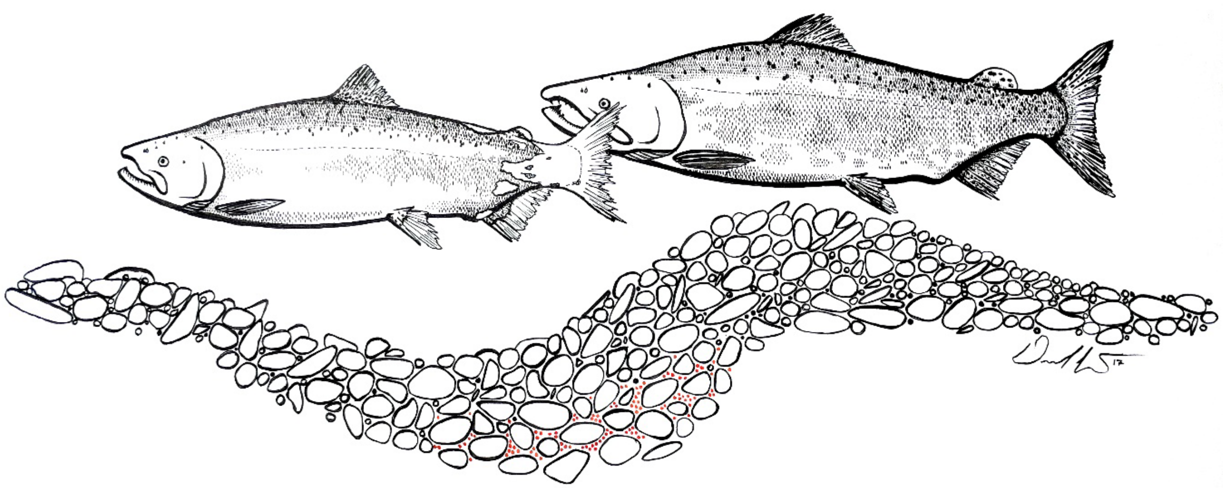
U.S. Fish & Wildlife Service

Arcata Fisheries Technical Report TR 2024-71

Assessment of Adult Salmonid Spawning in the Trinity River

Stephen A. Gough[1], Reuben B. Smit[1], Kenneth Lindke[2], Kyle DeJuilio[3],
Christopher Laskodi[3], George Kautsky[4], and Billy C. Matilton[4]



U.S. Fish and Wildlife Service [1]
Arcata Fish and Wildlife Office
1655 Heindon Road, Arcata, California 95521
(707) 822-7201

California Department of Fish and Wildlife [2]
Arcata, California 95521
(707) 822-4230

Yurok Tribal Fisheries Program [3]
Willow Creek, California 95573
(530) 629-3333

Hoopa Valley Tribal Fisheries Department [4]
Hoopa, California 95546
(530) 625-4267

July 2024

Arcata Fish and Wildlife Office participation in this study was funded by the U.S. Fish and Wildlife Service. Participation of the Yurok Tribal Fisheries Program, Hoopa Valley Tribal Fisheries Department, and California Department of Fish and Wildlife was funded by the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. Shasta–Trinity National Forest participation was funded by the U.S. Forest Service.

The Arcata Fish and Wildlife Office Fisheries Program reports its study findings through two publication series. The **Arcata Fisheries Data Series** was established to provide timely dissemination of data to local managers and for inclusion in agency databases. The **Arcata Fisheries Technical Reports** publishes scientific findings from single and multi-year studies that have undergone more extensive peer review and statistical testing. Additionally, some study results are published in various professional fisheries journals.

To ensure consistency with Service policy relating to its online peer-reviewed journals, Arcata Fisheries Data Series and Technical Reports are now completely electronic and made available in the public domain. Paper copies will no longer be distributed.

keywords: carcass, Chinook Salmon, Coho Salmon, dewater, escapement, harvest, hatchery, pre-spawn mortality, redd, restoration, steelhead, superimposition, Trinity River

The correct citation for this report is:

Gough, S. A., R. B. Smit, K. Lindke, K. DeJuilio, C. Laskodi, G. Kautsky, B. C. Matilton. 2024. Assessment of Adult Salmonid Spawning in the Trinity River. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2024-71, Arcata, California.

Table of Contents

Table of Contents (continued)

Page

List of Tables

List of Tables (continued)

Page

List of Tables (continued)

Page

List of Figures

List of Figures (continued)

Page

List of Figures (continued)

Page

List of Figures (continued)

Page

List of Appendices

List of Appendices (continued)

Page

Assessment of Adult Salmonid Spawning in the Trinity River

Stephen A. Gough[1], Reuben B. Smit[1], Kenneth Lindke[2], Kyle DeJuilio[3], Christopher Laskodi[3], George Kautsky[4], and Billy C. Matilton[4]

[1] U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office
1655 Heindon Road, Arcata, California 95521
steve_gough@fws.gov
reuben_smit@fws.gov

[2] California Department of Fish and Wildlife
5341 Ericson Way, Arcata, California 95521
kenneth.lindke@wildlife.ca.gov

[3] Yurok Tribal Fisheries Program
Highway 96 Box 36, Willow Creek, California 95573
kdejuilio@yuroktribe.nsn.us
claskodi@yuroktribe.nsn.us

[4] Hoopa Valley Tribal Fisheries Department
P.O. Box 417, Hoopa, California 95546
hupafish@hoopa-nsn.gov
bmatilton@hoopa-nsn.gov

Abstract.— The Trinity River Restoration Program seeks to restore and maintain salmonid habitats in the Trinity River downstream of Lewiston Dam, California. To help monitor the effectiveness of the Program, and to guide the work going forward, we reviewed past reports and provided synthesized information to rehabilitation site designers for future restoration efforts. Escapement of spring- and fall-run Chinook Salmon, Coho Salmon, and steelhead to natural spawning areas and to the Trinity River Hatchery from 1978 to 2018 are summarized, as are natural- and hatchery-origin compositions, tributary use, and pre-spawn mortality from various monitoring projects. Trends in spawning distribution from redd surveys were assessed using data sets from 2002 to 2017 at restoration site, restoration reach, and system scales. Further analyses in this report include response to flow management, redd superimposition and dewatering, and a comparison of the responses of Chinook Salmon spawning between restored and unrestored areas.

1. Introduction

1.1 Trinity River Description and Background

The Trinity River, California, the principal tributary of the Klamath River, once supported large populations of naturally produced anadromous salmonids, including spring- and fall-run Chinook Salmon *Oncorhynchus tshawytscha* (Figure 1; 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 run 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 [river kilometer (rkm) 182.2], 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 funded by the U.S. Bureau of Reclamation, operated by California Department of Fish and Wildlife (CDFW), and co-managed by the Hoopa Valley Tribe (HVT) and Yurok Tribe Fisheries Program (YTFP) to mitigate the loss of Chinook Salmon, Coho Salmon *O. kisutch*, and steelhead *O. mykiss*, the anadromous life-history form of Rainbow Trout, 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 (near rkm 150).

1.2 Trinity River Restoration Program

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 (USDOI 2000) and the Trinity River Restoration Program (TRRP) was established. The goal of the TRRP is

> to restore the form and function of the Trinity River; restore and sustain natural production of anadromous fish populations in the Trinity River to pre-dam levels; and to facilitate full participation by dependent tribal, commercial and sport fisheries through enhanced harvest opportunities (adopted during TRRP refinements meeting November 15, 2019).

To achieve this goal, the TRRP implements a suite of actions (i.e., flow management, mechanical channel rehabilitation, coarse sediment augmentation, and watershed restoration) to restore riverine habitats and restore habitat-creating alluvial processes (USFWS and HVT 1999; USDOI 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 confluence, the Trinity River valley narrows 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).

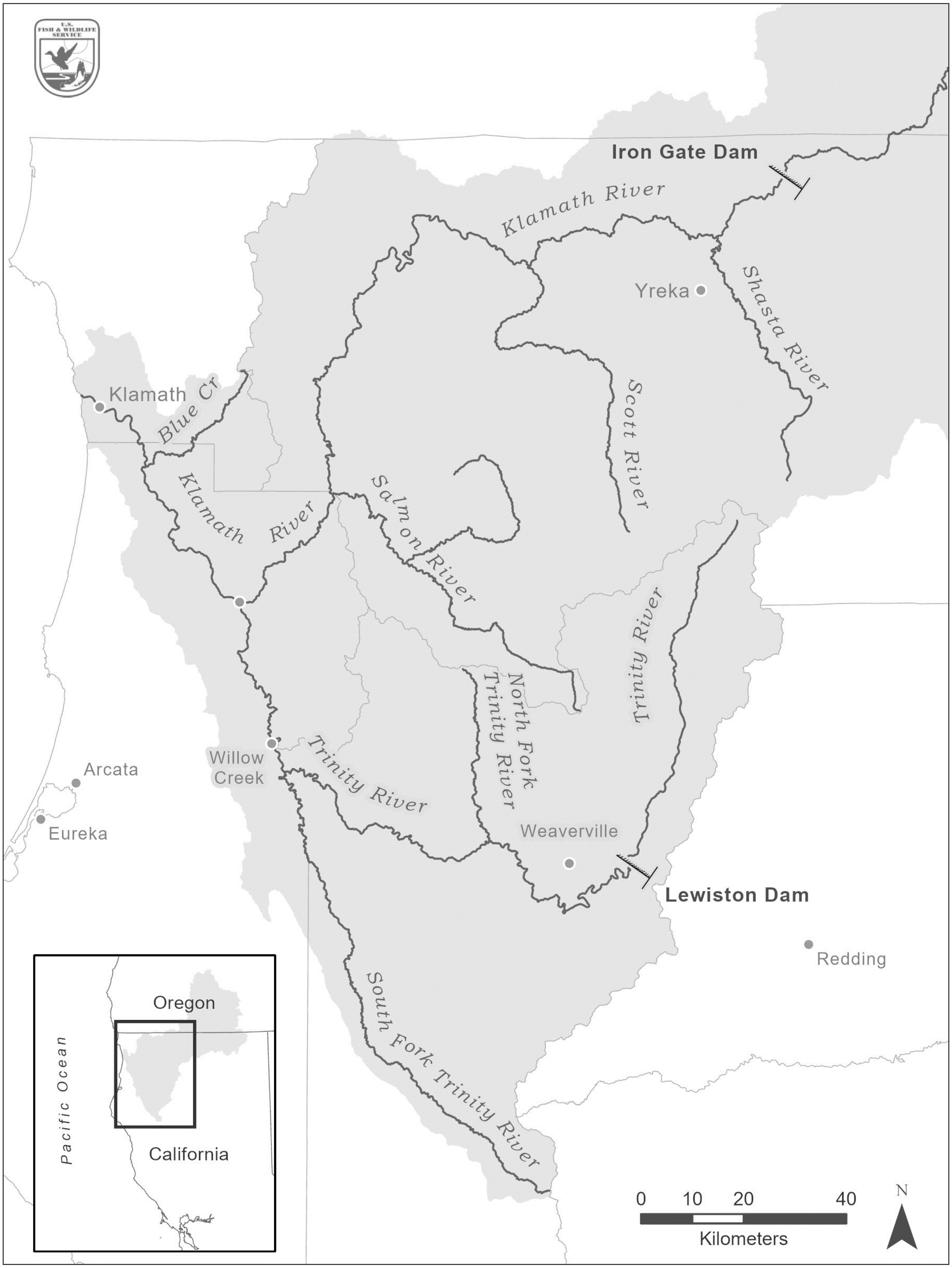


Figure 1. Map of the Klamath River Basin with major tributaries.

1.3 Integrated Assessment Plan — Objectives and Hypotheses

TRRP has identified the need to complete synthesis reporting of the salmonid redd, carcass, pre-spawning mortality, and escapement data, as part of long-term monitoring projects, to help inform the effectiveness of the program at meeting programmatic goals and objectives. This report will summarize and analyze the multi-year datasets and adult salmonid spawning abundance and distribution on the mainstem Trinity River, hatchery/natural composition in the entire anadromous basin upstream of Willow Creek Weir, pre-spawning mortality of Chinook Salmon in relation to summer/fall thermal regimes, and comparison of spawning escapement to TRRP spawning escapement goals. Information evaluated for this report addresses these components from Objectives 3 and 4 in the TRRP Integrated Assessment Plan (IAP; TRRP and ESSA 2009):

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

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

3.1.1. Optimize adult utilization of suitable spawning habitat areas in the mainstem within 3-4 brood cycles following rehabilitation of fluvial river processes

3.1.3. Reduce temperature related pre-spawning mortality and protect in-vivo egg viability of anadromous spawners in the mainstem Trinity River

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

Objective 4: 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

Sub-objective 4.1: Increase naturally produced fall-run Chinook Salmon adult production to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity

4.1.1. Increase escapement of naturally produced fall-run Chinook Salmon to 62,000 adults

Sub-objective 4.2. Increase naturally produced spring-run Chinook Salmon adult production to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity

4.2.1. Increase escapement of naturally produced spring-run Chinook Salmon to 6,000 adults

Sub-objective 4.3: Increase naturally produced Coho Salmon adult production to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity

4.3.1. Increase escapement of naturally produced Coho Salmon to 1,400 adults

Sub-objective 4.4. Increase naturally produced steelhead adult production to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity

4.4.1. Increase escapement of naturally produced steelhead to 40,000 adults

The IAP proposes assessing spawning at three spatial scales: (1) system, (2) reach, and (3) site. 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".

1.4 Purpose of This Report

Information generated by this report will help inform the TRRP on the response of adult salmonid spawners to collective and individual (e.g., flow, temperature) management actions. Additionally, this report can be used in future integrative synthesis reports that will combine information from other assessments for a program-wide synthesis report.

1.5 Existing Data Sources

The two main on-going monitoring projects from which data was compiled for this report were the weir operations led by CDFW in partnership with the HVT and spawning ground surveys organized by U.S. Fish and Wildlife Service (USFWS) in partnership with CDFW, HVT, YTFP, and U.S. Forest Service's Shasta–Trinity National Forest (USFS).

Annual escapement estimates of spring- and fall-run Chinook Salmon to natural spawning grounds in the Trinity River since 1978 are maintained by CDFW in the Klamath Basin 'megatables' (CDFW 2019a, 2019b). Escapement has been estimated for Chinook Salmon, Coho Salmon, and steelhead over this time period by a variety of methods. Since 1978, CDFW has led operations of two weirs in the mainstem Trinity River, one near the town of Willow Creek (Willow Creek Weir; WCW) and one near the town of Junction City (Junction City Weir; JCW). CDFW has partnered with the HVT since 1995 to conduct weir operations. Chinook Salmon, Coho Salmon, and steelhead are tagged at weirs with individually numbered 2-mm 'spaghetti' tags (Floy Tag and Manufacturing, Inc. FT-4) and released upstream to resume their spawning migration. Tagged and untagged fish are subsequently captured at TRH to constitute the recovery sample in a capture-recapture experiment. Natural- and hatchery-origin components of the run are separated based on species-specific marks (i.e., fin or maxillary clip) applied to juveniles prior to release from the hatchery. In addition, coded-wire tags (CWT) are used to separate spring and fall runs of Chinook Salmon. Further details for each species and run are provided below.

Salmon spawning ground surveys for redds and carcasses have been conducted on the Trinity River below Lewiston Dam since 2002. The redd surveys are documented in USFWS data series and technical reports (Chamberlain et al. 2012; Rupert et al. 2017a, 2017b; Gough et al. 2019). Carcass surveys prior to 2012 are documented in CDFW annual reports (Sinnen 2004a, 2004b; Currier and Sinnen 2005; Knechtle and Currier 2006; Garrison 2008; Hill 2009, 2010a, 2010b, 2011, 2013a, 2013b) and in the USFWS reports listed above after 2011. Methods used for these surveys are further detailed in the USFWS annual reports and below in Section 3.1. The pre-spawn mortality data sets from the CDFW and USFWS reports were extended to include data from 1978 to 1995 (Aguilar et al. 1996).

2. Adult Salmonid Monitoring and Escapement

This section details the data sources, methods, results, and analyses from the adult salmonid monitoring project from 1978 to 2018 on the mainstem Trinity River, California. Detailed methods of escapement, harvest, hatchery returns and separation of natural-origin and hatchery-origin fish for all species upstream of WCW and JCW can be found in Keir et al. (2019). Methods for tributary surveys downstream of WCW and spring-run Chinook Salmon dive surveys downstream of JCW are presented for the first time herein. The objectives of this project were to:

1) Estimate annual escapement of fall- and spring-run Chinook Salmon, Coho Salmon, and steelhead from data collected at the Willow Creek and Junction City weirs, tributary dive surveys, and angler harvest.
2) Quantify annual returns of natural- and hatchery-origin fall- and spring-run Chinook Salmon, Coho Salmon, and steelhead to the Trinity River Hatchery.

2.1 Data Sources and Methods

2.1.1 Fall-run Chinook Salmon

A subset of the fall-run Chinook Salmon population was trapped annually at WCW, which was typically operated from August into November (Appendix A). Captured Chinook Salmon were marked by applying individually numbered spaghetti tags (Floy Tag and Manufacturing, Inc. FT-4) and then released upstream of the weir to continue their spawning migration (Keir et al. 2019). In some years trapping operations encompassed the end of the spring-run Chinook Salmon migration, in which case spring and fall runs at WCW were separated based on CWT recoveries from weir-tagged fish at TRH. After tagging and before recovery at TRH, some tags were removed from the marked population either by catch-and-release anglers or suspected tagging mortality. The number of "effectively" marked fish was then estimated by subtracting tags removed by catch-and-release anglers and tagging mortalities from the marked population. Assumed tagging mortalities included fish found dead and unspawned less than 30 days after tagging during spawning ground surveys, washed back on the weir, or during bi-weekly boat surveys conducted in the 5 km upstream of the weir. Weir-tagged and untagged fall-run Chinook Salmon returning to TRH constitute the recapture sample of the capture-recapture experiment to estimate the total run upstream of WCW.

Age-specific abundances of the total run upstream of WCW and returns to TRH were estimated from scales collected at those facilities using bias corrections from scales of known-age fish based on CWT recoveries. These abundances were used to estimate total returns to natural spawning areas by subtracting age-specific abundances of TRH returns from age-specific abundances of total returns upstream of WCW. Harvest was estimated from angler return of reward and non-reward tags and was subtracted from estimates of the total run to yield estimates of escapement upstream of WCW. Under the current study design, model assumptions are largely met, thus limiting bias in the estimates of total run size (Hankin 2001; Bradford and Hankin 2012). However, underestimation of a harvest estimate would result in an overestimate of escapement using current methods. Harvest estimates rely on complete returns of higher valued reward tags by anglers, which may not occur in all years.

For purposes of this report, all adult age classes were combined, and age-2 fish (i.e., jacks) were excluded from the analysis. The number of hatchery-origin fish (N_h) in each of three sectors (total escapement, natural area escapement, and hatchery returns) was estimated by expanding CWT recoveries from hatchery-marked fish by respective sampling rates and associated production multipliers (Kier et al. 2019). The number of natural-origin fish (N_n) was then estimated by subtracting the number of hatchery-origin fish from the estimated total number of fish (N) within each sector. At TRH, CWTs have been applied to fall Chinook Salmon since 1978, but the proportion of tagged fish varied considerably through brood year 1999. In Brood Year 2000, a constant fractional marking program was instituted with an aim to tag 25% of the fish in each release group. This change in marking methods increased the accuracy and consistency in separating hatchery- and natural-origin components. In this report, estimates of hatchery- and natural-origin fish are separated beginning in 2002 when the first fish subjected to constant fractional marking returned to the Trinity River.

Escapement estimates downstream of WCW were derived from redd surveys conducted in the mainstem Trinity River, which are described in Section 3 (also see Appendix A). In addition, weekly spawning ground surveys were conducted from September until as late as November, as conditions allowed, in tributary streams on the Hoopa Valley Reservation (HVR), including Tish Tang, Campbell, Supply, Hostler, Mill, and Soctish creeks. Surveys began in tributaries in 1999 and in the mainstem in 2001. Tish Tang, Campbell, and Soctish creeks were surveyed from their confluences to the end of anadromy whereas Supply, Hostler, and Mill creeks were surveyed from their confluences to where crews were able to cover in a single day. Above the HVR and below WCW, Horse Linto Creek was surveyed by USFS on a weekly or bi-weekly basis as conditions and funding allowed. Flagging was placed near observed redds to avoid double counting in subsequent surveys. Adult abundances in the mainstem and HVR tributaries were estimated by multiplying the total redd count by two. Adult abundances in Horse Linto Creek were estimated as the sum of redds multiplied by two, plus live adults observed during the last survey day. Escapement estimates provided in this report include these additional fish when estimates were available (i.e., starting in 1999 and 2002), which comprise 12% or less (mean = 5%) of totals in all years.

2.1.2 Spring-run Chinook Salmon

Returns of spring-run Chinook Salmon to the Trinity River have only been consistently estimated upstream of JCW since 1980 (excluding 1983 and 1995 due to lack of funding), with additional surveys with less rigor and consistency conducted in major tributaries (Appendix B). The methods for estimating escapement upstream of JCW are essentially the same as for fall-run Chinook Salmon upstream of WCW except for age classification. Jacks were separated from the estimated spring-run population by identifying a length cutoff as the nadir on length-frequency histograms generated from Chinook Salmon measured at JCW. The jack proportion was then applied to the estimated spring-run population to produce an estimate of spring-run jacks above JCW. The remainder of the spring-run population, after jacks were removed, were considered adults and no attempt was made to further distinguish adult age classes. Annual trapping at JCW typically began in June, when flow conditions allowed for safe installation of the weir, and continued until the end of the spring run, which was commonly observed in late-September. Trapping continued as late as December in some years but for purposes unrelated to targeting spring-run Chinook Salmon.

Downstream of JCW, single-pass dive surveys have been conducted annually since 1980 in the South Fork Trinity River, Hayfork Creek, North Fork Trinity River, Canyon Creek, and the New River. Spring-run Chinook Salmon were visually identified and categorized as a jack (<56 cm total length) or adult (≥56 cm total length) using a visual length estimate. The total count of adults observed during the surveys were used as a minimum estimate of escapement for these tributaries, and all fish observed were assumed to be of natural origin. Estimates of total escapement provided in this report are the sum of capture-recapture estimates upstream of JCW and the minimum estimates in tributaries downstream of the weir. Some tributaries or reaches were not surveyed in some years due to staffing or safety concerns.

2.1.3 Coho Salmon

Returns of Coho Salmon upstream of WCW were estimated using the same capture-recapture methods described in Section 2.1.1 with a few modifications explained here. All tags applied to Coho Salmon have been non-reward tags since 1998. Jacks and adults were distinguished by a length cutoff determined annually by the nadir of length-frequency distributions. Like Chinook Salmon, age-specific abundances in natural spawning grounds were estimated by subtracting age-specific abundances at TRH from age-specific abundances of the estimated total run upstream of WCW. Hatchery-origin Coho Salmon were determined by the presence of right maxillary-clips. No production multiplier was applied to account for unmarked hatchery Coho Salmon since ≈100% of Coho Salmon have a right maxillary-clip applied prior to release from TRH. Legal harvest of Coho Salmon ended in 1997 when they were listed as threatened under the federal Endangered Species Act (ESA; NMFS 1997). However, occasional harvest has occurred since 1997 (e.g., due to the misidentification of species by anglers) and program spaghetti tags continue to be removed by catch-and-release anglers. Any poaching that occurred was assumed to affect tagged and un-tagged fish at the same rates, and therefore did not affect capture-recapture estimates. To minimize removal of program tags, only non-reward tags are applied to Coho Salmon so that anglers do not have an incentive to remove tags from fish that are illegal to harvest. Harvested and catch-and-release fish were accounted for using the same methods as for the other species described in Section 2.1.1. Coho Salmon escapement to tributaries of the Trinity River downstream of WCW are not included in this report. Coho Salmon are observed incidentally during spawning ground surveys for Chinook Salmon (see Section 3), but these surveys ended before the majority of Coho Salmon spawning occurred in almost all years. Direct counts of Coho Salmon observed during these surveys are presented where available.

2.1.4 Steelhead

Considerable debate remains among experts over the number and timing of runs of steelhead in the Klamath and Trinity Rivers and of the portions of runs that are represented by the capture-recapture estimates upstream of WCW. According to the status review for Klamath Mountains Province steelhead, two run types are generally recognized in North America, summer and winter (Busby et al. 1994). However, many experts who work in the Klamath Basin recognize three distinct runs: summer, fall, and winter. CDFW states that estimates upstream of WCW are for fall-run steelhead but acknowledge the estimate likely includes portions of the summer and winter runs (Sinnen et al. 2011). Regardless of what run(s) are represented by CDFW estimates, these estimates are known to represent some unknown proportion of the total steelhead run in the Trinity River. The foundational documents of the TRRP (e.g., USFWS 1983; USFWS et al. 2000; TRRP and ESSA 2009) do not distinguish among steelhead runs when presenting escapement and hatchery targets, thus TRRP targets were assumed to refer to the combined total of all runs of steelhead in the Trinity River. Consequently, the estimates provided herein are not comparable to the TRRP target of 40,000 natural-origin adult steelhead returns to natural spawning grounds, and no estimates are available to compare to that target. In contrast, estimates of hatchery-origin returns of steelhead to TRH are comparable to the TRRP hatchery escapement target of 10,000 adults. In this report steelhead runs were not separated.

Returns of steelhead upstream of WCW were estimated using the same capture-recapture methods described in Section 2.1.1 with a few modifications. All captured steelhead that measured ≥42 cm fork length (FL) were considered adults, and no attempt was made to distinguish adult age classes. Steelhead <42 cm FL were not tagged nor included in the estimate. Hatchery- and natural-origin components were determined using the same method as for Coho Salmon since 100% of the juvenile steelhead have an adipose fin-clip applied prior to release from TRH. Like Coho Salmon, no production multiplier is used to adjust for unmarked hatchery steelhead. Legal harvest of natural-origin steelhead ceased in 1998, but harvest is still allowed for hatchery-origin fish. Harvest and catch-and-release fish were accounted for using the same methods described in Section 2.1.1. Escapement of steelhead to tributaries downstream of WCW were not monitored. Additionally, steelhead are known to enter the mainstem Trinity River and migrate upstream throughout the year (Busby et al. 1994), thus the period of weir operation coincided mostly with ‘fall’ steelhead run and missed a substantial but unknown portion of the ‘summer’ and ‘winter’ runs. Because steelhead monitoring did not include the entire duration and distribution of adult returns, estimates reported here are an escapement index rather than an estimate of total escapement.

2.2 Annual Escapement Estimates

Escapement in this section pertains to fish returning to natural spawning areas of the Trinity River and to TRH. Escapement to natural spawning grounds and returns to TRH are also reported independently in Sections 2.3 and 2.4, respectively. For further analyses comparing pre-ROD (1978–2004) and ROD (2005–2018) escapement, see Section 4.2 in this report.

2.2.1 Fall-run Chinook Salmon

Annual escapement estimates of fall-run Chinook Salmon to the Trinity River, including natural spawning areas and returns to TRH, from 1978 to 2018 ranged between 4,704 in 2016 and 111,952 in 1986 (median = 24,048; Figure 2; Appendix C). Since 2002 the annual percentage of the returns that were natural-origin fish ranged between 7.8% in 2004 and 67.4% in 2016 (mean = 45.4%) and was above 40% in most years. Some of the lowest returns on record (2015–2017) occurred after implementation of the ROD, but these are not unprecedented. Similarly low returns occurred in 1984 and from 1990 to 1993. The median total return following full implementation of the ROD (25,471) was higher than before full implementation (23,049).

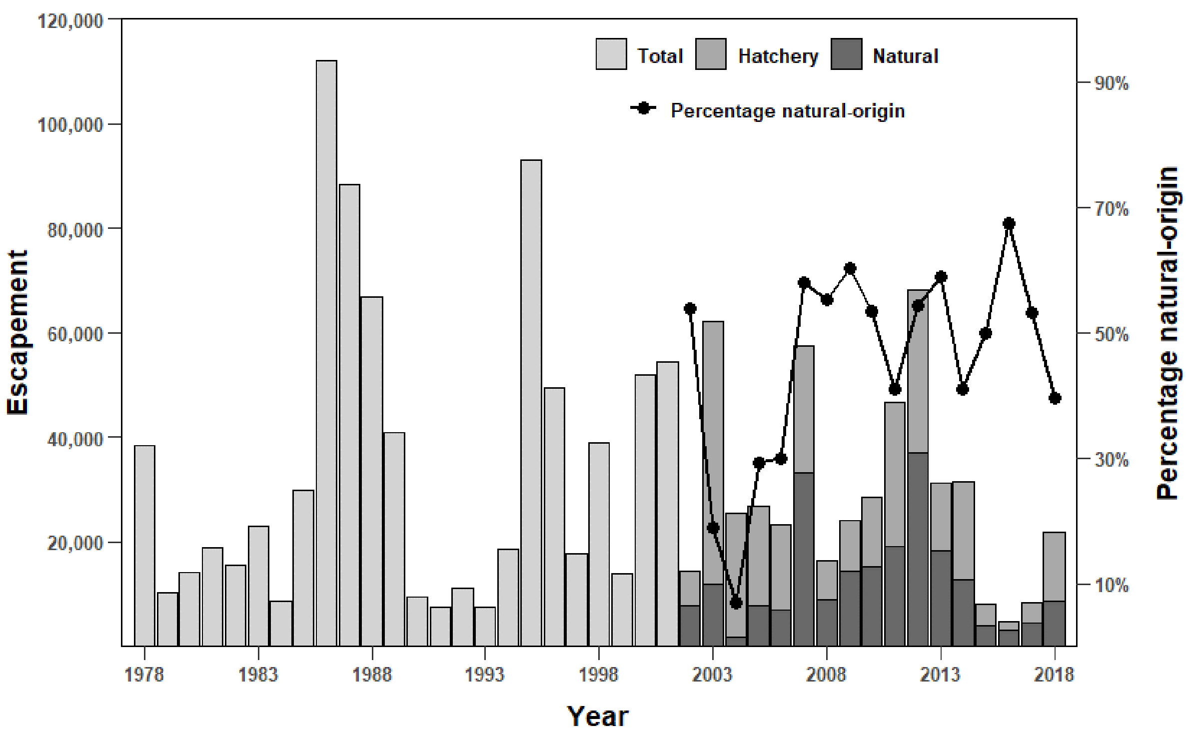


Figure 2. Time series of fall-run Chinook Salmon returning to natural spawning grounds and Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 2002, so only total escapements are provided for those years.

2.2.2 Spring-run Chinook Salmon

Annual escapement estimates of spring-run Chinook Salmon to the Trinity River, including natural spawning areas and returns to TRH, from 1980 to 2018 ranged between 930 in 1983 and 53,566 in 1988 (median = 8,899; Figure 3; Appendix D). Escapement of natural-origin spring-run Chinook Salmon from 2002 to 2018 ranged between 1,090 in 2015 and 13,268 in 2003 (median = 3,120). Since 2002, the annual percentage of the returns that were natural-origin fish ranged between 19.6% in 2007 and 59.4% in 2010 (mean = 37.8%). Unlike fall-run Chinook Salmon, the lowest returns of spring-run Chinook Salmon occurred prior to full implementation of the ROD. Despite the four lowest total annual returns occurring pre-ROD (1980, 1984, 1991, and 1992), the median return pre-ROD (12,622) was higher than the median return since full implementation (7,404).

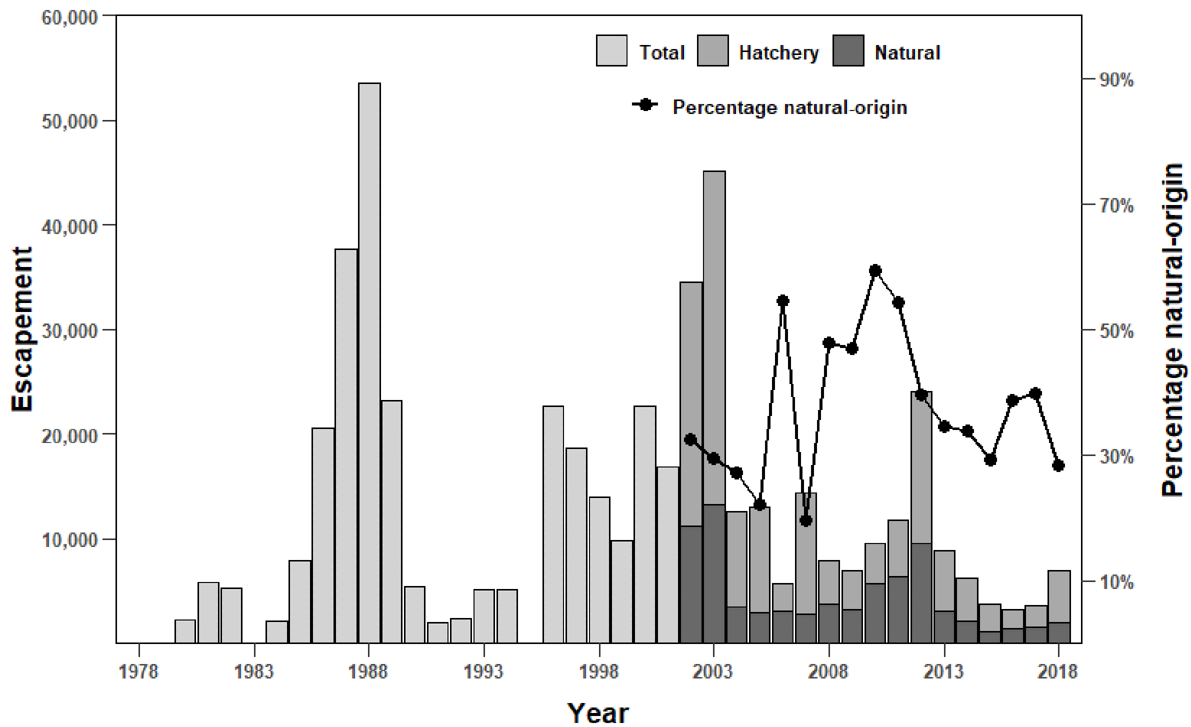


Figure 3. Time series of spring-run Chinook Salmon returning to natural spawning grounds and Trinity River Hatchery from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately before 2002, so only total escapements are provided for those years. Estimates are not available for years 1983 and 1995.

2.2.3 Coho Salmon

Annual escapement estimates of Coho Salmon to the Trinity River, including natural spawning areas and returns to TRH, from 1978 to 2018 ranged between 239 in 1994 and 48,871 in 1987 (median = 7,937; Figure 4; see also Appendix E). Escapement of natural-origin Coho Salmon since 1997 ranged between 44 in 2018 and 8,901 in 2004. Since 1997, the annual percentage of the returns that were natural-origin fish ranged between 3.4% in 2000 and 27.0% in 2004 (mean = 13.2%). Like spring-run Chinook Salmon, the median total return since full implementation of the ROD (5,994) was lower than pre-ROD (8,836).

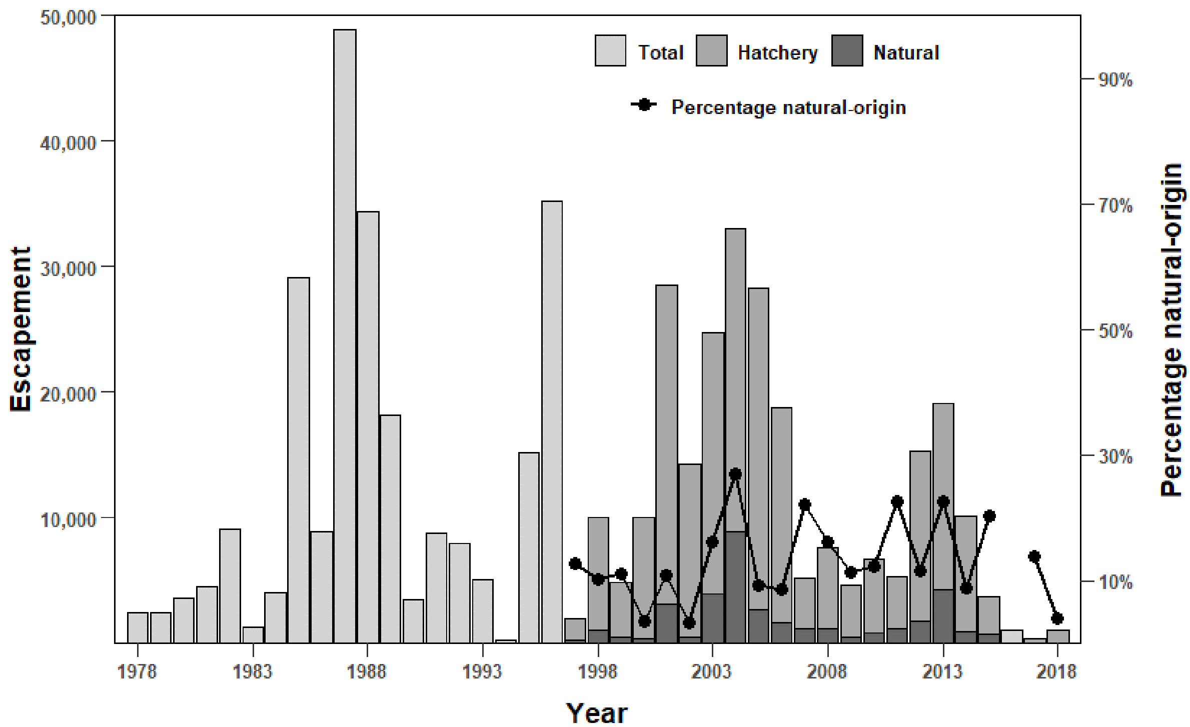


Figure 4. Time series of Coho Salmon returning to natural spawning grounds and Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 1997, so only total escapements are provided for those years.

2.2.4 Steelhead

Annual escapement index estimates of steelhead to the Trinity River, including natural spawning areas and returns to TRH, from 1980 to 2018 ranged between 2,754 in 1992 and 50,725 in 2007 (median = 9,460; Figure 5; Appendix F). Escapement indices of natural-origin steelhead since 1980, for years from which data are available, ranged from between 1,186 in 1993 and 14,564 in 1980. The annual percentage of the returns that were natural-origin fish ranged between 14.7% in 2007 and 81.3% in 1982 (mean = 39.7%). Unlike spring-run Chinook and Coho salmon, the median total return of steelhead was higher since full implementation of the ROD (15,263) compared to pre-ROD (7,563).

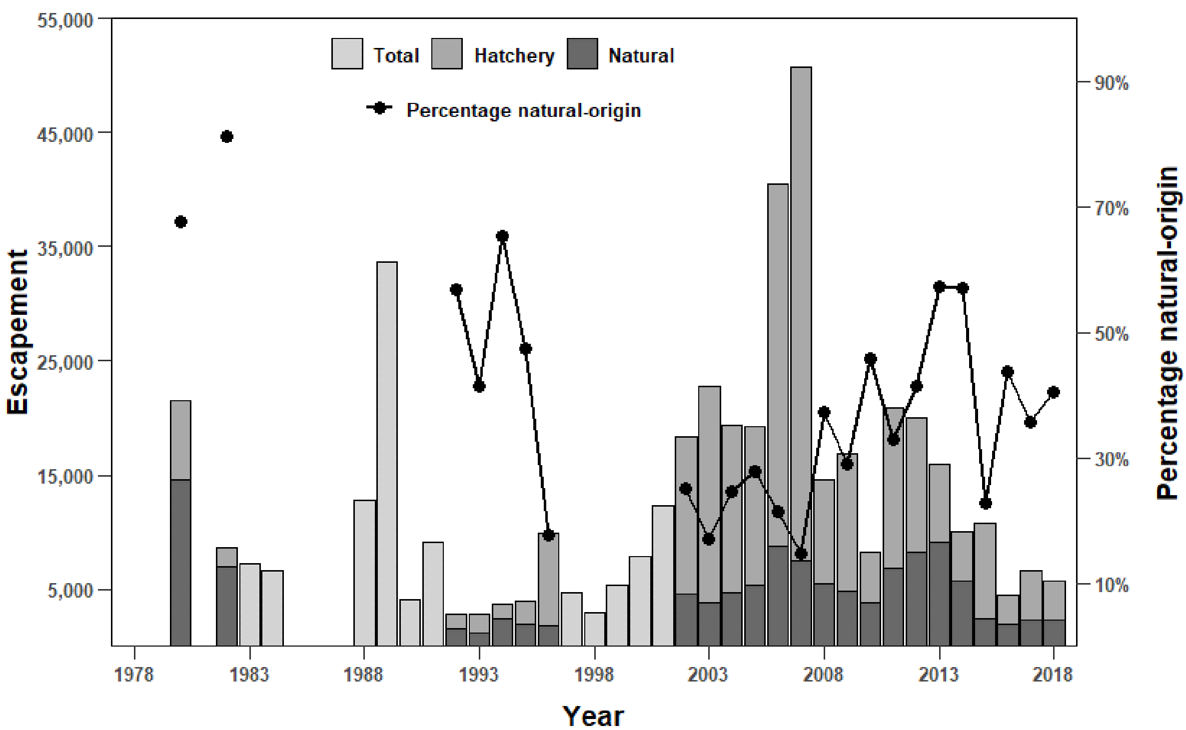


Figure 5. Time series of steelhead escapement indices returning to natural spawning grounds and Trinity River Hatchery from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement indices are provided for those years. Estimates are not available for years 1981 and 1985–1987.

2.3 Natural Area Escapement

2.3.1 Fall-run Chinook Salmon

Annual escapement estimates of fall-run Chinook Salmon to natural spawning areas in the Trinity River from 1978 to 2018 ranged between 3,562 in 2016 and 92,548 in 1986 (median = 15,216; Figure 6; Appendix G). Since full implementation of the ROD, median annual escapement to natural spawning areas was 15,956 fish, whereas the mean prior to full implementation was 13,168. Escapement of natural-origin fall-run Chinook Salmon to natural spawning areas since 2002 ranged between 1,177 in 2004 and 36,136 in 2012, and never met the TRRP target of 62,000. The TRRP target may have been met in 1986 if the percentage of natural-origin fish was 67% or greater. The target may have also been met in 1987 and 1995, but the percentage of natural-origin fish would need to have been greater than 86% and 79%, respectively. Escapement targets pre-date the Trinity River Basin Fish and Wildlife Management Program and are intended to reflect pre-dam levels (USFWS 1983). Consequently, we consider them to apply to the full data series. Since the distinction of natural and hatchery origins has been reliably estimated (since 2002), the annual percentage of natural-origin fall-run Chinook Salmon that returned to natural spawning areas ranged between 10.6% in 2004 and 88.1% in 2017 (mean = 62.0%).

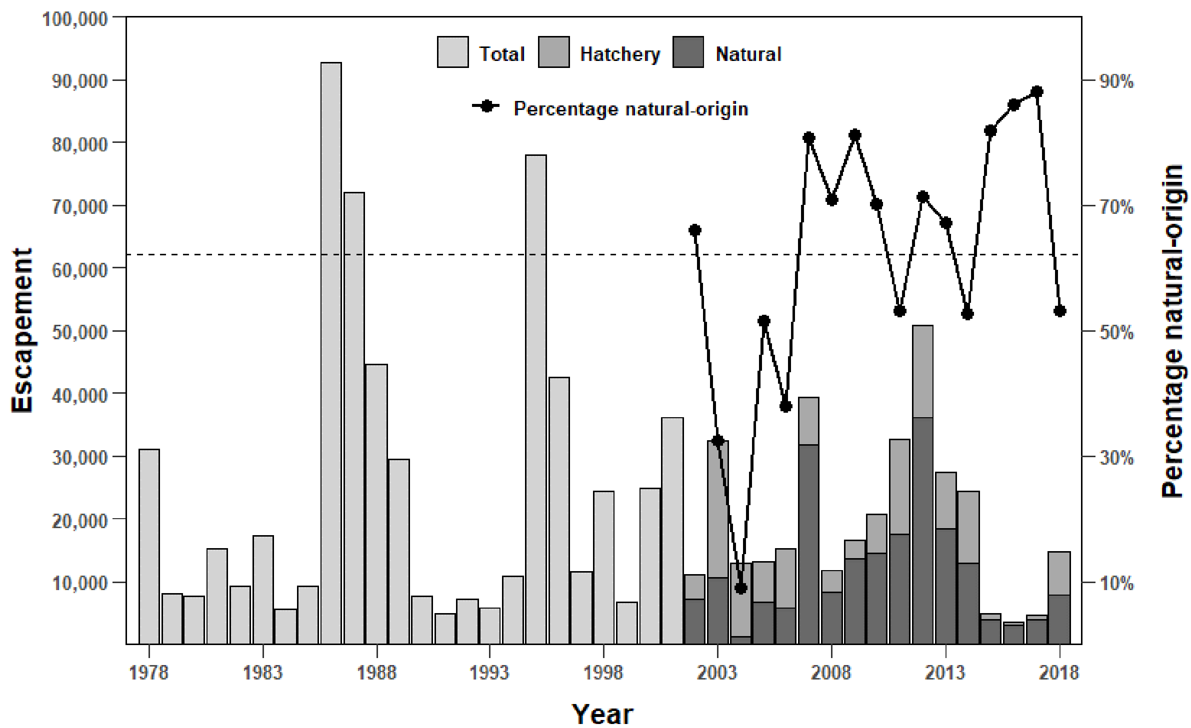


Figure 6. Time series of fall-run Chinook Salmon spawning escapement to natural spawning areas of the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 2002, so only total escapement is provided for those years. The dashed line denotes the TRRP escapement target of 62,000 natural-origin fall-run Chinook Salmon to natural spawning areas.

2.3.2 Spring-run Chinook Salmon

Annual escapement estimates of spring-run Chinook Salmon to natural spawning areas of the Trinity River from 1980 to 2018 ranged between 1,093 in 1992 and 39,661 in 1988 (median = 6,068; Figure 7; Appendix H). Since full implementation of the ROD, median annual escapement to natural spawning areas was 4,437 fish, whereas the median prior to full implementation was 7,371. Escapement of natural-origin spring-run Chinook Salmon to natural spawning grounds from 2002 to 2018 ranged between 817 in 2015 and 11,836 in 2003 and met the TRRP target of 6,000 in 4 of the 17 years for which estimates were available. During that same period, the annual percentage of natural-origin spring-run Chinook Salmon that returned to natural spawning areas ranged between 23.4% in 2007 and 88.6% in 2016 (mean = 55.5%). Despite methods used upstream of JCW and tributaries downstream of JCW being difficult to compare, a large majority of spring-run Chinook Salmon spawning in the Trinity River evidently occurred upstream of JCW. Counts of spring-run Chinook Salmon in tributaries were generally less than 5% of the estimated total escapement and exceeded 10% in only 2 of the 37 years for which estimates were available (Appendix H).

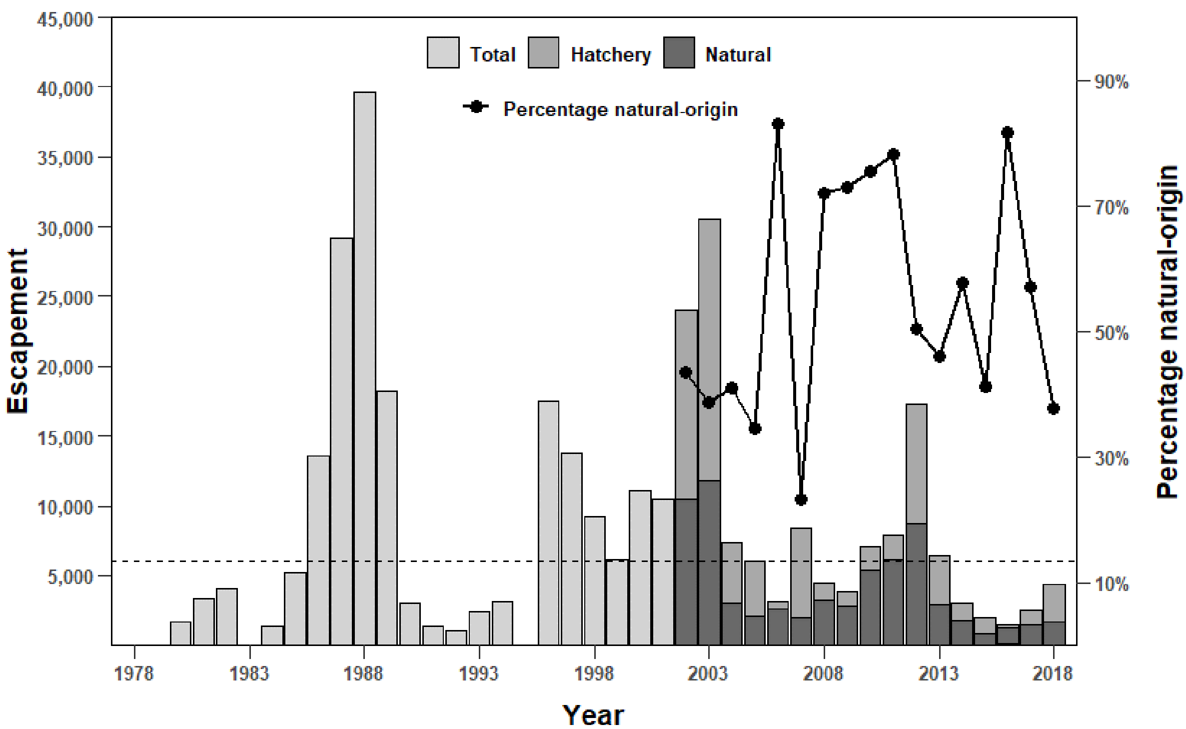


Figure 7. Time series of spring-run Chinook Salmon spawning escapement to natural spawning areas of the Trinity River from 1980 to 2018. Hatchery- and natural-origin fish were not estimated separately before 2002, so only total escapement is provided for those years. No estimates are available for 1983 and 1995. The dashed line denotes the TRRP escapement target of 6,000 natural-origin spring-run Chinook Salmon to natural spawning areas. Estimates are not available for years 1983 and 1995.

2.3.3 Coho Salmon

Annual escapement estimates of Coho Salmon to natural spawning areas in the Trinity River from 1978 to 2018 ranged between 105 in 1994 and 28,398 in 1987 (median = 5,097; Figure 8; Appendix I). Since full implementation of the ROD, median annual escapement to natural spawning areas was 2,918 fish, whereas the median prior to full implementation was 6,004. Escapement of natural-origin Coho Salmon to natural spawning areas since 1997 ranged between zero in 2018 and 7,830 in 2004 and met the TRRP target of 1,400 in 7 of the 22 years of record. During that same period, the annual percentage of natural-origin Coho Salmon spawning in natural spawning areas ranged between less than 0.1% in 2018 and 73.4% in 2015 (mean = 22.4%).

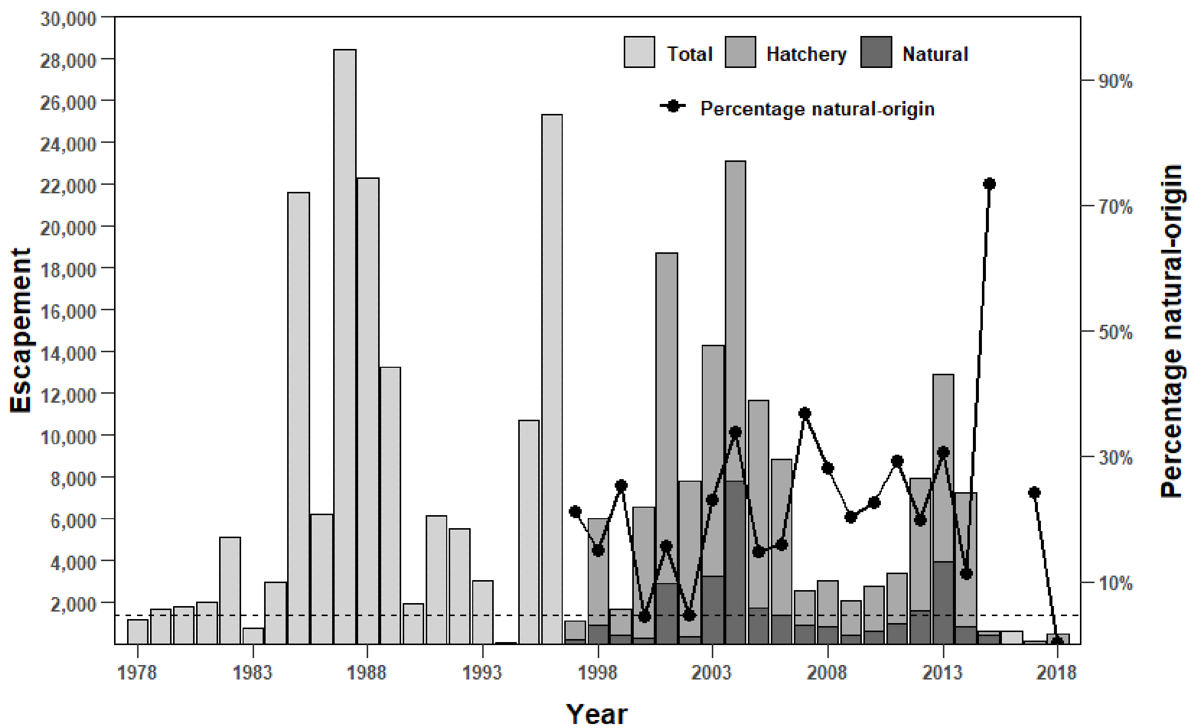


Figure 8. Time series of Coho Salmon spawning escapement to natural spawning areas of the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 1997, so only total escapement is provided for those years. The dashed line denotes the TRRP escapement target of 1,400 natural-origin Coho Salmon to natural spawning areas.

2.3.4 Steelhead

Annual escapement estimates of steelhead to natural spawning areas in the Trinity River from 1980 to 2018, excluding the four years for which no estimates were available, ranged between 1,977 in 1993 and 39,328 in 2007 (median = 7,487; Figure 9; Appendix J). Since full implementation of the ROD, median annual escapement to natural spawning areas was 11,579 fish, whereas the median prior to full implementation was 6,546. For years in which natural and hatchery origins have been estimated, the annual percentage of natural-origin steelhead spawning in natural spawning areas ranged between 18.9% in 2007 and 87.6% 1982 (mean = 51.9%).

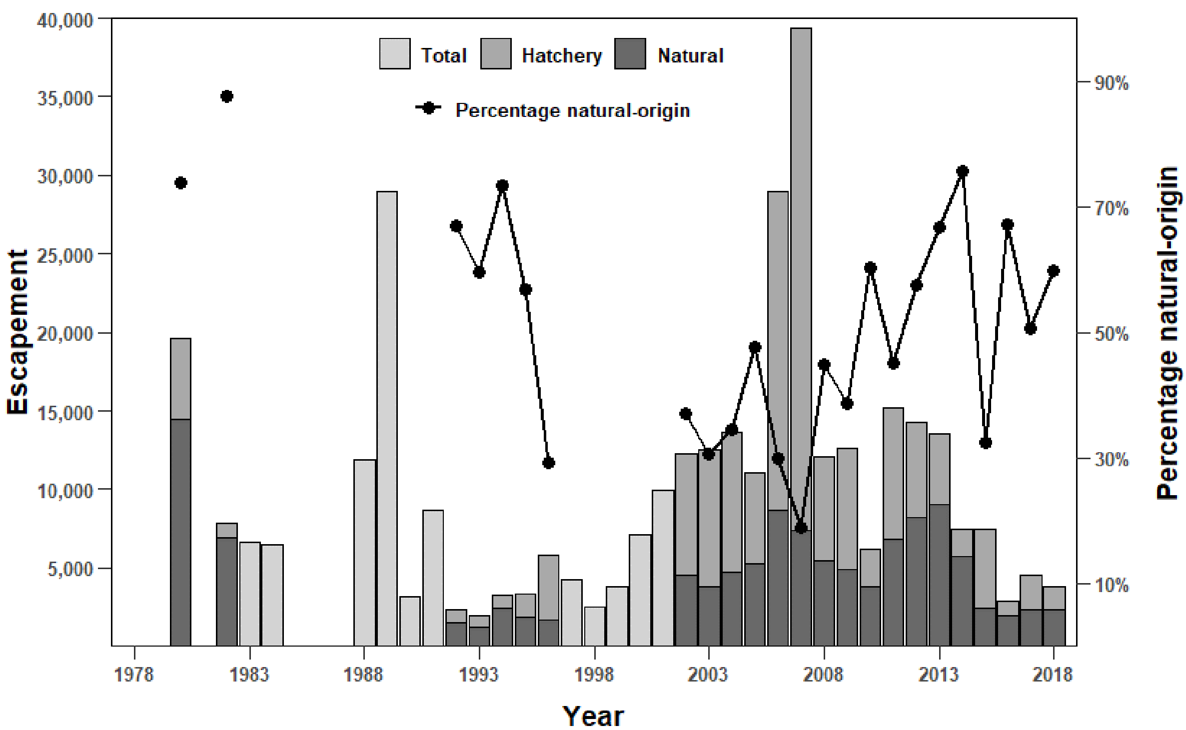


Figure 9. Time series of steelhead spawning escapement to natural spawning areas of the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement is provided for those years. Estimates are not available for years 1981 and 1985–1987.

2.4 Returns to Trinity River Hatchery

2.4.1 Fall-run Chinook Salmon

Annual returns of fall-run Chinook Salmon to TRH since 1978 ranged between 1,142 in 2016 and 29,752 in 2003 (median = 7,142; Figure 10; Appendix K). Annual hatchery-origin returns of fall-run Chinook Salmon to TRH from 2002 to 2018 ranged between 1,034 in 2016 and 28,509 in 2003 and have exceeded the TRRP target of 9,000 hatchery-origin fall-run Chinook Salmon in six of those years. The annual percentage of fall-run Chinook Salmon that returned to TRH from 2002 to 2018 that were of hatchery-origin ranged between 84.9% in 2002 and 100.0% in 2013 (mean = 92.0%). Under the assumption that the lowest proportion of hatchery-origin returns to TRH from 2002 to 2018 was also the lowest prior to 2002, the TRRP target would have been met in 37% of the years from 1978 to 2001. In addition, the median total return to TRH from 1978 to 2001 was 6,862 and 7,353 from 2002 to 2018. Together, these data suggest that returns of fall-run Chinook Salmon to TRH have not changed substantively during the entire period of record.

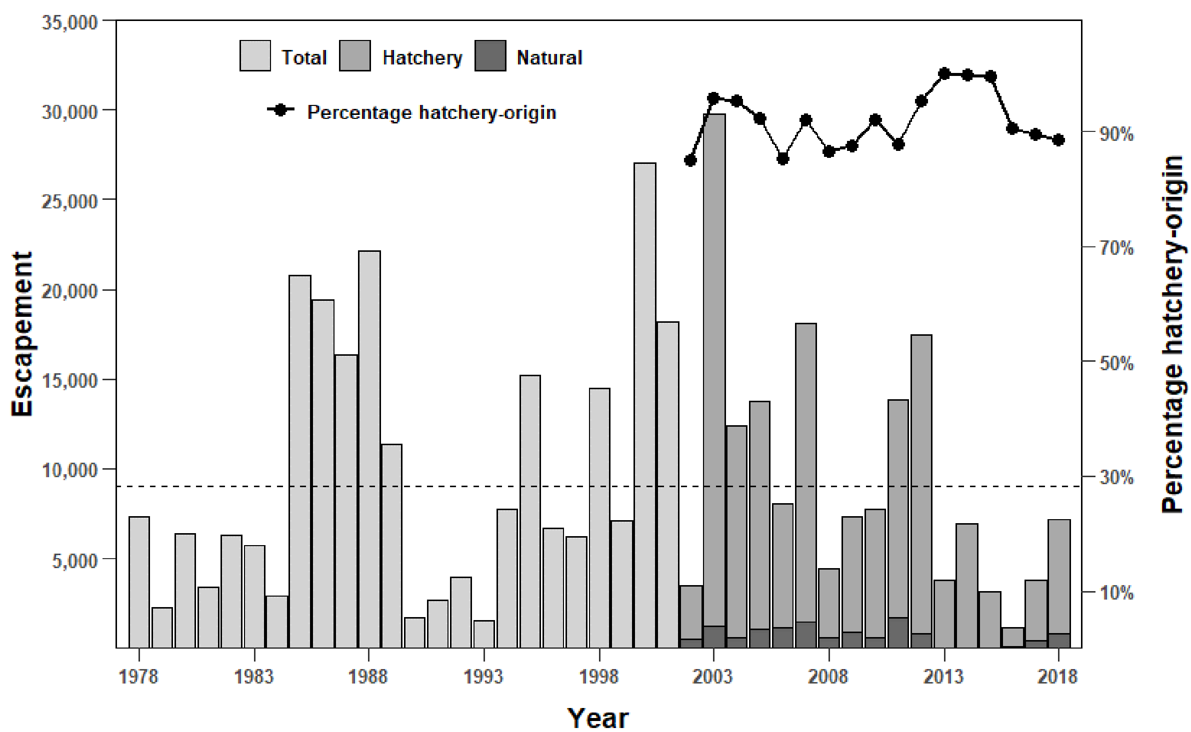


Figure 10. Time series of fall-run Chinook Salmon returning to Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 2002, so only total returns are provided for those years. The dashed line denotes the TRRP escapement target of 9,000 hatchery-origin fall-run Chinook Salmon to Trinity River Hatchery.

2.4.2 Spring-run Chinook Salmon

Annual returns of spring-run Chinook Salmon to TRH since 1980 ranged between 547 in 1980 and 14,512 in 2003 (median = 3,255; Figure 11; Appendix L). Hatchery-origin returns of spring-run Chinook Salmon to TRH from 2002 to 2018 ranged between 1,109 in 2017 and 13,080 in 2003 and have exceeded the TRRP target of 3,000 hatchery-origin spring-run Chinook Salmon seven times. The annual percentage of spring-run Chinook Salmon that returned to TRH from 2002 to 2018 that were of hatchery-origin ranged between 80.7% in 2006 and 97.8% in 2017 (mean = 89.4%). Similar to the fall run, if the minimum proportion of hatchery-origin fish from 2002 to 2018 is applied to hatchery returns prior to 2002, the TRRP target would have been met in 10 of the 22 years from 1980 to 2001. Also, the median total return from 1978 to 2001 was 3,158 and 3,255 from 2002 to 2018, which indicates that returns of spring-run Chinook Salmon to TRH have not changed substantively during the entire period of record. However, since full implementation of the ROD, annual returns have been less variable.

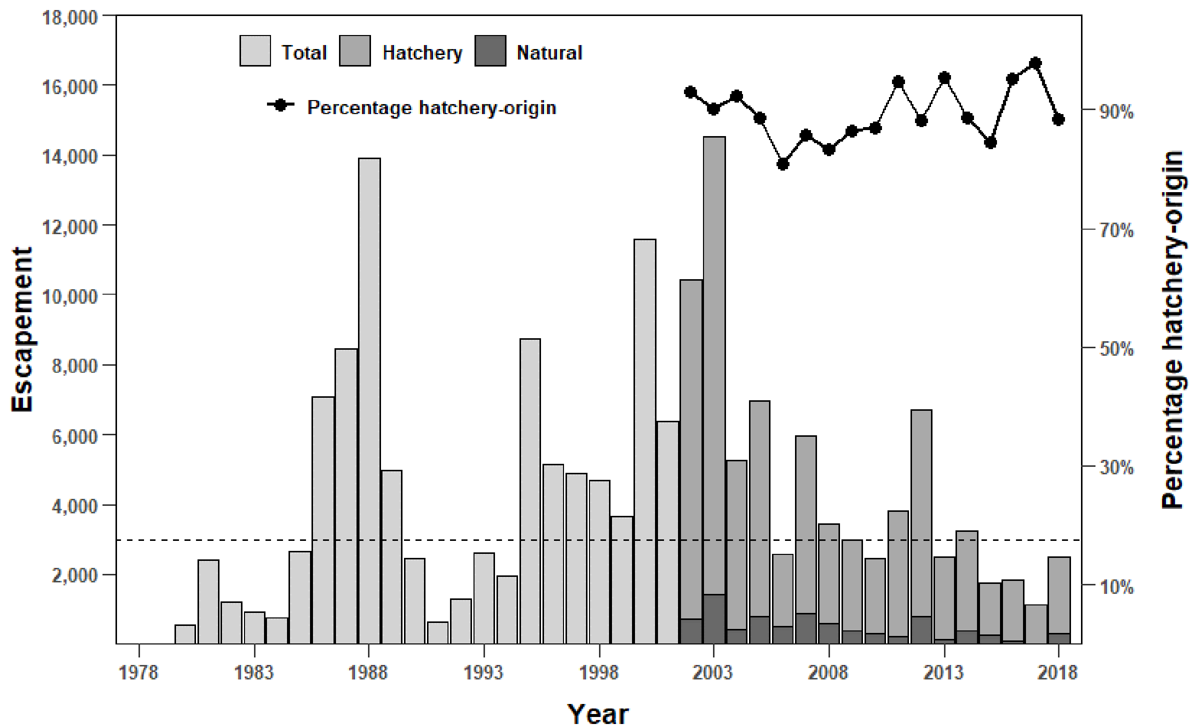


Figure 11. Time series of spring-run Chinook Salmon returning to Trinity River Hatchery from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately before 2002, so only total returns are provided for those years. The dashed line denotes the TRRP escapement target of 3,000 hatchery-origin spring-run Chinook Salmon to Trinity River Hatchery. Estimates began in 1980.

2.4.3 Coho Salmon

Annual returns of Coho Salmon to TRH since 1978 ranged between 134 in 1994 and 20,473 in 1987 (median = 3,059; Figure 12; Appendix M). Returns of hatchery-origin Coho Salmon to TRH from 1997 to 2018 ranged between 247 in 2017 and 15,704 in 2005 and have exceeded the TRRP target of 2,100 hatchery-origin Coho Salmon in 17 of those 22 years. The annual percentage of Coho Salmon that returned to TRH from 1997 to 2018 that were of hatchery-origin ranged between 84.6% in 2016 and 98.7% in 2002 (mean = 94.3%). Notably, the very low returns from 2016 to 2018 represent brood years of mandated reduced juvenile production at TRH starting in 2015, which provides a partial explanation for this stark change in hatchery escapement.

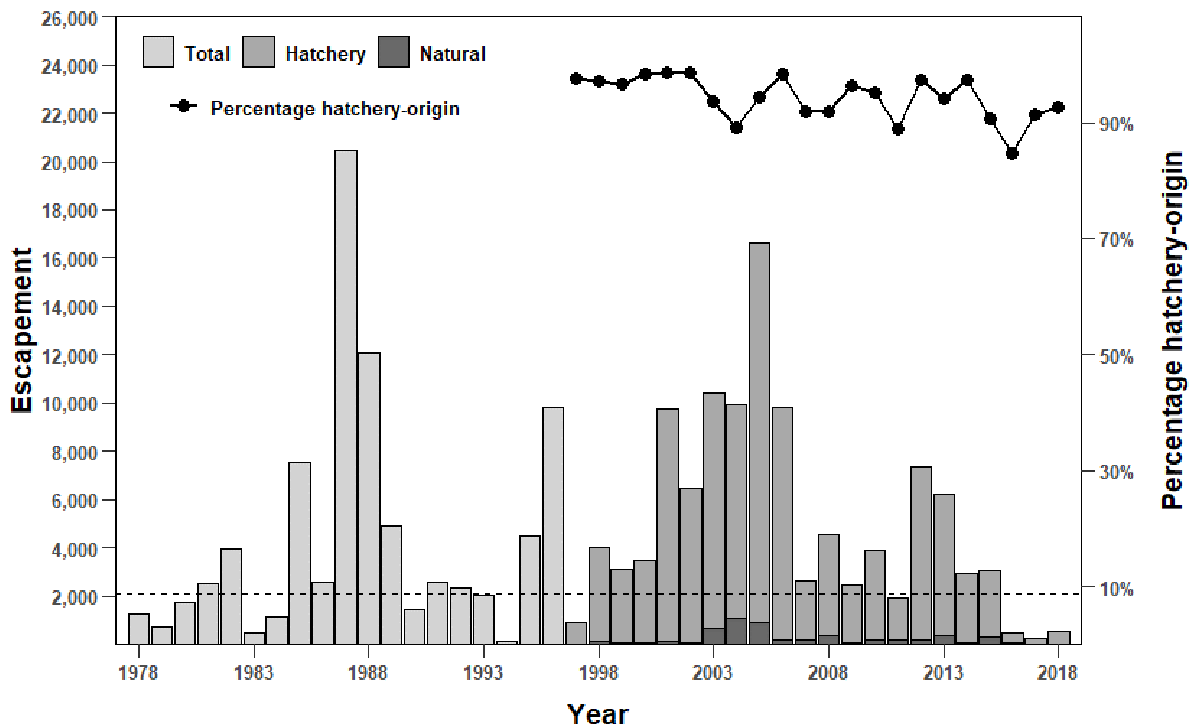


Figure 12. Time series of Coho Salmon returning to Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately before 1997, so only total returns are provided for those years. The dashed line denotes the TRRP escapement target of 2,100 hatchery-origin Coho Salmon to Trinity River Hatchery.

2.4.4 Steelhead

Annual returns of steelhead to TRH from 1978 to 2018 ranged between 142 in 1984 and 11,547 in 2006 (median = 2,005; Figure 13; Appendix N). The median return since full implementation of the ROD was 2,917, whereas the median from 1978 to 2004 was 817. Natural- and hatchery-origin returns to TRH are only available for three distinct periods, 1978–1982, 1992–1996, and 2002–present. The annual proportion of hatchery-origin returns increased across each period, though little information is available to evaluate whether the marking methods were consistent enough in the early years to consider those estimates reliable. Among the 27 years for which separate estimates are available for hatchery- and natural-origin steelhead, the TRRP hatchery escapement target of 10,000 fish was reached in only three years. Since 2002 the annual percentage of hatchery-origin steelhead returning to TRH ranged between 96.6% in 2013 and 99.7% in 2007 (mean = 98.8%). The mean percentage of steelhead that were of hatchery origin returning to TRH from 1978 to 1982 and from 1992 to 1996 were 90.2% and 97.4%, respectively.

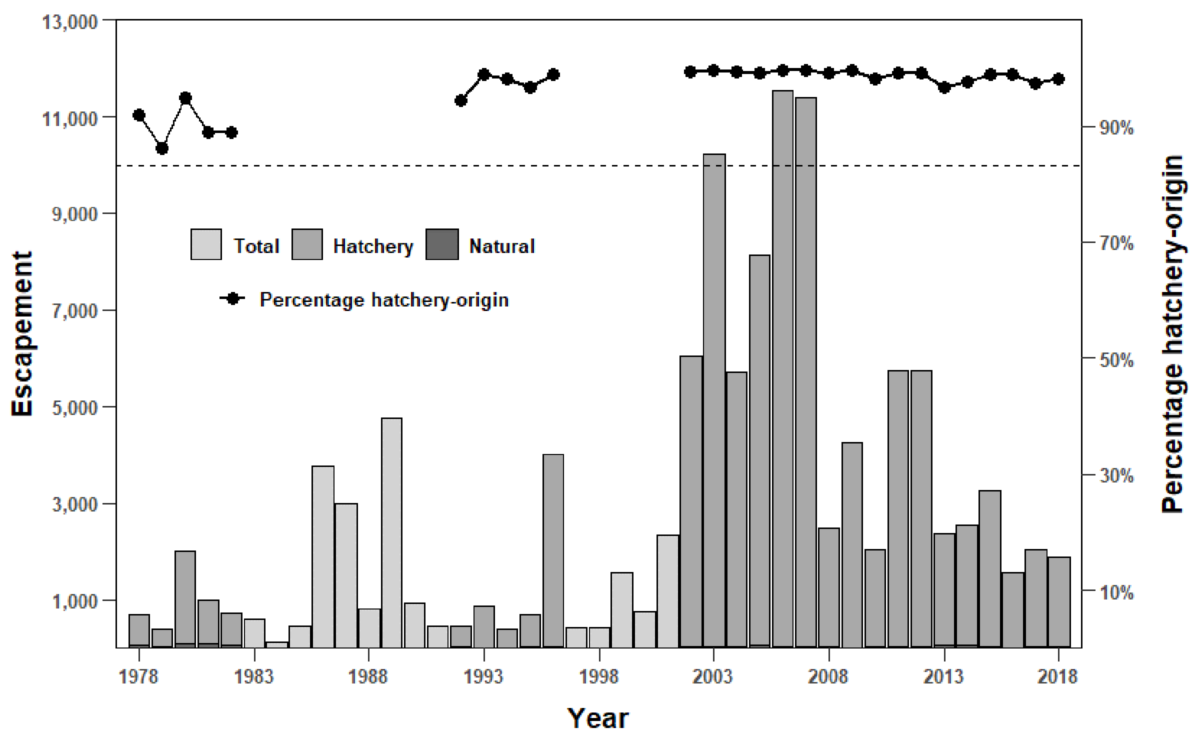


Figure 13. Time series of steelhead returning to Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total returns are provided for those years. The dashed line denotes the TRRP escapement target of 10,000 hatchery-origin steelhead to Trinity River Hatchery.

3. Spawning Ground Surveys

This section details the data sources, methods, results, and analyses from salmon spawning survey data collected from 2002 to 2017 on the mainstem Trinity River, California. The objectives of this project were to:

1) Assess the spatial distribution of Chinook Salmon redds, particularly in relation to TRRP management actions.
2) Quantify Chinook Salmon spawning in the mainstem Trinity River.
3) Quantify pre-spawn mortality of female Chinook Salmon.
4) Quantify and describe temporal and spatial distribution of natural- and hatchery-origin Chinook Salmon spawning.
5) Collect biological data ancillary to salmonid escapement (fork lengths for estimating size distribution and jack proportion, scales for age composition, sex ratio, etc.).

3.1 Data Sources and Methods

3.1.1 Mainstem Spawning Ground Surveys

The Trinity River from Lewiston Dam to its confluence with the Klamath River was delineated into 14 survey reaches ranging in length from 3.3 to 21.3 km (Figure 14; Table 1). Reach breaks were based on river access locations and channel distances that could be surveyed in a day. The 15.6-km whitewater section that includes the Burnt Ranch Gorge (Reach 11) was not surveyed. The 9.7-km Pigeon Point run (Reach 8) was only surveyed from 2002 to 2011. Reach 8 was removed from the survey in 2012 because it contains whitewater and relatively few fish spawned there during the years it was surveyed. 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.

Annual surveys started in late August or early September and concluded in mid- to late December. This period was intended to encompass the majority of Chinook Salmon spawning activity. Reaches 1–7 were surveyed weekly and Reaches 8–14 [excluding Reaches 8 (2012–2017) and 11] were surveyed every other week, as conditions permitted, for Chinook and Coho salmon carcasses and redds as described in Chamberlain et al. (2012) from 2002 to 2011 and in Rupert et al. (2017a) from 2012 to 2017. Coho Salmon spawning continued beyond the survey seasons. Therefore, analyses using Coho Salmon redd and carcass data are limited.

Annual discharge in the Trinity River below Lewiston Dam was typically at summer base flow (450 cfs; 12.7 m^3/s) throughout September to mid-October and at winter base flow (300 cfs; 8.5 m^3/s) throughout the remainder of the survey season (Appendix O). Discharge below Lewiston Dam was above summer base flow in some years (2003, 2004, 2012–2016) due to emergency flow augmentation releases to reduce fish disease (USBOR 2017). Annual Trinity River discharge at Hoopa, California, was typically stable from September through November but was variable in December depending on precipitation (Appendix P).

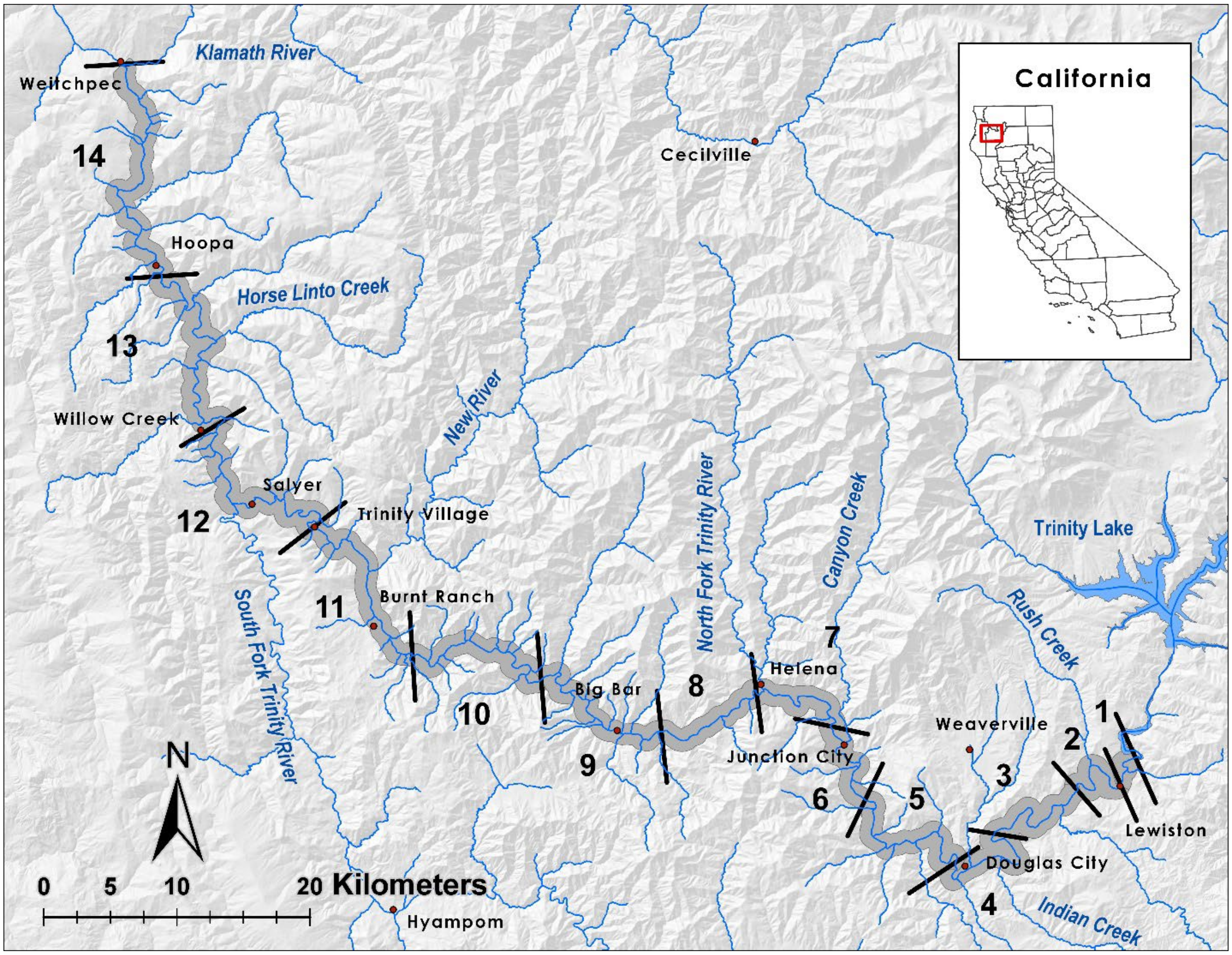


Figure 14. Survey Reaches 1–14 (Lewiston Dam to Weitchpec) on the mainstem Trinity River, California.

Data from Chinook Salmon carcasses are used to estimate pre-spawn mortality, escapement, and the species and origin composition of spawned salmon. Delineating individual Chinook Salmon redds provides spawning location and time. 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- and hatchery-origin Chinook and Coho salmon. Chinook Salmon released from the TRH are batch-marked with CWTs and externally marked using an ad-clip at a constant fractional mark rate of about 25%. 'Hatchery-origin' in this report refers to fish produced and released from TRH, and 'natural-origin' to 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 were used to investigate spawning distribution and abundance. Where applicable, performance measures set forth by the IAP were used to evaluate changes in spawning as responses to the restoration actions of the TRRP.

Table 1. Reach boundaries [and river kilometer (rkm)] for salmon spawning surveys in the mainstem Trinity River, California. Agencies involved in data collection include California

Department of Fish and Wildlife, Shasta–Trinity National Forest, U.S. Fish and Wildlife Service, Yurok Tribal Fisheries Program, and Hoopa Valley Tribal Fisheries Department.

	Boundaries		Distance
Reach	Upstream (rkm)	Downstream	(rkm)
1	Lewiston Dam (182.2) [a]	Old Lewiston Bridge	3.5
2	Old Lewiston Bridge (178.7)	Bucktail River Access	7.1
3	Bucktail River Access (171.6)	Steel Bridge River Access	10.9
4	Steel Bridge River Access (160.7)	Douglas City Campground	10.6
5	Douglas City Campground (150.1)	Evan's Bar [b]	12.7
6	Evan's Bar (137.4) [b]	Junction City Campground	10.3
7	Junction City Campground (127.1)	Pigeon Point Campground [d]	9.7
8 [c]	Pigeon Point Campground (117.4) [d]	Big Flat River Access	9.8
9	Big Flat River Access (107.6)	Del Loma River Access	13.8
10	Del Loma River Access (93.8)	Cedar Flat River Access	14.7
11 [e]	Cedar Flat River Access (79.1)	Hawkins Bar	15.7
12	Hawkins Bar (63.4)	Camp Kimtu in Willow Creek	20.8
13	Camp Kimtu in Willow Creek (42.6)	Roland's Bar in Hoopa Valley	21.3
14	Roland's Bar in Hoopa Valley (21.3)	Weitchpec (Trinity mouth; rkm 0.0)	21.3

[a] The spillway and pool directly downstream of Lewiston Dam were 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] Only surveyed from 2002 to 2011; not surveyed from 2012 to 2017.

[d] 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 is in Reaches 1–7.

[e] Not surveyed.

Prior to 2009, CDFW calculated pre-spawn mortality only within the restoration reach. The importance of describing pre-spawn mortality has increased in recent years with ongoing drought conditions and associated higher risks of epizootic events (causal effects explored in Section 4.3). As a result, the pre-spawn mortality metric was changed in 2009 to incorporate a larger spatial extent of the Trinity River. Spawning condition was also added to the Chinook Salmon carcasses assessment in 2009. Fresh carcasses were described as spawned (≤1/3 eggs retained), partially spawned (1/3–2/3 eggs retained), or unspawned (≥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. Interpretation of results pertaining to spawning success should consider that pre-spawn mortality can also occur outside of the temporal and spatial extent of the surveys. Pre-spawn mortality fish are available to the carcass survey because they expired prior to spawning. The spatiotemporal location of carcass recovery is unlikely to be an accurate depiction of when and where fish were destined to spawn had they survived. For example, 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 these data and analyses.

Chinook Salmon carcass tag-recovery (i.e., mark–recapture) methodologies were used to estimate escapement in Reaches 1 and 2. In this heavily used spawning area, carcass mark–recapture estimates are preferred over redd counts because it is assumed that redd superimposition (i.e., overlapping redds) here would lead to underestimated escapement. Carcass abundance estimates of Chinook Salmon in Reaches 1 and 2 were generated with carcass mark–recapture data via a Petersen estimator (Seber 1982) from 2005 to 2011 and a hierarchical latent variables model (Rupert et al. 2017a) from 2012 to 2017. The latter 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, which allows the estimation of weekly abundances. Finally, weekly estimates were summed to create an annual abundance estimate as a derived parameter. Carcass counts, but not mark–recapture data, are available from 2000 to 2004. A regression analysis using the 2005–2011 data set was used to predict carcass abundance from carcass counts from 2000 to 2004. Data from 2012 to 2017 was not used for this analysis because a new survey protocol was implemented in 2012 and the data sets were not comparable to the previous years.

3.1.2 Tributary Spawning Ground Surveys

Eleven tributaries to the Trinity River were surveyed from 1999 to 2016 for redds and live fish on redds (Figure 15). Tributaries were typically scheduled to be surveyed bi-weekly, but high flows and turbidity often prevented surveyable conditions. Therefore, tributaries were not consistently surveyed, and several tributaries were only surveyed infrequently during this time period. Big French Creek, Canyon Creek, Deadwood Creek, East Fork North Fork Trinity River, North Fork Trinity River, Rush Creek, and the South Fork Trinity River were surveyed at least once in most years; while Conner Creek, Dutch Creek, Manzanita Creek, and Soldier Creek were surveyed in five or less years. Survey areas of each tributary were limited by terrain, private property, and other access issues. Descriptions of each tributary survey can be found in Appendix Q.

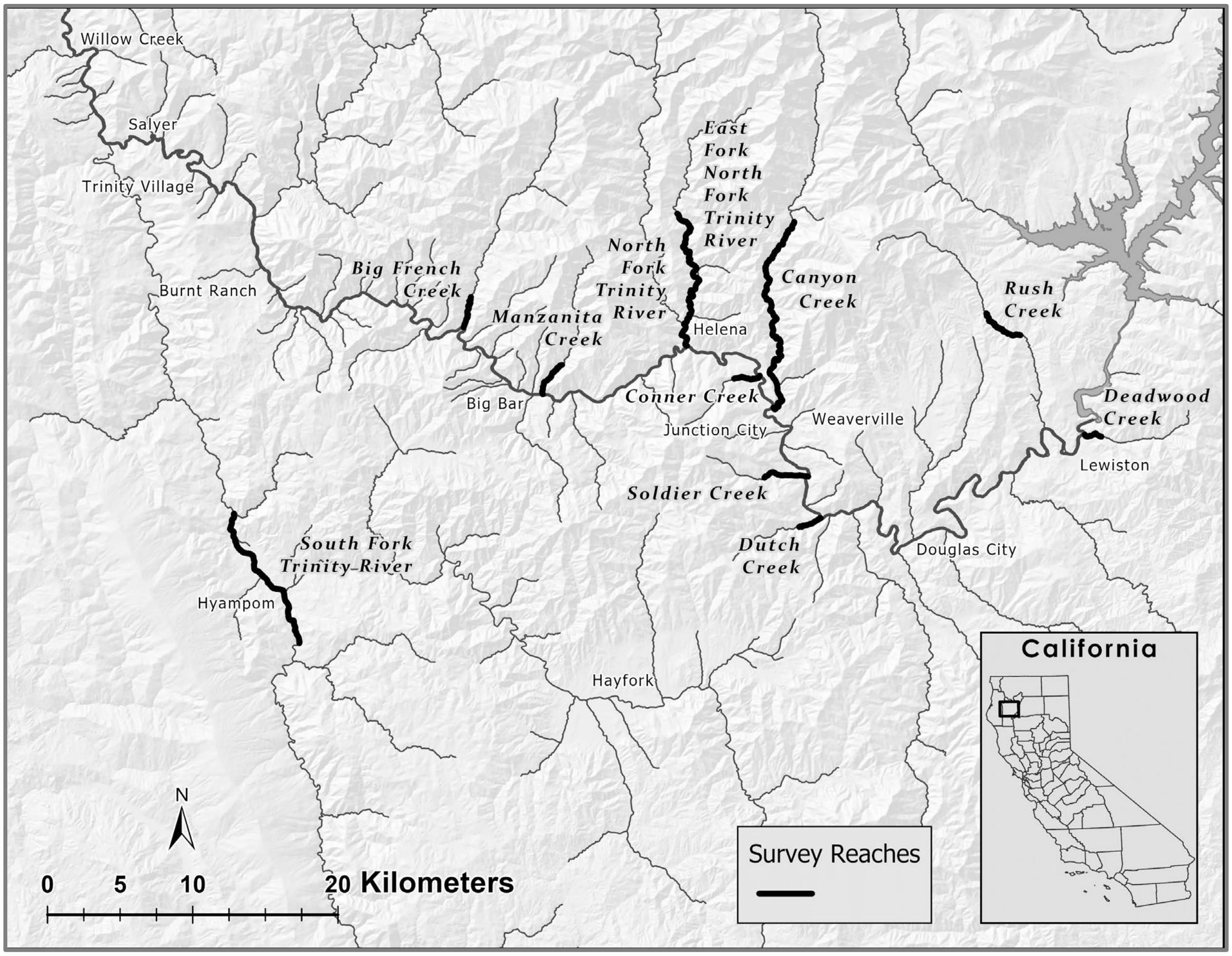


Figure 15. Locations of Trinity River tributary redd surveys.

These surveys also only covered a portion of the potential Chinook and Coho salmon spawning areas within Trinity River tributaries. Tributary surveys from 1999 to 2008 were surveyed by foot or raft (South Fork only) each fall when conditions (i.e., flow, visibility) were favorable and ended mid-November. Beginning in 2009, tributary surveys began earlier (mid-September), were more consistent, and continued until near the end of the Chinook Salmon spawning season (mid-December). No direct comparisons will be made between the two time periods because the survey methodologies changed.

3.2 Carcass Data and Analyses

3.2.1 Distribution and proportion of natural and hatchery spawners

From 2001 to 2011, between 41.8% and 68.0% (mean = 58.7%) of spring-run Chinook Salmon carcasses were female and of these, between 1.7% and 28.6% (mean = 17.2%) were estimated to be of hatchery origin (Table 2). In this time frame, between 48.7% and 67.1% (mean = 59.0%) of fall-run Chinook Salmon carcasses were female and of these, between

5.5% and 42.8% (mean = 22.9%) were estimated to be of hatchery origin. From 2012 to 2017, when spring- and fall-run Chinook Salmon were not identified separately, between 54.1% and 70.4% (mean = 61.9%) of Chinook Salmon carcasses were female and of these, between 5.7% and 25.0% (mean = 16.4%) were estimated to be of hatchery origin.

Fresh ad-clipped Chinook Salmon carcasses from 2009 to 2017 were identified by run (spring or fall) according to their CWT code, which corresponds to release groups. Of the spawned female hatchery-origin carcasses with associated CWT data, between 90% and 100% (mean = 93.2%) were recovered within 10 km of Lewiston Dam (Table 3, Figure 16).

Table 2. Annual percentages of female and hatchery-origin Chinook Salmon using data from carcasses observed during spawner surveys on the Trinity River, California, from 2001 to 2017.

Year	Female percentage		Hatchery percentage		*n* [a]	Reference
	Spring-run	Fall-run	Spring-run	Fall-run		
2001	59.5%	64.5%	23.9%	30.3%	5,515	Sinnen 2004a
2002	62.5%	59.2%	24.6%	13.5%	4,215	Sinnen 2004b
2003	67.6%	64.5%	24.0%	28.1%	15,572	Currier and Sinnen 2005
2004	68.0%	61.7%	28.6%	42.3%	4,825	Knechtle and Currier 2006
2005	57.8%	54.1%	25.7%	42.8%	3,320	Garrison 2008
2006	55.8%	55.6%	13.0%	29.1%	4,772	Hill 2009
2007	65.7%	67.1%	19.3%	12.5%	5,033	Hill 2010a
2008	47.6%	52.4%	10.3%	11.1%	3,564	Hill 2010b
2009	63.3%	62.8%	8.3%	11.1%	3,419	Hill 2011
2010	56.5%	48.7%	1.7%	5.5%	3,871	Hill 2013a
2011	41.8%	58.8%	9.7%	26.1%	10,078	Hill 2013b
2012 [b]	58.7%		15.7%		4,474	Rupert et al. 2017a
2013 [b]	61.3%		18.4%		1,371	Rupert et al. 2017a
2014 [b]	54.1%		25.0%		2,107	Rupert et al. 2017a
2015 [b]	63.6%		15.7%		619	Rupert et al. 2017b
2016 [b]	70.4%		5.7%		389	Rupert et al. 2017b
2017 [b]	63.4%		17.9%		527	Gough et al. 2019

[a] Includes all carcasses examined for 2001-2011 and fresh carcasses only for 2012-2017

[b] Spring and fall runs not separated

Table 3. Coded-wire tag (CWT) brood type summary from female Chinook Salmon carcasses in the Trinity River, California, from 2012 to 2017.

	Number of CWTs				Annual percentage of CWTs		
	Restoration reach		<10 rkm from dam		<10 rkm from dam		
Year	Spring	Fall	Spring	Fall	Spring	Fall	All
2012	54	54	53	48	98.1%	88.9%	93.5%
2013	21	33	20	30	95.2%	90.9%	92.6%
2014	8	77	8	71	100.0%	92.2%	92.9%
2015	5	5	4	5	80.0%	100.0%	90.0%
2016	6	3	6	3	100.0%	100.0%	100.0%
2017	7	13	5	13	71.4%	100.0%	90.0%

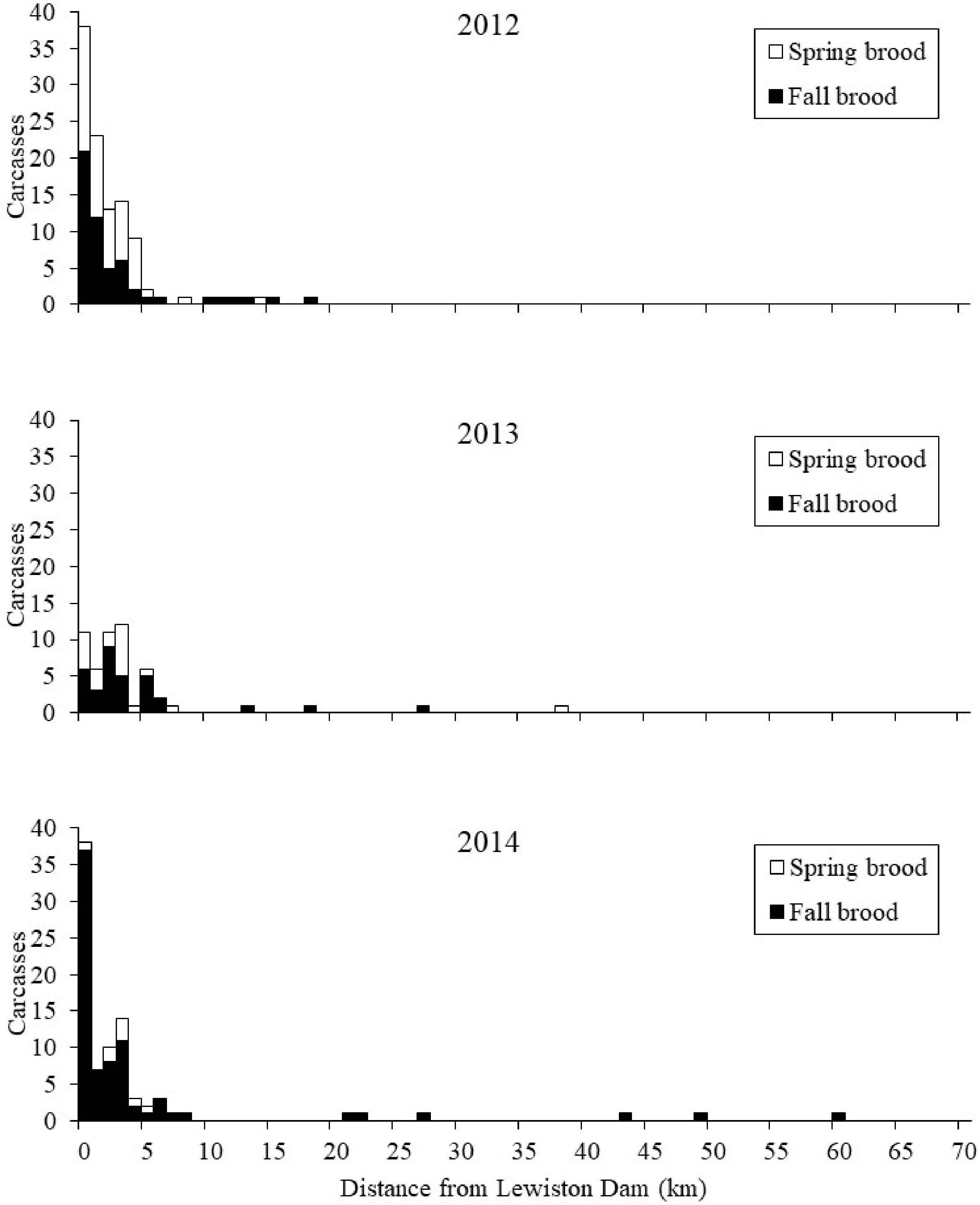


Figure 16. Distribution of coded-wire-tagged (CWT) spawned female Chinook Salmon carcasses by brood type (spring and fall) located in the mainstem Trinity River downstream of Lewiston Dam from 2012 to 2017.

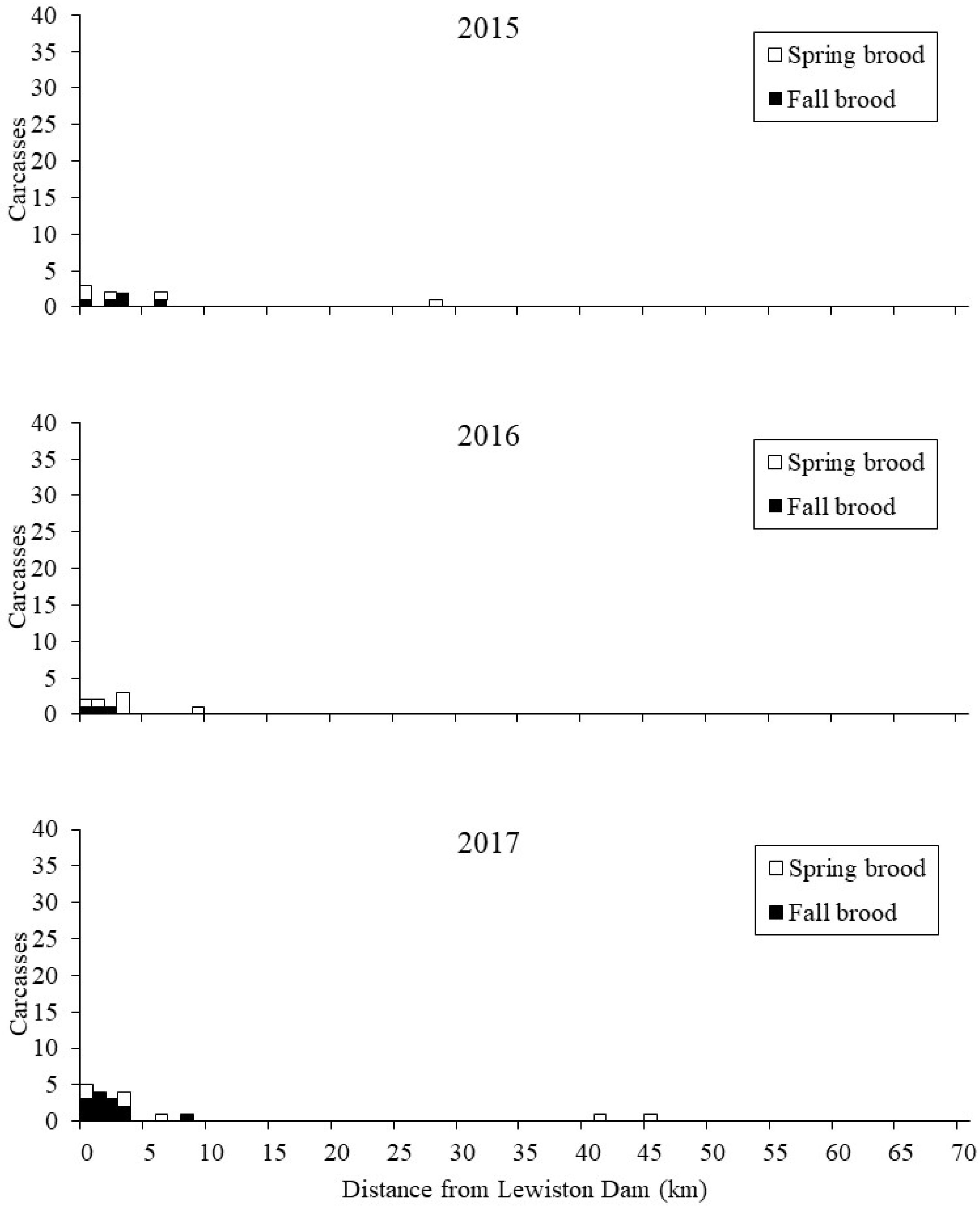


Figure 16 (continued). Distribution of coded-wire-tagged (CWT) spawned female Chinook Salmon carcasses by brood type (spring and fall) located in the mainstem Trinity River downstream of Lewiston Dam from 2012 to 2017.

From 2001 to 2014 (2015–2017 had insufficient sample sizes), between 38.7% and 60.0% (mean = 51.4%) of Coho Salmon carcasses were female and of these, between 51.9% and 91.1% (mean = 74.6%) were estimated to be of hatchery origin (Table 4). The limited number ($n \leq 10$) of spawned female Coho Salmon carcasses recovered inhibited the ability to differentiate Coho Salmon redds by origin from 2015 to 2017.

Table 4. Annual percentages of female and hatchery-origin Coho Salmon using data from carcasses observed during spawner surveys on the Trinity River, California, from 2001 to 2017.

Year	Female percentage	Hatchery percentage	n [a]	Reference
2001	50.5%	75.9%	692	Sinnen 2004a
2002	50.0%	91.1%	177	Sinnen 2004b
2003	56.8%	80.1%	468	Currier and Sinnen 2005
2004	55.5%	58.9%	2,029	Knechtle and Currier 2006
2005	53.5%	55.8%	961	Garrison 2008
2006	38.7%	91.1%	537	Hill 2009
2007	50.8%	77.1%	214	Hill 2010a
2008	58.1%	51.9%	318	Hill 2010b
2009	60.0%	62.7%	169	Hill 2011
2010	51.0%	86.7%	693	Hill 2013a
2011	47.7%	62.5%	261	Hill 2013b
2012	46.2%	88.6%	210	Rupert et al. 2017a
2013	53.4%	85.4%	459	Rupert et al. 2017a
2014	47.5%	77.0%	243	Rupert et al. 2017a
2015	- [a]	- [a]	10	Rupert et al. 2017b
2016	- [a]	- [a]	6	Rupert et al. 2017b
2017	- [a]	- [a]	3	Gough et al. 2019

[a] Includes all carcasses examined for 2001-2011 and fresh carcasses only for 2012-2017

[b] Sample sizes too low for reportable values

3.2.2 Pre-Spawn Mortality

Annual pre-spawn mortality rates for Chinook Salmon (spring and fall runs combined) were relatively low from 2009 to 2017 (range: 0.0%–9.5%; mean = 4.6%) in the restoration reach (Table 5; also see Appendix R). Aguilar et al. (1996) reported annual pre-spawn mortality rates between 1.1% and 44.9% (mean = 11.1%) in the mainstem Trinity River above the North Fork confluence from 1987 to 1995, 1978 to 1982, and in some years from 1955 to 1976.

Separate pre-spawn mortality rates for spring- and fall-run Chinook Salmon are available for a subset of the years listed above. Pre-spawn mortality rates for spring-run Chinook Salmon above the North Fork ranged between 0.0% and 71.1% (mean = 27.1%) from 1987 to 1994 (Aguilar et al. 1996) and between 5.9% and 8.6% (mean = 7.3%) from 2001 to 2008 (Sinnen 2004a, 2004b; Currier and Sinnen 2005; Knechtle and Currier 2006; Garrison 2008; Hill 2009, 2010a, 2010b; Table 5). Pre-spawn mortality rates for fall-run Chinook Salmon above the North Fork ranged between 0.7% and 43.7% (mean = 12.8%) from 1987 to 1994 and between 0.8% and 13.2% (mean = 6.3%) from 2001 to 2008.

Weekly Chinook Salmon pre-spawn mortality rates from 2009 to 2017 were typically highest at the beginning of the spawning seasons and decreased as the seasons progressed, which is consistent with previous observations in the mainstem Trinity River (Aguilar et al. 1996) as well as in the mainstem Klamath River (Gough and Williamson 2012). However, a small portion of the run is on the spawning grounds early in the season and most of the pre-spawn mortality occurs in the middle weeks of the spawning season (Figure 17). The highest annual proportion of females that died prior to spawning typically occurred between calendar weeks 44 and 49 (between late October and early December).

Pre-spawn mortality rates from the Coho Salmon carcasses observed in the Trinity River ranged between 6.6% and 29.8% from 2009 to 2014 (Table 6) but sample sizes from 2015 to 2017 were too low for estimation. Pre-spawn mortality rates for Coho Salmon were higher than those observed from Chinook Salmon (Table 5), however, rates are not recommended to make inferences on pre-spawn mortality in Coho Salmon since (1) surveys did not span the entire Coho Salmon spawning period (i.e., rates reflect the earlier portion of the spawning period when pre-spawn mortality was likely highest) and (2) sample sizes were too small in some years.

Table 5. Recent and historical 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). When available, pre-spawn mortality rates are differentiated for spring (s) and fall runs (f).

	Reaches 1-14 (Lewiston Dam to Klamath River)			Reaches 1-7 (Lewiston Dam to North Fork)			
Year	Natural-origin	Hatchery-origin	Combined	Natural-origin	Hatchery-origin	Combined	Citation
1955	-	-	-	-	-	1.5%	Gibbs (1956)
1956	-	-	-	-	-	6.0%	Weber (1965)
1963	-	-	-	-	-	6.2%	LaFaunce (1965)
1968	-	-	-	-	-	7.7%	Rogers (1970)
1969	-	-	-	-	-	1.2%	Smith (1975)
1970	-	-	-	-	-	5.1%	Rogers (1982)
1972	-	-	-	-	-	12.2%	Miller (1972)
1973	-	-	-	-	-	12.0%	Miller (1973)
1974	-	-	-	-	-	9.1%	Miller (1974)
1976	-	-	-	-	-	8.4%	Miller (1976)
1978	-	-	-	-	-	7.2%	Miller (1978)
1979	-	-	-	-	-	6.0%	Miller (1979)
1980	-	-	-	-	-	36.5%	Miller (1980)
1981	-	-	-	-	-	2.6%	Miller (1981)
1982	-	-	-	-	-	1.5%	Miller (1982)
1987	-	-	-	-	-	30.8% (49.9%s, 18.8%f)	Stempel (1988)
1988	-	-	-	-	-	44.9% (71.1%s, 43.7%f)	Zuspan (1991)
1989	-	-	-	-	-	31.3% (62.8%s, 23.1%f)	Zuspan (1992a)
1990	-	-	-	-	-	13% (21.6%s, 5.5%f)	Zuspan (1992b)
1991	-	-	-	-	-	1.1% (0.0%s, 1.2%f)	Zuspan (1994)
1992	-	-	-	-	-	2.2% (5.9%s, 0.7%f)	Aguilar/Zuspan (1995)
1993	-	-	-	-	-	5.4% (4.2%s, 6.3%f)	Aguilar (1995)
1994	-	-	-	-	-	2.3% (1.0%s, 3.1%f)	Aguilar (1996)
2001	-	-	(6.3%s, 9.2%f) [a]	-	-	-	Sinnen (2004a)
2002	-	-	(5.9%s, 1.7%f) [a]	-	-	-	Sinnen (2004b)
2003	-	-	(6.4%s, 13.2%f) [a]	-	-	-	Currier and Sinnen (2005)
2004	-	-	(8.5%s, 5.1%f)[a]	-	-	-	Knechtle and Currier (2006)
2005	-	-	(7.4%s, 6.5%f)[a]	-	-	-	Garrison (2008)
2006	-	-	2.8% (7.6%s, 0.8%f) [a]	-	-	-	Hill (2009)
2007	-	-	7.8% (7.5%s, 7.9%f) [a]	-	-	-	Hill (2010a)
2008	-	-	8.6%s, 5.6%f [a]	-	-	-	Hill (2010b)
2009	7.9%	7.4%	7.9%	6.7%	7.4%	6.8%	Rupert et al. (2017a)
2010	10.2%	10.2%	10.2%	9.4%	10.2%	9.5%	Rupert et al. (2017a)
2011	3.7%	6.6%	4.6%	3.6%	6.6%	4.6%	Rupert et al. (2017a)
2012	2.5%	2.1%	2.4%	2.5%	2.1%	2.4%	Rupert et al. (2017a)
2013	6.2%	2.2%	5.1%	8.3%	2.2%	6.1%	Rupert et al. (2017a)
2014	12.3%	10.5%	11.5%	8.6%	9.6%	9.1%	Rupert et al. (2017a)
2015	0.9%	0.0%	0.8%	0.0%	0.0%	0.0%	Rupert et al. (2017b)
2016	0.8%	0.0%	0.7%	0.8%	0.0%	0.8%	Rupert et al. (2017b)
2017	2.5%	0.0%	1.8%	2.8%	0.0%	2.0%	Gough et al. (2019)

[a] Reaches 1-10 surveyed

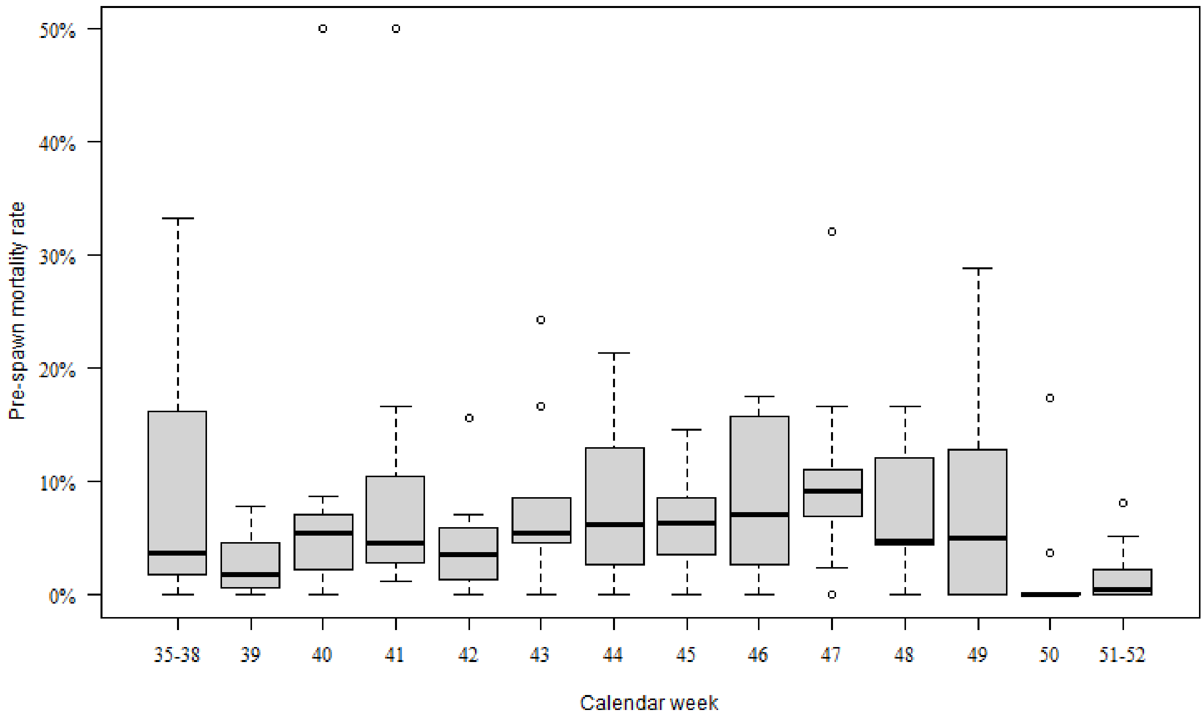


Figure 17. Box plot of weekly pre-spawn mortality rates in fresh female Chinook Salmon carcasses, Trinity River surveys 2009–2017. In each plot, the thick midline is the median, the bottom and top of the box are the first and third quartiles (25th and 75th percentiles), whiskers are the minimum and maximum (1.5 times the interquartile range), and circles are outliers. Calendar weeks 35–38 and 51–52 were combined because surveys were not conducted in those weeks every year.

Table 6. Pre-spawn mortality rates of natural- and hatchery-origin Coho Salmon, Trinity River surveys, 2009–2017. Note that these pre-spawn mortality rates were based on data collected through late December. Spawning success often varies, typically improving over time, and these surveys did not extend over the entire Coho Salmon spawning period.

	Coho Salmon pre-spawn mortality rate		
Year	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%
2015-2017	- [a]	- [a]	- [a]

[a] annual sample sizes for Coho Salmon carcasses were too small (≤5) to report pre-spawn mortality rates

3.2.3 Escapement Estimates

Chinook Salmon carcass counts were used to estimate escapement from 2000 to 2004 based on a linear regression analysis of carcass counts and mark-recapture escapement estimates from 2005 to 2011 ($p = 0.001$, $R^2 = 0.90$; Figure 18). Estimates of Chinook Salmon carcasses in Reaches 1 and 2 ranged between 705 and 19,135 from 2000 to 2017 (Table 7). Estimates of spawned female Chinook Salmon carcasses in Reaches 1 and 2 ranged between 555 and 11,477 from 2000 to 2017. The years 2003 and 2012 had the highest estimated abundance of carcasses. The lowest abundance estimates occurred in the final three years of this data set (2015–2017).

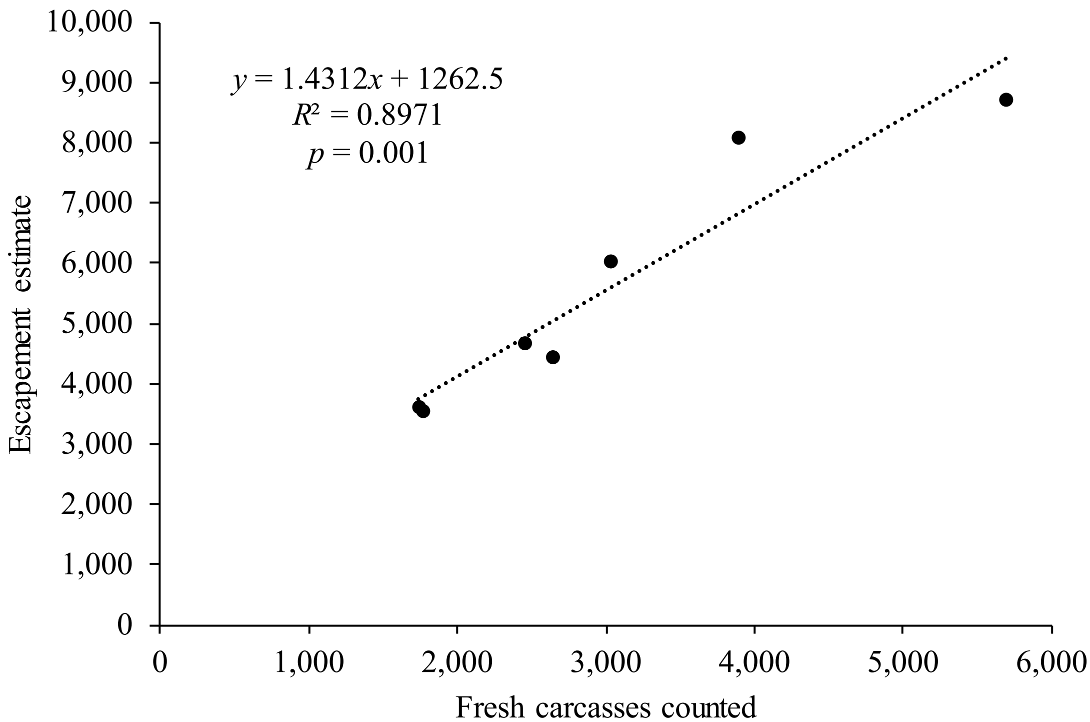


Figure 18. Linear regression of data from 2005 to 2011 used to estimate Chinook Salmon escapement for 2000–2004 from fresh carcass counts in Reaches 1 and 2 of the mainstem Trinity River.

Table 7. Carcass abundance estimates of Chinook Salmon in Reaches 1 and 2 of the Trinity River, California, from 2000 to 2017.

	All Chinook Salmon			Spawned female Chinook Salmon			
	Carcass	95% confidence limits		Carcass	95% confidence limits		
Year	estimate	Lower	Upper	estimate	Lower	Upper	Estimator
2000	9,400	-	-	3,881	-	-	Regression [a]
2001	8,137	-	-	4,518	-	-	Regression
2002	5,017	-	-	2,586	-	-	Regression
2003	19,135	-	-	11,477	-	-	Regression
2004	6,714	-	-	3,774	-	-	Regression
2005	4,471	4,224	4,718	2,306	-	-	Petersen [b]
2006	6,061	5,659	6,463	2,964	-	-	Petersen
2007	8,109	7,330	8,889	5,109	-	-	Petersen
2008	3,561	3,203	3,920	1,804	-	-	Petersen
2009	3,625	3,113	4,137	2,207	-	-	Petersen
2010	4,674	4,082	5,266	2,112	-	-	Petersen
2011	8,726	8,286	9,165	4,671	-	-	Petersen
2012	14,706	12,116	18,244	8,557	6,988	10,702	HLVM [c]
2013	1,764	1,369	2,486	986	747	1,420	HLVM
2014	4,032	3,216	5,281	2,239	1,722	3,066	HLVM
2015	831	515	1,349	555	333	920	HLVM
2016	705	408	1,194	477	270	838	HLVM
2017	864	633	1,234	566	404	828	HLVM

[a] Linear regression analysis of carcass counts and mark-recapture escapement estimates from 2005 to 2011

[b] Petersen mark-recapture estimator (Seber 1982)

[c] Hierarchical latent variables model (Rupert et al. 2017a)

3.3 Redd Data and Analyses

3.3.1 Redd Identification

Chinook and Coho salmon spawning in the mainstem Trinity River overlaps both temporally and spatially for both natural- and hatchery-origin salmon. Given that redds are not visually distinguishable by these species and origin types, the estimated proportion and spatiotemporal distribution of fresh female carcasses of hatchery- and natural-origin Chinook and Coho salmon were used to infer the probability of redd construction by species and origin. Since only female carcasses are used in the hatchery–natural analysis, the redds predicted to have been constructed by natural-origin females do not account for hatchery-produced males spawning with naturally produced females. Therefore, these probabilities should be considered maximum values of natural-origin spawning when not accounting for the hatchery–natural interaction. Generalized Additive Models 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. 2017a). 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. 2017a).

Redds and carcasses in Trinity River tributaries were not geo-referenced and no attempt was made to infer probability by species or origin. Prior to 2009, Chinook and Coho salmon redds were not differentiated. Beginning in 2009, all redds were apportioned to species following several rules. All redds counted were assumed to be from Chinook Salmon until the first adult Coho Salmon was observed during a survey on a particular tributary. When live Chinook and Coho salmon were encountered in the same survey, the total number of redds for that week were divided by the number of live fish counted to estimate redds per fish. The redds–fish ratio was then applied to the total number of each species observed that week to estimate Chinook and Coho salmon redds rounded to the nearest whole number. All redds were attributed to Chinook Salmon in streams where no Coho Salmon were observed or not known to occur (e.g., South Fork Trinity River, Big French Creek).

3.3.2 Trends in Redd Abundance and Distribution

Data from sixteen years (2002–2017) of mainstem Trinity River redd surveys were combined for long-term analyses of redd abundance and distribution (Chamberlain et al. 2012; Rupert et al. 2017a, 2017b; Gough et al. 2019). 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 were analyzed at three spatial scales: the system (~50–100 km sections), reach (~10–20 km sections), and site (~1–2 km sections) scales.

Changes in redd abundance and distribution at the system scale were evaluated over the entire mainstem and separately for the restoration reach (Reaches 1–7) and the remaining river downstream of the restoration reach (Reaches 9–10 and 12–14). Linear models were used to test for trends in redd abundance. Changes in the mean distance from Lewiston Dam of natural- and hatchery-origin Chinook Salmon redds built upstream of Cedar Flat were tested using linear regression models.

Ten reach-scale sections were also used to evaluate long-term trends in natural- and hatchery-origin Chinook Salmon redd abundance (Figure 19, Table 8). 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. These 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. Boundaries of the other five river sections downstream of the restoration reach were set similarly. Changes in spawning abundance within these reaches were analyzed using linear regression analyses 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.

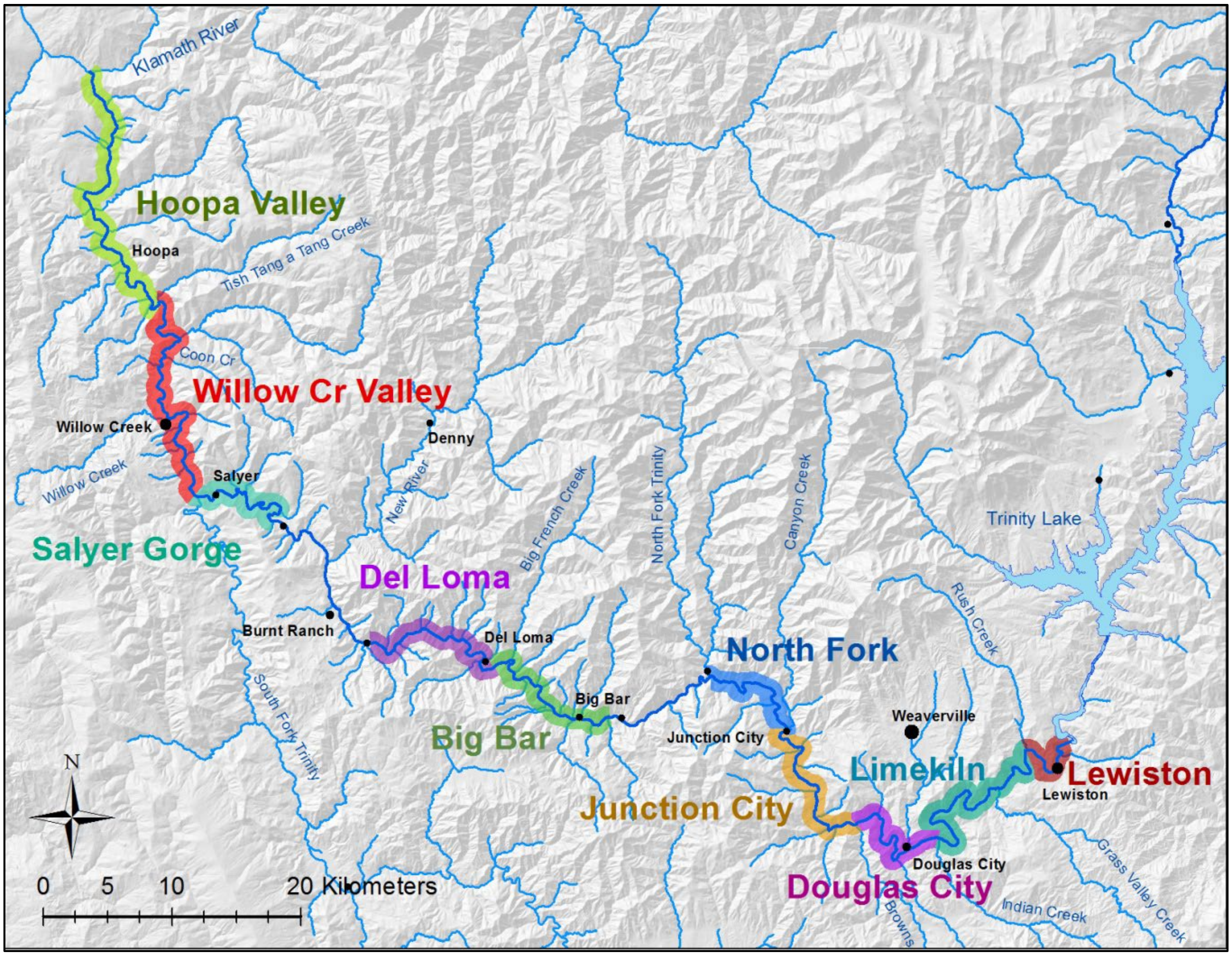


Figure 19. The ten sections of the mainstem Trinity River (denoted by different colors) used for reach-scale analyses of Chinook Salmon redd distribution.

Table 8. River sections [with river kilometer (rkm)] used for the reach-scale analysis of redd abundance.

Section	Boundaries		Length
	Upstream (rkm)	Downstream	(rkm)
Lewiston Rehab	Lewiston Dam (182.2)	Rush Creek	6.8
Limekiln Rehab	Rush Creek (175.4)	Indian Creek	20.0
Douglas City Rehab	Indian Creek (155.4)	Browns Creek	12.2
Junction City Rehab	Browns Creek (143.2)	Canyon Creek	13.8
North Fork Rehab	Canyon Creek (129.3)	North Fork Trinity River (rkm 117.4)	11.9
Big Bar	Big Flat access riffle unit (107.8)	Del Loma access riffle unit	13.8
Del Loma	Del Loma access riffle unit (94.0)	Cedar Flat access riffle unit (rkm 79.3)	14.7
Salyer Gorge	Hawkins Bar river access (63.8)	South Fork Trinity River	13.4
Willow Creek Valley	South Fork Trinity River (50.3)	Tish Tang a Tang Creek	23.4
Hoopa Valley	Tish Tang a Tang Creek (27.0)	Weitchpec (Trinity River mouth; rkm 0.0)	27.0

Contiguous groups of riffle units were combined to create the sections used for the site-scale analysis (Table 9). A riffle unit is defined as a section of river that corresponds to a singular pool–riffle–pool sequence that typically ranges between 0.1 and 0.5 km in length (Rupert et al. 2017b). These units were delineated by this sequence for redd abundance analyses because Chinook Salmon typically build redds in patches proximate to riffle crests. Therefore, riffle units generally contain an undivided 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, the deepest locations (i.e., pools) between these hydraulic controls were used 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 confluence with the North Fork Trinity River (excluding Reaches 8 and 11) because the morphological units developed by Gaeuman et al. (2016) were limited to the channel from Lewiston Dam to the confluence with the North Fork Trinity River (restoration reach). In total, the mainstem Trinity River was divided into 482 riffle units.

The site designations were generally based on the TRRP site designations of the Science Advisory Board (SAB) data-frame (Buffington et al. 2014). However, the total count of site-scale units was reduced from 57 to 44 by merging the smallest site-scale sections of the SAB data-frame 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 were analyzed using linear regression of the annual proportion (number of redds in the site / sum of redds in the restoration reach) of redds.

Table 9. 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 [river kilometer (rkm)] from the Klamath River confluence. TRRP = Trinity River Restoration Program.

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	1.52
	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

3.3.2.1 Redd Abundance and Distribution: System Scale

During the 2002–2017 surveys, between 1,671 and 7,588 Chinook and Coho salmon redds were identified each year. The majority of the redds (range = 1,607–7,335) each year were estimated to have been constructed by Chinook Salmon and the majority of those (range = 1,516–6,170) were estimated to have been constructed by natural-origin female Chinook Salmon (Table 10). Inconclusive evidence suggests that annual abundance of Chinook Salmon redds trended downward over this time period ($p = 0.09$, $R^2 = 0.1938$; Figure 20). Estimates of Coho Salmon redds ranged between 34 and 1,320 (1.4%–23.7% of the surveyed redds each year) from 2012 to 2017 (Table 11). The low numbers of spawned female Coho Salmon carcasses collected each year from 2015 to 2017 precluded the differentiation of hatchery- and natural-origin Coho Salmon redds.

Spawner abundance was hypothesized to increase following restoration actions (TRRP and ESSA 2009), but no trend is evident that the abundance of natural-origin Chinook Salmon redds in the mainstem Trinity River changed from 2002 to 2017 ($p = 0.41$, $R^2 = 0.0488$; Figure 20). Strong evidence shows that the abundance of hatchery-origin Chinook Salmon redds (redds constructed by hatchery-produced females regardless of male origin) trended downward from 2002 to 2017 ($p < 0.001$, $R^2 = 0.5175$).

Table 10. Estimated number of Chinook Salmon redds and 95% confidence limits (CL) by species and origin observed in the mainstem Trinity River, 2002–2017. Data compiled from Chamberlain et al. (2012), Rupert et al. (2017a, 2017b), and Gough et al. (2019). Natural- and hatchery-origin estimates are for the maternal first generation only.

	Natural origin			Hatchery origin			All			
		95% CL			95% CL			95% CL		Surveyed
Year	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper	reaches
2002	3,613	- [a]	- [a]	1,227	- [a]	- [a]	4,840	- [a]	- [a]	1-10, 12-14
2003	5,066	- [a]	- [a]	2,269	- [a]	- [a]	7,335	- [a]	- [a]	1-10, 12-14
2004	3,031	- [a]	- [a]	1,669	- [a]	- [a]	4,700	- [a]	- [a]	1-10, 12-14
2005	2,249	- [a]	- [a]	1,276	- [a]	- [a]	3,525	- [a]	- [a]	1-10, 12-14
2006	2,840	- [a]	- [a]	1,221	- [a]	- [a]	4,061	- [a]	- [a]	1-10, 12-14
2007	4,073	- [a]	- [a]	1,053	- [a]	- [a]	5,126	- [a]	- [a]	1-10, 12-14
2008	3,205	- [a]	- [a]	467	- [a]	- [a]	3,672	- [a]	- [a]	1-10, 12-14
2009	3,679	- [a]	- [a]	350	- [a]	- [a]	4,029	- [a]	- [a]	1-10, 12-14
2010	2,982	2,742	3,155	469	- [a]	- [a]	3,451	- [a]	- [a]	1-10, 12-14
2011	5,312	4,767	5,456	1,059	- [a]	- [a]	6,370	- [a]	- [a]	1-10, 12-14
2012	6,170	5,909	6,347	1,145	967	1,412	7,315	7,219	7,391	1-7, 9-10, 12-14
2013	2,682	2,551	2,833	603	459	726	3,285	3,225	3,345	1-7, 9-10, 12-14
2014	2,733	2,537	3,008	909	657	1,088	3,642	3,519	3,765	1-7, 9-10, 12-14
2015	1,772	1,632	1,948	331	155	471	2,103	1,994	2,162	1-7, 9-10, 12-14
2016	1,516	1,453	1,580	91	27	154	1,607	- [b]	- [b]	1-7, 9-10, 12-14
2017	1,600	1,435	1,762	348	186	348	1,948	- [b]	- [b]	1-7, 9-10, 12-14

[a] Confidence limits only calculated and reported for Reaches 1-10 but not Reaches 12-14 (Chamberlain et al. 2012)

[b] Confidence limits are generated with both Chinook and Coho salmon data. Not enough female Coho Salmon carcasses were found this year to calculate confidence limits.

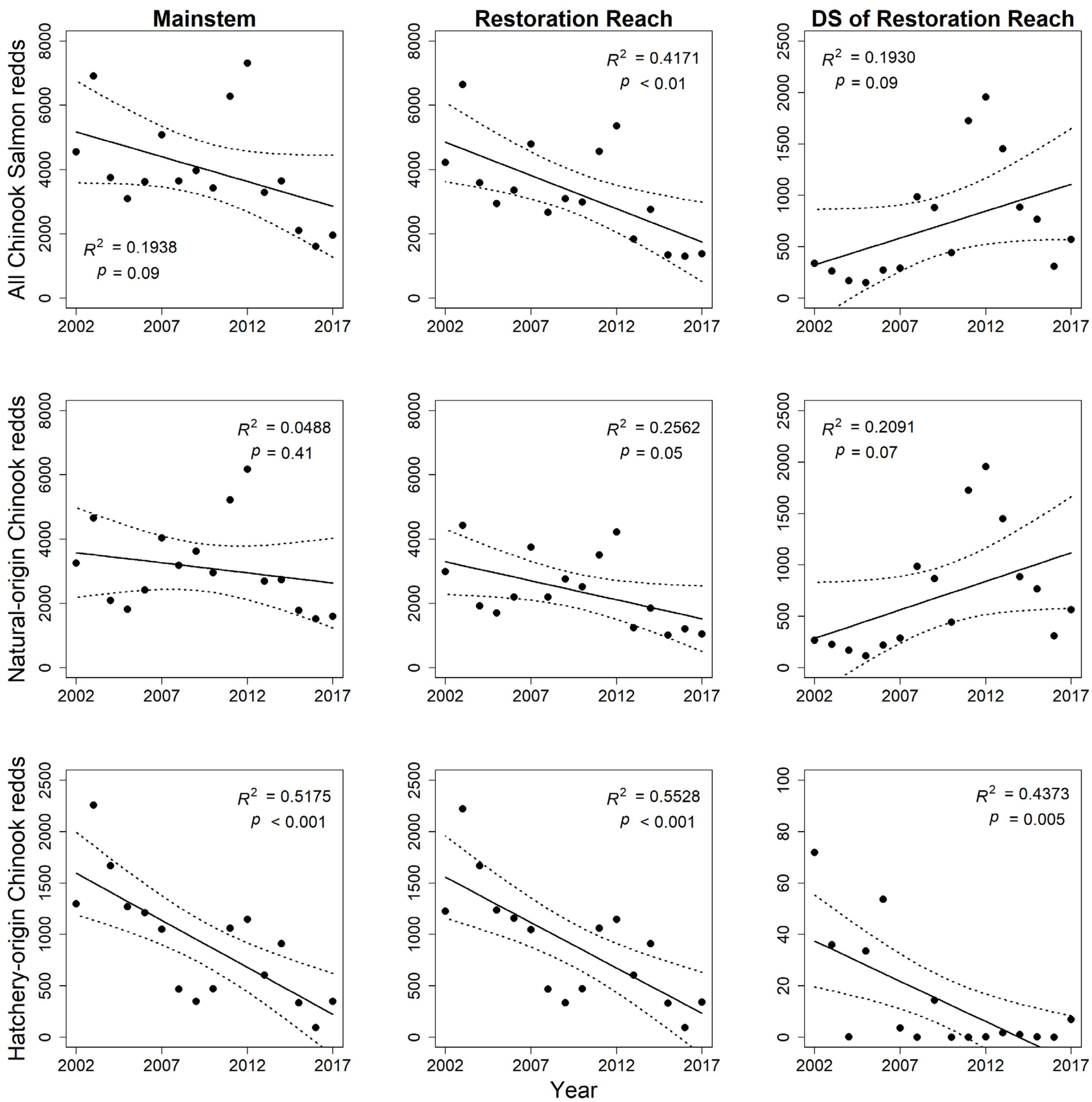


Figure 20. Estimated number of redds constructed in the entire mainstem Trinity River (left), within the restoration reach (center), and downstream (DS) of the restoration reach (right) by all Chinook Salmon (top), natural-origin Chinook Salmon (middle), and hatchery-origin Chinook Salmon (bottom) from 2002 to 2017. Each plot includes a linear model with the R^2 value, *p*-value, and 95% confidence limits (dotted lines). Note that the plots have different *y*-axis scales.

Table 11. Estimated of Coho Salmon redds and 95% confidence limits (CL) by species and origin observed in the mainstem Trinity River, 2012–2017. Annual surveys did not span the entire Coho Salmon spawning season and therefore these numbers should not be used as escapement estimates. Coho Salmon redds from 2002 to 2011 were estimated by subtracting Chinook Salmon redds from all salmon redds reported in Chamberlain et al. (2012). Natural- and hatchery-origin estimates are for the maternal first generation only.

	Natural origin			Hatchery origin			All			
		95% CL			95% CL			95% CL		Surveyed
Year	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper	reaches
2002	-	-	-	-	-	-	662	-	-	1-10, 12-14
2003	-	-	-	-	-	-	106	-	-	1-10, 12-14
2004	-	-	-	-	-	-	1,320	-	-	1-10, 12-14
2005	-	-	-	-	-	-	935	-	-	1-10, 12-14
2006	-	-	-	-	-	-	639	-	-	1-10, 12-14
2007	-	-	-	-	-	-	141	-	-	1-10, 12-14
2008	-	-	-	-	-	-	444	-	-	1-10, 12-14
2009	-	-	-	-	-	-	133	-	-	1-10, 12-14
2010	-	-	-	-	-	-	571	-	-	1-10, 12-14
2011	-	-	-	-	-	-	139	-	-	1-10, 12-14
2012	31	14	62	242	167	335	273	197	367	1-7, 9-10, 12-14
2013	149	85	224	869	784	945	1,018	958	1,078	1-7, 9-10, 12-14
2014	109	32	200	364	264	490	473	350	596	1-7, 9-10, 12-14
2015	NA [a]	-	-	NA [a]	-	-	59	0	168	1-7, 9-10, 12-14
2016	NA [a]	-	-	NA [a]	-	-	64	- [b]	- [b]	1-7, 9-10, 12-14
2017	NA [a]	-	-	NA [a]	-	-	34	- [b]	- [b]	1-7, 9-10, 12-14

[a] Not enough Coho Salmon carcasses were observed in 2017 to calculate separate estimates for natural- and hatchery-origin Coho Salmon redds.

[b] Confidence limits are generated with both Chinook and Coho salmon data. Not enough female Coho Salmon carcasses were found this year to calculate confidence limits.

Spatially, evidence supports that the distribution of Chinook Salmon redds shifted downstream from 2002 to 2017. In the section of river from Lewiston Dam to Cedar Flat (Reaches 1–10), the mean distance from Lewiston Dam of natural-origin Chinook Salmon redds shifted downstream ($p < 0.001$, $R^2 = 0.7530$; Figure 21). A trend is not evident for redds constructed by hatchery-origin Chinook Salmon ($p = 0.23$, $R^2 = 0.1004$) which consistently spawned near Lewiston Dam. In this section of river, the mean distance of redds from the dam ranged between 15.3 and 49.2 km for natural-origin and between 2.1 and 14.2 km for hatchery-origin Chinook Salmon.

The trends in redd abundance within the restoration reach were similar to the entire mainstem (Figure 20). From 2002 to 2017, the number of redds constructed annually by natural- and hatchery-origin Chinook Salmon in the restoration reach, though variable, shows moderate to strong evidence of a downward trend ($p = 0.05$, $R^2 = 0.2562$ and $p < 0.001$, $R^2 = 0.5528$, respectively).

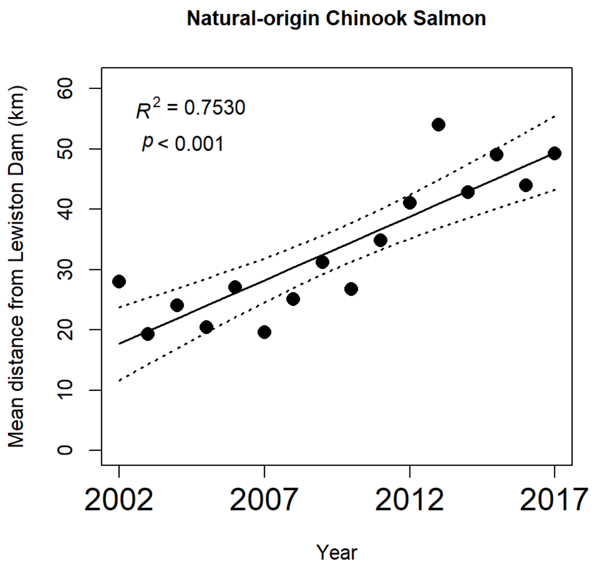


Figure 21. Mean distance from Lewiston Dam of redds constructed by natural- (left) and hatchery-origin (right) Chinook Salmon females between Lewiston Dam and Cedar Flat (0–102.8 km from Lewiston Dam; Reaches 1–10) on the mainstem Trinity River, 2002–2017. Each plot includes a linear model with the R^2 value, p-value, and 95% confidence limits (dotted lines). Note that the plots have different y-axis scales.

Downstream of the restoration reach, some moderate evidence suggests that the number of natural-origin Chinook Salmon redds constructed increased from 2002 to 2017 ($p = 0.07$, $R^2 = 0.2091$; Figure 20). Evidence shows that hatchery-origin Chinook Salmon redds trended downward over this time period ($p = 0.005$, $R^2 = 0.4373$), but relatively few or no redds were constructed annually by hatchery-origin Chinook Salmon in this section of river. From 2002 to 2006, between 0 and 72 redds per year were estimated to be constructed by hatchery-origin Chinook Salmon downstream of the restoration reach. From 2007 to 2017, between 0 and 14 redds per year were estimated to be constructed by hatchery-origin Chinook Salmon downstream of the restoration reach and only zero or one redd was estimated in 8 of those 11 years.

3.3.2.2 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 trended downward in the Lewiston ($p = 0.002$, $R^2 = 0.5252$) and Limekiln ($p = 0.03$, $R^2 = 0.3047$) reaches from 2002 to 2017 (Figure 22). Additionally, the annual proportion of natural-origin Chinook Salmon redds within each of the ten reach-scale segments, relative to the annual total in the entire mainstem river, were examined and similar relationships over time and space were found (Figure 23). This analysis revealed a shift in spawning distribution, with strong evidence that the proportion of natural-origin Chinook Salmon redds decreased in the two upstream-most reaches [Lewiston ($p < 0.001$, $R^2 = 0.8034$) and Limekiln ($p = 0.003$, $R^2 = 0.4771$)] and either did not change or trended upward in the eight reaches downstream of the Limekiln reach.

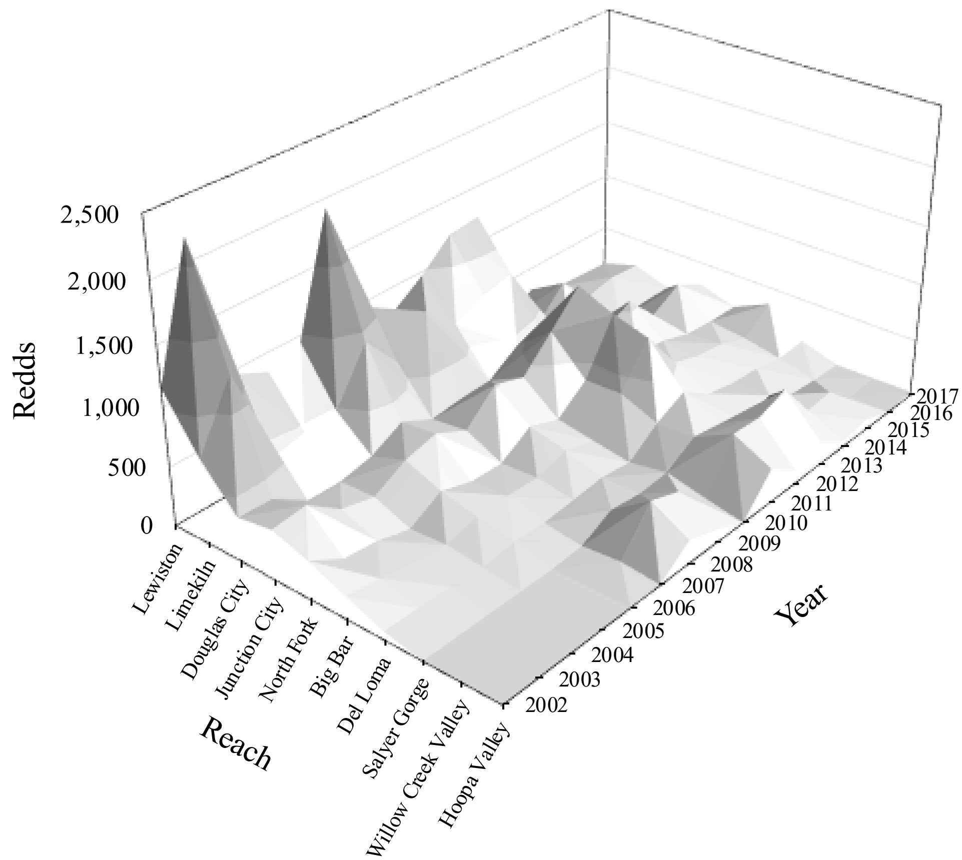


Figure 22. Spatiotemporal distribution of natural-origin Chinook Salmon redds in the mainstem Trinity River reach-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis within each reach.

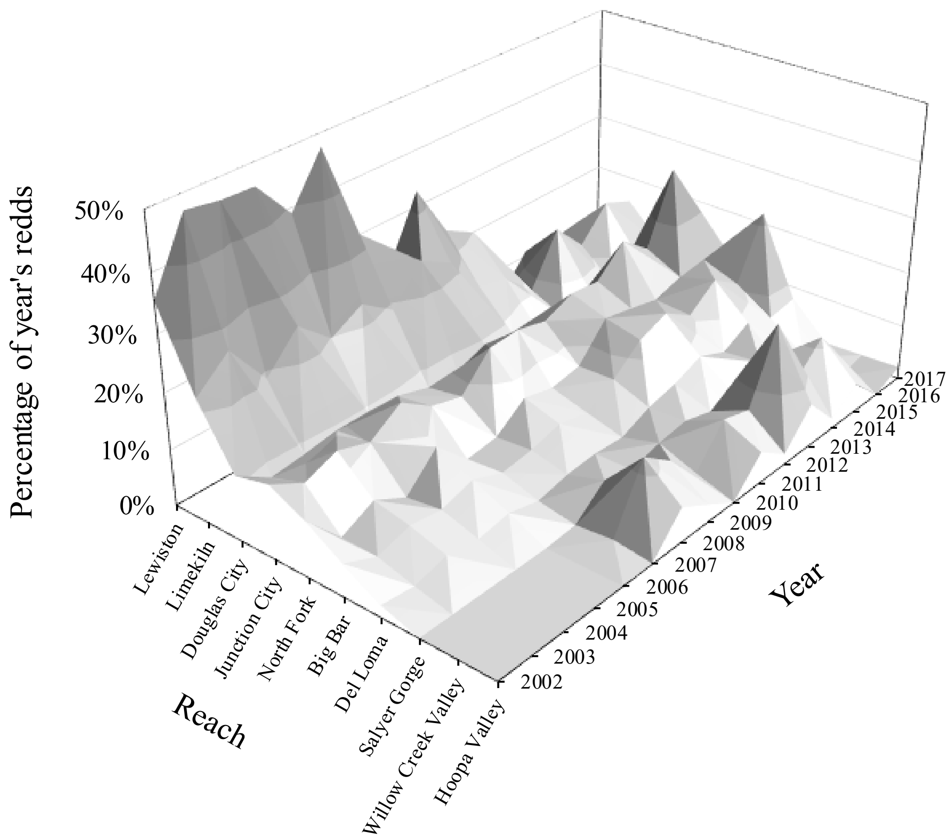


Figure 23. Spatiotemporal distribution of the annual percentages of natural-origin Chinook Salmon redds in the mainstem Trinity River reach-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis within each reach.

Most hatchery-origin Chinook Salmon redds were constructed in the Lewiston rehabilitation reach (range: 72–1,888 redds/year) and, to a lesser degree, in the Limekiln rehabilitation reach (range: 19–236 redds/year) from 2002 to 2017 (Figure 24). Over this time frame, the abundance of hatchery-origin Chinook Salmon redds decreased in the Lewiston reach ($p < 0.001$, $R^2 = 0.5648$) and some evidence suggests that they also decreased in the Limekiln reach ($p = 0.09$, $R^2 = 0.1893$). Fewer hatchery-origin Chinook Salmon redds were found downstream of the Limekiln reach to the Del Loma reach, where redd numbers averaged between 7 and 18 per year in each reach, and conclusive evidence of change was only observed in the Del Loma reach ($p = 0.04$, $R^2 = 0.2753$). No redds were predicted to be associated with hatchery-origin Chinook Salmon downstream of the Del Loma reach.

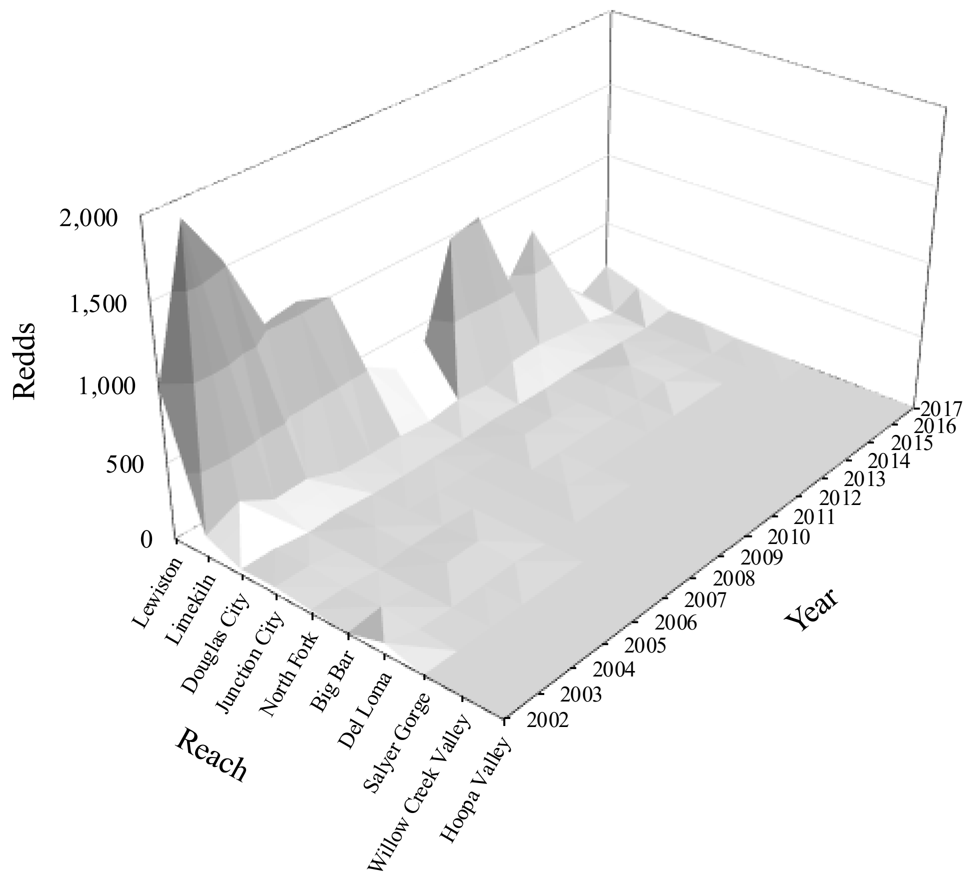


Figure 24. Spatiotemporal distribution of hatchery-origin Chinook Salmon redds in the mainstem Trinity River reach-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis within each reach.

To account for annual variation in run size, the annual proportion of hatchery-origin Chinook Salmon redds within each of the reaches was analyzed over time (Figure 25). Most of the hatchery-origin Chinook Salmon redds were consistently in the Lewiston reach (range = 51.7%–95.4%, mean = 82.3%) and, to a smaller degree, in the Limekiln reach (range = 3.5%–30.2%, mean = 11.5%) from 2002 to 2017. There was moderate evidence that the proportion of hatchery-origin Chinook Salmon redds in the Lewiston reach decreased ($p = 0.06$, $R^2 = 0.2331$) and stronger evidence that the proportion in the Limekiln reach trended upward ($p = 0.006$, $R^2 = 0.4229$) over this time period. The mean percentage of hatchery-origin Chinook Salmon redds in each reach downstream of the Limekiln reach ranged between 0.0% and 2.2% and did not change significantly in any of the reaches (Gough et al. 2019).

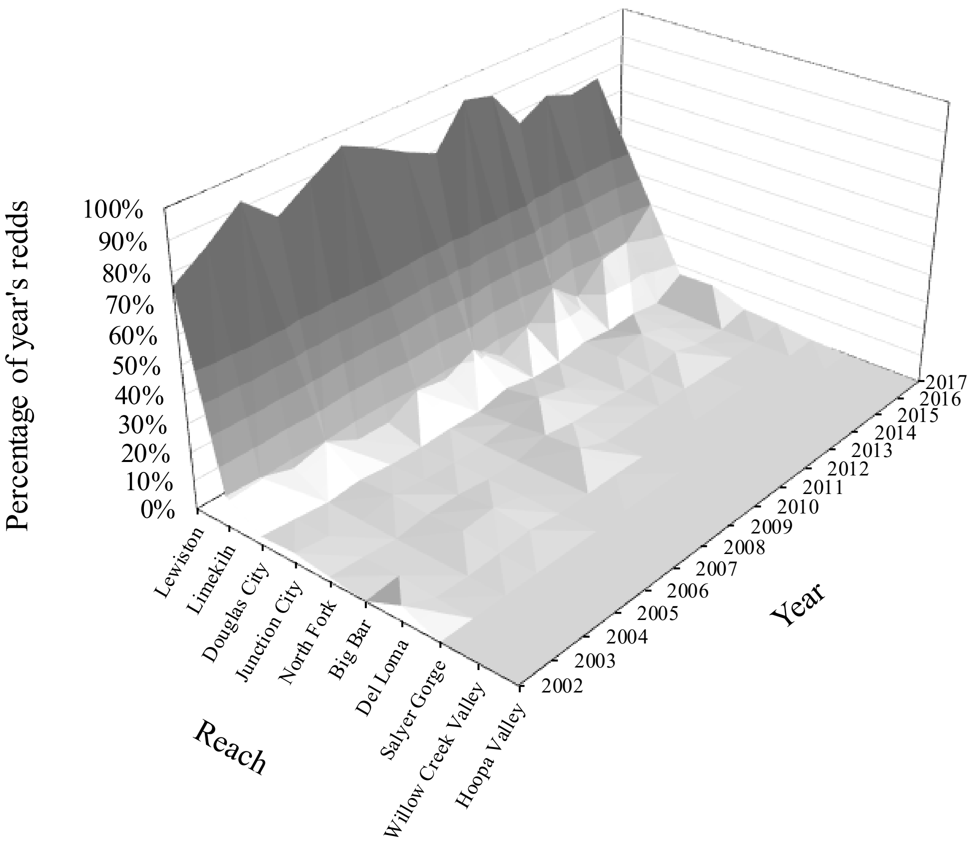


Figure 25. Spatiotemporal distribution of the annual percentages of hatchery-origin Chinook Salmon redds in the mainstem Trinity River reach-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis within each reach.

3.3.2.3 Redd Abundance and Distribution: Site Scale

The abundance of natural-origin Chinook Salmon within the 44 site-scale river sections showed a range of long-term (2002–2017) trends (Figure 26; see also Gough et al. 2019). Most sites (21) did not show evidence of a change, 17 sites showed evidence of an increasing trend, and 6 sites showed evidence of a decreasing trend. The annual percentage of natural-origin Chinook Salmon redds in four (Lewiston Hatchery, Sven Olbertson, Old Bridge, and Upper Rush Creek) of the five upstream-most sites trended downward (Figure 27). The annual percentage of natural-origin Chinook Salmon that spawned in each of the remaining 41 sites downstream of the Old Bridge site was typically less than 10% and frequently less than 5%. All sites where the annual percentage of natural-origin Chinook Salmon redds trended upward were among these downstream reaches.

Of the 22 mechanical channel rehabilitation sites with at least five years of post-construction data, the proportional abundance of natural-origin Chinook Salmon redds showed evidence of upward trend at 7 sites, downward trend at 2 sites, and displayed no evidence of change at 13 sites (Figure 28). Like the long-term trends, there was moderate or stronger evidence that the proportional abundance of natural-origin Chinook Salmon redds decreased in the upstream-most sites (Lewiston Hatchery to Sawmill sites), showed no evidence of change in the middle sites (Dark Gulch to Upper Douglas City sites), and moderate or stronger evidence of increased proportional abundance in the majority of downstream-most sites (Douglas City to Pear Tree Bar sites).

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 (Figures 29 and 30). Like the reach scale, the annual percentage of hatchery-origin fish were at or close to 0.0% at most sites below the Limekiln reach from 2002 to 2017.

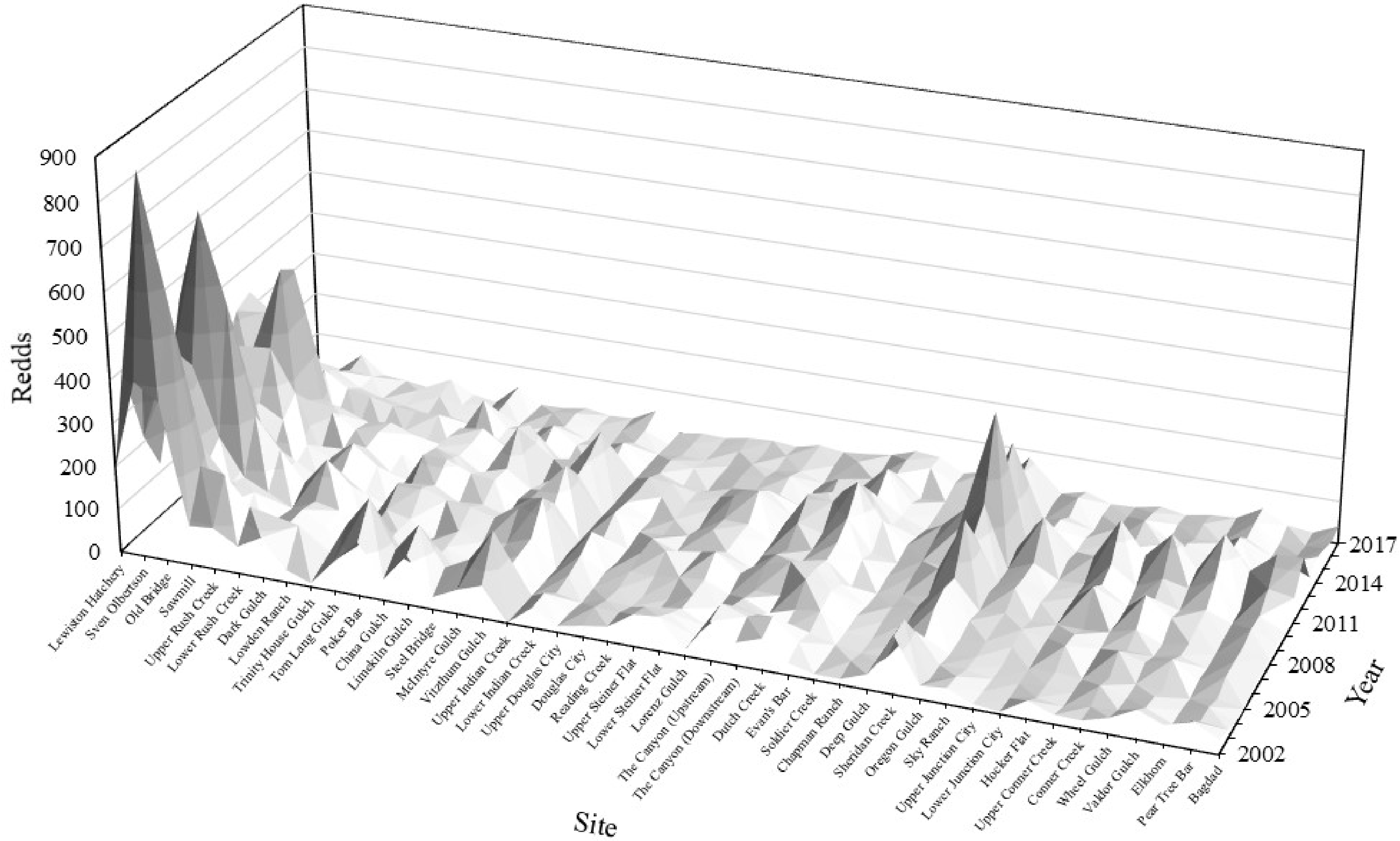


Figure 26. Spatiotemporal distribution of natural-origin Chinook Salmon redds in the mainstem Trinity River TRRP restoration reach site-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis at each site.

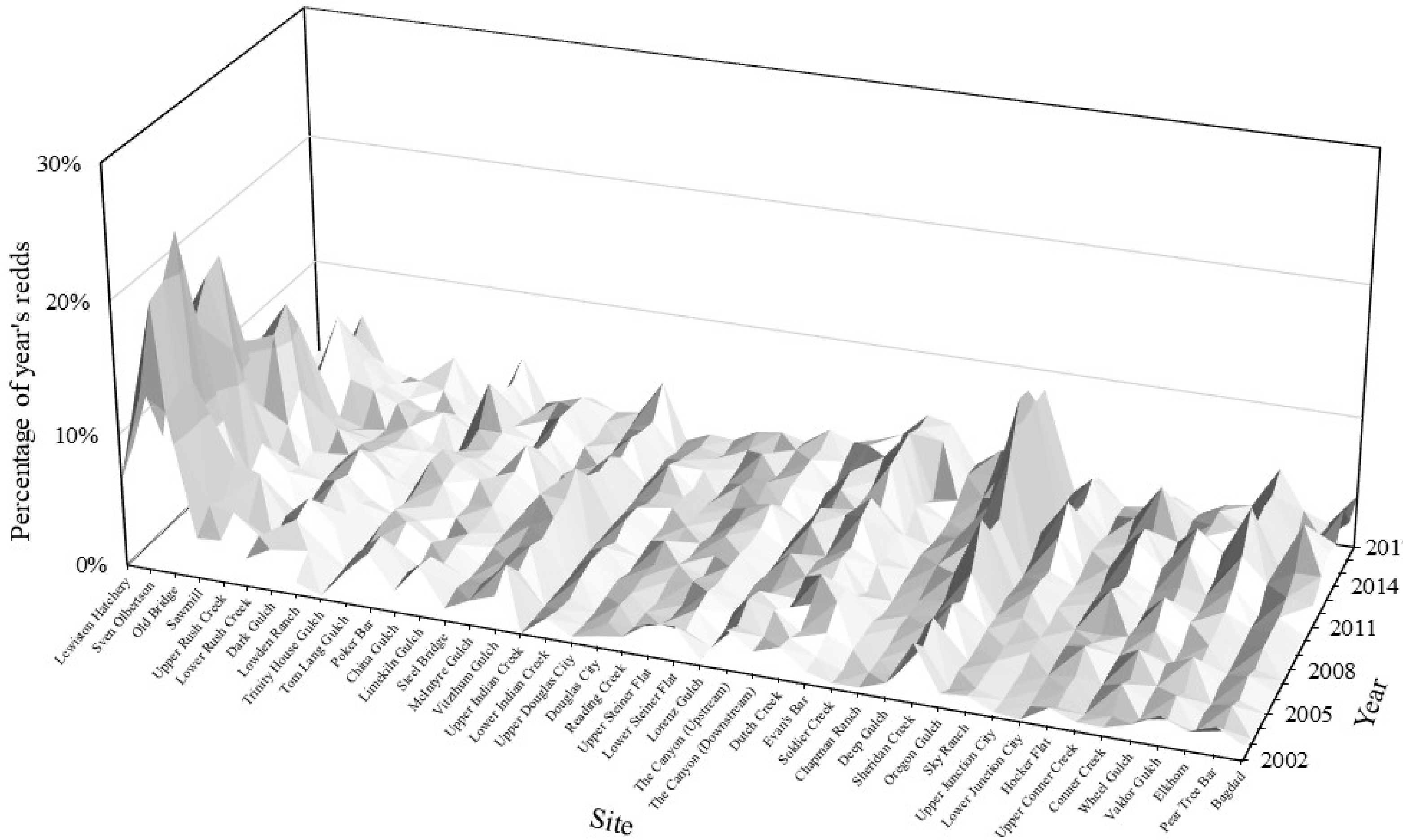


Figure 27. Spatiotemporal distribution of the annual percentages of natural-origin Chinook Salmon redds in the mainstem Trinity River TRRP restoration reach site-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis at each site.

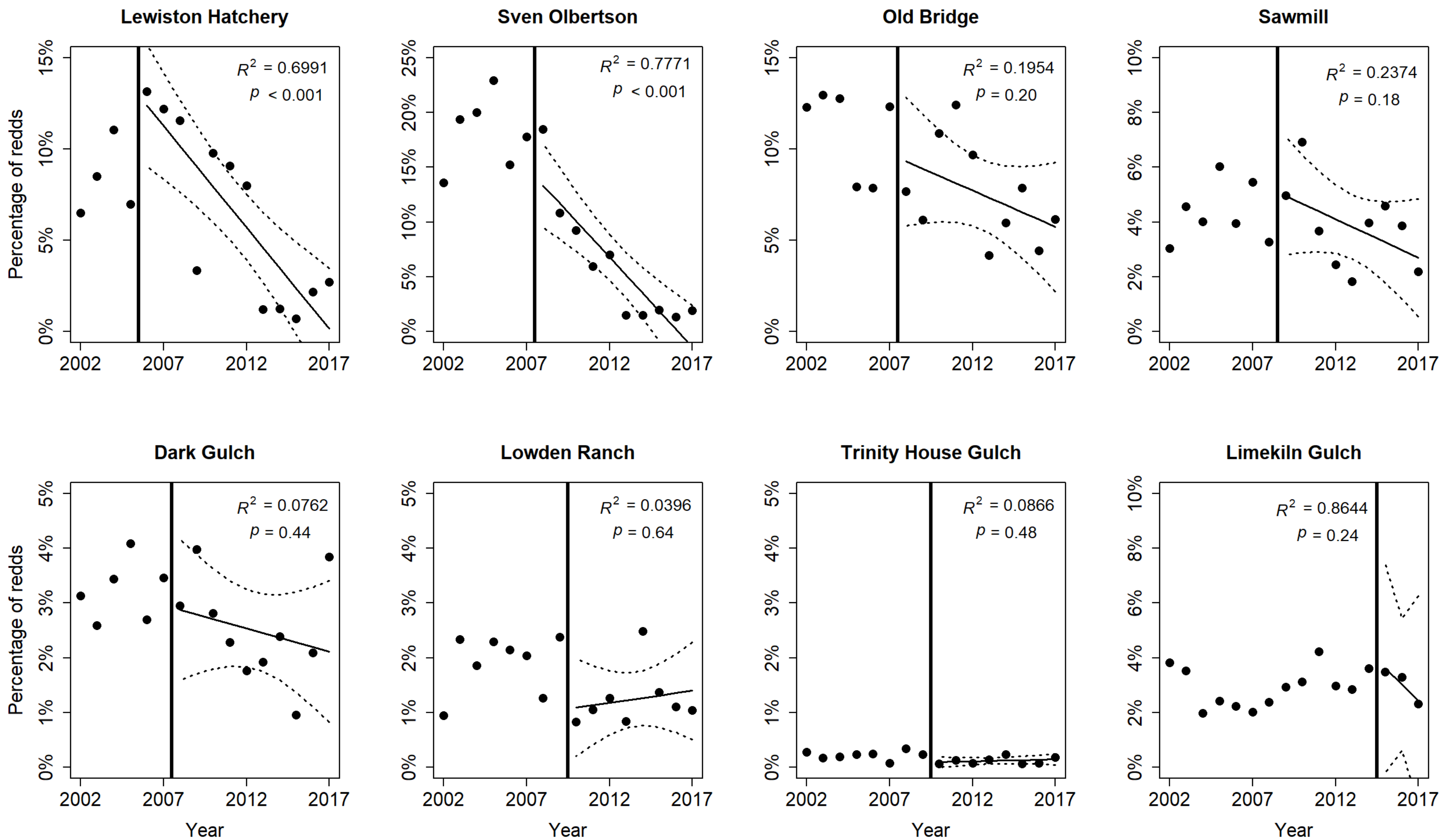


Figure 28. Percentage of natural-origin Chinook Salmon redds within site-scale sections in the TRRP restoration reach that encompass mechanical channel rehabilitation locations, 2002–2017. Each plot includes a post-construction linear model with the R^2 value, *p*-value, and 95% confidence limits (dotted lines). If conducted, the time that mechanical channel rehabilitation was initiated is shown with a vertical line.

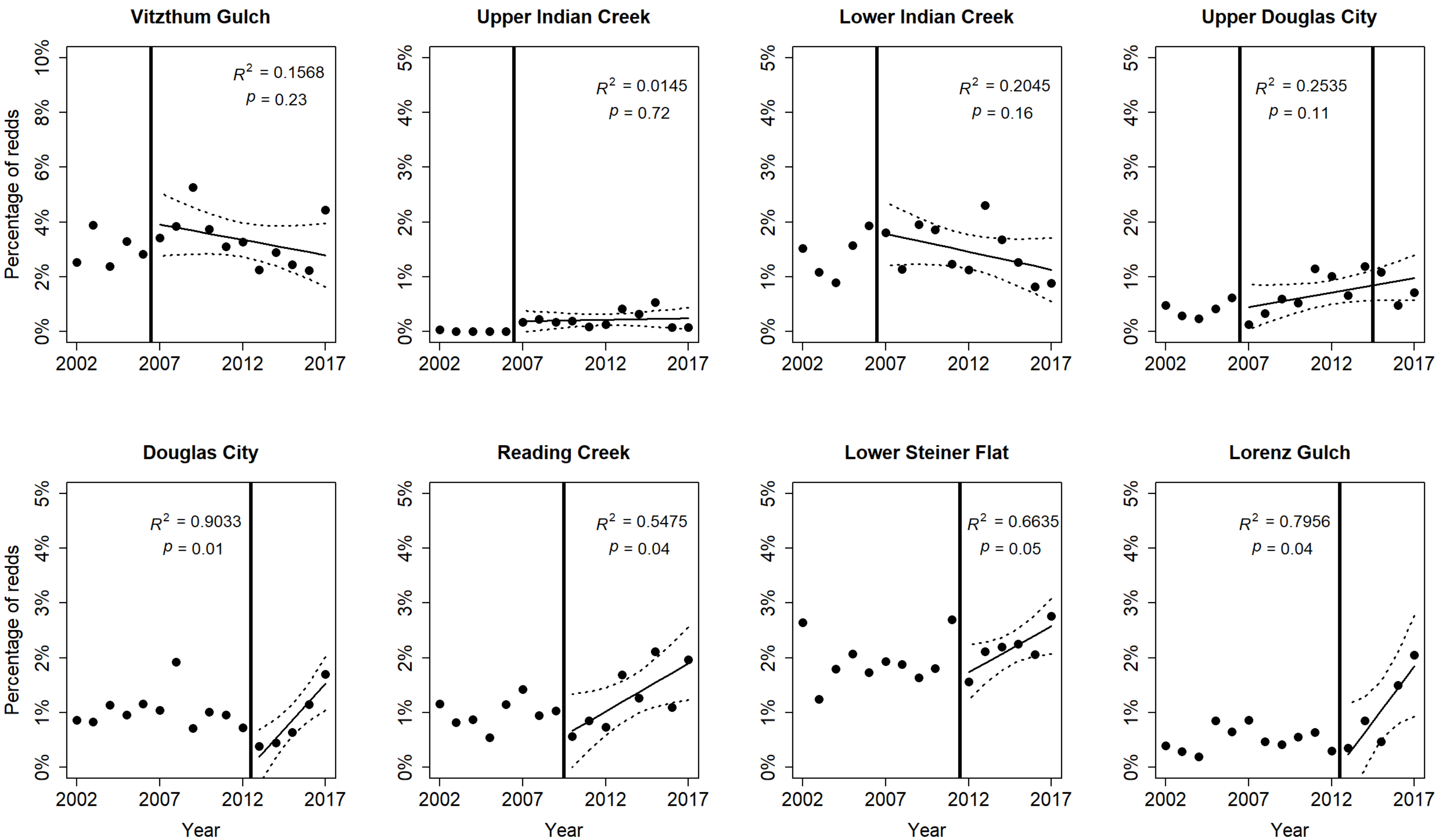


Figure 28 (continued). Percentage of natural-origin Chinook Salmon redds within site-scale sections in the TRRP restoration reach that encompass mechanical channel rehabilitation locations, 2002–2017. Each plot includes a post-construction linear model with the R^2 value, p-value, and 95% confidence limits (dotted lines). If conducted, the time that mechanical channel rehabilitation was initiated is shown with a vertical line.

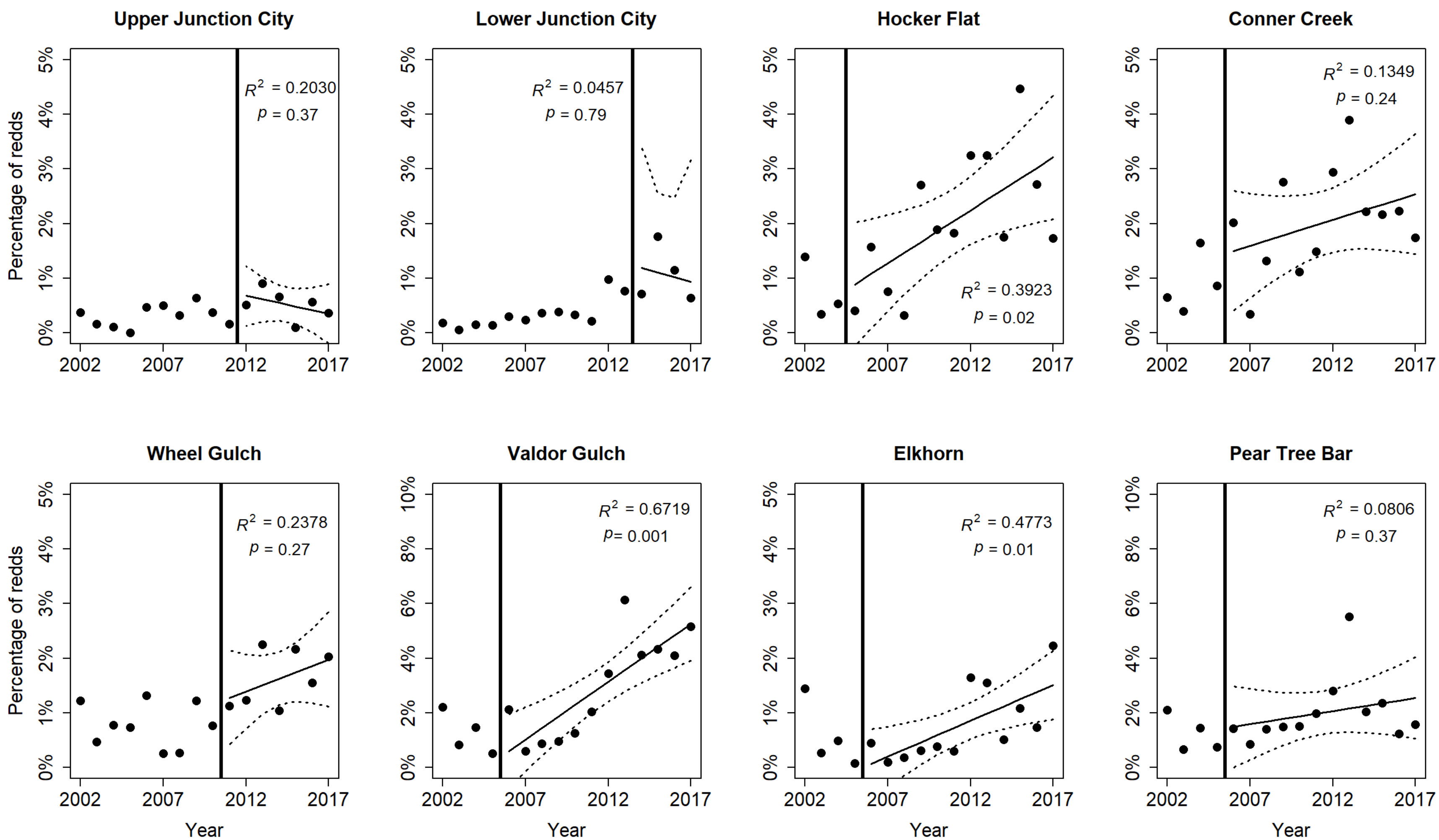


Figure 28 (continued). Percentage of natural-origin Chinook Salmon redds within site-scale sections in the TRRP restoration reach that encompass mechanical channel rehabilitation locations, 2002–2017. Each plot includes a post-construction linear model with the R^2 value, p-value, and 95% confidence limits (dotted lines). If conducted, the time that mechanical channel rehabilitation was initiated is shown with a vertical line.

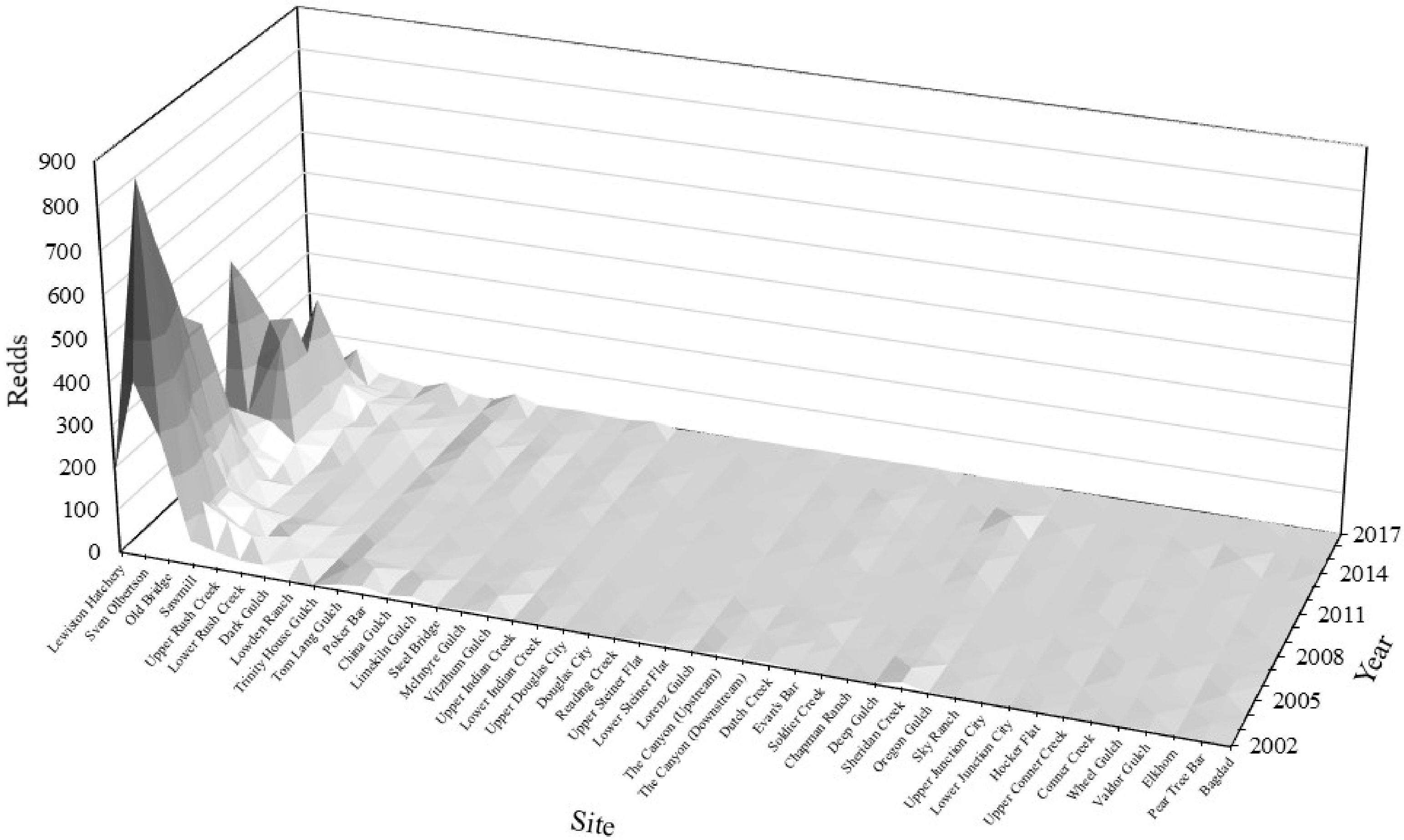


Figure 29. Spatiotemporal distribution of hatchery-origin Chinook Salmon redds in the mainstem Trinity River TRRP restoration reach site-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis at each site.

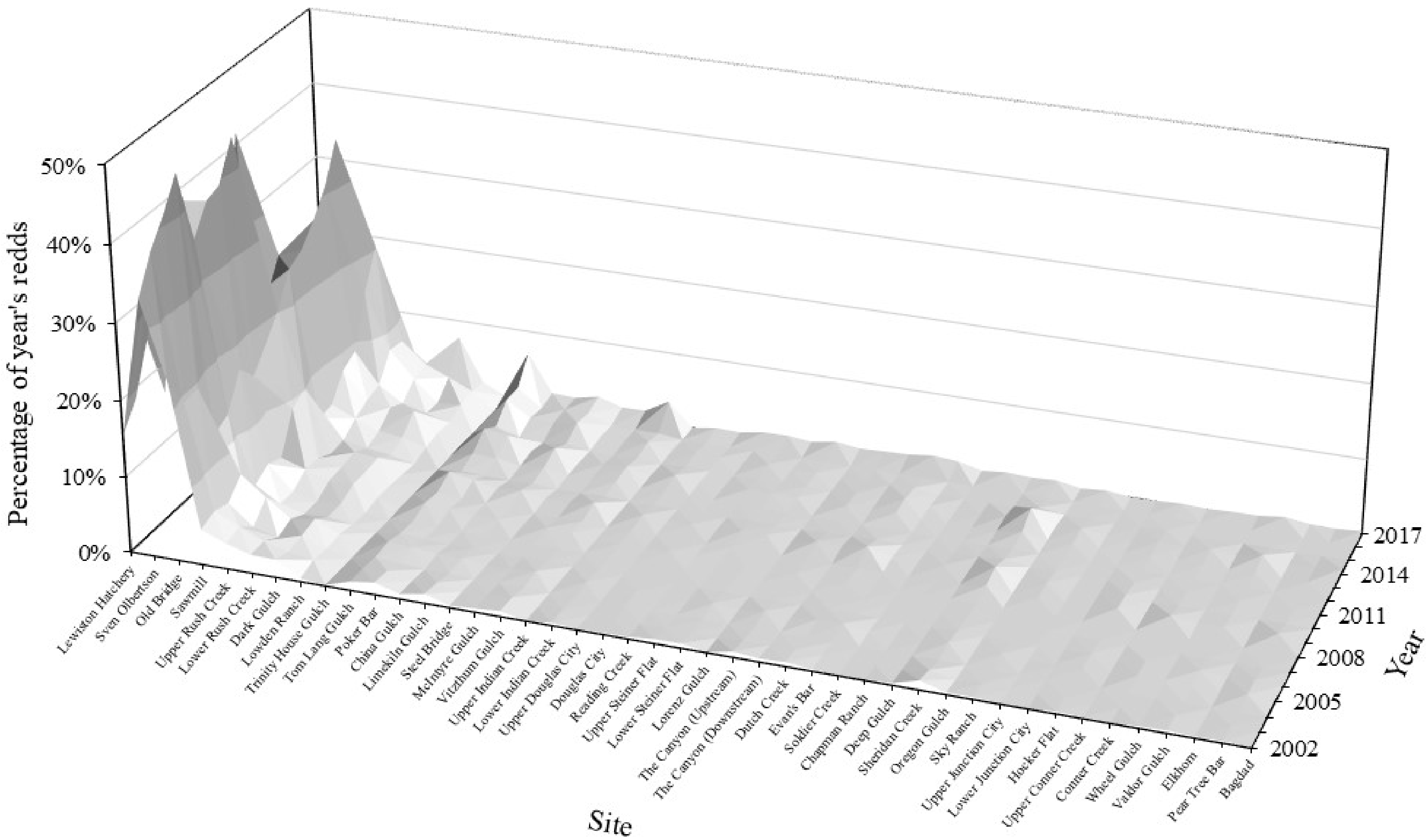


Figure 30. Spatiotemporal distribution of the annual percentages of natural-origin Chinook Salmon redds in the mainstem Trinity River TRRP restoration reach site-scale sections, 2002–2017. Refer to Gough et al. (2019) for more detail on the analysis at each site.

3.3.3 Tributary Spawning

Spawning surveys were conducted in 11 Trinity River tributaries in the fall and early winter from 1999 to 2008 (Table 12) and 7 of these tributaries were surveyed for redds several times annually in the fall and early winter from 2009 to 2016 (Tables 13 and 14).

The 1999–2008 period was marked by inconsistent surveys on an annual basis (Table 12). Canyon Creek, Big French Creek, Deadwood Creek, East Fork North Fork Trinity River, and Rush Creek were the only tributaries surveyed during most years. Conner Creek, Dutch Creek, Manzanita Creek, North Fork Trinity River, Soldier Creek, and the South Fork Trinity River were not surveyed consistently throughout this time period. Conner, Dutch, Soldier, and Manzanita creeks also had no documented redds during this time period. Big French Creek averaged less than one redd per year. The mean number of redds in Canyon Creek, Deadwood Creek, Rush Creek, North Fork Trinity River, and East Fork North Fork Trinity River ranged between 14.2 and 42.9 redds per year. The South Fork Trinity River had the most redds and ranged between 38 in 2006 and 457 in 2008 (mean = 251.0 redds). In addition to many streams not being surveyed annually, streams were not surveyed consistently throughout the year. This may have resulted in undercounted redd numbers in some tributaries. These surveys also did not account for species (Chinook or Coho salmon).

Table 12. Number of Chinook and Coho salmon redds (not identified by species) observed in tributaries to the Trinity River from 1999 to 2008. Dashes (-) represent no survey.

Year	Big French Creek	Canyon Creek	Conner Creek	Deadwood Creek	Dutch Creek	East Fork North Fork	Manzanita Creek	North Fork	Rush Creek	Soldier Creek	South Fork
1999	-	3	-	-	-	3	-	5	-	-	-
2000	0	6	-	-	-	3	-	6	0	-	-
2001	0	3	-	-	-	0	-	8	0	-	-
2002	2	18	-	8	-	18	-	40	5	-	-
2003	1	38	-	77	0	48	-	72	34	0	-
2004	0	55	-	98	0	107	-	33	29	0	-
2005	-	0	0	32	-	-	-	6	10	0	-
2006	-	8	-	75	-	30	-	42	13	-	38
2007	0	0	-	5	0	55	0	25	3	0	258
2008	2	11	-	5	0	27	0	19	10	0	457
Mean	0.7	14.2	0.0	42.9	0.0	32.3	0.0	25.6	11.6	0.0	251.0

Chinook Salmon redds were typically the most abundant type in the seven tributaries surveyed from 2009 to 2016 (Tables 13 and 14). However, these surveys typically encompassed the entire Chinook Salmon spawning season but only a portion of the Coho Salmon spawning season. No (zero) Coho Salmon redds were detected in Big French Creek and the South Fork Trinity River. Coho Salmon redds were more common in Deadwood and Rush creeks and outnumbered Chinook Salmon redd counts in some years. Like the counts from 1999 to 2008, the South Fork Trinity River had the most redds, all from Chinook Salmon, and ranged between 54 and 904 (mean = 366.9 redds).

Table 13. Number of Chinook Salmon redds observed in tributaries to the Trinity River from 2009 to 2016. Dashes (-) represent no survey.

Year	Big French Creek	Canyon Creek	Deadwood Creek	East Fork North Fork	North Fork	Rush Creek	South Fork
2009	8	18	-	18	18	-	147
2010	14	16	7	22	25	4	252
2011	15	70	10	131	44	17	886
2012	21	78	8	111	66	27	904
2013	3	6	2	7	4	9	172
2014	13	24	1	74	27	12	413
2015	7	8	0	8	9	0	54
2016	4	1	3	6	6	8	107
Mean	10.6	27.6	4.4	47.1	24.9	11.0	366.9

Table 14. Number of Coho Salmon redds observed in tributaries to the Trinity River from 2009 to 2016. Dashes (-) represent no survey.

Year	Big French Creek	Canyon Creek	Deadwood Creek	East Fork North Fork	North Fork	Rush Creek	South Fork
2009	0	3	-	0	0	-	0
2010	0	0	19	0	0	1	0
2011	0	14	10	15	0	10	0
2012	0	1	28	21	2	15	0
2013	0	16	3	10	13	80	0
2014	0	14	11	1	5	24	0
2015	0	8	0	3	2	19	0
2016	0	0	1	0	0	0	0
Mean	0.0	7.0	10.3	6.3	2.8	21.3	0.0

3.3.4. Comparison between Tributary and Mainstem Spawning

The Trinity River tributaries, especially the South Fork, are an important component of the natural spawning grounds for Chinook and Coho salmon in the Trinity River Basin. Tributaries hosted between 3.9% and 15.5% of surveyed redds on spawning grounds, mainstem and tributaries combined, from 2009 to 2016. Since tributary spawning surveys only covered a portion of the potential spawning areas, these redd counts were likely less than the actual number constructed.

Using the data from 2009 to 2016, a generalized linear model shows a positive correlation ($p < 0.001$, $R^2 = 0.88$) between the number of surveyed Chinook Salmon redds in the mainstem and those in tributaries (Figure 31); however, this analysis was conducted with a small data set and the relationship was largely driven by two data points (years 2011 and 2012). The relationship is less conclusive ($p = 0.21$, $R^2 = 0.36$) after removing the 2011 and 2012 data from the analysis. More years of empirical data may improve this model, which could make it a useful surrogate for years when tributaries are not surveyed due to unsuitable weather or water conditions.

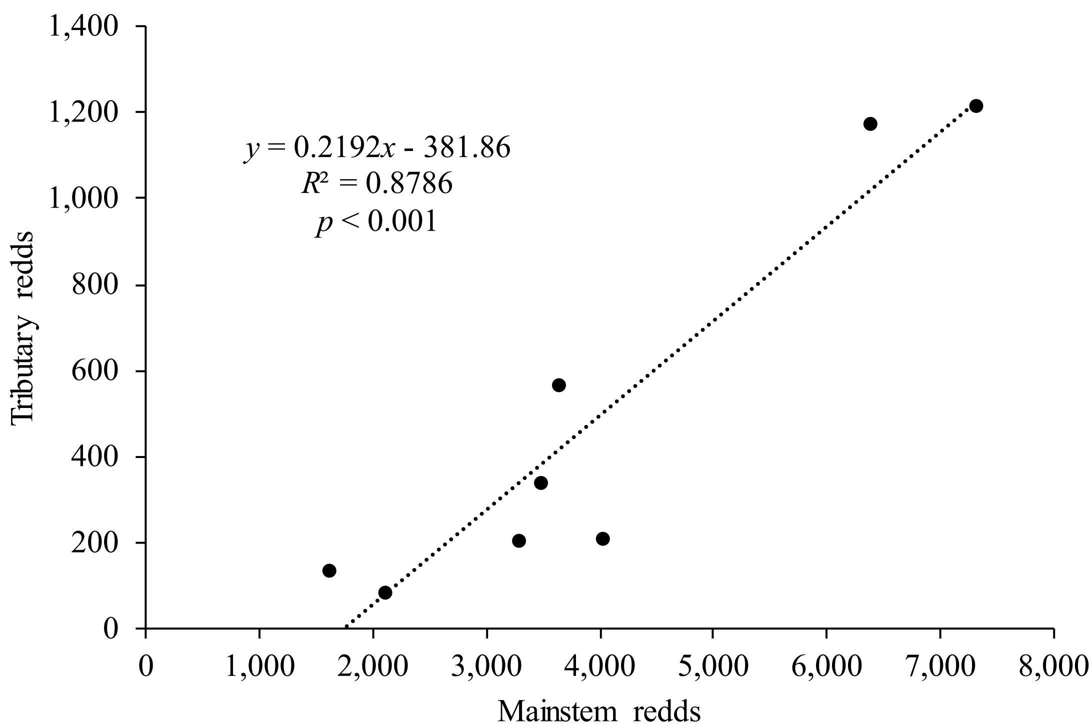


Figure 31. Relationship between the number of Chinook Salmon redds in the mainstem versus tributaries in Trinity River basin from 2009 to 2016.

4. Syntheses and New Analyses

4.1 Species Composition of Salmonid Escapement

Total annual salmonid escapement in this report refers to all adult spring- and fall- run Chinook Salmon, Coho Salmon, and steelhead that return to the Trinity River. The proportion of each species/run varies annually because each have independent population dynamics and different responses to environmental stressors. The annual proportions of each species of the total adult salmonid escapement to the Trinity River from 1980 to 2018 are presented in this section. Total escapement including hatchery- and natural-origin fish returning to natural spawning areas and the TRH was used because it represents the most complete time series across all species.

The annual species composition of the total salmonid escapement was variable from 1980 to 2018 (Figure 32, Table 15). Fall-run Chinook Salmon were typically the most abundant when escapement estimates were available for all species. The lowest fall-run Chinook Salmon proportion of the total salmonid escapement was observed in 2002, when a fish kill occurred in the lower Klamath River (Guillen 2003; CDFG 2004). However, escapement of spring-run Chinook Salmon to the Trinity River during that year (34,477 adults) was among the highest on record. Only in 1997 and 2002 did the spring Chinook Salmon run outnumber the fall run. The highest proportions of Coho Salmon were observed in 1985 and 2004. The highest proportions of steelhead were observed in 1980, 2006, 2007, and 2015. Steelhead escapement in 2006 and 2007 were the highest on record in the Trinity River. Below average escapement of other salmonid species in 1980 and 2015 largely explain the high proportions of steelhead in those years. Only minor changes to the mean relative species abundances were observed between the before and after ROD implementation periods (Figure 33).

The escapement estimates assessed in this report do not include harvest, which has varied substantially among species and across years. For example, no directed harvest of Coho Salmon and no harvest of natural-origin steelhead have been permitted since 1996, while harvest of fall-run Chinook Salmon varies annually and can be many thousands in some years. For this reason, the species composition of annual salmonid escapement is often not an accurate reflection of total adult production. Additionally, the inclusion of hatchery-origin fish in this analysis somewhat obscures the ability to make inferences about environmental stressors or comparisons between pre-ROD and ROD periods because they are isolated from many environmental stressors during early life-history phases and their production remains relatively constant across years.

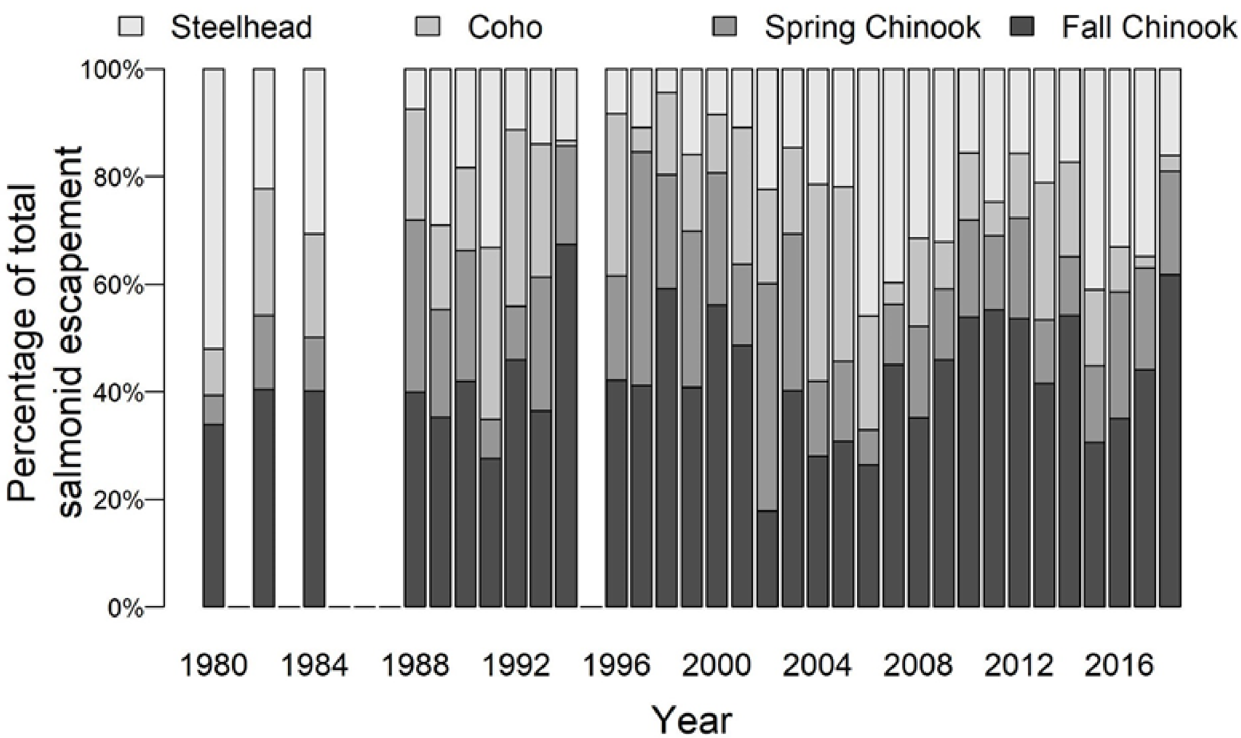


Figure 32. Annual species/run composition of total adult salmonid escapement to Trinity River Hatchery and natural spawning areas of the Trinity River. Only years for which escapement estimates for all species were available are presented.

Table 15. Estimated total escapement of four anadromous salmonid species/runs to Trinity River Hatchery and natural spawning areas of the Trinity River, including both hatchery- and natural-origin fish, 1980–2018. Species and years for which no estimates are available are indicated by 'NA'. Percentages sum to 100% for all years with available data. Estimates of total adult salmonid escapement correspond to totals presented in Appendices C–F.

	Total adult escapement				Percentage of total salmonid escapement			
Year	Fall-run Chinook Salmon	Spring-run Chinook Salmon	Coho Salmon	Steelhead	Fall-run Chinook Salmon	Spring-run Chinook Salmon	Coho Salmon	Steelhead
1980	14,055	2,235	3,595	21,568	33.9%	5.4%	8.7%	52.0%
1981	18,714	5,767	4,524	NA	64.5%	19.9%	15.6%	NA
1982	15,567	5,263	9,072	8,573	40.5%	13.7%	23.6%	22.3%
1983	23,049	NA	1,302	7,260	72.9%	NA	4.1%	23.0%
1984	8,586	2,142	4,105	6,572	40.1%	10.0%	19.2%	30.7%
1985	29,966	7,871	29,135	NA	44.7%	11.8%	43.5%	NA
1986	111,952	20,637	8,836	NA	79.2%	14.6%	6.2%	NA
1987	88,307	37,702	48,871	NA	50.5%	21.6%	27.9%	NA
1988	66,720	53,566	34,350	12,743	39.9%	32.0%	20.5%	7.6%
1989	40,816	23,248	18,167	33,698	35.2%	20.1%	15.7%	29.1%
1990	9,401	5,428	3,443	4,118	42.0%	24.2%	15.4%	18.4%
1991	7,554	1,953	8,753	9,077	27.6%	7.1%	32.0%	33.2%
1992	11,129	2,406	7,937	2,754	45.9%	9.9%	32.8%	11.4%
1993	7,449	5,073	5,048	2,862	36.5%	24.8%	24.7%	14.0%
1994	18,612	5,079	239	3,699	67.4%	18.4%	0.9%	13.4%
1995	93,130	NA	15,183	3,996	82.9%	NA	13.5%	3.6%
1996	49,306	22,584	35,143	9,842	42.2%	19.3%	30.1%	8.4%
1997	17,714	18,637	1,986	4,696	41.2%	43.3%	4.6%	10.9%
1998	38,948	13,940	10,018	2,904	59.2%	21.2%	15.2%	4.4%
1999	13,817	9,811	4,814	5,388	40.8%	29.0%	14.2%	15.9%
2000	51,926	22,687	10,047	7,865	56.1%	24.5%	10.9%	8.5%
2001	54,327	16,800	28,473	12,271	48.6%	15.0%	25.5%	11.0%
2002	14,509	34,477	14,307	18,304	17.8%	42.3%	17.5%	22.4%
2003	62,251	45,069	24,678	22,778	40.2%	29.1%	15.9%	14.7%
2004	25,329	12,622	33,023	19,394	28.0%	14.0%	36.5%	21.5%
2005	26,893	13,034	28,326	19,205	30.7%	14.9%	32.4%	22.0%
2006	23,272	5,728	18,709	40,479	26.4%	6.5%	21.2%	45.9%
2007	57,446	14,397	5,205	50,725	45.0%	11.3%	4.1%	39.7%
2008	16,281	7,930	7,604	14,590	35.1%	17.1%	16.4%	31.4%
2009	24,048	6,877	4,587	16,832	45.9%	13.1%	8.8%	32.2%
2010	28,558	9,555	6,669	8,254	53.8%	18.0%	12.6%	15.6%
2011	46,688	11,733	5,318	20,944	55.1%	13.9%	6.3%	24.7%
2012	68,212	23,966	15,268	20,012	53.5%	18.8%	12.0%	15.7%
2013	31,162	8,899	19,087	15,935	41.5%	11.9%	25.4%	21.2%
2014	31,425	6,276	10,199	10,074	54.2%	10.8%	17.6%	17.4%
2015	7,968	3,728	3,684	10,732	30.5%	14.3%	14.1%	41.1%
2016	4,704	3,261	1,117	4,444	34.8%	24.1%	8.3%	32.9%
2017	8,350	3,642	411	6,593	44.0%	19.2%	2.2%	34.7%
2018	21,989	6,868	1,059	5,728	61.7%	19.3%	3.0%	16.1%
Min [a]	4,704	1,953	239	2,754	17.8%	5.4%	0.9%	3.6%
Max [a]	111,952	53,566	48,871	50,725	82.9%	43.3%	43.5%	52.0%
Mean [a]	33,080	13,538	12,623	13,283	45.9%	18.5%	16.9%	21.9%

[a] Summary statistics are calculated from years for which escapement estimates are available for all species

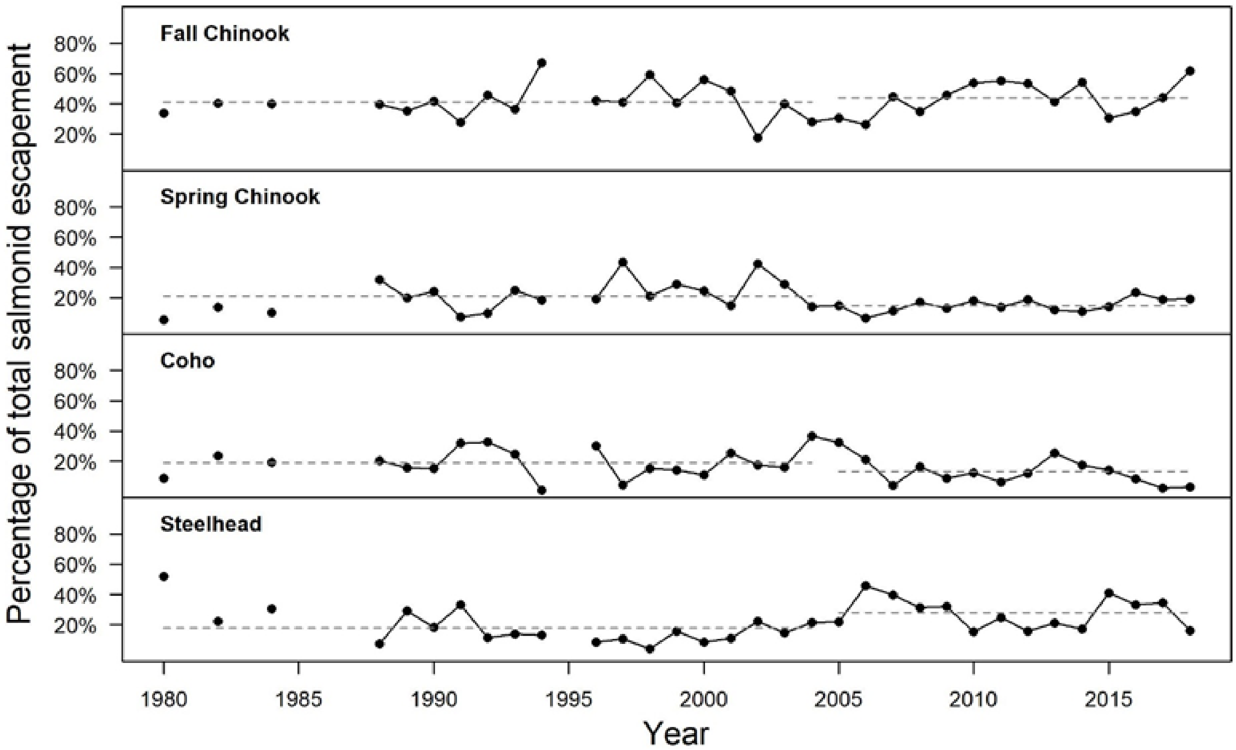


Figure 33. Annual species composition of total adult salmonid escapement to Trinity River Hatchery and natural spawning areas of the Trinity River with mean percentages before and after the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) implementation. Dashed lines represent mean percentages of each species pre-ROD (1980–2004) and after full implementation of the ROD (2005–2018). Only years for which escapement estimates for all species were available are presented.

4.2 Pre-ROD and ROD Escapement Comparison

To better understand how escapement of adult salmonids has changed since full implementation of the ROD, the means and coefficients of variation of total escapement were calculated for the years that data were available before (1980–2004) and after (2005–2018) ROD implementation (Table 16). Changes in these metrics following implementation of the ROD were also quantified as a percentage. Escapement estimates used in this analysis include both hatchery- and natural-origin fish returning to all sectors of the Trinity River (including TRH but excluding harvest; Sections 2.1 and 2.2) because they are included in the most consistent time series of data across species and because hatchery-origin Chinook Salmon were not separated prior to implementation of constant fractional marking. Since hatchery-origin fish are isolated from many of the environmental factors affecting natural-origin fish during early life-history phases and production of hatchery fish has generally been consistent across years, the effects of TRRP management actions on escapement using total escapement are difficult to assess.

Mean annual escapement to the Trinity River of spring- and fall-run Chinook Salmon and Coho Salmon has decreased (by 20.6, 44.8, and 37.8%, respectively) since full implementation of the ROD (Table 16). Variability in annual escapement of spring- and fall-run Chinook Salmon also decreased but variability in Coho Salmon escapement did not change. In contrast, mean steelhead escapement increased (by 68.3%) with very little change in variability.

Table 16. Means and coefficients of variation (CV) of total salmonid escapement to the Trinity River before and after full implementation of the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000). Total escapement includes natural spawning areas and returns to TRH of natural- and hatchery-origin fish.

	Mean return			CV of total return		
Species	Pre-ROD (1978-2004)	ROD (2005-2018)	Change	Pre-ROD (1978-2004)	ROD (2005-2018)	Change
Fall Chinook	35,725	28,356	-20.6%	0.83	0.65	-21.7%
Spring Chinook	16,304	8,992	-44.8%	0.90	0.61	-32.2%
Coho	14,602	9,089	-37.8%	0.91	0.91	0.0%
Steelhead	10,381	17,468	68.3%	0.79	0.76	-3.8%

4.3 Causal Effects of Pre-Spawn Mortality

4.3.1 Pre-ROD and ROD Comparison

Chinook Salmon annual pre-spawn mortality rates in the restoration reach were compared between the pre-ROD (1955–1999) and full implementation of the ROD (2005–present) periods. The period from 2000 to 2005 was not included in this analysis because pre-spawn mortality data was not differentiated between the restoration reach and the entire mainstem Trinity River. Median annual pre-spawn mortality, variance between years, and overall range were greater in the pre-ROD time period (Figure 34). In addition, four years (1987–1989 and 1995) emerged as outliers where annual pre-spawn mortality rates were disproportionately greater. Median annual pre-spawn mortality rates between the two time periods were then compared using a Mann-Whitney-U test. A nonparametric test was used because the parametric assumptions of a normal distribution or equal variance of residuals were not met, even after several iterations of transformations. The test revealed no evidence of a difference in pre-spawn mortality between the median of the pre-ROD or full implementation time periods ($W = 81$, $n_1 = 26$, $n_2 = 9$, $p = 0.18$). The variance of annual pre-spawn mortality rates between the two time periods was also examined using a Brown-Forsythe test, which is less sensitive to non-normal data. The variances of the two groups ($F = 3.70$, $p = 0.07$) approached moderate evidence of difference. Other factors, such as water temperature and run size more likely influenced pre-spawn mortality.

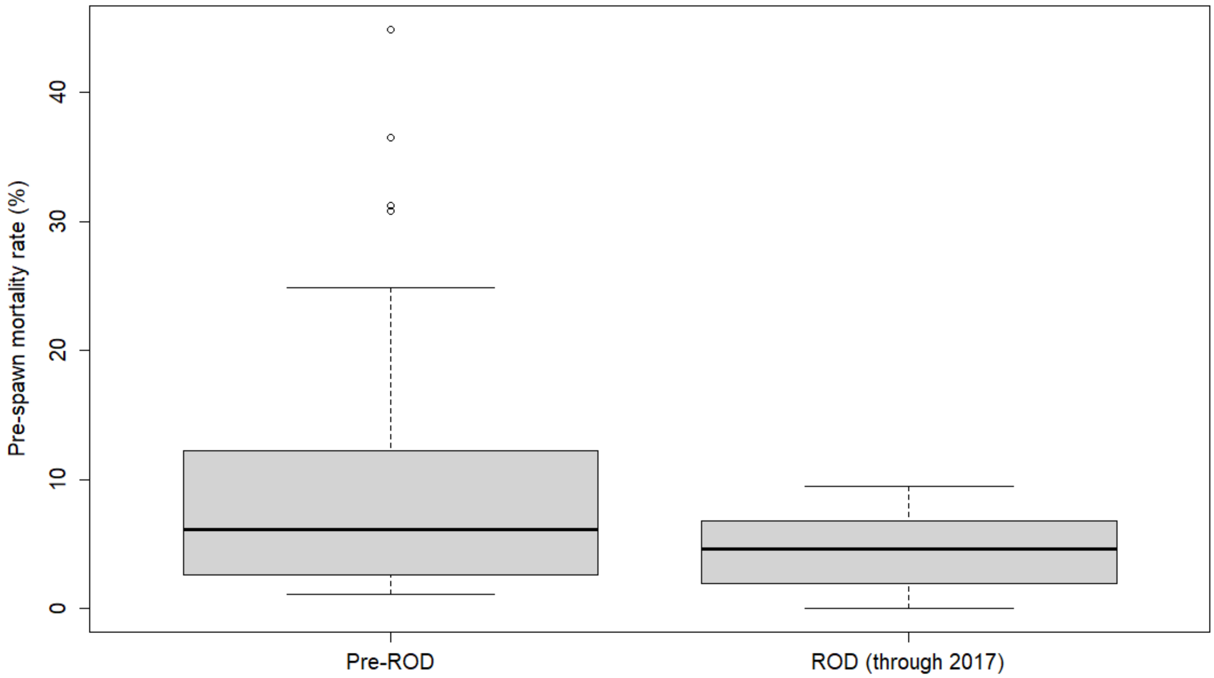


Figure 34. Box plot of pre-spawn mortality rates for Chinook Salmon in the Trinity River before (1955–1999) and after (2005–2017) implementation of the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000). In each plot, the thick midline is the median, the bottom and top of the box are the first and third quartiles (25th and 75th percentiles), whiskers are the minimum and maximum (1.5 times the interquartile range), and circles are outliers.

4.3.2 Water Temperature and Flow

The Trinity River has several temperature targets that were implemented to try and reduce pre-spawn mortality in adult salmon, including those recommended by the Trinity River Flow Evaluation (USFWS and HVT 1999). These temperature targets were used as a basis to evaluate the relationships between water temperature and Chinook Salmon pre-spawn mortality. Since pre-spawn mortality is often the result of chronic stressors (Carter 2005), the cumulative number of degree days exceeded at two USGS Trinity River gaging stations, Douglas City (DGC; 11525655) and above North Fork Trinity River near Helena (NFH; 11526400), were also calculated. Temperature targets were subtracted from the mean daily temperature and summed over the dates of the temperature target when mean daily temperature exceeded the temperature targets established at DGC and NFH. In addition, studies by Carter (2005) and Bowerman et al. (2017) suggest using metrics based on maximum weekly average temperature (MWAT), maximum weekly maximum temperature (MWMT), or seven-day daily maximum (7DADM) to test for sub-lethal and lethal effects of maximum temperatures. As such, we also evaluated evidence for the effects of MWMT, calculated from NFH data, on pre-spawn mortality rates. Temperature data was compiled from DGC and NFH for years 1993–2017 except 1995 from DGC, which was not available.

Linear and logistic regression models were developed to compare pre-spawn mortality to these water temperature metrics. In all cases, parametric assumptions of these models were not met. As such, we tested hypotheses regarding these temperature effects on pre-spawn mortality with nonparametric statistical methods. This is accomplished via a method coupling least squares regression, residual-type computations based on specified slope hypotheses, and Spearman's rank correlations (Conover 1999). For the standard case of testing against the null hypotheses that the slope equals zero, this nonparametric test simplifies to a Spearman rank correlation test of the response variable with the explanatory variable.

Based on these tests, no evidence showed that cumulative number of degree days exceeded at DGC ($p = 0.62$) and NFH ($p = 0.79$) nor maximum weekly maximum temperature ($p = 0.84$) were associated with pre-spawn mortality rates. Relatively low power was expected to detect a trend in these data given the sample size and nonparametric methods employed.

In addition to the temporal (i.e., weekly) analysis of pre-spawn mortality in Section 3.2.2, the spatial distribution of pre-spawn mortality in Chinook Salmon was also analyzed using the 2009–2017 data set. The highest annual proportions of female pre-spawn mortality carcasses in the mainstem Trinity River were in the upmost two reaches (Figures 14 and 35). The mean annual percentage of pre-spawn mortality female carcasses was 44.4% in Reach 1, 16.9% in Reach 2, ranged between 3.2% and 8.0% in Reaches 3–7, and ranged between 0.2% and 3.5% in Reaches 8–14. The highest rates of pre-spawn mortality were in the lower river, but the number of fish affected in the lower river is comparatively low.

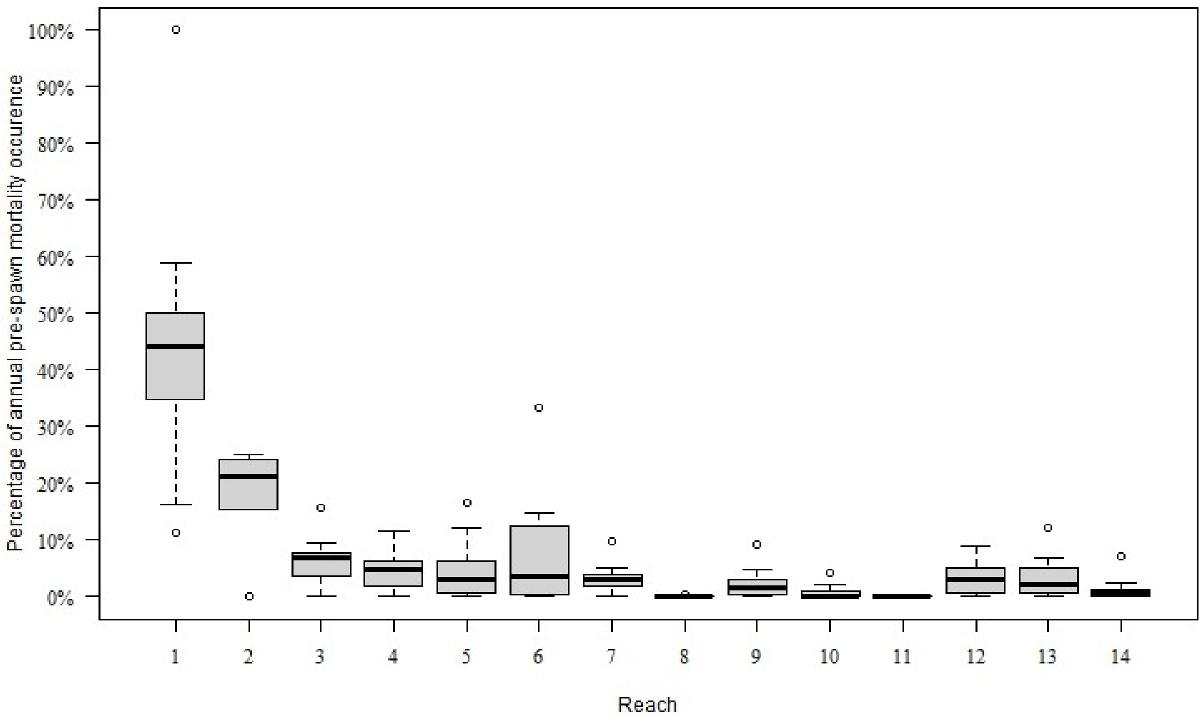


Figure 35. Box plot of spatial distribution of fresh female Chinook Salmon carcasses that were pre-spawn mortalities, Trinity River surveys 2009–2017. In each plot, the thick midline is the median, the bottom and top of the box are the first and third quartiles (25th and 75th percentiles), whiskers are the minimum and maximum (1.5 times the interquartile range), and circles are outliers. Reach 11 was not surveyed and Reach 8 was only surveyed from 2009 to 2011.

4.3.3 Run Size

Aguilar et al. (1996) hypothesized a positive relationship between pre-spawn mortality rate and run size existed for Trinity River Chinook Salmon from 1978 to 1995 but no empirical evidence was provided. Rupert et al. (2017b) found no correlation between numbers of redds and pre-spawn mortality rate from 2009 to 2016, however, escapement is a better explanatory variable than the number of redds because it is estimated before most pre-spawn mortality occurs. Adult escapement data from 1988 to 2017 was derived from estimates in Section 2. Total escapement for the Trinity Basin was calculated by combining spring and fall hatchery-origin Chinook Salmon that returned to the Trinity River Hatchery with spring- and fall-run natural spawners in the mainstem Trinity River. As above, assessment of parametric assumptions proved problematic, and the same nonparametric method as described in Section 4.3.2 was employed in this analysis as well. Based on this model and these data, no evidence supported a relationship between the rate of pre-spawn mortality and escapement (p = 0.21).

4.4 Redd Superimposition

Redd superimposition occurs when a female salmon constructs her redd in a location that overlaps the area of another salmon's preexisting redd. High levels of redd superimposition can be a major source of mortality for incubating salmon embryos (McNeil 1964). Superimposition is traditionally acknowledged to occur where available spawning habitat is limited and when the density of spawning salmon is high (Fukushima et al. 1998). On the Trinity River during the post-dam era, the density of spawning salmon has been highest in close downstream proximity to Lewiston Dam and the location of TRH (Rogers 1972; Chamberlain et al. 2012; Rupert et al. 2017a, 2017b). Corresponding to these high redd densities, redd superimposition was assumed to be highest in this area. TRRP restoration actions are hypothesized to decrease redd superimposition by increasing the amount of spawning habitat (TRRP and ESSA 2009). Specifically, the 3.2-km section of the Trinity River directly below Lewiston Dam (Reach 1) is expected to experience reduced redd superimposition.

Redd superimposition in the Trinity River was evaluated using a proximity analysis, for which locations of redds from the 2009–2016 data were used to determine redd spacing through a given survey year (Chamberlain et al. 2012; Rupert et al. 2017a, 2017b). Only Chinook Salmon redds were included in this analysis. Coho Salmon may superimpose redds on Chinook Salmon redds but Coho Salmon redds were not included in the analysis because only the early portion of the Coho Salmon spawning season was surveyed for these data sets. Additionally, Coho Salmon redds are typically far less abundant than Chinook Salmon redds in the mainstem river and the preferred spawning areas of Chinook and Coho salmon do not completely overlap. Redds were georeferenced at the upstream-most edge of the redd mound since this point was assumed to be the center of the redd and above the egg pocket. All redds were assumed to be circular with a diameter of 2.9 m, which is based on the average Chinook Salmon redd size of 6.72 m^2 determined by Gallagher and Gallagher (2005) from several northern California streams. Redd pits were assumed to have a diameter of 1.6 m, which is an average pit diameter for Chinook Salmon redds in the Trinity River (Evenson 2001). The distance between each located redd in each survey week and the closest neighboring redd located in subsequent survey weeks was measured using the *Near* tool in ArcGIS. Redds were considered superimposed if the distance to a subsequent redd was within 2.9 m (i.e., two redd radii). Superimposed redds were further classified as 'mild' if the proximity of a subsequent redd was greater than 1.6 m and less than 2.9 m and classified as 'severe' if the distance was less than or equal to 1.6 m (i.e., two redd pit radii). Under mild superimposition, the edges of the redd structure probably overlapped but did not disturb the redd's egg pocket, dislodge embryos, and cause mortality. In cases of severe superimposition, the redds' egg pockets probably overlapped, disturbing the eggs of the previous spawner and causing embryo mortality. If a redd was determined to have been affected by severe superimposition, all of its eggs were assumed lost and therefore could not be affected again by subsequent redd placements. However, if a redd was determined to have been mildly superimposed upon, the redd remained in the proximity analysis and could potentially be affected again by additional subsequent redds.

Most Chinook Salmon redd superimposition occurred in Reach 1 from 2009 to 2015 but was higher in the restoration reach downstream of Reach 1 in 2016, which was also the year with the lowest redd counts (Table 17). Mild redd superimposition (i.e., redds with overlapping edges, but not egg pockets) was more frequent than severe superimposition (i.e., redds with overlapping egg pockets) in all spatial sectors and all years. In Reach 1, between 10.3% and 54.2% (mean = 38.3%) of redds were estimated to share an edge with another redd and between 6.0% and 29.7% (mean = 19.5%) were predicted to have sustained some level of pit disturbance each year from 2009 to 2016 (Figure 36). In the remaining portion of the restoration reach downstream of Reach 1, between 13.3% and 23.8% (mean = 17.9%) of redds were estimated to share an edge with another redd and between 4.5% and 10.7% (mean = 6.5%) had overlapping egg pockets. Downstream of the restoration reach (Reaches 9–10 and 12–14), between 5.6% and 16.0% (mean = 9.3%) of redds were estimated to share an edge with another redd and between 1.4% and 6.2% (mean = 3.1%) had overlapping egg pockets. Superimposition rates are based on only those redds that were detectable and therefore these rates may be underestimated.

The relationship between the number of Chinook Salmon redds and egg pockets lost showed significant positive density dependence in Reach 1 ($p < 0.01$, $R^2 = 0.98$), the remainder of the restoration reach below Reach 1 ($p < 0.01$, $R^2 = 0.85$), and downstream of the restoration reach ($p < 0.01$, $R^2 = 0.80$; Figure 37). Significant positive linear relationships ($p < 0.01$) existed between redd numbers and undisturbed redds and pits throughout the Trinity River ($p < 0.01$, $R^2 = 0.98$–1.00; Figures 38 and 39). The carrying capacity of redds could not be determined with this data but could be beyond the upper range of redds counted from these years.

Table 17. Number of Chinook Salmon redds and percentage with mild and severe superimposition in the Trinity River, California, from 2009 to 2016.

		Total	Superimposed redds			Percentage of superimposed redds	
Area	Year	redds	Mild	Severe	Any	Mild	Severe
Reach 1	2009	844	397	205	602	47.0%	24.3%
	2010	1,090	547	315	862	50.2%	28.9%
	2011	1,823	988	541	1,529	54.2%	29.7%
	2012	2,070	1,115	580	1,695	53.9%	28.0%
	2013	327	78	25	103	23.9%	7.6%
	2014	858	305	142	447	35.5%	16.6%
	2015	251	79	37	116	31.5%	14.7%
	2016	116	12	7	19	10.3%	6.0%
	Total	7,379	3,521	1,852	5,373	47.7%	25.1%
Restoration Reach downstream of Reach 1	2009	2,377	404	126	530	17.0%	5.3%
	2010	2,116	430	149	579	20.3%	7.0%
	2011	2,849	678	305	983	23.8%	10.7%
	2012	3,557	772	282	1,054	21.7%	7.9%
	2013	1,337	178	61	239	13.3%	4.6%
	2014	2,174	365	134	499	16.8%	6.2%
	2015	1,113	180	67	247	16.2%	6.0%
	2016	1,192	169	54	223	14.2%	4.5%
	Total	16,715	3,176	1,178	4,354	19.0%	7.0%
Downstream of Restoration Reach	2009	883	57	12	69	6.5%	1.4%
	2010	463	26	7	33	5.6%	1.5%
	2011	1,749	280	109	389	16.0%	6.2%
	2012	1,961	205	70	275	10.5%	3.6%
	2013	1,463	175	54	229	12.0%	3.7%
	2014	914	77	28	105	8.4%	3.1%
	2015	764	63	21	84	8.2%	2.7%
	2016	315	24	9	33	7.6%	2.9%
	Total	8,512	907	310	1,217	10.7%	3.6%

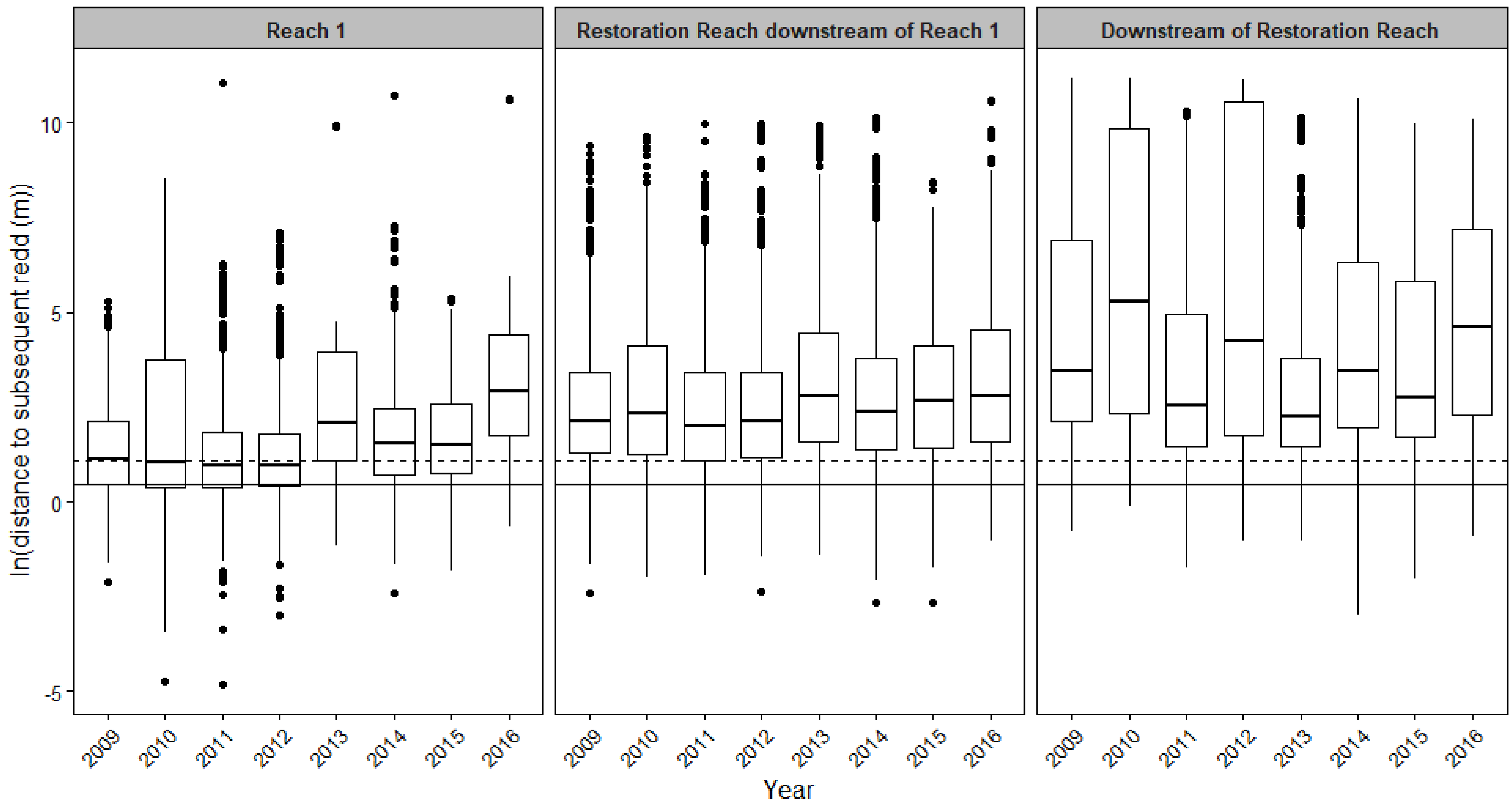


Figure 36. Box plot of distance between Chinook Salmon redds and natural log (ln) of the nearest subsequently constructed redd in the mainstem Trinity River, 2009–2016. Reach 1 is the 3.2-km section of the river directly downstream of Lewiston Dam. The dashed horizontal line represents a distance of 2.9 m between redds, which is the estimated distance at which redds begin to overlap. The solid horizontal line represents a distance of 1.6 m between redds, which is the estimated distance at which egg pockets become disturbed. In each plot, the thick midline is the median, the bottom and top of the box are the first and third quartiles (25th and 75th percentiles), whiskers are the minimum and maximum (1.5 times the interquartile range), and solid circles are outliers.

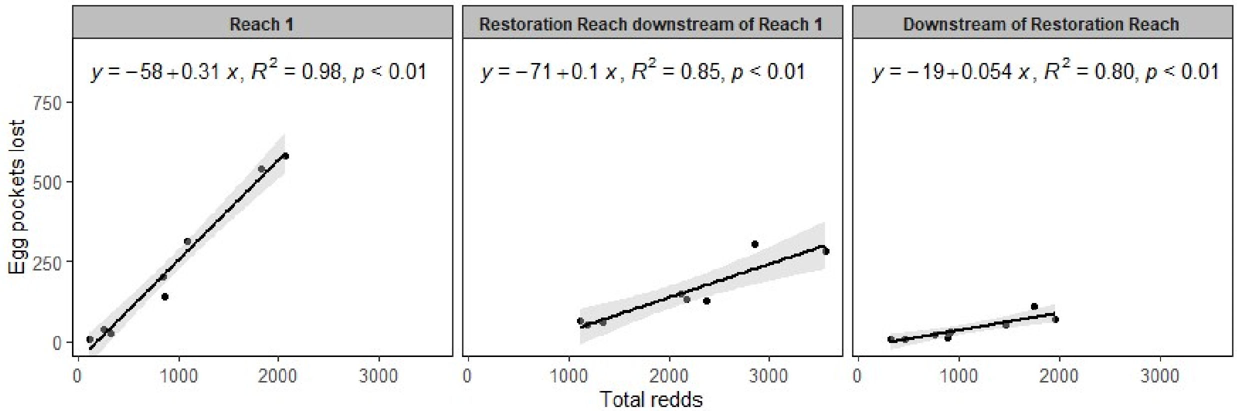


Figure 37. Estimated number of Chinook Salmon egg pockets disturbed from severe redd superimposition compared to the total number of redds within three sections of the mainstem Trinity River, 2009–2016. Reach 1 is the 3.2-km section of the river directly below Lewiston Dam. Each plot includes a linear model with the regression equation, R^2 value, p-value, and 95% confidence limits (shaded area).

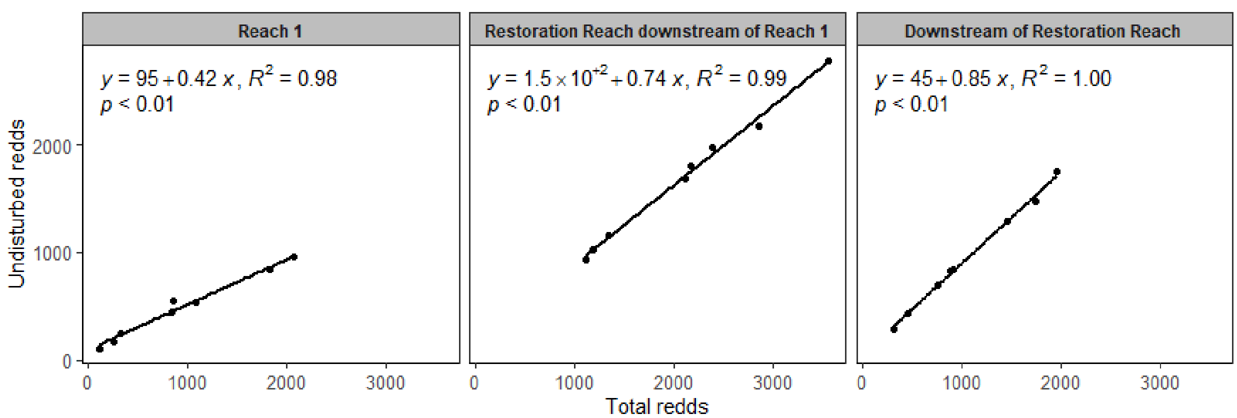


Figure 38. Relationships between total and undisturbed Chinook Salmon redds in Reach 1, the restoration reach downstream of Reach 1, and downstream of the restoration reach in the Trinity River from 2009 to 2016 Each plot includes a linear model with the regression equation, R^2 value, and p-value.

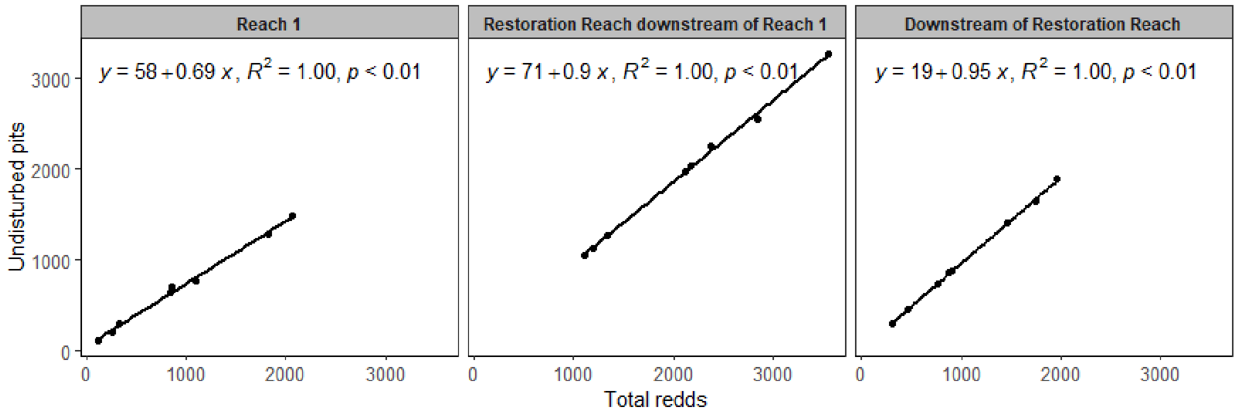


Figure 39. Relationships between total Chinook Salmon redds and undisturbed redd pits in Reach 1, the restoration reach downstream of Reach 1, and downstream of the restoration reach in the Trinity River from 2009 to 2016. Each plot includes a linear model with the regression equation, R^2 value, and p-value.

4.5 Redd Dewatering

Redd dewatering occurs when water levels recede and redds, or portions of redds, become exposed to the atmosphere. Chinook Salmon eggs have been found to survive redd dewatering if the dewatering is temporary and the eggs within the redd remain in suitable environmental conditions (i.e., cool and moist; Becker and Neitzel 1983; Reiser and White 1983; McMichael et al. 2005). However, if redds are dewatered for extended periods or experience large temperatures changes and reduced humidity (i.e., <100%), egg mortality rapidly increases (Becker and Neitzel 1985; Neitzel and Becker 1985; Young et al. 2011).

Redd dewatering in the Trinity River has been hypothesized to occur following the reduction of emergency fall Flow Augmentation Releases (C. Chamberlain, personal communication). Flow Augmentation Releases were implemented to reduce the risk of a large-scale adult fish kill in the Lower Klamath River in several years from 2003 to 2012 and each year from 2013 to 2016 (USBOR 2015, 2016, 2017). Supplemental water from Trinity Reservoir was released to elevate flows in the lower Klamath River after fish health criteria triggers were met (USBOR 2015). Starting mid-August in 2013, 2014, 2015, and 2016, flows out of Trinity Dam were increased by three to seven times the normal flow released during that time. These elevated flows were maintained through mid-September, which included the early portions of Chinook Salmon spawning period. Concerns were raised that salmon would construct redds in locations that would become dewatered after these high flows receded to the normal base flows.

Starting in 2013, dewatered redds were located and evaluated during the spawning surveys. Dewatered redds were described according to three levels of severity: 1) mound partially exposed (least severe), 2) mound fully exposed, and 3) pit fully exposed (most severe). Dewatered redds were reassessed on subsequent surveys, though the original mark date was retained.

Sixty-seven redds (22 in 2013, 21 in 2014, 6 in 2015, and 18 in 2016) were found dewatered during the 2013–2016 surveys (Figure 40). Of the 67 dewatered redds, 32 (47.8%) were dewatered when flows dropped following emergency high flow releases from Lewiston Dam and 35 (52.2%) were discovered following the annual flow reduction from summer (450 ft^3/s) to winter base flows (300 ft^3/s; Figure 40, Appendix O). Most dewatered redds were observed immediately following the reduction of water surface elevations. Most (50 of 67) dewatered redds were found in the 20 km section below Lewiston Dam and nearly all (64 of 67) were found in the restoration reach. Most dewatered redds were found with partially (46 of 67) and fully exposed mounds (19 of 67). Only two redds were found with a fully exposed pit.

Redd dewatering occurred on the mainstem Trinity River during each of the 2013–2016 spawning seasons, but infrequently and severity was generally mild. The annual number redds that experienced any degree of dewatering ranged between 0.3% and 1.1% of total redds in the mainstem. Though the interior environmental conditions of the dewatered redds were not monitored, those redds with a partially exposed mound likely maintained satisfactory condition for incubating eggs since surface water remained above the redd pit. However, those dewatered redds found with fully exposed mounds and fully exposed pits did not have surface flow and were presumably exposed to extended elevated temperatures known to increase egg mortality (Neitzel and Becker 1985).

These data support the hypothesis that redds become dewatered following Flow Augmentation Releases, though not always immediately after. Salmonids that spawn during periods of higher flows may build redds at higher bed elevations. When water surface elevations drop following flow reductions, these redds may become susceptible to dewatering many weeks after they were built.

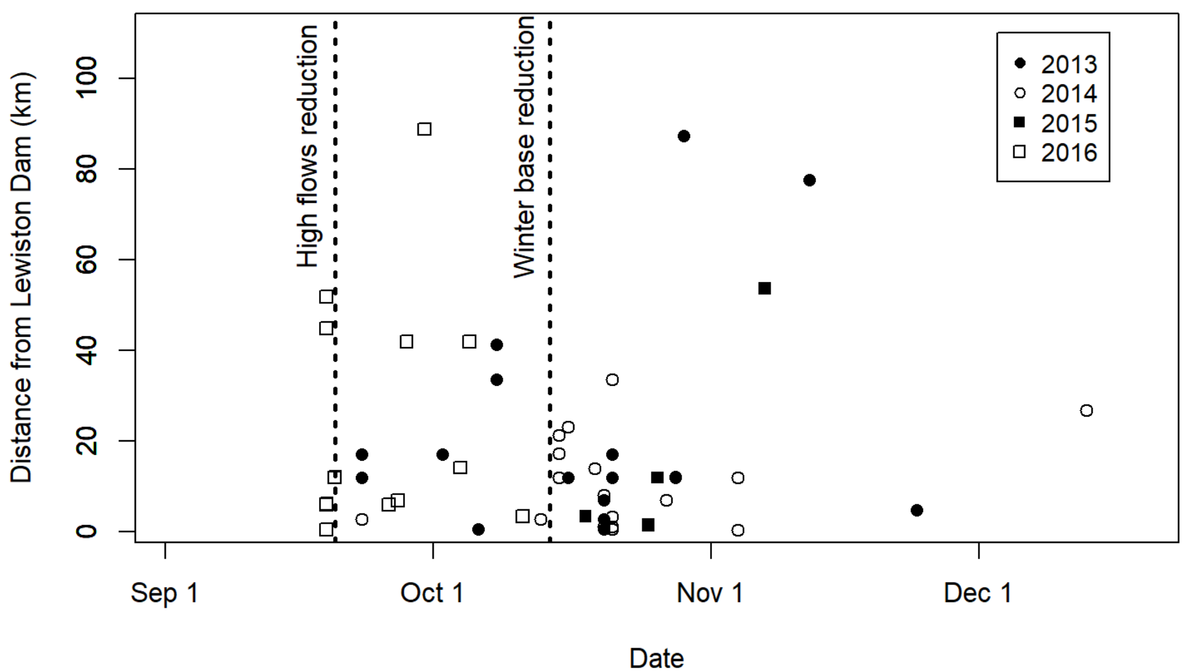


Figure 40. Spatial and temporal distribution of dewatered Chinook Salmon redds in the Trinity River, 2013–2016. Dashed lines show the approximate dates of managed flow reductions from Lewiston Dam.

4.6 Distribution of redds in channel rehabilitation areas compared to unrestored areas within the restoration reach

The proportional distribution of Chinook Salmon redds within rehabilitation (‘rehab’) areas and in areas where rehab has not taken place were compared using the 2002–2017 data set. Additionally, redd numbers pre- and post-construction at rehab sites were compared to evaluate the effect of rehab. Analyses were performed for the entire restoration reach and for rehabilitation reaches within the restoration reach.

The total number of Chinook Salmon redds per rehab site were enumerated each year. The annual proportion of redds within each rehab area was calculated by dividing the number of redds within the site by the total number of redds within the restoration reach for the respective year (Table 18). Next, the proportion of redds at each rehab site were summed to give a total proportion of redds within rehab areas each year. A generalized linear model was developed to describe the proportion of redds in rehab and non-rehab areas over time. A Mann-Whitney-U test was performed to determine if the mean proportion of redds at a rehab site changed after construction. The same process was performed at the reach scale except the number of redds per site were divided by the total number of redds within the specific reach for the respective year. A nonparametric test was used because the dataset did not meet parametric assumptions of normal distribution or equal variance of residuals even after several iterations of transformations. Rehab sites with less than 5 years of pre- and post-construction data were excluded from analysis because of the small sample size.

Table 18. Annual percentage of Chinook Salmon redds in each Trinity River rehab site within the restoration reach from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Rehab site	Year constructed	Percentage of redds (%)																Construction timing	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Cableway	2008	8.7	9.2	7.5	5.2	4.2	6.2	3.2	2.4	6.3	6.7	7.2	7.9	8.3	6.9	2.7	3.4	Pre	0.30
Conner Creek	2006	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.5	0.1	0.3	0.4	0.4	0.5	0.4	1.0	0.4	Post	N/A
Dark Gulch	2008	2.1	1.7	1.7	2.2	0.8	1.7	1.6	2.0	1.7	1.2	1.0	2.0	1.5	0.4	1.8	1.4	Post	0.45
Dark Gulch/Bucktail	2008/2016	0.5	0.6	1.0	1.2	1.0	0.9	1.0	1.3	0.8	0.4	0.4	0.9	0.5	0.7	0.3	2.5	Post	0.48
Deadwood	2008	6.4	3.4	6.5	2.7	4.4	4.1	5.3	4.0	5.0	6.0	4.9	4.8	4.6	5.0	0.8	3.2	Pre	0.96
Douglas City	2013	0.4	0.5	0.6	0.4	0.5	0.4	1.1	0.4	0.5	0.4	0.4	0.3	0.1	0.4	0.7	1.3	Post	0.73
Elkhorn	2006	0.6	0.1	0.1	0.0	0.2	0.0	0.1	0.2	0.2	0.1	0.9	0.5	0.2	0.6	0.6	1.5	Post	N/A
Hoadly	2008	0.8	2.4	0.8	2.5	1.8	3.2	0.4	1.2	2.3	2.7	1.5	3.1	2.3	3.7	2.4	3.4	Post	0.59
Hocker Flat	2005	0.9	0.3	0.2	0.3	0.9	0.6	0.2	2.4	1.4	1.4	2.5	1.6	1.2	3.3	2.4	1.4	Post	N/A
Indian Creek	2007	0.4	0.1	0.4	0.4	0.1	0.4	0.4	0.3	0.4	0.4	0.5	0.8	0.5	0.6	0.4	0.1	Post	0.16
Indian Creek	2007/2015	0.4	0.3	0.3	0.4	0.5	0.1	0.4	0.9	0.9	1.1	0.9	0.7	1.0	1.1	0.5	0.9	Post	0.03*
Lewiston Hatchery	2006/2007	30.3	28.8	35.7	33.4	42	33.8	35.3	16.5	22.9	22	19	12.0	11.2	4.0	4.4	7.6	Pre	N/A
Limekiln	2015	0.7	0.9	0.4	0.5	0.6	0.3	0.5	0.6	0.7	1.2	0.9	0.7	0.6	0.9	1.0	0.9	Post	N/A
Lorenz	2013	0.2	0.2	0.2	0.6	0.2	0.4	0.3	0.3	0.2	0.4	0.2	0.3	0.6	0.4	1.3	1.6	Post	0.02*
Lowden	2010	0.8	1.9	1.9	1.9	1.7	1.5	1.6	2.1	0.8	0.8	1.2	1.7	2.1	1.6	1.3	1.3	Pre	0.43
Lower Junction City	2014	0.1	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.7	0.4	0.5	1.3	1.0	0.5	Post	N/A
Lower Steiner	2012	0.9	0.3	0.6	1.0	0.6	0.9	0.9	0.7	1.1	1.5	0.8	0.8	0.9	1.0	1.2	1.6	Post	0.30
Pear Tree	2006	0.2	0.1	0.1	0.4	0.0	0.2	0.1	0.2	0.2	0.0	0.1	0.3	0.0	0.1	0.2	0.3	Post	0.91
Reading Creek	2010	0.8	0.6	0.8	0.4	0.7	1.1	0.8	0.9	0.4	0.7	0.6	1.0	0.9	1.6	1.0	1.7	Post	0.37
Sawmill	2009	3.3	4.8	5.0	6.5	3.8	5.2	4.0	5.5	8.1	3.9	2.9	6.7	6.2	7.7	5.8	3.4	Post	0.29
Sheridan Creek	2017	2.3	2.0	1.7	0.9	1.9	1.7	1.7	5.3	2.2	3.9	5.7	5.0	7.2	6.2	9.8	3.8	Pre	N/A
Sven Olbertson	2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0.8	1.4	2.5	2.1	0.5	0.7	0.4	0.0	Post	<0.01*
Trinity House Gulch	2010	0.2	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	Pre	0.17
Upper Junction City	2012	0.2	0.1	0.0	0.0	0.3	0.2	0.2	0.2	0.1	0.1	0.4	0.5	0.4	0.1	0.5	0.3	Post	0.01*
Valdor Gulch	2006	1.4	0.6	0.6	0.3	1.3	0.5	0.6	0.9	0.9	1.6	2.6	2.9	2.7	3.1	3.7	3.8	Post	0.07
Vitzthum	2009	1.6	2.5	1.4	1.5	1.4	2.4	2.8	4.4	2.6	2.0	2.3	1.8	1.7	1.7	1.7	3.9	Post	0.20
Wheel Gulch	2011	0.8	0.4	0.2	0.4	0.6	0.2	0.2	1.1	0.4	0.9	0.9	1.0	0.6	1.4	1.3	1.6	Post	<0.01*
All rehab sites		65.3	61.8	68.3	63.4	70.1	66.3	63.5	56.9	61.4	61.5	61.3	60.2	56.9	54.9	48.6	5.02		
All non-rehab sites		34.7	38.2	31.7	36.6	29.9	33.7	36.5	43.1	38.6	38.5	38.7	39.8	43.1	45.1	51.4	48.0		

4.6.1 Restoration Reach

The percentage of Chinook Salmon redds in rehab sites within the restoration reach declined at a rate of about 1% per year from 2002 to 2017 ($p < 0.001$, $R^2 = 0.665$; Figure 41). The proportion of redds at the rehab site scale at most sites were unaffected by construction (Table 18). Fifteen of the 20 rehab sites had no evidence of difference between pre- and post-construction redd proportions. All sites with evidence of changes were in the Douglas City Reach and downstream except for Sven Olbertson. The rehab sites with evidence of difference between the pre- and post-construction periods showed a higher proportion of redds post-construction. The percentage of redds changed from 0.4 ± 0.1% to 0.8 ± 0.3% at Indian Creek, from 0.3 ± 0.1% to 0.8 ± 0.6% at Lorenz, from 0.2 ± 0.2% to 0.7 ± 0.4% at Lower Junction City, from 0.0 ± 0.0% to 1.1 ± 0.9% at Sven Olbertson, from 0.2 ± 0.1% to 0.4 ± 0.2% at Upper Junction City, and from 0.5 ± 0.3% to 1.1 ± 0.4% at Wheel Gulch.

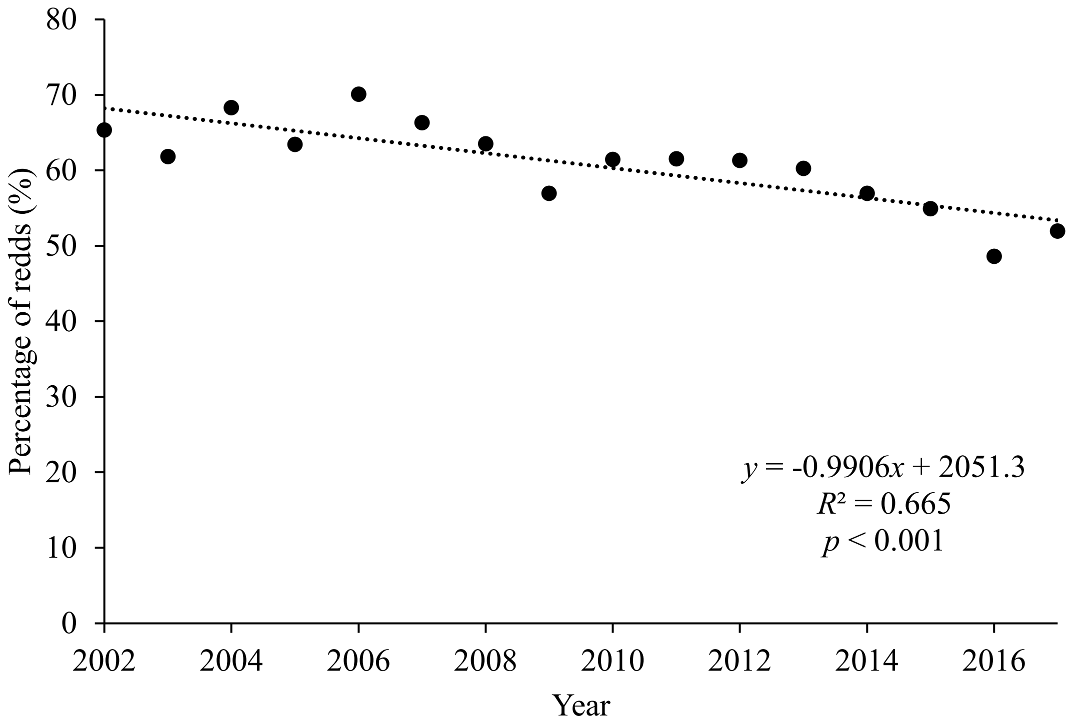


Figure 41. Annual percentage of Chinook Salmon redds in rehab areas within the restoration reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and p-value.

4.6.2 Rehabilitation Reaches

4.6.2.1 Lewiston

No evidence supports that the annual proportion of redds in rehab sites in the Lewiston reach changed from 2002 to 2017 compared to unrestored areas ($p = 0.86$, $R^2 = 0.0023$; Figure 42). All six sites within the Lewiston reach had a higher mean proportion of redds post-construction compared to pre-construction, though only two sites, Sven Olbertson and Sawmill, showed a significant change ($p = 0.01$; Table 19). The mean annual percentage of redds changed from 0 ± 0% pre-construction to 2.6 ± 2.1% post-construction at Sven Olbertson and from 7.6 ± 1.5% to 15.8 ± 7.0% at Sawmill.

4.6.2.2 Limekiln

No evidence supports that the annual proportion of redds in rehab sites in the Limekiln reach changed from 2002 to 2017 compared to unrestored areas ($p = 0.40$, $R^2 = 0.0513$; Figure 43). Also, the proportion of redds at all seven rehab sites in the Limekiln reach did not change between pre- and post-construction conditions (Table 20).

4.6.2.3 Douglas City

Strong evidence showed that the annual proportion of redds in rehab sites in the Douglas City reach increased from 2002 to 2017 compared to unrestored areas ($p < 0.002$, $R^2 = 0.5232$; Figure 44). The percentage of redds within rehab sites increased at a rate of about 1% per year but only one of the six rehab sites (Lorenz) underwent change between pre- and post-construction conditions (Table 21). The percentage of redds at Lorenz increased from 3.8 ± 1.9% pre-construction to 7.7 ± 4.2% post-construction.

4.6.2.4 Junction City

The annual proportion of redds in rehab sites in the Junction City reach did not show evidence of change from 2002 to 2017 compared to unrestored areas ($p = 0.14$, $R^2 = 0.1467$; Figure 45). None of the three rehab sites show evidence of change between pre- and post-construction conditions (Table 22).

4.6.2.5 North Fork

The annual proportion of redds in rehab sites in the North Fork reach did not show evidence of change from 2002 to 2017 compared unrestored areas ($p = 0.89$, $R^2 = 0.0014$; Figure 46). One of the six rehab sites (Pear Tree) showed evidence of change between pre- and post-construction conditions (Table 23). The percentage of redds at Pear Tree decreased from 6.7 ± 6.9% pre-construction to 2.0 ± 2.1% post-construction.

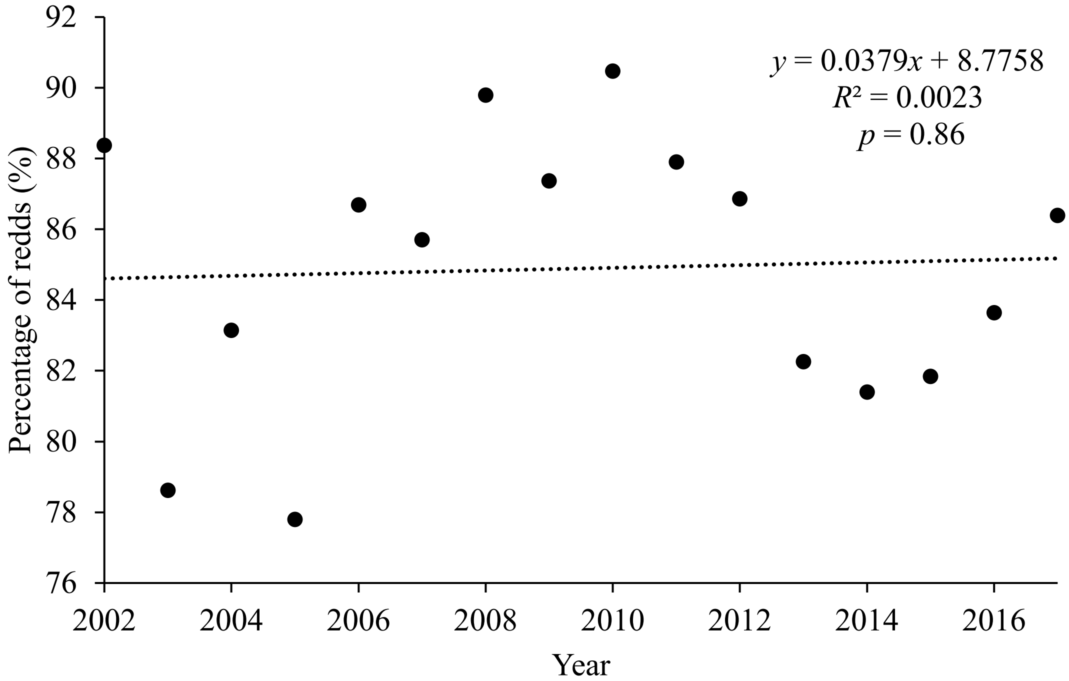


Figure 42. Annual percentage of Chinook Salmon redds in rehab areas within the Lewiston reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and *p*-value.

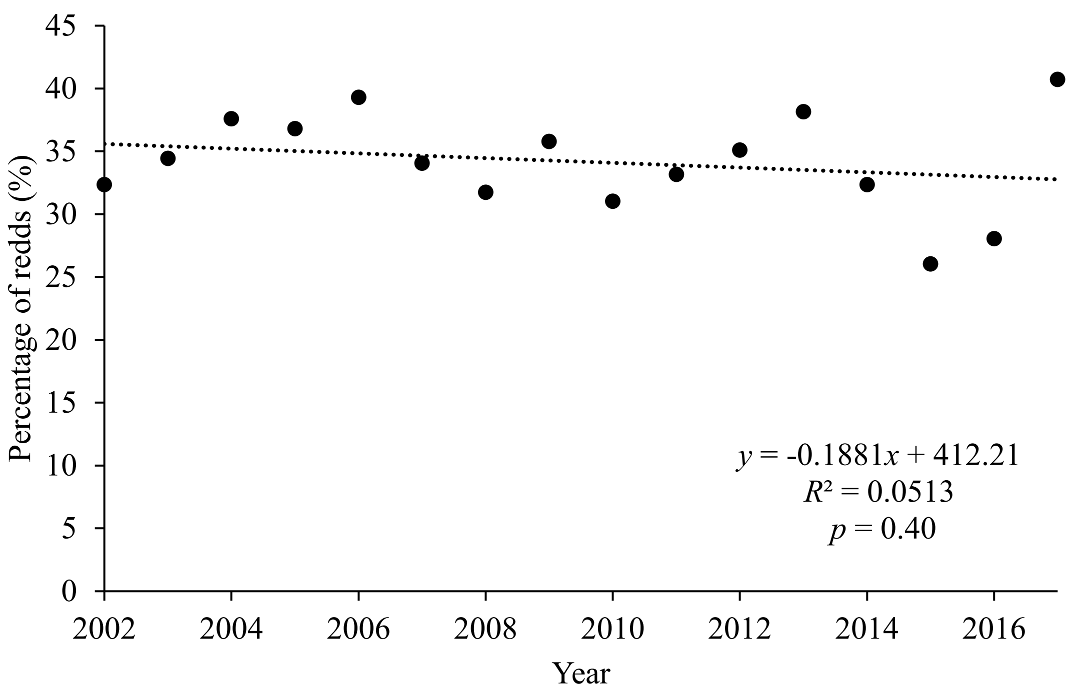


Figure 43. Annual percentage of Chinook Salmon redds in rehab areas within the Limekiln reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and *p*-value.

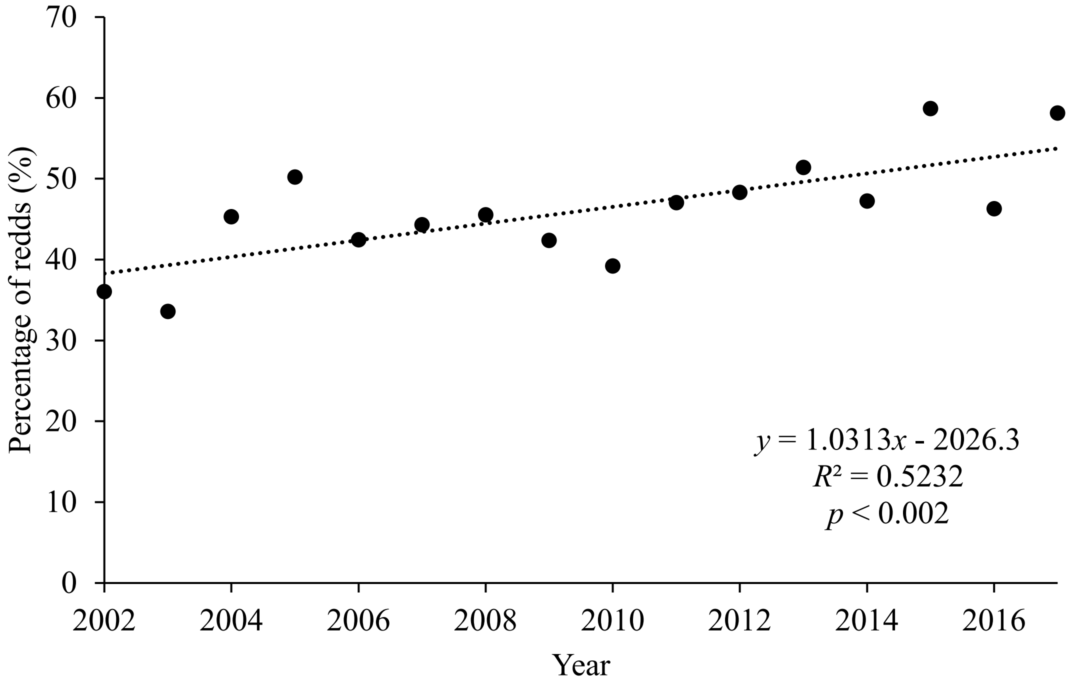


Figure 44. Annual percentage of Chinook Salmon redds in rehab areas within the Douglas City reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and *p*-value.

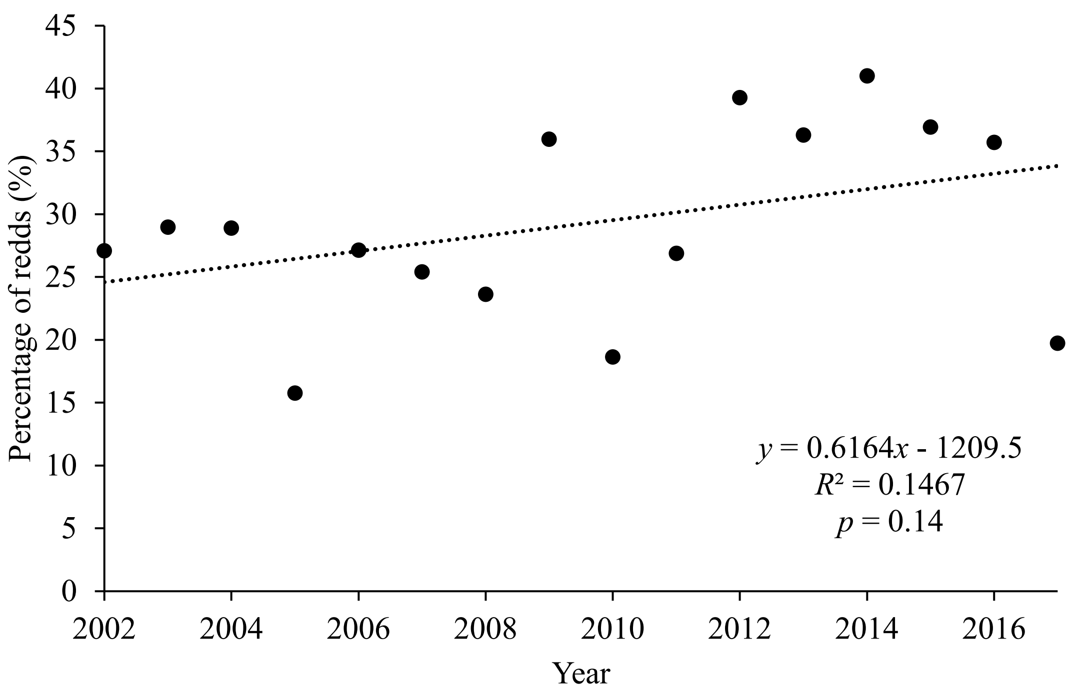


Figure 45. Annual percentage of Chinook Salmon redds in rehab areas within the Junction City reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and *p*-value.

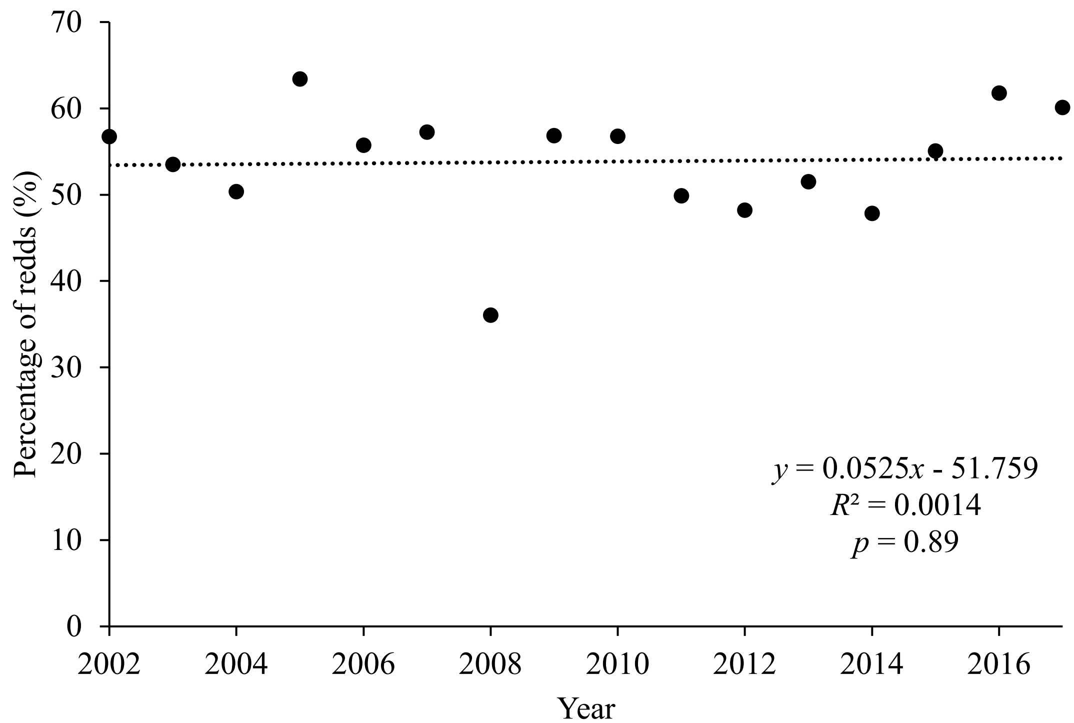


Figure 46. Annual percentage of Chinook Salmon redds in rehab areas within the North Fork reach of the Trinity River from 2002 to 2017. The plot includes a linear model with the R^2 value and p-value.

Table 19. Annual percentage of Chinook Salmon redds in each rehab site within the Lewiston reach of the mainstem Trinity River from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Site	Year constructed	Percentage of total redds in reach (%)																Construction timing	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Lewiston Hatchery	2006/2007	54.0	46.6	53.5	51.6	64.8	55.3	65.8	45.7	45.6	45.3	43.6	27	27.4	11.7	22.3	31.4	Pre	N/A
Sven Olbertson	2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	1.6	2.9	5.7	4.8	1.3	2.1	2.2	0.0	Post	0.01*
Deadwood	2008	11.4	5.6	9.7	4.2	6.8	6.6	10.0	11.0	9.9	12.4	11.2	10.7	11.3	14.6	4.1	13.3	Post	0.06
Cableway	2008	15.5	14.9	11.2	8.0	6.5	10.1	5.9	6.5	12.6	13.8	16.4	17.7	20.5	20.0	13.4	13.9	Post	0.28
Hoadly	2008	1.5	3.9	1.2	3.8	2.8	5.2	0.7	3.4	4.6	5.5	3.3	7.0	5.5	10.9	12.3	13.9	Post	0.07
Sawmill	2009	5.9	7.7	7.5	10.1	5.8	8.4	7.4	15.2	16.1	8.0	6.6	15.1	15.3	22.5	29.4	13.9	Post	0.01*
All rehab sites		88.4	78.6	83.1	77.8	86.7	85.7	89.8	87.4	90.5	87.9	86.9	82.3	81.4	81.8	83.6	86.4		
All non-rehab sites		11.6	21.4	16.9	22.2	13.3	14.3	10.2	12.6	9.5	12.1	13.1	17.7	18.6	18.2	16.4	13.6		

Table 20. Annual percentage of Chinook Salmon redds in each rehab site within the Limekiln reach of the mainstem Trinity River from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Site	Year constructed	Percentage of total redds in reach (%)																Construction timing	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Dark Gulch	2008	11.5	7.7	9.6	10.7	5.7	8.5	6.3	6.9	7.8	6.9	6.2	10.2	7.5	1.8	8.3	5.7	Pre	0.08
Dark Gulch/Bucktail	2008/2016	2.7	2.7	5.8	6.1	7.1	4.5	4.1	4.5	3.8	2.5	2.5	4.5	2.5	3.5	1.3	10	Pre	0.17
Lowden	2010	4.6	8.3	10.6	9.5	11.6	7.6	6.5	7.0	3.8	4.7	6.8	8.9	10.3	7.7	5.9	5.1	Pre	0.22
Trinity House Gulch	2010	1.1	0.6	1.0	0.8	1.0	0.3	1.1	0.7	0.3	0.6	0.4	0.9	0.9	0.4	0.3	0.9	Pre	0.11
Limekiln	2015	3.7	4.0	2.5	2.5	4.1	1.3	2.2	2.1	3.4	7.0	5.4	3.9	2.8	4.2	4.6	3.7	Post	N/A
Vitzthum	2009	8.9	11.1	8.1	7.3	9.8	11.8	11.2	14.7	11.9	11.4	13.5	9.3	8.3	8.5	7.6	15.4	Post	0.29
Indian Cree [a]k	2007	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.3	0.4	0.2	0.0	0.0	0.0	Post	0.17
All rehab sites		32.4	34.4	37.6	36.8	39.3	34.1	31.8	35.8	31.0	33.2	35.1	38.2	32.4	26.1	28.1	40.7		
All non-rehab sites		67.6	65.6	62.4	63.2	60.7	65.9	68.2	64.2	69.0	66.8	64.9	61.8	67.6	73.9	71.9	59.3		

[a] The Indian Creek site spans the Limekiln and Douglas City rehabilitation reaches. These values pertain to the portion of the site within the Limekiln reach.

Table 21. Annual percentage of Chinook Salmon redds in each rehab site within the Douglas City reach of the mainstem Trinity River from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Site	Year constructed	Percentage of total redds in reach (%)																Construction timing	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Indian Creek [a]	2007	5.0	2.6	5.9	6.4	2.1	5.6	3.9	4.1	4.2	3.7	6.3	9.9	5.5	6.6	3.4	1.2	Post	0.81
Indian Creek	2007/2015	4.8	4.6	5.0	6.0	7.6	1.6	4.3	11.2	10.0	11.6	13.4	9.9	11.7	12.4	4.7	7.0	Post	0.17
Douglas City	2013	4.6	7.9	9.4	6.4	8.4	5.8	13.6	4.8	5.1	4.6	6.0	3.8	1.5	5.0	6.7	10.5	Pre	0.43
Reading Creek	2010	9.1	10.0	12.8	6.4	10.9	14.6	9.7	10.8	4.8	6.8	8.4	13.2	11.0	19.0	9.4	14.0	Post	0.96
Lower Steiner	2012	10.1	5.6	9.7	16.1	10.5	11.1	10.5	8.2	12.9	15.8	11.3	10.8	11.0	11.6	10.7	12.8	Post	0.36
Lorenz	2013	2.4	2.8	2.5	8.8	2.9	5.6	3.5	3.3	2.3	4.4	2.9	3.8	6.6	4.1	11.4	12.8	Post	0.02*
All rehab sites		36.1	33.6	45.3	50.2	42.4	44.3	45.5	42.4	39.2	47.0	48.3	51.4	47.3	58.7	46.3	58.1		
All non-rehab sites		63.9	66.4	54.7	49.8	57.6	55.7	54.5	57.6	60.8	53.0	51.7	48.6	52.7	41.3	53.7	41.9		

[a] The Indian Creek site spans the Limekiln and Douglas City rehabilitation reaches. These values pertain to the portion of the site within the Douglas City reach.

Table 22. Annual percentage of Chinook Salmon redds in each rehab site within the Junction City reach of the mainstem Trinity River from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Site	Year constructed	Percentage of total redds in reach (%)																Construction timing	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Sheridan Creek	2017	23.3	26.8	27.6	14.5	22.0	20.3	18.9	32.4	16.1	25.1	32.8	31.2	36.6	30.3	30.9	16.4	Pre	N/A
Upper Junction City	2012	2.5	1.6	0.3	0.0	3.1	2.9	1.8	1.5	0.6	0.7	2.2	2.9	2.1	0.3	1.6	1.2	Pre	0.74
Lower Junction City	2014	1.3	0.6	1.0	1.2	2.0	2.2	2.9	2.1	1.9	1.1	4.3	2.2	2.4	6.3	3.2	2.2	Post	N/A
All rehab sites		27.1	29.0	28.9	15.8	27.1	25.4	23.6	36.0	18.6	26.9	39.3	36.3	41.0	36.9	35.7	19.8		
All non-rehab sites		72.9	71.0	71.1	84.2	72.9	74.6	76.4	64.0	81.4	73.1	60.7	63.7	59.0	63.1	64.3	80.2		

Table 23. Annual proportion of Chinook Salmon redds in each rehab site within the North Fork reach of the mainstem Trinity River from 2002 to 2017. Values from the pre-construction period are not shaded, while values from the post-construction period are shaded in grey. Construction timing refers to the time period relative to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000) which had a higher proportion of redds.

Site	Year constructed	Percentage of total redds in reach (%)																Pre/Post construction	*p*-value
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Hocker Flat	2005	13.2	9.2	7.9	12.2	15.7	22.1	5.7	25.8	25.1	16.6	16.6	12.6	10.7	20.3	16.2	9.1	Post	N/A
Conner Creek	2006	1.4	1.6	6.5	0.0	3.8	1.5	5.7	5.4	1.5	3.7	2.4	3.3	4.9	2.2	6.9	2.9	Post	N/A
Wheel Gulch	2011	11.2	13.0	7.2	18.3	10.2	7.6	4.1	11.7	7.0	10.2	5.7	7.4	5.5	8.8	8.8	10.6	Pre	0.37
Valdor Gulch	2006	20.1	23.2	21.6	14.6	22.1	17.6	15.6	9.4	16.6	18.1	17.2	22.5	24.6	19.4	24.5	25.5	Pre	N/A
Elkhorn	2006	8.0	3.2	3.6	1.2	3.4	0.8	2.5	2.3	3.0	1.2	6.0	3.6	1.7	3.5	3.9	10.1	Pre	N/A
Pear Tree	2006	2.9	3.2	3.6	17.1	0.4	7.6	2.5	2.3	3.5	0.0	0.4	2.2	0.3	0.9	1.5	1.9	Pre	N/A
All rehab sites		56.7	53.5	50.4	63.4	55.7	57.3	36.1	56.9	56.8	49.9	48.2	51.5	47.8	55.1	61.8	60.1		
All non-rehab sites		43.3	46.5	49.6	36.6	44.3	42.7	63.9	43.1	43.2	50.1	51.8	48.5	52.2	44.9	38.2	39.9		

5. Discussion and Next Steps

5.1 Escapement

Analyses of long-term datasets from various salmonid species/runs provide insight to escapement trends. The main themes are:

1) The majority of TRRP escapement targets have not been met.

2) Mean annual escapement estimates to all areas of the Trinity River of natural- and hatchery-origin Coho Salmon and spring- and fall-run Chinook Salmon has decreased since full implementation of the ROD.

3) Mean annual escapement estimates to the Trinity River of steelhead has increased since full implementation of the ROD.

4) Interannual variability in total escapement estimates decreased for all species.

5) The proportion of natural-origin contribution has increased for all species/runs except steelhead and interannual variability decreased for all species/runs except spring-run Chinook Salmon.

Escapement targets of naturally produced salmonids generated by the TRRP have largely not been met since implementation of the ROD. Escapement estimates of naturally produced fall-run Chinook Salmon and steelhead have not met the escapement targets of 62,000 and 40,000 adults, respectively, since implementation of the ROD, and may not have met targets pre-ROD in any year since reliable escapement estimates have been available (1980 and 1978, respectively) unless natural-origin proportions were very high. In contrast, the escapement target of 6,000 naturally produced spring-run Chinook Salmon adults was met in four of the years since implementation and the escapement target of 1,400 naturally produced Coho Salmon adults was exceeded in seven of the years.

Though escapement targets for Coho Salmon and spring-run Chinook Salmon were met in several years since ROD implementation, these stocks have yet to recover. Southern Oregon/Northern California Coast (SONCC) Coho Salmon remain federally listed as threatened under the ESA and Upper Klamath-Trinity Rivers spring-run Chinook Salmon were warranted for listing as threatened under the State of California ESA in June 2021 (California Fish and Game Commission 2021). Under the federal ESA recovery plan for SONCC Coho Salmon, the “abundance recovery target” for naturally produced returns to the Trinity River sums to 10,370 adults (NMFS 2014), almost tenfold the TRRP escapement target for this stock. In addition, TRRP escapement targets are inseparable from the harvest objective to “facilitate dependent tribal, commercial, and sport fisheries’ full participation in the benefits of restoration via enhanced harvest opportunity.” Loss of harvest opportunities for Coho Salmon starting in 1996 and natural-origin steelhead starting in 1998, and the reduced sport harvest season for spring-run Chinook Salmon in response to their candidacy for listing in 2019, also indicate that the intent of escapement targets (i.e., recovery of fisheries) have not been met. Escapement targets for Coho Salmon and spring-run Chinook Salmon may have been set too low to reflect stock recovery under restricted harvest management, or not apportioned properly between runs in the case of Chinook Salmon.

Harvest opportunity for naturally produced steelhead has also been lost and no escapement target is currently set for the segment of the population being estimated, which excludes significant portions of the summer and winter runs. Comparing the TRRP goal of 40,000 to this subset of the population is not appropriate as a measure of progress. Either efforts to estimate the entire population should be employed or targets for the population being monitored should be scaled to that specific run.

Escapement targets for returns of hatchery-origin fall- and spring-run Chinook Salmon to TRH have been met six and seven times, respectively, since 2002, and targets for Coho Salmon have been met 17 times since 1997. In contrast, the hatchery target for steelhead has only been met 3 of the 27 years in which data are available. The objectives (i.e., broodstock need for TRH, mitigation for lost production upstream of Lewiston Dam, a mix of objectives, or some other undefined objective) that the hatchery escapement targets are intended to meet is unclear. Environmental Impact Statements for the Trinity River (USFWS 1983) and the TRRP (USFWS et al. 2000) indicate that the in-river and hatchery escapement targets were derived by CDFW sometime prior to 1983, but the rationale and origins are not clearly documented. USFWS (1983) explicitly states that 10,000 steelhead are mitigation for lost habitat upstream of Lewiston Dam, but other species in this context are not mentioned. USFWS et al. (2000) states that the hatchery targets “represent numbers of adult fish needed by the hatchery, exclusive of fisheries for Chinook and Coho salmon” and “current goals are to release sufficient juveniles to provide for returns to the hatchery of 12,000 Chinook Salmon (3,000 spring-run and 9,000 fall-run), 2,100 Coho Salmon, and 10,000 steelhead through artificial propagation.” However, based on TRH annual reports and discussions with the current hatchery manager, broodstock needs for TRH are considerably less than the TRRP targets. Current broodstock needs for fall-run Chinook Salmon are approximately 4,000–4,500 adults (Glen 2014; Muir 2019) while the TRRP target is 9,000 adults. Broodstock needs for spring-run Chinook Salmon are approximately 2,000–2,500 adults (Glen 2014 and Muir 2019) while the TRRP target is 3,000. Notably, juvenile Chinook Salmon production goals for TRH have not changed since at least 1996. Prior to reduced production of Coho Salmon and steelhead in 2015, broodstock needs were approximately 1,000 adults for each species (Glen 2014) while the TRRP targets are 2,100 and 10,000 adults, respectively. The broodstock needs in 2019 were reported as 572 Coho Salmon and 942 steelhead (Muir 2019), though it is unclear why the broodstock needed for steelhead was reduced so little when production of both Coho Salmon and steelhead were reduced by approximately 40% in 2015. If the TRRP intends for hatchery adult escapement targets to reflect the broodstock need at TRH to meet juvenile production goals, the adult targets should be reconsidered in consultation with TRH management. If adult hatchery targets are intended to reflect mitigation for lost habitat upstream of Lewiston Dam, or some other objective, this should be clearly articulated in TRRP objectives and targets and, in particular, new Environmental Impact Statement and Environmental Impact Report if and when those are developed. If this is the intention, an analysis should be conducted to estimate lost production upstream of Lewiston Dam of Coho Salmon, spring- and fall-run Chinook Salmon, and steelhead.

Mean annual escapement estimates to the Trinity River of Coho Salmon and spring- and fall-run Chinook Salmon has decreased since full implementation of the ROD but the mean escapement index has increased for steelhead (Table 16). Shifts in abundance are common in Chinook Salmon populations (Mantua et al. 1997; Brown 2002) and are evident in the Klamath Basin (CDFW 2019a, 2019b). Notably, the three most recent years of very low Coho Salmon returns (2016–2018) coincided with returns of juvenile releases reduced in accordance with court ordered consent decree No. 13-02293-MMC issued in 2014 (*EPIC v. Lehr* et al. 2014). Starting in calendar year 2015, TRH reduced production goals for juvenile Coho Salmon from 500,000 to 300,000 and for steelhead from 800,000 to no more than 448,000 per year. Also, during this time, the Hoopa Valley Tribe began operating a selective harvest weir targeting fall-run Chinook Salmon and hatchery-origin Coho Salmon and steelhead. Spring- and fall-run Chinook Salmon experienced very low returns in recent years while hatchery production remained relatively stable (except for fall Chinook Salmon in brood year 2016, Appendices S-T), which makes understanding how these additional stressors may have affected returns during this time difficult. Ocean conditions, particularly during early ocean residency, strongly affect adult returns of salmonids (Kope and Botsford 1990; Hobday and Boehlert 2001; Koslow et al. 2002; Welch et al. 2011; Sharma et al. 2013; Woodson et al. 2013). Overall, terminal and marine harvest and freshwater and marine conditions influence in-river escapement and likely obscure responses to river restoration when simply evaluating escapement and spawning activity. Evaluating the effects of fisheries and escapement on successive broods of salmonids using a cohort reconstruction model is a much more robust approach for evaluating the response of anadromous populations to restoration actions (Bradford and Hankin 2012).

Steelhead, at least the portion of the run for which escapement indices are generated, appear to have disproportionately benefited from changes in management actions. Analyses or evidence to support this claim are not provided in this report. Instead, possible explanations based on current understanding of the Trinity River and steelhead life history are considered. Steelhead generally rear in fresh water longer and exhibit more life-history variation than other salmonids, which may increase their resiliency (Hodge et al. 2016). If juvenile rearing conditions in the mainstem have improved since full implementation of the ROD, the species that rear there the longest may benefit most. Evidence for improved juvenile rearing conditions in response to ROD implementation is provided in Pinnix et al. (2021). Mainstem habitat improvement and flow management, which includes consistent baseflow above pre-ROD conditions, may have afforded more benefit to steelhead that spawn primarily in tributaries and use the mainstem more for rearing as compared to species that rely on the mainstem river below Lewiston Dam for most of their spawning and early rearing. Management actions of TRRP are largely focused on improving conditions for juvenile salmonids (e.g., channel rehabilitation and flows in excess of baseflow), so species that use the mainstem primarily for the life history component explicitly managed for (i.e., juvenile life histories) are expected to benefit most.

Variability in annual escapement has decreased for Chinook Salmon (Table 16). One possible explanation is that annual flow and temperature patterns have been more consistent since implementation of the ROD. Annual summer flows have been especially consistent because base flows released from Lewiston Dam are unaffected by water year type and are higher than during the pre-ROD period. This stability may have contributed to the decrease in annual variability in escapement for all species/runs monitored. The change in variability is notably less for Coho Salmon and steelhead. Both species spawn and experience early juvenile rearing primarily in tributaries, whereas Chinook Salmon spawn primarily in the mainstem. Since Coho Salmon and steelhead experience important life history components in tributaries that are largely unaffected by TRRP management, they are expected to be less affected by ROD implementation. Unfortunately, only steelhead have shown increased escapement abundance since full implementation of the ROD. While this can be considered an improvement, the overall decline in mean annual escapement for salmonid species/runs is of concern.

The limitations of using estimates of total escapement to compare pre-ROD and ROD periods rather than using estimates of natural-origin escapement are important to point out. Total escapement includes hatchery-origin fish, which are not exposed to as many environmental stressors that affect natural-origin fish during early life-history phases. Also, annual hatchery production has been relatively constant while natural production has varied considerably. For these reasons, combining hatchery- and natural-origin fish obscures the ability to detect responses to TRRP management actions by natural-origin fish. Natural-origin Chinook Salmon were not assessed separately because inconsistent and sometimes very low marking rates of hatchery-origin Chinook Salmon prior to 2004 introduced inconsistent and sometimes high sampling error when CWT recoveries were expanded to estimate hatchery-origin numbers. Hatchery- and natural-origin Coho Salmon were only estimated separately for a few years prior to full implementation of the ROD. Origin types of steelhead were not estimated separately in several pre-ROD years, including some of the highest and lowest escapement years on record, which may have substantially affected the pre-ROD mean of natural-origin steelhead. For these reasons, mean escapement for the pre-ROD and ROD periods of natural-origin fish only were not estimated and, consequently, the results presented in Table 16 should be viewed with that consideration in mind.

The difference in annual proportions of Chinook Salmon returns that are of natural origin between pre-ROD and ROD implementation periods is difficult to assess because constant fractional marking began only a few years prior to full ROD implementation. As described in Section 2.1.1, low and inconsistent CWT marking rates prior to brood year 2000 resulted in larger sampling errors compared to the years following 2000. However, the increased proportion of natural-origin spring- and fall-run Chinook Salmon after full implementation of the ROD is consistent with Coho Salmon, for which reasonable sample sizes are available pre-ROD and after full implementation of the ROD (Figures 32 and 33). Coho Salmon have undergone an approximate 2.3% increase in natural-origin percentages since ROD implementation, which coincided with an approximate 21% decrease in interannual variability. Production of juvenile spring- and fall-run Chinook Salmon at TRH was below production targets in several years since 2010 (Appendices S and T), largely due to insufficient returns of adults to the hatchery, and juvenile Coho Salmon production at TRH decreased starting in 2015 (see above). Reduced production at TRH at least partially explains the increased proportion of natural-origin adult Coho Salmon returns since full implementation of the ROD.

Steelhead slightly decreased in both the proportion of natural-origin fish and interannual variability. This is largely driven by high returns of natural-origin fish in 1980 and 1982. Excluding brood year 1981, production of steelhead at TRH was relatively low in the early 1980s, which largely explains the higher proportion of natural-origin steelhead in 1980 and 1982 (Appendices S and T). In contrast, the mean number of natural-origin fish returning to the Trinity River from 1992 to 1996 were only 34% of the mean from 2002 to 2018. Taken together this indicates that the number of natural-origin steelhead returning to the Trinity River has increased slightly and become somewhat more stable over time following full implementation of the ROD.

5.2 Spawning

The analyses of long-term data from 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 generally decreased from 2002 to 2017.

2) The spatial distribution of natural-origin Chinook Salmon spawning shifted downstream.

3) Hatchery-origin Chinook Salmon spawning (i.e., straying) in the mainstem Trinity River shifted downstream but remained confined to areas near the hatchery (Lewiston Dam).

4) Pre-spawn mortality rates for Chinook Salmon have been consistently low across the period of record except for a few years prior to implementation of the ROD.

5) Impacts of superimposition increase with abundance and disproportionally affect spring-run Chinook Salmon.

6) Channel rehabilitation have not affected redd abundance or distribution.

The overall abundance of natural-origin Chinook Salmon redds has decreased since the implementation of the ROD. The decrease in abundance of Chinook Salmon redds reflects the same pattern observed for the species/runs in the escapement estimates. However, redd data helps to describe spatially where the losses in spawners may occur. The area with the largest reduction in spawners is just downstream of Lewiston Dam. Impacts to spawning such as hatchery influence, redd dewatering, pre-spawn mortality, and superimposition are typically highest in this section of the river early in the spawning season. These effects likely disproportionately impact the species/runs that are more concentrated close to Lewiston Dam or spawn earlier, including all hatchery-origin salmon and natural-origin spring-run Chinook Salmon.

Straying and spawning of hatchery-origin Chinook Salmon in the mainstem Trinity River is generally in close proximity to TRH (Table 3, Figure 16). Nearly all (>90%) hatchery-origin Chinook Salmon that spawn in the mainstem spawn in the Lewiston and Limekiln reaches. Though the mean distance of hatchery-origin Chinook Salmon redds from the hatchery increased in recent years, the current rate of change is relatively slow and the mean distance from the hatchery is not likely to move downstream of Reach 2 for decades. The high concentration of hatchery-origin spawners in the upper reaches may influence the genetic integrity of the Chinook Salmon population through hatchery-natural introgression, as observed for the late fall-run Chinook Salmon in California's Central Valley (Williamson and May 2005). Loss of genetic integrity can lead to loss of fitness and survival in salmonid populations (Swain and Riddell 1990; McGinnity et al. 1997; Williamson and May 2005), which may be occurring in the Trinity River as indicated by the proportion and number of hatchery-origin Chinook Salmon redds declining over time.

The proportions of redds in the mainstem Trinity River with mild and severe superimposition (30.2% and 23.7%, respectively) suggest that either (1) salmon spawning in the Trinity River prefer to build redds in close proximity to other redds or where other fish have recently loosened substrates or (2) that optimal spawning habitat is limited. Essington et al. (1998) and Gortazar et al. (2012) indicated that Brown Trout *Salmo trutta* redd superimposition was not due to habitat limitation, but due to females' preference to construct redds in groups with overlapping edges. Since the construction of Lewiston Dam, the highest salmon redd densities have typically occurred in Reach 1. Spawning by hatchery-origin Chinook and Coho salmon has also been most concentrated in Reach 1, presumably due to its proximity to TRH (Rogers 1972; Chamberlain et al. 2012; Rupert et al. 2017a, 2017b). Since redd superimposition precludes the ability to estimate escapement based upon redd enumeration in Reaches 1 and 2 of the mainstem Trinity River, escapement is estimated from carcass mark-recapture data in this section of the river. The effect on hatchery-origin Chinook Salmon is unclear since they may both disturb existing redds and have their redds disturbed by subsequent spawners. Additionally, the impacts of superimposition likely have a disproportionate effect on spring-run Chinook Salmon. Early spawning and limited spatial extent of spring-run Chinook Salmon in the mainstem Trinity River make their redds especially vulnerable to superimposition.

The mean distance from Lewiston Dam of natural-origin Chinook Salmon spawning has moved downstream since implementation of the ROD. The annual abundance and proportion of total spawners decreased in the upper reaches and increased, mainly in spawning proportion, in the middle river reaches. The change in distribution is likely explained by one, or both, of these two scenarios: (1) the distribution of spawning has shifted downstream as a result of more rearing habitat downstream and fish returning to their rearing grounds to spawn or (2) the populations that spawn further upriver have suffered size reductions. A downstream shift in spatial distribution of natural-origin Chinook Salmon redds would be consistent with the IAP's hypothesis that changes in longitudinal redd distribution would happen within three to four brood cycles following rehabilitation of fluvial river processes (TRRP and ESSA 2009; Sub-Objective 3.1 Primary Hypothesis B). Alternatively, run sizes have undergone reductions over the period of record and were particularly low in the most recent years analyzed. Since the decline of the Chinook Salmon population is most evident in the upper reaches of the mainstem Trinity River, the spring-run would likely have suffered disproportionally more reduction since they tend to spawn further upstream.

The IAP hypothesized that redd superimposition would be reduced by 25% during "normal runs" in the 3.2 km downstream of Lewiston Dam following rehabilitation of fluvial river processes (Sub-Objective 3.1 Primary Hypothesis C, TRRP and ESSA 2009). Furthermore, the IAP suggested that redd abundance from North Fork Trinity River to Cedar Flat would not increase until escapement began to approach the restoration goals. Neither claim was definitively supported by the data. The proportion of spawning below the North Fork Trinity River has increased without significant progress towards achieving escapement goals. Reductions in overall redd abundance and the amount of redd superimposition in Reach 1 appears to be density dependent and the decrease in superimposition in this section of river from 2009 to 2016 was likely the product of both reduced run sizes and a higher proportion of fish spawning downstream of Reach 1 and 2.

Changes in redd abundance at the site scale were specifically used to evaluate the effect of TRRP channel rehabilitation activities. Analyses revealed varying post-construction responses at rehabilitation sites. The site scale, despite being the smallest scale analyzed, may still be too spatially broad and too few years have passed since construction to detect responses to restoration (Rupert et al. 2017a). A positive response in the abundance of Chinook Salmon redds to channel rehabilitation may take many generations that encompass several years of geomorphic change and restoration site 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).

Pre-spawn mortality rates have been relatively low, not exceeding 9.5% in the restoration reach, since implementation of the ROD and have been much lower than rates during several years during the 1980s and 1990s upstream of the North Fork (Aguilar et al. 1996). Sustained high water temperatures have been shown to be detrimental to adult salmon survival and egg viability (Jensen et al. 2006; Groves et al. 2007). Flow management and water temperature are therefore important to consider since a large portion of the restoration flow volume, particularly during a dry year, is associated with adult holding temperature targets. However, the lack of correlation of pre-pawn mortality rates with exceedances of the current daily average temperature targets suggests that the existing targets should be reviewed. Temperature management base on longer intervals, such as weekly maximums or maximum weekly means, may be more appropriate. Many temperature criteria that are currently being developed use seven-day rolling averages or maximums. Additionally, the lack of correlation between pre-spawn mortality rates and management periods, excluding three years of outliers, indicates that other management methods may be similarly effective. Pre-spawn mortality may also be influenced by other factors beyond river conditions in some years. Causal effects addressed previously suggest that run size is a factor in predicting pre-spawn mortality rates. Additionally, a baseline pre-spawn mortality rate may be a historical and natural phenomenon and attempts to reduce it further may not be possible.

Channel rehabilitation has had little to no effect on the annual proportion of redds in the restoration reach (see Section 4.6.2). The overall decline in the proportion of redds in rehab sites in the restoration reach over the 2002–2017 time period appears to be a function of the overall shift of the proportion of redds downstream in the mainstem Trinity River. A higher proportion of redds may have been found in non-rehab areas because more restoration has been completed in the upper reaches compared to the lower reaches. In addition, at the reach scale, few sites showed post-construction effects on spawning and nearly every site that significantly changed had a higher proportion of redds post-construction. This indicates that construction of rehab sites has had little effect on spawning habitat and that broader patterns in longitudinal distribution may have swamped any effect of channel rehabilitation.

5.3 Revisiting IAP Objectives and Progress

The IAP (TRRP and ESSA 2009) is the main science, monitoring, and evaluation and planning document used by the TRRP and its various workgroups. Beginning in 2013, the TRRP identified a need to refine, reduce, and reorganize objectives listed in the IAP. The TRRP's Fish Workgroup re-evaluated 54 of these objectives and sub-objectives that were related to fish and assessed those objectives for redundancy and their connection to management actions. The first iteration of review resulted in 20 objectives (TRRP and ESSA 2009) to carry over into a new set of objectives and targets. Six of these objectives were deemed no longer relevant to TRRP goals or outside the management control of the program, two of which pertained to spawning adult salmon:

1. *Limit redd superimposition by increasing suitable spawning habitat areas.*
2. *Increase the proportion of Natural Influence (pNI) used as a surrogate for genetic interactions - mixing of hatchery and natural fish.*

In June 2018, the TRRP's Fish Workgroup reinitiated refinement of fish-related programmatic objectives and their associated targets (TRRP 2021). Workgroup members distilled the set of existing objectives and their associated targets down to a set that most closely supported fundamental goals of the TRRP, including those presented in the IAP. This resulted in 14 objectives and 12 targets that could be measured with a reasonable amount of effort and are within the scope of TRRP management activities. Three of these objectives were kept but not recommended to be quantifiable measures of program success. A list of IAP sub-objectives related to this report and their status is presented in Table 24.

Regarding Sub-objective 3.1.3 (Table 24), pre-spawn mortality has generally been below 10% in all years except for a few high abundance years prior to the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000; Table 5). Three pre-spawn mortality target options were developed and are under consideration by the TRRP Fish Workgroup at the time of this report:

1. Pre-spawn mortality target rate of ≤10%, given the baseline rate has been about 10%.
2. Variable pre-spawn mortality target rate as a function of run size (i.e., lower pre-spawn mortality when escapement is low and higher allowable rates of pre-spawn mortality as escapement increases). Past high rates of pre-spawn mortality were often associated with high escapement, which suggests some density dependence. Maintaining a low rate of pre-spawn mortality during high escapement could defer density-dependent mortality to later life stages (e.g., through redd superimposition or juvenile competition), which could ultimately limit juvenile production. Additionally, in high abundance years, an upper limit of pre-spawn mortality will be defined to prevent mass mortality.
3. A combination of the above two target options. A pre-spawn mortality rate of ≤10% until escapement targets are met, then increasing as allowable to maintain escapement targets.

Workgroup members believed that management actions available to the TRRP have little effect on redd superimposition and the reasons fish superimpose redds when apparently suitable spawning habitat goes unused is not well understood. In addition, this objective was considered redundant with the objective to maintain or increase the amount and quality of spawning habitat.

TRRP does not have management authority of Trinity River Hatchery and therefore only has limited ability to control mixing of hatchery and natural fish. However, resuming gravel augmentation adjacent to the hatchery is hypothesized to affect the distribution of spawning of hatchery-origin fish and may affect hatchery/natural interactions.

Table 24. Trinity River Restoration Program Integrated Assessment Plan sub-objectives relevant to adult salmonid spawning in the Trinity River.

Sub-objective	Description	Forwarded through current refinements process?	Addressed in this report?
3.1.1	*Optimize adult utilization of suitable spawning habitat areas in the mainstem within 3–4 brood cycles following rehabilitation of fluvial river processes*	No	Indirectly addressed. Data available; increasing spawning habitat during ascending base flows reported in Goodman et al. (2018).
3.1.3	*Reduce temperature related pre-spawning mortality and protect in-vivo egg viability of anadromous spawners in the mainstem Trinity River*	Yes	Yes (see p.96).
3.3.2	*Increase proportion of Natural Influence (pNI) to 0.7 or greater*	No	No. Requires action by independent entities outside of TRRP; not clearly linked to TRRP actions.
4.1.1	*Increase escapement of naturally produced fall-run Chinook Salmon to 62,000 adults*	Yes	Yes. Section 5.1. Has not been met since ROD implementation.
4.2.1	*Increase escapement of naturally produced spring-run Chinook Salmon to 6,000 adults*	Yes	Yes. Section 5.1. Met in four years since ROD implementation.
4.3.1	*Increase escapement of naturally produced Coho Salmon to 1,400 adults*	Yes	Yes. Section 5.1. Met in seven years since ROD implementation.
4.4.1	*Increase escapement of naturally produced steelhead to 40,000 adults*	Yes	Yes. Section 5.1. Has not been met since ROD implementation

5.4 Recommendations

1. Natural-origin escapement targets for adult salmonids should be re-evaluated.

A clear discrepancy exists between the natural-origin escapement targets for steelhead and fall-run Chinook Salmon versus those for Coho and spring-run Chinook Salmon, which is discussed in Section 5.1. Despite the listing of Coho and spring-run Chinook salmon under state and federal ESAs, TRRP targets have only been met in some years. The recovery standard for Trinity River Coho Salmon under the federal ESA is considerably higher than the TRRP target. In contrast, populations of steelhead and fall-run Chinook Salmon have consistently remained well below TRRP escapement targets while not being listed under state or federal ESAs, and fall-run Chinook have supported recreational, commercial, and tribal harvest except in very low abundance years.

Escapement targets for Coho and spring-run Chinook salmon may have been set too low and/or targets for steelhead and fall-run Chinook Salmon may have been set too high. Targets should be re-evaluated by program scientists and updated if warranted. To be consistent with a fully restored fishery and to make messaging more consistent across management, TRRP targets should exceed ESA targets.

Revisiting steelhead targets are especially important because only a portion of the run is estimated. These targets may be adjusted by (1) updating escapement goals to only reflect late summer- and fall-run steelhead or (2) expanding monitoring efforts so that summer- and winter-run steelhead can be included in the escapement estimate. The latter option may be accomplished by either operating the Willow Creek and/or Junction City weirs longer or incorporating additional survey techniques (e.g., ARIS and DIDSON sonar cameras, diver observation, etc.).

2. Clarification of the intent of hatchery escapement targets.

Whether adult hatchery escapement targets are intended to meet brood stock collection needs for annual hatchery production or to mitigate for lost production upstream of Lewiston Dam is unclear. Brood stock collection needs for TRH are lower than TRRP targets, and in some cases by a considerable margin. Production goals for TRH have remained consistent for decades except for the recent reduction for Coho Salmon and steelhead. The reason TRRP targets are different than TRH goals is unclear given TRH goals pre-dated the ROD and formation of the TRRP. If TRRP targets are intended to mitigate for lost production upstream of Lewiston Dam, straying of hatchery-origin fish to natural spawning grounds would be expected. However, a growing body of evidence demonstrates the negative effects of hatchery-origin strays to natural spawning grounds. For example, Chilcote et al. (2011) demonstrated a significant negative relationship between the proportion of hatchery-origin fish spawning in natural spawning areas and population-level recruitment performance for steelhead, Coho Salmon, and Chinook Salmon across a broad geographic range. Also, Jones et al. (2018) documented a considerable rebound of a wild Coho Salmon population following termination of hatchery production in an Oregon stream. In addition, experts and managers recommend operating TRH as an integrated hatchery (California HSRG 2012), which would seek to reduce the proportion of hatchery-origin fish spawning in natural spawning grounds and increase the proportion of natural-origin fish used in hatchery broodstock, among other measures. Recent studies and expert opinions suggest that hatchery-origin escapement goals that exceed the brood stock needs of TRH may be inconsistent with other TRRP goals to increase production. Excess escapement of hatchery-origin fish is also inconsistent with the ultimate intent of the 2014 court ordered consent decree to reduce production of Coho Salmon and steelhead at TRH (*EPIC v. Lehr* et al. 2014). This topic should be addressed by program scientists in consultation with hatchery management, including the U.S. Bureau of Reclamation and CDFW. If targets are to be updated, recommendations and scientific justifications should be presented to TMC for consideration.

3. Determine effect of ocean conditions on adult returns.

Harvest and environmental conditions influence in-river escapement, thus obscuring responses to river restoration when analyses are limited to escapement and spawning activity. Including ocean conditions as a covariate to such analyses may help explain why reductions in juvenile releases coincided with lower escapement but were not commensurate with reductions in escapement estimates.

4. Evaluate holding habitat.

An evaluation of the amount of suitable holding habitat for adult spring-run Chinook Salmon in the restoration reach of the Trinity River is currently underway. This effort is investigating the amount of suitable habitat that can be provided by longitudinal cooling of the river through an elevated release of cold water from Lewiston Dam. Furthermore, this work explores the feasibility of providing habitat through thermal stratification under low flow conditions using 2-D and 3-D temperature modeling. From this, the number of adult salmon that could be supported under current management and hypothetical management scenarios can be estimated.

The ongoing effort described above will help to address a previously identified outstanding TRRP Fish Workgroup target. The methods for providing sufficient suitable adult holding habitat and the amount required should be re-evaluated after the habitat assessment is completed. Once estimates of holding habitat are available, the possible implications for density-dependent pre-spawn mortality could be investigated.

5. Increase the quality and availability of spawning habitat area.

The IAP (TRRP and ESSA 2009) suggests that spawning success (and fry production) of Chinook Salmon, Coho Salmon, and steelhead will increase within three to four brood cycles following rehabilitation of fluvial river processes. Spawning habitat may be limiting production in the upper most reach of the Trinity River. Therefore, increasing spawning habitat in the upper reaches of the Trinity River may increase the overall productivity of the system by helping to alleviate density-dependent pre-spawn mortality and superimposition.

6. Achieve temperature objectives for adult salmonids and further evaluation of temperature targets.

Though no clear correlations between adult temperature objectives and pre-spawn mortality rates were found (Section 4.3.2), current measures appear to have been successful at accomplishing sub-objective 3.1.3. Baseline in-river pre-spawn mortality of adult salmonids occurs naturally in nearly all salmon-bearing streams (Quinn et al. 2007) and annual pre-spawn mortality in the Trinity River has generally been acceptably low under the current ROD. Therefore, pertaining to pre-spawn mortality, the efficacy of temperature objectives defined by less stringent requirements than daily average (i.e., 7DADM, MWMT, etc.) merit assessment. Additionally, the overall impacts to brood year production should be considered when setting targets for pre-spawn mortality since limiting one source of mortality may increase mortality from other density-dependent factors (e.g., redd superimposition, juvenile competition, juvenile food, and habitat limitations).

7. Internal and external review to identify efficiencies in the adult salmon monitoring and redd and carcass survey design.

The long-term monitoring data used to prepare this report represents the best data available by which to assess spawning and escapement within the Trinity River Basin. Adult escapement and harvest are not only used for fisheries management but are also the most intrinsic measure of success for the TRRP. The data provides information on annual abundance for different geographic areas, species/runs, and population segments (e.g., hatchery/natural origin, run timing). The inherent variability of salmonid populations requires this information to be collected annually and continuously to adequately evaluate population trends and to provide data for some of the program's most useful analytics (e.g., cohort reconstruction). The data also provide information about sources of mortality that can impact production (e.g., pre-spawn mortality, superimposition) and the distribution of spawning at different geographic scales.

Due to limited resources within the TRRP to meet the needs of science and monitoring to track long-term trends and inform adaptive management, the level of effort for each dataset (i.e., each project and geographic extent within each project) should be reevaluated. Refinement and identification of the most important uses of these long-term data sets should continue and the most parsimonious sampling design which meets the identified needs of the TRRP should be considered, along with economies of scale for expanded sampling design. Such informal and formal reviews have occurred in the past through the TRRP science planning process and in Hankin (2001) and Bradford and Hankin (2012). Several issues identified in those reviews have been addressed or further explored. Those efforts and this report now merit further consideration of the level of effort for current and future adult population monitoring.

6. Acknowledgements

We are grateful to work in partnership with the Yurok and Hoopa Valley tribes and recognize the importance of the salmon of the Trinity River to native history, culture, and subsistence. We extend gratitude to Charlie Chamberlain with the U.S. Fish and Wildlife Service and Derek Rupert with the U.S. Bureau of Reclamation for producing the initial study designs and modeling scripts that provided the foundation for much of this report's analyses. We also thank Derek for the cover art on this report. We thank Nicholas Som from USGS for his review and statistical guidance of analyses in this report. Thank you to Ken Collis and Allen Evans from Real Time Research for their thoughtful and thorough review of this document. Thank you to all field personnel from HVT, YTFP, CDFW, USFS, BOR, and USFWS that collected the data for these projects over the years.

7. 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.

Becker, C. D., and D. A. Neitzel. 1983. Salmonid redd dewatering: what do we know? Battelle Pacific Northwest Laboratory, Richland, Washington. Report No. PNL-SA-11841. 35 p.

Becker, C. D., and D. A. Neitzel. 1985. Assessment of intergravel conditions influencing egg and alevin survival during salmonid redd dewatering. Environmental Biology of Fishes 12(1):33–46.

Bowerman, T., A. Roumasset, M. L. Keefer, C. S. Sharpe, and C. C. Caudill. 2017. Prespawn mortality of female Chinook Salmon increases with water temperature and percent hatchery origin. Transactions of the American Fisheries Society 147:31–42.

Bradford, M., and D. Hankin. 2012. Trinity River Restoration Program adult salmonid monitoring evaluation. Prepared for Trinity River Restoration Program, 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.

Busby, P. J., T. C. Wainwright, and R. S. Waples. 1994. Status review for Klamath Mountains Province steelhead. NOAA Technical Memorandum NMFS-NWFSC-19, Seattle, Washington.

California Fish and Game Commission. 2021. June 16–17, 2021 meeting. https://cal-span.org/unipage/?site=cal-span&owner=CFG&date=2021-06-16.

California HSRG (Hatchery Scientific Review Group). 2012. California hatchery review statewide report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. www.cahatcheryreview.com.

Carter, K. 2005. The effects of temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon biology and function by life stage, implications for Klamath Basin TMDLs. California Regional Water Quality Control Board – North Coast Region (CRWQCB-NCR), Santa Rosa, California.

CDFG (California Department of Fish and Game). 2004. September 2002 Klamath River fish-kill: final analysis of contributing factors and impacts. Northern California North Coast Region.

CDFW (California Department of Fish and Wildlife). 2019a. Klamath River Basin fall Chinook Salmon spawner escapement, in-river harvest and run-size estimates, 1978–2018. California Department of Fish and Wildlife, Arcata, Californian.

CDFW (California Department of Fish and Wildlife). 2019b. Klamath River Basin spring Chinook Salmon spawner escapement, river harvest and run-size estimates, 1980–2018. 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.

Chilcote, M. W., K. W. Goodson, and M. R. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries and Aquatic Sciences 68(3):511–522.

Conover, W.J. 1999. Practical Nonparametric Statistics. 3rd Ed. John Wiley and Sons, New York, United States.

Currier, M., and W. Sinnen. 2005. Task 4. Salmon spawner surveys in the upper Trinity River. Pages 91–116 *in* N. Manji, supervisor. Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project 2003–2004 Season. California Department of Fish and Game, Northern California – North Coast Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

EPIC v. Lehr et al. 2014. Consent decree and order. Case No. 13-02293-MMC. April 28, 2014, San Francisco, California.

Essington, T. E., P. W. Sorenson, and D. G. Paron. 1998. High rate of redd superimposition by Brook Trout (*Salvelinus fontinalis*) and Brown Trout (*Salmo trutta*) in a Minnesota stream cannot be explained by habitat availability alone. Canadian Journal of Fisheries and Aquatic Sciences 55:2310–2316.

Evenson, D. F. 2001. Egg pocket depth and particle size composition within Chinook Salmon redds in the Trinity River, California. M.S. Thesis. Humboldt State University, Arcata, California. 63 p.

Fukushima, M., T. J. Quinn, and W. W. Smoker. 1998. Estimation of eggs lost from superimposed Pink Salmon (*Oncorhynchus gorbuscha*) redds. Canadian Journal of Fisheries and Aquatic Sciences 55:618–625.

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.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook and Coho salmon and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fisheries Management 25:284–300.

Garrison, P. 2008. Task 4. Salmon spawning surveys in the Upper Trinity River. Pages 98–124 *in* L. Hanson, editor. Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project 2005–2006 Season. California Department of Fish and Game, Northern California – North Coast Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

Glen, L. E. 2014. Annual report: Trinity River salmon and steelhead hatchery, 2013-2014. California Department of Fish and Wildlife, Northern Region, 601 Locust Street, Redding, California 96001.

Goodman, D. H., N. A. Som, and N. J. Hetrick. 2018. Increasing the availability and spatial variation of spawning habitats through ascending baseflows. River Research and Applications 34:844– 853. https://doi.org/10.1002/rra.3302.

Gortazar, J., C. Alonso, and D. Garcia de Jalon. 2012. Brown trout redd superimposition in relation to spawning habitat availability. Ecology of Freshwater Fish 21(2):283–292.

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.

Gough, S. A., N. A. Som, N. S. Quinn, W. C. Matilton, A. M. Hill, and W. Brock. 2019. Mainstem Trinity River Chinook Salmon spawning survey, 2017. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2019–62, Arcata, California.

Groves, P. A., J. A. Chandler, and R. Myers. 2007. The effects of the Hells Canyon Complex relative to water temperature and fall Chinook Salmon. Final Report submitted to the Federal Energy Regulatory Commission for Project Number 1971.

Guillen, G. 2003. Klamath River fish die-off, September 2002: report on estimate of mortality. U.S. Fish and Wildlife Service Report Number AFWO-01-03, Arcata, California. 28 p.

Hankin, D. 2001. A preliminary evaluation of the performance of methods used to estimate spawning escapement of Chinook Salmon in the Trinity River. Contract Agreement #000203 between the Hoopa Valley Tribal Fisheries Department and the Humboldt State University Foundation, Arcata, California. 41 p.

Hill, A. 2009, 2010a. Task 4. Salmon spawning surveys in the Upper Trinity River *in* L. Hanson, editor. Final Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project, 2 reports. California Department of Fish and Game, Northern California – North Coast Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

Hill, A. 2010b. Task 4. Salmon spawning surveys in the Upper Trinity River. Pages 109–142 *in* Final Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project 2008–2009 Season. California Department of Fish and Game, Northern Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

Hill, A. 2011, 2013a, 2013b. Task 4. Salmon spawning surveys in the Upper Trinity River *in* Final Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project, 3 reports. California Department of Fish and Game, Northern Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number R11AC20520.

Hobday, A. J., and G. W. Boehlert. 2001. The role of coastal ocean variation in spatial and temporal patterns in survival and size of Coho Salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Science 58:2021–2036.

Hodge, B. W., M. A. Wilzbach, W. G. Duffy, R. M. Quinones, and J. A. Hobbs. 2016. Life history diversity in Klamath River steelhead. Transactions of the American Fisheries Society 145(2):227–238.

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.

Jensen, J. O. T., W. E. McLean, T. Sweeten, W. Damon, and C. Berg. 2006. Puntledge River high temperature study: influence of high water temperatures on adult Chinook Salmon (*Oncorhynchus tshawytscha*) in 2004 and 2005. Canadian Technical Report of Fisheries and Aquatic Sciences 2662. www.dfo-mpo.gc.ca/librariesbibliotheques/tech-eng.htm.

Jones, K. K., T. J. Cornwell, D. L. Bottom, S. Stein, and K. J. Anlauf-Dunn. 2018. Population viability improves following termination of Coho Salmon hatchery releases. North American Journal of Fisheries Management 38:39–55.

Kier, M. C., J. Hileman, and K. Lindke. 2019. Annual report Trinity River basin salmon and steelhead monitoring project: Chinook Salmon and Coho Salmon and fall-run steelhead run-size estimates using mark-recapture methods 2018–2019 season. California Department of Fish and Wildlife, Northern Region, Redding, California.

Kery, M., and M. Schaub. 2012. Bayesian population analysis using WinBUGS. Academic Press, Oxford, United Kingdom.

Knechtle, M., and M. Currier. 2006. Task 4. Salmon spawning surveys in the Upper Trinity River. Pages 98–124 *in* N. Manji, supervisor. Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project 2004–2005 Season. California Department of Fish and Game, Northern California – North Coast Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

Kope, R. G., and L. W. Botsford. 1990. Determination of factors affecting recruitment of Chinook Salmon *Oncorhynchus tshawytscha* in Central California. Fishery Bulletin 88(2):257–269.

Koslow, J. A., A. J. Bogday, and G. W. Boehlert. 2002. Climate variability and marine survival of Coho Salmon (*Oncorhynchus kisutch*) in the Oregon production area. Fisheries Oceanography 11(2):65–77.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78(6):1069–1079.

McGinnity, P., C. Stone, J. B. Taggert, D. Cooke, D. Cotter, R. Hynes, C. McCamley, T. Cross, and A. Ferguson. 1997. Genetic impact of escaped farmed Atlantic Salmon (*Salmo salar* L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. Journal of Marine Science 54:998–1008.

McMichael, G. A., C. L. Rakowski, B. B. James, and J. A Lukas. 2005. Estimated fall Chinook Salmon survival to emergence in dewatered redds in a shallow side channel of the Columbia River. North American Journal of Fisheries Management 25(3):876–884.

McNeil, W. J. 1964. Redd superimposition and egg capacity of Pink Salmon spawning beds. Journal of Fisheries Research Board of Canada 21:1385–1396.

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.

Muir, D. 2019. Annual report: Trinity River salmon and steelhead hatchery, 2018–2019. California Department of Fish and Wildlife, Northern Region, 601 Locust Street, Redding, California 96001.

NMFS (National Marine Fisheries Service). 1997. Endangered and threatened species; threatened status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of Coho Salmon, final rule. Federal Register 62:87 (6 May 1997):24588–24609.

NMFS (National Marine Fisheries Service). 2014. Final recovery plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service, Arcata, California.

Neitzel, D. A., and C. D. Becker. 1985. Tolerance of eggs, embryos, and alevins of Chinook Salmon to temperature changes and reduced humidity in dewatered redds. Transactions of the American Fisheries Society 114(2):267–273.

Pennington, H. M. 1986. Emigration and mortality of juvenile steelhead in a nursery stream. M.S. Thesis, Humboldt State University, Arcata, California. 55 p.

Pinnix, W. D., S. P. Boyle, T. Daley, T. Wallin, and N. A. Som. 2021. Long-term analyses of estimates of abundance of juvenile Chinook Salmon on the Trinity River, 1989-2018. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TS 2022-40, Arcata, California.

Quinn, T. P., D. M. Eggers, J. H. Clark, and H. B. Rich, Jr. 2007. Density, climate, and the processes of prespawning mortality and egg retention in Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences. 64:574–582. Doi:10.1139/F07-035.

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.

Reiser, D. W., and R. G. White. 1983. Effects of complete redd dewatering on salmonid egg-hatching success and development of juveniles. Transactions of the American Fisheries Society 112(4):532–540.

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. 2017a. Mainstem Trinity River Chinook Salmon Spawning Survey 2012-2014. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2017–52, Arcata, California.

Rupert, D. L., S. A. Gough, N. A. Som, N. J. Davids, W. C. Matilton, A. M. Hill, and J. L. Pabich. 2017b. Mainstem Trinity River Chinook Salmon Spawning Distribution, 2015 and 2016. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2017–56, Arcata, California.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Macmillan Publishing Co., Inc., New York, New York. i–xvii + 654 p.

Sharma, R., L. A. Vélez-Espino, A. C. Wertheimer, N. Mantua, and R. C. Francis. 2013. Relating spatial and temporal scales of climate and ocean variability to survival of Pacific Northwest Chinook Salmon (*Oncorhynchus tshawyscha*). Fisheries Oceanography 22(1):14-31.

Sinnen, W. 2004a, 2004b. Task 4. Salmon spawning surveys in the Upper Trinity River. *in* N. Manji, supervisor. Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project, 2 reports. California Department of Fish and Game, Northern California – North Coast Region, 601 Locust Street, Redding, California 96001. Report to the U.S. Bureau of Reclamation, Cooperative Agreement Number 02FG200027.

Sinnen, W., S. Borok, A. Hill, J. Hileman, and M. C. Kier. 2011. Final annual report Trinity River basin salmon and steelhead monitoring project 2009–2010 season. California Department of Fish and Game, Northern California — North Coast Region, 601 Locust Street, Redding, California 96001.

Swain, D. P., and B. E. Riddell. 1990. Variation in agonistic behavior between newly emerged juveniles from hatchery and wild populations of Coho Salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences 47:566–571.

TRRP (Trinity River Restoration Program). 2021. Fish Work Group deliverable for Program objectives/targets refinements. Memorandum to TRRP Science Coordinator. Trinity River Restoration Program, Weaverville, California. January 12, 2021.

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. Draft long-term plan for protecting late summer adult salmon in the lower Klamath River. 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.

USBOR (U.S. Bureau of Reclamation). 2017. Final Environmental Impact Statement, Long-Term plan to Protect Adult Salmon in the Lower Klamath River. U.S. Department of the Interior, Bureau of Reclamation.

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). 1983. Final Environmental Impact Statement. Trinity River Basin Fish and Wildlife Management Program. U.S. Department of Interior, U.S. Fish and Wildlife Service, Sacramento, California INT/FES 83-53.

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.

USFWS (U.S. Fish and Wildlife Service), USBOR (U.S. Bureau of Reclamation), HVT (Hoopa Valley Tribe), and TC (Trinity County). 2000. Trinity River Draft and Final Environmental Impact Statement/Environmental Impact Report EIS/EIR.

Welch, D. W., M. C. Melnychuk, J. C. Payne, E. L. Rechisky, A. D. Porter, G. D. Jackson, B. R. Ward, S. P. Vincent, C. C. Wood, and J. Semmens. 2011. In situ measurement of coastal ocean movements and survival of juvenile Pacific salmon. PNAS 108(21):8708–8713.

Williamson, K. S., and B. May. 2005. Homogenization of fall-run Chinook Salmon gene pools in the Central Valley of California, USA. North American Journal of Fisheries Management 25:993–1009.

Woodson, L. E., B. K. Wells, P. K. Weber, R. B. MacFarlane, G. E. Whitman, and R. C. Johnson. 2013. Size, growth, and origin-dependent mortality of juvenile Chinook Salmon *Oncorhynchus tshawytscha* during early ocean residence. Marine Ecology Progress Series 487:163–175.

Young, P., J. Cech, Jr., and L. Thompson .2011. Hydropower-related pulsed-flow impacts on stream fishes: a brief review, conceptual model, knowledge gaps, and research needs. Reviews in Fish Biology and Fisheries 21(4):713–731.

8. Appendices

Appendix A. Years and locations where surveys were conducted for spawning escapement of fall-run Chinook Salmon in the Trinity River from 1978 to 2018. Shaded cells indicate the year and location where surveys were conducted. See Section 2.1.1 Fall-run Chinook Salmon for further details on survey methods at various locations.

Year	Willow Creek Weir	Mainstem redd counts	Hoopa tributaries	Lower Trinity tributaries
1978	shaded			
1979	shaded		shaded	
1980	shaded		shaded	
1981	shaded			
1982	shaded			
1983	shaded			
1984	shaded			
1985	shaded		shaded	
1986	shaded			
1987	shaded			
1988	shaded		shaded	
1989	shaded		shaded	
1990	shaded		shaded	
1991	shaded		shaded	
1992	shaded		shaded	
1993	shaded		shaded	
1994	shaded		shaded	
1995	shaded		shaded	
1996	shaded		shaded	
1997	shaded		shaded	
1998	shaded		shaded	
1999	shaded		shaded	
2000	shaded	shaded	shaded	shaded
2001	shaded	shaded	shaded	shaded
2002	shaded	shaded	shaded	shaded
2003	shaded	shaded	shaded	shaded
2004	shaded	shaded	shaded	shaded
2005	shaded	shaded	shaded	shaded
2006	shaded	shaded	shaded	shaded
2007	shaded	shaded	shaded	shaded
2008	shaded	shaded	shaded	shaded
2009	shaded	shaded	shaded	shaded
2010	shaded	shaded	shaded	shaded
2011	shaded	shaded	shaded	shaded
2012	shaded	shaded	shaded	shaded
2013	shaded	shaded	shaded	shaded
2014	shaded	shaded	shaded	shaded
2015	shaded	shaded	shaded	shaded
2016	shaded	shaded	shaded	shaded
2017	shaded	shaded	shaded	shaded
2018	shaded	shaded	shaded	shaded

Appendix B. Years and locations where surveys were conducted for spawning escapement of spring-run Chinook Salmon in the Trinity River from 1980 to 2018. Shaded cells indicate the year and location where surveys were conducted. See Section 2.1.2 Spring-run Chinook Salmon for further details on survey methods at various locations.

Year	Junction City Weir	South Fork Trinity	Hayfork Creek downstream of 9 mile bridge	North Fork Trinity excl. Rattlesnake Cr	Canyon Creek [c]	New River excluding East Fork
1980		a,d				
1981						
1982		a,d				
1983						
1984		a,d				
1985		a,d				
1986		a,d				
1987		a,d				
1988		a,d				
1989		a,d				a
1990		a,d				a
1991		a,d				a
1992						a
1993		a,d				a
1994		b				a
1995		b	b			a
1996		a	a,b			a
1997		a	a,b			a
1998			b		b	a
1999		b			b	
2000		b			b	
2001						
2002						
2003					b	
2004					b	b
2005					b	b
2006					b	b
2007		b				b
2008						b
2009		b				
2010		b				
2011		b	d			
2012		b	d			
2013		b			b	
2014		b				
2015						
2016		b			b	
2017		b		b		
2018						

[a] jacks not enumerated

[b] incomplete surveys

[c] incomplete surveys in Canyon Creek, excluded only the most upstream reach

[d] unknown if all reaches were surveyed

Appendix C. Total escapement of natural- and hatchery-origin fall-run Chinook Salmon to the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

	Fall-run Chinook Salmon escapement		
Year	Natural origin	Hatchery origin	Total
1978	-	-	38,411
1979	-	-	10,327
1980	-	-	14,055
1981	-	-	18,714
1982	-	-	15,567
1983	-	-	23,049
1984	-	-	8,586
1985	-	-	29,966
1986	-	-	111,952
1987	-	-	88,307
1988	-	-	66,720
1989	-	-	40,816
1990	-	-	9,401
1991	-	-	7,554
1992	-	-	11,129
1993	-	-	7,449
1994	-	-	18,612
1995	-	-	93,130
1996	-	-	49,306
1997	-	-	17,714
1998	-	-	38,948
1999	-	-	13,817
2000	-	-	51,926
2001	-	-	54,327
2002	7,796	6,713	14,509
2003	11,820	50,431	62,251
2004	1,995	23,557	25,552
2005	7,847	19,046	26,893
2006	6,949	16,323	23,272
2007	33,267	24,179	57,446
2008	8,972	7,309	16,281
2009	14,490	9,558	24,048
2010	15,223	13,335	28,558
2011	19,154	27,534	46,688
2012	36,974	31,238	68,212
2013	18,377	12,785	31,162

Appendix C (continued). Total escapement of natural- and hatchery-origin fall-run Chinook Salmon to the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

Year	Fall-run Chinook Salmon escapement		
	Natural origin	Hatchery origin	Total
2014	12,883	18,542	31,425
2015	3,980	3,988	7,968
2016	3,170	1,534	4,704
2017	4,430	3,920	8,350
2018	8,705	13,284	21,989

Appendix D. Total escapement of natural- and hatchery-origin spring-run Chinook Salmon to the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

Year	Spring-run Chinook Salmon escapement		
	Natural origin	Hatchery origin	Total
1980	-	-	2,235
1981	-	-	5,767
1982	-	-	5,263
1983[a]	-	-	930
1984	-	-	2,142
1985	-	-	7,871
1986	-	-	20,637
1987	-	-	37,702
1988	-	-	53,566
1989	-	-	23,248
1990	-	-	5,428
1991	-	-	1,953
1992	-	-	2,406
1993	-	-	5,073
1994	-	-	5,079
1995	-	-	8,722
1996	-	-	22,584
1997	-	-	18,637
1998	-	-	13,940
1999	-	-	9,811
2000	-	-	22,687
2001	-	-	16,800
2002	11,182	23,295	34,477
2003	13,268	31,801	45,069
2004	3,433	9,189	12,622
2005	2,892	10,142	13,034
2006	3,120	2,608	5,728
2007	2,829	11,568	14,397
2008	3,804	4,126	7,930
2009	3,229	3,648	6,877
2010	5,675	3,880	9,555
2011	6,382	5,351	11,733
2012	9,494	14,472	23,966
2013	3,064	5,835	8,899
2014	2,119	4,157	6,276
2015	1,090	2,638	3,728

[a] Estimates only include returns to Trinity River Hatchery.

Appendix D (continued). Total escapement of natural- and hatchery-origin spring-run Chinook Salmon to the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

Year	Spring-run Chinook Salmon escapement		
	Natural origin	Hatchery origin	Total
2016	1,358	1,903	3,261
2017	1,503	2,139	3,642
2018	1,966	4,902	6,868

Appendix E. Total escapement of natural- and hatchery-origin Coho Salmon to the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total escapement is provided for those years.

	Coho Salmon escapement		
Year	Natural origin	Hatchery origin	Total[a]
1978	-	-	2,447
1979	-	-	2,437
1980	-	-	3,595
1981	-	-	4,524
1982	-	-	9,072
1983	-	-	1,302
1984	-	-	4,105
1985	-	-	29,135
1986	-	-	8,836
1987	-	-	48,871
1988	-	-	34,350
1989	-	-	18,167
1990	-	-	3,443
1991	-	-	8,753
1992	-	-	7,937
1993	-	-	5,048
1994	-	-	239
1995	-	-	15,183
1996	-	-	35,143
1997	254	1,732	1,986
1998	1,010	9,008	10,018
1999	533	4,281	4,814
2000	343	9,704	10,047
2001	3,078	25,395	28,473
2002	458	13,849	14,307
2003	3,957	20,721	24,678
2004	8,901	24,122	33,023
2005	2,648	25,678	28,326
2006	1,586	17,123	18,709
2007	1,157	4,048	5,205
2008	1,223	6,381	7,604
2009	520	4,067	4,587
2010	817	5,852	6,669
2011	1,205	4,113	5,318

[a] Totals generally only from the Trinity River upstream of Willow Creek weir, except see footnote a in Appendix D.

Appendix E (continued). Total escapement of natural- and hatchery-origin Coho Salmon to the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total escapement is provided for those years.

Year	Coho Salmon escapement		
	Natural origin	Hatchery origin	Total[a]
2012	1,774	13,494	15,268
2013	4,305	14,782	19,087
2014	902	9,297	10,199
2015	748	2,936	3,684
2016[b]	-	-	1,117
2017	57	354	411
2018	42	1,017	1,059

[b] Insufficient data to separate hatchery-origin and natural-origin components in natural spawning areas, so only the total escapement is provided.

Appendix F. Total escapement of natural- and hatchery-origin steelhead to the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement is provided for those years.

Year	Steelhead escapement		
	Natural origin	Hatchery origin	Total
1980	14,564	7,004	21,568
1981	-	-	-
1982	6,968	1,605	8,573
1983	-	-	7,260
1984	-	-	6,572
1985	-	-	-
1986	-	-	-
1987	-	-	-
1988	-	-	12,743[a]
1989	-	-	33,698
1990	-	-	4,118
1991	-	-	9,077
1992	1,565	1,189	2,754
1993	1,186	1,676	2,862
1994	2,418	1,281	3,699
1995	1,891	2,105	3,996
1996	1,751	8,091	9,842
1997	-	-	4,696
1998	-	-	2,904
1999	-	-	5,388
2000	-	-	7,865
2001	-	-	12,271
2002	4,593	13,711	18,304
2003	3,879	18,899	22,778
2004	4,769	14,625	19,394
2005	5,343	13,862	19,205
2006	8,698	31,781	40,479
2007	7,436	43,289	50,725
2008	5,439	9,151	14,590
2009	4,894	11,938	16,832
2010	3,786	4,468	8,254
2011	6,900	14,044	20,944
2012	8,267	11,745	20,012
2013	9,119	6,816	15,935

Appendix F (continued). Total escapement of natural- and hatchery-origin steelhead to the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement is provided for those years.

Year	Steelhead escapement		
	Natural origin	Hatchery origin	Total
2014	5,753	4,321	10,074
2015	2,454	8,278	10,732
2016	1,944	2,500	4,444
2017	2,348	4,245	6,593
2018	2,326	3,402	5,728

Appendix G. Estimated escapement of fall-run Chinook Salmon to natural spawning grounds in the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

	Fall-run Chinook Salmon estimate				
	Downstream of WCW		Upstream of WCW		
Year	Tributaries	Mainstem	Natural origin	Hatchery origin	Total [a]
1978	-	-	-	-	31,052
1979	-	-	-	-	8,028
1980	-	-	-	-	7,700
1981	-	-	-	-	15,340
1982	-	-	-	-	9,274
1983	-	-	-	-	17,284
1984	-	-	-	-	5,654
1985	-	-	-	-	9,217
1986	-	-	-	-	92,548
1987	-	-	-	-	71,920
1988	-	-	-	-	44,616
1989	-	-	-	-	29,445
1990	-	-	-	-	7,682
1991	-	-	-	-	4,867
1992	-	-	-	-	7,139
1993	-	-	-	-	5,898
1994	-	-	-	-	10,906
1995	-	-	-	-	77,876
1996	-	-	-	-	42,646
1997	-	-	-	-	11,507
1998	-	-	-	-	24,460
1999	44	-	-	-	6,753
2000	872	-	-	-	24,880
2001	899	252	-	-	36,152
2002	530	194	6,549	3,761	11,034
2003	1,046	258	9,273	21,922	32,499
2004	402	998	0 [b]	11,768	13,168
2005	248	170	6,364	6,353	13,135
2006	524	126	5,114	9,452	15,216
2007	340	58	31,412	7,555	39,365
2008	824	598	6,951	3,457	11,830
2009	498	534	12,537	3,126	16,695
2010	476	32	14,104	6,197	20,809
2011	1,072	924	15,470	15,340	32,806

[a] Totals from 1978 to 2001 are only from the Trinity River upstream of Willow Creek weir.

[b] Actual estimate was -223 fish. Negative numbers occur when the estimated number of hatchery fish, based on expansion of coded-wire tag recoveries for sampling and production, exceeds the estimated total number of fish.

Appendix G (continued). Estimated escapement of fall-run Chinook Salmon to natural spawning grounds in the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years.

	Fall-run Chinook Salmon estimate				
	Downstream of WCW		Upstream of WCW		
Year	Tributaries	Mainstem	Natural origin	Hatchery origin	Total [a]
2012	836	598	34,702	14,615	50,751
2013	318	1,452	16,689	8,986	27,445
2014	1,083	262	11,528	11,577	24,450
2015	112	276	3,576	875	4,839
2016	117	92	2,853	500	3,562
2017	148	102	3,785	545	4,580
2018	140	208	7,538	6,961	14,847

[a] Totals from 1978 to 2001 are only from the Trinity River upstream of Willow Creek weir.

Appendix H. Observed counts of spring-run Chinook Salmon in major tributaries to the Trinity River and estimated escapement to natural spawning grounds upstream of Junction City Weir from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years. No estimates are available for 1983 and 1995.

	Spring-run Chinook Salmon count				
			Upstream of JCW		
Year	South Fork [a]	Miscellaneous tributaries [b]	Natural origin	Hatchery origin	Total
1980	25	49	-	-	1,688
1981	-	-	-	-	3,362
1982	161	8	-	-	4,037
1983	-	39	-	-	-
1984	27	25	-	-	1,406
1985	300	29	-	-	5,226
1986	183	-	-	-	13,554
1987	153	-	-	-	29,236
1988	59	273	-	-	39,661
1989	7	17[c]	-	-	18,265
1990	82	31[c]	-	-	2,995
1991	66	5[c]	-	-	1,339
1992	136	18	-	-	1,093
1993	284	45[c]	-	-	2,443
1994	217	22[c]	-	-	3,136
1995	471	91[c]	-	-	-
1996	1,097	73[c]	-	-	17,453
1997	647	49[c]	-	-	13,745
1998	171	32[c]	-	-	9,261
1999	157	15[c]	-	-	6,140
2000	231	16	-	-	11,093
2001	144	6	-	-	10,434
2002	347	16	10,097	13,577	24,037
2003	263	83	11,490	18,721	30,557
2004	45	12	2,966	4,348	7,371
2005	61	4	2,028	3,975	6,068
2006	138	70	2,418	537	3,163
2007	208	54	1,705	6,449	8,416
2008	-	23	3,210	1,260	4,493

[a] Includes Hayfork Creek in some years. See Appendix B for further details. All fish assumed to be of natural origin.
[b] Miscellaneous tributaries are North Fork Trinity River, Canyon Creek, and New River. Not all tributaries were surveyed in all years. See Appendix A for further details. All fish assumed to be of natural origin.
[c] Jacks were not enumerated, so all fish observed were assumed to be adults.

Appendix H (continued). Observed counts of spring-run Chinook Salmon in major tributaries to the Trinity River and estimated escapement to natural spawning grounds upstream of Junction City Weir from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total escapement is provided for those years. No estimates are available for 1983 and 1995.

	Spring-run Chinook Salmon count				
			Upstream of JCW		
Year	South Fork [a]	Miscellaneous tributaries [b]	Natural origin	Hatchery origin	Total
2009	107	46	2,672	1,052	3,877
2010	108	180	5,066	1,744	7,098
2011	240	361	5,577	1,732	7,910
2012	779	358	7,569	8,548	17,254
2013	295	166	2,487	3,469	6,417
2014	83	105	1,559	1,274	3,021
2015	-	0	817	1,163	1,980
2016	58	42	1,168	163	1,431
2017	17	32	1,429	1,030	2,508
2018	17	11	1,650	2,702	4,380

[a] Includes Hayfork Creek in some years. See Appendix B for further details. All fish assumed to be of natural origin.
[b] Miscellaneous tributaries are North Fork Trinity River, Canyon Creek, and New River. Not all tributaries were surveyed in all years. See Appendix A for further details. All fish assumed to be of natural origin.

Appendix I. Estimated escapement of Coho Salmon to natural spawning grounds in the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total escapement is provided for those years.

	Coho Salmon escapement			
	Tributaries	Upstream of WCW		
Year	downstream of WCW [a]	Natural origin	Hatchery origin	Total [b]
1978	-	-	-	1,168
1979	-	-	-	1,695
1980	-	-	-	1,817
1981	-	-	-	1,995
1982	-	-	-	5,097
1983	-	-	-	788
1984	-	-	-	2,971
1985	-	-	-	21,586
1986	-	-	-	6,247
1987	-	-	-	28,398
1988	-	-	-	22,277
1989	-	-	-	13,274
1990	-	-	-	1,981
1991	-	-	-	6,163
1992	-	-	-	5,565
1993	-	-	-	3,024
1994	-	-	-	105
1995	-	-	-	10,680
1996	-	-	-	25,308
1997	2	232	865	1,099
1998	9	886	5,109	6,004
1999	-	430	1,266	1,696
2000	1	288	6,297	6,586
2001	3	2,945	15,770	18,718
2002	-	372	7,440	7,812
2003	27	3,264	10,991	14,282
2004	-	7,830	15,287	23,117
2005	-	1,728	9,974	11,702
2006	-	1,416	7,454	8,870
2007	-	940	1,612	2,552
2008	-	861	2,204	3,065
2009	-	429	1,681	2,110

[a] Incidental observations during Chinook Salmon spawning ground surveys. Data only available from some years.
[b] Totals generally from the Trinity River upstream of Willow Creek weir, except see [a].

Appendix I (continued). Estimated escapement of Coho Salmon to natural spawning grounds in the Trinity River from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total escapement is provided for those years.

	Coho Salmon escapement			
	Tributaries	Upstream of WCW		
Year	downstream of WCW [a]	Natural origin	Hatchery origin	Total [b]
2010	-	624	2,146	2,770
2011	-	991	2,403	3,394
2012	-	1,577	6,335	7,912
2013	-	3,948	8,935	12,883
2014	-	823	6,405	7,228
2015	-	459	166	625
2016[c]	-	-	-	635
2017	-	34	107	141
2018	-	1	502	503

[a] Incidental observations during Chinook Salmon spawning ground surveys. Data only available from some years.
[b] Totals generally from the Trinity River upstream of Willow Creek weir, except see [a].
[c] Insufficient data to separate hatchery-origin and natural-origin components.

Appendix J. Estimated escapement of steelhead to natural spawning grounds in the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement is provided for those years.

	Steelhead escapement estimate		
Year	Natural origin	Hatchery origin	Total
1980	14,462	5,101	19,563
1981	-	-	-
1982	6,889	971	7,860
1983	-	-	6,661
1984	-	-	6,430
1985	-	-	-
1986	-	-	-
1987	-	-	-
1988	-	-	11,926[a]
1989	-	-	28,933
1990	-	-	3,188
1991	-	-	8,631
1992	1,540	759	2,299
1993	1,176	801	1,977
1994	2,410	878	3,288
1995	1,867	1,424	3,291
1996	1,703	4,127	5,830
1997	-	-	4,267
1998	-	-	2,463
1999	-	-	3,817
2000	-	-	7,097
2001	-	-	9,938
2002	4,551	7,715	12,266
2003	3,837	8,717	12,554
2004	4,732	8,937	13,669
2005	5,280	5,782	11,062
2006	8,660	20,272	28,932
2007	7,405	31,923	39,328
2008	5,415	6,680	12,095
2009	4,877	7,704	12,581
2010	3,749	2,468	6,217
2011	6,850	8,344	15,194
2012	8,215	6,060	14,275
2013	9,039	4,521	13,560

Appendix J (continued). Estimated escapement of steelhead to natural spawning grounds in the Trinity River from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total escapement is provided for those years.

	Steelhead escapement estimate		
Year	Natural origin	Hatchery origin	Total
2014	5,691	1,822	7,513
2015	2,417	5,043	7,460
2016	1,927	943	2,870
2017	2,295	2,249	4,544
2018	2,289	1,543	3,832

[a] Overestimate due to unknown number of fish harvested by anglers upstream of Willow Creek weir.

Appendix K. Observed counts of fall-run Chinook Salmon entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total counts are provided for those years.

Year	Fall-run Chinook Salmon count		
	Natural origin	Hatchery origin	Total
1978	-	-	7,359
1979	-	-	2,299
1980	-	-	6,355
1981	-	-	3,374
1982	-	-	6,293
1983	-	-	5,765
1984	-	-	2,932
1985	-	-	20,749
1986	-	-	19,404
1987	-	-	16,387
1988	-	-	22,104
1989	-	-	11,371
1990	-	-	1,719
1991	-	-	2,687
1992	-	-	3,990
1993	-	-	1,551
1994	-	-	7,706
1995	-	-	15,254
1996	-	-	6,660
1997	-	-	6,207
1998	-	-	14,488
1999	-	-	7,064
2000	-	-	27,046
2001	-	-	18,175
2002	523	2,952	3,475
2003	1,243	28,509	29,752
2004	595	11,789	12,384
2005	1,065	12,693	13,758
2006	1,185	6,871	8,056
2007	1,457	16,624	18,081
2008	599	3,852	4,451
2009	921	6,432	7,353
2010	611	7,138	7,749
2011	1,688	12,194	13,882
2012	838	16,623	17,461

Appendix K (continued). Observed counts of fall-run Chinook Salmon entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total counts are provided for those years.

Year	Fall-run Chinook Salmon count		
	Natural origin	Hatchery origin	Total
2013	0 [a]	3,799	3,799
2014	10	6,965	6,975
2015	16	3,113	3,129
2016	108	1,034	1,142
2017	395	3,375	3,770
2018	819	6,323	7,142

[a] Actual estimate was -82 fish. Negative numbers occur when the estimated number of hatchery fish, based on expansion of coded-wire tag recoveries for production, exceeds the total number of fish returning to the hatchery.

Appendix L. Observed counts of spring-run Chinook Salmon entering Trinity River Hatchery from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total counts are provided for those years.

Year	Spring-run Chinook Salmon count		
	Natural origin	Hatchery origin	Total
1980	-	-	547
1981	-	-	2,405
1982	-	-	1,226
1983	-	-	930
1984	-	-	736
1985	-	-	2,645
1986	-	-	7,083
1987	-	-	8,466
1988	-	-	13,905
1989	-	-	4,983
1990	-	-	2,433
1991	-	-	614
1992	-	-	1,313
1993	-	-	2,630
1994	-	-	1,943
1995	-	-	8,722
1996	-	-	5,131
1997	-	-	4,892
1998	-	-	4,679
1999	-	-	3,671
2000	-	-	11,594
2001	-	-	6,366
2002	722	9,718	10,440
2003	1,432	13,080	14,512
2004	410	4,841	5,251
2005	799	6,167	6,966
2006	494	2,071	2,565
2007	862	5,119	5,981
2008	571	2,866	3,437
2009	404	2,596	3,000
2010	321	2,136	2,457
2011	204	3,619	3,823
2012	788	5,924	6,712
2013	116	2,366	2,482
2014	372	2,883	3,255
2015	273	1,475	1,748

Appendix L (continued). Observed counts of spring-run Chinook Salmon entering Trinity River Hatchery from 1980 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 2002, so only total counts are provided for those years.

	Spring-run Chinook Salmon count		
Year	Natural-origin	Hatchery-origin	Total
2016	90	1,740	1,830
2017	25	1,109	1,134
2018	288	2,200	2,488

Appendix M. Observed counts of Coho Salmon entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total counts are provided for those years.

Year	Coho Salmon count		
	Natural origin	Hatchery origin	Total
1978	-	-	1,279
1979	-	-	742
1980	-	-	1,778
1981	-	-	2,529
1982	-	-	3,975
1983	-	-	514
1984	-	-	1,134
1985	-	-	7,549
1986	-	-	2,589
1987	-	-	20,473
1988	-	-	12,073
1989	-	-	4,893
1990	-	-	1,462
1991	-	-	2,590
1992	-	-	2,372
1993	-	-	2,024
1994	-	-	134
1995	-	-	4,503
1996	-	-	9,835
1997	20	867	887
1998	115	3,899	4,014
1999	103	3,015	3,118
2000	54	3,407	3,461
2001	130	9,625	9,755
2002	86	6,409	6,495
2003	666	9,730	10,396
2004	1,071	8,835	9,906
2005	920	15,704	16,624
2006	170	9,669	9,839
2007	217	2,436	2,653
2008	362	4,177	4,539
2009	91	2,386	2,477
2010	193	3,706	3,899
2011	214	1,710	1,924
2012	197	7,159	7,356

Appendix M (continued). Observed counts of Coho Salmon entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately prior to 1997, so only total counts are provided for those years.

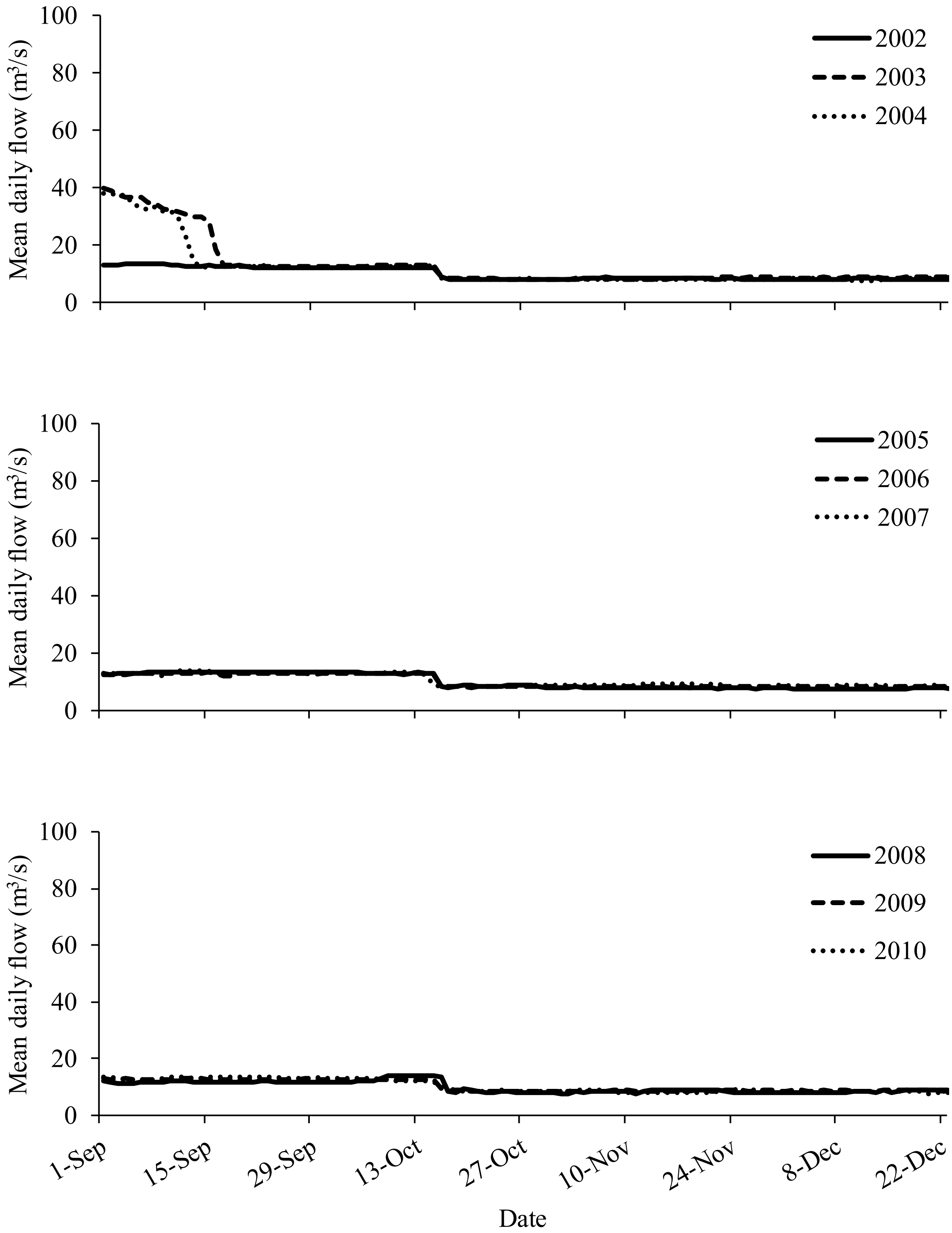
Year	Coho Salmon count		
	Natural origin	Hatchery origin	Total
2013	357	5,847	6,204
2014	79	2,892	2,971
2015	289	2,770	3,059
2016	74	408	482
2017	23	247	270
2018	41	515	556

Appendix N. Observed counts of steelhead entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total counts are provided for those years.

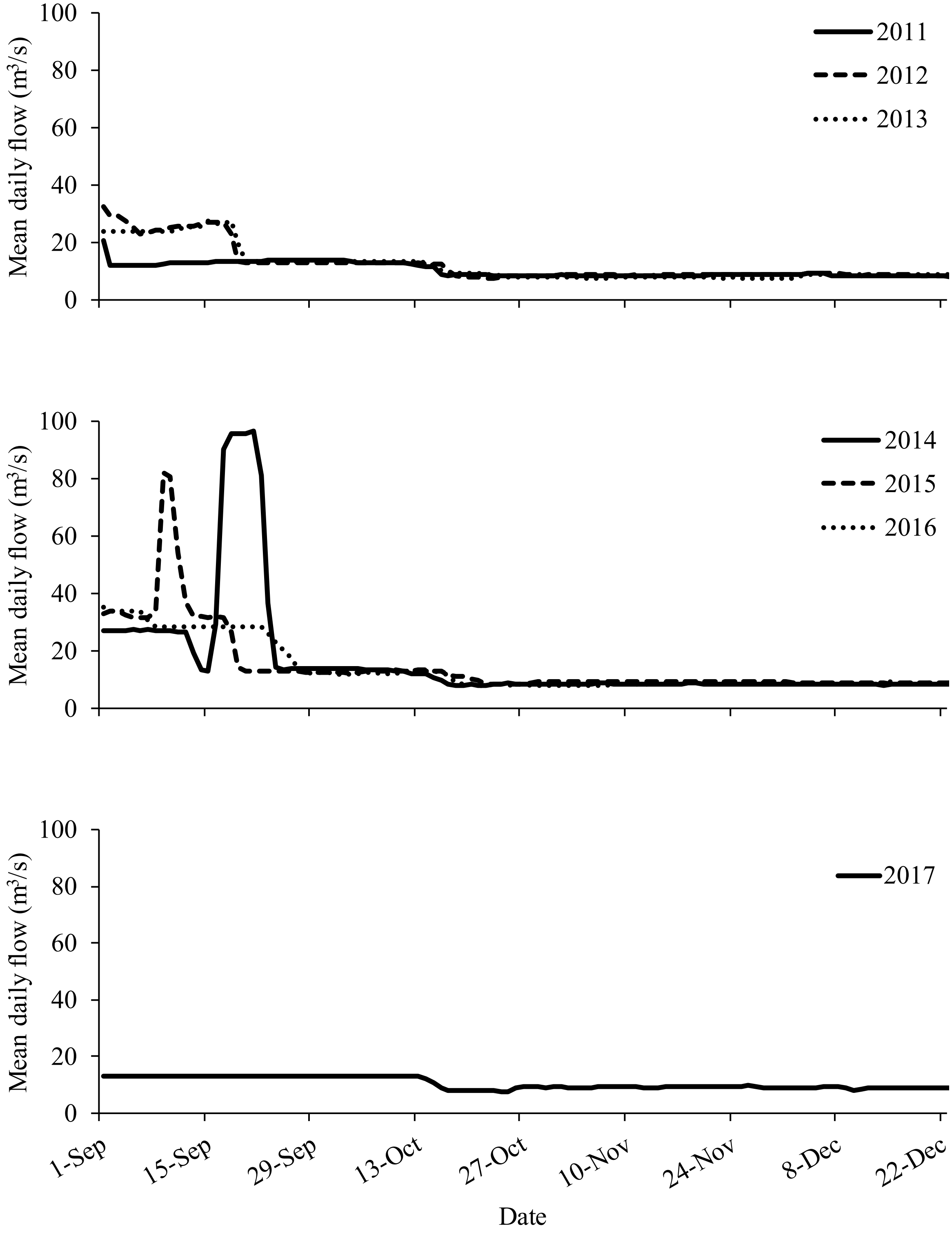
Year	Steelhead count		
	Natural origin	Hatchery origin	Total
1978	55	628	683
1979	53	329	382
1980	102	1,903	2,005
1981	112	892	1,004
1982	79	634	713
1983	-	-	599
1984	-	-	142
1985	-	-	461
1986	-	-	3,780
1987	-	-	3,007
1988	-	-	817
1989	-	-	4,765
1990	-	-	930
1991	-	-	446
1992	25	430	455
1993	10	875	885
1994	8	403	411
1995	24	681	705
1996	48	3,964	4,012
1997	-	-	429
1998	-	-	441
1999	-	-	1,571
2000	-	-	768
2001	-	-	2,333
2002	42	5,996	6,038
2003	42	10,182	10,224
2004	37	5,688	5,725
2005	63	8,080	8,143
2006	38	11,509	11,547
2007	31	11,366	11,397
2008	24	2,471	2,495
2009	17	4,234	4,251
2010	37	2,000	2,037
2011	50	5,700	5,750
2012	52	5,685	5,737

Appendix N (continued). Observed counts of steelhead entering Trinity River Hatchery from 1978 to 2018. Natural- and hatchery-origin fish were not estimated separately in some years, so only total counts are provided for those years.

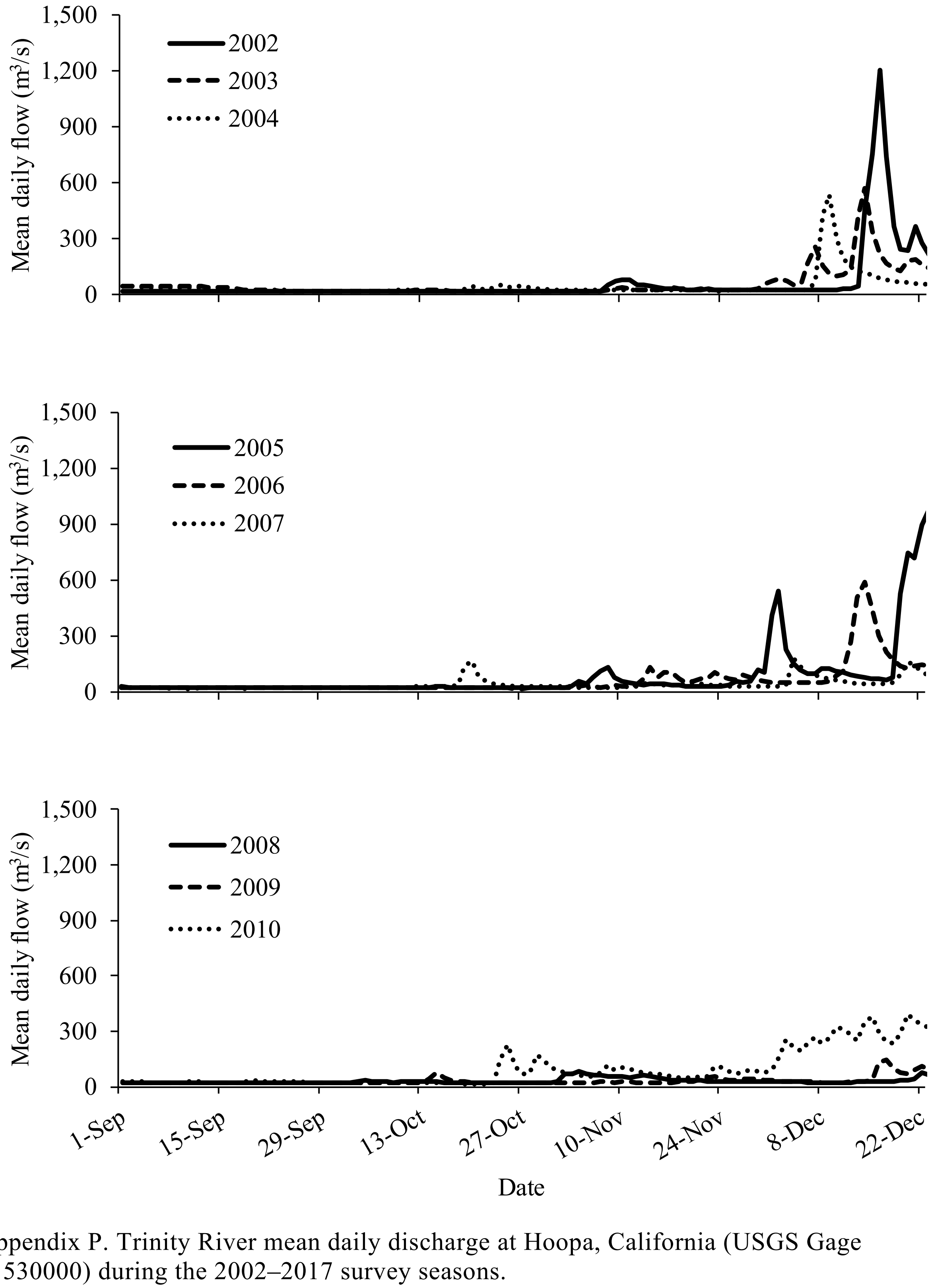
Year	Steelhead count		
	Natural origin	Hatchery origin	Total
2013	80	2,295	2,375
2014	62	2,499	2,561
2015	37	3,235	3,272
2016	17	1,557	1,574
2017	53	1,996	2,049
2018	37	1,859	1,896



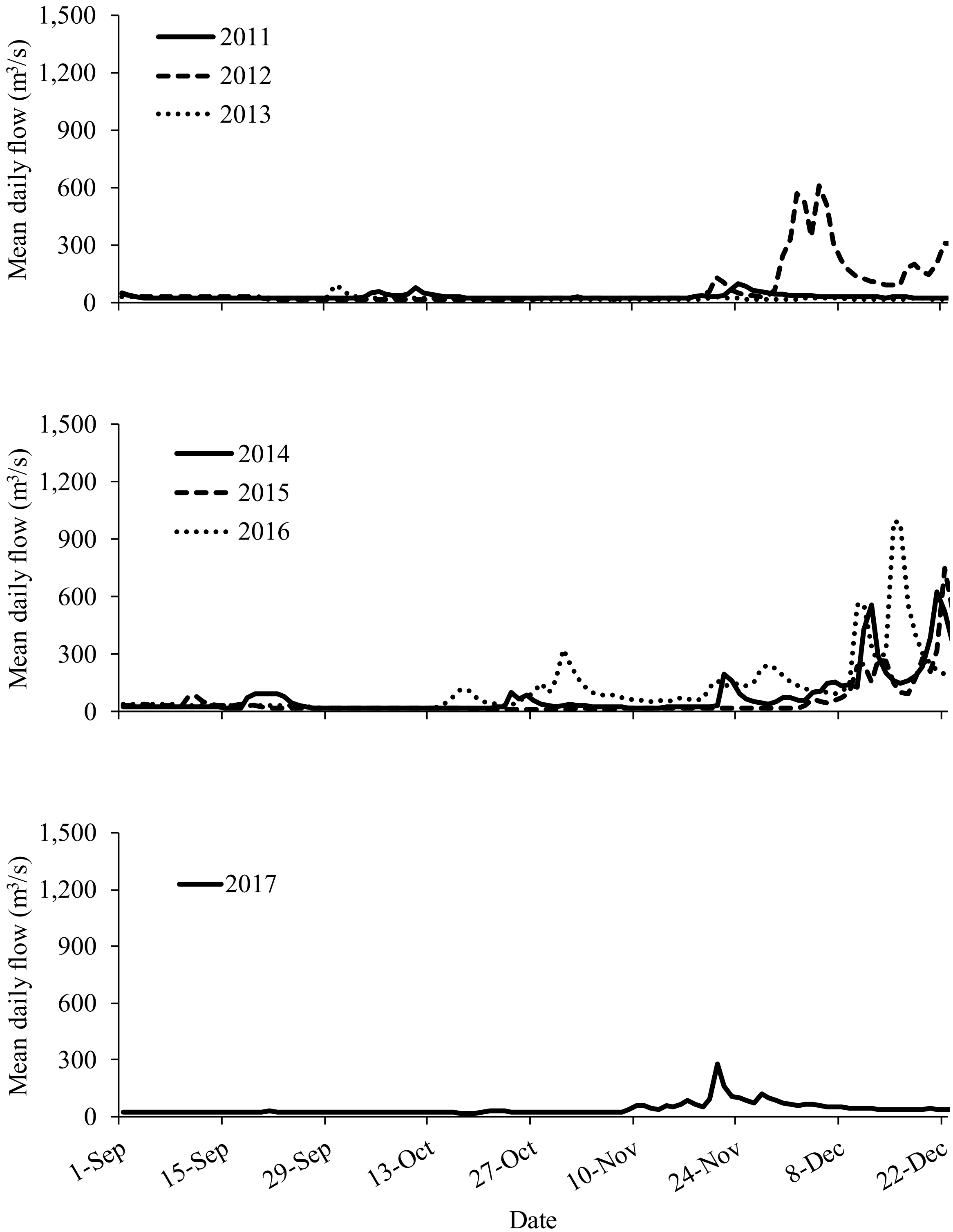
Appendix O. Trinity River mean daily discharge at Lewiston (USGS Gage 11525500) during the 2002–2017 survey seasons.



Appendix O (continued). Trinity River mean daily discharge at Lewiston (USGS Gage 11525500) during the 2002–2017 survey seasons.



Appendix P. Trinity River mean daily discharge at Hoopa, California (USGS Gage 11530000) during the 2002–2017 survey seasons.



Appendix P (continued). Trinity River mean daily discharge at Hoopa, California (USGS Gage 11530000) during the 2002–2017 survey seasons.

Appendix Q. Tributary reach descriptions for Trinity River, California, salmon spawning surveys. Data collected by Shasta–Trinity National Forest (USFS).

Canyon Creek was surveyed from the Fischer Gulch Bridge downstream approximately 15.1 km to the confluence with the Trinity River. The survey stopped approximately 2.5 km short of the confluence with the Big East Fork of Canyon Creek, which is the known upstream extent of Chinook and Coho salmon distribution here.

Big French Creek was surveyed from an access point, downstream approximately 1.2 km to the Trinity River confluence. The extent of distribution for Chinook and Coho salmon is unknown in this stream. Habitat surveys performed by the USFS in the late 1970s identified a bedrock falls approximately 7.3 km upstream of the mouth that was assumed to be the distribution limit for Chinook Salmon here. Adult Coho Salmon have never been documented here but juvenile fish surveys, conducted during the summer, routinely show juvenile Coho Salmon utilizing habitat in the lower 0.4 km of Big French Creek. Presumably, these juvenile Coho Salmon have moved into Big French Creek in search of more favorable habitat.

Conner Creek was surveyed approximately 100 m above and below the Red Hill Road bridge. Several barriers exist in lower Conner Creek, but it is unknown whether these barriers completely impede fish passage.

Deadwood Creek was surveyed from a bedrock falls, downstream approximately 1.2 km to the Trinity River confluence. These falls are considered the upstream distribution limit for Chinook and Coho salmon.

Dutch Creek was surveyed from the terminus of Dutch Creek Road downstream for approximately 1.5 km to the Trinity River Confluence. The upstream limit of Chinook and Coho salmon is unknown.

East Fork North Fork Trinity River was surveyed from a primitive campground site, downstream for approximately 6.9 km to the North Fork Trinity River confluence. The upstream distribution limits for Chinook and Coho salmon are unknown but are assumed to be 7.4 km upstream of the upper most portion of the redd survey based past observations of juvenile Chinook and Coho Salmon.

Manzanita Creek was surveyed from the Highway 299 bridge upstream approximately 1.6 km. The limit of anadromy is approximately 3.2 km above the Trinity River confluence (Pennington 1986).

North Fork Trinity River was surveyed from the East Fork North Fork confluence, downstream for approximately 1.9 km to the Trinity River confluence. The distribution of fall-run Chinook and Coho salmon on the North Fork Trinity River extends upstream for approximately 0.4 km from the upstream end of the survey. The distribution of spring-run Chinook Salmon extends to a falls located approximately 8.5 km from the upstream end of the survey. However, it should be noted that very few Chinook Salmon (adults or juveniles) and no Coho Salmon (adults or juveniles) have been observed during summer surveys on the North Fork upstream of the East Fork North Fork confluence since 2009.

Rush Creek was surveyed from a point just below the Rush Creek Estates boundary, downstream approximately 5.0 km to an access point on National Forest. The survey terminates approximately 5.5 km upstream of the Trinity River confluence due to a lack of landowner permission. The Rush Creek survey contained three reaches of lengths 1.4, 1.4, and 1.5 km, separated by sections of private property which were excluded from the survey. The distribution limit for Chinook and Coho salmon within Rush Creek is known and occurs at a bedrock cascade located approximately 3.8 km upstream of the end of the survey reach.

Soldier Creek was surveyed from the Big Creek Road bridge crossing downstream approximately 2.3 km to the Trinity River confluence. The upstream limits for Chinook and Coho salmon are unknown.

South Fork Trinity River was surveyed from the Lovers Leap access point, downstream 9.5 km to the Eltapom Creek confluence. The distribution of fall-run Chinook Salmon on the South Fork continues upstream for approximately 4.8 km to the Butter Creek confluence. The distribution of spring-run Chinook Salmon on the South Fork Trinity continues upstream for approximately 64.5 km to the East Fork South Fork Trinity River confluence. Coho Salmon have historically been found within the South Fork Trinity River watershed, but juvenile and adult fish surveys conducted since 2009 have failed to identify any Coho Salmon here.

Appendix R. Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2009 unmarked

Calendar		Reach													All reaches	
week	Dates	1	2	3	4	5	6	7	8	9	10	12	13	14	*n*	Rate
36	Aug 30-Sep 5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 6-12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
38	Sep 13-19	2	2	-	NS	NS	-	-	-	-	-	NS	NS	NS	**4**	**100.0%**
39	Sep 20-26	1	0	-	-	-	-	-	NS	NS	NS	NS	NS	NS	**1**	**33.3%**
40	Sep 27-Oct 3	2	0	3	1	0	0	-	-	-	-	NS	NS	NS	**6**	**15.0%**
41	Oct 4-10	2	1	1	0	0	-	-	NS	NS	NS	-	-	-	**4**	**4.2%**
42	Oct 11-17	0	1	0	0	NS	0	3	NS	NS	NS	NS	NS	NS	**4**	**3.9%**
43	Oct 18-24	1	4	3	1	1	1	0	NS	NS	NS	-	1	-	**12**	**6.7%**
44	Oct 25-31	2	1	10	7	8	0	1	-	0	1	NS	NS	NS	**30**	**12.6%**
45	Nov 1-7	2	2	0	0	0	2	2	NS	NS	1	0	-	-	**9**	**4.6%**
46	Nov 8-14	3	15	0	0	NS	1	0	0	3	0	NS	NS	NS	**22**	**10.7%**
47	Nov 15-21	2	3	1	0	0	1	0	NS	NS	NS	1	0	1	**9**	**3.5%**
48	Nov 22-28	NS	NS	4	0	0	NS	0	0	10	1	NS	NS	NS	**15**	**22.1%**
49	Nov 29-Dec 5	2	5	0	0	0	0	1	NS	NS	NS	7	2	0	**17**	**8.3%**
50	Dec 6-12	0	0	0	NS	0	NS	NS	-	0	NS	NS	NS	NS	**0**	**0.0%**
51	Dec 13-19	0	0	0	-	NS	NS	NS	NS	NS	0	2	NS	NS	**2**	**2.9%**
52	Dec 20-26	0	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
	All weeks	**19**	**34**	**22**	**9**	**9**	**5**	**7**	**0**	**13**	**3**	**10**	**3**	**1**	***135***	***7.8%***

2009 ad-clipped

Calendar		Reach													All reaches	
week	Dates	1	2	3	4	5	6	7	8	9	10	12	13	14	*n*	Rate
36	Aug 30-Sep 5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 6-12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
38	Sep 13-19	2	-	-	NS	NS	-	-	-	-	-	NS	NS	NS	**2**	**50.0%**
39	Sep 20-26	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	**-**	**-**
40	Sep 27-Oct 3	0	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
41	Oct 4-10	0	0	-	-	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
42	Oct 11-17	0	0	-	-	NS	-	-	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
43	Oct 18-24	0	-	-	-	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
44	Oct 25-31	0	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
45	Nov 1-7	0	-	-	-	-	-	-	NS	NS	-	-	-	-	**0**	**0.0%**
46	Nov 8-14	1	-	0	-	NS	-	-	-	-	-	NS	NS	NS	**1**	**25.0%**
47	Nov 15-21	1	-	0	-	-	-	-	NS	NS	NS	-	-	-	**1**	**7.1%**
48	Nov 22-28	NS	NS	0	-	-	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
49	Nov 29-Dec 5	0	1	-	-	-	-	-	NS	NS	NS	-	-	-	**1**	**20.0%**
50	Dec 6-12	0	-	0	NS	-	NS	NS	-	-	NS	NS	NS	NS	**0**	**0.0%**
51	Dec 13-19	0	-	-	-	NS	NS	NS	NS	NS	-	-	NS	NS	**0**	**0.0%**
52	Dec 20-26	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**4**	**1**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***5***	***9.4%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2010 unmarked

Calendar		Reach													All reaches	
week	**Dates**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**13**	**14**	***n***	**Rate**
36	Aug 29-Sep 4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep 5-11	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
38	Sep 12-18	2	0	1	-	-	-	-	-	-	-	NS	NS	NS	**3**	**33.3%**
39	Sep 19-25	1	-	0	-	-	-	1	NS	NS	NS	NS	NS	NS	**2**	**28.6%**
40	Sep 26-Oct 2	1	0	0	1	0	-	-	-	1	-	NS	NS	NS	**3**	**12.0%**
41	Oct 3-9	1	2	1	0	0	0	0	NS	NS	NS	-	1	1	**6**	**9.7%**
42	Oct 10-16	0	1	1	0	1	4	0	0	1	-	NS	NS	NS	**8**	**5.4%**
43	Oct 17-23	1	1	0	0	0	4	0	NS	NS	NS	-	-	-	**6**	**4.2%**
44	Oct 24-30	0	0	2	2	1	0	2	-	2	NS	NS	NS	NS	**9**	**8.5%**
45	Oct 3 -Nov 6	3	0	2	1	1	4	0	NS	NS	-	1	-	-	**12**	**8.7%**
46	Nov 7-13	6	NS	0	2	0	4	0	NS	0	0	NS	NS	NS	**12**	**12.8%**
47	Nov 14-20	4	7	0	0	1	1	1	NS	NS	NS	1	-	0	**15**	**9.9%**
48	Nov 21-27	NS	5	1	-	0	0	0	NS	-	0	NS	NS	NS	**6**	**9.0%**
49	Nov 28-Dec 4	20	10	1	NS	0	0	0	NS	NS	NS	5	NS	NS	**36**	**16.8%**
50	Dec 5-11	0	4	-	1	-	NS	NS	NS	NS	NS	NS	NS	NS	**5**	**14.3%**
51	Dec 12-18	3	2	1	0	-	0	0	NS	NS	NS	NS	NS	NS	**6**	**10.9%**
52	Dec 19-25	1	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**1**	**3.3%**
	All weeks	**43**	**32**	**10**	**7**	**4**	**17**	**4**	**0**	**4**	**0**	**7**	**1**	**1**	***130***	***10.1%***

2010 ad-clipped

Calendar		Reach													All reaches	
week	**Dates**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**13**	**14**	***n***	**Rate**
36	Aug 29-Sep 4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep 5-11	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
38	Sep 12-18	1	1	-	-	-	-	-	-	-	-	NS	NS	NS	**2**	**66.7%**
39	Sep 19-25	0	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
40	Sep 26-Oct 2	-	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
41	Oct 3-9	-	-	-	-	-	-	-	NS	NS	NS	-	-	-	-	-
42	Oct 10-16	0	-	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
43	Oct 17-23	-	0	-	-	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
44	Oct 24-30	0	-	-	-	-	-	-	-	-	NS	NS	NS	NS	**0**	**0.0%**
45	Oct 3 -Nov 6	0	0	-	-	-	-	-	NS	NS	-	-	-	-	**0**	**0.0%**
46	Nov 7-13	0	NS	-	-	-	-	-	NS	-	-	NS	NS	NS	**0**	**0.0%**
47	Nov 14-20	0	0	-	-	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
48	Nov 21-27	NS	0	-	-	-	-	-	NS	-	-	NS	NS	NS	**0**	**0.0%**
49	Nov 28-Dec 4	3	0	-	NS	-	-	-	NS	NS	NS	-	NS	NS	**3**	**25.0%**
50	Dec 5-11	-	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	-	-
51	Dec 12-18	0	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
52	Dec 19-25	0	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
	All weeks	**4**	**1**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***5***	***12.5%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2011 unmarked

Calendar		Reach													All reaches	
week	Dates	1	2	3	4	5	6	7	8	9	10	12	13	14	*n*	Rate
36	Aug 28-Sep 3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep 4-10	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**5**	**100.0%**
38	Sep 11-17	-	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
39	Sep 18-24	3	3	0	1	0	-	-	NS	NS	NS	NS	NS	NS	**7**	**41.2%**
40	Sep 22-Oct 1	6	2	0	1	1	0	-	-	-	1	NS	NS	NS	**11**	**23.9%**
41	Oct 2-8	3	0	0	0	0	0	0	-	-	-	NS	NS	NS	**3**	**2.9%**
42	Oct 9-15	0	1	1	0	0	0	0	NS	-	1	NS	NS	NS	**3**	**1.2%**
43	Oct 16-22	1	3	0	2	0	0	2	NS	NS	NS	0	2	2	**12**	**3.1%**
44	Oct 23-29	1	1	3	0	0	0	0	NS	0	0	NS	NS	NS	**5**	**1.2%**
45	Oct 30-Nov 5	4	0	0	1	1	1	1	NS	NS	NS	0	0	-	**8**	**2.8%**
46	Nov 6-12	0	2	2	NS	0	0	1	1	0	0	NS	NS	NS	**6**	**2.5%**
47	Nov 13-19	7	8	1	0	0	0	0	NS	NS	NS	1	0	-	**17**	**6.4%**
48	Nov 20-26	14	10	NS	NS	NS	0	0	NS	0	NS	NS	NS	NS	**24**	**6.6%**
49	Nov 27-Dec 3	31	8	2	0	0	0	0	NS	NS	0	2	0	NS	**43**	**5.9%**
50	Dec 4-10	25	5	0	0	0	0	0	NS	1	0	NS	NS	1	**32**	**4.7%**
51	Dec 11-17	11	2	0	0	-	NS	NS	NS	NS	NS	4	0	0	**17**	**3.5%**
52	Dec 18-24	0	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**1**	**0.9%**
	All weeks	**111**	**46**	**9**	**5**	**2**	**1**	**4**	**1**	**1**	**2**	**7**	**2**	**3**	***194***	***4.4%***

2011 ad-clipped

Calendar		Reach													All reaches	
week	Dates	1	2	3	4	5	6	7	8	9	10	12	13	14	*n*	Rate
36	Aug 28-Sep 3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
37	Sep 4-10	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
38	Sep 11-17	-	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
39	Sep 18-24	1	2	-	-	-	-	-	NS	NS	NS	NS	NS	NS	**3**	**75.0%**
40	Sep 22-Oct 1	1	-	-	-	-	-	-	-	-	-	NS	NS	NS	**1**	**100.0%**
41	Oct 2-8	0	-	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
42	Oct 9-15	0	-	-	0	-	-	-	NS	-	-	NS	NS	NS	**0**	**0.0%**
43	Oct 16-22	0	-	-	-	0	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
44	Oct 23-29	1	0	0	-	-	-	0	NS	-	-	NS	NS	NS	**1**	**7.7%**
45	Oct 30-Nov 5	0	-	-	-	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
46	Nov 6-12	0	0	0	NS	-	0	-	-	-	-	NS	NS	NS	**0**	**0.0%**
47	Nov 13-19	2	1	-	0	-	-	-	NS	NS	NS	-	-	-	**3**	**13.6%**
48	Nov 20-26	0	3	NS	NS	NS	-	-	NS	-	NS	NS	NS	NS	**3**	**6.0%**
49	Nov 27-Dec 3	8	0	-	-	-	-	-	NS	NS	-	-	-	NS	**8**	**9.2%**
50	Dec 4-10	5	1	-	-	-	-	-	NS	-	-	NS	NS	-	**6**	**8.5%**
51	Dec 11-17	0	0	-	-	-	NS	NS	NS	NS	NS	-	-	-	**0**	**0.0%**
52	Dec 18-24	0	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
	All weeks	**18**	**7**	**0**	**0**	**0**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	***25***	***7.0%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2012 unmarked

Calendar		Reach												All reaches	
week	**Dates**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**12**	**13**	**14**	***n***	**Rate**
36	Sep 5-8	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**3**	**100.0%**
37	Sep 9-15	5	3	5	-	1	-	-	-	-	NS	NS	NS	**14**	**100.0%**
38	Sep 16-22	7	1	2	0	-	-	-	NS	NS	NS	NS	NS	**10**	**62.5%**
39	Sep 23-29	1	5	1	0	0	1	-	1	-	NS	NS	NS	**9**	**25.0%**
40	Sep 30-Oct 6	3	3	0	1	1	0	1	NS	NS	NS	NS	NS	**9**	**6.1%**
41	Oct 7-13	4	1	0	0	1	0	0	1	0	NS	NS	NS	**7**	**1.9%**
42	Oct 14-20	0	0	0	3	0	1	0	NS	NS	-	3	2	**9**	**2.0%**
43	Oct 21-27	0	0	2	0	2	2	4	0	0	NS	NS	NS	**10**	**1.5%**
44	Oct 28-Nov 3	8	0	0	0	0	0	0	NS	NS	0	NS	NS	**8**	**1.8%**
45	Nov 4-10	0	8	0	NS	0	0	0	0	0	NS	NS	NS	**8**	**1.9%**
46	Nov 11-17	8	2	2	2	NS	0	NS	NS	NS	1	0	1	**16**	**3.0%**
47	Nov 18-24	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**3**	**0.7%**
48	Nov 25-Dec 1	5	0	NS	NS	1	0	0	NS	NS	NS	NS	NS	**6**	**0.8%**
49	Dec 2-8	0	0	-	-	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
50	Dec 9-15	0	-	-	-	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
51	Dec 16-22	0	0	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
52	Dec 23-29	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**47**	**23**	**12**	**6**	**6**	**4**	**5**	**2**	**0**	**1**	**3**	**3**	***112***	***2.3%***

2012 ad-clipped

Calendar		Reach												All reaches	
week	**Dates**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**12**	**13**	**14**	***n***	**Rate**
36	Sep 5-8	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 9-15	1	4	-	-	-	-	-	-	-	NS	NS	NS	**5**	**100.0%**
38	Sep 16-22	2	-	-	-	-	-	-	NS	NS	NS	NS	NS	**2**	**100.0%**
39	Sep 23-29	1	-	-	-	-	-	-	-	-	NS	NS	NS	**1**	**100.0%**
40	Sep 30-Oct 6	0	0	0	-	-	-	-	NS	NS	NS	NS	NS	**0**	**0.0%**
41	Oct 7-13	0	0	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
42	Oct 14-20	0	0	-	-	0	-	-	NS	NS	-	-	-	**0**	**0.0%**
43	Oct 21-27	0	0	-	0	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
44	Oct 28-Nov 3	0	0	-	-	-	-	-	NS	NS	-	NS	NS	**0**	**0.0%**
45	Nov 4-10	3	0	-	NS	-	-	-	-	-	NS	NS	NS	**3**	**11.1%**
46	Nov 11-17	4	0	0	-	NS	0	NS	NS	NS	-	-	-	**4**	**10.0%**
47	Nov 18-24	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
48	Nov 25-Dec 1	0	0	NS	NS	-	-	-	NS	NS	NS	NS	NS	**0**	**0.0%**
49	Dec 2-8	0	0	-	-	-	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
50	Dec 9-15	0	-	-	-	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
51	Dec 16-22	0	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
52	Dec 23-29	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**11**	**4**	**0**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***15***	***3.6%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2013 unmarked

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
36	Sep 1-7	2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**2**	**50.0%**
37	Sep 8-14	-	1	-	1	-	-	-	NS	NS	NS	NS	NS	**2**	**100.0%**
38	Sep 15-21	1	-	1	1	-	-	-	-	-	NS	NS	NS	**3**	**75.0%**
39	Sep 22-28	1	1	0	0	0	-	-	NS	NS	NS	NS	NS	**2**	**9.1%**
40	Sep 29-Oct 5	0	1	1	0	0	0	1	NS	NS	NS	NS	NS	**3**	**5.8%**
41	Oct 6-12	0	0	0	1	0	0	0	NS	NS	NS	NS	NS	**1**	**1.5%**
42	Oct 13-19	1	0	0	1	NS	0	0	0	0	NS	NS	NS	**2**	**3.1%**
43	Oct 20-26	0	1	0	0	0	0	0	NS	NS	-	1	-	**2**	**2.7%**
44	Oct 27-Nov 2	1	4	1	1	0	0	0	1	0	NS	NS	NS	**8**	**6.9%**
45	Nov 3-9	0	0	0	0	0	0	0	NS	NS	1	0	-	**1**	**1.7%**
46	Nov 10-16	3	0	0	-	NS	0	0	0	0	NS	NS	NS	**3**	**5.1%**
47	Nov 17-23	3	1	0	0	0	0	0	NS	NS	0	0	-	**4**	**5.6%**
48	Nov 24-30	2	0	NS	NS	NS	-	-	0	0	NS	NS	NS	**2**	**4.3%**
49	Dec 1-7	2	0	-	NS	0	0	-	NS	NS	0	1	0	**3**	**4.2%**
50	Dec 8-14	0	-	0	-	0	-	-	0	0	NS	NS	NS	**0**	**0.0%**
51	Dec 15-21	0	0	-	-	NS	-	-	NS	NS	0	1	0	**1**	**1.7%**
52	Dec 22-28	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**16**	**9**	**3**	**5**	**0**	**0**	**1**	**1**	**0**	**1**	**3**	**0**	***39***	***5.0%***

2013 ad-clipped

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
36	Sep 1-7	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 8-14	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	**-**	**-**
38	Sep 15-21	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
39	Sep 22-28	1	-	-	-	-	-	-	NS	NS	NS	NS	NS	**1**	**100.0%**
40	Sep 29-Oct 5	0	-	-	-	0	-	-	NS	NS	NS	NS	NS	**0**	**0.0%**
41	Oct 6-12	1	0	-	-	-	-	-	NS	NS	NS	NS	NS	**1**	**9.1%**
42	Oct 13-19	0	0	-	-	NS	0	-	-	-	NS	NS	NS	**0**	**0.0%**
43	Oct 20-26	0	0	-	0	-	-	-	NS	NS	-	-	-	**0**	**0.0%**
44	Oct 27-Nov 2	0	-	0	-	-	-	0	-	-	NS	NS	NS	**0**	**0.0%**
45	Nov 3-9	1	1	-	-	-	-	-	NS	NS	-	-	-	**2**	**22.2%**
46	Nov 10-16	0	0	-	-	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
47	Nov 17-23	0	-	-	-	NS	-	-	NS	NS	-	-	-	**0**	**0.0%**
48	Nov 24-30	0	0	NS	NS	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
49	Dec 1-7	0	-	-	NS	0	-	-	NS	NS	-	-	-	**0**	**0.0%**
50	Dec 8-14	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
51	Dec 15-21	-	-	-	-	NS	-	-	NS	NS	-	-	-	**-**	**-**
52	Dec 22-28	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	***4***	***6.3%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, ‘0’ indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2014 unmarked

Calendar week	Dates	Reach 1	2	3	4	5	6	7	9	10	12	13	14	All reaches *n*	Rate
36	Aug 31-Sep 6	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 7-13	1	-	-	-	-	-	-	NS	NS	NS	NS	NS	**1**	**100.0%**
38	Sep 14-20	-	1	NS	NS	NS	-	-	NS	NS	NS	NS	NS	**1**	**100.0%**
39	Sep 21-27	1	2	0	0	-	-	-	NS	NS	NS	NS	NS	**3**	**30.0%**
40	Sep 28-Oct 4	0	0	0	0	0	0	-	1	1	NS	NS	NS	**2**	**4.7%**
41	Oct 5-11	0	0	0	0	0	0	0	NS	NS	1	0	0	**1**	**1.7%**
42	Oct 12-18	0	0	0	0	0	4	2	0	0	NS	NS	NS	**6**	**6.7%**
43	Oct 19-25	2	0	0	0	1	0	0	NS	NS	2	2	NS	**7**	**4.5%**
44	Oct 26-Nov 1	2	2	1	1	0	0	1	1	0	NS	NS	NS	**8**	**4.6%**
45	Nov 2-8	7	2	1	1	0	0	0	NS	NS	2	5	5	**23**	**15.2%**
46	Nov 9-15	15	5	1	1	NS	0	1	0	0	NS	NS	NS	**23**	**10.6%**
47	Nov 16-22	12	8	1	0	0	0	1	NS	NS	7	10	6	**45**	**18.1%**
48	Nov 23-29	8	4	NS	NS	NS	0	0	0	0	NS	NS	NS	**12**	**15.6%**
49	Nov 30-Dec 6	0	0	-	-	0	2	-	NS	NS	2	2	1	**7**	**23.3%**
50	Dec 7-13	0	0	0	NS	NS	0	-	-	-	NS	NS	NS	**0**	**0.0%**
51	Dec 14-20	-	0	-	-	-	NS	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
52	Dec 21-27	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**48**	**24**	**4**	**3**	**1**	**6**	**5**	**2**	**1**	**14**	**19**	**12**	***139***	***11.0%***

2014 ad-clipped

Calendar week	Dates	Reach 1	2	3	4	5	6	7	9	10	12	13	14	All reaches *n*	Rate
36	Aug 31-Sep 6	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
37	Sep 7-13	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	**-**	**-**
38	Sep 14-20	-	1	NS	NS	NS	-	-	NS	NS	NS	NS	NS	**1**	**100.0%**
39	Sep 21-27	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	**-**	**-**
40	Sep 28-Oct 4	0	0	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
41	Oct 5-11	0	0	0	-	-	0	-	NS	NS	1	-	-	**1**	**20.0%**
42	Oct 12-18	-	0	-	-	0	-	-	-	-	NS	NS	NS	**0**	**0.0%**
43	Oct 19-25	0	1	-	-	-	0	-	NS	NS	-	-	NS	**1**	**33.3%**
44	Oct 26-Nov 1	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
45	Nov 2-8	1	0	-	-	-	-	-	NS	NS	-	-	-	**1**	**7.7%**
46	Nov 9-15	6	0	0	0	NS	-	-	-	-	NS	NS	NS	**6**	**15.4%**
47	Nov 16-22	0	4	2	0	-	1	-	NS	NS	-	1	-	**8**	**12.9%**
48	Nov 23-29	8	-	NS	NS	NS	-	0	-	-	NS	NS	NS	**8**	**24.2%**
49	Nov 30-Dec 6	-	-	-	-	-	-	-	NS	NS	-	-	-	**-**	**-**
50	Dec 7-13	0	-	-	NS	NS	-	-	-	-	NS	NS	NS	**0**	**0.0%**
51	Dec 14-20	-	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
52	Dec 21-27	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**-**	**-**
	All weeks	**15**	**6**	**2**	**0**	**0**	**1**	**-**	**-**	**-**	**1**	**1**	**-**	***26***	***15.4%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2015 unmarked

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
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	-	-
	All weeks	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	***3***	***0.8%***

2015 ad-clipped

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
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	-	-
	All weeks	**0**	**0**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***0***	***0.0%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

2016 unmarked

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
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	-	-
	All weeks	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**	**-**	**-**	***2***	***0.8%***

2016 ad-clipped

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
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	-	-
	All weeks	**0**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***0***	***0.0%***

Appendix R (continued). Chinook Salmon pre-spawn mortality numbers by week and reach and pre-spawn mortality rates by week of unmarked and ad-clipped fresh female carcasses, mainstem Trinity River surveys 2009–2017. Also included are weekly pre-spawn mortality rates among like 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, '0' indicates that fresh carcasses were observed but none were pre-spawn mortalities, and dashes (-) represent a sample size of zero (i.e., no fresh carcasses were observed).

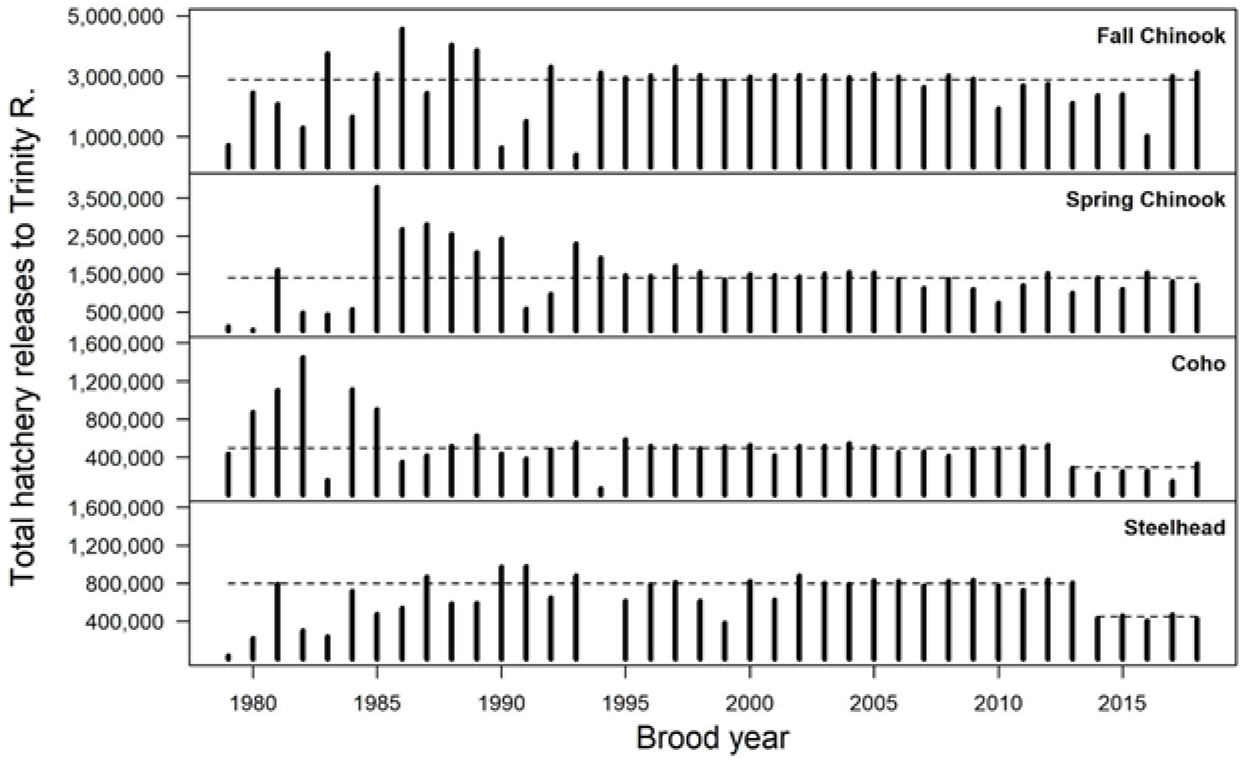
2017 unmarked

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
35	Aug 27-Sep 2	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
36	Sep 3-9	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	-	-
37	Sep 10-16	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
38	Sep 17-23	1	0	-	-	1	-	-	NS	NS	NS	NS	NS	**2**	**40.0%**
39	Sep 24-30	-	0	-	-	-	-	NS	-	-	NS	NS	NS	**0**	**0.0%**
40	Oct 1-7	0	0	0	0	-	0	NS	NS	NS	-	-	-	**0**	**0.0%**
41	Oct 8-14	0	0	0	0	0	1	0	-	0	NS	NS	NS	**1**	**4.2%**
42	Oct 15-21	0	0	0	0	0	0	0	NS	NS	-	-	NS	**0**	**0.0%**
43	Oct 22-28	0	0	0	0	0	1	0	0	0	NS	NS	NS	**1**	**1.9%**
44	Oct 29-Nov 4	0	0	0	0	0	0	0	NS	NS	-	0	-	**0**	**0.0%**
45	Nov 5-11	0	0	0	0	0	0	0	0	0	NS	NS	NS	**0**	**0.0%**
46	Nov 12-18	0	0	0	0	-	-	-	NS	NS	NS	NS	NS	**0**	**0.0%**
47	Nov 19-25	1	0	0	NS	NS	0	NS	NS	NS	NS	NS	NS	**1**	**3.7%**
48	Nov 26-Dec 2	1	0	0	0	-	0	-	-	0	NS	NS	NS	**1**	**3.2%**
49	Dec 3-9	0	0	0	-	-	-	-	NS	NS	-	NS	NS	**0**	**0.0%**
50	Dec 10-16	0	0	-	-	-	-	NS	-	-	NS	-	-	**0**	**0.0%**
51	Dec 17-23	-	0	-	-	-	NS	NS	-	-	-	-	-	**0**	**0.0%**
	All weeks	**3**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**-**	**-**	**-**	***6***	***2.0%***

2017 ad-clipped

Calendar		Reach												All reaches	
week	Dates	1	2	3	4	5	6	7	9	10	12	13	14	*n*	Rate
35	Aug 27-Sep 2	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
36	Sep 3-9	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	-	-
37	Sep 10-16	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
38	Sep 17-23	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	-	-
39	Sep 24-30	-	-	-	-	-	0	NS	-	-	NS	NS	NS	**0**	**0.0%**
40	Oct 1-7	-	0	0	-	-	-	NS	NS	NS	-	-	-	**0**	**0.0%**
41	Oct 8-14	0	-	-	-	0	-	-	-	-	NS	NS	NS	**0**	**0.0%**
42	Oct 15-21	-	0	-	-	-	-	-	NS	NS	-	-	NS	**0**	**0.0%**
43	Oct 22-28	0	-	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
44	Oct 29-Nov 4	0	0	-	-	0	-	-	NS	NS	-	-	-	**0**	**0.0%**
45	Nov 5-11	-	-	-	-	-	-	-	-	-	NS	NS	NS	-	-
46	Nov 12-18	0	-	-	-	-	-	-	NS	NS	NS	NS	NS	**0**	**0.0%**
47	Nov 19-25	0	0	-	NS	NS	-	NS	NS	NS	NS	NS	NS	**0**	**0.0%**
48	Nov 26-Dec 2	0	0	-	-	-	-	-	-	-	NS	NS	NS	**0**	**0.0%**
49	Dec 3-9	0	-	-	-	-	-	-	NS	NS	-	NS	NS	**0**	**0.0%**
50	Dec 10-16	-	-	-	-	-	-	NS	-	-	NS	-	-	-	-
51	Dec 17-23	-	-	-	-	-	NS	NS	-	-	-	-	-	-	-
	All weeks	**0**	**0**	**0**	**-**	**0**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	***0***	***0.0%***

Appendix S. Time series of juvenile salmonids reared at Trinity River Hatchery (TRH) and released into the Trinity River for brood years 1979–2018.All release types (e.g., fry, fingerlings, yearlings) and release locations (TRH or off-site) are included. Fish reared at TRH and released outside of the Trinity River are excluded. No steelhead were released from brood year 1994. Data were compiled from TRH annual reports, original release receipts, and the Regional Mark Processing Center. Horizontal dashed lines indicate TRH production targets.



Appendix T. Releases to the Trinity River of juvenile salmonids reared at Trinity River Hatchery (TRH) for brood years 1979–2018. All release types (e.g., fry, fingerlings, yearlings) and release locations (TRH or off-site) are included. Fish reared at TRH and released outside of the Trinity River are excluded.

	Total releases to the Trinity River			
Brood year	Fall-run Chinook Salmon	Spring-run Chinook Salmon	Coho Salmon	Steelhead
1979	712,450	123,728	434,383	33,327
1980	2,452,918	35,128	879,016	221,107
1981	2,072,913	1,607,743	1,110,031	790,713
1982	1,291,743	484,167	1,449,423	299,169
1983	3,741,116	434,457	156,150	237,000
1984	1,659,598	563,970	1,111,913	715,163
1985	3,074,365	3,789,170	908,738	470,524
1986	4,561,706	2,680,777	347,256	534,703
1987	2,443,505	2,803,226	421,100	870,000
1988	4,034,394	2,547,494	519,134	580,690
1989	3,849,348	2,074,151	627,739	591,568
1990	643,910	2,439,803	439,523	971,509
1991	1,515,335	585,489	384,555	976,229
1992	3,314,111	973,479	480,790	647,730
1993	415,838	2,298,220	549,983	879,841
1994	3,103,997	1,933,964	71,993	NA
1995	2,948,961	1,462,557	584,970	614,828
1996	3,018,277	1,449,404	516,192	784,844
1997	3,311,761	1,715,029	519,273	811,513
1998	3,043,583	1,548,118	493,727	611,443
1999	2,854,960	1,349,525	513,400	382,903
2000	2,986,470	1,495,268	530,285	822,505
2001	3,024,118	1,458,249	418,139	624,650
2002	3,032,478	1,435,158	517,774	877,268
2003	3,014,621	1,506,598	520,563	798,449
2004	2,962,754	1,552,542	545,851	792,861
2005	3,064,593	1,532,098	514,592	824,988
2006	2,986,572	1,364,666	456,561	823,210
2007	2,641,049	1,128,065	459,546	772,514
2008	3,023,237	1,365,760	414,326	820,429
2009	2,902,403	1,105,109	490,998	833,962
2010	1,936,149	733,351	491,741	776,227
2011	2,689,747	1,199,088	511,518	728,925
2012	2,740,787	1,525,916	528,016	839,751

Appendix T (continued). Releases to the Trinity River of juvenile salmonids reared at Trinity River Hatchery (TRH) for brood years 1979–2018. All release types (e.g., fry, fingerlings, yearlings) and release locations (TRH or off-site) are included. Fish reared at TRH and released outside of the Trinity River are excluded.

	Total releases to the Trinity River			
Brood year	Fall-run Chinook Salmon	Spring-run Chinook Salmon	Coho Salmon	Steelhead
2013	2,118,989	1,004,477	287,720	804,079
2014	2,357,931	1,403,161	230,834	434,381
2015	2,400,715	1,101,933	248,722	453,842
2016	1,028,336	1,540,967	258,243	402,130
2017	2,998,946	1,307,210	149,807	465,063
2018	3,126,151	1,218,711	329,640	418,616