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DEPARTMENT OF FISH AND GAME

2011 CDFG FRGP REPORT

UPPER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) ABUNDANCE PROJECT
2000 - 2011 Seasons
CDFG PROJECT 2a5

Prepared by

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Northern Region

Anadromous Fisheries Resource Assessment and Monitoring Program
Fisheries Restoration Grant Program (Project No. 0910529_01)

December 19, 2012

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ABSTRACT

Juvenile anadromous salmonid trapping in YR 2011 was conducted for the twelfth consecutive year in upper Redwood Creek, Humboldt County, California during the spring/summer emigration period (late March – August). The purpose of the study is to describe juvenile salmonid out-migration and estimate smolt population abundances for wild 0+ Chinook salmon, 1+ coho salmon, 1+ steelhead trout, and 2+ steelhead trout using mark/recapture methods. The long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in upper Redwood Creek in relation to watershed conditions and restoration activities in the basin, and to provide data for Viable Salmonid Population Analysis. A rotary screw trap and fyke net/pipe trap collectively operated 136 day/nights out of 140 possible, and captured 48,413 0+ Chinook salmon (ocean type), zero 1+ Chinook salmon (stream type), 35,853 0+ steelhead trout, 4,662 1+ steelhead trout, 398 2+ steelhead trout, 4 cutthroat trout, and 1 0+ pink salmon to total 89,331 individuals. Juvenile coho salmon were not captured in YR 2011. Average weekly trapping efficiency was 31% for 0+ Chinook salmon, 21% for 1+ steelhead trout, and 17% for 2+ steelhead trout. The total 0+ Chinook salmon population estimate with 95% confidence intervals in YR 2011 equaled 187,440 (170,443 – 204,438), and was 15% less than abundance for the previous eleven year average. The decrease in abundance in YR 2011 compared to the previous eleven year average most likely reflected a decrease in the number of adult spawners upstream of the trap site since no streambed mobilization from flood flows occurred after reproduction. The population estimate for 1+ steelhead trout equaled 26,612 (22,587 – 30,637), and was 27% less than abundance for the previous eleven year average. 2+ steelhead trout population abundance equaled 1,919 (1,436 – 2,403) and was 57% less than abundance for the previous eleven year average. Population abundances in July, 2011 were much greater than previous years for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout, and may be attributable to higher than average stream flow during the trapping period. The two most important months for migration in YR 2011 were April/May for 0+ Chinook salmon, April/June for 1+ steelhead trout, and April/July for 2+ steelhead trout. Population abundances of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout each showed a significant, negative trend over the twelve consecutive study years ($p < 0.10$). Population abundances of 0+ Chinook salmon were also negatively related to flood type flows during adult reproduction and the egg incubation period ($p < 0.10$). Population abundances of 1+ and 2+ steelhead trout were negatively related to flood type flows during winter months ($p < 0.10$), and may indicate over-winter conditions were not favorable for survival.

The average daily stream temperature during the trapping periods significantly decreased over time, and the average stream temperature in YR 2011 was the second lowest of record. Stream temperatures in July have also significantly decreased over the past eleven years. With respect to successful watershed restoration, we expect: 1) stream temperatures to decrease in the summer, 2) a change in the age class structure of steelhead migrants to favor older, larger smolts, and 3) a general increase in smolt population abundances.

[1/] This paper should be referenced as: Sparkman MD. 2012. Upper Redwood Creek juvenile salmonid (smolt) abundance project, study year 2011: a report to the Fisheries Restoration Grants Program. CDFG AFRAMP, 2a5: 63 p.

INTRODUCTION

This report presents results of the twelfth consecutive year of juvenile salmonid downstream migrant trapping in upper Redwood Creek, Redwood Valley, Humboldt County, California during the spring/summer emigration period. The study began in YR 2000, and was funded by the Redwood Creek Landowners Association (RCLA). Study years 2001 – 2011 have been a cooperative effort between the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) and RCLA. The department's Steelhead Trout Report Restoration Card Program has assisted this study in the past, and the Fisheries Restoration Grant Program (FRGP) has assisted in funding this study from YR 2005 to the present (YR 2011, FRGP Project No. 0910529_01).

The initial impetus for the study was to determine how many wild salmon and steelhead smolts were emigrating from upper Redwood Creek. Prior to this study, no information about smolt emigration and population estimates from upper Redwood Creek existed; this also applied to the remainder of mainstem Redwood Creek as well. Scientific studies which quantified anadromous salmonids within the Redwood Creek watershed were primarily limited to the estuary (juveniles) and Prairie Creek (adults and juveniles), which is tributary to lower Redwood Creek at river mile (RM) 3.7. Redwood Creek is a difficult stream to monitor adult salmon and steelhead populations because the adult fish migrate upstream during late fall, winter and early spring. Thus, when the adults are present, the stream flow is often high and unpredictable, which limits the reliability and usefulness of any adult weir. Additionally, the stream flow during this time period often carries large amounts of suspended sediments, which render visual observations of adult fish (both live and carcass) and redds (eg spawning surveys) unreliable and unlikely for long term monitoring, particularly in average or above average water years. However, efforts are currently underway to count adult fish migrating upstream in lower Redwood Creek with a DIDSON unit (USGS California Cooperative Fish and Wildlife Research Unit at Humboldt State University), and to count redds in randomly selected areas within the Redwood Creek watershed (CDFG AFRAMP). Scientific studies which focus on salmonids in tributaries to Redwood Creek are less affected by these processes (high, muddy stream flow), however, the tributaries are less likely to adequately represent or account for the majority of the salmonid populations in Redwood Creek because the majority of adult salmon and steelhead trout spawn in the mainstem. An exception is the Prairie Creek watershed which accounts for a considerable amount of the coho salmon and cutthroat trout production in Redwood Creek (Duffy and Sparkman, In progress). Tributaries to Redwood Creek are often steep, with limited anadromy (RNP 1997, Brown 1988). Additionally, some of the tributaries can dry up prior to late summer, which cause the juvenile fish to migrate into the mainstem Redwood Creek to rear.

Determining and tracking smolt numbers over time is an acceptable, useful, and quantifiable measure of salmonid populations which many agencies (both state and federal), universities, consultants, tribal entities, and timber companies perform each year. Juvenile salmonid out-migration can be used to assess: 1) the number of parents that produced the cohort (Schmidt et al. 1996, Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2006), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and Scrivener 1990), 3) in-stream habitat quality and watershed health (Bisson and Sedell 1984; Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003, Roni et al. 2006), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003, Ebersole et al. 2009), and 6) future recruitment to adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000).

This paper will present the results of trapping in study year 2011 with various comparisons to the average of the previous eleven study years (YRS 2000 - 2010), and YR 2010.

Site Description

Redwood Creek lies within the Northern Coast Range of California, and flows about 67 miles through Humboldt County before reaching the Pacific Ocean (Figure 1). Headwaters originate at an elevation of about 5,000 ft and converge to form the main channel at about 3,100 feet. Redwood Creek flows north to northwest to the Pacific Ocean, and bisects the town of Orick in Northern California. The basin of Redwood Creek is 179,151 acres, and about 49.7 miles long and 6.2 miles wide (Cashman et. al 1995). The study area upstream of the trap site encompasses approximately 65,000 acres of the middle and upper Redwood Creek watershed, with about 37 stream miles (59.5 km) of accessible salmon and steelhead habitat (Brown 1988).

Geology

The Redwood Creek watershed is situated in a tectonically active and geologically complex area, and is considered to have some of the highest uplift and seismic activity rates in North America (CDFG NCWAP 2004). The geology of the Redwood Creek basin has been well-studied and mapped (Cashman et. al 1995).

> "Redwood Creek drainage basin is underlain by metamorphic and sedimentary rocks of the Franciscan assemblage of Late Jurassic and Early Cretaceous age and by shallow marine and alluvial sedimentary deposits of late Tertiary and Quaternary age. These units are cut by a series of shallowly east-dipping to vertical north to northwest trending faults. The composition and distribution of bedrock units and the distribution of major faults have played a major part in the geomorphic development of the basin. Slope profiles, slope gradients, and drainage patterns within the basin reflect the properties of the underlying bedrock. The main channel of Redwood Creek generally follows the trace of the Grogan fault, and other linear topographic features are developed along major faults. The steep terrain and the lack of shear strength of bedrock units are major contributing factors to the high erosion rates in the basin" (Cashman et al. 1995).

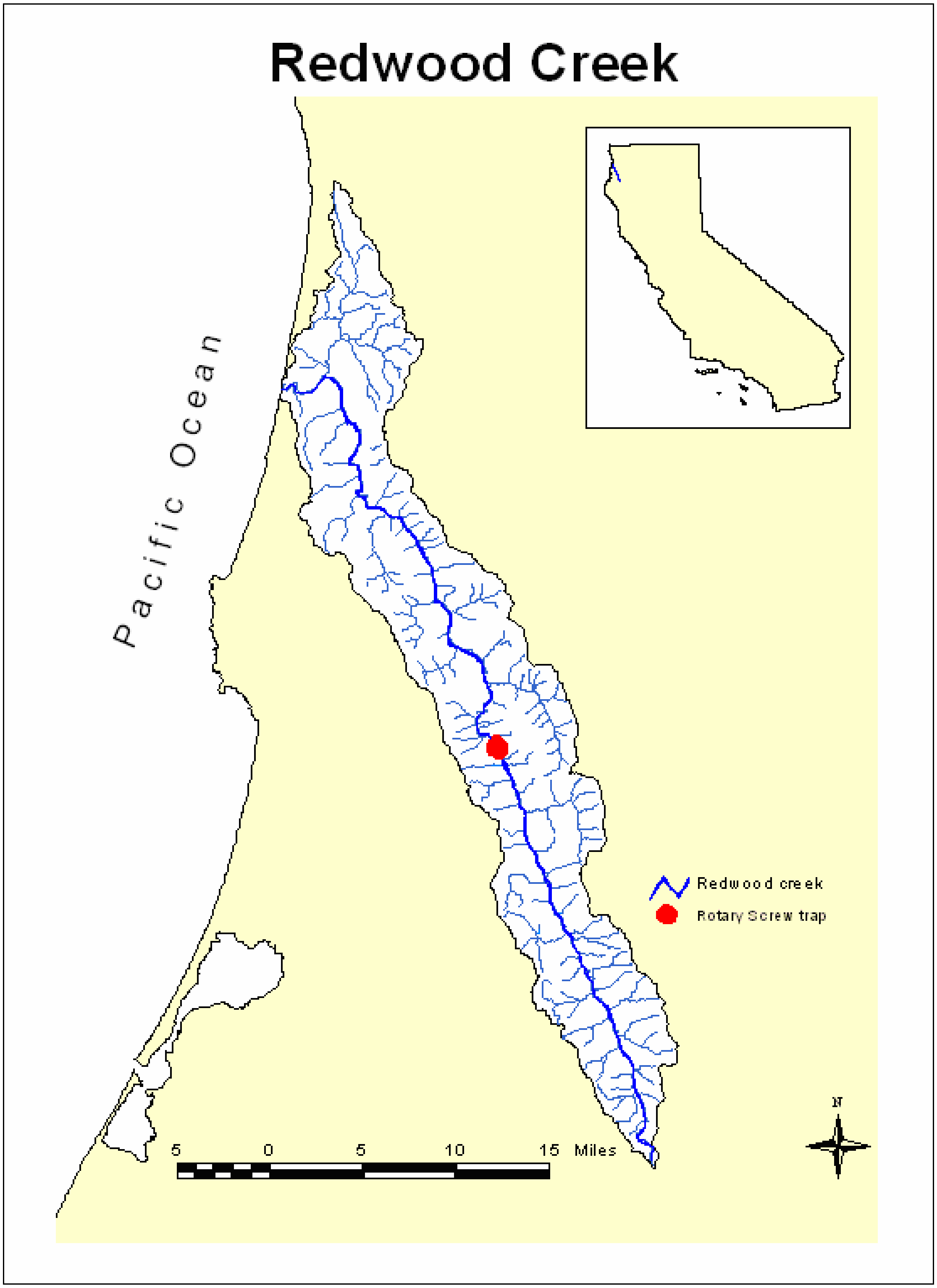

Figure 1. Redwood Creek watershed with rotary screw trap location (RM 33) in Redwood Valley, Humboldt County, CA., (scale is slightly inaccurate due to reproduction process; Charlotte Peters pers. comm. 2001).

Climate and Annual Precipitation

The climate of Redwood Creek basin varies dependent upon location within the watershed and season. Coastal areas have a moderate climate due to proximity to the ocean, and differ from inland areas (i.e. upper Redwood Creek) which experience higher and lower temperatures. Summers are typically cool and moist on the coast, and hot and dry inland. Ambient air temperatures in Redwood Valley often exceed 32 ^{o}C (or 90 ^{o}F) during summer months. Upper Redwood Creek experiences cold temperatures during the winter, and snowfall is common. Rainfall in upper Redwood Creek is influenced by orographic effects, and can fall in considerable amounts.

Stream Discharge

A USGS/CDWR gaging station (Blue Lake O'Kane, #11481500) is located about 8.4 miles upstream of the trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2011 to total 40 years (USGS 2012; Vicki Ozaki, pers. comm. 2012). Following the pattern of rainfall, most of the high flows occur in the months of November - April, and typically peak in February; low flows usually occur from July - October (USGS 2012). The peak monthly flow in WY 2011 occurred in March (USGS 2012). Using all years' data, mean monthly discharge in upper Redwood Creek was 231 cfs (6.54 m^3/sec), and ranged from 7 - 537 cfs (USGS 2012). Average monthly discharge in WY 2011 equaled 269 cfs (7.6 m^3/sec) and was 1.2 times greater than the historic average discharge (USGS 2012). Average monthly discharge during the majority of the trapping season (April – July) in YR 2011 (230 cfs or 6.5 m^3/sec) was much higher than the historic average (142 cfs or 4.0 m^3/sec), and the previous eleven year average (144 cfs or 4.1 m^3/sec). Average daily discharge during the trapping period in YR 2011 equaled 195.6 cfs (USGS 2012), and tracked well with the gage height measured at the trapping site (Appendix 2).

Overstory

The overstory in the Redwood Creek watershed is predominately second and third growth Redwood (*Sequoia sempervirens*) and Douglas Fir (*Pseudotsuga menziesii*), mixed with Big Leaf Maple (*Acer macrophyllum*), California Bay Laurel (*Umbellularia californica*), Incense Cedar (*Calocedrus decurrens*), Cottonwood (*Populus* spp.), Manzanita (*Arctostaphylos* spp.), Oak (*Quercus* spp.), Tan Oak (*Lithocarpus densiflorus*), Pacific Madrone (*Arbutus menziesii*), and Red Alder (*Alnus rubra*).

Understory

Common understory plants include: dogwood (*Cornus nuttallii*), willow (*Salix lucida*), California hazelnut (*Corylus rostrata*), lupine (*Lupinus* spp.), blackberry (*Rubus* spp.), plantain (*Plantago coronopus*), poison oak (*Toxicodendro diversilobum*), wood rose (*Rosa gymnocarpa*), false Solomon's seal (*Smilacina amplexicaulis*), spreading dog bane (*Apocynum* spp.), wedgeleaf ceanothus (*Ceanothus* spp.), bracken fern (*Pteridium* *aquilinum*), blackcap raspberry (*Rubus* spp.), and elderberry (*Sambucus* spp.), among other species.

Redwood Creek History (Brief)

Redwood Creek watershed has experienced extensive logging of Redwood and other commercial tree species. By 1978, 81% of the original forest was logged, totaling 66% of the basin area (Kelsey et al. 1995). Most, if not all, remaining old growth Redwood is contained within Redwood National Park, which is downstream of the trap site. In conjunction with clear-cut logging, log removal via tractors, associated road building, geology types and geomorphic processes (eg debris slides and earthflows), and flood events in 1955 and 1964, large amounts of sediments were delivered into the stream channel (Madej and Ozaki 1996) with a resultant loss of stream habitat complexity (filling in of pools and flattening out of the stream channel, Marlin Stover pers. comm. 2000). Additional high flows occurred in 1972, 1975, and 1995 as well, and have helped influence the current channel morphology of Redwood Creek. Redwood Creek within the study area appeared to have experienced channel incision in flood gravel deposits, scouring of pools to increase depth, riparian growth, and input of woody debris (small), which collectively increased stream complexity. However, in YR 2005 and to a much larger degree in YR 2006, large amounts of small gravels/sands were deposited at the trap site and areas downstream of the trap site; these deposits at the trap site were up to 2.5 ft deep. In YRS 2007 - 2011 we noticed that some scouring of the deposits had occurred, however, most of the rocks and cobbles were still covered by the deposits, with the finer sediments present along the stream margin as well. Redwood Creek has been listed as sediment and temperature-impaired under section 303(d) of the Clean Water Act (CWA 2002; SWRCB 2003; USEPA 2003).

Federal ESA Species Status

Chinook (King) salmon (*Oncorhynchus tshawytscha*), coho (Silver) salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) are known to inhabit Redwood Creek. This study also shows that pink salmon (*O. gorbuscha*) are present in Redwood Creek. Chinook salmon (KS) of Redwood Creek belong to the California Coastal Chinook Salmon Evolutionarily Significant Unit (ESU), and are listed as "threatened" under the Federal Endangered Species Act (Federal Register 1999a). The definition of threatened as used by National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) is "likely to become endangered in the foreseeable future throughout all or a significant portion of their ranges" (NOAA 1999). Coho salmon (CO) belong to the Southern Oregon / Northern California Coasts ESU and were classified as "threatened" (Federal Register 1997) prior to the Chinook salmon listing. Steelhead trout (SH) fall within the Northern California Steelhead DPS (Distinct Population Segment), and are also listed as a "threatened" species (Federal Register 2000). Coastal cutthroat trout (CT) of Redwood Creek fall within the Southern Oregon / California Coasts Coastal Cutthroat Trout ESU, and were determined “not warranted” for ESA listing (Federal Register 1999b). Despite ESU listings of Redwood Creek anadromous salmonid populations, relatively little data exists concerning abundance and population sizes, particularly for juvenile (and adult) life history stages. Historically, the most prolific species in Redwood Creek was most likely the fall/early winter-run Chinook salmon.

Purpose

The purpose of this project is to describe juvenile salmonid downstream migration in upper Redwood Creek, and to determine smolt population abundances for wild 0+ (young-of-year) Chinook salmon (ocean-type), 1+ Chinook salmon (stream- type, between 1 and 2 years old), 1+ steelhead trout, 2+ (2 years old and greater) steelhead trout, 1+ coho salmon, and cutthroat trout. The long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in Redwood Creek in relation to watershed conditions and restoration activities in the basin; and to provide data needed for Viable Salmonid Population (VSP) Analysis. An additional goal is to document the presence or absence of juvenile coho salmon. Specific study objectives were as follows:

1) Determine the species composition and temporal pattern of downstream migrating juvenile salmonids, and enumerate species out-migration.
2) Determine population estimates for downstream migrating 1+ steelhead trout, 2+ steelhead trout, 0+ Chinook salmon, 1+ Chinook salmon, 1+ coho salmon, and cutthroat trout.
3) Record fork length (mm) and weight (g) of captured fish.
4) Collect and handle fish in a manner that minimizes mortality and potential stress.
5) Statistically analyze data for significance and trends.

METHODS AND MATERIALS

Trap Operations

The methods and materials used in this study in YR 2011 were the same as previous study years (Sparkman 2011). A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in upper Redwood Creek (RM 33) on April 1st, 2011 at the same location as in previous study years. We operated the rotary screw trap continually (24 hrs/day, 7 days a week) from April 1st through August 7th, except for four days when stream flow and potentially, high debris loading in the trap’s livebox were too high to safely trap. Beyond August 7th, a fyke net/pipe trap was used to trap smolts until the study ended on August 19th, 2011. The trapping season in YR 2011 was discontinued on August 19th when the catch distribution for most species at age reached zero, or when relatively few individuals were caught in consecutive days.

During periods of reduced stream flows, rock type weirs and weir panels were used with the rotary screw to: 1) keep the trap’s cone revolutions relatively high, and 2) maintain good trapping efficiencies by directing the fish into the cone area. Plywood was used to cover the weirs in June, July, and August to further increase flow into the cone area.

Biometric Data Collection

Fishery technicians carefully removed debris (e.g. alder cones, leaves, sticks, detritus, varying amounts of filamentous green algae, etc) from within the livebox nearly every night of trapping to reduce trap mortalities the following morning. The trap's livebox was emptied at 09:00 every morning by 2 - 4 technicians. Debris was once again inspected and carefully removed so that the smaller fish would not be released into the stream with the debris. Young of year fish were removed first and processed before 1+ and 2+ fish to decrease predation or injury to the smaller fish. 1+ fish were also kept separate from 2+ fish. Captured fish (0+ fish first, then 1+ and older) were placed into 5 gal. buckets and carried to the processing station. The methods of holding fish at the processing station were the same as in previous study years (Sparkman 2011). Each individual fish was counted by species and age, and observed for trap efficiency trial marks. Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the ice chest for enumeration and biometric data collection.

<u>Fork Lengths/Weights</u>

Fish were anesthetized with MS-222 prior to data collection in 2 gal. dishpans. Biometric data collection included 30 measurements of fork length (mm) and wet weight (g) for random samples of 0+ Chinook salmon (0+ KS), 1+ Chinook salmon (1+ KS), 0+ coho salmon (0+ CO), 1+ coho salmon (1+ CO), 1+ and greater cutthroat trout (CT), 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+ SH). 0+ steelhead trout were only measured for fork length (Sparkman 2011). FL's were taken every day of trap operation, and wet weights were taken every other day. Weights were taken nearly every day for 2+ steelhead trout due to expected, low sample sizes. Methods for aging juvenile salmonids were the same as previous study years (Sparkman 2011). After biometric data was collected, fish were placed into 5 gal. recovery buckets which received continuously pumped fresh stream water. Young of year fish were kept in separate recovery buckets from age 1+ and older fish to decrease predation or injury. When fully recovered from anesthesia, 0+ juvenile fish were transported 157 m downstream of the trap site, and aged 1 and older fish were transported 170 m downstream of the trap site and released into the stream.

Population Estimates

The number of fish captured by the trap represented only a portion of the total fish moving downstream in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly basis for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using stratified and non-stratified mark-recapture methods described by Carlson et al. (1998) (Sparkman 2011). Annual variation in both catches and population abundances over the 12 year period for each species at age were characterized by the standard deviation (SD) and standard error of the mean (SEM).

Physical Data Collection

Stream temperatures were recorded with an Optic StowAway® Temp data logger (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. A second probe was deployed at the same location for comparison. Both probes gave similar results, therefore only data from one probe is reported. Probes were set to record stream temperatures (^{o}C) every 30 minutes and recorded 6,720 measurements per probe over the course of the study (4/2/11 – 8/19/11). The shallowest stream depths during which measurements were taken (in August) were about 2 - 3 feet.

Statistical Analyses

The statistical analyses conducted in YR 2011 were the same as in previous study years (Sparkman 2011). Numbers Cruncher Statistical System software (NCSS 97) (Hintze 1998) was used for linear correlation, regression/ANOVA output, and descriptive statistics. Linear regression was used to estimate the catch for each species at age for days when the trap was not fishing by using data before and after the missed day(s) catch. The estimated catch (except for 0+ steelhead) was then added to the known catch in a given stratum and applied to the population model for that stratum (Roper and Scarnecchia 1999). Linear correlation slope and equation line were used to determine if total catches and population size of a given species at age were increasing or decreasing over the twelve years of study. Peak winter flows coded as 1 or 0 were also included in additional correlation tests with study year on total catch and population size for 0+ Chinook salmon, and 1+ and 2+ steelhead trout. The test for 0+ Chinook salmon would indicate if the relationship of peak winter flows during egg incubation in spawning redds decreased survival, and hence impact the numbers migrating downstream. High bedload mobilizing flows were coded as 1 (for population estimates in YRS 2003, 2005, and 2006) and non-bedload mobilizing flows as 0 (for population estimates in YRS 2000 - 2002, 2004, and 2007 - 2011) (Zar 1999). Tests for 1+ and 2+ steelhead trout would indicate if high winter flows were affecting population abundance with respect to over-winter survival. Flows considered great enough to mobilize the bedload in upper Redwood Creek (> 6,000 cfs) were identified by Redwood National Park Hydrologists and Geologists (Sparkman 2011). Descriptive statistics were used to characterize the mean FL (mm) and Wt (g) of each species at age on a study year basis. If data violated tests of statistical assumptions, data was transformed with Log (x+1) to approximate normality (Zar 1999). The term ‘transformed’ in this paper refers to the log (x+1) transformation. “X” could be the independent or dependent variable in linear regression (NCSS 97). Power is defined as the probability of correctly rejecting the null hypothesis when it is false; and can also be thought of as the probability of detecting differences that truly exist (Zar 1999). The level of significance (alpha) was set at 0.10 for statistical analyses.

RESULTS

The rotary screw trap operated from 4/01/11 - 8/07/11 and trapped 124 day/nights out of a possible 128; the fyke net/pipe trap operated from 8/07/11 – 8/19/11 and trapped 12 day/nights out of a possible 12. The trapping rate in YR 2011 was 97% compared to 97% for the previous eleven year average (ranged from 92 - 100%).

Species Captured

Juvenile Salmonids

Species captured in YR 2011 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and pink salmon (*O. gorbuscha*). A total of 89,331 juvenile salmonids were captured in YR 2011 (Figure 2). The total trap catch of juvenile salmonids in YR 2011 was the fourth lowest of record, and about 1.4 times greater than the total catch in YR 2010. Over the 12 study years, we captured a total of 1,805,153 individuals.

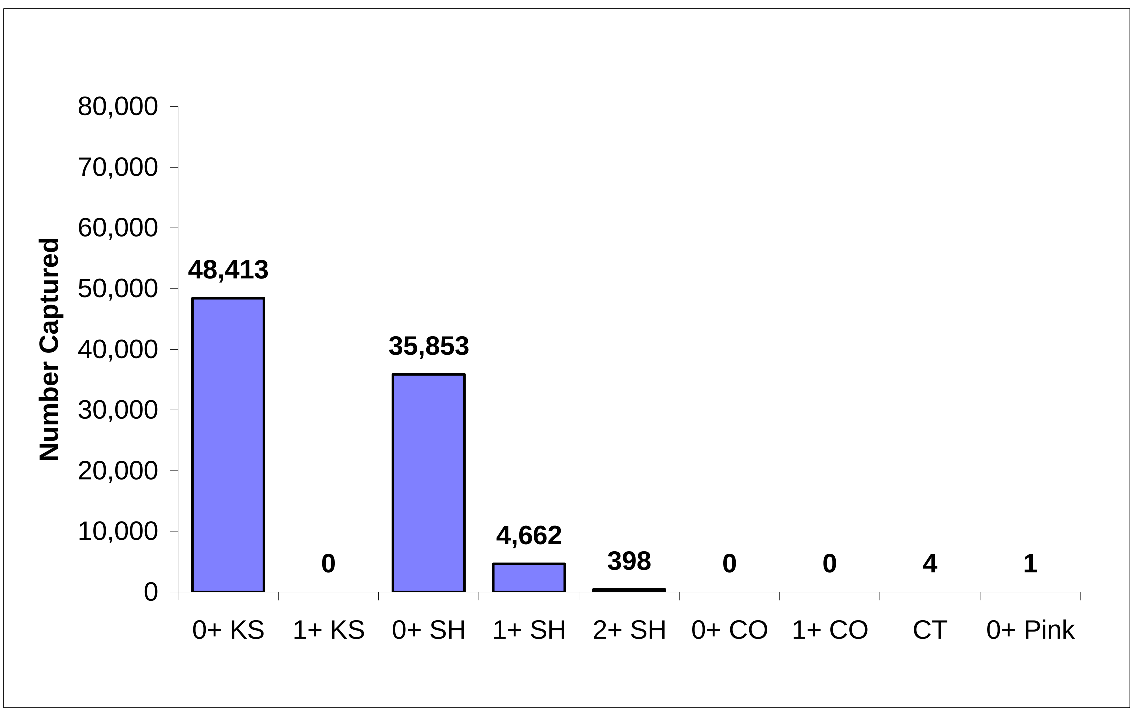

Figure 2. Total juvenile salmonid trap catches (n = 89,331) from April 2nd through August 19th, 2011, upper Redwood Creek, Redwood Valley, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 and older Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, 0+ CO = young-of-year coho salmon, 1+ CO = age 1 and older coho salmon, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

The average total catch by study year equaled 150,429 (SD = 110,817; SEM = 31,990). The 12 year average catch equaled 74,014 (SD = 81,642; SEM = 22,572) for 0+ Chinook salmon, 9 (SD = 10; SEM = 3) for 1+ Chinook salmon, 69,460 (SD = 35,696; SEM = 10,304) for 0+ steelhead trout, 8,308 (SD = 4,486; SEM = 1,295) for 1+ steelhead trout, 762 (SD = 412; SEM = 119) for 2+ steelhead trout, 5 (SD = 3; SEM = 1) for cutthroat trout, 3 (SD = 9; SEM = 3) for 0+ coho salmon, less than 1 (SD = 2; SEM = 1) for 1+ coho salmon, and 2 (SD = 3; SEM = 1) for 0+ pink salmon.

Miscellaneous Species

The trap captured numerous specie besides juvenile anadromous salmonids in YR 2011, including: prickly sculpin (*Cottus asper*), coast range sculpin (*Cottus aleuticus*), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus*), juvenile (ammocoete) lamprey and adult Pacific Lamprey (*Lampetra tridentatus*), among other species (Table 1). Catches of bullheads (catfish; *ameiurus* spp.) occurred in YRS 2003, 2005, and 2010, and catches of bull frogs occurred in YRS 2003 and 2004. Numerous and at times, countless numbers of invertebrates were captured as well.

Table 1. Comparison of miscellaneous specie captured by the smolt trap in YR 2011 with the previous eleven year average, upper Redwood Creek, Humboldt County, CA.

Species Captured	Prev. 11 Yr Avg.	YR 2011
Prickly Sculpin	3	1
Coast Range Sculpin	56	13
Sucker	26	8
3-Spined Stickleback	84	109
Bullhead	0	0
Adult Pac. Lamprey	30	12
Juvenile Lamprey*	1,628	1,548
Brook Lamprey	0	0
Pac. Giant Salamander	131	149
Painted Salamander	1	0
Rough Skinned Newt	21	6
Red-Legged Frog	1	0
Yellow-Legged Frog	13	14
Tailed Frog**	14	7
Crawfish	0	0
Bull Frog	0	0

* Ammocoete stage. ** Includes adult and tadpole stage.

Days Missed Trapping

Four days were not trapped during the course of the study in YR 2011 due to high flow events and potential, high debris loading in the trap's livebox. Days missed trapping did not influence the total catch or population estimate of any species at age to any large degree (Table 2).

Table 2. The estimated catch and expansion (population level) of juvenile anadromous salmonids considered to have been missed due to trap not being deployed (n = 4 d) during the emigration period of April 2nd through August 19th (as a percentage of total without missed days in parentheses), upper Redwood Creek, Humboldt County, CA., 2011.

Age/spp.*	Catch	Population Level
0+ KS	833 (1.75%)	9,348 (4.99%)
1+ KS	N/A	N/A
0+ SH	1 (0.00%)	-
1+ SH	112 (2.46%)	1,269 (5.01%)
2+ SH	17 (4.55%)	47 (2.51%)
0+ CO	N/A	N/A
1+ CO	N/A	N/A
CT	0 (0.00%)	-

* Age/species abbreviations are the same as in Figure 2.
Note: Regression methods were used to estimate the number of fish caught when the trap was not operating. The estimated catches were then added to the known catches for a given stratum (week) and used in the population estimate for that stratum (Roper and Scarnecchia 1999).

Trends in Catches

0+ Chinook Salmon
Linear correlation detected a significant, negative relationship of trap catches over study years (n = 12, p = 0.07, r = 0.53, power = 0.44). The correlation of 0+ Chinook salmon trap catches and flood type flows (dummy variable) during egg incubation with study years was also significantly negative (n = 12, p = 0.01, Adj. r = 0.75, negative slope for both 'x' variables, power = 0.56).

0+ Steelhead Trout
Linear correlation detected a significant, negative relationship of 0+ steelhead trout trap catches over study years (n = 12, p = 0.02, r = 0.66, power = 0.70).

1+ Steelhead Trout
Linear correlation detected a significant, negative relationship of 1+ steelhead trout trap catches over study years (n = 12, p = 0.01, r = 0.69, power = 0.78). The correlation of 1+ steelhead trout trap catches and flood type flows during winter months with study years was significantly negative as well (n = 12, p = 0.002, Adj. r = 0.84, negative slope for both 'x' variables, power = 0.82).

2+ Steelhead Trout
Linear correlation detected a significant, negative relationship of 2+ steelhead trout trap catches over study years (n = 12, p = 0.02, r = 0.67, power = 0.73). The correlation of 2+ steelhead trout trap catches and flood type flows during winter months with study years was also significantly negative (n = 12, p = 0.01, Adj. r = 0.73, negative slope for both 'x' variables, power = 0.52).

Trend analysis for 0+ coho, 1+ coho, cutthroat trout, 1+ Chinook salmon, and 0+ pink salmon could not be conducted because catches were either too low, or infrequent over the twelve study years.

Trapping Efficiencies

The average trapping efficiency by week and seasonal trapping efficiency for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2011 fell within the range of 16 to 31% (Table 3).

Table 3. Average weekly and seasonal trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout, Upper Redwood Creek, Humboldt County, CA., YR 2011.

	Trapping Efficiency (percentage)	
Spp. at age	Average Weekly	Seasonal
0+ Chinook Salmon	30.1	31.4
1+ Steelhead Trout	20.9	20.0
2+ Steelhead Trout	17.4	16.4

Population Estimates

0+ Chinook Salmon

The population estimate (or production) of 0+ Chinook salmon emigrating from upper Redwood Creek in YR 2011 equaled 187,440 with a 95% CI of 170,433 – 204,438. Population estimate error (or uncertainty) equaled $\pm$ 9.1% or about 16,997 individuals. Population emigration in YR 2011 was 2.1 times greater than emigration in YR 2010 (N = 90,485), and 15% less than the previous 11 year average (Nav_{11} = 221,729). The average population abundance over 12 years equaled 218,872 (SD = 213,314), and the standard error of the mean equaled 61,578 individuals. On average, there were about 31,368 less individuals each study year (Figure 3). Correlation of time (study year) on population estimates indicated a significant, negative relationship (n = 12, p = 0.08, r = 0.53, power = 0.43, alpha = 0.10) (Figure 3). The best model describing population trends over time (12 years) included study year and whether or not a flood type flow occurred during the spawning season and egg incubation period (Correlation, p = 0.005, Adj. r = 78, slope is negative for both variables, power = 0.65, alpha = 0.10).

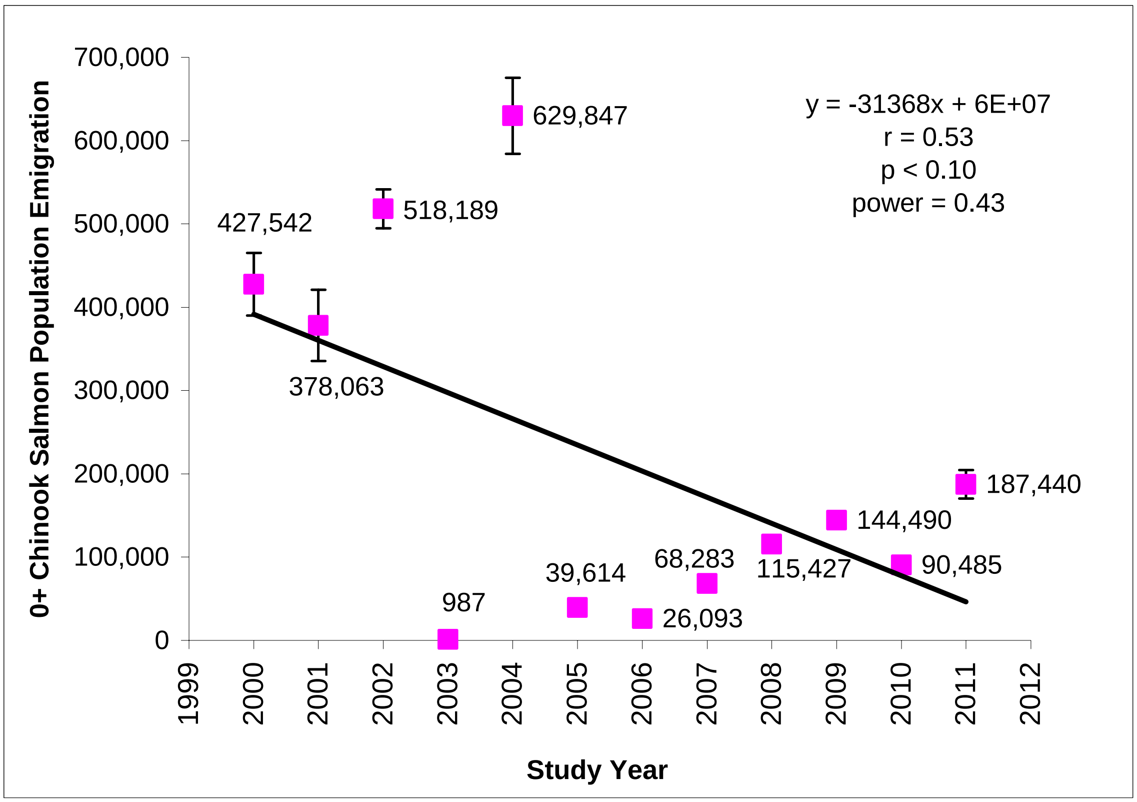

Figure 3. 0+ Chinook salmon population estimates (error bars are 95% confidence interval) in twelve consecutive years. Lack of 95% CI for YRS 2003, 2005, 2006 - 2010 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), p value, and power of the statistical test.

The pattern of migration in YR 2011 contrasted the pattern for the previous eleven year average (Figure 4). 0+ Chinook salmon population emigration by month in YR 2011 was less than emigration by month for the previous eleven year average, with exception to July and August (Figure 4). Abundance in July 2011 was 4.6 times greater than the average abundance in July, and abundance in August 2011 was 8.0 times greater than the average abundance in August. The biggest reductions in YR 2011 occurred in April (33% reduction or 26,550 less individuals), and June (39% reduction or 22,308 less individuals). The two most important months for 0+ Chinook salmon population emigration were April and May in YR 2011 (62% of total), and April and May (69% of total) for the previous eleven year average (Figure 4). In YR 2010, May and July (60% of total) were the two most important months.

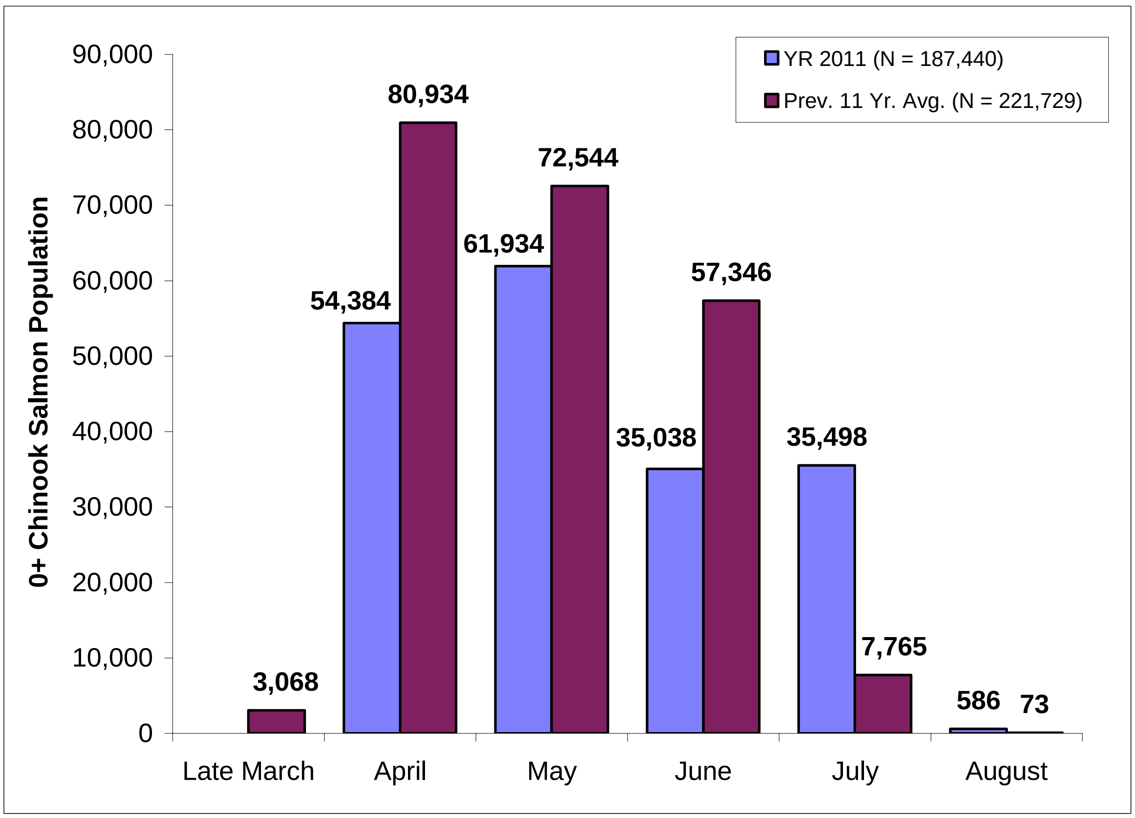

Figure 4. Comparison of 0+ Chinook salmon population emigration by month in YR 2011 with the previous eleven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Weekly population emigration in YR 2011 peaked during 6/25 – 7/01 (N = 22,004) (Table 4). The largest weekly peak occurred in YR 2004 (N = 165,782 individuals) and the smallest peak occurred in YR 2003 (N = 316 individuals) (Table 4). The average FL (mm) for 0+ Chinook salmon migrants during the two modes in population emigration in YR 2011 equaled 39.3 mm for 4/30 – 5/06, and 62.9 mm for 6/25 – 7/01 (Figure 5).

Table 4. Date of peak weekly 0+ Chinook salmon population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)	
2000	5/28 - 6/03	(56,457)
2001	5/07 - 5/13	(79,848)
2002	6/04 - 6/10	(63,093)
2003	6/11 - 6/17	(316)
2004	4/09 - 4/15	(165,782)
2005	4/23 - 4/29	(9,059)
2006	6/18 - 6/24	(4,287)
2007	6/04 - 6/10	(12,564)
2008	6/04 - 6/10	(15,451)
2009	5/28 - 6/03	(19,289)
2010	7/02 - 7/08	(16,654)
2011	6/25 - 7/01	(22,004)

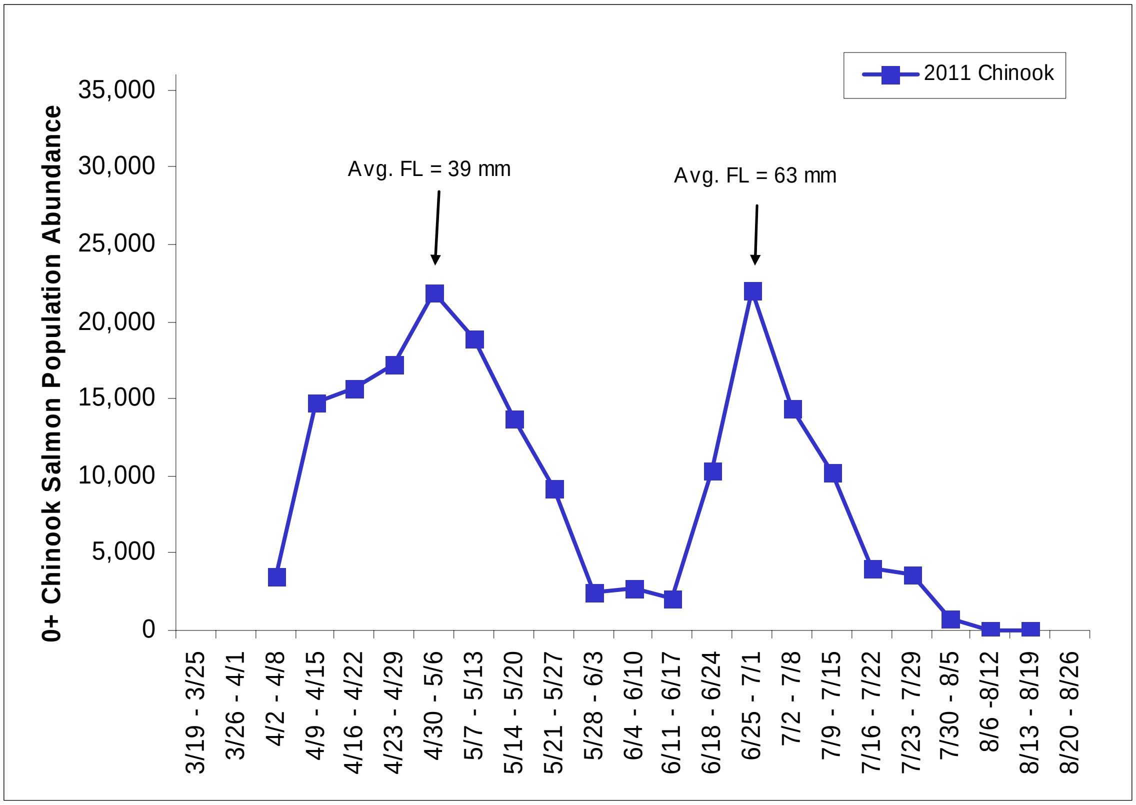

Figure 5. 0+ Chinook salmon population emigration by week in YR 2011, upper Redwood Creek, Humboldt County, CA.

0+ Chinook salmon downstream migrants consisted of fry (FL < 45 mm) and fingerlings (FL > 44 mm), and the number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 5). In YR 2011, fry comprised 62% and fingerlings comprised 38% of the total Chinook salmon population abundance (Table 5). The average size (FL) of fry equaled 39.2 mm in YR 2011, and for fingerlings (smolts) equaled 61.9 mm.

Table 5. Production of 0+ Chinook salmon partitioned into fry and fingerling categories each study year and for the previous eleven year average (expressed as a percentage in parentheses for YR 2011 and the previous eleven year average), upper Redwood Creek, Humboldt County, CA.

	0+ Chinook Salmon production as:	
Study Year	Fry (FL < 45mm)	Fingerling (FL > 44 mm)
2000	139,316	288,226
2001	226,351	151,712
2002	245,024	273,165
2003	8	979
2004	434,400	195,447
2005	22,957	16,657
2006	10,390	15,704
2007	31,615	36,668
2008	45,946	69,481
2009	50,938	93,552
2010	38,853	51,632
Avg.	113,254 (51)	108,475 (49)
YR 2011	115,428 (62)	72,012 (38)

1+ Chinook Salmon

The population abundance of yearling Chinook salmon in YR 2011 equaled zero, however, in YR 2009 abundance equaled 21 and in YR 2010 abundance equaled 19.

1+ Steelhead Trout

The population estimate (or production) of 1+ steelhead trout emigrating from upper Redwood Creek in YR 2011 equaled 26,612 with a 95% CI of 22,587 – 30,637. Population estimate error (or uncertainty) equaled ± 15.1% or 4,025 individuals. Population emigration in YR 2011 was 6% less than emigration in YR 2010 (N = 28,323), and 27% less than the previous eleven year average (Nav_{11} = 36,443). The average population abundance over 12 years equaled 35,624 (SD = 12,411). The standard error of the mean equaled 3,583 individuals.

On average, there were about 2,180 less individuals each study year (Figure 6). Correlation of time (study year) on yearly population abundances showed a significant, negative relationship (n = 12, p = 0.03, r = 0.63, power = 0.65) (Figure 6). The best model describing population trends over time (12 years) included study year and whether or not a flood type flow occurred during the winter before the outmigration periods (Correlation, p = 0.01, Adj. r = 74, slope is negative for both variables, power = 0.54, alpha = 0.10).

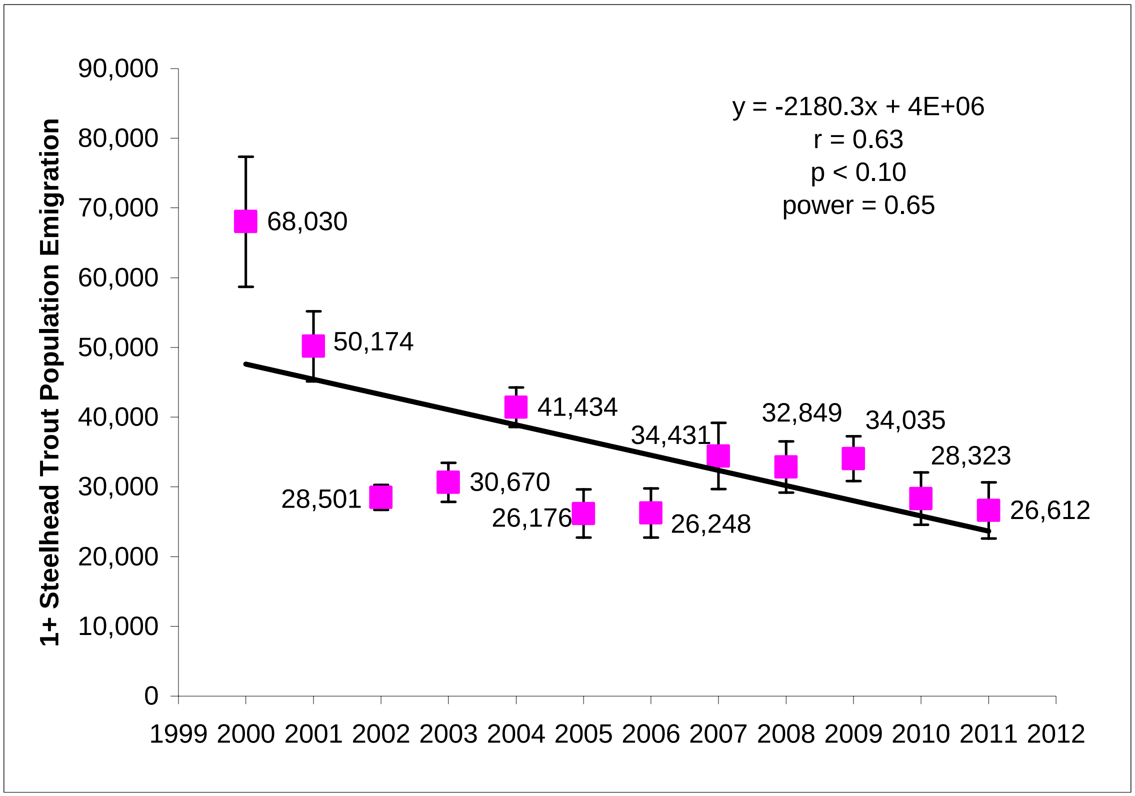

Figure 6. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in twelve consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), p value, and power of the statistical test.

1+ steelhead trout monthly population emigration in YR 2011 was less than monthly emigration for the previous eleven year average, except for the months of April and July (Figure 7). Emigration peaked in April in YR 2011 (N = 10,683 or 40% of total) and May for the previous eleven year average (N = 16,266 or 45% of total) (Figure 7). In YR 2011, the two most important months were April and June (N = 16,649 or 63% of total) compared to April and May (N = 25,164 or 69% of total) for the previous eleven year average (Figure 7). In YR 2010, the two most important months were April and May (N = 19,481 or 69% of total). Abundance in July 2011 was 2.8 times greater than the previous eleven year average for July (Figure 7).

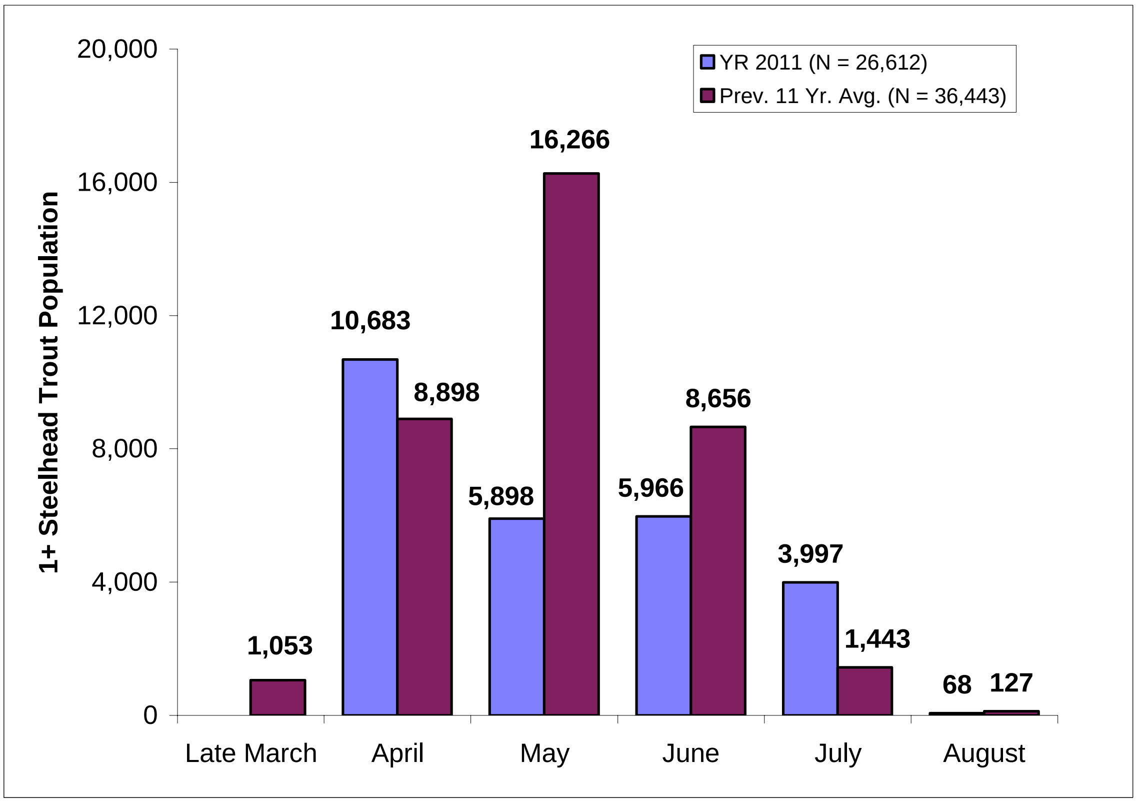

Figure 7. Comparison of 1+ steelhead trout population emigration by month in YR 2011 with the previous eleven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

The peak in 1+ steelhead trout weekly emigration (N = 3,509) in YR 2011 occurred in late June/early July (Table 6). The largest weekly peak occurred in YR 2000 (N = 16,244), and the smallest occurred in YR 2011 (N = 3,509) (Table 6).

Table 6. Date of peak weekly 1+ steelhead trout population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)
2000	5/07 – 5/13 (16,244)
2001	4/23 – 4/29 (6,963)
2002	5/14 – 5/20 (4,180)
2003	5/14 – 5/20 (4,483)
2004	5/14 – 5/20 (6,659)
2005	4/23 – 4/29 (4,834)
2006	5/21 – 5/27 (4,062)
2007	5/07 – 5/13 (6,777)
2008	5/28 – 6/03 (6,342)
2009	4/30 – 5/06 (4,971)
2010	4/16 – 4/22 (5,476)
2011	6/25 – 7/01 (3,509)

2+ Steelhead Trout

The population estimate (or production) of 2+ steelhead trout emigrating from upper Redwood Creek in YR 2011 equaled 1,919 with a 95% CI of 1,436 – 2,403 (Figure 8). Population estimate error (or uncertainty) equaled $\pm$ 25.2% or 484 individuals. Population emigration in YR 2011 was 36% less than abundance in YR 2010 (N = 3,015), and 57% less than the previous eleven year average (Nav_{11} = 4,447). The average population abundance over 12 years equaled 4,237 (SD = 3,145). The standard error of the mean equaled 908 individuals.

On average, there were about 564 less individuals each study year (Figure 8). Correlation of time (study year) on yearly population estimates showed a significant, negative relationship (n = 12, p = 0.02, r = 0.65, power = 0.68) (Figure 8). The best model describing population trends (transformed in this test) over time included study year and whether or not a flood type flow occurred during the winter before the outmigration periods (Correlation, p = 0.001, adj. r = 0.85, slope is negative for both variables, power = 0.84).

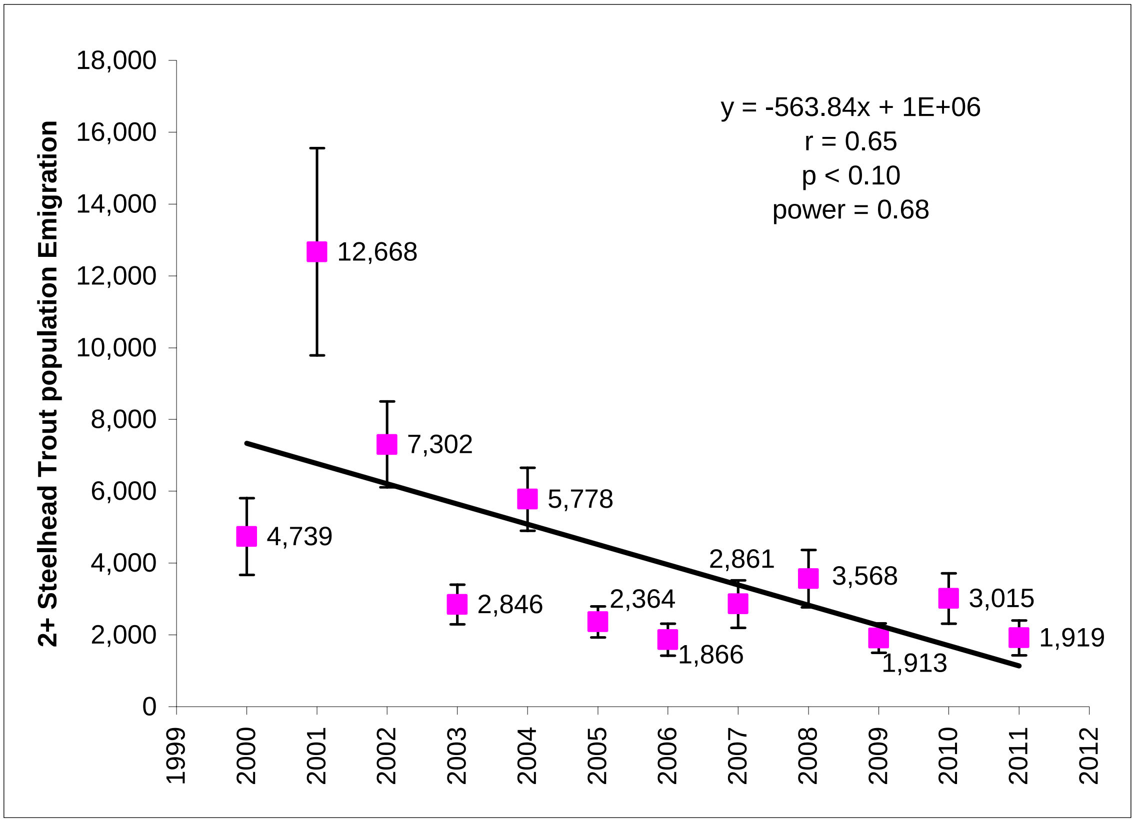

Figure 8. 2+ steelhead trout population estimates (error bars are 95% confidence interval) in twelve consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), p value, and power of the statistical test.

2+ steelhead trout monthly population emigration in YR 2011 was much less than monthly emigration for the previous eleven year average, with exception to the month of July (Figure 9). Emigration peaked in July (N = 703 or 37% of total) in YR 2011, compared to April (N = 1,462 or 33% of total) for the previous eleven year average (Figure 9). In YR 2010, monthly population abundance also peaked in July (N = 1068 or 35% of total). The two most important months for population emigration were April and July in YR 2011 (N = 1,246 individuals, or 65% of total), and April and May for the previous eleven year average (N = 2,873 or 65% of total) (Figure 9). In YR 2010, April and July were the two most important months (N = 2,104 or 70% of total). Migration in July 2011 was the second highest of record, and 2.3 times greater than the average abundance in July. The biggest reduction in abundance in YR 2011 occurred in May, which was about 80% below average.

The peak in 2+ steelhead trout weekly emigration in YR 2011 occurred in early July, unlike most study years (Table 7). The largest weekly peak occurred in YR 2001 (N = 1,463), and the smallest peak occurred in YR 2011 (N = 338) (Table 7).

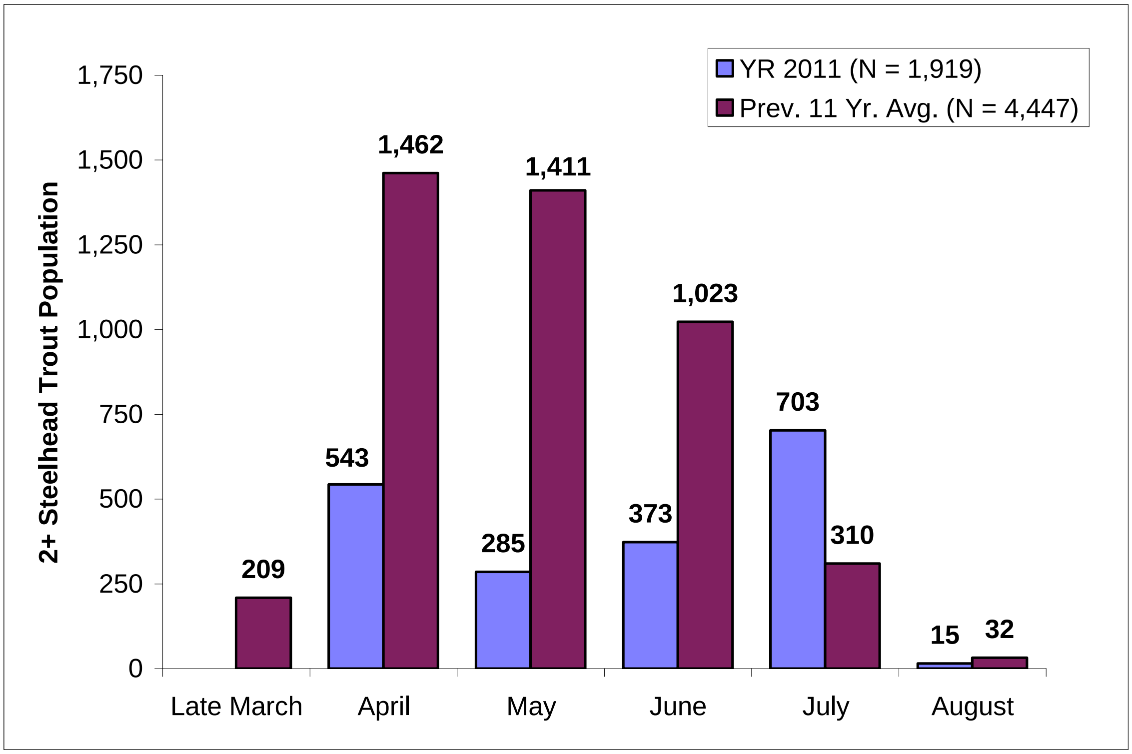

Figure 9. Comparison of 2+ steelhead trout population emigration by month in YR 2011 with the previous eleven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Table 7. Date of peak weekly 2+ steelhead trout population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)
2000	4/09 - 4/15 (1,094)
2001	5/28 - 6/03 (1,463)
2002	4/23 - 4/29 (1,061)
2003	5/14 - 5/20 (363)
2004	5/14 - 5/20 (645)
2005	4/16 - 4/22 (380)
2006	4/30 - 5/06 (365)
2007	6/04 - 6/10 (384)
2008	5/28 - 6/03 (871)
2009	4/23 - 4/29 (341)
2010	7/09 - 7/15 (398)
2011	7/02 - 7/08 (338)

0+ Coho and 1+ Coho Salmon

The population abundances of 0+ coho salmon and 1+ coho salmon in YR 2011 equaled zero.

Age Composition of Juvenile Steelhead Trout

The following percentages represent maximum values for 1+ and 2+ steelhead trout because their population estimates were compared to catches of 0+ steelhead trout (ie the actual catches of 0+ steelhead trout are less than expected 0+ steelhead trout population out-migration). Far more 0+ and 1+ steelhead trout migrated downstream than 2+ steelhead trout (Table 8). In YR 2011, 3% of the juvenile steelhead trout migrating downstream consisted of 2+ steelhead trout (Table 8). Using catch and population data, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout in YR 2011 equaled 19:14:1 compared to 16:8:1 for the ratio of the previous eleven year average. The ratio of 1+ steelhead trout to 2+ steelhead trout was 14:1 in YR 2011, 9:1 in YR 2010, and 8:1 for the ratio of the previous eleven year average.

The percent composition of age 1 and older steelhead trout smolts in YR 2011 equaled 93% for 1+ steelhead trout, and 7% for 2+ steelhead trout. Using all years' data, the percentage of 1+ steelhead trout in the total steelhead trout smolt abundance (1+ and 2+ SH) ranged from 80 – 95%, and for 2+ steelhead trout smolts ranged from 5 – 20%. On average, 1+ steelhead trout comprised 90% of age 1 and older steelhead trout emigrating from upper Redwood Creek.

Table 8. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2011 with the previous eleven year average, upper Redwood Creek, Humboldt County, CA.

	Percent composition of total juvenile steelhead trout out-migration		
Study Year	0+ steelhead*	1+ steelhead	2+ steelhead
2011	55.7	41.3	3.0
Prev. 11 Yr. Avg.	61.8	34.4	3.8
All years combined	63.5	32.6	3.9

* Uses actual catches instead of population estimate.

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 3,660 and weighed (g) 2,057 0+ Chinook salmon in YR 2011 (Table 9). Average FL and Wt in YR 2011 were less than values for the previous eleven year average (Table 9). The average FL over all years (n = 12) equaled 54.2 mm (SD = 5.2 mm; SEM = 1.5 mm) and average weight equaled 2.01 g (SD = 0.63 g; SEM = 0.18 g).

The average size of 0+ Chinook salmon migrants did not statistically change over time (years) (Correlation, FL: n = 12, test assumptions not met; Wt transformed: n = 12, p = 0.49, r = 0.22, power = 0.10, alpha = 0.10). Average FL and Wt were not related to population abundances (Regression, FL: n = 12, p = 0.20, R^2 = 0.16, power = 0.24, alpha = 0.10; Wt: n = 12, p = 0.14, R^2 = 0.20, power = 0.30, alpha = 0.10).

Table 9. 0+ Chinook salmon population estimates and average fork length (mm) and weight (g) for study YRS 2000 - 2011, upper Redwood Creek, Humblodt County, CA.

	0+ Chinook Salmon						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	427,542	3,661	55.5	0.2	913	2.03	0.04
2001	378,063	2,719	51.9	0.2	778	1.73	0.04
2002	518,189	3,517	52.4	0.2	1,545	1.70	0.03
2003	987	573	67.3	0.3	499	3.43	0.05
2004	629,847	3,571	50.8	0.2	1,593	1.61	0.03
2005	39,614	2,489	60.4	0.3	1,751	3.09	0.05
2006	26,093	2,123	55.5	0.3	1,684	2.07	0.04
2007	68,283	2,811	51.6	0.2	2,127	1.55	0.03
2008	115,427	2,937	48.0	0.2	2,001	1.32	0.02
2009	144,490	3,140	52.1	0.2	1,838	1.88	0.03
2010	90,485	3,092	53.5	0.2	1,873	2.11	0.04
Avg 00-10			54.5	1.6		2.05	0.20
2011	187,440	3,660	51.0	0.2	2,057	1.68	0.03

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt. ** Standard error of mean.

1+ Chinook Salmon

We measured (FL mm) and weighed (g) zero 1+ Chinook salmon in YR 2011, however, in past years average seasonal FL ranged from 104 – 118 mm, and average seasonal Wt ranged from 13.4 – 22.3 g (Table 10).

Table 10. 1+ Chinook salmon trap catches and fork length (mm) and weight (g) for study years 2000 – 2011, upper Redwood Creek, Humboldt County, CA.

	1+ Chinook Salmon						
	Catch or	Fork Length (mm)			Weight (g)		
Study Year	(Pop.*)	n	Avg.	SEM**	n	Avg.	SEM**
2000	0	0	-	-	-	-	-
2001	21	17	104.4	2.8	13	13.38	1.65
2002	18	17	108.5	3.9	17	16.62	1.96
2003	29	29	123.4	1.7	29	22.34	0.90
2004	0	0	-	-	-	-	-
2005	0	0	-	-	-	-	-
2006	0	0	-	-	-	-	-
2007	0	0	-	-	-	-	-
2008	9	9	118.2	1.8	9	18.19	0.78
2009	21*	14	106.8	3.3	14	13.92	1.34
2010	19*	11	115.9	4.0	11	18.63	1.97
6 Yr. Avg.		6	112.9	3.0	6	17.18	1.36
2011	0	0	-	-	0	-	-

* Denotes population abundance. ** Denotes Standard Error of the Mean.

0+ Steelhead Trout

We measured (FL mm) 3,220 0+ steelhead trout in YR 2011 (Table 11). Average FL in YR 2011 (Avg. = 36.0 mm) was slightly less than the previous eleven year average, and corresponded to the size of a parr life history form (Table 11). The average FL over all years (n = 12) equaled 38.0 mm (SD = 2.5 mm; SEM = 0.7 mm), and also corresponded to the parr life history form.

The average size of 0+ steelhead trout migrants did not statistically change over time (years) (Correlation, FL: n = 12, p = 0.12, r = 0.47, power = 0.34, alpha = 0.10). Average FL was not related to the total catch by year (Regression, n = 12, p = 0.91, R^2 = 0.001, power = 0.05, alpha = 0.10).

Table 11. 0+ steelhead trout total catch and average fork length (mm) for study years 2000 - 2011, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2000	55,126	2,669	40.9	0.2	-	-	-
2001	102,408	1,136	39.0	0.3	-	-	-
2002	124,426	3,228	38.7	0.2	-	-	-
2003	102,954	3,338	38.5	0.2	-	-	-
2004	128,885	3,615	37.5	0.2	-	-	-
2005	41,671	3,661	42.3	0.2	-	-	-
2006	48,759	2,670	35.9	0.2	-	-	-
2007	68,573	2,672	37.0	0.2	-	-	-
2008	57,805	2,076	33.1	0.1	-	-	-
2009	32,585	2,931	37.0	0.2	-	-	-
2010	34,475	3,617	39.9	0.2	-	-	-
11 Yr. Avg.			38.2	0.8	-	-	-
2011	35,853	3,220	36.0	0.2	-	-	-

* Denotes Standard Error of Mean.

1+ Steelhead Trout

We measured (FL mm) 2,668 and weighed (g) 1,483 1+ steelhead trout in YR 2011 (Table 12). Average FL and Wt in YR 2011 were slightly less than the previous eleven year average (Table 12). The average FL over all years (n = 12) equaled 86.7 mm (SD = 2.8 mm; SEM = 0.8 mm) and average weight equaled 7.72 g (SD = 0.61 g; SEM = 0.18 g).

The average size of 1+ steelhead trout migrants significantly decreased over time (years) (Correlation, FL: n = 12, p = 0.01, r = 0.69, power = 0.77, alpha = 0.10; Wt: n = 12, p = 0.07, r = 0.54, power = 0.46, alpha = 0.10). Average FL and Wt were positively related to population abundance (Regression, FL: n = 12, p = 0.005, R^2 = 0.56, power = 0.89, alpha = 0.10; Wt: n = 12, p = 0.07, R^2 = 0.29, power = 0.46, alpha = 0.10).

Table 12. 1+ steelhead trout population estimates and average fork length (mm) and weight (g) for study years 2000 - 2011, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	68,030	2,721	92.4	0.2	1,455	8.29	0.09
2001	50,174	2,761	91.9	0.3	908	9.27	0.11
2002	28,501	3,049	86.7	0.3	1,356	7.79	0.14
2003	30,670	3,064	84.8	0.3	1,633	7.14	0.09
2004	41,434	3,191	85.7	0.3	1,441	7.57	0.10
2005	26,176	2,473	88.1	0.2	1,592	8.02	0.09
2006	26,248	1,961	85.7	0.3	1,683	7.48	0.09
2007	34,431	2,414	85.4	0.3	1,954	7.41	0.09
2008	32,849	2,362	85.3	0.3	1,759	7.21	0.09
2009	34,035	2,717	83.1	0.3	1,627	7.05	0.09
2010	28,323	2,656	86.9	0.3	1,535	7.86	0.10
11 Yr. Avg.			86.9	0.9		7.74	0.19
2011	26,612	2,668	84.9	0.3	1,483	7.59	0.11

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt. ** Denotes standard error of mean.

2+ Steelhead Trout

We measured (FL mm) 381 and weighed (g) 369 2+ steelhead trout in YR 2011 (Table 13). Average FL and Wt in YR 2011 were less than the previous eleven year average (Table 13). The average FL over all years (n = 12) equaled 148.3 mm (SD = 7.2 mm; SEM = 2.1 mm) and average weight equaled 37.55 g (SD = 5.05 g; SEM = 1.46 g).

The average size of 2+ steelhead trout smolts significantly decreased over time (years) (Correlation, FL: n = 12, p = 0.06, r = 0.57, power = 0.47, alpha = 0.10; Wt: n = 12, p = 0.03, r = 0.63, power = 0.63, alpha = 0.10). The regressions of population abundances on average FL and Wt's violated test assumptions (n = 3 assumptions), and results were not valid (NCSS 97).

Table 13. 2+ steelhead trout population estimates and average fork length (mm) and weight (g) for study years 2000 - 2011, upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	4,739	710	164.4	0.6	480	49.12	0.61
2001	12,668	1,316	151.2	0.5	1,225	39.17	0.43
2002	7,302	1,528	147.5	0.6	1,463	37.87	0.51
2003	2,846	625	144.0	0.9	583	35.15	0.71
2004	5,778	1,277	144.1	0.7	1,244	35.44	0.47
2005	2,364	594	150.5	0.2	592	39.90	0.91
2006	1,866	396	159.8	1.4	391	44.86	1.06
2007	2,861	517	146.7	1.1	490	35.40	0.75
2008	3,568	624	139.9	0.8	613	32.29	0.61
2009	1,913	450	142.8	1.0	425	33.09	0.77
2010	3,015	488	144.7	1.0	468	33.94	0.72
11 Yr. Avg.			148.7	2.2		37.84	1.57
2011	1,919	381	144.4	1.1	369	34.41	0.75

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt. ** Denotes standard error of mean.

Cutthroat Trout

We measured (FL mm) four and weighed (g) three cutthroat trout in YR 2011 (Table 14). Average FL and Wt in YR 2011 were much greater than the average of seven years (Table 14). The average FL over all years (n = 8) equaled 196.8 mm (SD = 28.1 mm; SEM = 10.0 mm) and average weight equaled 80.61 g (SD = 34.39 g; SEM = 12.16 g).

Table 14. Cutthroat trout captures and average fork length (mm) and weight (g) for study years 2000 - 2011, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2000	2	-	-	-	-	-	-
2001	6	6	169.2	12.2	6	58.62	12.91
2002	9	8	191.6	6.8	8	74.43	7.78
2003	1	-	-	-	-	-	-
2004	4	4	189.5	17.5	4	74.88	18.67
2005	2	-	-	-	-	-	-
2006	3	3	176.0	3.6	3	52.27	2.82
2007	2	-	-	-	-	-	-
2008	5	5	185.4	6.0	5	70.06	7.89
2009	5	5	190.0	19.0	4	62.65	12.58
2010	13	13	214.5	18.9	11	91.56	17.60
11 Yr. Avg.			188.0	5.4		69.21	4.88
2011	4	4	258.3	23.3	3	160.4	43.29

* Denotes standard error of mean.

0+ Coho and 1+ Coho Salmon

No juvenile coho salmon fork lengths and weights were taken because none were captured in YR 2011.

Developmental Stages

1+ and 2+ Steelhead Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt designations (developmental stages) for 1+ and 2+ steelhead trout captured in YR 2011 and for the previous eleven year average (Table 15). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt). The majority of 1+ and 2+ steelhead trout were classified as smolts in YR 2011 (Table 15).

Table 15. Developmental stages of captured 1+ and 2+ steelhead trout in YR 2011 and the previous eleven year average, upper Redwood Creek, Humboldt County, CA.

	Developmental Stage (as percentage of total catch)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2011	0.1	12.3	87.6	0.0	0.3	99.7
11 Yr Avg.*	2.0	39.3	58.7	0.0	11.8	88.2

* Study years 2000 – 2010.

1+ Chinook Salmon

Zero 1+ Chinook salmon were captured in YR 2011, however in past study years all were classified as smolts.

Trapping Mortality

The mortality of fish that were captured in the traps and subsequently handled was closely monitored over the course of the trapping period. The trap mortality (which includes handling mortality) for a given age/species in YR 2011 ranged from 0.00 – 0.81%, and using all data, was 0.49% of the total captured and handled (Table 16). This level of trap mortality is very low, and considered negligible.

Juvenile salmonid trapping mortality in YR 2011 (0.49%) was slightly greater than average (0.40%) (Table 17). The variation in mortality among study years was primarily due to differences in debris loading in the trap’s livebox, and whether or not large sticks/logs jammed the trap’s cone.

Table 16. Trapping mortality for juvenile salmonids captured in YR 2011, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2011		
Age/spp.	No. captured*	No. of mortalities	Percent mortality
0+ Chinook	47,580	137	0.28
1+ Chinook	N/A	N/A	N/A
0+ Steelhead	35,852	289	0.81
1+ Steelhead	4,550	6	0.13
2+ Steelhead	381	1	0.26
0+ Coho	0	N/A	N/A
1+ Coho	0	N/A	N/A
Cutthroat trout	4	0	0.00
0+ Pink	1	0	0.00
Overall:	88,368	433	0.49

* Not expanded for missed day(s) catch during periods of trap non-deployment.

Table 17. Comparison of trapping mortality of juvenile salmonids in twelve consecutive study years, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality		
Study Year	No. captured*	No. of mortalities	Percent mortality
2000	191,761	934	0.49
2001	239,262	1,631	0.68
2002	361,426	1,480	0.41
2003	111,514	362	0.32
2004	350,486	1,192	0.34
2005	55,930	368	0.66
2006	56,369	128	0.23
2007	89,896	199	0.22
2008	100,906	200	0.20
2009	90,350	387	0.43
2010	62,267	216	0.35
2011	88,368	433	0.49
Average*	149,878	628	0.40
Pooled	1,798,535	7,530	0.42

* Not expanded for missed day(s) catch during periods of trap non-deployment.

Stream Temperatures

The average daily (24 hr period) stream temperature from 4/02/11 – 8/19/11 was 13.5 ^oC (or 56.3 ^oF) (95% CI = 12.7 – 14.3 ^oC), with daily averages ranging from 6.4 – 21.4 ^oC (43.5 – 70.5 ^oF). Median daily stream temperature equaled 13.3 ^oC (or 55.9 ^oF). Average stream temperature from 4/02/11 – 8/05/11 (truncated for equal comparisons with study years) equaled 12.8 ^oC, and was the second lowest of record (Table 18). Average daily stream temperatures showed variation among study years, and linear correlation detected a significant, negative trend over time (years) (Correlation, non-truncated data: n = 11, p = 0.002, r = 0.81, power = 0.96; truncated data: n = 11, p = 0.004, r = 0.78, power = 0.91).

Table 18. Average daily stream temperature (^oC) (standard error of mean in parentheses) with minimum and maximum recorded stream temperature during the trapping period in YR 2011 and previous ten years, upper Redwood Creek, Humboldt County, CA.

	Stream Temperature					
	Celsius			Fahrenheit		
Study Year	Avg.	Min.	Max.	Avg.	Min.	Max.
2001	16.3 (0.40)	5.7	28.2	61.3 (0.72)	42.3	82.8
2002	15.8 (0.39)	6.7	27.5	60.4 (0.71)	44.1	81.5
2003*	14.5 (0.46)	6.1	28.4	58.1 (0.82)	43.0	83.1
2004	15.8 (0.39)	6.7	28.8	60.4 (0.71)	44.1	83.8
2005*	13.5 (0.38)	6.2	25.8	56.4 (0.68)	43.2	78.4
2006*	14.9 (0.45)	5.7	29.5	58.8 (0.82)	42.3	85.1
2007**	14.8 (0.39)	5.7	26.7	58.6 (0.70)	42.3	80.1
2008**	14.0 (0.43)	4.4	25.2	57.2 (0.77)	39.8	77.3
2009	14.9 (0.41)	5.8	27.8	58.8 (0.74)	42.4	82.0
2010*	12.5 (0.38)	5.8	24.4	54.5 (0.68)	42.4	75.9
10 Yr. Avg.	14.7 (0.36)	4.4	29.5	58.5 (0.65)	39.8	85.1
2011*	12.8 (0.40)	5.1	24.4	55.0 (0.71)	41.2	75.9

*Data truncated to 8/5 for equal comparison among study years. ** Stream temperature data up to 8/5, beyond actual trapping period.

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2011 ranged from 7.9 – 18.3 ^oC (46.2 – 64.9 ^oF) (Table 19). Highest stream temperatures occurred in the later part of the trapping season (July) each study year (Table 19). Average daily stream temperatures in July significantly decreased over the past eleven study years (Correlation, n = 11, p = 0.008, r = 0.75, negative slope, power = 0.85).

Table 19. Average monthly stream temperature (^oC) (^oF in parentheses) at the trapping site in study years 2001 - 2011, upper Redwood Creek, Humboldt County, CA.

	Average stream temperature in Celsius (^oF in parentheses)				
Study Year	April	May	June	July	Avg.
2000	-	-	-	-	-
2001	9.4 (48.9)	15.1 (59.2)	17.5 (63.5)	20.9 (69.6)	15.7 (60.3)
2002	10.7 (51.3)	13.1 (55.6)	18.0 (64.4)	21.3 (70.3)	15.8 (60.4)
2003	8.5 (47.3)	11.2 (52.2)	17.2 (63.0)	21.1 (70.0)	14.5 (58.1)
2004	10.6 (51.1)	13.8 (56.8)	17.7 (63.9)	21.6 (70.9)	15.9 (60.6)
2005	9.2 (48.6)	11.6 (52.9)	13.4 (56.1)	19.4 (66.9)	13.4 (56.1)
2006*	8.7 (47.7)	12.4 (54.3)	17.7 (63.9)	21.1 (70.0)	15.0 (59.0)
2007	9.5 (49.1)	13.0 (55.4)	16.5 (61.7)	20.3 (68.5)	14.8 (58.6)
2008	8.4 (47.1)	12.2 (54.0)	16.1 (61.0)	19.9 (67.8)	14.2 (57.6)
2009*	9.7 (49.5)	12.8 (55.0)	16.6 (61.9)	20.7 (69.3)	15.0 (59.0)
2010	8.3 (46.9)	9.7 (49.5)	13.2 (55.8)	18.8 (65.8)	12.5 (54.5)
2011	7.9 (46.2)	9.8 (49.6)	13.9 (57.0)	18.3 (64.9)	12.5 (54.5)
Avg.	9.2 (48.6)	12.2 (54.0)	16.2 (61.2)	20.3 (68.5)	

* Denotes fish kill due to high stream temperatures during late July.

The minimum stream temperature in YR 2011 was 5.1 ^oC (41.2 ^oF) and occurred on 4/09/11; the maximum stream temperature was 24.4 ^oC (75.9 ^oF) and occurred on 7/29/11 (Time of day = 4:19 pm to 4:49 pm) (Figure 10).

Similar to past data, the average daily stream temperatures during the trapping period (non-truncated) in YR 2011 increased over time (Correlation, n = 140, p < 0.000001, r = 0.95, power = 1.00) (Figure 10), and were inversely related to average daily stream discharge during the trapping period (Regression, n = 140, p < 0.000001, R^2 = 0.54, power = 1.0). The previous ten year average daily stream temperatures also increased over time (Correlation, p = 0.000001, r = 0.97, power = 1.0) (Figure 11).

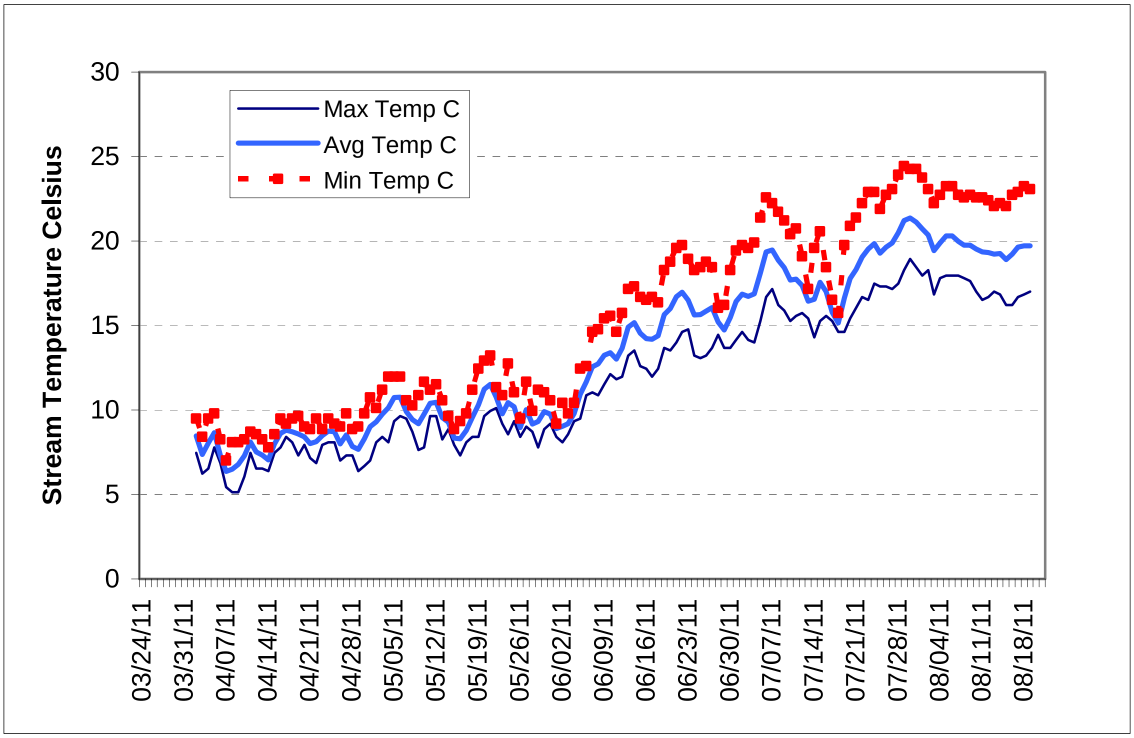

Figure 10. Average, minimum, and maximum stream temperature (Celsius) at the trap site, upper Redwood Creek, Humboldt County, CA., 2011.

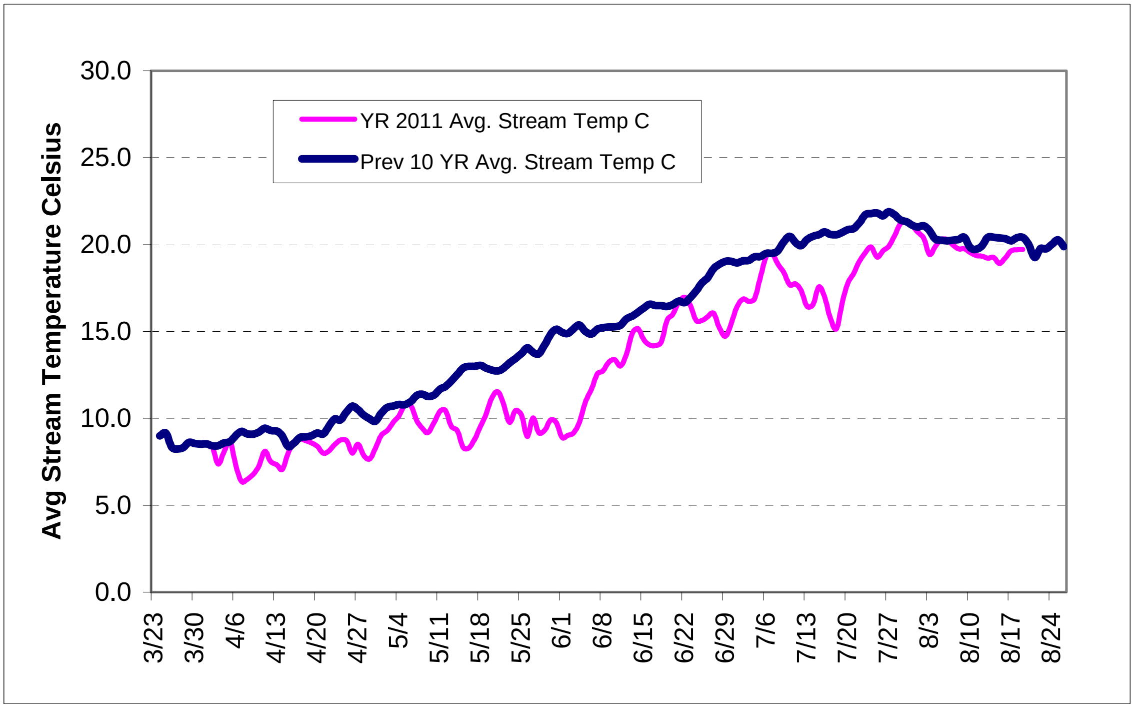

Figure 11. Comparison of average daily stream temperature in YR 2011 with the previous ten year average, upper Redwood Creek, Humboldt County, CA.

The MWAT during the trapping period in YR 2011 at the trap site was 20.7 °C (69.3 °F); and occurred on 7/30/11 (Table 20). MWMT in YR 2011 was 23.8 °C (74.9 °F) and occurred on 7/30/11 as well (Table 20). MWAT and MWMT in YR 2011 were less than most study years (Table 20).

Table 20. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site in upper Redwood Creek, Humboldt County, CA., study years 2001 – 2011.

	MWAT		MWMT	
Study Year	Date of Occurrence	°C (°F)	Date of Occurrence	°C (°F)
2000	-	-	-	-
2001	7/25/01	21.8 (71.2)	7/25/01	27.9 (82.2)
2002	7/29/02	21.9 (71.4)	7/27/02	26.4 (79.5)
2003	7/29/03	23.1 (73.6)	7/29/03	27.4 (81.3)
2004	7/25/04	23.3 (73.9)	7/25/04	28.2 (82.8)
2005	8/05/05	21.9 (71.4)	8/05/05	25.7 (78.3)
2006*	7/25/06	24.1 (75.4)	7/25/06	28.0 (82.4)
2007	7/25/07	21.5 (70.7)	7/25/07	24.9 (76.8)
2008	7/09/08	21.3 (70.3)	7/08/08	24.5 (76.1)
2009*	7/28/09	22.7 (72.9)	7/29/09	27.1 (80.8)
2010	7/26/10	20.4 (68.7)	7/25/10	23.7 (74.6)
2011	7/30/11	20.7 (69.3)	7/30/11	23.8 (74.9)

*Denotes study year when fish kill occurred due to high stream temperatures in late July.

DISCUSSION

The main goal of our downstream migration study in upper Redwood Creek is to estimate and monitor the production of Chinook salmon, steelhead trout, and coho salmon (if present) in a reliable, long-term manner. Redwood Creek is a difficult stream to monitor for adult salmon and steelhead populations on a long term basis using traditional techniques (weirs and spawning ground surveys) due to adult run timing, precipitation, hydrology, water depth, and stream turbidity. Recently, adult salmon and steelhead trout are counted as they move upstream in lower Redwood Creek with a DIDSON sonar unit (Duffy, pers. comm. 2012), and redds from spawning adults are being counted in randomly chosen areas within the watershed to get a basin wide estimate of the number of redds present (CDFG AFRAMP). The future for fisheries work in Redwood Creek is to continue enumerating smolts and adults in order to make Redwood Creek a life cycle monitoring station, which can then be used to assess smolt to adult survival, and adult to smolt survival. Knowing the number of adults that produced the smolts would also greatly increase our ability to detect positive effects on fish populations attributable to watershed restoration within the Redwood Creek basin. Determining the abundance of smolts in Redwood Creek is important for a variety of reasons, irrespective of a life cycle monitoring station. According to Seiler et al. (2004), "quantifying juvenile anadromous salmonid populations as they migrate seaward is the most direct assessment of stock performance in freshwater". In addition, studies in various streams have found that smolt numbers can relate to stream habitat quality, watershed condition, restoration activities, the number of parents that produced the cohort, and future adult populations.

The twelfth consecutive year of trapping in upper Redwood Creek occurred during an above average water year with respect to rainfall amounts in Redwood Valley, and above average stream discharge measured at the O'Kane gaging station. The peak monthly flow in WY 2011 occurred in March, compared to February for the historic average. Stream discharge during the majority of the trapping season (April – July) in YR 2011 (261 cfs) was much higher than the historic average (142 cfs). The environmental conditions for downstream migrant trapping in YR 2011 were more difficult to operate the trap in compared to previous study years when stream discharges were near average. The estimates for catch and subsequent expansions to the population level, based on the four missed trapping days, were negligible for each species at age; the greatest impact on a population estimate was estimated at 5.0% (1+ steelhead trout), and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point value. The uncertainty or error in the population estimate for a given species at age ranged from 9 – 25%. Thus, this season's trapping resulted in very good estimates of wild Chinook salmon and steelhead trout smolt emigration (production) from areas upstream of the trapping site.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) emigrating from upper Redwood Creek were the most numerous migrant captured by the smolt trap for six out of twelve years. Relatively low catches occurred in YRS 2003, 2005 - 2011; and the total catch in YR 2011 was 35% less than the average catch of the previous eleven years (Avg. = 74,014).

The population of 0+ Chinook salmon emigrating from upper Redwood Creek was variable over the twelve consecutive years of study; production was greater than 350,000 individuals for the first three years, less than 1,000 in the fourth year (cohort failure), and the fifth year experienced the greatest peak of 630,000. Production in YRS 2005 – 2007 was less than 70,000, and in YR 2008 and YR 2009 production was greater than 100,000 individuals. Production in YR 2010 was near 91,000 and in YR 2011 equaled 187,440 individuals. Production in YR 2011 was greater than the previous six years, and from YR 2005 onward there was a significant, positive trend in abundance ($p = 0.01$, $r = 0.87$, power = 0.87).

Production in YR 2011 was 15% below the previous 11 year average, and the observed reduction in YR 2011 compared to the previous 11 year average could be due to: 1) change in adult spawner distribution in the watershed, 2) simple decrease in the total number of spawners upstream of the trap site, or 3) a combination of factors 1 and 2. Flood type flows were ruled out because none occurred during spawning and egg development for the YR 2011 cohort. The probability that the decrease in abundance in YR 2011 was due to a change in the distribution of adult spawners in unlikely because abundance in lower Redwood Creek in YR 2011 was estimated at 147,719 individuals. Data in YR 2011 shows that more of the Chinook production occurred in the upper basin compared to the lower basin. The most plausible reason for the decrease in abundance in upper Redwood Creek in YR 2011 was a simple decrease in the number of returning adults. Although adult harvest is not allowed in Redwood Creek, the ocean salmon fishery in California does harvest an unknown number of adult Chinook salmon that belong to Redwood Creek. Therefore, scientific studies designed to determine the harvest and take of Redwood Creek Chinook salmon in the ocean fisheries are warranted.

The twelve year trend in population abundance over time showed a significant, negative decline, and on average there were about 31,000 less individuals each study year. The addition of flood type flows as a dummy variable in the regression model decreased the p value, increased the r value, and increased the power of the test. Thus, the best model describing the trend of 0+ Chinook salmon over time included study year (-) and whether or not there was a flood type flow (-) during the spawning season for a given cohort. Flood type flows in upper Redwood Creek occurred in YRS 2003, 2005, and 2006 (O'kane gaging station). Flood type flows in upper Redwood Cr can drastically reduce juvenile production, as evidenced by the cohort crash in YR 2003 ($N = 987$) and low production in YRS 2005 and 2006 ($N < 40,000$). Several investigators have shown that the scour of redds due to high streamflows or floods can often cause severe decreases in the production of juvenile salmonids (Gangmark and Bakkala 1960, McNeil 1966, Holtby and Healey 1986, Montgomery et al. 1996, Devries 1997, Schuett-Hames et al. 2000, Seiler et al. 2003, Don Chapman pers. comm. 2003, Greene et al. 2005); and that estimates of mortality attributable to high flows and redd scour can reach 90% (Schuett-Hames et al. 2000). Greene et al. (2005) were able to show that the flood recurrence interval (and magnitude of floods) during Chinook salmon intragravel development was the second most important variable in their models used to predict the return rate of adult Chinook salmon. They further report that "large flow events may be a key factor in regulating Chinook salmon populations in the Skagit River basin, Washington" (Greene et al. 2005). Three of the twelve current study years in upper Redwood Creek experienced flows capable of scouring spawning redds (or jostling the gravels/cobbles that make up the redds), a likely explanation for the poor production of each cohort the following spring. These high, potentially damaging stream flows in upper Redwood Creek are not uncommon; the recurrence interval is estimated to be around 3.1 years, a relatively small flood event for triggering widespread riffle and spawning gravel scour under normal circumstances (Randy Klein, pers. comm. 2008).

Subsequent to winter flows and emergence from redds, 0+ Chinook salmon migrated downstream nearly each day during the trapping period in YR 2011. Weekly peaks in population abundance during a given study year were relatively large, ranging from 22,004 – 165,782 individuals. In YR 2011 the peak in weekly abundance equaled 22,004 individuals, and occurred in late June/early July. The pattern in population abundance by month in YR 2011 compared to the previous eleven year average showed the temporal delay in migration in YR 2011. Abundance in July 2011 was 4.6 times greater than the average abundance in July, and abundance in August 2011 was 8 times greater than the average abundance in August. Peak monthly emigration occurred in May in YR 2011, compared to April for the previous eleven year average. The delay in peak monthly migration and the relatively higher emigration in July and August in YR 2011 were most likely attributable to higher than average stream flows during the trapping period. However, the two most important months in YR 2011 were April and May in YR 2011 (62% of total abundance) which were also the two most important months for the previous eleven year average (69% of total abundance). Population emigration during a given month can be quite large, reaching values up to 400,514 (April 2004), and in May 2011 population abundance equaled 61,934 individuals.

The 0+ Chinook salmon (ocean-type) migrants in upper Redwood Creek exhibit two different juvenile migratory life histories (fry and fingerling) based on size (FL, WT) and time of downstream migration. The fry (Avg. FL = 39 mm in YR 2011) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (Avg. FL = 62 mm in YR 2011) which have reared in the stream for a longer period of time prior to passing the trap site. Although there is some overlap in downstream migration, temporal differences in migration timing between the two life history forms are evident by the two peaks in migration. For example, the first weekly peak in population emigration in YR 2011 occurred during 4/30/11 – 5/06/11 (N = 21,904), and consisted mostly of fry (99%) with an average FL of 39 mm. A slightly larger peak occurred during 6/25/11 – 7/01/11 (N = 22,004) and primarily consisted of fingerlings (99%) with an average FL of 63 mm. The two noticeable weekly peaks or modes to the distribution in YR 2011 do not necessarily indicate two temporally different runs (spring vs. fall/winter) of adult Chinook salmon entered upper Redwood Creek because of great differences in FL or WT. If the modes represented two different runs of adults, we would expect the FL's during each peak to be nearly the same. In other words, if the second mode represented an entirely different group of adult fish, then their progeny should be smaller than what was observed due to differences in redd emergence timing (later timing and stream entry than the progeny for the first group of adults, assuming differences in intragravel water temperatures have a negligible affect on emergence timing), and the amount of time available to gain FL or WT in the stream (less time for growth if emerge from redds much later than the first group, assuming differences in water temperatures have a negligible affect on growth). A more likely explanation is that the fingerlings were born near the same time as the fry but further upstream; and grew in size as they remained in the stream and as they migrated downstream to be later captured. Some of the fingerlings could also have been fry born just upstream of the trap site that temporarily resided (upstream of the trap site) prior to downstream migration.

Large numbers of Chinook salmon fry emigrate soon after redd emergence in upper Redwood Creek, with percentages ranging from 33 – 69% of the total emigrant Chinook salmon population abundance per study year (excluding YR 2003). The percentages of juvenile Chinook salmon migrating as fry (62% of total or 115,428 individuals) and fingerlings (38% of total or 72,012 individuals) in YR 2011 were different than for the previous eleven year average, such that a higher proportion of fry and a lesser proportion of fingerlings were present in YR 2011. As expected, the proportion of fry and fingerlings present in YR 2011 was statistically non-random (eg different than a 50/50 ratio), and contrasted values for the previous eleven year average where nearly equal percentages of fry and fingerlings were determined.

Other streams besides Redwood Creek experience large migrations of Chinook salmon fry as well (Allen and Hassler 1986, Healey 1991, Taylor and Bradford 1993, Thedinga et al. 1994, Bendock 1995, Roelofs and Klatte 1996, Seiler et al. 2004, Greene et al. 2005, among others). Healey (1991) reported that it is common for Chinook salmon fry to migrate downstream soon after emergence, and cited at least five studies which documented this dispersal. Bendock (1995) reported ‘large’ numbers of post emergent fry were captured from the beginning of trapping in Deep Creek, Alaska, and Seiler et al. (2004) stated that about 53% (or 386,315 individuals) of the total juvenile Chinook salmon production (upstream of the trap site) migrated as fry in the Green River, WA. Unwin (1985) reported that 91 - 98% of the juvenile Chinook salmon emigrants were newly emerged fry in the Glenariffe stream, New Zealand; and Solazzi et al. (2003) show that Chinook salmon fry emigration in various Oregon streams can be substantial, numbering near one million individuals in the North Fork Nehalem River in YR 2002. Dalton (1999) determined that 93 - 98% of emigrating juvenile Chinook salmon migrated as fry in the Little North Fork Wilson River, Oregon, and similar percentages were found in the Little South Fork Kilchis River, Oregon. In contrast, Roper and Scarnecchia (1999) found only 10% of the juvenile Chinook salmon production emigrated at lengths < 50 mm FL in the South Umpqua River basin, Oregon.

Healey (1991) commented that fry are not surplus or lost production that will never augment future adult populations; therefore, I believe fry should be part of a juvenile Chinook salmon emigrant population estimate. Chinook salmon fry in upper Redwood Creek often appear smolt-like (very silvery, parr marks nearly absent or obscured to some degree by silver colored scales) and can undergo smoltification while migrating downstream from upstream spawning or rearing areas (Allen and Hassler 1986, Quinn 2005). In addition, Myers el al. (1998) summarize that ocean-type Chinook salmon fry can migrate immediately to the ocean in sizes ranging from 30 – 45 mm FL. Healey (1980), Carl and Healey (1984), Allen and Hassler (1986), and Healey (1991) also report that Chinook salmon fry can immediately migrate downstream to the estuary and ocean. Numerous authors also claim that estuaries are important areas for ocean-type fry to rear for some time period prior to ocean entry. However, by the time 0+ Chinook salmon pass by the trap in lower Redwood Cr (River Mile 4), about 19% of the total population in YR 2011 were fry (Sparkman 2012); when averaged over eight consecutive years, 7% of the 0+ Chinook salmon migrated as fry past the lower trap site. Clearly areas upstream of the trap site in upper Redwood Creek are important for adult Chinook salmon spawning; and by the time the juvenile Chinook salmon population are passing through lower Redwood Creek, most are in the fingerling (smolt) size category. Although fry to adult survival is likely less than that of fingerlings, some of the fry do survive to adulthood (Unwin 1997) and thus make a contribution to the adult population (Healey 1991). Supportive evidence of fry to adult survival is hard to find in the literature probably because most long lasting marks or tags are too big for fry, with the exception of coded wire tags (1/2 tags) and otolith marking (during egg incubation). The exact reasons (environmental, genetic, or some combination) why Chinook salmon fry migrate downstream immediately after redd emergence is worthy of additional study.

The average size (FL, Wt) of 0+ Chinook salmon emigrants in YR 2011 (51 mm, 1.68 g) was close in value to the average of the previous eleven years (54.5 mm, 2.05 g). 0+ Chinook salmon migrants from upper Redwood Creek are small in size, and most likely reflect the large numbers of fry that emigrate. The average size of 0+ Chinook salmon in YR 2011 passing by the trap in lower Redwood Creek was the lowest of record, and equaled 64 mm (FL), and 3.3 g.

1+ Chinook Salmon

1+ juvenile Chinook salmon (stream-type) in Redwood Creek represent the third juvenile Chinook salmon life history, and appear to be in very low abundance. Yearly catches ranged from 0 – 29 individuals, and in YRS 2000, 2004 – 2007, and YR 2011 zero were captured. The total number of 1+ Chinook salmon juveniles captured over twelve study years equaled 103 individuals, or 0.01% of the total juvenile Chinook salmon catch. Stream-type Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. For example, the average FL in April 2010 was 116 mm for 1+ Chinook salmon and 39 mm for 0+ Chinook juveniles.

When present, 1+ Chinook salmon from upper Redwood Creek are more likely to be progeny of fall/winter-run Chinook salmon adults than from spring-run adults (stream-type) because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (David Anderson, pers. comm. 2004). For example, in 23^{+} years of adult summer steelhead snorkel dives, adult spring Chinook salmon were only observed in one year (1988) and in very low numbers (< 7 individuals) (David Anderson, pers. comm. 2005). Additionally, stream flows during late spring/summer months can become so low that adult upstream passage into upper Redwood Creek can become problematic. High average stream temperatures (eg > 20 °C) and maximum stream temperatures (24+ °C or 75 °F) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. Thus, a spring run of Chinook salmon adults is probably not responsible for the production of yearling Chinook salmon juveniles in Redwood Creek. Bendock (1995) found both stream-type and ocean-type juvenile Chinook salmon in an Alaskan stream which only has one adult Chinook salmon race; and Connor et al. (2005) reported that fall Chinook salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history. Teel et al. (2000) found that for some populations of coastal Chinook salmon, ocean-type and stream-type juveniles were genetically undifferentiated, and probably arose from a common ancestor. They further report that the stream-type life history probably evolved after the ocean-type colonized (post glacial period) the rivers in study. An important question which may be unanswerable for Redwood Creek, is whether the one year old life history for juvenile Chinook salmon was more prevalent prior to the changes in the watershed associated with land use activities, flood events, and geomorphic processes. Perhaps with an increase in habitat quality we may see more 1+ Chinook salmon.

The 1+ Chinook salmon life history pattern in upper Redwood Creek may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (Don Chapman pers. comm. 2003, Sparkman 2011).

0+ Steelhead Trout

Considerable numbers of young-of-year steelhead trout migrate downstream from upper Redwood Creek during spring and summer months; over twelve consecutive study years we captured 833,520 individuals. In YR 2011 we captured 35,853 compared to catches of 9,864 in lower Redwood Creek (Sparkman 2012). 0+ steelhead trout were the most numerous juvenile salmonid captured in the trap in upper Redwood Creek in six out of twelve study years, and were also the most numerous age class migrant for juvenile steelhead trout in ten of the twelve current study years. In YR 2011, the ratio of 0+ steelhead trout catches to 1+ steelhead trout to 2+ steelhead trout at the population level was 19:14:1. Clearly, stream habitat upstream of the trap site is important for adult steelhead trout reproduction.

For the second year in a row, linear regression detected a significant, negative trend in catches over time. The catch in YR 2011 was about 51% less than the previous eleven year average. The overall decrease we observed over years could be due to a variety of factors: 1) changes in the number of adult steelhead spawning upstream of the trap site, 2) change in redd gravel conditions, 3) change in carrying capacity of stream habitat upstream of trap site, 4) decrease in the percentage of the total population that passively or actively migrates downstream, or 5) some combination of factors 1 - 4. The potential variable of trapping efficiency among study years would not account for the general decrease we observed in YR 2011 because the smolt trap was operated in the same manner as other study years (time of placement, use of weir panels, etc).

Most (87%) of the 0+ steelhead trout were captured in June and July (n = 31,036) in YR 2011, which were the same months for the majority of catches for the previous eleven year average (70% of total abundance, n = 50,951).

Average FL (36 mm) for 0+ steelhead trout in YR 2011 was the second lowest of record, and corresponded to a parr life history stage. The average size of 0+ steelhead trout captured in lower Redwood Creek in YR 2011 equaled 57 mm (Sparkman 2012).

I doubt that a large majority of the 0+ steelhead population that out-migrates prior to late summer low-flow periods can be viewed as surplus or lost production, which will not augment future adult steelhead populations. Meehan and Bjornn (1991) state that some steelhead populations normally out-migrate soon after emergence from redds to occupy other rearing areas, and I believe we observe this in Redwood Creek as well. Our experiments of marked 0+ steelhead trout released at the upper trap and recaptured 29 miles downstream in lower Redwood Creek in YRS 2006 and 2007 offered direct evidence that 0+ steelhead trout may travel considerable distances in search of suitable rearing areas. In streams that are temperature impaired (many if not most in Humboldt County, CA are, including Redwood Creek; see CWA List, 2002), out-migration prior to times when streams or sections of streams reach high (or maximum) temperatures (July/August) or dry up can be viewed as an advantageous life history strategy.

1+ Steelhead Trout

Fairly large numbers of 1+ steelhead trout emigrate from upper Redwood Creek during the spring/summer emigration period. Population emigration from YRS 2000 – 2010 ranged from 26,176 – 68,030 and averaged 36,443 individuals. Population emigration in YR 2011 (N = 26,612) was 27% less than the previous eleven year average. The population of 1+ steelhead trout declined over the twelve study years; linear correlation detected a significant negative trend in 1+ steelhead trout population abundance over time ($p < 0.10$), which indicated that fewer 1+ steelhead trout were emigrating each year compared to previous years. The best model describing the trend in abundance over time included study year and whether or not there were flood type flows in the upper basin each study year ($p = 0.01$). The relationship with flood type flows was negative, and may indicate poor overwinter survival when stream flows reach a critical threshold (cfs > 6,000) in mid to upper Redwood Creek. Redwood Creek follows a fault for many miles, and this fault limits the amount and degree of channel meandering and formation of off channel refugia (alcoves, backwaters, etc.). In addition, the lack of large woody debris limits over wintering habitat.

In addition to differences in population abundance among study years, there were temporal differences in monthly emigration in YR 2011 compared to the previous eleven year average. The most important month for migration was April in YR 2011, compared to May for the previous eleven year average, and the two most important months for migration were April and June in YR 2011, compared to April and May for the previous eleven year average. Population emigration during a given month can be quite large, reaching values up to 32,524 (May 2000). In contrast to previous study years, abundance in July 2011 was 2.8 times greater than the previous eleven year average. The prolonged migration observed in YR 2011 was most likely due to higher than average stream flow during the study period (similar to YR 2010), compared to historic values and previous study years (excluding YR 2010). The peak in weekly abundance in YR 2011 also occurred later than previous study years (6/25-7/01, N = 3,509).

The average size (FL, Wt) of 1+ steelhead trout was close in value to the average of the previous eleven years, however, the trend in size over 12 consecutive study years significantly declined. The average size of 1+ steelhead trout migrants over twelve years was positively related to population abundance, which indicates that with greater abundance for a given cohort, their average size is larger. This in turn suggests that carrying capacity has not been met because the yearlings are able to gain additional FL and Wt even under larger population abundances.

Information in the literature indicates steelhead smolting at age 1 is not uncommon, particularly in streams that are south of British Columbia (Quinn 2005, Busby et al. 1996). The percentage of 1+ steelhead trout showing parr characteristics in Redwood Creek was low each study year (0.0 - 19%; Avg = 1.8%), and indicated that few 1+ steelhead trout migrated downstream in a stream-residence form (parr). In contrast, the majority of 1+ steelhead trout (81 – 100%; Avg = 98.2%) in a given study year were emigrating in a pre-smolt and smolt stage. In YR 2011, 88% of the 1+ steelhead trout migrated downstream as smolts. Given more data years, we may continue to find relationships between developmental stages and physical variables measured in the stream. For example, I found that the percentages of 1+ steelhead trout showing smolt characteristics each year (YRS 2000-08) in upper Redwood Creek were negatively related to stream temperatures ($n = 9$, $p < 0.05$) (Sparkman 2010). Quinn (2005) reported both photo period and steam temperature play important roles in smoltification by providing an external stimulus for the endocrine system, which in turn drives the internal physiological changes necessary for smoltification.

1+ steelhead trout are actively migrating from the upper basin to the lower basin as evidenced by trap catches in lower Redwood Creek of efficiency trial fish and pit tagged fish released from the upper trap site. The marked 1+ steelhead trout emigrating from upper Redwood Creek and through lower Redwood Creek have also been captured in the estuary (Dave Anderson, pers. comm. 2011) since the beginning of our smolt trapping studies. 1+ steelhead trout marked and released at the lower trap (for trap efficiencies) have also been captured in the estuary each study year (Dave Anderson, pers. comm. 2011). We have not observed re-migration of 1+ steelhead trout into lower or upper Redwood Creek based upon elastomer marked releases in YR 2001 (n = 374), YR 2004 (n = 577), and YR 2005 (n = 146); and pit tagged releases in YRS 2005 (n = 46), 2006 (n = 246), 2007 (n = 484), 2008 (n = 203), 2009 (n = 417), and 2010 (n = 260). All 2+ steelhead trout captured by the traps were inspected for marks and scanned for pit tags, which would have been applied at age-1. These tests confirmed that the elastomer marked and pit tagged fish did not migrate back upstream to rear for another year and emigrate as age-2 steelhead trout smolts. Elastomer mark retention was assumed to be adequate for the studies because Fitzgerald et al. (2004) assessed elastomer mark retention in Atlantic salmon smolts and found that tag retention in the lower jaw was greater than 90% for the first 16 months. Pit tag retention was also assumed to be sufficient based upon a study by Newby et al. (2007).

Each study year the population of 1+ steelhead trout emigrating from upper Redwood Creek was far larger than 2+ steelhead trout population emigration. The ratio of 1+ to 2+ steelhead trout in YRS 2000 - 2010 ranged from 4:1 to 18:1 and averaged 10:1; in YR 2011 the ratio was 14:1. In lower Redwood Creek, the ratio of 1+ to 2+ steelhead trout was 3.7:1, and in Prairie Creek was 3.1:1 (Sparkman 2012). 1+ steelhead trout downstream migration is not unique to Redwood Creek, and other downstream migration studies have routinely documented 1+ steelhead trout emigration (USFWS 2001; Ward et al. 2002; Ward et al. 2003; Johnson 2004; Bill Chesney pers. comm. 2006, among many others).

Based upon studies in other streams, the number of returning adult steelhead trout that went to the ocean as one-year-old smolts is relatively low, and usually less than 23% (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, McCubbing 2002; McCubbing and Ward 2003). Based upon a limited number of scale samples from adult steelhead trout in Redwood Creek, 30% of the adults entered the ocean as one-year-old juveniles in YR 2006/07. More recently, data collected from adults in YR 2007/2008 showed that 50% of the adults had entered the ocean as a one year old smolt, and in YR 2008/09 the percentage equaled 40%. CDFG AFRAMP is currently collecting scale samples from adult steelhead to increase sample size (author, in progress). The percentage of adult steelhead trout that smolt and enter the ocean at age-1, and the reason(s) for the relative large number of 1+ steelhead trout emigrating from the basin of Redwood Creek warrants further investigation. Our pit tagging experiments with 1+ steelhead smolts should provide useful insights when conducted over multiple consecutive years because if most of the 1+ steelhead trout are not actually entering the ocean, we should then be able to recapture a given percentage of those fish the following year with the rotary screw trap in lower Redwood Creek and seine nets in the estuary; if we fail to recapture any of the marked 1+ steelhead trout the following year, then a logical conclusion would be that the fish either stayed in the stream and suffered severe mortality during winter, actually entered the ocean, or some combination of the two factors. To date, we have not recaptured any 2+ steelhead trout that were marked as 1+ steelhead trout the previous year. Thus, our data is showing, in combination with adult scale analyses, that 1+ smolts are entering the ocean at age-1.

I hypothesize that 1+ (and 0+) steelhead trout have changed their life history to limit the time spent in freshwater in order to avoid high, and at times, lethal stream temperatures that occur during summer months. In YR 2006 we observed and documented lethal stream temperatures in upper Redwood Creek, and every summer in late July we observe maximums in stream temperatures that range from 24.4 – 29.5 ^{o}C (or 75.9 – 85.1 ^{o}F) (Sparkman 2011). In addition, stream flow during summer months is very low, which decreases the amount of space available for rearing. Over-summer conditions, particularly in mid to late July, could be limiting the production of older age classes (2+ steelhead trout) in Redwood Creek. However, we may see decreases in sedimentation and stream temperatures due to restoration activities in the basin and natural processes, which in turn should provide more suitable over-summer conditions for 0+ and 1+ steelhead trout.

2+ Steelhead Trout

In several studies investigating steelhead trout life histories, the majority of the returning adult steelhead spent two or more years as juveniles in freshwater prior to ocean entry (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, Smith and Ward 2000; McCubbing 2002). For example, Pautzke and Meigs (1941) reported that 84% of returning adult steelhead in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult steelhead they examined had spent two or more years in freshwater prior to entering the ocean, McCubbing (2002) reported 92% of steelhead adults in a British Columbia stream had spent two or more years as juveniles in freshwater, and McCubbing and Ward (2003) reported that 71% of the adult returns in YR 2003 had entered the ocean as 2 or 3 year old smolts. If this applies to steelhead trout in Redwood Creek, then 2+ steelhead trout are the most important (and most direct) group of juvenile steelhead trout that contribute to future adult steelhead trout populations. The paradox for the 2+ steelhead trout smolt in upper Redwood Creek is that they were far less abundant (by about 74 - 94%) than 1+ steelhead trout smolts in any given study year. With respect to the combined population of 1+ and 2+ steelhead trout smolts each year, 2+ steelhead trout comprised 5 – 20% of the population. The ratio of 2+ steelhead trout to 1+ steelhead trout in YR 2011 equaled 0.07:1.

The population abundance of 2+ steelhead trout in YR 2011 was the second lowest of record, and about 57% less than the average abundance over the previous eleven years. The average population abundance over 12 years equaled 4,237 individuals. The trend in population abundances over twelve study years was significantly negative ($p = 0.02$). Thus, the 2+ steelhead trout populations are decreasing over time, and on average, there were about 564 less individuals each study year. This significant, negative trend was first detected in YR 2007 ($n = 8$ years of data), and has been significantly negative ($p < 0.10$) ever since. The addition of flood type flows as a dummy variable in the trend regression decreased the p value ($p = 0.001$), increased the r value, and increased the power of the test. Thus, the best model describing the trend of 2+ steelhead trout population abundance over time included study year (-) and whether or not there was a flood type flow (-) during the winter for a given cohort prior to migrating downstream in spring/summer months. One possible explanation is that during winter flood type flows there may be less suitable habitat (alcoves, backwaters, side channels, etc.) available for rearing and survival.

2+ steelhead trout monthly population emigration in YR 2011 was less than monthly emigration for the previous eleven year average except for the month of July. Similar to

YR 2010 data, the majority of smolts in YR 2011 migrated downstream during April and July (65% of total emigration), which contrasted the pattern for the previous eleven year average when April and May were the two most important months. Monthly migration in YR 2011 peaked in July, and was 2.3 times greater than the average abundance in July. The peak in weekly migration in YR 2011 occurred in July, which was much later than peaks in previous study years, with exception to YR 2010 when weekly abundance also peaked in July. These late peaks were most likely attributable to the higher stream discharge and cooler stream temperatures which occurred in YR 2010 and YR 2011. Usually, greater numbers of 2+ steelhead trout emigrated earlier in the trapping season when stream discharge was greater (due to increases in discharge) and stream temperatures were cooler compared to later in the season (April and May).

The average size (FL, Wt) of 2+ steelhead trout in YR 2011 was less than values for the previous eleven year average, however these differences are unlikely to be biologically meaningful because the smolts could grow as they migrate downstream and reside in the estuary. Similar to 1+ steelhead trout, the average size of 2+ steelhead trout smolts has significantly declined over the twelve study years. Since size is correlated with survival to adult, the decrease in size over years along with a decrease in smolt abundance, could limit the number of returning adults.

The percentage of 2+ steelhead trout showing parr characteristics was zero each study year, and indicated 2+ steelhead trout do not emigrate from upper Redwood Creek in a parr stage (stream resident form). Rather, most of the 2+ steelhead trout are emigrating in a smolt form. The percentage of 2+ steelhead trout emigrants showing smolt characteristics in YR 2011 (99.7%) was greater than most study years, and only 0.3% were classified as pre-smolts. The percentages of 2+ steelhead trout showing smolt characteristics over the twelve current years of study were negatively related to population abundances, and negatively related to average stream temperatures during the trapping periods (data not provided in report). Thus, there were less smolt designations for higher population abundances and during study periods with higher stream temperatures. Quinn (2005) reported that stream temperatures play an important role in smoltification, and our data from the upper basin showed that 53% of the variation in smolt percentages over twelve study years can be attributed to the variation in stream temperatures.

2+ steelhead trout are actively emigrating from upper Redwood Creek through lower Redwood Creek because the trap in lower Redwood Creek (RM 4) has consistently captured efficiency trial fish each study year. Additionally, 2+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of our smolt trapping studies (Dave Anderson, pers. comm. 2011). Elastomer marked 2+ steelhead trout released at the upper trap in YRS 2004 and 2005 were also captured by the lower trap in those years. More recently we have been applying pit tags to 2+ steelhead trout in the upper basin (eg YR 2009 n = 29; YR 2010 n = 22), and none were recaptured as three years old the following year(s). The lack of large numbers of 3+ steelhead trout captured in upper Redwood Creek provides more evidence that 2+ steelhead trout are actively migrating to the ocean, rather than re-distributing to later migrate to the ocean at age 3.

Although there seems to be few studies that specifically look at steelhead smolt to adult survival, steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive linear relationship between out-migrating 2+ smolts and returning adult steelhead (Ward and Slaney 1988; Ward 2000, Ward et al. 2002). Ward (2000) cites other authors who report similar, positive linear relationships between smolts and adults along the British Columbia coast as well (eg Smith and Ward 2000). Survival from smolt to adult can be variable, and may range from an average of 15% (during 1976-1989) to an average of 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where steelhead must overcome dams and travel long distances to reach spawning grounds. It is difficult to make specific inferences about 2+ steelhead trout smolt to adult survival for upper Redwood Creek populations based upon successful studies in the literature because of differences in latitude/longitude, geography, ocean conditions (physical and biological), estuaries, and trap locations in the watershed. However, the belief that the number of 2+ smolts relates to future adults (and watershed conditions) is hard to dismiss or invalidate.

With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead trout is unavailable, un-attainable, or inaccurate. 2+ steelhead trout have overcome the numerous components of stream survival that younger steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc), and 2+ steelhead smolts are the most direct, juvenile recruit to adult steelhead populations. The 2+ steelhead trout are also an excellent indicator of watershed and stream conditions because they spend the longest amount of time in freshwater habitat. Along these same lines, Ward et al. (2003) reported that the 2+ steelhead smolt was a more reliable response variable with respect to stream restoration than late summer juvenile densities because of being less variable.

0+ Pink Salmon

Pink salmon in California are recognized as a “Species of Special Concern” by CDFG, and California is recognized as the most southern border for the species (CDFG 1995). Although not in large numbers, pink salmon have been historically observed in the San Lorenzo River, Sacramento River and tributaries, Klamath River, Garcia River, Ten Mile River, Lagunitas River, Russian River, American River, Mad River, and once in Prairie Creek, which is tributary to Redwood Creek at RM 3.7. Pink salmon were observed spawning in the Garcia River in 1937, and the Russian River in 1955 (CDFG 1995). Adult pink salmon were seen spawning in the Garcia River in 2003 (Scott Monday pers. comm. 2004) and in Lost Man Creek (tributary to Prairie Creek) in 2004 (Baker Holden, pers. comm. 2005). More recently, adult pink salmon were observed and photographed in sections of Redwood Creek during the fall of 2010 by Redwood Creek National Park Fisheries Biologists (Dave Anderson, pers. Com. 2010).

I know of no historic records or anecdotal information documenting pink salmon presence in Redwood Creek prior to our downstream migration trapping efforts. The pink salmon in upper Redwood Creek are in very low numbers, and were only captured in YRS 2000, 2002, 2004, 2005, 2008, and 2011. The total catch over study years equaled 23 individuals. Based upon trap catches, adult pink salmon spawned in odd and even years, with most catches corresponding to adult returns in odd numbered years.

It is hard to say if the parents of the juvenile pink salmon were strays or remnants of a historic run because so little information exists about adult salmon in Redwood Creek. I hypothesize that the pink salmon are remnants of a historic run because they have been captured in more years than what random straying would account for. According to the Habitat Conservation Planning Branch (HCPB) of CDFG, pink salmon are considered to be "probably extinct" in California (CDFG 1995). However, the HCPB does state that "more efforts need to be conducted to prove (or disprove) that reproducing populations exist anywhere in California" (CDFG 1995). Based upon our trapping data from upper Redwood Creek, it appears that pink salmon are occasionally present and reproducing, albeit in low numbers.

Coho Salmon

One of the greatest discoveries in YR 2007 was the capture of six young-of-year coho salmon for the first time in eight consecutive years of study. Prior to YR 2007, we captured, observed, and counted 1.37 million juveniles without a single juvenile coho salmon observation. In previous reports I mentioned that we should occasionally see at least a small number of juvenile coho salmon from adults that strayed upstream from downstream tributaries or mainstem reaches. In YR 2008, the greatest discovery was the capture of seven 1+ coho salmon and 32 0+ coho salmon. The capture of 1+ coho salmon was the first time in nine consecutive years, and indicates that freshwater conditions were sufficient enough to allow some of 0+ coho salmon in YR 2007 to successfully survive the summer and winter periods. Coho salmon are still considered to be a rare occurrence in upper Redwood Cr in recent times, and in YR 2011 we did not capture any juvenile coho salmon. We did capture juvenile coho salmon in YR 2011 passing through lower Redwood Creek at Rm 4. Population abundance for 0+ coho salmon in lower Redwood Creek equaled 884, and for 1+ coho salmon smolts equaled 113 (Sparkman 2012). The adult spawning surveys conducted in Redwood Creek have failed to observe any adult coho salmon on redds in Redwood Creek excluding Prairie Creek, even though the smolt trapping in lower Redwood Creek proves that they are present, albeit in low numbers. Low population abundances of adult coho salmon and the patchiness of their distribution make it difficult for a randomized designed redd survey to encounter adult coho salmon in Redwood Creek. In addition, spawning surveys in the mid to upper basin can only be conducted when stream flows are less than 200 cfs, which on average, occur only 9% of the time from November – March of a given year (USGS 2011). Unfortunately, all of the surveyable days, based upon historic flow information, occurred in November. Adult coho salmon are known to return to Redwood Creek in the months of November – January, and in some years as late as February. Thus, redd surveys in the mainstem of Redwood Creek have a low likelihood of detecting adult coho salmon. I recommend that other techniques (such as snorkeling sections of streams and tributaries in the summer months) be used for delineating the spatial distribution of coho salmon in Redwood Creek. In addition, if the redd surveys fail to observe coho salmon on redds, then that finding should not support zero occurrence when smolt trapping shows otherwise.

Coho salmon were historically present in areas upstream of the trap site based upon observations by Marlin Stover and Bill Chezum (long time residents in Redwood Valley, pers. comm. 2000 and 2001). I talked with both Marlin and Bill about coho salmon distribution in upper Redwood Creek. Bill Chezum (pers. comm. 2001, he has since passed away) observed schools of adult coho salmon in areas upstream of the current trap site while growing up in Redwood Valley. He particularly mentioned seeing coho in the 1940's and early 1950's. Every year he watched the fish swim past him in schools during their spawning run, and around the time of the 1955 flood event, the coho seemingly disappeared. Marlin Stover (pers. comm. 2000), who is also a long time resident in Redwood Valley, corroborates Bill Chezum's observations of adult coho in upper Redwood Creek. Minor Creek, a tributary to Redwood Creek upstream of the trap site, supposedly supported runs of coho salmon. Lacks Creek, a tributary to Redwood Creek downstream of the trap site by about 9 miles, currently supports coho salmon (Bill Jong, pers. comm. 2003; CDFG 1953); and Prairie Creek (tributary to Redwood Creek at about RM 3.7) supports a fairly stable population of coho salmon. Prior to our catches in YR 2007, the most recent citing of juvenile coho salmon upstream of the trap site occurred in 1997 (Tom Weseloh, pers. comm. 2003).

The next important observation for juvenile coho salmon in upper Redwood Creek will be whether they will return and persist over time, which will be evidenced by trap captures. Optimistically, we may document the return of coho salmon populations in upper Redwood Creek. We plan on taking genetic samples from juveniles, if present, to determine how many adults were responsible for the juveniles we captured using mitochondrial DNA analysis techniques.

Cutthroat Trout

A low number of cutthroat trout were captured in all eleven previous study years (< 13 individuals each year, total = 52), and only four individuals were captured in YR 2011. All cutthroat trout that were captured were in a smolt stage. An unknown number or percentage of cutthroat trout will residualize in the stream for varying years, and not out-migrate to the estuary and ocean; thus the low trap catches may not necessarily reflect a low population size in upper Redwood Creek. However, if there were large numbers present, we would probably catch much more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture hundreds of cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy, pers. comm. 2010), and in YR 2011 a total of 1,198 cutthroat trout were captured in the smolt trap in lower Prairie Creek (Duffy and Sparkman, In progress).

We did not consider any of the young-of-year steelhead trout to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured in any given year (average 5 per year). Upper Redwood Creek has far more older juvenile steelhead trout (1+ and 2+) than cutthroat trout as evidenced by trap catches. In the twelve study years, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year ranged from 349:1 to 7,881:1, and using data from all years (pooled) equaled 1,943:1. The ratio in YR 2011 was 1,265:1. Ratios would be even higher if juvenile steelhead trout population data were used instead of catch data. It seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the juvenile trout captures. Therefore, we considered the percentage of 0+ cutthroat trout included in the 0+ steelhead trout catch to be low and negligible.

We used three characteristics to identify coastal cutthroat trout: upper maxillary that extends past the posterior portion of the eye, slash marks on the lower jaws, and hyoid teeth; spotting is usually more abundant on coastal cutthroat trout as well. Kennedy et al. (2009) reported that field misclassifications of smolts as steelhead or cutthroat trout were low, with values of 1% for steelhead trout and 2% for cutthroat trout. Hybrid juveniles, the product of mating between steelhead trout and cutthroat trout, are commonly noted to be missing one or two of these characters, or having a combination of cutthroat trout and steelhead trout characters (Kennedy et al. 2009). We have observed four individuals in the twelve study years that could have been hybrid juveniles. Thus, out of 108,842 1+ and 2+ steelhead trout catches, only 0.004% appeared to show hybrid characteristics. Based upon visual identification, the number of potential hybrids (age 1 and greater) is extremely rare in upper Redwood Creek.

Stream Temperatures

Similar to past study years, average daily stream temperature in YR 2011: 1) significantly increased over the study period, 2) was negatively related to stream discharge, and 3) was negatively related to stream gage height at the trapping site. The average daily stream temperature (truncated) (12.8 ^{o}C) during the trapping period in YR 2011 was the second lowest of record, most likely due to the increased stream discharge during the trapping period compared to previous study years. Average daily stream temperature over the eleven years of data collection significantly decreased over years, as did the average daily stream temperature in July.

The maximum stream temperature occurred in late July which was normally when the stream temperatures reached maximum values in past study years. However, maximum stream temperatures in YRS 2011 and 2010 (24.4 °C) were much lower than previous study years due to increased discharge in YRS 2011 and 2010. In past years, most of the migration was over by the time stream temperatures reached maximum values in late July. However in YRS 2010 and 2011, migration was comparatively much higher in July because of increased stream discharge. In general, emigration prior to times when streams or sections of streams reach high or maximum temperatures (July/August) can be viewed as an advantageous life history strategy, and one that juvenile salmonids in upper Redwood Creek may employ.

RECOMMENDATIONS

This study is one of the few studies that is designed to document smolt abundance and population trends of the California Coastal Chinook salmon ESU, Southern Oregon/Northern California Coasts Coho salmon ESU, Northern California Steelhead Trout ESU, and Southern Oregon/California Coasts Coastal Cutthroat Trout ESU over a relatively long time period. With respect to the Chinook salmon ESU, this study might be the only one that provides population data for a relatively large stream.

The most important recommendation to make is to continue this study over multiple consecutive years (20+) in order to:

1. Encompass as much environmental and biological variation as possible, including changes attributable to climate change.

2. Cover multiple cohort life cycles over time.

3. Collect baseline data for future comparisons.

4. Collect data on juvenile salmonid life histories in upper Redwood Creek, which will increase our understanding of juvenile salmonids (smolts).

5. Detect changes in population abundance which can be used to assess the status and trends of Chinook salmon, steelhead trout, and coho salmon in upper Redwood Creek.

6. Detect any fish response (population, fish size, age class composition, etc) to stream and watershed conditions, and restoration activities in the upper basin.

7. Help focus habitat restoration efforts and needs in the basin.

8. Install a DIDSON sonar unit in upper Redwood Creek to count returning adult salmon and steelhead trout in order to more fully assess freshwater conditions, and to assess freshwater/marine survival.

This study, when combined with juvenile salmonid monitoring efforts in the lower basin (smolt trap in lower Redwood Creek at RM 4, Prairie Creek, and estuarine studies) will also help determine potential bottlenecks to anadromous salmonid production in Redwood Creek.

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LITERATURE CITED

Allen MA, and TJ Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest): Chinook salmon. US Fish and Wildlife Service Biological Report 82 (11.49). US Army Corps of Engineers, TR EL-82-4, 26 p.

Bendock T. 1995. Marking juvenile Chinook salmon in the Kenai River and Deep Creek, Alaska, 1993-1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-17, Anchorage. 34 p.

Bisson PA, and JR Sedell. 1984. Salmonid populations in streams in clearcut vs. old-growth forests of western Washington. Pages 121-129 *in* WR Meehan, TR Merrell, Jr., and TA Hanley, editors. Proceedings, fish, and wildlife relationships in old-growth forests symposium. American Institute of Fishery Research Biologists, Asheville, NC.

Bradford MJ, RA Myers, and JR Irvine. 2000. Reference points for coho salmon (*Oncorhynchus kisutch*) harvest rates and escapement goals based on freshwater production. Canadian Journal of Fisheries and Aquatic Sciences 57:677-686.

Brown R. 1988. Physical rearing habitat for anadromous salmonids in the Redwood Creek basin, Humboldt County, California. MS thesis, Humboldt State University, Arcata, California. 132 p.

Busby PJ, TC Wainwright, GJ Bryant, LJ Lierheimer, RS Waples, FW Waknitz, and IV Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-27, 261 p.

Carlson SR, LG Coggins Jr., and CO Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5(2):88-102.

Cashman SM, HM Kelsey, and DR Harden. 1995. Geology of the Redwood Creek Basin, Humboldt County, California. Pages B1 – B13 *in* KM Nolan, HM Kelsey, and DC Marron, editors. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. US Geologic Survey Professional Paper 1454.

[CDFG] California Department of Fish & Game. 1953. Lacks Creek stream survey. Call number 3496.

[CDFG] California Department of Fish and Game. 2004. North Coast Watershed Assessment Program, http://www.ncwatershed.ca.gov/

[CDFG] California Department of Fish and Game. 1995. Habitat Conservation Planning Branch, Fish Species of Special Concern in California, Pink Salmon. http://www.dfg.ca.gov/hcpb/cgi-bin/read_one.asp?specy=fish&idNum=58

[CWA] California Water Act. 2002. CWA section 303(d) list of water quality limited segment; approved by the State Water Resources Control Board, February 4, 2003.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Contribution No. 543, College of Fisheries, University of Washington, Seattle, Washington. 35 p.

Cleary JS. 2001. Increasing coho productivity in the Chilliwack River Watershed. Pages 1 – 6 *in* Watershed Restoration Technical Bulletin Streamline, Vol. 6 No.1, 20 p.

Connor WP, JG Sneva, KF Tiffan, RK Steinhorst, and D Ross. 2005. Two alternative juvenile life history types for fall Chinook salmon in the Snake River Basin. Transactions of the American Fisheries Society 134:291-304.

Dalton TJ. 1999. Juvenile salmonid outmigration in the Little North Fork Wilson and Little South Fork Kilchis Rivers, 1998-1999. Oregon Department of Fish and Wildlife, Annual Report, Corvallis, Oregon. 15 p.

Devries P. 1977. Riverine salmonid egg burial depths: review of published data and implications for scour studies. Canadian Journal of Fisheries and Aquatic Sciences 54:1685-1698.

Duffy WG and MD Sparkman. In progress. Smolt abundance in Prairie Creek in YR 2011, Humboldt County, CA

Ebersole, JL, ME Colvin, PJ Wigington, SG Leibowitz, JP Baker, MR Church, JE Compton, BA Miller, MA Cairns, BP Hansen, HR LaVigne. 2009. Modeling stream network-scale variation in coho salmon overwinter survival and smolt size. Transactions of the American Fisheries Society 138:564-580.

Federal Register. 1997. Endangered and Threatened Species: Threatened status for coho salmon in the Southern Oregon/Northern California Coast Evolutionarily Significant Unit in California. Federal Register, Washington D.C. 62: 24588 – 24609.

Federal Register. 1999a. Endangered and Threatened Species: Threatened status for two Chinook Salmon Evolutionarily Significant Unit in California. Final Rule. Federal Register, Washington D.C. 64: 50394 – 50415.

_____________ 1999b. Endangered and Threatened Status for Southwestern Washington/Columbia River Coastal cutthroat trout in Washington and Oregon, and delisting of Umpqua River cutthroat trout in Oregon: Proposed Rule. Federal Register, Washington D.C., 64: pps 16397-16413.

Federal Register. 2000. Endangered and Threatened Species: Threatened status for one steelhead Evolutionarily Significant Unit in California. Federal Register, Washington D.C. 65: 36074 – 36094.

Fitzgerald JL, TF Sheehan, and JF Kocik. 2004. Visibility of visual implant elastomer tags in Atlantic Salmon reared for two years in marine net-pens. North American Journal of Fisheries Management 24: 222-227.

Gangmark HA, and RG Bakkala. 1960. A comparative study of unstable and stable (artificial channel) spawning streams for incubating king salmon at Mill Creek. California Fish and Game. 46:151-164.

Giannico GR, and SG Hinch. 2003. The effect of wood and temperature on juvenile coho salmon winter movement, growth, density, and survival in side-channels. River Research and Applications 19:219-231.

Greene CM, DW Jensen, GR Pess, EA Steel, and E Beamer. 2005. Effects of environmental conditions during stream, estuary, and ocean residency on Chinook salmon return rates in the Skagit River, Washington. Transactions of the American Fisheries Society 134:1562-1581.

Hartman GF, and JC Scrivener. 1990. Impacts of forest practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences. 223 p.

Healey MC. 1991. Life history of Chinook Salmon (*Oncorhynchus tshawytscha*). Pages 313 – 393 *in* C. Groot and L. Margolis (eds.). Pacific Salmon life histories. UBC Press, University of British Columbia, Vancouver BC.

__________1980. Utilization of the Nanaimo River estuary by juvenile Chinook salmon, *Oncorhynchus tshawytscha*. Fishery Bulletin Vol. 77, No. 3, 653-668.

Hicks BJ, JD Hall, PA Bisson, and JR Sedell. 1991. Responses of salmonids to habitat changes. Pages 483 – 518 *in* WR Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Hintze J. 1998. Number Crunchers Statistical System. NCSS 97, Version 6.0.

Holtby LB**,** and MC Healey. 1986. Selection for adult size in female coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 43:1948-1959.

Johnson S. 2004. Summary of habitat and fish monitoring data from East Fork and Upper Mainstem Lobster Creeks 1988: 2004. Western Oregon Research and Monitoring Program, Oregon Department of Fish and Wildlife, 13 p.

Kelsey HM, M Coghlan, J Pitlick, and D Best. 1995. Geomorphic analysis of streamside landslides in the Redwood Creek Basin, Northwestern California. Pages J1 - J12 *in* KM Nolan, HM Kelsey, and DC Marron, editors. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. US Geologic Survey Professional Paper 1454.

Kennedy BM, J. Baumsteiger, WL Gale, WR Ardren, and KG Ostrand. 2009. Morphological, physiological, and genetic techniques for improving field identification of steelhead, coastal cutthroat trout, and hybrid smolts. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:45-56.

Madej MA, and V Ozaki. 1996. Channel response to sediment wave propagation and movement, Redwood Creek, California, USA. Earth Surface Processes and Landforms, Vol. 21, 911 – 927.

Maher FP and PA Larkin. 1955. Life history of the steelhead trout of the Chilliwack River, British Columbia. Transactions of the American Fisheries Society 84:27-38.

McCubbing D. 2002. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C. during Spring 2002. Habitat Conservation Trust Fund. Contract Number: CBIO3006. Province of British Columbia, Ministry of Water, Land, and Air Protection, Biodiversity Branch, Fisheries Research and Development, University of British Columbia, Vancouver, BC. 34 p.

McCubbing DJF, and BR Ward. 1997. The Keogh and Waukwaas rivers paired watershed study for B.C.'s Watershed Restoration Program: juvenile salmonid enumeration and growth 1997. Province of British Columbia, Ministry of Environment, Lands and Parks, and Ministry of Forests. Watershed Restoration Project Report No. 6:33 p.

McCubbing D, and B Ward. 2003. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C., during winter and spring. Habitat Conservation Trust Fund Contract No: CBIO4051. Province of British Columbia, Ministry of Water, Land and Air Protection, Biodiversity Branch, Aquatic Ecosystem Science Section, University of British Columbia, Vancouver, B.C. V6T1Z4. 51 p.

McNeil WH. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. Fishery Bulletin Volume 65, Number 2. Contribution Number 198. College of Fisheries. University of Washington, Seattle.

Meehan WR, and TC Bjornn. 1991. Salmonid distributions and life histories. Pages 47-82 *in* W.R. Meehan (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19, American Fisheries Society. Bethesda, MD.

Montgomery DR, JM Buffington, NP Peterson, D Schuett-Hames, and TP Quinn. 1996. Streambed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53:1061-1070.

Myers, JM, RG Kope, GJ Bryant, D Teel, LJ Lierheimer, TC Wainwright, WS Grand, FW Waknitz, K Neely, ST Lindley, and RS Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

National Oceanic and Atmospheric Administration (NOAA). 1999. Fact Sheet: West Coast Coho Salmon (*Oncorhynchus kisutch*). 2 p.

NCSS. Number Crunchers Statistical Software. 1997. Jerry Hintze.

Newby NC, TR Binder, and ED Stevens. 2007. Passive integrated transponder tags (PIT) tagging did not negatively affect the short-term feeding behavior or swimming performance of juvenile rainbow trout. Transactions of the American Fisheries Society 136:341-345.

Nickelson T. E. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon Production Area. Canadian Journal of Fish and Aquatic Sciences 43: 527-535.

Pautzke CF, and RC Meigs. 1941. Studies on the life history of the Puget Sound steelhead trout (*Salmo Gairdnerii*). Transactions of the American Fisheries Society, 70:209-220.

Quinn TP, and NP Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53:1555-1564.

Quinn TP. 2005. The behavior and ecology of pacific salmon and trout. American Fisheries Society, Bethesda Maryland in association with University of Washington Press, Seattle, 378 p.

Redwood National and State Parks (RNP). 1997. Redwood Creek Watershed Analysis. In house, 91 p.

Roelofs TD, and B Klatte. 1996. Anadromous salmonid escapement and downstream migration studies in Prairie Creek, California, 1995-1996. Report for the California Department of Transportation, Sacramento, California. 18 p.

Roelofs TD, and MD Sparkman. 1999. Effects of sediments from the Redwood National Park bypass project (CALTRANS) on anadromous salmonids in Prairie Creek State Park 1995-1998. Final report to the California Department of Transportation, contract No. 001A0162. Department of Fisheries, Humboldt State University, Arcata, California. 28 p.

Roni P, SA Morley, P Garcia, C Detrick, D King and E Beamer. 2006. Coho salmon smolt production from constructed and natural floodplain habitat. Transactions of the American Fisheries Society 135:1398-1408.

Roper BB, and DL Scarnecchia. 1999. Emigration of age-0 Chinook salmon (*Oncorhynchus tshawytscha*) smolts from the upper South Umpqua River basin, Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 56: 939-946.

Schmidt DC, AKE Tarbox, BE King, LK Brannian, GB Kyle and SR Carlson. 1996. Kenai River sockeye salmon: An assessment of overescapements as a cause of the decline. Pages 628-638 *in* SD Rice, RB Spies, DA Wolfe, and BA Wright, editors. Proceedings of the *Exxon Valdez* oil spill symposium. American Fisheries Society Symposium 18.

Schuett-Hames DE, NP Peterson, R Conrad, and TP Quinn. 2000. Patterns of gravel scour and fill after spawning by chum salmon in a Western Washington stream. North American Journal of Fisheries Management 20:610-617.

Seiler DS, S Neuhauser, and L Kishimoto. 2003. 2002 Skagit River wild 0+ Chinook production evaluation annual report. Washington Department of Fish and Wildlife, Olympia.

Seiler D, G Volkhardt, P Topping, and L Kishimoto. 2004. 2001 Green River juvenile salmonid production evaluation. Washington Department of Fish and Wildlife, Fish Program, Science Division, Olympia, Washington 98501-1091; 36 p.

Sharma R, and R Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (*Oncorhynchus kisutch*) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58(7):1453-1463.

Slaney PA, CJ Perrin, and BR Ward. 1986. Nutrient concentration as a limitation to steelhead smolt production in the Keogh River. Proceedings of the Annual Conference Western Association of Fish and Wildlife Agencies 66:146-158.

Smith BD, and BR Ward. 2000. Trends in wild adult steelhead (*Oncorhynchus mykiss*) abundance for coastal regions of British Columbia support the variable marine survival hypothesis. Canadian Journal of Fisheries and Aquatic Sciences 57:271-284.

Solazzi MF, TE Nickelson, SL Johnson, and JD Rodgers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 57:906-914.

Sparkman, MD. 2011. Upper Redwood Creek juvenile salmonid (smolt) abundance project, study year 2010: a report to the Fisheries Restoration Grants Program. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program, study 2a5: 51 p.

____________2012. Lower Redwood Creek juvenile salmonid (smolt) abundance project, study year 2011: a report to the Fisheries Restoration Grants Program (Project No. P0810509). CDFG AFRAMP, study 2a7: 81 p.

_____________ 2010. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2008. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program, 2008 Annual Report, 2a5: 131 p.

[SWRCB] State Water Resources Control Board. 2003. Resolution number 2003 – 0009. Approval of the 2002 Federal Clean Water Act Section 303 (d) List of Water Quality Limited Sections.

Taylor GC, and MJ Bradford. 1993. Results of rotary auger trap sampling, lower Stuart River, British Columbia, in April and May 1992. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2211:1-18.

Thedinga JF, ML Murphy, SW Johnson, JM Lorenz, and KV Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Tripp DB, and VA Poulin. 1986. The effects of logging and mass wasting on salmonid spawning habitat in streams on the Queen Charlotte Islands. British Columbia Ministry of Forests and Lands, Land Management Report 50, Vancouver.

Tripp DB. 1986. Using large organic debris to restore fish habitat in debris-torrented streams. British Columbia Ministry of Forests and Lands, Land Management Report 47, Victoria.

[USEPA] United States Environmental Protection Agency. 2003. Approval of the Clean Water Act Section 303(d) List of Water Quality Limited Segments as approved by the State Water Resources Control Board on February 4, 2003 as Resolution No. 2003-0009.

[USFWS] United States Fish and Wildlife Service. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek, 1997 – 2000. Annual Report of the Klamath Fisheries Assessment Program, Arcata Fish and Wildlife Office, Arcata, CA. 106 p.

[USGS] United States Geological Service. 2010. Surface water data for California: monthly stream flow statistics. Web page *http://water.usgs.gov/ca/nwis/monthly?*

Unwin MJ. 1985. Stream residence time, size characteristics, and migration patterns of juvenile chinook salmon (*Oncorhynchus tshawytscha*) from a tributary of the Rakaia River, New Zealand. New Zealand Journal of Marine and Freshwater Research, VOL. 20: 231-252.

_______. 1997. Fry-to-adult survival of natural and hatchery-produced chinook salmon (*Oncorhynchus tshawytscha*) from a common origin. Canadian Journal of Fisheries and Aquatic Sciences 54:1246-1254.

Ward BR. 2000. Declivity in steelhead (*Oncorhynchus mykiss*) recruitment at the Keogh River over the past decade. Canadian Journal of Fisheries and Aquatic Sciences 57:298-306.

Ward BR, DJF McCubbing, and PA Slaney. 2002. Stream restoration for anadromous salmonids by the addition of habitat and nutrients. Sixth International Atlantic salmon Symposium, 15th – 18th July, 2002. Edinburgh, Scotland. 23 p.

Ward BR, DJF McCubbing, and PA Slaney. 2003. The addition of inorganic nutrients and stream habitat structures in the Keogh River Watershed for steelhead trout and coho salmon. Pages 127–147 *in* JG Stockner, (ed.). Proceedings of the International Conference on Restoring Nutrients to salmonid ecosystems, April 24 – 26, 2001, Eugene. Oregon.

Ward BR, and PA Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship of smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Zar JH. 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey. 663 p.

PERSONAL COMMUNICATIONS

Anderson, David. 2004 - 2011. Redwood National and State Parks, Fisheries Biologist, Orick, California.
Chapman, Don W. 2003 - 2011. McCall, Idaho.
Chesney, Bill. 2006. California Department of Fish and Game Fisheries Biologist, Yreka, Ca.
Chezum, Bill. 2001. Upper Redwood Creek resident and property owner. Redwood Valley, Humboldt County, CA.
Duffy, Walter G. 2003 - 2011. California Cooperative Fishery Research Unit Project Leader, U.S. Geological Survey, Humboldt State University, Arcata, CA.
Holden, Baker. 2005. Redwood National and State Parks, Fisheries Biologist Orick, CA.
Jong, Bill. 2003. California Department of Fish & Game, Fisheries Biologist, Arcata, CA.
Klein, Randy. 2003 - 2009. Redwood National Park Service, Hydrologist. Arcata, CA.
Madej, Mary Ann. 2003 - 2011. USGS, Research Geologist, Arcata, CA.
Monday, Scott. 2004. California Department of Fish and Game, Fisheries Biologist, 1031-A South Main St, Ft. Bragg, CA. 95437
Ozaki, Vicki. 2003 - 2011. Redwood National Park Service, Geologist. Arcata, CA.
Peters, Charlotte. 2001. Redwood Creek Watershed Map. Information Services, California Department of Fish and Game, Eureka, CA.
Stover, Marlin. 2000. Upper Redwood Creek long time resident and property owner. Redwood Valley, Humboldt County, California.
Weseloh, Thomas J. 2003. California Trout, McKinleyville, CA.

APPENDICES

Appendix 1. Reasons for collecting genetic samples from Chinook salmon, steelhead trout, and coho salmon (if present).

Chinook Salmon:

1. To test for possible genetic differences between 0+ Chinook (Ocean-Type) and 1+ Chinook (Stream-Type).
2. To test for possible genetic differences between 0+ Chinook salmon fry and 0+ Chinook salmon fingerlings.

Steelhead Trout:

1. To test for any hatchery introgression into the wild steelhead stock in Redwood Cr.
2. To test for possible genetic differences between age-1 and age-2 smolts.
3. To test for possible genetic differences between emigrating 0+ steelhead trout and 1+ steelhead trout the following year.

Coho Salmon

1. To determine the number of parents responsible for the juveniles captured in the fish trap.

All Species:

1. To test for possible genetic differences between fish captured in the lower basin and upper basin.
2. To construct a genetic data base for future comparisons and analyses.

Appendix 2. Graphical representation of daily stream gage height (ft.) at trapping site and average daily streamflow (cfs) measured at O'Kane gaging station (USGS 2012), upper Redwood Creek, Humboldt County, CA.