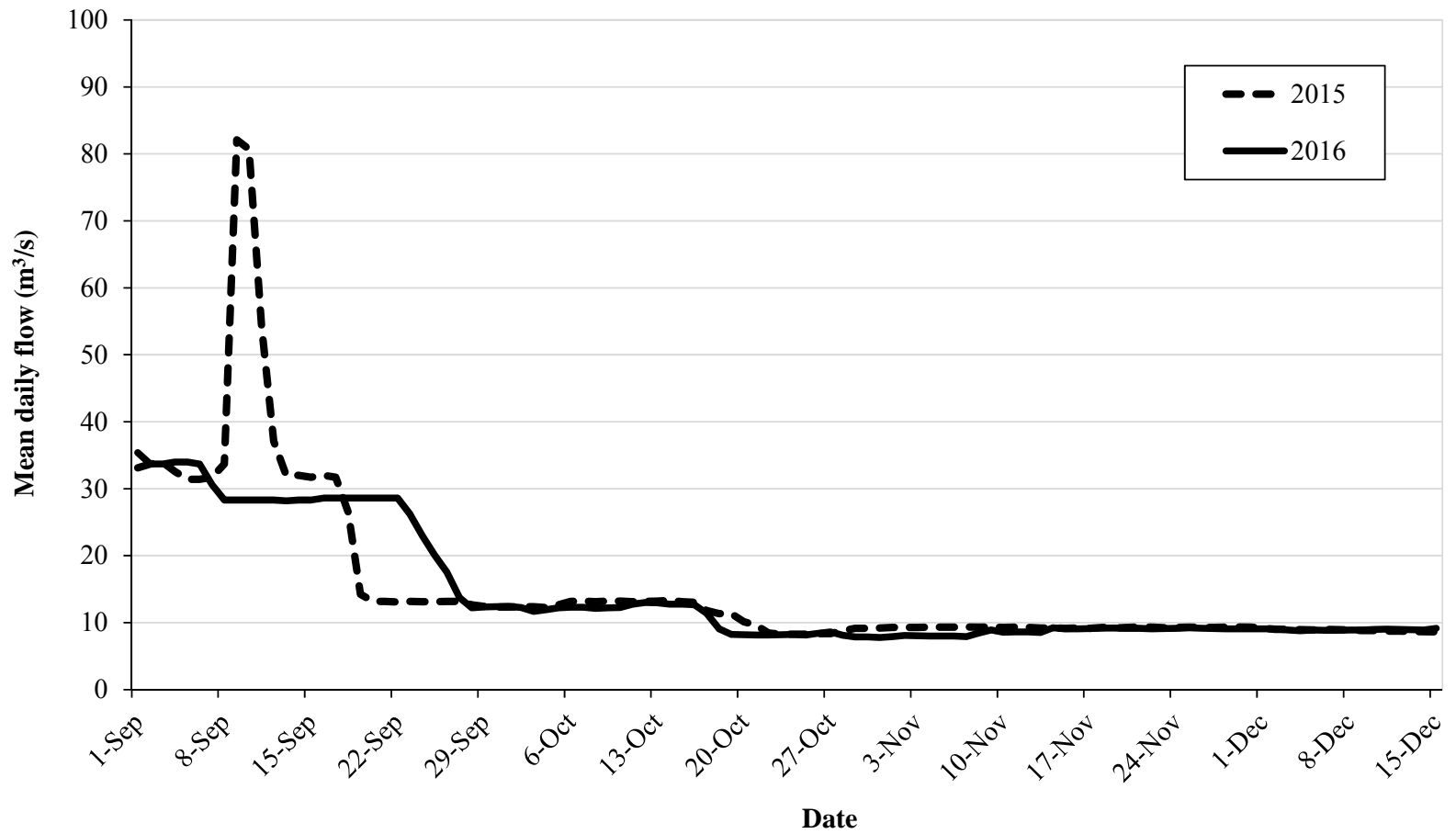


Appendix B. Trinity River water visibility by week and reach throughout the 2015 survey period. Grey boxes represent surveys with sub-optimal visibility. NS = No Survey for scheduled surveys that were missed. Dashes (-) represent days when surveys were not scheduled or performed.

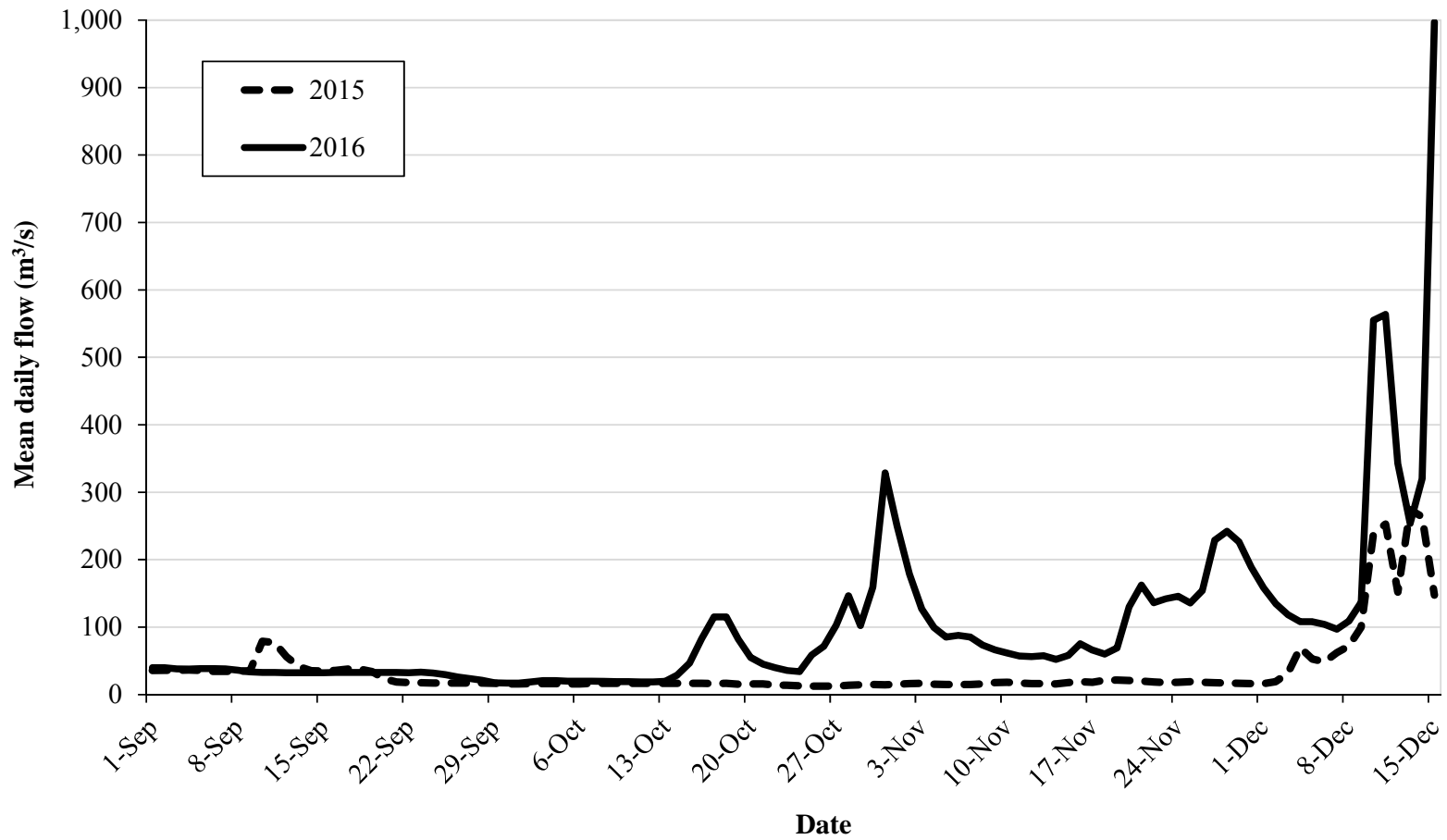
Week start	Reach												
	1	2	3	4	5	6	7	9	10	12	13	14	
8/31	0.9-1.5	-	-	-	-	-	-	-	-	-	-	-	-
9/7	0.9-1.5	0.9-1.5	0.9-1.5	NS	NS	0.9-1.5	0.9-1.5	-	-	-	-	-	-
9/14	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	<0.9	0.9-1.5	0.9-1.5	0.9-1.5	<0.9	-	-	-	-
9/21	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	-	-	-	-
9/28	0.9-1.5	0.9-1.5	0.9-1.5	<0.9	0.9-1.5	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	-	-
10/5	<0.9	<0.9	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	0.9-1.5	1.5-3.0	1.5-3.0	1.5-3.0
10/12	<0.9	<0.9	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	1.5-3.0	-	-	-	-
10/19	<0.9	<0.9	<0.9	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0
10/26	<0.9	<0.9	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	-	-
11/2	<0.9	<0.9	0.9-1.5	1.5-3.0	0.9-1.5	0.9-1.5	0.9-1.5	-	-	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0
11/9	<0.9	<0.9	<0.9	NS	0.9-1.5	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	-	-	-	-
11/16	0.9-1.5	0.9-1.5	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	0.9-1.5	1.5-3.0	0.9-1.5	0.9-1.5
11/23	0.9-1.5	NS	NS	NS	NS	0.9-1.5	0.9-1.5	0.9-1.5	NS	-	-	-	-
11/30	0.9-1.5	0.9-1.5	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	0.9-1.5	0.9-1.5	NS	NS
12/7	0.9-1.5	0.9-1.5	0.9-1.5	1.5-3.0	NS	0.9-1.5	<0.9	NS	NS	-	-	-	-
12/14	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	1.5-3.0	0.9-1.5	0.9-1.5	-	-	NS	NS	NS	NS

Appendix C. Trinity River water visibility by week and reach throughout the 2016 survey period. Grey boxes represent surveys with sub-optimal visibility. NS = No Survey for scheduled surveys that were missed. Dashes (-) represent days when surveys were not scheduled or performed.

Week start	Reach												
	1	2	3	4	5	6	7	9	10	12	13	14	
8/29	0.9-1.5	-	-	-	-	-	-	-	-	-	-	-	-
9/5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	-	-	-	-
9/12	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	-	-
9/19	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	-	-	-	-	-	-
9/26	0.9-1.5	0.9-1.5	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	1.5-3.0	1.5-3.0	-	-	-	-
10/3	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	1.5-3.0	1.5-3.0	1.5-3.0	-
10/10	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	1.5-3.0	0.9-1.5	0.9-1.5	NS	NS	-	-	-	-
10/17	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	NS	NS	NS	NS
10/24	0.9-1.5	1.5-3.0	1.5-3.0	NS	1.5-3.0	0.9-1.5	0.9-1.5	NS	NS	-	-	-	-
10/31	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	NS	NS	NS	NS
11/7	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	1.5-3.0	-	-	-	-
11/14	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	-	-	0.9-1.5	NS	NS	NS
11/21	1.5-3.0	1.5-3.0	NS	NS	NS	0.9-1.5	0.9-1.5	NS	NS	-	-	-	-
12/28	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.5	NS	NS	NS	NS
12/5	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	1.5-3.0	NS	NS	NS	NS	-	-	-	-
12/12	1.5-3.0	0.9-1.5	0.9-1.5	NS	NS	NS	NS	-	-	NS	NS	NS	NS



Appendix D. Trinity River mean daily discharge at Lewiston Dam during the 2015 and 2016 survey seasons. Flow measured at USGS Gage 11525500, courtesy of the U.S. Geological Survey.



Appendix E. Trinity River mean daily discharge at Hoopa, California, during the 2015 and 2016 survey seasons. Flow measured at USGS Gage 11530000, courtesy of the U.S. Geological Survey.

Appendix F. Pre-spawn mortality numbers by week and reach of unmarked and ad-clipped fresh (Conditions 1 and 2) female Chinook Salmon carcasses, mainstem Trinity River surveys 2015. Also included are weekly pre-spawn mortality proportions among like mark-type carcasses. Ad-clipped carcass numbers were not expanded by CWT-specific production multipliers and are therefore about 25% of hatchery-origin carcass numbers. Likewise, unmarked carcass numbers include hatchery-origin carcasses that were not ad-clipped. ‘NS’ = no survey and dashes (-) represent a sample size of zero.

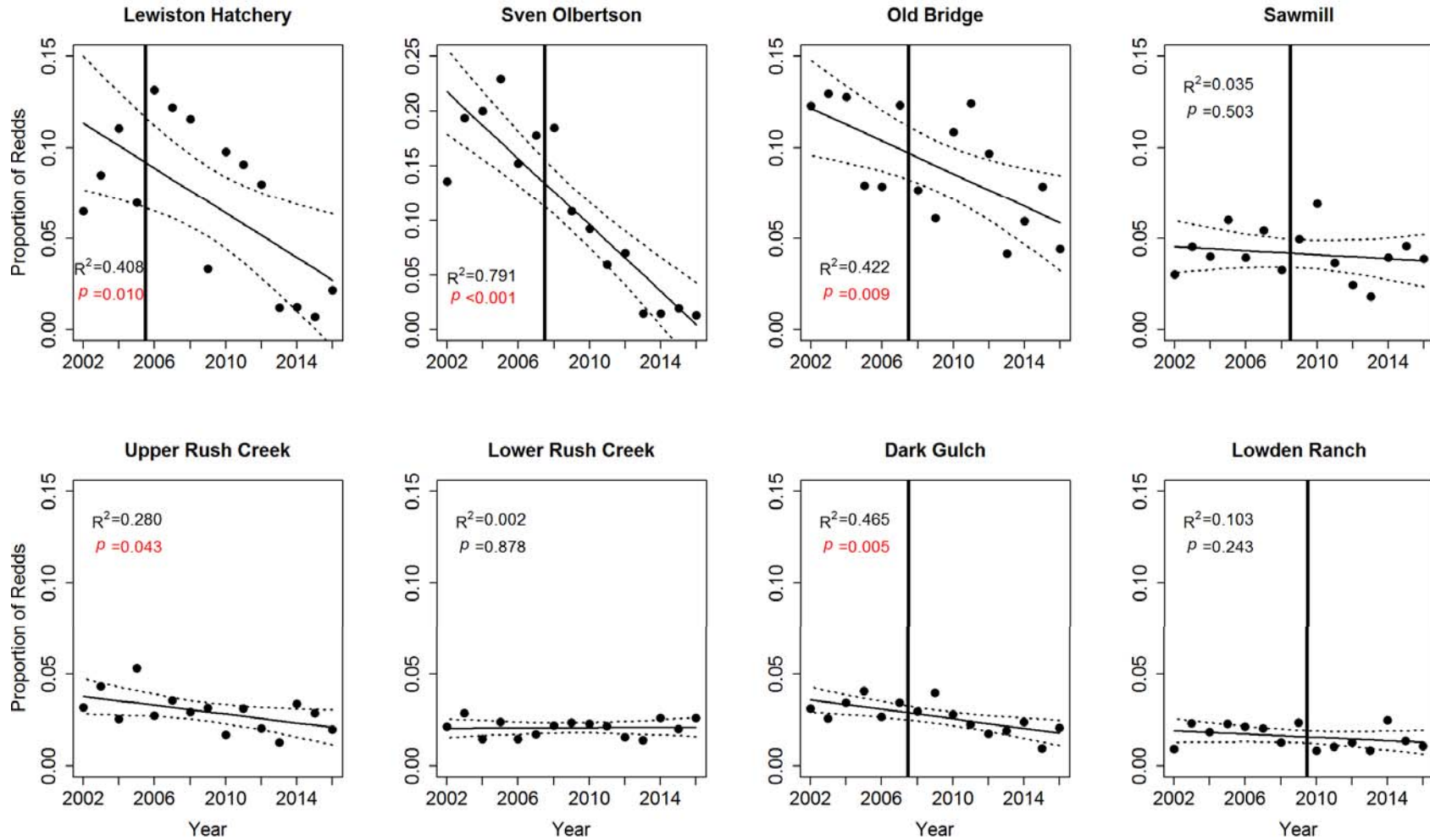
		Unmarked												All reaches	
Calendar week	Dates	Reach												n	Pct.
		1	2	3	4	5	6	7	9	10	12	13	14		
36	Aug. 30 - Sep. 5	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep. 6 - 12	-	-	-	NS	NS	-	-	NS	NS	NS	NS	NS	-	-
38	Sep. 13 - 19	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
39	Sep. 20 - 26	0	0	0	0	0	-	-	NS	NS	NS	NS	NS	0	0.0%
40	Sep. 27 - Oct. 3	0	0	0	0	0	0	-	0	-	NS	NS	NS	0	0.0%
41	Oct. 4 - 10	0	0	0	0	0	0	0	NS	NS	-	-	-	0	0.0%
42	Oct. 11 - 17	0	0	0	0	0	0	0	0	0	NS	NS	NS	0	0.0%
43	Oct. 18 - 24	0	0	0	0	0	0	0	NS	NS	0	1	1	2	2.1%
44	Oct. 25 - 31	0	0	0	0	0	0	0	0	0	NS	NS	NS	0	0.0%
45	Nov. 1 - 7	0	0	0	0	0	0	0	NS	NS	0	0	0	0	0.0%
46	Nov. 8 - 14	0	0	0	NS	-	0	0	0	0	NS	NS	NS	0	0.0%
47	Nov. 15 - 21	0	0	-	-	-	0	0	NS	NS	0	0	0	0	0.0%
48	Nov. 22 - 28	-	NS	NS	NS	NS	-	-	0	NS	NS	NS	NS	0	0.0%
49	Nov. 29 - Dec. 5	0	0	-	-	-	-	-	-	-	0	1	-	1	5.6%
50	Dec. 6 - 12	0	-	-	-	NS	-	-	-	-	NS	NS	NS	0	0.0%
51	Dec. 13 - 19	0	0	-	-	-	-	-	-	-	NS	NS	NS	0	0.0%
52	Dec. 20 - 26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All weeks		0	0	0	0	0	0	0	0	0	0	2	1	3	0.8%

		Ad-clipped												All reaches	
Calendar week	Dates	Reach												n	Pct.
		1	2	3	4	5	6	7	9	10	12	13	14		
36	Aug. 30 - Sep. 5	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep. 6 - 12	-	-	-	NS	NS	-	-	NS	NS	NS	NS	NS	-	-
38	Sep. 13 - 19	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
39	Sep. 20 - 26	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
40	Sep. 27 - Oct. 3	0	-	-	-	-	-	-	-	-	NS	NS	NS	0	0.0%
41	Oct. 4 - 10	0	0	-	-	-	-	-	NS	NS	-	-	-	0	0.0%
42	Oct. 11 - 17	-	0	0	0	-	-	-	-	-	NS	NS	NS	0	0.0%
43	Oct. 18 - 24	0	-	-	-	-	-	-	NS	NS	-	-	-	0	0.0%
44	Oct. 25 - 31	-	0	-	-	-	-	-	-	-	NS	NS	NS	0	0.0%
45	Nov. 1 - 7	0	-	-	-	-	-	-	NS	NS	-	-	-	0	0.0%
46	Nov. 8 - 14	0	-	-	NS	-	-	-	-	-	NS	NS	NS	0	0.0%
47	Nov. 15 - 21	0	-	-	-	-	-	-	NS	NS	-	-	-	0	0.0%
48	Nov. 22 - 28	-	NS	NS	NS	NS	-	-	-	NS	NS	NS	NS	-	-
49	Nov. 29 - Dec. 5	0	-	-	-	-	-	-	-	-	-	-	-	0	0.0%
50	Dec. 6 - 12	-	-	-	-	NS	-	-	-	-	NS	NS	NS	-	-
51	Dec. 13 - 19	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
52	Dec. 20 - 26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All weeks		0	0	0	0	-	-	-	-	-	-	-	-	0	0.0%

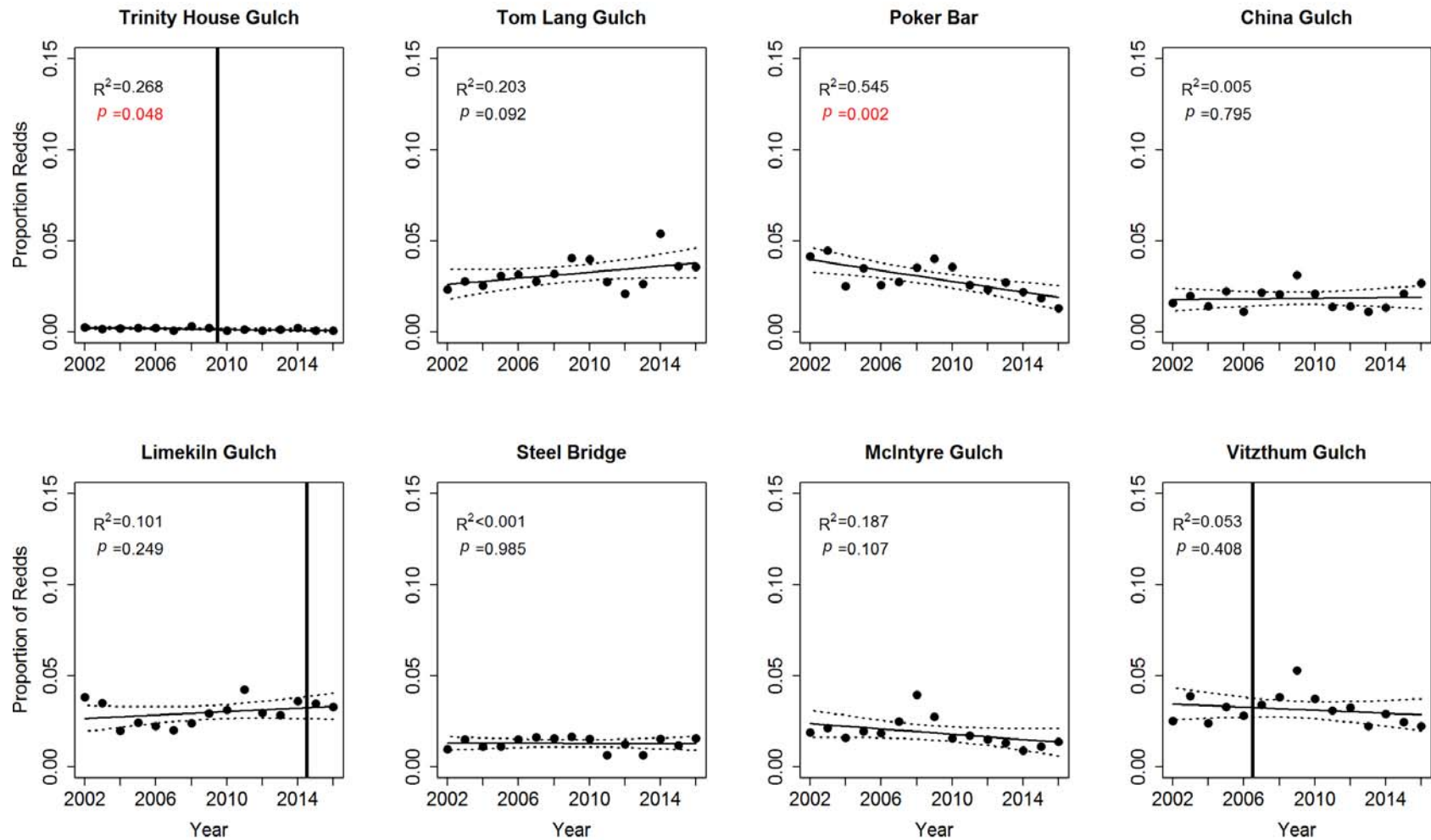
Appendix G. Pre-spawn mortality numbers by week and reach of unmarked and ad-clipped fresh (Conditions 1 and 2) female Chinook Salmon carcasses, mainstem Trinity River surveys 2016. Also included are weekly pre-spawn mortality proportions among like mark-type carcasses. Ad-clipped carcass numbers were not expanded by CWT-specific production multipliers and are therefore about 25% of hatchery-origin carcass numbers. Likewise, unmarked carcass numbers include hatchery-origin carcasses that were not ad-clipped. ‘NS’ = no survey and dashes (-) represent a sample size of zero.

		Unmarked												All reaches	
Calendar week	Dates	Reach												n	Pct.
		1	2	3	4	5	6	7	9	10	12	13	14		
36	Aug. 29 - Sep. 4	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep. 5 - 11	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
38	Sep. 12 - 18	0	-	-	-	-	-	-	-	-	NS	NS	NS	0	0.0%
39	Sep. 19 - 25	-	-	0	-	-	-	-	NS	NS	NS	NS	NS	0	0.0%
40	Sep. 26 - Oct. 2	1	0	0	0	0	0	-	-	-	NS	NS	NS	1	7.1%
41	Oct. 3 - 9	1	0	0	0	0	0	-	NS	NS	-	-	-	1	2.8%
42	Oct. 10 - 16	0	0	0	-	0	0	0	NS	NS	NS	NS	NS	0	0.0%
43	Oct. 17 - 23	0	0	0	0	0	0	0	0	0	NS	NS	NS	0	0.0%
44	Oct. 24 - 30	0	0	0	NS	0	0	0	NS	NS	NS	NS	NS	0	0.0%
45	Oct. 31 - Nov. 6	0	0	0	0	0	0	-	NS	NS	NS	NS	NS	0	0.0%
46	Nov. 7 - 13	0	0	-	-	0	0	-	-	0	NS	NS	NS	0	0.0%
47	Nov. 14 - 20	0	-	0	-	-	-	-	NS	NS	-	NS	NS	0	0.0%
48	Nov. 21 - 27	0	0	NS	NS	NS	-	-	NS	NS	NS	NS	NS	0	0.0%
49	Nov. 28 - Dec. 4	0	0	-	-	-	-	-	-	-	NS	NS	NS	0	0.0%
50	Dec. 5 - 11	0	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	0	0.0%
51	Dec. 12 - 18	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
52	Dec. 19 - 25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All weeks		2	0	0	0	0	0	0	0	0	-	-	-	2	0.8%

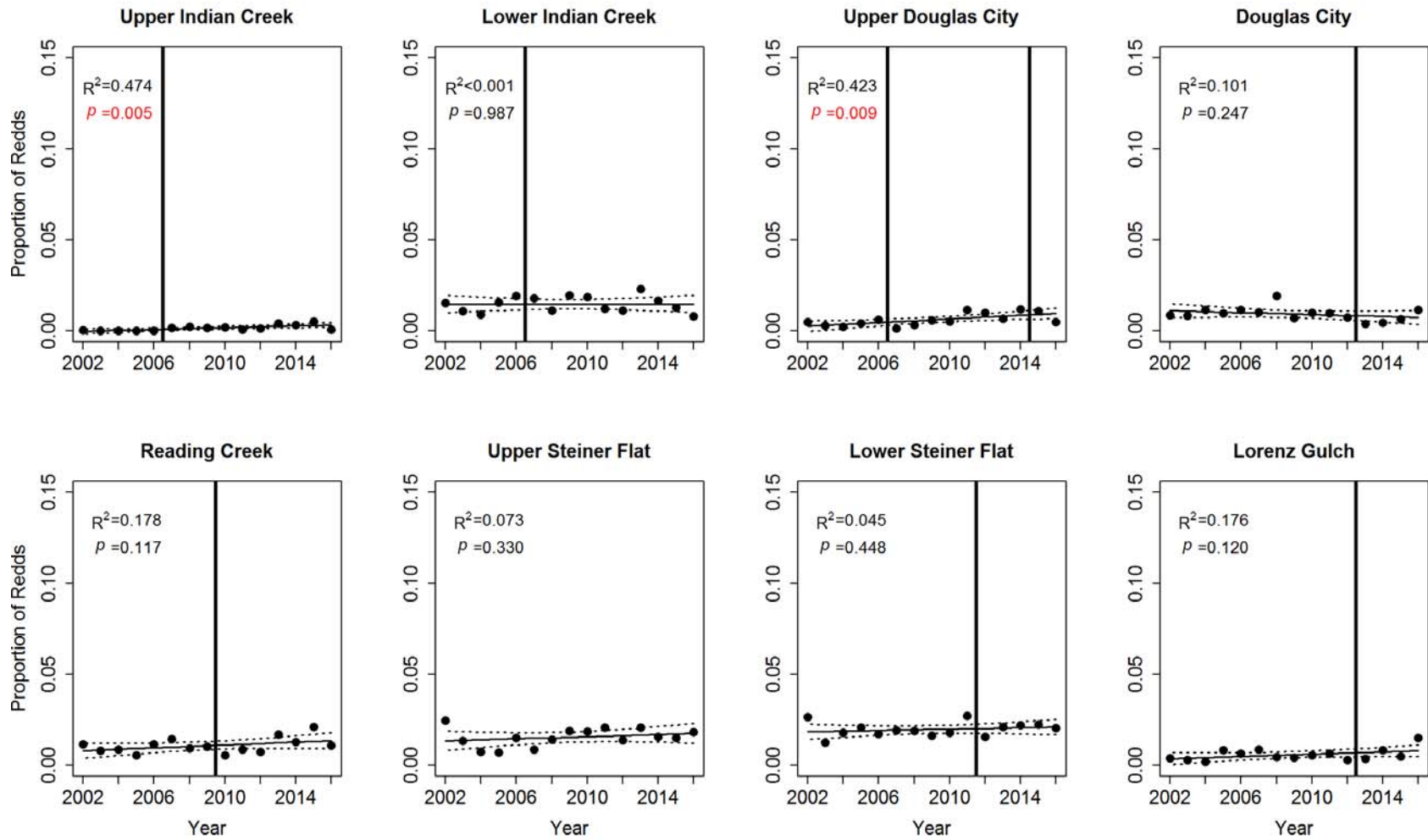
		Ad-clipped												All reaches	
Calendar week	Dates	Reach												n	Pct.
		1	2	3	4	5	6	7	9	10	12	13	14		
36	Aug. 29 - Sep. 4	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep. 5 - 11	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
38	Sep. 12 - 18	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
39	Sep. 19 - 25	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
40	Sep. 26 - Oct. 2	0	-	0	-	-	-	-	-	-	NS	NS	NS	0	0.0%
41	Oct. 3 - 9	0	0	-	-	-	-	-	NS	NS	-	-	-	0	0.0%
42	Oct. 10 - 16	-	0	-	-	-	-	-	NS	NS	NS	NS	NS	0	0.0%
43	Oct. 17 - 23	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
44	Oct. 24 - 30	-	-	-	NS	-	-	-	NS	NS	NS	NS	NS	-	-
45	Oct. 31 - Nov. 6	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
46	Nov. 7 - 13	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
47	Nov. 14 - 20	0	-	-	-	-	-	-	NS	NS	-	NS	NS	0	0.0%
48	Nov. 21 - 27	-	-	NS	NS	NS	-	-	NS	NS	NS	NS	NS	-	-
49	Nov. 28 - Dec. 4	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
50	Dec. 5 - 11	-	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	-	-
51	Dec. 12 - 18	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
52	Dec. 19 - 25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All weeks		0	0	0	-	-	-	-	-	-	-	-	-	0	0.0%



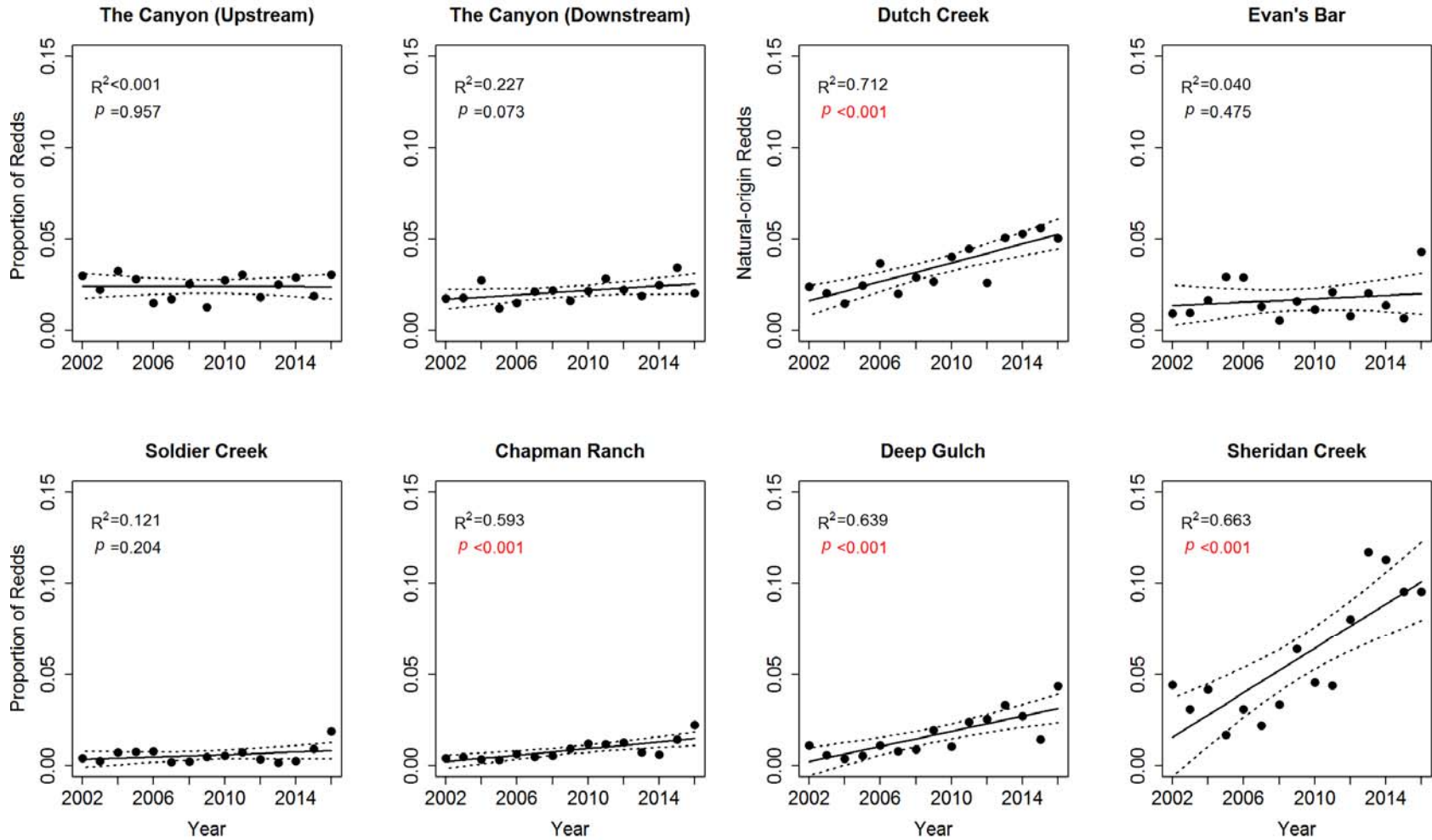
Appendix H. Proportion of TRRP restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars. Note the change in y-axis scale in the Sven Olbertson site.



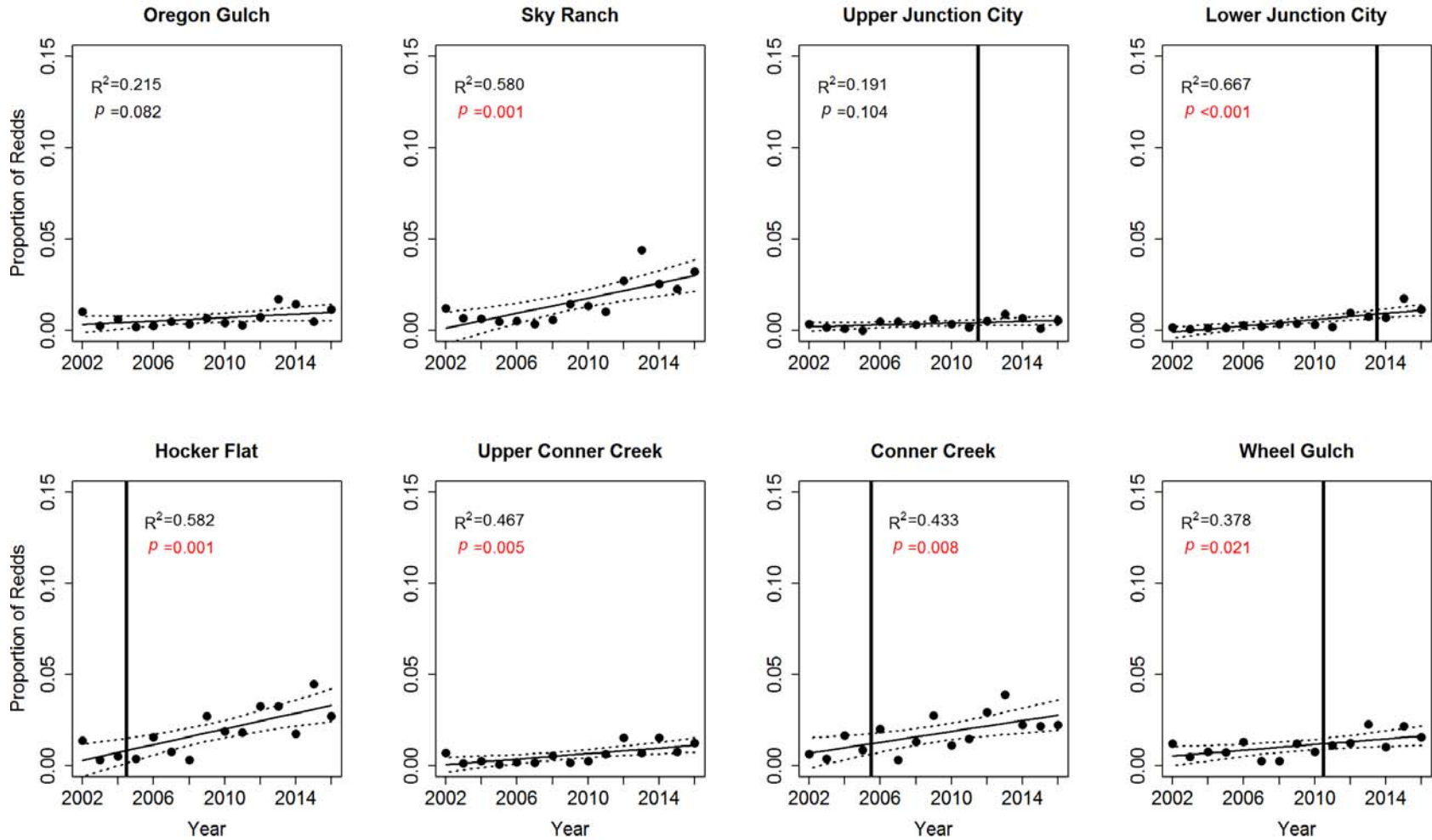
Appendix H (continued). Proportion of restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if < 0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.



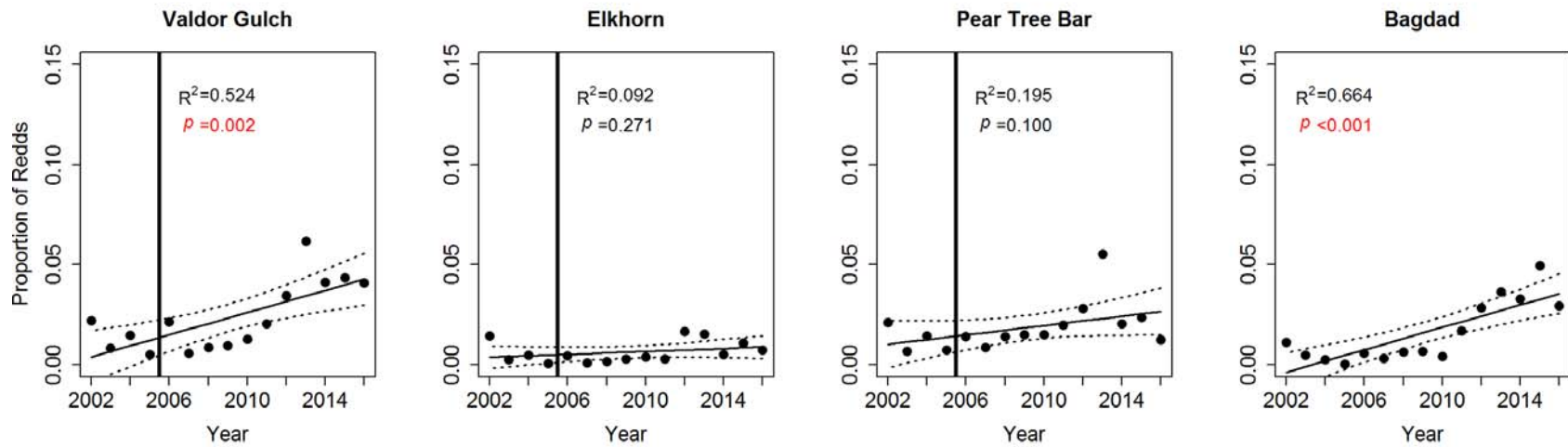
Appendix H (continued). Proportion of restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.



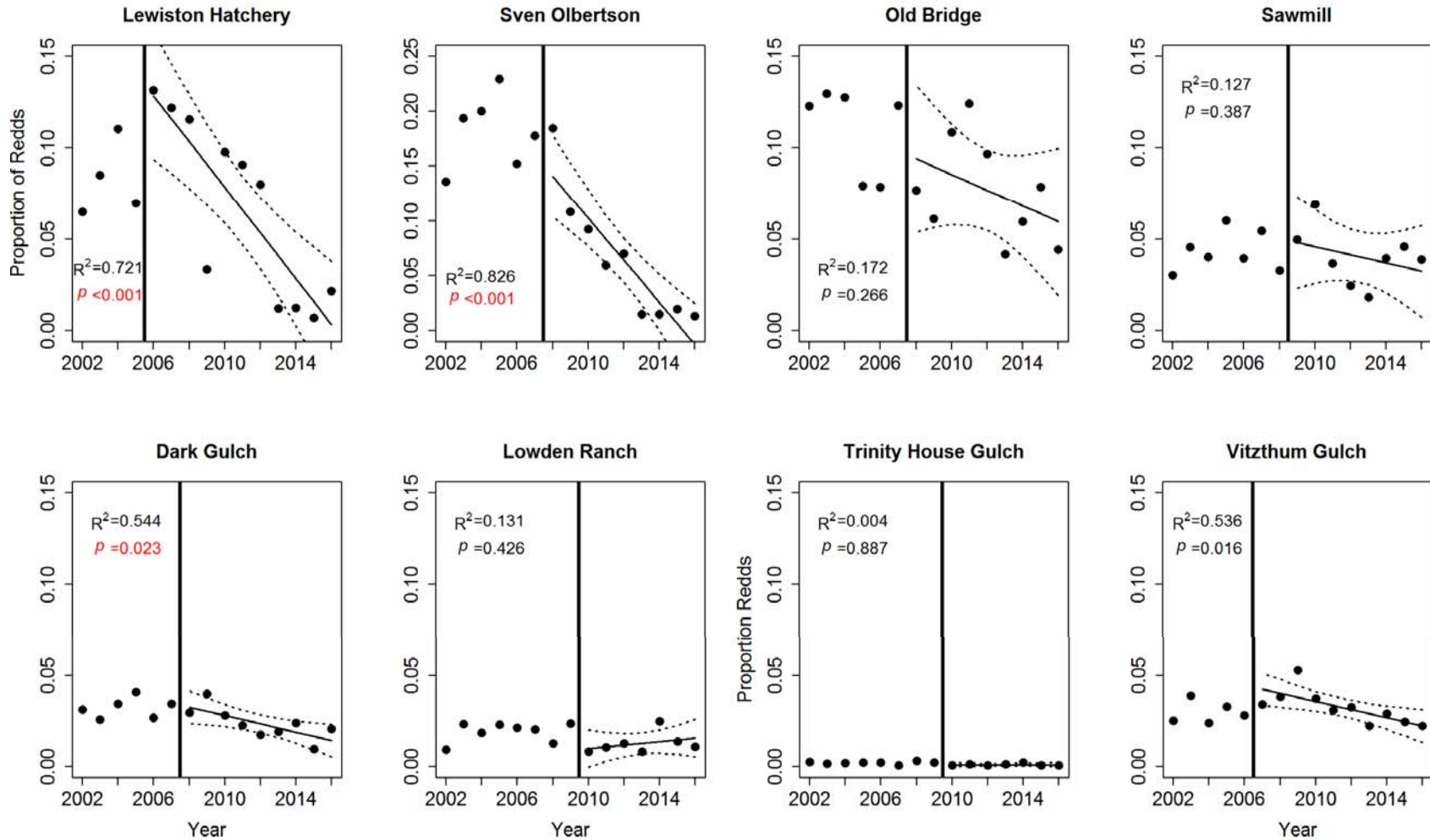
Appendix H (continued). Proportion of restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if < 0.05), and 95% confidence limits (dotted lines).



Appendix H (continued). Proportion of restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.

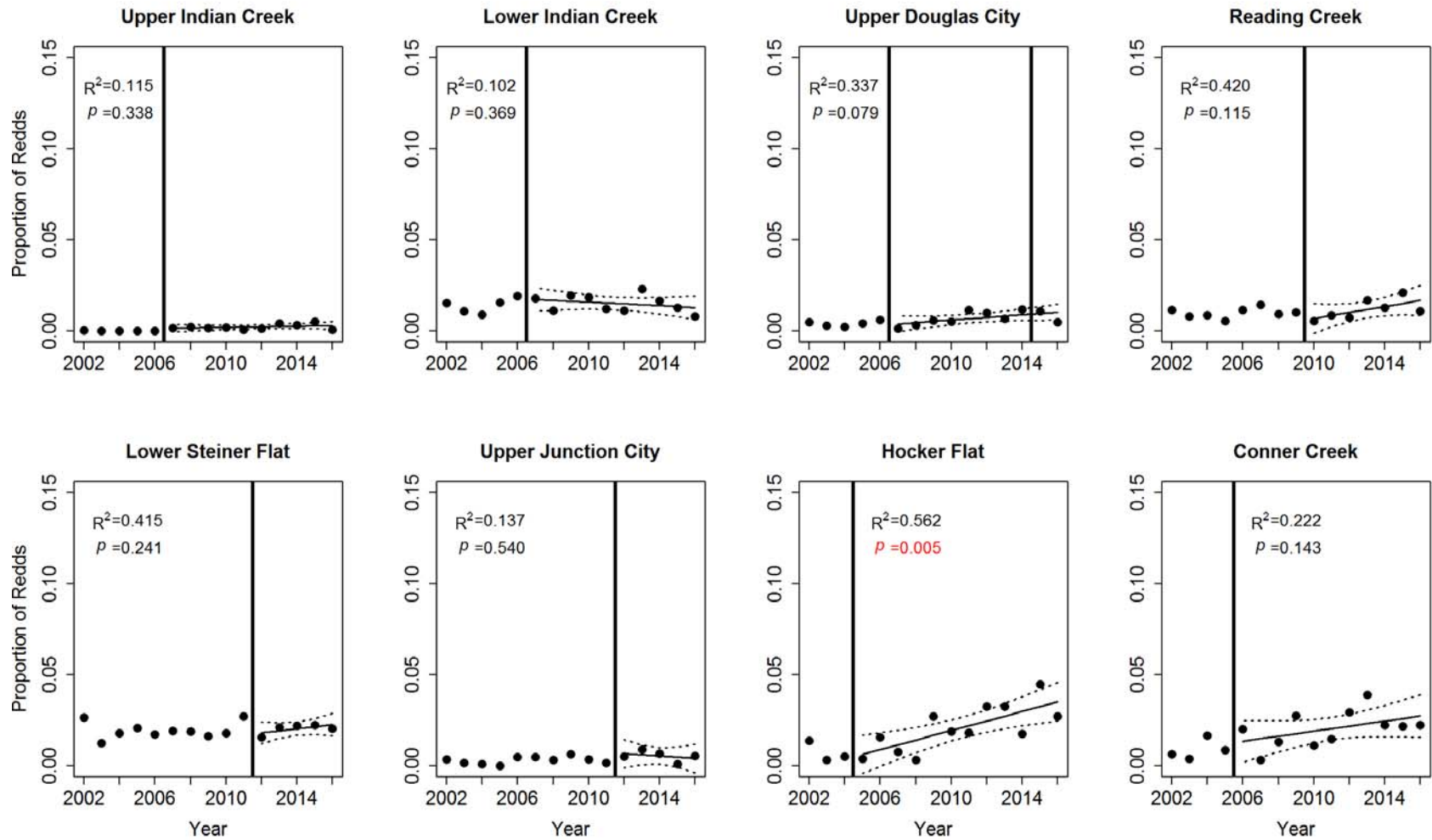


Appendix H (continued). Proportion of restoration reach natural-origin Chinook Salmon redds within site-scale sections, 2002–2016. Each plot includes a linear model with the R^2 value, p -value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.



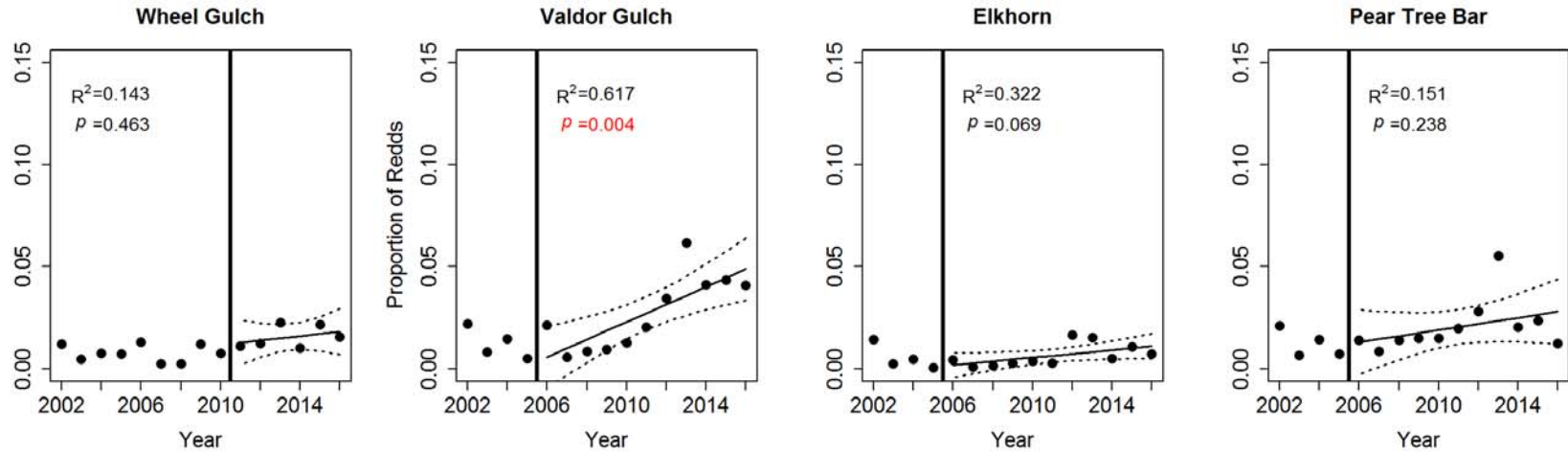
50

Appendix I. Proportion of TRRP restoration reach natural-origin Chinook Salmon redds within site-scale sections that encompass mechanical channel rehabilitation locations with at least five years of post-construction data, 2002–2016. Each plot includes a linear model with the R^2 value, p-value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.

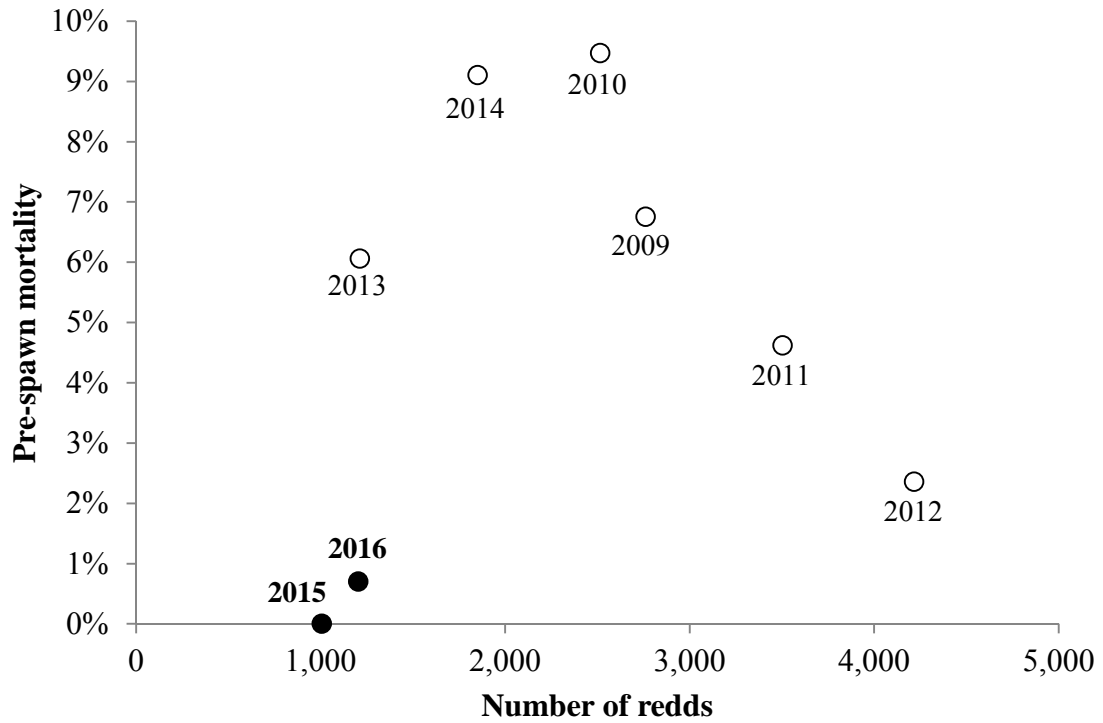


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Appendix I (continued). Proportion of TRRP restoration reach natural-origin Chinook Salmon redds within site-scale sections that encompass mechanical channel rehabilitation locations with at least five years of post-construction data, 2002–2016. Each plot includes a linear model with the R^2 value, p-value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.



Appendix I (continued). Proportion of TRRP restoration reach natural-origin Chinook Salmon redds within site-scale sections that encompass mechanical channel rehabilitation locations with at least five years of post-construction data, 2002–2016. Each plot includes a linear model with the R^2 value, p-value (red if <0.05), and 95% confidence limits (dotted lines). The time mechanical channel rehabilitation was initiated is shown as black vertical bars.



Appendix J. Natural-origin Chinook Salmon redd counts versus estimates of pre-spawn mortality from Lewiston Dam to the North Fork confluence, Trinity River surveys, 2009–2016.